



Drivers and barriers for
heat pumps in multi-
family buildings

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Heat pump retrofit projects
for multi-family buildings

p. 18

Market Report from
Finland

p. 24

Heat Pumping Technologies **MAGAZINE**

A HEAT PUMP CENTRE PRODUCT

The next step in the green revolution:
**Heat pumps in
multi-family buildings**

Marek Miara, Germany, OA Annex 50

"THE CHALLENGE OF APPLYING HEAT PUMP TECHNOLOGIES AND RENEWABLE ENERGY IN MULTI-FAMILY BUILDINGS IS RATHER COMPLEX."

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Heat Pumping Technologies MAGAZINE

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In this issue

This issue of the HPT Magazine focuses on the possibilities of heat pumps in multi-family buildings. In the topical articles you can read about drivers and barriers for heat pumps and they also go into some of the aspects of retrofit projects.

We know that the energy system of tomorrow cannot look like the ones today. Fossil fuels must be replaced by renewable energy sources and energy systems must transform. And in that transition, heat pumps are a crucial component both on individual and systematic level.

In this issue, you can read about the big and quite unique market for heat pumps in Finland. The significance of heat pumps has grown in several kinds of buildings and play an important role as a producer of renewable energy.

The fight against the Corona virus and its effects has an impact on almost everything we do, and restrictions continues with variations between nations and over time. We adjust our actions and plans and one of these adjustments is the transformation of the 13th IEA Heat Pump Conference in Jeju, South Korea, to a hybrid conference.

Enjoy your reading!

Sara Skärhem, Editor

Heat Pump Centre

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

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Heat pumps in multi-family buildings

There is no doubt about the urgency of climate change. And there is also no doubt that we need to act decisively to diminish its future scale by reducing greenhouse gas emissions. One of the significant sources of CO₂ emissions amplifying the negative effects of climate change is people's need for heating and cooling in their homes.



Using heat pumps as an alternative to fossil fuel technologies is substantially reducing CO₂ emissions in the heating and cooling sector. Heat pumps are already the number one technology in new, typically single-family, houses in several countries, particularly in Europe. This trend must continue and evolve even more.

Although there are good examples of heat pump implementations in multi-family buildings, it has not yet gained much traction either in new or existing buildings. Yet as the current demographic trend towards moving to high-density cities persists, multi-family houses are becoming more important.

In view of this, the need is great to discover and provide optimal solutions for heat pump implementations in new and existing multi-family buildings.

The challenge of applying heat pump technologies and renewable energy in multi-family buildings is rather complex. In many cases, it is not just technical barriers that stand in the way of successful implementation. For example, the issue of ownership varies among countries. While multi-family houses are often owned by local cities, communities or housing corporations in some countries, in others ownership is private and divided into separate flats.

Multi-family houses also involve a range of heat demand characteristics. Firstly, the share of domestic hot water demand on overall heat demand varies due to varying building standards and different climates. Secondly, the temperature level of the heating system is influenced by these factors, together with the installed heating transfer system. The variety of heat demand characteristic thus poses a challenge to a more widespread adoption of heat pumps in multi-family buildings.

In this issue of the HPT Magazine, you can find three topical articles from the working group Annex 50, "Heat Pumps in Multi-Family Buildings for Space Heating and DHW". They all show results from ongoing activities within Annex 50, from overviews of the participating countries to individual success stories from Switzerland on implementing heat pumps in existing buildings. One article describes the holistic approach of Annex 50 including a general classification of possible solutions, detailed description of individual solutions, and visualization of an installation realized using an online database.

I hope you find this issue enjoyable and informative!

Marek Miara

Annex 50 Operating Agent
Business Developer Heat Pumps at Fraunhofer ISE, Germany

Diversification of heat-pump-related technologies

To address the global requirements on halving greenhouse gas emissions, major scientific and technological challenges must be faced. In October 2020, Prime Minister of Japan Suga Yoshihide issued a general policy statement announcing Japan's commitment to become a completely carbon-neutral society by 2050. For this purpose, the industry needs to radically change its business model and strategy. Japan's government has declared that it will do its utmost to support the private sector in pursuing and implementing bold technological initiatives and innovations.

Energy-saving heat pump technologies have been widely applied in refrigeration, air conditioning, hot water supply, and industrial cold-hot process control systems. The production of heat pump systems is still expanding in Japan. More than 7 million domestic heat pump water heaters using environmentally friendly CO₂ as a refrigerant have already been made commercially available. Even in the context of achieving net-zero emissions, heat pump technologies are expected to continue to spread as excellent energy-saving alternatives with positive economic impacts.

Heat pump technologies can also be used in humidity control applications. In summer, in humid countries like Japan and tropical climate regions, dehumidification improves comfort. In winter, when the humidity drops, controlling the humidity may help prevent colds and viral infections. Typically, a desiccant is used to control humidity. Desiccant-based air-conditioning control systems operate through a moisture adsorption and desorption process using solid or liquid desiccants. These systems require the simultaneous removal (for adsorption) and addition (for desorption) of heat to operate. A hybrid humidity control air conditioning system with extremely high performance can be obtained using a single heat pump for the cooling and heating process simultaneously. Additionally, this system can be driven efficiently even when significant ventilation is required. Therefore, it may be useful as a countermeasure for coronavirus infections.

Solid silica gel and liquid lithium chloride are commonly used as desiccants. Liquid desiccants are preferred for highly efficient cycles from a thermodynamics viewpoint. However, lithium chloride is highly corrosive and usually carried in dehumidified air, causing significant corrosion in metal building materials. That's why liquid desiccant dehumidification systems with lithium chloride have almost disappeared from the market. To tackle this issue, our research group has developed a non-corrosive ionic fluid desiccant, focusing attention on liquid desiccants in air conditioning systems. We also developed a hybrid humidity control air-conditioning system combining the non-corrosive ionic fluid with a centrifugal chiller using water as a refrigerant. The developed hybrid system showed a COP of 7.9. Moreover, we developed a general-purpose energy system analysis simulator, "Energy flow + M". Our results show that annual CO₂ reduction exceeded 40% when utilizing the hybrid humidity control air-conditioning system. The system developed in this work is being used for metro stations that have high humidity.

The applications for heat pump technologies are gaining in popularity. Although they are still in the developmental stage, their applications are expected to grow in many sectors.

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The 13th IEA Heat Pump Conference Mission for the Green World

The 13th IEA Heat Pump Conference (HPC2020) will take place on April 26-29, 2021, as announced in the previous issue of the HPT Magazine. The conference venue will be Ramada Plaza Hotel Jeju, Korea.



The 13th IEA Heat Pump Conference will take place one year later than originally scheduled. Due to the coronavirus outbreak, the conference will be held as online-on-site hybrid event. The on-site conference will be held at Ramada Plaza Hotel Jeju in Korea. The upcoming conference will be the thirteenth in a series of conferences held by the International Energy Agency (IEA) Heat Pumping Technologies TCP (HPT TCP). It is the fourth Heat Pump Conference to be held in Asia, and the first to be held in the Republic of Korea.

The 13th IEA Heat Pump Conference will serve as a forum to discuss the latest developments in heat pumping technologies and to exchange valuable knowledge about markets, policy, and standards information on related technologies. Exhibitions will be held at the conference that share information about products and technologies from domestic and foreign companies.

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

For online participants, an online conference platform will be provided that also allows attendees to view the presentations over an extended period of time. Access to all the highlights of the 13th IEA Heat Pump Conference will be given to registered from April 18 until May 1 – on-demand, wherever and whenever they please.

[See the program at hpc2020.org >](http://hpc2020.org)

Is Cooling the Future of Heating? - a commentary from IEA

In December 2020, IEA published a commentary written by the IEA analysts Thibaut Abergel and Chiara Delmastro. This commentary, starts with pointing out that high-efficiency heat pump technology is the cornerstone of sustainable buildings. Heating and cooling systems, are the two main end-uses in building operations, and since cooling demand is expected to grow considerably, a cold crunch is looming behind the buildings heat decarbonisation challenge.

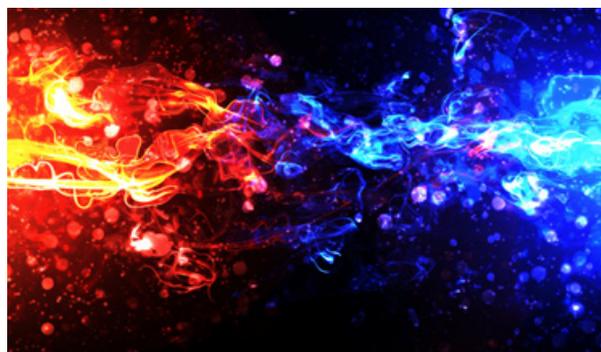
In the article, it is pointed out that low-carbon heating and cooling in buildings need a common strategy and a third of the global population will require heat pumps for both heating and cooling. The authors recommend to exploit synergies across heating and cooling strategies to lower the cost, since this can accelerate the deployment of more efficient reversible heat pumps, help to phase out fossil fuel equipment and therefore support buildings sector decarbonisation objectives. In particular, heat pump sales for heating need to triple by 2030 and become the leading technology in the long-term. They reach more than 50% of heating equipment stock by 2050 for both residential and commercial applications in the Sustainable Development Scenario.

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

The authors conclude that governments hold the key to low-carbon heating and cooling – to stimulate deployment they should apply the following measures:

- » Incentives for low-carbon heating technologies
- » Performance-based labels
- » Remove fossil fuel subsidies

[Read the full commentary at iea.org >](https://www.iea.org)



HTP TCP welcomes two new Annexes!

ANNEX
57

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

The new Annex 57 will focus on the implementation of heat pumps in district heating and cooling systems, describing possible solutions and barriers for heat pumps on these markets. This Annex will study the possible flexibility in the thermal network and electrical grid.

Worldwide, there is a governmental focus on using energy more efficiently and increasing the use of renewable energy, which will lead to a lower dependence of fossil fuels and a reduction of greenhouse gas emissions. (Goal 7 for affordable and clean energy of the United Nations.)

The objectives of the IEA HPT Technology Collaboration Programme is to support the energy security and to demonstrate applications in existing and new energy systems and buildings. Another objective is new cross-cutting, affordable solutions for heating and cooling, where heat pumping technology is a key element through collaboration with other TCP's, enabling energy savings, flexibility, and responsiveness in energy systems.

IEA HPT Annex 47 Heat Pumps in District Heating and Cooling systems, which ended in March 2019, focused on existing solutions and technology for heat pumps in district heating grids. This annex showed that up to 50% of heating demand in Europe could be covered by district heating (DH) and heat pumps can cover up to 25 % of the energy supply to the DH grid. This means that the potential for heat pumps is large. Annex 47 showed that heat pumps can be integrated in different ways in the DH grid which means that the losses can be reduced, and the efficiency can be improved.

