Technology Collaboration Programme
by iea

Heat Pumping Technologies MAGAZINE

A HEAT PUMP CENTRE PRODUCT

The next step in the green revolution:

Climate Leap – how investors reach major emission cuts in existing property portfolios

RELEASE OF IEA WORLD ENERGY OUTLOOK 2021

”SOLUTIONS TO REACH NET ZERO EMISSIONS ARE AVAILABLE, COST-EFFECTIVE AND OFFER SHELTER FOR FOSSIL FUEL PRICE SHOCKS – HEAT PUMPS ONE OF THE HIGHLIGHTED EXAMPLES”

VOL.39 NO 3/2021

ISSN 2002-018X

Heat Pumping Technologies
MAGAZINE

VOL.39 NO.3/2021

In this issue

The recent IPCC Special Report released in August 2021 reaffirmed the scientific urgency, and it issued a climate "a code red for humanity" earlier this year. The only way to save our planet is to (i) invest heavily in renewable electricity production such as wind and solar power; this very topic is addressed in the foreword of this issue. (ii) invest to stimulate a rapid deployment of heat pumping technologies in the building as well as the industrial sector. The column section explores the impact and opportunities of the Green Deal to boost the deployment of heat pumps in the building sector from the Italian point of view.

World leaders from many countries gathered in November for the COP26 summit to revisit their ambitious 2030 climate pledges; in the HPT news section, you can read a summary of global temperature warming projections based on the impact of COP 26 policies and action, the Release of the IEA World Energy Outlook 2021, and an extract of the key commitments of the UK Heat and Buildings Strategy 2021.

According to the IEA special report called Net Zero by 2050 – A Roadmap for the Global Energy Sector, the challenges and prospects of deploying 1.8 billion heat pumps to achieve net-zero emissions by 2050 have dominated recent talks. The industry, academia, policymakers, investors, and consumers will have to sing from the same hymn sheet to rise to the transition challenges to a low-carbon economy. Under the theme of "Climate leap – How investors reach major emission cuts in existing property portfolios", the topical articles of this issue are all addressing the major motivations in investment decisions in combating climate change and speeding the deployment of essential technologies.

Enjoy your reading!

Metkel Yebiyo, Editor
Heat Pump Centre
The central communication activity of Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP)

Published by Heat Pump Centre
c/o RISE - Research Institutes of Sweden,
Box 857, SE-501 15 Borås, Sweden
Phone: +46 10 516 53 42

Publisher:
Heat Pump Centre
P.O. Box 857, S-501 15 BORÅS
SWEDEN
Tel: +46-10-516 53 42
hpc@heatpumpcentre.org

www.heatpumpingtechnologies.org

Editor in chief: Monica Axell
Technical editors: Metkel Yebiyo, Caroline Haglund Stignor, Anneli Rosenkvist
- Heat Pump Centre.

Front page: iStock by Getty Images

ISSN 2002-018X
https://doi.org/10.23697/16d8-0h30

Without investments, there will be no change – except climate change

Heating of buildings accounts for a significant proportion of carbon dioxide emissions as fossil fuels presently provide the vast majority of heating. To reduce CO_2 emissions, we have to stop burning fossil fuels and, in the longer term, biofuels. Heating must be electrified. Heat pump technology offers a highly competitive way to abandon burning. Heat pump investments are still virtually at the starting post but rapidly increasing, at least in areas where the conditions for investment are favorable.

Investments will not occur without an appropriate investment climate

Conditions for heat pump investments are favorable in Europe's northernmost regions. In these contexts, Sweden, Finland and Norway could be called no-gas-infrastructure countries instead of Scandinavia. Proportionally the highest heat pump investments in the world have been made in these countries, a fact which is mainly explained by the lack of a distribution system of low-cost gas. Other factors behind this success are cheap and clean electricity, high demand for energy due to the northern climate, good drilling conditions, high quality of buildings, housing and building services engineering, as well as high living standards. In this Nordic region, with a population of about 20 million, over EUR 20 billion has been invested in heat pumps. For the entire building stock in these countries, heat pumps already provide about 20 % of the heating.

In countries where cheap gas or fossil energy is readily available, subsidies for cleaner technology have been the quickest approach to improve investment climate. However, a longer-term solution is to set the fossil energy prices right so that they fully reflect fossil energy's contribution to pollution. Although raising fossil energy prices has proven to be extremely difficult and slow politically, emission-based fuel pricing is the only realistic and sustainable long-term solution to reduce CO_2 emissions.

Who is investing?

Out of the investment of approximately EUR 20 billion made in the Nordics, the majority consisted of investments made by consumers using their own money, as the conditions for investment have been in order, i.e., their investments have been worthwhile. Generally, these investments have also been made without subsidies. Investments have gradually shifted from single-family houses to larger units and areas such as apartment buildings, commercial and service buildings, industry, recovery of waste heat, and production of district heating. This has also widened the spectrum of investors.

Energy service companies have entered the arena offering heating and cooling as a service using waste heat and through the ground and air around buildings. Investors also include developers and owners who use the life-cycle concept. Many large companies owning real estate are systematically cleaning up their real estate properties together with expert companies to get their investment program up and running. The objective, of course, is to own a more cost-effective, low-emission and sustainable building stock that is more attractive to customers.

The Heat as a Service model is likely to gradually spread even to traditional heating energy companies that suffer from old investment stock and rigidity. Instead of maximizing sales volumes, energy sellers just have to find business models where centralized supply, as well as energy conservation and the use of local, building-specific community energy, can be applied.

Heat pump investments are a way to combat climate change.

Jussi Hirvonen
Executive Director, Finnish Heat Pump Association SULPU ry
Delegate of Finland in HPT TCP by IEA
jussi.hirvonen@sulpu.fi

Green Deal – an opportunity to boost the deployment of heat pumps in the building sector – an Italian focus

Heat pumps are one of the most important space heating and cooling technologies for decarbonizing the building sector. Currently, the building sector is responsible for about 35% of the CO_2 emissions at the European level. If we add that it accounts for 40% of the final energy consumption, the huge potential for decarbonization becomes evident.

Heat pumps are a well-established solution in more industrialized countries, where technologies, knowledge and investments have matured to the point where they may be expanded into new markets. Heat pumps are now ready to meet the European Green Deal's objectives in single-family homes, multi-family homes, renovations, and new constructions, as well as small and large commercial buildings and industrial plants.

In terms of greenhouse impact, they are at least twice as efficient as high-efficient gas boilers for the same useful effect, with the potential to improve this factor further as the share of renewable energy (RES) in electricity generation grows. In this context, it is worth noting that by 2030, the RES share of EU electricity production is expected to more than double, from 32% now to roughly 65% or more. This combination means that heat pumps would be even closer to becoming a fully climate neutral solution.

The Green Deal has been well received by all players in the heat pump supply chain since it represents a unique opportunity for synergy between political guidelines and the energy-economic potential of a technology that would significantly contribute to the ecological transition. Like other countries such as France, Germany, and the Netherlands, Italy has implemented heat pump and boiler replacement programs.

Measures like the Super Ecobonus, which combines economic growth with residential decarbonization and covers up to 110% of energy renovation expenditures until the end of 2022, are just one of the numerous specific actions of the Italian policy. It must comply with stringent conditions, such as improving the energy performance of the renovated building by at least two classes as a result of improved insulation and a new heating system. It is applied in the form of a tax deduction, but the transfer of credit and the direct invoice discount are also allowed. The replacement of heating equipment with (also) heat pump is included among the so-called leading works required to gain access to the deduction. Undoubtedly, this could be a significant opportunity to grow the heat pump market, which still has a large spread potential in the country.

Other sectors, aside from building renovation, still need to be sensitized in order to fully meet the Green Deal objectives; for example, the reorganization of the tariff and incentive system, the installers' formation and the information/communication for the end-user awareness to name a few.

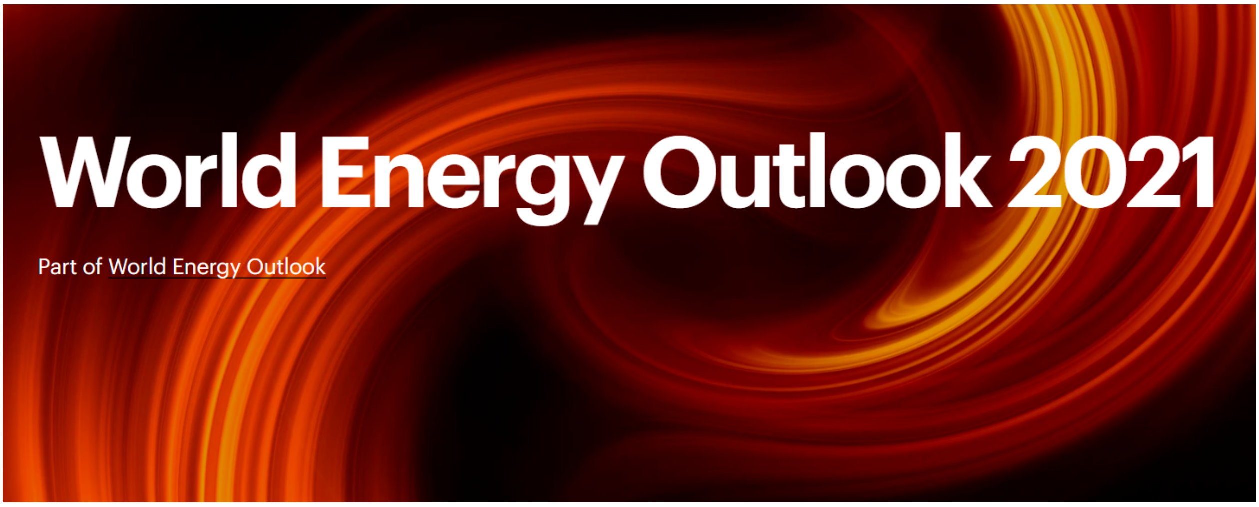
MAURIZIO PIEVE

ENEA,
IPSE Lab (Laboratory of Processes and Systems Engineering for Energy Decarbonisation)

RANIERO TRINCHIERI

ENEA,
IPSE Lab (Laboratory of Processes and Systems Engineering for Energy Decarbonisation)

Release of IEA World Energy Outlook 2021



Solutions to reach Net Zero Emissions (NZE) are available, cost-effective and offer shelter for fossil fuel price shocks – heat pumps one of the highlighted examples

This year's edition of the World Energy Outlook (WEO), released on October 13, was designed, exceptionally, as a guidebook to COP26. It spells out clearly what is at stake – what the pledges to reduce emissions made by governments so far mean for the energy sector and the climate. And it makes clear what more needs to be done to move beyond these announced pledges towards a pathway that would have a good chance of limiting global warming to 1.5 °C and avoiding the worst effects of climate change.

The report tells that a new global energy economy is emerging. During 2020, despite the pandemic, renewable sources of energy such as wind and solar PV continued to grow rapidly, and electric vehicles set new sales records. The new energy economy will be more electrified, efficient, interconnected, and clean. However, the transformation still has a long way to go. At the moment, every data point showing the speed of change in energy can be countered by another showing the stubbornness of the status quo. The direction of travel is a long way from alignment with the IEA's landmark **Net Zero Emissions by 2050 Scenario (NZE)**, published in May 2021, which charts a narrow but achievable roadmap to a 1.5 °C stabilisation in rising global temperatures and the achievement of other energy-related sustainable development goals. At a pivotal moment for energy and climate, the WEO-2021 provided an essential guidebook for COP26 and beyond.

Different scenarios are compared in the report. In the run-up to COP26, many countries have put new commitments on the table, detailing their contributions to the global effort to reach climate goals; more than 50 countries, as well as the entire European Union, pledged to meet net-zero emissions targets. If these are implemented in time and in full, as modeled in detail in the new **Announced Pledges Scenario (APS)**, they start to bend the global emissions curve down.

However, a lot more needs to be done by governments to fully deliver on their announced pledges. Looking sector-by-sector at what measures governments have actually put in place, as well as specific policy initiatives that are under development, reveals a different picture, according to the report, which is depicted in the **Stated Policies Scenario (STEPS)**.

According to the analysis, today's pledges (APS) cover less than 20% of the gap in emissions reductions that needs to be closed by 2030 to keep a 1.5 °C path within reach. A doubling of clean energy investment and financing over the next decade in the APS, but this acceleration is not sufficient. In particular, over the crucial period to 2030, the actions in this scenario fall well short of the emissions reductions that would be required to keep the door open to a **Net Zero Emissions by 2050 (NZE)** trajectory.

Solutions to close the gap with a 1.5 °C path are available – and many are highly cost-effective

The WEO-2021 highlights four key measures that can help to close the gap between today's pledges (APS) and a 1.5 °C trajectory (NZE) over the next ten years – and to underpin further emissions reductions post-2030. According to the report, more than 40% of the actions required are cost-effective, meaning that they result in overall cost savings to consumers compared with the pathway in the APS.

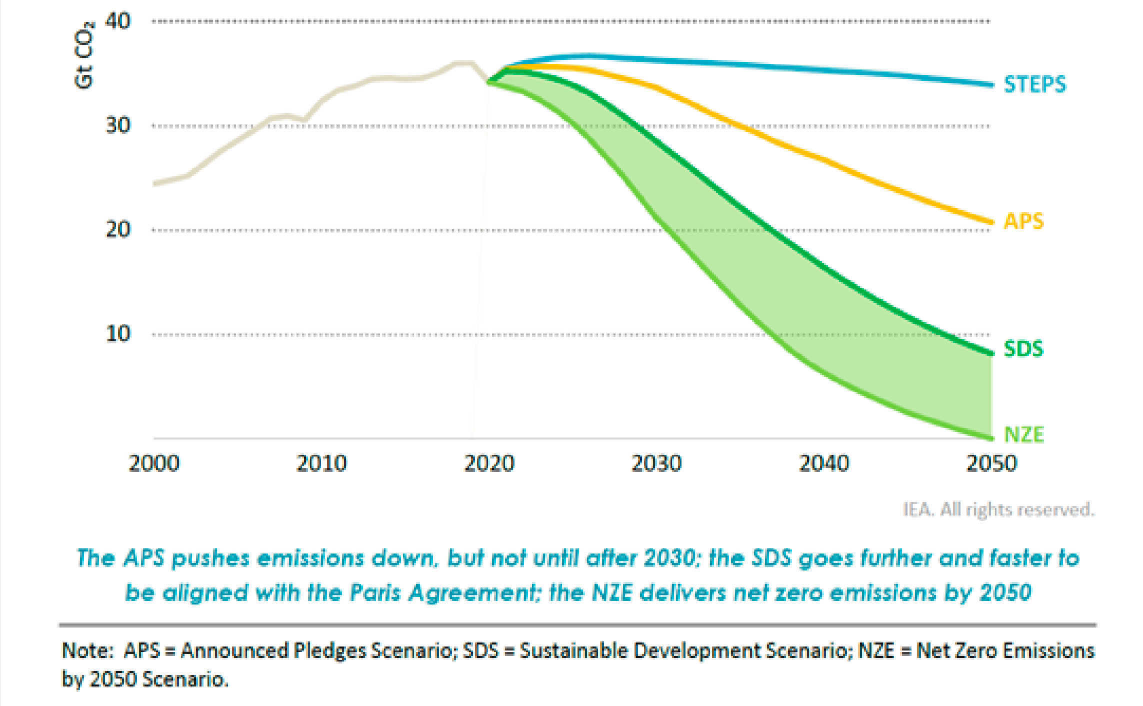


Figure 1.4. CO_2 emissions in the WEO-2021 scenarios over time.
Source: IEA World Energy Outlook 2021

The four measures are:

» A massive **additional push for clean electrification** that requires a doubling of solar PV and wind deployment relative to the APS; a major expansion of other low-emissions generation, including the use of nuclear power where acceptable; a huge build-out of **electricity infrastructure** and all forms of system **flexibility**, including from hydro-power; a rapid phase-out of coal; and a drive to expand electricity use for transport and **heating** (i.e. **heat pumps**).

» A relentless **focus on energy efficiency**, together with measures to temper energy service demand through materials efficiency and behavioral change.

» A broad **drive to cut methane emissions from fossil fuel** operations.

» A big **boost to clean energy innovation**.

IEA states that there is a looming risk of more turbulence ahead for energy markets, but transitions can offer some shelter for consumers against oil and gas price shocks, **if consumers can get help to manage the upfront costs of change**. In a transforming energy system such as the NZE, households are less reliant on oil and gas to meet their energy needs, thanks to efficiency improvements, a switch to electricity for mobility, and a move away from fossil fuel-fired boilers for **heating**. This will require policies that assist households with the additional upfront costs of efficiency improvements and low emissions equipment such as electric vehicles and **heat pumps**. As electricity takes up a progressively larger share of household energy bills, governments have to ensure that electricity markets are resilient by incentivising investments in **flexibility, efficiency and demand-side response**.

IEA concludes in the report that the costs of inaction on climate are immense, and the energy sector is at risk. The potential prize is huge for those who make the leap to the new energy Economy. Making the 2020s the decade of massive clean energy deployment will require unambiguous direction from COP26.

