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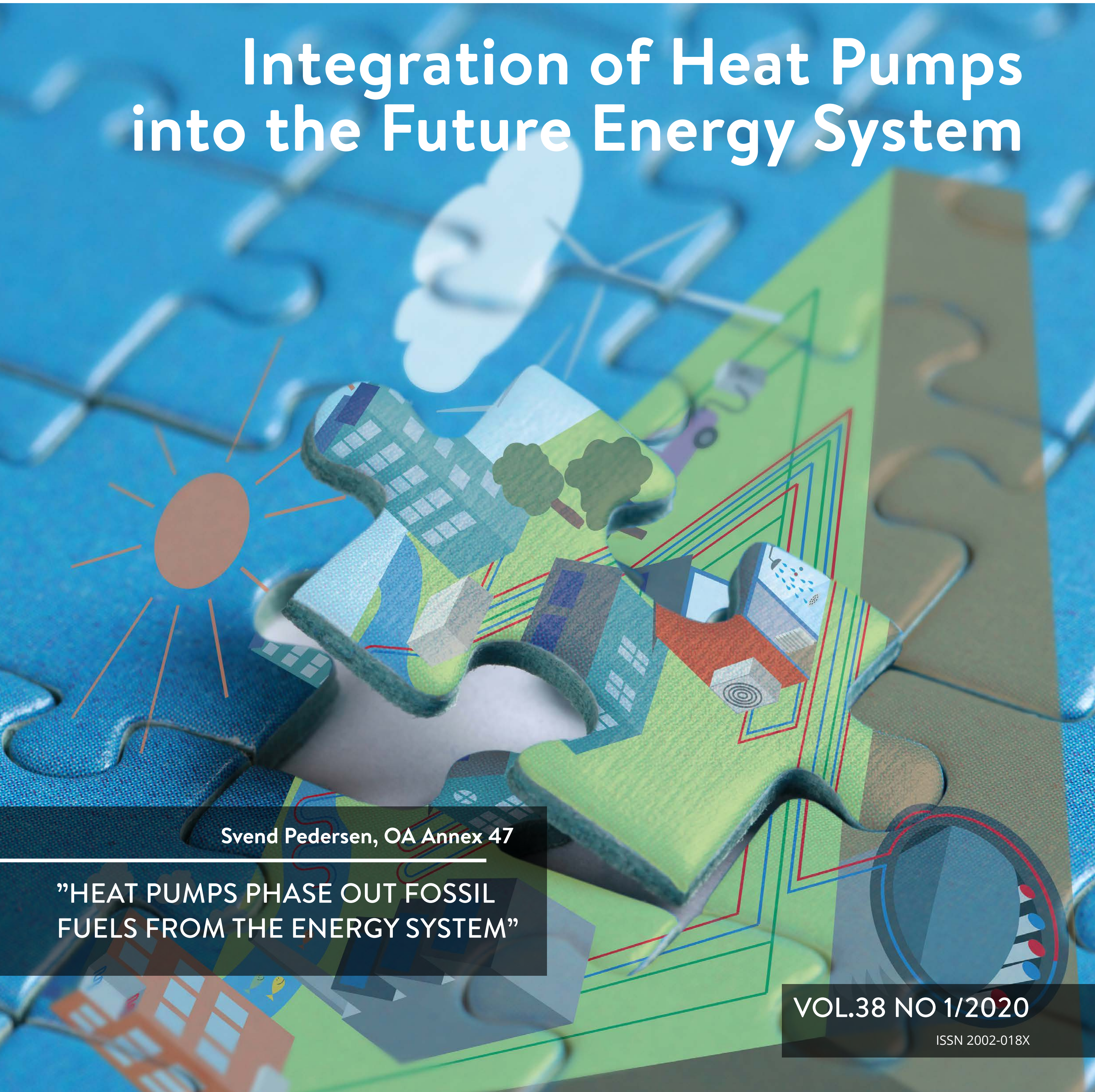
IEA HPT



# Heat Pumping Technologies MAGAZINE

A HEAT PUMP CENTRE PRODUCT



## Integration of Heat Pumps into the Future Energy System

Svend Pedersen, OA Annex 47

"HEAT PUMPS PHASE OUT FOSSIL FUELS FROM THE ENERGY SYSTEM"

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Heat Pumping Technologies
MAGAZINE

VOL.38 NO.1/2020

# In this issue

The actual and potential global effects of the Corona virus are massive. For HPT, the most significant effect so far is postponing of the 13th IEA heat pump conference. When this is being written, several countries have closed their borders and are also taking other measures to reduce contamination and the numbers of severely ill people. We agree with Fatih Birol, Excecutive Director of IEA, who urges "that governments can use the current situation to step up their climate ambitions and launch sustainable stimulus packages focused on clean energy technologies. The coronavirus crisis is already doing significant damage around the world. Rather than compounding the tragedy by allowing it to hinder clean energy transitions, we need to seize the opportunity to help accelerate them".

We already know that the energy system of tomorrow cannot look like the one of yesterday. In the future, fossil fuels must be replaced by renewable energy sources, due to environmental impact and resource depletion. Such distributed and intermittent production could, of course, be problematic. But this issue of HPT Magazine, with the topic “Integration of heat pumps into the future energy system”, shows that solutions are within reach.

The Foreword points out how heat pumps can be used to both reduce energy use and to decrease the reliance on fossil fuels. As an example, the recently completed HPT Annex related to heat pumps in district heating networks is highlighted. The Magazine also presents the recently started Annex 56 “Internet of Things for Heat Pumps”.

The two topical articles cover heat pumps in district heating systems, and grid control of heat pumps. They go into some of the aspects of a future energy system where heat pumps are a crucial component both on an individual and a systemic level.

**Enjoy your reading!**

Johan Berg, Editor

**Heat Pump Centre**

- the central communication activity of Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP)





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FOREWORD

# Integration of Heat Pumps into the Future Energy System

Worldwide goals of implementing renewable energy sources are creating a change in our energy system. New technologies and energy solutions providing balancing services valuable for the grid are emerging in line with the increasing expectations of lower greenhouse gas generation. A key element is an intelligent energy and supply system where fluctuating energy sources are optimally integrated to create much more flexibility in the use of energy.

Most countries focus on the electrification of the energy system and the phase-out of fossil fuels to decarbonise the energy system. As the production cost per kWh electricity has reduced to a level where it is competitive with fossil fuels, most countries are investing in both photovoltaic panels and wind power to stabilise, optimise, and increase the renewable electricity production. Thus, the demand side needs to be more flexible. Heat pumps, both large-scale and small ones clustered in pools, can act as balancing units in the grid. However, currently, the incentive or economical gain is very low for the consumer, since the flexible part of the price for electricity is only a minor part of the cost per kWh.

The article "Grid flexible control of heat pumps", which is based on the results from the EU project "Flexible heat and power", describes the possibilities and challenges that occur when heat pumps are used as a balancing source in the electrical grid.

Studies show that heat savings can cost-effectively reduce the total heat demand in Europe by 30-50% if waste heat is captured and used. HPT Annex 47, "Heat Pumps in District Heating and Cooling Systems" describes that district heating can cover up to 50% of the heating demand in Europe and heat pumps can deliver 25% of the energy to the district heating grid, which means that $CO_2$ emission can be reduced by more than 70% compared to the current situation. The interest in heat pumps in district heating networks is growing, and 39 case studies were described in Annex 47.

In order to support the fast-growing demand for heat pumps in district heating networks, the HPT Executive Committee has approved the formation of a new Annex, called "Flexibility by implementation of heat pumps in multi-vector energy systems and networks". The members currently include Austria, Denmark, Switzerland and Sweden. The aim is to describe the potential of heat pumps in district heating grids, and the kind of flexibility that heat pumps can add to energy networks when they are linked together. Good examples in which the flexibility is investigated will be described, and knowledge will be shared among countries.

The two topical articles in this issue of the HPT magazine provide more insight information into the possibilities and challenges regarding the implementation of heat pumps in the energy systems in the future.

**Svend Pedersen**
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# Heat Pump R&D for Appliance Applications

After space heating and space cooling, water heaters and white goods products, such as clothes dryers and dishwashers, are among the largest energy users among residential equipment in the US. Research and development (R&D) is underway to reduce both the energy consumption and global warming impact of these products.

Heat pump water heaters (HPWHs) are much more efficient than conventional water heaters, with potential to reduce energy consumption by more than 50%. Current HPWH products rely on R-134a, a relatively high global warming potential (GWP) refrigerant. R&D is underway to evaluate lower GWP alternatives to R-134a in vapor compression cycle-based HPWHs. A range of working fluids including hydrocarbons (like R-290), hydrofluoroolefins (like R-1234yf), and blends (like R-450a and R-513a) have been examined. Most of the alternatives have been shown to match or exceed the efficiency of baseline R-134a technology, while requiring little to no modification of the heat pump system. Up to a 10% improvement in efficiency has been achieved with near equal capacity. Additionally, R-290 can yield a significant reduction (more than 50%) in the refrigerant charge compared to R-134a technology.

Residential clothes dryers and dishwashers currently use electric resistance heating, and the adoption of vapor compression (VC) heat pumps faces numerous challenges for these products, including space constraints, noise, cost, and uncertainty over refrigerants. In the US, electric clothes dryers consume 185 TWh of primary energy per year. Recent clothes drying R&D has focused on the use of solid-state thermoelectric (TE) heat pump technology, which relies on the Peltier effect to achieve heat pumping. While these devices are typically less efficient than VC heat pumps at a given temperature lift, clothes drying is an application in which the large temperature glide of the process air is well suited to TE modularity (i.e., many small heat pumps, instead of a single heat pump). The modularity of TEs allows them to operate at relatively low lift. Unlike VC heat pump clothes dryers (HPCDs), they do not use refrigerants. Recent work has shown a 40% reduction in energy use for TE-HPCDs compared with conventional ER dryers. If ongoing research efforts are successful in reducing the cost and drying time of HPCDs, it will have a significant impact on market acceptance and energy usage.

In terms of dishwashing, the residential primary energy consumption in the US is 83 TWh per year, most of which is for water heating and drying. As such, heat pumps can be used to increase their efficiency significantly. As with TE-HPCDs, current R&D is being conducted to leverage the unique features of thermoelectrics to accomplish heat pump water heating, heat pump drying, and heat pump recovery of energy from the drain water. This work has the potential to reduce the energy consumption associated with residential dishwashing by as much as 25 TWh per year.

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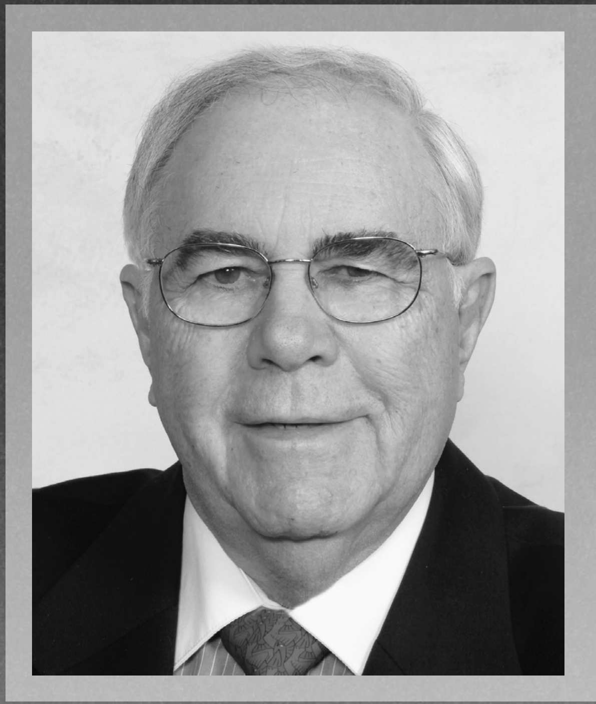
# In Memory of Gerald Groff, 1934-2019

## In September 2019, we lost a key member of our international heat pump community, Gerald "Jerry" Groff.



Jerry played a very significant role at the IEA Heat Pump Programme almost since its beginning. He was instrumental in the creation and coordination of the US National Team. For 12 years, from 1990 to 2002, he served as a member and Chairman of the International Advisory Board of the Programme, representing both the US and Canada. He was actively involved in the IEA Heat Pump Conferences, starting at the first one held in Graz, Austria, in 1984 and helped organize all of the conferences through the 2014 conference in Montreal. In 2008, he received the Ritter von Rittinger prize awarded by the IEA Heat Pump Programme, in recognition of his career and wide contribution to the heat pump domain.

Jerry had impressive experience and expertise in the area of heat pumping technologies, having worked over 50 years in international research, technical management and marketing activities.  He had a Master of Science degree in Mechanical Engineering from the University of Minnesota, a Master of Science degree in Engineering Administration from the Syracuse University, and advanced management courses from the Harvard School of Business.  His dedication to the field of heat pumping technologies began when he was an undergraduate student at the University of Minnesota, where he participated in a research program in the installation of solar-assisted heat pumps.

He then served in the US Navy Civil Engineering Corps, supervising the building construction and air conditioning and refrigeration installations at the Naval Air Station in Washington DC. He had been an instructor of air conditioning and refrigeration courses at the University of Minnesota.  He worked 10 years for Carrier as Director of Research Laboratories, Director of Technology Planning, and Director of Technology and Product where he led a research team that conducted pioneering work on heat pumps in the US, Canada, France and Germany. He was then Director of the Solar Heat Research Division at the US Solar Energy Research Institute (SERI) (now the National Renewable Energy Laboratory or NREL), and then President and CEO of Marquardt Switches, Inc. (an international electric and electronic switch manufacturer) before he retired.

He was a member and Officer/Director of the US National Committee for the International Institute of Refrigeration (USNC/IIR) for over 25 years. He received the W. L. Pentzer Award in 1999 from the USNC/IIR for his leadership at this institute. He served eight years as Vice-President of the IIR Science and Technology Council and President of Section E: Heat Pumps and Air Conditioning. He served as Chairman of the Strategic Planning Committee in 1998-1999, and of the Strategic Plan Review Committee in 2004. He was Co-chairman of the XXI (21st) IIR International Congress held in Washington in 2003 and received from ARI, the American Air Conditioning and Refrigeration Institute, a Special Recognition Award for his leadership in that role.

Jerry joined ASHRAE in 1956 and received numerous awards over the years including:

- ASHRAE Fellow – 2004;
- Distinguished 50-Year Member Award – 2006;
- F. Paul Anderson – 2010 (ASHRAE's highest award, for service to the profession and society);
- Distinguished Service Award – 2013;
- Exceptional Service Award – 2014;
- John James Award – 2017 (recognizing members who have done the most to enhance ASHRAE's international presence).

Throughout his career Jerry has been recognized for his technical leadership, collaboration, and vision. We will miss Jerry and his contributions to our scientific community. His legacy in international collaboration and technology advancement will continue through association and program events, including the triennial IEA Heat Pump Conference.

# Welcome to the 13$^{th}$ IEA Heat Pump Conference, 2020


**The 13$^{th}$ IEA Heat Pump Conference (HPC2020) will be held in Ramada Plaza Hotel Jeju, Korea, September 21-24, 2020 (originally planned for May, but postponed to September due to the new corona virus, see below).**

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

On Monday September 21, the first day of the Conference will start with a number of technical workshops with challenging topics organized by HPT Annex participants and other IEA TCPs. Six workshops are moderated by Operating Agents of on-going or finalized HPT Annexes. The other two workshops are moderated by the Heat Pump Centre. The workshops will have speakers from all continents, giving an overview of the state of the art in the market, experience and current research topics with challenging issues for discussion.