The possibilities to use waste and ambient heat as well as to increase the share of renewable energy in District Heating and Cooling (DHC) systems and in the entire energy system by implementation of heat pumps will be one of the focus areas of the new Annex 57. In addition, minimizing the system losses by using heat pumps will also be an objective. The results of this study will provide an overview of the possibilities and barriers regarding the implementation of heat pumps in DHC systems.

ANNEX
58

HIGH-TEMPERATURE HEAT PUMPS

Heat pump-based heat supply at high temperatures has a considerable potential but is often facing various challenges. To fully exploit the potential, it is important that high-temperature heat pumps are considered as a key-technology in the planning of industrial energy systems.

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

The worldwide ambitions to decrease the greenhouse gas emissions require a considerable reduction of fossil-fuel based heat supply for industrial processes. In 2015 European process heating and cooling accounted for approximately 50 % of the final energy consumption of the industry. Electrically driven heat pumps are a promising technology for increasing system efficiencies and decreasing GHG emissions, using potentially emission free electricity.

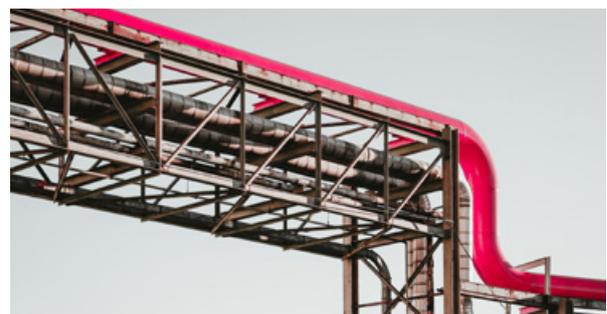


Photo by Martin Adams on Unsplash

The overall objective of the Annex is to provide an overview of the technological possibilities and applications as well as to develop concepts and strategies for the transition towards heat pump-based process heat supply. The intention is to improve the understanding of the technology/s potential among various stakeholders, such as manufacturers, potential end-users, consultants, energy planners and policy makers. In addition, the Annex aims to provide supporting material to facilitate and enhance the transition to a heat pump-based process heat supply for industrial applications.

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.

DESIGN AND INTEGRATION OF HEAT PUMPS FOR nZEB	49	AT, BE, CH , DE, NO, SE, UK, US
HEAT PUMPS IN MULTI-FAMILY BUILDINGS FOR SPACE HEATING AND DHW	50	AT, CH, DE , DK, FR, IT, NL
ACOUSTIC SIGNATURE OF HEAT PUMPS	51	AT , DE, DK, FR, IT, SE
LONG-TERM MEASUREMENTS OF GSHP SYSTEMS PERFORMANCE IN COMMERCIAL, INSTITUTIONAL AND MULTI-FAMILY BUILDINGS	52	DE, FI, NL, NO, SE , UK, US
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
COMFORT AND CLIMATE BOX	55	AT, BE, CA*, CH*, CN, DE, IT, NL , SE, TR*, UK, US
INTERNET OF THINGS FOR HEAT PUMPS	56	AT , CH, DE, DK, FR, NO, SE
FLEXIBILITY BY IMPLEMENTATION OF HEAT PUMPS IN MULTI-VECTOR ENERGY SYSTEMS AND THERMAL NETWORKS	57	DK , NL
HIGH-TEMPERATURE HEAT PUMPS	58	AT, CA, DK , DE, FR, NO

*) Participates from ECES TCP



NEW



FINALIZED

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
49DESIGN AND
INTEGRATION OF
HEAT PUMPS FOR
nZEB

The EU requires all new buildings as of January 1, 2021 to be nearly zero-energy buildings, according to the recast of its Energy Performance of Buildings Directive (EPBD). In the US and Canada as well as in Japan and China, nZEB targets are to be introduced from 2020 to 2030. However, current definitions of nZEB differ in criteria, metrics and limits, since the EPBD left the detailed definition of nZEB up to the member states. A comparison among the EU member states is further impeded by different calculation methods and different boundary conditions on climate data and internal loads. The different definitions also hinder the development of standardised system solutions for nZEB.

Achieving the high performance levels of nZEB requires both the building and the system technology to be high-performing and renewable energy production to take place on-site or nearby. Thus, nZEB building technology is a compelling solution for building designers and companies, the heating industry and other stakeholders to meet the high-performance requirements. Moreover, policymakers need performance data from actual buildings to shape the requirements.

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

increase on-site self-consumption of the renewably generated electricity and unlock energy flexibility potentials for grid support through storage integration and smart controls. Annex 49 has investigated the heat pump application in nZEB. The annex has been structured into four tasks, which cover the different aspects:

Task 1 analyzed the state of nZEB introduction and heat pump application in the different participating countries and elaborated a methodology for comparing nZEB implementations.

Task 2 investigated integration options to cover the different building services with the heat pump as well as storage integration. This also covers the integration of on-site renewable production with the heat pump system.

Task 3 evaluated real-life heat pump operations in nZEB in terms of more than 15 partly long-term monitored nZEB. For example, Figure 1 shows a five-storey plus energy building and Figure 2 two multi-family passive premium-certified buildings built by the social housing company NTH that was monitored in Annex 49. Other residential and non-residential nZEB buildings with heat pumps have been monitored, some for several years.

Moreover, several compact and highly integrated prototypes also including DHW and space cooling/dehumidification functions have been developed and tested within Annex 49. The façade-integrated prototype for PV-driven space heating and cooling depicted in Figure 3 has been developed at the Institute of Thermal Engineering (IWT) at TU Graz. At the Oak Ridge National Laboratory (ORNL), different integrated heat pump (IHP) systems have been developed. Figure 4 shows an air-source prototype. The ground-source system is already on the market.

Task 4 performed an in depth analysis through simulation of the monitored system and other simulation studies regarding the integration, design and control of heat pumps in nZEB.



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



Figure 2: Passive house premium certified multi-family buildings in Innsbruck-Vögelebichl built by the social housing company NTH (Source: NTH) that were monitored over four years and studied in simulations by Annex 49 at the University of Innsbruck.

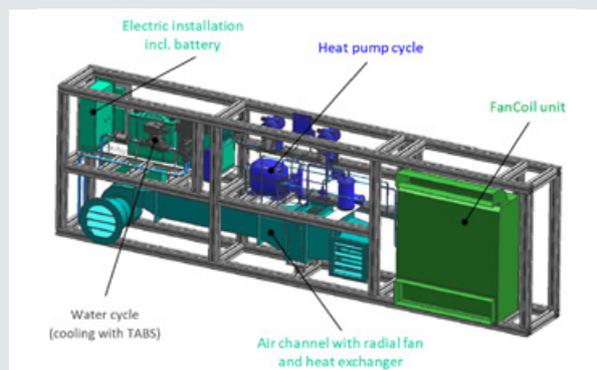


Figure 3: Façade-integrated heat pump prototype for PV-driven space heating and cooling (Source: IWT, TU Graz).

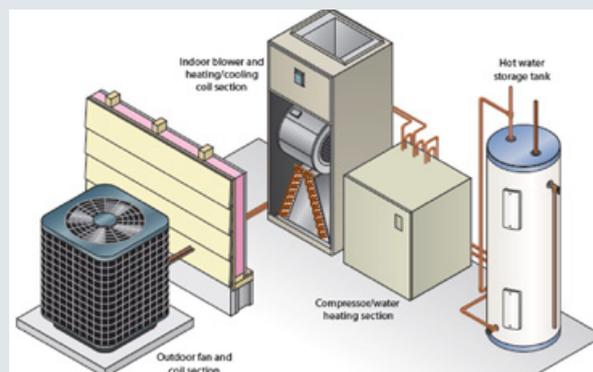


Figure 4: Integrated heat pump (IHP) development of ORNL, with integrated space heating and cooling as well as DHW and dehumidification functions.

One focus was the system configuration and component design needed to reach the nZEB balance – a challenge in larger residential and non-residential buildings. Task 4 also investigated the integration of on-site electricity production in order to increase the self-consumption of PV electricity and demand response with the system technology. The objective of the tasks were field-proven, optimised solutions for heat pump systems in nZEB applications as well as high-performing multi-functional prototypes as future developments. Moreover, recommendations were proposed for the design, control and integration of the components.

Objectives

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

Meetings and final reports

IEA HPT Annex 49 concluded in 2020. One meeting was held in late February 2020 in Brussels to discuss the final results and their presentation in the final Annex 49 reports. Final reports were completed at the end of 2020 concerning the different annex tasks, and will be published in April 2021 on the IEA HPT Annex 49 website.

Results

Monitoring results of Task 3

The high performance of heat pumps in nZEB applications was confirmed in more than 15 partly long-term monitoring projects in Annex 49. Some of the design targets of the

monitored buildings are thus more ambitious than the legal requirements in the countries. High seasonal performance factors up to an SPF of 5.5 for all building services were measured, facilitating attainment of the nearly zero-energy requirements cost-effectively. For an optimised system for low temperature lifts, monthly performance factors up to 7 in heating-only operations have been recorded. In turn, nZEB requirements can become a market driver for heat pumps also in larger buildings in order to achieve high performance.

Despite the high performance of the heat pump systems, the monitoring also shows that ambitious balance criteria like the net zero or even plus energy balance pose a challenge in larger residential and non-residential buildings, where space for on-site renewable energy production is limited. In some projects, the ambitious targets of a plus energy balance were not reached.

In the five-storey multi-family building in Figure 1, a surplus of 40% PV electricity was evaluated in the 2019 monitoring period. However, the building was only scarcely occupied in this period. For standard occupancy levels, the surplus will be cancelled out by the higher electricity and DHW demands, and even with a large additional façade integrated PV system of 36 kWp, reaching the nZEB balance including household appliances and plug loads will be a challenge.

Also in the two multi-family buildings shown in Figure 2, the nZEB balance was not reached in the monitoring of the built system. However, a detailed simulation model was derived at the department of energy efficient building at the University of Innsbruck from the four-year measurement data. Optimizations performed with the model confirm that an optimised system configuration can help to reach the balance based on the system technology. However, for an overall balance including household electricity, an additional façade integration for renewable energy production would be required. Figure 5 shows results from the investigated variants of the system configuration:

- » with and without solar thermal system and a scaled PV

system, which uses the whole roof area and replaces the solar thermal system in Figure 5.

» a direct coupling of the heat pump to the heating system (case A) and optimized desuperheater operation (case B) in Figure 5.

System integration and simulation studies on design and control of Task 2 and Task 4

In addition to the optimization of the monitoring projects as shown in Figure 5, Annex 49 conducted simulation studies on heat pump and thermal and electric storage integration and control, partly based on the monitoring projects. Different studies found that self-consumption of on-site renewable electricity production can be notably increased by smart control, either with rule-based or more advanced model predictive control strategies.

