ISSN 1307-3729

REHVA
Federation of European Heating, Ventilation and Air Conditioning Associations

The REHVA European HVAC Journal

Volume: 59 Issue: 3 June 2022 www.rehva.eu

Cătălin Lungu

REHVA President 2022-2025

"Proud enough to be the REHVA's first voice, humble enough to serve our entire REHVA family"

The REHVA European HVAC Journal

www.rehva.eu

Volume: 59 Issue: 3 June 2022

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.
Fikirtepe Mah., Rüzgar Sk. No: 44C
A3 Blok, Kat:11 D:124 Kadıköy/Istanbul, Turkey

Cover photo: Cătălin Lungu (REHVA president 2022-2025)

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.

Presidential address of REHVA president Cătălin Lungu (2022-2025)

The world is going through an everlasting transformation, especially during these times, due to the SARS-CoV-2 pandemic and the war in Ukraine. REHVA, whose notoriety has been tremendously growing in the last years, now has to adapt faster to decarbonization and digital transformation, to objectives like a safer and healthier indoor (but also outdoor) environment. So that, in this dynamic and globalized world, REHVA must continue to grow.

We say that REHVA represents 26 European countries, which is very accurate, and we also say that we represent more than 120 000 HVAC specialists, which is quite far from reality. What should we do with those engineers who aren't English speakers, who don't understand English very well? They are numerous and sending them news about our activities and initiatives (like the REHVA journal, guidebooks, e-newsletters, social media messages, etc.) is still an unsolved matter in a significant proportion. We need to be able to reach all those non-English speakers, engineers, and architects (and even go over that 120 000 limit), we need to motivate our REHVA Member Associations to be more active and more conscious about their vital role in spreading our European technical advanced knowledge. Also, a large part of the MAs shall be persuaded about our high potential and strong will to support local activities, developing mutually profitable projects, i.e., courses, EU projects, research for supporters, different professional certification schemes, etc.

Nowadays, we are struggling with a workforce crisis in many fields, including ours. The lack of engineers and, moreover, the lack of well-trained engineers for design, execution, commissioning, and operation can become an interesting opportunity for REHVA, considering the massive need for continuous education for HVAC engineers, energy assessors, and even for other HVAC and non-HVAC market operators. This is the right moment to innovate and wisely promote courses for those members who don't have any educational programmes or updated ones, and we need to do it together with our most experienced members. We saw this important market need for education during the COVID pandemic, when REHVA played a major role worldwide, recognized by WHO and by some other international organizations.

At the European level, today, REHVA is one of the most reputed actors in our activity fields. Based on our office staff's intensive and effective work, well-managed by our Executive Director, we will be involved further in new Horizon Europe and LIFE projects. Our operating financial budget will be consolidated.

Regarding the worldwide strategy, REHVA should cooperate more closely with all our MoU partners around the globe and propose the most rewarding actions from which all can benefit mutually. In this respect, the REHVA directors have to pay more attention to our supporters' and members' needs, working closely with their representatives, reporting more often and providing solutions rather than defining issues.

Through this short message I am addressing to all of you who know me best, who have barely heard of me, or even at all, to older and younger engineers and architects, to students and academics, to future REHVA members, partners and supporters, emphasizing my intentions for the next presidential term, 2022-2025, with the following sets of keywords: time investment and devotion, pragmatism and respect, growth and leadership, research and education, loyalty and partnership, innovation and mentorship, fun and joy.

Finally, I am expressing my gratitude to all our prior presidents, vice-presidents, office employees and all those who contributed or still contribute to a so united and strong REHVA community, ensuring all that I am proud enough to be the REHVA's first voice, and also humble enough to serve our entire REHVA family. ■

Proud enough to be the REHVA's first voice, humble enough to serve our entire REHVA family

CĂTĂLIN LUNGU, REHVA PRESIDENT 2022-2025

Education

- PhD in Civil Engineering (2004) at the Technical University of Civil Engineering from Bucharest (UTCB) with specialized training at the Paris XII Val de Marne University, France;
- Master in Civil Engineering at UTCB (1996) and the Paris XII Val de Marne University, France (1998);
- Bachelor Degrees in building services engineering (1995) at UTCB and economics (2000) at the Bucharest University of Economic Studies.

Career development

Mr. Lungu is Associate Professor at the Technical University of Civil Engineering (www.utcb.ro) and was for seven years a visiting professor at the "Ecole Nationale Superieure de l'Energie, l'Eau et l'Environment ENSE3" (Grenoble, France). He is specialized in dynamic simulation of HVAC and RES systems, including EPB assessment and NZEB design.

He represents AIIR (the Romanian Association of Building Services Engineers, www.aiiro.ro) as first Vice President (since 2020), and REHVA as President since May 22nd, 2022 (former Vice President and treasurer, 2017-2022). He is also OAER president (the Romanian Chamber of Energy Auditors, www.oaer.ro) since April 2022 (former CEO between 2011 and 2022) and the main national organizer of the training and continuous learning courses for the Romanian energy assessors.

Dr. Lungu was the organizing committee chair of the HVAC World Congress CLIMA 2019 (2016-2019).

He has been a project manager of five research projects and member in other four, including the project for recasting the national methodology for the calculation of the energy performance of buildings, according to the new set of EPB standards. He is also member of six standardization technical committees (five national and one ISO).

As main author or co-author, Dr. Lungu has published six books (one was awarded in 2021 by the Romanian Academy) and more than 30 scientific or technical articles.

Outcome of the CLIMA 2022 congress – a blueprint for further actions!

After a very successful CLIMA 2022 some may feel exhausted. But the climate-crisis, the impact of the war in Ukraine on European on our safety and the continuing COVID epidemic doesn't allow us to slow down. For Europe the REpowerEU is added to the policy initiatives: Greendeal, the Renovation Wave and the Fit for 55 towards Zero Carbon emission by 2050.

The well-chosen core themes of CLIMA 2022 are reflecting our top priorities for the coming years:

- Energy efficiency and decarbonisation
- Health and Comfort (IEQ) with an emphasis on indoor air quality and ventilation
- Circularity, in relation to the renovation wave a focus of reuse of our systems and buildings where possible and forward thing with new building and system design.
- Digitization, essential to support the Energy, Decarbonisation and Circularity possible and future sustainable.
- Learning and Education, essential to upgrade and expand our professional workforce.

The presentations at CLIMA 2022 include a lot of information on these themes, for those who didn't yet have the opportunity to join sessions the papers and several live-streams are still online for those who registered for the conference. In the coming RJ issues, we will publish selected articles on the various themes.

The expected EPBD revision by the end of this year will have its impact on the current set of EPBD standards. We expect the use of hourly calculation procedures to assess the Energy Performance of Buildings with a clear focus on decarbonisation. The already planned revision of the IEQ standard EN 16798-1 will also focus on the COVID guidance published by REHVA regarding the IAQ and ventilation requirements. For most of the EPB standards we expect that updates are needed. This work is expected to start in 2023 if resources are available to support this.

Some observations regarding the Annex III of the EPBD draft:

When focussing on operational decarbonisation we have to realise that some concepts we use on basis of the current 2018 EPBD and the EN ISO 52000-1 where the focus is on energy efficiency and the use of renewables, should be reviewed. This focus on renewables lead to the introduction of RER the Renewable Energy Ratio. This concept encourages to report on renewables used. Depending on the assessment boundary: ambient energy, ground source energy, free cooling etc. could be added to the equation calculating the amount of renewables used. This may be an interesting number in relation to the non-renewable part of the energy use. But it is the non-renewable part we have to focus on.

The concept of "total primary energy" as also included in the current EPBD proposal is confusing if we want to consider a carbon neutral approach. We should only focus on minimising the non-renewable primary energy still used in buildings. Where still needed compensate this non-renewable amount by renewable production onsite, nearby or from the grid. To avoid that this may lead to poor EP buildings it is wise to maximise this allowable non-renewable energy use, as proposed in Annex III of the EPBD. Renewable energy from on-site nearby or the grid should not be used to compensate for poor performing buildings or building use.

In this context it doesn't make sense to assess renewables contributions from ambient, free air cooling, ground source, etc. In the simple example of a building using a HP for heating we just have to assess the energy used by the compressor and auxiliaries of this HP system, this energy has for a great extend to come from renewable sources (onsite, nearby or the grid). The remaining non-renewable energy use has finally to be compensated elsewhere to meet the decarbonisation goals set by 2030 for new buildings. ■

JAAP HOGELING
Editor-in-Chief
REHVA Journal

A new draft standard with calculation procedures regarding adaptive building envelope elements: prEN ISO/DIS 52016-3

DICK VAN DIJK
Convenor of ISO/TC 163/SC 2/WG 15
EPB-research@dickvandijk.nl

A new draft standard in the (EN) ISO 52000 family of standards to assess the overall energy performance of buildings has been published for public enquiry until July 14, 2022: prEN ISO/DIS 52016-3, to provide calculation procedures to assess the energy performance of a building with adaptive building envelope elements.

Keywords: EPB standards, Energy efficiency, Smart buildings, Adaptive facades, EPBD, SRI

Set of CEN and ISO standards to assess the overall energy performance of buildings (EPB)

The set of international standards to assess the overall energy performance of buildings (CEN/ISO EPB standards, published in 2017 [1]) has been developed on the basis of a Mandate (M/480) from the European Commission ([2]) to develop a methodology to support the EPBD ([3], [4]), that is fit for use in the context of national building regulations: to check compliance with minimum energy performance of buildings (EPB) requirements and as information for the energy performance rating on a EPB certificate. The core of the set of EPB standards consists of the **(EN) ISO 52000 family** of standards.

The relevant standards in the set of EPB standards take into account adaptive facades only to a very limited extent and in a highly simplified manner. As a result, the advantages of this type of facade are largely not honoured. This is even more the case for adaptive facades with performance properties that can adapt to (sub-)hourly changes in outdoor conditions and building use, aiming for less energy use and improved comfort over the seasons.

Creating a level playing field for different techniques is crucial here.

On the other hand, this set of EPB standards provides is ready for the integration of dynamic facade components in the energy performance calculation, because it offers hourly calculation time intervals and it has a modular set up.

Most relevant EPB standard: EN ISO 52016-1

The most relevant EPB standard in this context is EN ISO 52016 1:2017, *Energy performance of buildings - Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads - Part 1: Calculation procedures* [5].

EN ISO 52016-1 :2017 provides a (recommended) hourly method to calculate the energy needs for heating and cooling, internal temperatures and sensible and latent heat loads.

> The standard also contains a simple monthly method, using monthly correction coefficients to account for dynamic (hourly) interactions between building, systems, building use and weather conditions. This monthly method has strong limitations, especially when dealing with adaptive facades and other innovative technologies.*

EN ISO 52016-1 contains a normative Annex G that offers already a **framework** for calculation procedures involving adaptive building envelope elements.

Work on a new standard providing fully developed calculation procedures

Instead of only a framework, a new work item was initiated, collaboratively by CEN (TC 89) and ISO (TC 163/SC 2, to develop a new standard, providing fully developed calculation procedures to assess the energy performance of a building with adaptive building envelope elements.

The work was assigned to ISO/TC 163/SC 2/WG 15, with the title:

> EN ISO 52016-3, *Energy performance of buildings - Sensible and latent heat loads and internal temperatures - Part 3: Calculation procedures regarding adaptive building envelope elements* ([6])

The work started in 2019 and is expected to be finished in 2023. The draft version (prEN ISO/DIS 52016-3) has been published for public enquiry until July 14, 2022.

Main challenges

Four main challenges arose during the standardization process:

Challenge 1. To focus on a generic "horizontal" approach

There are many different types of products with adaptive components, with different combinations and functions. The first question was which types should be covered in the standard (at least for the moment) and how these should be categorized, from a 'generic' physics perspective (for the modelling).

Challenge 2. To focus on standardization

In practice, the control scenarios of actively controllable adaptive building envelope elements vary widely in complexity. They also vary with the aim to optimize for a specific building or space category, orientation, composition of the adaptive building envelope element, et cetera. Reference control scenarios, specified for different control types, adaptive building envelope elements and space categories (residential and non-residential) are needed to create a level playing field for comparison of options.

Challenge 3. To clearly describe the link with EN ISO 52016-1

The calculation procedures in EN ISO 52016-3 are a kind of extension to the calculation procedures of Part 1 (EN ISO 52016-1). The challenge is to describe these additional calculation procedures in a clear and unambiguous way without duplicating content of Part 1.

* See e.g. EPB Center webinar on this subject: https://epb.center/news/news_events/fourth-webinar-epb-standards-hourly-vs-monthly-met/

Note that merging Part 3 into Part 1 is not a good solution, because EN ISO 52016-1 is one of the most widely used EPB standards around the globe and adding the special and novel standardized calculation procedures on adaptive building envelope elements to EN ISO 52016-1 would complicate and could jeopardize the acceptance of Part 1 and the adoption of Part 1 in national and regional building codes. Moreover, the calculation procedures on adaptive building envelope elements require special expertise, so the commenting, approval and also maintenance of the document needs to be done as a separate track.

Challenge 4. To prepare for digitization of standards

Because CEN and ISO are speeding up their initiatives towards a future of **machine readable standards** ([15]), the draft standard has been pro-actively re-edited in such a way that it 'almost only' contains the recipe for a calculation: most of the explanations are moved to an **accompanying technical report**. Such a technical report is in preparation simultaneously with the standard, as required for each EPB standard anyway, to provide justification, explanation and worked examples: CEN ISO/TR 52016-4 ([7]). It is intended to make a rough draft available, just for information, along with the draft standard.

The scope of prEN ISO/DIS 52016-3:2022

prEN ISO/DIS 52016-3 specifies procedures for the calculation of the energy needs for heating and cooling, internal temperatures and sensible and latent heat loads of a building according to the hourly calculation methodology in EN ISO 52016-1, with additions or modifications of the calculations if the building envelope contains one or more adaptive building envelope elements: building envelope elements with adaptive components that are either environmentally or actively controlled as a function of specific conditions. The adaptive building envelope element replaces the transparent building element in the calculation according to EN ISO 52016-1.

The three types of adaptive building envelope elements covered in this document are:

- Building envelope elements with dynamic solar shading
- Building envelope elements with chromogenic glazing
- Building envelope elements with an actively ventilated cavity

Environmentally activated control is described for building envelope elements with chromogenic glazing, but can also occur for other types of adaptive building envelope elements. In that case the same approach applies as for environmentally activated chromogenic glazing.

This document is applicable to the assessment of the energy performance of buildings (energy performance labels and certificates), including comparison between buildings and checking compliance with minimum energy performance criteria.

The document is also applicable to assess the contribution of the adaptive building envelope element to the smartness readiness of a building.

In addition, this document provides indicators for the impact of the adaptive building envelope element on the performance of the building compared to a reference building envelope element.

This document is applicable to buildings at the design stage, to new buildings after construction and to existing buildings in the use phase.

Links with Energy Performance of Buildings Directive (EPBD)

The EC's proposal for the EPBD revision [8], published in December 2021, clearly shows that the changes compared to the current EPBD will have impact on certain EPB standards.

The proposed EPBD demands that the energy needs and energy use for space heating, space cooling, domestic hot water, ventilation, lighting and other technical building systems are calculated using **hourly or sub-hourly calculation time intervals**, in order to account for varying conditions that significantly affect the operation and performance of the system and the indoor conditions, and in order to optimise health, indoor air quality and comfort levels defined by EU Member States at national or regional level.

Hourly calculation procedures are indeed essential for the assessment of the impact of adaptive building envelope elements on the energy needs for heating and cooling and thermal comfort.

The revised EPBD will also reinforce the **Smart Readiness Indicator** (SRI, see REHVA article [9]).

An adaptive building envelope element can significantly contribute to the smart readiness of a building and EN ISO 52016-3 is a tool to quantify the impact, as part of the set of EPB standards. Again, assessment of the actual impact requires an (sub-)hourly calculation time interval.

Types of adaptive building envelope elements

As can be read from the scope, three types are distinguished:

Adaptive building envelope elements with dynamic solar shading (blind or shutter), defined as:

A product installed to provide or modify characteristics such as thermal, visual, security level, of a window, door, curtain walling or facade to which it is applied.

Examples:

- Internal blind (venetian blind, roller blind, vertical blind, pleated blind, honeycomb blind, …)
- External or integrated blind (vertical roller blind, venetian blind, …)
- Shutters (roller shutter, wing shutter, concertina shutter, …)

Adaptive building envelope elements with chromogenic glazing, defined as:

Glazing with optical and visual properties that can vary (passively or actively) as function of a specific environment condition.

Examples:

- Thermochromic glazing, thermotropic glazing and photochromic glazing (passive)
- Electrochromic glazing, liquid crystal glazing, suspended particle device (active)

Adaptive building envelope elements with actively ventilated cavity, defined as:

A cavity between two layers of glazings or blinds that are part of a building envelope element that can be intentionally ventilated with the purpose to exchange heat between the air and these layers or the internal environment.

Examples:

Naturally, hybrid or mechanically ventilated cavity in a double envelope façade or in a window with integrated venetian or roller blinds; with fixed or operated vent openings

Model of the adaptive building envelope element

With respect to the modelling of the adaptive element, two options are distinguished:

Simplified adaptive building envelope element, defined as:

An adaptive building envelope element that is described with the same (simplified) 2 layers (2 nodes) model as used to describe a transparent building element in ISO 52016-1, with thermal, daylight and solar properties that, for a given state, are constant and thus can be pre-calculated for the full year. See illustration in **Figure 1**.

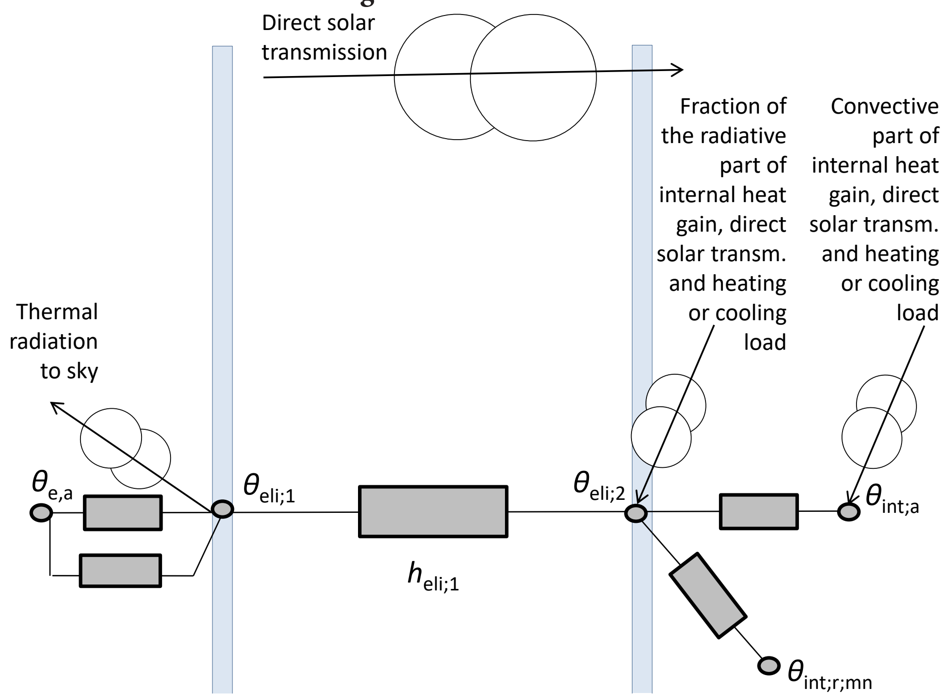


Figure 1. Illustration of the simplified model for transparent building element in EN ISO 52016-1.

The reason for the simplification in EN ISO 52016-1 was to avoid that for the hourly calculation method more input data are needed than for the monthly calculation method. Without this simplification the threshold to use the hourly calculation method would be higher, which would have an adverse impact on the road towards more realistic calculations. For conventional glazing these simplifications are justified. For adaptive building envelope elements such simplification is not always possible or justified, as described in the following paragraph.

Detailed adaptive building envelope element, defined as:
An adaptive building envelope element that is described with a more complex N layers (N nodes) model than a simplified adaptive building envelope element. For a given state, the thermal, daylight and solar properties of the adaptive building envelope element may depend on the conditions. These are calculated at each time interval on the basis of the model and the properties of the individual components. This typically refers to the models as provided in the standards ISO 15099 ([11]) and EN ISO 52022-3 ([12]), but without the spectral and detailed spatial distribution.

Such a more detailed model is also needed if specific layer properties are needed for the control, e.g. the temperature of a glass pane or cavity air.

prEN ISO/DIS 52016-3 describes how to build and connect the more detailed model to the model of the building from EN ISO 52016-1.

The different routes for the simplified and the detailed model are illustrated in **Figure 2**:

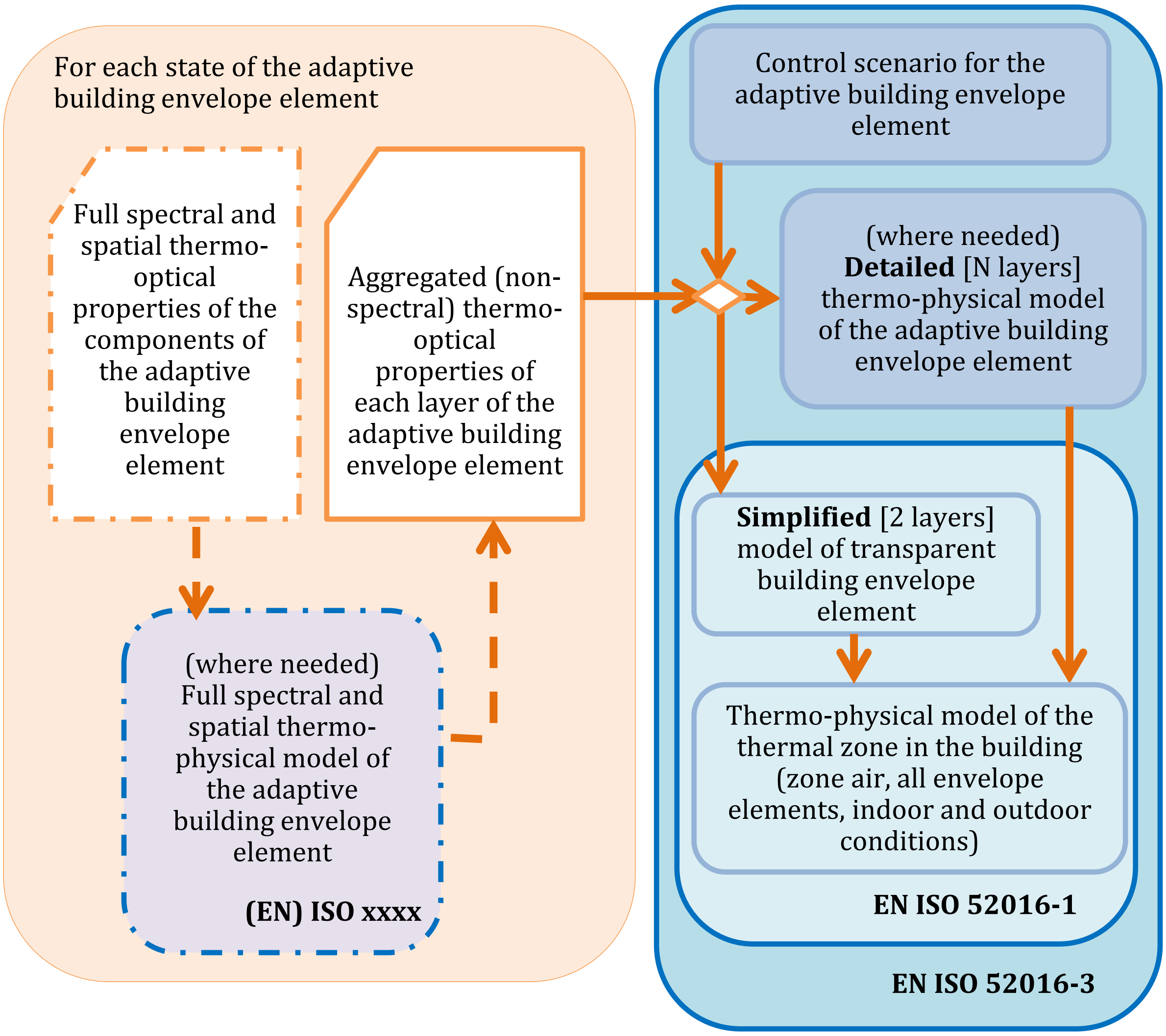


Figure 2. Illustration of the adaptive building envelope element linked to the calculation of heating and cooling load and internal temperatures according to EN ISO 52016-1.