Read the Executive summary and the full report here.

Key commitments of the UK Heat and Buildings Strategy 2021

Leading up to the COP26, the UK government have published a comprehensive Net Zero Strategy – a cross-sector strategy that will hopefully set out the government's vision for transitioning to a net-zero economy and making the most of new growth and employment opportunities across the UK. An extract of some of the policies, proposals and vision for a decarbonized economy to meet the 2050 targets are given below.

According to the net-zero strategy document, the policies and proposals for heat and buildings in the Net Zero Strategy will Support up to 190,000 jobs by 2025 and up to 440,000 jobs by 2030, and leverage up to £90 billion of private investment by 2030.

To achieve net-zero emissions, all sources of emissions must be addressed, and heating for homes and workplaces accounts for over a third of all UK carbon emissions. As a result, the energy efficiency of housing and non-domestic properties across the UK will increase, requiring less energy to heat them, making them cheaper to run and more comfortable to live and work in while reducing reliance on imported energy. The UK government has set a target of replacing all new heating appliances installed in homes and workplaces with low-carbon technology such as electric **heat pumps** or hydrogen boilers by 2035, once costs have been reduced. According to the strategy, it is critical to note that this will be a gradual transformation that works with the grain of customer choice. However, low-carbon technology costs can fall quickly if we continue to engage with industry; the UK government expect a **heat pump** to be as cheap to buy and run as a gas boiler this decade. In order to reduce the electricity costs, options such as shifting or rebalancing energy levies (such as Renewables Obligation (RO) and Feed-in-Tariff (FITs)) and obligations (such as the Energy Company Obligation (ECO)) away from electricity to gas can be explored when the current gas price spikes settle. According to the net-zero strategy document green products are more efficient and cheaper in the long run, and fairness and affordability at the heart of the strategy's approach.

Key policies:

» An ambition that by 2035, no new fossil gas boilers will be sold.

» A new £450 million three-year Boiler Upgrade Scheme will see households offered grants of up to £5,000 for low-carbon heating systems, so they cost the same as a gas boiler now.

» A new £60 million **Heat Pump** Ready program that will provide funding for pioneering **heat pump** technologies and will support the government's target of 600,000 installations a year by 2028.

» Delivering cheaper electricity by rebalancing of policy costs from electricity bills to gas bills this decade.

» Further funding for the Social Housing Decarbonization Scheme and Home Upgrade Grants, investing £1.75 billion. Additional funding of £1.425 billion for Public Sector Decarbonization, with the aim of reducing emissions from public sector buildings by 75% by 2037.

» Launching a Hydrogen Village trial to inform a decision on the role of hydrogen in the heating system by 2026.

Read the full report here: BEIS (2021), 'Net Zero Strategy'

Welcome to the 14th IEA Heat Pump Conference, 2023

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

Conference goals

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

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

Conference program highlights

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

Conference program highlights include the following:

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

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

- Residential and commercial building comfort conditioning, focusing on topics such as: space heating, air-conditioning, net-zero buildings, renovation, hybrids, domestic hot water, and multifamily buildings.
- Non-residential applications, focusing on industrial heat pumps, waste heat, district heating, commercial refrigeration, and transport air conditioning and refrigeration.
- Innovation and Research and Development (R&D), fo-

cusing on aspects such as ground sources, advanced storage systems, working fluids, sorption technologies, advanced vapor compression, non-vapor compression technologies, smart grids/energy, cold and hot climate applications, advanced air conditioning technologies, gas-driven heat pumps and combinations with other renewable technologies.
- Policy topics and market status, trends, strategies, and future opportunities.

Who should attend?
The wide variety of heat pump related discussions that will take place during the Conference is intended to attract a diverse group of attendees, including:
- Policy makers, government officials, energy efficiency program leaders
- Executives and representatives from industry, utilities, and the public sector
- Manufacturers, distributors, and technology supporters
- Designers and developers of heat pump systems and components
- Researchers from industry, utilities, academia, and private and public R&D institutes

Call for papers
Abstracts (250 words maximum) covering the conference theme may be submitted on the conference website from 15 November 2021. The abstracts will be screened, and authors will be advised of acceptance by 15 June 2022.

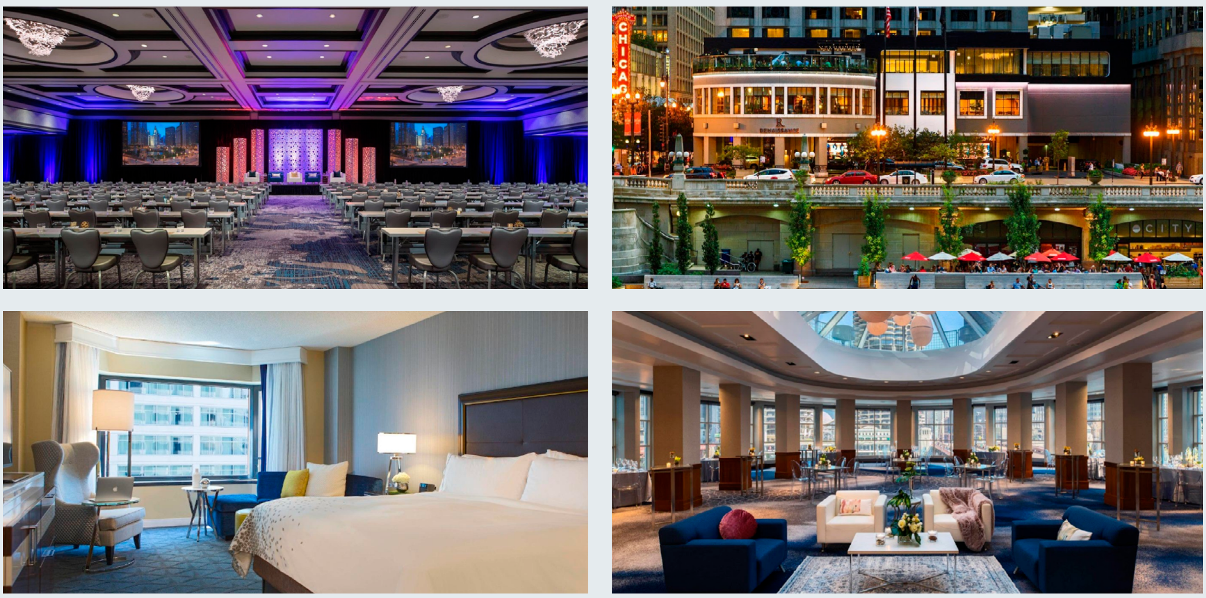
Important conference dates:
- Abstract submission opens 15 November 2021
- Abstract submissions due 15 May 2022
- Authors advised of acceptance 15 June 2022
- Full paper submissions due 15 November 2022
- Final paper submissions due 15 February 2023

Conference information
Those wishing to attend the Conference should visit the conference website: www.hpc2023.org. Detailed information, including registration and hotel accommodation forms, will be available together with a second announcement in autumn 2022.

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

Additional updates and details will be provided on the website of the conference www.hpc2023.org and via www.heatpumpingtechnologies.org.

14th IEA HEAT PUMP CONFERENCE



Chicago Venue

COP 26 – The benchmarks for hindrance or indispensable breakthrough

In November, world leaders from many countries have gathered during the COP26 summit to revisit their ambitious 2030 climate pledges to narrow the enormous emissions gap already visible. The recent IPCC Special Report released on August 2021 reaffirmed the scientific urgency, and it issued a climate "a code red for humanity" earlier this year.

According to the climate action tracker (Figure 1), it is evident that there is a major credibility, action, and commitment gap that casts a long and dark shadow of doubt on the net-zero goals proposed by more than 140 countries. The Climate Action Tracker diagram highlights the global temperature warming projections based on the impact of policies & action, 2030 targets only, pledges and targets and optimistic scenarios.

As a conclusion, analysts show we are on the verge of exceeding 1.5°C in the near future. According to IEA (https://www.iea.org/reports/net-zero-by-2050), the only way to avoid crossing this line is to increase our efforts immediately and pursue the most ambitious pathways to, among other actions;

(i). invest heavily in renewable electricity production such as and wind and solar power

(ii). invest to stimulate a rapid deployment of heat pumping technologies in the building as well as the industrial sector

(iii). continuously develop the work in international collaboration programmes such as the **Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP)** within the IEA, which have actively been a leading player in generating and communicating independent knowledge on heat pumping technologies worldwide since 1978, and

(iv). introduce strategic governmental mission-driven policies to support the deployment of low carbon technologies.

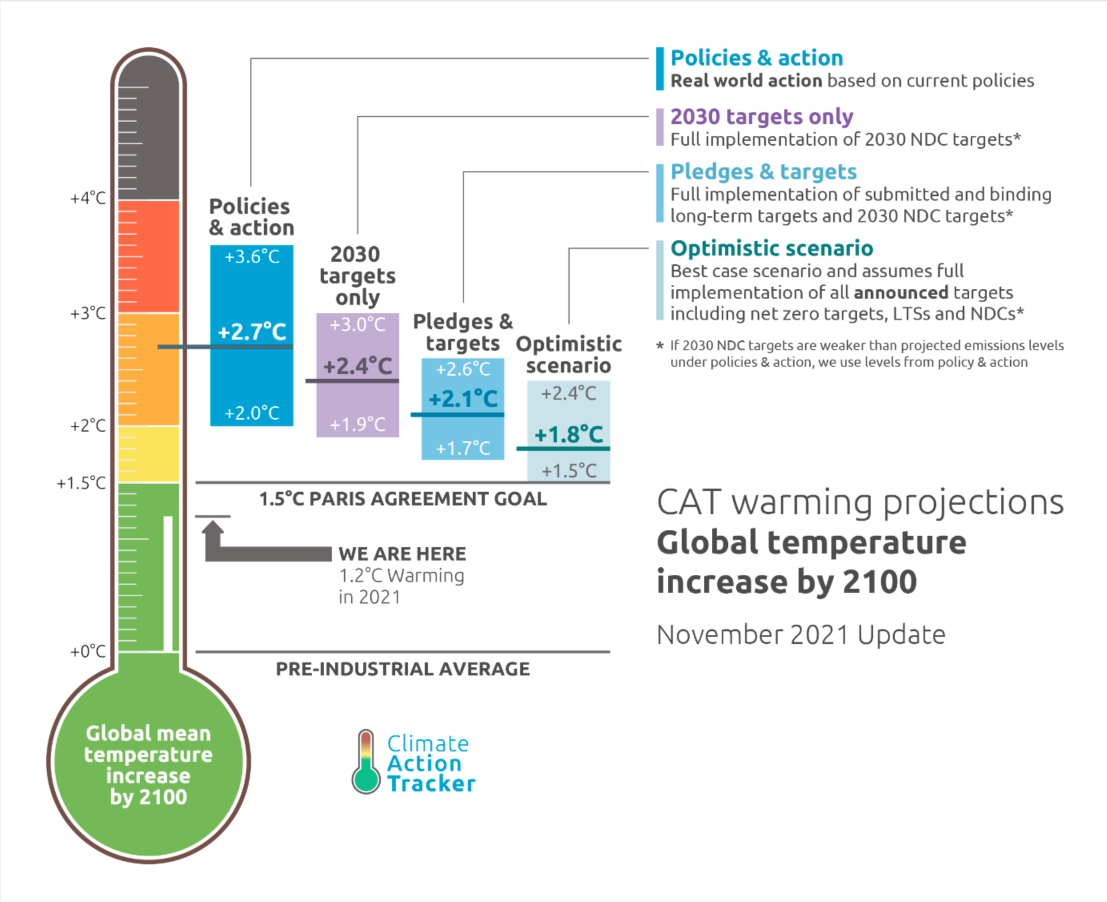


Figure 1. Climate Action Tracker. Nationally Determined Contribution (NDC) Long Term Strategy (LTS). Source: https://climateactiontracker.org/

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.

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	AT, **DK**, DE, NL, SE
HIGH-TEMPERATURE HEAT PUMPS	58	AT, BE, CA, **DK**, DE, FR, NL, NO, JP

*) 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) . Turkey (TR*), participates in joint Annex through Energy Storage TCP).

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

ANNEX 52

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

Introduction

Carefully instrumented and analyzed long-term performance measurements from large GSHP systems are highly valuable tools for researchers, practitioners and building owners. Analyses of good quality long-term performance measurements of GSHP systems are sparse in the literature, and there is no consensus on key figures for performance evaluation and comparison. Within Annex 52, a bibliography on long-term measurement of GSHP systems has been compiled, and the participants are measuring performance of more than 55 GSHP systems. Based on this experience, the annex is revising the current methodology to better characterize the performance of larger GSHP systems. These systems have a wide range of features and can be considerably more complex than single-family residential GSHP systems. The case studies 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 SEPEMO system boundary schema developed for non-complex residential heat pump systems.

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

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.

Key data

- Project duration: Jan 2018 – Dec 2021
- Operating Agent: Signhild Gehlin, Swedish Geoenergy Center, signhild@geoenergicentrum.se
- Participating countries: Finland, Germany, Netherlands, Norway, Sweden, UK, USA
- Website: http://heatpumpingtechnologies.org/annex52/

Figure1. Rosenborg office building in Stockholm, Sweden. Photo: Vasakronan.

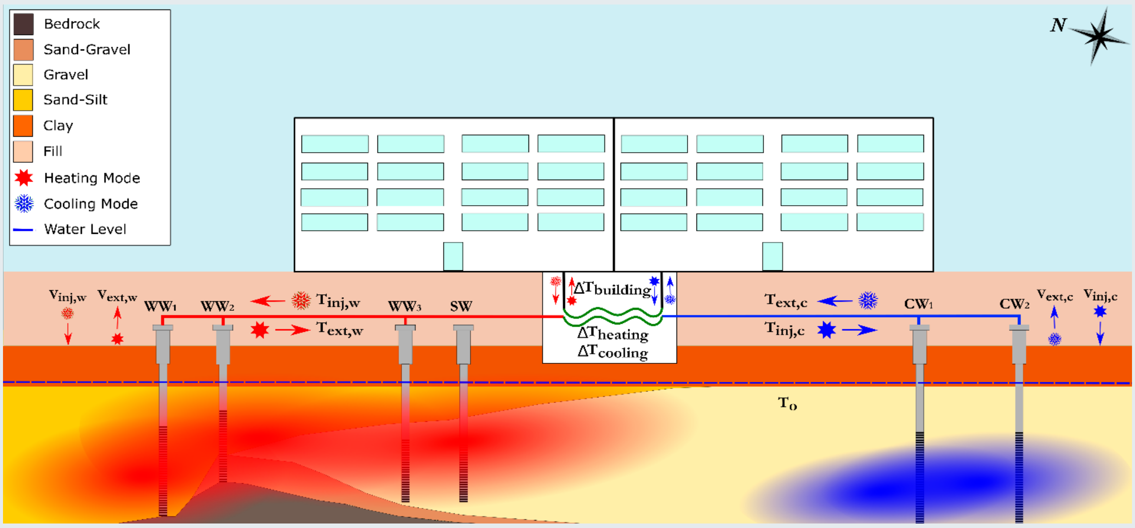


Figure 2. Aquifer thermal energy storage serving an office building in Stockholm. Diagram: Mohammad Abuasbeh

Recent progress

During this final year of Annex 52, the focus has been on the completion of the case study reports for the many monitored GSHP systems. The pandemic has limited access to some sites, and therefore some projects are delayed, and some are so delayed that they will be omitted from the annex. The results from many of the monitoring projects are now being analyzed as a group and summarized for the final Annex 52 reports, prepared for the final Annex 52 experts' meeting in November 2021. Preliminary results for the first 12 projects with 73 years of data total have been collated. Not all projects can measure at the same boundaries, but 8 projects with 54 years of data have measurements for boundary 2, which includes the ground heat exchanger and heat pump(s). Seasonal performance factors within this boundary for heating and cooling together (SPF_{HC2}) are in the range 1.4-12.6, with an average of 4.7. 78% of the project-years have SPF_{HC2} of 3 or higher. Another German building with 14 years of data that makes significant use of direct cooling from the ground has an average SPF_{HC2} of 8.2, and it has increased over time from an SPF_{HC2} of about 6 to 12.8 for the last two years of measurements.

The final drafts of the instrumentation and measurement guidelines, as well as the uncertainty analysis guide, are now near publication. Compilation and systematization of key performance indicators other than SPF and COP are ongoing.

Two new open-access journal papers presenting results from case studies within Annex 52 have been published in late 2021, in addition to the five previously published journal papers. The journal paper by Todorov et al. (2021) covers the long-term performance of the Aalto University borehole storage system in Helsinki, while Abuasbeh et al. (2021) report on an aquifer thermal energy storage serving an office building in Stockholm (see Figures 1 & 2) Four Annex 52-related conference papers were presented and published at the hybrid conference HPC2021 in Jeju, South Korea.

Aalto University in Helsinki, Finland.
Photo credit: Aalto-yliopisto/Aalto University.
Source: https://www.aalto.fi/en/locations/vare

Aalto University, School of Arts and A-Block (shopping center). Photo by Mikko Raskinen.