A single-family plus energy building was investigated at TU Braunschweig. Figure 6 contains the results of the five-year monitoring and the storage integration. A plus energy balance could be confirmed for all years monitored. The figure summarizes variations of both thermal and electric storage capacities by an extension of the thermal water storage for buffering of space heating or DHW energy and electric batteries. On-site self-consumption can be increased and grid interaction reduced. In this way, heat pumps in nZEB can also provide energy flexibility to support electrical grids.

A simulation study of IWT at TU Graz also confirms that thermal storage in activated building structures like floor heating of concrete core activation of the ceiling for heating and cooling can increase the energy flexibility with rather simple control strategies.

The storage demand-side management for demand response was also investigated for a group of eight single-family buildings in the project Herzo-Base at TH Nürnberg. The buildings are connected by a thermal grid for space heating, and each building is equipped with decentralised booster heat pumps for charging the local DHW storage

units. At the two central speed-controlled central heat pumps, an electric battery storage and thermal buffer storage are installed for load management of the 99 kWp PV system installed on the roof of these eight single-family houses. On-site PV self-consumption could be increased by both the electric and thermal storage and heat pump management, and a reduction of grid interaction could be confirmed through simulations. The rule-based control strategy is modulating the speed-controlled heat pump and charging the central thermal storages and decentral DHW storage units to higher temperatures in case of PV yield and reduces storage charging at low PV yield. Figure 7 shows an evaluation of the simulation results for the winter period January–March. The direct PV consumption could be increased up to 21%, thereby decreasing the electric battery feed-in by 10% and the grid feed by 11%. As a result, grid interactions could also be decreased, since grid load peaks could be reduced by up to 24%. Ongoing investigations also evaluate more advanced control strategies using model predictive control (MPC).

Conclusions

Integrated heat pumps are a favorable system technology for nZEB applications and for establishing nZEB as a standard system. High performance values are confirmed by long-term monitoring in more than 15 residential and non-residential buildings within Annex 49. Nevertheless, monitoring projects in larger buildings also confirm that reaching ambitious energy targets like a net zero or plus energy balance remains a challenge, and high system performance is required. In this way, nZEB introduction may become a market driver for heat pumps also in larger buildings to reach ambitious energy targets. Highly integrated heat pump prototypes in Annex 49 for all building functions of space heating and DHW as well as space cooling and dehumidification as needed confirm further performance increases and partly self-sufficient operations driven by the on-site PV-production, e.g. during summer cooling operations. Thanks to the on-site renewable energy production in nZEB, the heat pump also interacts with the

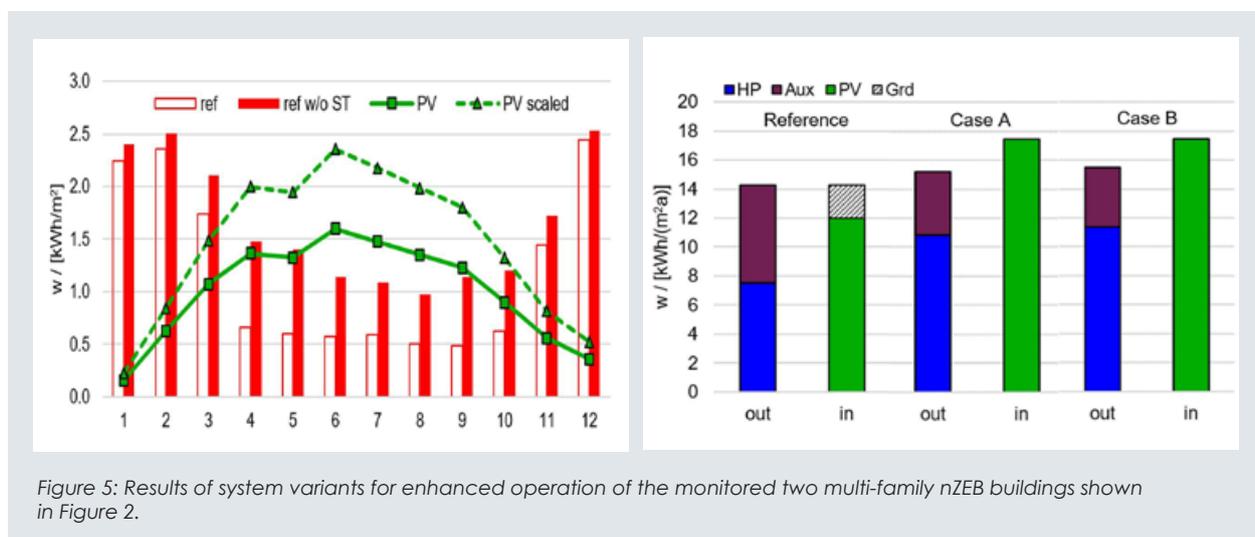


Figure 5: Results of system variants for enhanced operation of the monitored two multi-family nZEB buildings shown in Figure 2.

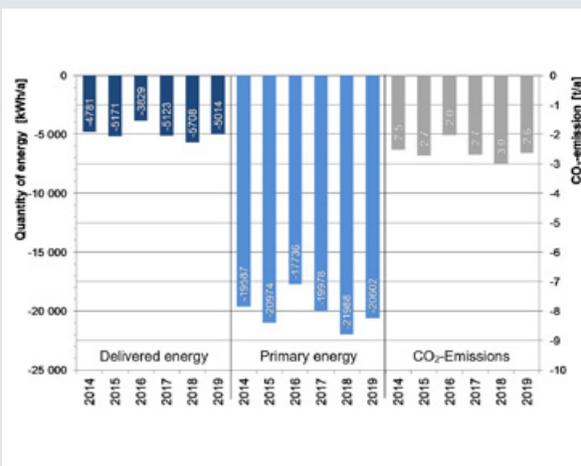


Figure 6: Monitoring results of a single-family plus energy building and results of storage integration and control variants concerning PV self-consumption and grid support (Source: IGS, TU Braunschweig)

on-site electricity production and the grid. Accompanying simulations confirm that the integration of the heat pump and electric as well as thermal storage enables demand response of the local production and a reduction of grid interaction. Thereby, heat pumps in nZEB can become a backbone for more renewable and sustainable energy production and flexible electricity grids.

As future perspective nZEB requirements are also extended to districts and the existing building stock, which offers future market opportunities for heat pumps. European countries are required to develop solutions that aim for nearly zero energy use even in existing buildings, and research envisages positive energy and climate neutral districts and cities. The Annex 49 results confirm the importance of heat pumping technologies for these future challenges and emphasize the role of heat pumps as key technology in a future sustainable energy system and built environment.

Publications

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

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

Annex website

<https://heatpumpingtechnologies.org/annex49/>

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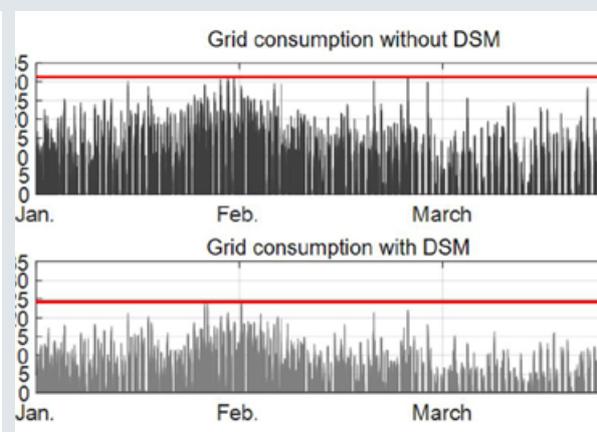
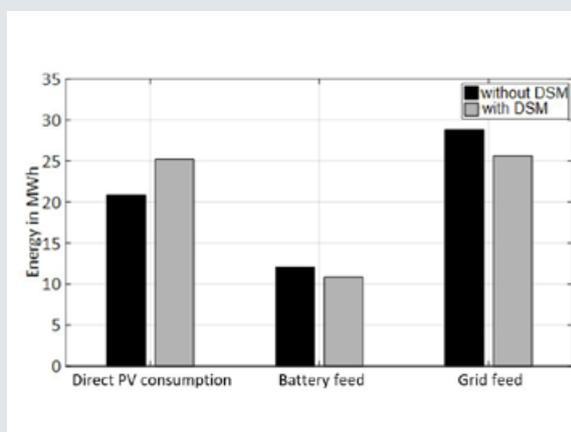


Figure7: Change of direct PV consumption, battery and grid feed (left) and reduction of load peaks (right) through rule-based control in the project Herzo-Base.

ANNEX
51ACOUSTIC SIGNATURE
OF HEAT PUMPS**Introduction**

To further increase the adoption of heat pumps, acoustic emissions must be reduced. To minimize noise annoyance, more focus must be placed on acoustics emissions at steady state and on the transient behaviour of acoustic signatures during different operating conditions. Heat pump placement is also critical, since sound emissions exhibit a pronounced directivity. Air-to-water heat pumps in particular provide a convenient and effective way to exploit potential energy savings and are often used in retrofit installations making acoustic improvements crucial because of their noise-producing components like compressors and fans. Members of the HPT Annex 51 team first convened at CETIAT (France), RISE (Sweden), DTI (Denmark) and ISE (Germany) and then had two online meetings on March 18–19 and on September 9, 2020. The final meeting focused primarily on the publication of the promised deliverables, which will be available for download in the middle of 2021 on the HPT TCP Annex 51 website. Psychoacoustic tests, which will provide input to the test design used in Annex 51, were carried out by RISE in Sweden and the Acoustic Research Institute of the Austrian Academy of Sciences. A joint acoustic data set is currently being analyzed using psychoacoustic hearing tests. The interesting results will be summarized in a document which will also be available for free download. A concluding webinar guiding participants through the results of HPT TCP Annex 51 took place on November 30, 2020 (see Figure 1).

