ISSN 1307-3729

REHVA

Federation of European Heating, Ventilation and Air Conditioning Associations

The REHVA European HVAC Journal

Volume: 58 Issue: 4 August 2021 www.rehva.eu

Heat Pump Special

EU Green Deal – Fit for 55 by 2030

A Paradigm Shift on Ventilation

The REHVA European HVAC Journal

www.rehva.eu

Volume: 58 Issue: 4 August 2021

Editor-in-Chief: Jaap Hogeling
jh@rehva.eu

Associate Editor: Stefano Corgnati, Italy
stefano.corgnati@polito.it

Editorial Assistant: Alexandre Dziergwa,
adz@rehva.eu

General Executive: Ismail Ceyhan, Turkey

ADVERTISEMENTS
Nicoll Marucciová, nm@rehva.eu

SUBSCRIPTIONS and CHANGES OF ADDRESSES
REHVA OFFICE:
Washington Street 40
1050 Brussels, Belgium
Tel: +32-2-5141171
info@rehva.eu, www.rehva.eu

PUBLISHER
TEKNİK SEKTÖR YAYINCILIĞI A.Ş.
Barbaros Mahallesi, Uğur Sk. No: 2/2
Üsküdar/İstanbul, Turkey

Contents

Download the articles from **www.rehva.eu** -> REHVA Journal

Advertisers

Next issue of REHVA Journal

Instructions for authors are available at **www.rehva.eu** (> Publications & Resources > Journal Information). Send the manuscripts of articles for the journal to Jaap Hogeling **jh@rehva.eu**.

European Green Deal: Fit for 55 by 2030!

The European Commission adopted a package of proposals to make the EU's climate, energy, land use, transport and taxation **policies fit for reducing net greenhouse gas emissions by at least 55% by 2030**, compared to 1990 levels. Achieving these emission reductions in the next decade is crucial to Europe becoming the world's first climate-neutral continent by 2050 and making the European Green Deal (https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en) a reality. With these proposals, the Commission is presenting the legislative tools to **deliver on the targets agreed in the European Climate Law** and fundamentally transform our economy and society for a fair, green and prosperous future. (see article of Jasper Vermaut, REHVA, page 63).

EU Commissioner for energy Kadri Simson said:

The revision of the Renewable Energy Directive is a key part of today's package, which outlines how we intend to **reduce emissions by 55% by 2030**. By 2050, most of our energy has to come from renewable sources. Planning and building energy infrastructure takes time, so to get to net zero by mid-century, we need an unprecedented transformation during this decade already.

The steady renewables evolution of recent years and decades must become a revolution. Renewable electricity is by now the cheapest option in many places. And often, it's European companies and European technology providing that green power. By pushing our 2030 renewables target to 40%, we are not only promoting cleaner and cheaper energy production, we are also boosting an economic sector with remarkable potential to create jobs, growth and trade.

Today's proposal is looking to further accelerate the rise of renewables, providing additional incentives for improvement where progress is slow, such as in buildings or transport, but also introducing greater flexibility in our energy system which will serve to facilitate new technologies, such as renewable hydrogen, and the smooth integration of offshore renewables into the grid.

Focus on Heat Pump technology

After renovating our building stock to reduce the heating and cooling demand applying Heat Pump technology to heat (space and DHW) and cool our buildings is the most logic step. For new buildings: NZEB, zero carbon and positive energy buildings are feasible, even in those cases the use of HP's will play an important role. For sure these investments are assuming that towards 2050 our electricity grids will be to a great extent decarbonised. This RJ issue includes several articles on Heat Pump technology, in the first article we explain the complexity around standards on HP technology.

A Paradigm Shift

As the COVID-19 pandemic is still on the frontpages we also included an article with the title: *"A Paradigm Shift, are technical systems for ventilation important for public health? Or are they primarily designed to create comfort for occupants? What are the objectives and what are the means?"*. Given the nature of this article and the intention to generate a feedback and dispute based on this article, your editor has with some help added some footnotes to stimulate reactions. In this context it is important to know that the REHVA TRC installed a Task Force "IEQ requirements – input for revising EN 16798-1", illustrating the interest of REHVA in addressing IEQ. ■

JAAP HOGELING
Editor-in-Chief
REHVA Journal

Heat pumps: *lost in standards…*

The different EU directives and regulations have been and are the main driver for the development of CEN standards on Heat Pumps, from basic product standards towards system standards.

Keywords: EU Directives, Regulations, Heat pump standards, CEN

LAURENT SOCAL
Consultant
socal@iol.it

Introduction

EU is pushing energy conservation and emissions reduction with a set of directives, which already underwent amendments and recast.

EPBD, Energy performance of Buildings Directive, targets efficiency in buildings and related technical systems. The objective is making any building habitable to a standard comfort level using the least possible amount of non-renewable primary energy and/or greenhouse gas emissions. Minimum requirements and building labels are based on the actual building description with the standard climate of the actual location and a standard use. This directive includes both minimum requirements and a display mode (the EPCs) to make users aware of energy performance.

ErP and Ecolabeling directives[**1**] target efficiency of products. They extend minimum requirements to access EU market to the energy efficiency of products. The objective is having only efficient products on the market. Ecodesign EU regulations define what are "efficient products" and "Ecolabeling" regulations define how to display the efficiency level of products so that consumers can recognise their added value. Minimum requirements of products are based on their behaviour in a standardised average condition of use.

The Energy Efficiency Directive, targets the total final uses of energy of EU countries. Since comfort in buildings and products are already subject to specific directives, it complements with requirements to other energy consuming sectors, such as industry, by e.g. compulsory energy audits.

After energy use has been reduced, **RES, Renewable Energy Sources, Directive** asks to cover the energy use with renewable resources, so that we will not deplete non-renewable sources and energy will be always available in the future.

All these directives aim to the same goal. However, they were developed in parallel and the coordination between them is not perfect. There are some overlaps and the groups of people and stakeholders interested in each directive are not the same and they do not always coordinate optimally. Currently, there is an effort to make them consistent to cover rationally the entire topic of energy use in Europe.

The need for coordination is also emerging in the supporting EN standards for directives EPBD and ERP.

EPBD and ErP share the same starting point, the products, and in both cases you need a calculation based on product properties but the approach is quite different.

ErP directive approach

The intent of ErP directive is to ban inefficient products from the EU common market. Ecodesign sets minimum requirements on products and Ecolabeling displays products efficiency to encourage EU citizens to select and buy the best performing ones. This is fine for "off the shelf" products, where the citizen is alone in making the decision of which product to buy and then use.

To apply ErP directive, you have to define a method, based on product tests and some calculations, to determine the "efficiency" of each product and label it. EU regulations have been issued for "lots" of products: they define the testing conditions and the calculation method to simulate an average use of the product and rate the product efficiency as a stand-alone item.

To have a fair rating, it shall be based on a representative mix of operating conditions. Obviously, this shall be the same for all products and provide one single rating figure for the product. For the testing and/or calculation method, EU regulations may refer to "harmonised" EN standards. In that case, the so called "annex Z" defines how to use the harmonised EN standard for EU regulation compliance purpose. ErP application is strictly the same all across Europe since it's a common market issue and part of the CE marking.

ErP compliance is a key concern of manufacturers. They have to achieve a minimum rating to be able to sell the products (that's a survival issue for them!) and possibly a good rating to sell many products.

Table 1. *Overview of CEN standards on heat pumps.*

Context	Standard	
Basic product standard	EN 14511	Air conditioners, liquid chilling packages and heat pumps for space heating and cooling and process chillers, with electrically driven compressors Part 1: Terms and definitions Part 2: Test conditions Part 3: Test methods Part 4: Requirements
	EN 16247	Heat pumps with electrically driven compressors - Testing, performance rating and requirements for marking of domestic hot water units
	EN 15879	Testing and rating of direct exchange ground coupled heat pumps with electrically driven compressors for space heating and/or cooling – Part 1: Direct exchange-to-water heat pumps Part 2: Water(brine)-to-direct exchange and direct exchange-to-direct exchange heat pumps (draft)
	EN 12309	Gas-fired sorption appliances for heating and/or cooling with a net heat input not exceeding 70 kW Part 1: Terms and definitions (under review) Part 2: Safety Part 3: Test conditions Part 4: Test methods Part 5: Requirements Part 7: Specific provisions for hybrid appliances
	EN 16905	Gas-fired endothermic engine driven heat pumps Part 1: Terms and definitions Part 2: Safety (under review) Part 3: Test conditions Part 4: Test methods (under review)
EPBD application	EN 15346-4-2	Energy performance of buildings - Method for calculation of system energy requirements and system efficiencies Part 4-2: Space heating generation systems, heat pump systems, Module M3-8-2, M8-8-2
ErP (Ecodesign) and Ecolabeling	EN 14825	Air conditioners, liquid chilling packages and heat pumps, with electrically driven compressors, for space heating and cooling, commercial and process cooling - Testing and rating at part load conditions and calculation of seasonal performance
	EN 16247	Heat pumps with electrically driven compressors - Testing, performance rating and requirements for marking of domestic hot water units
	EN 12309	Gas-fired sorption appliances for heating and/or cooling with a net heat input not exceeding 70 kW Part 6: Calculation of seasonal performances
	EN 16905	Gas-fired endothermic engine driven heat pumps Part 5: Calculation of seasonal performances in heating and cooling mode
System design	EN 15450	Heating systems in buildings - Design of heat pump heating systems

EPBD directive approach

The intent of EPBD directive is:

- to have only efficient new buildings, hence all new buildings shall be NZEB;
- to push efficient renovation of existing buildings, hence requirements when renovating envelope and/ or technical systems;
- to increase the market value of efficient buildings, hence provide an EPC before selling and renting.

A calculation method of the "energy performance of the building" is required. This has to take into account the performance of the products incorporated in the building and its technical systems in the specific operating conditions required by the building, system set and climate. EPBD directive does not specify the calculation method, it only requires that a number of features are taken into account and that the actual method enforced by the MSs be described in terms of equivalent options of the EN overarching standards. A full set of EN standards has been developed indeed, to support a uniform EPBD directive application throughout EU, i.e. to calculate the energy performance of the building.

EPBD compliance and rating is a key concern of building owners and building designers.

Heat pump technology

The "generation sub-system" is that part of the technical systems that uses an energy carrier delivered from outside the building (i.e "delivered energy) to provide the type of energy that you need inside the building (e.g. heat, heat extraction, light). The most obvious example is a combustion boiler that converts the chemical energy of the delivered fuel into heat. Likewise, a lamp is a "light generator" as well as a fan is an "air flow rate generator".

In the last decades the market of heating generators for buildings has been dominated by combustion boilers. It's a mature product, simple, easy to use, powerful, cheap per kW. There are other alternative generation techniques but they are limited in availability (example: district heating), complicated to use at building level (cogeneration, which requires simultaneous electrical and thermal loads) or unable to provide a full year-round service (thermal solar). Of course, you may find exceptions but have a look around you and you will see quite few popular alternatives.

Heat pump technology has been always used for cooling but now there is a strong push for its massive use for heating, as well. Well insulated buildings and low temperature emitters allow to overcome the inherent limitations of this technology which are the still high cost per kW installed, the need for a source of free heat and the drop in efficiency when asking for a high temperature difference between the source and the sink (the heated object).

It's no doubt that taking heat from a cold source where it can be extracted for free and pumping it into the heated fluid (or directly into the heated space) can be a much more efficient process than obtaining the same amount of heat by converting an equivalent amount of chemical energy in a combustion boiler. This makes heat pump technology a serious competitor menacing the boiler supremacy.

"Heat pump" is a wide and complex world:

- there are several heat pumping technologies: the most popular is gas compression cycle driven by an electric motor (internal combustion engines are used as well), then there is absorption, adsorption, Peltier cells, … even a thermocouple could be used;

- there are several types of heat sources being used:
  - air, probably the most available and used but it makes the performance of the heat pump strongly dependent on climate conditions;
  - ground, makes it less dependent on climatic conditions but needs an extensive and expensive heat exchanger (vertical bore hole or horizontal network);
  - ground water, needs pumping energy;
  - surface water, only where available;

- there are several heat sinks in use
  - indoor air;
  - technical water, e.g. water circulating in the system;
  - domestic hot water, for domestic hot water heaters;

- the main energy carrier can be electricity, a fuel, waste heat…

and then the heat pump can be single stage, staged, modulating, splitted, etc.

No surprise if it takes some time to "normalise" this multi-faceted world.

Heat pump performance

The performance of a heat pump is extremely sensitive to operating conditions. A typical heat pump may have a COP from 2 to 6 within the winter operating range. The dependency of efficiency on operating conditions is typically non-linear and there are several factors to take into account:

- source and sink temperatures: one single degree less or more in temperature difference between sink and source means 2…3% change in efficiency;
- part load operation;
- defrosting cycles, when outdoor air is used as a source.

This makes it difficult to represent accurately the whole performance map with only few test points.

An example of the dependency of COP and maximum power output on source and sink temperature is given in figures 1 and 2, that refer to an air to water heat pump. **Figure 1** shows the wide range of the COP and its dependency on both source and sink temperature. **Figure 2** shows the dependency of maximum output power on the evaporator (source) temperature. Recent inverter heat pumps have limitations in output power at high external temperature because it is unlikely that a high power be required in these conditions.

An example of the potential effect of part load (at constant source and sink temperature) is shown in **Figure 3** which shows some correction curves of full load efficiency that are adopted in several standards. For inverter heat pumps you may expect some increase of the COP with a moderate part load, up to a maximum, and then the COP decreases significantly with intermittent operation. When the part load goes below 20% the correction is quite significant. Often this happens for low loads so it is somewhat masked. Furthermore, a heat storage may help reducing this issue.

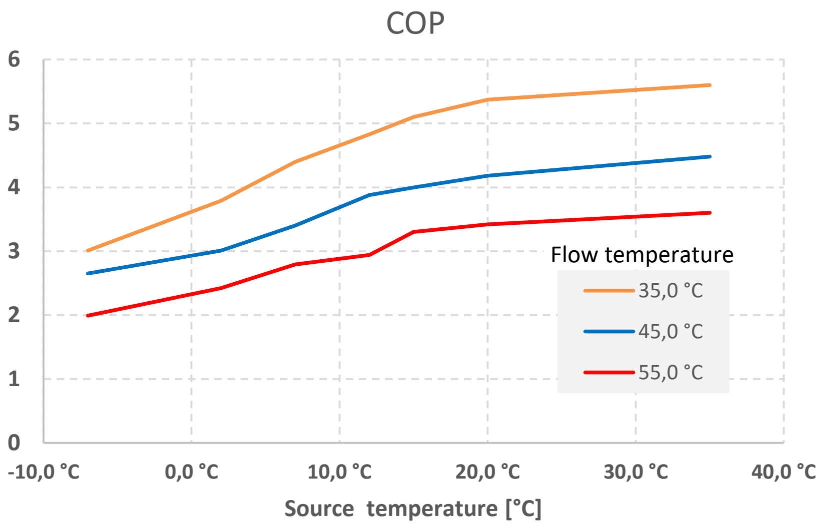


Figure 1. Typical AW heat pump COP.

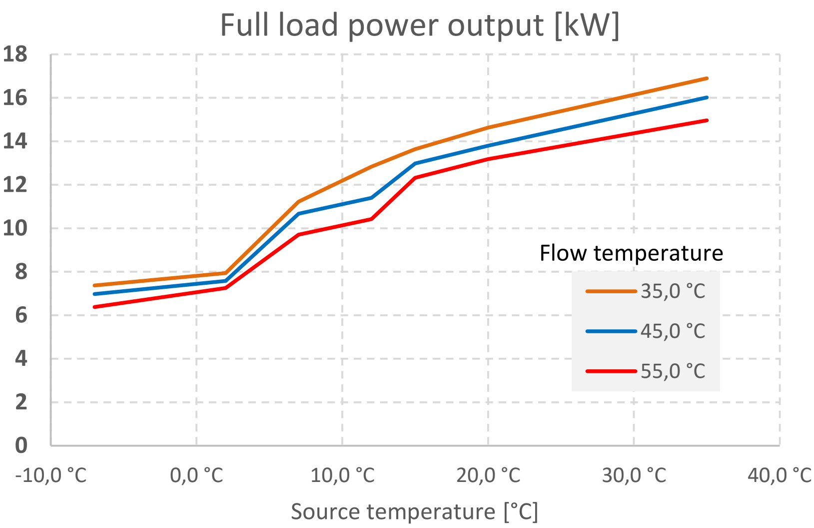


Figure 2. Typical AW heat pump maximum output.

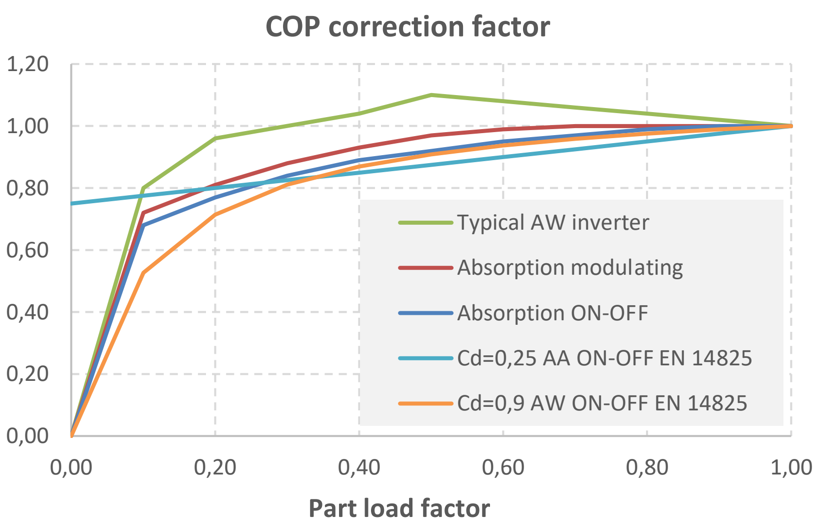


Figure 3. Typical part load correction factors of COP.

For ON-OFF heat pumps, each start-up means that the compressor has to pressurise again the condenser and when stopping the pressure will be equalised and some work done by the compressor is wasted.

For modulating and staged heat pumps, some part load can be beneficial for the compressor efficiency.

The COP depends on the pressure difference seen by the compressor, which in turn depend on condensation and evaporation temperatures. Performances of heat pumps are not displayed as condensation and evaporation temperature but on air and/or water temperature.

Source temperature, for both air and water heat pumps, is the entering temperature in the evaporator. The evaporation temperature is lower due to the temperature drop of air or water across the evaporator (typically 5…7°C), plus the approach of the evaporator. At low load the approach is reduced and this increases the COP. The temperature drop of air or water is reduced as well but this is true only if their flow rate is maintained, which means increased relative auxiliary energy use and noise.

When using water, the sink temperature is the leaving water temperature. The difference with condensation temperature is only given by the approach of the condenser, which is usually 2…3 degrees. The effect of part load is small here. When using air, the sink temperature is the inlet temperature to the condenser. To get to the condensing temperature you have to add both the temperature increase of the heated air and the approach of the condenser. In this case part-load is very beneficial because both the heated air temperature increase is reduced and the approach. However, this is really true only if the air flow rate across the condenser is kept constant when modulating down. To get a quieter operation, the condenser fan speed is often reduced at low load and the increase in air temperature may stay constant. In other words, you may trade-off between comfort (quiet operation) and efficiency (fan at full speed, which means draft in the heated space). This should be taken into account when dealing with part load efficiency of air-to-air heat pumps.

Since part load operation is a concern, the conventional way to express operating conditions when declaring performance data of heat pump, such as A7W35 should be extended to include the information on part load factor during the test, with any of following: $A7W35_{100}$, $A7W35_{50}$, $A7W35_{FL}$, $A7W35_{MIN}$…

Even part load definition is tricky with heat pumps. Since the maximum power output strongly depends on operating conditions it should be the ratio between actual output power and maximum output power for the same source and sink temperature (maximum compressor speed). Sometimes the maximum compressor speed is limited electronically depending on source and sink temperature for a number of good reasons. In that case the apparent maximum output is already a part load. This should be taken into account as well.

EN Standards on heat pumps

EN 14511

The basic product standard on heat pumps is EN 14511. It deals with electric heat pumps and it defines the testing procedures and a set of testing points depending on the type of source and sink. The first published version dates back to 2004.

Product tests concern the maximum power output (heating capacity) and COP at full load depending on the source and sink temperature. There is no specific testing for part load operation mentioned in EN 14511.

EN 14825

EN 14825 is intended to support the application of Eco-design and Ecolabeling directive. It provides a method to calculate a "seasonal" performance (SCOP and SEER) with an assumed operating condition. It complements EN 14511 in defining part load test conditions suitable to provide the data for the calculation of the SCOP and SEER.

The $SCOP_{ON}$ is a weighted average of the part load COP measured for 4 operating conditions, labelled A to D, plus an extra point G for cold climate. Then other components of auxiliary energy (stan-by, crankcase heating,…) are taken into account to get $SCOP_{NET}$.

The weighting factors are given by a simulated bin calculation assuming that the required power output increases linearly from design power P_{des} at the design outdoor temperature (T_{des} = −22°C, −10°C and +2°C depending on the reference climate) to zero at 16°C external temperature. For each bin, the COP is determined by linear interpolation according to external temperature between the values of COP measured at conditions A, B, C and D and possibly point E.

The test conditions are tailored for the purpose and expressed as special variants to test conditions defined by EN 14511 which is still the basic test standard. If the heat pump should cycle on-off in a given test point (single stage machines or power request below minimum modulation), then the test is performed indeed at the minimum capacity and then the result is corrected by a given function with a default correction parameter Cd. The manufacturer may provide a tested value of the correction parameter.

The procedure makes sense to test and label a product. A simple linear model is used to simulate the heating demand and it is assumed that all conditions vary linearly between the 4 tested points.

It shall be noted that the weighting can be somewhat "optimised" by the manufacturer: by declaring a bivalent temperature $T_{BIV} < T_{DES}$, an electric heater is taken into account to compensate for the missing energy in the colder bins but the part load factor in conditions B, C and D improves and may compensate the loss at A (or G).

It has to be noted that in the 4 (or 5) tests all the operating conditions are varying simultaneously: source temperature, sink temperature and required power output. Sink temperature is kept constant for fixed flow temperature units, which are quite an exception.

A point of attention when reading EN 14825 is the difference between PLR (part load ratio) and CR (capacity ratio).

The PLR (part load ratio) is a descriptor of the load model: it is the ratio between the load at a given outdoor temperature and the load at design temperature. The range is 0 to 1 and the value is the same for all heat pumps at a given test point and temperature.

The CR (capacity ratio) is a descriptor of the heat pump loading: it is the ratio between the load at a given outdoor temperature and the maximum capacity of the heat pump at that given outdoor temperature. It is not the same as PLR because the maximum capacity of the heat pump $\Phi_{hp;out;max}$ depends on the temperature (see **Figure 5**).

Then the IR (intermittency ratio) should be introduced to complete the description of the behaviour of modulating heat pumps. As the required output power decreases, it will drop below the minimum continuous operation capacity of the heat pump. Then, the heat pump will start to cycle ON-OFF, ideally at the minimum power. The IR should be defined as the ratio between the load at a given outdoor temperature and the minimum continuous operation capacity of the heat pump at that given outdoor temperature. If we call CR_{min} the value of CR, then $IR = CR/CR_{min}$.

For a single stage heat pump, the minimum capacity is the same as the maximum, hence IR = CR.

For a modulating heat pump, IR = 1 (continuous operation) until $CR > CR_{min}$ and then $IR = CR/CR_{min}$.

EN 14825:2018 fails to identify explicitly IR, which is essential for the correct application of the degradation coefficient to modulating heat pumps.

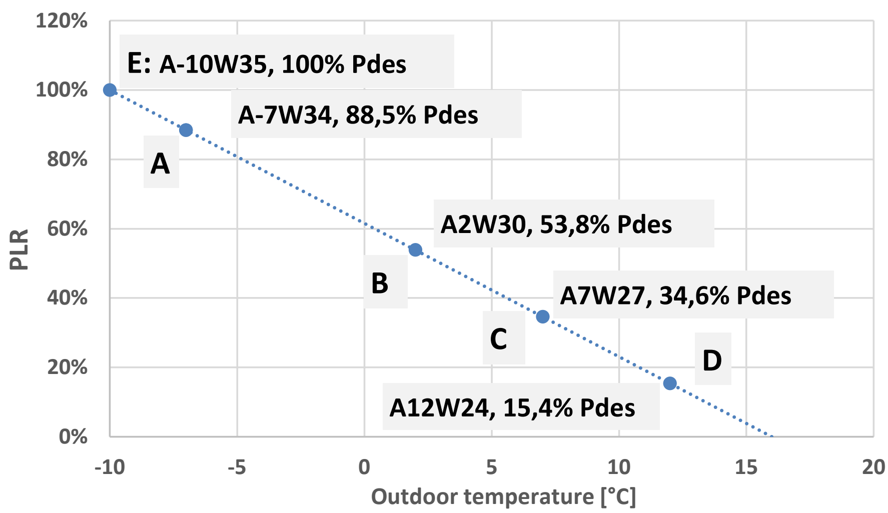


Figure 4. Diagram with test conditions for AW heat pumps.

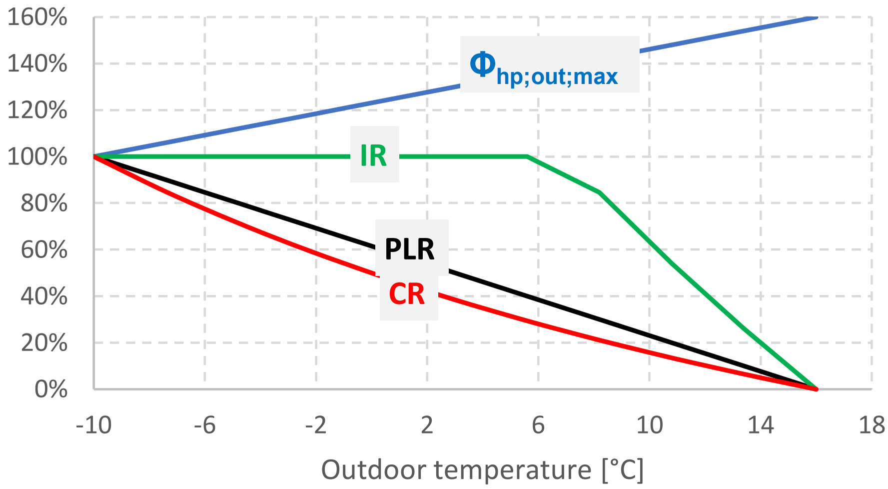


Figure 5. Relationship between PLR, IR and CR for a modulating heat pump.

EN 15316-4-2

EN 15316-4-2 is part of the CEN-EPB package of standards. This package was first drafted according to a mandate of the EU Commission in 2006 to support the implementation of EPBD directive. The first published version dates back to 2008.

The aim of this standard is to assess the energy performance of the heat pump taking into account the operating conditions according to the actual building needs, technical system configuration and control options.

For each calculation interval, which can be monthly, hourly or bin, the other modules of the calculation determine the required power output and flow temperature. EN 15316-4-2 module has to determine:

- if the heat pump can fulfil the whole load or only part of it;
- the required energy input, main for compressor, auxiliary and integrated back-up.

The new draft of this standard [**2**] has a common calculation frame which allows to select one of two calculation paths depending on the type of heat pump and the available data to take fully into account all relevant operating conditions.

When using the so called "path A", first the full load COP and available output power are determined according to EN 14511 test data (or other relevant product data like EN 12309 and EN 16905). Then a part load correction factor is applied to full load COP to take into account the actual part load operation CR in the calculation interval. The difficulty is that there several ways available to do that, also depending on the heat pump type. The underlying assumption is that the correction factor or method doesn't depend on the sink and source temperature. Some examples of correction factors are given in **Figure 4**.

The intent of the so called "path B" is to leverage test data measured according to EN 14825. The difficulty is that the 4 measuring points have been selected based on an assumed linear load pattern and all influence variables are changing from one test point to another. It is therefore impossible to extract the influence of only one parameter from EN 14825 data set. To overcome this difficulty, this calculation path assumes that the II principle efficiency [**3**] of the heat pump be a function only of the required output power. This correlation is extracted once for all from the test data according to EN 14825. So the procedure is: calculate II principle efficiency dependency on the required output power, then calculate COP based on source and sink temperature. One limitation is that data on the maximum output power is available only for on-off heat pumps. For modulating heat pumps it is assumed that the maximum power is that at TOL. The increase in available power is not taken into account. This makes it difficult to handle situations with multiple generators, where one has to determine the contribution of each one based on their capacity.

Another limitation of path B is that no specific data is given for the domestic hot water production.

The two calculation paths coexist and there is an ongoing discussion about their use.

Figure 6 shows a calculated distribution of COP as a function of outdoor temperature for a correctly sized heat pump (continuous operation). The effect of part load is quite visible for the higher temperatures where the load is reduced.

