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Heat Pumping Technologies MAGAZINE

A HEAT PUMP CENTRE PRODUCT

Heat Pumps in District Heating and Cooling Energy Grids

"FURTHER INNOVATION IS POSSIBLE BY COMBINING MOBILITY, POWER AND HEAT IN A 5TH GENERATION LOW-TEMPERATURE AMBIENT LOOP"

GREENSCIES AND THE FUTURE OF LOW-CARBON DISTRICT HEAT NETWORKS

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MAGAZINE

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In This Issue

Welcome, dear readers, to the vibrant and insightful third edition of Heat Pumping Technologies Magazine. In this issue, we embark on an exciting exploration of the cutting-edge domain of "Heat Pumps in District Heating and Cooling Energy Grids."

Our journey takes us through the intricate tapestry of district energy systems, unraveling the innovative role that heat pumps play in reshaping the way we heat and cool our communities. From urban centers buzzing with life to the peaceful neighborhoods of suburbia, we uncover the transformative potential of heat pumps in our everyday lives.

Titled Empowering Communities: GreenSCIES and the Future of Low-Carbon District Heat Networks, our Foreword section sets the stage for a deep dive into the world of sustainable energy solutions. It illuminates the path toward greener practices, guiding us toward a future where heat pumps are not just a choice but a transformative necessity in the face of climate change urgency.

In our Column section, we explore the intriguing concept that “The colder the climate, the easier it is to sell heat pumps,” shedding light on the strategic nuances that drive the success story of Finland’s adoption of heat pumps in diverse environments.

From uncovering the multidimensional aspects to navigating the challenges and seizing the opportunities, the articles featured in this issue will be your guide. As we traverse the landscape of energy efficiency and sustainable solutions, let this edition serve as a beacon, illuminating the potential of heat pumps as cornerstones in the realm of district heating and cooling.

Thank you for joining us on this enlightening journey. Together, let’s explore, learn, and pave the way towards a greener, more sustainable future.

Enjoy your reading!

Metkel Yebiyo, Editor
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Empowering Communities: GreenSCIES and the Future of Low-Carbon District Heat Networks

In the UK, decarbonising the heat sector will be crucial if the UK climate change goals are to be met by 2050. These hard-to-abate emissions are significant; heating buildings represent half of all energy consumed, and a third of emissions are from heating homes (BEIS, 2021). The huge challenge is that around 85% of UK households are currently heated by Natural Gas (ESC, 2020). In addition, the global energy crisis has created a major cost of living issue, which will have the greatest impact on vulnerable groups in society with the least resources to adapt.

District Heat networks can help to make low-carbon energy available at an affordable cost and a solid level of energy security. The UK Government believe that developing the market for low-carbon heat networks will be a no-regrets action. In recognition of the UK's Climate Change Committee's recommendation for around 18% of UK heat to come from heat networks by 2050 as part of a least-cost pathway to meeting net-zero[1]. These networks will benefit strongly from the UK's intention to decarbonise the electricity grid by 2035[2]. There are also legacy Gas CHP (Combined Heat and Power) systems which are coming to the end of their life and need to be replaced with new heat pump technology ready for electrification. This is an exciting time as the role of heat pumps take centre stage, and we all need to support the upskilling and training of the work-force to deliver this low-carbon energy transition.

Many innovation opportunities are being explored as we transition to a low-carbon energy system. The GreenSCIES Research Project[3], explored an innovative social and technical solution to meet the objective of decarbonising buildings in urban areas. This project was led by London South Bank University and funded by InnovateUK. The research investigated a novel smart local energy system (SLES), a district heat network that can deliver low-carbon heat by recovering waste heat in urban areas and integrating mobility (electric vehicles) and renewable power into the system.

Further innovation is possible by combining mobility, power and heat in a 5th generation low-temperature ambient loop as it enables whole energy systems to decarbonise in a cost-effective manner. Central to the GreenSCIES approach is the concept of widespread sharing of energy resources and, in particular, heat. In London, as part of our research, London South Bank University have identified >39 TWh of recoverable urban heat from many sources, including data centres, substations, supermarkets, wastewater treatment plants, etc., and this is sufficient to decarbonise >60% of the heating and hot water demand.

The uptake of smart local energy systems like GreenSCIES provides widespread opportunities to decarbonise urban areas. The availability of waste heat is significant in many countries. However, we recognise that the design of district scheme will need to be developed to meet the local needs. The potential scale is huge but will require community engagement, financing, skills and a resourced supply chain, and we have set up the GreenSCIES Centre of Excellence in the UK to develop and exploit. International collaboration and exchange of knowledge will be vital as we go forward together to a low-carbon energy future, and we would be delighted to work with the IEA Heat Pumping Technologies TCP industrial and academic community to progress.

Kristina Roszynski, Catarina Marques, Henrique Lagoeiro and Graeme Maidment
The GreenSCIES Centre of Excellence, London South Bank University

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2. https://www.gov.uk/government/news/plans-unveiled-to-decarbonise-uk-power-system-by-2035
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The Colder the Climate, the Easier it is to Sell Heat Pumps

We often hear the claim that heat pumps do not work in cold conditions. However, if you look at the statistics, the situation seems quite the opposite. Europe's coldest countries – Finland, Sweden and Norway – sell by far the most heat pumps per capita or in proportion to the number of households. In 2023, for example, 6 heat pumps were sold per 1,000 households in Germany compared to 70 in Finland. In Europe's coldest country, Finland, 1.5 million heat pumps were sold to a population of just over 5 million, and already 8 billion euro has been invested in heat pumps. Heat pumps already provide almost 20% of heating of buildings. Similar type and level of figures are found in the neighbouring countries, Sweden and Norway.

Does the success story of Finland's heat pumps owe its existence to cold living conditions? Yes and no. Finland is territorially about the same size as Germany but has only one-fifteenth of its population. Very fortunately, building a comprehensive gas network has not been economically feasible. The solution has instead been to build a strong electricity network and district heating networks in urban areas and, to a reasonable extent, the use of oil heating. Electricity production moved to the right direction: to cost-efficient and CO_2-free hydro, nuclear and bio power. Electrification of heat first began in Finland as early as the 80s. This led to the building of approximately 0.8 million electrically heated houses in the country. Consequently, strong electricity networks were constructed. Only just over 200,000 houses had oil heating installed.

In the 90s, the situation was perfect for the launch of the heat pump success story. The technology started to be there for both air and ground source heat pumps. Heat pumps made it possible to save electricity not only in electrically heated houses but also by replacing oil heating with heat pumps and by installing heat pumps in at least new single-family houses, and why not in bigger buildings, too? As the production of district heating moved from low-cost fossil production to more expensive bio-based production, some of it started to be transferred to heat pumps at either end of district heating pipelines: either producing district heating centrally with heat pumps or by decentralised building-specific heat pumps at the other end of the pipeline. Progress has been made in all sectors and is still continuing at lightning speed. In 2022, 200,000 heat pumps were sold in Finland, and more than a billion euro was invested in them.

Supply chains and business models had to follow market development. It should be borne in mind that the heat pump itself only makes up 20–30% of the investment. Therefore, the company's profit margins, errors and successes rely on the heat pump system's delivery expertise. Heat pump investments in the Nordic countries are so profitable that state aid has not played an important role. Lessons have been learned, of course, from subsidy-related market failures, such as stop-go situations while waiting for aid and as they end and subsidies trickle into prices.

As a special Nordic feature, one might mention heat pump market sectors, which are missing completely from many countries. The amount of electricity used for heating is reduced by replacing electric heating with environmental energy captured by heat pumps. Combustion-based district heating production is replaced with heat pumps at each end of the district heating pipeline. In the Nordics, the heat pump market started already in the 90s. Approximately 5 million heat pumps have already been installed, and consequently, the third market replacement for heat pumps is quite significant.

As the technology and operation of heat pumps in cold Scandinavian conditions have not proved to be a barrier – nor much of a challenge – to their use, heating is becoming more and more heat pump-sourced, and therefore, many sequels will be written to this heat pump success story.

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Member of the Board, European Heat Pump Association EHPA
Delegate of Finland, HPT TCP by IEA

Model Predictive Control as a System Integrator in a Heat Pump-Driven District Heating Network

Jelger Jansen, Lieve Helsen, Belgium

Though often seen as distinct ways to decarbonise the (residential) heating sector, heat pumps and district heating can complement each other. Their integration is crucial for decarbonizing current and future district heating networks. However, as these integrated systems tend to become very complex, today's rule-based controllers might lead to suboptimal operation and low system efficiencies. This article shows the potential of model predictive control to increase the efficiency of a heat pump-driven district heating network at equal or better thermal comfort.

Introduction

If the European Union wants to achieve its ambitious climate goals by 2050, the decarbonization of the residential heating sector is a top priority. This goal can be achieved on the one hand by renovating the building envelopes, resulting in lower heat use. On the other hand, heat generation also needs to be done more efficiently and in a carbon-neutral way, thus preferably by using renewable energy sources and/or residual heat.

In areas with a relatively low heat demand density, decarbonization can be achieved by installing heat pumps (HPs). In the urban areas, on the other hand, district heating (DH) networks will play a significant role in the reduction of greenhouse gas emissions. Both methods can also complement each other: heat generated by one or multiple (collective) HPs can be transported via a DH network to multiple buildings and, if needed, upgraded locally to a higher temperature using a booster HP (BHP). An example of such an innovative system can be found in Bruges, Belgium.

Almshouses De Schipjes (Figure 1) is a social housing neighbourhood of twelve buildings in Bruges's historic city centre. The neighbourhood was built at the start of the 20th century and classified as heritage in 2009. In 2014, the Flemish Agency for Innovation and Entrepreneurship funded a demonstration project to deeply renovate De Schipjes with a focus on the energetic and ecological aspects. Despite the limitations set by the neighbourhood's classification as heritage, a fully-renewables-based heat supply to the buildings was achieved by the combination of a central ground-source HP (GSHP), a low-temperature DH network (so-called fourth generation DH network) and decentral BHPs.

An important aspect of such a complex thermal system is the operation: if the different components are not functioning in an efficient and collaborative manner, this might result in a significant decrease in system performance. This article shows, based on the results of a simulation study, how a model predictive controller (MPC) can act as a system integrator for the different components in the thermal system to increase global system performance. The presence of the GSHP dictates the optimal control actions taken by the MPC. The content of this article is based on the following research publications: [1,2].

Thermal network of De Schipjes

A simplified hydronic scheme of the thermal network of De Schipjes is shown in Figure 2. Heat is generated centrally by a GSHP and solar thermal collectors (STCs), each connected to a water tank (WT) of 950 litres. The area of the STCs is, however, limited to preserve the neighbourhood's classification as heritage. The temperature of WT2 is operated around 50°C and transported to the twelve buildings, where heat is extracted through the buildings' substation, consisting of a heat exchanger and a control valve (V2).

Figure 1: Almshouses De Schipjes.

Space heating (SH) in the buildings is provided by low-temperature radiators in every room and a floor heating system on the ground floor level. Since a supply temperature of 50°C in the DH system is insufficient to produce domestic hot water (DHW), a BHP feeds a small DHW tank with water at 60°C in each house.

The currently used rule-based controller (RBC) can be summarised as follows: the GSHP and BHPs are controlled in an on/off manner using a hysteresis curve. For SH within the buildings, a heating curve has been implemented. The indoor temperature setpoints are set at 21°C during the day and at 17°C at night, including a reheating period of one hour in the morning. Some variations of the RBC's control rules, in an attempt to improve the RBC's performance, are described in an article published by Jansen et al. [3]

Model predictive control

The SySi (Thermal Systems Simulation) research group, led by Professor Lieve Helsen, has over a decade of experience with MPC. The working principle of MPC is shown in Figure 3 for the operation of a building's HVAC system. To control the setpoints of the HVAC system in an optimal way, the MPC uses four crucial building blocks.