Aalto Univeristy, New Campus Complex from the air (new building group in the middle of photo). Photo by Suomen Ilmakuva

ANNEX 53

ADVANCED COOLING/ REFRIGERATION TECHNOLOGIES DEVELOPMENT

Introduction

It is widely acknowledged that air conditioning (AC) and refrigeration systems are responsible for a large share of worldwide energy consumption today, and this demand is expected to increase sharply over the next 50 years absent action to ameliorate the increase. IEA projects that AC energy use by 2050 will increase 4.5 times over 2013 levels for non-Organization of Economic Coordination and Development (OECD) countries and 1.3 times for OECD countries (see figure below). Worldwide action, both near-term (e.g., increase deployment of current "best" technologies) and longer-term (RD&D to develop advanced, higher efficiency technology solutions), is urgently needed to address this challenge. HPT Annex 53 was initiated in late 2018 and focuses on the longer-term RD&D need. Technologies under investigation include the vapor compression (VC) based systems, thermal compression-based systems (absorption and adsorption), and non-traditional cooling approaches. Advanced VC R&D underway by participant teams includes a combined absorption/VC/thermal storage concept, a large chiller based on water (R-718) as refrigerant, a novel pressure exchange (PX) concept for expansion work recovery, and enhanced source and sink stream matching using zeotropic refrigerants. Significant efforts are also underway aiming at advancing the state of development of systems based on magnetocaloric (MC), elastocaloric (EC), and electrocaloric effect (ECE) cooling cycle concepts. This includes work on identifying materials with improved fatigue performance, etc., for MC, EC, and ECE concepts.

Objectives

Annex 53's main objective is longer-term R&D and information sharing to push the development of higher efficiency and reduced greenhouse gas (GHG) emission AC/refrigeration focused HP technologies. Specific areas of investigation include but are not limited to the following:

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

Key data

- Project duration: Jan 2019 – Dec 2022
- Operating Agents: Reinhard Radermacher, University of Maryland, raderm@umd.edu
  Van Baxter, ORNL, vdb@ornl.gov
- Participating countries: China, Germany, Italy, South Korea, and the USA
- Website: https://heatpumpingtechnologies.org/annex53/

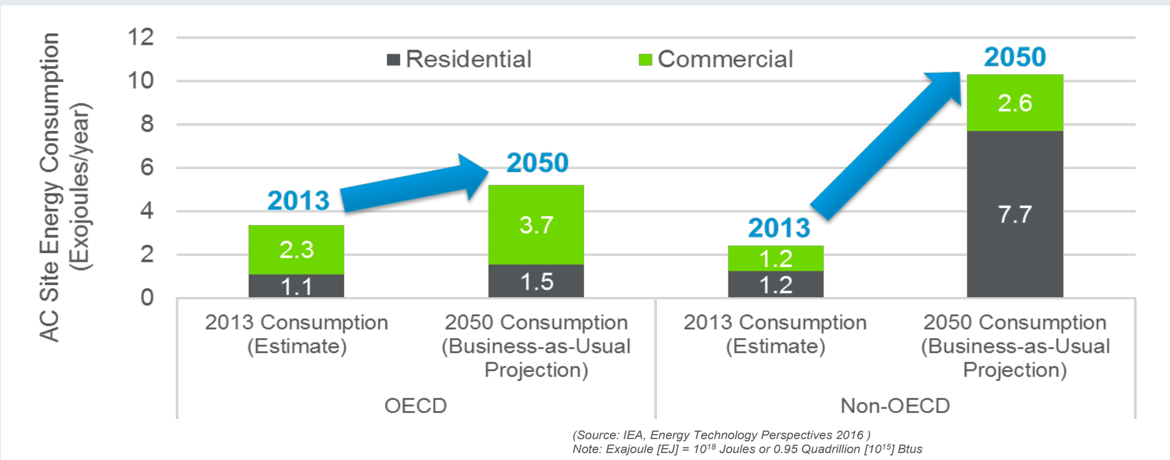


Figure 1. Current and projected space cooling site energy consumption for OECD and Non-OECD countries. Courtesy W. Goetzler, Guidehouse, Inc.; Source: IEA ETP 2016.

Progress highlights

China's Annex 53 team at Xi'an Jiaotong University aims to develop a heat-driven elastocaloric (EC) cooling system. The latest progress is the development of a regenerative shape memory alloy (SMA) actuator that could harvest low-grade thermal energy by using hot water at 80 to 110°C. Figure 2 illustrates the operation of the system. The actuator shrinks upon heating and thus converts thermal energy to mechanical energy that drives the super elastic (SE) cooling material. Simulation results indicated a thermal to cooling efficiency of 1.08 with a heat source temperature of 100°C when assuming the actuator could shrink by 3% upon heating. Lab test results with the prototype SMA actuator achieved up to 4% stroke. Modifications to the SMA actuator are underway to improve heat transfer effectiveness so that higher operating frequency can be achieved. If successful, this heat actuated EC concept could significantly reduce the size and weight of EC systems. This technology has the potential to be used for residential-scale solar-driven air conditioners and off-grid refrigerators.

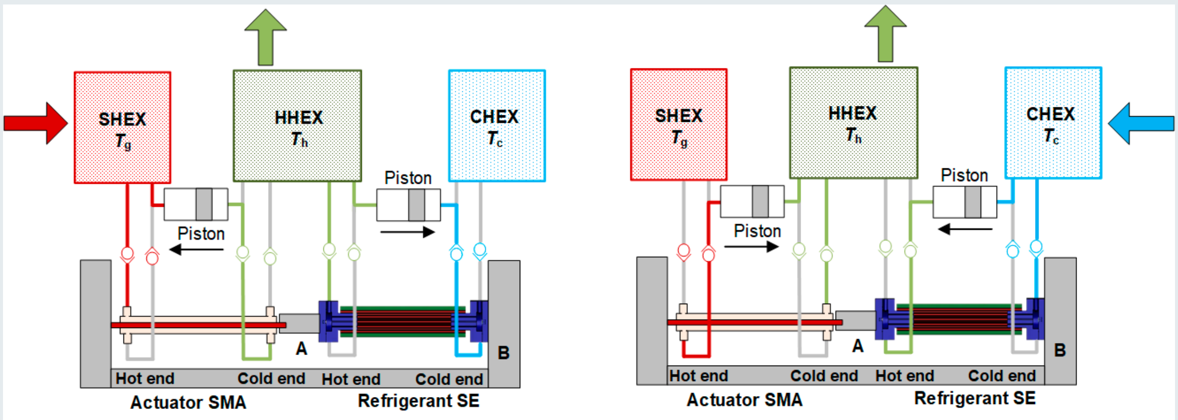


Figure 2. Schematic of the heat-driven EC cooling cycle.
(a) Heating of actuator and loading of refrigerant
(b) Cooling of actuator and unloading of refrigerant

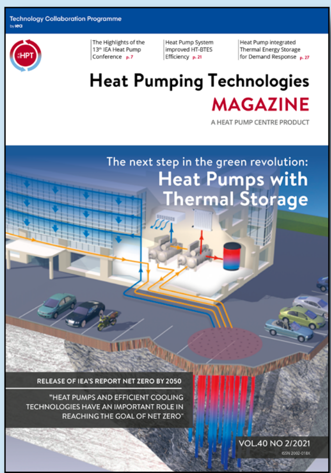
INFORMATION

Become a subscriber

The Heat Pumping Technologies Magazine

Three times a year, the Heat Pump Centre issues the Heat Pumping Technologies Magazine. The Magazine can be found at the HPT web site and is free of charge. At the same time as the Magazine is launched, a Newsletter is distributed. The Newsletter contains shorter versions of the Magazine articles with links to the full Magazine and is a good reminder that there is a new Magazine issue to read.

Read our Magazine and become a subscriber at:
https://heatpumpingtechnologies.org/the-magazine/



ANNEX
54

HEAT PUMP SYSTEMS WITH LOW GWP REFRIGERANTS

Introduction

Heat pump systems have garnered the public's attention as a renewable heating and cooling solution in the carbon-neutral world to come. Therefore, low-GWP refrigerants are considered to be used for environmentally friendly heat pump systems. Due to the unique thermophysical characteristics of low-GWP refrigerants considered, minor to major components and system design modifications are necessary for each low-GWP refrigerant. Especially, component-level design and optimizations are much needed for energy efficiency and reduced-charge designs.

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 (ongoing)
» analysis of the Life Cycle Climate Potential (LCCP) impacts by the current design and optimized design with low-GWP refrigerants (ongoing)
» Making an outlook for heat pumps with low-GWP refrigerant for 2030 (planned)

Key data

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

Progress

In 2021, we achieved considerable progress in the following two areas: 1) Task 2: case studies and design guidelines for optimizing components and systems. 2) Task 3: review of design optimization and advancement impacts on LCCP reduction. The progress accomplished by participating countries is described below. The work can be a valuable reference for researchers, engineers, and policymakers across the HVAC industry.

Fedele and his research team from the CNR-ITC, Italy, reported available thermophysical properties data for

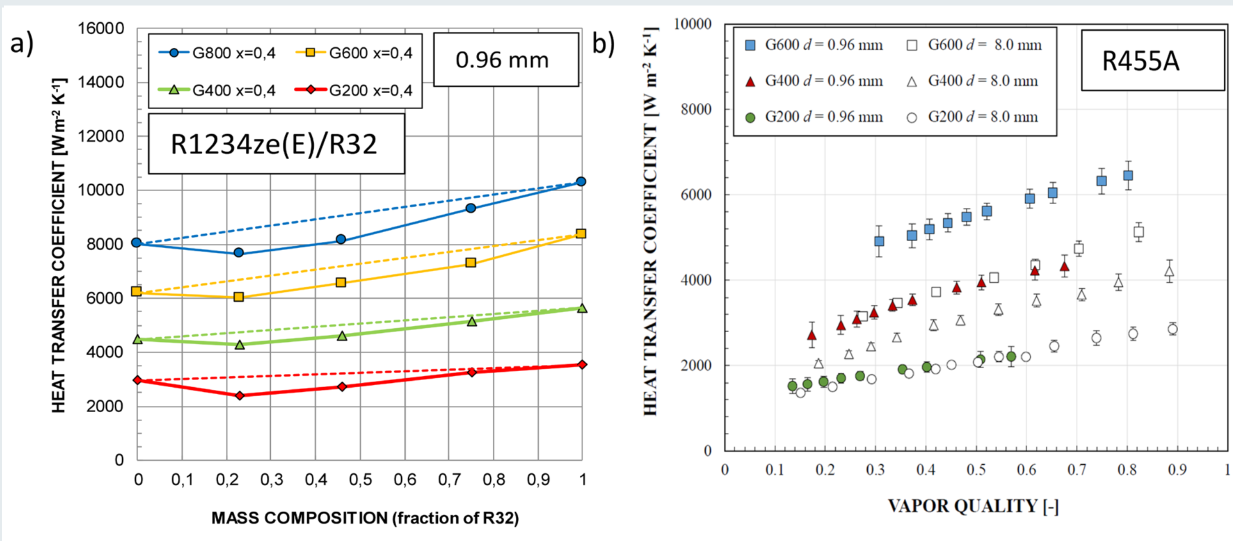


Figure 1.
a) Heat transfer coefficient (HTC) versus mass composition for pure R1234ze(E), pure R32 and three R32/ R1234ze(E) blends (mass velocity G = 200 – 800 kg m-2 s-1, vapor quality x = 0.4);
b) HTC of R455A measured in the 0.96 mm and in the 8.0 mm diameter channel.

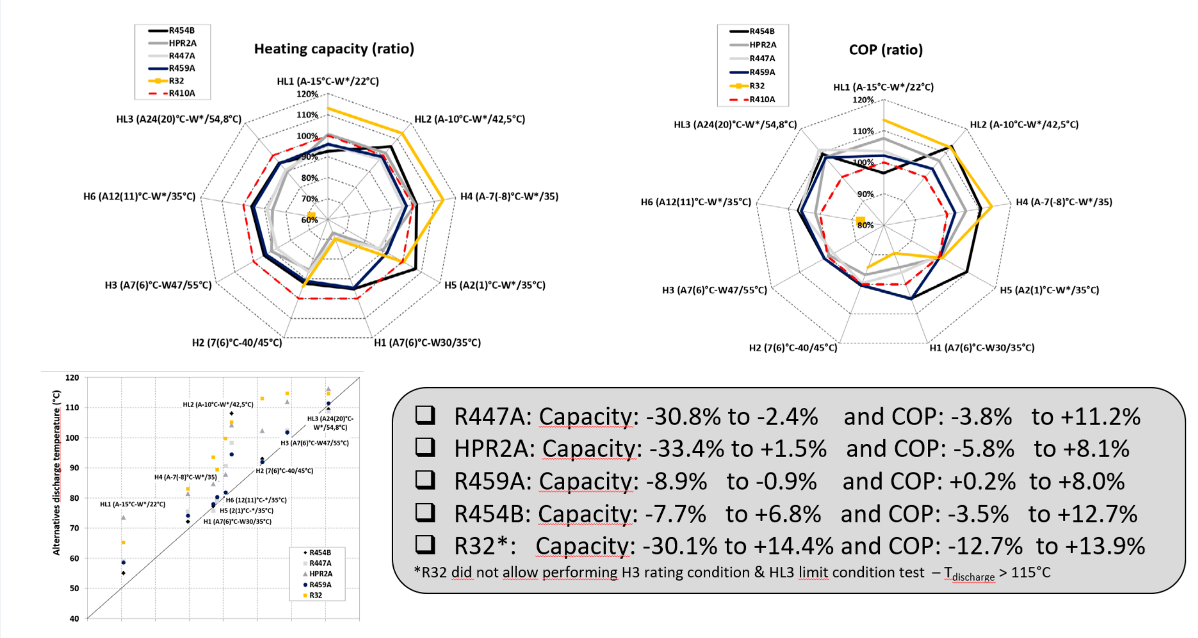


Figure 2. Heat pump performance comparison for six low-GWP refrigerants

pure HFO refrigerants through the literature review. The authors concluded that the amount of available data is still insufficient for many fluids to develop accurate equations of state or dedicated equations for the transport properties, so that further research is needed.

Azzolin and his team from the University of Padova, Italy, measured condensation and flow boiling heat transfer coefficients inside channels of different diameters (0.96 mm, 3.4 mm and 8.0 mm) with low-GWP refrigerants. Figure 1a illustrates the effect of R32 mass fraction on the condensation heat transfer coefficient (HTC) of R1234ze(E)/R32 mixtures in the 0.96 mm internal diameter mini channel at 40 °C mean saturation temperature. One important finding is that among the three mass fractions studied, the HTC penalization is the largest, with the mixture 23/77% (temperature glide of 11 K), while it is the lowest with the 75/25% mixture (temperature glide of 3.2 K). The heat transfer penalization is more evident at mass flux G = 200 kg m-2 s-1. Figure 1b shows the effect of the channel diameter (0.96 mm and 8.0 mm) on the condensation HTC for the ternary mixture R455A.

CETIAT researchers Pardo and Mondot, experimentally evaluated ten low-GWP refrigerants for air-to-water heat pumps, water-to-air heat pumps, and heat pump water heaters. Figure 2 illustrates the heating capacity ratio and COP ratio of five low-GWP refrigerants as compared to R-410A. The authors plan to continue the study using natural refrigerants.

Allymehr and his research team from Fraunhofer ISE, Germany, in cooperation with SINTEF, Norway, investigated the refrigerant charge requirement in an optimized fin-tube evaporator versus plate heat exchanger to prove the feasibility of minimized charge concepts for R-290 air-to-water heat pumps based on a cross-evaluation between two different simulation codes. Dankwerth and his research team, from Fraunhofer ISE, Germany, presented experimental results on COP and the optimized charges on a low-charge R-290 heat pump.

The flammability and performance of R-410A and R-32 in the window, wall-mounted and ceiling-mounted-air conditioners were compared by Kim and Ko from the LGE in Korea,. Then authors concluded that the seasonal efficiency of the R-32 is higher than that of R-410A.

In a small water-to-water heat pump Molinaroli, from Politecnico di Milano, Italy, experimentally evaluated the performance of R-134a, R-450A, and R-513A. Test results show that R-450A has the most similar COP to R-134a, whereas R-513A shows a similar heating capacity.

Menegazzo and his research team, from the CNR-ITC, Italy, thermodynamically analyzed the eight low-GWP refrigerants to replace R-134a and R-410A for the ground-source heat pump. Authors reported that R-516A results to be the most promising substitutes for R-134a with an average COP increase of 8%, and R-454B with regenerative cycle shows an average improvement of 17% in terms of the COP.

Nawaz and his team from the Oak Ridge National Laboratory, USA, evaluated five refrigerants including R-134a, CO2, R-290, R-1234yf, R-1234ze, and R-513A in the residential heat pump water heater and concluded that these fluids could be a drop-in replacement for R-134a.

Wan and his team from the University of Maryland, USA, reviewed the invention and evolution of life cycle climate potential (LCCP) and compared the LCCPs of R-32, R-290, R-452B, and R-466A as compared to that of R-410A. Then, the authors concluded that the indirect emissions caused by energy consumption is 70 to 80 percent of the LCCP of air conditioning systems in high-emission-factor countries, but this contribution will decline in importance as electric power supply shifts rapidly from fossil fuel to renewable energy sources, which have near-zero carbon intensity.