The topics of the workshops are:

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

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

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

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

**Track 3:**
Three sessions of air-conditioning technologies, Four sessions of industrial heat pumps including waste heat application, Domestic hot water heat pumps;

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

In the HPC2020, more than 220 high quality papers will be presented in the technical sessions, and participants will encounter numerous cutting-edge presentations on heat pumps. In addition, the conference will serve as a forum to discuss the latest developments in heat pumping technologies, and exchange valuable knowledge regarding market, policy, and standards. Exhibitions will be held at the conference, to share products and technologies from domestic and foreign companies. On Wednesday September 23, a technical tour is arranged to power plant and seawater heat pump demonstration sites.

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

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

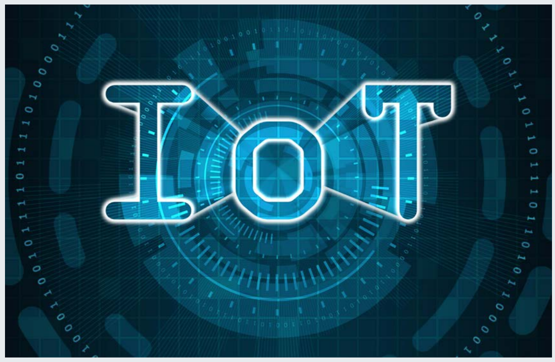
13th IEA HEAT PUMP CONFERENCE
2020 | JEJU KOREA

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

# HPT TCP welcomes Annex 56

## ANNEX 56 INTERNET OF THINGS FOR HEAT PUMPS

The IoT Annex focusses on the opportunities and challenges of IoT-enabled heat pumps. Connected devices will play a major role in the future addressing multiple aims, such as increased comfort for the user, reduction in energy consumption and decarbonization of heat supply. The Annex will include both heat pumps for household and commercial applications, as well as heat-pumps for industrial applications.




**Objective**

In this Annex, opportunities and challenges of IoT-enabled heat pumps will be elaborated. It aims to increase knowledge at different levels (OEMs, heat pump manufacturers, consultants, installers, legislators, etc.) and to provide guidance and contributions to the development of future standards.

The results of the Annex will be disseminated to relevant target groups such as OEM, heat pump manufacturers, associations and regulatory authorities by means of tailored messages. The Annex will thereby provide guidance, data and knowledge about heat pumping technologies with respect to IoT applications.

Read more on the Annex homepage:
https://heatpumpingtechnologies.org/annex56/

# Heat pumps is key to net zero target

**The UK Heat Pump Association (HPA) has set forth its roadmap of how heat pump technology can help the UK achieve its 2050 net-zero carbon emissions target.**

According to the HPA, its vision report – Delivering Net Zero: A Roadmap for the Role of Heat Pumps – outlines the industry's commitment and readiness to step up to the challenge of delivering the necessary decarbonisation of heat through the scaling up of heat pump deployment. It highlights three key pillars to delivering this objective:

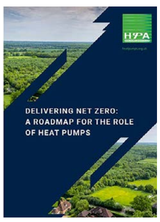
- putting the consumer at the heart of change;
- upskilling the installer base;
- working with government to ensure a supportive policy mix.

This would also rely on collaboration with government, certification organisations, other trade associations, and installers.

The decarbonisation of heat is seen as a key priority following the government's announcement that the UK will become the first major nation to commit to reaching a net-zero carbon emissions target by 2050.

The report explains how pumps can make vast carbon savings immediately, something that the report claims will be vital to avoiding the worst consequences of the climate crisis. It emphasises that emissions from the burning of fossil fuels will not fall unless low-carbon heating systems are attractive to consumers, either by improving comfort levels or saving them money. The vision report enforces a message to consumers that heat pump technology can help to address other policy issues, such as fuel poverty and air quality.

Properly trained and skilled technicians are also seen as vital to be able to design, install and operate heat pump systems effectively. The HPA says it will work with other leading organisations over the coming months to roll out a programme of training that will take existing heating engineers through the whole process of designing, installing and maintaining efficient low-carbon heating systems.




"The heating industry has been one of the biggest contributors to carbon emissions and we now find ourselves at a pivotal moment as we look to decarbonise our heating supply," said HPA chairman Graham Wright. "The HPA believes that there is a huge opportunity for the country to embrace heat pump technology at this time, and we want to re-emphasise the fact that heat pumps provide strong carbon savings now that will only increase further in the future."

**Source:**
https://www.coolingpost.com/uk-news/heat-pumps-key-to-net-zero-target/

# Ongoing Annexes in HPT TCP

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 the objectives may vary from research to implementation of new technology.

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NEW

*) Operating Agent from Germany, but no other parties from the country participate.

**The Technology Collaboration Programme on Heat Pumping Technologies participating countries are:**

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

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

ANNEX 46

DOMESTIC HOT WATER HEAT PUMPS

## Introduction

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

Regarding Heat Pump Water Heaters we generally mean a mono-bloc air source heat pump (Figure 1), defined as a single unit with heat pump (containing compressor, expansion valve, evaporator and condenser), with a storage tank integrated, often located underneath the heat pump. These mono-bloc systems will remain the preferred solution in many cases for single family houses. However, there are a large number of alternatives for sanitary hot water with heat pumps in domestic applications, other than the mono-bloc, for single family houses and multifamily buildings, as well as for sanitary hot water systems for hotels, hospitals, sporting facilities, etc. There is a large number of technologies available with regional differences in demand and usage, thus showing a greater complexity than space heating/cooling systems.

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

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

The necessary short-term effect for increased market penetration is to attain larger policy awareness of the market potential of heat pump water heaters. In advocating the right policy there is a fine line between supporting the interests of commercial market players selling or installing heat pump technologies, and the sometimes large economic interests of companies selling competing and often traditional technologies. Straightforward policy support for DHW HPs is therefore very rare and not consistent across Europe, North America and Asia. The good best practice example "Introduction Subsidy Scheme" initiated by the Japanese Government for the ECO-Cute cannot simply be copied by other countries. Awareness must be achieved at the political level. This can be achieved by summarizing the conclusions and recommendations in comprehensible language on one-pagers (flyers) that can be distributed or used by individual countries.

## Objectives

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

## Progress in 2019

The work during 2019 was characterized by summarizing the results of the annex work into reports that will be published. A number of discussions, which actually started at the end of 2018, have led to definitive reports, and the conclusions have been adopted by the participants and the national teams supporting the experts. The main conclusions are:

- Refrigerants: For Heat Pump Water Heaters, no single alternative refrigerant fulfills all the ideal requirements at this point in time. The F-gas Regulation provides incentives for the use of refrigerants with reduced GWP. Thus, direct emissions from Heat Pump systems are expected to be reduced. However, this does not

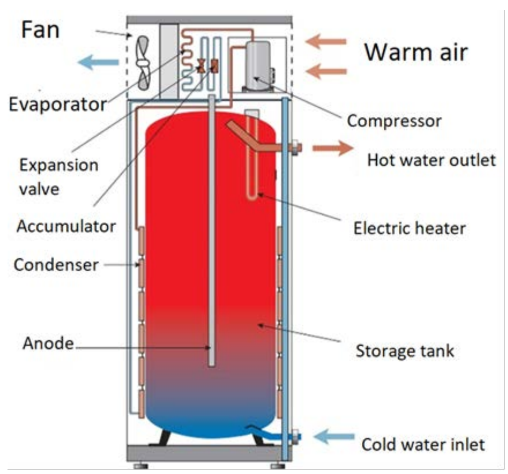


*Fig. 1: A common type of Heat Pump Water Heater, mono-bloc air source heat pump.*

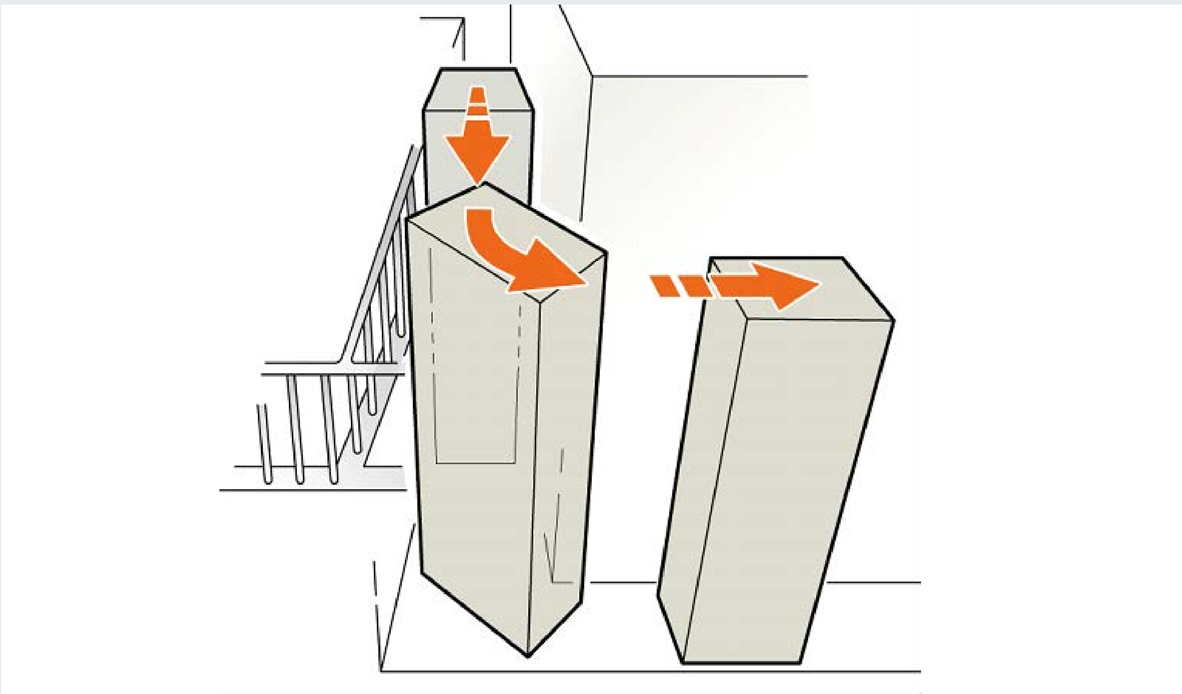

*Fig. 2: Since Japanese houses are often small, the compactification of appliances is also progressing. Companies have developed slim and compact hot water storage tanks, to enable installation even in very narrow spaces.*

necessarily result in lowering the climate impact, expressed in terms of the Life Cycle Climate Performance (LCCP) value. LCCP evaluation can be necessary in order to account for the entire climate impact of a system when selecting an alternative refrigerant.

» Legionella: Heat pumping technologies for single-family buildings as well as in collective systems for multi-family buildings, sports centres, hospitals, etc., are well suited and capable to deliver the required temperatures to fight Legionella.

» System models: Objective comparison of systems from a policy point of view has to be based upon the chain efficiency, where the overall efficiencies for the complete chain from primary (fossil) energy to the end user are compared, and the weakest links in the chain are analysed. There is no publicly available model considering the technologies of water heating in systems nor innovative solutions for multifamily buildings.

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

» Research and Development: In the participating countries, some specific programs for R&D on heat pump water heaters are or have been running, and some general R&D programs run in which heat pump water heater technologies are supported, among other techniques. A large number of the main heat pump manufacturers/suppliers are not Original Equipment Manufacturers. R&D from these manufacturers is mostly 'application development', focusing on existing and future markets and customer needs and preferences. This is an interesting market where innovation is of great importance in order to reach the market. Important topics for development, focusing on local market acceptance are

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

**Annex website**
https://heatpumpingtechnologies.org/annex46/

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ANNEX
# 49

# DESIGN AND INTEGRATION OF HEAT PUMPS FOR nZEB

Nearly zero energy buildings have been introduced for new public buildings in the EU-member states about a year ago, on January 1, 2019. Even though requirement differ among countries, efficient heating systems and other building system technology is advantageous to fulfil the requirements. In less than one year, by the deadline of January 1, 2021, the requirements will be extended to all new buildings.

In Task 1 of IEA HPT Annex 49, the requirements in the different participating countries are compared and conclusions for the heat pump applications are drawn. On this basis, in Task 2, heat pump integration options are assessed, and in Task 4 implications for design and control of the heat pump application in nZEB are investigated.

In Task 3 the monitoring of heat pumps in real built nZEB is evaluated in parallel to each other. Norway, for instance, has several monitoring projects in larger nZEB buildings, among them a hotel, a supermarket, a school building and a cluster of five office buildings. Even though the measured performance is good in most of the monitored buildings, there are also optimisation potentials found for improved heat pump operation. The school building Justvik Skole in Kristiansand, southern Norway, is built with an energy reference area of 3,480 $m^2$ according to the Norwegian passive house standard (NS 3701), see Figure 1.

In the design phase, the DHW share was evaluated to 55% of the total heat energy. Therefore, a ground source $CO_2$ heat pump is applied, with high performance values for DHW operation. At the test point of 3 °C/ -2 °C and 30 °C/70 °C, a COP of 2.9 is reached. In order to also achieve good performance in space heating operation, the heat emission system is specifically adapted to create low return temperatures for the heat pump. Since the performance of $CO_2$ heat pumps is strongly affected by the return temperature of the systems connected to the gas cooler, the COP and the heating capacity are improved at low return temperatures. The heating system is thus composed of low temperature radiators with operating temperatures of 45 to 40 °C, a floor heating system working between 35 and 30 °C and ventilation air heating from 30 to 18 °C, in series. The DHW heating, 14 °C inlet and 55 °C outlet on the water side, is connected in parallel and can always be operated. During the monitoring period Feb. – Sept. 2018, a moderate average COP of 3.0 and a degree of coverage of 78% were measured. This is below the design values of a COP of 3.4 and 94% coverage, and indicates optimisation potential. One reason is a low DHW use, which limits the decrease of the return temperatures and thus the performance of the heat pump.

The $CO_2$ heat pump had a malfunction in the temperature sensor for the gas cooler, which led to sub-optimal pressure and temperatures in the gas cooler. Thus, the performance was reduced, and the heating capacity was affected. Possible optimisation is improved measurement of gas cooler temperatures, with accurate control of gas cooler temperature and pressure. Also, the radiator set point should be lower and ventilation air temperatures increased, lowering the return temperature in the heating system. Further, the source system is undersized and should be extended with an additional borehole, and a higher DHW use would increase the system performance by lower return temperatures for the $CO_2$ heat pump.