Firstly, the MPC contains a mathematical model of the real-life system called the controller model. The MPC needs to understand the effect of a specific control action on the system's operation. For example, increasing the supply temperature to the heating system will result in an increase in heating power. In addition to the controller model describing the behaviour of the system, the MPC also needs predictions. The building is subject to disturbances such as weather and occupancy behaviour,

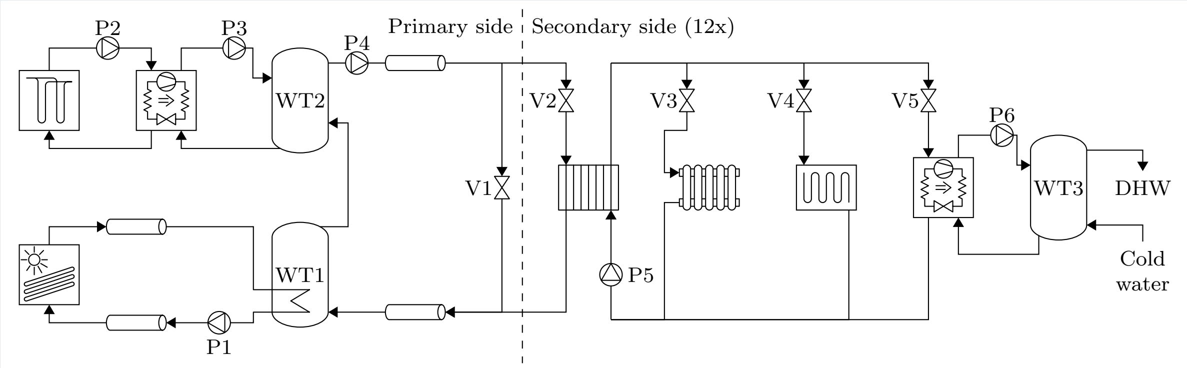

Figure 2: Simplified hydronic scheme of the thermal network of De Schipjes.

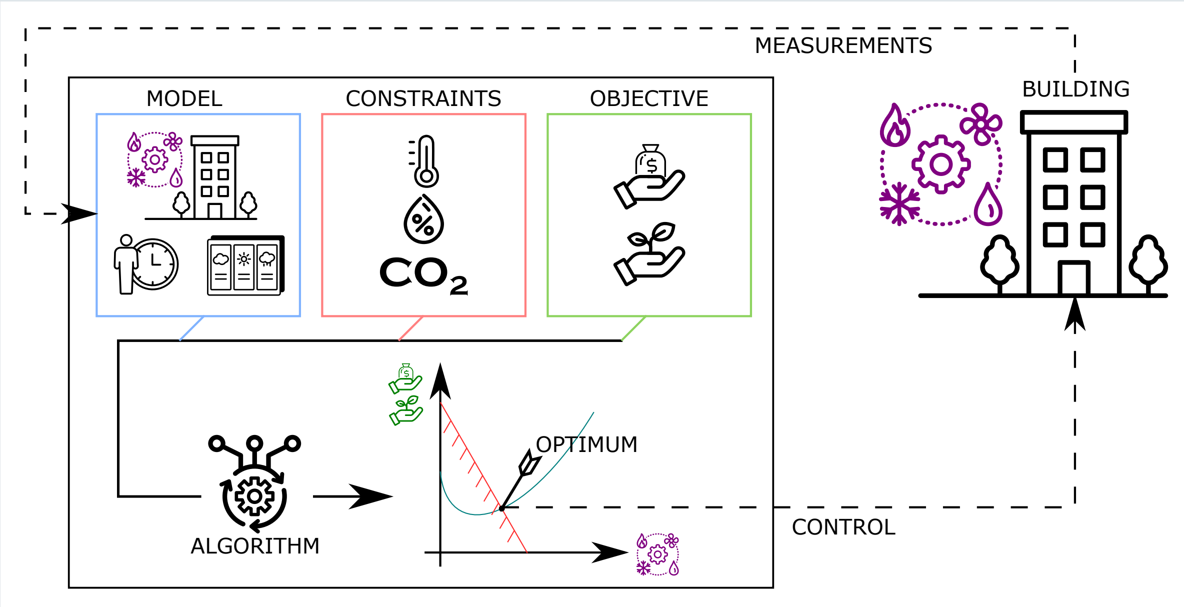

Figure 3: MPC working principle (figure used with permission of D. Picard & F. Jorissen, Builtwins BV).

which influence the temperature and air quality inside the building. This information needs to be provided to our MPC. The fact that the MPC uses both a model and predictions to determine optimal control actions also explains the name of this controller.

Secondly, the MPC must consider specific constraints that have been imposed, such as a minimum and/ or maximum indoor temperature, to ensure thermal comfort. Thirdly, the MPC has a cost function that is optimised, for example, to minimise operational costs or maximise the share of renewable energy. The information in these three building blocks – 'the model with predictions,' 'constraints,' and 'cost function' – is then used as input for an optimisation algorithm, which determines the optimal control actions for the building.

However, this scheme does not yet fully describe how an MPC operates. Another important aspect is that when determining the optimal control setpoints, their impact on the system's behaviour in the future is also considered, known as the prediction horizon (feedforward action). This strategy allows us to anticipate future events, for example, a significant change in the outdoor temperature or setpoint in the building. The optimal control actions are, therefore, determined for the entire prediction horizon. Still, only the first inputs of the first control interval are applied to the real-life system, after which the available sensors send their measurements to the MPC to update the controller model (feedback action). The optimisation is repeated for a new prediction horizon that is shifted with a one-time step.

Simulation study for De Schipjes

To compare the performance of this MPC approach for De Schipjes to the existing RBC, a simulation study was conducted. For this purpose, a detailed simulation model of the real-life DH system was developed in Modelica. Simulations were carried out with the current RBC and an MPC that minimises the electrical energy use of the entire DH system, comprising the electrical energy use of the central GSHP, decentral BHPs, and all circulation pumps while ensuring thermal comfort in the buildings.

Two simulations of three days were performed: one in winter (February 9-12) and one in spring (April 22-25). Table 1 shows the most important performance indicators: the electrical energy use of the overall system, the thermal discomfort in the buildings, the COP of the GSHP, and the average COP of all BHPs.

The values in the first two columns show that during the winter period, MPC provides significantly better thermal comfort compared to RBC using a similar amount of electrical energy (+0.4%). In the spring period, on the other hand, MPC and RBC reach the same level of thermal comfort, but the former uses 31% less electrical energy.
To better understand these results, we zoom in on some more detailed simulation results. Figure 4 shows the indoor temperature evolution in one of the buildings. During the winter period, the reheating period of one hour, included in the RBC rules, appears to be insufficient, leading to significant thermal discomfort in the morning. However, during the spring period, one hour is more than sufficient, explaining the minimal thermal discomfort in that period.

In order to reach thermal comfort in the winter period, the MPC makes use of its ability to anticipate (feedforward action): the MPC knows that it should be 21°C from 7 a.m. onwards, and since the physics of the building are partially captured in the controller model, the MPC knows when to start reheating the building. However, this is not efficient from an energy point of view, because the heat losses of the building are now higher at night due to the higher indoor temperatures. So, how can this 'remarkable' control behaviour be explained? For that, it's necessary to look at the main heat source of the system: the GSHP.

	Electrical energy use [kWh]	**Thermal discomfort [Kelvin-hour/day /building]**	**COP GSHP [-]**	**COP BHPs [-]**
Winter (9-12 February)				
RBC	506	3.81	3.93	4.19
MPC	508	0.25	4.27	3.99
Spring (22-25 April)				
RBC	110	0.03	4.06	4.10
MPC	75	0.03	4.67	3.13

Table 1: Performance indicators in the winter period and spring period for RBC and MPC.

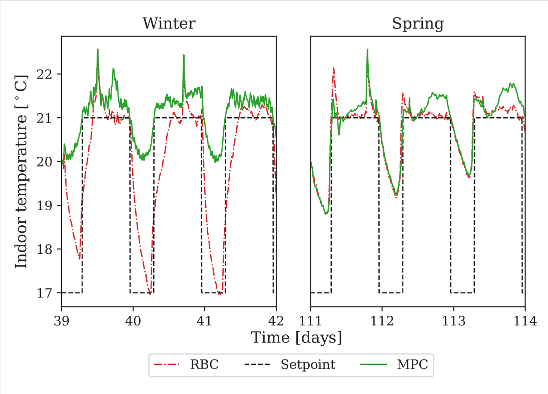

Figure 4: Indoor temperature in one of the buildings in the winter period and spring period for RBC and MPC.

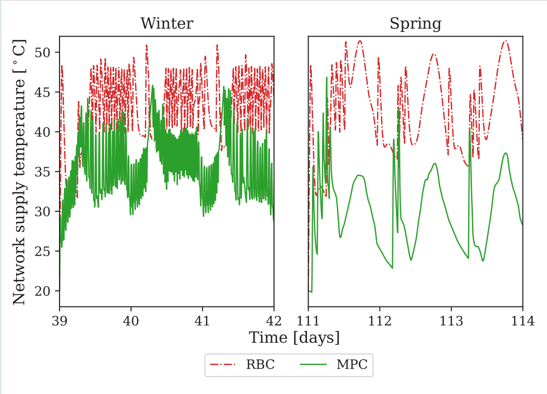

Figure 5: Network supply temperature in the winter period and spring period for RBC and MPC.

The COP of this HP depends on the temperature that needs to be generated on the condenser side, which is the DH network supply temperature for the thermal system of De Schipjes. The lower this temperature, the higher the COP will be. Figure 5 shows that the MPC aims for a significantly lower DH network supply temperature compared to the RBC. This results in a higher COP for the GSHP, as indicated by the values in column 3 of Table 1, and therefore explains the lower electrical energy use for the MPC compared to the RBC. On top of that, the lower network temperatures also lower the heat losses of the DH network pipes compared to the RBC.

However, the lower network temperature also lowers the heat emission power of the radiators and floor heating system. The only way the MPC can ensure thermal comfort in the morning is by sufficiently heating the buildings at night. Another drawback of the lower network supply temperature is a decrease in the BHPs' COP (column 4 of Table 1) due to the lower evaporator inlet temperature. However, the lower electrical energy use for MPC shows that the higher COP of the GSHP dominates the lower COP of the BHPs and higher heat losses in the buildings, both in the winter period (in which the DHW demand is about 8% of the total heat use) and in the spring period (in which the DHW demand is about 45% of the total heat use).

Conclusions

Based on the results, we can conclude that MPC outperforms RBC in terms of electrical energy use and/or thermal comfort. Three important reasons for this are:

1. *Heating the buildings at night, thereby using the flexibility provided by the thermal inertia of the building envelopes.*
2 *Reducing the network temperatures to increase the COP of the GSHP.*
3. *Using predictions to anticipate future events.*

For the DH system of De Schipjes, characterised by a central GSHP and decentral BHPs for DHW production, the COP of the GSHP appears to be dominant in the MPCs operation strategy.

In general, the use of an MPC, acting as the system integrator for the different parts of the thermal system, can lead to a significant increase in the overall system performance in multiple aspects: energy efficiency, cost, share of renewable and residual energy sources, GHG emissions.

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New Heat Pump Concept for Temperature Flexible Low-Temperature Operation Used for District Heating

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This article describes the new approach to low-temperature district heating using a new type of heat interphase unit equipped with micro-heat pumps called Flex-Booster. The system will be demonstrated in a network with about 300 consumers. The network will use plastic pipes and a heat supply from a heat pump, partly powered by solar electricity. Concept and technology are described, as well as perspective on market potential. The special focus is on the benefits and problems solved with the Flex-Booster concept vs using traditional district heating systems.

Introduction

Approximately 350,000 homes in Denmark are still heated with natural gas. To reduce the emission of greenhouse gases, these homes must be converted to CO_2-neutral heat supply as soon as possible. A new innovative heat pump concept for low-temperature (LT) district heating (DH) has been developed, focusing on temperature-flexible operation on both primary and secondary sides. It will be based on a CO_2-neutral heat supply and tested as an attractive alternative to traditional district heating solutions.

The project is co-financed by EUDP, the Danish Development and Demonstration program for Energy Technology grant number 64021-2022, "Flex Temperature DH with local co-production and use of new Flex Booster units".

The project consortium consists of METRO THERM A/S (heat pump manufacturer), COWI A/S Energy International (consulting engineers), RUBRIK (communication bureau), EBO Consult A/S (district heating administrator) & Hvidovre Fjernvarmeselskab (district heating company).

The demonstration is located in Avedøre Landsby, situated about 10 km west of Copenhagen Centre in Denmark. It consists of mainly single-family detached and terraced housing, i.e., small and medium-sized consumers of 7-14 kW plus a few larger consumers up to 72 kW design load.

New hybrid heat pump assisted district heating system

The project innovates, demonstrates, and evaluates a new hybrid district heating system on full scale for a village district with 300 consumers. The demonstration includes the full energy supply chain from production over the distribution system to end-user installations and local co-production.

The system makes use of 3 new technologies:

1) Cost-efficient temperature flexible DH heat interface unit with built-in heat pump
2) Temperature flexible operation of district heating grid called Flex-Temperature District Heating
3) Flex-Energy Central with cascade coupled heat-pump system with a boiler modified for green fuels and a PV array – all installed in an energy community sharing the benefits.