However, only little energy is supplied in the range where the part load correction factor drops dramatically. **Figure 7** shows the distribution of energy output according to the part load correction factor, for the same calculation: only 10% of the energy is supplied

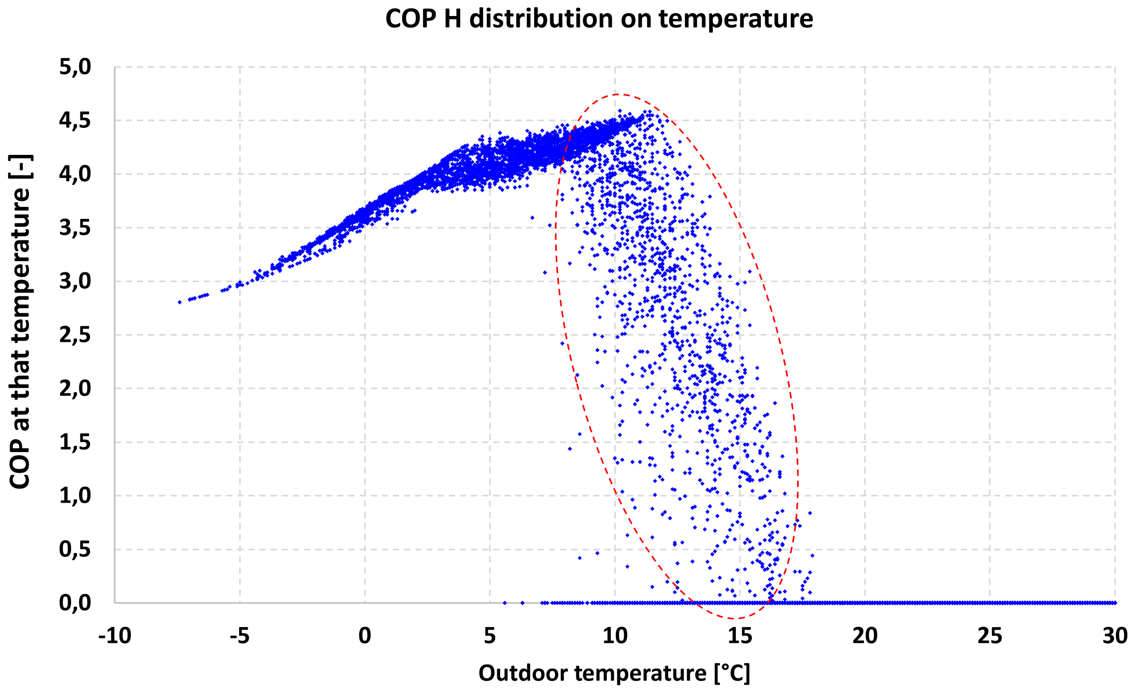


Figure 6. Sample COP as a function of outdoor temperature.

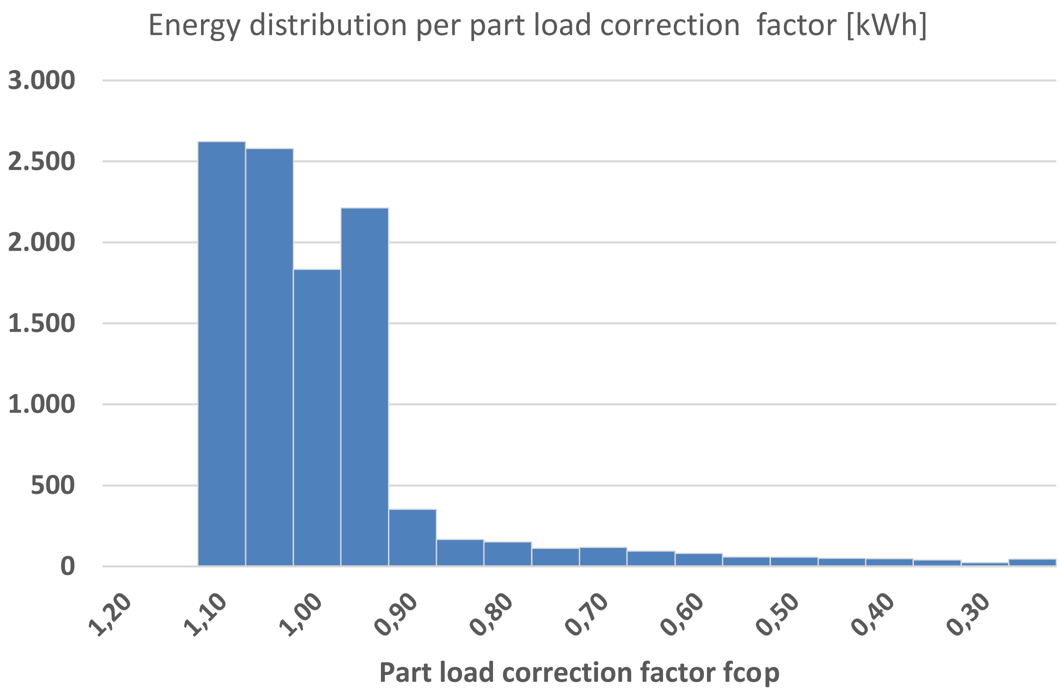


Figure 7. Distribution of supplied energy according to part load correction factor.

with a correction factor which is less than 0,85. So, the main influencing factors are still the source and sink temperatures except for badly oversized heat pumps. This is another reason to size them tight.

To identify correctly heat pump performance, some more product data will be required. In principle, to be able to isolate the influence of each parameter, only one of them should change from one test point to another one. This is already the case for data according to EN 14511, where source and sink temperature change one at a time in a set of values. A series of test at several CR for one condition of source and sink temperature may suffice to identify the COP correction factor.

A suggestion can be to test a modulating heat pump at:

- CR= 1, this is already done according to EN 14511
- CR = 0,6, this is a likely point of maximum increase of COP for AW inverter type heat pumps and indeed nearly half-way to minimum compressor speed.
- CR=CR_{min} at minimum compressor speed, so that it is defined and then intermittency

For constant speed (ON-OFF) heat pump, part load effect is always decreasing the efficiency. The CD and CC equations are used in this case. It should be noted that an appropriate storage volume may reduce the effect of intermittent operation by limiting the number of on off-cycles. This is not yet mentioned in the current standards.

Domestic hot water

EN 16247 establishes test methods and calculation for heat pump domestic hot water heaters.

Modelling is simpler here because the only variable is outdoor temperature.

The heat pump providing heating can also be used to heat a domestic hot water store. This requires extra data that are not included in the standard: operation as a heat pump with outdoor temperature up to 35°C at least. An extrapolation of data from 12 to 35°C is not likely to be very accurate. This range of outdoor temperature should be used when a heat pump is intended for domestic hot water use.

Absorption and combustion engine driven heat pumps

There are two specific standards dealing with these typologies: EN 12309 and EN 16905.

These standards were developed after EN 14511 and EN 14825. So, they already cover all the issues of the basic EN 14511 and EN 14825, e.g. providing test data and a method to rate the product.

Design of heat pump systems.

EN 14150 complements EN 12828 with special provisions for the design of heat pumps systems. This standard is currently under revision.

Conclusion

Standardisation on heat pumps is far from complete. Heat pumps are both subject to Ecodesign and a key product for EPBD purpose.

The focus of the standardisation effort has been on ErP in the last years, since this is an obvious top priority for manufacturers. The focus has been on specific products, one at a time as they were included in lots and in a simple well defined operating condition.

EPBD supporting standards have a much wider scope. They have to deal with any product on the field and they have to describe all operating conditions, even the wrong ones. Actually, it is a must because the reliable demonstration of the potential gains with new products or improved operating conditions is needed to support recommendations in general and within an EPC. ■

References

[1] DIRECTIVE 2009/125/EC of 21 October 2009, establishing a framework for the setting of ecodesign requirements for energy-related products; COMMISSION REGULATION (EU) 2016/2281 of 30 November 2016 implementing Directive 2009/125/EC establishing a framework for the setting of ecodesign requirements for energy-related products, with regard to ecodesign requirements for air heating products, cooling products, high temperature process chillers and fan coil units

[2] The enquiry of this new prEN 15316-4-2 : 2021 is expected in a few months

[3] The "II principle efficiency" of a heat pump is the ratio between it's COP in a given operating condition and the maximum theoretical COP with the same source and sink temperature.

Gas driven Absorption Heat Pumps in domestic heating

LORENZO PISTOCCHINI
lorenzo.pistocchini@polimi.it *

ANDREA STORONI
andrea.storoni@polimi.it *

TOMMASO TOPPI
tommaso.toppi@polimi.it *

MARIO MOTTA
mario.motta@polimi.it *

In the near future, Gas driven Absorption Heat Pumps could achieve relevant market penetration and play an important role in reducing CO_2 emissions from space heating and DHW production in existing residential buildings – where gas boiler is the leading technology – thanks to peculiar features and margins for cost and size reduction.

Keywords: Heat pump, domestic heating, absorption, energy efficiency, renewable energy, global warming mitigation

Introduction

Decarbonization of the building sector is clearly a top priority of national and international policies on climate change mitigation. According to the scientific community, even if we completely stop emitting greenhouse gases right now, global warming will continue to happen for at least several more decades [1–2]. Moreover, it is not possible to immediately switch to a zero-carbon energy system. Concerning the building sector and heating demand, a possible long-term strategy consists in one or a combination of the following measures, each one bringing its own issues:

- Green electricity and electrical heat pumps: national electricity grids have not yet the capacity, both in terms of power generation and distribution, to hold the load of a fully electrified heating sector [3–4];
- Energy efficient buildings: most of the stock of existing buildings in Europe has a high-temperature heat distribution system (radiators) [5]; furthermore, the building renovation rate is still very low: 1% on the average.
- Green or blue hydrogen replacing natural gas fuel: a switch to a hydrogen-based energy system, which implies H_2 production, storage, and distribution, requires large investments. Moreover, hydrogen is likely to supply the transport and the industrial sectors with a higher priority as compared to the building sector, making quite unlikely, in short and medium term, a scenario dominated by hydrogen fuelled boilers for domestic heating.

For these reasons, the Gas-driven Absorption Heat Pump (GdAHP) is presented in this paper as an alternative and viable heating technology that can contribute to the decarbonization of the building sector both in the medium and long term.

Potential of Gas-driven Absorption Heat Pumps in the EU

As pointed out in [6], GdAHPs can provide consistent CO_2 savings with respect to the condensing boiler and compete with both full electrical (EHP+AEH) and hybrid (EHP+CB) air-source electrical heat pumps. For example, focusing on the EU average and warm climate and considering primarily lightly renovated buildings, where the air-source electrical heat pump is the current replacement technology, CO_2 savings ($kgCO_2/y$) and relative variation compared to the condensing boiler are shown in **Table 1**.

*Department of Energy, Politecnico di Milano, Via La Masa 34, 20156 Milano, Italy

Considering the above results, two main considerations arise.

(1) In the medium term, Gas driven Absorption Heat Pumps (GdAHP) could play an important role in reducing the CO_2 emissions for space heating and domestic hot water production in existing buildings: they can replace gas boilers while exploiting the existing gas networks and operating efficiently, even with a high-temperature heat distribution system (radiators) and if air sourced.

(2) In the long term, thanks to the transition of European gas market towards bio-methane and hydrogen (as pure gases or mixed with fossil methane) [7–8], GdAHPs can benefit from the decreased carbon intensity of a cleaner gaseous fuel mix. The target of such policy is increasing the share of renewable energy, reducing emissions in the urban context, and exploiting these energy carriers as a seasonal storage of the summer over-production of renewable electricity, in an increasingly likely scenario of massive deployment of photovoltaics [9–10]. In this scenario, on the one hand GdAHPs will maintain its competitiveness in terms of CO_2 savings with respect to electrical heat pump, on the other hand they make a more efficient use of valuable and expensive gas mixtures with respect to gas boilers.

State of the art of Absorption technology in heating sector

Although absorption is a mature technology, its presence in the heating sector is still marginal, with mainly one manufacturer of ammonia-water heat pumps on the market. Such company has proven their feasibility and reliability by means of thousands of installations in the commercial sector.

Reliability is a precondition for the spreading of GdAHPs in the residential heating sector: considering ammonia /water absorption units, the ammonia sealed circuit must operate with no maintenance for thousands of hours per year, for at least ten years. On the other hand, the current market of GdAHPs does not have a suitable scale to boost their industrialization and the resulting cost reduction.

Ammonia has been inherently a further limit to such industrialization, as it requires steel components and rules out most of the available products in the field of refrigeration, which are either made of copper alloys, or have sizes suitable for large industrial plants. As a result, the heat exchangers of the ammonia circuit have been so far realized in-house by the few manufacturers engaged in the development of this technology.

To achieve a consistent market penetration and obtain the expected impact on CO_2 emissions, the challenge is to make air-source, ammonia-water, GdAHP a safe, compact, and cost-effective product.

Table 1. *CO_2 savings ($kgCO_2/y$) and relative variation compared to the condensing boiler for lightly renovated buildings in EU, source: [6].*

	Average climate		Warm climate	
EHP+AEH	1 337	(–44%)	1 678	(–58%)
EHP+CB	1 120	(–37%)	1 264	(–44%)
GdAHP	917	(–30%)	1 016	(–35%)

Small capacity Gas-driven Absorption Heat Pump

Aiming at demonstrating the possibility of overcoming such a challenge, a compact 8 kW-rated GdAHP prototype is under development at the Department of Energy of Politecnico di Milano.

Our project follows a specific path with the purpose of reducing heat pump cost and dimensions without penalising efficiency:

- Components must come from large series production, in particular the heat exchangers. This approach is made possible by a relatively recent development in the manufacturing process of plate heat exchangers (PHE), the fusion-bonding technology, which allows seamless assembly of 100% stainless steel PHEs
- Compact dimensions of the heat pump, which must be comparable to those of a standard domestic condensing boiler – 500 mm wide, 400 mm deep, 850 mm high – with ammonia charge well below 2 kg. Such small dimensions, and the choice of a configuration with indirect expansion – that is, with a remote air to brine heat exchanger – can allow the internal wall-hung installation of the GdAHP in small flats, greatly expanding its potential market.
- Variable refrigerant and ammonia-water solution valves are used to tune the GdAHP operation to the wide range of thermal loads and ambient conditions related to heating and DHW production, maximizing performances.

Some pictures, showing the main components and dimensions of the sealed circuit – which is the heart of the prototype – are shown in **Figure 1** (most of the valves and transducers installed on the prototype are related to the laboratory activity, and would not be present on a commercial product).

The compactness we could achieve is due to the wide use of PHEs and the special design of the generator and the solution pump, which are new developments.

The prototype has been tested in an accredited laboratory in compliance to standard EN 12309-6:2014 [11].

The main performance indicator resulting from the application of the Standard is the Gas Utilization Efficiency (GUE), which is the ratio between the effective heating capacity and the gas input, measured under specific working conditions, defined by the EN 12309-6:2014 and reported in **Table 2** for high temperature application and average climate. Based on the measured values of GUE, the Seasonal Gas Utilization Efficiency (SGUE), i.e., the weighted average value over the heating season of the GUE can be calculated. The measured GUE (based on the NCV) of the developed prototype over the five test conditions is reported in **Figure 2**, while the resulting SGUE is 1.58.

In the light of the reported results, some remarks can be made about the potential benefits of our prototype (and GdAHPs in general):

- Unlike existing GdAHPs on the market and some condensing boilers, the developed prototype can be partialized down to 15% of its rated power without compromising performance, thanks to the use of variable valves;
- Unlike compression heat pumps, performances remain high even at large temperature lifts;
- The high SGUE shows good prospective annual savings in terms of gas consumption and emissions compared to gas boilers, the technology that the GdAHPs aim to replace.

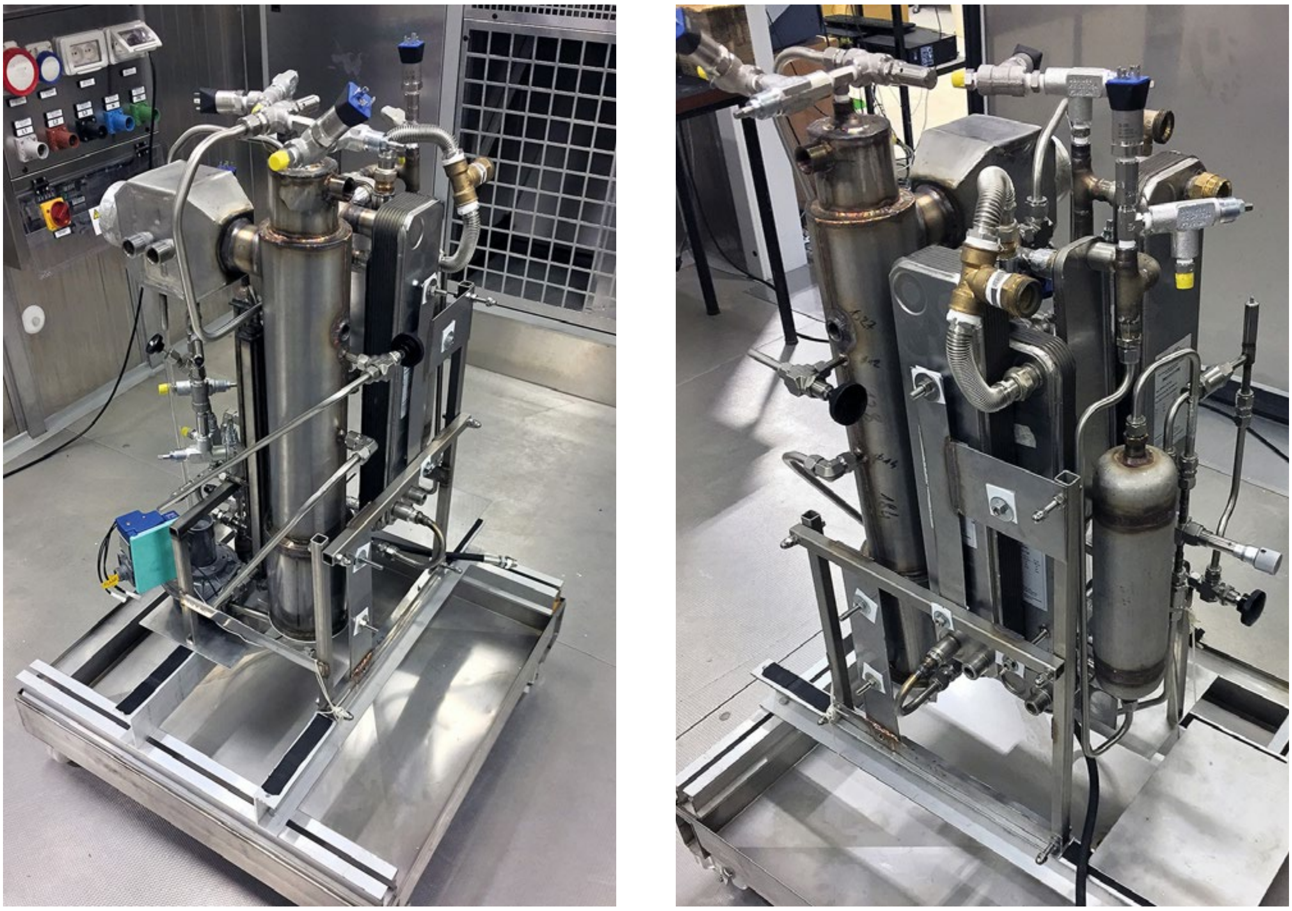


Figure 1. View of two sides of the GdAHP prototype, showing the assembly of components.

Table 2. Test conditions for the measurement of the GUE for the average climate and high temperature application.

Load	Heating capacity kW	Tair dry bulb °C	Tair wet bulb °C	Twater in °C	Twater out °C
100%	8.00	–10	–11	42	55
88%	7.04	–7	–8	40	52
54%	4.32	2	1	33	42
35%	2.80	7	6	29	36
15%	1.20	12	11	25	30

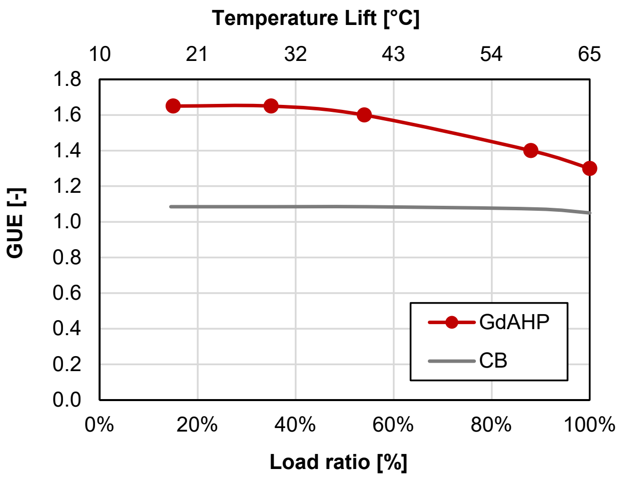


Figure 2. Measured values of GUE based on the conditions reported in Table 2 as function of the thermal lift and comparison with the corresponding efficiency of a condensing boiler.

Conclusions

Gas-driven Absorption Heat Pump is an alternative and viable heating technology that can contribute to the decarbonization of the building sector in the medium and long term. In principle, in the EU average and warm climate and in lightly renovated buildings, where the air-source electrical heat pump is the current replacement technology, GdAHPs can provide consistent CO_2 savings with respect to the condensing boiler and compete with both full electrical (EHP+AEH) and hybrid EHPs (EHP+CB).

However, more efforts are required to make GdAHPs safe, compact and cost-effective products, capable to occupy consistent market shares while achieving the expected impact on CO_2 emissions.

The prototype under development presents some distinguishing features that contribute to make GdAHPs viable for a large deployment in residential buildings:

- It uses stainless steel PHEs that can be manufactured in large series;
- Its dimensions, except for the external air heat exchanger, are comparable to those of a standard domestic condensing boiler – 500 mm wide, 400 mm deep, 850 mm high – and the ammonia charge is well below 2 kg;
- Its experimental performances are quite promising, with a calculated SGUE of 1.58, thanks to the use of variable valves that allow to optimize its operation over a wide range of thermal loads and ambient conditions. ■

References

[1] Peters GP, Andrew RM, Boden T, Canadell JG, Ciais P, Le Quéré C, Marland G, Raupach MR, Wilson C. The challenge to keep global warming below 2 °C. *Nature Climate Change* 2000;**3**:4–6

[2] Budzianowski WM. Time delay of global warming. *International Journal of Global Warming* 2011;**3**,3:289-306.

[3] Love J, Smith AZP, Watson S, Oikonomou E, Summerfield A, Gleeson C, Biddulph P, Fong Chiu L, Wingfield J, Martin C, Stone A, Lowe R. The addition of heat pump electricity load profiles to GB electricity demand: Evidence from a heat pump field trial. *Applied Energy* 2017;**204**:332-342.

[4] Fawcett T, Eyre N, Layberry R. Heat pumps and global residential heating. Proceedings of ECEEE Summer Study on energy efficiency: First fuel now; 2015; 6-321-15.

[5] Peeters L, Van der Veken J, Hens H, Helsen L, D'haeseleer W. Control of heating systems in residential buildings: current practice. *Energy and Buildings* 2008;**40**:1446-1455.

[6] Scoccia R, Toppi T, Aprile M, Motta M. Absorption and compression heat pump systems for space heating and DHW in European buildings: Energy, environmental and economic analysis. *Journal of Building Engineering* 2018;**16**:94-105.

[7] Van Nuffel L., Gorenstein Dedecca J., Yearwood J., Smit T., Bünger U., Altmann M., Fischer C., Michalski J., Raksha T., Zerhusen J., De Vita A. 2019. Impact of the use of the biomethane and hydrogen potential on trans-European infrastructure. Final Report for European Commission.

[8] POST- UK Parliamentary Office of Science and Technology. 2017. POSTNOTE 565, Decarbonising the Gas Network.

[9] MISE. 2020. Piano Nazionale Integrato per l'Energia e il Clima (PNIEC2030).

[10] European Commission. 2018. A Clean Planet for all - A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy. In-depth analysis in support of the Commission Communication COM(2018) 773.

[11] EN 12309-6:2014 Gas-fired sorption appliances for heating and/or cooling with a net heat input not exceeding 70 kW. Calculation of seasonal performances.

Application of Heat Pumps in Existing District Heating System


MARTINA MUDRÁ
martina.mudra@stuba.sk *

JÁN TAKÁCS
jan.takacs@stuba.sk *

*Department of Building Services, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Slovakia

The content of the article is a proposal for streamlining the existing operation of a heat source for the district heating system through a cogeneration unit and heat pumps. The existing heat source consists of three hot water boilers burning natural gas. A cogeneration unit and water-to-water heat pumps will be added to the existing heat source operation. The operation of the cogeneration unit and heat pumps is designed without an external connection to the electricity grid. Aligning the output of the cogeneration unit with the consumption of heat pumps and their peripherals is the main goal of the design. The cogeneration unit and heat pumps will be used to prepare hot water in an accumulative manner. The proposal is based on real operational data for the period 2016–2018.

Keywords: district heating system, cogeneration unit, heat pump, hot water

Introduction

The non-renewable nature of fossil fuels, climate change, and the consequences of human activity that result in rising levels of atmospheric CO_2 concentration force society to consider using alternative or renewable energy sources [2]. One way to decarbonise the heat supply in buildings by using environmentally friendly and high-energy-efficiency equipment and technologies that save primary energy is through existing district heating and cooling systems that supply several buildings at once [6]. The European Directives on the energy performance of buildings and on energy efficiency promote high-efficiency alternative systems, such as:

a) decentralized energy supply systems using energy from renewable energy sources,
b) combined heat and power generation – cogeneration,
c) district heating or cooling, especially if it uses energy from renewable energy sources in full or in part,
d) use of environmental energy by means of heat pumps, as far as it is technically, functionally and economically feasible [3, 4, 5].

Operation of the Existing Heat Source

Description of the Site

Combined heat and power through a cogeneration unit and heat pumps will be designed for the West housing estate located in the town of Brezno, Slovakia. The existing hot water boiler plant is situated near the Hron River. The proximity of a watercourse creates preconditions for an excess of groundwater in the surrounding subsoil – a source of low-temperature energy. This energy will be transformed to a higher temperature level by water-to-water heat pumps [1]. The district boiler plant is a source of heating water and domestic hot water for 782 flats, ice arena, restaurant and a retirement home [7, 8].

Condition of the Boiler Plant

During heating season, there is uninterrupted 24-hour operation. In summer, the boiler plant is in operation from 4:00 am to 11:00 pm, i.e. 19 hours. The heat transfer medium is hot water with the original design temperature gradient of 90/70°C. The heat source is represented by three hot water boilers with a total output of 6.76 MW [1]. **Figure 1** shows the interior view of the existing boiler plant.

Energy Balance of the Heat Source

Hourly consumption of natural gas in m³ was provided by the heat source operator for the period of 2016–2018. **Figure 2** logically shows that the largest

Figure 1. Interior view of the existing three hot water boilers [1]

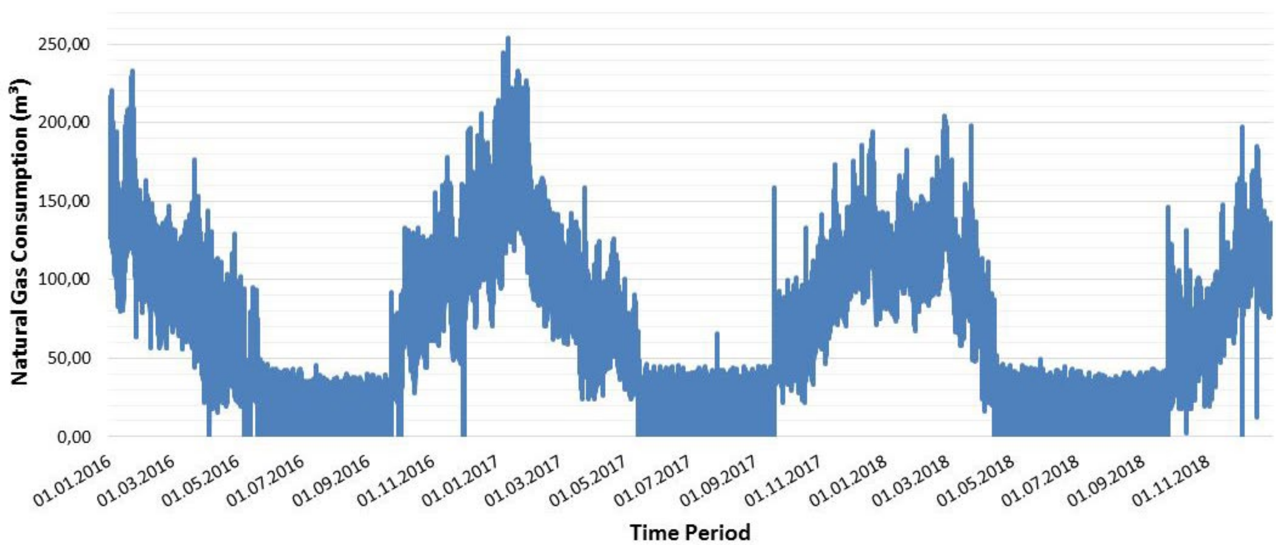


Figure 2. Natural gas consumption in m³ over 2016 – 2018. [1]

consumption of natural gas was in the heating season and the lowest in the summer season. The natural gas consumption also depends on the climatic conditions in a given period [1]. By multiplying the values of natural gas consumption by the calorific value of the fuel, the total amount of heat contained in the natural gas was obtained.

Design Model for the Application of New Devices

Operation of the New Heat Source

A cogeneration unit and heat pumps shall be installed instead of the existing heat source – hot water boilers. The energy source for driving the cogeneration unit will be natural gas. The energy source for driving the heat pumps will be the electricity produced by the cogeneration unit. The cogeneration unit and heat pumps will be used to prepare hot water in an accumulative way. The storage tank will be located behind the cogeneration unit and heat pumps and, at a time when the demand for hot water consumption is reduced, the heated hot water will accumulate in it. The accumulated heat will be supplied to the grid at the time of increased demand. The essence of the design is ensuring a continuous operation of the equipment so that it works as long as possible and with a minimum of starts [1].

Cogeneration Unit and Heat Pumps

To determine the optimal heat output of the device, we need to know the domestic hot water consumption over 24 hours. The heat output of the device can be determined based on the average hourly heat demand for domestic hot water preparation in June. Working days – Monday, Wednesday will be compared with a free day – Saturday. **Figure 3** shows that the domestic hot water is supplied between 4:00 am and 11:00 pm, i.e. 19 hours. On weekdays, the hot water consumption is highest in the morning and evening. On weekends, the hot water consumption is increased compared to working days and it is on average the same throughout the day [1].

The average hourly heat demand for domestic hot water preparation in 2016 was 275 kW, in 2017 it was 280 kW, and in 2018 it was 267 kW. By comparing the data for the period 2016 – 2018, the heat output of the cogeneration unit and two heat pumps was set to 270 kW [1].