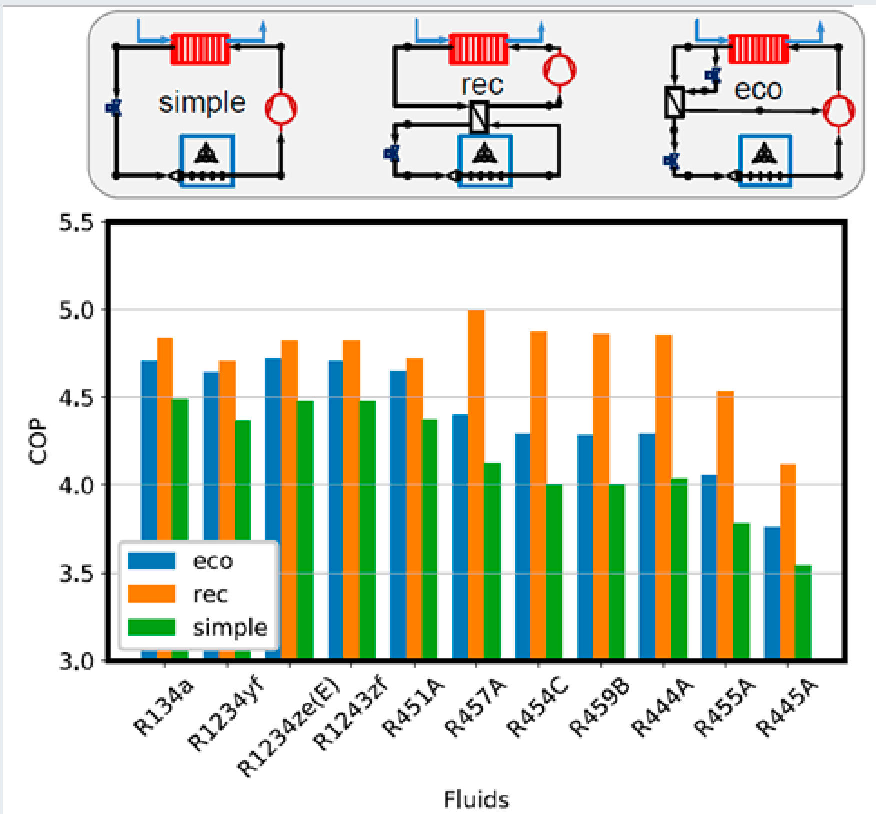


Figure 3. COP Comparison of 11 fluids with three refrigeration cycles

INFORMATION

Do you want to read more about the results and outcome of the HPT TCP Annexes?

Welcome to the HPT TCP publications database
Here you find the results of the projects implemented by the Technology Collaboration Programme on Heat Pumping Technologies, HPT TCP, and Heat Pump Centre, HPC.

Publication database:
https://heatpumpingtechnologies.org/publications

ANNEX 55 COMFORT AND CLIMATE BOX

Introduction
Integrated systems consisting of heat pumps, storage and controls are in general considered as an important technological option to accelerate the deployment of renewable energy in the domestic sector. Improving the coordination and integration of heat pump operation and storage, performance of the system can be enhanced in several ways: price, compactness, reliability, efficiency, and serviceability etc. Meanwhile, a better smart-grid integration and a larger share of direct renewable energy use becomes feasible.

Under the combined direction of the IEA Technology Collaboration Programs (TCPs) on energy storage (ECES) and heat pumping technologies (HPT), HPT Annex 55 has started in early 2019 and will focus on improving combined systems of heat pumps, storage, and controls.

Integrated systems consisting of heat pumps and storage are an important technological option to accelerate the use of renewable energy for heating and cooling. By combining heat pumps and storage, several issues may be tackled in one and the same process, such as:
Balancing & controlling electricity grid loads; Capturing a larg(er) share of renewable (local/regional) energy input; Optimizing economics, CO_2 emissions, fuel use throughout time; Providing optimal supply security to buildings.

Commercial development of this type of solution is progressing very slowly, so the combined Annex 55 (ECES Annex 34) will accelerate market development of combined heat pump / storage packages (working title “Comfort and Climate Box”, or ‘CCB’). This is the first Annex to integrate the work from the TCPs HPT and ECES, building upon the earlier work in the fields of Heat Pumps and Storage systems.

Comfort & Climate Box (CCB)
The central concept in Annex 55 is the Comfort and Climate Box (Figure 1), a concept that denotes the combined package, consisting of a Heat Pump, an Energy Storage Module and Controls. This package may form an actual physical unit but can also consist of separate modules that form an integrated ‘virtual pack-age’, where all components of the CCB should be designed to work together in a modular fashion and should be operated under a dedicated and optimal integrated control strategy.

Objectives
Annex 55 is not meant to be a classic theoretical ‘research and dissemination Annex’. All contributing projects in the participating countries are aiming to focus on developments that are ‘almost market ready’.

The goal of this Combined Annex is to develop improved CCBs in existing buildings to speed up market development. We will focus on systems that will be close to market availability, i.e. technology readiness level (TRL ladder) upwards from 7, and have a high quality adopted for their local market requirements.

The work will be oriented around the nine quality criteria as mentioned to define the concept of improved quality. The underlying drive is to accelerate the market development for CCBs to enable rapid growth of the application of these systems in various climate zones. By exchanging the lessons learned from the separate developments in each participating country, the aim is to enable the participants to help each other to speed up their local market development. Annex 55 is also in twined with the global Mission Innovation program Task 7. MI -7 functions as a non-hierarchical platform to enhance technology development within the building envelop.

Key data
- Project duration: Jan 2019 – Sept 2021, final delivery has been postponed to Jan 2022
- Operating agent: Business Development Holland, Peter Wagener, wagener@bdho.nl, Paul Friedel, deputy OA, friedel@bdho.nl
- Participating countries: Austria, Belgium, Canada, China, Germany, Italy, the Netherlands, Sweden, Switzerland, Turkey, United Kingdom, United States of Amerika
- Website: https://heatpumpingtechnologies.org/annex55/

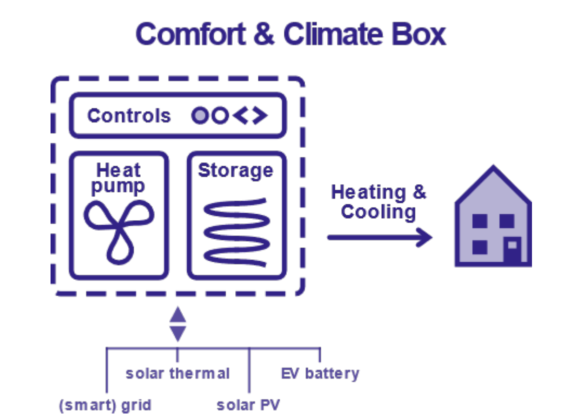


Figure 1. The possible components of a Comfort and Climate Box (CCB)

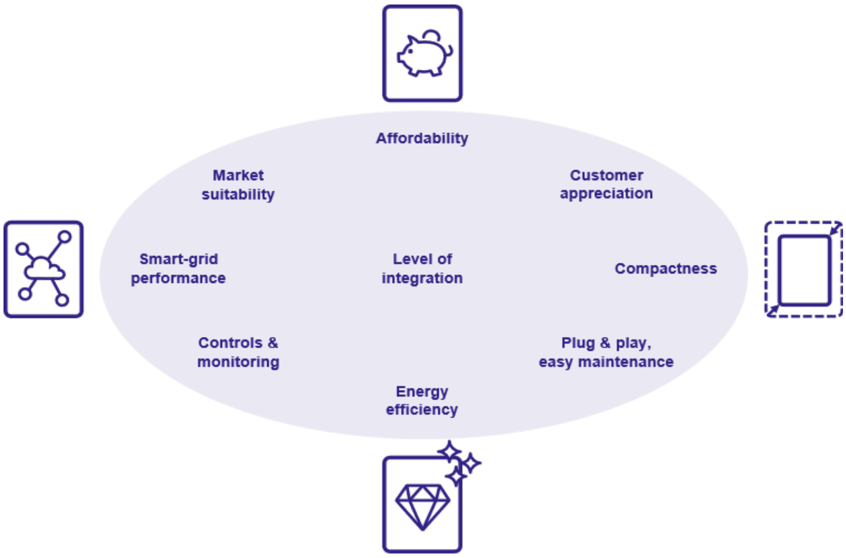


Figure 2. The four implementation strategies for a CCB and the associated quality criteria

Recent Progress
CCB, or integrated systems of Heat Pumps and Storage Units, can achieve much better performance if they are designed to function as a single unit, with a specific optimization goal in mind. Therefore it is important to realize that there is no single 'perfect CCB'. Depending on the circumstances, system performance may be very different across performance criteria, such as SPF, compactness, investment, or ease of installation.

To achieve a good match between optimized CCBs and the local market conditions, it is very important for policy makers to consider which goals are to be met. High market volume? Excellent performance of single systems? Or maximum flexibility and grid balancing capacity?

We have developed a set of four CCB 'archetypes' that should help policy makers to design appropriate support mechanisms to achieve their policy goals within the local market context (Figure 3).

1. 'Budget CCB'
   Focus on lowest investment, and, consequentially, rapid market growth and high volume.
2. 'Flexible CCB'
   Maximum flexibility, to allow optimal grid balancing and auto-consumption of renewable energy.
3. 'Compact CCB'
   Small components and easy installation, to allow the use of Heat pumps in densely populated areas where space constraints are dominant.
4. 'Top quality CCB'
   Maximum performance in terms of energy efficiency. This comes with a higher investment, less flexibility and a large installed footprint.

The Annex 55 working group has been working towards a set of recommendations for policy makers and other stakeholders to help them stimulate those four CCB types, as appropriate for their local market conditions and climate and building policy goals.

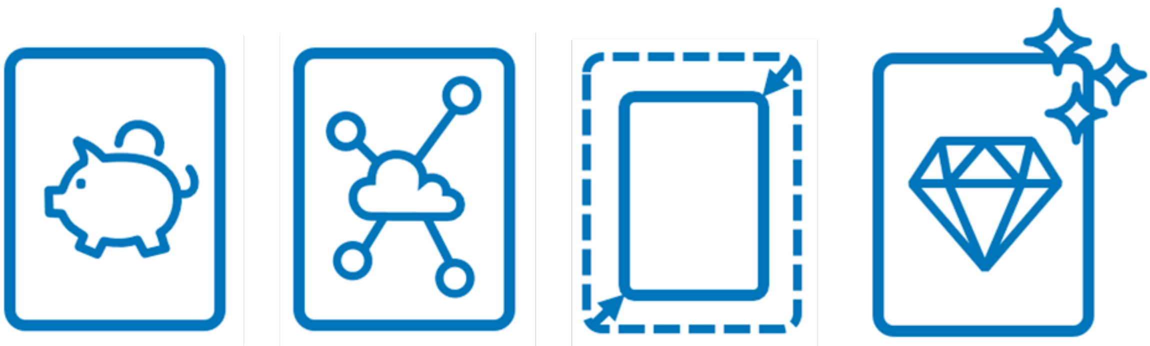


Figure 3. Four archetypes for CCBs: budget, flexibility, compactness, and top quality.

ANNEX
56

INTERNET OF THINGS FOR HEAT PUMPS

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

With heat pumps and their components becoming connected devices on the Internet of Things, various new use cases and services can be enabled. Such services and applications can be related to all stages of the life-cycle of a heat pump, to the connection or organization layer (e.g., Figure 1). Each level of participation of a heat pump in a connected world is also associated with different important risks and requirements for connectivity, data analysis, privacy, and security for various stakeholders. Therefore, this Annex will have a broad scope looking at different aspects of digitalization to analyze heat pump specific challenges and opportunities.

Objectives
The results of the Annex will be disseminated to relevant target groups such as OEM, heat pump manufacturers, associations and regulatory authorities by means of tailored messages. The Annex will thereby:

- Provide guidance, data and knowledge about heat pump technologies with respect to IoT applications
- The Annex will increase knowledge at different levels (OEMs, heat pump manufacturers, consultants, installers, legislators, etc.) and may contribute to future standards development.

Thus, the Annex will:

- Review the status of currently available IoT enabled heat pumps, heat pump components and related services. A common glossary for the most important digitalization topics is currently being elaborated.
- Identify requirements for data acquisition from newly designed or already implemented heat pump systems considering types of signals, protocols and platforms for buildings and industrial applications and related privacy issues and ongoing standardization activities
- Evaluate data analysis methods and applications (digital twins) for one or many heat pumps and sensors. Including machine learning, semantic models, BIM (Building Information Modelling) and soft sensors.
- Evaluate market opportunities created by IoT enabled heat pumps and identify success factors and further demands to software and hardware infrastructure.

Key data

- Project duration: Jan 2020 – Dec 2022
- Operation Agent: Veronika Wilk, Austrian Institute of Technology GmbH, Austria veronika.wilk@ait.ac.at
- Participating countries: Austria, Denmark, France, Germany, Norway, Sweden, Switzerland
- Website: https://heatpumpingtechnologies.org/annex56

Recent Progress
Modeling is a key element in the field of IoT and heat pumps, as the model allows to infer information and to predict on collected real-world data. In three Deep Dive sessions consisting of presentations by the participants on completed, ongoing and planned research work in the field of IoT and heat pumps, different aspects of heat pump modeling were analyzed:

Semantic models contain information on how data relates to the real world, an example is Building Information Modeling (BIM). It was developed to consolidate the large number of different information sources throughout the life-cycle of a building. Current research projects focus on the integration of HVAC components in BIM, such as heat pumps or air handling units, the combination of real-time construction information with BIM to create a digital twin for deviation detection and analytics, the use of BIM information to set up building performance simulations and the use of BIM for fault detection for facility management. It was concluded that standardization, which is key for efficient data exchange and interoperability, and integration of HVAC components in BIM, is not fully realized yet.

Data-driven models and machine learning approaches make use of large quantities of data, e.g., by supervised or unsupervised learning, clustering and classification. In the presented research projects, these methods are used for applications such as an automatic framework for the generation of regression models in the building domain, e.g., for the prediction of room temperature depending on supply air temperatures, valve settings, etc. as well as the prediction of the heating value of heterogeneous waste based on weather data. These methods can also be transferred to building and heat pump applications.

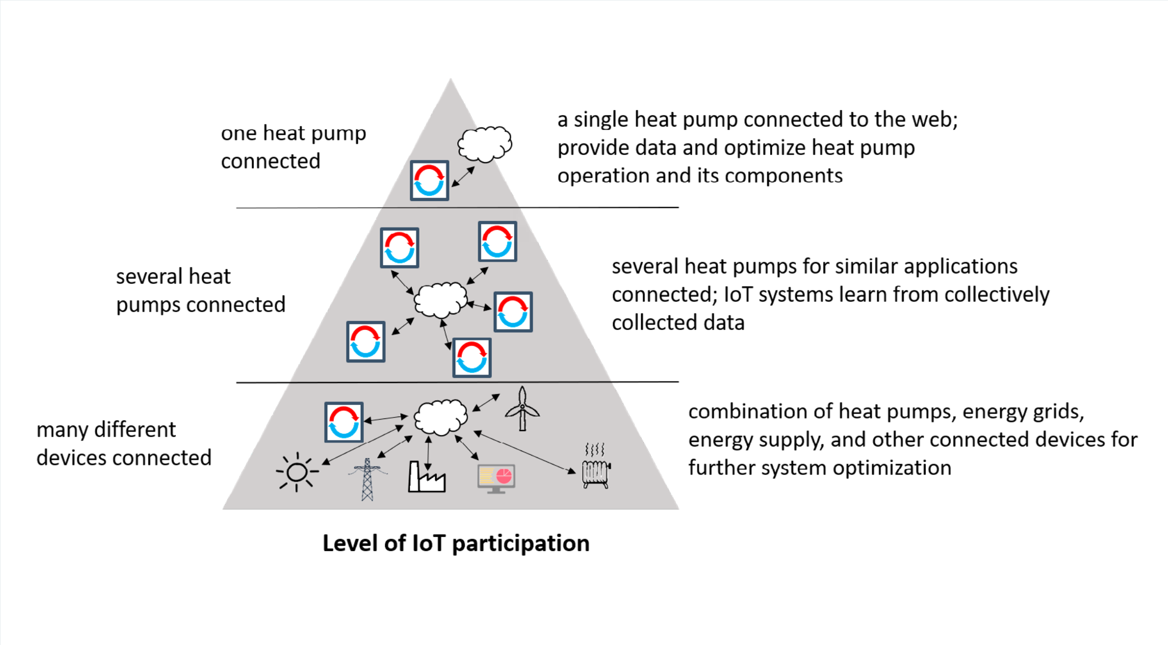


Figure 1. Heat pumps as a part of the Internet of Things (source: AIT Austrian Institute of Technology GmbH)

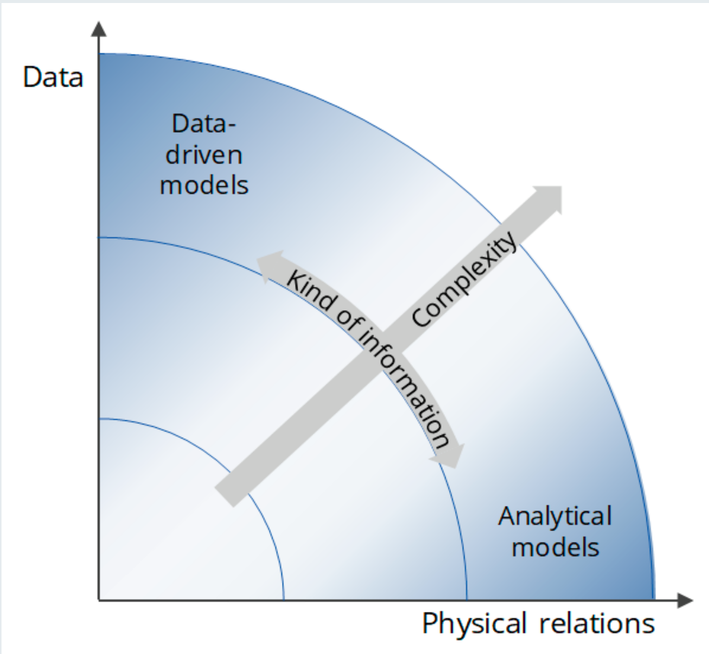


Figure 2. Hybrid models based on data and physical relations (source: Danish Technological Institute)

Hybrid models or grey box models combine analytical models with detailed physical relations with data-driven models based on statistics to find a good compromise on complexity and accuracy (Figure 2). The different presentations provided insight into several applications of grey-box models, such as advanced system monitoring and fault detection with model-based interpretation of system alerts for supermarket refrigeration systems, identification of incorrect settings in heat pumps for domestic heating and adaptive parameter selection for online calibration of a heat pump model during performance testing. The task of correctly recording environmental influences on the observed system to be able to distinguish a fault from an observed change was identified as one main issue for HVAC systems.