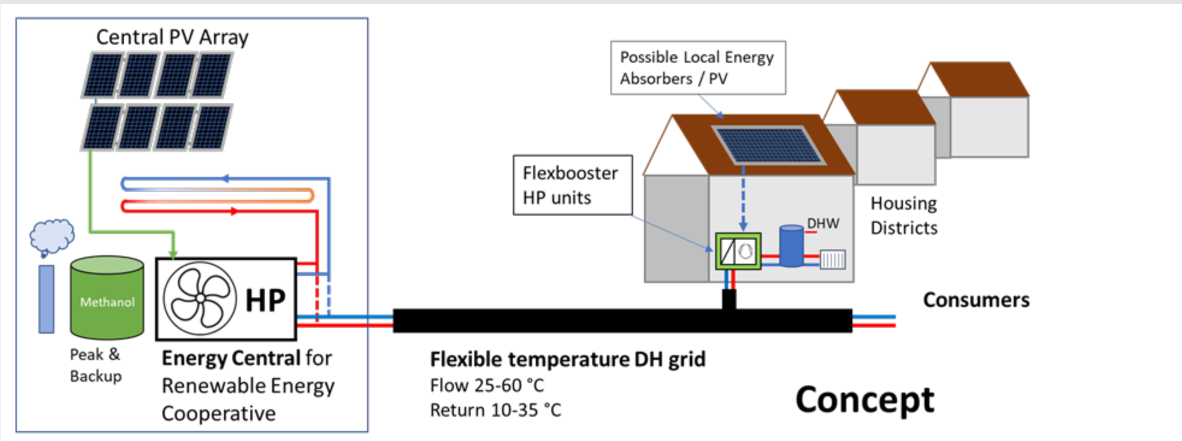

Figure 1: The new concept for temperature-flexible DH.

The purpose is to open up a wider use of 5th-generation District Heating systems in the green transition at lower cost and easier integration in existing buildings.

The purpose is also to demonstrate a zero-carbon energy system.

Low-temperature district heating areas - state-of-the-art

In recent years, DH companies have become more aware of the possibilities of lowering the temperature in the network down to the limit required for DHW production, where, in the past, they tended to run with a larger margin.

Furthermore, stronger competition in the heat market has arrived, where the main question is: “Should the future of heat supply be based on DH or decentralised heat pumps?”. However, a new vision is now emerging in the industry, which is not "either / or" but rather a "both" with an optimised interaction between the different solutions. It is this realisation that the present article sets into scene. The use of electricity from solar and wind is increasing rapidly, and the electricity supply in Denmark and other countries is now getting green with much lower CO_2 emission – and in combination with a heat pump, the CO_2 emission related to the produced heat can get very low – hence heat pumps in DH systems have become interesting.

Advantages of low-temperature and ultra-low-temperature district heating:

- Lower heat losses in pipes and systems, as the temperature difference to the surroundings is reduced.
- Lower temperature provides better opportunities to integrate renewable energy sources such as, solar heat, geothermal heat, surplus heat, condensing heat etc. The lower temperatures ensure higher efficiency in the exploitation of these resources.
- The use of low operation temperature enables the use of plastic distribution pipes, which are easier to install than steel pipes, with no need for specialised steel welders and an expected life span of over 50 years.

Disadvantages of ultra-low temperature district heating:

- Existing housing supplied with natural gas most likely has heating systems originally designed for high temperatures, e.g. 80/60°C, but often still need about 70°C supply temperature under design conditions (depending on present insulation standard), so when LTDH is supplied, there is a need of installing bigger radiators and a need of rebuilding heating systems from single string to double string systems to reduce the return temperature to an acceptable level for DH supply.
- DHW systems with hot water tanks normally need a DH supply temperature above 60-65°C or 58°C with flow through heat exchangers.

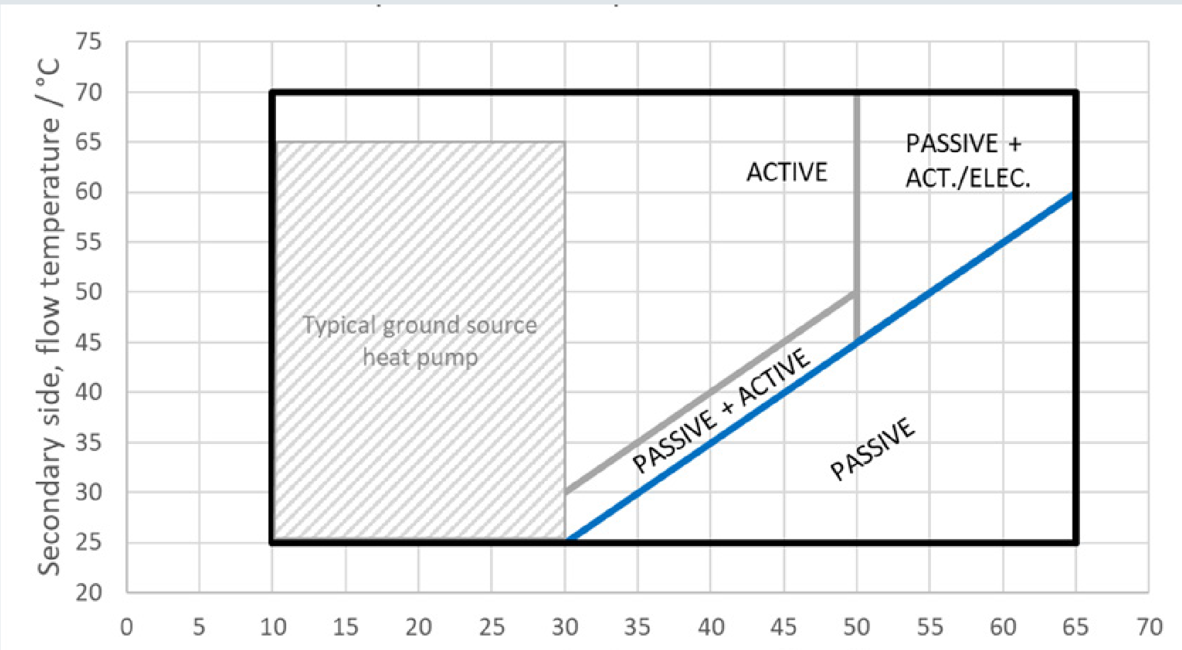

Figure 2: Operational envelope of the Flex-Booster Heat Interface Unit.

- With LTDH, the temperature difference between supply and return is often reduced, leading to bigger pipe dimensions and higher capital costs or less capacity in existing DH networks.
- The use of distributed heat pumps to boost the end-users' temperature needs normally comes with a relatively high cost when using normal ground source heat pumps, and the COP is relatively low as the evaporator temperature will be no higher than 15-20°C, as traditional heat pumps are not designed for high-temperature flexibility of the inlet temperature.

Advantages of the new flex-temperature district heating system and Flex-Booster heat interface units

- Flex temperature operation: Investigations from more sources have shown that the most economic DH grid is achieved with a design supply temperature of about 60-65°C under peak conditions, but during the rest of the year, the temperature could be lowered significantly to reduce heat losses. Calculations show that the optimum supply temperature is 40-45°C when all costs are considered under normal operation for the actual case in Avedøre raising until 63°C under peak load. The low supply temperature gives a good COP from the heat source as it is a central air-to-water heat pump.
- With the Flex-Booster HIU, DHW can be delivered under safe temperature conditions, and there is no need to rebuild the existing space heating installation. The Flex-Booster HIU is a combination of a passive HEX for LTDH and a micro heat pump where the heat pump covers the temperature needed at the end-user to the extent that the passive HEX can't meet the demand. This means that it is no longer the users with the highest temperature demand that defines the needed operating temperature of the DH grid.
- The Flex-Booster operates at higher COP (than traditional ground source heat pumps) as it can accept higher evaporator temperatures.
- The additional cost for the Flex-Booster HIU, all included compared to normal HIU's for LTDH, is of the same magnitude when the need for rebuilding the user's heating installation is also considered.

Figure 3: The houseinstallation with the Flex-Booster HIU to the left and DHW tank to the right.

- As the Flex-Booster refrigerant filling does not exceed 150 g propane, it is not required to have certified inspections every second year. The costs associated hereto are saved compared with normal heat pumps.
- Another major advantage of the Flex-Booster is that it sub-cools the return temperature by about 10°C. This means that the DH system can be designed for a design temperature difference of 30-35°C, which reduces pipe dimensions.

Test of prototype and configurations

With one Flex-Booster unit, it is possible to supply about 7 kW from the passive heat exchanger and 5.5 kW from the built-in heat pump with a COP of 4 for the heat pump and COP of 9.18 for the total unit when the DH temperature is 60/30°C. On top of that, a built-in 1.5 kW immersion electric heater can increase the peak capacity to 14.1 kW.

For apartment blocks, a Flex-Booster unit can be placed as a wall-hanged unit in each apartment. The sound level is comparable to a fridge.

How to deal with bigger single consumers?

When there is a higher energy demand, two Flex-Booster units can be combined in master–slave configuration, as seen in Figure 4. This doubles the capacity.

If the need for DHW is high, then a combination of one Flex-Booster and one Micro-booster VS unit. The Micro-booster has a built-in spiral for preheating and a micro heat pump for additional heating, similar to the Flex-Booster, but the hot water tank has an increased volume of 190 l, and it can serve 247 l hot water at 40°C. This option has the advantage that the Flex-Booster can operate at lower temperatures as it only needs to serve the space heating, which in many hours has a lower demand for service temperature than DHW.

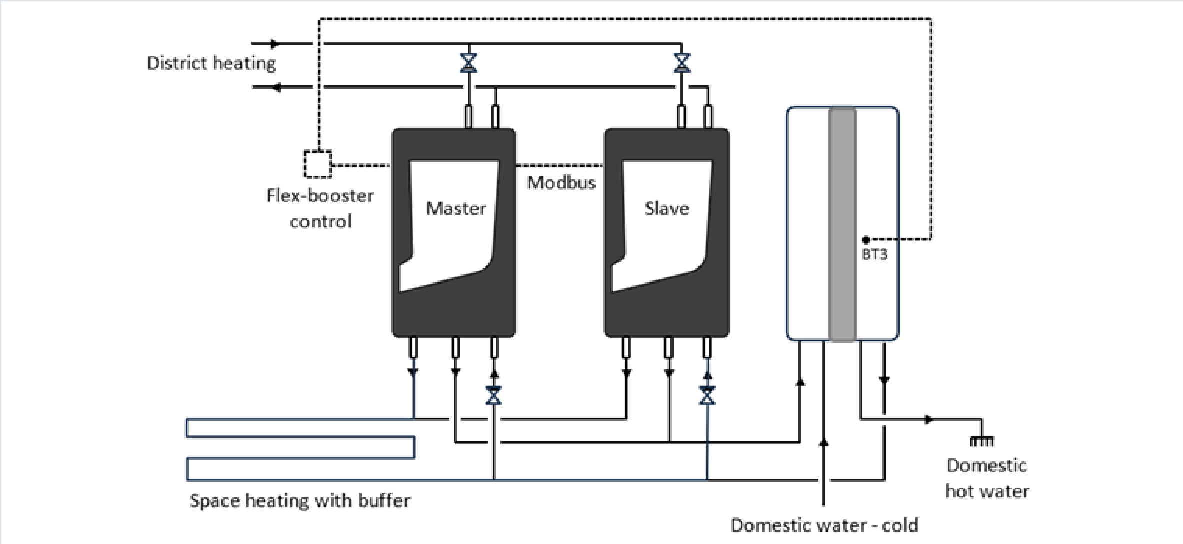

Figure 4: Modular master-slave configuration for larger consumers.