The cogeneration unit and heat pumps will be located in front of the boilers in the direction of the return heating water flow. The heat transfer medium – heating water has a temperature of 45°C. The aim is to produce a heat-transfer working substance – heating water with a temperature of 60°C. The temperature drop in the hot water system is therefore 60/45°C, which means that the temperature difference (Δθ) is 15 K. The volume flow at a heat output of 270 kW and a temperature difference of 15 K is 15.48 m³/h. The heat pumps operate with a primary gradient of 5/1°C – this means that a low-temperature heat source enters the heat pumps (groundwater from wells) and is transformed in the heat pumps to a higher temperature, transferred to the secondary heating system circuit. Return heating water with a temperature of 45°C enters the heat pump and is heated up by 10 K, which means that the water temperature at the outlet of the heat pump will be 55°C. This time the temperature difference (Δθ) is known to be 10 K and the volume flow (M) through both heat pumps is 15.48 m³/h.

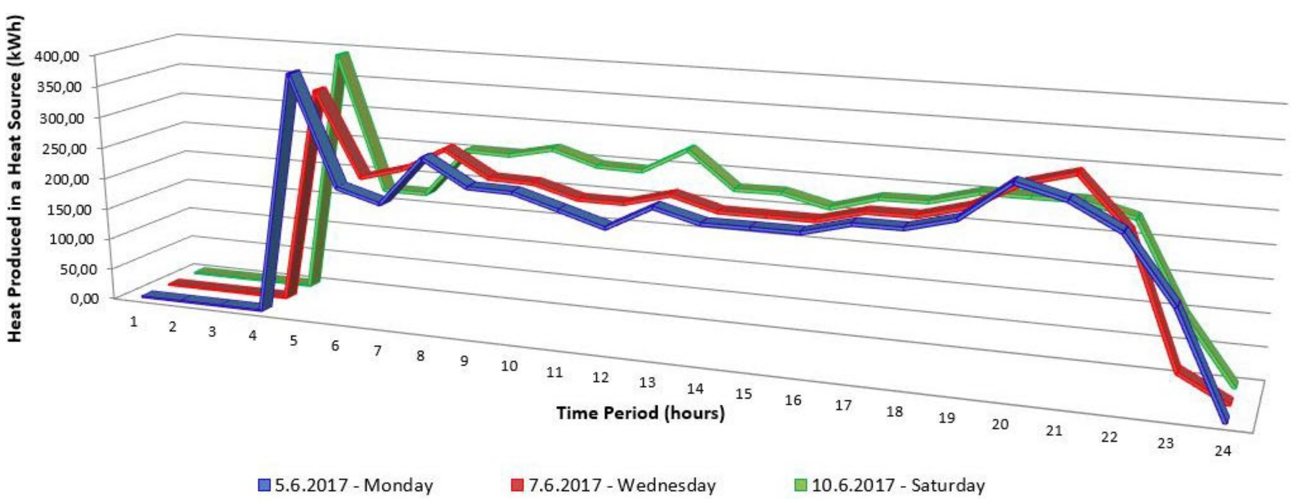


Figure 3. Hourly heat demand for domestic hot water preparation over 24 hours on 3 June 2017 [1]

Schematic diagram and Determination of the Output of the Cogeneration Unit and Heat Pumps

Figure 4 shows the schematic diagram of the cogeneration unit and heat pumps in the district heating system.

The output of both heat pumps was calculated to be 180 kW. It follows from the above that the heat output of the cogeneration unit will be 90 kW. The cogeneration unit works with a temperature gradient (Δθ) of 20 K as standard. This means that if water with a temperature of 55°C enters the cogeneration unit, the cogeneration unit will heat the water to 75°C at the outlet of the cogeneration unit. We know determine the volume flow rate that the cogeneration unit must take to reach 60°C at the outlet of the unit and before entering the hot water storage tank. The volume flow through the cogeneration unit to reach 60°C at the outlet of the unit and before entering the hot water storage tank is 3.87 m³/h. For better controllability of the system, two identical two-stage water-water heat pumps are proposed. The advantage of a two-stage heat pump is that it has two output stages and can therefore be operated on a single compressor with half the output. Because the heat transfer medium cools the primary heat transfer medium – the pumped water, it could freeze and form icing on the heat pump evaporator, which would be destroyed after a certain time. Therefore, a separation heat exchanger was used in the primary circuit to ensure an intermediate circuit with antifreeze between the pumped groundwater and the heat pump. Through a detailed recalculation, the design of two identical heat pumps was determined, while the heat output of one was 89.6 kW. For the cogeneration unit together with the heat pumps to create a set, it is necessary to harmonize their thermal outputs and also electrical inputs, as the cogeneration unit will supply electricity to the heat pumps. The interaction between the heat pumps and the cogeneration unit was simulated using calculation programs in cooperation with the supplier of these devices. From the three simulations performed, the most solution was selected, which set the heat output of the cogeneration unit at 90 kW [1].

Hot Water Storage Tank

During the operation of the cogeneration unit and heat pumps during the heating season, all the heat energy produced by these devices is used to prepare domestic hot water and to heat the heating water. In summer, when the produced thermal energy is consumed only for the preparation of heat, there may be an excess of heat produced. These surpluses must be stored in a hot water storage tank, from which they are tapped during peak periods in the event of greater heat demand. If this excess energy does not accumulate but flows into the system, the temperature of the return heating water entering the heat pumps can gradually increase, leading to overheating of the heat pumps that may reach complete shutdown. The volume of the storage tank was determined to be 10,000 litres by detailed calculations [1].

Discussion

The reason to apply the cogeneration unit and heat pumps in the given operation was the fact that district heating systems have the potential for high-efficiency combined heat and power generation and efficient use of environmental energy through heat pumps. These devices can be installed separately, but as mentioned in the article, there is also a presumption of the interaction of both devices.

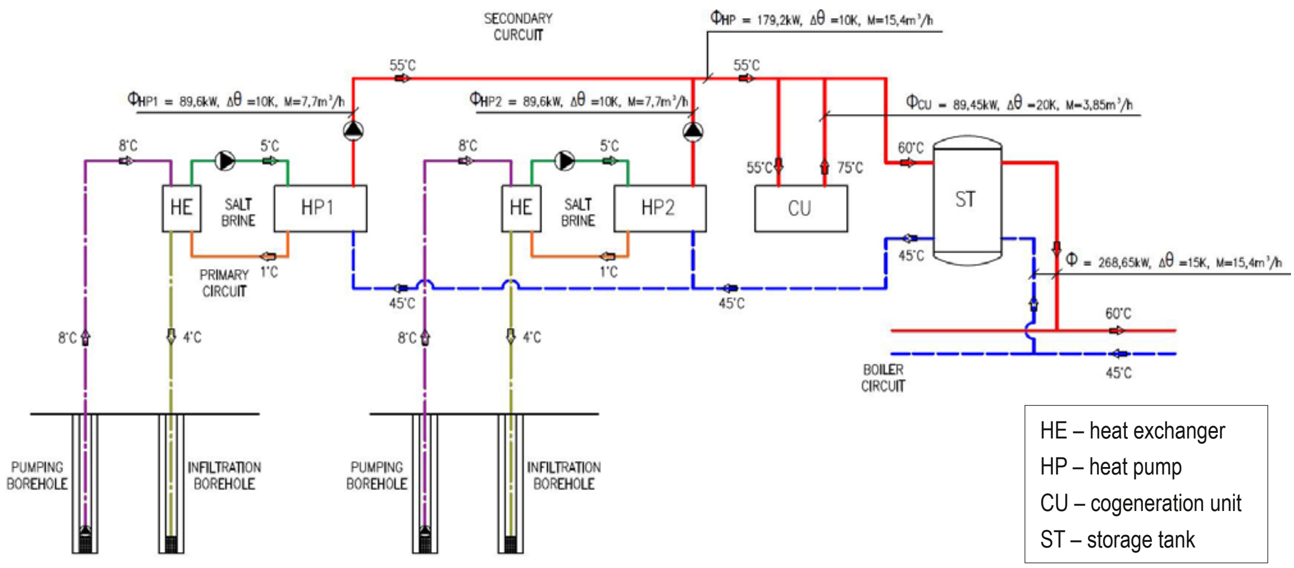


Figure 4. Schematic diagram of cogeneration unit and heat pumps. [1]

The cogeneration unit could also supply electricity to the public electricity network, but at the time of this optimization study, there was a ban on connecting new larger sources of electricity to the public electricity network.

The application of a cogeneration unit and heat pumps to the existing operation of hot water gas boilers saves fossil fuel – natural gas, the reserves of which are gradually running out. The energy of the environment – groundwater – is used instead. From an energy point of view, the same or more heat energy is produced but less fuel is consumed. As far as the economy is concerned, saving fuel also saves money that would otherwise be spent on buying it. Electricity is produced through a cogeneration unit and there is no need to supply electricity to the installations from the public grid, except in cases where there is a failure or maintenance of the cogeneration unit. They also evaluate the annual sales for combined heat and power generation positively.

Conclusion

To ensure energy efficiency, the original technologies are gradually being replaced by modern equipment. A cogeneration unit and heat pumps were used to produce the heat needed to prepare hot water in an accumulative way, especially in the summer. During the heating season, the additional heat produced will not accumulate but will be supplied to the heating network.

The application of a cogeneration unit and heat pumps to the existing operation of hot water gas boilers saves fossil fuel – natural gas, the reserves of which are gradually running out. The energy of the environment – groundwater – is used instead. From an energy point of view, the same or more heat energy is produced but less fuel is consumed. As far as the economy is concerned, saving fuel also saves money that would otherwise be spent on buying it. Electricity is produced through a cogeneration unit and there is no need to supply electricity to the installations from the public grid, except in cases where there is a failure or maintenance of the cogeneration unit.

Only through the application of renewable energy sources and combined production of electricity and heat in district heating systems will Slovakia manage to meet its targets by 2030. These include reduction of greenhouse gas emissions by 20% and increasing the share of energy from renewable energy sources in gross final energy consumption by 19.2% [6]. ■

Acknowledgement

This work was supported by the Ministry of Education, Science, Research and Sport of the Slovak Republic through the grants VEGA 1/0304/21, VEGA 1/0303/21 and KEGA 005STU-4/2021.

References

[1] MUDRA, M. Streamlining the operation of heat source TP5 for the housing estate Západ in Brezno [diploma thesis]. Bratislava: Slovak University of Technology in Bratislava, Faculty of Civil Engineering, Department of Building Services, 2019. 106 p.

[2] PETRÁŠ, D. - LULKOVIČOVÁ, O. - TAKÁCS, J. - FÜRI, B. Renewable energy sources for low temperature systems. Bratislava: Jaga Group, 2009. 223 p. ISBN 978-80- 8076-075-5.

[3] Directive 2010//31/EU of the European Parliament and of the Council of 19 May 201O on the energy performance of buildings.

[4] Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency.

[5] Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency.

[6] Integrated National Energy and Climate Plan 2021 – 2030. Ministry of Economy of the Slovak Republic. Bratislava. October 2019. From: https://www.mhsr.sk/uploads/files/zsrwR58V.pdf (online)

[7] https://www.veolia.sk/pre-zakaznikov/mesta-obce/centralne-zasobovanie-teplom (online)

[8] https://vesr.sk/sk/veolia-energia-brezno (on line)

Heat pumps rescued Xylem's heat storage facility in Emmaboda, Sweden

OLOF ANDERSSON
PhD/Adj. prof – former Sen. consultant at Sweco AB
Geostrata HB
olle.geothermal@hotmail.com

NIKLAS HÅKANSSON
Operations engineer
Xylem Water Solutions
niklas.hakansson@xyleminc.com

LEIF RYDELL
Sen. Consultant – former Operations engineer at Xylem Water Solutions
Reikab AB
leif.rydell61@gmail.com

In 2010, Xylem installed High Temperature Borehole Thermal Energy Storage (HT-BTES). The idea was to store waste heat in the summer season to be recovered for space heating during the winter. The system worked effectively for charging the storage, but turned out to be less effective for extraction of the stored heat. By installing a heat pump system to support the heat extraction the BTES system now works properly both ways. This article presents the performance and economics of such a system.

Background

Already in 2010, Xylem (formerly Flygt) in Emmaboda commissioned a high temperature storage facility for the recovery of waste heat. The storage was designed for charging 3.6 GWh of waste heat in the summer of which 2.2 GWh was estimated to be recovered for space heating during the winter. The storage working temperature was expected to be between +60 and +40°C. The objective with the BTES was to replace a significant amount of purchased district heating, see **Figure 1**.

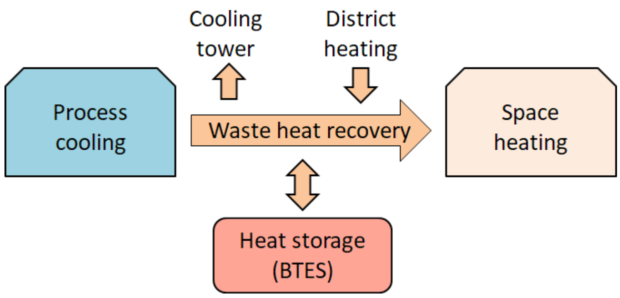


Figure 1. Xylem's system for heat recovery based on process cooling includes heat storage (BTES) for seasonal storage of waste heat. The storage reduces disposal of waste heat through the cooling tower for cooling and purchased district heat for space heating.

In the first years of operation, it was found that the expected high temperature waste heat quantity was not sufficient. Therefore, a number of measures were taken to also capture low-grade waste heat. As an example, a heat pump was installed for the foundry's ventilation system, which in the process acts as a climate cooling in this otherwise warm workplace. The measures allowed more and more heat to be recovered both directly and for storage. In 2014, storage capacity was basically reached. By this time, about 10 GWh had been loaded into the storage, raising the temperature to just over 40°C. Over the next three years, the temperature stabilized to a maximum of 45°C, despite the fact that the availability of waste heat remained high. The reason was that a large part of the stored heat spread sideways, which in turn led to increased storage losses. Thus, the temperature in the storage did not become high enough to be directly used for space heating. As a result, only about 10% of the stored heat was recovered the years 2015–2017. Thus, in order for the storage to survive, a reinforced heat extraction capacity was needed, in this case with a heat pump system. This solution was recommended in a scientific follow-up report that studied the general function of the plant [1].

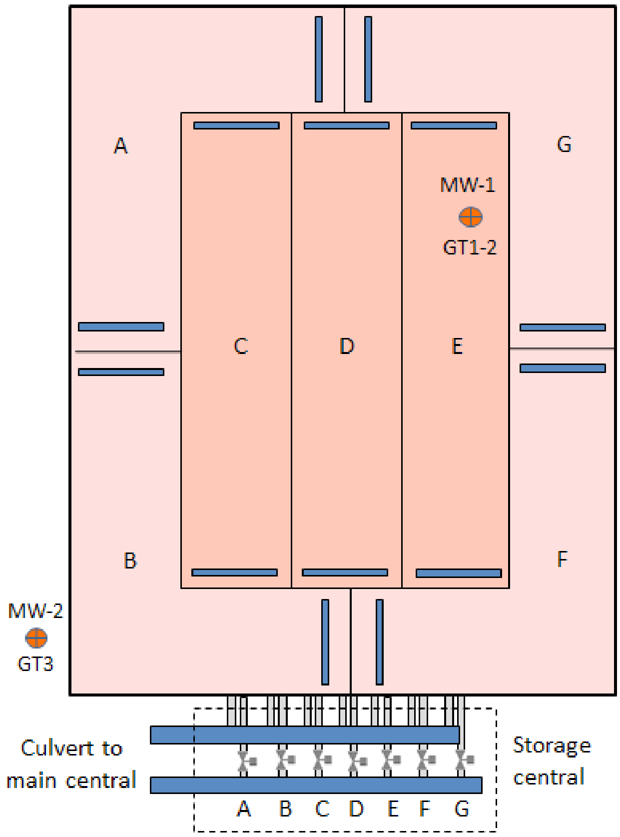


Figure 3. The design of the borehole storage with seven sections (A-F). Each section has 20 boreholes of which two are in series. The boreholes are connected with OD 40 pipes, and ends up to OD 90 field manifolds at both section ends (blue). Finally, the field manifolds connect to larger manifolds in the storage central. MW: monitoring wells. GT: temperature sensors

Design of the borehole storage

The storage consists of 140 boreholes, 150 m deep and with a c/c-distance of 4 m. It is located on a flat grass surface just outside the factory area and has a rectangular shape measuring 60 × 40 m. It was constructed during the winter of 2009–2010.

The borehole heat exchangers are of a coaxial type consisting of double pipes with intermediate insulation in lengths of 10 m. One of the advantages of this type of heat exchanger is that it allows for bidirectional flow. Thus, the highest storage temperature can always be located at the bottom of the storage. Another advantage is that the thermal resistance is significantly less compared to a conventional U-pipe. The latter option usually has thermal resistance around 0.08 K(W/m). The resistance of the coaxial heat exchanger was measured at 0.02, thus four times more efficient.

The boreholes are divided into seven sections (A-G) with 20 holes in each, see **Figure 3**.

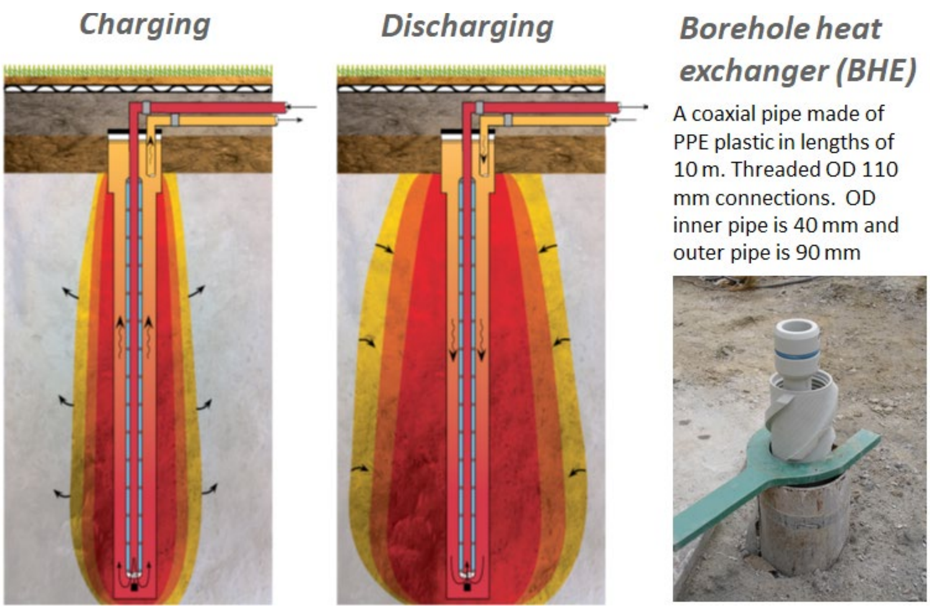


Figure 2. System with coaxial borehole heat exchanger with dual flow function. The flow is reversed when discharged compared to charging. Thus, the temperature is always warmest at the bottom of the storage, which reduces heat losses and provides the highest possible temperature at extraction of heat.

The three inner sections are thought to have the highest temperature and the four outer ones to act as a buffer zone with slightly lower temperatures. The idea behind this lay-out is to adjust the extraction temperature to fit the demand. To achieve this function control valves are placed on the assembly pipes in the storage central, as shown in the figure.

Heat pump system

It took a few years to get the decision through, but in September 2018, a heat pump system was ready for commissioning. This consists of 8 parallel connected real estate heat pumps (Nibe F1345-60). The evaporator side connects to the supply and return pipes of the storage and the condenser side connects to the internal heating grid, see **Figure 4**. The warm temperature on the evaporator side allows the system to deliver significantly higher capacity than the nominal, in the current case up to 800 kW. The heat pumps together with the direct recycling can handle the heat demand down to about –5 degrees outside temperature. At lower outdoor temperatures, the external district heating enters for peak shaving.

Monitoring system

The horizontal piping system of the storage is embedded in about 30 cm of sand, after which there is a 40 cm thick layer of insulating foam glass, followed by about 30 cm of topsoil. The insulating ability is measured with temperature sensors under and above the foam glass and in the upper part of the topsoil. For measuring the storage temperature there are two monitoring wells (MW), one inside and one a few meters outside the storage. In these wells temperature sensors are installed (GT1-3 in **Figure 3**). Furthermore, supply and return temperatures to and from each of the sections are measured, as well as the pressure in the two assembly pipes in the storage central.

From the main technical central, about 200 m from the storage, the heat carrier is circulated via a culvert using a frequency-controlled circulation pump designed for a maximum flow of 21 ℓ/s (3 ℓ/s and section). Heat is supplied or collected from the storage via a heat exchanger (HEX) that on the secondary side is connected to Xylem's internal heating grid. In the system there are sensors for instantaneous measurement of temperatures, flow and pressure, see **Figure 4**. In addition, electricity consumption for the heat pumps and the circulation pumps each side of the HEX in order to calculate the system SPF.

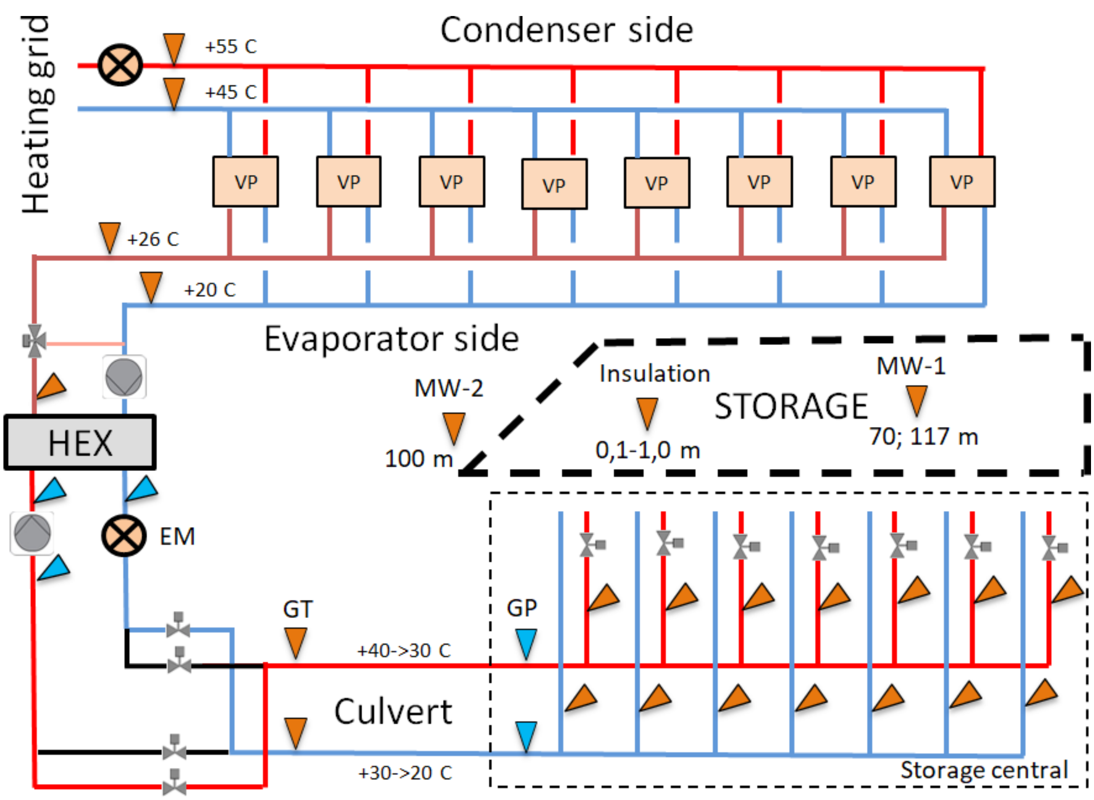


Figure 4. Simplified flowchart for heat extraction with sensors for energy measurement (EM), system pressure (GP) and temperatures (GT). In addition, electricity consumption is measured for heat pumps and circulation pumps.

Operational results

The system performance is monitored in an international research project, IEA HPT Annex 52 *"Long-term measurements of GSHP system performance in commercial, institutional and multi-family buildings"* where Xylem's plant is one of some 40 shallow geothermal installations and the only one associated with an industry. Operational data is now available after three full winter seasons with the heat pumps. As shown in **Figure 5**, the accumulated heat extraction from the storage has drastically increased compared to former years.

The higher withdrawal of heat in the last three years has gradually reduced the temperature in the storage down to approx. +25°C at the end of the heating season. As a result, the temperature gradient between the storage center and the boundary has decreased, which means that the lateral heat flow has more or less ceased, see **Figure 6**.

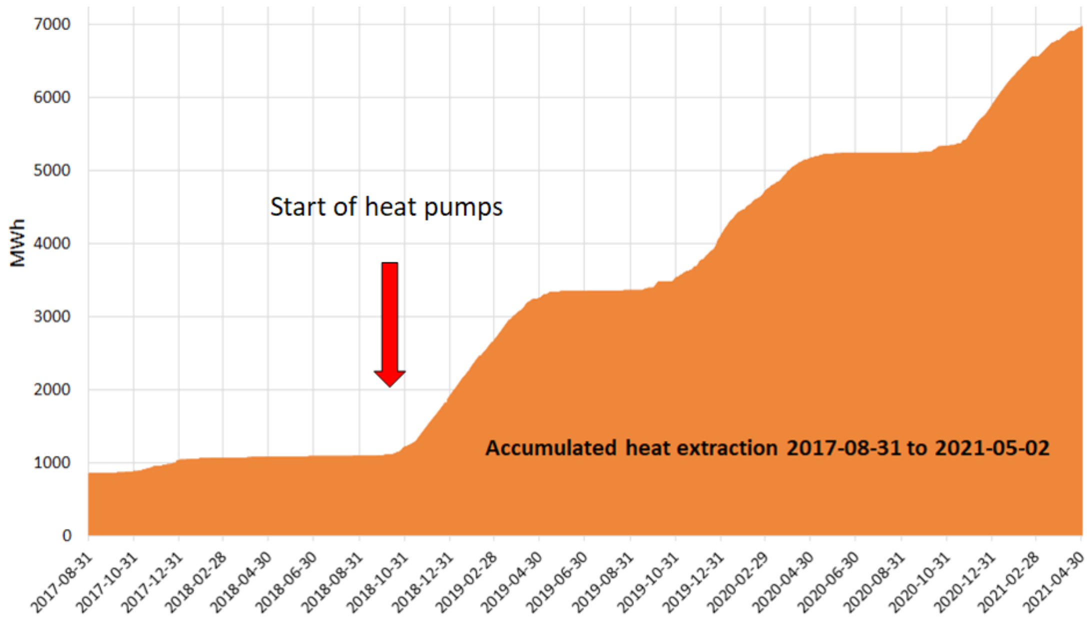


Figure 5. The accumulated heat extraction from the storage in the last five years.

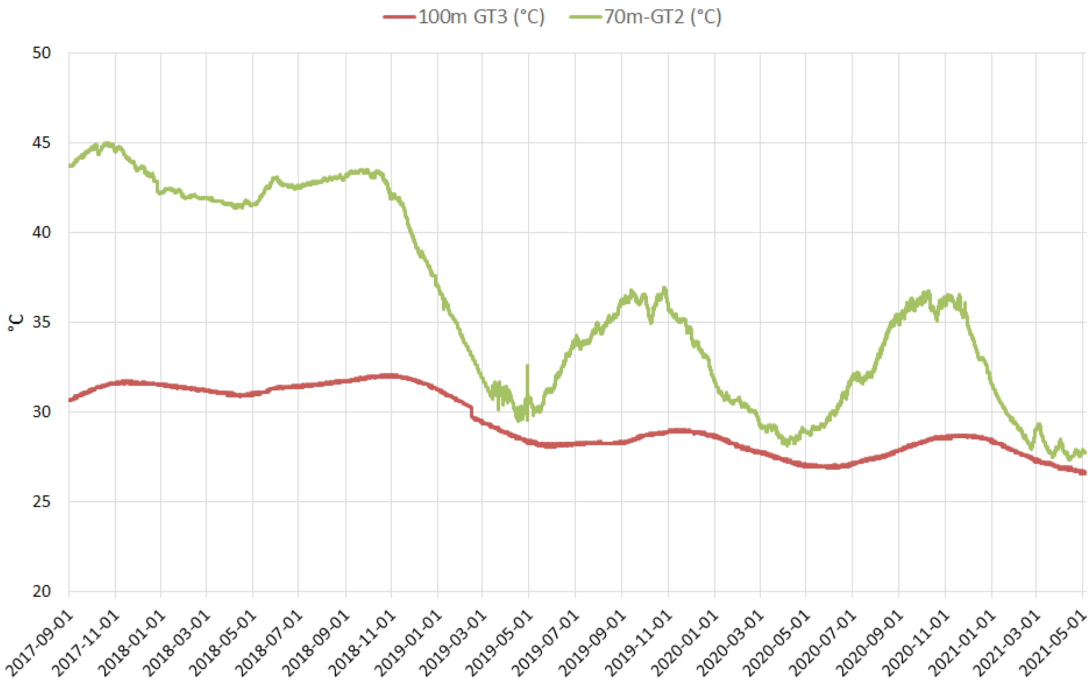


Figure 6. Temperature development inside the storage (GT1) and just outside (GT3) in the last five years.

The lowered average temperature of the storage, with the target to work at 40/20°C, also entails a number of other advantages, of which the following are tangible.

- The storage system has a significantly higher cooling capacity during the summer, which in turn means that more heat can be stored with reduced cooling tower operation as a result.
- Reduced heat losses due to less lateral flow of stored heat.
- Heat pumps for the recovery of low-grade waste heat can be operated with a lower condensation temperature and thus higher COP.
- Reduced risks of technical problems in the storage heat carrier loop, which means reduced potential for circulation pump cavitation, degassing of the heat carrier and clogging of pipes and the heat exchanger.