Selection of control types

Four control types are distinguished, each with a different level of complexity, in line with the four classes in ISO 52120-1. See **Table 1**.

From these four control types, the type that applies best to the adaptive building envelope element and how it is controlled shall be selected for the calculation.

For level 4, integrated control, no reference control scenario is foreseen for EN ISO 52016-3.

Output of the calculation

The output of the calculation is the output of the hourly calculation methodology of EN ISO 52016-1. Additional output consists of key performance indicators to show the difference between the performance, in terms of building (zone) energy needs and thermal comfort, with the adaptive building envelope element versus a reference or other building envelope element.

The calculation procedures, step-by-step

The calculation procedure consists of the following steps:

Step 1: Identify the type of adaptive building envelope element.

Step 2:

- If the adaptive building envelope element is "simplified": gather the input data of the adaptive building envelope element
- If the adaptive building envelope element is "detailed": determine the details of the model the adaptive building envelope element and gather the input data of its components

Step 3: Connect the model of the adaptive building envelope element to the model of the thermal zone in EN ISO 52016-1

Step 4: Select the control scenario.

Table 1. *Control types.*

Level	Name	Description
0	Environmentally activated control	Also known as passive control: activated by a specific environment condition.
1	Manual operation with manual control	Manual operation requiring an effort or a force. EXAMPLE 1: By crank or cord
2	Motorized operation with manual control	The operation is motorized but requires a manual activation. EXAMPLE 2: Remote or wall switch. For active chromogenic glazing, manual operation is not applicable and 'motorized' shall be read as 'driven by electric power'.
3	Automated control	Rule based, open or closed loop control, using one or more input variables. In an open-loop controller the control action from the controller is independent of the "process output": the state of the adaptive building envelope element that is being controlled. It does not use feedback to determine if its output has achieved the desired goal of the input command(s) or process set point(s). Usually, the automated control allows a manual override by the occupant(s).
4	Integrated control	More complex functions, with e.g. predictive algorithms or combined with control of HVAC and lighting, including feedback to determine if its output has achieved the desired goal.

Select the control type:
Four control types are distinguished, each with a different level of complexity, in line with the four classes in EN ISO 52120-1 ([10]).

Example 1:
Environmentally activated or actively controllable (manual, motorized, automated)

For an environmentally activated adaptive building envelope element: model the control scenario: the adaptive properties as function of the environmental conditions (can be discrete or continuous). See example in **Figure 3.**

For an **actively controllable adaptive building envelope element**: model the control scenario, which involves the following sub-steps:

a) Select the applicable conditions and events for the control and select which methods apply to identify the conditions and events.

b) Select the applicable sensors to detect the conditions or events and gather the associated extra input data.

Example 2:
Solar irradiance or illuminance meter; clock + location + algorithm to identify sun position.

c) Selection of methods to identify the conditions or events.

Example 3:
For daytime versus night time: measured solar irradiance, calculated sun path or pre--calculated table with sunrise and sunset.

d) Apply the basic reference control scheme: qualitative description of the conditions and events that lead to a state change of the adaptive building envelope element.

Example 4:
Roller blinds fully extended when high solar irradiance.

e) And specify the criteria (values) for the conditions and events as function of control type, space category and other factors.

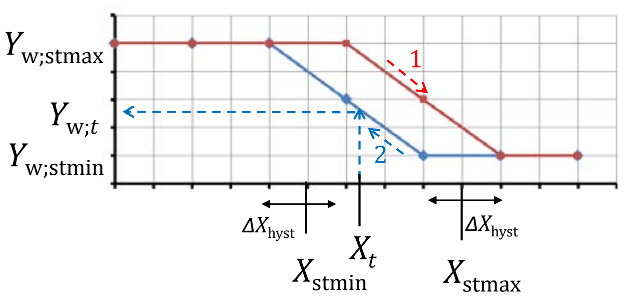
Example 5:
Illuminance > 75000 resp. < 37500 lux for retracting resp. extending roller blinds in case of automated control if cooling mode.

Step 5: Perform the hourly calculation according to EN ISO 52016-1 with the additions and adaptations from Step 1 through Step 4.

Step 6: Post-processing of the output of the calculation: monthly values, summer and winter thermal comfort indicator, etc.

Spreadsheet for evaluation of the calculation procedures of EN ISO 52016-3

According to the common quality procedures for each EPB standard for each EPB standard a spreadsheet has to be developed in parallel, to check the calculation procedures. These spreadsheets are publicly available at the EPB Center website ([13]). For EN ISO 52016-3 the situation is different, because the calculation is an ‘addendum’ to the calculation according to EN ISO 52016-1. Therefore, the spreadsheet is a sheet that will be embedded in the spreadsheet on EN ISO 52016-1 ([14]). A first version with this extra feature in operation will be made publicly available in summer 2022 at the EPB Center website. ■



Key:

Y: property of the adaptive building envelope element, *e.g. total solar energy transmission (g-value)*

X: environmental parameter, e.g. glazing temperature

1: increasing X-values

2: decreasing X-values

Figure 3. Example of different states of environmentally activated thermochromic glazing.

Acknowledgements

The author likes to thank all experts from the ISO/TC 163/SC 2/WG 15 working group who actively contributed to prepare prEN ISO/DIS 52016-3: Prof. Shady Attia (University of Liège, Belgium), Mrs. Maure Creager (SageGlass, Minnesota, USA), Mrs. Anne Minne (Saint-Gobain Glass, Belgium), Mr. Charlie Curcija (Lawrence Berkeley Lab (LBNL, Cal., USA), Mr. Hervé Lamy (European association for the solar shading branch (ES-SO), Belgium), Mr Robert Marshall (private consultant, Ontario, Canada), Ass.Prof. Fabio Favoino and Prof. Vincenzo Corrado (Politecnico di Torino, Italy) and Prof. Gerhard Zweifel (Hochschule Luzern, Switzerland).

References

[1] Information on all EPB standards (overview, webinar presentations, short videos, FAQs, tools: see EPB Center website: https://epb.center/.

[2] Mandate M/480: Mandate to CEN, CENELEC and ETSI for the elaboration and adoption of standards for a methodology calculating the integrated energy performance of buildings and promoting the energy efficiency of buildings, in accordance with the terms set in the recast of the Directive on the energy performance of buildings (2010/31/EU), December 14, 2010.

[3] Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast), OJ 153, 18.6.2010.

[4] 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. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2018.156.01.0075.01.ENG.

[5] EN ISO 52016 1:2017, *Energy performance of buildings - Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads - Part 1: Calculation procedures.*

[6] prEN ISO/DIS 52016 3:2022, *Energy performance of buildings - Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads - Part 3: Calculation procedures regarding adaptive building envelope elements* (to be published spring 2022).

[7] CEN ISO/TR 52016-4, *Energy performance of buildings — Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads — Part 4: Explanation and justification for ISO 52016-3* (under preparation).

[8] *Proposal for a Directive of the European Parliament and of the Council on the energy performance of buildings* (recast) https://ec.europa.eu/info/law/better-regulation/.

[9] Andrei Vladimir Lițiu, Olli Seppänen, Spyridon Pantelis, Jaap Hogeling, *The smart readiness indicator for buildings: current status and next steps*, REHVA Journal, Issue 3, 2021 https://www.rehva.eu/rehva-journal/chapter/the-smart-readiness-indicator-for-buildings-current-status-and-next-steps.

[10] EN ISO 52120-1:2021, *Energy performance of buildings — Contribution of building automation and controls and building management — Part 1: General framework and procedures.*

[11] ISO 15099:2003, *Energy performance of buildings — Thermal, solar and daylight properties of building components and elements — Part 3: Detailed calculation method of the solar and daylight characteristics for solar protection devices combined with glazing.*

[12] EN ISO 52022-3:2017, *Energy performance of buildings — Thermal, solar and daylight properties of building components and elements — Part 3: Detailed calculation method of the solar and daylight characteristics for solar protection devices combined with glazing.*

[13] Spreadsheets on EPB standards publicly available at the EPB Center website https://epb.center/support/documents/?title=&group=3.

[14] Spreadsheet on EN ISO 52016-1, publicly available at the EPB Center website https://epb.center/support/documents/demo-en-iso-52016-1/.

[15] IEC-ISO SMART Standards Programme https://connect.iso.org/display/standards/ISO+SMART.

Technical comments on the zero-emission building definition in EPBD recast proposal

JAREK KURNITSKI
REHVA Technology and Research Committee, Tallinn University of Technology
jarek.kurnitski@taltech.ee

JOHANN ZIRNGIBL
Ingenieurunion – Germany

The definition of the zero-emission building (ZEB) is a major topic in the EPBD recast proposal. It sets requirements and threshold values for primary and renewable energy impacting the installation of technical building systems. ZEB also defines class A of the Energy Performance Certificates (EPC).

In this document the problem with the actual requirements of the EPBD recast proposal of the ZEB definition are explained and illustrated by a calculation example of a residential building in Nordic climate fulfilling the current Estonian NZEB level. Proposals are made to improve the zero-emission definition.

Actual definition of the zero-emission building

The EPBD recast proposal dated 15.12.2021 defines in **article 2.2:**

> "zero-emission building" means a building with a very high energy performance, as determined in accordance with Annex I, where the very low amount of energy still required is fully covered by energy from renewable sources generated on-site, from a renewable energy community within the meaning of Directive (EU) 2018/2001 [amended RED] or from a district heating and cooling system, in accordance with the requirements set out in Annex III"

Article 16 « Energy performance certificates » requires that **class A of an EPC shall correspond to zero-emission buildings.** The definition of the **best energy performance class A shall ensure the convergence** of the **energy performance class** scale towards a common understanding of **zero-emission** buildings.

Annex III provides additional details:

- The total annual primary energy use of a new or renovated zero-emission building shall be fully covered, on a net annual basis, by
  - energy from renewable sources generated on-site and fulfilling the criteria of Article 7 of Directive (EU) 2018/2001 [amended RED],
  - **renewable** energy provided from a **renewable energy community** within the meaning of Article 22 of Directive (EU) 2018/2001 [amended RED], or
  - **renewable** energy and waste heat from an **efficient district heating and cooling system** in accordance with Article (24(1) of Directive (EU) …/… [recast EED]
- A zero-emission building shall not cause any on-site carbon emissions from fossil fuels
- Only where, due to the nature of the building or lack of access to renewable energy communities or eligible district heating and cooling systems, it is technically not feasible to fulfil the requirements under the first paragraph, the total annual primary energy use may also be covered by energy from the grid complying with criteria established at national level.

Understanding and commenting the terms of the actual version

Total primary energy

There was a discussion among the **total primary energy** used in EPBD. It seems that this is partly caused by some terminology issues. There are differences in energy terminology details in EED (and energy statistics) and EPBD, coming from the scope and purpose of directives.

EPBD use bottom-up definitions for energy calculation in buildings and makes a reference to European standards, especially to the overarching EPB standard EN ISO 52000-1.

EED recast Article 2 'primary energy consumption' definition is different from total primary energy, because EED defines primary energy as the gross available energy from which ambient heat is excluded.

Amended RED defines clearly that solar thermal, solar photovoltaic, geothermal energy and ambient energy are renewable energy and therefore are to be accounted in the total primary energy in the context of EPBD.

Historically this might have been the reason that EPBD used just **'primary energy'** which was specified in the cost optimality regulation and EN standards to be **non-renewable primary energy**. Because EED recast Article 2 definition 44 **'efficient individual heating and cooling' uses non-renewable primary energy**, this should be used consistently throughout EPBD to enable meaningful energy calculation.

"net" annual basis

"net" is not defined in the EPBD recast proposal.

It is understood that "net" emphasizes the energy exchange between the building (e.g. exported on-site PV) and the energy infrastructure (e.g. electricity grid).

It is proposed to add a definition of "net" (see proposal in "summary"

fully "covered"

it **is understood** that the **low amount of energy** still required can be **supplied by other energy carrier than the renewables defined in annex III**, e.g. by the electrical grid, but that the total primary energy use amount shall be **compensated** (equal or lower) by the amount of renewable energy from on-site, energy communities or district heating

It should be made clear that **other energy carriers than those mentioned to "cover" the energy still required can be used. This formulation excludes the renewable part of electricity from grid.**

It is proposed to change "covered" by "compensate" and to include renewable energy from the energy infrastructure in the compensation.

It is not specified how the compensation has to be done, for example **only by self-use**, or **also by exported energies**. As some countries allow exporting energy others not, this **decision can be taken at national basis**.

If exported energy is not taken into account, the self-use of PV will be accounted on a net annual basis.

No on-site carbon emission

The EPBD recast proposal states that a zero-emission building **shall not cause any on-site carbon emissions** from fossil fuels. Therefore, the possible **delivered energy carriers of ZEB** will only be:

- district heating and cooling;
- biomass;
- grid electricity and on-site and nearby PV electricity.

This formulation is not **technology neutral** because **gas boilers and cogeneration are phased out on-site** while they are **admitted at district heating level until 2050 according to EED recast.**

A **technology neutral option** would be to require that emissions from fossil fuels shall be compensated by renewable energy generation.

Technically not feasible

If "due to the ***nature of the building*** *…it is technically not feasible* to fulfil the requirements …the ***total annual primary energy use*** may also be ***covered by energy from the grid*** complying with criteria established ***at national level".***

This clause makes it possible to side pass the requirements.

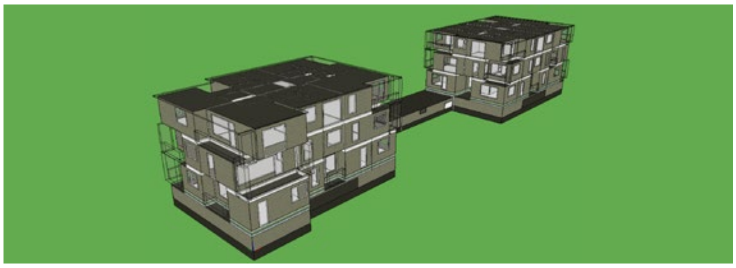
It is proposed to delete this clause. If it is technically not feasible to fulfil the requirements, then the building will simply not be able to reach the zero-emission level.

> *Attention:*
> *Class A of an EPC shall correspond to zero-emission buildings (article 16).*
> *There are several requirements (e.g. threshold, coverage) to be fulfilled to be classified as zero emission building.*
> ***It is not defined** what happens if **one of these definitions is not fulfilled. Which class the building will be if not all requirements are reached**? It is needed to define a class A for the EPC.*

Example case: Comparison of a Nearly Zero Energy apartment Building (NZEB) in Nordic climate with the zero emission requirements

In the example hereafter (**Figure 1**) ZEB requirements in the EPBD recast proposal are applied to a NZEB apartment building in Nordic climate to check if and under which conditions these requirements could be fulfilled.

Apartment building calculation example (Nordic climate)					input data
Primary energy factors & CO_2 emission coefficients					
	non-ren.	renewable	total	$kgCO_2/kWh$	€/kWh
Grid electricity & PV export	2.3	0.2	2.5	0.42	0.2
Natural gas	1.1	0	1.1	0.22	0.1
DH (district heat)	0.6	0.6	1.2	0.12	0.08
RE (solar, geo, ambient)	0	1	1	0	0



Uwall=0.14; Uroof=0.12; Ufloor=0.14; Uwindow=0.9; q50=1.5 m³/hm². Heat recovery ventilation, 80% temp.ratio, electric reheating coil. No cooling (passive measures to control summer thermal comfort). Heat source options: DH (district heating), Gas (gas boiler), GSHP (ground source heat pump) and AWHP (air to water heat pump).

System efficiencies, -	
Boiler efficiency, DH	0.90
Boiler efficiency, gas	0.95
Em&distr. efficiency	0.97

Heat pump, -	GSHP	AWHP
Energy ratio	0.78	0.81
SPF space heating	4.2	2.8
SPF DHW	2.6	2.0

	Energy calculation	Energy need kWh/m² a	Energy use kWh/m² a			
			DH	**Gas**	**GSHP**	**AWHP**
	Space heating	25.9	29.7	28.1	10.8	12.8
	DHW	30	33.3	31.6	11.5	15.0
	Supply air heating	4.4	4.4	4.4	4.4	4.4
	Fans and pumps	5.5	6	6	5.5	5.5
	Fixed lighting	1.4	1.4	1.4	1.4	1.4
	PV generation	16				
	PV self use,-		0.55	0.55	0.7	0.7
	PV self use, kWh/m² a		8.8	8.8	11.2	11.2
	PV export[1], 0/1	1	7.2	7.2	4.8	4.8
→	Non-ren. primary energy, kWh/m² a		28	56.0	40.6	53.1
EPBD No 1	**Total primary energy[2], kWh/m² a**		**81.1**	**71.2**	**93.7**	**101.8**
EPBD No 2	**Renewable energy[3], kWh/m² a**		**53.8**	**16.0**	**49.5**	**44.1**
→	CO_2 emissions, $kgCO_2/m^2$ a		5.8	11.4	7.4	9.7
	add. PV to compensate total primary energy		10.9	22.1	17.7	23.1
	add. PV to compensate CO_2 emission		13.8	27.1	17.7	23.1
	Energy cost[4], €/m² a		5.2	6.1	4.2	5.3

1) PV export not taken into account =0, is taken into account = 1
2) If PV export=0, only self used PV is accounted in the total primary energy
3) Renewable energy does not include renewable energy from grid electricity as specified in EPBD draft
4) Exported electricity compensation is assumed to be 1/3 of the electricity price

Figure 1. Example case: Comparison of NZEB building in Nordic climate and the zero-emission level.

This building configuration meets current Estonian NZEB requirements with District heating (DH) and Ground Source Heat Pump (GSHP) if PV generation is 16 kWh/(m².y). Air to Water Heat Pump (AWHP) would need some improvement and gas would need major changes.

EPBD recast proposal sets, as first requirement, the total primary energy for residential ZEB in Nordic climate to **75 kWh/(m².y).**

Figure 1 indicates the primary energy factors and CO_2 emission coefficients of the different energy carriers (including renewables as thermal energy extracted by the heat pumps).

Figure 1 line **"EPBD No 1"** shows that only **the gas boiler will reach** this first requirement of the zero-emission definition when calculated with PV export. Especially heat pump systems will have difficulties because the total primary energy (see **Figure 1**) includes the renewable part taken form the environment.

The **second** requirement in the ZEB definition ask to **fully cover**, on a net annual basis, the total primary energy use by renewables (without renewables from the energy infrastructure). **Figure 1** line **"add. PV to cover "tot. prim. energy"** shows that to fulfil this requirement a high amount of **additional on-site PV generation** would be needed. This would be practically impossible in the example because the roof allows only to install **24 kWh/(m².y)** PV generation.

These results show that the total primary energy-based requirements are not sound.

Proposals to revise the ZEB definition

First requirement (threshold on primary energy use):

It is proposed to revise the first requirement by changing from "**total** primary energy use" to "**non-renewable** primary energy use".

Rational:

If "**total** primary energy" is calculated according to existing, physical correct definitions (including the ambient heat recovered by the heat pump, heat pumps will have very high total primary energy use because of extracting energy from ambient. The valorisation of on-site renewables will be less.

Figure 1 shows that the non-renewable primary energy-based requirements can be reached. It is in line with the NZEB definition. **The non-renewable primary energy use will allow to limit the non-renewable primary consumption and valorise the renewables.**

It is understood that the reason to use the **total primary energy** was chosen to **keep a good quality of the building envelope** and high system efficiencies which should not be possible to compensate with extensive amounts of renewable energy generation. Therefore, by changing from "total" to "non-renewable" primary energy **this limitation must be re-established.**

These limitations could be related to the building needs (e.g. for NZEB building), to the efficiency of the technical building systems, etc. They should be defined in the chapter related to NZEB buildings.

It is proposed that Annex III refer to it.

Second requirement (zero emission level):

The **first requirement is close to the definition of a nearly zero (non-renewable) primary energy building** (low amount of energy). The **second requirement** of the EPBD recast proposal add as **zero-emission level** by the coverage (compensation) of the total primary energy use by **renewables.**

It is proposed to **replace** the coverage of the **total primary energy use** by the coverage of the **CO_2 emissions**. This makes this requirement straightforward, clearly focussing on the target of zero-emission.

To illustrate how to reach to zero-emission level **Figure 1** line **"add. PV to compensate CO_2 emission"** shows the amount of how much additional **PV should be installed** to cover the emissions. It is likely that zero-emission is not reachable in Nordic climate, because of the higher heat losses and lower solar radiation than in southern countries. Future cost optimality calculations, including better insulation, DHW heat recovery, higher system efficiency or a higher amount of delivered renewables, would help to clarify the situation.

Zero Energy Buildings

Summary

If including onsite renewables in the total primary energies, the **total** primary energy does not allow meaningful energy calculation because not distinguishing renewable not causing CO_2 emissions from non-renewable energy causing CO_2 emissions. Also, the sustainability of renewables is neglected.

Attention is also drawn to the target of ZEB definition to be zero-emission. Not primary energy but CO_2 emissions should be fully covered/compensated by renewable energy to be zero-emission.

Therefore, and to clarify several terms, the following improvements could be proposed:

Article 2 Definitions

"Net energy" means the balance of energy exchange between the building (e.g. exported on-site PV) and the energy infrastructure (e.g. public grid).

Article 2.2. Definitions

"zero-emission building" means a building with a very high energy performance, as determined in accordance with Annex I, where the very low amount of **CO_2 emissions due to** energy ~~still required~~ **use** is fully ~~covered~~ **compensated** by energy from renewable sources generated on-site, from a renewable energy community within the meaning of Directive (EU) 2018/2001 [amended RED] or from a district heating and cooling system **or from energy infrastructure**, in accordance with the requirements set out in Annex III.

ANNEX III

The ~~total~~ **non-renewable** annual primary energy use "of a new zero-emission building shall comply with the maximum thresholds indicated in the Figure below. **If the national cost optimal level has a higher ambition than the national level shall apply**.