### Annex website

http://heatpumpingtechnologies.org/annex49/

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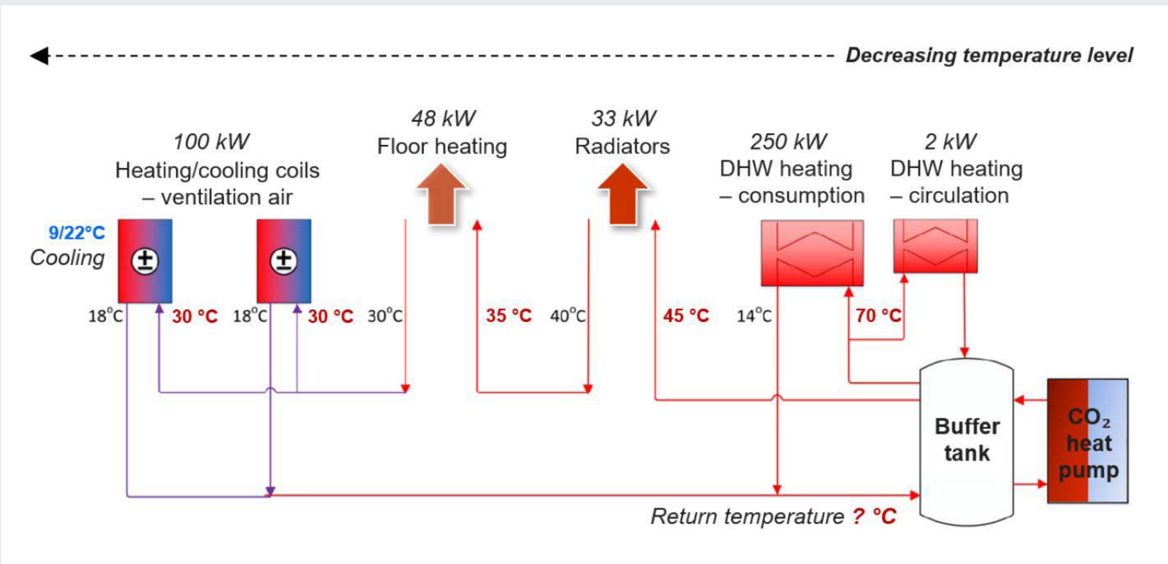


*Fig. 1: Schematic of the heating system of Justvik Skole in Kristiansand, southern Norway in Fig 1, with $CO_2$ heat pump and adapted heat emission system*

ANNEX 50

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

**Introduction**

The building sector plays a significant role for the energy consumption in all countries. Apart from the power generation and transportation sectors it is the most important sector regarding emission of greenhouse gases. Accordingly, the radical reduction of $CO_2$ emissions from buildings is crucial for achieving climate neutrality.

Applying heat pump technologies and renewable energy is more complex for multifamily buildings than for newly built apartments, since multifamily houses have a range of special heat demand characteristics. Firstly, the share of domestic hot water demand of the overall heat demand varies with varying building standards as well as with different climates. Secondly, the temperature level of the heating system is influenced by these aspects as well as by the installed heat transfer system. Thus, dealing with the variety of heat demand characteristics is a challenge on the way to a broader dissemination of heat pumps in multifamily buildings.

Thus, Annex 50 will focus on solutions for multifamily houses with the attempt to identify barriers for heat pumps on these markets and how to overcome them. According to the demands of the participating countries, both new buildings and retrofit will be considered, as well as buildings with higher specific heating demands.

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

**Objectives**

» Enhancement of HP systems and/or HP components for their adaptation in multi-family buildings;

» Development and demonstration of concepts for application of HP in energetically renovated buildings and in buildings without improved building envelope;

» Finding the optimal bivalence temperature for bivalent or hybrid systems;

» Identification of needs on the characteristics of HP components and figuring out, which are neither fulfilled by market available products nor a scope in ongoing research and development projects;

» Present recommendations for the optimal (multi) heat source and operating mode (fuel driven, electric driven, hybrid) solutions depending on building type and ecologic-economic situation and climatic zone.

**Progress**

*Success Stories:*

1. In order to consider the heating demand, take variables such as the occupants' behaviour, the type of heat pump and the structure of the building need to be considered. Thus, Annex 50 has developed a 'system-matrix tool', Figure 1. This system matrix divides the consideration of a multi-family building into three steps. First, a division is made into one of the seven schemes that describe the type and use of the heat pump in general, Figure 2. This is followed by an analysis with a more detailed description of the heat pump and an assessment with pro and contra arguments of each solution. In the last step, a fact sheet will be published, describing a real-use case with all relevant information, such as a

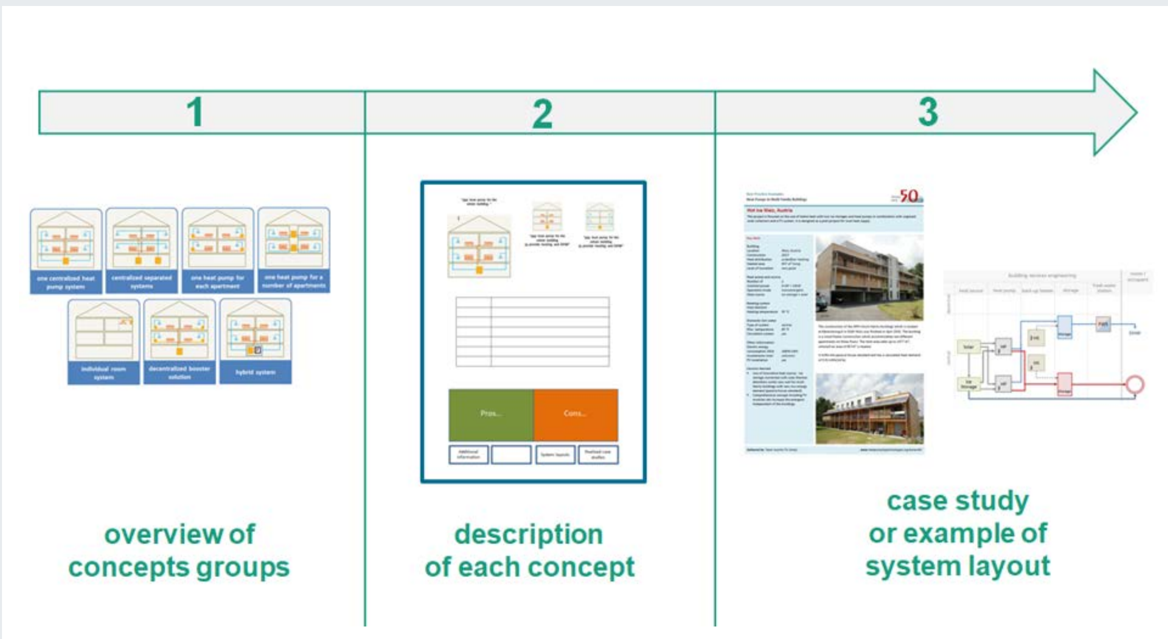


*Fig. 1: Thanks to the new Matrix tool, it is now possible to structure multi-family buildings with installed heat pumps. This enables even more meaningful forecasts to be made about the development of the heat pump in the housing market.*

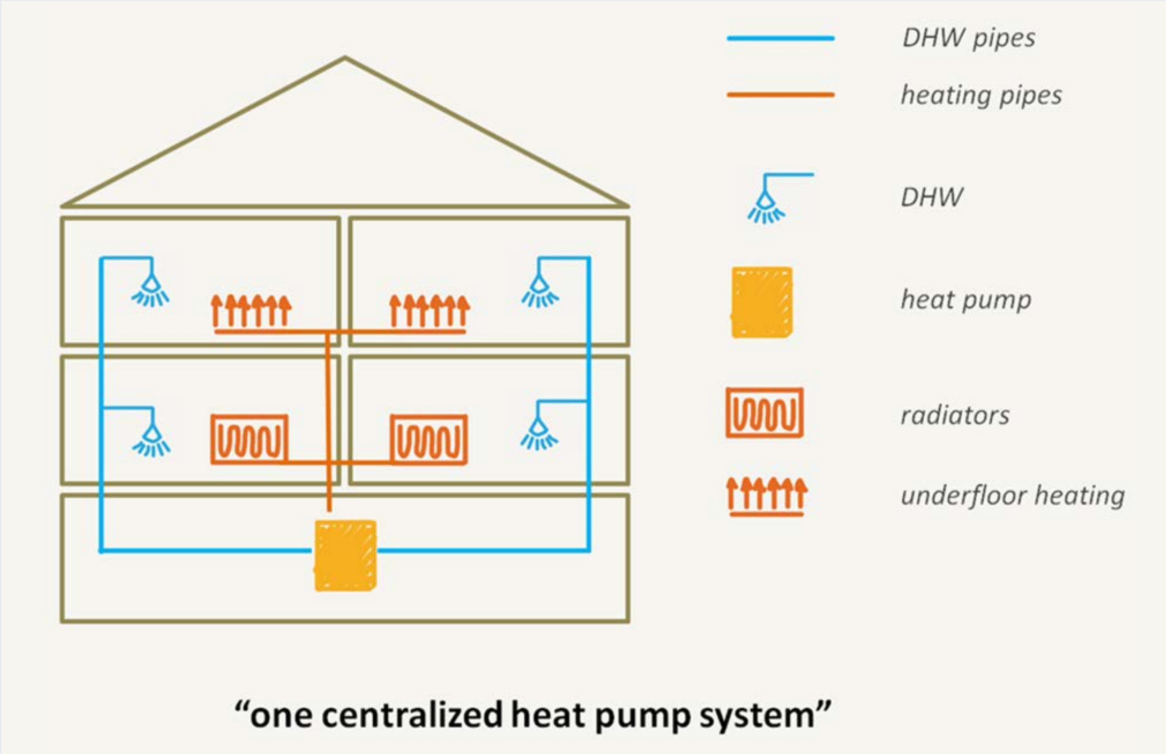


*Fig. 2: This illustration shows one of the seven schemes for structuring the multi-family buildings.*

description, pictures and a technical concept. The fact sheets provide a good overview of the different uses of heat pumps in multi-family buildings, and comparisons can also be made.

2. Thanks to the collaboration with all the participating countries, it was possible to find and present a large number of successful examples of heat pumps in multi-family buildings. All of this is available to everyone on our website using an interactive map. On the map you will find images and a brief description of the objects equipped with heat pumps. In addition, it is possible to download the detailed fact sheets. The map is constantly being expanded with new buildings, but it is also possible for anyone to submit a multi-family object with a heat pump in order to appear on the map after an analysis is done using the system matrix.

**Annex website**
https://heatpumpingtechnologies.org/annex50/

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ANNEX
51

# ACOUSTIC SIGNATURE OF HEAT PUMPS

## Introduction

In order to further increase the acceptance of heat pumps, reduction of acoustic emissions is important. To minimize noise annoyance, the focus must be on the acoustics emissions at steady state and on the transient behaviour of acoustic signatures during different operating conditions. The placement of the heat pumps is also of utmost importance, as sound emissions exhibit a pronounced directivity. Especially air to water heat pumps provide a convenient and effective way to exploit potential energy savings and are often used in retrofit installations. However, some of their components, such as compressors and fans, typically produce significant levels of noise. This makes acoustic improvements crucial for their deployment.

In Annex 51, acoustic emissions are covered in a hierarchical approach considering the following levels: the component level (low noise components), the unit level (system approach of combining the components, unit control, transient acoustic features) and finally the application level (building and neighbourhood including smart grid, psychoacoustic effects and acoustic propagation).

## Objectives

- » Increase the acceptance of heat pumps;
- » Increase knowledge and expertise at different levels;
- » Provide input to national and international standardization;
- » Preparation of seven Annex meetings: six meetings held (Austria Vienna 06-2017, France Lyon 01-2018, Sweden Borås, 06-2018, Denmark Aarhus, 01-2019, Germany Freiburg 10-2019, online 03-2020), one final planned (Italy, Milano 09-2020);

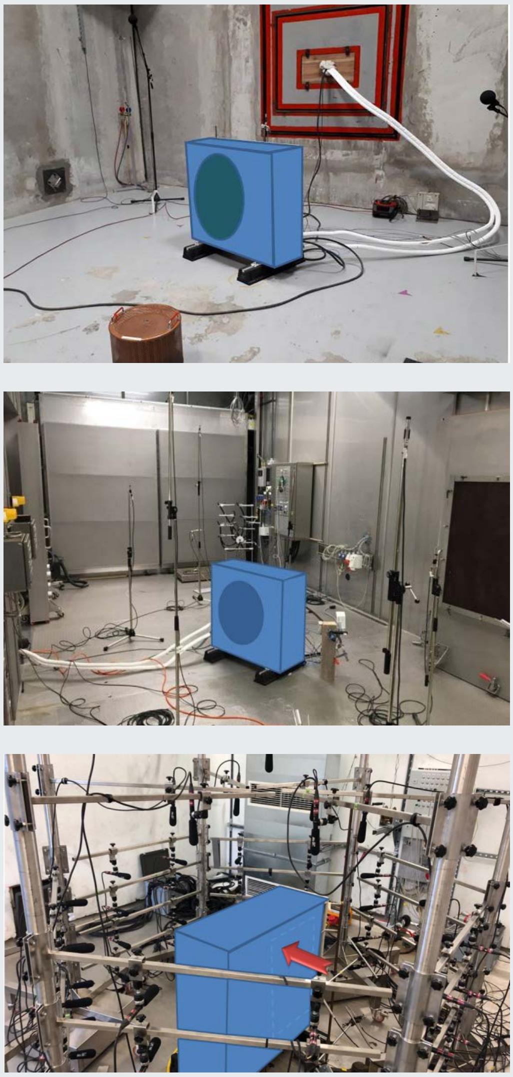

*Fig. 2: Examples of the heat-pump installation in a reverberant test room (top) and climatic chambers (middle and bottom). A microphone array can be seen in the bottom image. [Source: CETIAT, France (top), ISE, Germany (mid) and AIT, Austria (bottom)]*

*Fig. 1: Meeting photo of the 5th working meeting hosted by Fraunhofer ISE on October 17-18 2019 in Freiburg, Germany [Source: ISE, Germany]*

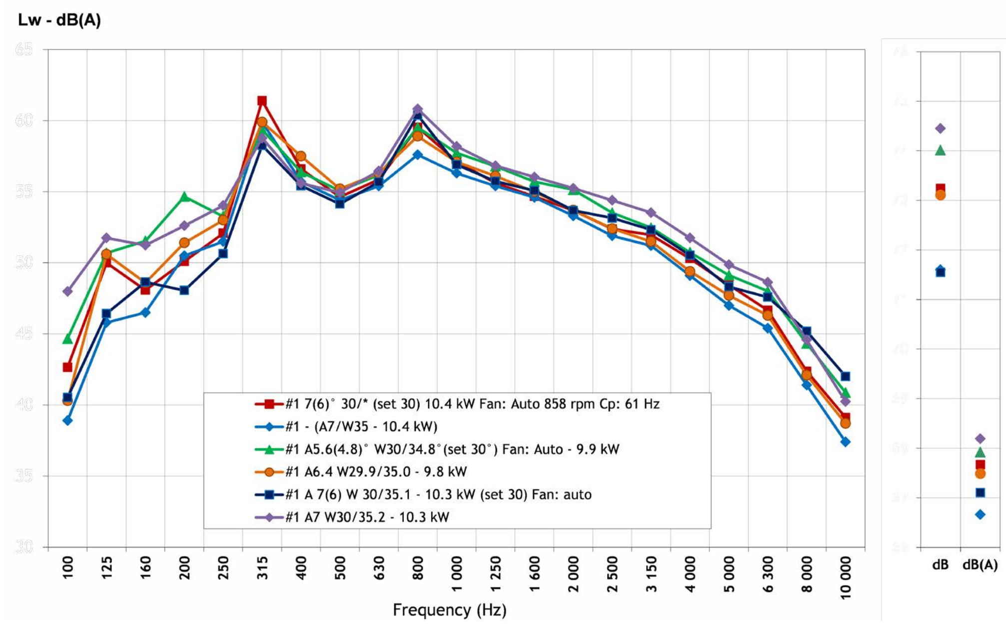


*Fig. 3: Spectrum of A-weighted sound power levels for Standard rating conditions EN 14511 (#1) from 6 laboratories [Source: CETIAT, France]*

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

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

The documents on *Introductions to Acoustic, Measurement Techniques and Regulations*, which have been prepared under the task led by Politecnico di Milano, Italy, saw their first release to public and are available on the IEA HPT Annex 51 website for download. Comments and additions have been gathered and the updated documents will be added to the website mid of 2020.

