Heat Pumping Technologies MAGAZINE

A HEAT PUMP CENTRE PRODUCT

Heat Pumping Technologies in near Zero Emission Buildings (nZEB)

CARSTEN WEMHOENER, Switzerland

"HEAT PUMPS IN nZEB WILL CONTRIBUTE TO A SUSTAINABLE LOW CARBON SOCIETY"

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In this issue

Heat pumps is an excellent choice for nZEB and other low energy buildings. This is evidenced in a number of HPT TCP Annexes (projects) that have been devoted to them, Annexes 32, 40 and 49, as well as the number of countries that have been participating in them, nine countries in Annex 40. This issue of the HPT Magazine describes various aspects of heat pumps in nZEB.

The Operating agent (Project leader) of these Annexes presents the topic in the Foreword. In the present issue, two of the topical articles discuss nZEB in relation to legislation, directives and standards, while the other three focus on the role of heat pumps in the building. The Column describes possible reasons to the modest attention that heat pumps receive in EU policy. There is also a summary of two recently finalised Annexes - Cold Climate Heat Pumps and Heat Pumps in Smart Grids. Read also the News in focus and the report from a Conference, both regarding the increasing use of air-source heat pumps in China.

Enjoy your reading!

Johan Berg, Editor

Heat Pump Centre

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

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FOREWORD

Heat pump application in nZEB

By the year 2021, all new buildings in the European Union shall be nearly Zero Energy Buildings (nZEB). Also globally, in North America and East Asian countries such as Japan, the objective of Net Zero Energy Buildings (NZEB) shall be implemented in the time frame between 2020 and 2030. However, the definition of nZEB in the EU and other countries is still underway and existing definitions are not harmonised yet, but vary both in criteria and limits. While some countries will make a further step towards high performance buildings, other countries will hardly change their ambition level compared to current requirements.

For the concept of nZEB, the passive components are weighted with the active components – the building envelope and building system efficiency with on-site renewable production - to meet the (nearly) "Zero" requirement. Even though the concept is a pure energy weighting, it also affects the cost of the building, since there is a trade-off between building and system efficiency on the one hand and renewable energy production on the other hand. At current market conditions this may result in a better overall economy of systems which may have higher investments, but reduce on-site production needs due to higher efficiency. In particular, for the heat pump the higher efficiency results in less required on-site solar PV area and may lead to an overall lower investment to reach the nZEB requirement, depending on the market conditions. Due to the low space heating temperature requirements in nZEB, excellent performance of the heat pump is expected. This may boost heat pump markets in new buildings, as for instance in nZEB in Switzerland where more than 90 % of the certified buildings are equipped with heat pumps.

The concept of nZEB also has the further implication that the building changes from a consumer to a prosumer with a thermal (and increasingly also electric) storage and thus becomes an active part of the energy grid. For the integration of the building into the energy system, the heat pump becomes the link between the thermal energy consumption and the electric energy production on-site. By the combination of the heat pump with active (heat storage) and passive (building thermal mass) storage, the interaction and impact on the local grid can be reduced, which also may further improve the economy. In some markets, it is already more economic to install a heat pump with solar PV than without. From the utility's perspective of the energy system, this includes the vision of virtual prosumer power plants offering positive and negative operation reserve, peak shaving options and temporary self-sufficiency. From the building owner's perspective, partial independence of future energy prices, temporary self-sufficiency and economic optimisations are linked to the combination of solar PV and heat pumps.

Thus, perspectives offered by the introduction of nZEB seem promising. However, it still has to be proven that the concrete implementation of the nZEB concept in the single EU member states and globally is a further step to higher energy efficiency and lower carbon emissions of the built environment, that it contributes to the required higher renewable shares for the energy transition, and that it is compatible with local power grid integration. Moreover, nZEB requirements are currently related primarily to new buildings, while a main challenge is the transformation of the existing building stock. Additionally, by increase of the PV production there is a seasonal mismatch between summer surplus electricity and winter electricity needs, which has to be addressed in the future. Nevertheless, a higher share of well-performing heat pumps in nZEB will definitely contribute to the cost-effective transition to a sustainable low carbon society, leading to an increasingly important role of heat pumping technologies as key technologies for the energy transition.

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Heat pumps – Obvious but... neither 'hot' nor 'cool'?

Major reference research organisations have placed heat pump technologies under very favourable light in recent years. For many good reasons, as heat pumps eliminate the need for undesirable fossil fuel imports, they decarbonise and make Europe's economy competitive by using renewable or waste energy. They offer smart and highly efficient solutions for the residential, commercial and industrial sector and can operate well in combination with other heating and cooling solutions.

It is striking however that - although the EU will not be able to meet its climate and energy goals without their massive deployment - heat pumps still seem not to deserve the same degree of attention from policy-makers as other clean technologies. In this regard, the Clean Energy for All Europeans' package adopted by the European Commission in November 2016 (currently discussed by the EU co-legislators) fuels the EU energy policy framework with fresh examples of the continuous "apathy" of policy makers towards heat pumps*. This is a serious issue, as the visibility granted to certain solutions over others conveys signals to potential private and public investors that would be able and willing to accelerate the deployment of sustainable solutions for our societies.

So why are EU policy makers so "shy" about heat pumps?

Heat pumps are not 'hot'...

A first possible explanation could be the **lack of awareness** on the functioning of heat pumps and on their multiple benefits for the consumers and the energy system, which makes it more difficult for policy-makers to spontaneously promote them.

Second, **technology-neutrality** has often been the leitmotiv of policy-makers, who argue that the promotion of one technology over another can distort the energy market and possibly lead to lock-in effects. However, it is worth noting that this concept has not been applied to other 'hotter' systems, which have been openly promoted across EU policies...

Or maybe it is the **double affiliation** of heat pumps to the communities of 'high-efficiency systems' and 'renewable technologies' that can explain their lack of visibility?

Heat pumps are not 'cool'...

Another problem could be their lack of physical visibility (compared with PV or windmills). This could prevent policy-makers from leaving a tangible legacy of their political achievements...
The difficulty may also come from the word 'heat pump' itself (and not only in English!), which is neither poetic, nor able to fully convey the integrative nature of the technology (that is also used for cooling, storage, etc.).

However, it is still possible to re-enchant policy-makers and make heat pumps 'hot' and 'cool' again. Therefore, it is crucial that the heat-pump community remains constantly active on raising awareness on the technology not only for tomorrow's desired green, competitive and digital EU, but also for today's.

* In the proposed new Renewable Energy Directive, there is a specific article on district heating (article 24). There is no equivalent article relating only to heat pumps. Moreover, heat pumps are still the only renewable technology in that Directive subject to efficiency requirements (article 7) to be accounted for as renewable.
In the new proposed Energy Performance of Buildings Directive, the mentioning of 'heat pumps' as one of the 'high efficiency alternatives' to be considered by planners for new buildings (article 6) and renovations (article 7) has been removed from the text. In the same document however, considerable attention has been given to electric charging points for vehicles...

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The 13th IEA Heat Pump Conference in Jeju (HPC2020) May 11 – 14, 2020

The Republic of Korea will organize the 13th IEA Heat Pump Conference at Jeju, South Korea from May 11th – 14th, 2020. HPC2020 is subtitled 'Heat Pumps – Mission for the Green World', to indicate the potential countermeasures against global warming.

After a few years on other continents, the conference is now returning to an Asian country; the most recent Asian conferences took place 2011 in Tokyo, Japan and 2002 in Beijing, China. Following up its successful history of the IEA Heat Pump Conference, the HPC2020 will give all the worldwide participants a chance to share a series of up-to-date presentations on technology, recent developments, and market and policy-making strategies on heat pumps.

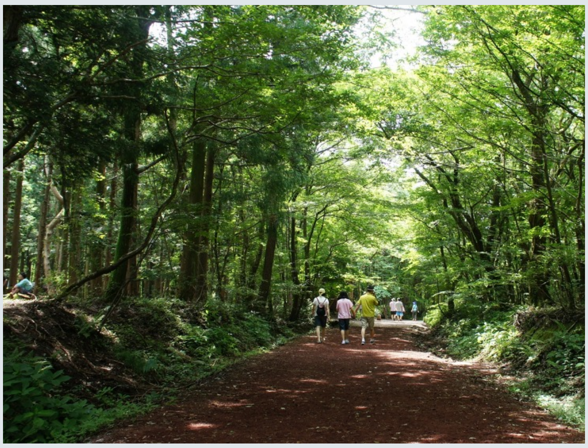
The conference venue, Ramada Plaza Hotel Jeju, is located in the main city of Jeju Island which has long been the country's favourite tourist region thanks to its unique and historic gathering in the midst of the enchanting environment of the World Natural Heritage.

The conference program of HPC2020 will cover recent advances within all of the following issues:

- Environment-friendly Technology
- Systems and Components
- Applications
- Research and Development
- Policy, Standards, and Market Strategies
- Markets
- International Activities

The state-of-the-art technologies will be covered in the topics of smart grids, district heating and cooling, NZEB, industrial applications, waste heat recovery, air conditioning, etc.

For further notice, we will soon distribute the 1st announcement of the 13th IEA Heat Pump Conference.



2017 China Heat Pump Alliance Annual Conference

The 2017 China Aerothermal Energy Conference (China Heat Pump Alliance Annual Conference) was held in Suzhou on August 3-4, organized by the China Heat Pump Alliance (CHPA) and the Heat Pump Committee of the China Energy Conservation Association (CECA). The conference received support from the China National Development and Reform Commission, as well as the Ministry of Industry and Information Technology, Ministry of Housing and Urban-Rural Development. Over 500 participants attended the conference.

In the meeting, the latest market trends in China, as well as global heat pump industry-related policies and the latest heat pump technology progress, were presented and fully discussed. Because of the haze problem (air pollution creating significant threats for peoples' health, especially severe in the north of China), the government has issued policies to encourage the usage of clean energy technology, such as heat pumps, to replace coal fired boilers. This helps the heat pump market to grow very fast.

In 2017, China will complete the "coal to clean energy heating replacement" for 3 million households. The replacements include heat pumps, gas boilers, and clean coal furnaces, as well as district heating in cities. Of the heat pumps, so far most are air to water. For instance, Beijing

plans to install around 300 000 household air-to-water heat pumps. The provinces Shandong, Shanxi, Hebei, and Henan will take actions within the program as well, and may follow the Beijing strategy to adopt heat pumps as a key technology.

Since 2012, the China Aerothermal Energy Conference (China Heat Pump Alliance Annual Conference) has been held every year. This has already become the most influential conference in China, and one of the most influential heat pump conferences in all of Asia. It mainly focuses on policies, technologies, and market trends, in order to facilitate the development of the heat pump industry.

Key note speakers of the conference:

1. *General Secretary of CHPA, Mr. Song Zhongkui*
2. *Chairman of CHPA, Mr. Fangqing*
3. *Vice Chairman of CHPA, Mr. Frank Gao*
4. *General Manager of Heat Pump Centre, Mrs. Monica Axell*
5. *General Secretary of Heat Pump & Thermal Storage Technology Center of Japan, Mr. Mabuchi Katsuzuo*
6. *Vice General Secretary of CHPA, Mr. Cooper Zhao*
7. *Mr. Marek Miara, Fraunhofer, Germany*
8. *Mr. Lukas Bergmann, Delta-ee, United Kingdom*
9. *Prof. Ding Guoliang from Shanghai Jiaotong University*

Brokerage event on the new Horizon 2020 Energy Work Programme – Fund your next project idea

The European Technology and Innovation Platform on Renewable Heating & Cooling (RHC-ETIP) together with the Deep Geothermal ETIP and the DHC+ Technology Platform is hosting a brokerage event on the upcoming Horizon 2020 Energy Work programme, for the period 2018-2020. The event will take place on 16 November in Brussels (at the Ateliers des Tanneurs).

This brokerage event comes as a response to the Commission's call for better cooperation between the different low carbon sectors during the next funding period.

The new Horizon 2020 programme aims to take forward the targets of the COP21 Paris Agreement, as well as the Commission's ambition on energy and climate policy, embodied in the Energy Union. Furthermore, the work programme will support research, demonstration, innovation and market-uptake actions as well as maximize synergies between EU and national public support.

The European heat pump association (EHPA), together with the other members of the RHC-ETIP, already plays a decisive role in fostering cooperation and strengthening efforts towards technological innovation and development in Europe.

For this event, many associations have decided to team-up and involve their network of energy stakeholders to discuss project ideas and set up project consortia, which would deliver new solutions for low-carbon buildings, sustainable data centers, and less polluting industries.

During the morning session of the event, the EU commission will introduce the work programme and explain the policy background of the energy and environment-related calls. This first part of the day will also include a specific presentation on the SMEs Instrument, a bottom-up initiative, which provides business innovation support for SMEs, and SPIRE that looks at fossil energy intensity and a reduction in the use of non-renewable resources in industrial processes. For the afternoon session, the audience will be divided into parallel groups dedicated to specific calls for proposals such as energy efficient buildings renovation, renewable technologies for renewable district heating & cooling, sustainable solutions for energy islands and smart cities, energy modelling, and more.

The event represents a unique opportunity to both get to know all relevant information on the upcoming calls as well as to meet valuable partners from different technology sectors, to exchange experiences and potentially create strong and successful project proposals.

For the heat pump sector, the Horizon 2020 programme has always been a good chance to deploy and adapt heat pumps to different applications (from industrial processes to smart buildings to district heating) in different countries and climatic areas. Our industry has always been responsive in delivering quality projects and it should not miss the chance to hear more about the many funding opportunities offered by the EU for their next project.

To register, please get in contact EHPA before the 16th of November.

NEWS IN FOCUS

China's policies to promote clean energy, including heat pumps

In connection with the growing interest for heat pumps in China (as shown, for instance, at the 2017 China Aerothermal Energy Conference – China Heat Pump Alliance Annual Conference & 6th Asian Air-Source Heat Pump Conference Heat Pump Forum, (see the report 2017 China Heat Pump Alliance Annual Conference in this issue), it is interesting to look at China's policy to promote clean energy, including heat pumps. These policies are motivated by several factors, primarily air quality, greenhouse gas emissions, and economy.

On the regional/municipal level, during 2017, a number of heating plants (district heating) powered with coal are being replaced with other types of heating, as was reported at the conference. The replacements include heat pumps, gas boilers, and clean coal furnaces, as well as district heating in cities. For instance, Beijing plans

China's policies promote clean energy, including heat pumps. These policies are motivated by several factors, primarily air quality, greenhouse gas emissions, and economy. [Source: www.shanghaidaily.com]

to install around 300 000 household air-to-water heat pumps. It is presumed that almost no coal consumption will take place in Beijing's plain areas by 2020. The provinces Shandong, Shanxi, Hebei, and Henan will take actions within the program as well, and may follow the Beijing strategy to adopt heat pumps as a key technology.

Regarding national policy, China is forecasted to be the global growth leader regarding renewable electric power, being responsible for 40 % of global renewable capacity growth during 2017-2022, driven by concerns about air pollution and capacity targets that were outlined in the country's 13th five-year plan to 2020. This is particularly the case for photovoltaic elecricity generation (PV). China is a critical actor in the market development and prices for solar PV worldwide. Today, the country represents half of global solar PV demand, while Chinese companies account for around 60 % of total annual solar cell manufacturing capacity globally.

The increasing share of renewables in the electric grid makes the heat delivered by electrically driven heat pumps even more renewable; the heat captured by them from the surrounding air is already renewable energy. Thereby, each of the two trends described above increase the effect of the other one.

Source:
Regarding heating:
http://language.chinadaily.com.cn/2017-03/17/content_28591593.htm [see the section beginning "We will make our skies blue again"]
http://www.shanghaidaily.com/nation/Beijing-plain-areas-to-go-coalfree-by-2020/shdaily.shtml

Regarding the greening of the electric grid: IEA's Renewable Energy Market Report
http://www.iea.org/Textbase/npsum/renew2017MRSsum.pdf, from http://www.iea.org/renewables/

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.

Status	Annex	No.	Participants
FINALIZED	COLD CLIMATE HEAT PUMPS	41	AT, CA, JP, **US**
FINALIZED	HEAT PUMPS IN SMART GRIDS	42	AT, CH, DE, DK, FR, KR, **NL**, UK, US
	FUEL-DRIVEN SORPTION HEAT PUMPS	43	AT, **DE**, FR, IT, KR, SE, UK, US
	PERFORMANCE INDICATORS FOR ENERGY EFFICIENT SUPERMARKET BUILDINGS	44	DK, **NL**, SE
	HYBRID HEAT PUMPS	45	CA, DE, FR, **NL**, UK
	DOMESTIC HOT WATER HEAT PUMPS	46	CA, CH, FR, JP, **NL**, KR, UK, US
	HEAT PUMPS IN DISTRICT HEATING AND COOLING SYSTEMS	47	AT, CH, **DK**, SE, UK
	INDUSTRIAL HEAT PUMPS, SECOND PHASE	48	AT, CH, **DE***, FR, JP, UK
	DESIGN AND INTEGRATION OF HEAT PUMPS FOR NZEB	49	BE, **CH**, DE, NO, SE, UK, US
NEW	HEAT PUMPS IN MULTI-FAMILY BUILDINGS FOR SPACE HEATING AND DHW	50	AT, **DE**, FR, NL
NEW	ACOUSTIC SIGNATURE OF HEAT PUMPS	51	**AT**, FR, SE
NEW	LONG-TERM MEASUREMENTS OF GSHP SYSTEMS PERFORMANCE IN COMMERCIAL, INSTITUTIONAL AND MULTI-FAMILY BUILDINGS	52	BE, NL, **SE**

FINALIZED NEW

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

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

ANNEX **41** | COLD CLIMATE HEAT PUMPS (CCHP)

The primary aim of Annex 41 has been to identify and evaluate technology solutions to improve performance of heat pumps for cold climate locations. The primary focus is electrically driven air-source heat pumps (ASHP) but novel ground-source heat pump (GSHP) and solar assisted heat pump (SAHP) approaches are being investigated as well. The main near term outcome of this Annex is information-sharing for use by designers and manufacturers to develop ASHPs with significantly improved cold climate performance. In the longer term, the technology advancements made under the Annex should help facilitate development of future ASHPs with better low-temperature heating performance and bring about a much stronger heat pump market presence in cold climates (loosely defined as having significant hours with ambient temperatures < -7 °C).