An additional requirement shall be added to avoid that the energy use (building quality) is too much compensated by renewable energy.

Replace **"total"** by **"non-renewable"** in the Figure and note.

- The total annual ~~primary energy use~~ CO_2 emission of a new or renovated zero-emission building shall be fully ~~covered~~ compensated, on a net annual basis, by energy from renewable sources generated on-site, energy infrastructure and fulfilling …
- With proposed changes the following requirement becomes redundant and can be deleted. ~~A zero-emission building shall not cause any on-site carbon emissions from fossil fuels.~~
- To avoid negative side-effect of exceptions, delete the following: ~~Only where, due to the nature of the building … from the grid complying with criteria established at national level~~.

The proposed updates of the ZEB definition summarise the EU's main objectives (Energy efficiency, use of renewables, CO_2 neutrality) with a couple of common indicators. This set of indicators is based on the NZEB definition, underlining the convergence of the energy performance class scale towards zero-emission buildings by limiting negative effects of a single indicator. ■

Field investigation of the airborne infection risk in fitness centres during COVID-19 pandemic





NABANEETA SHARMA
NTNU, Trondheim,
Norway
nabanees@stud.ntnu.no

YANG BI
NTNU, Trondheim,
Norway

EVANGELIA GIOTI
NTNU, Trondheim,
Norway

EMMA DYVESVEEN MYRBEKK
NTNU, Trondheim,
Norway

GUANGYU CAO
NTNU, Trondheim,
Norway

The objective of the study is to evaluate the effect of social distance requirements set by Norwegian authorities for group activities in closed rooms on airborne infection risk. The CO_2 concentration was measured in two gyms with different activity levels of fitness classes. The ventilation airflow rate was obtained by steady-state mass balance equations. The Wells Riley model was used to assess the risk of infection among people in the room during the exercise class. Moreover, the relationship between social distancing and the number of infected people was obtained. Results show a close relation between CO_2 concentration and activity level. The ventilation airflow rate in Yoga room was calculated to be 343.2 m^3/h, while in Tabata room was 2063.9 m^3/h. Calculations showed that with 1 m social distance and one infected person in the room, the airborne infection risk is 2.23% for the Yoga and 2.14% for the Tabata room. Different levels of activity caused the body to release different concentrations of the virus leading to similar rates of infection in both rooms despite the huge difference in the air change per hour. The conclusion is that social distancing is not the only parameter affecting the airborne infection risk, the ventilation rate also plays a key role.

Keywords: fitness centres, social distance, pandemic, airborne infection risk, activity levels, ventilation rate

Introduction

Since 2019, the COVID-19 pandemic has changed the way people lived. Norway imposed restrictions that are divided into three levels of actions, depending on the infection situation: general level (yellow), somewhat elevated level (orange), and more elevated level (red) [1]. These measures include a section dedicated to smaller, closed rooms with group activities at fitness centres, which is the focus of this study. According to general level, a social distance of 1m was recommended for low-intensity training and 2m for high-intensity training (yellow level). In a closed room, social distance is directly proportional to density of people.

Airborne transmission has been identified as one of the modes of transmission of the SARS COV-2 virus [2]. Therefore, this study carried out field measurements to evaluate the indoor infection risk in the gym where social distancing has been implemented during the pandemic.

Theoretical Modelling

Wells Riley is a risk assessment model that is prevalently used in infection risk evaluation for indoor environments where ventilation is considered as the only mechanism to remove viruses [3].

$$P = 1 - \exp\left(-\frac{Iqpt}{Q}\right) \quad (1)$$

Where, P = infection rate, %; I = number of infected people. p = quanta per hour per person. q = breathing rate m^3/h. t = time in hours. Q = ventilation rate m^3/h.

Under steady state, the mass balance equation for the quantity of pollutants generation can be expressed:

$$Q(c_r - c_i) = G \quad (2)$$

Where, G = emission rate of CO_2 inside of the room, g/h. c_r and c_i = concentration measured at the exhaust and supply air of the ventilation system, g/m^3.

Experimental methods

Measurement set up

In this study, measurements were done in two fitness centres, Sit Portalen and Sit Gløshaugen, in Trondheim, to measure the ventilation rate in rooms with different activities and determine the infection risk. In Portalen the measurements were done in a larger room, where Yoga was performed, while in Gløshaugen, the measurements took place in a smaller room, where Tabata was performed.

The measuring procedure was done with respect to the participants in the group activities. In both rooms, the instruments were placed in a corner, in front of the participants (facing the instruments) with a 2-3 m distance from the walls and the people to minimize the impact.

For results:

- Measurements taken every 15 minutes in an hour
- CO_2 concentration, every 15 minutes for 4 minutes in a row
- Last 4 minutes, values of every 20 seconds recorded

Instruments

For the measurements in both gyms, the following instruments were used: Thermal anemometer, Elma DT – 802.

Measurement conditions

Activity	Number of people performing the activity	Number of people NOT performing the activity	Volume of the room [m^3]
Yoga (Portalen)	15	2	445.72
Tabata (Gløshaugen)	13	2	286.68

Results

CO_2 concentration

Figure 1 shows the change of CO_2 concentration in the two gyms. The measurements started at 0mins, when people came into the room, and the class ended at 55 minutes. The CO_2 concentration in Yoga room is 2500-2700 ppm, and there is a slow rise over time. It falls back to the initial level 5 minutes after the end of the course. The CO_2 concentration in Tabata room is around 700-1000 ppm. A slight increase can be observed during the whole time. The values obtained by steady state methods is used as the calculation values. Ventilation in the two rooms is 2063.9 m^3/h, in Tabata room (7.2 ACH), and 343.2 m^3/h in Yoga room (0.76 ACH).

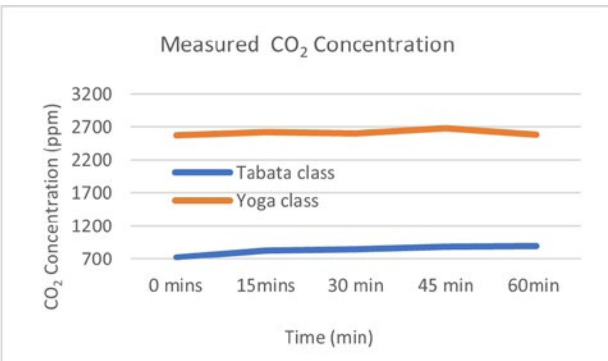


Figure 1. Measured CO_2 concentration in two rooms.

Calculated Infection Risk

Based on the literature [4], the virus release rate of Yoga activity was set at 5.6 quanta/h·person and for Tabata activity at 13.5 quanta/h·person. The respiration rate in Yoga room was 1.38 m^3/h, and in Tabata room was 3.3 m^3/h [5].

Assuming, usable area of the room to be 80% of total area, the per capita area can be obtained according to the number of people. By maintenance of distance between people, the relationship of the number of infected people to social distance can be obtained.

Figures 2 and 3 show the variation of the number of infections with social distance in the two rooms, with various sources of virus infection. The estimated number of infections was calculated using the Wells Riley Model. In Tabata class according to Wells Riley model, when there was only one source of release, the infection rate for an hour was 2.14%. With social distance of 1m, the room can hold a maximum of 88 people. Calculating, the number of infected people in the whole room 1.88, 3.72 and 5.52 respectively at the source of one, two and three people. Considering 2m social distance, the maximum number of people in the room is 22. Accordingly, the number of infected people dropped to 1.28, 0.93 and 0.47, These values decrease to 0.21, 0.42 and 0.64 with social distance of 3 meters (The maximum number pf is 11).

In Yoga class, probability with presence of one infected was 2.23%. When the social distance is 1m, maximum number of people in the room is 99, and the expected number of infected people after a class is 2.2, 4.36 and 6.46 respectively when the virus sources are 1, 2 and 3. These value decease dramatically to 0.24, 0.48 and 0.71.

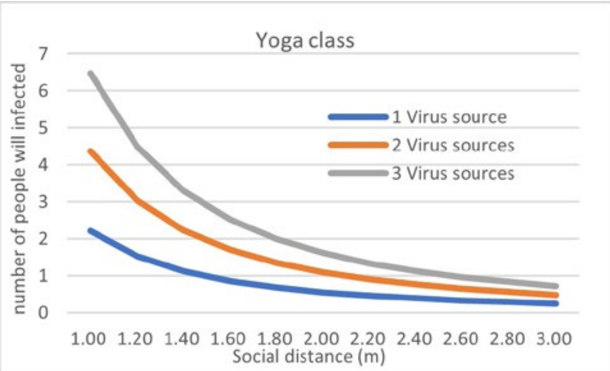


Figure 2. The relation between the number of people likely to get infected and the distance between the participants in Yoga class. This relation is shown for different numbers of infected people in the room/virus sources.

Discussion

Activity Level in relation to CO_2 Concentration

Yoga and Tabata

The measurements for CO_2 in Yoga room were higher than the Tabata room (no interval between classes) and it was around 2500-2700 ppm. This combined with a low ventilation rate and a very heavy breathing of the participants throughout the exercises caused high CO_2 levels. Activities started with subtle exercises, increased in the middle, and again relaxed towards the end, as it is shown in **Figure 1**.

In Tabata, activities started slowly then increased and remained mostly constant in a high level, except the last minutes that included lighter activities. **Figure 1** shows that the CO_2 concentration increased throughout the whole class. The graph corresponds well with the activity level, except at the end where concentration was expected to decrease. This increase is due to opening of the door at the end of the class and the CO_2 concentration that was higher outside the room.

Social Distancing

In Yoga room, with a social distance of 1 m, maximum number of infections is 2.2, is high. However, when the number is limited to less than 20, it drops below 0.5. When the ventilation rate increased, this value decreased further. Therefore, it is not enough to limit social distancing to reduce the possibility of infection, especially when ventilation airflow rate is low. Considering ventilation volume, room type and ventilation method, it is important to effectively reduce infection by using multi measures like social distancing and increased ventilation rate. Related results were

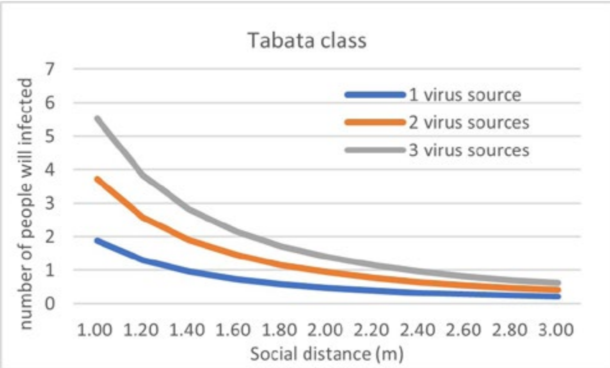


Figure 3. The relation between the number of people likely to get infected and the distance between the participants in Tabata class. This relation is shown for different numbers of infected people in the room/virus sources.

found in Tabata room. However, the ventilation rate was high, so the only possibility to reduce the infection risk is to reduce the number of participants. At the time of this study, the number of people in the room was 13, and then the expected number of infections was 0.32 when one person released the virus.

Figures 2 and 3 show that the social distance requirement has a profound influence on the infection risk. Even though this analysis does not consider direct exposure via droplet transmission, the results have shown that social distance also affects the risk of airborne infection.

As mentioned, the requirements distinguish between the social distance for low and high intensity activity. Yoga room has less ventilation than Tabata room, but their infection rates are almost similar. Because, in Yoga room people had a lower activity level but had many breathing exercises. If the rooms were similar with same ventilation conditions, the airborne infection risk in Yoga room would have been smaller than the risk in the Tabata room, with the same social distancing. The distance dependent on activity level can be assumed to be a more important infection risk for the droplet transmission than the airborne transmission.

Conclusion

The infection risk was calculated and discussed in relation to the Norwegian requirements on social distancing. Social distance alone is not sufficient to eliminate the airborne infection risk during COVID-19 pandemic. Combined measures, for example social distancing with an appropriate ventilation rate to create a safer indoor environment should be considered. As observed, in Yoga room the ventilation rate was low, and this had a larger influence on infection risk than social distance had. Considering different activity levels, room volume and ventilation type are quite important to reduce the infection risk.

The categorization of the rooms, in high and low activity levels, is quite reasonable as the CO_2 emitted from people during the exercise works as an indicator for the infection risk. Therefore, the results of this study suggest that infection control measures should be classified according to the activity level in different built environments with different ventilation flow rate. It also indicates that if it is not feasible to change the ventilation flow rate, then enlarging social distancing requirements may help to reduce the infection risk to a similar level. ■

References

[1] COVID-19 — Infection control measures for fitness centres — Rev.4. 2021, Standard Norge.

[2] Li, Y., et al., Probable airborne transmission of SARS-CoV-2 in a poorly ventilated restaurant. Building and Environment, 2021. 196: p. 107788.

[3] Sze To, G.N. and C.Y.H. Chao, Review and comparison between the Wells–Riley and dose-response approaches to risk assessment of infectious respiratory diseases. Indoor Air, 2010. 20(1): p. 2-16.

[4] Buonanno, G., L. Stabile, and L. Morawska, Estimation of airborne viral emission: Quanta emission rate of SARS-CoV-2 for infection risk assessment. Environment International, 2020. 141: p. 105794.

[5] Kurnitski, J., Ventilation rate and room size effects on infection risk of COVID-19. REHVA Journal, 2020. 05: p. 26-31.

ARTICLES

Critical versus non-critical path control in Residential DC-MEV

KEVIN VERNIERS
R&D Digital Innovation,
Renson Ventilation NV,
Waregem, Belgium
kevin.verniers@renson.be

FREDERIK LOSFELD
R&D Digital Innovation,
Renson Ventilation NV,
Waregem, Belgium

IVAN POLLET
R&D Digital Innovation,
Renson Ventilation NV,
Waregem, Belgium

Critical path control is considered in demand controlled mechanical extract ventilation (DC-MEV) systems to improve the energy efficiency. A multizone simulation study is presented discussing the impact on mean operating pressure and auxiliary fan consumption of residential DC-MEV systems when critical path control is applied instead of non-critical path control.

Keywords: mechanical extract ventilation, demand control, residential, energy efficiency, critical path control, multizone simulations, smartzone and non-smartzone Healthbox 3

Introduction

Traditional demand controlled ventilation systems are based on constant pressure control in a specific duct position to indirectly alter the airflow rate of the fan(s) in the air handling unit [1]. Unfortunately, this approach does not adequately benefit the energy efficiency of a ventilation system when the demand changes in one or more rooms. For this reason, an optimized fan control strategy taking into account the damper position of each room was proposed [1,2,3].

This optimized control strategy considers the duct with the highest pressure losses for a given demand at a given moment as the critical path and fully opens the damper on this critical path to minimize the maximal operating pressure and in that way the fan consumption. As a consequence, the system pressure is variable and determined by the pressure loss of the critical path. This optimized control strategy is indicated here as critical path control, whereas the constant pressure approach is non-critical path control.

The impact of both control approaches on mean operating pressure and auxiliary fan consumption of demand controlled mechanical extract ventilation (DC-MEV) is discussed in this article by means of multizone simulations.

Multizone simulations

The studied DC-MEV system is the Healthbox 3.0 (HB3). Air is naturally supplied into the habitable rooms via window vents, while demand controlled mechanical extraction takes place in the functional rooms (bathroom, toilet, …). In addition, demand controlled mechanical extraction points can be provided in the habitable rooms to improve the indoor air quality or thermal comfort. This extended configuration is indicated as Smartzone (SZ) and comprises of seven ducts, whereas the initial configuration is referred to as non-Smartzone (non-SZ) containing four ducts. The multizone simulations treated both HB3 configurations each once equipped with critical and non-critical path control.

Table 1 lists the parameters utilized in the multizone simulations. A single detached house was considered that was equipped with either a SZ or non-SZ HB3, an open or closed kitchen, and an airtightness level (v50) of 0.6; 3; or 6 m³/(h.m²). This resulted in six houses and for each was a total of 100 simulations with four variable parameters (occupancy, orientation, …) conducted. Each simulation encompassed the heating season.

Figure 1 shows the flow of one simulation as means of an example. The first step generates mechanical extraction ventilation rates over the heating season for a random house configuration. The second step creates conductance values (C values) describing the entire ductwork as well as the air inlets. Thus, the C values represent the system characteristic and are based on field big data. The third step utilizes the extraction rates over the heating season and both the system and fan characteristic to calculate the operating fan pressures during the heating season for the case of critical as well as non-critical path control. The fan characteristics were measured in laboratory. The fourth step derives the fan power (and consumption) over the heating season by means of the earlier obtained fan pressure operating points. For each heating season, the average of the fan operating pressure, power, and consumption are determined.

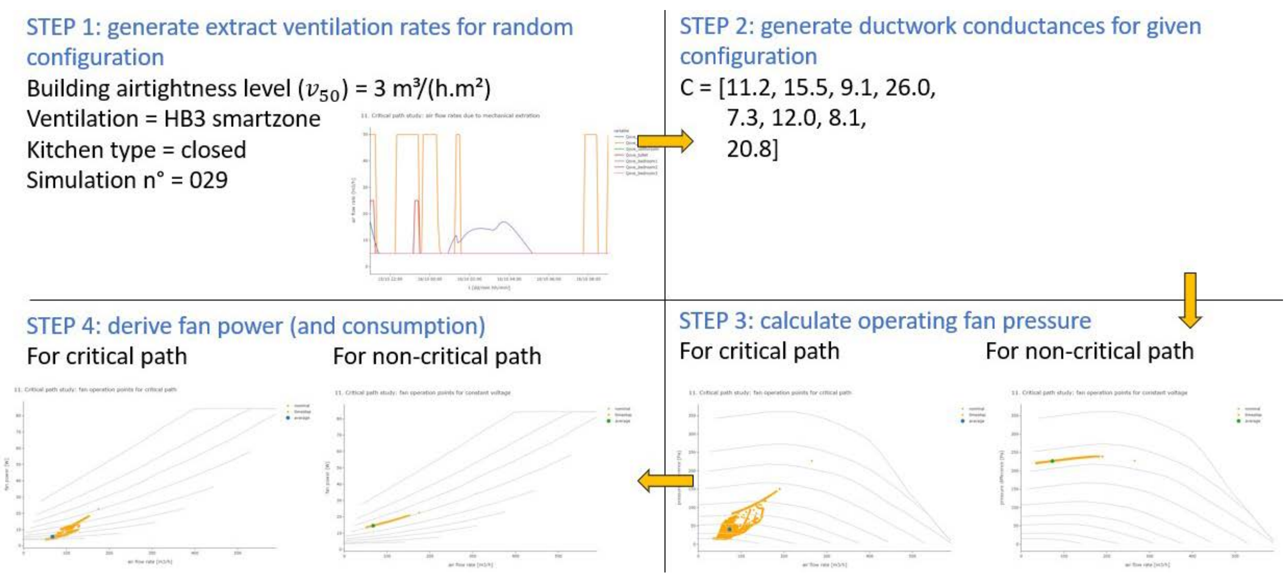


Figure 1. Flow of a single simulation. This example is simulation n° 29 out of 100 for the house configuration consisting of a closed kitchen, a building airtightness level of 3 m³/(h.m²), and a HB3 Smartzone ventilation system.

Table 1. *Considerations for the multizone simulations.*

Parameter	Description
Dwelling	• 1 detached house with open or closed kitchen and 3 airtightness levels (v_{50}): 0.6; 3; 6 m³/(h.m²) • Heating season: 1st of October up to 15th of April • Per configuration: set of 100 simulations with 4 variable parameters: occupancy, terrain roughness, dwelling orientation and day start type • 2*3 times 100 or a total of 600 possible house configurations
Ventilation system	• Healthbox 3.0 without (4 ducts) and with Smartzone (7 ducts)
Ductwork down and upstream	• Generation of multiple (up to 1000) ductwork configurations including air inlets, C values derived from field big data, checked with lab measurements on components at the nominal airflow rate
Fan operating airflow rate (m³/h)	• Average airflow rate per simulation over the heating season • Moving average over set of simulation up to convergency
Fan operating pressure (Pa)	• Average pressure per simulation over the heating season • Moving average over set of simulation up to convergency
Fan power (W)	• Average fan power per simulation over the heating season • Moving average over set of simulation up to convergency
Fan consumption (kWh)	• Average fan consumption per simulation over the heating season • Moving average over set of simulation up to convergency
Reduction factor f	• Ratio of average fan consumption in case of critical path to non-critical path control

Results and discussion

Figure 2 is subdivided into four cases where the dwellings consisted of either an open or closed kitchen while being equipped with either a non-SZ or a SZ HB3 configuration. The ventilation system was once performed with critical path control on the one hand and non-critical path control on the other hand. The result for each case represents the average of the fan operating pressure and airflow rate for each simulation over the heating season.

For all cases, as expected, critical path control provides the lowest operating pressure in contrast to non-critical path control. The observation originates from the fact that non-critical path control generally has no entirely opened damper as opposed to critical path control. The maximal average operating pressure for non-critical path control rises up to about 350 Pa, except for the non-SZ with a closed kitchen where the highest value is around 300 Pa. Non-SZ has less ducts as there are less rooms to extract polluted air from, consequently there is less chance of a duct exhibiting high pressure losses. Additionally, a closed kitchen has a lower required minimum ventilation rate compared with an open kitchen according to the Belgian regulations (difference of 25 m^3/h). These items explain why non-SZ with closed kitchen exhibits only a maximal average operating pressure of 300 Pa, while SZ with open kitchen achieves most frequently the value of 350 Pa compared to the remaining cases. 350 Pa is the maximum achievable operating pressure of the fan according to its characteristics that were measured in laboratory and utilized in the simulations. In Belgium, there are no requirements regarding the operating pressure, the recommendation is to keep it as low as possible for energy and acoustic reasons. Similar conclusions are drawn from the minimal average operating pressures during non-critical path control. The explanations from non-critical path control apply also for critical path control that obtains a clearly lower minimal and maximal average operating pressure.