Economics

The investment cost of the original system was in total approx. SEK 12.5 million, of which 30% was received as a state contribution. The assessment was that the investment would be repaid after 5–6 years. It was then assumed that some 2,000 MWh/year of purchased district heating could be replaced by stored waste heat. That turned out not be the case. Only 1,200 MWh of recovered heat between 2014 and 2017 was far from enough. On the other hand, the storage concept led to a strengthened utilization of low-grade waste heat carried out during the years 2011–14. These were in themselves profitable in that the direct heat recovery during the winter could be doubled to about 7,000 MWh/year (2020).

A bonus is that the foundry has received climate cooling and that the amount of purchased city water for cooling in chilling pools has decreased significantly. Furthermore, the operating and maintenance costs of the cooling tower have decreased as a result of the increased waste heat use. However, the value of these benefits has not yet been priced.

The additional investment in the new heat pump system to amounted to about SEK 2.5 million. During the first three years of operation, a total of 6,500 MWh of heat has been produced by using 1,440 MWh of electricity for running the system. This ends up with a seasonal performance factor (SPF) of 4.5, thus saving around 78% of energy. The value of the savings with the energy prices currently applicable to Xylem is approximately SEK 3.8 million. Hence, the investment in the new heat pump system is more than repaid after three heating seasons.

Lessons Learned

In general, this type of BTES tends to be overestimated in terms of temperature at recovery of the stored heat. Our assessment is that a heat pump system is needed to be able to make full use of the storage. It is possible that a HT-BTES can work with heat exchange alone, but the temperature when charging must then be kept significantly higher than that reached during discharge.

Technically, it is not a problem to construct a HT-BTES in almost any geological formation, but the investment cost is rather high. However, since the life span is long (>50 years), the investment can be written off for a long time. Since the stored waste heat is basically free, there is great potential to create storages with a high profitability, including the cost of helping heat pumps when discharged.

In the Emmaboda case, the investment in coaxial borehole heat exchangers has helped to obtain a thermally favorable temperature profile in the storage. However, this advantage has not been sufficient to prolong a high temperature when extracting the heat. The recommendation is therefore to use conventional borehole heat exchangers (thermal resistant U-pipes) in a fully closed loop to avoid various technical problems, such as vacuum pressure and stripping of gas. In Emmaboda, this problem has been a major concern, especially in the early years of operation. To our opinion it is better to accept a less efficient borehole heat exchanger and compensate this choice with a heat pump solution for an efficient recovery of the stored heat. ■

Acknowledgement

This article is prepared within the scope of IEA HPT Annex 52 witch has been has funded by Energimyndigheten (Swedish Energy Agency), Geostrata HB, Reikab AB, and Xylem Water Solutions.

References

[1] Nordell, B., Liuzzo Scorpio, A., Andersson, O. Rydell, L., Carlsson, B. 2016. "The HT BTES plant in Emmaboda. Operation and experiences 2010-2015". Div. of Architecture and Water, Luleå University of Technology, January 2016.

TRI-HP PROJECT | Trigeneration systems based on heat pumps with natural refrigerants and multiple renewable sources

Natural refrigerant heat pumps for residential buildings

DANIEL CARBONELL SANCHEZ
SPF Institute for Solar Technology, Rapperswil, Switzerland
dani.carbonell@ost.ch,

MIHAELA DUDITA
SPF Institute for Solar Technology, Rapperswil, Switzerland

SPYRIDON PANTELIS
REHVA, Brussels, Belgium

ALIREZA ZENDEHBOUDI
Norwegian University of Science and Technology, Trondheim, Norway

XABIER ANTON PEÑA
Tecnalia, Gipuzkoa, Spain

MAIKE SCHUBERT
SPF Institute for Solar Technology, Rapperswil, Switzerland

Joining the forces for a clean energy transition, the partners from EU funded TRI-HP project* have a holistic approach for providing energy to multi-family residential buildings with high share of renewables. TRI-HP project focuses on developing affordable and efficient trigeneration systems able to provide heating, cooling and electricity.

Keywords: heat pumps, multi-family residential buildings, ice-slurry systems, renewable heating and cooling, supercoolers, heat exchangers, energy storage, natural refrigerants, icephobic coatings.

TRI-HP project in a nutshell

Funded by the European Union's Horizon 2020 Research and Innovation Programme, and coordinated by SPF Institute of Solar Technology, TRI-HP project (https://www.tri-hp.eu/project) is a four-year Horizon 2020 project that started in March 2019. Within the project, two main systems will be developed:

- Dual-source/sink heat pump system with the possibility to use ground and/or air as heat sources/sinks.
- Solar-ice system based on supercooling ice-slurry heat pump with solar energy as the main renewable heat-source.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N. 814888. The sole responsibility for the content of this paper lies with the authors. It does not necessarily reflect the opinion of the European Commission (EC). The EC is not responsible for any use that may be made of the information it contains.

* https://www.youtube.com/watch?v=DYunHAQ1Nd4

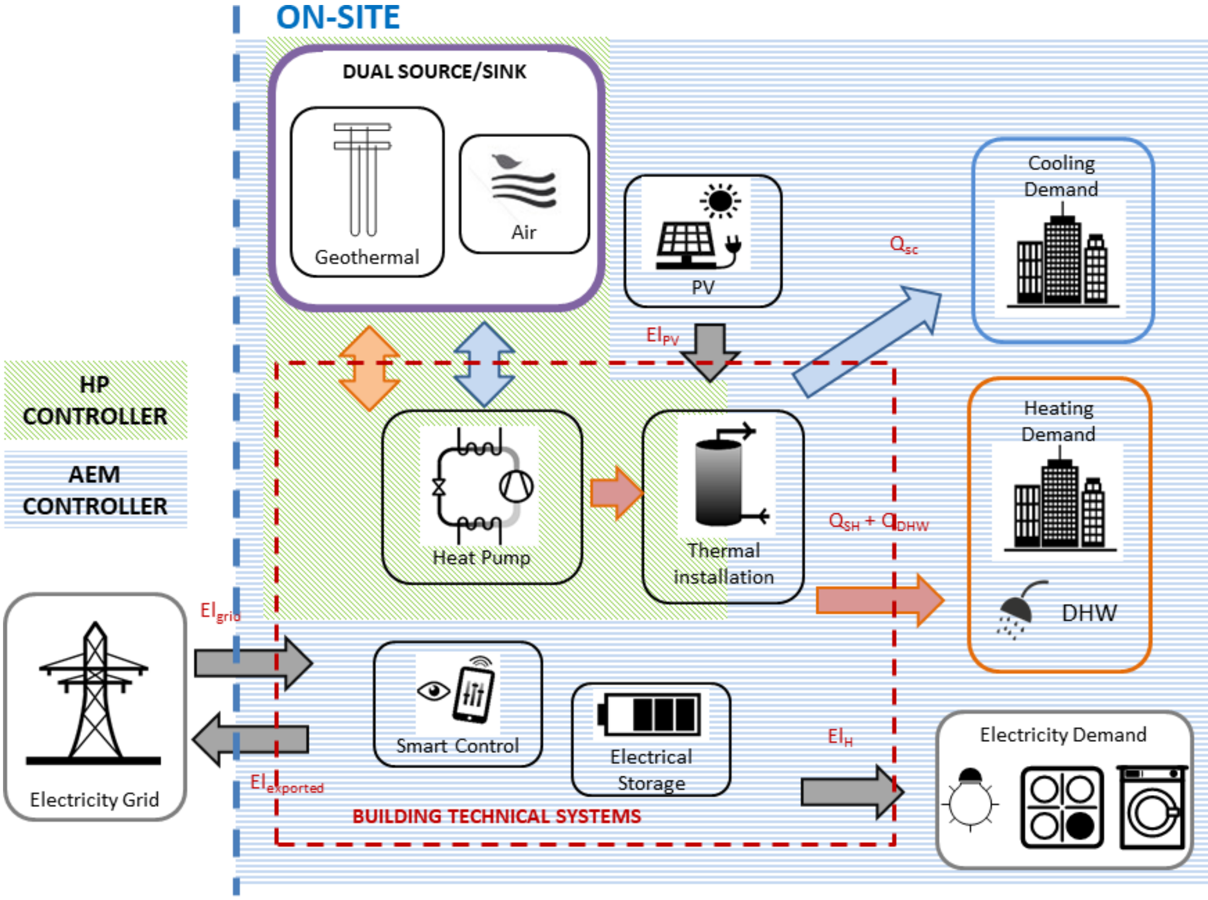


Figure 1. Dual-source/sink heat pump system with the possibility to use ground and/or air as heat sources/sinks.

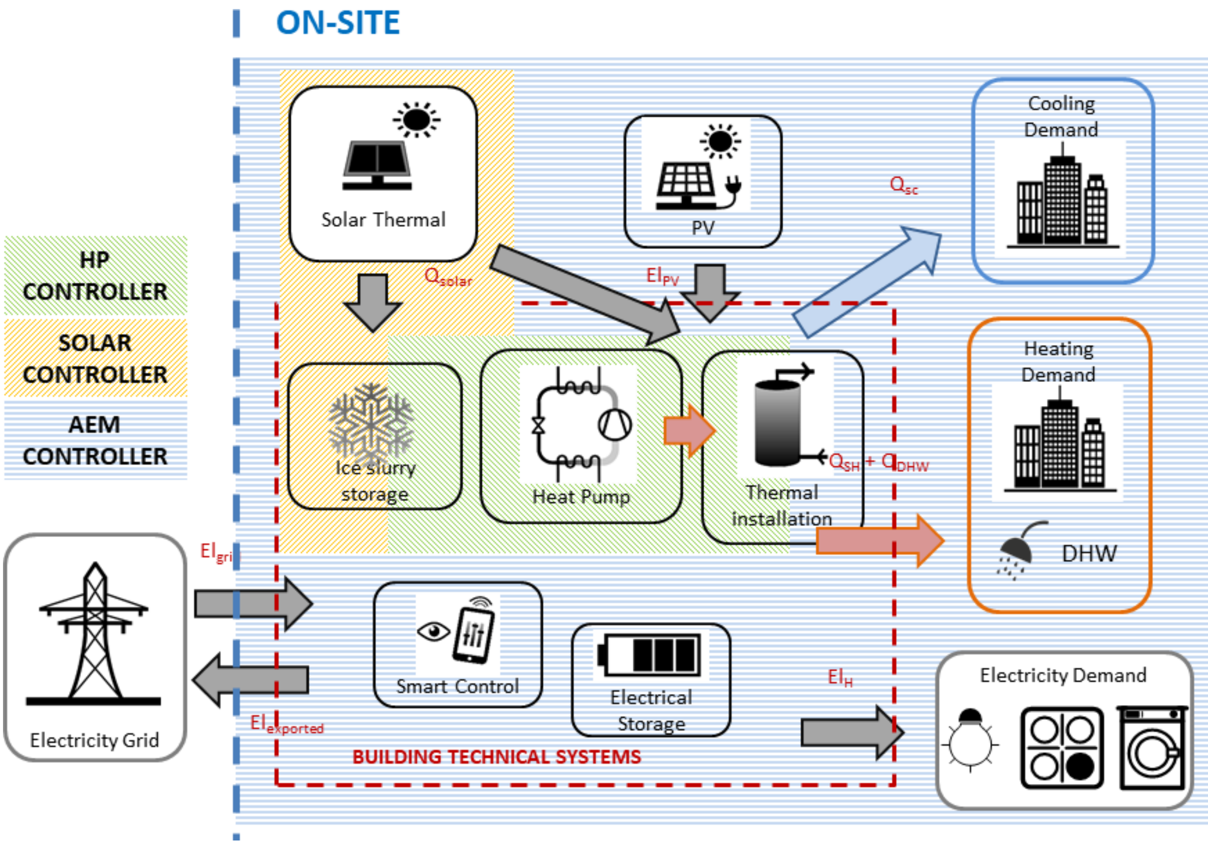


Figure 2. Solar-ice system based on supercooling ice-slurry heat pump with solar energy as the main renewable heat source.

TRI-HP systems will include advanced controls, managing electricity, heat and cool in a way that optimises the performance of the system and increases its reliability via failure self-detection. Moreover, TRI-HP will provide the most appropriate knowledge and technical solutions to cope with stakeholder's needs, building demand characteristics, local regulations and social barriers, with an on-site renewable share of 80%, reducing the installation cost by 10-15%.

Solar ice systems & supercoolers for ice slurry production

Buildings can be efficiently supplied with renewable heating and cooling using what is known as solar-ice systems. These systems combine solar thermal collectors, heat pumps and ice storage to supply the energy needs in heating dominated regions with enough solar irradiation, e.g. Central Europe.

Solar-ice systems use solar thermal collectors as the only heat source for the heat pump. Solar thermal collectors are also used to supply heating and domestic hot water demands directly. As long as the sun is shining or the ambient temperature is not too low, solar collectors act as a direct heat source for the heat pump. During cold nights or days with low solar irradiation, when the energy from the solar collectors is insufficient to generate enough heat for running the heat pump directly from the solar collectors, the ice storage is used as a temporary heat source. Turning liquid water into ice releases a lot of thermal energy: icing 1 kg of water provides approximately the same energy as cooling down the same amount of water from 80°C to 0°C. Thus, the ice storage can store solar heat with a high volumetric storage capacity.

The solar ice-slurry system is a particular case of the solar-ice system. The main difference between them is that in the ice slurry concept, the ice storage contains no heat exchangers, which reduces the system installation cost by 10%. Moreover, the heat exchanger (supercooler) is always free of ice and thus has a higher efficiency compared to ice-on-coil.

The solar ice–slurry system can be compared to ground source heat pumps (GSHP) with the benefits of not having to drill boreholes and thus not being restricted by water protection laws. Moreover, there is no need to regenerate the ground as in the case of boreholes, even if the storage is buried in the ground since it regenerates on a yearly base by solar energy. This system concept is developed in the TRI-HP project for heating-dominated climates with cooling as an add-on feature using the ice-slurry produced in the storage vessel.

The main technological barrier for solar ice-slurry systems is related to supercoolers, i.e., heat exchangers that can decrease water temperature below 0°C, allowing the existence of water in a meta-liquid state and suppressing the ice formation.

In the context of the TRI-HP project, efficient supercoolers were designed and tested by SPF Institute for Solar Technology (SPF) [**1**] from OST Eastern Switzerland University of Applied Sciences [**2**]. For the new supercoolers, icephobic coatings made by the Danish Technological Institute (DTI) [**3**] from Denmark and Industrielack AG (ILAG) [**4**] were used and applied to heat exchangers from ALFA LAVAL [**5**]. The cost of these coatings under the assumption of 250 m² of plates surfaces coated per day is in the range of €4 per kW nominal heat pump capacity.

The tested TRI-HP supercoolers reached supercooling degrees up to 4 K, which is well beyond the 2 K achieved by state-of-the-art technologies. The

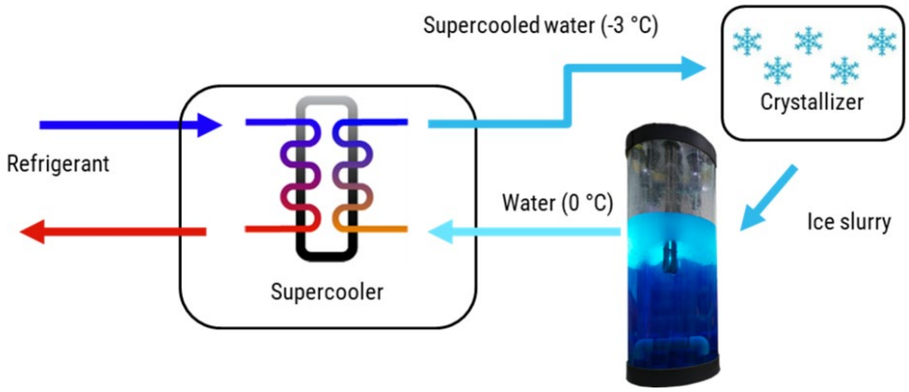


Figure 3. Schematic representation of the supercooling method used in TRI-HP for the ice-slurry production.

average supercooling temperature was evaluated for seven freezing cycles for different icephobic coatings. Supercooling powers of around 6 kW were achieved with the new heat exchangers. The new supercoolers will be further tested by SPF together with heat pumps during summer 2021. The aim is to assess the full capacity range and reliability under dynamic conditions.

New heat pumps with natural refrigerants

The use of natural and environmentally friendly refrigerants with low Global Warming Potential (GWP) such as hydrocarbons, water, ammonia and carbon dioxide (CO_2) has recently attracted much attention as a measure to mitigate the greenhouse gas emissions from refrigeration, air-conditioning and heat pumping systems. In this vein, new heat pumps with natural refrigerants (propane and carbon dioxide) are being developed and tested in the context of the TRI-HP project.

The Norwegian University of Science and Technology (NTNU) [**6**] from Trondheim (Norway) has developed a single tri-partite gas cooler unit for a new CO_2 heat pump design. This innovative heat pump design includes three brazed plate heat exchangers developed by ALFA LAVAL and aims to simplify the heat pump layout and reduce the piping requirements.

Experimental investigation shows promising performance while having a more compact design and a cost of around €308 per kW nominal heat pump capacity. Under the design conditions, the heat duty meets the requirements to provide the supply temperatures of 35°C and 70°C for space heating and domestic hot water applications.

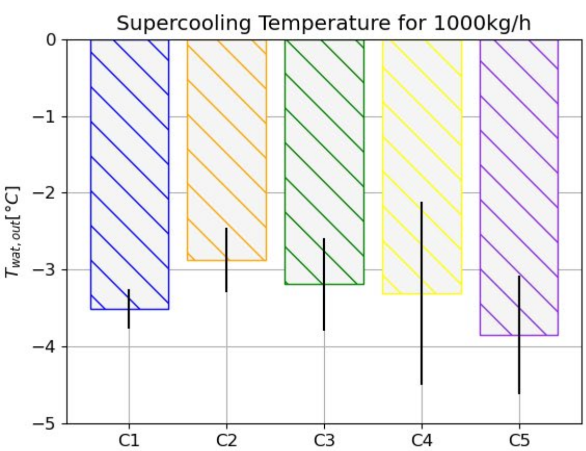
TECNALIA [**7**] from Azpeitia (Spain) has developed a dual source heat exchanger for a new propane heat pump design. This innovative heat pump is able to exchange heat with geothermal brine/water or directly with air or against both simultaneously in a smart way without complicate control strategies and the requirement of secondary water loops. Under the design conditions, the heat duty meets the requirements to provide the supply temperatures of 35°C or 70°C for space heating or domestic hot water applications, and 7ºC for space cooling applications. More information can be found on the TRI-HP website.

Critical review of heat pump prototype operation

In the testing facilities of SPF Institute for Solar Technology (SPF) the performance of the following heat pump prototypes was tested under different working conditions and operation modes (see **Figure 1** and **Figure 2**):

- (R744) CO_2-ice heat pump
- (R290) propane-ice heat pump
- (R290) propane-dual source heat pump

The experiments analysed in detail the effects of different operating parameters on the overall coefficient of performance, heat duty, and compressor energy consumption.



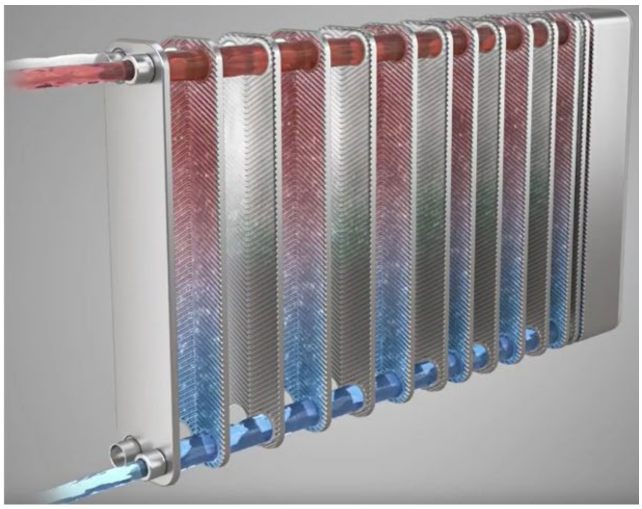


Figure 4. Experimental supercooling degrees (left) achieved in the SPF test bench using icephobic coatings applied on flat plate heat exchangers (right).

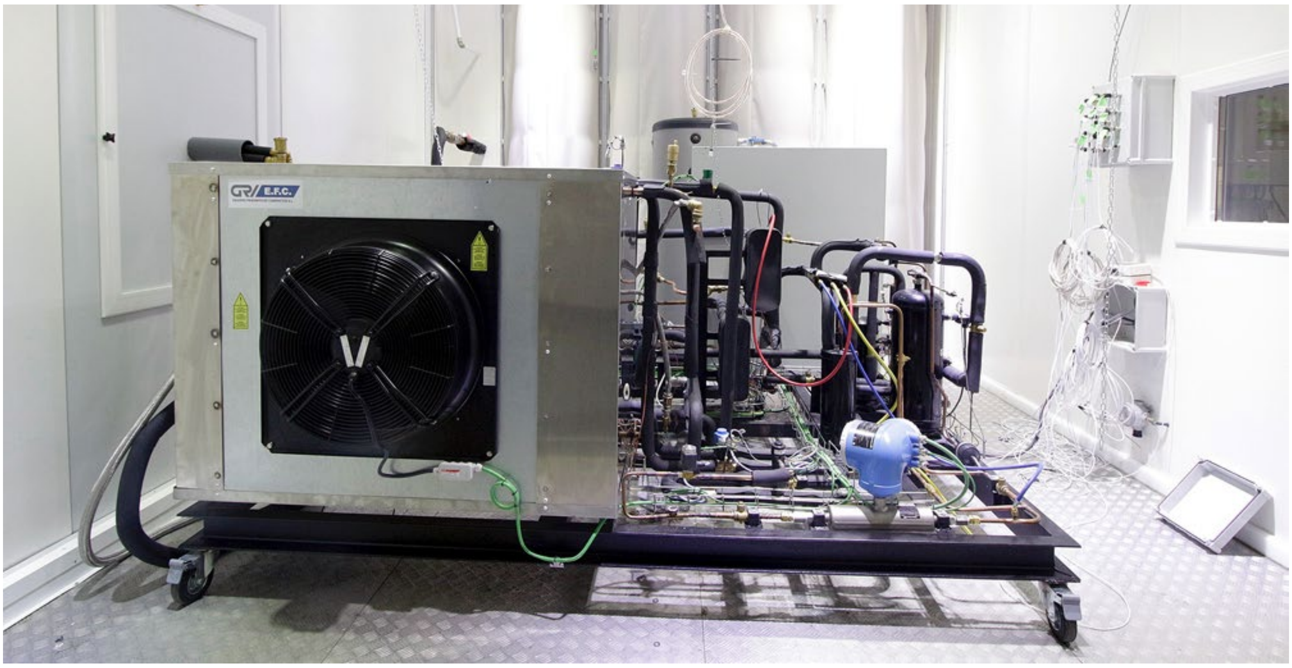


Figure 5. The propane-dual source heat pump test bench inside the climatic chamber of Tecnalia's laboratory.

The **CO_2-ice heat pump** includes a rotary compressor coupled to an inverter, the tri-partite brazed plate gas cooler, an evaporator, an internal heat exchanger, an ejector, a throttling valve, and a liquid separator. The heat pump unit is designed with a capacity of 10 kW, 8 kW, and 10 kW under only domestic hot water, only space heating, and simultaneous domestic hot water and space heating modes to provide the tap water heating and space heating water up to 70°C and 35°C, respectively. According to the results, the **CO_2-ice heat pump** shows good performance for high DHW demand with large temperature differences at the gas cooler if the inlet temperature of the gas cooler is low (10°C to 20°C, such typical temperature level of fresh water). In DHW mode, the COP varies between 3.6 and 4.3 for set temperatures of 55°C to 65°C.

The **propane-ice heat pump** prototype is designed with a capacity of 10 kW and consists of a scroll compressor with inverter, two plate heat exchangers in the heat sink side (desuperheater and condenser), an evaporator, an internal heat exchanger, and several expansion valves. Similarly, to the **CO_2-ice heat pump**, the **propane-ice heat pump** was studied at a steady state for only space heating operation, only domestic hot water operation, and simultaneous domestic hot water and space heating operation. The results indicate that the COP for space heating temperature 30/35°C ranges between 4.4 and 5.4. However, the COP of the unit for domestic hot water with a set temperature of 65°C drops to between 2.5 and 2.8.

The **propane-dual source heat pump** with a capacity of 10 kW is designed and manufactured to use both air and/or water/brine coming from geothermal boreholes as heat source/sink, allowing to test this unit under heating and cooling working modes. The results of the **propane-dual source heat pump** indicate a slightly lower heat duty than the requirements under the design conditions (70 Hz.), while the COP/EER varies between 3.2 and 3.7, depending on the operating mode.

More information about the experiments, the methods and results can be found on D5.5 on TRI-HP's website: https://www.tri-hp.eu/documents ■

Links

[1] https://www.spf.ch/

[2] https://www.ost.ch/en/

[3] https://www.dti.dk/

[4] https://www.ilag.ch/en.html

[5] https://www.alfalaval.com/

[6] https://www.ntnu.edu/

[7] https://www.tecnalia.com/

IIR Informatory Note on *Air source heat pump for space heating and cooling*

Summary for policymakers

Currently, energy consumption in the building sector accounts about 30% of total energy consumption worldwide, of which almost half is consumed by heating, ventilation and air-conditioning (HVAC) systems. Traditionally, both a chiller and a boiler are used in a building for cooling and heating respectively, and electricity is even used directly for heating in some areas, while these technologies are neither environmentally friendly nor energy efficient. Among the promising technologies that can provide both heating and cooling with a single device, air-source heat pump (ASHP) has been widely developed and used all over the world and is playing an increasingly important role in reducing greenhouse gas emissions.

The IIR Informatory Note "Air source heat pump for space heating and cooling" [**a**] aims to raise awareness that ASHP is an energy-efficient technology which could be used for both cooling and heating, notably more energy-efficient than direct electric heating. At the same time, the state of the art of ASHP technologies on how to improve the heating performance at low ambient temperatures, how to effectively prevent frost or defrost, and alternative refrigerants are presented to further emphasise that ASHP can be used for different functions in different climate. The main facts and recommendations are summarised as follows:

- By the year 2018, buildings accounted for 30% of global energy consumption and 28% of global greenhouse gas emissions [**b**]. About 40% of the energy consumed by buildings was used for space heating and cooling [**c**].
- ASHP is an energy-efficient technology for heating at different ambient temperatures. The normal heating efficiency of ASHP is three to four times higher than that of direct electric heating. ASHP can be used in different climates, from −25°C to +50°C, by developing technologies such as variable frequency compressor, cascade ASHP, two-stage compression and quasi-two-stage compression.
- The significant improvement in defrosting for ASHPs has been achieved over the last two decades. Anti-frosting technologies, different types of defrosting technologies, and smart control defrosting strategies have been developed to ensure that ASHPs operate efficiently and reliably in a humid environment.

Global warming is motivating researchers, manufacturers etc. to consider alternative refrigerants for ASHPs. Low GWP refrigerants have been applied in different types of ASHPs.

Of course, there are still many challenges for the development and application of ASHPs, such as reducing initial costs, developing more energy-efficient and environmentally friendly products, etc. Considering that many cooling and heating technologies have much lower efficiency and the quick growth of air conditioners worldwide, more favourable policies for manufacturers and customers should be applied all over the world.

This Informatory Note, see an extract of this note below, provides detailed information on the principles of ASHP, the state of the art of ASHP technologies and their application all over the world.

The International Institute of Refrigeration (IIR) is at the disposal of its members and governments, companies, public and private actors, to help them achieve the United Nations' Sustainable Development Goals.

The International Institute of Refrigeration (IIR) is an independent intergovernmental organisation.
It is the only one in the world to gather scientific and technical knowledge in every sector of refrigeration.

Founded in 1908, it has developed a worldwide network of leading experts.

The IIR is committed to disseminating knowledge of refrigeration to improve the quality of life for all, while respecting the environment and taking into account economic imperatives.

The IIR has resolutely stepped up its efforts to become a major global player taking action to implement sustainable refrigeration in all its uses. This is evidenced by the report on the IIR's 2020 actions according to the UN Sustainable Development Goals available below.

IIF IIR INTERNATIONAL INSTITUTE OF REFRIGERATION

a) The IIR Informatory Note "Air source heat pump for space heating and cooling" is accessible following this link: https://iifiir.org/en/iir-informatory-notes (free for IIR members after logging-in on the website)

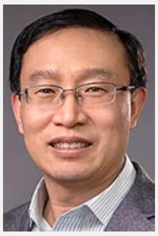
b) International Energy Agency, 2019 Global status report for buildings and construction.

c) http://energy.mit.edu/news/cooling-buildings-worldwide/.

41st IIR Informatory Note on Refrigeration Technologies

Extract of the Informatory Note;
the full text of this Informatory Note is available here:
https://iifiir.org/en/fridoc/air-source-heat-pumps-for-space-heating-and-cooling-41-lt-sup-gt-st-lt-sup-gt-143232

Air source heat pumps for space heating and cooling



XIANTING LI
President of IIR Section E

BAOLONG WANG
Secretary of IIR Section E

Introduction

Since the energy crisis in the 1970s, energy conservation has always been a hot topic for policymakers and practitioners worldwide. Currently, energy consumption in buildings accounts for about 30% of total energy consumption [**1**]. Owing to the increasing demand for improved thermal comfort in the building environment, the energy use of heating, ventilation and air conditioning (HVAC) systems accounts for almost half of the energy consumption of buildings. Therefore, it is important to increase the energy efficiency of HVAC systems in order to meet energy saving and low carbon emission targets.

Traditionally, both a chiller and a boiler are used in a building for cooling and heating, respectively. However, boilers, such as coal-fired and gas-fired boilers, are not environmentally friendly because of the emissions of greenhouse gases and particles during combustion. The electric boiler, or direct electric heating, is not energy-efficient due to low primary energy efficiency. Thus, as one of the promising technologies for efficient heating and cooling with a single device, the heat pump has been widely developed and used all over the world. Depending on the type of heat source/sink, the heat pump can generally be classified as an air-source heat pump (ASHP), ground-source heat pump (GSHP), water-source heat pump (WSHP), etc.