Electric ASHPs generally have the lowest installation cost of all heat pump alternatives, but also the greatest performance challenges at cold outdoor temperatures. One of these is loss of heating capacity at low outdoor temperatures; the other major issue is the loss of capacity due to frosting and defrosting of the outdoor heat exchanger (OHX).

Annex 41 is now completed and the final reports have been published. The table below, extracted from the final report, summarizes the principal outcomes resulting from the activities of each Annex participant to address the challenges noted above.

Annex publications

- HPT TCP Annex 41 Cold Climate Heat Pumps: Two-page summary
- HPT TCP Annex 41 Cold Climate Heat Pumps: Final report
- HPT TCP Annex 41 Cold Climate Heat Pumps: Executive summary

Annex website

The Annex website is http://heatpumpingtechnologies.org/annex41/

Contact

Co-Operating Agents: Van D. Baxter, vdb@ornl.gov, and Professor Eckhard Groll, groll@purdue.edu, in the United States.

Table 1. Principal outcomes of heat pump performance improvement techniques for cold climate applications investigated by Annex participants.

ANNEX PARTICIPANTS	CCHP INVESTIGATED TECHNIQUES	RESULTING PERFORMANCE IMPROVEMENTS
Austria, Austrian Institute of Technology, AIT	Coil frost measurements and analyses	• Wind tunnel tests of OHXs show that multiport extrusion (MPE) compact heat exchangers experience less air flow reduction due to frost growth than conventional tube-and-fin (CTF) heat exchangers at both +10 °C and -25 °C air temperature (80 % RH in both cases); therefore, they can maintain better air flow.
Austria, Technical University, Graz	Evaluation of compressor liquid injection (LI) for cold climate performance improvement	• Lab tests show LI capability to extend compressor performance envelope for air-water heat pumps down to -20 °C or lower with high water supply temperatures • System analyses for several cold climate locations show seasonal COP improvements of up to 12 %
Canada, CanmetENERGY	Novel SAHP (solar-assisted HP) using ice-based thermal storage	• Lab tests/simulations estimate > 60 % space and water heating energy savings potential • Potential cost-effective alternative to GSHPs in Canadian climates especially for retrofit applications
	Zeotropic refrigerant mixtures	• Evaluations of potential for zeotropic mixture of R32 and CO_2 to improve system efficiency and low temperature capacity • Results show possibility of ~30 % seasonal COP improvement with variable mixture composition control components included in heat pump system • Future plans to build & test lab prototype
Canada, Hydro Québec, Laboratoire des technologies de l'énergie (LTE)	Revisions to seasonal efficiency rating standard to better represent heat pump performance in cold climates	• Field testing of ASHP systems pointed out inadequacies in seasonal efficiency rating metrics per Canadian Heat Pump rating standard CAN/CSA-C656-05 for cold climate applications • Office of Energy Efficiency issued bulletin requiring changes in ASHP heating performance ratings and reporting; specifically required adding capacity and COP ratings for -17.8 °C outdoor temperatures by 2014.

The table continues on the next page.

Table 1. Principal outcomes of heat pump performance improvement techniques for cold climate applications investigated by Annex participants.

ANNEX PARTICIPANTS	CCHP INVESTIGATED TECHNIQUES	RESULTING PERFORMANCE IMPROVEMENTS
The table is a continuation from the previous page.		
Japan	Coil surface frosting R&D (Waseda University)	• Innovative frost growth measurement & visualization technique (resolution to 0.02 mm) • Frost growth model developed; comparison with measurements for different surface geometries • Applied frost model to heat pump system model; coil frost growth measured vs. simulated
	Novel frost-free air source heat pump water heater (ASHPWH) system (Central Research Institute of the Electric Power Industry, CRIEPI)	• System retards frosting by dehumidifying air using a desiccant-coated heat exchanger • Potential for 20-30 % boost in COP at a temperature of -7 °C and relative humidity of 60-80 %.
United States	Two (parallel, equal-sized) compressor field test CCHP prototype (ORNL, Emerson)	• Achieved measured $SCOP_h$ ~3.0 over two winters (2015 and 2016) • 40 % energy savings in coldest month; possible to eliminate backup electric heat • Heating COP at -25 °C was >2.0; ~3.8 at 8.3 °C (including cycling losses)
	Novel oil-flooded HP cycle development and evaluation (Purdue University Herrick Labs)	• Approaches isothermal vapor compression process • High oil circulation rates remove heat of compression & significantly reduce discharge temperature, which expanded compressor operation envelope to much lower ambient temperatures • Improvements in heating capacity range up to 19 % at the lowest ambient temperature tested (-17.8 °C)
Complementary market promotion activities*	U.S. Northeast Energy Efficiency Partnership	• Established voluntary CCHP specification; latest version (2017) posted on NEEP web site • For variable speed (VS) ASHPs only; requires rated $SCOP_h$ ≥2.93 per ANSI/AHRI Standard 210/240 • Web site contains list of nearly 300 ASHPs that meet the requirements; 80 % are ductless minisplit or multisplit (VRF) types
	U.S. Electric Power Research Institute (EPRI), Next Generation (NextGen) Heat Pump specifications	• ASHPs only but VS compressor not required; other capacity control approaches acceptable • Two levels of NextGen specification requirements • Tier 1 requires same rated $SCOP_h$ as NEEP CCHP spec above; rated heating capacity at -8.3 °C to be ≥ 80 % of rated capacity at 8.3 °C; requires control scheme to limit backup heat use; must have demand response capability • Tier 2 requires rated $SCOP_h$ ≥3.81; rated heating capacity at -15 °C to be ≥ 80 % of rated capacity at 8.3 °C; requires control scheme to limit backup heat use; must have demand response capability; only ~7 % of ASHPs listed on NEEP site currently meet Tier 2 requirements
** These efforts were conducted independently of the Annex but took place during the Annex working period and will continue for foreseeable future*		

ANNEX **42** HEAT PUMPS IN SMART GRID

Heat pumps in smart grids can contribute to solutions for several energy system-related obstacles. Within the Annex 42 working group, we distinguish five main smart heat pump contributions:

1. Keeping grid load under control while renewable energy production grows, to restrict or even avoid grid capacity investments.
2. Keeping grid load under control during extreme conditions (i.e. 'coldest week'), again avoiding grid capacity investments.
3. Increase self-consumption of renewable energy sources (achieving better grid balance and higher economic end user value).
4. Selling flexibility to the grid, for the benefit of balance of responsible parties, grid operators, traders, etc.
5. Allowing for a higher share of heat pumps in the energy system without risking local overload problems.

Enabling the ***realisation*** of these solutions has been the basic driver for the Annex 42 participants.

It turns out that there is a real – and often pressing – benefit in implementing smart grids in all participating countries. Table 1 below summarizes the main recommendations and actions that should be considered when trying to stimulate further development of smart grids.

Structure of the Annex work

The Annex 42 work has been split into the topics Roadmap, Market overview, Case scenarios and modelling, and Demonstration projects.

Table 1. Main recommendations and actions that should be considered when trying to stimulate further development of smart grids.

CHALLENGE DOMAIN	ACTIONS NEEDED	MAIN STAKEHOLDERS INVOLVED
Sources of value	Carry out field trials that implement a 'full market model', including complete financial handling of flexibility contracts. Governments may facilitate this by authorizing dispensation for obstructing legislation where appropriate.	DSOs*, Aggregators, Energy suppliers, BRPs**, Policy makers
	Invest in development of new customer propositions. Possible directions are: monitoring & energy saving assistance, heating as a service, identifying alternate ('non- energy') benefits, increasing self-consumption of renewable energy.	Aggregators, Researchers
Technical barriers	Set up field trials to explicitly focus on building thermal mass. Preferably, flexibility limits should be tested ***without*** using any heat storage vessels at all.	Aggregators, DSOs*, Researchers
	Start quantifying building thermal mass potential for groups of buildings in relation to typical building characteristics (e.g. size, materials used, building codes, occupation, etc.)	Researchers, Manufacturers
	Gain insight in end user behaviour patterns through field trials. How much demand response potential is actually available in a given end user group?	DSOs*, Aggregators
Regulatory framework	Develop alternate taxation models, for instance taxing ***as a percentage*** of the commodity price, instead of adding a fixed tax tariff.	Policy makers, DSOs*
	Increase absolute energy price levels, either directly or indirectly through a CO_2 tax.	Policy makers
	Enforce development of (open) communication standards.	Policy makers, Manufacturers, DSOs*
	Estimate negative effects of energy market unbundling and stimulate market cooperation and information exchange to counter these effects.	Policy makers, TSOs***, DSOs*, BRPs**, energy suppliers
End user behaviour	Develop simple and effective business propositions, focussing on customer engagement rather than return value maximisation.	Aggregators
	Privacy and data integrity will grow to be more important. Explicitly address these issues in new business models.	Aggregators

) DSO = Distribution system operator **) BRP = Balance responsible party *) TSO = Transmission system operator*

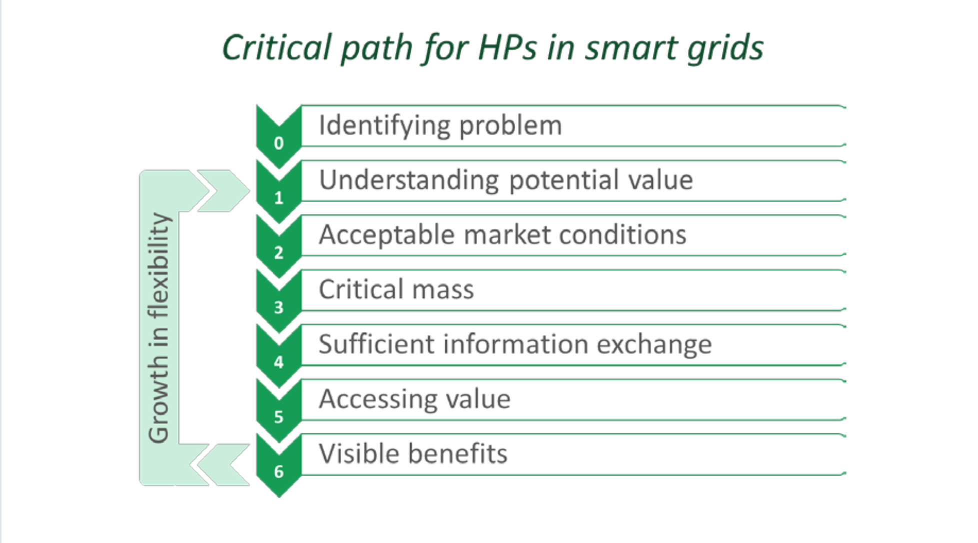


Figure 1. Critical path for heat pumps in smart grids.

Road map

Looking at the 'critical path' for smart grid applications, see Figure 1, we have found that most countries do acknowledge various (future) problems within their respective energy markets. However, by failing to quantify and understanding the potential value of flexibility to solve at least part of these problems, there is little movement towards explicitly designing or enabling flexibility-friendly market conditions. That is: most countries are 'stuck' on the first rung of the critical path. However, some initiatives have found ways to progress along the critical path.

Market overview

For each participating country, an extensive market overview has been carried out. Metrics were drawn up to give an indication of how well suited each country is to the development of heat pumps in smart grids. Table 2 on next page gives an overall suitability score for each country. Notably, only France and Switzerland are at the moment reasonably well prepared for (large scale) smart HP implementation. In both countries, pressing capacity and power management challenges are expected in the near future. Heat pumps already play a major role in the Swiss domestic heating sector, making for a natural factor to consider in solving these challenges. France has a lot of experience with smart heating appliance management and now faces the challenge to apply this experience to heat pumps.

Case scenarios and modelling

The topic of smart grids is too broad and multifaceted to allow drawing overall and clear-cut conclusions. The picture is even more complex due to the fact that every country considers somewhat distinct aspects of the topic, addresses diverse problems and, accordingly, searches for different solutions, while defining various factors to express the results. Additionally, various models and methods are used for these purposes.

The overarching topic, flexibility, can be divided into two sub themes: load shifting potential and length of off-blocks (times without heat pump operation). These topics are closely connected, despite their individual specifics. Generally speaking, the flexibility describes how long a heat pump can be switched off without diminishing the comfort of the end users, or alternatively how much energy a heat pump can "absorb" from the grid, if forced to run.

Overview of some country studies:

- The UK study underlines a significant influence of building fabric on the amount of flexibility. Oversizing of a heat pump was the next most important factor. It may be concluded that heat pump installations in existing buildings could provide a useful level of flexibility without additional intervention.
- The analysis from several countries indicated that a substantial improvement of the flexibility for heat pumps in smart grids is possible through integration of thermal storages. However, a drawback of the additional storage (in particular small volumes) is a reduced heat pump efficiency, which limits the financial benefit of the flexibility.
- The Danish, Swiss and UK studies addressed the length of off-blocks. How long a heat pump can be switched off depends predominantly on the thermal capacity of buildings.

- The German study underlines the conclusion that a smart operation leads to higher overall electricity consumption, mostly due to decreased HP efficiency and to additional storage heat losses caused by raising the operating temperatures.

The overview allows for the general conclusion that heat pump systems are able to provide a useful level of flexibility without significant interventions to the heating system or the building fabric.

Table 2. An overall suitability score for each country.

COUNTRY	SCORE	MARKET SNAP-SHOT
AT	±	There is a potential smart HP need expected within the coming decade. However, uptake of HPs by households has been modest, and end-users are not used to flexible tariffs. Energy system challenges justifying smart grids are not quantified, making it difficult to devise solid business cases.
CH	+	The need for flexibility is, in a 2020-2030 timeframe, related to managing load on the high voltage grid. HPs are a large potential flexible resource – The Swiss HP market is the most mature of all participant countries, with HPs the technology of choice in single family homes.
DE	±	Supply/demand balancing and grid congestion are recognised as a medium-term (5-10 year) challenge for which demand side flexibility will be needed. The typical heating solution in Germany looks stronger than other markets in terms of potential flexibility. However, energy price structures do not currently encourage market growth or give benefits for end-users from providing flexibility, which is the biggest challenge to overcome.
DK	±	Denmark faces challenges within the next 5 to 10 years, related to managing and balancing production and load on the high voltage grid. There are market barriers to overcome to increase the HP market share in non-district heating areas. The main barrier is high electricity prices and low fossil fuel and biomass prices. Also, the very high share of taxes in consumer electricity prices do not encourage market growth.
FR	+	Capacity margins and grid congestion are already a challenge. The electric heating market is Europe's largest; HPs are a significant part of this. Thus, there is a large potentially flexible resource, and there is a lot of experience in controlling/influencing operating times of electric heating. Main challenge: translating what has worked for electric heating to HPs, and capturing flexibility in an aging building stock.
KR	±	Faces an immediate challenge to fill a capacity margin gap which has already resulted in black-outs. Capturing demand-side flexibility is therefore high on the political agenda. For HPs to contribute to this flexibility, market challenges must be overcome (e.g. end-users' preference for gas, and unattractive electricity tariffs), and thermal storage potential in floor heating and the young building stock should be tapped into.
NL	−	The need for flexibility is recognised, particularly for managing grid congestion in the medium-term. However the HP market is small and there are challenges of lack of space for storage. The flexibility potential from HPs is therefore quite low – hybrids could be key to unlocking flexibility here.
UK	−	The UK will need demand side flexibility in the medium term (5-10 years), particularly to manage growing distribution grid congestion. The HP market is expected to grow quickly in the next few years, but the flexibility potential from HPs is constrained e.g. by the old, poorly insulated buildings, lack of space for storage, an end-user preference for gas, and 'spiky' heat demand patterns. The availability of flexible tariffs, and the growth of hybrids, could be key to unlocking more flexibility potential from HPs.
US	±	Demand response has historically had far stronger drivers in the US than in Europe, so the market is more advanced, leading to greater experience with "3rd party control" (even if the use of HPs within demand response has seen only small-scale activity so far). The total HP market is huge - but the dominance of air/air HPs (mostly in southern regions), and lack of storage, does create a constraint on potential flexibility. An emerging ground-source HP market and a growing DHW HP market offer greater demand levelling opportunities.

Demonstration projects

The analysis of the key findings and challenges of the projects summarised by the Annex 42 participants has shown that there is one key challenge many of the projects have in common – the customer. Other recurring topics are of a more technical nature and relate mainly to a lack of standardisation and protocols for demand response, as well as the challenge of integrating automated and direct control platforms with the controllers of the HPs.

Regarding customer-related challenges, engagement is one key area where differences between the trials can be observed. On the one hand, customers in some trials were found to have "small understanding and interest in heating technologies". On the other hand, some trials report that customers "were interested in the project and gave a positive feedback". Understanding better what differentiates these two diverging attitudes towards heating and the smart HP projects could provide important insights into if and how customer engagement with those technologies could be improved, e.g. by tailoring the message and incentives better to the target audience.

Another key area is the customer's response to and experience of demand response events and the smart technology. Here some significant differences were observed. Several trials report that customers did not perceive any disruption to their comfort, or the studied measured success through customers not overriding the remote heating control function. On the other hand, other trials found that their control systems were blamed for small comfort level violations, did not sufficiently make clear the value from the controlled operation of the HP, or were generally perceived as "obscure and complex".

Understanding how to improve this perception of demand response could prove to be the key to the further deployment of the technology in the residential sector.