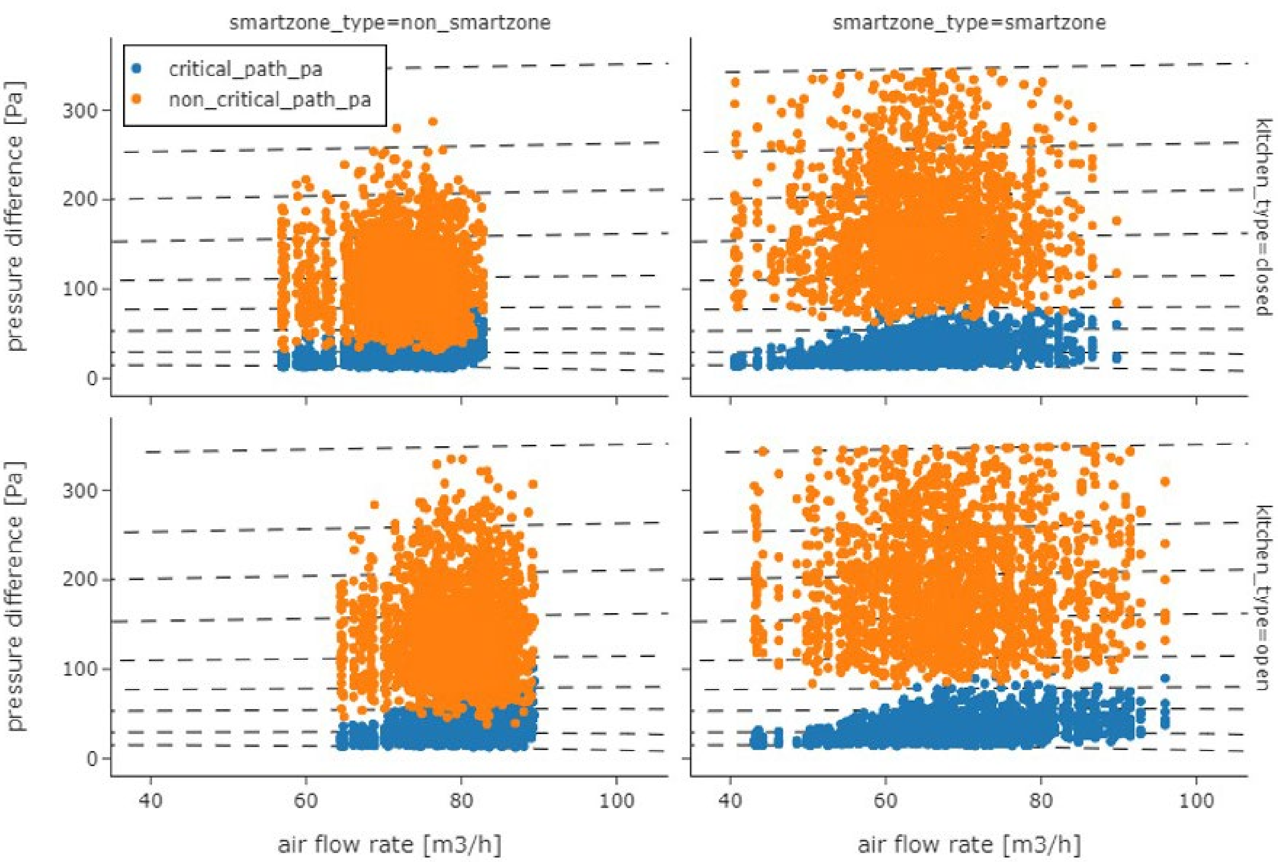


Figure 2. Average operating pressure (Pa) in function of the average airflow rate (m^3/h) for four cases (closed/open kitchen and Smartzone/non-Smartzone). Ventilation system based on critical or non-critical path control. Dashed lines represent the ventilator curves at different voltages.

For all cases, the average airflow rate varied from 40 to 100 m^3/h which is mostly less than one third of the installed nominal extraction capacity of the ventilation unit. For a similar exposure to CO_2, the deployment of non-SZ results in a higher airflow rate compared to SZ, although the occurrence of these higher airflow rates is rather limited. The difference is caused by smaller local minimal airflow rates (10% instead of 30%, Belgian regulations) and window vents designed at 10 Pa instead of 2 Pa for the SZ system.

The result for each case in **Figure 3** represents the average fan consumption as a function of the outlet duct conductance obtained for each simulation over the heating season. Similar to **Figure 2**, for each case are the lowest fan consumption values of at most 50 kWh obtained when critical path control is deployed. Critical path control reduces the fan consumption by about 50 to 75%.

The absolute difference in fan consumption between critical and non-critical path control becomes smaller when the conductance of the outlet duct increases. This is due to the fact that for a high conductance of the outlet duct, the additional pressure over the inlet ducts has less impact on the total pressure, and thus on the fan consumption. To conclude, critical path control shows the highest saving potential for outlet ducts with a low conductance or a high resistance.

Figure 3 shows also that non-critical path control exhibits a slightly lower average fan consumption in a dwelling containing a closed kitchen when compared with a dwelling having an open kitchen due to lower average operating pressures, while there is no difference when critical path control is applied.

For each simulation was a reduction factor (f) calculated based on the average fan consumption of critical path control relative to that of non-critical path

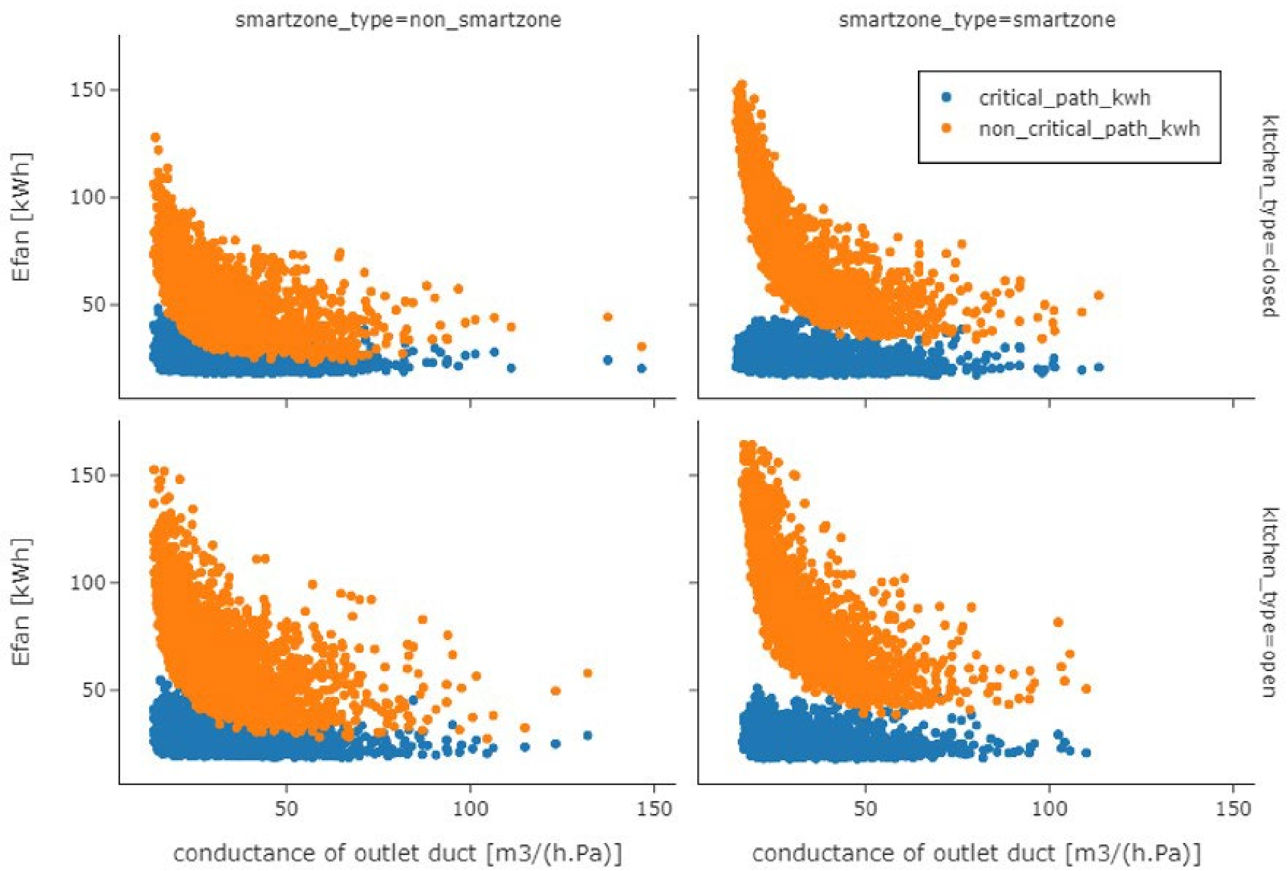


Figure 3. Average fan consumption (kWh) as a function of the outlet duct conductance ($m^3/(h.Pa)$) for four cases (closed/open kitchen and Smartzone/non-Smartzone). Ventilation system based on critical or non-critical path control.

control. The result for the considered cases is depicted in **Figure 4**. Each boxplot demonstrates quite some difference amongst the obtained reduction factors. The median value varies between about 30 % and 50 %. According to **Figure 4**, the largest reduction in fan consumption is obtained when a SZ ventilation system is deployed in a dwelling containing an open kitchen. In this case, the median value of the reduction factor equals about 33 % which is lower than the median values of the other boxplots. The median value of the reduction factor increases to 44 % in case of a dwelling composed of an open kitchen while being equipped with non-SZ ventilation system. Therefore, it can be concluded that adopting a SZ ventilation system with critical path control instead of non-critical path control leads to the highest reduction in energy consumption when compared to a non-SZ ventilation system. This higher reduction is related to the higher number of extract ducts in case of the SZ system.

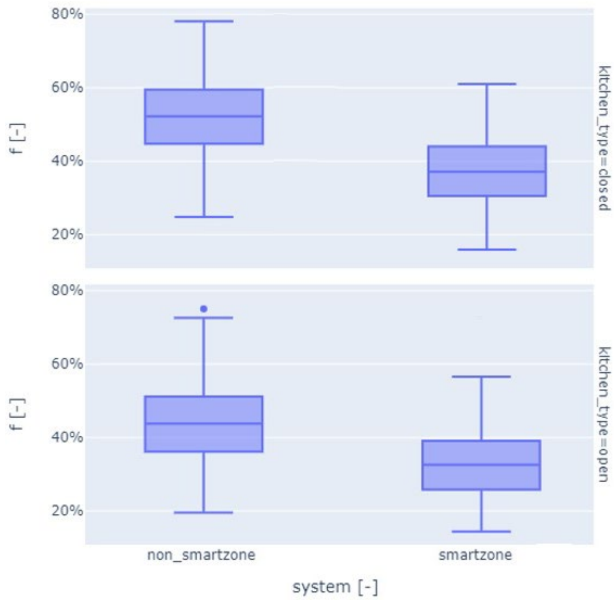


Figure 4. Boxplots of reduction factors obtained for four cases (closed/open kitchen and Smartzone/non-Smartzone). Reduction factor = average fan consumption critical path control divided by average fan consumption non-critical path control.

Conclusion

The impact of critical versus non-critical path control on the mean operating pressure and auxiliary fan consumption for residential DC-MEV systems was examined by means of multizone simulations during the heating season. The results demonstrated that critical path control leads to the lowest operating pressure over the duct work while also obtaining the lowest auxiliary fan consumption. The smartzone DC-MEV exhibits a higher operating pressure than non-smartzone due to the higher amount of ducts present in the system. The fan power consumption reduction factor based on critical path control relative to non-critical path control indicates that a house with open kitchen that is equipped with smartzone DC-MEV achieved a value of 33 % in contrast to the 44 % for non-smartzone DC-MEV. ■

Acknowledgements

This research has received no external funding.

References

[1] Mysen M., Woollett J. (2015) Commissioning for energy—optimal demand controlled ventilation. REVHA European HVAC Journal, vol. 52, no. 2, pp. 20–24.

[2] Truninger K. (2013). VAV system with genuinely demand-controlled fans. REHVA European HVAC Journal, vol. 50, no. 4, pp. 15–18.

[3] Mysen M., Schild P. G. (2011). Requirements for well functioning Demand Controlled Ventilation. REHVA European HVAC Journal, vol. 48, no. 5, pp. 14–19.

Improved Cooling Performance Testing of Radiant Ceiling Panels




JUN SHINODA
International Centre for Indoor Environment and Energy, Department of Environmental and Resource Engineering, Technical University of Denmark, Denmark
junshi@dtu.dk

ONGUN B. KAZANCI
International Centre for Indoor Environment and Energy, Department of Environmental and Resource Engineering, Technical University of Denmark, Denmark

SHIN-ICHI TANABE
Department of Architecture, Waseda University, Japan

BJARNE W. OLESEN
International Centre for Indoor Environment and Energy, Department of Environmental and Resource Engineering, Technical University of Denmark, Denmark

Radiant cooling is a promising option for providing thermal comfort with low energy use. The cooling capacity of radiant ceiling panels measured according to standards do not directly represent the cooling provided to the room. An improved measurement method was proposed to improve the prediction of their cooling performance.

Keywords: Chilled Ceiling, Radiant Cooling, Cooling Capacity, Standards, System Sizing

Introduction

Suspended radiant ceiling panels are one of the common radiant cooling solutions in buildings. One of the benefits of using radiant panels is the fact that they are prefabricated. Unlike systems that require pipes to be embedded in a concrete structure (i.e., thermally active building systems, TABS), prefabricated radiant panels can have their cooling capacity measured in a test chamber in advance. Testing and reporting procedures for radiant panels are given in standards such as EN 14240 [1] and ISO 18566-2 [2]. The latter is specifically intended for suspended panels in an open ceiling, in contrary to a closed ceiling that separates the room and the plenum spaces. According to these standards, the cooling capacity of radiant panels are measured by calculating the heat removed by the water circulation. However, when radiant panels are installed as a closed ceiling, the panels will provide cooling to both the room and the plenum. The heat extracted from the room and plenum cannot be distinguished by the cooling capacity, which is measured at the water-side. Therefore, sizing the radiant system based on the cooling capacity of the panels may result in an undersized system. The proportion of heat extracted from the room-side should be provided in addition to the cooling capacity of a panel.

Cooling Capacity Measurement

To evaluate the room-side cooling performance of suspended radiant ceiling panels, an improvement to the current measurement procedure was proposed, by taking the room and plenum temperature difference as an additional parameter [3, 4]. The proposed methodology requires cooling load simulators (heated metal cylinders) to be installed in the plenum, which will allow the plenum temperature to be controlled. Other chamber specifications were kept to be the same as those specified in EN 14240. This was intended to keep modifications to the current measurement facilities and procedure to a minimum, so that the panel manufacturers can adopt the new methodology easily. **Figure 1** illustrates a detailed comparison of the conventional and proposed measurement procedures.

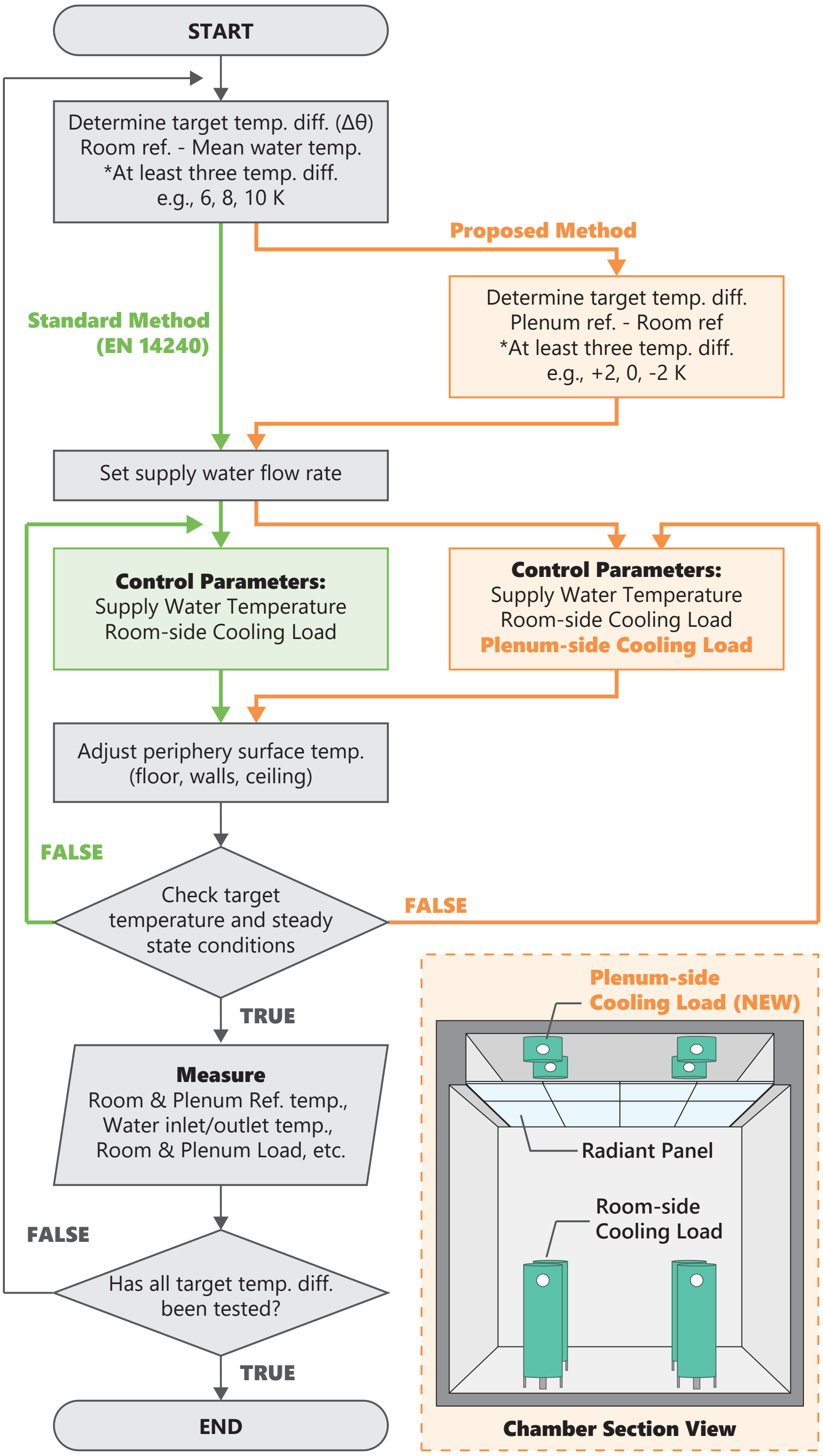


Figure 1. Standard and proposed cooling capacity measurement flow.

The standard procedure gives the cooling capacity (P_a, in W/m²) as a function of the difference between the room reference temperature and the mean water temperature of the circuit ($\Delta\theta$). Measurements are conducted with three temperature differences to obtain a cooling capacity curve. For the standard measurement procedure, the temperature in the plenum is not controlled during these measurements. The proposed methodology in the present study repeats the three sets of measurements at three different temperature differences between the room and plenum ($\theta_{plenum} - \theta_{room}$), corresponding to nine measurement cases in total.

Measurements following the proposed methodology were conducted in a chamber that complied with EN14240 to quantify the effects of plenum temperature on the cooling performance of suspended radiant ceiling panels and to demonstrate the applicability of the new methodology. Two panels of the same product line of the same manufacturer were selected. The two panels had the same properties except for the insulation on the plenum-side surface. One had no insulation and the other had an insulation layer (32 kg/m³ glass wool, 40 mm, 0.036 W/(m·K)). The non-insulated and insulated panels had a nominal cooling capacity (cooling capacity at $\Delta\theta$ = 8 K) of 61 W/m² and 58 W/m², respectively. The insulated panel had a lower nominal cooling capacity because the plenum temperature was not controlled during the measurement and had less heat extraction from the plenum. A full set of measurements (9 cases) was conducted for the non-insulated panels, and three cases were conducted for the insulated panels.

Figure 2 shows the heat extracted from the room and plenum. The sum of the heat extracted from both spaces is the cooling capacity of the panel. The results show that an increase in the plenum temperature resulted in an increase in the cooling capacity and the plenum-side heat extraction, while decreasing the room-side heat extraction. When the plenum temperature was higher than the room temperature, more than half of the cooling capacity was dedicated to the cooling of the plenum-side. The percentage of room-side cooling to the cooling capacity ranged between 77 and 92% for insulated panels, while it was between 46 and 71% when panels were not insulated. Insulation is an effective way to increase the percentage of room-side cooling, but up to approximately 20% of the cooling was from the plenum under the tested conditions, even with insulation. High plenum temperatures can be expected in cases such as when the panels are installed on the top floor where the ceiling slab is exposed to solar radiation or on any floors where waste heat from lighting armatures may be present. In such situations, attention must be given to the plenum temperature and the resulting plenum-side heat extraction of the panels.

Developed Model

Based on the measurement data shown in **Figure 2**, an empirical prediction model to predict the cooling capacity and room-side cooling ratio of a specific panel was developed, as illustrated in **Figure 3**. The prediction model is specific to each panel, and can be developed based on measurement data obtained according to **Figure 1**. The detailed method and equations are presented in [3]. The difference between the room and mean water temperature ($\Delta\theta$) and the temperature difference between the room and plenum ($\theta_{plenum} - \theta_{room}$) are used as inputs to the model. For example, assuming $\Delta\theta$ = 8 K and $\theta_{plenum} - \theta_{room}$ = −2 K (plenum temperature 2 K lower than room temperature), the total cooling capacity for the non-insulated would be 76 W/m², and the room-side cooling ratio would be 68%. This corresponds to 52 W/m² of cooling at the room-side. With the same temperature conditions, the insulated panels would yield a cooling capacity of 60 W/m², of which 56 W/m² would be dedicated to the room-side. This example shows that the proposed methodology can give a clearer guidance on the cooling performance of the radiant panels in a given temperature condition.

Validation in the Field

To validate the developed model, we conducted field measurements in an office building that was equipped with the same non-insulated panels tested in the chamber measurements. The case study building was a 32-floor, high-rise office building situated in the Greater Tokyo Area of Japan. The office floor had dimensions of 56.4 × 56.4 m, with a large open plan layout along the north, west, and south sides. The ceiling and plenum heights were 2.8 m and 1.08 m, respectively, and radiant panels covered 58% of the ceiling. Measurements were conducted on the 24th floor for one week during August 2020.

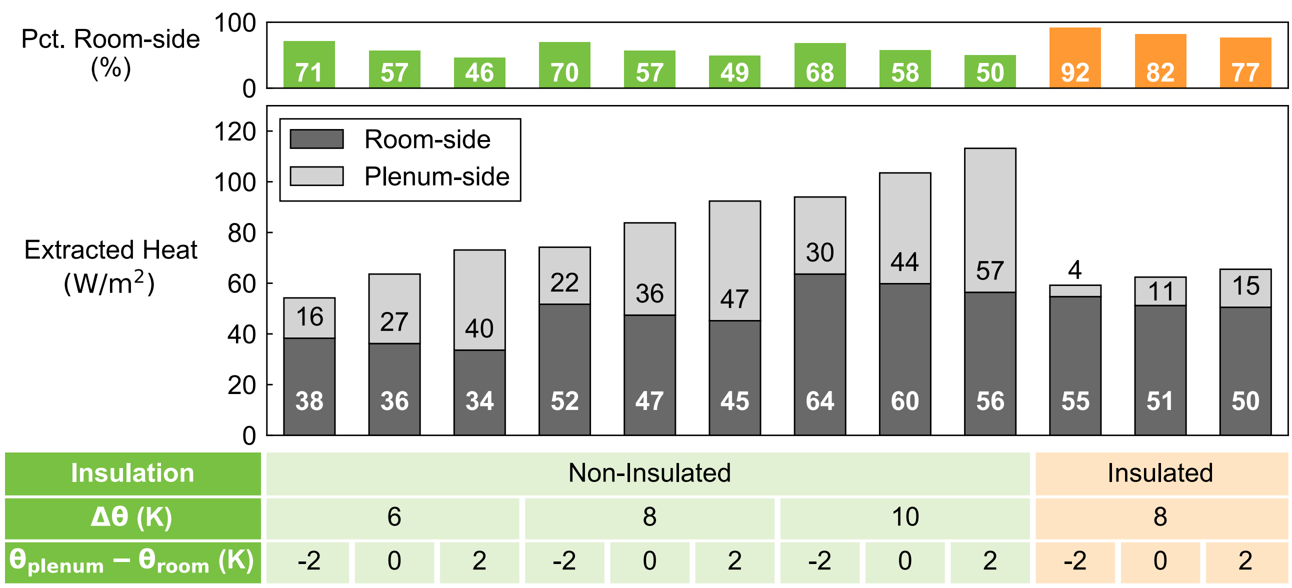


Figure 2. Heat extraction from the room and plenum by the non-insulated and the insulated panels.