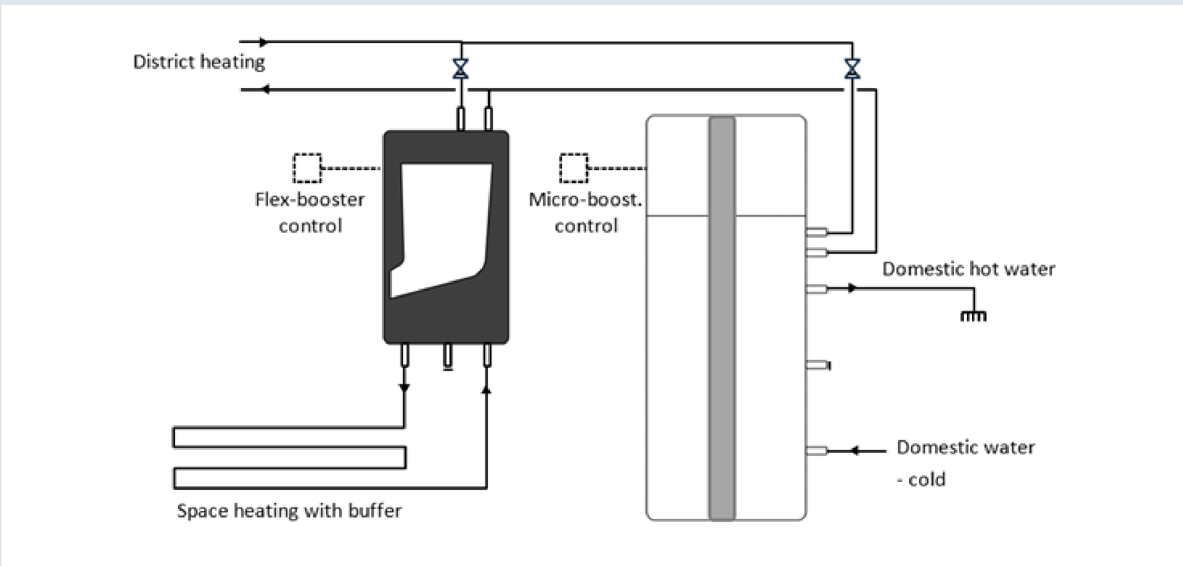

Figure 5: Configuration with large DHW consumption.

For the very large consumers

For large consumers up to 500 kW, it will be better to use a number of dual compressor Ground-Source heat pumps, but they are not optimised to use a DH as a source (they are normally only rated for 3-5 bars pressure on the primary side and usually do not allow inlet temperatures of above 25–30°C. But with a heat exchanger and control, as shown below, it will be possible to operate well, especially if the system is serial coupled to the DH return, which will have a well-suited temperature for the heat pump. However, the COP for the heat pump will be lower due to the higher temperature lift compared with the Flex-Booster couplings.

The heat pumps can be owned and operated by the DH Company, ensuring optimal operation conditions and maintenance, and the electricity to the heat pump can either be supplied through a common purchase agreement with the DH Company or supplied by the private consumer, which may have a PV and battery system to run the decentral heat pump by solar energy to the extent possible.

Conclusions

With these new concepts introducing the Flex-Booster HIU together with heat pumps, it is now possible to operate u-LTDH grids with temperature flexibility independent of the end-user's higher temperature need. Further, it is not necessary to rebuild end-user radiator systems from single string to double string or install bigger radiators.

The new Flex-Booster HIU's increase the delta T by about 10°C, reducing the need for pipe dimensions in new grids or increasing the existing grid's capacity. Further, it enables to use of the main DH return as a source in selected Flex-Temperature districts.

The system described is no "one-size-fits-all" solution, but it opens a variety of configurations with improved performance based on a detailed assessment of each individual case required to reach the best system design.

The system addresses the market of N-gas conversions of individual houses, DH districts where the return pipe can be used as a source, and individual houses that can be co-producers (prosumers).

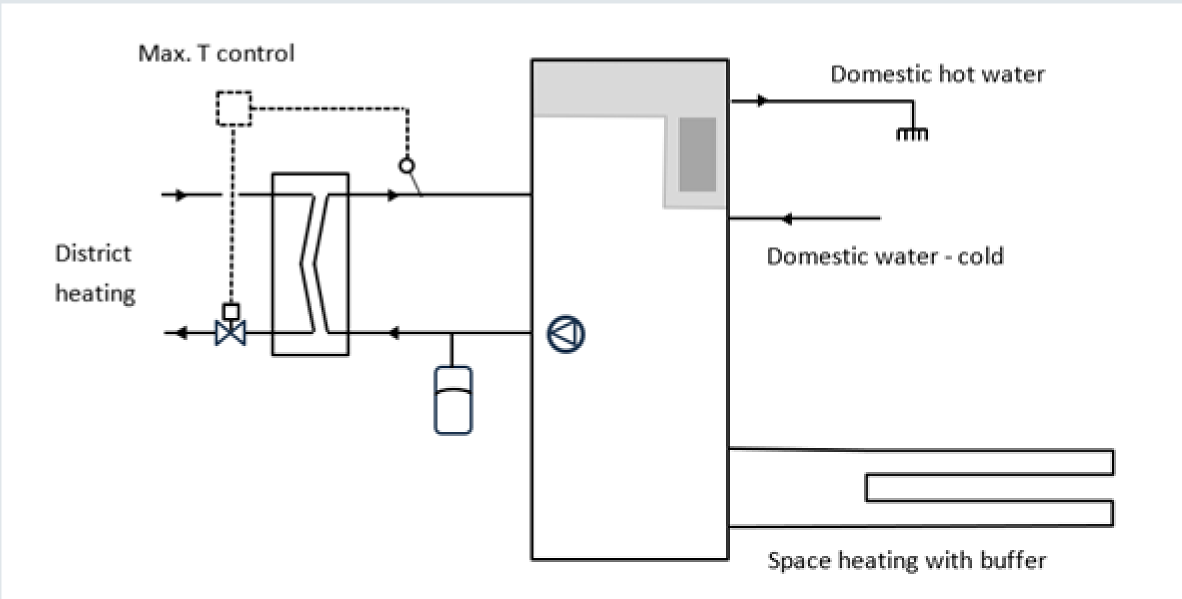

Figure 6: Configuration for very large consumer coupled on the main DH return pipe.

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The Agony of the Choice in District Heating: The Impact of Heat Source for Heat Pumps

Sebastian Ostlender, Robin Kannengießer, Peter Kröning, Christian Vering, Dirk Müller, Germany

Decarbonizing the heating sector requires the increased use of large-scale heat pumps in district heating. In Germany, these are still very rare due to high investments and operating costs. To reduce the operating costs, a high plant efficiency is required. Science efficiency strongly depends on the temperature lift between the heat source and sink; selecting the right source depending on the application is essential for the penetration of large-scale heat pumps in district heating networks. In this article, the most important factors influencing the selection of a heat source are discussed based on potential studies with typical types of heat sources for large-scale heat pumps.

Introduction

About 75 % of the heat supply in Germany is based on fossil fuels [1]. In particular, 8.2% of the heat supply is covered by district heating, and gas or oil boilers provide most of the remaining heat [2]. While heat pumps and hybrid heat pump systems can replace gas and oil boilers in buildings in relatively small power classes (< 50 kWth), large-scale solutions are necessary for district heating. Today, large-scale heat pumps (up to multiple MWth) are already used for district heating, with up to 14 % of generation shares in countries like Norway, Sweden, and Finland. In Germany, however, heat pumps are rarely used to supply district heating [3]. In 2023, there were just 30 plants with a total capacity of 60 MWth and a planned capacity extension of 600 MWth. For comparison, more than 11,500 plants with an overall capacity of about 70 GWth are installed in German networks [3]. In further detail, Agora Energiewende [3] provides an overview of the potential of large-scale heat pumps in Germany, their technical assessment, and political framework.

The available heat source has an impact on the heat pump efficiency. The higher the efficiency, the lower the operating costs. Therefore, the heat source is an essential factor influencing the costs for heat and, thus, market penetration of large heat pumps in Germany.

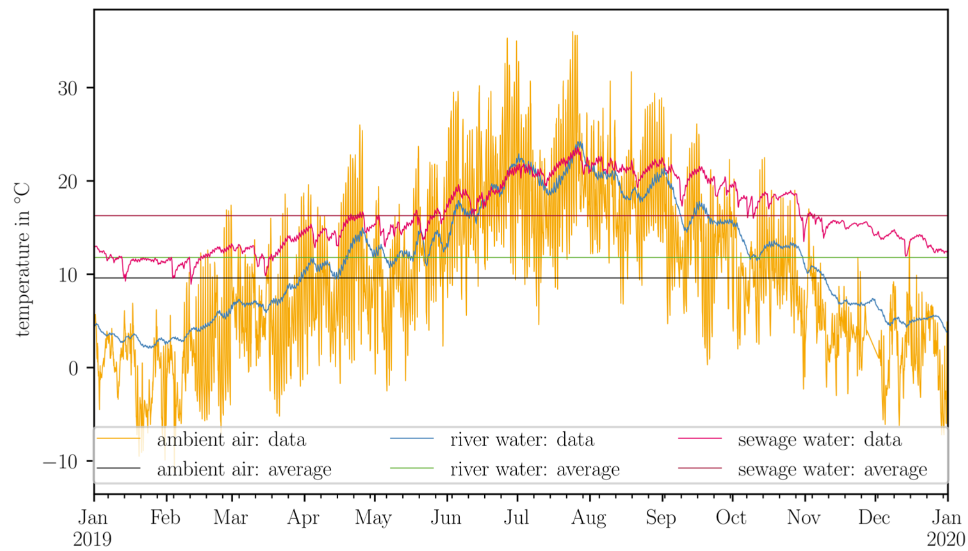

Figure 1: Typical tempature profils for ambient air [5], river water [6] and sewage water.

Agora Energiewende investigates possible heat sources and their potential for application in large heat pumps. Based on the typical temperature ranges of each source type, possible COP ranges for each source type are given. Since the COP ranges differ considerably, the distribution of the operating points within these ranges over a year also impacts the potential of each heat source. Still, this is an open issue. [3]

Closing this gap would allow for a detailed evaluation of the source potentials. For this, the temperature distribution over a typical year must be analyzed, and the integrated efficiency (Seasonal Coefficient of Performance) calculated. This article presents a more detailed consideration of source potentials for typical heat sources in Germany.

Potential heat sources for district heating

Potential heat sources can be divided into two categories. On the one hand, natural heat sources include air, geothermal energy, or water, independent of industrial processes. On the other hand, there are non-natural heat sources (waste heat) behind which there are industrial processes. These include, for example, waste heat from industrial processes, the ventilation of subways, or sewage water. [4]

Air as a heat source for a heat pump process is generally freely available and unlimited. Figure 1 shows the profile of the ambient air temperature of a German weather station [5]. On average, the air temperature is 9.6 °C. The annual variation is 47.7 K, with a minimum temperature of -11.2 °C (February) and a maximum temperature of 36.5 °C (July). Furthermore, the monthly mean values are shown. From this, it can be seen that in the winter months (October to February), the temperatures average between -1°C and + 10 °C. In the summer months (March to September), the average temperature varies between 8 °C and 19 °C.

The daily fluctuations also vary over the months (cf. Figure 2). While the difference between the daily maximum and minimum in the summer months is up to 15 K, it is only 6 to 10 K in winter. Compared to the air, the temperatures of river water [6] and sewage water fluctuate less. The difference between the annual maximum and minimum is 22.1 K for river water and 15.8 K for sewage water. The difference between river water and sewage water in the summer months is only marginal, and the temperatures average about 15 °C. On the other hand, the temperature is higher in the winter months. In winter, however, river water is colder than sewage water (5 °C vs. 11 °C). The daily variations are more minor than for air and range between 0.5 K and 3 K.

Overall, the temperature profiles differ in their characteristics. Air shows the highest fluctuations, whereby the most elevated temperatures are reached in the summer and the lowest in winter. River water and sewage water show only slight daily changes. The average temperature of sewage water is highest at 16 °C. River water has an average temperature of 11.8 °C and air 9.6 °C. Since the heat source temperature directly impacts the thermodynamically maximum possible efficiency (Carnot-COP) of a heat pump, the different characteristics of the heat sources following the choice of the heat source have to be considered in planning a new heat pump.

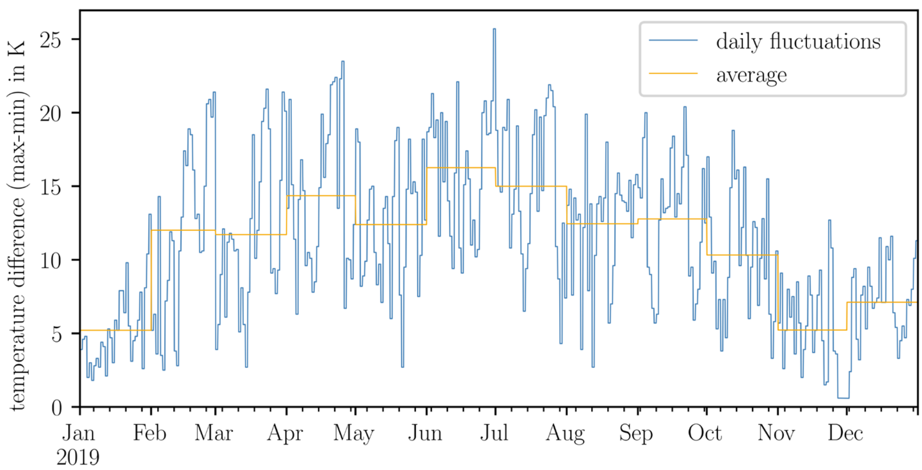

Figure 2: Daily air temperature fluctuations.