ANNEX 57
FLEXIBILITY BY IMPLEMENTATION OF HEAT PUMPS IN MULTI-VECTOR ENERGY SYSTEMS AND THERMAL NETWORKS

Introduction

The CO2 reduction goals means that the need for using excess heat from industries, the commercial sector and other sources are increasing as well as thermal solar power. In combination with District Heating, heat pumps are a way to make these energy sources available to use in buildings. At the moment, the interest in heat pumps for district heating and processes is growing.

Annex 57 focuses on coming technologies and the possibilities of heat pumps to increase the flexibility in energy systems with different sources such as PV, wind-power, and biomass and where end users can be consumers or prosumers or both (Multi-Vector). Heat pumps in DH systems provide many benefits since they enable the possibility of running DH systems at lower temperatures, which increases the possibilities of using waste heat. Thus, the grid can run more efficiently as the heat losses can be reduced.

Objectives

This Annex focuses on implementing heat pumps in district heating and cooling systems, describing possible solutions and barriers for heat pumps on these markets. The creation of the possible flexibility in the thermal network and the electrical grid is a main part of the annex.

The possibilities of increasing a larger share of renewable energy and excess heat as well as reducing the CO2 emission in the used heating systems by using heat pumps will be a focus area of the Annex. In addition, minimizing the system losses by using heat pumps will also be an objective, as will the reduction of CO2 emissions.

Key data

- Project duration: Jan 2021 – Dec 2023
- Operating agent: Danish Technological Institute, Mr. Svend Pedersen, svp@teknologisk.dk
- Participating countries: Austria, Sweden, Germany, The Netherlands and Denmark
- Website: https://heatpumpingtechnologies.org/annex57/

Recent Progress

The participants got their funding in place; the Annex had a kick-off meeting in January and task 1 start-up meeting in February. A workshop for the IEA Heat Pump Conference was set up in April.

At ExCo meeting in spring, it was decided that flexibility from individual heat pumps should be a part of the annex. This means that we are working on the implementation of that part in Task 1.

Task 2 is at the moment in the preparation phase, where we are going to find cases where heat pumps are bringing flexibility to the electrical and thermal grid.

Achievements

- Meetings: Kick-off meeting in January, Task 1 meeting in February, Task 1 meeting in September.
- Workshop: Preparation and coordination of a workshop at the IEA Heat Pump Conference in April.

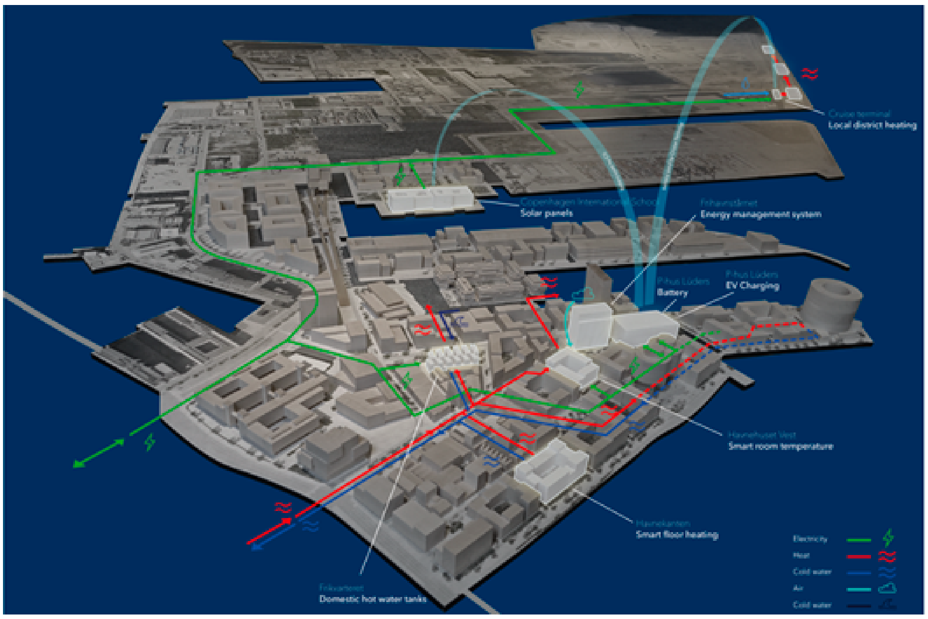


Figure 1. Integrated energy sytems in EnergyLabs Nordhavn

ANNEX 58 HIGH-TEMPERATURE HEAT PUMPS

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

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

Objectives
The overall objective of the Annex is to provide an overview of the technological possibilities and applications as well as to develop best practice recommendations 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.

This will be achieved by the following sub-objectives:

» Provide an overview of the technology, including the most relevant systems and components that are commercially available and under development (Task 1 – Ongoing).
» Identify technological bottlenecks and clarify the need for technical developments regarding components, working fluids and system design (Task 1 – Ongoing).
» Present best practice system solutions for a range of applications to underline the potential of HTHPs (Task 2 – Planned).
» Present strategies for the transition to heat-pump based process heat supply (Task 3 – Planned).
» Enhance the information basis about industrial heat pumps, potential applications and potential contribution to the decarbonization of the industry (Task 1, 2 & 3 – Ongoing).
» Develop guidelines for the handling of industrial heat pump projects with a focus on the HP specifications and the testing of these specifications (Task 4 – Planned).
» Disseminate the findings to various stakeholders and add to the knowledge base for energy planners and policy makers (Task 5 – Ongoing).

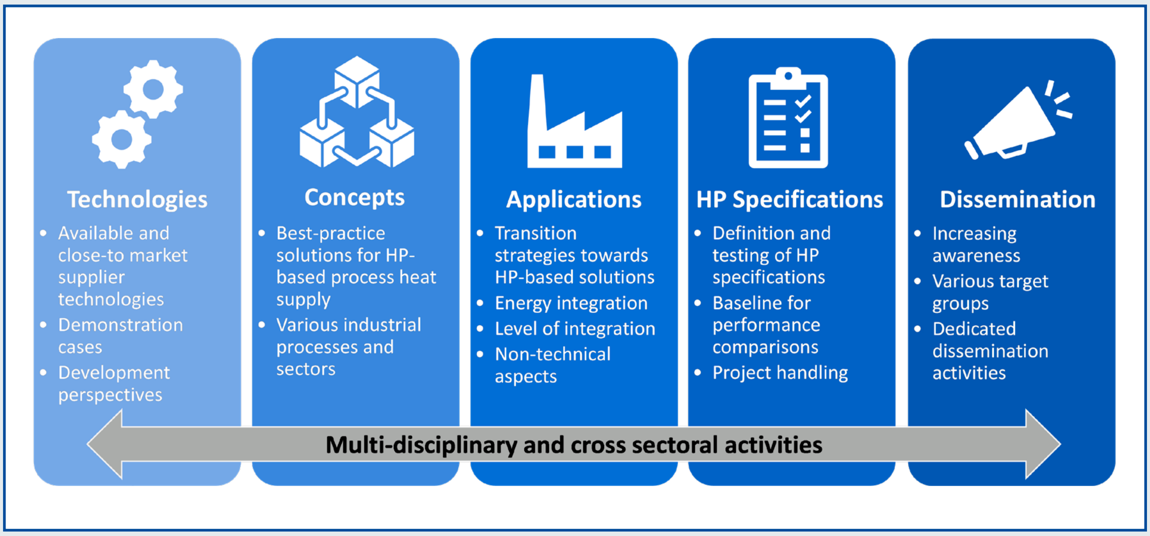


Figure 1. Overview of activities in Annex 58.

Key data

- Project duration: Jan 2021 – Dec 2023
- Operating Agent: Danish Technological Institute, Benjamin Zühlsdorf, bez@dti.dk, +45 7220 1258
- Participating countries with national representatives in brackets: Austria (AIT and TU Graz), Belgium (University Ghent, KU Leuven), Canada (National Resources Canada, University of Sherbrooke, Emerson), Denmark (DTI, DTU, Rambøll, Viegand Maagøe, Fenagy, Johnson Controls), France (EDF), Germany (DLR, Fraunhofer ISE and University of Paderborn), Japan (CRIEPI), Netherlands (TNO), Norway (SINTEF)
- Further countries are preparing their participation, including Switzerland, UK and US.
- Website: https://heatpumpingtechnologies.org/annex58/

Progress and first results

High-temperature heat pumps (HTHP) are attracting growing interest and are considered a key technology for decarbonizing industrial process heating. The recently published IEA report "Net Zero by 2050 – A Roadmap for the Global Energy Sector" outlined the importance of industrial heat pumps and concluded that heat pumps should cover 15% of the process heat demand of light industries at temperatures up to 400°C in 2030, while this share should increase to 30% by 2050. This corresponds to a required installation capacity of 500 MW per month over the next 30 years. The majority of these systems are expected to have supply temperatures above 100°C and are accordingly considered high-temperature heat pumps.

The relevance of high-temperature heat pumps is confirmed by the large interest in the Annex 58. Nine countries have already confirmed their participation, and in total, up to twelve participating countries are expected to join the Annex. The national support groups comprise R&D institutes and universities, technology suppliers, consultants, and others and are accordingly supplemented with knowledge from various national and international R&D projects.

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

By now, 20 supplier technologies were described, while more than 30 are expected in total. This is in contrast to the 8 demonstration cases for which information has been gathered.

The review is still ongoing and will be concluded in the coming month before being published during the first half of 2022. If you are aware of any technologies or demonstration cases that should be included in the review, please reach out to the operating agent (Benjamin Zühlsdorf, bez@dti.dk).

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

Climate leap – How investors are reaching major emissions cuts in existing property portfolios

Sarianna Sipola, Portfolio Manager, Varma, Finland
Jonni Ahonen, VP, Sales and Accounts, LeaseGreen, Finland

Many investors have made carbon neutrality the holy grail of their brand goals. Some are still figuring out how to reach that goal, with the actual plan still on the drawing board. There are many questions, and the challenge is considerable. If you have 500 properties in your portfolio, where do you begin the work towards making them energy efficient? What if you have 30 properties? How do you make sure that the work is financially worthwhile?

In buildings, the energy consumption arising from electricity and heating is the main source of carbon dioxide emissions. Improving the energy efficiency of buildings is one of the most viable paths to decreasing this consumption and the associated carbon emissions. Carbon dioxide emissions are easily reduced by using renewable energy, either by producing one's own energy or buying green energy.

It sounds simple, but where do you begin the work towards making buildings energy efficient, if you have 500 properties in your portfolio? What if you have 30 properties? How do you make sure that the work is financially worthwhile?

Varma, a Finnish pension insurance company, and LeaseGreen, Finland's leading cleantech service company, are working together to reduce the emissions from Varma's properties.

Varma is one of Finland's largest real estate investors. It owns over 60 residential buildings, including approximately over 4,000 flats. Varma has ambitious climate goals. The main goal is to reduce the carbon dioxide emissions of its direct real estate investments by switching to fossil-free heating and electricity by 2030 and 2025, respectively. Varma will replace the heating system in 36 apartment buildings in its housing stock from 2020–2022. The decision is expected to lead to an estimated 48% reduction in CO_2 emissions from Varma's properties by 2023.

In this project, the KPIs include economic variables, carbon emission reduction and energy consumption reduction targets. From 2020 to 2035, Varma will develop its portfolio towards carbon neutrality, and no stone will be left unturned.

A comprehensive analysis of a wide range of properties

A full-scope examination of a large section of Varma's properties (nearly 60 residential buildings, in this case) offered a quicker and more efficient path to reducing emissions than the modernization of individual buildings. It was this work that Varma began in collaboration with LeaseGreen.

LeaseGreen is a cleantech service company specializing in energy efficiency and innovative solutions for large properties. It implements optimal energy overhauls on customers' properties in terms of life-cycle costs, market value, and carbon footprint.

LeaseGreen helps investors to put together a profitable strategy that includes a solid road-map towards carbon neutrality. This was also carried out with Varma. LeaseGreen's portfolio analysis (Figure 1) is based on the initial data from the customer's property portfolio, such as data on energy use and location. Property investors usually have this data on hand, but it is still not being taken advantage of fully. The data is enriched by LeaseGreen's experts with tens of different data points, such as energy market price development and comprehensive market prices for energy overhauls. They then add to the analysis their own experience from hundreds of energy projects.

LeaseGreen uses this analysis to look for property-specific opportunities to use geothermal energy and solar energy, as well as other opportunities to improve energy efficiency. With energy investments, the focus is usually on the difference between technical solutions. It is equally important to identify issues related to energy markets and the location of the properties. Houses, offices, and logistics centres benefit from different types of solutions. It is also a completely different thing to produce geothermal energy in Espoo in Southern Finland than, for example, 600 km further north in Oulu. The results of the portfolio analysis are ready in a few weeks. Local emission coefficients, technical feasibility, as well as the property investor's strategy all affect the outcome of the analysis.

The concrete goal of the analysis is to divide the properties into meaningful investment baskets according to the size and content of the investment portfolio. The baskets show on which properties it is worth carrying out energy efficiency and production improvements, what improvements are sensible and when they should be done. At the same time, the baskets show how much needs to be invested in the properties and what kind of benefits can be expected. It is recommended to start with the most effective and profitable projects and proceed systematically one basket at a time.

For example, according to the analysis, Varma's residential real estate portfolio consisted of 60 properties, which were divided into five different baskets, as shown in Figure 2. The energy overhauls carried out on the first basket of 13 properties cut the CO_2 emissions of Varma's entire property portfolio by a fifth. The entire project will move Varma towards its ambitious climate goals.

Figure 1-4. The LeaseGreen's way to find the most profitable path to the climate objectives of the property investor. According to the analysis, Varma's residential real estate portfolio consisted of 60 properties, which were analysed and divided into five different baskets. This analysis was made at the end of 2019, and the energy overhaul on Varma's first basket was carried out during 2020-2021. By the end of September 2021, Varma has decided to carry out energy efficiency and production improvements to baskets 1-3.

Figure 3 shows the chosen energy improvements for Varma's property baskets. The investment and savings of each improvement are analyzed in detail to reach a comprehensive understanding of the possibilities. Figure 4 shows the CO_2 reduction potential in certain baskets for 2020–2023.

The goal is to find the most profitable path to the climate objectives of the property investor. There are concrete improvements along that path that are timed for the coming years. All of this is supported by a thorough portfolio analysis and experience from hundreds of energy overhauls. The customer ends up with an energy-efficient portfolio that includes everything needed for increasing its value. The reduction in carbon emissions ensures that the portfolio attracts capital also in the future.

Sustainability does not conflict with return expectations

LeaseGreen was tasked with planning and implementing the energy overhaul, which replaced the buildings' district heating with geothermal heat pumps, solar panels and property-specific heat pumps that recover heat from exhaust air. Energy-saving measures in apartment buildings are a natural step towards becoming emission-free. This comprehensive solution includes new automation, solar panels and modern lightning in addition to geothermal heat pumps and heat recovery systems. The energy overhaul on Varma's first basket was carried out during 2020-2021.