Heat flux sensors were installed to measure the room- and plenum-side heat flux of a selected radiant panel. The room and plenum temperatures of the office area and the supply and return temperatures of the panel circuit were measured to obtain the input values necessary for the prediction model.

Figure 4 shows the comparison of the measured and predicted room-side heat flux (cooling). The model shown in **Figure 3** was used for the prediction, with the measured values as inputs. During the whole measurement period, the plenum temperature was within ±2 K of the room temperature, which was the temperature range tested in the chamber. The percentage of room-side cooling was mostly within the range of 65–70% when the panels were operating. The measured and predicted values were in good agreement, with an average error of 6% with a standard deviation of 3%.

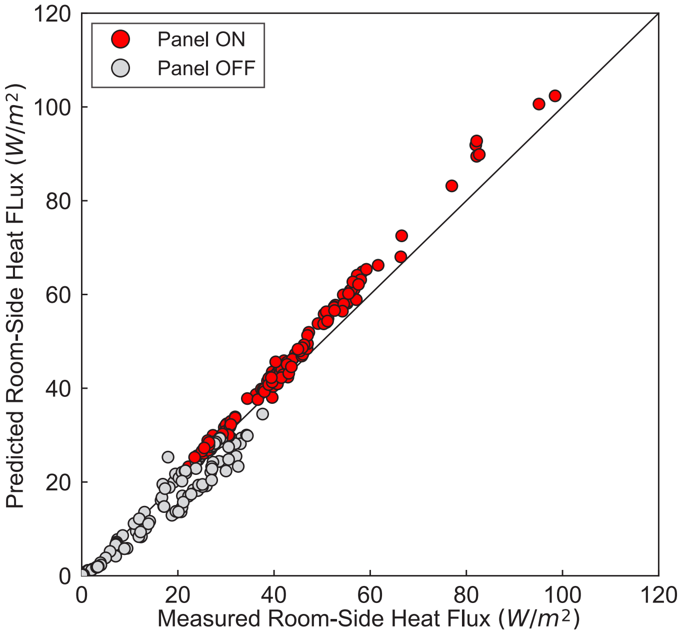


Figure 4. Comparison of measured and predicted heat flux.

Conclusion

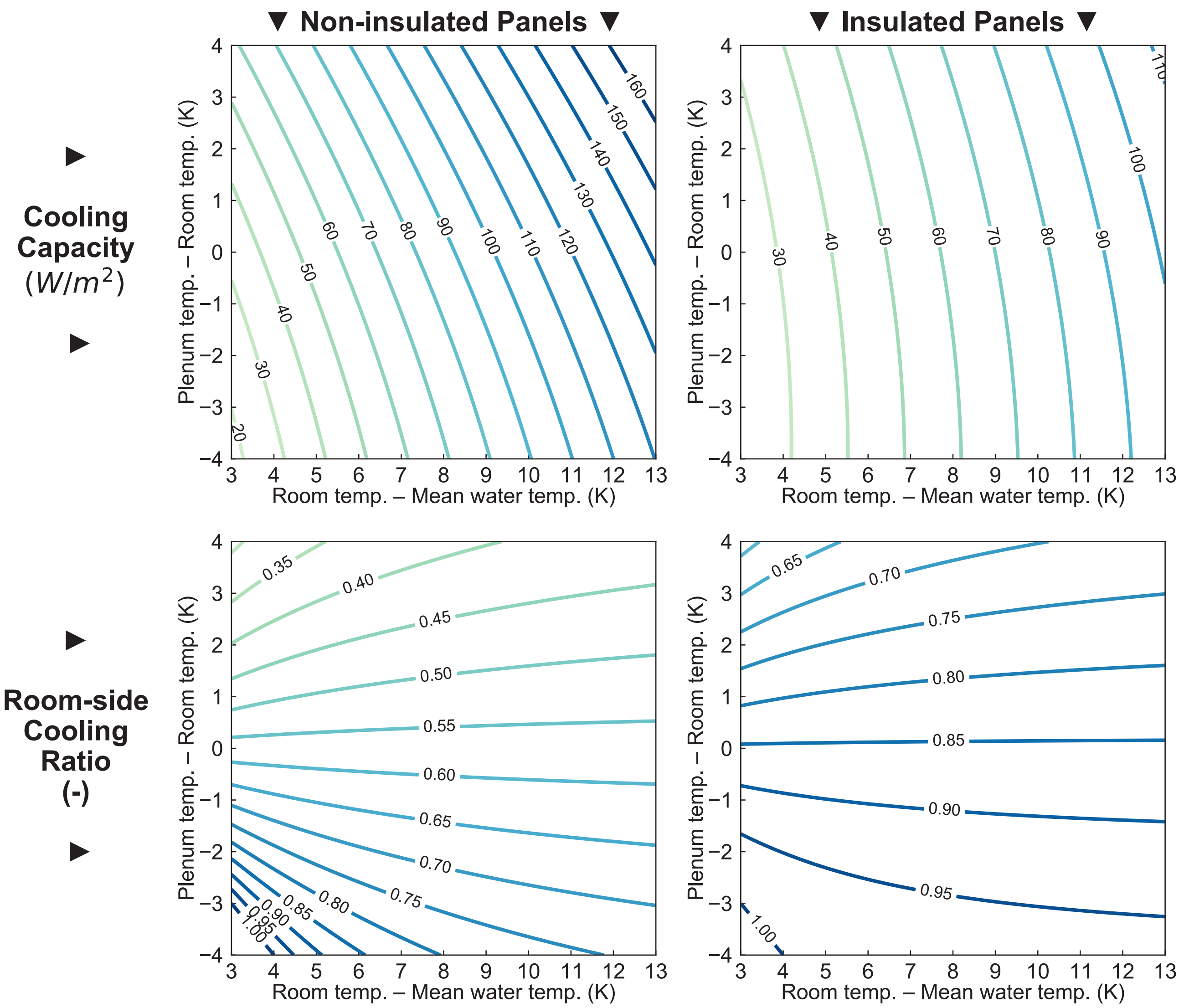


Figure 3. Developed prediction model for the tested panels.

Test chamber measurements showed that the plenum temperature, in relation to the room temperature, has a large influence on the cooling performance of suspended radiant ceiling panels. Regardless of any insulation of the panels, the plenum temperature must be considered, especially if high temperatures in the plenum are expected. The current cooling capacity measurement method cannot fully document the cooling performance of suspended radiant ceiling panels i.e., how much heat is removed from the room and plenum. An improvement to the measurement and reporting method, with minimal changes to the current measurement facilities, was therefore proposed. The newly proposed method enables the distinction between the total heat extracted from the panels and the heat extracted from the room-side. This would allow more accurate sizing of the panels and an improved operation and control of them. It is recommended that standards applicable to closed-type suspended radiant ceiling panels (such as EN 14240) incorporate plenum temperature control in their measurement procedure, as described in the present study. ■

References

[1] EN14240: Ventilation for Buildings - Chilled Ceilings - Testing and Rating, European Committee for Standardization, 2004.

[2] ISO18566-2: Building Environment Design - Design, Test Methods and Control of Hydronic Radiant Heating and Cooling Panel Systems - Part 2: Determination of Heating and Cooling Capacity of Ceiling Mounted Radiant Panels, International Organization for Standardization, 2017.

[3] Shinoda, J., Kazanci, O. B., Hidari, K., Watanabe, H., Takahashi, Y., & Tanabe, S. (2022). Improvements to the cooling capacity measurements of suspended radiant ceiling panels to prevent under-sizing. Journal of Building Engineering, 51, [104242]. https://doi.org/10.1016/j.jobe.2022.104242.

[4] Shinoda, J., Kazanci, O. B., Tanabe, S., Hidari, K., Watanabe, H., & Takahashi, Y. (2022). Room-side and Plenum-side Cooling Prediction of Suspended Radiant Ceiling Panels. CLIMA 2022 Conference. https://doi.org/10.34641/clima.2022.137.

Testing Portable Air Cleaning Units –Test Methods and Standards: A Critical Review

ALIREZA AFSHARI
Department of the Built Environment, Aalborg University, Denmark
aaf@build.aau.dk

JINHAN MO
Department of Building Science, Tsinghua University, Beijing, China

ENZE TIAN
Songshan Lake Materials Laboratory, Institute of Physics, Chinese Academy of Sciences, China

OLLI SEPPÄNEN
Nordic Ventilation Group & FINVAC

Standards and Procedures for Portable Air-cleaning Units

The most effective ways to reduce exposure to indoor air pollutants are to eliminate individual sources of pollution or to reduce their emissions. Another approach is source control i.e. if the outdoor pollution level is low, ventilation reduces the concentration of indoor particles by means of dilution. In addition, research studies show that removal control i.e. air filtration can be an effective supplement to source control and ventilation. Using a portable air cleaner, also known as air purifiers or air sanitizers can help to improve indoor air quality. Portable room air cleaners can clean the air in poorly ventilated spaces such as aged classrooms and offices, prisons, homeless shelters, etc., when continuous and localised air cleaning is needed.

To make an informed choice of a portable air cleaning (PAC) device. the following information is recommended:

- A metric for measuring the performance of residential air purifiers
- Filters: efficiency, size and amount of filter media
- Noise level
- Motor quality
- Safety – no ozone and uses no technology that could introduce contaminants

There are no standard definitions of portable air cleaning (PAC) devices. Sultan et al., [1] defined a PAC as an energy consuming device used to reduce the concentration of airborne pollutants, including but not limited to dusts, particles, environmental tobacco smoke, allergens, micro-organisms (e.g., mould, bacteria, pollen, viruses, and other bioaerosols), fumes, gases or vapours and odorous chemicals from the indoor air of a residential space. PAC technologies include, but are not limited to, mechanical air cleaners (e.g. HEPA filters), electrically charged filters, electrostatic precipitators, ionizers, photocatalytic oxidation, plasma-cluster ion, ozone generators, activated carbon (with and without chemical impregnated compounds) filters and others. PACs include devices of any size used for cleaning the air in a residential room of any size or in a whole house which could be stand-alone devices designed as wall-, floor-, ceiling-, table-, combination- or plug-in types.

There are a wide range of different portable air cleaners marketed for the removal of particles and gases. It is difficult for potential users or purchasers to select one device that is best suited for removing a certain pollutant and what technical information to request, consider and assess during the selection process. It is often difficult for non-experts to comprehend the differences between them or evaluate manufacturer claims.

In several years, the dominated market for portable air cleaner is largely in the U.S. among countries in North America and China in Asia. There are several test methods in the world for use in determining how well an air cleaner works in removing pollutants from indoor air. Majority of these test methods focus mainly on particle removal and estimate the efficiency or effectiveness of an air-cleaning device in removing particles from indoor air and can be used for comparisons among different devices. ISO 29464:2017 [2] is applicable to particulate and gas phase air filters and air cleaners used for the general ventilation of inhabited enclosed spaces.

Summary of the test methods and standards

This summary **Table 1 and 2** are standards and procedures for evaluating the particle and gaseous contaminant removal performance of portable air cleaners (PAC).

Table 1. *Summary of the test methods and standards for particle removal.*

Standard/Protocol (Ref.)	Country	Method	Challenge Particles	Measured Particle Size Range	Performance Index
ANSI/AHAM [3]	US	Pulldown	Environmental tobacco smoke, Arizona road dust, paper mulberry pollen	0.1 to 1.0 µm 0.5 to 3.0 µm 5 to 11 µm	CADR [a]
GB/T-18801 [4]	China	Pulldown	Environmental tobacco smoke, Arizona road dust, paper mulberry pollen	0.1 to 1.0 µm 0.5 to 3.0 µm 5 to 11 µm	CADR
NRC Protocol [5]	Canada	Pulldown	Polydisperse sodium chloride (NaCl)	50 nm to 5 µm	CADR
NCEMBT Procedure [6]	US	Pulldown	Polydisperse potassium chloride (KCl)	0.1 to 11.5 µm	CADR
Lucerne University (2012) [7]	Switzerland	Pulldown	ISO 12103-1 A1 Ultrafine test dust.	0.2 to 5 µm	
JIS C 9615 [8a]	Japan	Singlepass	JIS Z 8901 standard dusts	…	Removal rate
XP B44-200 [9]	France	Singlepass	DEHS, Cat allergens, *Staphylococcus epidermidis* *Aspergillus niger*	0.3 and 5 µm	SPE [b], CADR
ISO 29464:2017 [10a]	International	Singlepass	$PM_1 - PM_{10}$	0.3 and *X* µm	SPE
Nord test method – NT CONS 009 [45]	Nordic	Singlepass	Particles	e. g. 0,3 µm, 0,5 µm, <1 µm	SPE

Notes: (a) CADR: clean air delivery rate; (b) SPE: Single-pass efficiency.

Note: A "Pulldown" test method consists of three test periods under full-recirculation mode of the chamber operation: VOC or particle injection period, static period and dynamic period. The injection of known amount of contaminants into the experimental system, followed by a quasi-static period, result in stable initial high concentration levels. The time when the air cleaner is turned on is defined as time zero, at which the dynamic period begins. Using the measured concentration decay rate from the dynamic period, the clean air delivery rate (CADR) of the cleaner can then be calculated for each VOC and different size particles [39].

Note: SPE- Single-pass efficiency (η) represents the fraction of pollutants removed from the airstream as it passes through the air cleaner [39].

EUROPEAN STANDARD

EN ISO 29464:2019 (MAIN)
Cleaning of air and other gases - Terminology (ISO 29464:2017)

This document establishes a terminology for the air filtration industry and comprises terms and definitions only. This document is applicable to particulate and gas phase air filters and air cleaners used for the general ventilation of inhabited enclosed spaces. It is also applicable to air inlet filters for static or seaborne rotary machines and UV-C germicidal devices. It is not applicable to cabin filters for road vehicles or air inlet filters for mobile internal combustion engines for which separate arrangements exist. Dust separators for the purpose of air pollution control are also excluded. This European Standard was approved by CEN on 12 August 2019.

Table 2. *Summary of the test methods and standards for gaseous removal.*

Standard/Protocol (Ref.)	Country	Method	Challenge Gaseous	Measured Gaseous	Performance Index
ANSI/AHAM [3]	US	N/A	N/A	N/A	N/A
GB/T-18801 [11]	China	Pulldown	Single species gas	*e.g.,* Formaldehyde toluene	CADR
GB/T-18801 [11]	China	Singlepass	Single species gas	*e.g.,* Formaldehyde toluene	SPE
NRC Protocol [5]	Canada	N/A	N/A	N/A	N/A
NCEMBT Procedure [6]	US	Pulldown	Eight VOCs mixture [a]	$TVOC_{toluene}$ [b] formaldehyde	CADR
Lucerne University (2012) [7]	Switzerland	N/A	N/A	N/A	N/A
JIS C 9615-2007 [8b]	Japan	Singlepass	NO_2, SO_2	NO_2, SO_2	SPE
JEM 1467-1995 [8b]	Japan	Pulldown	Tobacco smoke	Ammonia, acetaldehyde, and acetic acid	Removal rate
XP B44-200 [9]	France	Singlepass	Four VOCs mixture [c]	Acetone, acetaldehyde, heptane, and tolune	SPE, CADR
ISO 29464:2017 [10b]	International	Singlepass	VOCs, acids, bases, and others	VOCs, acids, and bases, and others	SPE

Notes: (a) The components of the challenge VOC mixture include n-hexane, n-decane, toluene, dichloromethane, tetrachloroethylene, iso-butanol, 2-butanone, and formaldehyde; (b) Total hydrocarbon as toluene equivalent measured by the INNOVA 1312 Photoacoustic Multi-gas Monitor; (c) The components of the challenge VOC mixture include acetone, acetaldehyde, heptane, and toluene.

ANSI/AHAM: This standard is only for PM: dust, cigarette smoke and pollen.

NRC Protocol: This standard is only for PM: NaCl.

Lucerne University (2012): This standard is only for PM: DEHS

EXISTING TEST METHODS FROM THE USA

ANSI/AHAM AC-1: 2020

In the early 1980s, AHAM developed an objective and repeatable performance test method for measuring the ability of portable household electric room air cleaners to reduce particulate matter from a specific size room. The standard, ANSI/AHAM AC-1-2006, Method for Measuring the Performance of Portable Household Electric Room Air Cleaners, is designed to evaluate portable household electric room air cleaners regardless of the particle removal technology utilized.

In 2020, the U.S. Environmental Protection Agency (EPA) updated the referenced test procedure, for use in measuring the cigarette smoke Clean Air Delivery Rate (CADR) and operating power to determine certification for ENERGY STAR Room Air Cleaners i.e. titled ANSI/AHAM AC-1 test method "*Portable Household Electric Room Air Cleaners* ("ANSI/AHAM AC-1-2020"). For the purposes of ENERGY STAR certification, room air cleaners should be tested using ANSI/AHAM AC-1-2020 moving forward. AHAM describes this standard as establishing a uniform, repeatable procedure or standard method for measuring specified product characteristics of household portable air cleaners. The standard methods provide a means to compare and evaluate different brands and models of household portable air cleaners on the basis of characteristics significant to product use [12].

CADR – Clean Air Delivery Rate

The most used parameter for understanding the effectiveness of portable air cleaners is the clean air delivery rate (CADR). Clean Air Delivery Rate or CADR is a rating system that can help determine the effectiveness of an air purifier based on how many cubic meters per hour (m^3/h) of particulate matter it can filter. A higher CADR relative to the room size increases the effectiveness of a portable air cleaner i.e. the higher the CADR value, the faster the air purifier is at processing air. According to the Association of Home Appliance Manufacturers, an air purifier should have a CADR rating of at least two-thirds of your room's square footage. A CADR can theoretically be generated for either gases or particles; however, the current test standards only rate CADRs for particle removal [13]. CADR is a method for testing the capacity to reduce smoke, dust and pollen particles in the 0.10 to 11 µm size range from the air.

A factor that CADR does not account for is an air purifiers' long-term efficiency. Air purifiers start declining in efficiency after only one hour of usage, the extremely

short twenty-minute CADR test will not accurately reflect a purifiers' performance in the long term. CADR also does not test for air purifiers' performance against ultrafine particles. The three contaminants that CADR tests for (dust, pollen, and smoke) are on the larger side of the spectrum of airborne contaminants that are commonly filtered, ultrafine particles smaller than 0.1 microns make up 90% of the particles found in the air and harmful biological aerosols typically come in these sizes. It is important to note that the CADR system has its limitations, and it is in the best interest of the consumer not to base their decision in getting an air purifier solely on its CADR rating alone.

ASHRAE Standard 52-2 (1992)

ASHRAE Standard 52-2 (1992), provides for filter efficiency ratings by evaluating the fractional efficiencies in three particle size ranges i.e. 0.3 to 1.0 µm, 1.0 to 0 3 µm and 3.0 to 10 µm. The filter efficiency ratings are designated by Minimum Efficiency Reporting Value (MERV) between 1 and 20. For the test, a standard synthetic dust is fed into the air cleaner and the proportion (by weight) of the dust trapped on the filter is determined. Because the particles in the standard dust are relatively large, the weight arrestance test is of limited value in assessing the removal of smaller, respirable-size particles from indoor air [14].

EXISTING TEST METHODS FROM NORDIC COUNTRIES

Nord test method – NT CONS 009 Approved 1985-02

This NORDTEST method is used to test the technical performance of room air cleaners which are provided with fibrous or electrostatic filters. The air cleaners designed for public and industrial rooms are excluded. It contains tests for: Filtration efficiency of the filter, Air volume flow through the equipment, Equivalent clean air production which can be determined instead of the removal efficiency and volume flow, Outflow profile of the equipment and Noise properties of the equipment.

For measuring the performance of a room air cleaner, the following test methods are used: 1) The filtration efficiency of the filter determined by measuring the test particle concentrations in the inflow and outflow of the equipment. 2) The volume flow through the equipment is determined by using a measuring bag of a known volume and an auxiliary blower. 3) The equivalent clean air production is determined by measuring the decrease of the particle concentrations in the test room as a function of time and by calculating the product "filtration efficiency x volume flow" from the curve of the measured values. 4) The outflow profile is determined by feeding smoke to the outflow part of the equipment and by photographing the outflow profile. The critical flow velocity can be measured by an anemometer. 5) The noise properties (sound power level) are determined in an anechoic chamber with the precision method (ISO 3745) and 6) The ozone production of the equipment is determined by measuring the outflow and inflow ozone content of the air cleaner.

EXISTING TEST METHODS FROM CHINA

NATIONAL STANDARD OF THE PEOPLE'S REPUBLIC OF CHINA GB/T 18801—2015, AIR CLEANER

This standard is drafted according to the regulations published in GB/T 1.1-2009 [4]. This standard replaces GB/T 18801-2008 "Air cleaner". This standard stipulates the terminology, definition, model and nomination, requirements, test methods, inspection rules, labels, user instructions, packing, shipping and storage of the air cleaner. This standard applies to air cleaner for household use and similar use. This standard applies to, but is not limited to air cleaner of the following operating principle: filter type, absorption type, molecular complex locking type, chemistry catalytic type, photo catalytic type, static electricity type, plasma type and combination type, etc. With combination type means that the air cleaner uses two or more than two above-mentioned purifying technologies, and it can remove one or more than one kind of air pollutants.

Air purifier long-term performance: CCM (Cumulate clean mass)

Cumulative clean mass (CCM) measures the efficiency of an air purifier based on its ability to filter out particulate matter and formaldehyde. The cumulative total of purified particles is calculated when the CADR is degraded to half its original value through a series of tests deliberately made to wear out the air purifier's filter.

The tests conducted to reduce CADR to half its initial value include sealing it off in a chamber, lighting 100 to 200 cigarettes for the filter to clean, and exposing it to formaldehyde and other volatile organic compounds to wear out filtration media such as activated carbon filters. The purpose of this rigorous testing is to simulate how much volume of particular matter, odours, and formaldehyde an air purifier can process before its overall efficiency starts to diminish over time.

The final CCM rating indicates the continuing efficiency of an air purifier to clean indoor air even after long and heavy usage. CCM is tested for particle pollution as follows (per the GB/T 18801-2015 standard):

EXISTING TEST METHODS FROM JAPAN

There are two standard methods for assessing the performance of air-cleaning appliances in Japan, JIS C 9615 (Japanese Industrial Standards Committee [JISC] 2007) and JEM 1467 (Japan Electrical Manufacturers' Association [JEMA] 2015). These two test methods were standardized to examine the removal efficiency of (mainly) particles and odours; however, other chemical substances, such as HCHO and volatile organic compounds (VOCs), were not considered.