General annex information

Publications

- HPT TCP Annex 42 Heat Pumps in Smart Grids: Two-page summary
- HPT TCP Annex 42 Heat Pumps in Smart Grids: Executive summary
- HPT TCP Annex 42 Heat Pumps in Smart Grids: Final report
  - Appendix 1 – Heat Pumps in Smart Grids: Market status summary per country
  - Appendix 1a – Heat Pumps in Smart Grids: Market overview – Country report for Austria
  - Appendix 1b – Heat Pumps in Smart Grids: Market overview – Country report for Switzerland
  - Appendix 1c – Heat Pumps in Smart Grids: Market overview – Country report for Germany
  - Appendix 1d – Heat Pumps in Smart Grids: Market overview – Country report for Denmark
  - Appendix 1e – Heat Pumps in Smart Grids: Market overview – Country report for France
  - Appendix 1f – Heat Pumps in Smart Grids: Market overview – Country report for South Korea
  - Appendix 1g – Heat Pumps in Smart Grids: Market overview – Country report for the Netherlands
  - Appendix 1h – Heat Pumps in Smart Grids: Market overview – Country report for the United Kingdom
  - Appendix 1i – Heat Pumps in Smart Grids: Market overview – Country report for the United States
  - Appendix 2 – Heat Pumps in Smart Grids: Case scenarios per country
  - Appendix 3 – Heat Pumps in Smart Grids: Overview of demonstration project

Annex website

The Annex website is http://heatpumpingtechnologies.org/annex42/

Contact

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ANNEX **44**

PERFORMANCE INDICATORS FOR ENERGY- EFFICIENT SUPERMARKET BUILDINGS

The work in this Annex has focused on finding average values for the energy consumption of supermarket buildings, using available performance indicators. This information can be used by policy makers and researchers to set a reference for average supermarket energy consumption. It can also be used by supermarket owners to compare the energy consumption of a specific supermarket to the average consumption, and thus determine whether the specific supermarket is energy efficient (below average) or not.

Supermarkets are defined as "retail sale in non-specialized stores, with food, beverages or tobacco predominating" which excludes small specialized stores and hypermarkets. The most common performance indicators for supermarkets are size (total area or sales area), opening hours, refrigeration system type, installed refrigerating capacity and climate or geographical location. More uncommon performance indicators are sales volume, year of construction (or refurbishment), management attitude and system control and dynamics.

The supermarket energy consumption comprises the consumption of all subsystems: lighting, electric equipment, heating and ventilation, air conditioning and refrigeration. In many publications only the supermarket electricity consumption is considered, but since the introduction of heat recovery from the refrigerating system, energy consumptions for heating and for cooling can no longer be treated separately.

Data, see Table 1, from the countries participating in the Annex (Denmark, Sweden and the Netherlands) show a good similarity between countries concerning average energy intensity, the average total yearly energy consumption per m² of supermarket area, of around 400 kWh/m² per year (± 10 %).

Energy intensities based on total energy / total area or on electrical energy / sales area do not differ much, since total energy ≈ 1,4 · electrical energy and total area ≈ 1,4 · sales area for the data sets considered. In these data sets, the overall average total supermarket area is 1360 m² and the average opening time is 73 hours per week.

The energy intensity decreases with increasing supermarket area, approximately 1 % for each 100 m² of additional total supermarket area.

The energy intensity increases when opening hours are extended, approximately 0.5 % for each additional (weekly) opening hour.

Data sets from the USA, Canada and UK show energy intensity values well above 400 kWh/m² per year.

Statistical analyses confirm that the simple approach of relating total energy consumption to supermarket area provides better results than elaborate schemes of relating energy consumption to the added volumes of refrigerated and frozen display cabinets and storage cells. However, for the (electrical) energy consumption for refrigeration, an approach based on adding refrigeration capacities of all refrigerated display cabinets can provide good results. The electrical energy consumption for refrigeration is approximately 50 % of the total electrical energy consumption.

Two data sets from The Netherlands were available containing information on the presence or absence of 65 different energy saving options. It was attempted to extract relations between energy intensity and energy saving options from these data sets, but no statistically relevant relations could be extracted – neither by means of a t-test nor by means of a multivariate regression method.

Table 1. Data from the countries participating in the Annex show a good similarity between countries concerning average energy intensity, the average total yearly energy consumption per m² of supermarket area, of around 400 kWh/m² per year (± 10 %).

DATA SET	ENERGY INTENSITY (kWh / m² per year)	
	BASE: TOTAL ENERGY / TOTAL AREA	BASE: ELECTRICAL ENERGY / SALES AREA
Sweden	396	
The Netherlands 2013	397	422
The Netherlands 2014	369	413
Denmark (2015)		390

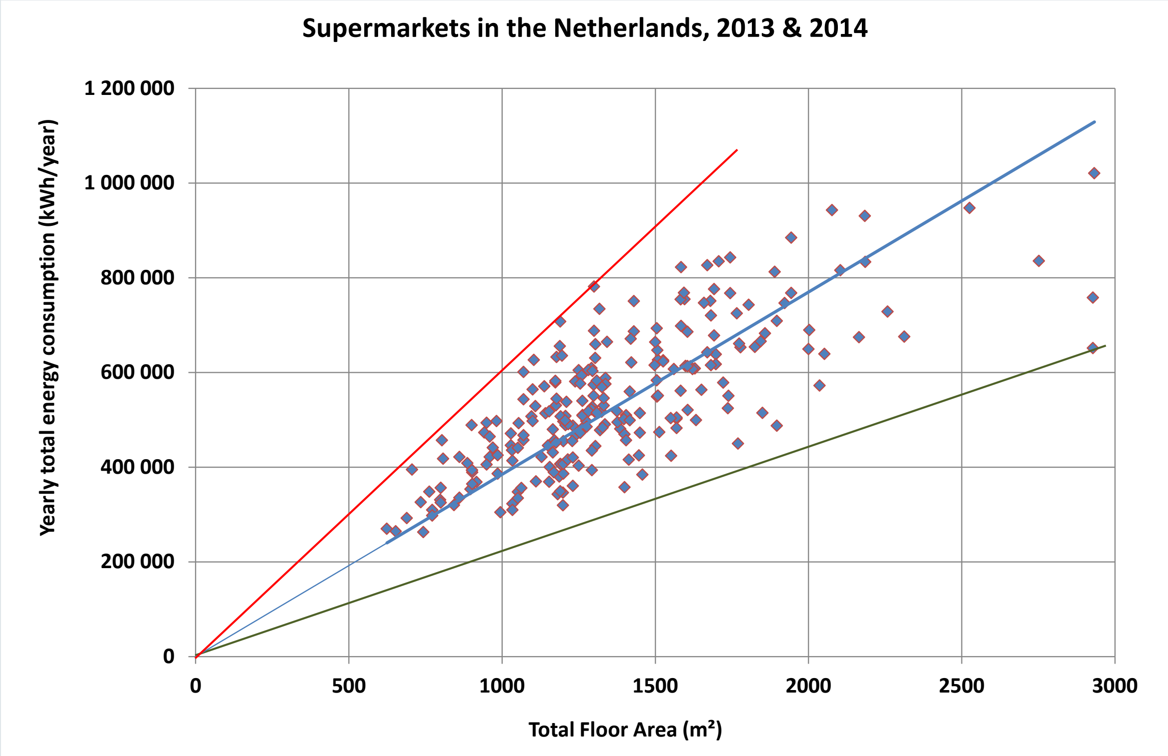

Figure 1. Energy Intensity data for Dutch supermarkets (combined data 2013 & 2014) showing the regression line (blue) at 385 kWh/m² per year and spread in data indicated by the red line (+55 %) and green line (-40 %).

Energy intensity is not only influenced by "classical" energy saving options, but also by more uncommon performance indicators such as system control & dynamics and the management attitude. Surprisingly, the sales volume does not influence the energy intensity. What is important is the year of construction or latest refurbishment, as the uptake of efficient technologies (LED lighting, glass doors and new efficient refrigeration systems) has a beneficial effect on energy intensity.

Energy monitoring in supermarkets is seldom performed, except for the delivery measurements by the energy supplier. Product (refrigerated) temperatures are monitored for HACCP purposes, but indoor and outdoor temperature and humidity monitoring related to energy consumption seldom takes place. However, extensive measurements of the technical systems are performed almost continuously for the purpose of control of these systems, and there is a recent development to exploit these measurements for purposes of energy efficiency evaluation. In this manner evaluations can be made of the refrigeration system's Coefficient of Performance (COP) and of the efficiency in relation to an ideal refrigeration cycle (Carnot efficiency or system efficiency index, SEI).

Supermarket energy consumption remains a field where improvements in energy efficiency can be made, as long as there are supermarkets with an energy intensity (slope of the regression line) of 55 % above the average value (i.e. have a value of 155 % of the average) and at the same time supermarkets that can do with only 60 % of the average energy consumption, see Figure 1.

Annex website

The Annex website is http://heatpumpingtechnologies.org/annex44/

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ANNEX 49

DESIGN AND INTEGRATION OF HEAT PUMPS FOR nZEB

In less than two years all new public buildings in the European Union (EU) shall be nearly Zero Energy Buildings (nZEB), and by the beginning of 2021 all new buildings in the EU shall fulfil this requirement. Thus, cost-effective systems for the implementation of nZEB are of high interest. Annex 40 has already investigated heat pump application in nZEB. Annex 49 is an extension of the research motivated by approaching political deadlines, new definitions and new market situations.

Background: Annex 40 results

In Annex 40 case studies for the application of heat pumps in nZEB have been performed in the different participating countries. Despite the different climate and market conditions, heat pumps range among the best systems for nZEB both in the central European and in the Scandinavian countries. Furthermore, differently adapted prototype heat pumps for low loads and with multiple functionalities, which have been or are to be introduced on the market, have been developed in Annex 40. In Japan, for instance, a 70 % energy reduction for air-conditioning application could be evaluated in field tests with a desiccant heat pump which decouples the sensible cooling loads from the latent ones. Field results in residential and non-residential nZEB confirmed the good performance of heat pumps in this application, and remaining optimization potentials were identified, promising even more efficient operation in the future. Also, first evaluations of grid integration have been evaluated, confirming that heat pumps can increase self-consumption of on-site solar PV electricity and reduce grid interaction.

Continuation of work in Annex 49

Currently, the countries Belgium, Germany, Norway, Sweden, Switzerland and the USA have joined the Annex 49 and continue the research on heat pump application in nZEB. Further, Austria, Finland/Estonia, Japan and the UK have declared interest to join the Annex 49. Figure 1 shows a group photo from the Annex 49 working meeting at HSR University of Applied Sciences in Rapperswil, Switzerland.

Based on the results of Annex 40, Annex 49 deals with a more in-depth evaluation of integration options of the heat pump with other building technology, e.g. solar components, the ventilation system or both thermal and electrical storage. Moreover, the design and control of heat pump concepts for nZEB are investigated, also from the viewpoint of load management options to improve economic operation by self-consumption or grid-supportive operation.

Moreover, compared to Annex 40, the scope of the Annex is extended to also cover the potential of groups of buildings and neighbourhoods connected by grids.

Figure 1. Group photo of the Annex 49 working meeting at the HSR Rapperswil.

Table 1. Overview of contributions of participating and interested (in italic) countries to Annex 49

COUNTRY/INSTITUTION	CONTRIBUTION TO IEA HPT TCP ANNEX 49
Austria *Univ. of Innsbruck*	• *Monitoring and simulation of two nZEB buildings for performance optimisation*
Belgium **Free Univ. Brussels**	• Cost-effective integration and design of nZEB system
Finland/Estonia *Aalto Univ., Tallinn Univ*	• *Modelling and simulation of ground-coupled heat pumps (e.g. energy piles, horizontal collectors)* • *Design of heat pumps and heat emission systems for nZEB application*
Germany TH Nürnberg, Uni Braunschweig, TEB	• System integration, design and field monitoring of 8 terrace houses and a passive house • Integration and operation strategies of electrical storage systems • Development of control strategies for smart grid integration
Japan *University of Nagoya*	• *Case studies for nZEB office buildings with heat pumps for Japanese and European load conditions* • *Documentation of monitoring*
Norway SINTEF, NTNU, Cowi AS	• Design tool for cost-effective heat pumps • Developments of integrated heat pumps with natural refrigerants • Investigation/monitoring of nZE demonstration buildings and neighbourhoods in Norway
Sweden RISE	• Monitoring and comparison of heat pump system in two equal test houses • Evaluation of 20 field monitored heat pump systems
Switzerland IET HSR	• Integration and design options of solar absorber and heat pump system • Field monitoring of plus energy building with façade integrated PV
UK *Glen Dimplex*	• *Evaluation of design and control of nZEB model houses in collaboration with home building company*
USA ORNL,NIST CEEE Uni Maryland	• Concluding field monitoring of integrated heat pump variants (IHP) • Technology testing and comfort evaluation in NZEB test facility (NZERTF) • Development and evaluation of personal cooling methods

A connection of different buildings types such as residential buildings and offices by grids may enable load balancing among the buildings and augment options for heat recovery. For instance, heat rejection from cooling in office buildings can be recovered for DHW production in residential buildings. Also electrical surplus can help to level out deficits of those buildings which have less favourable conditions for the generation of PV electricity. Thereby, it may be easier and more cost effective to reach the zero balance in the group of buildings than for each single building by itself.

Furthermore, building technology may get new tasks, e.g. the provision of flexibility to the connected energy grids, in particular the electricity grid. This may have an impact on future system design and on storage integration. Besides the thermal storage capacity of the building, thermal mass and conventional water storages are usually installed in buildings; also electrical storage capacities may increase in future buildings by connecting electric vehicles and stationary batteries.

However, not only the short-term flexibility but also the seasonal mismatch between summer electricity surplus and winter electricity needs has to be taken into account for a holistic assessment of the building and system concept. Austria is working on a methodology to take the seasonal mismatch into account by adequate monthly weighting factors in the nZEB balancing. In this regard, a high performance thermal insulation of the building envelope may pay off to decrease winter electricity demand for the heat pump. On the other hand, a ground-coupling with seasonal storage option to bridge the gap between the seasons and store source energy from the summer to the winter months by ground regeneration of boreholes, can be a strategy. This would reduce winter electricity requirements due to a higher winter performance of the heat pump, based on better source temperatures. Field testing of built nZEB in order to accomplish an evaluation of concepts will also be continued in the frame of Annex 49.

Table 1 gives an overview of contributions by the single participating and interested countries in Annex 49.

Interim results of Task 1 on the state-of-the-art analysis

Currently, an updated state-of-the-art analysis is performed in the participating countries, in order to prepare the work in the follow-on task on the system integration as well as on the design and control. It is confirmed by the analysis that definitions vary among the countries. The objective of an ongoing simulation study is to illustrate the different ambition levels in the countries and the impact of different definitions on system choices and design. Furthermore, it is to be defined a common objective, which ambition level of nZEB will be used for the follow-on tasks in the Annex 49 as far as possible.

In Switzerland, for instance, a new building directive in the course of the Energy Performance of Buildings Directive (EPBD) is currently in implementation at the cantonal level, defining the future level of nZEB in Switzerland. Consequently, revised label requirements of the voluntary MINERGIE®-labels for the certification of high performance buildings have been published in the beginning of 2017, setting a new balance boundary which includes all building energy including plug load for the balance. These settings notably change the boundary conditions for the design of components. However, first evaluations for the single family houses confirm the results of Annex 40 that heat pumps range among the most energy-efficient and cost-effective building technologies, also with the new requirements. But ground-coupled heat pumps systems are even more economic, since the solar PV area can be reduced due to the better performance values.

Next steps and exchange with other Annexes and TCPs

Since both the HPT Annex 49 and the HPT Annex 50 have a focus on residential buildings, an information exchange has been established in order for all of these Annexes to be informed on the ongoing work and make use of synergies between the activities in the Annexes. An interesting issue for nZEB is also the integration into the energy grid and load management in order to improve grid interaction and perform an economic optimisation of solar PV self-consumption. EBC Annex 67 deals with energy flexible buildings, so an information exchange has been established between these Annexes, too. All three Annexes have presented at a joint workshop on the IEA Heat Pump Conference in Rotterdam, as reported in the HPT Magazine 2/2017.

Annex website

http://heatpumpingtechnologies.org/annex49/

Contact

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ANNEX 51 — ACOUSTIC SIGNATURE OF HEAT PUMPS

Annex 51 has been initiated and started in April 2017 to further increase the acceptance of heat pumps by minimizing their acoustic emissions. Work is focusing on component, unit and application level with an overall aim to increase education and training efforts and providing guidance for future standards. The main topics will cover the effect of the operating conditions of heat pumps, psychoacoustic analysis and the important influence of heat pump installation on the surrounding environment.

Participants from France, Sweden, Germany, Italy and Austria (see Figure 1) gathered in Vienna to hold a two-day kickoff meeting in June 2017, forming a strong acoustic alliance featuring a lot of synergies. Acoustic measurements in the Austrian SilentAirHP project are scheduled for October 2017 and will lead to quantitative data on the acoustic effects of various noise reduction measures. Furthermore the Austrian team (Vienna University of Technology, Graz University of Technology, Austrian Academy of Sciences and Austrian Institute of Technology) recently submitted their application to the national Annex program.

The newly established annex is open for new partners and we cordially invite everyone interested to get in contact.

Annex website

http://heatpumpingtechnologies.org/annex51/

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Figure 1. Group photo of the Annex 51: 13 happy faces at the kickoff meeting at on June 20th-21st, 2017 in Vienna, Austria.

ANNEX 52

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

We are pleased to announce that the ExCo of the HPT TCP recently approved the new Annex 52: **Long-term measurements of GSHP (Ground Source Heat Pumps) system performance in commercial, institutional and multi-family buildings**. The annex will start in January 2018 and will run for four full years, concluding in December 2021. Sweden is the Operating Agent for the new annex, and, as of today, Belgium and The Netherlands have formally joined. The annex welcomes more countries to join. Researchers are asked to form national project teams and contact the Operating Agent, Signhild Gehlin, and their national Executive Committee delegates about their interest in joining. Annex 52 will also collaborate with the IEA Technology Collaboration Programmes of ECES (ECES TCP) and Geothermal (Geothermal TCP).