Achievements

- » Increased the adoption of heat pumps
- » Increased knowledge and expertise at different levels
- » Provided input to national and international standardization bodies
- » Prepared seven annex meetings – five physical meetings have been held (Austria Vienna June 2017, France Lyon January 2018, Sweden Borås, June 2018, Denmark Aarhus, January 2019, Germany Freiburg October 2019), and two online (March 2020 and September 2020)

» Workshop on acoustics of heat pumps held at the ICR2019 in Montreal, presentation published on the HPT TCP Annex 51 website

» Concluding international workshop and compilation of proceedings realized as a webinar in November 2020

» Worldwide dissemination to heat pump manufacturers

» Generated and distributed Acoustic Guidelines for the different levels (Component, Unit % Application Level)

The report for Task 5.1, Heat pump installation with a special focus on acoustic impact, has been compiled by AIT, TU Graz, DTI and IBP Fraunhofer, with a first version available for download from the HPT TCP Annex 51 website. It presents tools for calculating sound pressure levels ranging from simple calculation tools to two-dimensional visualization, advanced sound propagation calculation tools and full three-dimensional calculations of sound propagation. The virtual placement of heat pumps (see Figure 2) includes acoustic measurements of noise sources, auralization and methods for calculating sound propagation as well as a chapter on modelling, mapping, hardware and software for visualization and acoustics. The analysis of the acoustic interaction of multiple heat pumps is discussed in detail using a terraced housing estate as an example. Several scenarios have been investigated including one heat pump per household, one heat pump per house and a local heating supply. For these cases, the maximum sound pressure level at a number of sound emission points of interest (e.g. windows and borders) was calculated and presented using a penalty point system. This delivery also included the analysis of unit placement, indoor and outdoor sound propagation, a discussion of the potential of sound absorption at nearby surfaces, and a compilation of common “unclever” decisions in heat pump placement, such as incorrect locations, installation on roofs, development of neighboring property, improper sound absorbing measures and installation of further units in a neighborhood.

Annex website

<https://heatpumpingtechnologies.org/annex51/>

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Figure 1: The Webinar “Acoustic Signature of Heat Pumps” (view online at the Annex 51 website).



Figure 2: Parts of the augmented reality and acoustic app [Source: AIT, Austria]

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

Carefully instrumented and analyzed long-term performance measurements from large GSHP systems are highly valuable tools for researchers, practitioners and building owners. Analyses of good quality long-term performance measurements of GSHP systems are sparse in the literature, and there is no consensus on key figures for performance evaluation and comparison.

Within Annex 52, a bibliography on long-term measurement of GSHP systems has been compiled, and the participants are measuring the performance of more than 55 GSHP systems.

Based on this experience, the annex is revising current methodology to better characterize the performance of larger GSHP systems. These systems have a wide range of features and can be considerably more complex than single-family residential GSHP systems. The case studies will provide a set of benchmarks for comparisons of such GSHP systems around the world, using an extended system boundary schema for calculation of system performance factors. This schema is a further development of the SEPE-MO system boundary schema developed for non-complex residential heat pump systems.

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

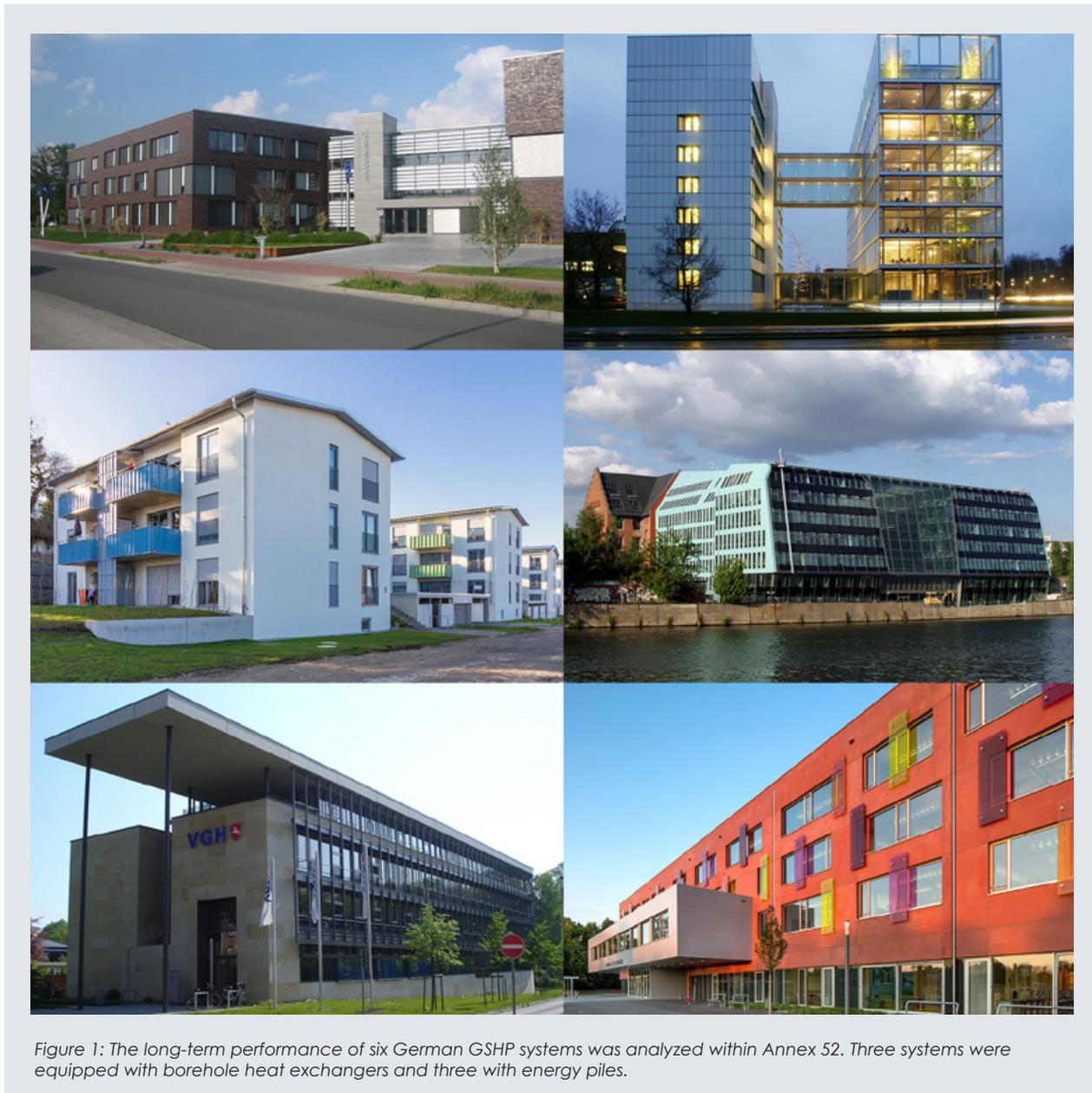


Figure 1: The long-term performance of six German GSHP systems was analyzed within Annex 52. Three systems were equipped with borehole heat exchangers and three with energy piles.

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 and ground heat exchangers are included in the scope.
- » Refine and extend current methodology to better characterize GSHP system performance serving commercial, institutional and multi-family buildings with the full range of features shown on the market, and to provide a set of benchmarks for comparisons of such GSHP systems around the world.
- » The guidelines provided by the SEPEMO project will be refined and extended to cover as many GSHP system features as possible and will be formalized in a guidelines document.

Recent progress

The final year of HPT Annex 52 has now begun, and most of the seven participating countries are writing their case study reports. The system boundary schema developed in Annex 52, revised from the SEPEMO schema for more complex GSHP systems, has now been implemented for all the Annex 52 case studies. Performance analysis of the six German case studies (see Figure 1), of which three are equipped with borehole heat exchangers and three use energy piles, has been completed. The GSHP systems have been monitored and their performance evaluated over ten years of operation with special emphasis on control strategies. For GSHP systems that provide cooling directly from the boreholes, seasonal performance factors above 10 were achieved, with some systems exceeding 100 in some years.

Two guideline documents are nearly complete. The drafts of the instrumentation and measurement guidelines, as well as the uncertainty analysis guide, have both been substantially revised and expanded. Both documents will be a help for the case studies and for future studies. Compi-

lation and systematization of key performance indicators other than SPF and COP were initiated during 2020 and are ongoing.

The annotated bibliography that has been compiled within the Annex now contains some 80 publications describing more than 55 buildings where long-term performance monitoring of larger GSHP systems has been performed, and some form of measured SPF has been reported.

The 2020 pandemic disrupted our annex meeting arrangements and has affected collection of measurement data and site visits. It has also delayed publication of conference papers and presentations related to the annex. A new open-access journal paper presenting results from a case study within Annex 52 was published in late 2020, in addition to four previously published journal papers. The journal paper by Liu et al. (2020) covers the long-term performance of a clubhouse in Gothenburg, Sweden, where both the SEPEMO and Annex 52 boundary schemes for evaluating and benchmarking the performance of the ground source heat pump system were used and compared. The study confirms previous findings within the annex: auxiliary system components, in particular legionella protection systems, may have a large impact on overall system performance.

Annex website

<http://heatpumpingtechnologies.org/annex52/>

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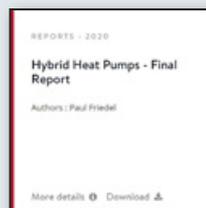
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Heat pumps in multi-family buildings, drivers and barriers

Odile Cauret, France

In Europe, the residential heat pump market has been steadily increasing for several years in most countries. However, the figures vary depending of the type of building. Whereas heat pumps are the most widespread solution in new individual houses, the market for them in multi-family buildings (MFBs) remains low, both in new buildings and in existing ones.



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The HPT TCP Annex 50, dedicated to heat pumps in MFBs, aims to gather and analyze data from the eight participating countries¹ in order to identify both individual and common characteristics of buildings, technical aspects and regulatory schemes that can explain the state of heat pump use in MFBs and can determine individual and common barriers that must be overcome in order to develop heat pumps in MFBs.

Place of heat pumps in European buildings

In all participating countries, annual sales of residential heat pumps have been increasing over the last decade, particularly since 2014. The increased sales can be viewed in terms of residential market penetration (see Figure 1, page 16). We can thus observe more or less pronounced dynamics, with sometimes still modest heat pump penetration rates despite booming sales, but a clear and increasingly rapid progression.

However, specific figures differ depending on the type of residential building. Indeed, heat pumps still represent a small portion of heating systems in the global building stock in all participating countries, from a few percent up to 10%. Except for some countries, such as Austria, Switzerland or France where there are significant differences between heat pump shares in MFBs (1–7%) and individual houses (10–15%), differences in heat pump adoption that depend on the building type are not very significant when considering stocks.

However, differences in the market development of heat pumps between individual houses and MFBs are more obvious in new buildings. In some countries, such as Austria, France and Germany, heat pumps are the heating system of choice in newly built individual houses, at around 50% or more. But this percentage increases more or less rapidly in newly built MFBs in all countries.

Thus, if we consider the three countries mentioned, heat pumps represent only 4–5% of heating systems in new collective housing in France but more than 20% in Germany and Austria.

The driver: policy framework

All participants represent European countries. Except for Switzerland, the countries share the same policy landscape, with the main relevant directives concerning the energy performance of buildings, energy efficiency and performance requirements of energy-related products. Moreover, these countries are affected by the 2020 and 2030 targets in terms of CO₂ emission reductions, energy efficiency and use of renewables.