Contrary to WSHP and GSHP, ASHP takes/rejects heat from/into the ambient air, which is cheap and can be implemented anywhere. Therefore, ASHP plays an increasingly important role in cases where both heating and cooling are required. In recent years, many efforts have been devoted to extending the application of reversible ASHP in the heating and cooling of buildings.

This Informatory Note provides detailed information about the principles of ASHP, the state of the art of ASHP technologies and their applications all over the world. Since the research on ASHP cooling has been well developed in recent years, the current challenge comes from heating. Therefore, this Informatory Note focuses mainly on new developments in the field of heating, and some technologies are also applicable to cooling.

Applications

As a promising technology for space cooling and heating, ASHP has been applied in various commercial and residential buildings worldwide. Over the past decades, the radiator has been used as the main terminal for space heating, resulting in high supply water temperatures. However, in recent years, the increasing use of fan coil and floor heating has led to a decrease in the temperature of supply water. This has contributed to an increase in ASHP applications in recent years. Besides, another reason for the increase in ASHP applications is the growing demand for both cooling and heating equipment.

According to statistics by International Energy Agency [**2**], the global stock of air conditioning (including room air conditioner, VRF system, packaged window units, etc.) reached about 1.5 billion units in 2016 (**Figure 1**). Among all types of air-conditioning systems, room air conditioners and VRF systems account for the majority, as shown in **Figure 2(a)**. In addition, the stock in China and the United States accounts for more than half of total sales (**Figure 2(b)**). Other countries with more than 20 million units include Japan, Korea, Brazil and India.

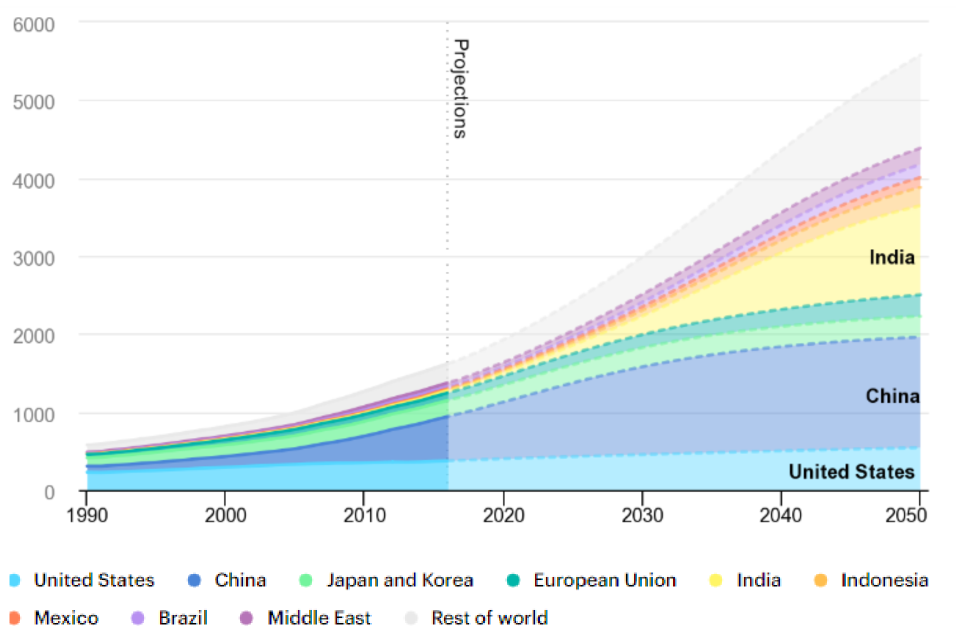
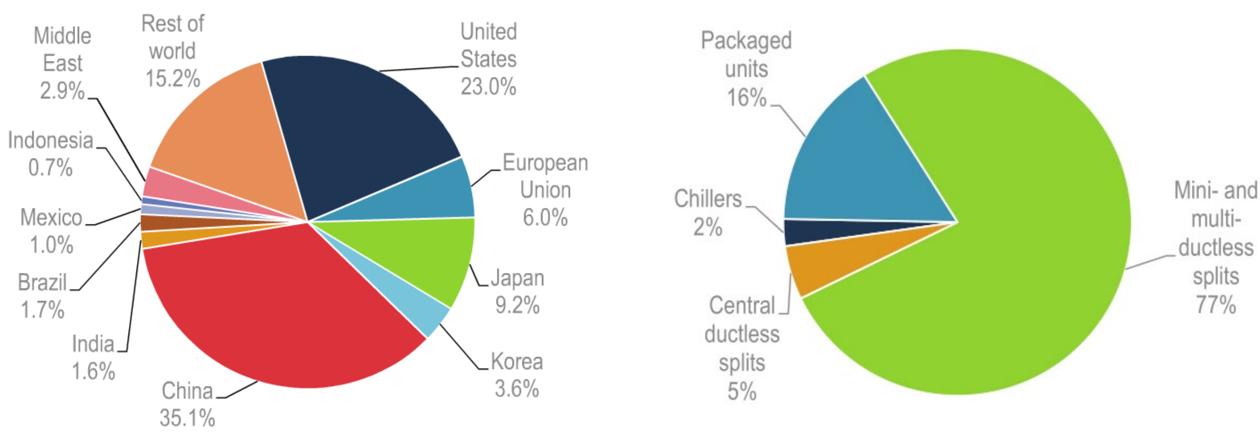


Figure 1. Global air conditioner stock, 1990-2050 (million units).[2]



(a) Stock of ACs by type, end 2016

(b) Stock of ACs by country/region, end 2016

Figure 2. Global air conditioner stock, 1990-2050.[2]

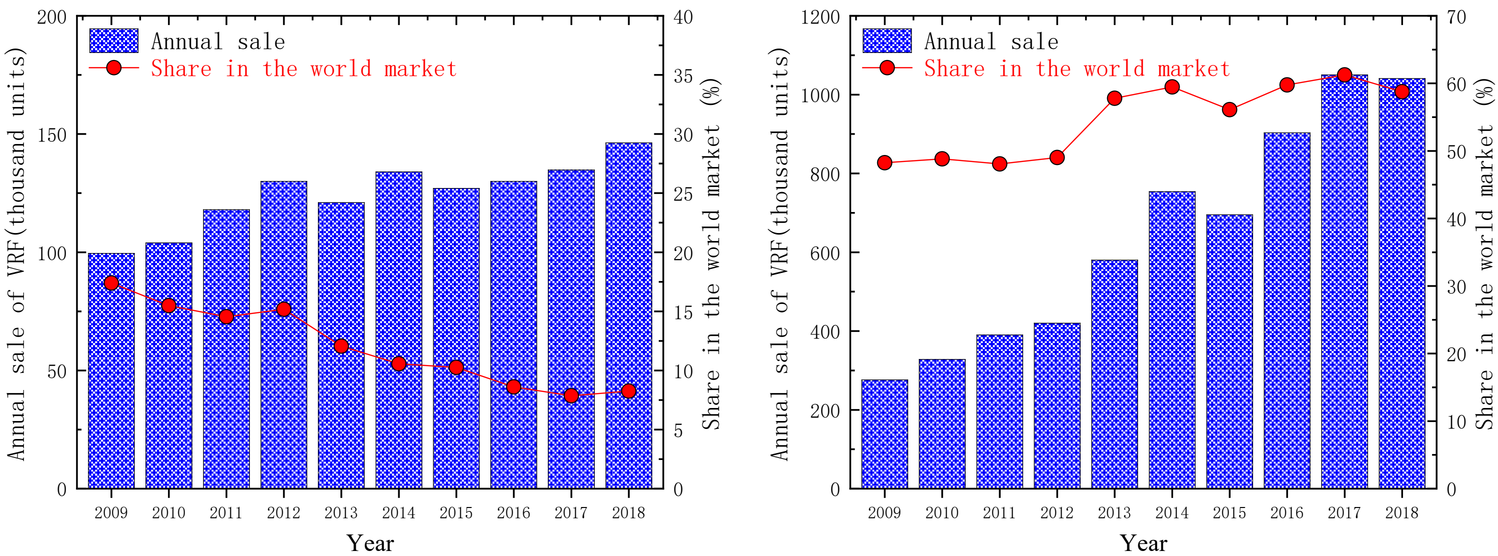
The application of multi-split VRF system has developed rapidly all over the world since its creation in 1982 in Japan. The multi-split VRF system reached the European market in 1987, the Chinese market at the end of the 1990s, and the American market after 2000, successively [**3**]. In 2018, the annual sale volume of multi-split VRF systems in Japan reached 146,000 units (**Figure 3(a)**) [**4**]. In China, VRF systems have for many years maintained the highest share and growth rate among the central air-conditioning market, which is used in about half of medium-sized commercial buildings and one third of large commercial buildings [**5**]. According to statistics, VRF sales volume in China in 2018 reached about 1 million units, which accounts for 58.8% of the world market (**Figure 3(b)**). Moreover, such a huge sales volume in the Chinese market has promoted the development of VRFs in European and American markets.

In order to combat air pollution from traditional boilers, low-temperature ASHPs have been widely used in cold regions around the world, including northern Europe, northern China and Canada. In recent years, northern Chinese provincial administrations have launched programmes to accelerate the phase-out of coal in rural domestic heating [**6**], which has led to the booming development of low-temperature ASHP. Among the main alternative options, direct expansion heat pumps designed for heating in very cold regions have experienced rapid growth in recent years. In addition, novel heating equipment such as ASHP air heaters [**7**] are widely applied in northern China. In 2017, the output value of ASHP used for space heating in China reached RMB 5.6 billion (USD 850 million) [**8**]. Low-temperature ASHPs with quasi two-stage or two-stage compression have been widely applied in northern China, even in areas with ambient temperatures as low as –35°C.

IIR recommendations

Heat pump can play an important role in decreasing the energy consumption of buildings and in meeting global targets for energy savings and low carbon emissions. Because it extracts heat directly from the ambient air or rejects it into the air, the convenient air source heat pump is the most widely used type of heat pump, and is expected to become an essential part of the green heating objective.

Although ASHPs have been investigated and implemented for decades, their total installed capacity worldwide is still much lower than that of direct burning of fossil fuels and direct heating with electricity. Many measures still need to be taken to



(a) Japan (b) China

Figure 3. Market sales of the multi-split VRF system in Japan and China.[2]

accelerate the use of ASHPs in buildings. The main conclusions and recommendations are as follows:

- Over a year (2018), buildings account for 30% of global energy consumption and 28% of global greenhouse gas emissions. About 40% of the energy consumed by buildings is used for space heating and cooling. ASHPs can play an important role in reducing greenhouse gas emissions.
- ASHP is an energy-efficient technology that allows heating at different ambient temperatures. The normal heating efficiency of ASHP is 3 to 4 times higher than that of direct electric heating. ASHPs can be used in different climates, from –25°C to +50°C, by developing technologies such as variable frequency compressor, cascade ASHP, two-stage compression and quasi two-stage compression.
- ASHPs with higher energy efficiency should be continuously developed, adapted to local ambient conditions and the economic situation. International communication and cooperation should be encouraged.
- The actual performance in the field is the most important factor to consider in order to reduce real energy consumption, as it is generally lower than the performance under nominal conditions. Developing field-adaptive intelligent controls is necessary.
- Further efforts should be made to raise awareness among decision-makers and the public about the benefits of air-source heat pumps. ■

References

[1] International Energy Agency, 2019 Global status report for buildings and construction.

[2] International Energy Agency. The future of cooling: Opportunities for energy- efficient air conditioning (2019).

[3] Shi W., Cheng J., Zhao W., Guidelines for Implementation of Multi-connected Air Conditioning Technology and Related Standards. Standards Press of China. 2011. (in Chinese)

[4] Japan Air Conditioning, Heating & Refrigeration News. VRF Special Issue (2019).

[5] Central Air Conditioning Market. China Central Air Conditioning Market Summary Report, (2018). (in Chinese)

[6] Ministry of Environmental Protection. Technical Guide for Comprehensive Control of Pollution Caused by Civil Coal Combustion (Trial) (2016). (in Chinese)

[7] Chinese Standard JB/T13573-2018. Low ambient temperature air source heat pump air heaters. MIIT, Beijing, China: Standards Press of China (2018). (in Chinese)

[8] Air Source Heat Pump Market Development Report in China (2017). (in Chinese)

The REHVA Knowledge Hub is an online knowledge platform offering independent, high quality, trustable information from the HVAC sector.

COVID19 exclusive content

Extracts from REHVA COVID-19 course, calculation tools, webinars, lectures and a lot more

EPB Standards

The entire set of EPB standards explained through videos, webinars and papers

Circular Economy

A series of presentations on what challenges and tools are to integrate circular economy principles in the HVAC sector

European heat pump market

Despite a challenging market environment, European heat pump sales grew by +7.4% in 2020. 1.62 million units were sold across Europe, a number that marks a new record hight.

THOMAS NOWAK
Secretary General EHPA
thomas.nowak@ehpa.org

Assuming a life expectancy of approx. 20 years, the current European heat pump stock amounts to 14.86 million units (see **Figure 1**). 13.2 million of these units are heating heat pumps. Putting this into the perspective of between 115 and 120 million residential buildings in Europe, the heat pump market share in the building stock is about 11% 13,2/115.

Heat pump market growth is mainly influenced by three trends:

1. From a technology perspective today's heat pumps can cover a wide temperature range. They can operate at outdoor temperature levels of down to –25°C and increasingly often they provide hot water at 65°C in an efficient manner. That enables their deployment in a much larger share of buildings than a decade ago. Hybrid systems enable heat pumps even in completely unrenovated parts of the renovation segment. Considering the industrial and large thermal capacity segment, heat pumps cannot provide 50 MW and more, if installed in cascades and can provide up to 160°C. 200°C heat pumps are under development.
2. The need to accelerate the energy transition also in the heating and cooling sector moves heat pumps to the centre of attention of policy makers. Legislation passed in the past 8 years is now transposed in all member states and it starts to show impact. Building standards limit maximum heat demand per square meter, mandate the integration of renewable energy and favour smart buildings. This is often substantiated by institutional and financial subsidies that make market development easier.
3. Continuously larger and growing sales numbers result in lower cost. Economies of scale are materialising on the component and the product level. The fast decline of the production cost of PV systems also influences the heating market: using self-produced electricity in combination with a heat pump system provides a very low-cost energy source for buildings. Additional benefits like demand response services provided to the grid (which could become a business model and provide an income for their providers) are on the horizon, but have not yet materialised.

These developments contribute to the development of Europe's heat pump markets.

	Sales	Stock
2005	446 037	1.15 million
2006	509 794	1.66 million
2007	589 118	2.24 million
2008	804 457	3.05 million
2009	734 282	3.77 million
2010	800 388	4.57 million
2011	808 591	5.37 million
2012	750 436	6.11 million
2013	769 879	6.87 million
2014	792 621	7.64 million
2015	892 809	8.52 million
2016	999 682	9.49 million
2017	1.12 million	10.58 million
2018	1.27 million	11.81 million
2019	1.51 million	13.29 million
2020	1.62 million	14.86 million

Figure 1. Development of heat pump sales and stock, EU-21.

Most markets experienced substantial growth. The strongest relative gains were achieved in Poland (+43.8%), Germany (+37.2%), and the Netherlands (+30.5%). Declines are notable only in Norway, with –12.6% fewer heat pumps sold in 2020. For Estonia, Ireland and Belgium 2020 market figures are not yet available. Until they are reported, last years' sales numbers are used.

The development of sales especially against the backdrop of the COVID-19 pandemic indicates an on-going strong market expansion for the heat pump industry in Europe.

87% of the European market volume was sold in only ten countries. The five biggest European heat pump markets in 2020 were France (394 129 units sold; –0.7% growth vs. 2020), Italy (232 834; +12.2%), Germany (140 390; +37.2%), Spain (127 856; –0.2%), and Sweden (107 723; +4.4%). The biggest absolute gains were achieved in Germany (38 040), Italy (25 324), Poland (18 504), the Netherlands (13 475) and Denmark (5 117). In relative terms, seven markets showed substantial increases above 10%.

The Nordic countries show the biggest market penetration for heat pumps in the building stock and experience also significant shares of the technology in the renovation sector. In sum, Sweden, Norway, Denmark and Finland grew by 677 units. The decrease in Norway (–13 233) is offset by gains in Denmark (5 117), Sweden (4 701) and Finland (4 093). However, it should be noted that figures for the Swedish market do not include the growth in air-air heat pumps. Thus, the Swedish market does look better in reality than what data indicates.

While Norway's market is maturing today, its development history reveals a significant growth perspective for Europe. If all countries had the same market penetration as Norway, annual heater sales would be dominated by heat pumps. Consequentially, this would go in parallel with a significant decarbonisation of the heating sector.

In 2020, heat pumps with a thermal capacity of 14.24 GW were installed producing approx. 27.11 TWh of useful energy and integrating 16.92 TWh of renewables in heating and cooling while avoiding 4.31 Mt of CO_2-equivalent emissions.

In order to produce the 2020 sales volume and to maintain the installed stock, a total of 89 784 FTE of employment were necessary. Obviously real employment related to the heat pump market is larger, as not all employees work full-time on heat pumps only.

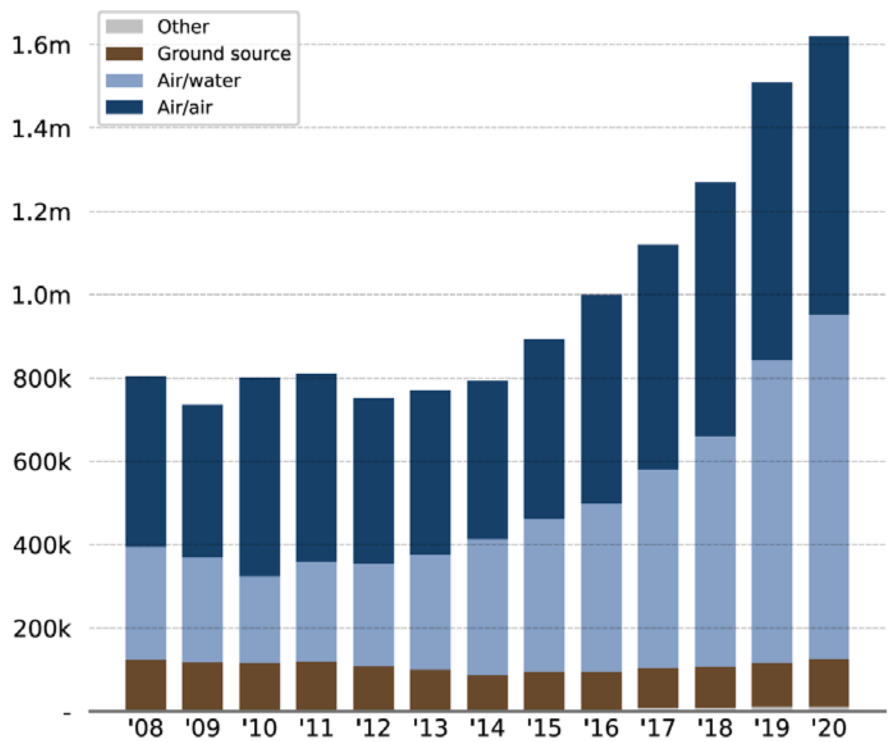


Figure 2. Sales development by type ("H-" indicates primary heating function).

For policymakers, this is good news as it shows a huge untapped potential to reduce Europe's energy demand for heating, cooling and hot water production. However, achieving it by 2030 would require an annual 15% growth rate and a tremendous effort with regards to framework conditions, efficiency requirements for buildings, upskilling of installer* and planner/architect qualification as well as the introduction of flanking measures.

In aggregated terms, nearly 14.86 million heat pump units were installed since 1996. This amounts to an installed thermal capacity of 128.7 GW. All installed heat pumps produce 252.6 TWh of useful energy, 160.2 TWh of which being renewable. Their use saved 204.8 TWh of final and 93.11 TWh of primary energy.

Figure 3 shows the split of renewable energy production from heat pumps on a country level. France is the country that produces the most renewable energy, followed by Sweden, Germany and Italy.

Emission savings from stock

The heat pump stock in 2020 (heat pumps sold in the past twenty years) contributed 41.07 Mt of greenhouse gas emission savings (see **Figure 4**). The distribution of emission savings per country is very similar to that of renewable energy production, since both calculations are directly linked to the number of units installed and the related reduction in demand for fossil energy. However even the 14.4% growth achieved in 2020 is not more than a step in the right direction. The current growth rate of heat pump markets across Europe is insufficient to decarbonise heating and cooling by 2050. It needs brave governmental decision makers to address the elephant in the room: a distorted price mechanism that favours the use of fossil fuels and fossil fuel technology.

Instead of making the polluter pay for emissions by adding related cost to the price for fossil energy, most governments still support their use – directly or indirectly – and leave the cost of environmental damage of fossil fuel for society to pay. Latest figures show that 6.5% of the global GDP or $ 5.4 trn are spent for fossil energy subsidies. A perceived cheap way of heating is actually paid for via other budgets, namely by health and environmental protection services.

The heat pump industry reiterates its call on decision makers in the European Commission and the Member States to address this issue. Heating and cooling industries need to decarbonise over the next 30 years. This

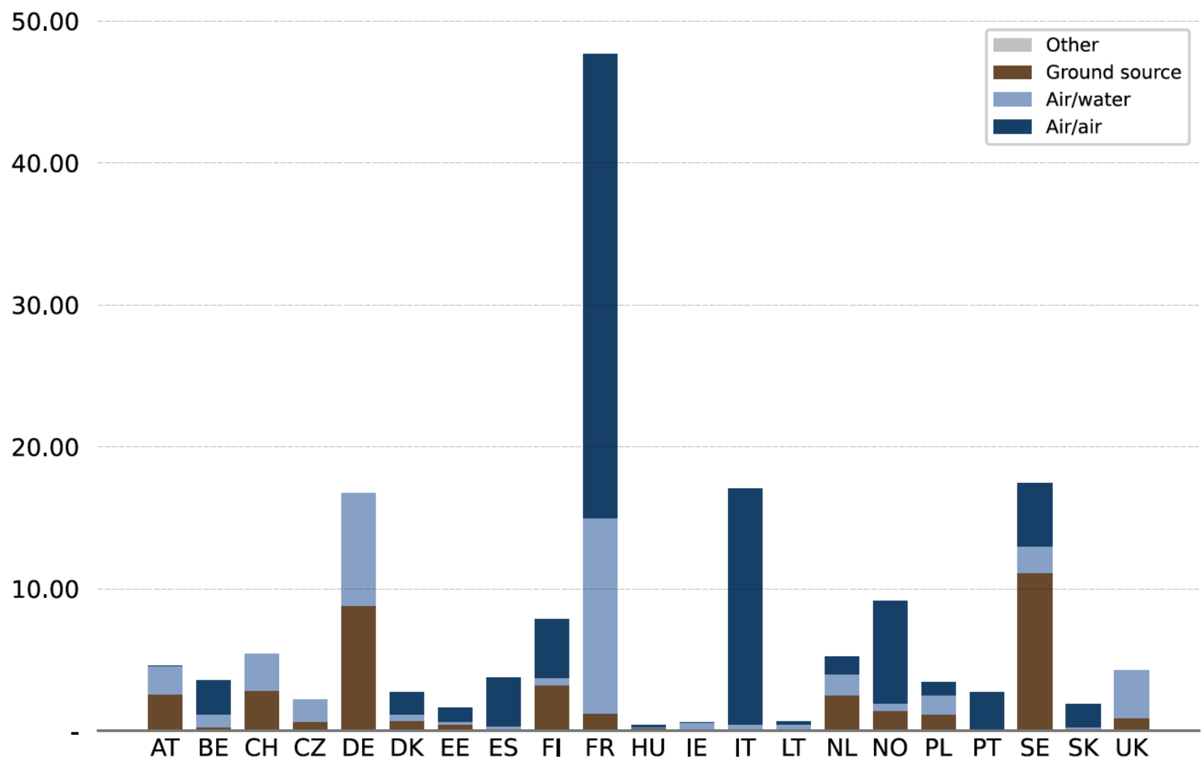


Figure 3. Renewable thermal energy provided per country, by type, 2020 (in TWh); "H-" indicates primary heating function.

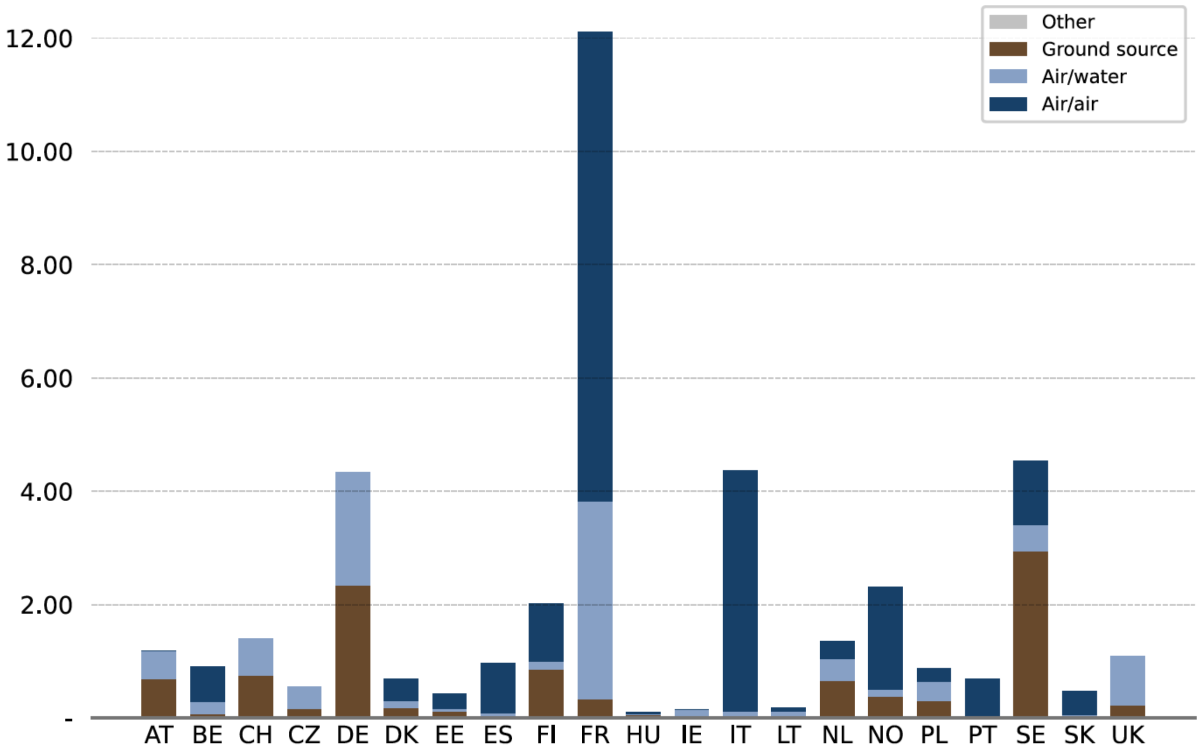


Figure 4. Greenhouse-gas emission savings based on sales 2020, per country (in Mt);"H-" indicates primary heating function.

is a tremendous challenge that needs to be started as soon as possible. The benefits of heat pumps make this technology a prime candidate for a central role in a sustainable European energy system. Clearly, today's business as usual will not be enough to unearth the technology's potential, instead significant government intervention is necessary to shape the sustainable energy supply in all Member States of the European Union. ■

VRF indoor units' airflow limit:

A step further for guaranteed performances

ALI ALEXANDRE NOUR EDDINE
Dr., Project manager VRF,
Eurovent Certita Certification
aa.nour-eddine@eurovent-certification.com

MORGANE LAJEUNESSE
Head of the Thermodynamic Department,
Eurovent Certita Certification
m.lajeunesse@eurovent-certification.com

In the context of the continuous development of the Variable Refrigerant Flow (VRF) certification programme, a review of the tested VRF units for the 2019 certification campaign showed many units with a very high airflow rate. Despite the firm certification and surveillance rules of the program, this showed that some units potentially used inflated airflow rate to increase the performances. To avoid this kind of certification rules circumvention, the certification committee decided to apply a limit of 275 m³/h/kW on the airflow of each indoor unit. This decision is based on scientific studies concerning the performances required of HVAC systems to ensure dehumidification and comfort requirement.

Literature review

The international standards in the HVAC industry are permanently changing and adding new measures to improve the comfort conditions in air-conditioned buildings. This results in a set of limits to the design parameters of a VRF systems such as Sensible Heat Ratio (SHR), Bypass Factor (BF), Air Flow rate (AF), etc.

The comfort conditions of HVAC systems are widely studied in the literature, specifically the humidity conditions. A recent ASHRAE research project investigated the dehumidification level of several commercial buildings (including offices, schools, restaurants, and retail stores). The sensible heat ratios were calculated for any hour in a year when the air conditioning system was ON and the building's occupancy was greater than zero. The study results by fixing the SHR limit to SHR < 0.82 at 100% load and SHR < 0.85 at 75%.

The coil Bypass Factor has been also calculated by ASHRAE [1] under Air-conditioning and Refrigeration Institute (ARI) conditions and has been set to an approximate range of 0.049 ≤BF≤ 0.080.

While usually a set of parameters is fixed including the airflow rate of the unit to determine the design supply temperature of the unit, some studies showed that the airflow rate must also be monitored since it has a direct effect of the dehumidification and hence thermal comfort cannot be reached even in an ideal design supply temperature of the unit. Murphy [2] tested the dehumidification level in a classroom under different weather scenarios. The base of the study is to fix the airflow rate of the cooling unit and calculating the supply temperature. The results show that with an air flow rate as high as 400 m³/h/kW the relative humidity of the classroom will be higher than 67%, either in peak dew point condition or during cool, rainy-day conditions which means the comfort cannot be reached in the classroom even with a set temperature of 23.3°C. This is because contrary to popular belief, high indoor humidity levels can be an issue in nearly all geographic locations, not just in areas where hot, and humid conditions prevail. Whenever high relative humidity levels exist at or near a cold, porous surface, moisture adsorption increases and moisture-related problems (such as increased health risks from mould

Photo: Kaffeebart / Unsplash

growth and premature replacement of equipment and furnishings) become likely. Finally, there are ways to improve the dehumidification performance like reducing the airflow which results in a lower supply air temperature for a given load condition, and therefore, more moisture is removed from the air.