Within the scope of Annex 52, quality long-term measurements of GSHP system performance for commercial, institutional and multi-family buildings will be made by the annex participants. Experiences with these and past measurements will inform new guidelines on instrumentation, measurements and analysis of system performance. Reports on the measurements will provide a set of benchmarks for comparisons of GSHP systems around the world.

We expect to include projects at a range of different stages in the Annex work, roughly categorized as follows:

- Stage III: Project instrumentation, data collection, and analysis are essentially complete. Some further analysis may be done, but the primary contribution of these projects will be to provide benchmarking data, lessons learned, and a case study chapter.
- Stage II: Project instrumentation is complete, data collection has begun, but analysis has not been completed and additional data collection may be needed.
- Stage I: Project instrumentation is underway; data collection has not begun.

The Annex 52 webpage is launched at heatpumpingtechnologies.org/annex52/ where you will find more information and updates on the annex work.

The newly established annex is open for new partners and we cordially invite everyone interested to get in contact. Interested persons are encouraged to contact Dr Signhild E.A. Gehlin (signhild@geoenergicentrum.se) or Professor Jeffrey D Spitler (spitler@okstate.edu), and your national HPT delegate regarding the annex.

Annex website

http://heatpumpingtechnologies.org/annex52/

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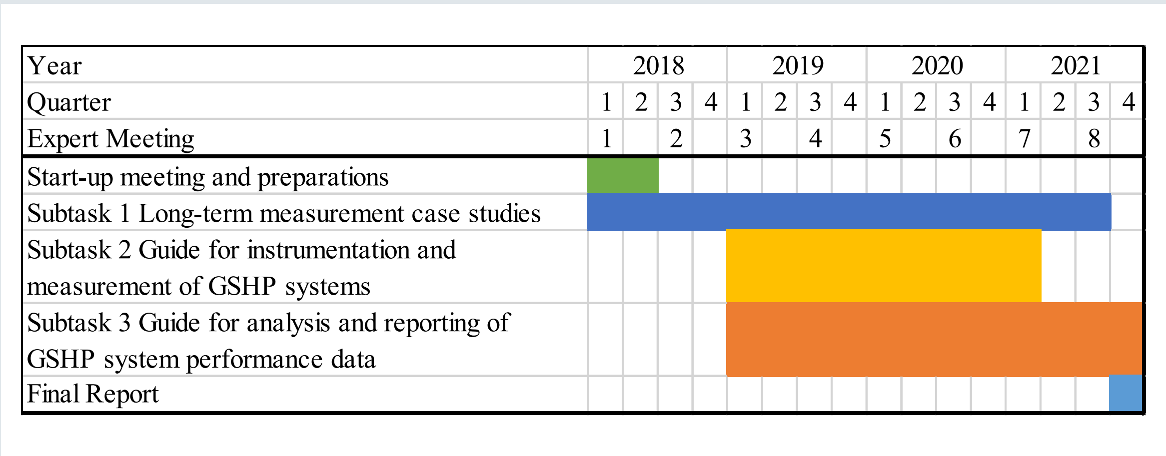

Figure 1. The schedule of project tasks and milestones in the HPT TCP Annex 52.

Load management of nZEB - an important element for future energy supply and implementation of renewable energy sources

Franziska Bockelmann and Christina Betzold - Germany

This article describes two projects in nZEB housing including heat pumps, where the aim was to create and operate buildings which meet future demands on energy efficiency and living comfort. The guiding principle for the development and operation of these buildings is that an optimal use of solar energy should be implemented. This results in a higher energy gain than the buildings' needs. Both projects use control strategies to increase the use of photovoltaic electric power and reduce grid consumption. In order to reach this target the energy concepts make use of flexible components, i.e., heat pumps in combination with thermal and electrical storages. Thus, a high share of solar electricity usage can be achieved.

Introduction

This article describes two building projects in nZEB housing, where the aim was to create and operate buildings which meet future demands on energy efficiency and living comfort.

The houses described are a single family house "Berghalde" and the terraced houses "Herzo Base". They aim to show the energy potential of EnergyPlus Buildings for reaching a high degree of photovoltaic (PV) self consumption and contributing to stabilize the grid. The houses are characterized by a high PV production and a low energy demand. This results in a positive energy balance, on an annual basis. The energy concepts for both types of buildings are based on the control of heat pumps in combination with PV, as well as the application of thermal and electrical energy storages.

Through a sustainable energy concept and a high share of solar self usage, the presented EnergyPlus-Houses provide part of the solution to the challenge of our future energy supply and the implementation of nZEB.

During the course of the projects, a comprehensive monitoring and optimization program, as well as pre-simulations for load management, were carried out in order to obtain and document verified knowledge about the performance of the buildings and the facilities. The focus was on optimization measures to increase the share of self-consumption of the PV production of electricity.

Architecture and energy concepts

The single family house Berghalde near Stuttgart, Germany, was completed by the end of 2010. See Figure 1. The building's net floor area is approximately 260 m². The northern part of the basement is dug into a slope and the southern part opens up to the valley with a

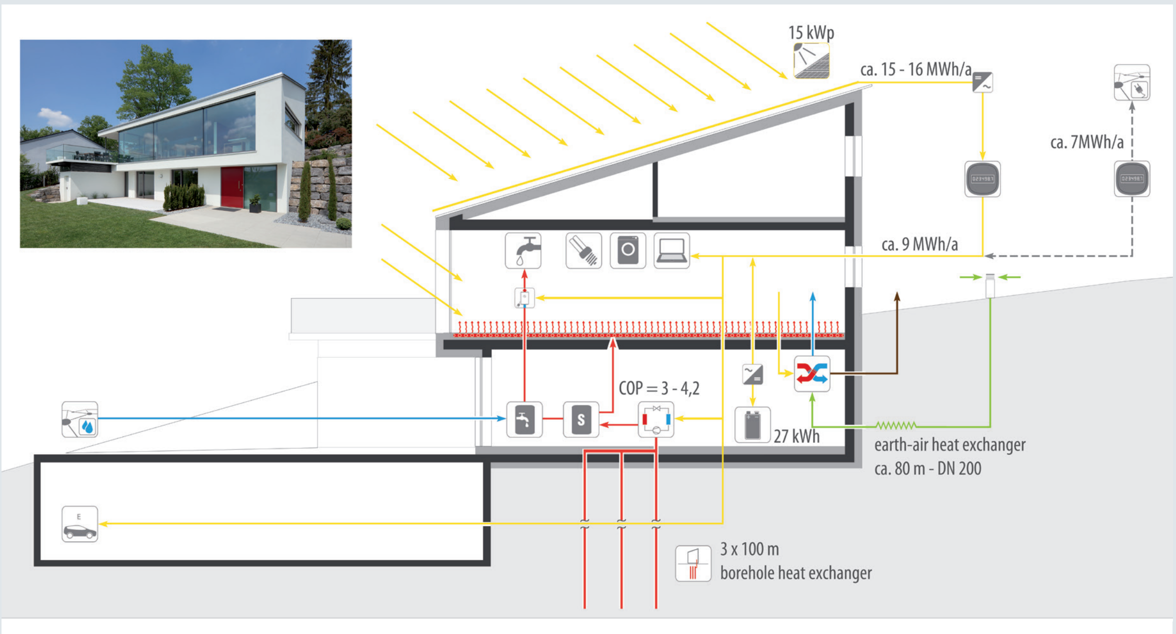

Figure 1. Berghalde - energy concept

large window front. The north, east and west façades are mainly kept opaque. Due to the slope, all living spaces are oriented towards the south (to the left in the figure). The children's and guest rooms are located in the ground floor with a room-high window front. A large adjacent kitchen, dining and living area is located on the first floor. The secondary rooms, such as bathrooms, utility room and building equipment are located on the north side. A structural sun protection for the ground floor is provided by the cantilever of the top floor. Sun protection for the first floor is provided by an external shading system.

The terraced houses Herzo Base (See Figure 2) will be finished by the end of 2017, and consist of eight units. The net floor area is approximately 150 m² per terraced house, distributed on three floors and a basement. The orientation is east-west, which leads to a balanced PV production during the day. The technical equipment is located in a common installation room in the basement.

The basic idea of both energy concepts is to supply the electrical power from the PV system. The self-generated energy primarily covers the demand for electricity in the building during the daytime. Energy surplus is stored in batteries, which provide the energy for instance for the artificial lighting and household appliances in the evening. Only the remaining surplus is then fed into the public grid.

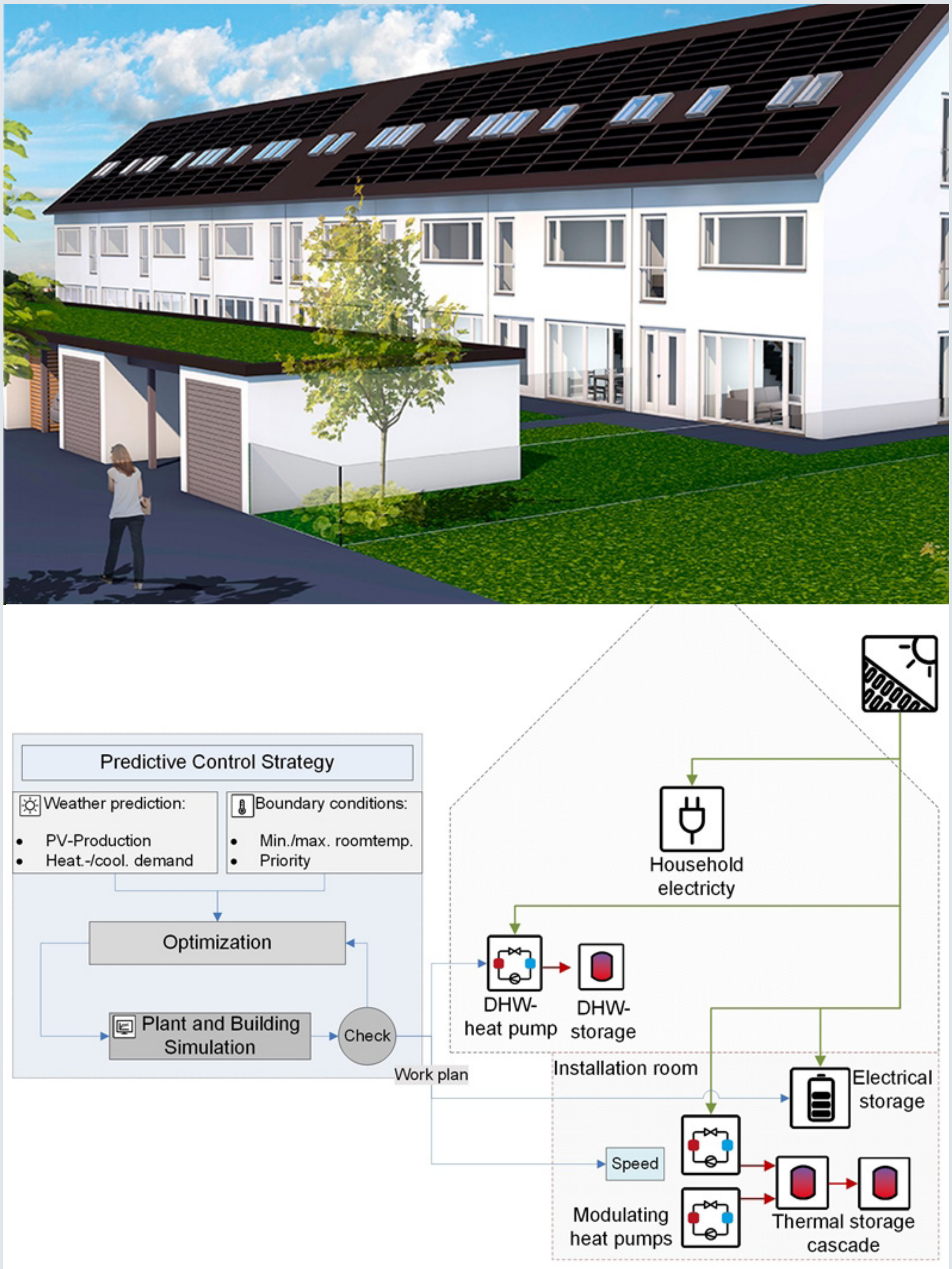

Figure 2. Herzo Base - energy concept

Heating energy is generated by a heat pump, which is coupled to borehole heat exchangers. The Herzo Base houses have two common Modulating (variable speed) Heat Pumps (MHP), that are located in the common installation room. The heat transfer in the building takes place via floor heating and additional radiators in the bathrooms. The hygienic ventilation is ensured by a mechanical ventilation system with heat recovery. In Herzo Base, the domestic hot water is provided by decentralised domestic hot water heat pumps (DHW-HP) that are integrated in each terraced house.

EnergyPlus Standard

The applied definition and calculation method for the EnergyPlus standard is based on the specification and the definition of the German Federal Ministry of Transport, Building and Urban Development (BMVBS) for the “Effizienzhaus Plus”, see here (in German). For the calculation of the EnergyPlus standard, either the building or the property boundary is defined as a balance limit. The balance includes all energy needed for conditioning and operating the building as well as the equipment. It includes the demand for heating and cooling, ventilation, lighting, and auxiliary energy sources, as well as household appliances and wireless computer network.

The energy consumption is compared to the renewable energy production based on the annual balance. The difference (consumption minus production) must be less than zero regarding both final energy and primary energy.

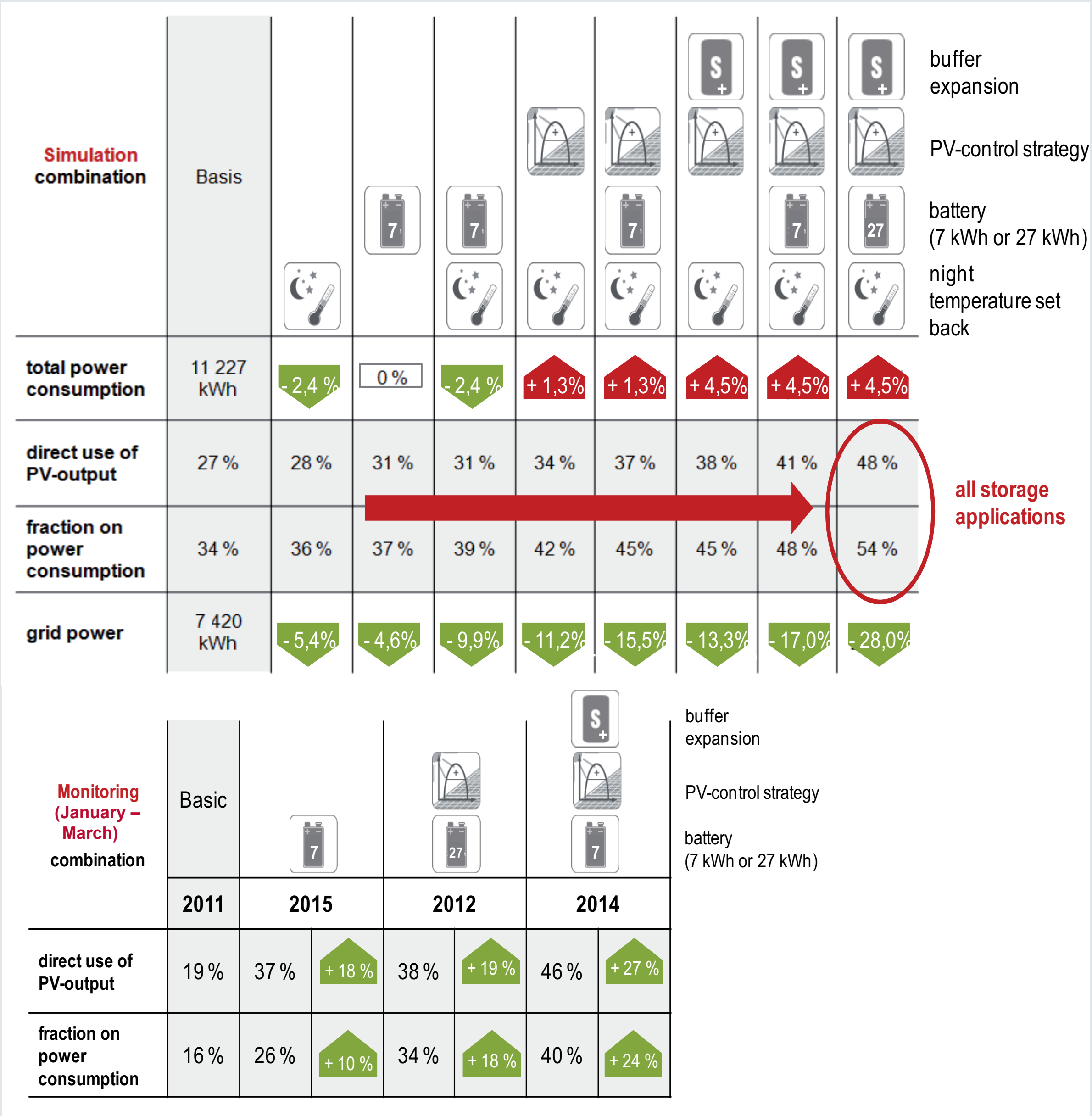

Figure 3. Berghalde - Simulation (top) and monitoring results (bottom)

Berghalde: Increase of self usage share

To increase the direct use of power, different measures were taken in advance by building and system simulations, and afterwards implemented in the building during test phases.

The selected system options (see below) for increasing the share of self usage of power consumption are based on thermal and electrical storage of self-produced electricity. The main focus of the simulation study was to increase self-consumption of PV output and thus reduce the feed-in to, and the extraction from, the public grid.

The following five options build on each other. Each is complemented by a new component, compared to the previous one.