To meet these targets, each participating country has developed a specific regulatory scheme to encourage renewables and reduce energy consumption in the building sector. Among all the regulations in force in each country, two rules are key drivers for the heating system market: buildings regulations for new buildings and incentive programs for existing ones.

Most of the countries have established building regulations based on maximal consumption. The maximal consumption value and the uses included in the accounting vary from one country to another. Some regulations add a performance requirement on the building structure to minimize energy needs. This encourages shared efforts between building structure and system efficiency to reduce energy consumption. Other regulations are stricter concerning energy consumption requirement that it implies to make effort on both aspects even if no requirement on building structure efficiency is imposed. It should be noted that France is the only country where the requirements are different, and less strict, in collective housing than in individual houses.

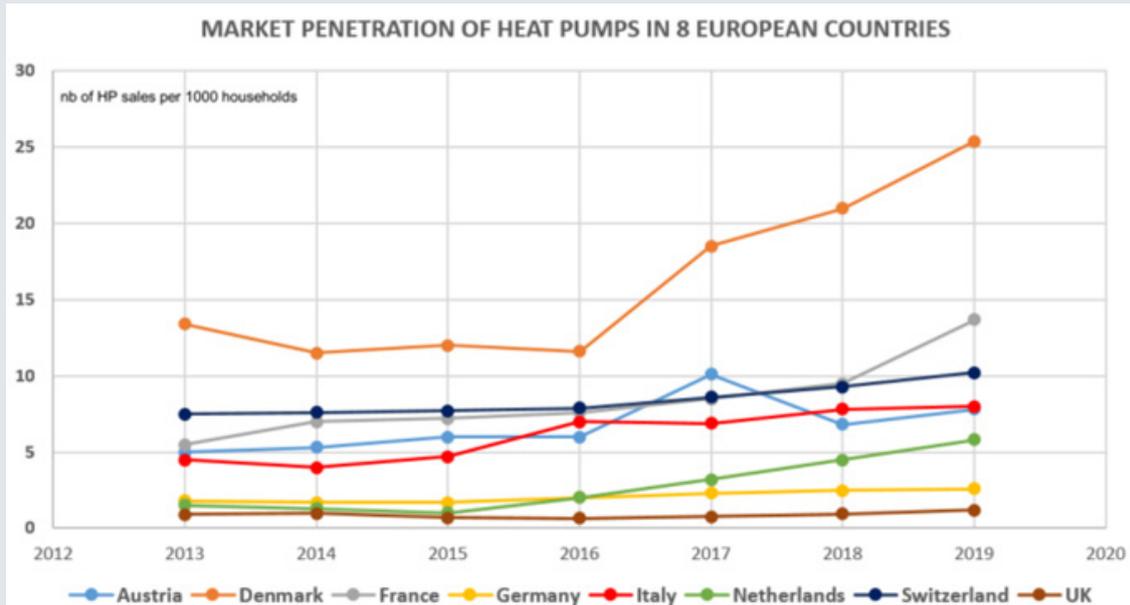


Fig. 1: Residential market penetration in the 8 participating countries (source EHPA www.stats.ehpa.org)

In addition, several countries have implemented or are planning to implement a ban on fossil fuels, including natural gas, in newly constructed buildings (Denmark in 2013, Netherlands in 2018, France in 2021 and UK announced for 2025). Without being so radical in their stated desire to eliminate fossil fuels, the regulations of other countries are, however, sufficiently restrictive in terms of energy consumption for heating and domestic hot water use to promote the development of efficient systems like heat pumps.

Incentives schemes take on different forms depending on the country: promotion of efficient technologies for all markets, contribution of big energy consumers to energy efficiency actions (energy savings or energy-efficiency certificates), incentives for existing building and equipment renovations with a wide scope of supported technologies, specific programs to replace fossil fuel boilers in existing buildings, etc. Whatever the reason for the incentive, heat pump installation is included in the scheme and even becomes the central part of it. In all countries, heat pumps are supported by grants, tax credits or tax reductions.

In conclusion, although policies are being tightened, they are becoming more favorable to the development of heat pumps in buildings. The few differences noted in the regulations do not fully explain the weak development of heat pumps in collective housing compared to single-family homes. Thus, besides regulatory barriers, other barriers have to be overcome to obtain a sustainable development of heat pumps in MFBs.

Barriers to overcome

Technical barriers

Heating capacity and supplied temperature

The multi-family building stock is quite old in all participating countries, with 52–60% of buildings on average being built before 1970. The majority of MFB stock was built before the first building regulations. For these MFBs (earlier than 1970), the heating demand represents 120–150 kWh/m²/an. Without any refurbishment, these MFBs need high heating temperatures (above 60°C), which do not easily suit heat pump applications.

Moreover, in most countries, state-of-the-art heat pumps provide heating capacities below 50 kW. These types of products are only adapted for efficient buildings, not for collective heating production in old ones.

Access to heat sources

Most multi-family buildings are located in cities, with rather high building density. Therefore, access to the heat source, in particular geothermal sources, is complicated. For air-source heat pumps, a collective heat source is often the only solution to avoid multiple visible outdoor units. These can be difficult to integrate, even forbidden, from an architectural perspective. In the collective case, the unique outdoor unit has to be installed on the roof, which presupposes a terrace roof, or in an outdoor car park or garden near the technical room.

Economic barriers**Capital costs**

In MFBs, high capital costs affect the competitive position of heat pumps compared to fossil-fuel boilers or direct electric heating. This criteria is particularly significant in new builds, often (75% of total cases) managed by private developers. The main concern of private market players is the cost of flats, and consequently their selling price. Indeed, for each new build, the developer estimates a maximum selling price, corresponding to the type of flat, its location, etc. Among these criteria, a renewable heating system is not at top of mind. As developers are rarely able to value heating by heat pumps in their buildings, this quite expensive heating system directly affects the cost price without any effect on the selling price. For the moment, clients and developers are not convinced.

Energy prices

Current prices for oil, natural gas and biomass greatly impact the heat pump market.

Because the prices for crude oil and other fossil-fuel energy sources have been falling in recent years and kept stable at low levels, there is a significant barrier for investing in new heating technologies that use electricity. The price of electricity varies substantially from one participating country to another but is always high compared to gas prices. The electricity/gas price ratio is 1.7 to 4. If an average seasonal performance factor (SPF) around 3 is considered, in a few countries (Denmark, Germany,

UK), this SPF does not compensate the energy price ratio. This means that even operating costs can be higher for a heat pump installation than for a gas boiler one.

Conclusion

In the seven European countries participating in Annex 50, heat pumps are expanding rapidly in single-family homes but are still struggling to gain market share in collective housing, despite regulations that are increasingly favorable to their installation in all countries. Common barriers have been identified. They can be technical (access to the cold source, capacity of available products) or economic (investment cost, energy prices).

An essential point common to all countries should be added: the lack of knowledge on the part of the building sector and customers. Heat pumps are still too often considered as a product for individual houses. Significant demonstration efforts are needed to highlight the potential offered by heat pumps in collective housing.

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Heat pump retrofit projects for multi-family buildings – An obstacle run

Nicole Calame, Switzerland

The use of heat pumps in existing multi-family buildings represents an important underexploited potential to help decarbonize the building sector in terms of the heat requirements of urban areas on a large scale. However, challenges may arise which could either turn out to be obstacles or a complete “no-go” for heat pump projects. Legal, technical, administrative, financial and awareness considerations are reviewed here in a Swiss context. Lessons learned provide specific examples that can help to address the situation. Proposed solutions for addressing the difficulties are presented, as are identified paths to improved adoption of heat pump solutions.



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Introduction

Supplying sustainable heat for households plays a key role in the Swiss energy strategy. Heating and domestic hot water needs account for about 30% of national CO₂ emissions. Heat pumps sold in Switzerland are increasingly used for retrofit projects but still only marginally for large buildings. More than 72% of the Swiss population currently lives in multi-family buildings, which make up about 43% of the built environment. And it is the existing building stock that will comprise most of tomorrow's housing. If this is a major target in the hunt to decarbonize the domestic heat sector, why is retrofitting large buildings with heat pumps still lagging behind? Mainly because it has long been considered unrealistic. The truth is, such projects are cross-disciplinary with a tendency to multiply the challenges. Here is a review of various practical considerations that might hinder a project, both country-specific and generally applicable.

Regulatory and financial considerations

The energy prescriptions model application proved to be an efficient tool in the Cantons where it came into effect with more heat pump retrofit projects realized in MFBs where a minimum of 10% or 20% of renewable energy is mandatory for heating system replacements. Feasibility studies revealed the difficulty of complying with these requirements in an urban context where air-to-water heat pumps often proved to be the only achievable solution. The prescription model was established to harmonize the different regions. It applies to building conception as well as authorization procedures, and its full implementation in its latest version (MoPEC 2014) is not yet effective in many parts of the country.

Regarding funding, discrepancies range from no subsidy policy for heat pump retrofits to generous ones including the distribution system replacement. A lack of subsidies either stems from technology reluctance or, in contrast, because they are considered the most profitable

option in the long run. Some people push for geothermal heat pumps or apply for electric heating system replacement only. Interestingly, the attractiveness of funding is not always reflected in the number of projects realized. Some regions use heat pumps to a great extent despite a lack of incentives, possibly because they are more aware of and confident in the technology from the installers. Other factors include doubts about the reliability in higher-altitude areas whereas rural zones often face fewer worries with noise issues. The contribution models for heat pump retrofits usually consist of a fixed base subsidy with a variable portion linked to the heating power installed. However, some models index the subsidy to the size of the dismantled heating system or to the energy reference surface of the building in order to discourage oversizing and promote heating reduction through envelope sanitation [1].

The Swiss tenancy law is a barrier. Large buildings are mainly inhabited by tenants who do not contribute financially to heating system renewal even though they would benefit from cheaper resulting energy charges. Owners therefore lack an incentive to opt for a renewable solution. To help carry out projects, a successful energy contracting system has been implemented in Geneva by the local public utility SIG.

Implementing a heat pump often requires constructive adaptations, which triggers a building permit application procedure for these works. This can become an administrative nightmare. Each and every function concerned will be consulted with regard to noise, environment, fire protection, monuments and sites, town and country planning. If one function decides negatively, the entire application is rejected. In Geneva, 14 different forms must be filled in. This heavy administrative burden is detrimental to heat pump retrofits because it blocks projects or involves potentially heavy cost overruns for the owners. Height limitations for buildings and installations on top



Figure 1: Exemplary integration in a historical building realized in the Altmarkt-Galerie in Dresden, Germany (Source: Güntner GmbH)

of them can constitute a major problem and make it difficult to find an installation location for the heat pump. The aesthetics of the machine can increase the acceptance of city-compatible air-to-water heat pumps. Indoor installations are not spared, with possibly large air intake and outlet modifying the façade. Split units could help mitigate these challenges. Cultural heritage laws make it even tougher in old city centers, where patrimonial protection could seal the end of a project. This can, however, be surmounted as shown in Figure 1, where air coolers are ingeniously hidden underneath painted grids.