District heating currently accounts for a significant proportion of the carbon dioxide emissions from Varma's residential properties. This is because of burning various fossil fuels and biofuels in the district heating power plants. In 8 residential buildings, geothermal heating entirely replaced district heating.

Varma's previous partnership with LeaseGreen also focused on other energy overhaul projects. Varma and LeaseGreen previously collaborated on the energy refurbishment of the headquarters of Elisa Oyj, a Finnish Telecom company. The headquarters is owned by Varma, and the partnership focused on reducing the building's energy consumption and carbon footprint by around 40%.

The Elisa energy refurbishment, announced in May 2019, targets yearly savings of around 250 tonnes of CO_2, equivalent to the annual output for more than 1,000 solar panels. Savings can also be used to offset the emissions of more than 2,000 return flights between Helsinki and Stockholm.

According to Varma, the waste heat from the data centers is recovered and transferred to the building's heating and air conditioning system. The energy provided will reduce the consumption of district heating and the need for cooling energy. At the same time, costs will be reduced for both the owner and users of the property. It is always a pleasure to carry out investments like this since their returns clearly exceed the typical rate of return in real estate investment. Achieved cost savings have a significant effect on the value of properties.

Responsible companies are promptly carrying out economically viable investments in energy efficiency. In recent years, the profitability of energy refurbishments has improved clearly due to fast technological development. Varma has tightened its own energy efficiency goals because the company achieved them ahead of time. Digital monitoring will be used to optimize the settings for the building services technology according to the weather conditions and assist in monitoring progress and energy efficiency improvements.

Financially, this is also a good investment for Varma. With these kinds of energy solutions, Varma is looking to mitigate climate change as well as achieve good returns. Energy investments are one of the most efficient ways of improving the profitability and value of real estate investments as well as making them more environmentally sustainable. From a real estate investor's perspective, in general, making allowances for sustainability does not conflict with return expectations. For Varma, sustainability is a means of securing long-term returns.

Varma's inspiring example proves that companies can reduce emissions while at the same time increasing financial wellbeing.

SARIANNA SIPOLA
Varma
Finland
sarianna.sipola@email
https://doi.org/10.23697/3b5m-7f14

INFORMATION

Heat as a Service propositions: One of the keys to unlocking the residential retrofit market for heat pumps

Lindsay Sugden, Delta-EE, the United Kingdom

Heat contract propositions such as heat as a service, which can reduce the upfront costs and risks for residential end-users of switching from fossil boilers to lower carbon heating like heat pumps, are emerging rapidly across Europe. They offer promise as a way of driving uptake of heat pumps in existing residential buildings – a notoriously difficult segment to decarbonize. Today, <1% of heating systems sold across Europe annually are sold "on a contract", but this could reach 10% of the market by 2030.

Download and share this article

While heat pump uptake in new build accelerates thanks to increasingly tight building regulations across many parts of Europe, only small steps have been made in driving heat pump market growth in existing buildings. As a result, heat pumps make up less than 2% of the installed base of heating systems in dwellings across Europe. Two of the major challenges to increasing uptake of heat pumps in existing buildings are the poor customer economics, and the lack of end-user trust in the technology. To meet decarbonization targets and drive HP market growth to meet current ambitions, a significant shift is required in the rate of heat pump uptake in existing buildings, especially displacing gas boilers. There is an urgent need for a new way of selling heat pumps, which can remove some of the perceived risks from end-users, and make the economics look more attractive. Emerging heat contract propositions – including heat as a service - offer promise to tackle both of these challenges. There are an increasing number of market players engaging, from energy companies to heating manufacturers, to start-ups and specialist service providers.

What is heat as a service, and how can it overcome barriers to heat pump uptake in existing homes?
Figure 1 shows Delta-EE's risk-based framework for analyzing heating propositions. Propositions range from leasing, financing and maintenance contracts, to heat (output) as a service and even comfort (heat outcome) as a service. The more risks taken on by service providers, the less risk the end-user takes on.

The two biggest challenges for heat pumps in existing buildings are their poor end-user economics and the pervasive lack of trust in the technology

» End-user economics rarely stack up for heat pumps, particularly compared to gas – an installed heat pump costs two to four times that of a gas boiler, and in many markets, it is difficult for heat pumps to achieve running cost savings with current energy price ratios. 'Heat as a Service' can improve the customer economics, by removing – or reducing - the upfront cost barrier for a heat pump, and giv-

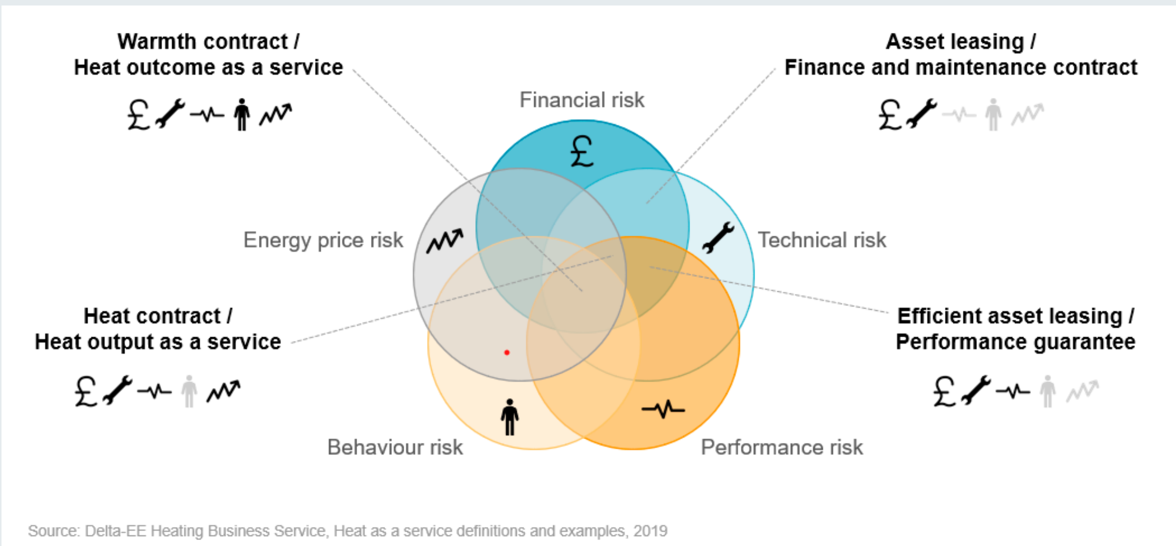


Figure 1. Defining the range of heat service propositions based on the risks taken by the provider

ing greater certainty about running costs through a fixed-rate heat cost.

» Awareness and trust in heat pumps remain low amongst a large share of heating customers in many of Europe's biggest markets, so buying a heat pump remains a "risky" prospect. 'Heat as a service' can remove the risk of poor heat pump performance and break-downs from the end-user by providing maintenance, remote monitoring, and guaranteeing the heat outcome.

Who is offering heat as a service or other heat contracting models?

Energy suppliers are the leading providers of service-based contracts today, and we expect them to drive much of the growth in sales over the next decade. Rental/leasing models are also offered by a number of established and new entrant specialist heating service providers, who are increasing the competition in the market. A small number of ambitious HVAC manufacturers are beginning to offer service-based contracts directly to customers, taking steps to reposition themselves as service providers and not only product suppliers.

Figure 2 shows some examples of companies with different types of heat contracting models using heat pumps across Europe.

How many heating systems are sold on a contract – and what is the outlook?

The majority of the market for heat contract sales is taken by gas boilers; there is a long history in Germany of such contracts. In the Netherlands, as much as 8% of all heating systems are sold on a contract (mainly gas boilers). Currently, only around 3,000 heat pumps per year are sold on a contract in Europe's main markets, but these sales could grow to as much as 100,000 per year this decade (see Figure 3).

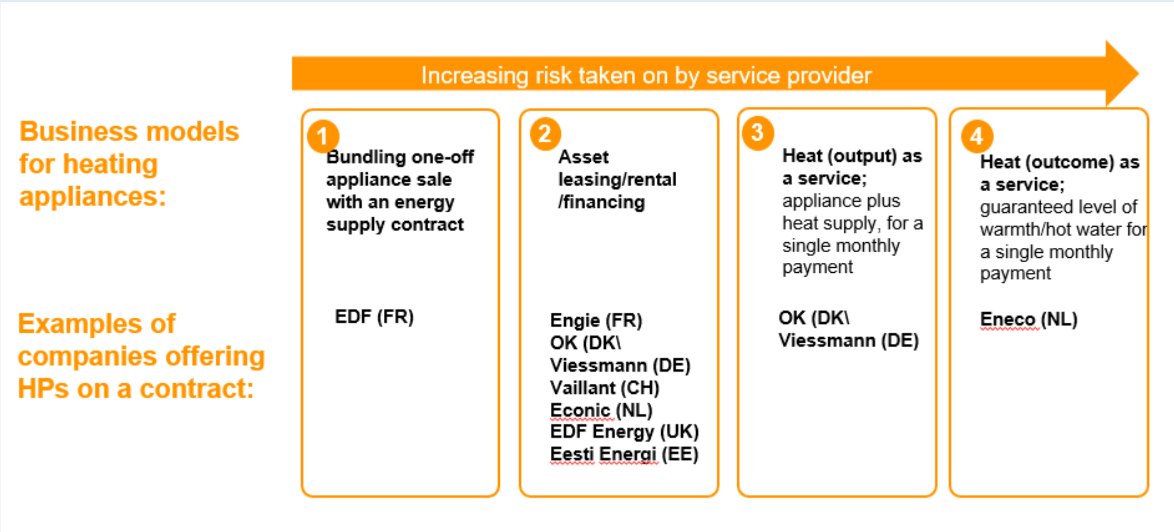


Figure 2. Who is offering heat pumps on a contract?

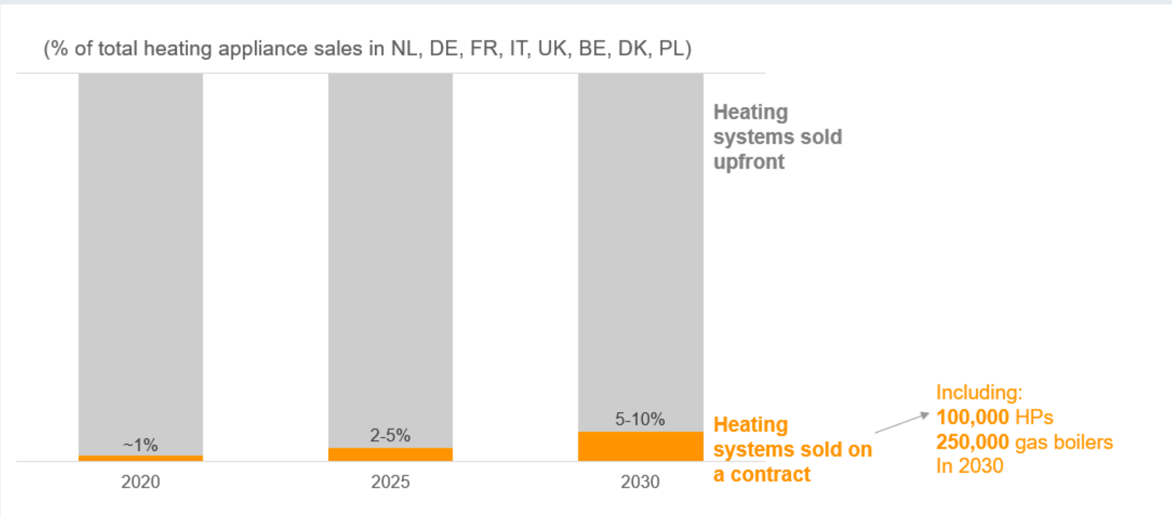
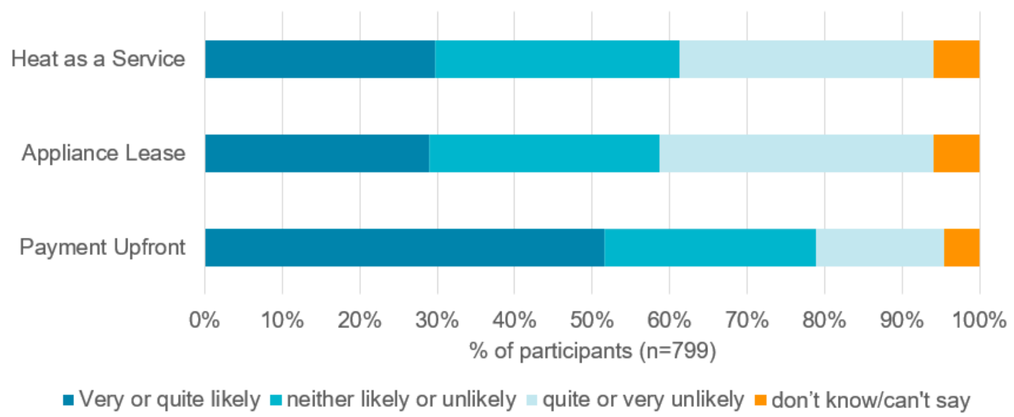


Figure 3. Share of heating systems sold on a contract today, and forecast to 2030



Source; Delta-EE, 2021. Based on a sample of 799 domestic customers in the UK, France, Germany, Italy and the Netherlands. (Survey restricted to those who own their home outright or with a mortgage, and make decisions jointly or solely about the heating system in the household).

Figure 4. How likely would end-users be to take up heat contract propositions?

This growth could be possible for a number of reasons:

- A growing number of companies are now becoming interested in the heat services market, and we expect strong growth as players seek new revenue streams to take advantage of the expanding heat pump market, and make up for lost revenue from energy sales. Offerings are increasingly "customer-centric" compared to traditional heating propositions, as innovative concepts emerge.
- Heat as a Service and related models are attractive to customers. See Figure 4, which illustrates outcomes of Delta-EE's customer research assessing the end-user preferences on how they would consider buying their heating; ~25% of end-users surveyed would be interested in taking up such an offer if it was available.
- Experience to date indicates that once customers buy heat rather than kWh of gas or electricity, it becomes easier to switch the heating system – so switching a gas customer who is already on a heat contract towards a heat pump will be easier than switching a gas customer who has paid upfront to a heat pump.
- There are opportunities to add further value to these business models by incorporating value streams from subsidies, time of use tariff or PV optimization, and (increasingly in future) demand-side flexibility values.

Challenges remain to meet such growth levels – for example, regulations limiting 3rd party access to subsidies can block revenue streams so the business model cannot work, or forcing service providers to supply the lowest running cost source of energy often does not work in the favor of heat pumps. However, the increasingly ambitious heat decarbonization targets being set by European governments mean that existing buildings, and in particular those heated by gas today, need to be shifted away from fossil fuels. Heat as a Service offers a lower risk, lower upfront cost way for these difficult to decarbonize end-users to move away from gas, and policy-makers are waking up to this in some markets. We expect greater support for innovation in business models and the removal of barriers over this decade.

Conclusions

Heat as a service, and the range of service-based heat propositions discussed in this paper, can play a key role in the decarbonization of heat in the existing buildings segment, potentially supporting the installation of a further 100,000 heat pumps per year or more across Europe's main markets by 2030. From an end-user perspective, heat as a service offers a lower risk, lower upfront cost way for residential customers to access lower carbon heating systems such as heat pumps. From a service provider perspective, heat as a service offers new and regular revenue streams from heat contract sales as well as future growth in revenue by layering new value streams from optimization or demand-side response. From a policy-maker perspective, heat as a service overcomes some of the major barriers to decarbonizing heat in existing buildings and could be one of the key tools in the toolbox to tackle this segment, where very little progress has been made to date.

References

1. Delta-EE, 2019, Heat as a Service: Definitions and examples, Heating Business Service
2. Delta-EE, 2021, Heat as a Service: State of the Market, Heating Business Service
3. Delta-EE, 2021, Annual Customer Research, Heating Business Service

LINDSAY SUGDEN
Head of Heat
The United Kingdom
lindsay.sugden@delta-ee.com
https://doi.org/10.23697/z0k7-9a58

Heimstaden's Ambitious Climate Goals: what role do heat pumps play

Katarina Skalare, Heimstaden, Sweden

Heimstaden recently presented new sustainability goals aiming to significantly reduce its total CO_2 emissions in line with the Paris Agreement's ambition level to limit global warming to 1.5°C and is investing approximately 500 million EUR to meet the goals. The company has set a climate road-map to achieve this ambitious target by focusing on five pillars and concrete KPIs, which are presented in this article, with a special focus on heating infrastructure.

Download and share this article

Climate change is a real threat to our entire civilization. Mobilizing to reduce our emissions in line with the Paris Agreement, energy-efficiency in our homes, and building resilience to climate change are all important in tackling the climate crisis head-on. As one of Europe's leading residential real estate companies, Heimstaden recognizes its responsibility to reduce its environmental footprint. Accordingly, in the coming years, we will reduce our greenhouse gas emissions in line with the Paris Agreement's ambition level to limit global warming to 1,5˚C and have set a budget of SEK 5 billion for the same, which will grow as the company grow. Sustainability is integrated into Heimstaden's business model, and Sustainable Mindset is an important strategic pillar of Heimstaden's core business strategy. The company has an extensive climate road-map, with local pathways for all country organizations, on how to reach the bold targets.