Mustafa [3] specifically investigated the effect of the airflow rate on the humidification parameters. The results show that above a defined airflow, the humidity level increases with increasing the airflow rate.

Finally, a study on different airflow rate scenarios to maintain the indoor test conditions of 27°C DB and 19°C WB showed that the airflow rate should not exceed 247 m³/h/kW in ideal heat exchanger conditions (BF=0) [4]. This air flow rate is suitable for considering thermal comfort with the current test method.

However, considering that the realistic BF of current heat exchangers is closer to 0.1 than to 0, an airflow rate of 275 m³/h/kW is more representative of the dehumidification condition.

Eurovent Certification Committee decision

As a result of the scientific studies and following numerous programme committee meetings, it was decided that the airflow at standard air condition defined in the standard EN 14511-3:2018 shall not exceed 275 m³/h/kw for both cassette and ducted VRF indoor units. The limit shall apply in cooling and heating mode and only for units above 12 kW. This new rule is effective since March 2021 which made a great impact on the unit ranges in the 2021 catalogues of several manufacturers. For some manufacturers, it is represented by the appearance of new ranges of products and the stop of the production of previous indoor unit versions. For others, the performances of the same unit on the 2021 catalogue are decreased to that of 2020. For all cases, 2021 has marked a new era of guaranteed certified performances. ■

References

[1] ANSI/ASHRAE, «Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs» chez ANSI/ASHRAE Standard 140-2001, 2004.

[2] J. Murphy, Dehumidification Performance of HVAC Systems» ASHRAE Journal, pp. 23-29, 2002.

[3] A. T. Mustafa, «Experimental study of air flow rate effects on humidification parameters with preheating and dehumidification process changing» ARPN Journal of Engineering and Applied Sciences, vol. 6, n°9, 2011.

[5] Daikin, Consideration of thermal comfort for the review of Lot 10 - Cooling mode testing, 2020.

Can we still trust in EN 442?

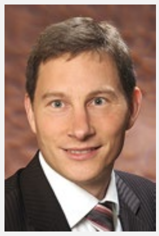
New Operating Definitions for Radiators

– *Part 2: Model Based Analysis and Results*

Part 1 was published in REHVA Journal 2021-01:
https://www.rehva.eu/rehva-journal/chapter/can-we-still-trust-in-en-442-new-operating-definitions-for-radiators-part-1-measurements-and-simulations-1





R. GRITZKI
TU Dresden

C. FELSMANN
TU Dresden

M. RÖSLER
TU Dresden

A. GRITZKI
BAuA, formerly TU Dresden

M. IIVONEN
Purmo Group

J. NAUMANN
GWT-TUD, Dresden

Abstract

In Part 1 it has been shown, that under EN 442 standard conditions the heat outputs of the simulated radiators were in all cases in very good accordance to the design data in the data sheets.

However, it also became apparent that in case of radiator type 22, for all supply temperature levels and already in the range of typical mass flow rates simulations such as measurements show higher heat outputs (up to approx. 10%) than calculated by the exponential approach according to EN 442-2.

On the other hand, the simulated heat output of radiator types without additional convection plates are for a wide range of flow rates in good accordance to the heat output values based on the exponential calculation approach using the logarithmic over-temperature (again called "exponential approach" in the following). Only at very low mass flow rates the actual heat output is lower compared to the exponential approach. This is also in accordance with the theory found in the literature. For typical fields of application, the exponential approach fits very well.

Symbols

k heat transfer coefficient, W/(m² K)
K_m radiator model constant, –
ΔT_m, ΔT_{ar} over-temperature (logarithmic or arithmetic), K
$\dot{m}$ mass flow rate, kg/h
$\dot{Q}$ heat output, W
Φ heat output (EN 442-2), W
T_{in} supply temperature, °C
T_{out} return temperature, °C
T_r room air temperature (control point), °C
c_p specific heat capacity, J/(kg K)
ΔT difference supply – return temperature, K

Indices

N nominal point / design point
ar arithmetic
ln logarithmic
50 design point (at 50 K over-temperature, EN 442-2)

Detailed investigations bring forth that, if convection plates are present the external heat transfer coefficients decrease with increasing mass flow rates and thus decreasing temperature spreads. In this case, the vertical temperature distribution of the water within the radiator is different from that of the radiator surface and is therefore no longer representative for the external heat transfer. The stronger cool down of the lower parts of the convection plates leads in total to a lower external heat transfer than in case of big temperature spreads.

For this case the application of an extended calculation approach, based on EN 442-2, is introduced to take into account the vertical temperature distribution of the radiator surface. For the examined radiator models with convection plates this calculation approach leads to a significantly improved agreement of the calculated heat outputs with the data based on the numerical simulations.

Introduction

From Part 1 [1] we have learned that the EN 442-2 [2] approach used to adjust the heat output of radiators to specific temperature conditions lead to some deviation of about 10% compared to both real and virtual radiator performance test results. It has been shown that this uncertainty of the conventional exponential approach is somehow related to radiators with convection plates (type 22) and mainly occurs in case of low mass flow rates, see **Figure 1**.

In **Figure 1** the heating power of two panel radiators with convection plates gained in high performing virtual experiments and the corresponding mass flow rates are displayed as a function of the difference between supply and return temperature (the temperature spread). The heat output under standardized reference conditions (75-65-20) is highlighted. In addition, the diagrams also show the heat output of the radiators at different operating temperature. The adjustment of heating power was done by the EN 442 exponential approach either by using the logarithmic over-temperature ΔT_{ln} or the arithmetic over-temperature ΔT_{ar}. Logarithmic over temperature is more accurate for heating power prediction but as already discussed lead to some uncertainty as well.

Looking at these results the question arises, what the mismatch causes. First assumption is, that it could be a result of the inhomogeneity of the temperature distributions (see the temperature stratification graphs in Part 1) at the entire radiator surface caused by large temperature spreads. Detailed additional investigations (based on the same logarithmic over-temperature and greatly varying temperature spreads) showed that indeed there is a difference in the vertical

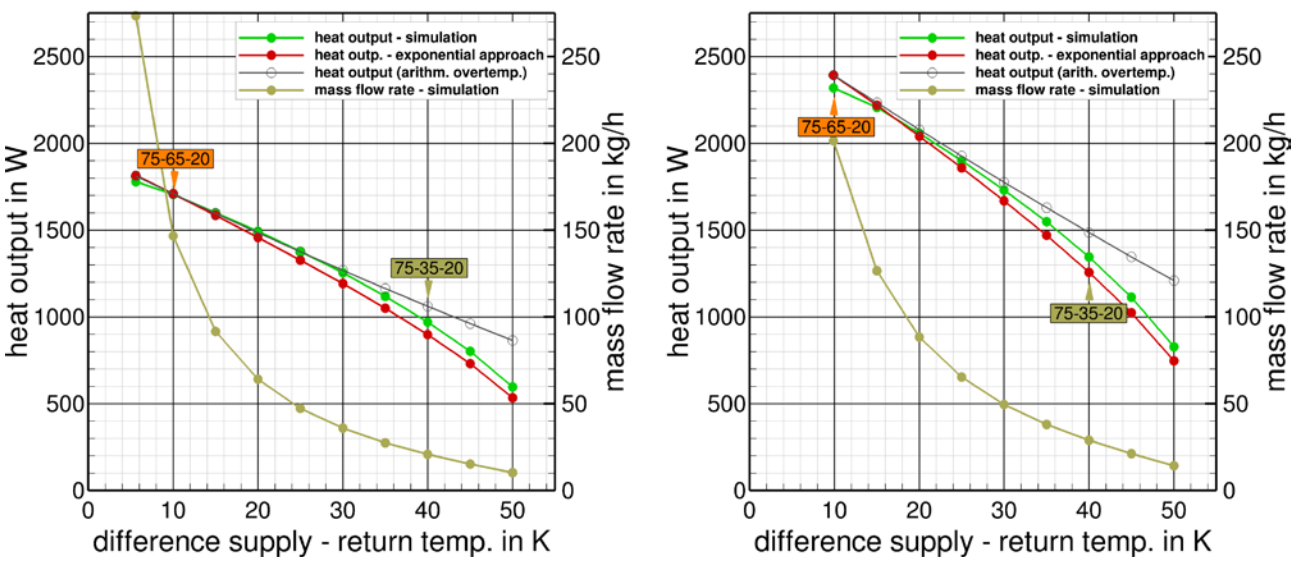


Figure 1. Simulated (green) and catalogue heat output data based on exponential approach (red/gray) at constant supply temp. of 75°C and changed mass flow rates, panel radiators with convection plates, type 22 – left: 1.0 m length, right: 1.4 m length.

temperature distribution of the different radiator parts, see **Figure 2**. The diagrams show the surface temperatures that have been averaged along small horizontal slices for the entire radiator and for the radiator components (water, radiator shell, convection plates). The radiator surface consists of the radiator metal itself and the convection plates.

In case of the large temperature spread (**Figure 2b**) caused by low mass flow rate, the temperature gradient above the radiator height is quite similar in all parts of the radiator (water, radiator metal and convection plates; the radiator surface reported is a combination of metal and convection plates). So, the averaged radiator temperature follows the water temperature and the vertical temperature distribution of the water is representative for the external heat transfer. So, it is obvious that once the logarithmic over temperature is calculated just based on supply and return water temperatures the radiator surface temperature can be concluded without knowing the exact temperature distribution.

Unfortunately, there is a slightly different situation in the case of small temperature spread (**Figure 2a**) caused by a high water mass flow rate. The temperature of the convection plates drops much faster from the upper part of the radiator to the lower part than the temperature of the water. Subsequently the vertical temperature distribution of the water is different from that in the whole radiator surface. Keep in mind, that the logarithmic over temperature in EN 442 calculated just from the water temperature entering and leaving the radiator cannot account for these phenomena!

Beside we can argue with heat transfer theory that the external heat transfer coefficients of the radiator decrease if the vertical stratification of temperature becomes lower due to high mass flow rates. Considering this, two effects caused by low mass flow and thus large temperature spreads have been isolated:

1. The logarithmic over temperature is not representing the temperature distribution on the radiator's heat emitting surface including convection plates.

2. The less stratified vertical temperature profile on the radiator surface in case of high mass flow rates has a limiting impact on the heat transfer coefficient. Heat transfer mechanism is accelerated if there is a significant temperature stratification.

It has to be mentioned that EN 442 standardized testing conditions are characterized by a low temperature spread of 75°C – 65°C=10 K, i.e. radiator model parameter K_m and n are estimated for a more unfavourable operation in terms of heat transfer.

To also ensure, as a next step, that the exponential approach based on the logarithmic over-temperature is valid for arbitrary mass flow rates (provided that load-dependent radiator model parameters are known), some additional investigations with constant mass flow

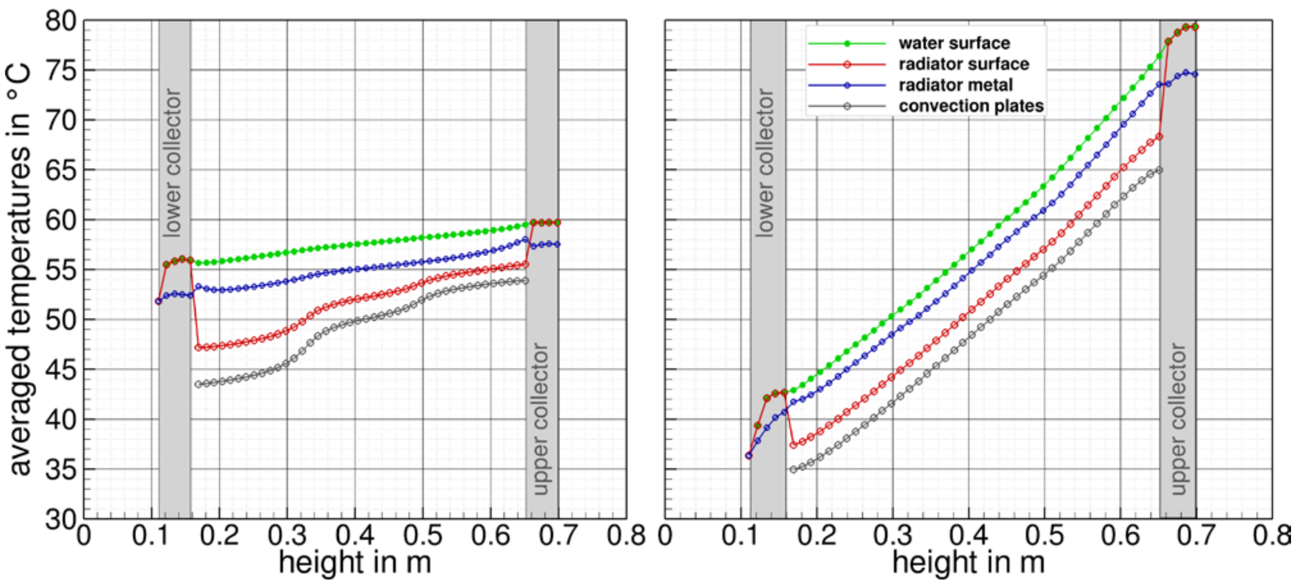


Figure 2. Averaged temperatures based on horizontal slices for different mass flow rates but the same logarithmic over-temperature of 38,2 °C, panel radiator with convection plates, type 22, 1.0 m length – left (a): 256 kg/h, right (b): 28 kg/h.

rates and varying supply temperatures were done. As an example of this **Figure 3** shows the heat output data based on the exponential approach (K_m and n always adapted to the respective mass flow) as well as based on the simulations for the panel radiator type 22 (1.4 m) and for two different base mass flow rates. The results clearly show that the adapted exponential approach for all supply temperatures is in very good accordance to the simulated heat output. This also confirms the findings in the literature [3].

Radiators without convection plates (panel and tubular radiators)

In **Figure 4** and in **Figure 6** the heat output data and the mass flow rates of the other four radiators without convection plates in dependence on the difference between the supply and the return temperature are displayed for the simulations as well as for the catalogue data based on the logarithmic over-temperature (and based on ΔT_{ar}). It is obvious that catalogue data (i.e. the exponential approach) and the simulations fit

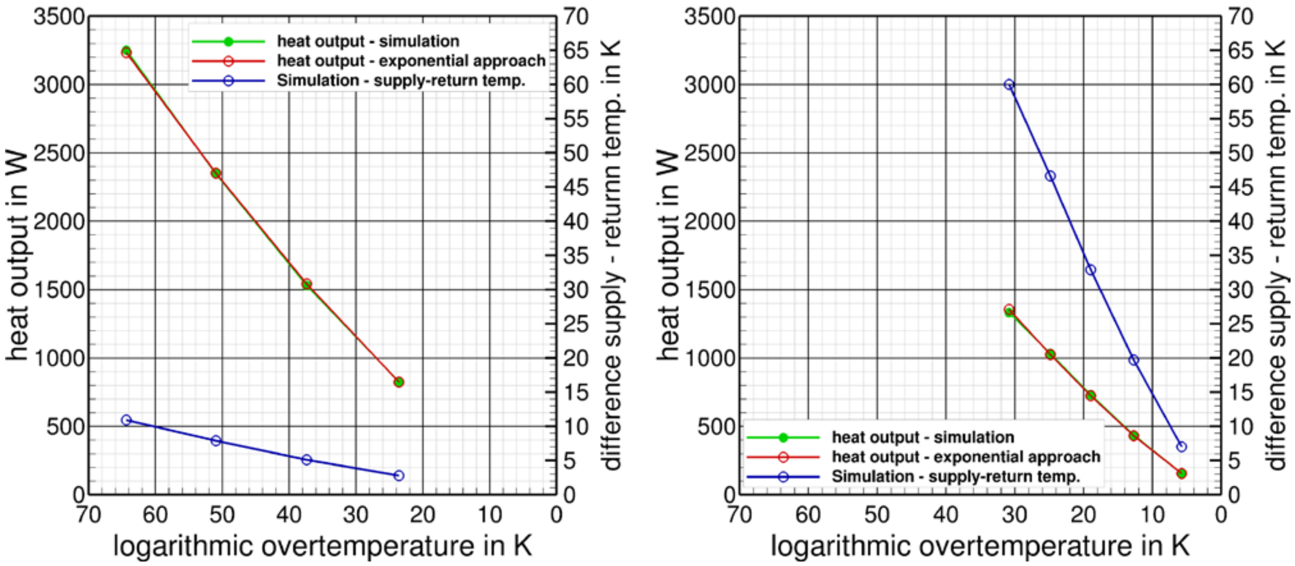


Figure 3. Simulated (green) and heat output data based on exponential approach (orange) at constant mass flow rate and different supply temperatures, panel radiator with convection plates, type 22, 1.4 m – mass flow rate left: 250 kg/h, right: 15 kg/h.

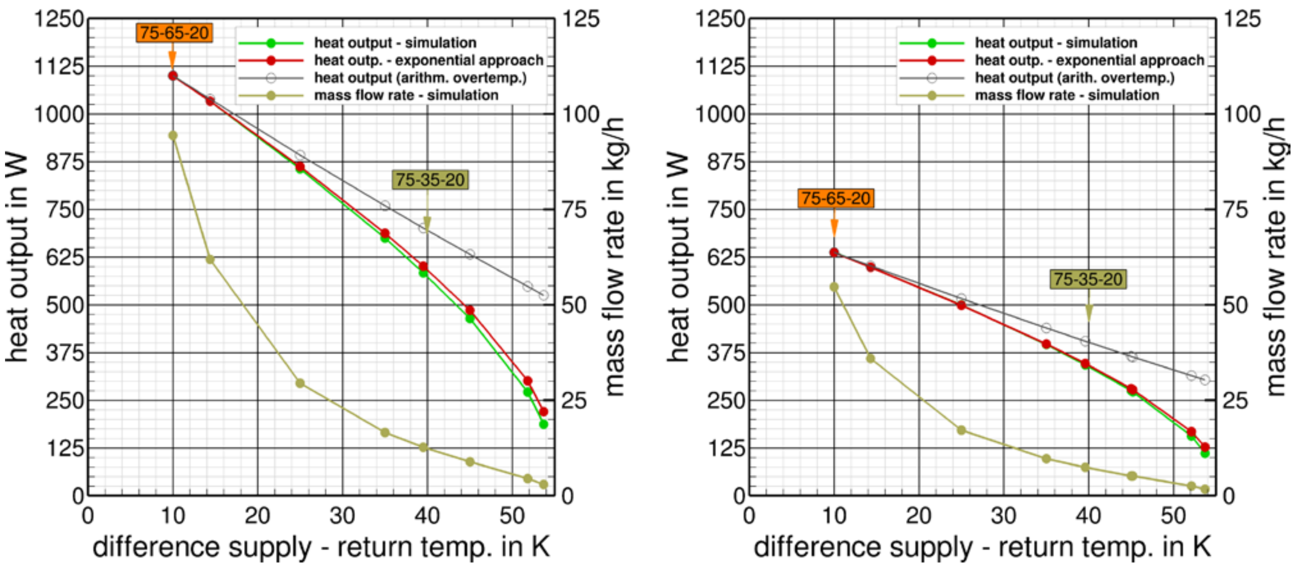


Figure 4. Simulated (green) and catalogue heat output data based on exponential approach (red/gray) at constant supply temperature of 75°C and changed mass flow rates, panel radiators – left type 20, right type 10.

much better and that in these cases the differences are much smaller. Only at very low mass flow rates the simulated heat output values are slightly lower than the values based on the exponential approach.

The detailed investigations based on the same logarithmic over-temperature and greatly varying temperature spreads showed in this case that the vertical temperature distribution of the water and the entire radiator surface are practically identical, see **Figure 5**. That means, the vertical temperature distribution of the water is representative for the external heat transfer and in both cases the same values of km and n can be used to predict the heat output.

As radiator surface temperature distribution clearly depends also on the presence of convection plates. The results support the presumption that radiator surface temperature distribution and its impact on heat transfer has to be taken into account when looking for a more accurate calculation approach (rather than that already published in EN 442-2), valid also for large temperature differences between supply and return temperature. A new approach is introduced in the next section.

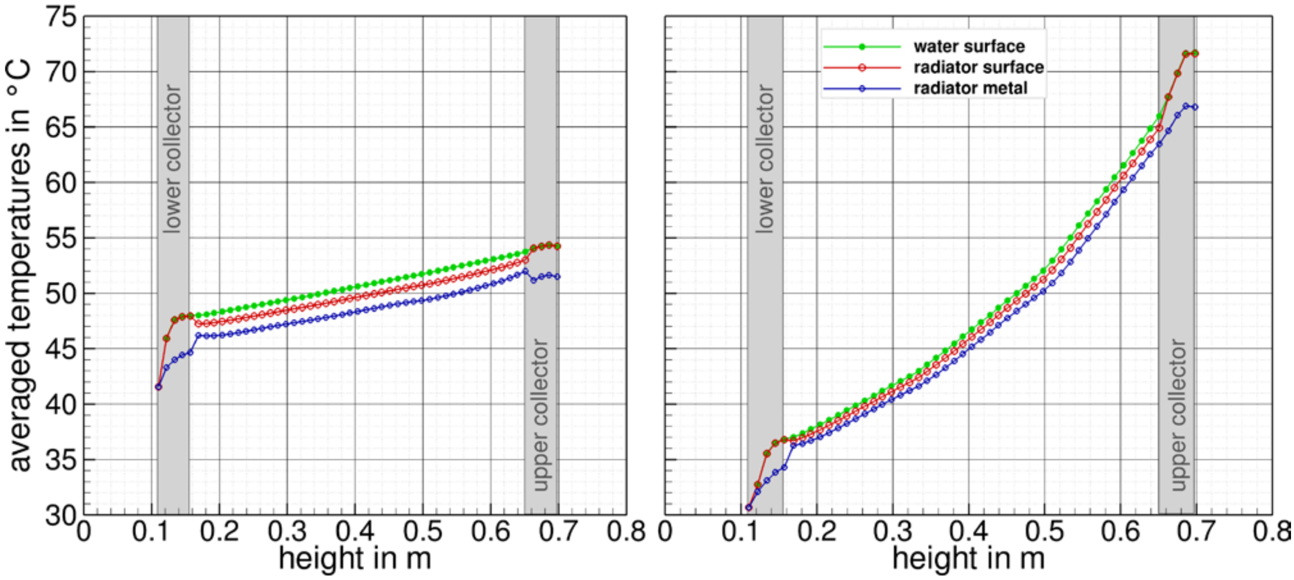


Figure 5. Averaged temperatures based on horizontal slices for different mass flow rates but the same logarithmic over-temperature of 38,2 °C, panel radiator with convection plates, type 20, 1.0 m length – left: 256 kg/h, right: 28 kg/h.

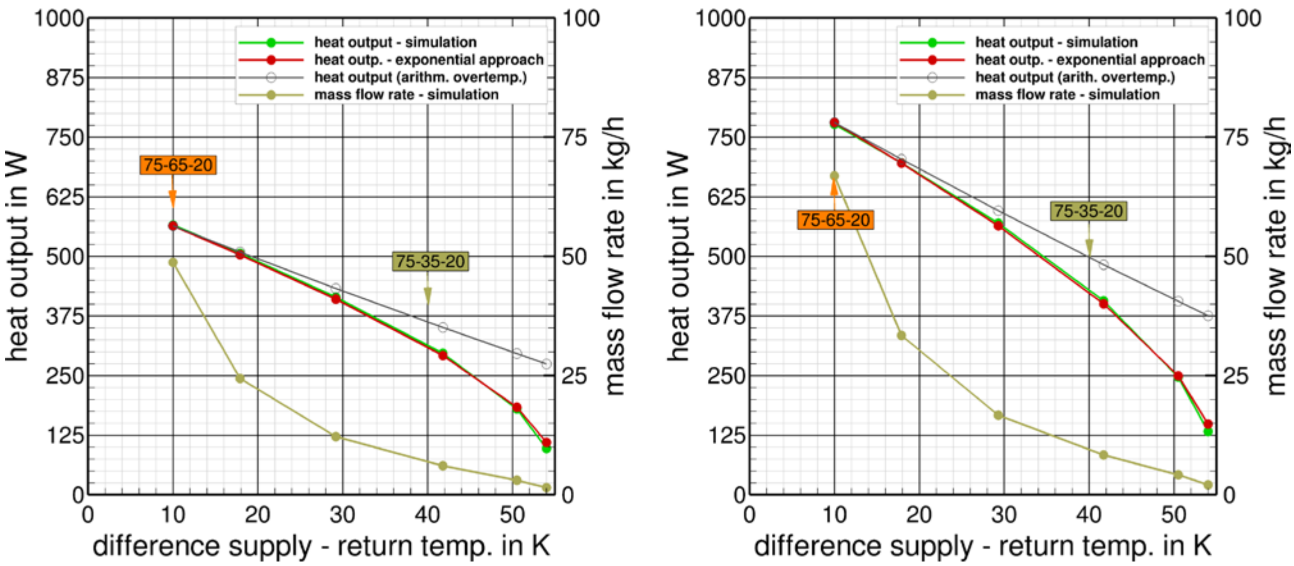


Figure 6. Simulated (green) and catalogue heat output data based on exponential approach (red/gray) at constant supply temperature of 75°C and changed mass flow rates, tubular radiators – left: 2 tubes, right: 3 tubes.

Extended approach according to EN 442-2 – Theory and Results

In the previous sections we have explained that the presence of convection plates disturbs the relation between water temperature and surface temperature of the radiator which is one of the basic assumptions for the application of the exponential approach. That means, the original problem occurs, if panel radiators with convection plates are handled as "normal" radiators ignoring the phenomena of heat transfer within the convection plates.

In this section an extended calculation approach for determining the heat output of radiators according to EN 442-2 is presented. The approach is again based on the logarithmic over-temperature ΔT_{ln} but is taking into account the new insights derived from numerical simulations of the two radiators with convection plates (type 22). It should be noted that this approach does not solve the original problem, it only circumvents it in order to apply the existing procedure as far as possible.

The theoretical approach for determining the heat transfer coefficient as a function of temperature conditions based on a given nominal point N (design point), described among others by Knabe [4] is

$$\frac{k}{k_N} = \left(\frac{\Delta T_{ln}}{\Delta T_{ln,N}}\right)^p = \frac{\Phi}{\Phi_N} \cdot \frac{\Delta T_{ln,N}}{\Delta T_{ln}} \tag{4}$$

with p = 0.25…0.4 for radiators. Based on this correlation one can determine the heat output of radiators at other operation points by equation

$$\Phi = \Phi_N \cdot \left(\frac{\Delta T_{ln}}{\Delta T_{ln,N}}\right)^{p+1} \tag{5}$$

and based on the specifications of the EN 442-2 (constant mass flow, design temperatures of 75-65-20°C, which means 50 K (ΔT_{ln} = 49.83 K) over-temperature) it reads

$$\Phi = K_{m,50} \cdot \Delta T_{ln}{}^n \quad \text{with}$$

$$K_{m,50} = \frac{\Phi_{50}}{\Delta T_{ln,50}{}^n} \quad \text{and} \quad n = 1 + p \tag{6}$$

Since in the simulations as well as in the measurements both K_m and n depend on the temperature spread (which increases with decreasing mass flow rates), it seems reasonable to apply a further correction factor F to the approach according to EN 442-2 which considers both the impact of the temperature spread on the vertical temperature distribution of the radiator surface as well as the non-representative over-temperature calculated just on the water temperature on the external heat transfer. Therefore equation (6) is extended by a factor based on a ratio of the actual temperature spread $\Delta T = T_{in} - T_{out}$ and the spread at the design point ΔT_{50} and an radiator model specific exponent q:

$$\Phi = F \cdot K_{m,50} \cdot \Delta T_{ln}{}^n \quad \text{with}$$

$$F = \left(\frac{\Delta T}{\Delta T_{50}}\right)^q \cdot \left(\frac{\Delta T_{ln}}{\Delta T_{ln,50}}\right)^{-nq} \tag{7}$$

In this approach, which was originally derived on the basis of mass flow ratios, the heat transfer changes only as a function of the radiator temperatures (but we should keep in mind, that in fact effective radiator temperatures are a result of supply water temperature and water mass flow rate). For the two investigated radiators with convection plates (one type, different lengths) the determined values of q are 0.0357 (1.0 m length) and 0.0486 (1.4 m length).

www.purmo.com

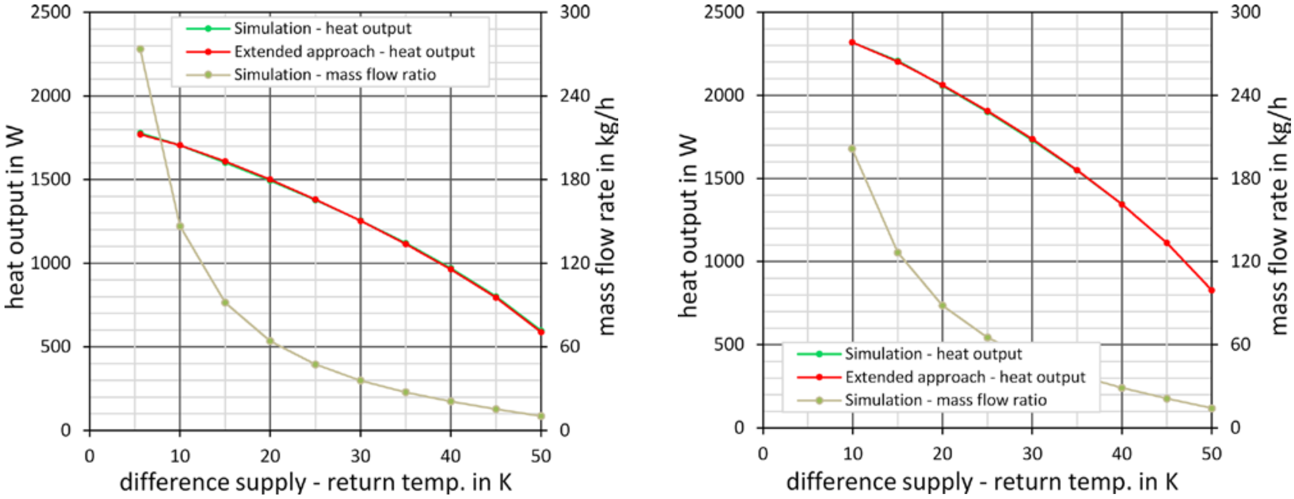


Figure 7. Simulated (green) and catalogue heat output data based on the extended exponential approach (red) at constant supply temperature of 75°C and changed mass flow rates, panel radiators with convection plates, type 22 – left: 1.0 m length, right: 1.4 m.