Three heat pumps have been "on tour" through Europe at the participating institutes. These are an Air-to-water Heat Pump (see Figure 2), an Exhaust-air Heat Pump Water Heater (HPWH) and an Air-to-air Heat Pump. Their final tests were performed during 2019.

Results from the measurement campaign of the Air-to-water Heat Pump show, in most of the cases, similar results in the participating laboratories, see Figure 3. The differences that can occur are acceptable, given the variety of test environments and acoustic test methods. When some larger difference appeared, it was often due to a difficulty of adjusting operating conditions rather than an acoustical measurement problem. One laboratory implemented measurements with a dodecagonal polar frame around the outdoor unit, with 55 microphones. The data from 12 microphones (see Figure 2 bottom), allows the plot of the relative directivity diagram, presented in A-weighted overall level in Figure 4 left. The directivity diagram in Figure 4 right (which is rotated by 15 degrees compared to Fig 4 left) shows the acoustic radiation directivity of the unit for each octave band in dB(A).

A dissemination workshop "Acoustics of Heat Pumps" has been be organized by the Annex 51 team in the framework of the 25th IIR International Congress of Refrigeration in Montreal, Canada, August 2019. The presentations are available on the IEA HPT Annex 51 website for download. There were six presentations of Annex 51 partners, and a panel discussion.

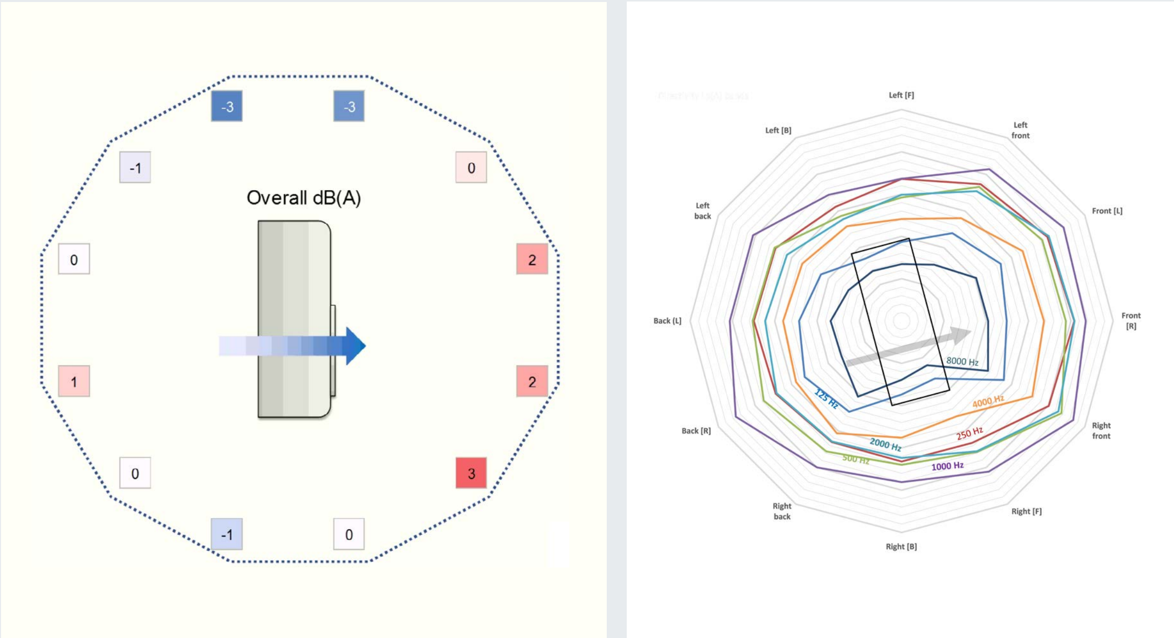


*Fig. 4: Directivity for the overall A-weighted sound pressure level at 75 cm height (left) and directivity for each A-weighted octave band (right) [Source: AIT, Austria]*

**Annex website**
https://heatpumpingtechnologies.org/annex51/

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## INFORMATION

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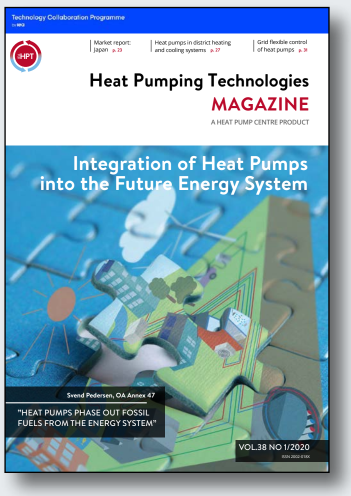

ANNEX
# 52
## LONG-TERM MEASUREMENTS OF GSHP SYSTEMS PERFORMANCE IN COMMERCIAL, INSTITUTIONAL AND MULTI-FAMILY BUILDINGS

### Introduction
HPT Annex 52 – *Long-term performance monitoring of GSHP systems for commercial, institutional and multi-family buildings*, has now reached its midway point. Seven countries are participating in the annex (Sweden, USA, Finland, Norway, Germany, UK and Netherlands). The seven participants are contributing 40 case studies of long-term monitored GSHP systems, all serving commercial, institutional or multi-family buildings with heating and/or cooling systems of varying degrees of complexity.

The outcomes from this annex will help building owners, designers and technicians to evaluate, compare and optimize GSHP systems. It will also provide useful guidance to manufacturers of instrumentation and GSHP system components, and developers of tools for monitoring, controlling and fault detection/ diagnosis. This will lead to energy and cost savings.

To date, outcomes of the annex include a bibliography with published long-term performance analyses of larger GSHP systems, four published journal papers on three case studies included in Annex 52, and four conference papers. Open source measurement data are available for two of the published case studies.

### Objectives
» Survey and create a library of quality long-term measurements of GSHP system performance for commercial, institutional and multi-family buildings. All types of ground sources (rock, soil, groundwater, surface water) are included in the scope.

» Refine and extend current methodology to better characterize GSHP system performance serving commercial, institutional and multi-family buildings with the full range of features shown on the market, and to provide a set of benchmarks for comparisons of such GSHP systems around the world.

» Compile guidelines documents for instrumentation, data collection, analysis and reporting of key performance indicators for large GSHP systems.

### Progress
The first objective of Annex 52 has been to compile an annotated bibliography of long-term performance monitoring of larger GSHP systems. This bibliography now contains over 70 publications describing some 60 buildings where long-term performance monitoring of larger GSHP systems have been performed and that contain some form of SPF measurement. Spitler and Gehlin (2019) present a comprehensive review of the performance measurement literature for large GSHP systems. The review made clear that nomenclature for performance indicators used by different authors is inconsistent, reflecting a lack of consensus on how to evaluate, express and present performance for complex large-scale GSHP systems.

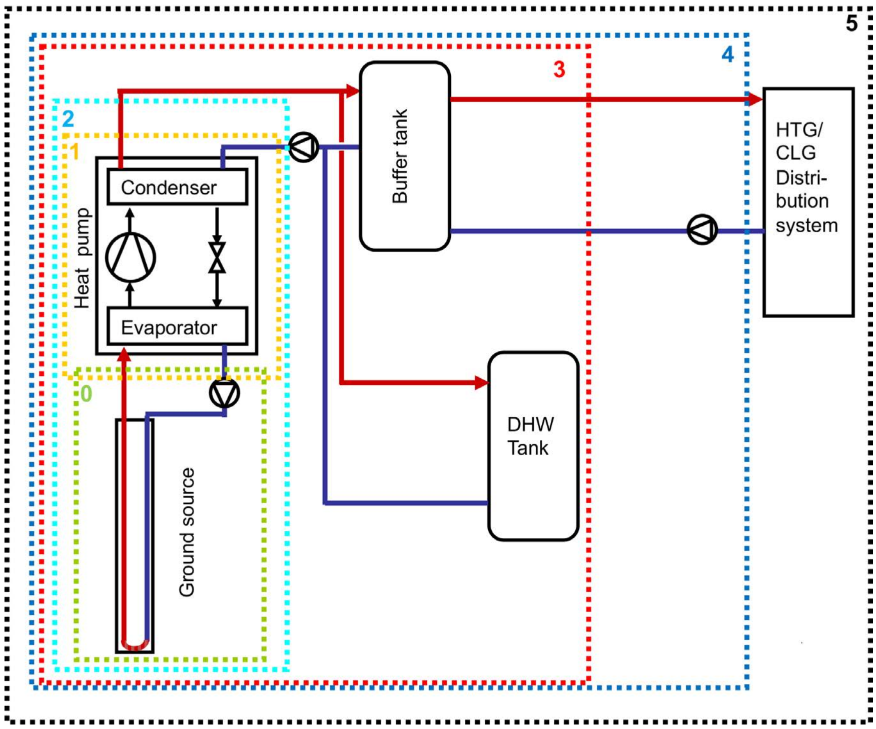


*Fig. 1: Proposed Annex 52 system boundary schema. Auxiliary heating and cooling could be added at any boundary level, which will then be indicated with a "+" superscript. From Gehlin and Spitler (2020).*

The starting point for performance analysis of the Annex 52 case studies was the system boundary schema developed within the EU project SEPEMO. Published in 2012 (Nordman 2012) this schema was primarily developed for non-complex residential heat pump systems, not specifically GSHPs, and is today used for SPF calculations of ground, air and water source heat pumps in the EU renewable energy directive. When applied to the case studies included in Annex 52 it soon becomes evident that the SEPEMO boundary schema used for SPF calculation is insufficient for covering the complex nature of large-scale GSHP systems. The performance literature review revealed that there are at least five other similar schemas published in the literature. However, for the most part, these schemas are, just as the SEPEMO schema, aimed at small monovalent or bivalent heat pump systems. They have limitations when accounting for the complexity of larger GHSP systems used in commercial, institutional and multi-family residential buildings such as in Annex 52 (Table 1). Hence, one necessary step within Annex 52 has been to develop a system boundary schema for calculation of system performance factors that can handle complex large-scale GSHP systems.

The Annex 52 group has now proposed a new system boundary schema, consisting of six defined boundaries and an indicator for use of supplemental heating or cooling (Figure 1). The system boundary schema may

*Table 1: SPF system boundaries in literature. From Spitler and Gehlin (2019)*

| | | **Heat pump** | **CP & fans on source-side** | **Auxiliary heating** | **CP & fans on load-side (between HP & BT)** | **CP & fans on load-side (between BT & building heat distribution system)** | **Fan coil unit fans** | **Supplementary Cooling** | **Notes** |
|---|---|---|---|---|---|---|---|---|---|
| SEPEMO (Nordman 2012) | H1 | X | | | | | | | No boundary at the buffer tank. |
| | H2 | X | X | | | | | | |
| | H3 | X | X | X | | | | | |
| | H4 | X | X | X | X | X | | | |
| | C1 | X | | | | | | | |
| | C2 | X | X | | | | | | |
| | C3 | X | X | | X | X | | | |
| | C4 | X | X | | X | X | | X | |
| Winiger, et al. (2013) | I | | X | | | | | | Applies to both heating and cooling; supplementary cooling not accounted for. |
| | II | X | X | | | | | | |
| | III | X | X | X | | | | | |
| | IV | X | X | X | X | X | | | |
| GroundMed (Mendrinos,D. Karytsas, C., 2016). | I | X | | | | | | | Heating, cooling defined with same scheme. Supplementary heating, cooling are not treated. |
| | II | X | X | | | | | | |
| | III | X | X | | X | X | | | |
| | IV | X | X | | X | X | X | | |
| Miara et al. (2011) | 0 | X | | | | | | | Only defined for heating. Buffer tanks for space heating and for DHW not included. |
| | 1 | X | X | | | | | | |
| | 2 | X | X | X | | | | | |
| | 3 | X | X | X | X | | | | |
| VDI 4650 (2016) | 1 | X | | | | | | | Only defined for heating. |
| | 2 | | X | | | | | | |
| | 3 | X | X | X | | | | | |
| | 4 | X | X | X | X | X | | | |
| Koenigsdorff (2011) | a' | X | | | | | | | Only defined for heating. *Including buffer tank for space heating, but not for DHW **Including buffer tanks for space heating and for DHW with in-built electric heater. |
| | a" | | X | | | | | | |
| | b | X | X | X | | | | | |
| | c | X | X | X | X* | | | | |
| | d | X | X | X | X** | | | | |
| | e | X | X | X | X | X | | | |
| | f | X | X | X | X | X | X | | |

be used for seasonal performance factors (SPF), shorter time intervals, e.g. daily, monthly (DPF, MPF), or binned performance factors (BPF). The system boundary schema is an extension of the SEPEMO schema, such that every SEPEMO boundary matches one of the Annex 52 boundaries (Table 2). The proposed schema is now being tested on the 40 included case studies within Annex 52.

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## Annex website

http://heatpumpingtechnologies.org/annex52/

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

*Table 2: System boundary schema comparison of the SEPEMO scheme and the proposed Annex 52 schema for SPF and COP. (Mapping corresponds with having auxiliary heating (H) or cooling (C) only at the same levels as SEPEMO. For the proposed schema, the "+" superscript indicates auxiliary heating/cooling within the boundary). From Gehlin and Spitler (2020).*

# ANNEX 56 — INTERNET OF THINGS FOR HEAT PUMPS

**Introduction**

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

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

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

**Objectives**

The Annex focuses on opportunities and challenges of IoT-enabled heat pumps. Connected devices will play a major role in the future, addressing multiple aims, such as increased comfort for the user, reduction in energy consumption and decarbonization of heat supply. The results of the Annex will be disseminated to relevant target groups, such as component manufacturers, heat pump manufacturers, associations and regulatory authorities, by means of tailored messages.