Effect of source characteristics on theoretic efficiency

Figure 3 shows the Carnot-COP of the three considered sources and a constant sink temperature of 75 °C. Due to the high daily variation in air temperature, the Carnot-COP for air varies between 5 and 9 a day in the summer months. In winter, when the daily variations in temperature are more minor, the Carnot COP varies between 4 and 5. The variations in river water and sewage water sources are minor. In the winter months, the Carnot-COP is 5 and 5.5, respectively, with sewage water having the larger Carnot-COP due to the higher temperature. In the summer, there are hardly any temperature differences between river and sewage water. The Carnot-COP is up to 6.5, and the daily fluctuations are negligible in each case.

Since the heat demand differs, on the one hand, every month and the other in the day, the momentary Carnot-COP at any point in time is insufficient to decide on a good heat source. For this, the Carnot-COP has to be weighted with the demand. The weighted Carnot-COP can be represented as Carnot-SCOP. The district generator is used to get a typical annual demand profile for district heating in Germany [7]. The district generator generates the heat demand profiles for space heating and domestic hot water based on weather data and typical quarter buildings, shown in Figure 4. Carnot-SCOP can be determined by determining the electrical power via the Carnot-COP (cf. Figure 3) and integrating the electrical and thermal power. The resulting utilization rates, depending on the source type, are illustrated in Figure 5.

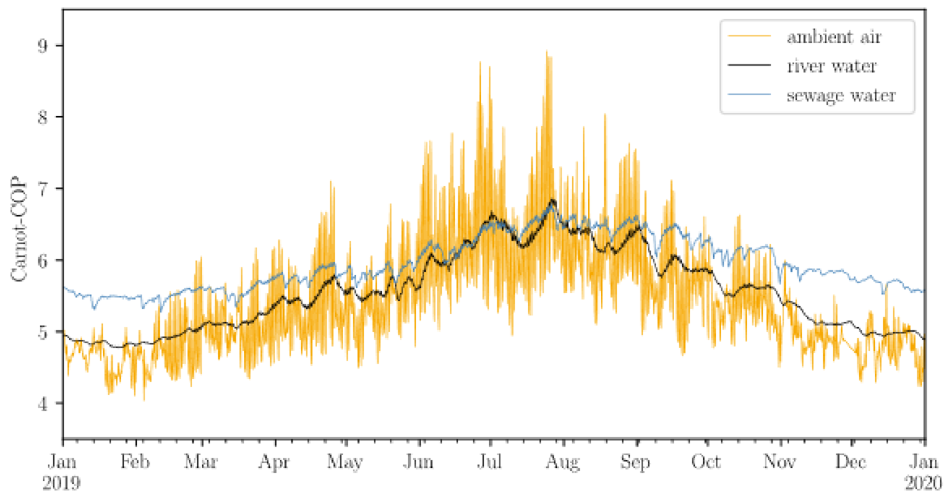

Figure 3: Theoretical achievable efficiency (Carnot-COP) for ambient air, river water, and sewage water as a heat source at a constant district heating temperature of 75 °C.

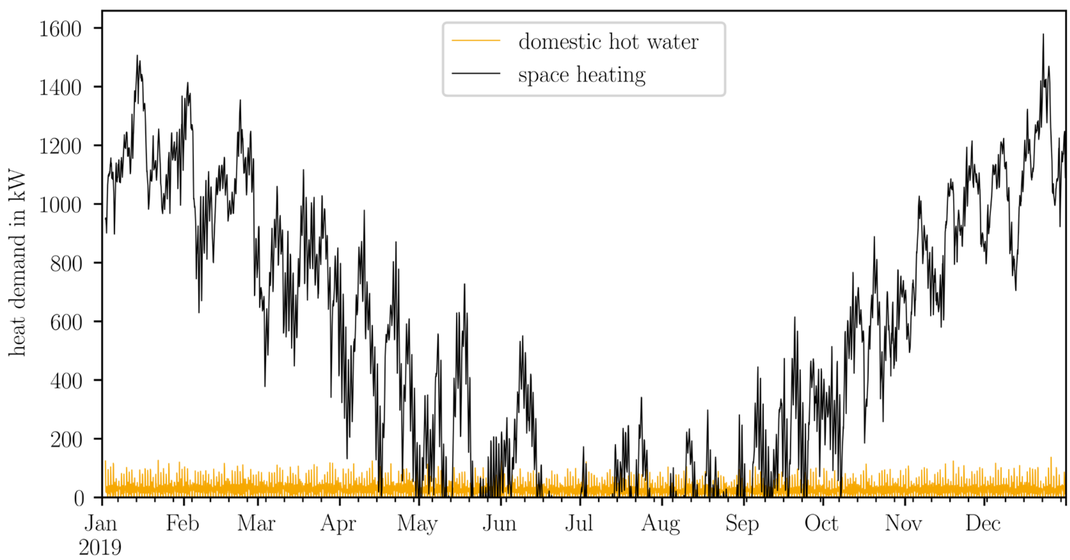

Figure 4: Heat demand of a typical district (calculated using the District Generator).

The year is divided into quarters to analyze the heat demand's influence better. In all quarters, sewage water shows the highest Carnot-SCOP. While this behavior is understandable in winter, one would expect air to have the best Carnot-SCOP in summer, caused by higher maximal temperatures. To explain why sewage water has a higher SCOP, the daily fluctuations must be looked at more closely. There is still a small demand for space heating in the summer, mainly at night. During these hours, the air temperature is minimal, and the sewage water has a higher temperature. This results in a higher Carnot-COP and Carnot-SCOP. Over the entire year, sewage water has the highest potential based on the Carnot-SCOP of 5.71. The Carnot-SCOP decreases by 9.8 % when using river water and 13.5 % when using air as a heat source.

Conclusions

This work provides a detailed analysis of heat sources' impact on air, river water, and sewage water temperature. The Carnot-COP and Carnot-SCOP for each heat source are calculated based on a simplified thermodynamic assessment, including typical temperature and heat demand profiles. Overall, the results illustrate the agony of choosing a heat source. The choice of heat source only based on the maximal or minimal temperatures can lead to efficiency disadvantages. Temperature deviations and fluctuations must be considered instead of the interactions between head demand. A better understanding of the influencing factors on the efficiency of large-scale heat pumps, such as the choice of the heat source, improved the penetration of large-scale heat pumps in district heating.

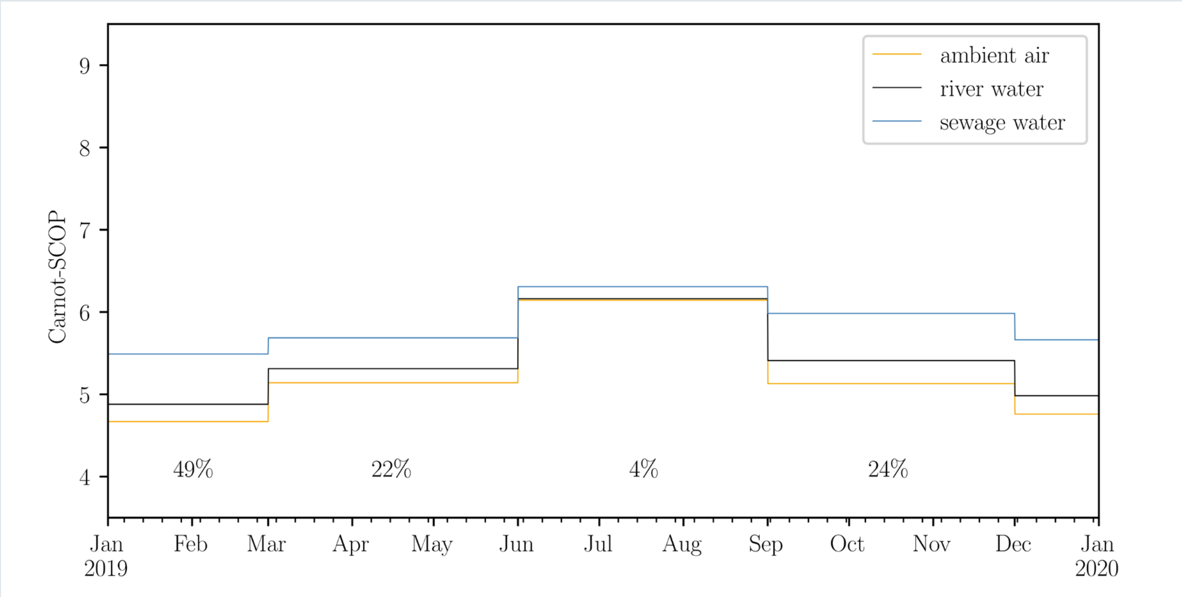

Figure 5: Theoretically achievable seasonal efficiency for ambient air, river water, and sewage water as a heat source at a constant district heating temperature of 75 °C (In addition, the share of the annual heat demand for each quarter is entered).

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Large-Scale Demand Response of Heat Pumps to Support the National Power System

Markus Lindahl, Tommy Walfridson, Claes Sandels, Marco Tiloca, Rikard Höglund, Niclas Ericson, Sweden

In a power system with an increased share of electricity from intermittent renewable sources, such as wind and solar, a more flexible electricity consumption will be needed. In this article, the possibilities and constraints to control residential heat pumps on a large scale are investigated. The goal is to support the electricity grid with demand response based on the heat pump manufacturers' already existing hardware and cloud solutions. The article discusses barriers related to technical constraints in the heat pumps and the electricity market, as well as potential communication standards and cybersecurity.

Introduction

We see a clear trend of intermittent electricity production from wind and solar increasing all over the world. In a power system with an increased share of electricity from intermittent renewable sources, a more flexible electricity consumption is most likely needed. Flexibility, also called demand response, can help reduce problems due to bottlenecks and shortage of capacity in the electricity grids, as well as avoid curtailment of renewable energy sources. Today, there is ongoing work to find affordable solutions to increase the robustness and flexibility of the power system.

The findings in the article are based on expert interviews with relevant stakeholders, literature review, and field tests carried out within the Swedish research project "Large scale Electrical Grid Flexibility Control of Heat Pumps", financed by the Swedish Energy Agency. The article focuses on Swedish conditions, but the results are likely relevant in several countries. Barriers related to technical constraints in heat pumps and the electricity market as well as communication standards and cybersecurity, are discussed for a concept where heat pumps are controlled on a large scale to support the electricity grid. The concept uses the heat pump manufacturers' existing hardware and cloud solutions to communicate the load control to the individual heat pumps.

Demand response of heat pumps

Controlling individual heat pumps for demand response via the manufacturers' already existing cloud and application programming interface (API) would enable rapid deployment of heat pumps as a flexibility resource. If no hardware changes are needed to get the flexibility solution up and running, the investment cost to use heat pumps as flexibility resources is lower compared to solutions where new hardware is needed.

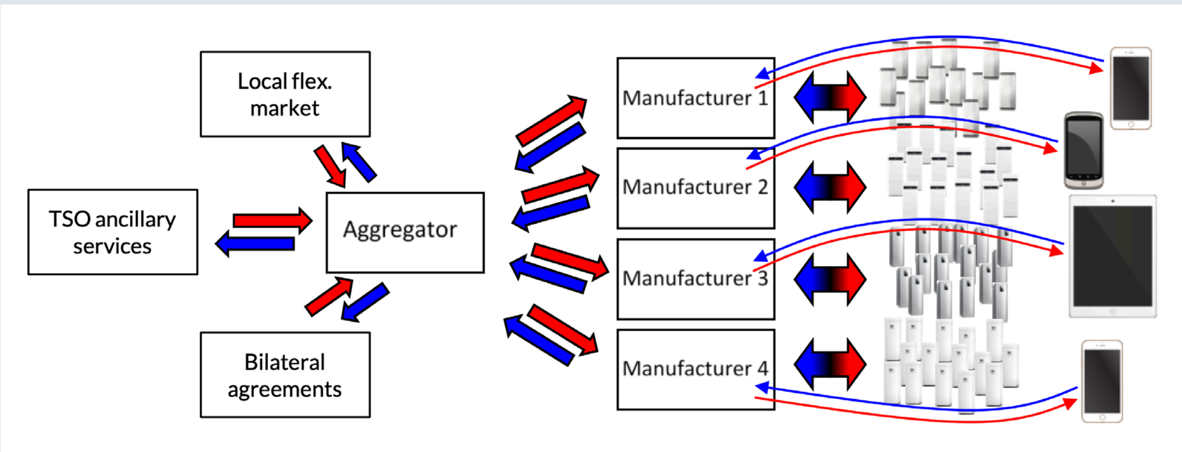

Figure 1. Overview of the communication flow for demand response from heat pumps using the manufacturers' cloud solution.