JEM 1467 (Japan Electrical Manufacturers' Association)

JEM 1476 test method applies to air cleaners designed to be used at home, offices, etc which are able to reduce odours and particulate levels indoors [4]. The JEMA describes a method to measure the performance at the initial stage and after loading phases on gas and particulate pollutants. In this method, tobacco smoke is employed as the challenge gas, and ammonia, acetaldehyde, and acetic acid are the test pollutants. The air cleaner is installed within an airtight small chamber (1 m^3) whose air is polluted by burning cigarettes, and after operating the air cleaner for 30 min, the removal efficiency is assessed by estimating the reduction rate of the pollutant concentrations [15].

JIS C 9615 (Japanese Industrial Standards Committee [JISC] 2007)

In this method, NO_2 and SO_2 are supplied as challenge gases, and the removal efficiency is calculated by measuring their concentrations at the inlet and outlet of the air cleaner after 10 min of operation in an airtight chamber; however, the chamber volume is not specified [16].

EXISTING TEST METHODS FROM KOREA

Korea Association of Cleaning Air (CA) certificated air cleaners which had been commercially available in Korea from 2003 to 2015 were analysed. Among the test parameters such as flow rate, particle collection efficiency, clean air delivery rate (CADR), ozone emission, odour removal efficiency and noise level, noise level and CADR are correlated with flow rates. [17].

EXISTING TEST METHODS FROM FRANCE

The standardization process began in France with the official creation by AFNOR in 2007 of a working group "Air cleaners". The experimental standard XP B44-200 was published in May 2011.

This test method applies to assess the air cleaning efficiency but also the harmlessness of residential air cleaners. It considers the various kind of contaminants i.e., particles, gas, allergens, and microorganisms at concentration that are representative of typical concentration levels found in indoor settings. The basis of this test method has been used to develop a new standard in France. For particles the fraction efficiency (by particle size) of the air cleaner under test is measured on DEHS (between 0.3 and 5 µm). For gases a mixture of acetone, acetaldehyde, heptane, and toluene. For allergen, it was used cat allergens Felis domesticus. For microorganisms, it was used Staphylococcus (bacteria) and Aspergillus Niger (fungi). The test rig is mainly composed of a chamber (1.5 m × 1.5 m × 1.5 m) divided to parts. With an upstream and downstream duct respectively [18].

EXISTING TEST METHODS FROM CANADA

This protocol establishes a test procedure for evaluating the performance of portable air cleaning (PAC) devices intended primarily for residential environments. This protocol describes a method for evaluating the particle and gaseous contaminant removal performance of portable air cleaners used primarily in residential settings with mixing-type ventilation systems. For the IAQ performance, PACs are evaluated for their emissions and by-product formation as well as particle and VOC removal. A standard emissions test performed under steady state conditions are used to determine the PACs emissions of selected pollutants and their by-product formation. For PAC particle and VOC removal, a "pulldown" method will be used to conduct the test (AHAM, 2006).

For acoustic measurements, the experiments are conducted in a reverberant test chamber that conforms to the requirements of the ISO 3743-1 method (ISO, 1999). The comparison procedure for determining the sound power of a test source to an 'engineering' grade of precision described in ISO 3743-1 is adopted. This requires the comparison of measurements of the PAC source with those of a reference sound source, such as the ILG reference sound source. The reference source is calibrated to a 'precision' grade according to ISO 3741 and must meet all of the requirements in ISO 6926 for reference sound sources. The electrical power measurements are conducted under PAC running and standby modes [19].

ANSI/UL. UL standard 867:

This Standard addresses the safety of portable and fixed (including duct-connected) electrostatic air cleaning equipment. Standard UL 867 is also used to evaluate portable and fixed ion generators. This standard deals with electrostatic air cleaners rated at 600 volts or less, intended to remove dust and other particles from the air and intended for use in accordance with the National Electrical Code, ANSI/NFPA 70 [20]

CSA. CSA Standard 187:

This Standard applies to electrostatic air cleaners intended to remove dust and dirt from the air and intended for general indoor residential and commercial use, air ionizer type air cleaners, other similar ionizing equipment, duct-mounted type electrostatic air cleaners, air ionizers, and other similar ionizing equipment intended for general indoor residential use. This Standard applies to equipment for commercial use that intentionally produces ozone in a temporarily unoccupied space. This Standard applies to cord-connected and permanently-connected equipment operating at nominal supply voltages up to 600 V, single-phase or polyphase, that is intended to be installed or used in accordance with CSA C22.1, Canadian Electrical Code, Part I. This Standard applies to portable and duct-mounted air-cleaning devices that incorporate a UV (ultraviolet) lamp that emits UV radiation between 100 and 280 nm (UVC) [21]

ANSI/ASHRAE. ANSI/ASHRAE Standard 52.2.:

This standard describes a method of laboratory testing to measure the performance of general ventilation air-cleaning devices. The method of testing measures the performance of air cleaning devices in removing particles of specific diameters as the devices become loaded by standardized loading dust fed at intervals to simulate accumulation of particles during service life. The standard defines procedures for generating the aerosols required for conducting the test. The standard also provides a method for counting airborne particles of 0.30 to 10 µm in diameter upstream and downstream of the air-cleaning device in order to calculate removal efficiency by particle size. 2.3 This standard also establishes performance specifications for the equipment required to conduct the tests, defines methods of calculating and reporting the results obtained from the test data, and establishes a minimum efficiency reporting system that can be applied to air-cleaning devices covered by this standard [22].

Discussion

Particle Removal

Afshari et al., (2020) [23] carried out a literature review, taking into account, among other things, the existing test methods for PAC, with focus on particle removal. The authors described that the Pulldown test method is the most used in standards or protocols for assessing the removal of particles in the air using PACs. Standards or protocols using this method include the ANSI/AHAM AC-1 standard [3], National Research Council Canada (NRC) protocol [24], National Center for Energy Management and Building Technologies (NCEMBT) method [25], China standard [11], and the Swiss standard [26]. The Pulldown test method is applied to all technologies (e.g., Electrostatic Precipitators media filtration and photocatalytic technology). The Pulldown test method typically involves particles being dosed into a chamber containing the PAC to be tested and observing the first-order decay of particle concentrations with and without the PAC in operation. The difference in particle decay is used to determine the performance of the PAC.

Standards or protocols differ in terms of particles being used as challenge aerosols and an index to characterize PAC performance. In the former, challenge aerosols may provide consumers with information on PAC performance in removing certain types of particles. The challenge aerosols can provide information on the PAC performance in removing particles of different sizes. For instance, considering that ESP technology has been promoted as being efficient for the removal of UFPs, only a few standards consider UFP removal performance. In terms of the performance index, the most commonly used is the device clean air delivery rate (CADR) values measured in cubic feet per minute (cf/m) or cubic meters per hour (cm/h). Depending on the challenge particles, the CADR values are reported for the removal of particle types or particle sizes. The Swiss, Chinese, and Japanese standards used the concept of the half-life to report the performance of PACs for particle removal. The AHAM, China, and NRC standards relate the CADR performance obtained in chamber settings to actual service conditions by recommending room sizes to achieve an 80% indoor particle concentration reduction under steady-state conditions. The NRC protocol developed a minimum efficiency reporting value-like particle removal rating to rate the PACs. Details on particle challenges and performance index differences are summarized in **Table 1**.

The other method for assessing PAC performance is the Single-pass efficiency test method, which is an approach similar to the ASHRAE standard 52.2 method for testing media filters in a test rig. The French standard, XP B44-200 [9], measures upstream and downstream concentrations of di-ethyl-hexyl-sebacat (DEHS) (between 0.3 and 5 μm) particles, cat allergens, Staphylococcus epidermidis, and Aspergillus niger in a special chamber for PACs. The removal efficiencies and CADR of the particles are given. Although the Pulldown test method and Single-pass efficiency method are theoretically related, air mixing, portable air cleaning, and/or chamber short-circuiting may violate the relationship [27]. The Japanese standard also employs a Single-pass test using a special chamber [28]. Upstream and downstream filters of light transmittances are used to evaluate the removal rates of standardized challenge particles.

The AHAM AC-3 standard [29], JIS 9615 standard [8], China standard [4], and Swiss procedure [29] are the only published standards available that evaluate long-term PAC particle removal performance. In these standards, known amounts of particles are artificially loaded into PACs in a chamber dedicated to simulating long-term operation under a "standard" condition. Upon loading, the PACs are subjected to an initial performance evaluation [3]. The JIS standard includes a particle capacity test by determining the total particle amounts following an 80% flow reduction or determining whether the removal rate decreased by 85%.

Gaseous contaminant removal

The performance test procedures of PACs for gaseous contaminant removal are very similar to those for particle removal, and are often included in the same standard. For example, GB/T-18801 [11] and NCEMBT Procedure [6] used same Pulldown test for particle removal to obtain CADR for gaseous contaminant. Different from particle removal, the Single-pass test method is the most used in standards or protocols for assessing the gaseous contaminant removal efficiency of PACs. Standards or protocols using this method include China standard [11], Japan standard [8b], France standard [9], and ISO standard [10b]. Nevertheless, the performance index of SPE and CADR can be converted to each other.

The most significant difference between the different standards is the challenged and measured gas.

The JEM 1467-1995 [8b] standard, which was released as a voluntary restraint, described a procedure to evaluate the removal rate of PACs for ammonia, acetaldehyde, and acetic acid. For each gas, the removal efficiency is calculated based on the initial gas concentration and the gas concentration measured after 30-min use in a 1-m^3 air tight chamber. And the overall efficiency is defined as the weighted sum of the different gas filtration efficiencies. The XP B44-200 [9] standard and NCEMBT Procedure [6] also used VOCs mixture as challenging gas. Possible VOCs generation methods include placing liquid phased contaminants in a stainless-steel container and heat the container with regulated temperature [9]. For formaldehyde generation, solid paraformaldehyde is an option instead [6]. Besides, JIS C 9615-2007 [8b] standard tested the SPE for inorganic gaseous contaminant (NO_2 and SO_2), and the international standard [10b] considered almost all kinds of gases, including VOCs (*e. g.*, toluene), acids (*e. g.*, SO_2), bases (*e. g.*, NH_3), and other gases (*e.g.*, CO_2) [10b]. GB/T-18801 [11] standard also considered all kinds of gases, but each gas should be tested separately.

Since adsorbent for gas removal would have limited capacity [40], and catalyst for gas decomposition may be poisoned during the working period [41], the long-term performance of PACs for gaseous contaminant should be carefully considered. Though, the long-term performance is now only available in limited published standards [8b][9-11]. Besides, the interference between particles and gaseous contaminants in indoor air should also be carefully considered. For example, PACs may remove some particles adsorbed with organic compounds and then re-emit VOCs or by-products from the collecting media [42,43]. And using ozone to remove some specific VOCs may result in by-products and significant secondary ultra-fine particle formation, which are harmful for human beings [44]. Until now, only JEM 1467-1995 [8b] standard combined the particle and gaseous contaminant removal in a single test, but the challenge pollutant is tobacco smoke, which has limited types of VOCs. In the future, standards are expected to provide reliable test methods for the synergistic removal of particles and gaseous contaminants, which is consistent with the actual working conditions.

Safety (Ozone Production)

Two methods assess ozone production from PACs: 1) measuring the concentration and 2) determining the generation rate. For the concentration measurement method, an ozone production test standard procedure is included in the US Underwriters Laboratory (UL) standard 867 [30]. According to the UL standard, the ozone concentration should not exceed 0.05 ppm after 24 h of continuous operation of a cleaner in an enclosed chamber of 31.1 m^3, and the interior surface must be made of stainless steel or other nonporous and nonreactive material. The UL standard 867 specifies that the ozone must be measured at 50 mm downstream of the product air outlet, which is primarily a measure of the outlet concentration instead of the chamber concentration. As a result, the actual ozone generation rate of the air cleaner and its influence on the room ozone concentration depends on the airflow rate of the air cleaner. In addition, the size of a typical bedroom can be smaller or larger than the size specified, and the actual indoor surface materials can be different from those in the UL standard test chamber. It may be a concern that an ESP-based air cleaner that has passed the UL standard test may still pose an ozone exposure hazard to occupants because of differences in room sizes and deposition velocities associated with different interior surfaces.

According to the CSA C-187 Cl. 7.4 [31] standard, the 8-h time-weighted average (TWA) ozone concentration from ESPs measured for 24 h should not exceed 0.05 ppm, and this measure was updated to 0.02 ppm in 2016. This standard requires measurements in a chamber similar in size to that of the standard UL 867 but performed under static conditions.

Other standards or procedures have been proposed with a method to calculate the ozone generation rate, which is an intrinsic property of ESP. The methods involved use a well-mixed and positive-pressured chamber supplied with air filtered for particles and ozone. Typically, two tests are made for measuring ozone generations, first with PAC powered on and the second with PAC powered off to obtain deposition loss to surfaces. From the measured data, the ozone generation rate of the PAC is calculated and then modelled to determine the predicted indoor ozone concentration in actual buildings. The NCEMBT procedure [32] calculates ozone generation rates (in milligrams/hour) of PACs using the measured ozone concentration in a 55 m^3 stainless steel chamber but does not provide guidance for the PAC on expected ozone concentrations in actual residences. The NRC protocol [33] measures the ozone generation rates of PACs from a steady-state ozone concentration in a chamber similar to that used in the NCEMBT procedure and suggests that PACs may or may not exceed the indoor ozone concentration set by the Health Canada guideline of 50 ppb based on a "typical" Canadian residential bedroom.

Running noise

Portable air cleaners use different technologies to remove airborne particulates and gaseous pollutants and noise is a significant issue with many portable air cleaners. Portable air cleaner performance ratings are determined at maximum airflow and therefore typically maximum noise levels. It means that the higher the airflow rate the higher the CADR will be, but it will also be higher noise production. Therefore, there is a risk that occupants may turn them off to avoid the noise. However, at lower airflow settings, an air cleaner may have lower noise production, but it will also be less effective at pollutant removal. Some intervention studies involving the use of

portable air cleaners have noted that portable air-cleaning units were used less frequently over time. Fewer operating hours reduces their effectiveness and, therefore, their potentially positive effect on indoor air quality and health outcomes [34] (EPA, 2018). Peck et al. 2016 [35] reported that association between the noise level and CADR of 5 air cleaners. CADR values were determined with diesel particles while operating on maximum and minimum speeds. The results showed that the total sound pressure Levels (A-Weighted) were between 26.6 dBA and 35.5 dBA at lowest speeds and between 45.4 dBA and 53.4 dBA at highest speed. It means that the measured sound pressure levels were above the EPA indoor activity interference and annoyance level (45 dBA) [36]. In addition, exposure to noise has several negative health impacts i.e., immediate effect by changing the time we spend in certain sleep stages [37], short-term effect is shown as a result of the potential consequences of sleep disruption (Halperin, 2014), and long-term effect is shown as high blood pressure, heart disease, etc [38].

Possibility and limits of CADR

The CADR is a good way to keep from being misled in marketing messages. The advantage of the CADR rating is that it gives the consumer a way to compare air purifiers that consider both air flow and filter efficiency. CADR is given in cubic meters per hour. It's the volume of air flow through the filters on the highest fan speed.

How CADR is tested

- The CADR is measured with the air purifier run on the highest fan speed. If you will not be running the air purifier on a lower fan speed, then the CADR that you will realize will be lower.
- The CADR is tested with a new, clean filter so it does not reflect the performance of the air purifier over time. A small, thin filter may test well in the

CADR test but soon after show a large drop in performance. To better understand this our suggestion is to find out how much filter media is in the filters. In addition, the size of the air filters will factor into the expected performance over time. A large filter with a lot of filter media will perform much better than a smaller, thinner filter. You may want to watch out if the manufacturer does not provide this information.

- The CADR rating does not factor in noise level.
- The CADR is not a safety test, so it does not measure ozone production, motor reliability or energy usage.
- There are two types of CADR specified in the national standard for air purifiers: CADR (PM2.5, dust, etc.) and formaldehyde CADR. The two parameters represent two aspects, which are also presented separately in the test report.

There are a few issues with the CADR rating:

- If you run the air purifier on a lower fan speed your CADR will be lower, and the testing does not report these values.
- Higher efficiency filters have a higher air flow resistance so it's harder to push air through the filters. This results in lower CADR values. So, if you use higher efficiency filters you can remove the most dangerous particles which is better for your health. But you get a lower CADR because it is so much harder to push the air through a better filter.
- It does not measure the air filter performance over time.
- It is only based on removing airborne particles sized 0.3 microns and larger. This represents dust and larger particulates. It does not measure the smaller particles and gases. These smaller airborne particles make up 90% of all particulates and cause most health issues. So, if you have the best true HEPA air purifier on the market you do not get credit in removing the smallest particles since they are not part of the test.
- The CADR rating is only valid for a given filter as used in a specific equipment design, and when the filter is brand new. The rating is based on a 20-minute test.
- The CADR is an approximate and heavily simplified method that assumes air is well-mixed and does not consider location of the unit, entrainment of the air, or many other complexities, but does provide a simple way of comparing devices.
- Due to the measurement process, the CADR rating is intended for use only with equipment designed for residential spaces. Clean rooms, hospitals, and airplanes use high-efficiency HEPA filters and do not use a CADR rating, but instead may use MERV ratings.

CCM

According to the international definition, CCM, cumulate clean mass, refers to the total quality of cleaning the target pollutants when the CADR of the air purifier reduces to 50%. The particle CCM is divided into four levels P1-P4 and the formaldehyde CCM F1-F4. The higher the level, the bigger the CCM value, which means a longer period of replacing or cleaning the filter screen. CCM (cumulative purification, in mg) is another important parameter in the new standard for air purifiers, which specifies the amount of particulate matter or formaldehyde that can be eliminated before the filter is "discarded".

How CMM is tested

- Measure the CADR of the purifier in normal settings to get an initial value.
- Light up a cigarette in a three square-meter chamber and blow the smoke around briefly with a fan.
- Turn on the fan that's in the room, too, and seal off the chamber.
- Light 50(!) cigarettes one after another (not at the same time!) in the chamber and wait for the purifier to get the particulate concentration below 0.035 milligrams per cubic meter (mg/m^3).
- Turn off the purifier and let it sit in the chamber for another 30 minutes before taking it out.
- Repeat these steps for 100 cigarettes, 150, 200, and beyond until the CADR is less than half of that initial value you got in step 1.

Particulate Matter		Formaldehyde	
P1	3000 – 5 000 mg	F1	300 -600 mg
P2	5 000 – 8 000 mg	F2	600 – 1 000 mg
P3	8 000 – 12 000 mg	F3	1 000 – 1 500 mg
P4	>12 000 mg	F4	>1 500 mg

Conclusions

As the portable air cleaners are becoming more common in our buildings and the range of products on offer is growing, it's becoming more difficult for the ordinary consumer to make the right choice. Manufacturers make claims about efficiency and safety and may promote their products for labelled uses, but the lack of a uniform and easily understood way of declaring capacity and performance makes it difficult to compare the products on the market.

The present review shows that four key information are important in choosing an air cleaner i.e., the size of the room and how many air changes per hour is recommended in different space, CADR rating for the room size, clean cumulative mass (CCM) grade for an air cleaner's long-term performance and formaldehyde, and noise level. In addition, it is also important to consider the filter life to make sure the filter will work well over time. If you have an air ionizer or any other electronic device, you run the potential risk of generating some levels of ozone.

More studies are needed to investigate the long-term performance of portable air cleaner devices and integrate performance data of air cleaners into building system design in conjunction with source control and ventilation strategies for better IAQ. ■

References

Please see the full list of references in the HTML version of this article on rehva.eu

Horizontal Living – Healthy Homes Design Competition

LEVIN KÜMMERLE
Master Student, Energy Efficient Design at University of Applied Sciences Augsburg
levin.kuemmerle1@hs-augsburg.de

MARTINA HEILIG
Master Student, Energy Efficient Design at University of Applied Sciences Augsburg

REHVA announced the Healthy Homes Design Competition 2022 with the aim to encourage students in different building disciplines to design a building with increased comfort quality. The winning Team emerged "Horizontal Living" — **a concept that** addresses the challenge of energy transition, environment and wellbeing.

Today, one out of six Europeans reports living in unhealthy homes, i.e. buildings that have problems with dampness, underventilation, lack of daylight, inadequate heating during winter or overheating problems during summer. Because of this, the buildings we develop now must be ready for future challenges. By designing a new building, we have to take into account a variety of comfort parameters, sustainability challenges, social and resilience qualities.

Figure 1. Overview of the Horizontal Living building and its location in Pernis, Rotterdam.

South facade with renewables and north facade with green development

The angle of the south facade is inclined at 70° for a perfect exploitation of the winter sun. The facade consists of thermal flat-plate collectors which, in combination with a seasonal warm water storage, supply the building with heat independently. Each unit has a private loggia overlooking Pernis and the buildings small park. The development is on the north side of the building and leads to the apartments via a wooden arcade. The outer construction of the arcade is planted with climbing plants for a natural wellbeing when the residents arrive. The roof is designed as a green roof, where nature can spread as an ecological niche, also increasing the visual comfort of the occupants. The arcade serves as a community meeting place and second balcony in the hot summer months. From here, you can enjoy the Rotterdam skyline.

Outdoor and indoor spaces

The outdoor facilities are south facing to enjoy long hours of daylight, sheltered from noisy and air pollutant ship traffic. A small park to the southeast provides shade for residents to encourage outdoor living even in the increasingly hot summers. A volleyball field, urban gardening, a bicycle workshop and a common room invite you to get to know the neighbours. The building consists of 21 apartments, 2 of which are guest rooms. In hot summers, for example, the guest rooms offer protection to elderly people. All apartments can be reached barrier-free via an elevator. The interspersed rooms allow daylight from two sides and good cross ventilation. The footprint of the building is very small at 603 m².

The property is regularly flooded, with the water reaching up to 1 m, due to the increasing climate change. To make it resilient, a small dam was laid around the property. In the event of a flood, six flood protection doors are operated to protect the building

The Horizontal Living apartment

Horizontal Living is the building's design concept. Air, light and heat penetrate the building in a horizontal direction. Views are provided horizontally. The windows are placed opposite to each other to direct the wind through the building. Daylight reaches the building from at least two sides. The detailed apartment is one of several maisonette apartments. Apartments on the 4th floor are all designed as maisonettes, as the stack ventilation only extends to the 3rd floor. In this way, thermal ventilation is achieved via the difference in height of the apartment. The apartments should accommodate everything you need in a small space. Nevertheless, the feeling of space should be an airy one.

Figure 2. South elevation (top): tilted facade with solar thermal collectors and loggias; North elevation (bottom) with wooden arcade and green roof.

The residents arrive at their apartments through the arcade. Galleries in front of the apartment entrances arrange semiprivate spaces and create distance to private windows. The aim was, to have access to daylight and fresh air in every room, even in the bathroom. Common rooms are designed for maximum flexibility and as an open space. With sliding panels, the bedroom can be extended. The daylight simulation confirms a daylight factor over 2% in more than 56% of the flat.

Water as storage medium for energy transition

Electricity is the noblest form of energy because it can be converted into all other forms. It should therefore be used very sparingly and not be converted into heat. We believe that the energy transition is a matter of storage. Our concept is based on the self-sufficient production of heat by means of a solar thermal facade and storing it in a seasonal hot water storage. The roof is equipped with photovoltaic cells, which cover 83% of the building's electricity needs through the year. Water as a storage medium is available all over the world, it is non-toxic, infinitely recyclable and has a high thermal storage capacity. Compared to conventional battery storage, it has a very long service life and requires very little maintenance. By placing the storage tank inside the building, the storage losses correspond to the normal transmission that heat losses of the building envelope. The waste heat from the storage is used entirely to heat the building. The losses are thus at zero.