In January 2021, Heimstaden Bostad was one of the first pan-European residential real estate companies to commit to the Science-Based Targets initiative (SBTi). After a thorough internal process and review of the operational and economic ramifications of raising its ambitions, the board approved the new climate targets in September:

» Reduce absolute scope 1 and 2 greenhouse gas emissions (GHG) by at least 46% by 2030.
» Reduce the amount of purchased energy by, on average, 2% per year and sqm till 2025.
» Require that suppliers covering 70% scope 3 emissions will set science-based targets by 2025.

The new targets will supplement our existing sustainability targets.

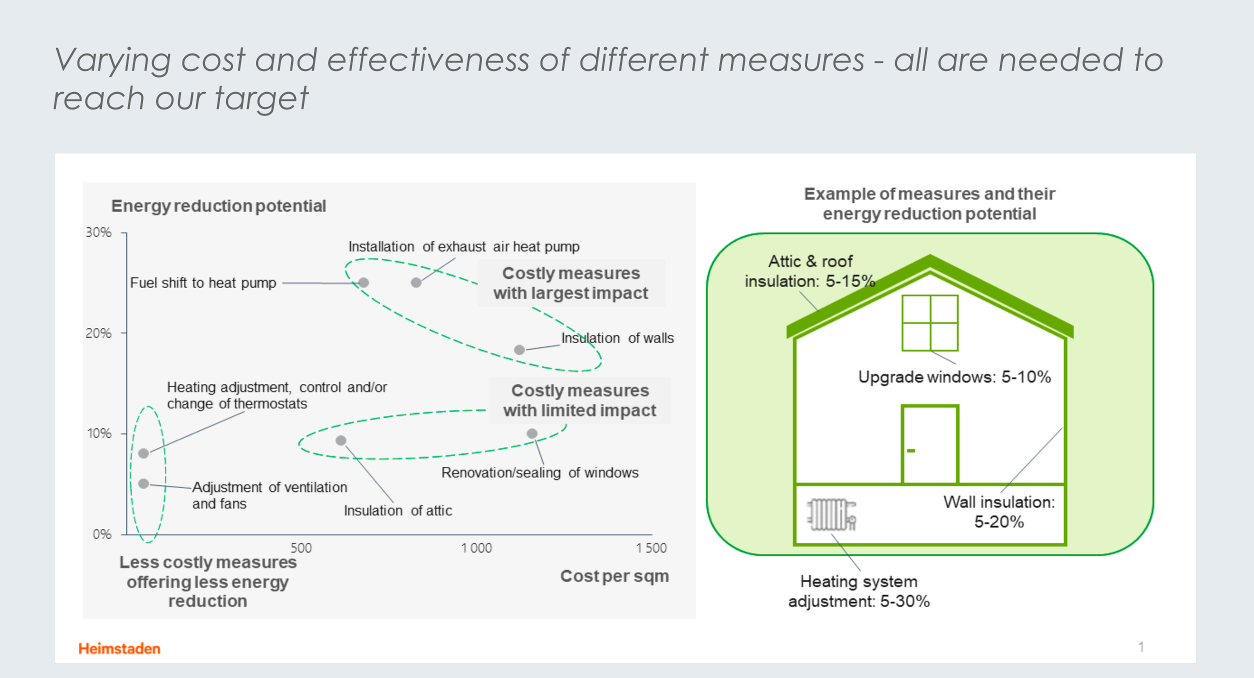


Figure 1. Relationship between energy reduction potential and varying cost and effectiveness of different measures

To succeed in such extensive work, we must be sure that the strategy is feasible and that the measures we implement have the effects we want. Therefore, we will submit our targets to the Science-Based Targets initiative (SBTi) and are looking forward to receiving validation and feedback from them. With the support from the initiative and a division of responsibilities that extends throughout the organization, from the Board of Directors (BoD) and senior executives to line managers and to individual employees, we are confident in our ability to realize these ambitions.

Climate change is a societal challenge that cannot be tackled without a concrete strategy, and our climate road-map includes the following five pillars:

- » Origin-certified renewable electricity
- » Fuel shifts
- » Energy provider improvements
- » Energy efficiency improvements
- » Encourage tenants to reduce energy usage

Table 1. describes each of the pillars in more detail.

Heimstaden has local pathways for each country that will help us achieve the company-wide target. We will focus on the above-mentioned five pillars to lower our company-wide carbon dioxide emission. A major chunk of our emissions comes from the Czech Republic, which has a high proportion of solid fuels such as coal in the energy systems. 37 000 flats are connected to district heating infrastructure, which partly uses coal as a source of energy. Therefore, in the Czech Republic, the focus will mainly be on shifting from coal-based local boilers to more efficient central gas boilers. We will also disconnect from fossil-based district heating to heat pumps driven by origin-certified renewable electricity in selected buildings. These measures will increase the standard of living for tenants and drive major emission reduction.

We have already seen how energy efficiency measures and fuel shifts can lead to a substantial positive impact. For example, in Sweden, in one of our properties in Katrineholm, the buildings' energy usage went down by 10% from 2017 to 2019 by installing new, local building connected, district heat exchangers, pumps, valves, and control systems. Similarly, in one of our properties in Trelleborg, by installing heat pumps (heat recovery from the exhaust and air ventilation), completed with other optimization actions and fine-tuning, we managed to reduce the energy usage of the property by 37% from 2017 to 2019. Many of our buildings have these kinds of systems where exhaust air fans with no heat recovery are installed. This area is one of our focus areas where we have performed various installations of heat pumps, and this is ongoing also for the coming years.

Table 1: Additional information, pillar by pillar

Origin-certified renewable electricity
- » Ensure origin-certified renewable electricity for all properties
- » Include renewable energy production in all newbuilds
- » Substantially increase renewable energy production capacity for existing properties

Fuel shifts
- » Local heating and energy production
- » Install heat pumps or electric boilers with origin-certified renewable electricity rather than fossil-based heating

Energy provider improvements
- » Actively engage energy providers to reduce their use of fossil fuels

Energy efficiency improvements
- » Insulation, ventilation improvements
- » Smart control systems & optimization of heating systems

Encourage tenants to reduce energy usage through the following measures
- » Customer Engagement Program
- » Nudging projects
- » Create awareness through smart technical solutions

Conclusions

There is a consensus within the global scientific community that climate change is real, rapidly escalating, and caused by humans. Heimstaden bases its sustainability strategy in climate science, and by raising our climate ambitions, we strive to have a positive impact on the global effort to combat climate change and takes responsibility for our environmental footprint, for the betterment of the planet and, hopefully, to the inspiration of the housing industry.

References/Footnotes

About the Science Based Targets initiative:
The Science Based Targets initiative (SBTi) is a collaboration between Carbon Disclosure Project (CDP), the United Nations Global Compact, World Resources Institute (WRI), and the World Wildlife Fund (WWF) to define and promote best practice in science-based target setting. Offering a range of target-setting resources and guidance, the SBTi independently assesses and approves companies' targets in line with its strict criteria.

Green House Gas Emissions Scopes:
Scope 1 covers direct emissions from owned or controlled sources. Scope 2 covers indirect emissions from the generation of purchased electricity, heating, and cooling consumed by the reporting company. Scope 3 includes all other indirect emissions that occur in a company's value chain.

KATARINA SKALARE
Chief Sustainability Officer
Sweden
katarina.skalare@heimstaden.com
https://doi.org/10.23697/ycgx-4b79

Why risk profiling is key to making large-scale decarbonization financially executable

Lars Bierlein, Qvantum Energi, Sweden
Tim Meanock, Tallarna, Sweden

For most building owners, the scale of investment required to make net-zero a reality is now unaffordable. Even when external financing is available, high-interest rates are frequently accompanied by a lack of capital. The reason for this is that projects are frequently viewed as a risk by building owners and project investors. Outside of engineering circles, the technical risk of decarbonization is poorly understood, and poor communication between stakeholders prevents adequate project costing explanations, leaving funding out of reach; this article explains why risk profiling is critical to making large-scale decarbonization financially feasible.

The phasing out of fossil-fuel-based heating is internationally recognized as fundamental to combating the climate crisis. For new city development projects, heat pump solutions have become the default alternative. But the situation is more challenging for existing building stock. Too often, large-scale infrastructure changes are required, which are not practical. If we are to keep global heating under 1.5°C, innovative technical and financial solutions will need to be adopted at scale.

The installation of heat pumps in conjunction with ultra-low temperature district heating and cooling systems, also known as 5GDHC, offer a way forward. Such projects support the large-scale energy transformation in dense urban areas for both new builds and retrofits. 5GDHC systems work by connecting several buildings with low-temperature water (typically 10-20°C) using one or several energy sources supplying the grid. This means that buildings in the grid area can easily access the best available energy source, maximizing space, flexibility, and energy efficiency. Each connected building has decentralized heat pumps installed to raise or lower the water temperature to the individually required level. This results in one infrastructure for both heating and cooling systems.

For the peak capacity demand hours, heat pumps connected to the grid can supply buildings with 70°C, making it easier to replace gas. Building energy efficiency measures can then be done gradually, thereby not impeding the shift to climate-neutral heating. Heat pumps and the thermal inertia of buildings are an untapped source of demand-side management potential, which is useful to balance the increasingly renewable and volatile electricity supply.

Step-by-step transformation of the built environment is possible with 5GDHC systems. Each building can be connected whenever suitable and local systems work very well autonomously with no need for coordination over large areas. But improving the way homes are heated is just one piece of the puzzle and must be considered in conjunction with energy efficiency projects and on-site renewable energy generation. Not only do joined-up projects accelerate decarbonization, helping building owners with legislative compliance, but they increase project Return of Investment (ROI) as the technologies work together in a synergistic ecosystem.

At the moment, the scale of investment required to make net-zero executable is prohibitive for most building owners. Even where external finance can be found, high-interest rates are too often coupled with insufficient funds. The reason for this lies in the fact projects are too often seen by building owners and project investors as a shot in the dark. The technical risk of decarbonization is little understood outside engineering circles, and poor communication between stakeholders prevents adequate explanation of project costing, leaving funding out of grasp.

In recent years, mathematical models have been developed that translate technical risks into financial ones. This makes projects understandable across the value chain, as well as enabling project performance to be guaranteed by third-party insurers. Such financial risk metrics are achieved through stochastic energy modeling. Here, multiple outcomes for a given retrofit option are mapped according to likelihood and magnitude. These account for the human ‘chaotic’ factor and the variable performance of technology to produce an ‘as used’ energy forecast. The risk of this can then be analyzed according to an insurer’s criteria in preparation for underwriting.

Managing performance risk and enabling guaranteed cash flows is key to both convincing building owners in project success and attracting infrastructure capital. It also enables a multi-technology approach in which heat pumps act as a gateway for greater energy efficiency measures. Suppose such projects’ predicted energy sav-

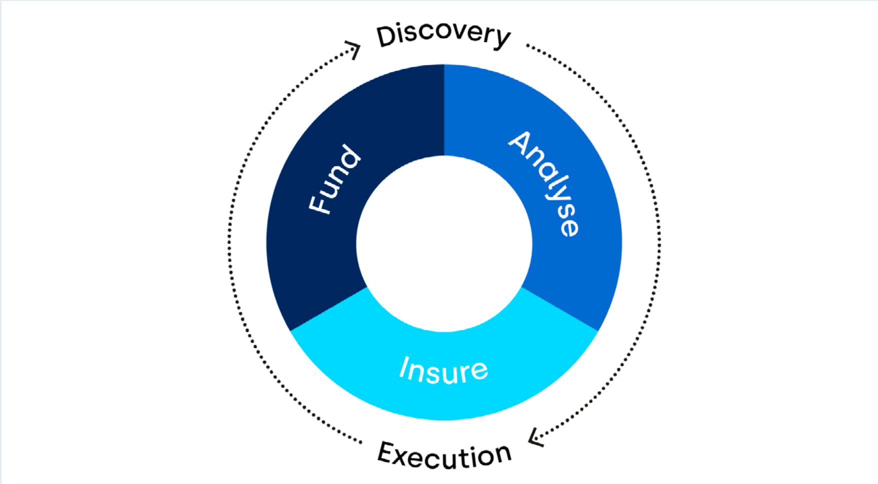


Figure 1. Positive feedback loop created for heat-pump driven retrofits through com-bining data analytics, insurance, and efficient funding.

ings could be insured. In that case, they can effectively pay for themselves, helping address the split incentive between landlord and residents prevalent in the social housing and private rented space.

But private finance is desperately needed for such retrofits due to the poor balance sheet capacity of landlords. Decarbonizing UK social housing stock alone, approximately 18% of all houses, will cost over £100 billion. While the British government has so far pledged £3.8 billion, private ESG (environmental, social and governance) infrastructure funds will be crucial to plugging the funding gap and helping the UK, as well as others, meet the terms of the Glasgow Climate Pact. The way to attract such funds is by quantifying, mitigating, and insuring heat pump technology in conjunction with other active and passive energy efficiency measures. Retrofit projects for thousand property portfolios have already been scoped using this methodology, with insurance and financing giving the green light.

The deployment of large-scale financing solutions for heat-pump driven retrofit projects is in an early phase but has significant opportunities to accelerate decarbonization in the built environment. Such solutions lead to the creation of positive feedback loops, where generated profits are poured back into green retrofits, which increases demand on the supply chain. As this happens, prices come down, resulting in economies of scale and greater ROI, in turn making projects more attractive to investors.

Thinking of decarbonization at scale will be fundamental to aligning supply chains and the training of employees. This issue is clearly seen in the UK, where heat pump installation is stymied by lack of workers and materials. According to an analysis by EY, there are currently only 1,200 heat pump installers in the UK. Given government targets, we should be aiming for 10,000 installers by 2025.

Combining innovative private financing and technology will make decarbonization financially executable. But initial projects will need to be authority-led, encouraged by government grants in conjunction with large-scale private finance, which is ready to go. Parallels can be drawn between the deployment of heat pumps in decarbonization projects and the progress of wind turbines over the past few decades.

The first development of utility-scale wind turbines was set up by NASA in the 1970s using government funding. Thirteen experimental turbines were erected. Inspired by their success, the creation of the world's first wind-farm went ahead in New Hampshire, US, with 20 turbines. Although this wind farm proved ineffective, it paved the way for many of the technologies used today. While government grants helped get wind power off the ground, the technology fundamentally had to stand on its own two feet with private capital to flourish. Today, the largest wind farm in the world consists of 7,000 turbines located in China, with a planned installed capacity of 20 GW.

The same journey will be true in the deployment of 5GDHC. Smaller, government-sponsored projects have already been achieved and show the trans-formative potential of this solution. Slowly but surely, the private sector is embracing these projects, made possible through risk analysis and mitigation. A domino effect is building. And once this happens, climate-neutral buildings will be financially possible at scale.

LARS BIERLEIN
CEO
Sweden
Lars.bierlein@qvantum.com

TIM MEANOCK
CEO
Sweden
tim@tallarna.com

https://doi.org/10.23697/f5qt-1233

Denmark: Strategic Market Outlook

Svend Vinther Pedersen, Danish Technological Institute, Denmark

The number of heat pumps sold per year has doubled since 2016. In new build, a ban on gas and oil boilers is a key driver for heat pumps. In existing buildings, a ban on replacement oil boilers, as well as available subsidies to switch from gas or oil to heat pumps, are driving a shift towards heat pumps. A large number of heat pumps (particularly air/air) are also being sold without subsidies, driven by the running cost savings achievable and the simplicity of the heating system (especially compared to wood/biomass). In relation to consumers' running costs, the price of electricity in relation to other forms of heating such as gas, oil, district heating or biomass (wood/pellets) is critical, and Denmark has had some of the highest electricity prices in Europe. To counteract this, a reduction in the tax on electricity for heating was introduced in 2016, and by 2021, this tax has been reduced almost to zero. In recent years, the drop in gas prices has made it more challenging for electric heating, so hydronic heat pump sales did not increase as much as anticipated, but the gas price rises in 2021 have been positive for heat pumps.

With the massive political focus on phasing out fossil fuels, heat pumps for residential heating are today a popular form of heating among Danish homeowners, and sales have doubled in the last 5 years, where heat pumps have displaced mainly oil boilers. Large heat pumps are also growing fast. The climate goals to reduce CO_2 emissions by 50-54% in 2025 and 70% in 2030 compared to the 1990 level, and the fact that the district heating companies aim to phase out biomass by 2040 to achieve the target, means that it is necessary to implement a large proportion of heat pumps in the district heating network and utilize excess heat in a higher proportion than today.

The heating market in Denmark

There are 2.8 million households in Denmark. Today, the total building area in Denmark is heated by district heating (54.5%), gas (18.1%), oil (10.9%), direct electric heating (6%), biomass boilers or furnaces (6%), and individual heat pumps (4%), see Figure 1. The gas network was greatly expanded from 1980 to utilize the gas from the North Sea, but as the production is declining, there is now a great focus on reducing the use of natural gas and oil and converting to district heating or heat pumps.