The manufacturers' cloud and API solutions have been in use for approximately ten years, which means that many installed heat pumps are ready to be used for flexibility purposes once the communication is in place. In Sweden, all the major manufacturers of hydronic heat pumps provide users with functionalities for controlling and monitoring their heat pumps via an app by connecting the heat pump to the manufacturer's cloud infrastructure. From a control point of view, functionality is still lacking to enable demand response to the power system via these cloud services, but as the hardware has been in place for several years, the potential of heat pumps with the hardware already installed is assessed as large. Figure 1 shows a schematic overview of the proposed communication flow to deliver flexibility from heat pumps to the power system.

Communication standards

For the communication between the aggregator, the cloud service, and the individual heat pumps, there are existing communication standards to use. A first, high-level evaluation points out four interesting alternatives. OpenADR and IEEE 2030.5 are two US-based standards that seem to have great potential for enabling demand response from heat pumps. A potential drawback is that they are not that common in Europe today. Interesting European alternatives are EEBus and EFI/S2. All these four standards are free to use or can be bought at limited costs.

Flexibility services

Using heat pumps for demand response is still in the start-up phase, but there are identified potential markets for demand response. Here, we focus on demand response from aggregated heat pumps delivering explicit flexibility to the power grid by having 1) a bilateral agreement with a grid owner, 2) participates at the Swedish Transmission System Operator (TSO, Svenska kraftnät) ancillary services or 3) is active at a local flexibility market. Implicit flexibility, when the heat pump adjusts its heat production based on variations in electricity prices or to lower costs for power tariffs, is not within the scope, neither are conditional agreements included. See Figure 2 for an overview of different flexibility services.

Electricity market barriers in Sweden

Traditionally, aggregated resources, like residential heat pumps, have not been used for the TSOs balancing markets in Sweden, given that the requirements are not always adapted for the new resources. Today, there is even a volume limit of about 10%-15% on the Frequency Containment Reserve (FCR) market for bids from aggregated resources, indicating how cautious the TSO is on these new flexibility resources.

An obstacle for heat pumps to participate in the balancing markets is the lack of standards and definitions of demand response. For example, there is no standard for verifying delivered flexibility today. Each actor must describe this themselves and define their own working methods and how to measure and evaluate their performance. Another barrier is the minimum bid size (100 kW electricity or more) for the balancing markets, which requires the aggregation of many heat pumps. A third barrier is the need to have the same balance responsible party (BRP) for all customers in a bid. The likelihood of customers having the same BRP is very low, as there are several BRPs in Sweden, which is a significant obstacle to scaling up demand response.

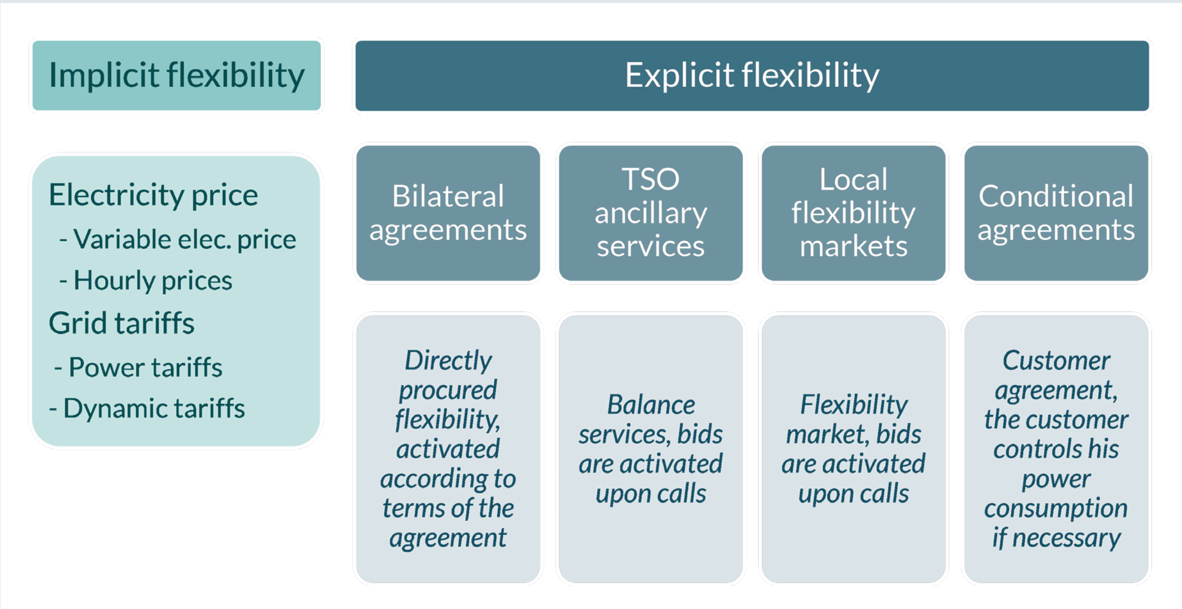

Figure 2. Overview of different flexibility services to the power system [1].

There is also a market requirement for the balancing service provider to measure their flexibility resources in real-time. This can be costly and difficult for an aggregator because heat pumps are usually not measured individually today. This obstacle can be hard to circumvent. Either real-time measurement needs to be added to each participating heat pump, or the aggregator needs to get an exception from the TSO to instead measure or calculate the delivered flexibility in another way.

Technical barriers in the heat pump

Technical experts from the four major heat pump manufacturers in Sweden were interviewed about technical obstacles and possibilities of using their heat pumps for demand response.

As the current heat pumps lack electricity meters, alternative ways to measure or estimate the power consumption were discussed with a focus on measurement uncertainty. Variable speed drive (VSD) heat pumps may have the possibility to measure the power consumption within the inverter, controlling the speed of the compressor. On/off compressors have no technical possibility to measure the power consumption; instead, it needs to be calculated based on the operating temperatures of the compressor and known compressor equations. Based on discussions with the experts, the estimated measurement uncertainty of the power consumption for VSD heat pumps is 2-10%, while on/off heat pumps have an uncertainty of 10-20%. The auxiliary heater has an uncertainty of 0.5-5% if the voltage is known; otherwise, the uncertainty is higher.

For heat pumps, the required activation time for the different flexibility markets is an obstacle. The experts had common ground in how fast their heat pumps could be controlled to decrease or increase power consumption. The auxiliary heater can change its power in a second, but it may need new software to work as a flexible resource. In normal operation, the use of the auxiliary heater in the heat pump is minimized to keep performance up. On/off compressors can also stop in a second, but they need some time to restart. VSD heat pumps are much slower to change their power. It can take minutes to start or stop them or control their speed when they are already running. Control-wise improvements can likely be made to speed up the process of starting and stopping, but some technical aspects will still limit what is possible.

The requirements for the TSO's different ancillary services were discussed, and according to the experts, the heat pumps can technically meet the requirements for FCR-N and FCR-D services, which need 50% activation in 5s. However, they doubt that heat pumps can meet the FFR service, which needs activation in less than 2s. aFRR and mFRR have longer activation times, and it will likely be possible for heat pumps to fulfil the requirements also for these two services. The answers should not be interpreted as an indication that solutions are ready, which might well be the case, but rather that the issues in question are technically feasible to solve by adopting such solutions.

Cybersecurity

Heat pumps need to be controlled over the Internet to effectively contribute to flexibility. This can, as for all Internet-connected devices, make them vulnerable to cyberattacks. On top of ensuring secure interaction with heat pumps, a key cybersecurity challenge stems from the long lifespan of the heat pump systems. Heat pumps are expected to operate for at least 15–20 years, and new cyber threats may demand software and even hardware updates for many years.

The threat from cyber-attacks must be taken seriously as hacked heat pumps could, at least in the future, cause severe problems not only for the heat pump owner but also to the national power system. In the report “Förslag på åtgärder för att möta cyberhot mot elsystemet” [2], RISE has shown that a large-scale cybersecurity attack on heat pumps can already today cause a significant impact on the Swedish power system.

Conclusions

The article investigates a concept where residential heat pumps are aggregated and controlled via the manufacturers’ cloud service to support the power system with demand response. Delivering flexibility to the power system is a new area for the heat pump industry, and these new functions are outside their core business today.

There are still several barriers to overcome to make it easier to use residential heat pumps for flexibility. The benefit of using the concept described in the article is that all hardware needed to control the heat pump for demand response is already in place, and many older heat pump models have had the hardware for several years. Thereby, the investment costs to use heat pumps as a flexibility resource will be lower compared to the alternatives. What may be missing is whether electricity meters will be required to measure the delivered demand response from the individual heat pumps.

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Belgium: Heat Pump Market Report

Heat Pump Platform steering group, Belgium

Belgium has been a relatively slow mover in the installation of heat pumps in the first decades of this century. In new buildings, the adoption of heat pump technologies increased at a nice speed. Also, many exemplary and eye-catching public buildings were constructed with four heat pumps to provide comfort. Research keeps a nice focus on hot spots that make a difference. In the past 4 turbulent years, however, we have witnessed ups and downs in the sector. Staying on a dedicated and robust path has always been a challenge in this small European country, so the platform is really lacking quiet moments.

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The introduction and diffusion of heat pumps for space heating in Belgium coincided with the introduction of energy-efficient buildings in 2006. Lowering the heat demand step by step due to the integration of the regional approach of European EPBD legislation made the conditions for heat pumps better and better in the newly built domestic market.

The total sales volume of heat pumps (air to water, water to water and domestic hot water heat pumps) during the first semester of 2023 is 46.583 units. This is an increase of 140% compared to 2022 (thus resulting in 240 % compared to the previous year).

In the domestic market, heat pumps are mainly used for space heating. Domestic hot water heaters still have a strong increase of 140%, mainly due to the exchange of electrical boilers. But sales are decreasing, if we look at the same period a year earlier the increase factor was 236%.

We conclude that the energy crisis and the resulting low electricity/gas price ratio are important drivers for these very positive sales of heat pumps. Generally speaking, this price ratio in Belgium has always been situated around 4-5, which is very high compared to other countries, making it nearly impossible to have a final cost benefit. The tax shift from electricity to gas, the solution for this paradox, was on the political agenda for years, but it remained an unsolvable wicked problem, it seemed.

With the Ukraine conflict, the tax component and its influence on the end user price decreased sharply, and at one point in September 2022, the price ratio was reduced to 2.7, which was the lowest level ever. This heavily influenced the market demand. In August 2023, this ratio is back up to 4.3, which seems to be reflected in a lower sales increase (but still an increase) of 94% in July and 41% in August 2023.

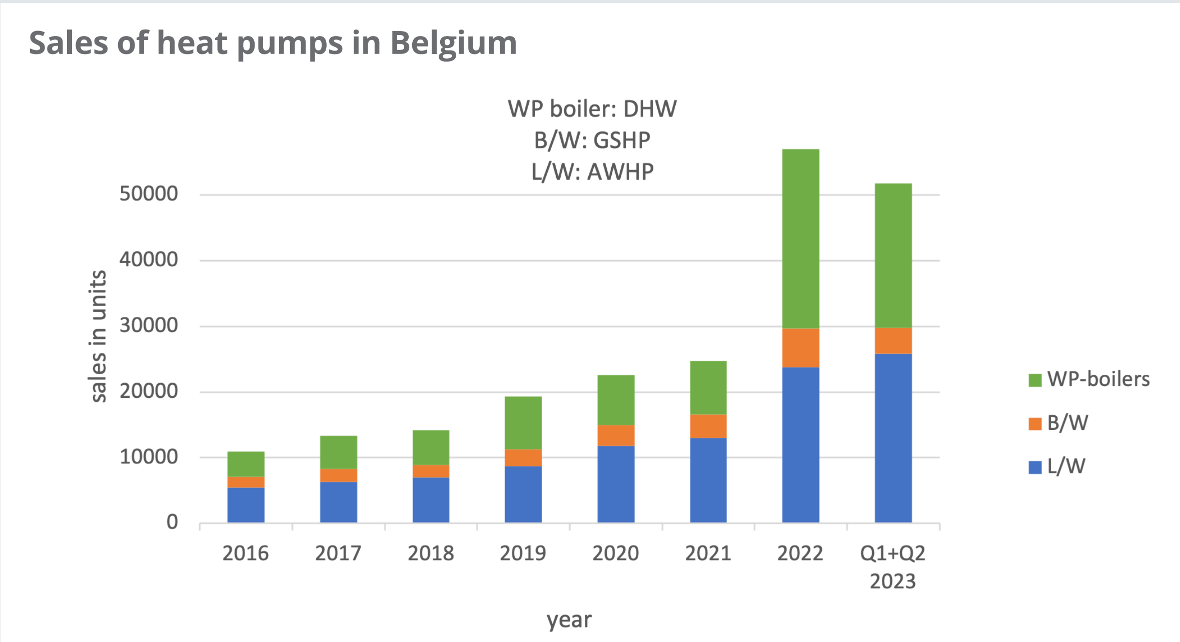


Figure 1: Sales of heat pumps in Belgium.