Technical considerations

More heat pumps were sold in Switzerland in 2019 than fossil-fuel boilers, of which 84% consist of heating power under 20kW (97% < 50kW) [2]. Despite a growing market, it is still a challenge to find standardized and silent heat pumps for large capacities. The two options are either cascading smaller modules or choosing a larger industrial range product which is not designed for residential use (Figure 2). Resorting to tailor-made products provides an alternative.

The maximum sound level allowed depends on the sensitivity of the zone. The threshold value is legislated and must be respected at the hearing points, not at the emission point. A relative noisy heat pump impact can be limited through a wise implantation and additional noise- and vibration-reduction measures. Considering the average distance to neighbors in urban areas, the target value of the acoustic power should be around 50-55 dB(A). The energy efficiency (COP or COPA) of the selected machine is key for a profitable operation. The challenge is to try to reduce the supply temperatures, although high temperatures are achievable.

Various implementation concepts are available for indoor, outdoor and split alternatives (Figure 3). Each solution comes with a different set of issues but can also help to address local constraints. Two main integration

modes are possible: monovalent (100% of the production by heat pump) or hybrid with a second heat source. The latter can be a pragmatic and economical solution to secure heating needs throughout the year without oversizing. Heat pumps are ideal as monovalent heat generators for floor heating and radiators operating at less than 50°C (area-specific standard heating load of about < 75 W/m²).

Hydraulic integration schemes have to be specifically developed with the manufacturer to reliably integrate the heat pumps with the constraint of existing heat and DHW distribution systems.

The dimensions and weight of the heat pump and storage tank are critical since a lack of available space may compromise a project. Height especially is a key consideration to ensure a large and properly stratified heat storage that prevents constant switching on and off. Sufficient space is also needed to access the implementation site. The air intake and outlet of indoor installations requires large sizes to avoid noise generation or aspiration issues (vacuum effect clogging). Linking the machine to the boiler room can be tricky too. Insulated connecting pipes of a non-negligible diameter might have to cross the entire building. One option is to run them outside.

Installing a heavy heat pump in an existing structure requires a preliminary static evaluation by an experienced civil engineer who should take into account the heat pump's weight including water and refrigerant content, stand and hydraulic components. Be aware that structure-borne sound that reverberates through the slabs can occur from compressor-induced vibrations. Another practical consideration not to be overlooked is the electrical introduction of the building. Chances are the existing one will have to be reinforced due to the important absorbed power at start-up, potentially implying significant cost overruns [4].



Figure 2: Two rooftop projects with air-to-water heat pumps realized in Geneva. Right: industrial heat pumps with over 80dB(a) at emission with surrounding noise-reduction walls (Source: SIG/ CSD Ingénieurs SA)

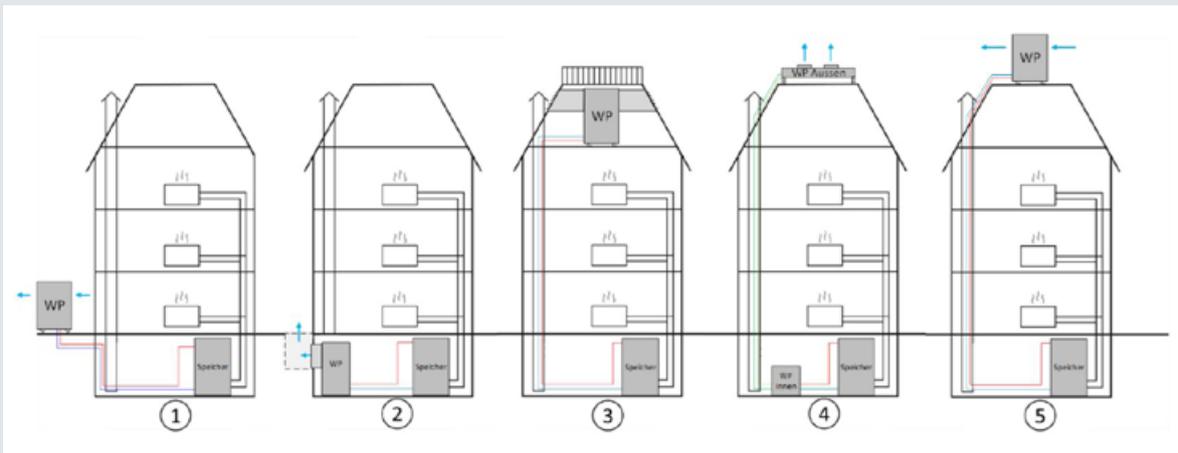


Figure 3: Solutions for heat pump (WP) and storage tank (Speicher) implementation [3]

Large heat pumps contain a substantial refrigerant charge. The same problem is faced by natural ammonia as by new HFO fluids regarding the protection measures requested in a closed room. This particularly implies an important ventilation capacity with possibly high associated costs.

A gap with expected performances may be observed [5]. Experience shows that discrepancies likely originate from the realization phase. A careful follow-up of the installer's work is needed. A monitored running-in period is highly recommended to optimize the installation until results can be considered final.

The complexity of multi-family retrofit projects implies a good management of ancillary works. This is reflected in initial investments that are 3 to 6 times higher for air-to-water heat pumps than for fossil-based heating systems. Nevertheless, the specific annual heating costs including the investment, operation and maintenance do not reflect such differences (Figure 4).

Such projects require technical engineering expertise and a solid understanding of laws and finance. The usual skills needed for small installations are not sufficient. Various professional training courses for installers and

engineers are available today as well as energy and incentive consulting. Information dissemination is done at the national, cantonal and municipal levels.

Another line of action lies in demonstrating achieved projects as undertaken by [1] presenting 32 examples of buildings ranging from 13.5kW to 220kW (3 to 77 dwellings), by [3] with eight objects with heating needs from 30kW to 186kW, by HPT TCP Annex 50 displaying case studies from across Europe [6] and others.

Conclusions

Various challenges can stand in the way of large heat pump retrofit projects for multi-family buildings, whether technical, regulatory or financial, or whether due to a lack of knowledge or simply being unsolvable. However, realized examples of a variety of sizes and solutions should inspire and encourage more such projects. Environmental awareness and the desire to maintain property values are already driving owners to choose heat pumps even for larger buildings. The evolution of the regulatory framework following the energy transition strategies and the will to develop adapted tools and training prove that this topic has been identified and is being addressed at different levels. This is encouraging, given the vast application potential and underlying benefits.

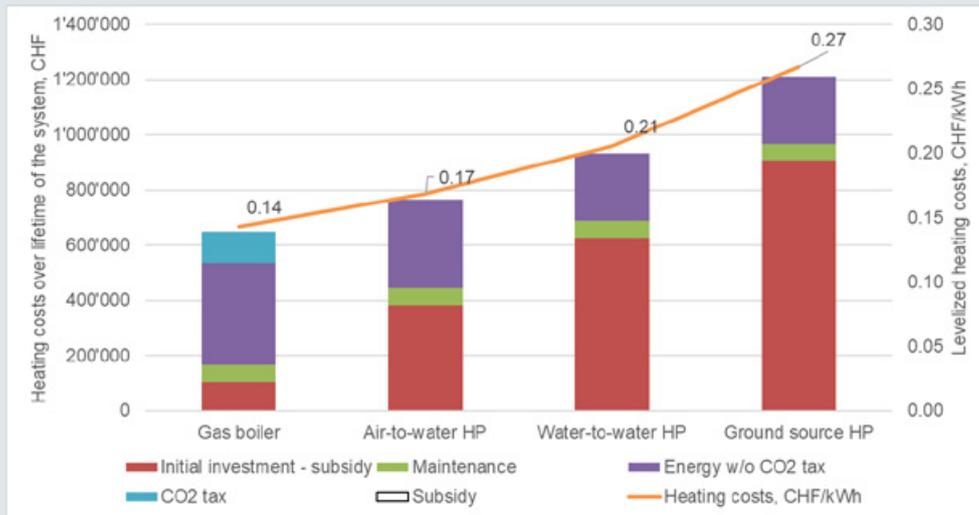


Figure 4 : Heating costs of an average multi-family building (1,700 m² ERA; 113kW thermal power) according to technology. The bar graph refers to the investments, and the orange line to the heating costs in [CHF/kWh] [5]

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Categorization of heat pump systems in multi-family buildings

Marek Miara, Germany

The use of heat pump systems in apartment buildings is already being practiced, as many examples from several countries show. Nevertheless, there is still no evidence pointing to a wider adoption of this solution for heat supply due to both administrative and technical reasons. Within the framework of Annex 50, "Heat Pumps in Multi-Family Buildings for space heating and DHW", a concept was developed to categorize the possible solution variants of heat pump systems in multi-family buildings on a higher level. As a result, five "solution groups" were presented. In parallel, practical examples were identified and described in a standardized way. All examples are available on the annex website at www.heatpumpingtechnologies.org/annex50/case-studies/.



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Introduction

The building sector plays a significant role in energy consumption in every country. Next to electricity generation and transportation, it is a top producer of greenhouse gas emissions. The massive reduction of CO₂ eq emissions from buildings and the long-term achievement of a climate-neutral building sector should therefore be considered inseparable.

New residential buildings are often built with an envelope and heating system designed for low energy consumption and with potential for using renewable energy technologies like heat pumps. For multi-family houses, the challenge of using heat pump technologies and renewable energies is more complex. Ownership of multi-family buildings varies between the member countries of the Technology Collaboration Programme on Heat Pumping Technologies. In some countries multi-family buildings are often owned by local municipalities or housing associations, while in other countries building ownership is divided among apartment owners. Various heating

considerations are important in multi-family buildings. Firstly, the share of hot water demand on overall heat demand varies due to different building standards and different climates. Secondly, the temperature level of the heating system is influenced not only by the energy condition of the building and its location, but by the installed heat transfer system. Addressing the multiplicity of heat demand characteristics will thus pose a challenge on the way to a more widespread dissemination of heat pumps in multi-family buildings.

The "solution matrix"

The project partners within the framework of Annex 50 have proposed a holistic approach to categorize, describe and visualize possible heat pumps application solutions in multi-family buildings. The entire method (internally called a "solution matrix") is presented schematically in Figure 1.