1. Integration of a 7 kWh Battery
2. Battery (7 kWh) + night temperature setback of supply temperature
3. Battery (7 kWh) + night temperature setback + PV-control strategy
4. Battery (7 kWh) + night temperature setback + PV-control strategy + buffer-expansion (add another water storage)
5. Integration of a 27 kWh-battery + night temperature setback + PV-control strategy + (water storage) buffer-expansion

The PV-control strategy is outlined as follows:

- All available thermal storages such as floor heating and the buffer are used for running the heat pump, while enough solar energy is available;
- Raising the temperature in the buffer (up to 60 °C) to increase the storage capacity;
- Increasing the reference value of surface and supply temperature of the floor heating.

Buffer expansion:

- A second buffer (700 l) is connected and coupled to the existing buffer (825 l). Thus, the volume increases from 825 liters to 1 525 liters;
- A restriction of the user comfort is not to be expected at any time by the proposed measures.

The simulation results show that the use of the various components (battery, buffer, etc.) leads to a direct increase of use of PV-power from 27 % (base) to 48 % and the PV solar fraction of power consumption increased from 34 % (base) to 54 %, see Figure 3. In addition, the share of electricity from the grid can be reduced by up to 28 % by implementing all options mentioned above. However, the electricity demand will also increase by up to 4.5 % by the measures, due to lower COPs from the heat pump (higher temperature) and battery losses.

Within the scope of the monitoring, and in order to make a comparison between theory and practice, different combinations of measures were implemented within three test phases. The test phases were evaluated for the period January to March (See Figure 3, lower part). It can be seen that the previously simulated predictions in direct use and fraction on power consumption are well met in the application inside the building.

Herzo Base: A simulation study

The focus of the terraced houses is the development of Demand Side Management (DSM) that controls the MHPs and DHW-HPs in order to reduce the additional grid power and at the same time increase the consumption of electric power generated by PV. Since the MHPs are able to adjust their speed from a fraction of the maximal speed of 0.1 to 1, the DSM can adapt the speed of the MHPs to the PV power. Two thermal storage units are connected to a storage cascade. The second 2 000 litre surplus storage can be switched on in order to increase the storage capacity during PV production. As each DHW storage has a small volume of 200 litres, the water will be renewed daily. This prevents Legionella contamination of the DHW system (in accordance with German legislation). Regarding the advantages of a high temperature source for heat pumps, the water-water HPs use the thermal storage cascade as a heat source. In addition to the thermal storage units, an electrical storage is installed for storing the surplus PV production after filling the electrical demand of the household and heat pumps. Furthermore, the DSM also influences the temperature level of the thermal storage units.

During PV production in the heating period:

1. The temperature level of the DHW storage units increases from 50 °C to 65 °C;
2. The surplus storage is also charged and the temperature level is 35 °C during the heating period.

During battery and grid consumption in the heating period:

1. The temperature level of DHW storage units is 50 °C;
2. The MHPs decrease the speed to 0.4 because the best COP is for a speed between 0.3 and 0.4 of the maximal speed.
3. The first storage is charged to 35 °C.

A minimum storage temperature of 27 °C has to be guaranteed during the heating period.

In the summertime, the heating demand is restricted to DHW. The inlet source temperature for the DHW-HPs is limited to a minimum value of 20 °C. For that reason, only the first storage unit of the storage cascade is charged to a temperature of 30 °C.

The developed control strategy was evaluated as a basic variant with a standard control strategy. The basic control strategy consists exclusively of a heat-controlled operation of heat pumps with an on-off speed and developed control strategy.

Important values for evaluating the DSM are the efficiency of the heat pump systems and the

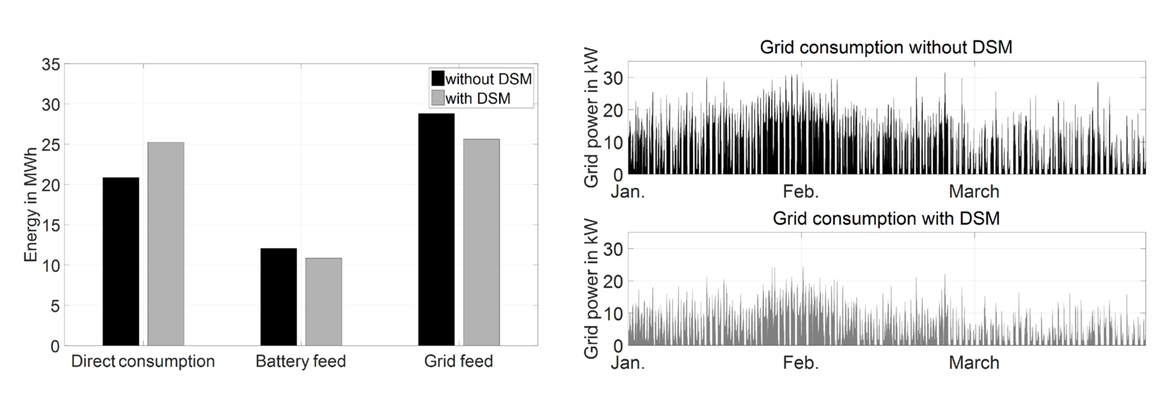

Figure 4. Herzo Base - PV-selfconsumption and load peak reduction

self-consumption of PV electricity. The SCOP of both geothermal heat pumps increased from 4.5 (on-off speed) to 5.3 (modulating speed; not taking the auxiliary energy into account). This higher COP is due to the modulation of the heat pumps with a lower compressor speed. The PV self-consumption increased by 21 % (See Figure 4). As an effect of the increased direct consumtion, the battery feed decreased by 10 % because of the low surplus afterwards. Nevertheless, the grid feed decreased by 11 %. Another result of the DSM is its contribution to the grid integration of nZEBs. The maximum load peak was reduced by 24 % (See Figure 4). The reduction of grid consumption, PV feed and load peaks show the impact of the terraced houses on stabilizing the grid.

Conclusion

The EnergyPlus-Houses, which include heat pumps and have a high PV power self supply, are important elements for our future energy supply and implementation of renewable energy sources.

The results of the optimization and increase of the self consumption show that there is still potential to increase the self-use of solar electricity.

The flexible heat pumps in combination with thermal storage units can adapt to PV power. The adaption and the increase of storage capacity results in an increase of PV power use and a reduction of additional grid power and load peaks.

Both approaches and buildings show that today's load management is indispensable for the implementation of energy-efficient buildings with energy supply from renewable energies.

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Heat load profile for ZEB and requirements for heat pump technology

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The heat load characteristics of ZEB-oriented buildings were analysed to survey the effects of ZEB on the building heat load. ZEB reduces the annual integral heat load and maximum heat load and lowers the ratio of the heat load to the maximum heat load. A major factor for a lower heat load is the reduction of the room sensible heat load, and it was found that this would cause changes to the reduction of the sensible heat ratio and the cooling/heating ratio of the heat load. In response to these effects, technological development required for heat pumps was considered. Here we describe a full product lineup of low-capacity heat pumps, improvement operation efficiency under partial load, standby power and energy consumption of auxiliary devices for heat transfer.

Introduction

Japan intends to reduce CO_2 emissions by 26 % by 2030, compared to 2013. To realize this, energy conservation efforts must be made in each of the public, transportation and industrial sectors. Particularly, the public sector must achieve a high goal of approximately 40 % reduction [1]; ZEB will be one of the effective measures to that end. Setting the goals of ZEB introduction into newly constructed public buildings by 2020 and into new buildings on average by 2030, the Japanese government is enhancing its efforts [2].

For recent efforts related to ZEB, the Society of Heating, Air-conditioning and Sanitary Engineers of Japan published the definition and evaluation method of ZEB in 2015 [3], and the Ministry of Economy, Trade and Industry formulated and published the roadmap and the definition of ZEB in November 2015 [4] and published a design guideline in 2017 [5]. Also, a subsidy system has been operated since 2012 to promote ZEB, realizing approximately 270 subsidized projects so far [6]. Under these circumstances, the superiority of heat pumps has been recognized more than ever as a necessity in order to achieve ZEB. As ZEB implementation has increased, the performance demanded for the heat pumps includes not only higher efficiency, but also the use for a variety of needs.

In this article, we consider the heat load change of ZEB-oriented buildings, and review the effects of ZEB on heat load. We then consider technological development required for heat pumps in response to those effects.

Heat load profile for ZEB

The following describes the heat load characteristics of ZEB-oriented buildings. Assumed for the purpose of analysis was a 5-story office building located in Tokyo (latitude 35 degrees North), Japan and having a total floor area of approximately 10 000 m² and a standard floor area of approximately 2 000 m². Also, model buildings were setup based on the standard and

Table 1. The model building based on the energy conservation specifications adopted maximum heat load reduction technologies.

Envelope performance	Exterior wall: 0.4 W/m²K Roof: 0.55 W/m²K Window: 1.6 W/m²K Shading coefficient: 0.24
Internal heat gain intensity	Lighting: 2W/m² , 500 lx (LED+Lighting control+Blind control) Plug Daytime: 5 W/m² Nighttime: 1.25 W/m²
Other	Natural ventilation Air-to-air total heat exchanger

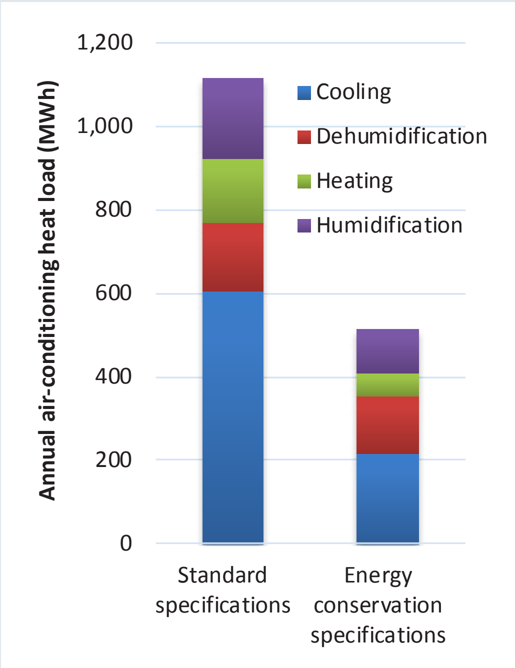


Figure 1. Comparison of annual integral heat load values of model buildings.

energy conservation specifications with respect to this office building. The model building based on the standard specifications adopted conventional general specifications. The one based on the energy conservation specifications adopted maximum heat load reduction technologies, such as higher building envelope performance, indoor temperature/humidity mitigation, heat load conditions reflecting the use of high-efficiency devices, natural ventilation and the use of total heat exchangers (see Table 1) [7].

Figure 1 shows the results of the heat load calculation of the target buildings. In the breakdown of the annual heat load of each building, cooling and dehumidification load, related to the cooling load, accounts for more than half of the total in the case of the building with the standard specifications (left in Figure 1). In the case of high-level energy conservation specifications aiming at achievement of ZEB (right in Figure 1), it is confirmed that the annual heat load is greatly reduced. A major factor for such halved annual heat load is the reduced room sensible heat load due to higher building envelope performance and use of high-efficiency lighting device and others.

In the breakdown of the annual heat load, it is seen that the heat load related to dehumidification hardly changes with respect to the sensible heat load such as cooling and heating. This is because the latent heat processing of indispensable fresh outside air accounts for the majority. This suggests that when designing a system for realization of ZEB, it is an important issue to build a high-efficiency system for processing a latent heat load.

Furthermore, based on the result that the room sensible heat load is reduced, but the latent heat load hardly changes, it is presumed that the sensible heat factor is reduced. In most cases, it is expected that sufficient dehumidification cannot be achieved by conventional supercooling and dehumidification.

Figure 2 shows the frequency of a ratio (load factor) of the hourly heat load to the maximum heat load. Indicated in the figure is the maximum heat load of the buildings with different specifications. The maximum heat load in both cooling and heating were lowered. It is seen that a ratio of the heat load to the maximum heat load was reduced more for the energy-conserving building than the standard one. This reduction was particularly considerable with the heating load; a period of less than 10 % was 274 hours for the standard specifications and 428 hours for the energy conservation specifications.

Requirements for heat pump technology

Full product lineup of small-capacity heat pumps available for heat load reduction

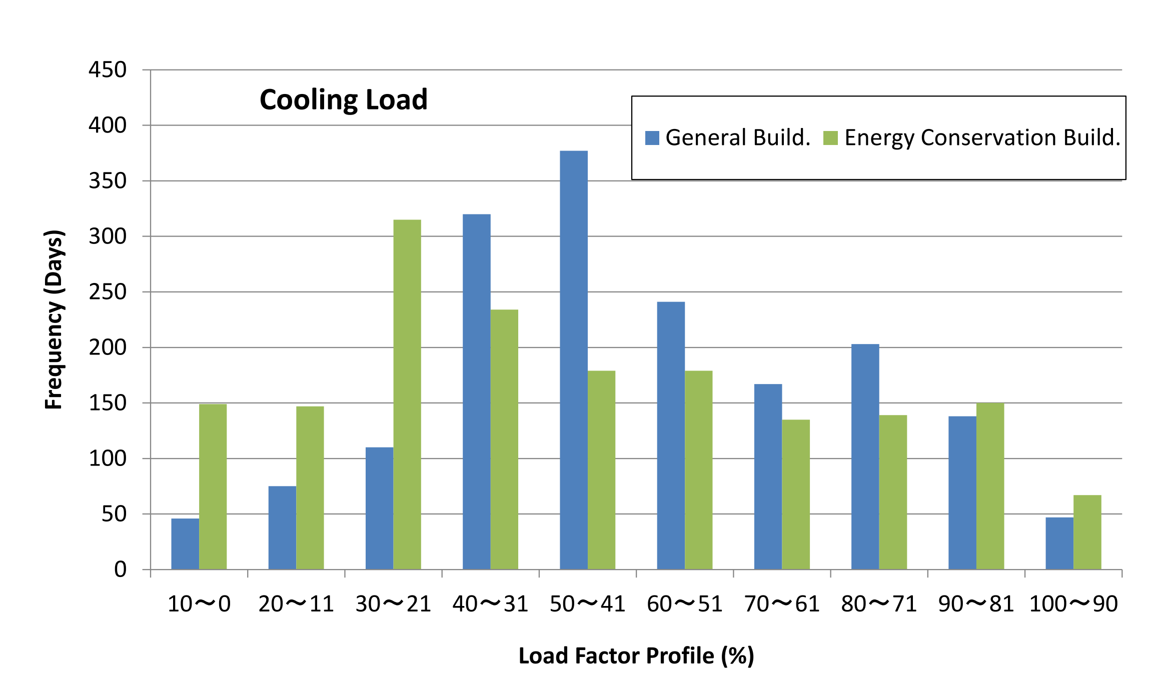
It is presumed that promotion of ZEB will accelerate heat load change such as a reduction of the annual integral heat load and the maximum heat load. It is likely that there will be an increasing demand for smaller-capacity heat pumps than the existing ones. Accordingly, it is necessary to augment the product lineup of small-capacity heat pumps.

Improvement operation efficiency under partial load operation

As mentioned previously, the ratio of the heat load to maximum heat load is lowered along with promotion of ZEB. This increases the effect of operation efficiency at partial load on system operation efficiency. Accordingly, technological development will be continuously needed in the future for higher operation efficiency of the heat pumps under partial load. In addition to this, it is also indispensable in the system design to incorporate measures such as decrease the number of equipment and actively utilizing renewable energy sources such as ground-source energy.

Focus on standby power and energy consumption of auxiliary devices for heat transfer

Decreased heat load means lower energy consumption of the heat pumps. Lower energy consumption of the heat pumps cause energy consumption to draw more attention, which has not been noted due to its low ratio. For example, the standby power of the heat pumps and energy consumption of auxiliary devices such as heat transfer pumps. Development and design of heat pumps needs to focus on the energy consumption during standby and of auxiliary devices.



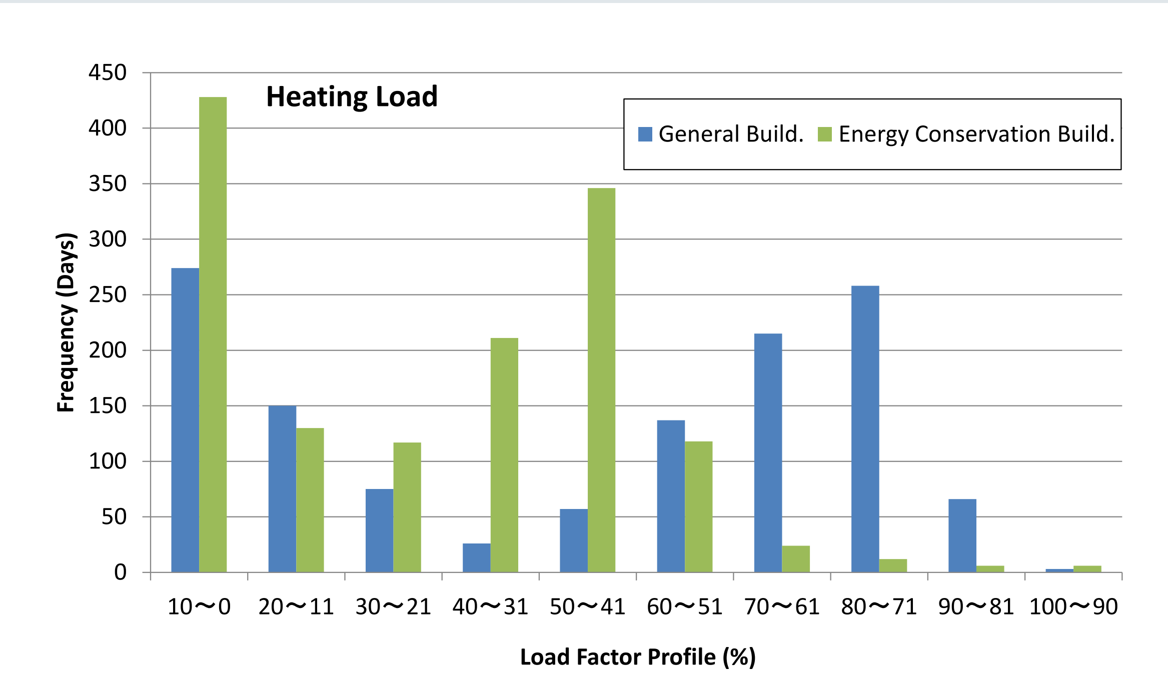


Figure 2. Ratios of hourly heat load to maximum heat load.