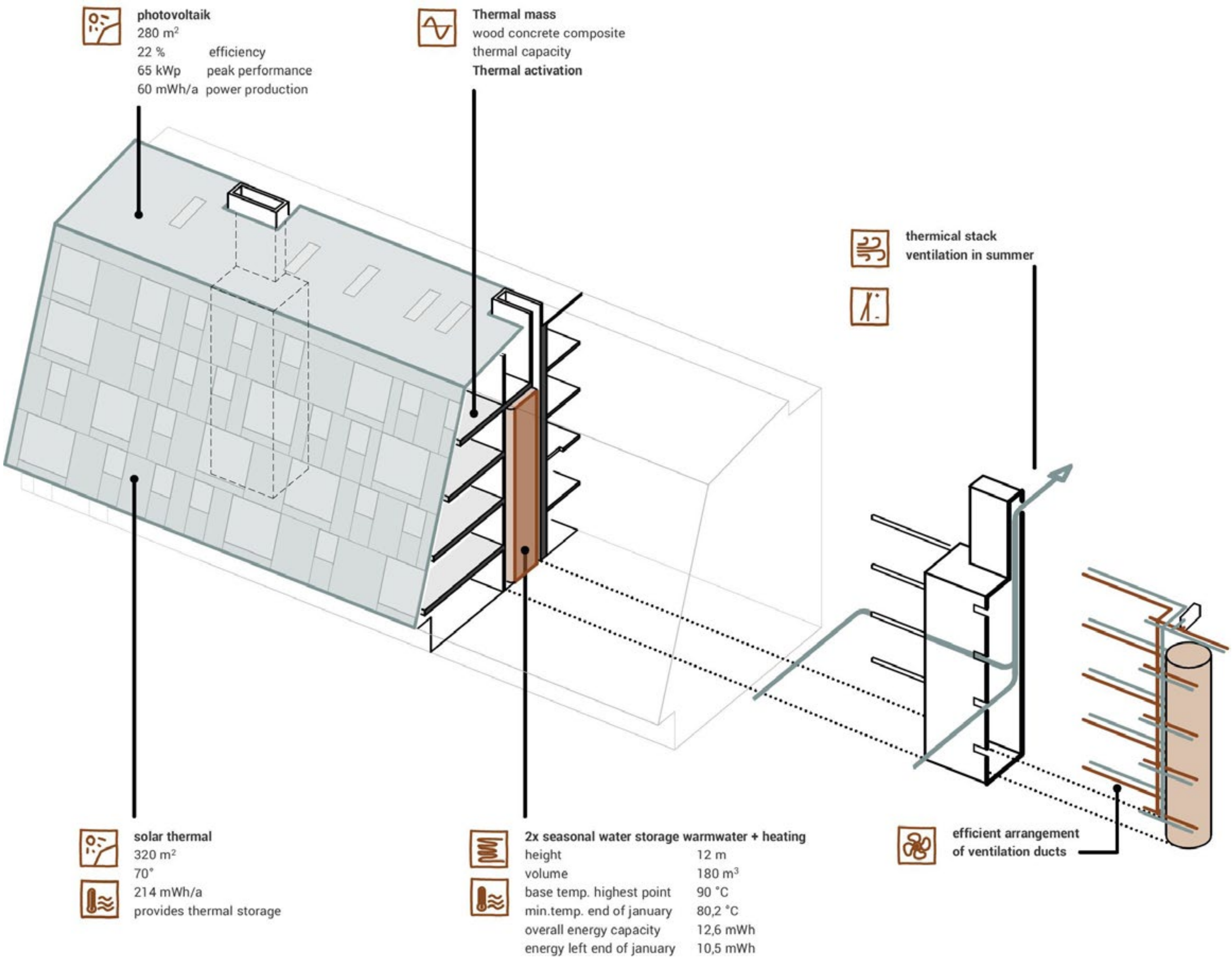


Figure 3. Axonometry with the different functions of the seasonal warm water storage and thermal stack – for storing heat energy and creating thermal ventilation through the storage stack in summer.

Comfort strategy for Winter and Summer

The heating strategy is structured as a graduated concept. Due to the living spaces' consistent orientation towards the south, the glazing catches the low-lying winter sun, and the high thermal mass of the built-in materials stores the solar heat and releases it with some delay. A component activation located in the ceiling provides the residents with a pleasant basic temperature (21°C). If the residents want an individual temperature, e.g. in the bathroom (23°C), this is achieved using wall heating. The mechanical ventilation system supplies them with fresh air. The ventilation strategy in summer is optimized for different cases. Controlled windows provide residents with sufficient fresh air. At night, the building is cooled down by cross-ventilation and the coolness is stored in the thermal mass.

If the shipping traffic in the north disturbs the air and noise, the residents can switch from natural ventilation to stack ventilation. Fresher and less noisy southern air comes into the apartment and the exhaust air is transported away through the storage shaft to the north. The thermal lift in the chimney is controlled by a regulated heat exchanger with the excess of hot water, which will be available in summer. The building envelope was designed close to the passive house standard. Strict southern orientation, compact design, minimized thermal bridges and a highly insulated building envelope.

The aim was to keep the buildings CO_2-emissions to a minimum. Basically, there is always a conflict of objectives with positive timber construction and a high thermal mass of the building. This was achieved using a demountable hybrid wood-concrete ceiling. The outer walls are made of a timber frame with wood fiber insulation.

Further design information

To calculate the storages, the heating requirement (25.2 kW) and the hot water consumption (1720 ℓ/day) of the building were determined. The heating degree days and the collector yield Rotterdam serve as the data basis. The result is the solar coverage (118.2%) and the usable storage energy content in the respective month. The solar thermal area has a surface of 320 m² and produces overall 78.82 MWh/a

Figure 4. Section through one of the maisonette apartments; visualization of the heating, ventilation and smart control strategy.

heat energy. The two storages are 12 m in height and have a diameter of 2.6 m. The overall storage volume combined is 180 m³. That corresponds to an overall energy capacity of 12.6 MWh. Looking at the cold month of January, the warmest layer of storage water has a temperature of 80.2°C and the storage has a remaining energy content of 10.51 MWh. This means that the buffer is great enough to have no shortage of thermal energy even during dark doldrums in winter. The heating requirement was determined by using an assumed heating load, which is based on the requirements of passive houses (with a factor of 1.3 as a buffer, using the storage design sheet). 40 ℓ/d and person were assumed to determine the hot water consumption. Since the building is equipped with passive cooling, no additional cooling energy is required.

The ventilation, the auxiliary energy, and the energy for electrical devices and light are included as electricity consumption. The ventilation energy was calculated with the peak performance of the two ventilation devices (2 kW) and 3 months running time. The auxiliary energy was assumed to be 3% of the thermal energy. The demand for electric appliances and lighting was calculated from public data for the households in the building. The photovoltaic system was determined using the global radiation at the Rotterdam location and the peak performance of the modules. The total energy consumed results from the required thermal energy (0), the required electricity (37.58 kWh/ m²a) minus the electricity production of the photovoltaic system (31.2 kWh/m²a). This means that the annual average energy requirement is only 6.43 kWh/m²a (**Figure 5**).

The calculation of the life cycle was calculated for a balance according to DIN EN 15978 (**Figure 5**). Life cycle phases A-D were included. The supporting structure of a conventional building made of reinforced concrete and brick was compared with our building. Ökobaudat.de served as the data basis for the life phases of the materials. ■

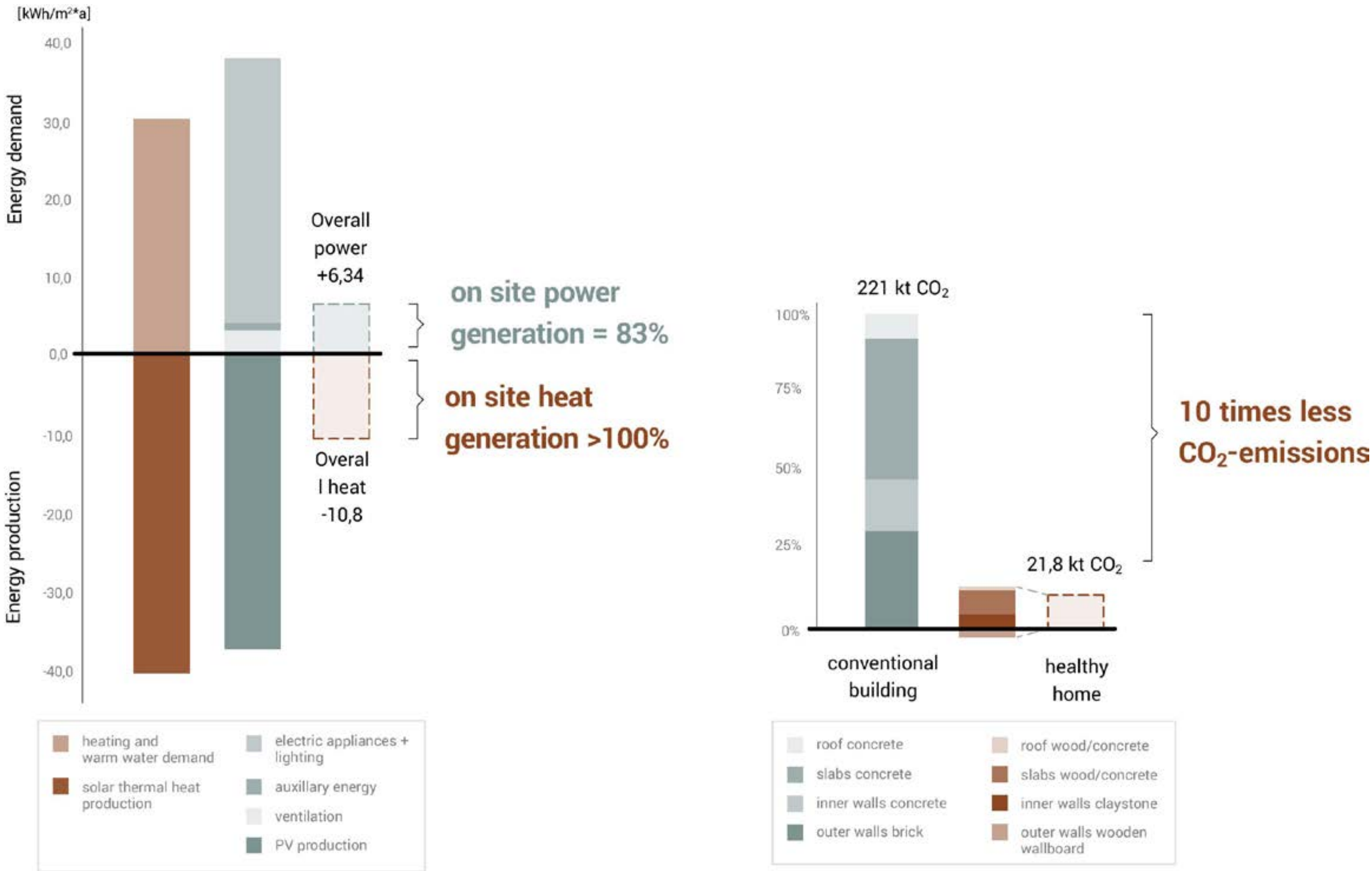


Figure 5. Comparison of energy demand and production (left) – the building is independent from supplied heat energy due to the seasonal warm water storage; comparison of CO_2-equivalents of the load bearing structure of a conventional construction and the Horizontal Living project (right).

Lindab introduces

App controlled, wireless ventilation

Lindab UltraBT™

Room control system made easy

The Ultra BT system allows you to upgrade room by room, it requires no reconstruction of walls, no long-term shut down of offices and will result a huge reduction of ventilation costs and energy consumption.

The UltraLink Demand Controlled Ventilation regulator, Bluetooth sensors and Lindab apps on your smartphone – that is all you need to get a cost-effective ventilation upgrade with full operation control at room level.

Potential of Waste Water Heat Recovery in reducing the EU's energy need




PAVEL SEVELA
MSc.
Unit of Energy Efficient Building, University of Innsbruck, Innsbruck, Austria
bauphysik@uibk.ac.at

JOHANNES FRENGER
MSc.
Unit of Energy Efficient Building, University of Innsbruck, Innsbruck, Austria

JÜRGEN SCHNIEDERS
Dr.
Passive House Institute, Darmstadt, Germany

RAINER PFLUGER
Assoz. Prof. Dr.-Ing.
Unit of Energy Efficient Building, University of Innsbruck, Innsbruck, Austria

Keywords: Waste-Water Heat-Recovery, Fit for 55 climate action, EPBD, hot water production, system losses, energy efficiency first, ZEB, state of the art.

Abstract

After extensive research, **Waste-Water Heat-Recovery (WWHR)** technology was identified as the most promising technology to unlock the under-addressed potential in reducing the energy need for water heating.

Particularly interesting application of WWHR is for showering, which accounts for about 70 to 82% of the daily residential hot water tapping profile. Shower-wise installed heat-exchangers offer a cost-effective way of utilizing otherwise wasted heat for preheating cold fresh water, thus reducing the temperature span covered by the water heater. The total energy demand **savings for hot water heating can be up to 40%**. The unique advantage of WWHR, is achieving high thermal energy savings without compromising on user comfort with low material and monetary needs. The cost-effectiveness of WWHR is best in climates with cold ground temperatures and in cases where showers are used extensively.

At European level, the WWHR itself is theoretically capable of surpassing the energy savings targets planned in the "Fit for 55" climate action in the hot water sector, if all buildings are equipped accordingly. If between 2022 and 2030, every second anyways renovated or newly constructed building in Europe were equipped with the WWHR system, **35.7 TWh less energy would have to be generated and 6.6 Megatons of CO_2e emissions less emitted.**

Although WWHR has been a well-proven technology for decades in some countries; it is still unknown in most European regions. Further action, in particular the creation of a European legal framework, the training of professionals and the granting of subsidies, is needed to accelerate the adaptation of this promising, sustainable technology into practice.

Problem statement

Buildings are the single largest energy consumer in Europe. Heating, cooling and domestic hot water account for 80% of the energy that we, citizens, consume [1].

The EU has committed to reduce the greenhouse gas (GHG) emissions by at least 55% by 2030, compared to 1990 levels. This climate act known as the "Fit for 55" package is the EU's contribution under the "2015 Paris Agreement", with a target of limiting the increase of global temperature to just 1.5°C compared to pre-industrial levels. For the EU building sector, it means to reduce its energy consumption of heating and cooling by 18%, compared to energy consumption (delivered energy) levels in 2015 [2].

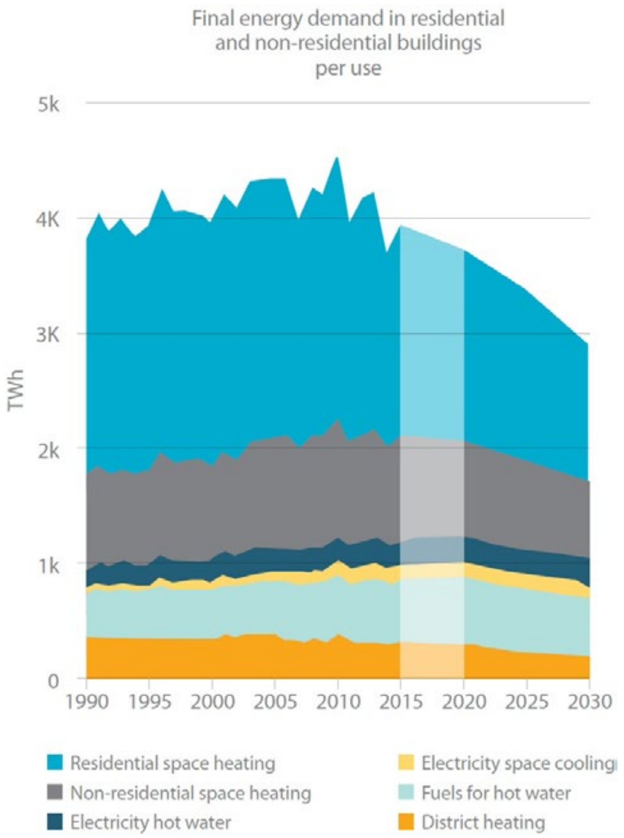


Figure 1. Final energy demand in residential and non-residential buildings by energy use [4].

As illustrated in **Figure 1**, the energy for space heating has decreased significantly in the past decades specially thanks to applied insulation, however this has not been the case for water heating. According to Eurostat, the hot water preparation in the current residential building stock represents 14.8% of the whole energy consumption in buildings [3].

Since the cold water temperature is naturally given by geographic location and the desired hot water draw-off temperature and duration is set by the user, the only way to reduce the energy demand for water heating is to reduce the flow rate or to pre-heat the cold water to reduce the temperature rise by the water heater. The WWHR is the last unaddressed systematical thermal leak in the building thermal envelope, as lightly illustrated on **Figure 2**.

Using **wastewater heat recovery (WWHR)** technology, lowering comfort by reducing hot water flow rates is not necessary while reducing the domestic hot water (DHW) energy demand. WWHR can utilize the waste heat that leaves the building and would otherwise end up in the environment. With this technology, the heat is recovered from the warm wastewater and transferred to the cold fresh water and thus the amount of energy required to reheat the cold water is reduced.

For wasting energy from hot water, showering plays the dominant role, accounting for about 70-82% of the daily hot water tapping profile [5] [6]. Furthermore, the duration of most other hot water draw-offs or its temperature is not great enough to overcome the dynamics at the beginning of the WWHR process. Therefore, **showering is the most effective application of WWHR technology**, as the hot water draw-off at a high temperature level and the fresh cold water supply occur simultaneously and takes on average between 4,5 – 8,5 minutes [7].

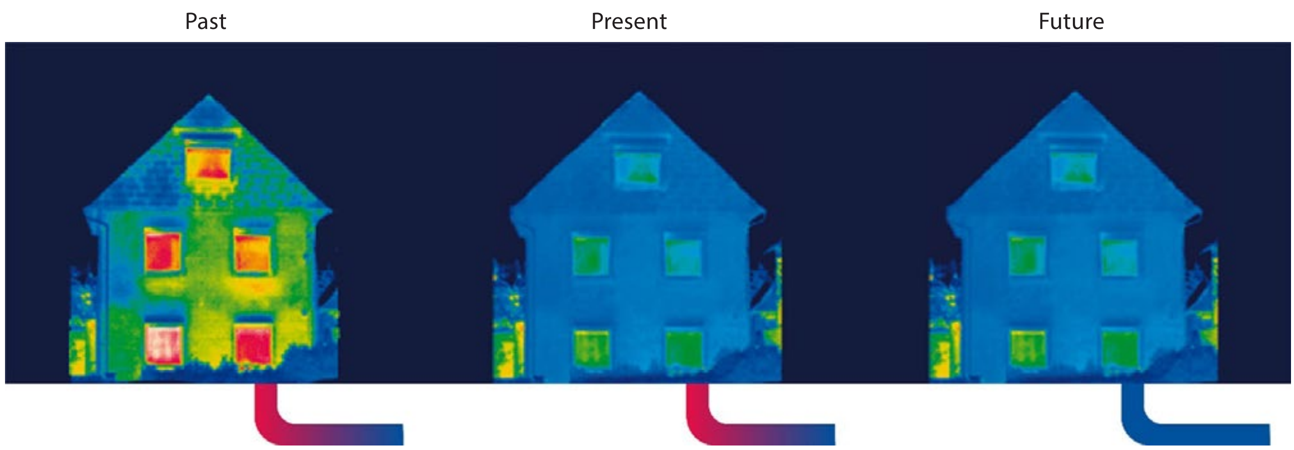


Figure 2. Illustration of the thermal development in building technology as an infrared thermography.

State of the art of WWHR

For decades, heat recovery has been a standard for reducing energy demand in industrial processes by transferring waste heat to another fluid via a heat exchanger that separates the media materially but allows the heat to conduct through. Different techniques to recover energy from warm domestic wastewater are also applied. From municipal applications to centralized (building-wise) installed heat exchangers or de-centralized (shower-wise) devices, the latter shows the most **promising potential and a number of certified products** are already in existence.

Decentralized heat exchangers (**Figure 3**) are placed as close as possible to the source of the warm wastewater (typically 32-36°C). If the heat exchanger is placed further away from greywater source, the warm effluent cools and could be mixed with other colder effluents. Most widespread decentralized devices are screed embedded linear shower drains with horizontal exchanger tubes or vertically installed devices replacing appx. two meters of sewer pipe, which benefit from "no maintenance" at low prices compared to the horizontal ones. However, the space and access required to the floor below can cause difficulties with retrofits. So-called active heat recovery systems pump the shower water into a heat exchanger and are often driven with a vertical heat exchanger but can be installed on the shower level.

Other preinstalled shower units are even equipped with a primary heat source e.g. an electrical water heater. Those benefit from synchronized components without complex plumbing and high circulation losses. As independent hot water modules, they can be evaluated with the existing EU energy label. Beside a smaller hot water storage volume, the WWHR decreases the required power of flow heaters. Almost loss-free DHW production on demand can get a future technology, especially when combined with electric mobility via power-load throw-off.

The energy saving potential of various decentralized WWHR system are mainly influenced as follows:

Efficiency of heat exchanger device

Counterflow driven exchangers with high thermal length and fluid turbulence result in best efficiencies. The robust design for highly polluted wastewater and the double wall construction according to EN1717 limit the efficiency of those heat exchangers. The steady-state efficiency of typical devices range between 37-60% for horizontal systems, 57-78% for vertical systems and 60-82% for active systems [8].