The first step – overview of concept groups – presents possible solutions grouped into so-called "solution families". There are numerous possibilities for differentiating

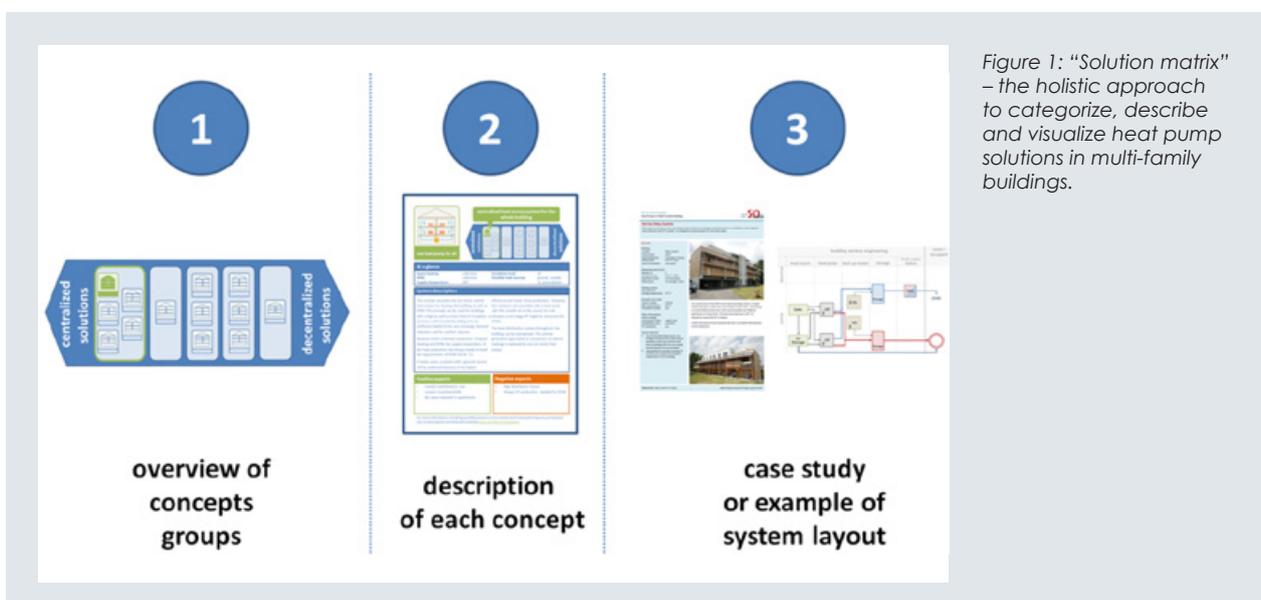


Figure 1: "Solution matrix" – the holistic approach to categorize, describe and visualize heat pump solutions in multi-family buildings.

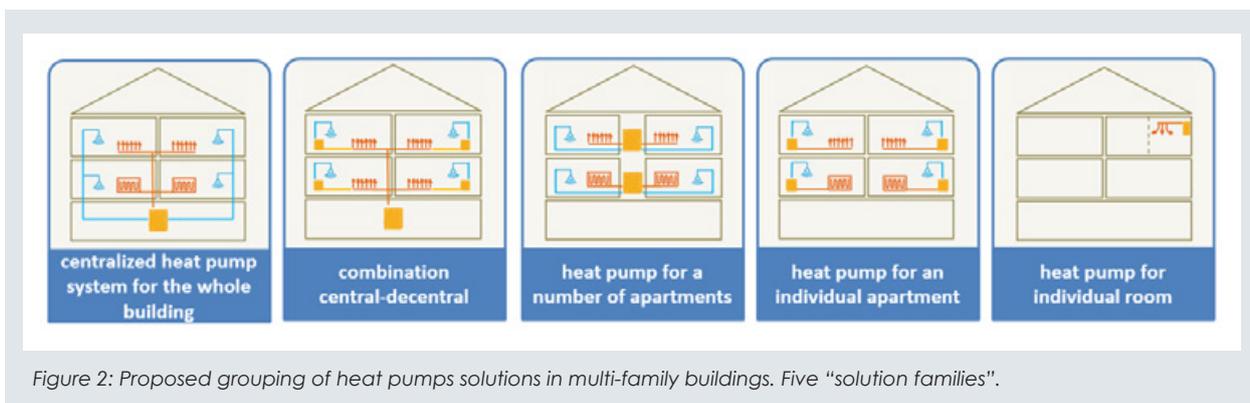


Figure 2: Proposed grouping of heat pumps solutions in multi-family buildings. Five "solution families".

and grouping heat pump solutions for multi-family houses. The methods differ in terms of the main focus ("the perspective") and the level of detail for one or several factors. The consideration of a multitude of differentiation criteria leads to a multidimensional matrix, which is very extensive which may compromise its clarity. Within the framework of Annex 50, a simple overarching grouping and presentation were developed (they are thus somewhat incomplete). This resulted in five "solution families", which represent the general types of WP solutions in MFH (see Figure 2). Each family consists of several "family members", which represent different variants of the main solution. The proposed method does not specify the heat source in most of the families. The type of heat transfer system is likewise not specified in most cases, being either underfloor heating or "conventional" solutions such as radiators.

Brief characteristics of the families:

- » "Centralized heat pump system for the whole building": All apartments in the building are centrally supplied by one or more heat pumps. The heating of the rooms, as well as preparation of the domestic hot water, are centralized.
- » "Combination central-decentral": All apartments are heated by a central heat pump. Domestic hot water preparation is provided by decentralised booster heat pumps, which are installed individually in each apartment.
- » "Heat pump for a number of apartments": The apartments form a group (e.g. by floor), which is heated by one heat pump. This solution is an intermediate solution between a decentralised and a centralised solution.
- » "Heat pump for an individual apartment": Each apartment is equipped with a decentralised heat pump. The heat pumps usually provide both hot water and space heating.
- » "Heat pump for individual room": The individual rooms of the apartment are heated individually by a small air-to-air heat pump. Hot water preparation is not included in this solution.

The second step of the solution matrix describes in detail each of 13 family members. The description includes key schematic scheme of the solution, key facts, detailed explanation as well as positives and negative aspects of the solution.

The third step consists of the corresponding (to the theoretical family members from the step two) case studies, showing the realized system. All case studies are collected and presented on the dedicated website www.heatpumpingtechnologies.org/annex50/case-studies/.

Next steps

The single steps of the described method are still under development and improvement. The first step can be considered as finished. The current activities of Annex 50 focus on step two, a description of each solution. Step three, "case studies data base", is already available on the annex website and will be expanded with new cases. Annex members aim to further develop the presented methodology and also create an online tool called a solution finder. This tool should include the number of different selection criteria (for example, building type, energy demand, heat source, etc.), giving the user a preselected solution from the members of the family solutions.

Summary

Heat pumps in multi-family buildings are still the exception rather than a standard solution. Both regulatory and technical challenges stand in the way of a broader implementation of the technology. Yet examples from many countries prove the applicability of heat pump systems in multi-family houses. Within the framework of Annex 50, "Heat Pumps in Multi-Family Buildings for Space Heating and DHW", a concept was developed to categorize the possible solutions in a simplified way. As a result, five solution families were identified. In parallel, existing case studies were collected, described in a standardized way and visualized online in form of case studies database.

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Finland: Heat Pump Market Outlook

Jussi Hirvonen, Finnish Heat Pump Association

Finland recently reached one million heat pump installations. With a population of 5.5 million, Finland's per capita heat pump sales and stocks are among the greatest in the world. Heat pumps produce over 12TWh/a, or 15% of the Finnish heating market. Investments in heat pumps now amount to EUR 6 billion. Last year, heat pump sales continued to grow. Over 600 million euros were invested in more than 100,000 heat pumps. According to recent studies, in 2030 heat pumps will produce 22TWh/a with two million heat pumps. The Finnish government announced recently that Finland will be carbon neutral by 2035, which means a very challenging 35 TWh/a target for heat pumps.



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Introduction

A heat pump is by far the most popular form of heating in new single-family houses, and heat pumps are increasingly replacing oil and electric heating as well as district heating in old buildings. The significance of heat pumps has also grown in multi-storey buildings as well as large service-facility buildings, such as shopping centres and logistics centers. Also, the use of heat pumps is continuously increasing in heat-recovery and process solutions as well as in the production of district heating and cooling. The role of heat pumps as a producer of Finnish renewable energy is even today much greater than that of solar and wind power, for example.

The Heat Pump Market in Finland

On a European scale, the Finnish heat pump market is substantial and quite unique. When looking at the number of heat pumps per type, the heat pump market is dominated by air-source heat pumps, while ground-source heat pumps lead the market when looking at the figures in euros or as in RES. 75% of single-family house builders choose a heat pump. Heat is already being extracted from 150,000 geothermal wells, the combined depth of which totals over half of the earth's circumference (25,000 km).

The main reason behind the success is clear. In Finland, heat pump systems are a highly profitable investment.

Cumulative Heat Pump sales in Finland (pcs)

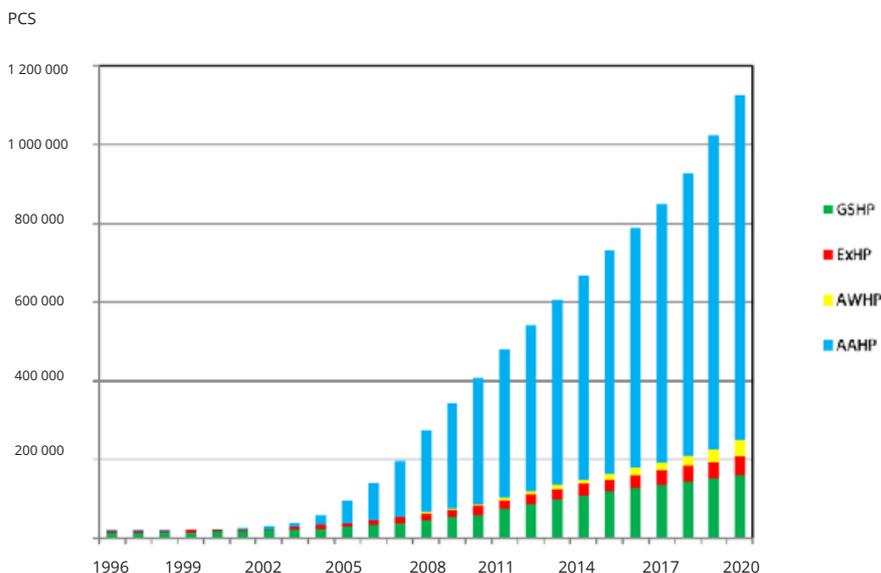


Figure 1: Number of heat pumps installed in Finland, cumulative 1996-2020 [1]

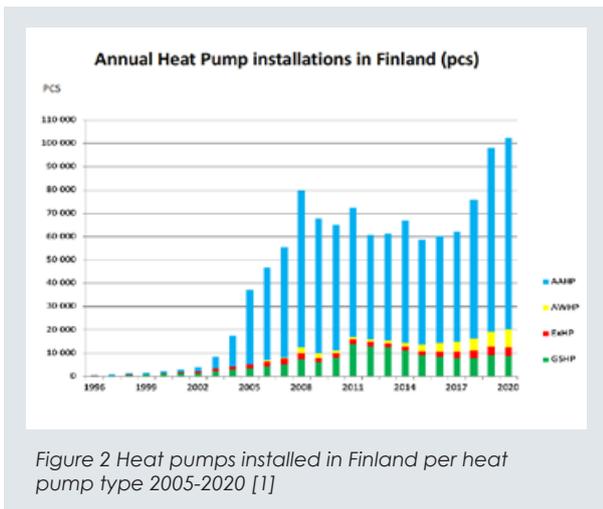


Figure 2 Heat pumps installed in Finland per heat pump type 2005-2020 [1]

The return on capital invested is often 10-15% per year. The Finnish government offers only very limited subsidies to heat pump projects, apart from a household tax deduction that can be claimed for the labor needed to install a heat pump.