Conclusions

The heat load characteristics of ZEB-oriented buildings were analyzed to review the effects of ZEB on building heat load. In response to these effects, technological development demanded for the heat pumps was also described. In addition to the technological development of the heat pumps themselves, it will be necessary to successfully design and operate them as part of the system.

It is expected that use of renewable energy will continue to expand globally. Meanwhile, heat pumps capable of converting electric power into thermal energy can provide a method to effectively utilize surplus power from renewable energy, in combination with thermal storage technology. It is imagined that DC power supply technology capable of directly utilizing DC power without conversion losses will become more effective through increased use of renewable energy. Thus, the use of heat pumps that can use DC power is expected to grow.

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nZEB energy performance comparison in different climates and countries

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In this article nZEB energy performance requirements of two Central European and two North European countries are compared. A reference office building with economic insulation thickness in all climates was used as a starting point of the comparison. Primary energy values were simulated with national input data and technical solutions were changed so that close enough compliance was achieved in every country. It is concluded that there is no direct way to compare the performance level of national nZEBs; instead a reference building simulation method has to be used. Generally, national input data caused much more difference than the climate did.

Introduction

The European Energy Performance of Buildings Directive (EPBD) recast from 2010 set an ambitious energy performance target of nearly zero energy buildings (nZEB). According to the nZEB definition in the directive, these buildings shall have a very high energy performance. Definition of a very high energy performance is left to each Member State (MS) to decide based on local conditions and their own national methodology for energy calculations. This creates the need to be able to compare energy performance of buildings built according to the requirements of different MS.

The European Commission Joint Research Centre has recently evaluated all existing national nZEB definitions [1]. In 2016 the number of MS with an nZEB definition with a numerical target of primary energy use has increased, but still the definition was not approved in 9 countries, as shown in Figure 1, "NZEB Definition" column.

National nZEB requirements were found to be quite different in terms of numeric values, building categories for which they apply, energy flows included and renewable energy accounting, as well as national input data used for energy calculation. Most of the MS use primary energy requirements, i.e. delivered energy is multiplied with national primary energy factors and exported energy (multiplied with the same factors) is subtracted from the final requirement value. However, in some countries Class A or % of existing minimum level type of recommendations exist. A full set of national requirements can be found in the JRC report. In Table 1 these are shown for four countries, benchmarked in this article.

Table 1. The primary energy national requirements (PE indicator) for office buildings, energy flows included, and primary energy factors according to national regulations. For comparison, existing 2016 requirements are shown; nZEB is required for buildings completed in 2021.

	PE INDICATOR	ENERGY FLOWS	OFFICE BUILDINGS REQUIREMENT		PRIMARY ENERGY FACTORS	
			2016	nZEB	2016	nZEB
Finland	E [kWh/(m² · a)]	DHW, heating, ventilation, cooling, auxiliary, lighting appliances	170	100	Electricity 1.7 District heating 0.7 Natural gas 1.0	Electricity 1.2 District heating 0.5 Natural gas 1.0
Estonia	ETA [kWh/(m² · a)]	DHW, heating, ventilation, cooling, auxiliary, lighting, appliances	160	100	Electricity 2.0 District heating 0.9 Natural gas 1.0	Same as for 2016
France	C_{ep} [kWh/(m² · a)]	DHW, heating, ventilation, cooling, auxiliary, lighting	$C_{ep, max} = 50 \cdot M_{c, type} \cdot (M_{c, geo} + M_{c, alt} + M_{c, surf} + M_{c, ges})$ [1] 110 [3]		Electricity 2.58 District heating 1.0 Natural gas 1.0	Same as for 2016
Brussels Capital region	CEP [kWh/(m² · a)]	Heating, ventilation, cooling, auxiliary lighting	$45 + max(0; 30 - 7.5C) + 15 \cdot max(0; 192/V_{EPR} - 1)$ 88.2 [3]	$95 - (2.5C)$ ***or*** $95 - (2.5C) + 1.2(X - 15)$ [2] 88.2 [3]	Electricity 2.5 District heating 2.0 Natural gas 1.0	Same as for 2016

[1] Depending on building type, location, altitude and heating system
[2] If space heating *X<15.0 kWh/m² · a* then use this equation *95-(2.5C)*. Depending on net needed energy for heating
[3] for the reference building used in this study

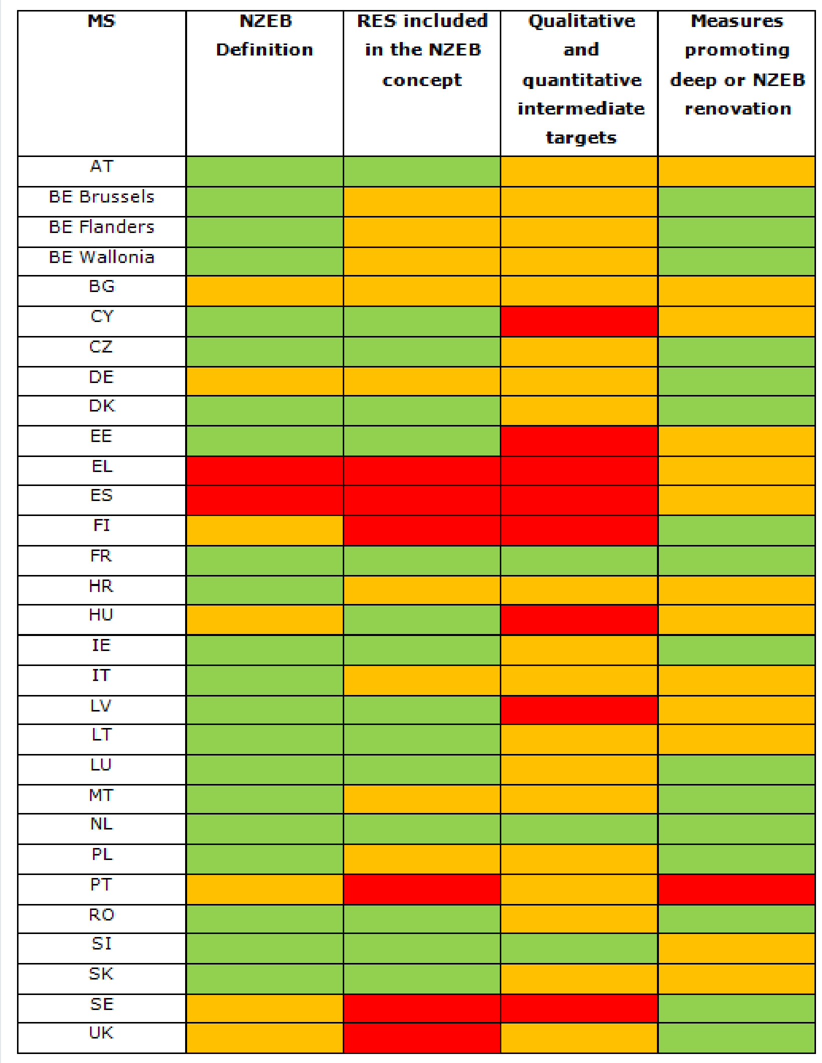

Figure 1. nZEB development evaluation in MS, available definitions, renewable energy included in definitions/system boundary, availability of intermediate targets and promotion measures [1]. Green: satisfactory development; orange: partial development; red: not defined/unclear.

According to national regulation, the Finnish and Estonian office buildings have to comply with fixed PE values (Table 1), which do not depend on geometry and location of offices. In contrast, the French regulation considers a coefficient that depends on the floor surface area ($M_{c,\ surf}$), which can influence the PE requirement. However, the coefficient is zero when it is considered as the average surface area of the building or part of the building. For the Brussels capital regulation, the net heated area, heat loss area and compactness (depends on region) determines the PE requirement.

Since comparison and assessment of national nZEBs is challenging, the European Commission has published official recommendations, EU 2016/1318 [2], in order to ensure that nZEB targets are possible to meet by 2020. The main recommendations reflect EC concerns about low ambition of national nZEB targets as well as the challenge with time schedule to deliver nZEB by the end of 2020.

Some highlights of the recommendations:

- Set national definitions of **nZEB at a high level of ambition** – not below the cost-optimal level of minimum requirements.
- Use **renewables in an integrated design concept** to cover the low energy requirements.
- Assure proper indoor environment to avoid deterioration of **IAQ, comfort and health**.

The recommendation of the nZEB ambition level states that the nZEB level for new buildings has to be determined **by the best technology that is available and well introduced on the market at that time, financial aspects, and legal and political considerations at national level**. In order to make proper ambitions transparent, EC has set **numeric benchmarks for nZEB** primary energy use in four climate zones, Table 2.

Table 2. Numeric benchmarks for nZEB primary energy use set by EC recommendations EU 2016/1318. Net primary energy means that primary energy from that on-site renewable energy is reduced. Default values of on-site renewables are also provided.

	MEDITERRANEAN	OCEANIC	CONTINENTAL	NORDIC
	Zone 1: Catania, Athens, Larnaca, Luga, Seville, Palermo	**Zone 4**: Paris, Amsterdam, Berlin, Brussels, Copenhagen, Dublin, London, Nancy, Prague, Warszawa	**Zone 3**: Budapest, Bratislava, Ljubljana, Milan, Vienna	**Zone 5**: Stockholm, Tallinn, Helsinki, Riga, Gdansk, Tovarene
Offices kWh/(m² · a)				
net primary energy	20-30	40-55	40-55	55-70
primary energy use	80-90	85-100	85-100	85-100
on-site RES sources	60	45	45	30
New single family house kWh/(m² · a)				
net primary energy	0-15	15-30	20-40	40-65
primary energy use	50-65	50-65	50-70	65-90
on-site RES sources	50	35	30	25

Compared to values in Table 1, EC values in Table 2 do not include appliances (small power loads) which are included in Finland and Estonia in Table 1, accounting for 27 and 38 kWh/(m² · a) respectively as regulated values. Therefore, Estonia complies well with the EC Nordic recommendation and Finland is very close, but France and Brussels are quite far from the Oceanic recommendations. However, such a direct comparison is very rough and can be biased by different EC vs. national input data and primary energy factors, which is demonstrated in the following analyses.

This article does not specifically focus on heat pumps. However, the subject is very relevant for the present and future legislative landscape that heat pumps are facing, thus motivating that it should be published in the HPT Magazine.

How compare energy performance requirements?

NZEB buildings represent the aspect of energy performance requirements comparison for high performance buildings. Similarly, energy performance comparison could be in the interest of investors or building owners for existing buildings with different locations. In the following, a new method enabling climate and national input data- and methodology-dependent comparisons is discussed.

In order to enable physically meaningful comparisons of energy performance, the method should be able to address three major issues:

1. To normalize heating, cooling and lighting needs in different climates;
2. To account for national methodology and input data differences;
3. To consider cost effectiveness constraints such as economic insulation thickness in different climates.

Because national energy performance values depend on energy calculation input data and calculation rules, it is important to know how much variation these can cause. If the difference is significant, as shown in this study, the comparison is more complicated. A building which exactly complies with requirements in one country can be simulated with input data and calculation methodology of another country in order to see how close the technical solutions of this building are to energy performance requirements of that other country.

In order to account for climate differences, an economic insulation thickness concept may be applied to ensure that buildings are optimally insulated in the climates under comparison. If an economic insulation thickness

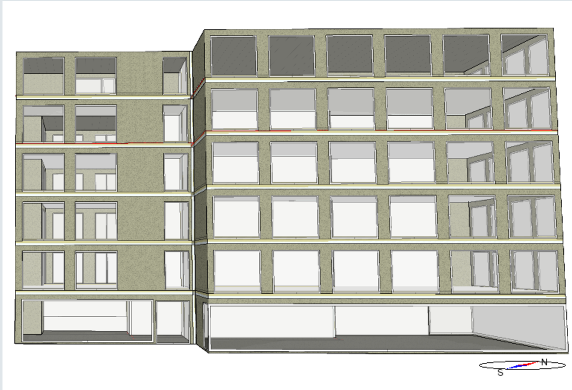

Figure 2. 3D model of simulated reference office building.

is known (or can be estimated) for one climate, it can be calculated for another climate as follows:

$$U_{opt}^{i} = U_{opt}^{ref} \sqrt{\frac{HDD_{ref}}{HDD_i}}$$

where
U^{i}_{opt} is the U-value in W/(m² · K) corresponding to an optimal insulation thickness in climate *i*;
U^{ref}_{opt} is the known reference U-value in W/(m² · K) corresponding to optimal insulation thickness in the reference climate;
HDD_i is heating degree days in K · d in climate *i*;
HDD_{ref} is heating degree days in K · d in the reference climate.

In the following, a reference office building complying with Estonian requirements is simulated with three other climates and input data in order to see how it complies with requirements of other countries. The building model is shown in Figure 2.

Four cases were simulated for the 2021 nZEB energy requirements as shown in Table 3. NOR (Normal) cases used the reference office building with the reference (Estonian) input data values for all countries, whereas NAT (National) cases used the national input data. NOR cases represent the situation where Estonian insulation thickness was applied to other countries, thus clearly over-insulating in France and Belgium. NOR*i* and NAT*i* cases applied economic insulation thickness to avoid this problem. As national input values deviate strongly, NAT and NAT*i* cases show the effect of this variation.

Reference (Estonian) and national input data as well as economic insulation thickness data are shown in Table 3. Energy need in the building was simulated according to the hourly weather data of respective countries. Building operation hours etc. data called 'Other parameters' in the Table 3 were set to NAT and NAT*i* cases according to the national regulation. It can be seen that economic insulation thickness and corresponding U-values change significantly according to the climate. On the other hand, national input data of occupancy, ventilation and temperature setpoints show quite a remarkable variation.

Table 3. Case description for simulation.

CASE CODE	CASE DESCRIPTION
Case 1: NOR	Reference office building with reference input data, but with national climate files
Case 2: NAT	Reference office building with national input data
Case 3: NAT*i*	Reference office building with economic insulation and national input data
Case 4: NOR*i*	Reference office building with economic insulation and reference input data

Table 4. Input data for NOR, NAT, NORi, NATi cases.

Building insulation thickness and U-values in NOR*i* and NAT*i* cases				
	FINLAND	ESTONIA[1]	FRANCE	BRUSSELS
External wall [m]	0.205	0.20	0.125	0.135
Roof [m]	0.308	0.30	0.188	0.20
External wall [W/(m² · K)]	0.168	0.17	0.268	0.25
Roof [W/(m² · K)]	0.111	0.11	0.175	0.166
Window glazing unit [W/(m² · K)]	0.607	0.62	1.007	0.935
Window 10% frame [W/(m² · K)]	0.646	0.66	1.006	0.942
Window 30% frame [W/(m² · K)]	0.725	0.74	1.005	0.955
Other parameters in NAT and NAT*i* cases				
	FINLAND	ESTONIA[2]	FRANCE	BRUSSELS
Occupant [m²/person]	17	17	10	15
Appliances [W/m²]	12	12	1.6	3
Lighting [W/m²]	6	6	9.8	9.8
Appliances & lighting operation hour	7:00-18:00	7:00-18:00	8:00-18:00	8:00-18:00
Usage factor	0.65	0.55	0.6	0.6
Hot water consump-tion [l/m² · a]	100	100	35	0
Fan operation hour	6:00-19:00	6:00-19:00	6:00-19:00	6:00-19:00
Air flow rate [l/m² · s]	2.0	2.0	0.7	1.2
Heating set point [°C]	21	21	19	19
Cooling set point [°C]	25	25	26	23

1] Estonian input values of Building insulation thickness and U-values apply to NOR and NAT cases of other countries.
*2] Estonian input values of Other parameters apply for NOR and NOR**i** cases for all other countries.*

With the input data of Table 4 energy simulations were run, Figure 3. For NOR cases, the variation of heating and cooling is caused by the difference in climate. In the Estonian case, there is no difference between NOR and NAT, because Estonian input data was used as a reference. In Finland only small changes can be seen, therefore the Finnish input data is similar to the Estonian one. In France and Belgium, the national input values have caused remarkable changes in delivered energy. This is because the lower ventilation rate, lower number of operation hours and different installed lighting and appliances power, which follow the French and Brussels capital regulation. Generally, it can be seen that national input data can cause more difference than the climate does.

In the NOR*i* cases, the heating need has significantly increased in France and Belgium, but is still smaller than in Estonia and Finland. In these cases the same cost-benefit-justified economic effort is done in

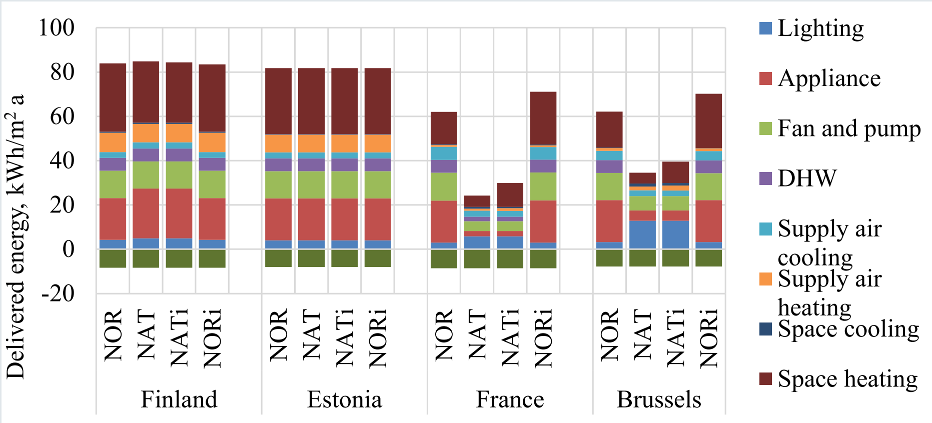

Figure 3. Comparison of delivered energy use in simulated cases with reference and national input values.