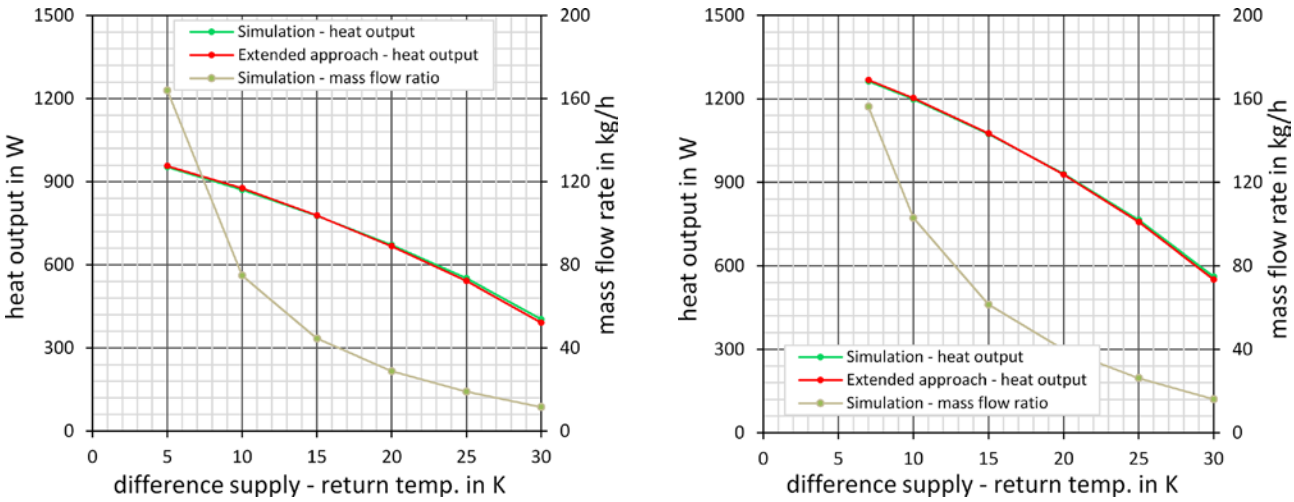


Figure 8. Simulated (green) and catalogue heat output data based on the extended exponential approach (red) at constant supply temperature of 55°C and changed mass flow rates, panel radiators with convection plates, type 22 – left: 1.0 m length, right: 1.4 m.

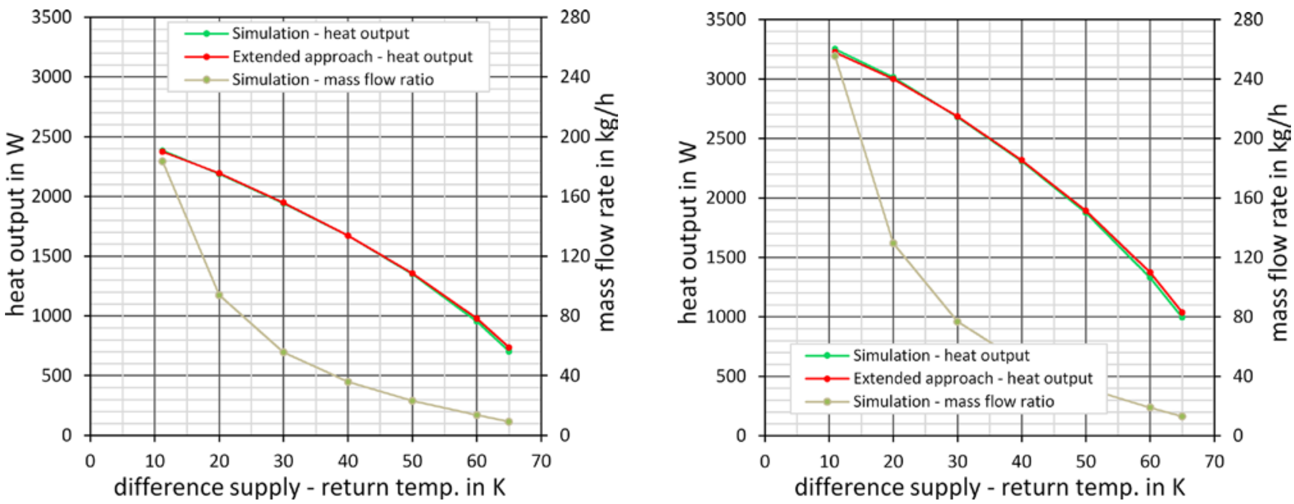


Figure 9. Simulated (green) and catalogue heat output data based on the extended exponential approach (red) at constant supply temperature of 90°C and changed mass flow rates, panel radiators with convection plates, type 22 – left: 1.0 m length, right: 1.4 m.

In **Figure 7** to **Figure 9** the heat output values and the mass flow rates of these two radiator models in dependence on the difference between the supply and the return temperature are displayed for the simulations as well as for the catalogue data based on the extended calculation approach. The consideration of the mass flow induced temperature distribution at the radiator leads to a significant improvement at low mass flow rates and large temperature differences between inlet and outlet. This applies to all temperature levels and both radiator lengths. The relative deviations when using the extended approach for calculating the heat output are in the range of ±1%. Only at very small mass flows below 10% of the design, deviations can be up to ±4%.

Remaining deviations between simulation and calculation are due to inaccuracies of the logarithmic over-temperature, simplifications of the CFD simulation and the neglect of the (weak) temperature dependence of the exponents n and q.

For the extended calculation approach, both exponents n and q can be assumed to be approximately constant for a radiator type, independent of the flow and temperature conditions.

As might be expected, for deviating radiator lengths a relation to determine the exponent q may be found. In the case of the present radiator type, the exponents changed proportionally to the radiator length or the design heat output ("q1.0m" = 0.0357; "q1.4m" = 0.0486):

$$q1.4\text{ m} \approx (1.4\text{ m} / 1.0\text{ m}) \cdot q1.0\text{ m}$$

To determine the exponent q und thus the additional factor F, only an additional data set (based on one measurement) with significant deviation from the design mass flow (for example 30 % of the design mass flow rate) is appropriate.

Summary

The investigations showed that the EN 442 approach is reliable for a wide range of flow rates to predict the heat output of a radiator with no additional convection plates. Only at very low mass flow rates and thus large temperature drop the exponential approach shows some weakness. Nevertheless, for typical fields of application the exponential approach fits very well, it seems that additional corrections are not necessary.

If convection plates are present, the EN 442 predicts lower higher heat outputs (up to approx. 10%) than either measured by Rettig ICC or virtually tested. This applies to all supply temperature levels already in the range of typical mass flow rates. Detailed investigations showed that the external heat transfer coefficients decrease with decreasing temperature stratification on the radiator surface. Stratification is high for low mass flow rates. In this case the temperature distribution of the water within the radiator is different from that of the radiator surface and is therefore no longer representative for the external heat transfer. In other words, the ratio of the vertical temperature distribution of water and radiator surface is different for different mass flow rates and therefore the radiator model parameters are different as well.

In case of radiators with convection plates, the application of an extended calculation approach to take into account the mass flow-induced change in the external heat transfer coefficient leads to a significantly improved consistency and reliability of the calculated heat outputs. The findings and the suitability of the extended approach should be checked for further radiator models (larger height/length, towel radiators) and connection types as well as the way of determining the additional exponent q in order to ensure their generality. From the practical point of view, it has to be decided if uncertainties of the recent approach justify any effort for improvements. Anyway, the TU Dresden virtual test cabin for radiator testing according to EN 442 is very helpful to analyse heat transfer phenomena at radiators. ■

References

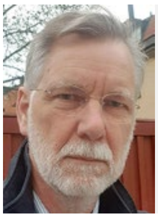
[1] Gritzki, R., Felsmann, C., Rösler, M., Gritzki, A., Iivonen, M., Naumann, J. New operating definitions for radiators based on different flow conditions – part 1, Measurements and Simulations, REHVA 2021

[2] EN 442-2. 2014. Radiators and convectors – Part 2. Test methods and rating. Beuth Verlag, Berlin.

[3] H. Bach, D. Schlapmann. 1977. Effektive Übertemperatur zur einheitlichen Darstellung der Wärmeleistung von Raumheizkörpern. Ki 10/77, Teil 6, S. 592-597.

[4] Knabe G. 1992: Gebäudeautomation. Verlag für Bauwesen Berlin, München.

A Paradigm Shift?



GÖRAN STÅLBOM
Allmänna VVS Byrån AB /
KTH Health informatics
goran.stalbom@vvs-byran.se / gest@kth.se

Preface from editor:
Given the nature of this article and the intention to generate a feedback and dispute based on this article the RJ editor has with some help added some footnotes to stimulate reactions. The REHVA TRC installed recently a TF "IEQ requirements – input for revising EN 16798-1", illustrating the interest of REHVA in addressing IEQ.

Are technical systems for ventilation important for public health? Or are they primarily designed to create thermal and olfactory comfort for occupants? Or wellbeing? What are the objectives and what are the means in our quest for a better indoor environment? Have risk assessments, thoughts, expectations and health prevention during the last 50 years among researchers, industry and authorities been well-founded? In any case, we are now facing a new time and new way of thinking.

Indoor air and health

Contaminated indoor air can pose major health risks. This leads globally, according to the WHO, to a shortened life expectancy for more than three million people every year.[**1**] However, such serious risks are mainly associated with cooking indoors over open fireplaces. They are not primarily associated with inadequate ventilation. The problem in this case, is the design of the fireplaces and chimneys.

Public health should prioritize the obvious health risks, as well as the risks that can be easily remedied. The risks in kitchens associated with cooking and combustion are good examples. In Europe, the risks are significantly lower than the one mentioned above. But frying food without a good exhaust hood undoubtedly involves some risk.

Fireplaces, gas stoves, candles, especially scented candles, and other combustion activities can produce unpleasant and toxic air pollutants. Frequent and long indoor exposures from chain-smoking people is not risk-free. The use of cleaning products with unclear chemical content and other chemicals always requires caution. The warning texts should be heeded. Those

Paradigm shifts in science

Thomas Kuhn, American philosopher of science, published The Structure of Scientific Revolutions in 1962. His statements are today more relevant than ever. Kuhn introduced the term **paradigm shift** and he made claims concerning the progress of scientific knowledge: 1. Scientific fields undergo periodic ”paradigm shifts” rather than solely progressing in a linear and continuous way. 2. The paradigm shifts opens new approaches to understand what scientists not considered valid before. 3. The notion of "a scientific truth", at any given moment, cannot be founded solely by objective criteria, but is defined by a consensus of a scientific community. 4. Paradigms are often incommensurable, they present competing and contradictory versions of reality. 5. With a paradigm shift, new terminology is often created, which contributes to incommensurability.

Kuhns conclusion was that our knowledge never can rely on ”objectivity” alone. Science must account for subjective perspectives.

Open fireplaces for cooking are a major smoke problem and a serious health risk in many countries.

who live close to industrial areas or next to a busy street should consider strategies for when window ventilation should take place, depending also on weather and wind.

For the residents, caution and good judgment is essential. It can be difficult to do more. One option for the anxious one may be to buy an effective air purifier.

The kind of risks that are mentioned should be paid more attention. At the same time, critical questions should be asked about many of the health and discomfort risks that have been highlighted since the 1980s. Are there discomfort risks that have been far too dramatized in an unfortunate interaction between politicians, media, researchers, authorities, and anxious people?

Science or belief?

I wish my confidence in the research on "ventilation and health" in recent decades had been higher.

▶ REHVA Journal observation #1: Countries like Sweden have done fantastic research over the last 50 years or so (just google Jan Sundell, Britta Berglund, Carl Gustav Bornehag, etc.). Also, other countries have been quite active in IA research (e.g. USA, Canada, Japan, China, Korea, Singapore, Australia, France, Germany, Denmark, Norway, Finland, ...) The research community is there (see e.g. www.isiaq.org). More research needed? Yes, but the problem is: 1. Lack of serious funding to conduct real large indoor air studies, 2. too little focus on transmission of infectious diseases via the air amongst IA researchers, 3. Authorities that don't listen to what the indoor air community has to say....

But now there are reports from a new European research program, which started in 2010. The task was to elucidate the issues concerning "ventilation and health". I hope their results will increase the knowledge. More on that later. First, an example of the new thinking of our time. In the REHVA Journal 2-2021, Pawel Wargocki writes:

> *"There are many beliefs regarding ventilation, and many are only partly true. Among the few, it is assumed that more ventilation will always improve indoor air quality, that low ventilation rate always means poor air quality, that it is simple to measure ventilation, that ventilation can be used as a metric predicting human responses, that outdoor air and air supplied indoors are clean, that ventilation systems are clean"*

Tobacco smoke has been a major comfort problem in indoor environments and above all a big health risk for the smoker. It is possibly the most disturbing and unhealthy indoor air pollution we have voluntarily been exposed to in modern times. It is now difficult to understand that smoking was generally accepted in indoor environments from the 1930s until around 2005. The picture shows the Swedish Prime Minister lighting his pipe at a press conference in 1973.

He further writes that buildings need ventilation that is

> *"reliable, flexible and well-functioning, adaptable, and responsive to different needs and unusual events".*

I agree with him. I believe also that we must abandon outdated ideas and find new relevant criteria for building ventilation. This requires, as he writes, *"out-of-the-box thinking"*.

The thinking since the 1980s that has long characterized the view of "ventilation and health" and have guided research, industry and authorities. It should have been abandoned long ago. I have stated this in many articles since the late 1990s.

Modern ventilation

Ventilation systems in modern buildings usually have a technology and design that shows they are primarily designed and built with a focus on creating comfort. The notion that our ventilation systems would be of great importance for health is well established. This is the case in industrial environments, but in offices and schools the function is primarily to avoid olfactory and thermal discomfort.

Now we seem to be facing a radical paradigm shift. Some health risks have been greatly exaggerated by the ventilation industry, authorities, and media with the support of outdated research. Fortunately, "ventilation and health" is now being brought to the attention of a new generation of researchers. An example is the Healthvent project that started in 2010. They approach the issue in a clear, wise, and balanced way. The focus seems good, and there are still important and principal questions to investigate and answer.

The Healthvent project

The new research changes the relationship between *air quality* and ventilation (*air supply rate)*. So far, ventilation industry and authorities have had a strong focus on high *air change rates*.

▶ REHVA Journal observation #2: At the same time many authorities focussed on Energy Performance which caused a reduction of air change.

This doctrine has prescribed that with a certain minimum *air change rate*, all requirements for air quality will be met. But the Healthvent project seems to abandon this idea. Instead, the factual *quality of the air* (an exposure level) is presented as the central issue.

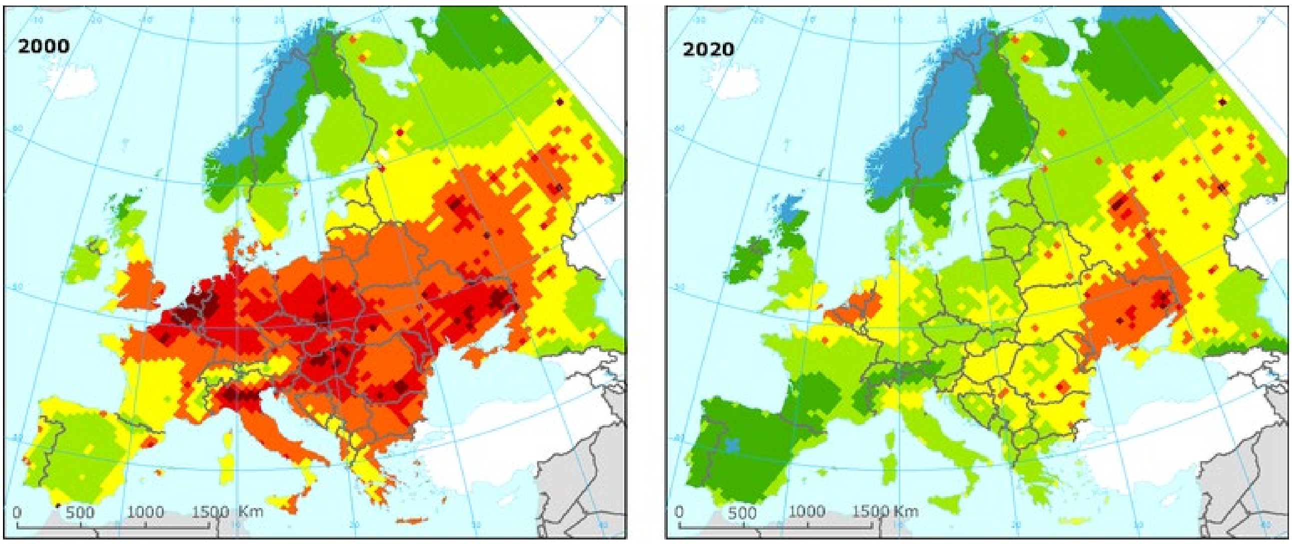
▶ REHVA Journal observation #3: In this context it would make sense to focus more on performance requirements (e.g. in the form of maximum pollution levels that are allowed) than on means.

They pay attention to measurable air pollutants listed in WHO guidelines. Details need to be discussed further. But it is a wise step forward, towards rationality.

The Healthvent project emphasizes the importance of source control and proposes a relatively low requirement for a "base ventilation rate". This is 4 ℓ/s per person (equivalent to about 1 600 ppm CO_2).

▶ REHVA Journal observation #4: Not sure if this understanding of base ventilation is correct, see how it was reported in EN 16798-1, tables B6-B14, "The HealthVent group also concluded that increasing outdoor air supply rates in non-industrial environments improves perceived air quality; that outdoor air supply rates below 25 l/s per person increase the risk of SBS symptoms, increase short-term sick leave, and decrease productivity among occupants of office buildings; and that ventilation rates above 0.5 air changes per hour (h–1) in homes reduce infestation of house dust mites in Nordic countries.

The level was chosen to achieve a safety margin in accordance with current knowledge. This level: "will ensure no elevated risks for health due to exposure to human bioeffluents when all other pollutants meet the guideline values".



Loss in statistical life expectancy that can be attributed to man-made emissions of $PM_{2.5}$

Months: 0–1 | 1–2 | 2–4 | 4–6 | 6–9 | 9–12 | 12–36 | Outside report coverage

Particles PM2.5 are now known as a measurable air pollutant that poses a health risk to humans. The maps shows that the outdoor air content has clearly decreased. Source EEA 2016.

But it is said that the level: "should be revised if more evidence on the effects of human bioeffluents become available, whether up or down". Perhaps research will soon provide confirmation of what I see as proven experience – that bioeffluents are a comfort risk – not a health risk.[**2**]

Nowadays, we are well aware of the fact that viruses and other infectious agents are a significant indoor health risk. Different infectious agents have different strategies, which need to be studied further. The confusion surrounding ventilation and the Covid-19 shows that the Healthvent project also has a major task here. But it is important that such research is conducted without preconceived notions.[**3**]

Objectives and means

In the preface to Wargocki's article in REHVA Journal 2-2021, five "incompletely resolved questions concerning ventilation" are listed. As I see it, they can-not yet be answered. What is required first is the agreement on what should be considered as *objectives* – and what to be *means* for achieving them. This must be clarified much better. The ventilation industry and authorities has too seldom made difference between *objectives* and *means*.

▶ REHVA Journal observation #5: Correct performance based requirements (max values for PMx, CO_2, TVOC…) should be the basis for our designs.

Since the 1980s, modern technical systems have been considered necessary for health. *Ventilation* and *air change rates* have been perceived as *objectives*. Measured "statutory air change rate" has been considered the measure of good "air quality".

This is unreasonable and must be reversed. The objectives should reasonably be *air quality*, *health, well-being* and *comfort*. Examples of means are *source control*, *ventilation (air change)*, *air purification* and *air cleaning*. This is obvious to anyone who is active in the industry. Yet still too few, almost none, have reflected upon it. Even "purchased energy", such as electricity, heating and cooling, are means, whose use must be limited with efficient systems, correct ventilation, temperature and operating times as well as utilization of the thermal dynamics of the building and the technical systems.

The benefits for "office work performance" and "school learning performance" is often presented as an objective for ventilation, but the causality is still unclear and requires more research.

The objectives, *air quality*, *health, comfort* and well-being, can be difficult to formulate and define. However, technical systems for ventilation are easy to plan, design, install, control and measure. We are easily seduced by the visible and the measurable. But the concepts of *health, well-being* and *comfort* are complex and elusive. There are established definitions - but they are debatable.[**4**] And the concept of *"air quality"* has been particularly difficult to define.

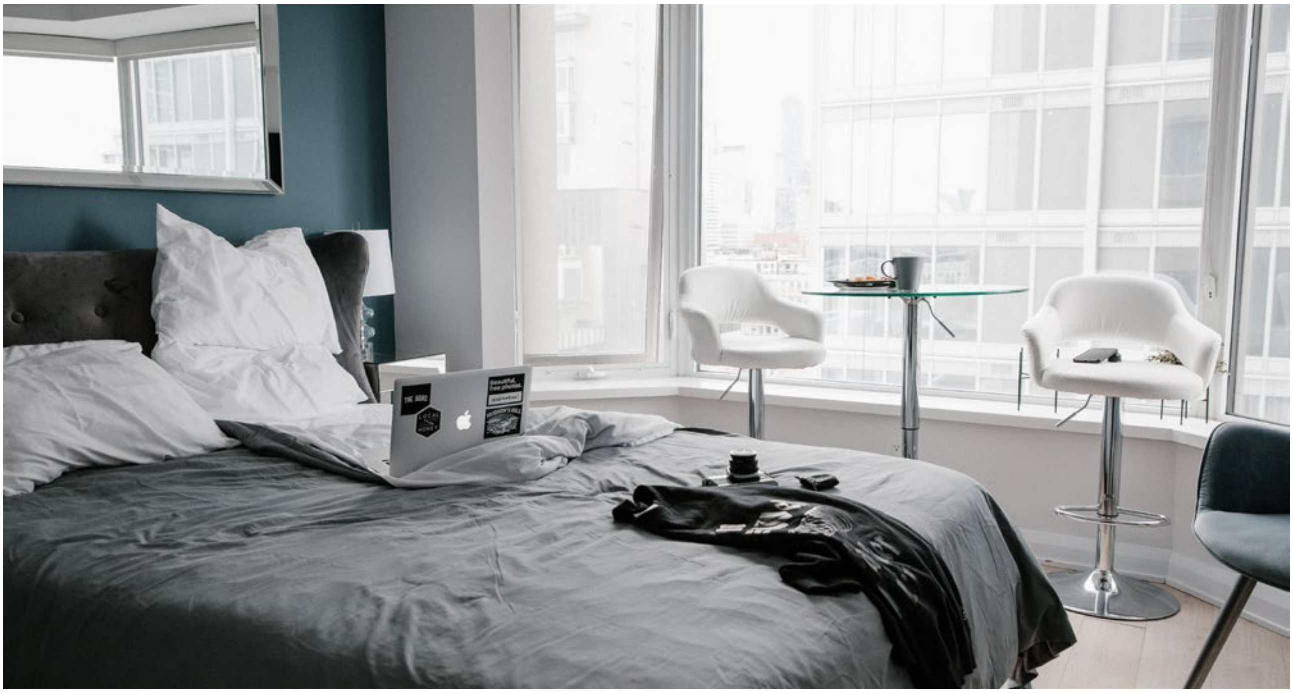


Photo by Andrew Neel on Unsplash

What is "air quality"?

Large air change rates can sometimes provide thermal comfort. The ventilation industry and authorities have long argued that it is also important for health. Of course, this is the case in polluted environments, for example in industry. Not necessarily in schools and offices.

The term "air quality" has been used since 1967 for outdoor air. Later also for indoor environments, but still without an established definition. The term has been used in several different ways. The air quality criterion has been based on, for example:

- to achieve a minimum (outdoor) air change in a room (now common in Sweden),
- to measure selected air pollutants for which a maximum guideline value has been specified (WHO Guidelines referred by the Healthvent project),
- people's subjective perception of the quality of air (suggested by P.O. Fanger).

Air in ordinary buildings is in constant motion. It penetrates the windward wall, leaves from the leeward. Heating creates thermals. People move and breathe - the air swirls. Doors and windows are opened and closed. The sun affects. The Danish artist Vilhelm Hammershøi studied air movements with great interest. 1990 he painted "Dust Motes Dancing in Sunbeams". Can "unventilated" spaces be created despite all this? If so, it has probably limited practical significance for health risks.

The concept of air quality has therefore to me remained vague and unclear and is often met with scepticism. In this text it is used in this traditional sense with the hope of better future terminology. Both meteorologists and indoor researchers nowadays often prefer to use its opposite, the more specific "air pollution".

Where do we stand now?

Harsh criticism can and should be directed towards older research and current guidelines, advice, and rules. I have presented these opinions previously in Swedish journals. This article is part of an ongoing discussion. I welcome critical comments to my interpretations and preliminary conclusions. Based on future objections, I will be happy to clarify and develop the reasoning further – and adjust if necessary. Our knowledge grows through constant critical review and necessary reconsideration.

▶ REHVA Journal observation #6: Yes we guess that one of your points is that we should develop new models and new standards that are more performance based, that try to find a good balance between energy use (related to ventilation) and health/comfort on the other side, that address also the risk for transmission of infectious diseases via the air etc?

Now it is time for the ventilation industry and authorities to begin the work to develop well-founded and useful guidelines based on proven experience and the science of our time. ■

References

[1] WHO, *Burning Opportunity: Clean Household Energy for Health, Sustainable Development, and Wellbeing of Women and Children*, 2016.

[2] Carrer et al, On the Development of Health-Based Ventilation Guidelines: Principles and Framework, 2018.

[3] Lidia Morawska et al., A paradigm shift to combat indoor respiratory infection, *Science* 14 May 2021: Vol. 372, Iss. 6543, p. 689-691.

[4] Altomonte et al, Ten questions concerning well-being in the built environment, *Building and Environment* (2020),

Fit for 55 package

– an action plan that fits perfectly with Daikin's renewable heating operations

A greener Europe is one step closer. After having developed a strategy for a more sustainable Europe through the Green Deal, the European Union launches its implementation through the "Fit for 55" package. As one of the world's largest CO_2 markets, the EU's 'Fit for 55' package aims to set the EU on course to slash greenhouse gas emissions by 55% by 2030 and try to hit net zero emissions by 2050.

As the market leader in heat pumps, Daikin, who has committed to becoming a carbon-neutral company globally by 2050, not only supports this package, it has also anticipated it through the disclosure of a 4 steps guide to make it successful and help decarbonize the heating sector. The "Fit for 55 package" is completely in line with this guide and shares the same objective: to make Europe greener, practically.

What is Fit for 55?

Announced on July 14 2021, "Fit for 55" is the European Commission's ambitious plan to put the decarbonization strategy into practice and set the EU on course to slash greenhouse gas emissions by 55% by 2030.The directive maintains that a policy targeting higher energy efficiency and a switch from fossil-based heat supply to renewable sources is imperative.

Wide-ranging in scope, the Green Deal encompasses renewables, energy efficiency first, energy performance of buildings, land use, energy taxation, effort sharing and emissions trading. Heat pump technology will be instrumental in decarbonizing European homes as a viable option for new buildings and a replacement for fossil fuel boilers. To meet the new Green Geal's objectives, Daikin has unveiled a 4-step guide to decarbonize homes and help ensure Europeans are trailblazers in climate action.

Patrick Crombez, General Manager Heating and Renewables at Daikin: "We welcome this "Fit for 55 package" with great enthusiasm. It allows the vision of the Green Deal to be clearly put into practice. With this breakthrough, Daikin sees its mission to make heat pumps accessible to all households strengthened."

A perfect match

Fit for 55's four objectives for the heat pump market and the 4 steps guide are logically interconnected. The package's objective 3, which aims to guide citizens to efficient and renewable heating and cooling solutions for their buildings, is a direct continuation of the first step of the Daikin Guide which commits to enhanced new build rules on energy use. Moreover, increasing the "replacement rate" that is so important for the heating sector to be able to achieve decarbonization targets is also reflected in the Fit for 55 -package. The first objectives of the package tend towards incentivizing fossil fuel switching and encourage technologies that are both efficient and renewable and thus unlock the full potential of heat pump technologies.

Finally, the last steps of Daikin's guide correspond to the last objectives of the European package: ending fossil fuel incentives by reviewing energy pricing which will also help to make renewable heating standard in replacement. "The match between our 4-step guide and the new European package is perfect. This shows that beyond commitments and fine words, Daikin is fighting on the ground every day to improve the quality of life of its citizens while preserving the planet. We will continue to guide citizens and support heating installers, alongside the European Union, on the ground towards more sustainable heating solutions" concludes Patrick Crombez.

Daikin unveils the 4-step guide to decarbonizing our homes Daikin unveils the 4-step plan to transform residential heating and cooling for a greener Europe

The majority of residential housing is still heated with outdated systems, often using polluting fossil fuels such as coal and oil. As of today, the European building stock is responsible for approximately 36% of all CO_2 emissions in the EU. In some European countries, renewable heating via heat pumps has become the new standard in new builds, while the potential they offer calls for more exposure in replacement. This observation contrasts sharply with the raised EU goal of CO_2 emission cuts from 40% to 55 % by 2030 in the recently signed European Climate Law, which forms the basis for the Renovation Wave strategy [1].