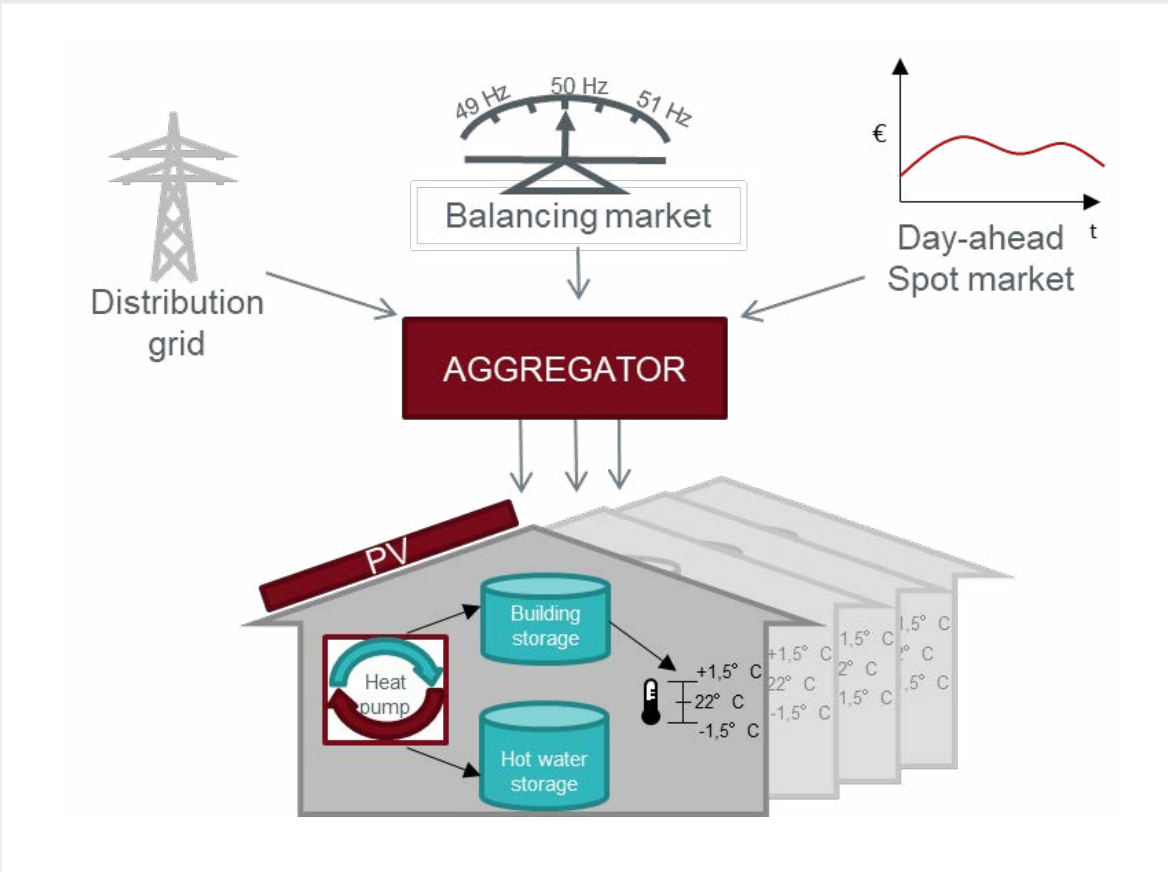


*Fig. 1: Different levels a heat pump can be part of the Internet of Things (source: AIT Austrian Institute of Technology GmbH)*

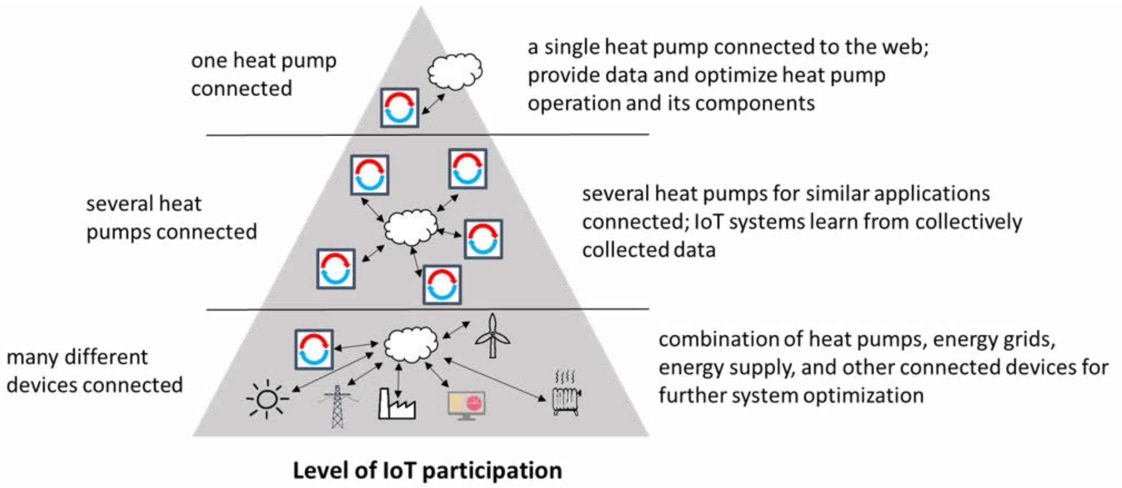


*Fig. 2: A pool of connected heat pumps participating on the energy market (source: Tara Esterl, Johanna Spreitzhofer, AIT Austrian Institute of Technology GmbH)*

The Annex will thereby

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

**Overview of Tasks**

*Task 1 - State of the Art*
This task aims at reviewing the status of currently available IoT-enabled heat pumps, heat pump components and related services. A common glossary for the most important digitalization topics will be compiled.

*Task 2 – Interfaces*
Identify requirements for data acquisition from new built and already implemented heat pump systems, considering types of signals, protocols and platforms for buildings and industry applications and related privacy issues and ongoing standardization activities.

*Task 3 – Data analysis*
Evaluate data analysis methods and applications (digital twins) for one or many heat pumps and sensors. Including machine learning, semantic models, Building Information Modeling (BIM) and soft sensors.

*Task 4 – Services*
Evaluate market opportunities created by IoT-connected heat pump devices and identify success factors and further demands to software and hardware infrastructure.

*Task 5 – Dissemination*
This task aims at reporting results and disseminating information developed in the Annex.

**Annex website**
http://heatpumpingtechnologies.org/annex56/

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# Market Report: Japan

**Hideaki Maeyama, Heat Pump & Thermal Storage Technology Center of Japan (HPTCJ), Japan**

**This article describes trends in the shipments of room air conditioners, commercial air conditioners, and domestic heat pump water heaters, which are typical products in the Japanese heat pump market, over the past 20 years. Recent product technology trends are also described. In addition, the trends in use of industrial heat pumps is overviewed based upon information obtained from HPT Annex 48 activities. Finally, the role of heat pumps in Japan's energy conservation policy and the direction of technology developments by sector in energy conservation technology development strategies are described.**



## Introduction

Japanese heat pumps have evolved as products that correspond to the Japanese climate, housing style, and lifestyle. There is growing use of room air conditioners that individually air-condition each room and can be used for heating and cooling, heat pump water heaters (Eco-Cute) using $CO_2$ refrigerant that can store hot water at high temperatures, and multi air conditioners for buildings that can be connected to many indoor units. In industrial use, the spread of industrial heat pumps is promoted by the energy conservation measures of the Agency for Natural Resources and Energy of the Ministry of Economy, Trade and Industry, and future growth can be expected.

## Japan's climate and heat pumps

Figure 1 shows the monthly average, maximum and minimum temperatures in Tokyo. The maximum summer temperature is about 32 °C and the minimum winter temperature is about 2 °C. A heat pump can be used for both cooling and heating, and a high COP can be secured in both uses. Therefore, room air conditioners that heat and cool have been developed and commercialized for a long time, and air conditioners for both cooling and heating became mainstream in the 1980s. In addition, as a technology to compensate for the imbalance between cooling and heating capacities, a variable speed technology for the compressor using an inverter, electronic expansion valve and optimal system control has been continuously developed. It is also applied to other heat pump products.

## Market trends and features of each product

Representative heat pump products in Japan are described below. They include room air conditioners, commercial air conditioners, domestic heat pump water heaters and industrial heat pumps.

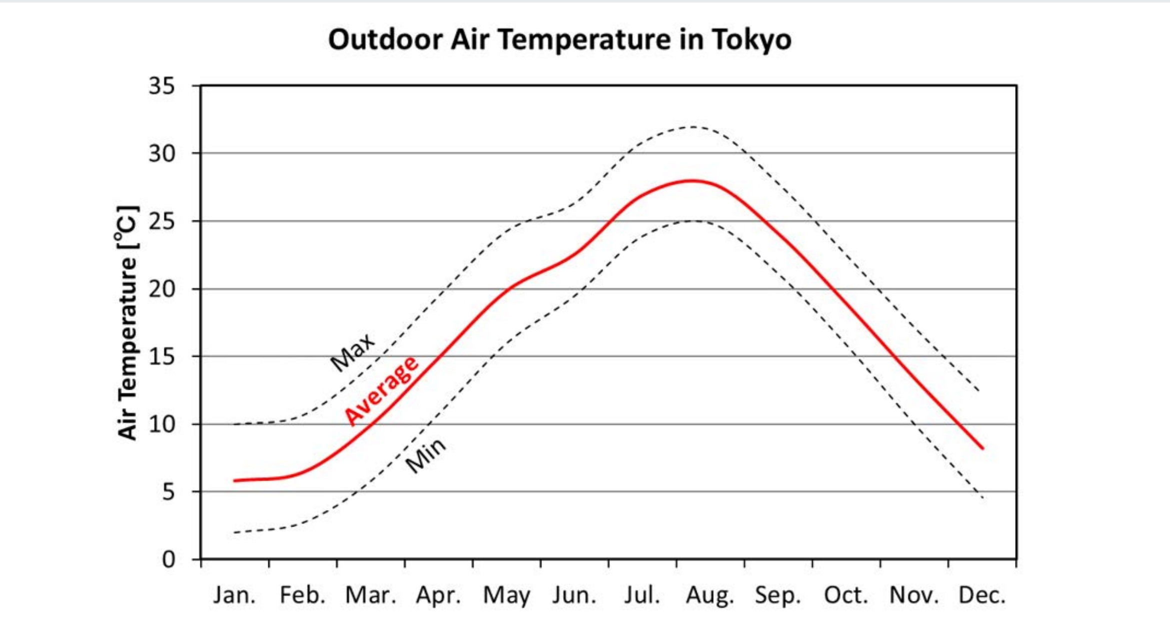


*Fig. 1: Outdoor Air Temperature in Tokyo (Average of 2009–2018). Source: Aggregate JMA data [1]*

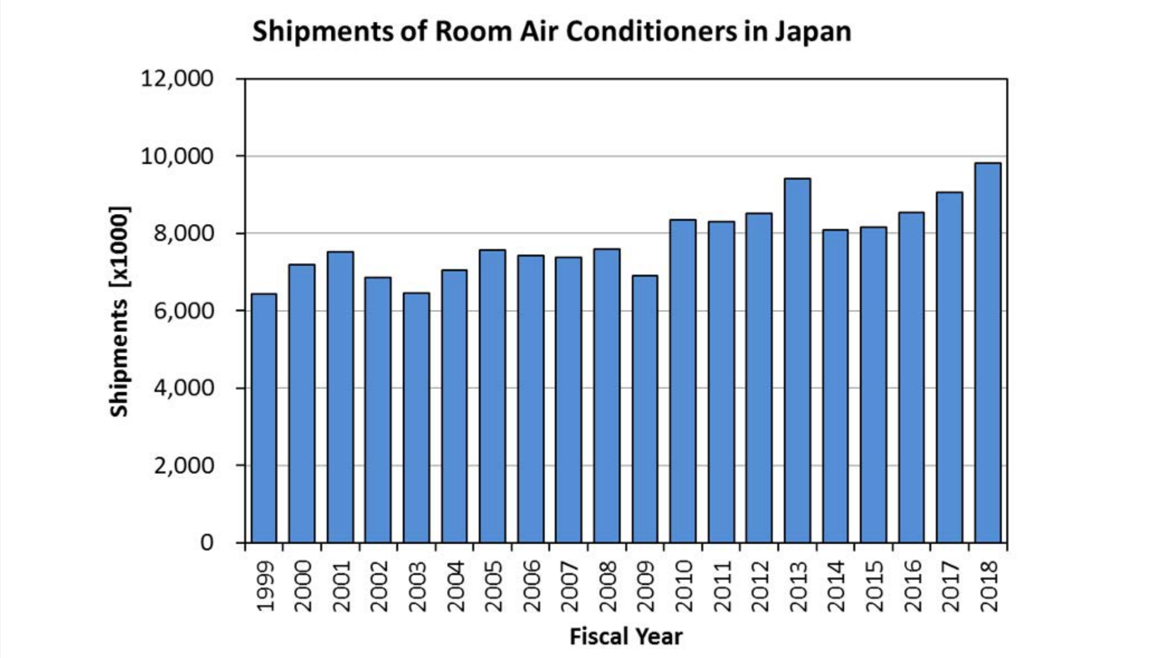


*Fig. 2: Shipments of Room Air Conditioners in Japan. Source: Aggregated from JRAIA statistical data [3]*

## Room air conditioners

According to a survey conducted by the Statistics Bureau of the Ministry of Internal Affairs and Communications in 2014[2], the room air conditioner penetration rate in Japan was 90%, and the number of units owned per 1,000 households was 2,723 units. About half of the households have more than 3 room air conditioners (households of 2 or more people). The number of room air conditioners shipped is 9.8 million units per year (2018), as shown in Figure 2, and continues to rise moderately.

Since Japanese room air conditioners are often installed in each room after a house is built, separate units that do not affect the building during installation work and wall-mounted indoor units that do not affect the room layout are the mainstream.

The power consumption of room air conditioners has decreased significantly, due to the effects of the energy-saving Top Runner Program started in 1999. Power consumption has improved significantly between 1999 and 2009. However, the amount of improvement has slowed down during the last ten years. As for refrigerants, the conventional R410A was updated to R32, with one-third of the GWP value, from 2011 to 2013.

In addition to performance improvements, additional functions are also advanced. For example, some humidity controls have a function of dehumidifying without lowering the room temperature and a non-supply water humidifying function of absorbing moisture from the outside air to humidify the room. Also, many air conditioners have an air purifying function. In addition to the function of automatically cleaning the filter, a function of automatically cleaning the inside of the air conditioner has also been developed. Technology that detects people in the room and saves electricity by heating and cooling the necessary area only, and blowing technology that individually controls comfort, are also progressing. In terms of operability, the application of IoT technology has enabled remote operation with mobile phones.

## Commercial air conditioners

Figure 3 shows the shipment volume of commercial air conditioners. Overall shipments declined after peaking at 1,050,000 units per year in 1991, and have been almost flat at around 800,000 units since 2011. By application, VRF building multi air conditioners have been increasing since 2000, and have been doubling over about 20 years.

R32 refrigerant has been introduced in commercial air conditioners since around 2014, following its introduction in room air conditioners. Commercial air conditioners use more refrigerant than room air conditioners, so there are more issues in applying mildly flammable R32 refrigerant, but the use of R32 refrigerant started sequentially from small-capacity models, and R32 had been adopted in about half of commercial air conditioners by 2017.

## Domestic heat pump water heaters

As shown in Figure 4, shipments of heat pump water heaters have increased significantly since their release in 2001. Shipments reached 570,000 units per year in 2010, but decreased after the Great East Japan Earthquake in 2011. In 2015, the downward trend bottomed out and shipments increased again, and recently recovered to 480,000 units in fiscal year 2018 (1 April 2018 to 31 March 2019; FY2018). Total shipments reached 6.39 million units at the end of FY2018. The target for FY2030 is a total of 14 million units.