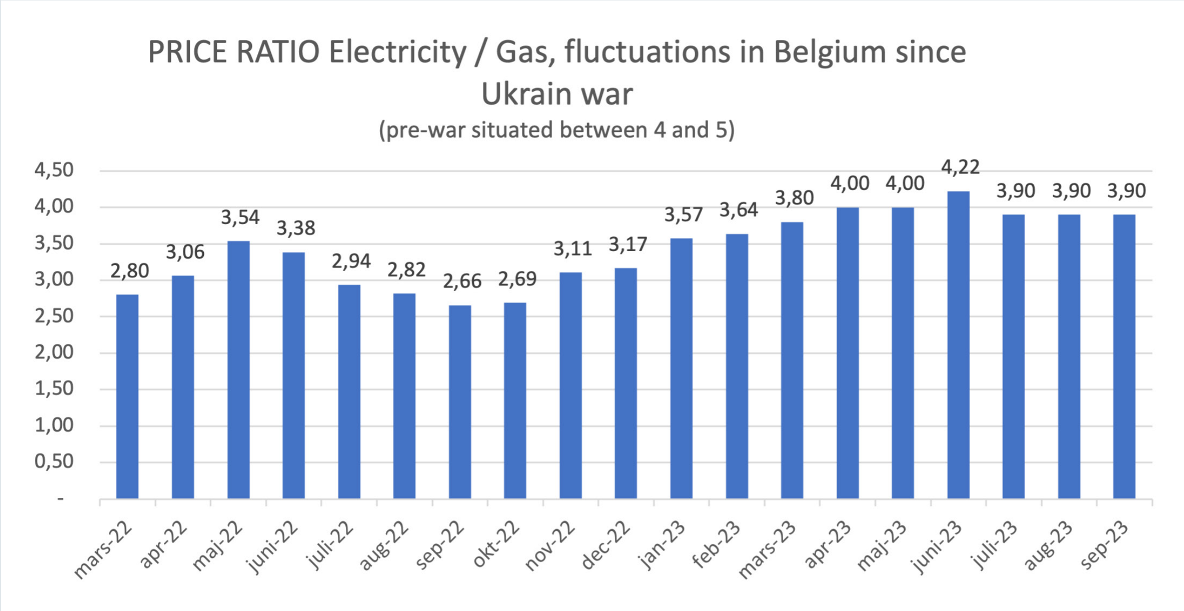


Figure 2: Price Ratio electricity / Gas, Fluctuations in Belgium.

These are the first signs of a market slowing down due to, among others, high-interest rates, unstable energy prices and investment scariness of our population.

On a regional level, we also see positive integration of policy. Some examples are the ban on gas connections for new multi-family buildings in 2022, the drop of public grants on the connection on the gas networks for new buildings, the interdiction of oil boilers in new buildings or exchange and in 2025, the restriction to gas grid connection in new build individual houses.

At this moment, it's unclear if VAT taxation on demolition and reconstruction of buildings and heat pumps stays at 6% or will increase to 21% again. These temporary measures are drivers in sales but also create stop-go moves due to the temporary character.

For a healthy and steady development of sales, we need a stable overall policy. A clear roadmap avoids market fluctuations and associated stop-go moves that result in delayed transition and economic challenges.

The focus of academic research has shifted to industrial high-temperature applications, integration in larger systems and system integration, clean (fossil-free) hybrid solutions and advanced control and design of larger systems.

We are hopeful that policy makers will succeed in creating a path with a stable policy and an important tax shift (from electricity to fossil fuels). This will be the major game changer towards further reductions of CO_2 emissions for heating. Together with innovative products and system integration, and thus collaboration between different stakeholders of the heat pump industry and carbon-free technologies, Belgium could still walk the talk towards 2050.

The outlook seems therefore positive, as plans on city levels to heat buildings are considering two solutions: either individual heat pumps or thermal grids. Knowing that large industrial heat pumps will be an important supplier of the grid option as well this gives the technology a sunny long term view.

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.

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

Soon to be finalized

The Technology Collaboration Programme on Heat Pumping Technologies participating countries are:
Austria (AT), Belgium (BE), Canada (CA), China (CN), Czech Republic (CZ), Denmark (DK), Finland (FI), France (FR), Germany (DE), Ireland (IE), Italy (IT), Japan (JP), the Netherlands (NL), Norway (NO), South Korea (KR), Spain (ES) Sweden (SE), Switzerland (CH), the United Kingdom (UK), and the United States (US).
Bold, red text indicates Operating Agent (Project Leader).

ANNEX
54

HEAT PUMP SYSTEMS WITH LOW GWP REFFRIGERANTS

Introduction
Heat pump systems are becoming increasingly popular as a renewable heating and cooling solution in the carbon-neutral world to come, and low-GWP refrigerants are essential for environmentally friendly heat pump systems. However, due to the unique thermophysical characteristics of low-GWP refrigerants, component-level design and optimizations are much needed for energy efficiency and reduced-charge designs.(EC), and electrocaloric effect (ECE) cooling cycle concepts. This includes work on identifying materials with improved fatigue performance, etc., for MC, EC and ECE concepts.

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

- A comprehensive review of recent R&D progress on component optimization using low-GWP refrigerants (fulfilled),
- In-depth case studies of component optimization, which can provide design guidelines and real-world experiences (fulfilled)
- Optimization of heat pump systems for low-GWP refrigerants (fulfilled)
- Analysis of the Life Cycle Climate Potential (LCCP) impacts by the current design and optimized design with low-GWP refrigerants (fulfilled)
- Making an outlook for heat pumps with low-GWP refrigerant for 2030 (ongoing)

Key data
- Project duration: Jan 2019 – Dec 2023
- Operating Agent: Yunho Hwang, University of Maryland, College Park, yhhwang@umd.edu
- Participating countries: France, Germany, Italy, South Korea, Sweden, and the United States
- Further information: All workshop presentation materials, meeting agenda, minutes, and attendee list are available from the Annex 54 website at https://heatpumpingtechnologies.org/annex54/

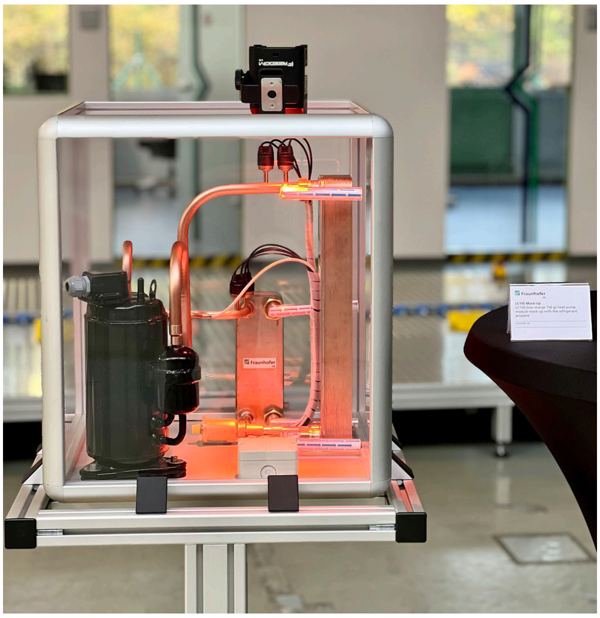
Results and Progress
Heat pumps are a highly efficient way to heat and cool buildings, and they can be used to reduce our reliance on fossil fuels. However, traditional heat pump refrigerants have a high global warming potential (GWP), which means that they contribute to climate change. Research is underway to develop new low-GWP refrigerant solutions for heat pumps. Some of the most promising candidates include natural refrigerants such as propane and carbon dioxide, as well as new synthetic refrigerants with low GWPs.

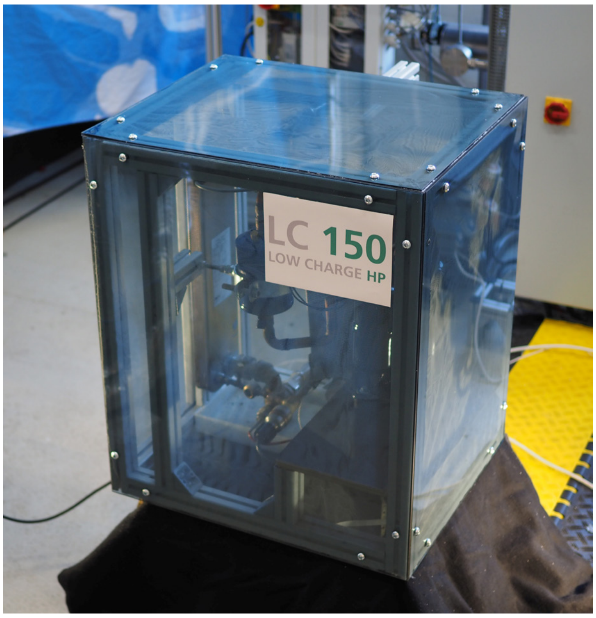
Recently, propane has increasingly been seen as a significant natural refrigerant in the heat pump industry. The advantages of propane as a refrigerant include:
- Excellent thermodynamic properties, which allow higher COPs compared to conventional refrigerants.
- Massively reduced global warming potential
- Naturally occurring and widely available
- Relatively inexpensive

However, the flammability of propane is a significant disadvantage, and it is important to take steps to minimize this risk. Reducing the refrigerant charge to below 150 g is one way to do this, as it reduces the amount of propane that is present in the system in the event of a leak. The Fraunhofer Institute for Solar Energy Systems has been working on the LC150 research project as a promising development path for reducing the refrigerant charge to below 150 g.

This will assist heat pump manufacturers to develop and produce low-charge propane heat pumps. In October 2022, the LC150 team announced it had developed a heat pump refrigerant circuit capable of achieving a maximum heating capacity of 12.8 kW and a COP of 4.7 with only 124 g of propane. In June 2023, the team developed a functional brine heat pump using a fully hermetic compressor with a heating capacity of 11.4 kW using only 146 g of propane.

> ***I believe the LC150 research project is a significant step forward in developing low-GWP refrigerant heat pump systems. By reducing the refrigerant charge to below 150 g, manufacturers can develop heat pumps that are both efficient and safe.***





In the measurement campaign, dozens of heat pump component combinations are tested under different operating parameters.

ANNEX
60

RETROFITTING HEAT PUMP SYSTEMS IN LARGE NON-DOMESTIC BUILDINGS

Introduction

IEA analysis shows that over 85% of our buildings need to be net zero by 2050. With heating accounting for over 50% of sector emissions, heat pumps are expected to make a very significant contribution. Heat pumps sales have begun to rise: by 15% globally and 35% in the EU in response to the energy crisis. But installations have to more than triple by 2030 to meet net zero targets.

New buildings can be addressed relatively easily through the building codes. But existing buildings – which make up over half of the potential savings – are much harder. The EU is planning a range of measures including minimum energy performance standards and bans on fossil-fuelled boilers. The UK is considering approaches such as heat pump installation targets for manufacturers. This policy focus will get more intense over the next few years.

Non-domestic buildings are responsible for around 30% of the sector's emissions. However they are notoriously difficult to address because, unlike households, the building stock varies in form, size, function and therefore energy use, leading to a wide variety of possible heat pump system options. Building owners and operators tell us that this creates a considerable degree of confusion about which heat pump system is right for their building.