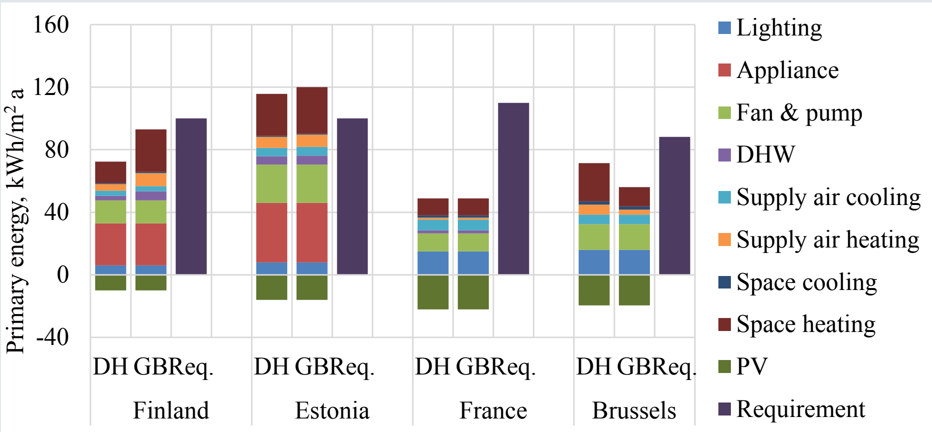

Figure 4. Primary energy in NATi cases office buildings compared with nZEB regulation. DH refers to district heating, GB to gas boiler and Req. to nZEB energy performance requirement. Negative values of PV have to be subtracted from positive values in order to obtain the primary energy value (which can be compared with the requirements).

insulation, which suggests that energy performance should be equal in all countries. However, in warmer climates the heating need naturally remains smaller.

Ambition of national nZEB requirements

The NAT*i* cases of all countries have economic insulation thickness as well as input values according to national regulation. The delivered energy reported in Figure 3 does not show the compliance with energy performance requirements, because the requirements are for primary energy and PE factors are to be applied. PE use in office buildings for NAT*i* cases are shown in Figure 4.

The Estonian nZEB requirement appears to be the strictest one of the building regulations. The Estonian building with DH system just fulfilled the nZEB requirements, whereas in the building with GB system it was necessary to increase the onsite electricity production (need to increase the PV panel area from 213 to 266 m²) to fulfill the nZEB requirements. For the other countries there was room to change some building and system parameters in order to be closer to nZEB requirement.

The following changes were made:

- In the Finnish, Belgium Brussels and French nZEB office building the PV system was removed,
- In Finland, the nZEB level was targeted with DH and in Brussels with GB, which are common heating solutions in these countries (due to lower primary energy factors these allow to use more delivered energy),
- In Finland and Brussels, 2016 building insulation, fan power, heat recovery efficiency, and glazing U value 1.4W/(m²· K) were applied,
- In France even less insulation was used, the U-value of external walls, roof and windows were changed to 0.6 W/(m²· K), 0.4 W/(m²· K) and 2.0 W/(m²· K), respectively. Specific fan power

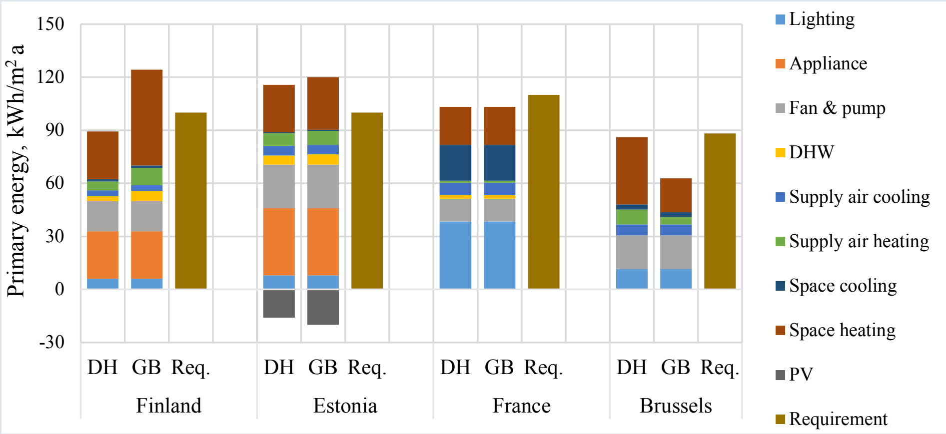

Figure 5. Primary energy in nZEB office buildings with changed parameters in order to target nZEB requirements.

(SFP) of ventilation system was increased to 1.82 kW/(m³ · s) and daylight control of lighting was removed.

The results after these changes are shown in Figure 5.

It can be seen that the Finnish nZEB requirement can be considered the second strict after Estonia, because the result is closer to the requirement than that in Belgium Brussels. The French nZEB regulation appeared clearly the less strict, as it allowed to use highest U-values and SFP and no daylight control.

Conclusions

It may be concluded that there is no simple way to compare the performance level of national nZEB. In Central and North Europe comparisons, national input data caused much more difference than the climate. To make the comparison, a reference building with economic insulation thickness and otherwise with the same technical solution was simulated with national input data. The technical solutions were selected so that the building complied with requirements in one country. Primary energy values simulated with national input data were then compared with national requirements in other countries, and if a gap existed, the technical solutions were changed to minimize the gap. The requirement of the country needing the technical solutions with highest performance level corresponds to the strictest nZEB level. Results show that the strictest requirement did not necessarily have the lowest primary energy numeric value. The results are reported and discussed in more detail in the research article [3].

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Field testing of two prototype air-source integrated heat pumps for net zero energy home (nZEH) application

Van D. Baxter and Jeffrey D. Munk - USA

Integrating multiple functions into a single system offers potential efficiency and cost reduction benefits. Oak Ridge National Laboratory (ORNL) and its partners have designed, developed, and tested two air-source heat pump designs that not only provide space heating and cooling, but also water heating, dehumidification, and ventilation functions. Details on the design, simulated performance, prototype field test, measured performance, and lessons learned are provided.

Introduction

The US Department of Energy's Building Technologies Office (DOE-BTO) defines a net zero energy building (nZEB) as "an energy-efficient **building** where, on a **source energy** basis, the actual **annual delivered energy** is less than or equal to the on-site renewable **exported energy**" [1]. Achieving nZEB performance requires both maximizing the building envelope efficiency and minimizing energy use for space heating and cooling (SH, SC), water heating (WH), and indoor humidity control. ORNL has been working with BTO and manufacturer partners to develop advanced integrated heat pump (IHP) technologies to help meet this challenge.

Systems description

An IHP is a heat pump system with multiple functions - e.g., SH, SC, WH, dehumidification (DH), etc. This article summarizes the development and field testing of two prototype air-source integrated heat pumps (AS-IHPs). One (AS-IHP 1) uses a single variable speed (VS) compressor and fans, illustrated schematically in Figure 1. An optional ventilation (V) air intake can be included to provide pre-conditioned fresh air through the heat pump air handler section. However, the field test prototype did not include dedicated V or DH modes [2]. Figure 2 is a photograph of the prototype in the field test house in Knoxville, TN, USA.

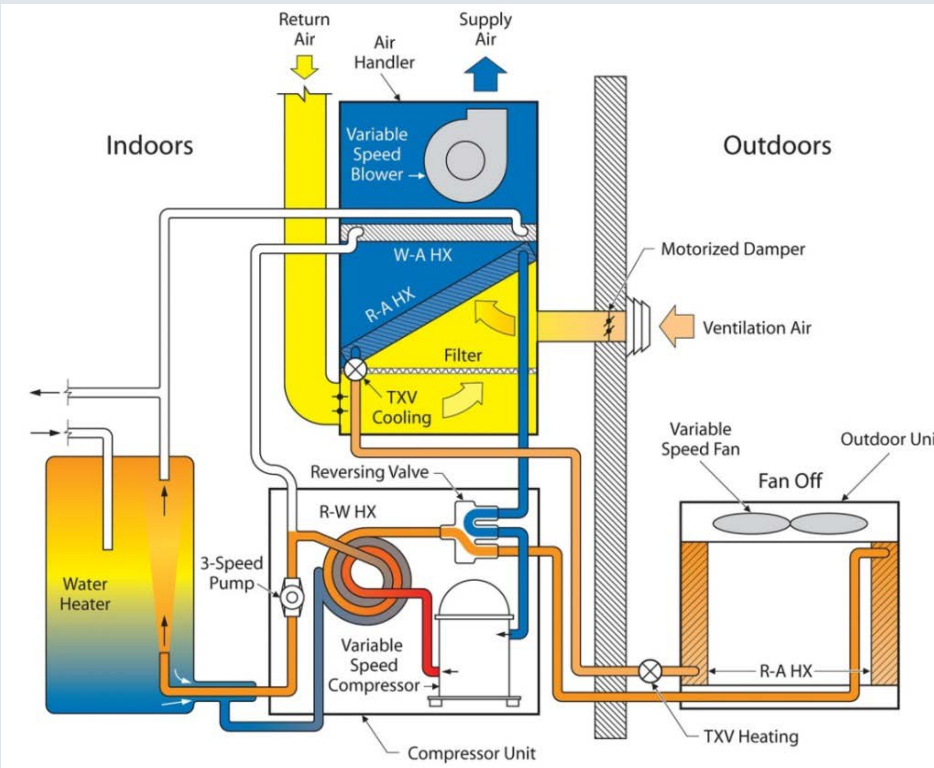

Figure 1. AS-IHP 1 concept schematic.

Figure 2. AS-IHP 1 field test prototype installation; left) indoor sections (hot water storage tank, compressor and water heating module, and indoor fan coil), right) outdoor section.

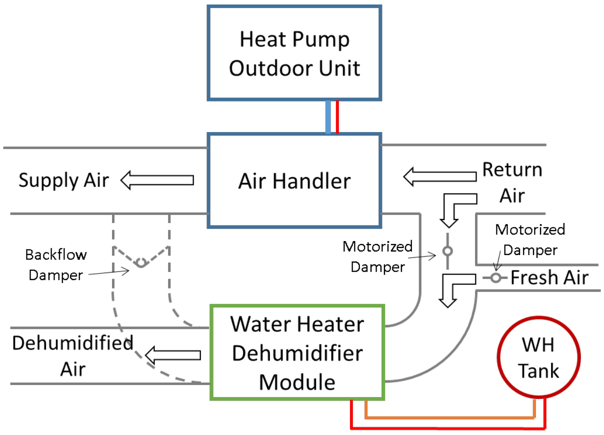

Figure 3. AS-IHP 2 concept schematic.

The second configuration (AS-IHP 2) combines a commercially available high-efficiency air-source heat pump (ASHP) with a separate prototype module for WH, demand DH, and V control - WH/DH module [3], see Figure 3. The major components of the prototype WH/DH are a single-speed compressor and water pump, a VS fan, and separate condensers for WH and DH modes. It included a solid-state microcontroller to manage competing WH and DH demands, with WH having priority. The VS blower uses the same speed for WH and DH but slows down for controlled fresh-air ventilation. As shown in Figure 3, the WH/DH module may be integrated with the ASHP unit via connections to the air handler return and supply duct work. When operating in WH or DH mode, it pulls air from the ASHP return duct and discharges it to either the supply duct or directly to the conditioned space (the configuration used in the field test). It operates in V mode when there is no WH or DH call, to ensure that adequate fresh air is supplied to the home. Figure 4 shows the indoor sections of AS-IHP 2 field test system.

Figure 4. AS-IHP 2 field-test prototype in installation process.

The separate WH/DH module for the AS-IHP 2 system also allows maximum flexibility for retrofit applications. If an existing WH tank is remote from the ASHP system, the WH/DH unit can be co-located with the tank, thus upgrading the WH to a combined WH/DH and V appliance. But integration with the ASHP return duct may not be possible in this case.

AS-IHP development and field test summary

AS-IHP 1

We worked with Nortek Global HVAC, Inc. (formerly Nordyne) to develop the design and build two lab test prototypes. The lab test results were used to calibrate a detailed heat pump simulation model [4] for the system to generate performance maps. These maps were input to a TRNSYS [5] simulation to estimate annual energy savings for a high efficiency ~240 m² house with a 7 kW design SC load in several locations. Table 1 summarizes the performance predictions for AS-IHP 1 vs. a baseline consisting of a minimum efficiency ASHP ($SCOP_c$ of 3.8 and $SCOP_h$ of 2.3) and an electric WH with rated energy factor (EF) of 0.9. Electric resistance backup energy use for SH was zero in all locations except Chicago where it was ~12 % of the total SH energy use.

A field test prototype based on the final lab test system (design cooling capacity of 10.6 kW) was installed in a 223 m² test house and monitored from May 2014 to May 2015. The house was unoccupied but occupancy and domestic hot water loads were simulated as described in [2] and [3].

Two baseline systems were field tested during 2011-2012 in the same area (at a different but similar-size house) achieving an average measured $SCOP_h$ of 1.65 and $SCOP_c$ of 2.29. AS-IHP 1 field test results are compared to the base systems' field performance in Table 2. Since the tank and hot water distribution line losses were not included in the AS-IHP 1 field performance, they are also omitted from the baseline (e.g. baseline WH COP = 1.0). The largest savings come from WH, at 61 % or 1905 kWh. SC and SH energy savings are estimated at 1800 kWh (55 %) and 1461 kWh (20 %), respectively. Estimated total annual savings for AS-IHP 1 vs. baseline at the Knoxville test site were about 38 %. It must be noted that the field test house thermal envelope performance was much poorer than that of the house used in the performance predictions shown in Table 1 [2]. Figure 5 shows the field measured SH

Table 1. Predicted annual energy savings for AS-IHP 1 based on lab tested performance.

CITY	BASELINE SYSTEM	AS-IHP 1	
	Energy use, kWh	Energy use, kWh	Percent savings
Atlanta	7 361	3 433	53.4 %
Houston	6 476	2 960	54.3 %
Phoenix	14 676	3 543	47.1 %
San Francisco	7 351	2 019	61.1 %
Chicago	11 209	6 066	45.9 %

Table 2. AS-IHP 1 2014-2015 performance vs. estimated baseline performance at test site.

	AS-IHP	ESTIMATED BASELINE PERFORMANCE	PERCENT SAVINGS
Space cooling			
Load (kWh)	7 416	7 416	
Energy used (kWh)	1 444	3 244	55 %
Space heating			
Load (kWh)	12 125	12 125	
Energy used (kWh)	5 899	7 360	20 %
Water heating			
Load (kWh)	3 104	3 104	
Energy used (kWh)	1 199	3 104	61%
TOTALS			
Energy used (kWh)	**8 542**	**13 708**	**38 %**

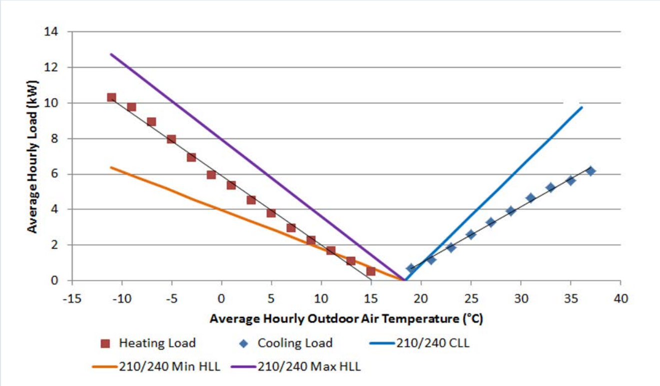

Figure 5. Field-test house 2015–2016 heating and cooling load lines vs. Ref [6] load lines.

and SC load lines (LL) for the test house compared to standard LLs from the U.S. ASHP rating standard [6]. The measured SH LL is seen to be closer to the maximum SH LL, but the house used for the Table 1 analyses had an SH LL closer to the minimum LL from [6]. Thus, back-up SH energy use was higher than expected; ~26 % of the total SH energy use. This and higher indoor blower energy usage (vs. lab measured performance) negatively impacted the SH performance of the field prototype system.

AS-IHP 2

We worked with Lennox Industries, to develop the WH/DH design and build two lab test prototypes. Test results were used to calibrate a WH/DH model [4]. Performance maps for the WH/DH and a high-efficiency, commercially available ASHP were generated for input to TRNSYS to estimate annual energy savings. For these simulations a two-speed ASHP (SCOP$_c$ of 5.4 and SCOP$_h$ of 2.7; design SC capacity of 7 kW) was coupled with the WH/DH module. The simulations were made for

Table 3. Predicted annual energy savings for AS-IHP 2 based on lab tested performance.

CITY	BASELINE SYSTEM	AS-IHP 2	
	Energy use, kWh	Energy use, kWh	Percent savings
Atlanta	7 941	5 071	36.0 %
Houston	8 187	5 264	35.7 %
Chicago	11 514	7 762	32.6 %

Table 4. AS-IHP 2 2015-2016 performance vs. estimated baseline performance at test site.