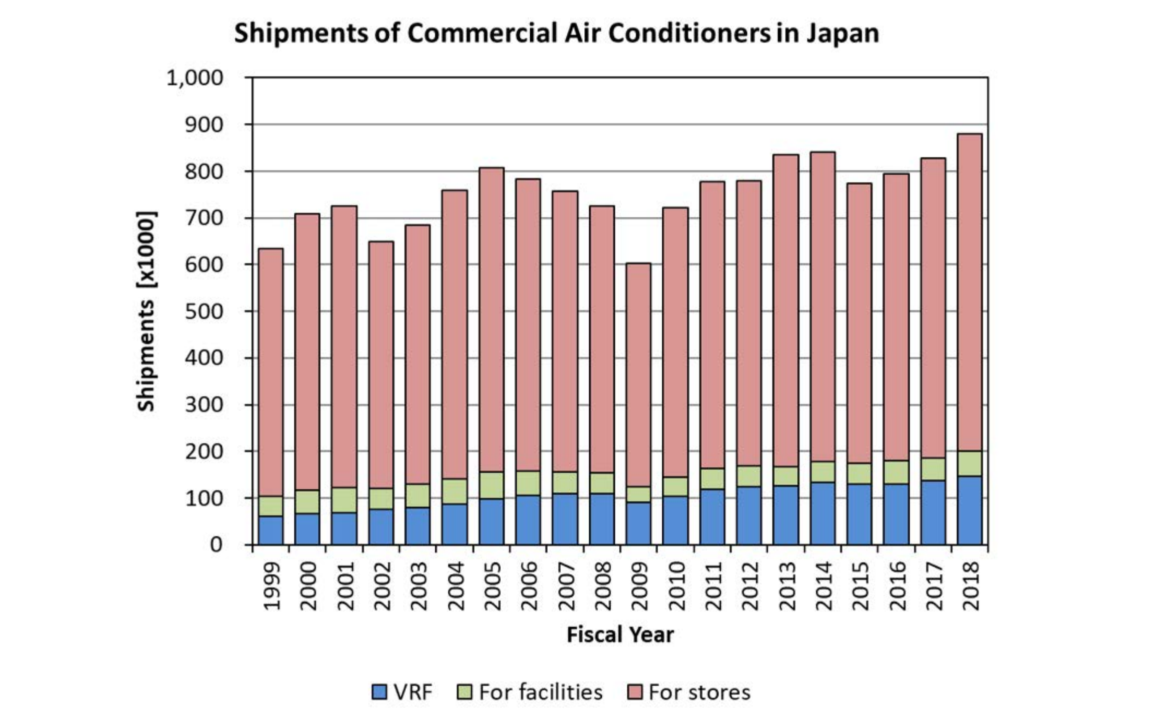


*Fig. 3: Shipments of Commercial Air Conditioners in Japan. Source: Aggregated from JRAIA statistical data [3]*

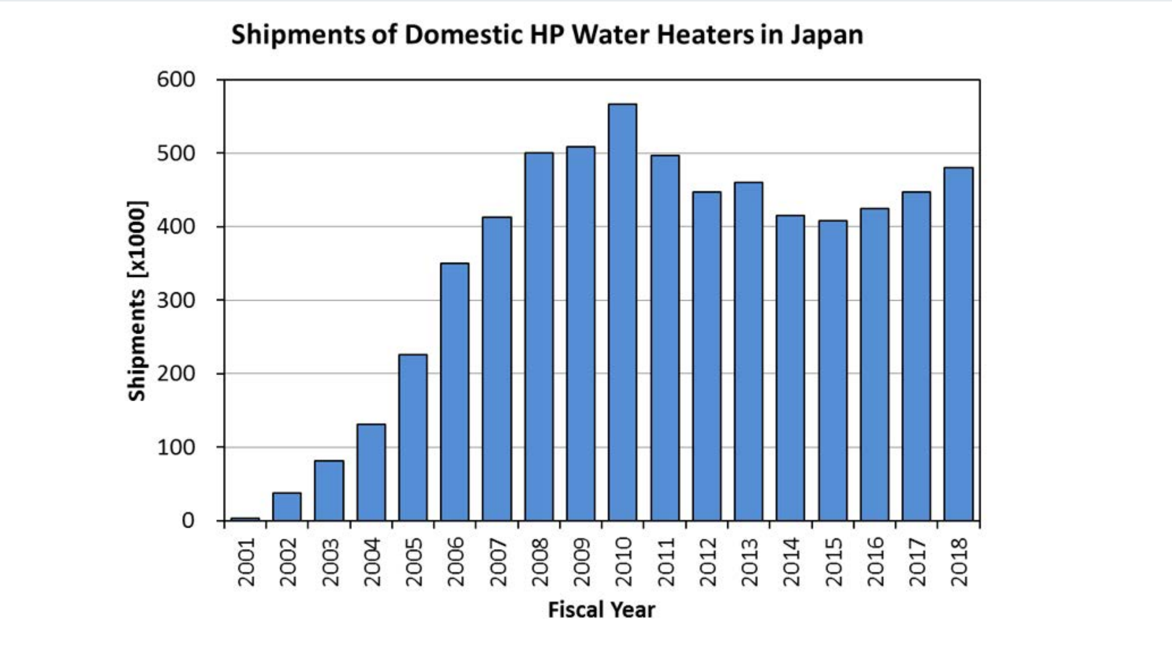


*Fig. 4: Shipments of Domestic Heat Pump Water Heaters in Japan. Source: Aggregated from JRAIA statistical data [3]*

Domestic heat pump water heaters have used natural $CO_2$ refrigerants since the initial product launch in 2001. $CO_2$, which has a lower critical temperature than conventional HFCs, has good performance for a single-pass temperature-rise heating operation that increases the temperature of the feedwater up to a high degree in one rush, and high-temperature hot water can be obtained. In Japan, $CO_2$ heat pumps that can store hot water (65 °C to 90 °C) are suitable because of the large amount of hot water used in bathtubs, and due to the fact that there are many soft-water areas and scaling due to mineral precipitation is unlikely to grow even at high temperatures. In addition, the inverter and control technologies developed for room air conditioners realize stable tapping temperature control even within a temperature increase range of 50 to 80 °C.

In addition to performance improvements, functions that improve convenience have been introduced. Examples include a technology that uses microbubbles to improve the effectiveness of hot baths in bathtubs, as well as functions to clean piping using microbubbles, to increase shower pressure and to suppress the growth of bacteria in bathtubs using silver ions.

## Industrial heat pumps

Industrial heat pumps have various applications, with a large span of temperatures. It is difficult to obtain statistics using specific indicators. As a result of a trial calculation in 2015 at the Heat Pump and Thermal Storage Technology Center of Japan [4] it was found that out of a total industrial boiler heating heat of 1,530 TJ (terajoules), about 440 TJ may be output by heat pumps.

At the current state of industrial heat pumps, the application of industrial heat pumps collected during the continuous efforts of IEA HPT Annex 48 [5] can be summarized as follows.

In Japan, industrial heat pumps are mainly used as equipment in production factories, and are applied to food, machinery, chemicals, electronics, agriculture/fisheries, and paper manufacturing in descending order of the number of applications. As for heat sources, air heat sources and simultaneous heating/cooling dual-use technology each occupy approximately one-third of the market. R410A, $CO_2$, and R134a dominate the refrigerants used. As an introduction result, the average primary energy reduction rate of the collected cases is 42% and the average $CO_2$ reduction rate is 49%, which indicates that there has been a great effect. Although the necessary supply temperature varies depending on the field and application, there are heat pumps that can generate steam at a maximum of about 120 °C.

## Energy conservation policy and impact on heat pumps

In the energy conservation measures formulated by the Agency for Natural Resources and Energy of the Ministry of Economy, Trade and Industry, the target for energy conservation measures in FY2030 is set to 50.3 million $m^3$ crude oil equivalent compared to 2013.

Specific measures related to heat pumps include the introduction of high-efficiency air conditioning and industrial HP (heating and drying) in the industrial sector, the introduction of commercial water heaters and refrigerant management technology in the commercial sector, and the introduction of high-efficiency water heaters and the improvement of energy-saving performance of equipment by the Top Runner Program in the household sector.

In the energy-saving technology strategy, "next-generation heat pump systems" are positioned as a cross-sectional technology strategy for each sector of industry, domestic, commercial and transportation. The direction of heat pump development by sector has been proposed. As individual technology for each sector, higher efficiency of heat pumps and development of new refrigerants are promoted. By sector, the development of exhaust heat utilization systems and high-temperature heat pumps are being promoted in the industrial sector. In the domestic and commercial sectors, the performance of component device improvements, demand control and response functions, and equipment and systems for new refrigerants are being promoted. In the transportation sector, development of heat pumps for next-generation automobiles is being promoted.

## Conclusions

Room air conditioners are improving year by year in terms of performance and functions as products suitable for the Japanese climate and form of housing. Shipments in 2018 have reached 9.8 million units and continue to grow moderately.

Commercial air conditioner shipments are around 800,000 units and are almost flat in quantity. In terms of applications, the building multi type has grown, and shipments have doubled over the past 20 years.

Domestic heat pump water heater shipments have reached 480,000 units (2018) and have been increasing since 2015. They are also listed in the Ministry of Economy, Trade and Industry's energy-saving policy, targeting a total of 14 million units in 2030.

Industrial heat pumps have the potential to produce heat pump output as high as 440 TJ as replacements for industrial boilers, and have application examples in industries such as food, machinery, chemistry, electronics, agriculture/fisheries, and paper manufacturing. They are listed in the Ministry of Economy, Trade and Industry's energy conservation policy, and future growth can be expected.

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# Annex 47: Heat Pumps in District Heating and Cooling Systems

**Svend Pedersen, Denmark**

**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 in 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.**



## District heating replaces fossil fuels

Annex 47, which looks into the aspects of heat pumps in district heating systems, has been an important annex under the IEA Heat Pumping Technologies program, since gradually more countries realize that district heating is a way to phase out fossil fuels.

## Initiating a new Annex

The project group consists of members from Austria, Denmark, Sweden, Switzerland, and United Kingdom, and during the project period the interest for heat pumps in district heating has grown in other countries. Consequently, a new annex has been initiated which looks into the "Flexibility by implementation of heat pump in multi-vector energy systems and thermal networks".

Annex 47, which started in 2016, is now finalized, and all the reports and case studies are available at [https://heatpumpingtechnologies.org/annex47](https://heatpumpingtechnologies.org/annex47).

## Large-scale heat pumps show great potential

The Heat Roadmap Europe 4 (HRE4) project showed that for the vast majority of European urban areas, district heating (DH) is a cost-efficient solution, which can provide at least half of the total heat demand in the 14 countries included in the study, while efficiently reducing $CO_2$ emissions and the primary energy demand of the heating and cooling sector (see Figure 1). Based on the results, the project also suggests that large-scale heat pumps (HP) should play a large role in future DH systems in order to develop flexible and supply-safe systems.

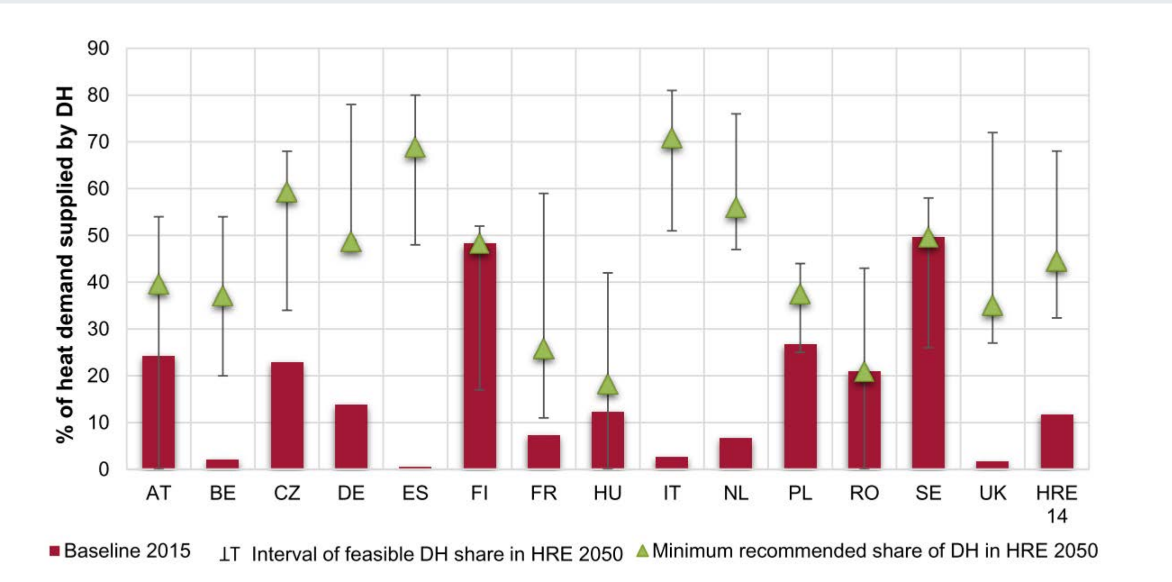


*Fig. 1: Share of district heating in 2015 (Baseline 2015), recommended level of district heating share in Heat Roadmap Europe 2050, and the range of economically feasible district heating within a 0.5% total annual energy system cost change sensitivity.*

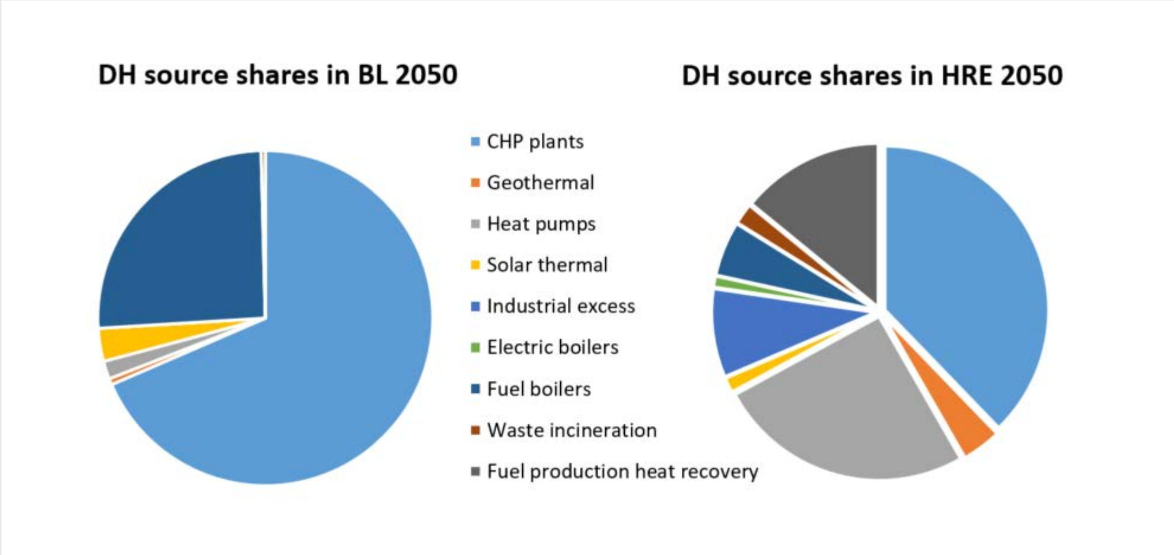


*Fig. 2: District heating sources share for BL 2050 and HRE 2050 scenarios.*

According to the HRE4 project, the European share of DH in the heating sector should increase from 12% (current values) to 50% by 2050. This is an important shift in the European heating sector, and it shows that DH can be cost-effective and essential to significantly reduce $CO_2$ emissions in the energy sector.

Three main scenarios were developed in the HRE4 project (see Figure 2):

» BL 2015 – baseline scenario representing the current situation of the heating and cooling sector, based on data from 2015.

» BL 2050 – this scenario represents the development of the baseline scenario under the current agreed policies regarding savings and RES, etc., but without any additional measures to improve the decarbonisation of the system.

» HRE 2050 – scenario representing a highly-decarbonised energy system with a redesigned heating and cooling sector, which also includes energy savings. This scenario is solely based on proven technologies and does not depend on unsustainable amounts of bioenergy.

In the modelled energy efficiency scenario for 2050 (HRE 2050), DH is supplied mostly by decarbonised energy sources, and 25% of the total DH demand is met by large-scale HPs. This scenario would bring a higher variety of energy supply to the DH, which will increase the flexibility of the system, as well as the security of supply. The HRE 2050 scenario shows that it would be possible to achieve a much more decarbonized DH in 2050 than in the BL 2050 scenario, reducing $CO_2$ emissions by more than 70%.