The role of cooling in the Finnish climate is not great. However, the demand for it in housing, too, has increased due to living-comfort reasons as well as nearly zero-energy buildings. This is beginning to have an impact on the profitability of investments, since heating and cooling are provided through the same investment.

The threshold of 100,000 hp exceeded

According to Finnish Heat Pump Association (SULPU ry) statistics [1], 102,000 heat pumps were sold in 2020. The number of air-source heat pumps sold was just over 80,000, ground-source heat pumps 9,000, air-to-water heat pumps 8,000, and exhaust-air heat pumps 3,500. Aid granted to replace oil heating drove sales, especially of air-to-water heat pumps. Sales increased by 25%. Sales of ground source heat pumps showed a slight decrease of 4%, but as the size of delivered heat pump systems grew significantly, sales in euro within the sector increased.

Deployment of large heat pumps

Ground-source and exhaust-air heat pumps and their combinations are rapidly becoming more widespread in apartment buildings. They usually replace district heating. Approximately 500 apartment buildings have already been fitted with heat pumps that recover the heat of exhaust air. This reduces as much as 50% of the building's district heating or other energy consumption. A growing number of housing companies have decided to install ground-source heat in conjunction with an exhaust-air heat pump and to switch completely from district heating to a heat-pump-based heating and cooling solution.

Key role in electricity demand response

The fact that heat pumps are the perfect tool for demand

response and for managing the grid's electricity demand will be vital in the future. A heat pump provides a unique bridging technology between heat and electricity. This technology has the ability to use volumes of water, buildings, energy wells as well as bidirectional cooling/heating features as storage. With heat pumps' thermal power linked to demand response, heat pumps would already be able to provide approximately 5,000 MW of thermal power and, last year, about 500 MW more was generated. As much as roughly 1,500 to 2,000 MW of controllable electric power would already be available through the current heat pump stock.

An untapped potential in apartment buildings

There is certainly potential for heat pumps. In Finland, about 120,000 to 150,000 houses are oil heated. Every two hours, 30,000 apartment blocks release a houseful of 23-degree exhaust air outdoors, all year round. If, for instance, 100,000 users of oil heating are encouraged to switch to clean heating and exhaust-air heat pumps are deployed to recover the waste heat from exhaust air in 10,000 apartment blocks [3], this would mean fast-track viable investments that provide local employment at a value of approximately EUR 3 billion. With political will, this investment could realistically be carried out in five years, with the help of a reasonably light-handed carrot-and-stick approach and financial instruments. Most of this "carrot money" will return to the state in the form of VAT and other taxes, employment, economic resurgence as well as exports. In these two examples alone, we are talking about approximately 5 TWh of emission- and combustion-free production per year and a cut in emissions of several million tonnes of CO₂-eq.

Summary

The heat-pump industry has become a significant renewable-energy business in Finland. Over 1,000,000 heat pumps produce 12 TWh/a of energy. This already represents as much as 15% of the heating energy of all Finnish buildings [5]. The prospects for heat pumps are good, and the market will certainly develop in the future. The heat pump business can be described as an integrator or bridge technology that operates amidst and between renewable energy, electricity, and heating and cooling production. Heat pump technology and its applications can also be seen as an interface to a carbon-free age.

According to a survey [2] in 2030, there will be 2 million heat pumps in Finland producing 22 TWh of heating energy. By then, a total of over EUR 10 billion will have been invested in heat pumps. More pressure or possibilities for heat pumps have been created by the political promise to make Finland carbon neutral by 2035. For this purpose, the Smart Energy Transition consortium has published a study estimating that heat production by heat pumps should be increased to 38 TWh/a by 2040 [4]. In the Finnish heating system, district heating plays a significant role, about 50% of the heating market. Decarbonization of the heat market by heat pumps means a lot of heat pumps in the production of district heating

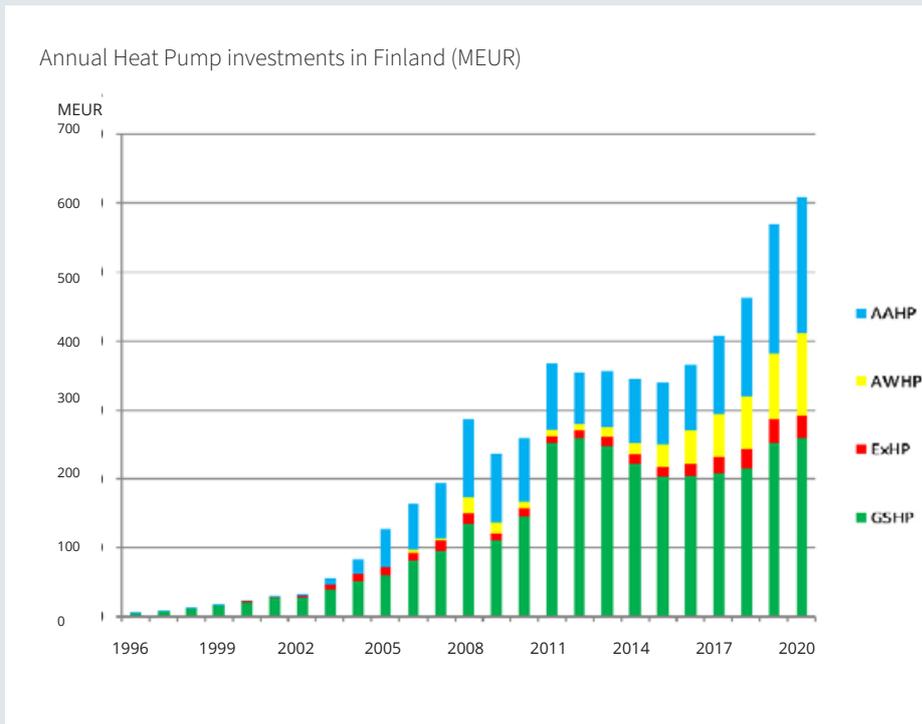


Figure 3 Heat pumps installed in Finland, in euros, 2005-2020 [1]

(Megawatt-size district heating/cooling, shopping center, service building, industrial HPs as well as planning, service, etc. are missing from figures in graph.)

but also saving district heating by heat pumps installed locally in individual houses.

The main reason behind the success is clear, yet this reason also stands out on a European scale. In Finland, heat pump systems are a highly profitable investment. The return on capital invested is often 10-15%/a. The Finnish government does offer only very limited subsidies to heat pump projects apart from the household tax deduction that can be claimed for the installation work of a heat pump.

Heat pumps are easy to use, hassle-free, require little space and have a cooling feature. These are arguments that also speak in favor of choosing a heat pump. Affordable electricity, the lack of a gas network, the high consumption of heating energy caused by Nordic conditions, a suitable bedrock for drilling, and a customer-friendly heat pump system supply all create favorable preconditions for profitable investments.

After fulfilling a 1 million heat pump vision in 2020, the next target of 2 million heat pumps can be set for 2030.

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Events 2021

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

2021

26-29 April

13th IEA Heat Pump Conference 2020 (postponed to 2021)

Jeju, South Korea & Virtual

<http://hpc2020.org/>

3-5 May

Euroheat & Power

Vilnius, Lithuania & Virtual

<https://www.ehpcongress.org/>

23-28 May

Purdue International Compressor Engineering, Refrigeration & AC, High Performance Buildings Conferences

<https://engineering.purdue.edu/Herrick/Conferences/2020>

7-11 June

9th International Conference on Caloric Cooling and Applications of Caloric Materials (Thermag IX)

Virtual Conference

<https://ceee.umd.edu/events/thermag-ix>

16-18 June

2nd IIR Conference on HFOs and Low GWP blends (HFO2021)

Virtual Conference

<https://biz.knt.co.jp/tour/2021/06/hfo/index.html>

21-23 June

Healthy Buildings, Europe 2021

Virtual and possibly also Oslo, Norway

<https://www.hb2021-europe.org/index.html>

26-30 June

ASHRAE Annual Conference

Virtual Conference

<https://www.ashrae.org/conferences/2021-annual-conference-phonix>

22-25 August

International Sorption Heat Pump Conference 2021

Berlin, Germany

https://www.eta.tu-berlin.de/menue/ishpc_2021

25-27 August

8th International Building Physics Conference (IBPC)

Copenhagen, Denmark (possibly hybrid)

<https://www.ibpc2021.org/>

1-3 September

13th IIR Conference on Phase-Change Materials and Slurries for Refrigeration and Air Conditioning

Vicenza, Italy (possibly virtual)

<http://static.gest.unipd.it/PCM2021/>

1-3 September

6th IIR Conference on Thermophysical Properties and Transfer Processes of refrigerants

Vicenza, Italy (possibly virtual)

<http://static.gest.unipd.it/TPTPR2021/>

3-4 September

52nd AiCARR International Conference

Vicenza, Italy

<http://www.aicarr.org/Default.en.aspx>

6-8 September

12th International Conference on Compressors and their Systems

London, UK

<https://www.city.ac.uk/events/conferences/compressorsconference>

13-15 September

IAQ 2020: Indoor Environmental Quality Performance Approaches - Transitioning from IAQ to IEQ

Athens, Greece

<https://www.ashrae.org/conferences/topical-conferences/indoor-environmental-quality-performance-approaches>

16-18 September

9th IIR Conference on Ammonia and CO₂ Refrigeration Technologies

Ohrid, Macedonia

<https://iifir.org/en/events/9th-iir-conference-on-ammonia-and-co2-refrigeration-technologies>

22-24 September

2021 ASHRAE Building Performance Analysis Conference

Denver, Colorado, USA

<https://www.ashrae.org/conferences/topical-conferences/2021-ashrae-building-performance-analysis-conference>

14-15 October

International Symposium on New Refrigerants and Environmental Technology 2020

Check link for more info.

<https://www.jraia.or.jp/english/symposium/index.html>

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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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