	AS-IHP	ESTIMATED BASELINE PERFORMANCE	PERCENT SAVINGS
Space cooling + DH			
Load (kWh)	9 189	9 189	
Energy used (kWh)	2 201	4 013	45 %
Space heating			
Load (kWh)	11 561	11 561	
Energy used (kWh)	5 225	7 061	26 %
Water heating			
Load (kWh)	2 739	2 739	
Energy used (kWh)	1 146	2 739	58 %
TOTALS			
Energy used (kWh)	**8 572**	**13 813**	**38 %**

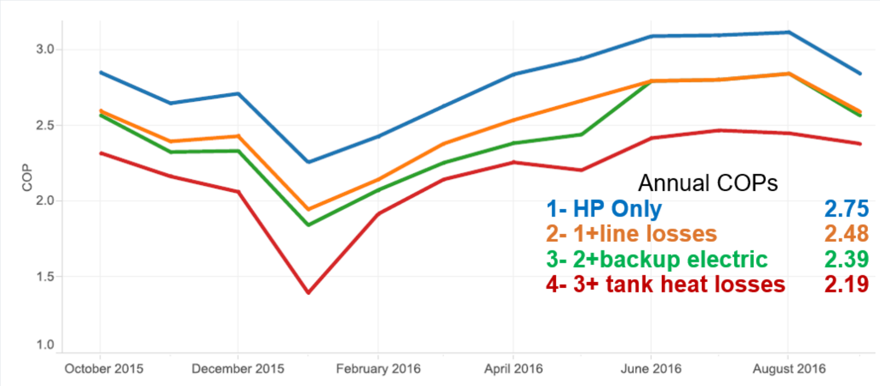

Figure 6. Monthly average WH mode COPs of the WH/DH module. Note: HP – heat pump.

the same house model as used for AS-IHP 1 but only in locations having significant year-round DH loads. Table 3 summarizes the performance predictions. In this case backup SH energy was ~1.5 % of total SH in Atlanta and ~14 % in Chicago. Since AS-IHP 2 includes the demand DH and V functions, the baseline system included a standalone dehumidifier (with rated energy factor (EF) of 1.4 litre/kWh) and V fan in addition to the minimum efficiency ASHP and electric WH.

A field test prototype based on the final WH/DH lab prototype coupled with a variable speed ASHP ($SCOP_c$ of 6.3 and $SCOP_h$ of 2.9; design SC capacity of 10.1 kW) was installed in the same house as AS-IHP 1 and tested from Oct. 2015 to Oct. 2016.

AS-IHP 2 field results are compared to its base systems in Table 4, with SC and demand DH combined. The base system ASHP is assumed to meet the same total SC and DH loads as the AS-IHP 2 prototype. The table shows that the largest savings come from WH, at 58 % (1593 kWh). SC+DH and SH energy savings are estimated at 1812 kWh (45 %) and 1836 kWh (26 %), respectively. Estimated total annual energy savings vs. the baseline at the Knoxville test site were about 38 %. Again, the relatively poor SH performance of the house envelope resulted in higher back up energy use than expected; ~24 % of the total SH energy use.

Figure 6 summarizes WH mode COPs for the WH/DH (heat pump) only, heat pump with tank-to-WH/DH connecting line losses (~10 %), with backup resistance use (~5 % of total WH energy use), and entire WH/DH system including WH tank heat losses. There were no hot water draws for 20 days in January causing the dip in efficiency that month.

The WH/DH did an excellent job of maintaining the house RH <55 % year-round, with an average annual efficiency of 1.7 L/kWh. Re-evaporation of evaporator coil condensate during V mode degraded DH mode efficiency. Adjustment of the controls to minimize V air flow significantly reduced the re-evaporation and led to reduced DH mode runtime.

Conclusions

Integrated heat pumps have the potential to reduce space conditioning, water heating, dehumidification, and ventilation energy use by 40-60 % over minimum efficiency equipment. Two different system designs were presented and field tested by ORNL and its partners with promising results. Field performance would have shown better results if the test house had better thermal envelope performance (e.g., near-zero-energy ready). Additional work on equipment packaging and optimizing controls is needed to further advance the designs toward commercial products.

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Heat pumps in buildings with low energy demand - comparisons with a current test standard

Ola Gustafsson and Kerstin Rubensson - Sweden

How does a traditional heat pump system operate in a house with a low heating demand? In what way does a smart grid connection affect the heat pump? Will the operational parameters differ from those that heat pumps of today are optimized for? And how? These questions are relevant as nearly zero energy buildings (nZEBs) soon will be standard for new-built throughout Europe due to the Energy performance of buildings directive. The results from this recent research indicate that the standard for testing of heat pumps should be revised.

Introduction

In a few years' time, in 2021, all new buildings in Europe are supposed to be nearly zero energy buildings (nZEB). The low energy demand in these houses give rise to other usage profiles for space heating and domestic hot water (DHW) than the profile encountered in more traditional houses. This, in turn, might lead to a need for adjustment of heat pump optimization. It might also give opportunities for new designs of the entire heating and ventilation systems.

Two different systems including heat pumps have been tested and evaluated in two new-built one-family nZEBs, in order to find out how to design and optimize systems for the future. This has been done under the HPT TCP Annex 49 by RISE, Research Institutes of Sweden. The research is a continuation of the work carried out under Annex 40. The national project is financed by the Swedish Energy Agency via the research program Effsys Expand and by the project partners Danfoss Heat Pumps AB, Bosch Thermoteknik AB, NIBE AB, Skanska, and TMF.

Setup, results, and discussion

The two houses (See Figures 1a and 1b) can be described as sister villas, as they share many important characteristics:

- Final energy use around 20 kWh/($m^2 \cdot$ yr)
- Balanced ventilation with heat recovery
- Ground source heat pump
- Sensors for climate, heating etc.
- Further, they are the same size and both have photo-voltaic power generation.

But they also differ in some aspects. The residents in house A belong to a fictive family, where activities are modelled on expected behaviour for a family. In house B there is an actual family living. More importantly, in house A a 4.5 kW on-off heat pump is installed, and is connected to an accumulation tank. In house B, the 6 kW heat pump operates at variable speed leading to variable capacity in the system, due to existing preconditions. Also, house A only has a floor heating system, whereas house B has both floor heating and radiators. Thus, there is information on real-life operating parameters for both heat pump types, possibly for both medium- and low-temperature systems.

The setup of the project will make it possible for the researchers to gain increased knowledge on heating demand and heat pump operation in real-life nZEB buildings. It is also possible to compare some of the

Figure 1. House A (to the left) and House B (to the right).

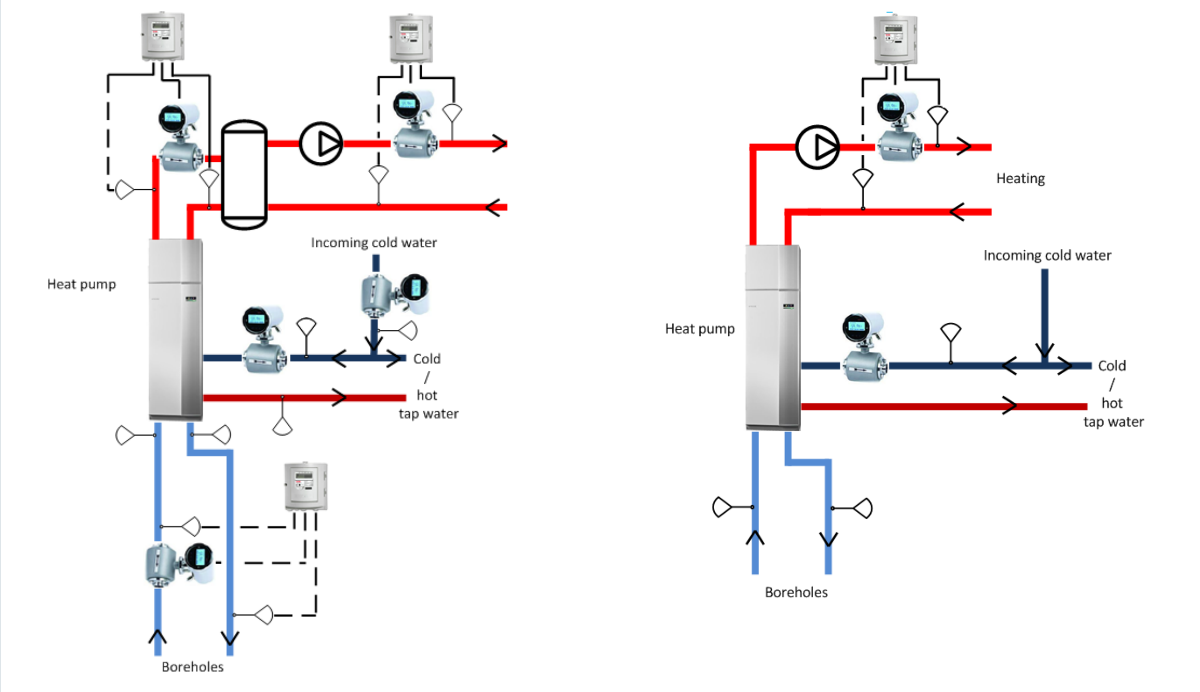

Figure 2. Schematics of the measurement equipment in the two heating systems. To the left, the system in house A with an on/off heat pump and an extra storage tank is shown. On the right, the system in house B with the inverter controlled heat pump is shown.

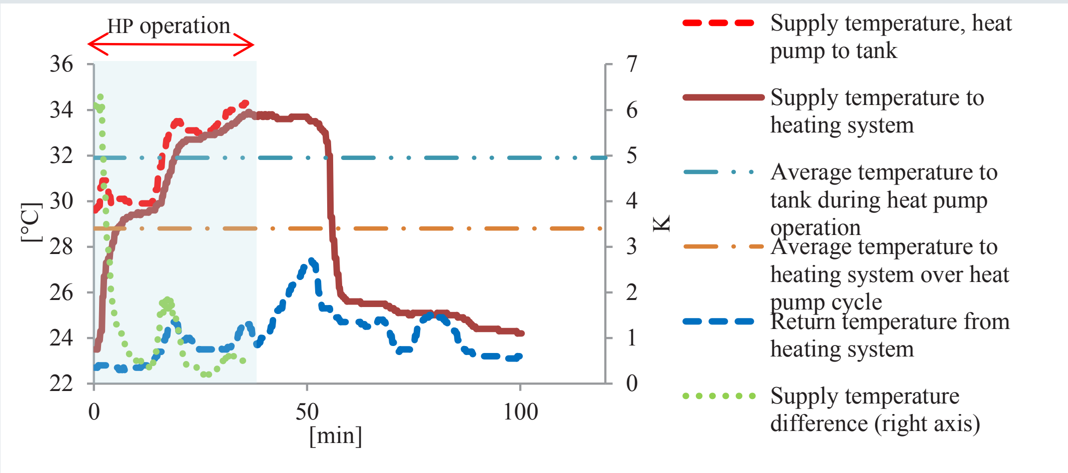

Figure 3. Supply (and return) temperatures to the tank and to the heating system during an on-off cycle in villa A during a period with an outdoor temperature of 2 °C.

results with the parameters for testing heat pumps, as determined in the standard EN14825, which is the standard that the Eco-design and Energy label regulations for heat pumps refer to.

As can be seen in Figure 2, in house A, an accumulation tank is introduced into the system to increase the cycle time of the heat pump, and it is investigated how the operating parameters are affected. This is also relevant for testing the behaviour of the heat pump for future smart grid integration. Results show that the on/off heat pump on average operates with at 1.0-1.5 K higher condensation temperature due to the extra storage tank. In addition, there is an efficiency loss due to the fact that the heat pump is operating on/off, not continuously. Both the on/off control and the tank result in a temperature increase of more than 3 K, representing an efficiency loss of around 8 %.

The brine temperature is also of great importance for the efficiency of the heat pump. In EN 14825 heat pumps are tested at an inlet temperature of 0 °C and, as can

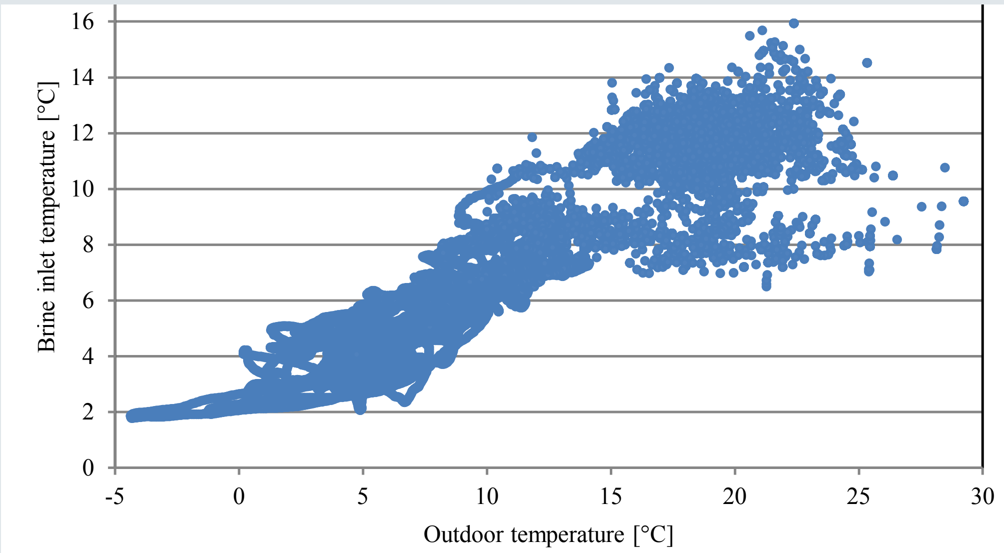

Figure 4. Brine inlet temperatures during on-periods of the operation cycle in villa B as a function of daily averaged outdoor temperature. Data from March 2016 to February 2017.

be seen in Figure 4, such a low temperature was never measured during the whole year. These results suggest that the standard should be revised.

The results indicate that, for nZEB houses, the heating curves of the standard EN14825 coincide well with the measurements except for occasions with low heating demand in House B. The reason is probably that the heat pump system has a variable liquid flow operation and the heating curve of the standard assumes constant liquid flow.

Another finding from the project relates to the control of the heating system. In both houses, the floor heating system is separate in the sense that it has its own thermostats. There is a lack of communication between that system and the heat pump system, causing some problems with temperature regulation. Hence, the efficiency of the heating system is not as good as it could have been with a better control strategy.

In the future part of the project the researchers will investigate how the heat pump should be optimized in an nZEB concerning space heating versus DHW production. Since the heating demand is so low, the ratio between heating and DHW differs from that of an older house. In order to obtain an ideally performing heat pump, this ratio needs to be investigated. Finally, the research team will look into how the operating parameters are affected if the heat pump system is integrated with a ventilation and heat recovery system, and how such integration could be done.

Conclusions

This project has made it possible to relate the preconditions stated for testing heat pumps in the EN14825 standard with real-life conditions. The actual brine temperature to the system is higher than the temperatures stated in the standard. Since the testing temperatures are crucial in determining the SCOP for a heat pump, these results suggest that the standard should be revised. It is important to notice, though, that further real-life testing is needed in order to draw a final conclusion.

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Events 2017

16 November
RHC-ETIP, DG ETIP and DHC+ brokerage event on the H2020 Energy Work Programme 2018-2020
Brussels, Belgium
http://www.rhc-platform.org/singleview/article/rhc-etip-and-dhc-brokerage-event-on-the-h2020-energy-work-programme-2018-2020/?tx_ttnews%5BbackPid%5D=7&cHash=1aab452454316f570066acc7bc1ed9c6

11-12 December
EUREKA 2017
Berlin, Germany
https://www.eureka-hvacr.eu/

Events 2018

20-24 January
ASHRAE Winter Conference
Chicago, Illinois, USA
https://www.ashrae.org/membership--conferences/conferences/2018-ashrae-winter-conference

12-15 March
Cold Climate HVAC 2018 - The 9th International Cold Climate Conference Sustainable new and renovated buildings in cold climates
Kiruna, Sweden
http://www.cchvac2018.se/

6-8 April
5th IIR Conference on Sustainability and the Cold Chain
Beijing, China
http://iccc2018.medmeeting.org/en

25-28 April
14th International Energy Storage Conference – EnerSTOCK2018
Adana, Turkey
http://www.enerstock2018.org/

10-13 June
The 9th Asian Conference on Refrigeration and Air-conditioning
Sapporo, Japan
http://www.acra2018.org/

18-20 June
13th IIR Gustav Lorentzen Conference on Natural Refrigerants
Valencia, Spain
http://www.gl2018.upv.es/

23-27 June
ASHRAE Annual Conference
Houston, Texas, USA
https://www.ashrae.org/membership--conferences/conferences/2018-ashrae-annual-conference

9-12 July
2018 Purdue Compressor/Refrigeration and Air Conditioning and High Performance Buildings Conferences and Short Courses
West Lafayette, Indiana, USA
https://engineering.purdue.edu/Herrick/conferences

27-28 July
International Conference on Emerging Technologies for Sustainable and Intelligent HVAC&R Systems
India
http://iifiir.org/clientBookline/recherche/NoticesDetaillees.asp?VIEWALL=TRUE&ToutVisualiser=1&INSTANCE=EXPLOITATION&iNotice=7&ldebut=

2-5 September
1st IIR International Conference on the Application of HFO Refrigerants
Birmingham, United Kingdom
http://www.hfo2018.com

23-26 September
7th International Building Physics Conference
Syracuse, New York, USA
http://ibpc2018.org/

4-5 October
The Third International Conference on Efficient Building Design — Materials and HVAC Equipment Technologies
Beirut, Lebanon
https://www.ashrae.org/membership--conferences/conferences/ashrae-conferences/third-international-conference-on-efficient-building-design

16-18 October
Chillventa 2018
Nuremberg, Germany
https://www.chillventa.de/en

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

Vision
The HPT TCP is the foremost worldwide source of independent information and expertise on environmental and energy conservation benefits of heat pumping technologies (including refrigeration and air conditioning). The HPT TCP conducts high value international collaborative activities to improve energy efficiency and minimise adverse environmental impact.

Mission
The HPT TCP strives to achieve widespread deployment of appropriate high quality heat pumping technologies to obtain energy conservation and environmental benefits from these technologies. It serves policy makers, national and international energy and environmental agencies, utilities, manufacturers, designers and researchers.

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

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