## An attractive alternative

One of the main objectives of Annex 47 is to show the possibilities regarding the implementation and integration of heat pumps in district heating grids. Thus, one aim was to create an ideas catalogue, which shows different implementation cases. 39 different cases have been described where heat pumps are integrated in a district heating grid.

Research shows that large heat pumps have been integrated in the district heating networks since the 1980's, especially in the Scandinavian regions. The widespread use of district heating networks and the increasing share of fluctuating power sources such as photo voltaic (PV) and wind power, combined with decreasing electricity prices have been the driving factors, especially in Denmark. Currently, Sweden is a forerunner using heat pumps in district heating and cooling networks. Approximately 7% of the district heating demand is produced by heat pumps.

In other countries, the heat pump market consists mainly of devices for the supply of single and multi-family houses. Due to high system temperatures prevailing in many of the heating networks, adapted concepts are needed in order to be able to guarantee the cost-effectiveness of the systems. The aim of current research projects such, as fit4power2heat, is therefore to establish heat pumps by participating in various energy markets as an attractive alternative. In the last few years, many efforts have been initiated all over Europe to foster heat pump integration in district heating and cooling (DHC) networks.

## Creating a sustainable system

The basis for economical operation is the correct design and hydraulic integration of the systems. Advantages can be achieved through different modes of operation. Instead of monovalent operation, additional heat generator(s) for peak load times can save a large part of the investment costs and risks.

Different circuit options can be used in order to achieve optimum operation of the system. Depending on which framework conditions exist, it is possible to exploit considerable potentials in terms of efficiency and costs. The correct design of the heat source system and the heat sink plays as much of a role as the dimensioning of the heat pump itself.

As a first clue, AIT internally developed an Excel-based tool, which can be used to pre-estimate feasibility and cost-effectiveness. With the help of simple calculations and by comparing them to already realized plants, first conclusions can be drawn. The more detailed information about the planned project, the more accurate the initial assessment can be. Through the conversion into Excel by means of VBA, and the database integrated in the tool as well as the user interface, the calculations can be carried out relatively easily and without prior knowledge of special software. The quick and easy adaptation of the underlying database is, therefore, also guaranteed.

In addition to the electrically driven compression heat pumps, thermally driven heat pumps are used as well. Depending on the field of application, the advantages of the different technologies can be used.

## Best practice strategies

With reference to the results achieved by the investigations mentioned above, the importance and contributions of heat pumps in district heating networks were pointed out, and recommendations for "best practice" strategies for the operation of heat pumps in combination with a central storage unit were presented, see Figure 3:

- » heat pumps with dynamic pricing and demand-side management (DSM) are more resilient to market risks as dynamic operation counteracts fluctuations in fuel and electricity prices;
- » heat pumps increase the flexibility of district heating systems by expanding the heat generation portfolio, which enables higher reactivity through fast commissioning and low start-up costs as well as takes advantage of the volatility of the electricity market and thermal batteries;
- » heat pumps can be used to increase renewable heat generation. In addition, low-temperature heat sources and alternative heat sources (e.g., waste heat) can be used.

## Implementation barriers, possibilities, and solutions

District heating networks are essential for the future energy system, especially in urban areas. The integration of heat pumps can reduce investment risks in DH networks, increase supply security, reduce $CO_2$ emissions and thus contribute to the COP 21 objectives agreed on in Paris. At present, heat pumps play a minor role in European district heating networks.

Barriers to the large-scale integration of heat pumps are, e.g. the lack of heat sources (often only available in small decentralized quantities) or a low temperature level of the sources (low efficiency). Similarly, most operators (still) have a lack of experience regarding the integration and operation of heat pumps in existing district heating systems compared to well-known biomass or gas-based generation units.

Another barrier is the high temperature of the existing heat networks which reduces the heat pump's efficiency. Furthermore, the high temperatures of these networks


*Fig. 3: Task cases. All the cases can be found at https://heatpumpingtechnologies.org/annex47.*

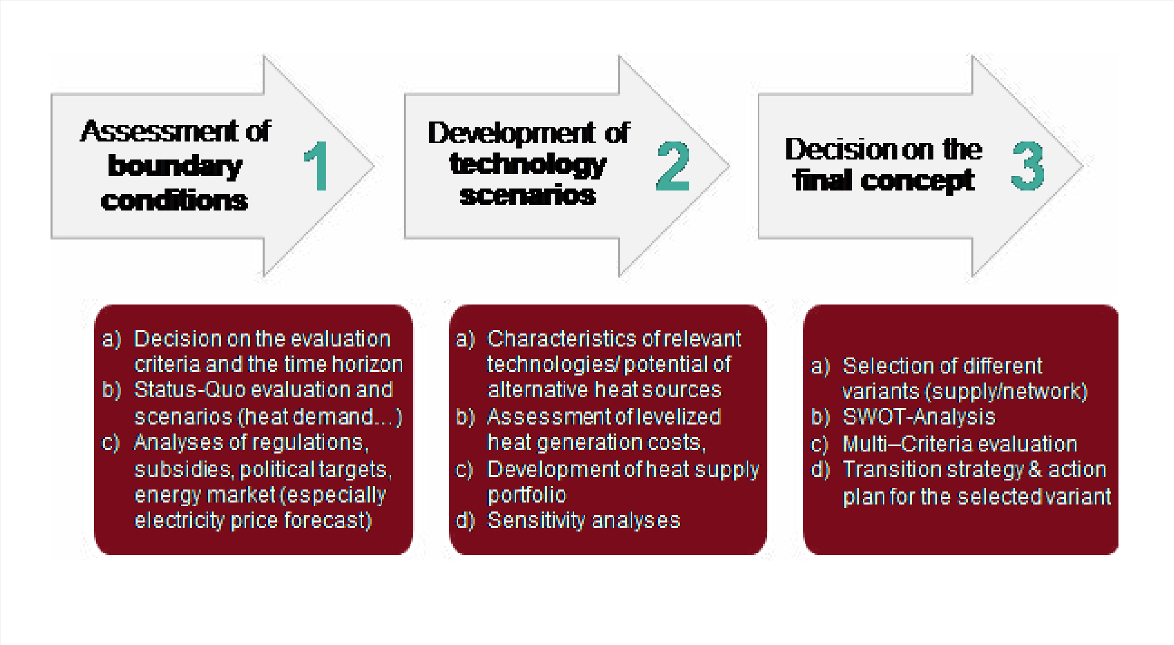


*Fig. 4: Three phases for the development of a heat supply strategy (Source: AIT).*

lead to large heat losses especially in residential buildings, which make heat networks almost unsustainable in very energy- efficient buildings. Thus, low temperature networks implementation would help to increase the use of heat pumps in these networks.

## An opening for R&D projects

Nevertheless, in recent years there has been greater acceptance of heat pumps among district heating operators. This has led to many innovative heat pump projects. The optimum combination of heat generation plants in DH networks depends on the various parameters and is correspondingly individual for each network. A method for the development of sustainable heat supply concepts for district heating networks consists of three phases as shown in Figure 4.

To achieve a sustainable heat supply which includes a significant proportion of alternative heat sources, the implementation of more demonstration sites is necessary. The success factors are:

» Strong partners
(companies, institutes, start-ups, etc.)

» Projects (demo, best practice, show up experiences and motivation to install HPs)

» Learning by doing (requires pioneers who are willing to "pay their dues ")

» Energy spatial planning (localizing waste heat, avoiding double infrastructure)

» Standardized solutions (R&D, cost degression/ economy of scale)

» Price signals (to the use of fossil fuel; reduce the burden from tax and levy on clean energy)

## A key technology in future district heating

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 the $CO_2$ emissions can be reduced with more than 70% compared to the current situation.

Heat pumps can be a key technology in the future district heating grid in different ways:

1. Heat pumps can act as a balancing technology when the electrical production fluctuates.

2. Heat pumps phase out fossil fuels from the energy system.

3. Heat pumps make it possible to use very low (below 60 °C) and ultra-low (below 45 °C) temperatures in the district heating grid.

4. Heat pumps make it possible to minimize grid losses in the district heating grid.

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# Grid Flexible Control of Heat Pumps

**Markus Lindahl, Sweden**

**Within the EU project Flexible Heat and Power (FHP), RISE Research Institutes of Sweden has, together with the other project partners, evaluated the possibilities and limitations for external control of today's and tomorrow's heat pumps. This in order to control the power consumption, as well as providing demand response. Both indirect control, via temperature sensor override, and direct control of the compressor speed has been evaluated by laboratory tests of a ground source heat pump. Direct control gives the best accuracy, while indirect control works on more or less all heat pumps.**



## Introduction

The European power system is undergoing a major transformation driven by a steadily increasing share of power from renewable intermittent energy sources, such as wind and sun. Heat pumps, with their possibility to convert power to heat, can support the transformation of the power system. Making use of the building's thermal inertia in combination with controlling the heat pump´s power consumption makes it possible to also provide demand response.

The EU project Flexible Heat and Power (FHP) was completed during fall 2019, and included partners from seven different research institutes and companies in Europe. RISE Research Institutes of Sweden has, together with the other project partners, evaluated the possibilities and limitations for external control of today's and tomorrow's heat pumps, with focus on space heating of buildings. By external control of the heat pumps and their power consumption, demand response can be offered to the power grid. The term "demand response" includes controlling the power consumption to better match the consumption with the power supply. Demand response can be used to avoid power peaks, balance the power consumption, avoiding curtailment of power production from intermittent renewable sources, etc. The aim of the FHP-project is to use demand response to secure that electricity from intermittent, renewable sources, such as wind and sun, can be used. In the FHP project this is done by making dynamic clusters of heat pumps, giving higher flexibility when controlled together.

## The Flexible Heat and Power project

Within the FHP project, the demand response possibilities of heat pumps have been investigated. The benefit with heat pumps, when it comes to demand response, is their possibility to transform power to heat. In combination with the thermal inertia in buildings, or thermal storages, it gives a possibility to control, within certain limits, when the building needs to be heated and still maintain a good indoor climate. By controlling the power consumption of the heat pump, it is possible to help balancing the power systems variations in supply and demand. However, controlling the power output from a single heat pump gives low flexibility to the grid, so in order to provide a useful scale of demand response, a coalition of heat pumps needs to be controlled. In order to do this in an efficient and functional way, several steps are needed.

The first step is to calculate the available thermal flexibility from the individual buildings. This is done by dynamic thermal models, calibrated with data from existing buildings, using machine learning. The models are used to create a plan, a so called "Flex Graph", including when and how much power the heat pump will need for heating the building. It also shows available flexibility for heating. The "Flex Graphs" for each individual building are sent to a central "Dynamic Coalition Manager" used for gathering the available flexibility for a number of heat pumps in a community or a neighbourhood. The aggregated plan can for example be used in collaboration with the local Distribution System Operator (DSO) in order to avoid local grid problems or in cooperation with the Balance Responsible Party (BRP) to offering balancing services. Finally, the selected control of the heat pump coalition will be disaggregated and dispatched to the individual heat pumps, where the contribution from each single heat pump, most probably, will vary over time, based on the local situation at the moment. This is done by an iterative process made by a distributed optimization algorithm called ADMM.

## Control of heat pumps

One important step in the chain to provide demand response is to be able to control the heat pump based on external signals in order to make the heat pump use the amount of electricity asked for, in this case the power consumption "negotiated" by the ADMM-algorithm. The heat pumps on the market today are developed to give high comfort with as high efficiency as possible. External control of a heat pump can be divided into two main categories, direct or indirect control. Within the FHP project RISE has tested both of these possibilities on a ground source heat pump. The aim was to evaluate different strategies for external control and to give recommendations regarding the best way to control a grid flexible heat pump.

## Indirect control

The heating demand of a building is dependent on the outdoor temperature and a heat pump is programmed to adjust its heat production based on the outdoor temperature. Most heat pumps are equipped with an outdoor temperature sensor, giving information about current temperate, used to estimate the heating demand of the building. A lower outdoor temperature gives a higher heating demand, which causes the inverter heat pump to increase its compressor speed and thereby the heat production, and the power consumption will increase. At low winter temperatures, the backup heater may need to start in order to cover the total heating demand of the building. Manipulating the temperature sensor and sending a fake outdoor temperature to the heat pump is a possible way to indirect control the heat pump's heat production and power demand. An alternative way to control the heat pump indirectly is to adjust the heat pump's heating curve. In the tests related to this project the outdoor temperature sensor was replaced with an adjustable precision potentiometer and thereby it was possible to manually set the outdoor temperature desired.

## Direct control

During direct control the heat pump's ordinary, internal control, which sets the compressor speed and switches between space heating and production of domestic hot water, is bypassed, and the compressor is controlled directly. This makes it possible to control the heat pump's power consumption quicker and with better accuracy. To make this work, it is necessary that the heat pump is prepared for external control and that it is possible to communicate with it. No heat pump on the market has this functionality today.

During the laboratory tests at RISE with direct control, a program developed by the heat pump manufacturer of the tested heat pump was used. The program is normally used for internal testing by the manufacturer. Via a computer connected to the heat pump, the program makes it possible to set the compressor frequency directly. As a complement to the program, RISE developed an add-on which makes it possible to create a test sequence that automatically changes the compressor speed at desired times, making it easier to test longer sequences with varying compressor speed or to make fast changes.

## Test cycle for grid-flexible heat pumps

In order to standardise testing and evaluate the control of a grid-flexible heat pump, an eight-hour test cycle for laboratory testing was developed. The purpose with the test cycle is partly to evaluate how close the heat pump in combination with the external control manages to follow a specified test profile, and partly to test if the heat pump control manages to handle a number of functions, such as start and stop or varying the compressor speed, see Figure 1.