Decarbonization objectives at a national level

In 2012, the first political objectives came, which influenced the sale of heat pumps. The main goals are the phasing out of fossil fuels and increased electrification. The objective is that Denmark's energy demand should be covered by renewable energy in 2050, the production of electricity and heat should be renewable by 2035, and 50% of electricity consumption should be covered by wind energy in 2020. At the same time, an

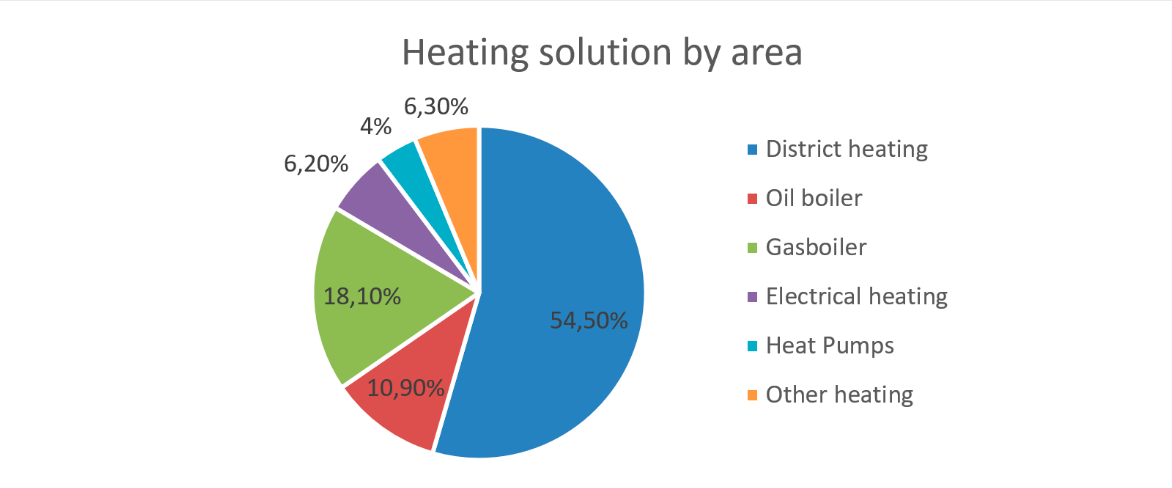


Figure 1. Heating solution by area

energy agreement was made which banned the installation of oil boilers and natural gas in new buildings from 2013 and banned the installation of oil boilers in existing buildings with access to natural gas and district heating from 2016. In addition, the electricity tax for electric used for heating was reduced by 4 euro cents/kWh, which means that the total electricity price decreased by 6.7 euro cents/kWh. In 2018, this tax was further reduced by 2 Euro cents.

In 2020, another political energy agreement was signed, which states that oil and gas boilers must be phased out with green alternatives such as district heating or heat pumps. A scrap-page scheme was established to provide incentives for the scrapping of oil-fired boilers, and the building renovation scheme was also established, which incentivizes energy renovation and conversion to heat pumps or district heating. In addition, it is a requirement that to receive the financial support, the heat pump installer must have passed the course for renewable heat installer for heat pumps (VE-G). As a result, in the last year, almost 1000 installation companies have been certified. In addition, the electric heating tax is reduced to 0.1 Euro cent.

The most recent energy agreement in May 2021 strengthened even further the drive away from fossil fuels in the heating sector. The goal is for CO_2 emissions reductions to 50-54% in 2025 and 70% in 2030 compared to 1990, and to achieve climate neutrality in 2050.

Policy drivers for individual heat pumps

The main drivers in the Danish market have been the bans on the installation of oil and gas boilers in new buildings from 2013 and the ban on installation of oil boilers in natural gas and district heating areas from 2016, as well as the reduction of electricity tax which makes electric heat pumps competitive with gas on running costs. The two subsidies have also been key drivers: firstly, the energy renovation scheme, which provides incentives for energy renovation including heat pumps, worth up to approx. 3000 euros, and attracting 19,000 applicants in 2020; and secondly, the scrap-page scheme for oil-fired boilers established in 2016 (which attracted around 20,000 applications in its first year) for subsidies for the installation of a heat pump.

Another driver has been the availability of alternative ways to buy heat pumps – like leasing and subscription models, which means heat pumps are available to consumers for a low investment cost. In 2013, the Danish Energy Agency launched several demonstration projects to test models for offering heat pumps on subscription and leasing. This has meant that today there are a number of players, including district heating suppliers and energy providers, who sell solutions with individual heat pumps on subscription or leasing.

In addition, it has been key to ensure there are enough qualified installers to meet the growing demand for heat pumps. To receive subsidies for an installation, the installer should be approved as a renewable energy installer (VE-G). It has meant that since July 2020 until today, there have been over 1000 installers on the installation course and that there are approx. 1000 VE-G approved installation companies.

Market development in individual heat pumps

The heat pump sales for individual heat pumps have been steadily increasing since 2016. Air to air heat pumps has a share of 73% of the heat pumps sold, and air to water 2%, see Figure 2. Since 2009, 431000 heat pumps have been sold in Denmark, of which 87,000 are systems for hydronic heating systems. The number has doubled since 2015.

Air to air heat pumps are often used as the primary energy source, especially in houses with electrical heating. Holiday houses (of which there are approximately 228,000) are a big market, but also permanent houses with electrical heating. Air to air heat pumps are also installed for secondary heating in garages and other secondary building areas.

Hydronic heat pumps have primarily been installed instead of oil boilers or in newly built houses, and heat

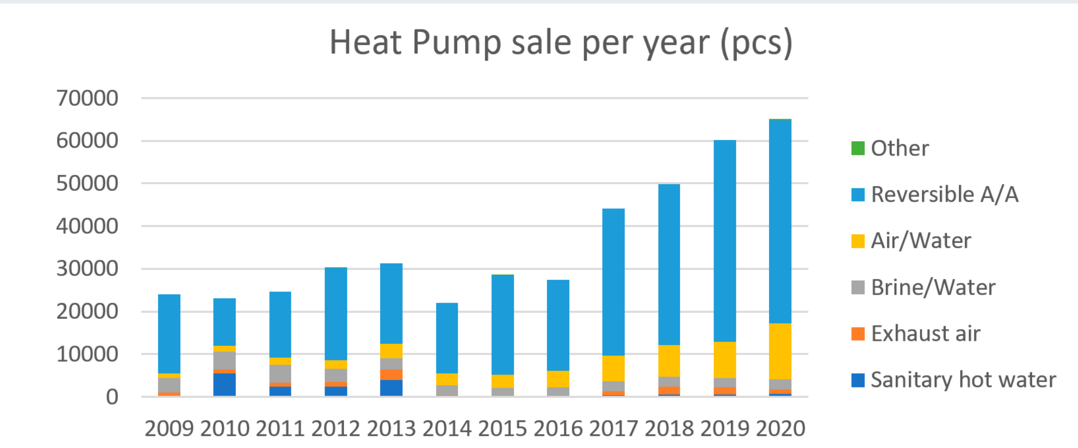


Figure 2. Heat Pump sale per year

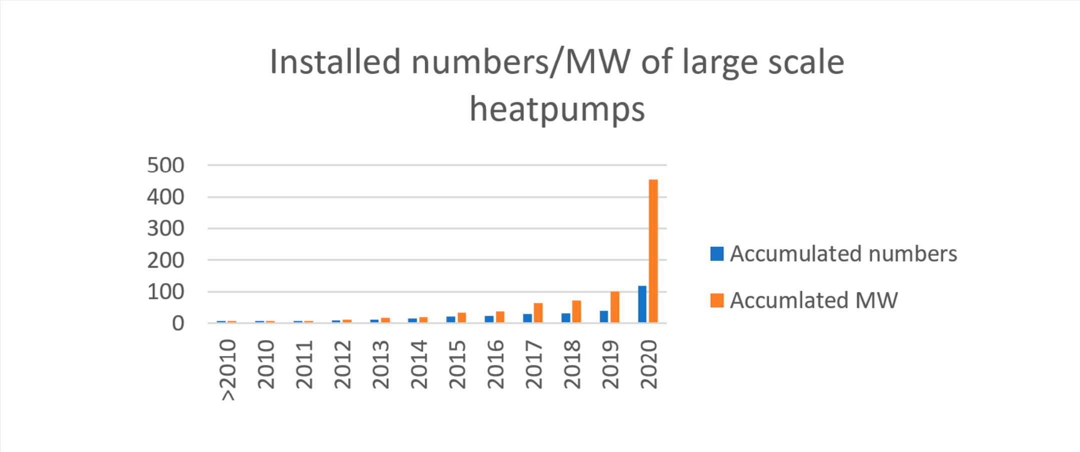


Figure 3. Heat Pump sale per year

pumps have been chosen in 29% of all new buildings (compared with 53% district heating). As gas prices in the period from 2015 have generally been low, it has been difficult for heat pumps to compete in the replacement market for gas boilers, but this currently seems to be changing with the current increases in oil and gas prices, which are to the advantage of heat pumps, also supported by the reduction in tax for electricity used for electricity for heating.

Focus on large scale heat pumps

Today, district heating heats 54% of the heated area in Denmark. Most of the district heating comes from burning biomass CHP (31%), waste incineration (22%), gas (17%), biomass boilers (15%), heat pumps & solar panels (8%) and other sources make the remaining (8%). In recent years, there has been a conversion from coal-burning to biomass at the CHP plants, and the transition is now underway from biomass to heat pumps and other renewables.

Policy drivers for large heat pumps

Policy began to drive large heat pumps following 2018's energy policy agreement, which aimed to drive more renewable energy and greater electrification. In May 2021, this drive was strengthened further with the agreement on emissions reductions to 50-54 % in 2025 and 70% in 2030 compared to 1990, and to achieve climate neutrality in 2050. The pressure to convert from gas and oil to district heating with heat pumps is high.

To achieve the shift away from gas CHP, several measures have been introduced. District heating plants in Denmark have traditionally been incentivized to connect to the natural gas networks and operate co-generation plants to produce both heat and electricity. District heating plants have been released from their requirement to use co-generation and natural gas, so they are no longer required to produce electricity and are more free to consider alternatives like heat pumps and solar thermal as heat source. In addition, the obligation on consumers to connect and remain connected to the district heating system has been removed. This increases competition in the heating market and incentivizes district heating providers to offer the lowest running cost solutions; this is increasingly driving a shift to heat pumps and other sources like solar thermal in district heating, which are becoming the cheapest options.

Since 2020, start-up support has been available for collective electric heat pumps to drive the shift away from fossil fuels in large buildings. In addition, district heating plants have been able to apply for subsidies for the establishment of heat pumps. Business subsidies are given for energy efficiency projects for companies, and the companies can get subsidies for replacing boilers with heat pumps.

A further factor driving the large heat pump market is a projected increase in electricity consumption for data centers (of which there are many in Denmark). This is expected to correspond to 8.5 TWh in 2030, which corresponds to the electrical use in 2.1 million households (almost all of the Danish homes). This means that there is a great need to be able to utilize the waste heat in these data centers and from the industry if the CO_2 reduction goals should be achieved. The taxes on the use of waste heat are reduced to 3.33 euro/GJ, and in some cases, it can be removed completely; this will help promote the utilization of excess heat from industry and other industries, including supermarkets.

Market development in large heat pumps

The measures introduced over the last years, described above, have kick-started the implementation of large heat pumps in the district heating network. Therefore, it is seen that the number of plants with heat pumps is increasing sharply. In 2020 alone, 77 large scale heat pumps were installed with a total power of 353 MW, see Figure 3.

SVEND VINTHER PEDERSEN
Danish Technological Institute
Denmark
svp@teknologisk.dk
https://doi.org/10.23697/09cv-p209

Events 2022 – 2023

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

29 January–2 February
2022 ASHRAE winter Conference
Las Vegas, USA
https://www.ashrae.org/conferences/2022-winter-conference-las-vegas

31 January–2 February
AHR Expo
Las Vegas, USA
https://www.ahrexpo.com/

1–4 February
HVAC&R JAPAN 2022
Tokyo, Japan
https://www.jraia.or.jp/hvacr/en/index.html

17–19 February
ACREX India 2022
Bengaluru, India
https://www.acrex.in/home

21–23 March
ACEEE Hot Water Forum
Atlanta, USA
https://www.aceee.org/2022-hot-water-forum

8–10 April
The 10th Asian Conference on Refrígeration and Air-Conditioning (ACRA 2022)
Chongqing, China
https://acra2022.scimeeting.cn/en/web/index/

11–13 April
7th IIR Conference on Sustainability and the Cold Chain
Newcastle, United Kingdom
https://ior.org.uk/the-7th-iir-conference-on-sustainability-and-the

4–6 May
(postponed from 13-15 September, 2021)
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

22–25 May
CLIMA 2022
Rotterdam, The Netherlands
https://clima2022.org/

6–10 June
eceee in-person 2022 Summer Study
Hyères, France
https://www.eceee.org/all-news/news/eceee-announces-in-person-summer-study-in-june-2022/

13–15 June
15th IIR-Gustav Lorentzen Conference on Working Fluids
Trondheim, Norway
https://www.sintef.no/projectweb/gustavlorentzen_2022/

25–29 June
2022 ASHRAE ANNUAL CONFERENCE
Toronto, Canada
https://www.ashrae.org/conferences/2022-annual-conference-toronto

10–14 July
Purdue: International Compressor Engineering, International Refrigeration & Air-Conditioning
W. Lafayette, Indiana, USA
https://engineering.purdue.edu/Herrick/about/news/Conferences/2022

11–13 November
Chillventa
Nürnberg, Germany
https://www.chillventa.de/en

2023

15–18 May
The 14th IEA Heat Pump Conference in Chicago (HPC2023)
Chicago, Illinois, USA
https://www.hpc2023.org/

IN THE NEXT ISSUE
Refrigerants
Volume 40 - NO 1/2022

National Team CONTACTS

AUSTRIA
Dr. Thomas Fleckl
Austrian Institute of Technology
Tel: +43 50550-6616
thomas.fleckl@ait.ac.at

BELGIUM
Ellen Van Mello
ODE – Organization for Sustainable Energy
Tel: + 32 476792824
ellen.vanmello@ode.be

CANADA
Dr. Sophie Hosatte Ducassy
CanmetENERGY
Natural Resources Canada
Tel: +1 450 652 5331
sophie.hosatte-ducassy@canada.ca

CHINA
Prof. Xu Wei
China Academy of Building Research
Tel: +86 10 84270105
xuwei19@126.com

DENMARK
Mr. Svend Pedersen
Danish Technological Institute
Tel: +45 72 20 12 71
svp@teknologisk.dk

FINLAND
Mr. Jussi Hirvonen
Finnish Heat Pump Association
Tel: +35 8 50 500 2751
jussi.hirvonen@sulpu.fi

FRANCE
Mr. Paul Kaaijk
ADEME
Tel: +33 4 93 95 79 14
paul.kaaijk@ademe.fr

GERMANY
Dr. Rainer Jakobs
Informationszentrum Wärmepumpen und Kältetechnik
Tel. + 49 6163 57 17
jakobs@izw-online.de

ITALY
Dr. Maurizio Pieve
ENEA, Energy Technologies Dept.
Tel. +39 050 621 36 14
maurizio.pieve@enea.it

JAPAN
Mr. Tetsushiro Iwatsubo
New Energy and Industrial Technology Development Organization
Tel +81-44-520-5281
iwatsubotts@nedo.go.jp

Mr. Takahiro Asahi
Heat Pump and Thermal Storage Technology Center of Japan (HPTCJ)
Tel: +81 3 5643 2404
asahi.takahiro@hptcj.or.jp

NETHERLANDS
Mr. Tomas Olejniczak
Netherlands Enterprise Agency (RVO)
Tel: +31 88 60 233 17
tomas.olejniczak@rvo.nl

NORWAY
Mr. Rolf Iver Mytting Hagemoen
NOVAP
Tel. +47 971 29 250
river@novap.no

SOUTH KOREA
Mr. Hyun-choon Cho
KETEP
Tel: +82 2 3469 8301
energykorea@ketep.re.kr

SWEDEN
Ms. Emina Pasic
Swedish Energy Agency
Tel: +46 16 544 2189
emina.pasic@energimyndigheten.se

SWITZERLAND
Mr. Stephan Renz
Beratung Renz Consulting
Tel: +41 61 271 76 36
info@renzconsulting.ch

UNITED KINGDOM
Mr. Oliver Sutton
Department for Business, Energy & Industrial Strategy
Tel: +44 300 068 6825
oliver.sutton@decc.gsi.gov.uk

THE UNITED STATES
Mr. Van Baxter – Team Leader
Building Equipment Research
Building Technologies Research & Integration Center
Tel: +1 865 574 2104
baxtervd@ornl.gov

Ms. Melissa Voss Lapsa – Coordinator
Building Envelope & Urban Systems Research
Building Technologies Research & Integration Center
Tel: +1 865 576 8620
lapsamv@ornl.gov

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 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.

Heat Pump Centre
c/o RISE Research Institutes of Sweden
P.O. Box 857
SE-501 15 Borås
Sweden
Tel: +46 10 516 53 42
hpc@heatpumpcentre.org

www.heatpumpingtechnologies.org