Patrick Crombez, General Manager Heating and Renewables at Daikin: "*A clear and accessible strategy for decarbonizing residential heat is needed and renewable technologies are playing an essential role in achieving the new targets, especially in the replacement market. Daikin has adopted the ambitious new targets and takes the lead with a 4-step guide to transform residential heating.*"

The 4 steps to decarbonizing residential heat

The founding step of this new plan is to strengthen Energy Performance requirements for new buildings. Today, Daikin estimates that heat pumps already have up to 50% market share in new (single family) houses across Europe. Reinforcement of the current EP requirements must therefore be put in place, to make heat pumps the standard.

The second step is to increase the replacement rate. In order to achieve the objectives of the European Climate Law, the renovation rate must double from 1% to 2% by 2030. By increasing the replacement rate, old systems are being replaced by more energy-efficient ones, leading naturally to emission cuts. The next

challenge is therefore to motivate EU citizens to choose renewable solutions. This involves the need to explain on a wider scale that -low carbon emitting heating systems, like heat pumps, are an efficient, cost-effective and established solution.

The third step consists of ending fossil fuel incentives. Policy makers should avoid incentives for fossil fuels. Currently, direct or indirect incentives benefit oil or gas-based boilers over heat pumps. They are made cheaper and more accessible, and that's why low carbon emitting technologies like heat pumps also need a level playing field. The gap between today's electricity and gas prices in many member states is too high to make heat pumps accessible for all EU citizens.

The final step is to make low carbon emitting heating the standard in replacement. Daikin believes that heat pumps are the best solution [2]. Heat pumps are increasingly capable of high efficiencies even at lower outdoor temperatures. They are therefore fit for any type of house or apartment. Using renewable energy sources to heat your home reduces the consumption of polluting fossil fuels and CO_2 emissions.

Clear actions are needed

Daikin has set itself the ambition to become a carbon-neutral company on a global scale by 2050. These four steps are today the most effective method of decarbonizing residential heat and Daikin calls on all stakeholders to roll up their sleeves and join the movement.

As an industry leader in sustainable heating, Daikin is showing the way. *"At Daikin we're working on a daily basis to help making these 4 steps reality. Technology is in place, our investments support this. We are making sure our installer community is joining the movement. Heat pumps are the future in the replacement market and it is our duty to convince all stakeholders. All the signs are indicating that we need to act now. Words are no longer enough; clear actions are needed. This is the only way we can make Europe climate neutral by 2050,"* concludes Patrick Crombez. ■

References

[1] https://ec.europa.eu/energy/sites/ener/files/eu_renovation_wave_strategy.pdf

[2] This solution becomes even better as the carbon footprint of the connected electricity grid becomes zero, which is possible by the increasing production by PV and wind generation.

Fit for 55: Overview of most important policy proposals for the building sector

In its mission to deliver upon the European Green Deal, the European Commission has published the first part of the "Fit for 55" package on 14 July 2021. This is a set of 13 proposals to either introduce or revise EU policies related to climate, energy, land use, transport, buildings and taxation to get the EU's policies fit to reach the target of a 55% reduction of greenhouse gas (GHG) emissions by 2030, compared to 1990 levels. In this article we will briefly explain the context of Fit for 55 and give an overview of the policy proposals that are the most relevant for the building sector.

JASPER VERMAUT
REHVA, Project Communication and Promotion Officer
jv@rehva.eu

Context of Fit for 55

The package was accompanied by a Communication from the Commission called "Fit for 55: Delivering the EU's 2030 Climate Target on the way to Climate Neutrality". Meaning that these proposals aim to get the EU's policy environment ready to reach its 55% reduction of GHG emissions by 2030 with the long-term objective in mind to get Europe carbon neutral by 2050. As mentioned, the package is a set

of inter-connected proposals where the Commission has aimed to strike a cautious balance in its policy mix between pricing, targets, standards and support measures, as can be seen in **Figure 1**.

The proposals impact a wide variety of sectors such as energy, industry, transport, agriculture and buildings. The latter has been identified as one of the key sector tackle for the reduction of GHG, under the European Green Deal [1] which is exemplified by the Renovation Wave strategy [2] and the objective to double the annual renovation rate of buildings by 2030. In the following sections we will give outline of the four proposals that will likely impact the building sector the most under Fit for 55, being: the proposed extension of the EU's Emission Trading System (ETS) to the building sector; the revisions of the Energy Efficiency and Renewable Energy Directives; and the proposal to introduce a Social Climate Fund with the objective to tackle energy poverty for vulnerable households.

Revision of the EU Emission Trading System: Extension to the building sector

One of the most talked about topics in the months leading up to Fit for 55 was the extension of the ETS to the building and transport sectors. The ETS is a 'cap and trade' system [3] which puts a carbon price on the GHG emissions in a variety of sectors that together cover around 40% of GHG emissions in Europe. A cap is set on total amount of GHG that can be emitted by installations covered by the ETS, to gradually lower the emissions this cap is reduced over time. The owners of these installations can receive or buy emission allowances and trade with one another to remain within the cap of emissions. As the total number of allowances reduce over time, so do the emissions released through these installations.

The ETS already covers around 30% of building emissions from heating, related to the system's coverage of district heating and electricity used for heating.[4] The amendment proposed by the Commission would ensure that a new ETS covers all emissions related to fossil fuel combustion of heating in buildings, e.g. heating through gas, oil or coal. This means that a separate but adjacent trading system will be setup next to the currently existing ETS. This new and self-standing ETS would cover the transport and building sectors together and would avoid disturbances with the ETS that is already in place. The reason to setup a separate system is due to the difference in reduction potential between the already covered sectors and the transport & building sectors, as well as a large difference in factors that influence the demand. A possible merger between the two systems would be assessed a few years after the implementation of the new ETS.

Pricing	Targets	Rules
• Stronger Emissions Trading System including in aviation • Extending Emissions Trading to maritime, road transport, and buildings • Updated Energy taxation Directive • New Carbon Border Adjustment Mechanism	• Updated Effort Sharing Regulation • Updated Land Use Land Use Change and Forestry Regulation • Updated Renewable Energy Directive • Updated Energy Efficiency Directive	• Stricter CO_2 performance for cars & vans • New infrastructure for alternative fuels • ReFuelEU: More sustainable aviation fuels • FuelEU: Cleaner maritime fuels

Support measures

- Using revenues and regulations to promote innovation, build solidarity and mitigate impacts for the vulnerable, notably through the new **Social Climate Fund and enhanced Modernisation and Innovation Funds.**

Figure 1. Overview of policy mix of the first part of the Fit for 55 package.
Source: https://ec.europa.eu/info/sites/default/files/chapeau_communication.pdf

In the current proposal the new self-standing system would be established in 2025 where the regulated entities would only have to report the emissions related to previous years. The issuance of allowances and compliance obligations would start from 2026. The proposed rate of allowances should allow for a reduction of emissions of 43% by 2030 in the transport and building sectors together, compared to 2005 levels.[5]

It needs to be highlighted here that building sector will remain a part of the Effort Sharing Regulation. [6] Initially this Regulation set national binding annual GHG target for non-ETS sectors. In the current proposals the building sector will now be covered in both policies, as the Commission assessed that the combined inclusion of the buildings in both a carbon pricing-system and national target-setting would lead to important synergies that strengthen each other and avoid inefficiencies.[7]

Bibliography

European Commission Press Release on Fit for 55: https://ec.europa.eu/commission/presscorner/detail/en/ip_21_3541

European Commission - Delivering the European Green Deal: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/delivering-european-green-deal_en

Communication on Fit for 55: https://ec.europa.eu/info/sites/default/files/chapeau_communication.pdf

Revision of the EU Emission Trading System: https://ec.europa.eu/info/sites/default/files/revision-eu-ets_with-annex_en_0.pdf

Proposal for a Regulation to establish a Social Climate Fund: https://ec.europa.eu/info/sites/default/files/social-climate-fund_with-annex_en.pdf

Proposal for a revision of the Energy Efficiency Directive: https://ec.europa.eu/info/sites/default/files/proposal_for_a_directive_on_energy_efficiency_recast.pdf

Proposal for a revision of the Renewable Energy Directive: https://ec.europa.eu/info/sites/default/files/amendment-renewable-energy-directive-2030-climate-target-with-annexes_en.pdf

DG Energy Newsletter : https://ec.europa.eu/newsroom/ener/newsletter-archives/33800

Introduction of a Social Climate Fund

The abovementioned introduction of a carbon price will be especially large for households that use coal for heating, especially in lower income countries. To balance this the Commission has put forward a proposal to introduce a Social Climate Fund to support households finance investments in energy efficiency, heating & cooling systems and clean mobility. In the current proposal this Fund would be financed through up to 25% of the revenue created by extension of the ETS to the building and transport sectors would go towards this new Fund.[8]

To implement this all Member States would have to establish a Social Climate Plan with an update every two years, together with the national energy and climate plans[9] that will contain a set of measures and investments to address the impact of carbon pricing on vulnerable households.[10] The calculation of maximum financial allocation per Member State depends on a set of indicators related to total population, amount of population at risk of living in poverty in rural areas, GHG emissions from fuel combustion in households and the Member State's Gross National Income (GNI) per capita. In the current proposal Poland would be the largest receiver with a share of 17.61% of the fund, followed by France (11.20%), Italy (10.81%), Spain (10.53%) and Romania (9.26%).[11]

Revision of the Energy Efficiency and Renewable Energy Directives (EED & RED)

The new revisions of the EED & RED have to be seen within the context of the Renovation Wave objectives to at least double the annual renovation and to decarbonise heating & cooling, which are currently responsible for 80% of the energy consumed in residential buildings.

One of the main changes in the EED is that in the new Article 6 it is mentioned that each Member State shall ensure that at least 3% of buildings owned by public bodies shall be renovated each year to at least nearly zero-energy buildings (NZEB).[12] This both widens the earlier set target from government-owned to all publicly owned buildings and raises to depth of renovations to a minimum of NZEB level.

The annual energy savings obligation for Member States are almost doubled for the period between 2024 and 2030 in the new EED proposal, from 0.8% to 1.5%. [13] Furthermore, the revision of the EED introduces a higher target for reducing primary energy consumption (39%) and final consumption (36%) by 2030.

The newly proposed revision of the RED aims to raise the 2030 renewable energy target of gross final energy consumption up to 40%.[14]

The revision of the RED puts a high emphasis on the decarbonisation of the heating & cooling sector, with one of the main introductions being a higher obligation on Member States to increase the share of renewables in this sector by 1.1% per year. For district heating & cooling the annual target for increased shares from renewables and waste heat & cold is increased from 1% to 2.1%. Member States also have to ensure that third parties who supply energy from renewable sources and waste heat & cold can connect to heating & cooling systems with a capacity of above 25MWth.[15]

Next steps

The European Parliament and Council of the EU will now enter into "trialogues" to discuss and amend the proposals put forward by the Commission. An inter-institutional agreement and the entry into force of the legislative texts can easily take up to two or three years. The second part of Fit for 55 is planned for Q4 2021, where the Commission will put forward a proposal for a new revision of the EPBD [16] and provisions for the gas markets. ■

References

[1] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

[2] https://www.rehva.eu/rehva-journal/chapter/the-3rd-revision-of-the-energy-performance-of-buildings-directive-epbd

[3] https://ec.europa.eu/clima/policies/ets_en

[4] Source: European Commission – 2021/0211 (COD): Proposal for a Directive amending Directive 2003/87/EC establishing a system for greenhouse gas emission allowance trading within the Union, Decision (EU) 2015/1814 concerning the establishment and operation of a market stability reserve for the Union greenhouse gas emission trading scheme and Regulation (EU) 2015/757 – p. 5: https://ec.europa.eu/info/sites/default/files/revision-eu-ets_with-annex_en_0.pdf

[5] Ibidem, p. 19 & 34.

[6] https://ec.europa.eu/info/sites/default/files/proposal-amendment-effort-sharing-regulation-with-annexes_en.pdf

[7] Ibidem, p. 133.

[8] Source: European Commission – 2021/0206 (COD): Proposal for a Regulation establishing a Social Climate Fund – p. 11: https://ec.europa.eu/info/sites/default/files/social-climate-fund_with-annex_en.pdf

[9] https://ec.europa.eu/info/energy-climate-change-environment/implementation-eu-countries/energy-and-climate-governance-and-reporting/national-energy-and-climate-plans_en

[10] Ibidem, p. 23.

[11] Ibidem, p. 61 – 63.

[12] Source: European Commission – 2021/0203 (COD): Proposal for a Directive on energy efficiency (recast) – p. 81: https://ec.europa.eu/info/sites/default/files/proposal_for_a_directive_on_energy_efficiency_recast.pdf

[13] Ibidem, p. 87.

[14] Source: European Commission – 2021/0218 (COD): Proposal for a Directive amending Directive (EU) 2018/2001 of the European Parliament and of the Council, Regulation (EU) 2018/1999 of the European Parliament and of the Council and Directive 98/70/EC of the European Parliament and of the Council as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652 – p. 10: https://ec.europa.eu/info/sites/default/files/amendment-renewable-energy-directive-2030-climate-target-with-annexes_en.pdf

[15] Ibidem, p. 37.

[16] https://www.rehva.eu/rehva-journal/chapter/the-3rd-revision-of-the-energy-performance-of-buildings-directive-epbd

REHVA welcomes its new Supporter: Arçelik!

arçelik

The REHVA Supporters are leaders in building services that share our goal of advancing and developing high quality HVAC technologies, system solutions and engineering tools by international knowledge exchange, research and joint advocacy.

REHVA welcomes its new Associate Organisations: OAER and ISIB!

OAER

Romanian Chamber of Energy Auditors (OAER)

ISIB

TURKISH HVAC-R

REHVA Associate Organization are organizations, associations or institutions that pursue the same objective as REHVA.

REHVA
Federation of European Heating, Ventilation and Air Conditioning Associations

MEMBERS

ATIC vzw–asbl – Belgium www.atic.be	STP – Czech Republic www.stpcr.cz	DANVAK – Denmark www.danvak.dk	EKVU – Estonia www.ekvy.ee	FINVAC – Finland www.finvac.org
AICVF – France www.aicvf.org	VDI–e.V. – Germany www.vdi.de	ÉTÉ – Hungary www.eptud.org	MMK – Hungary www.mmk.hu	AiCARR – Italy www.aicarr.org
AHGWTEL/LATVAC – Latvia www.lsgutis.lv	LITES – Lithuania www.listia.lt	AIIRM – Republic of Moldova www.aiirm.md	TVVL – The Netherlands www.tvvl.nl	NEMITEK – Norway www.nemitek.no
PZITS – Poland www.pzits.pl	ORDEM DOS ENGENHEIROS – Portugal www.ordemengenheiros.pt	AIIR – Romania www.aiiro.ro	AFCR – Romania www.criofrig.ro	AGFR – Romania www.agfro.ro
ABOK – Russia www.abok.ru	KGH c/o SMEITS – Serbia www.smeits.rs	SSTP – Slovakia www.sstp.sk	SITHOK – Slovenia https://web.fs.uni-lj.si/sithok/	ATECYR – Spain www.atecyr.org
SWEDVAC – Sweden www.energi-miljo.se	DIE PLANER – Switzerland www.die-planer.ch	TTMD – Turkey www.ttmd.org.tr	CIBSE – United Kingdom www.cibse.org	

Network of 26 European HVAC Associations joining 120 000 professionals

REHVA Office: Rue Washington 40, 1050 Brussels - Belgium • Tel: + 32 2 514 11 71 - info@rehva.eu - www.rehva.eu

REHVA

Federation of European Heating, Ventilation and Air Conditioning Associations

SUPPORTERS

Leaders in Building Services

EPEE – Belgium
www.epeeglobal.org

Daikin Europe – Belgium
www.daikin.eu

Velux – Denmark
www.velux.com

Uponor – Finland
www.uponor.com

Halton – Finland
www.halton.com

Granlund – Finland
www.granlund.fi

LG Electronics – France
www.lgeaircon.com

Eurovent Certita Certification – France
www.eurovent-certification.com

Viega – Germany
www.viega.com

Rhoss – Italy
www.rhoss.com

Evapco Europe – Italy
www.evapco.eu

Aermec – Italy
www.aermec.com

Purmo Group – The Netherlands
www.purmogroup.com

Royal Haskoning DHV – The Netherlands
www.royalhaskoningdhv.com

SMAY – Poland
www.smay.eu

Dosetimpex – Romania
www.dosetimpex.ro

Systemair – Sweden
www.systemair.com

Swegon – Sweden
www.swegon.com

Lindab – Sweden
www.lindab.com

Fläkt Group – Sweden
www.flaktgroup.com

Camfil – Sweden
www.camfil.com

Belimo Automation – Switzerland
www.belimo.com

Friterm Termik Cihazlar Sanayi ve Ticaret – Turkey
www.friterm.com

Arçelik – Turkey
www.arcelik.com

REHVA Associate Organisations:

Enerbrain srl – Italia
www.enerbrain.com

Enviromech – United Kingdom
www.enviromech.co.uk

Romanian Chamber of Energy Auditors (OAER)
OAER – Romania
www.oaer.ro

ISIB – Turkey
www.isib.org.tr

Network of 26 European HVAC Associations joining 120 000 professionals

REHVA Office: Rue Washington 40, 1050 Brussels - Belgium • Tel: + 32 2 514 11 71 - info@rehva.eu - www.rehva.eu

Send information of your event to Ms Nicoll Marucciova nm@rehva.eu

Exhibitions, Conferences and Seminars in 2021

Conferences and seminars 2021

Due to the COVID19 circumstances, the dates of events might change. Please follow the event's official website

25 Aug – 27 Aug	8th International Buildings Physics Conference	Copenhagen, Denmark	https://www.ibpc2021.org/
31 Aug – 2 Sep	ISH Shanghai & CIHE	Shanghai, China	https://ishs-cihe.hk.messefrankfurt.com/shanghai/en.html
03 Sep – 04 Sep	52nd AiCARR International Conference 2021	Vicenza, Italy	http://www.aicarr.org/Pages/Convegni/52%20CONV%20INTERNAZIONALE/presentaz_call_for_paper_ing.aspx
13 – 15 Sep	IAQ 2020	Athens, Greece	https://www.ashrae.org/conferences/topical-conferences/indoor-environmental-quality-performance-approaches
21 Sep	Nordic Ventilation Forum	**Online**	http://www.scanvac.eu/nvf.html
22 Sep – 24 Sep	Aquatherm Tashkent 2021	Tashkent, Uzbekistan	https://www.aquatherm-tashkent.uz/en/
29 Sep – 2 Oct	ISK Sodex 2021	Istanbul, Turkey	http://www.sodex.com.tr/
29 Sep	Danvak Dagen 2021	København, Denmark	https://danvak.dk/produkt/danvak-dagen-2021/
26 – 27 Oct	European Heat Pump Summit	Nuremberg, Germany	https://www.hp-summit.de/en

Conferences and seminars 2022

04 – 06 May	CIAR Lisboa 2022	Lisbon, Portugal	http://www.ciar2022.com./
22 – 25 May	CLIMA 2022	Rotterdam, the Netherlands	https://clima2022.nl/
12 – 16 Jun	Indoor Air 2022	Kuopio, Finland	https://indoorair2022.org/

TVVL organises 'global summit' for the installation sector

CLIMA 2022 measures the temperature of the global installation sector

Anyone who wants to measure the temperature of the international world of installation should register for CLIMA 2022. The REHVA HVAC World Congress, which takes place once every three years, is coming to Rotterdam Ahoy in May. It is the first time in history that this conference is being held in the Netherlands, and TVVL is organising it. "This is the event where science and practice meet, and current knowledge is exchanged. If you want to know what is going on, what new insights there are and how the installation sector is developing, this is the place to be."

A**tze Boerstra**, president of CLIMA 2022, is already audibly enthusiastic when he thinks of the many different people who will participate from all over the world and the broad range of topics that will be discussed. Together with **Laure ltard** and **Lada Hensen Centnerová**, he is in charge of the content of this prestigious international congress they are setting up together with TVVL in a short time frame. "You could say that this REHVA congress is the European Championship for the installation world. Here, once every three years, we bring together the best people and all the current topics that our sector has to offer. It is a unique opportunity for the Dutch installation and construction industry to have such close and accessible access to it", says Boerstra, director of BBA Binnenmilieu and recently connected to TU Delft.

Mix of science and practice

Laure ltard, working at TU Delft, and Lada Hensen Centnerová, working at TU Eindhoven, are both vice presidents of CLIMA 2022 and, in that role, responsible for an important part of the content of the congress, namely the papers and workshops. Besides the not to be underestimated social aspect, the CLIMA congress is primarily a scientific event in the field of heating, cooling, ventilation, and air conditioning. This means that a huge amount of new knowledge and practical cases are brought to light to give a strong boost to the knowledge level in the European installation world.

"The congress attracts scientists from all over the world", says Laure ltard. "But the nice thing is that, here, they also get to meet people from the field in a fairly accessible way.

Installers, designers, consultants, manufacturers, but also students and media will be present in large numbers. It is this whole mix of professionals that makes this an event you definitely want to be at."

Vice Presidents Laure ltard (TU Delft) and Lada Hensen Centnerová (TU!e) and President Atze Boerstra (BBA Binnenmilieu) of CLIMA 2022.

TVVL wins organisation with impressive bid book

Once every three years, one of the European countries is allowed to host the REHVA HVAC World Congress. The bid book TVVL submitted in 2019 was so impressive that REHVA awarded the organisation for 2022 to our country. REHVA (Federation of European Heating, Ventilation and Air Conditioning Associations) was established in 1963 in The Hague with TVVL as one of the initiators.

REHVA represents a network of more than 100,000 professionals from more than 26 countries. The organisation aims to improve science and practical application in the field of installation technology. REHVA also stimulates students' interest in studying in the field and organises the international REHVA Student Competition.

Broad organising committee

Because TVVL is responsible for the organisation in 2022, it has sought cooperation with the universities TU Delft and TU/e. The president, vice-presidents, and members of the scientific committee of the congress have been recruited from these ranks, as well as from the TVVL members working in the practical field.

CLIMA 2022
Eye on 2030 — Towards digitalized, healthy, circular and energy efficient HVAC
REHVA 14th HVAC World Congress
15th - 18th May, Rotterdam, The Netherlands

For the Dutch members of the scientific committee, a deliberate decision was made to include one representative from science and one from practice for each topic. These 'topic champions' will also introduce the topics in this and the coming editions of TVVL Magazine. In addition, the following core team of five people from the TVVL office and management board has been put together for the actual organisation of the conference:

- Ing. Olaf Oosting MSc, General Managing Director Valstar Simonis and board member TVVL
- Ing. John Lens, General Director TVVL
- Esmeralda Pondman, Manager Knowledge Development TVVL
- Mylenne Hamaker, Events Coordinator TVVL
- Femke van Egmond, Marketing & Communication TVVL
- Sharen van Meurs, Online Marketing TVVL

Names, company, and function of the members of the scientific committee CLIMA 2022.

Name	Surname	Work	Function
Laure	Itard	TUD	SC chair (papers)
Lada	Hensen Centnerová	TU/e	SC co-chair (workshops)
At ze	Boerstra	TUD & BBA Binnenmilieu	President
Marcel	Loomans	TU/e	Planning sessions & papers
Martin	Tenpierik	TUD	Planning sessions & papers
Froukje	van Dijken	BBA Binnenmilieu	Workshops
Christian	Struck	Saxion University	Learning & Edu cation
Jan	Hensen	TU/e	Energy
Jan Jaap	Blüm	Alba Concept	Energy
Pieter	Pauwels	TU/e	Digitisation
Jan	Kerdel	Kerdel Business Development	Digitisation
Philomena	Bluyssen	TUD	Health & comfort
Annemarie	Eijkeleboom	EMG Architects	Health & comfort
Tillmann	Klein	TUD	Sustainability & circularity
Olaf	Oosting	Valstar-Simonis	Sustainability & circularity
Bob	Geldermans	TUD	Sustainability & circularity

Knowledge exchange around five topics

"You can bet that there will be a lot of start-ups here; companies and researchers who are working on digitalisation, for example: what benefits can monitoring air quality provide, but also how can we monitor energy use and manage it in real time. Everyone has an opportunity to give or participate in workshops and presentations here to enhance their knowledge", says Lada Hensen Centnerová. "This congress really sets the agenda in our sector. And that's what makes it so fantastic ", adds ltard.

"A few important subjects will determine the trends", Boerstra continues. "Of course, they relate to the energy transition. For example, the 'green deal' – which the EU is now prominently bringing to the public – for a great part determines the direction in which the installation world is developing. But the COVID-19 pandemic and the phenomenon health, ventilation and healthy buildings is a topic that will continue to be in the spotlight next year. Digitisation is another topic that will be given extensive attention at this conference."

The trio indicated that they will make CLIMA 2022 into a broad and very diverse congress, where everyone in the sector will find topics that appeal to them.

"For example, in addition to the three topics Atze mentioned, circularity is another important one. It is truly a defining issue for the future, one to which the EU is also firmly committed. In this respect, installation technology still lags behind compared to architecture and construction. And the fifth topic is learning & education, which includes new forms of knowledge dissemination," says ltard. "The congress will therefore also take place in a hybrid form; in addition to the many live sessions, we will stream some of the presentations, workshops, and lectures via the internet."

Workshops and papers

During the conference, a variety of presentations and workshops will be held, both in plenary sessions and in many sub-sessions. "It goes without saying that we will provide appealing keynotes. It is too early to announce names at this stage but the presentations will be related to the five topics mentioned. Our aim is to organise the subjects per overarching topic on fixed days during the congress days between 22nd and 25th of May," Boerstra says. "Attendees will be able to pick out the day or days that appeal to them most. At the same time, I think that many people will not limit this unique opportunity to just one day. Who wouldn't want to spend three consecutive days in a stimulating environment, networking with the top European experts in our field."

"We strongly encourage all market participants to submit topics for interactive sessions," says Hensen Centnerová. "Our goal is to offer a very wide range of subjects. These can come in the form of discussion forums, seminars or webinars, as well as courses or workshops. We call on specialists, scientists and, in particular, practitioners to submit their proposals before the summer.

More information on dates and rules can be found on the congress website, www.clima2022.org."

CLIMA 2022 will take place at the Rotterdam Ahoy Convention Centre, a brand new part of the well-known Ahoy complex in Rotterdam South.

Abstracts for papers and sessions can be submitted until 1 August

If there is a subject you want to write a paper about or about which you would like to give an interactive session during the congress, please send in an abstract no later than 1 August via the ConfTool on the website.

In September, the members of the scientific committee shall look at all the abstracts and proposals. They assess which abstracts of the papers and sessions best fit the purpose and the topics of this congress. As soon as they assess your submission as suitable, you will be notified, and you can start writing the paper in full or prepare the session.

You will find all the information for submitting an abstract on the website. www.clima2022.org

Optimal conditions at the RACC

The CLIMA 2022 congress will take place at the Rotterdam Ahoy Convention Centre, a brand-new part of the well-known Ahoy complex in Rotterdam South. This new building is a state-of-the-art, sustainably built conference centre with the largest auditorium in the Netherlands, beautiful foyers, luxurious rooms, and facilities.

The spacious and well-equipped venue also enables the organising committee to plan the sessions in a COVID-19-proof manner. The fact that some of the sessions can also be followed digitally also helps. Besides plenty of room for e.g. networking activities, there are also great places for companies and organisations to present themselves.

Are you interested in presenting your company at the congress? Please contact the organising committee to find out more. Please visit www.clima2022.org.

ltard continues: "The same goes for our call for papers. Traditionally, a REHVA congress is accompanied by a comprehensive volume containing a wide range of publications. If you want to submit such a contribution, please send us your abstract before 1 August. If the topic is accepted, you can develop the paper and it will be included in the congress proceedings and website. The contribution might also be published in the REHVA Journal or the TVVL Magazine."

Striving for diversity

The great diversity of CLIMA 2022 is also reflected in the opportunities for companies to offer sponsored workshops; sessions that visitors can attend both live and online. Organisations and companies can also present themselves with a booth at the congress. "There will be a lot to experience", says Boerstra. "For example, TVVL's Swiss sister organisation will be celebrating its 50th anniversary at the congress. And the award ceremony for the REVHA student competition will be held here, too. In addition, the winners of the new Healthy Hornes Design competition, created jointly by REHVA and Velux, will be announced during the venue. Of course, there will also be various get-togethers, the conference dinner on Tuesday, and other social events. All this makes CLIMA 2022 a unique event. Truly a 'once in a lifetime' experience; and a first for it to be held in the Netherlands."

Young REHVA manifests itself at CLIMA2022

In 2020, the REHVA Community of Young Professionals (RCYP} was established. This official section of REHVA was created to bring together young professionals working in the field from all over Europe, and to offer them the benefits such a venue provides.

At this time, the coordinator is Arash Rasooli, a former winner of the REHVA student competition. "We want to bring together young professionals at events and excursions, but we also give them discounts on workshops, courses and publications," says Rasooli. "REHVA provides us with a budget for this purpose. During the congress, we will organise social activities for our members, such as informal get-togethers, but also an excursion in Rotterdam, amongst other activities."

The requirements for becoming a member are that the young professionals have completed a Master's or PhD degree and are no more than 35 years old. If you want to become a member, please go to the RCYP's LinkedIn group and sign up.

https://www.linkedin.com/groups/89285 63/

"People should definitely not think that of it as an old boys network," adds ltard. "One of our main goals is to bring together our students, national and international. That is why Young TVVL (see box) is also developing its own activities at this congress. We badly need this generation to meet the challenges that lie ahead in each of the mentioned areas in the years up to 2030."

Hensen Centnerová concludes: "Apart from the fact that the content of the congress promises to be extremely varied, we also want CLIMA 2022 to be as diverse as possible. Perhaps it will not be quite as diverse as the visitors of the Eurovision Song Contest, which took place at Ahoy last month, but at CLIMA 2022 we also expect to see a lot of young people and women." ■