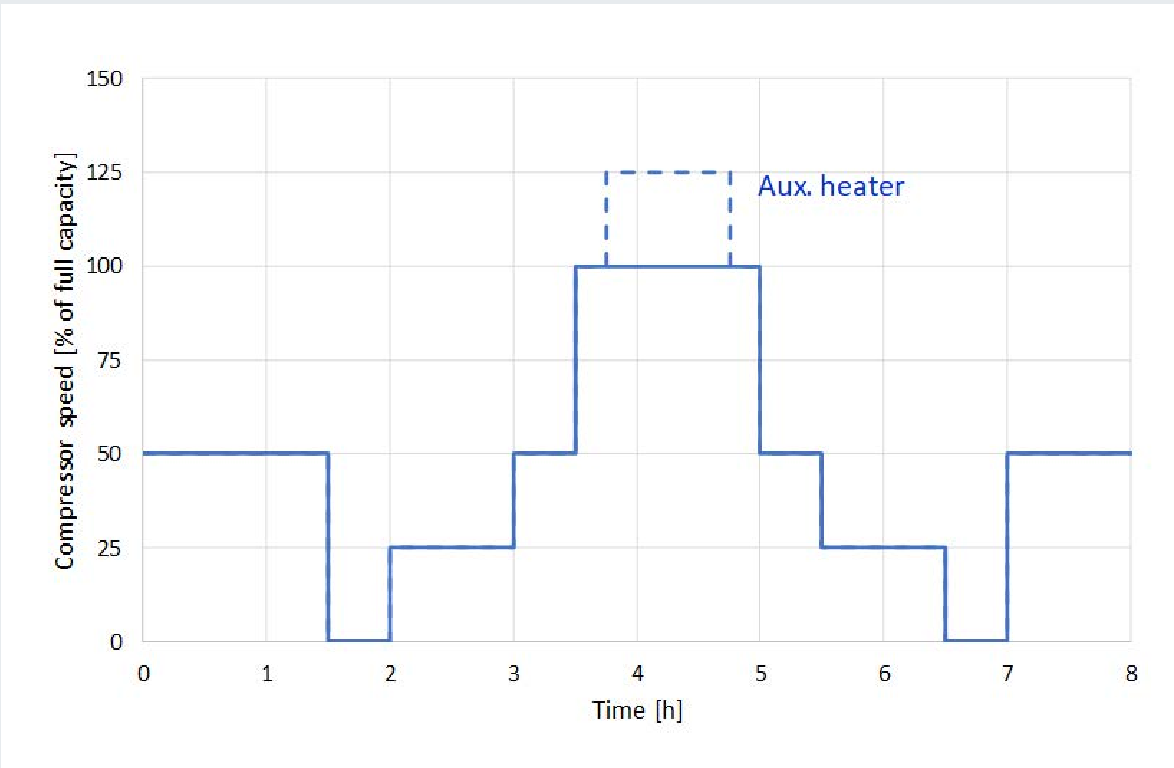


*Fig. 1: Test cycle for evaluation of a grid flexible heat pump*

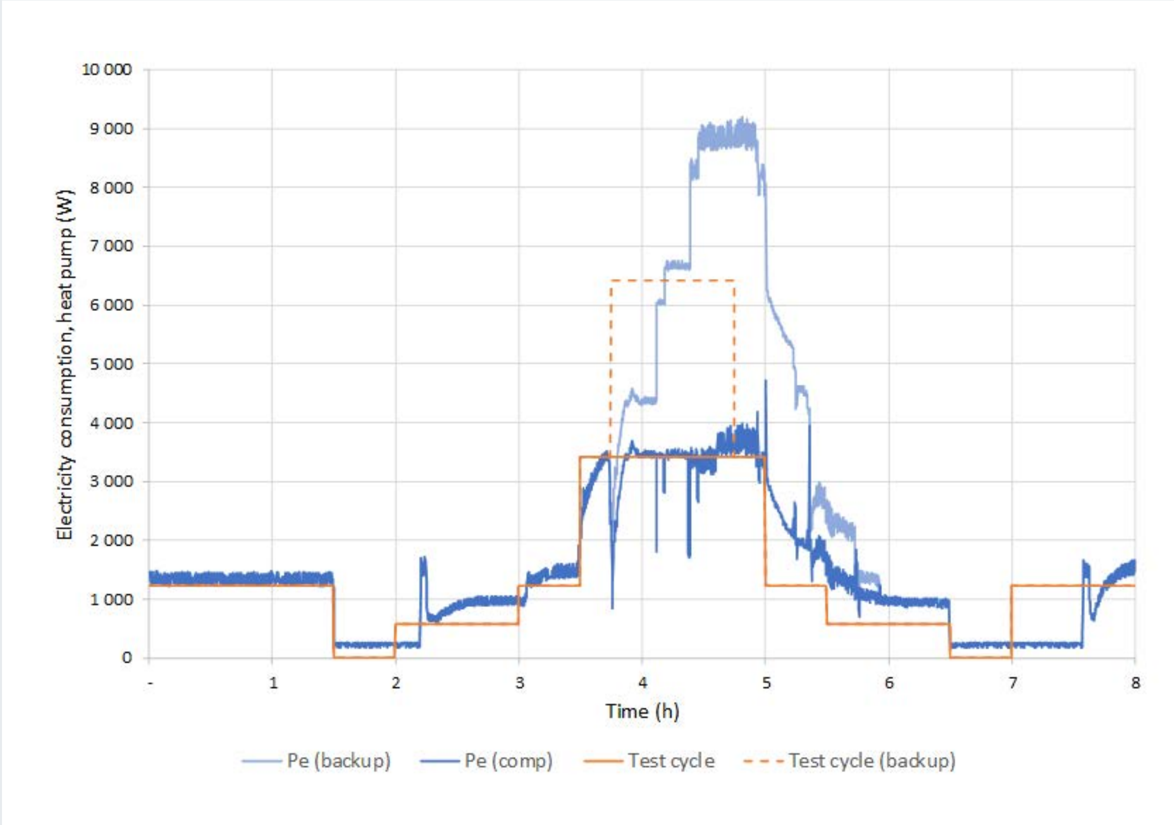


*Fig. 2: Test results, indirect control of the heat pump*

In Figure 2 the results for indirect control is shown, focusing on the power consumption. The results from the test shows that it is possible to follow changes in the test cycle by manipulating the outdoor temperature sensor. The heat pump cannot follow the test cycle in detail, but the general trend is followed relatively well, especially focusing on the control of the compressor without the backup heater. In average, the part load of the compressor deviates with 370 W from the test cycle and during 64% of the time the deviation from the test cycle is within ±10%. A self-learning algorithm can probably improve the agreement with the test cycle further.

Direct control of the heat pump's compressor speed, and thereby its power consumption, gives better possibilities to control the heat pump in detail. The results from the laboratory test with direct control of the compressor shows that it is possible to follow the test cycle with very high accuracy, see Figure 3. However, the tested version of the program for direct control has no functionality for controlling the backup heater, and thus the backup heater could not be started during the test. The power consumption of the compressor is on the average 100 W from the values of the test cycle, and for 97% of the time the heat pump is within ±10%.

The laboratory tests show that the COP often is affected negatively by the active external control; exactly how much the COP decreases depends on the shape of the profile. The lower COP value can be explained by the fact that the heat pump is forced to operate at less optimal conditions in order to provide demand response. In laboratory tests based on other load profiles and using direct control we have seen that the COP decreases with 0-10%, depending on the shape of the profile. For the test cycle described above, the COP decreased with 11% with direct control and with 13% with indirect control, focusing on the operation of the compressor. In real installations, the decrease in COP may be higher, since the test rig cannot fully simulate a real heat pump installation. If the profile forces the heat pump to start the backup heater, the efficiency will decrease significantly. In a practical context, the reduction in COP would have to be compensated by cost savings and service incentive earnings resulting from the demand response control.

## Conclusions and recommendations for external control

To be able to overrule the internal control and instead control the heat pump externally, the heat pumps of today need an individually tailor-made solution for each model. In order to get a general solution for external control, a standardised way to externally control the heat pump needs to be part of the manufacturers' standard protocol, as a complement to the internal control, based on temperature. For the future, direct control of the heat pump will give the best option to an accurate control of the heat pump's power consumption. To make this happen, the heat pump control system needs to be updated, to make it easier to use it for demand response. This

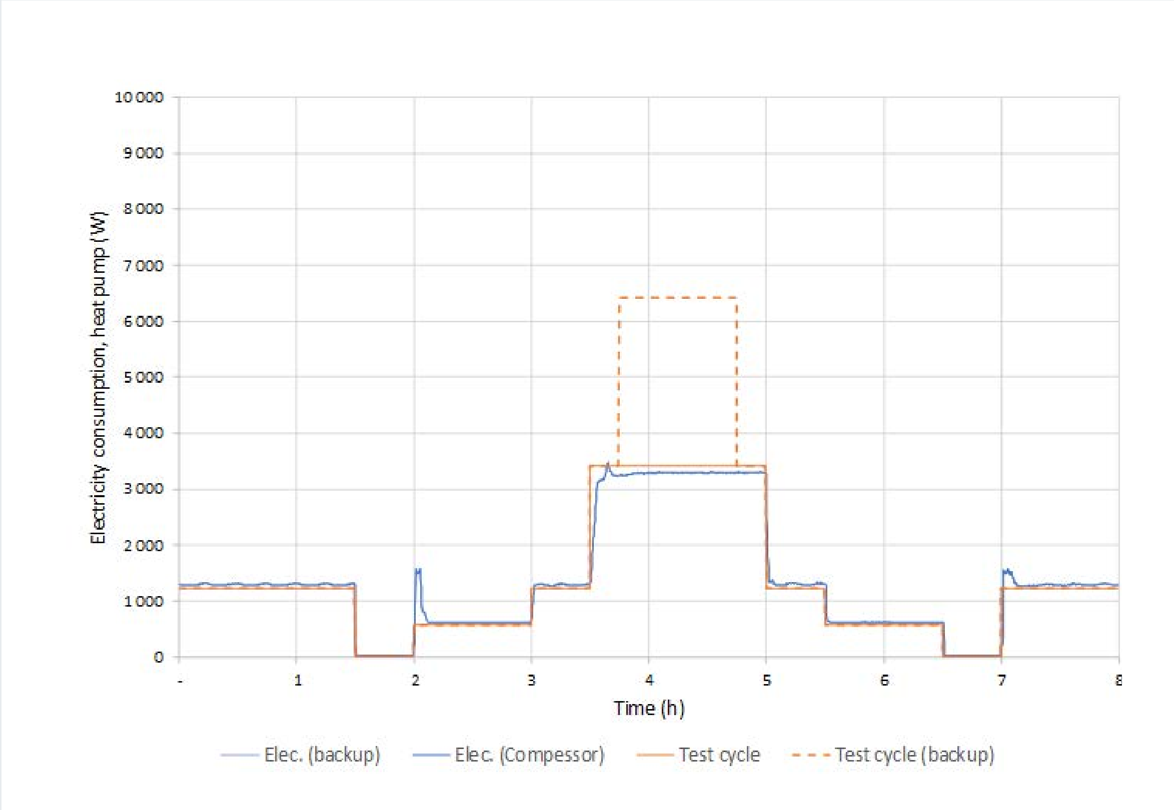


*Fig. 3: Test results, direct control of heat pump*

solution is, at least partly, in the hands of the heat pump manufacturers. From a strategic point of view, with all the external control, the heat pump alone will no longer have the full control of the indoor climate.

If there is a need to control heat pumps that are already installed, it is recommended to use indirect control by manipulating the temperature sensor. The benefit is that the solution will work on almost all heat pump models, both old and new. The downside is partly that the control will not have the same accuracy as with direct control, and partly that there is a need for an installation on site for each heat pump, to make it possible to take over the outdoor temperature sensor. An alternative in order to avoid an expensive installation can be to work with indirect control by actively changing the heating curve or similar by a web-API. Many premium heat pumps sold today give the owner the possibility to control the heat pump from a distance, for example via an app, a feature that may be used for controlling the heat pump without any installations of equipment at each individual heat pump.

## Acknowledgments
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# Events 2020/2021

**Any updates about the situation regarding the Corona virus have been added, as of 6 April 2020. Please closely check the info of any Conference you plan to attend.**

## 2020

**7-11 June**
**9th International Conference on Caloric Cooling and Applications of Caloric Materials (Thermag IX)**
College Park, Maryland, USA
**https://www.ashrae.org/File%20Library/Conferences/ASHRAE%20Endorsed%20Conferences/DRAFT_Thermag2020-3_VA1_Redlined.pdf**

**27 June – 1 July**
**ASHRAE Annual Conference**
Austin, Texas, USA
**https://www.ashrae.org/conferences/2020-annual-conference-austin-texas**

Will be replaced by a Virtual Conference. See https://www.ashrae.org/conferences/ashrae-2020-virtual-conference

**1-3 July**
**Asian Conference on Refrigeration and Air-conditioning**
Hangzhou, China
**https://10times.com/acra-hangzhou**

**1-3 July**
**8th Iberian-American Congress of Refrigeration Science and Technology (CYTEF 2020)**
Pamplona, Spain
**http://www.unavarra.es/cytef2020/?languageId=1**

**13-16 July**
**Purdue International Compressor Engineering, Refrigeration & AC, High Performance Buildings Conferences**
West Lafayette, Indiana, USA
**https://engineering.purdue.edu/Herrick/Conferences/2020**

**26-29 July**
**IIR Rankine 2020 Conference – Advances in Cooling, Heating and Power Generation**
Glasgow, United Kingdom
**https://ior.org.uk/rankine2020**

This conference is planned to be held at the original dates. However, that may change, so please check at https://ior.org.uk/events/rankine2020/covid

**12-14 August**
**2020 Building Performance Analysis Conference & Simbuild**
Chicago, Illinois, USA
**https://www.ashrae.org/conferences/topical-conferences/2020-building-performance-analysis-conference-simbuild**

**16-21 August**
**2020 Summer Study on Energy Efficiency in Buildings**
Pacific Grove, California, USA
**https://aceee.org/conferences/2020/ssb**

Please follow the situation at https://www.aceee.org/2020-summer-study-energy-efficiency-buildings

**2-4 September**
**Compressors 2020 – 10th International Conference on Compressors and Coolants**
Slovak University of Technology
**https://szchkt.org/a/conf/event_dates/49?locale=en_GB**

**8-10 September**
**IRENA Innovation Week 2020**
Bonn, Germany
**https://www.irena.org/events/2020/Sep/IRENA-Innovation-Week-2020**

**14-15 September**
**Engineering Buildings, Systems and Environments for Effective Operation**
Glasgow, UK
**https://www.cibse.org/symposium**

**14-16 September**
**Indoor Environmental Quality Performance Approaches - Transitioning from IAQ to IEQ**
Athens, Greece
**https://www.ashrae.org/conferences/topical-conferences/indoor-environmental-quality-performance-approaches**

**21-24 September**
**13$^{th}$ IEA Heat Pump Conference 2020**
Jeju, South Korea
**http://hpc2020.org/**

**28-30 September**
**ATMOsphere America 2020**
Dallas, Texas, USA
**http://r744.com/events/view/http_www_atmo_org_events_details_php_eventid_83**

**1-2 October**
**The Fourth International Conference on Efficient Building Design**
Beirut, Lebanon
**https://www.ashrae.org/conferences/topical-conferences/the-fourth-international-conference-on-efficient-building-design**

**13-14 October**
**BuildSim Nordic 2020 Conference**
Oslo, Norway
**http://www.ibpsa-nordic.org/index.html**

**6-9 December**
**14th IIR-Gustav Lorentzen Conference on Natural Refrigerants (GL 2020)**
Kyoto, Japan
**https://biz.knt.co.jp/tour/2020/12/gl2020/program.html**

**10-11 December**
**International Symposium on New Refrigerants and Environmental Technology 2020**
Kobe, Japan
**https://jraia-symposium.org/Kobe2020/en/index.php**

## 2021

**10-12 January**
**Climamed 2020**
Lisbon, Portugal
**http://www.climamed.org/en/**

**23-27 January**
**ASHRAE Winter Conference**
Chicago, Illinois, USA
**https://www.ashrae.org/conferences/2021-winter-conference-chicago**

**IN THE NEXT ISSUE**
Heat pumps for the retrofit and renovation markets
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**International Energy Agency**
The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an International Energy Programme. A basic aim of the IEA is to foster co-operation among its participating countries, to increase energy security through energy conservation, development of alternative energy sources, new energy technology and research and development.

**Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP)**
International collaboration for energy efficient heating, refrigeration, and air-conditioning.

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

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

**Mission**
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.

**Heat Pump Centre**
A central role within the HPT TCP is played by the Heat Pump Centre (HPC). The HPC contributes to the general aim of the HPT TCP, through information exchange and promotion. In the member countries, activities are coordinated by National Teams. For further information on HPC products and activities, or for general enquiries on heat pumps and the HPT TCP, contact your National Team at: www.heatpumpingtechnologies.org/contact-us/

The Heat Pump Centre is operated by RISE Research Institutes of Sweden.


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