Objectives

- The principal objective of this Annex is to help decision makers deal with this complexity by identifying and quantifying the heat pumps options available more clearly providing simple advice to guide them through the retrofit process. We will do this by reviewing the available published evidence, performance data and standards, both in the technical and academic literature. This will, we hope help us refine our understanding of the range of heat pump systems available and what guidance is already available that we can use or adapt. We will also use our industry contacts to speak to a range of organisations that have successfully retrofitted heat pump system to understand the barriers they faced and how they overcame them. The objective will be both to help develop the guidance and also to generate a list of case studies that can be published.
- Finally we will develop simple high-level on-line guidance, supported by case studies, to steer decision-makers through the complexity with examples that meet their circumstances. We envisage that the guidance will pose a series of questions with drop-down options that will generate a list of heat pump options together will links to suitable case studies.

Key data

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  Sept 2022–Dec 2024
- Operating Agent:
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- Participating countries:
  Austria, Canada, Italy, The Netherlands, Ireland, the United Kingdom
- Website:
  https://heatpumpingtechnologies.org/annex60/

Progress and Results

Literature review

The review uncovered very little information on non-domestic heat pump deployment and almost nothing on guidance for decision makers: perhaps 12 publications in total, mainly in technical or regulatory publications. This does not appear to be a topic that has attracted much academic attention except in general terms focussing on how investment decisions are made in large organisations.

The review did provide considerable background information on the range of heat pump system options available and some indication on how these can vary between countries, for example based on climate. A number of potential case studies were also identified for follow-up.

The limited results of the review mean that we do not plan to write up the results at this point. The publications have been archived and indexed and we will return to this later in the project. We do consider that there may be information available that has not been published for proprietary or confidentiality reasons which may come to light as the project develops.

Case study analysis

The lack of published information on non-domestic heat pump deployment places greater emphasis on identifying case studies and understanding what makes them successful. This meant that this stage of the project has been split into two objectives: to compile a list of case studies for publication and to extract information from the case study organisations to help design the guidance.

We developed a simple on-line survey for potential case study organisations to complete, asking for basic information on the organisation, the heat pump system adopted and the system it replaced. The survey, together with and explanatory note, was sent to 30-40 potential case studies in September 2023.

We will review progress at the end of October 2023. However we expect that this might be a bottleneck for the project. We may have to change our approach is we receive too few responses.

As a starting point to help us analyse the case studies we reviewed our key knowledge gaps and generated a list of the information we needed to collect once we have some case studies on board.

We also developed a template for the publication of the case studies based on that used for HPT Annex 50.

We also began to scope out how the Annex website would present the case studies, based on EBC Annex 81. We are in discussion with the HPT web team on how this might be implemented on the HPT platform because we do not have a budget to develop our own web platform.

Development of the guidance

We are confident that we understand the technical underpinnings for the guidance, i.e. the main heat pump system options available and how these can be deployed based on the fossil fuel HVAC system they are replacing (or part replacing).

We are still considering how the guidance will work in practice, but we have agreed in outline how the “logic model” will work, i.e. the key questions, filters and ranking criteria that we need to apply to narrow down the options based on the user’s own circumstances.

> ***The lack of published information on non-domestic heat pump deployment places greater emphasis on identifying case studies and understanding what makes them successful.***

ANNEX
61

HEAT PUMPS IN POSITIVE ENERGY DISTRICTS

Introduction

Climate change is rapidly progressing, and many institutions and cities around the world have declared a climate emergency. The carbon budget for reaching the 1.5 °C target of the Paris Agreement is surpassed within 6 years at current GHG emissions. The built environment is a key sector for fast emission reduction in many countries. For instance, in the EU, 36% of the emissions are due to buildings, so reaching ambitious climate targets will be strongly facilitated by transforming the building sector.

Heat pumps are seen as future heating systems in many scenarios around the world and already show strong market growth in many countries. However, with the massive introduction of heat pumps, the integration of the heat pumps, including heat sources and sinks, gets more important.

Positive energy districts are an ambitious concept introduced by the EU to pave the way for the urban energy transition to a zero-carbon society. Extending the system boundary to districts enables to benefit from synergies of different load profiles of consumers and can overcome limitations on the individual building level regarding heat source, on-site PV electricity production/self-consumption and promotes the use of waste heat, which will enable to reach ambitious targets like a positive energy or a zero-emission balance.

Due to its unique features, heat pumps are a very favourable technology in positive energy districts. They have a high energy performance, can produce heating and cooling energy even at the same time and can recover heat for other building services. They can also link the on-site electricity production to space heating and cooling loads, thereby providing energy flexibility within the district or for connected grids.

Annex 61 will investigate heat pump integration in building clusters and districts for both new and retrofit districts on a technical, economic and ecological basis. Results are used by building system technology designers and urban planners as well as by utilities and ESCO looking for new business opportunities. Based on the results, heat pump manufacturers can tailor and further develop their products for building cluster and district applications. Policy makers get evaluations to shape future ambitious energy targets.

Objectives

» Characterise the state-of-the-art of heat pump application in positive energy districts in the participating countries
» Develop generic system concepts for the integration of heat pumps in districts
» Perform techno-economic analyses of promising concepts by simulation
» Evaluate the real performance of heat pumps in districts by monitoring projects

Key data

» Project duration: Sept 2022 – Dec 2025
» Operating Agent: Carsten Wemhoener, IET Institute of Energy Technology, OST Eastern Switzerland University of Applied Sciences, Campus Rapperswil
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» Participating countries: Austria, Germany, Japan, Switzerland and the United States
» Website:
https://www.heatpumpingtechnologies.org/annex61

Results and Progress

The state-of-the-art analysis of heat pumps (HP) in existing Positive energy districts (PED) is to be concluded by the end of 2023. Besides other evaluations, 42 districts according to the label "Energieplus" in Germany and 48 districts according to the label "2000-W-site" in Switzerland have been analysed.

2/3 of the Energieplus PED is in realization, while 1/3 is still in the planning phase. All PEDs are equipped with PV, while installed solar thermal systems are below 20%. HP, with 60%, are the most applied heating system, followed by CHP and district heating with 40%. The sizes of the PEDs are quite different, but most have above 50 and below 200 flats.

In Switzerland, 48 projects are certified as 2000-W-sites, containing 25% in realization, while 75% are in planning or in transition, i.e. existing districts transformed to the 2000-W requirements. HP have a share above 90%, often combined with PV, which also reaches a fraction above 90%. More than half of the projects use heating grids, and about 30% use the ground as a heat source. The majority has a mixed-use with a range of 200 to 1,500 workplaces.

"The high energy performance and multi-functional use of heat pumps in positive energy districts enable the urban transition to a zero-carbon society."

Furthermore, archetypes of PED, e.g., purely newly built or a mixture of newly built and retrofitting, have been discussed to evaluate at which conditions a PED can be reached or what the difference to a PED is, respectively. For this purpose, load curves with different technology options, e.g. HP, district heating and CHP can be generated in simplified simulation tools.

In Task 2 categories of different integration options for the HP from a decentralized integration on individual building level to a fully centralized integration with a district heating grid have been defined. The integration options will be further detailed and characterised by a technical description with an evaluation of favourable application areas, which can serve as preselection for a more detailed concept comparison by e.g. simulations. Promising concepts will be evaluated in a techno-economic analysis in Task 3.

The work is also linked to monitoring plants in Task 4. Some of the monitorings are already ongoing and first data of the real perfor¬mance of heat pumps in districts have been evaluated. In one project, the performance of a ground water heat pump has reached a monthly performance factor (MPF) of 4.7-5.8 based on the compressor energy. However, including all pumps, the MPF decreases to 3.6-4. Thus, it is also important to consider and optimize auxiliary energies in order to achieve a high system performance.

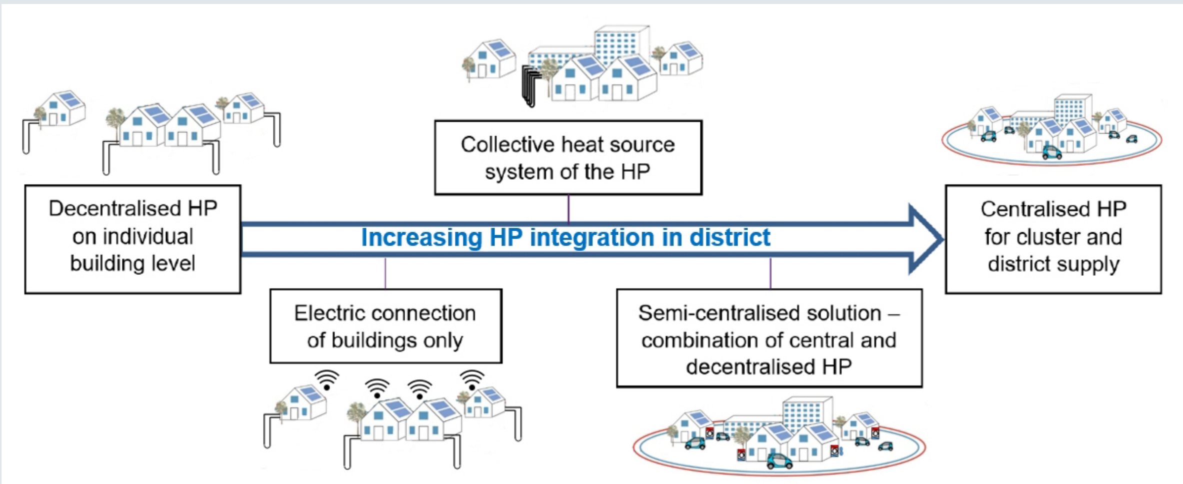

Figure 1: Generic system solutions for the integration of heat pumps in clusters of buildings and districts.

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The Agony of the Choice in District Heating: The Impact of Heat Source for Heat Pumps

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[1] Power Circle, 2022. ”Flexibilitet för ett mer stabilt och driftsäkert elsystem – en kartläggning av flexibilitetsresurser”, Sweden (In Swedish)

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Events 2024/2025

Please check for updates for any conference that you plan to attend. Venues and dates may change.

2024

April 8 – 10
China Refrigeration Expo 2024
Beijing, China
https://en.cr-expo.com/?gclid=EAIaI-QobChMIttyL0Ja4_gIV4gUGAB0lCw-p2EAAYASAAEgI7YPD_BwE

April 21 – 24
11th Asian Conference on Refrigeration and Air Conditioning (ACRA)
Jeju (Korea)
http://www.acra2024.org/

May 29 – 31
14th IIR Conference on Phase-Change Materials and Slurries for Refrigeration and Air Conditioning
Paris (France)
https://pcm-2024.colloque.inrae.fr

June 9 – 11
8th IIR Conference on Sustainability and the Cold Chain
Tokyo, Japan
https://biz.knt.co.jp/tour/2024/iccc2024/

July 15 – 18
27th International Compressor Engineering Conference at Purdue
West Lafayette, IN, United States
https://engineering.purdue.edu/Herrick/about/news/Conferences

August 11 – 14
16th IIR-Gustav Lorentzen Conference on Naturals Refrigerants
University of Maryland, United States
https://ceee.umd.edu/gl2024

August 21 – 24
10th IIR Conference on Caloric Cooling and Applications of Caloric Materials
Baotou, China
https://iifiir.org/en/events/11th-iir-conference-on-caloric-cooling-and-applications-of-caloric-materials

August 27 – 30
China Heat Pump Conference 2024
Shenzhen, China
https://iifiir.org/en/events/china-heat-pump-conference-2024

September 9 – 11
11th IIR Conference on Compressors and Refrigerants
Bratislava, Slovak (Republic)
https://szchkt.org/a/conf/event_dates/73?locale=en_GB

October 8 – 10
Chillventa 2024 – Refrigeration, AC & Ventilation, Heat Pumps Exhibition
Nuremberg, Germany
https://www.chillventa.de/en

2025

January 01 – 30
7th IIR Conference on Thermo-physical Properties and Transfer Processes of Refrigerants
College Park, United States
https://iifiir.org/en/events/7th-iir-conference-on-thermophysical-properties-and-transfer-processes-of-refrigerants

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IN THE NEXT ISSUE
Empowering Tomorrow: Heat Pumps Unleashing Flexibility and Sector Coupling Amidst Electric Grid Transformations and Strategic Investments
VOL 42. NO 1/2024

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International Energy Agency
The International Energy Agency (IEA) was established in 1974 within the framework of the Organization 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 are the cornerstone for a secure, affordable, high-efficiency, clean and net-zero emission energy system for heating, cooling and refrigeration. We are the key worldwide independent actor to achieve this vision across multiple applications and contexts.

We generate and communicate information, expertise and knowledge related to heat pumping technologies as well as enhance international collaboration.

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

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/
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