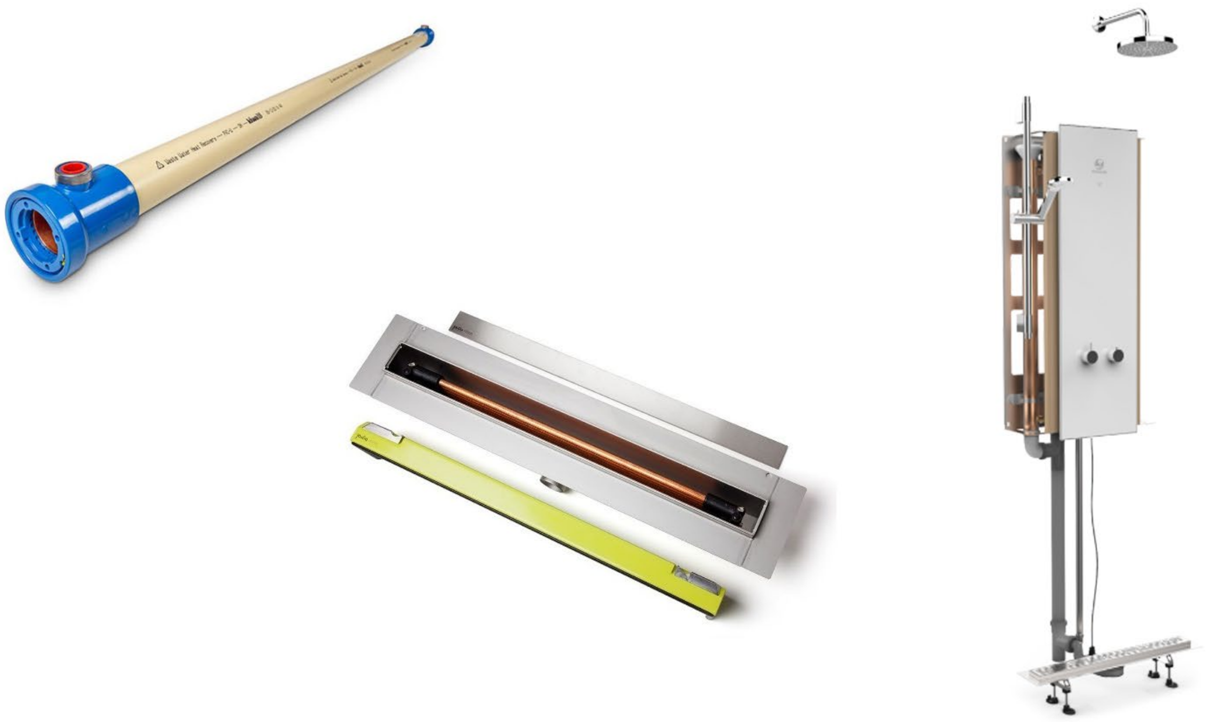


Figure 3. Shower water heat exchanger for vertical (left), horizontal (middle) application; active heat exchanger (right) source: Counter Flow Products B.V., Joulia ltd., Hamwells Nederland B.V.

Hydraulic connection of heat exchanger

Maximum energy transfer in the exchanger also relies on a balanced flow rate of fresh and wastewater side, see **Figure 4**. When applying a decentralised heat exchanger for a shower, wastewater only equals the freshwater flow if the preheated water feeds the shower mixer and the water heater. If the preheated water from the heat exchanger feeds only the shower mixer or the DHW heater, the waste water and fresh water flows in the heat exchanger are unequal, and therefore the efficiency of the heat exchanger could decrease due to the lower possible energy transfer.

Water temperatures and shower duration

Low shower temperatures combined with high freshwater temperatures e.g. in the EU´s southerly member states, have to be considered as less benefitting from WWHR. With increasing shower duration, the dynamic heat exchanger efficiency approaches its steady-state value and obviously supports the absolute energy savings.

Methodology of the energy savings calculation

In order to demonstrate the potential energy saving effect of DHW systems including WWHR, a calculation based comparison study was performed. Saving calculation on household level are based on PHPP [9].

(1) A vertical tube-in-tube heat exchanger with a typical efficiency of 67% was chosen [8], which causes costs of approx. 1000€ for the device itself and additional installation effort.

(2) One WWHR system per dwelling unit is assumed, with an European average occupation of 2.3 persons per dwelling unit [10]. Each person uses the equivalent of 32 l of domestic hot water at 60°C per day, of which 24 litres are shower water.

(3) The calculations were carried out under the assumption that the preheated water outlet is hydraulically connected to the water heater and the shower mixing valve.

(4) The data used for the upscale calculation on EU Level was extracted from each member in the EU´s 2019 statistics [3].

Results and interpretation of energy saving calculations with WWHR

Energy saving potential on household level

It is important to note that WWHR saves the same amount of energy needed for water heating in combination with all three used DHW systems. This means the amount of recovered heat is not depending on the DHW technique.

WWHR **savings in delivered energy (electricity, gas, etc.) vary depending on the water heating technique** due to significant differences in hot water distribution and storage thermal losses, as well as the efficiency of the actual heater, see **Figure 5**.

A clear trend towards higher yields in colder climates can be observed. This can be referred mainly to the colder ground water temperatures in the Nordic climate zone. Possible differences in user behaviour e.g.,

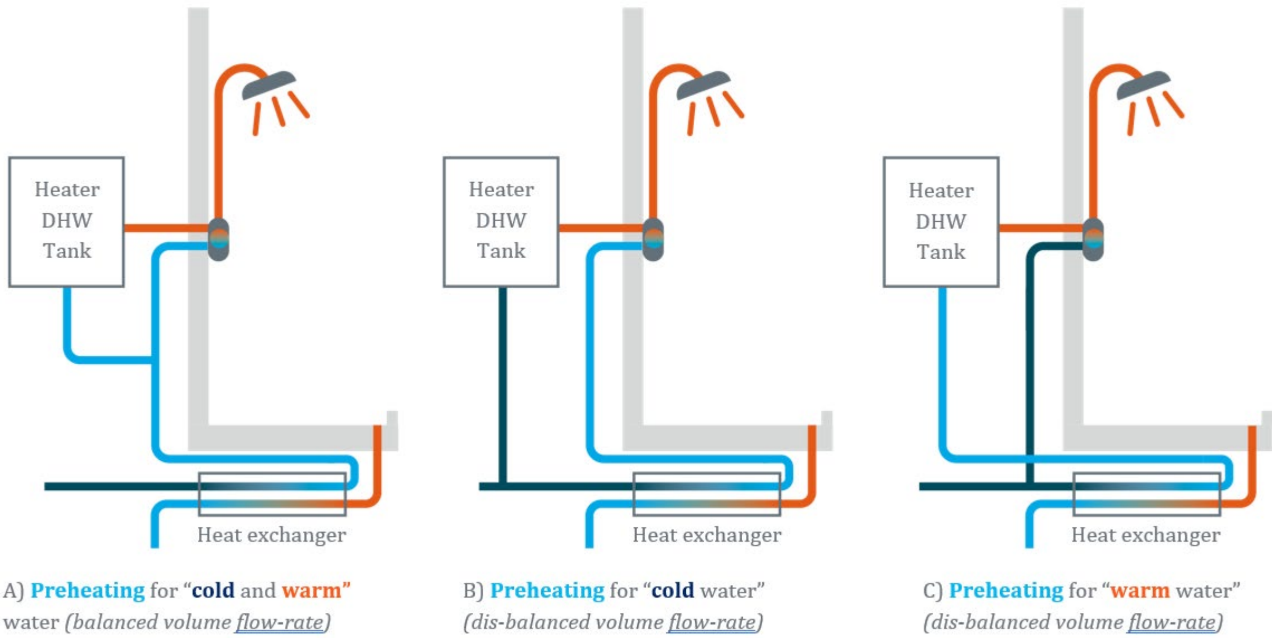


Figure 4. Hydraulic connection possibilities of a WWHR device.

tendentially warmer and longer showers in northern regions, which makes the WWHR more effective was neglected in this study to provide a conservative view of the results.

An obvious difference is that WWHR accounts for a larger share of the delivered energy by direct electric water heating; that is close to the actual energy need for DHW; as this system is a decentralized system with zero tank and circulation losses and lower distribution heat losses as by the central DHW system. **These losses account in average for about 1/3 of the delivered energy for DHW in the EU but in some systems can represent more than 50%.** The less efficient energy conversion when burning fossil fuels causes slightly higher possible energy savings.

The savings in energy consumption by WWHR in combination with a heat pump are lower in absolute terms than for the other two systems, since a heat pump requires a lower proportion of delivered energy (electricity) to produce the same amount of heat, thanks to its electricity to heat conversion factor (COP). Nevertheless, cold climate supports the application of WWHR combined with heat pumps because of the colder ambient and hence worse conversion rates of heat pumps. WWHR in heat pump systems can therefore be very cost effective, especially when used with shower-intensive tapping profiles.

Possible contribution of WWHR to the zero-emission building standard

The possible effect of WWHR on an example household is examined, assuming a 104 m² single family house occupied by 2.3 persons in oceanic climate zone. The intention was to evaluate the impact of the application of WWHR in this particular scenario on the reduction of "delivered electrical energy".

The building thermal envelope and HVAC were considered to be state of the art to meet the requirements of the **"zero-emission building" (ZEB) standard, coming into force in 2030.**

Assuming a heat pump-based water and space heating system with a yearly average COP of 2.4, the **annual savings correspond to 13% of the "total delivered**

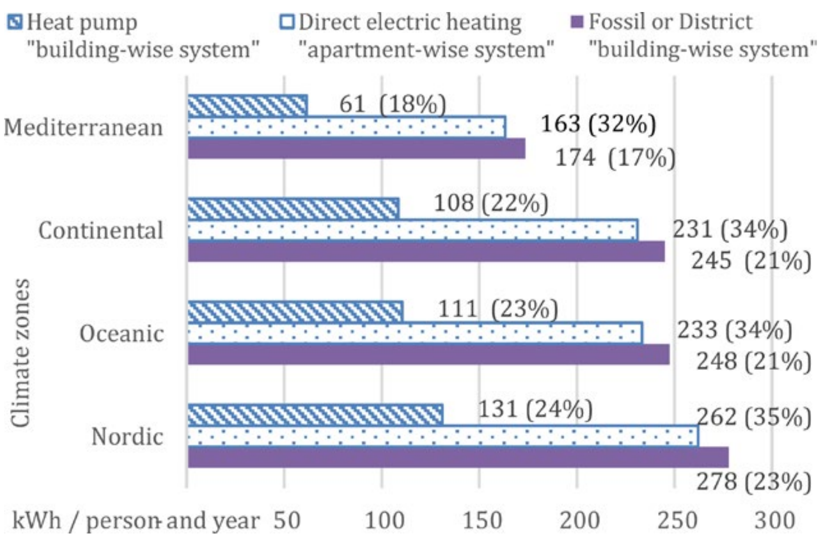


Figure 5. Savings in delivered energy for total DHW with WWHR in combination with various hot water systems per person (in brackets: as percentage of total delivered energy)

energy", as seen in **Figure 6.** In the context of the EPBD, which specifies a maximum primary energy of 60 kWh/m2/a for ZEB in this climate zone, the **WWHR reduce primary energy consumption by ca 7 kWh/m²/a when a primary energy factor of 2.1 is assumed.** Therefore, in cases of already advanced thermal envelopes or efficient heating technologies, WWHR can play the key role to reach this ambitious standard.

Energy and GHG saving potential depending on country

To evaluate a population independent saving potential, **Figure 7** shows the annual energy and emission savings per installed WWHR device by country. Actual GHG emissions for electrical power consumption were applied. The "steps" in energy savings are due to the use of reference values for mains water temperature and climate data for each climate zone. **Most promising energy savings are seen in northern countries** due to low mains water temperatures. At the same time, GHG emission savings are considerably lower in northern countries due to generally "low-carbon" energy production and high district heating supply rates. **Warm climatic regions with high-emission-power-production can therein still play an important role, despite its relatively lower energy savings.**

Energy saving potential on EU-27 level

To achieve the at least 55% European emissions reduction target for 2030, proposed by the Commission in September 2020, the EU must reduce greenhouse gas emissions in the building sector by 60% and thus the energy consumption of heating and cooling by 18%, compared to delivered energy consumption level in 2015 [11].

The possible energy and emission savings with WWHR were scaled up to EU-27 level to show the role of WWHR in the EU's "renovation wave" in different scenarios. A hypothesis was made by applying the WWHR in four scenarios with a share of 20, 50, 80 and 100% of the **total of 35 million renovated and 15 million newly built buildings between 2022 and 2030.** WWHR technology could be incorporated up to three-times more often as any bathroom or shower renovation is an opportunity for integration of WWHR. The amount of total installed devices and its savings were accumulated linearly during this time.

Figure 8 shows the impact in the hot water sector referring to the 18% energy savings goal compared to the consumption in 2015, although the energy savings by WWHR actually apply to the already higher energy consumption from 2020 onwards. Depending on the scenarios, approx. 4%; 11%; 16% or 25% of the planned energy reduction can be covered by WWHR only. If every renovated or newly built building in Europe were to be equipped with WWHR starting 2022, 25% of the 2030 "Fit for 55" goals in the warm water sector could be expected. If the total current building stock would be equipped with the described WWHR until 2030, **a significant consumption-drop of 100 TWh/a could be observed and the energy conservation goals for hot water would be surpassed by WWHR only.**

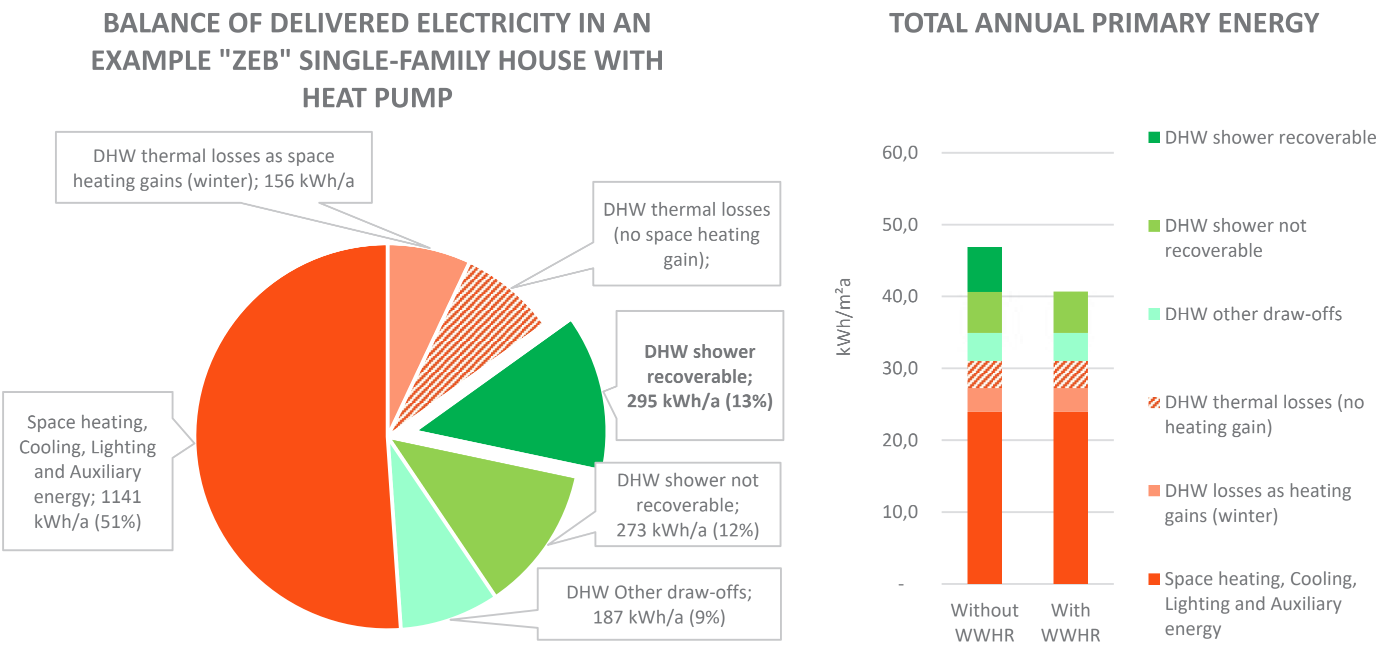


Figure 6. Delivered energy with respect to the recoverable share with WWHR in a single family "ZEB" house.

Conclusion

The main message of this paper is that there is a **14.8% share of the energy consumption in buildings (DHW)** [12] that has been overlooked and unaddressed by the main EU policies in recent decades.

WWHR saves usable energy for water heating from going down the drain, especially for the shower, which is the largest consumer of hot water in the home. **With WWHR, the delivered energy for today´s water heating in Europe could be reduced by 24%**

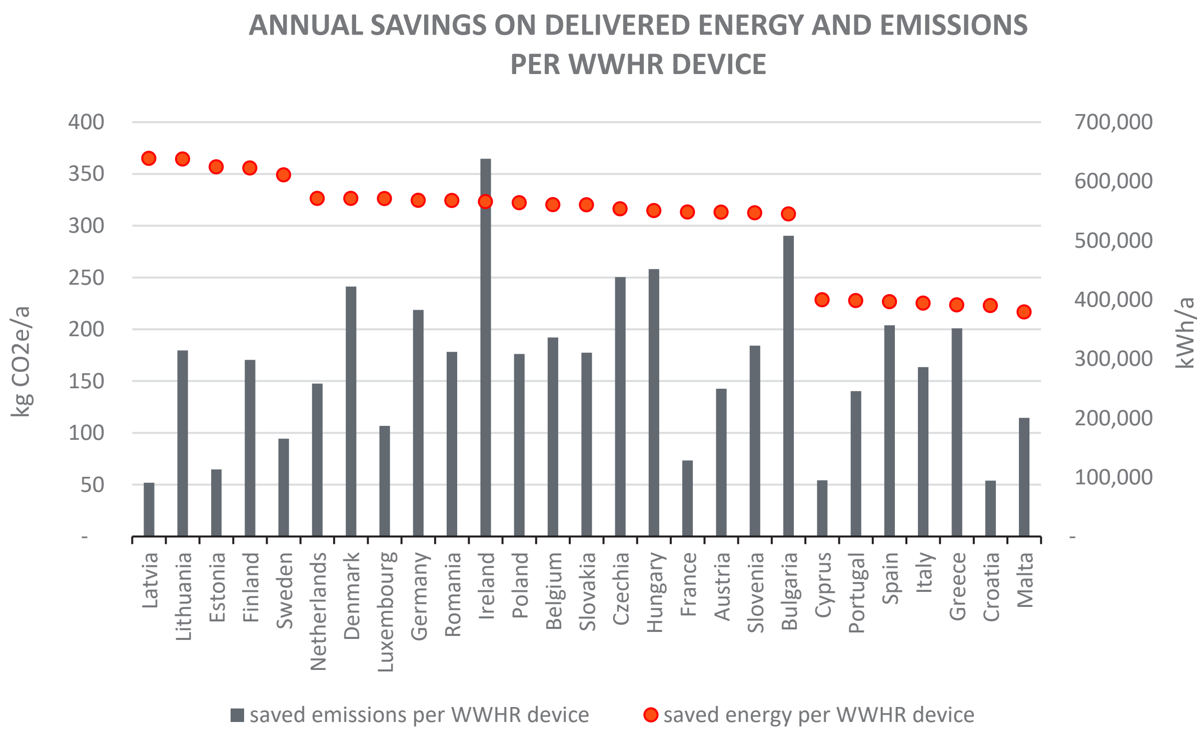


Figure 7. Annual energy and emission savings per WWHR device per country.

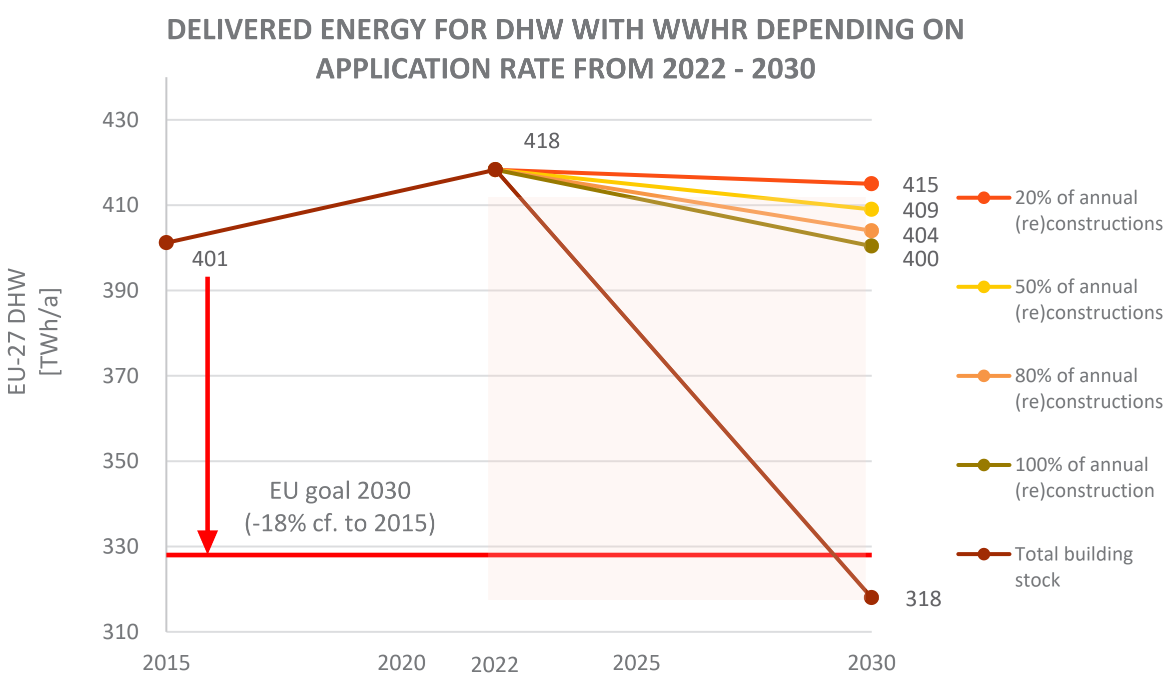


Figure 8. EU-27 (Targeted) Energy demand for DHW in 2030 depending on application rate of WWHR.

(100 TWh/a); see **Figure 6**; if "business as usual" is continued. Further savings potential lies in reducing heat losses from hot water circulation, distribution and storage, since WWHR cannot actively reduce these losses that represent on average about 1/3 and in some cases even more than 50% [7] of the delivered energy for DHW heating. It should be also noted that WWHR does not affect the energy required for not simultaneously tapped hot water, for example in a bathtub. On this background, **suitable devices integrated into a DHW system with optimized distribution, storage and circulation losses can reduce the amount of delivered energy water heating by about 40%.**

WWHR also contributes to minimize DHW technology, especially by systems with high investment costs per kW such as heat pumps with geothermal probes. With the WWHR the DHW systems can become also easier to operate by renewable energies. As the EC states: "**The energy efficiency and the deployment of renewable energy complement each other**" [13].

The economy is particularly good by application with multiple users such as sport facilities, businesses and hotels but also in climates with colder ground water. In all three technological scenarios, the **"price of energy saved", hence a fixed energy price for the next decades when using WWHR, is around or below the average energy price in the first quarter of 2021, rising since then.** One WWHR device can save more than a 100 € per family on the hot water operational costs every year.

Due to its high energy efficiency and level or recyclability, the life-cycle of WWHR devices (>20 years) causes a **minimal ecological footprint that is balanced by CO_2 savings already during the first year of its operation.**

The quick decarbonization of the building stock is limited by the low renovation rate of buildings; currently below 1% [14]. in the EU. **The building stock can be upgraded about three times faster with WWHR than with regular energy-saving measures** such as insulation of the building envelope. This is due to the fact that the renovation rate of HVAC systems is about three times higher, according to the Zentralverband Sanitär Heizung Klima, Germany. This makes WWHR a very effective tool with a rapid uptake in the resident market.

The WWHR is in some EU member countries an established technology, recognized as one of the top 10 most promising energy saving opportunities, scoring in several countries on a first rank, according to the Member State Annex Report done by EC [15]. WWHR is an emerging technology bringing a number of benefits that are in line with the EU climate action plan. These are the identified barriers and measures that need to be taken for the European legal framework to unlock the WWHR´s potential of in the EU and globally:

- The WWHR is currently **not officially recognized in the EPC, EPBD or other building rules** and thus the application of WWHR does not bring constructors any legal improvements in the energy efficiency, despite the obvious energy savings.
- **New European norms** on planning and hygiene criteria of application of WWHR system in the buildings shall be created as well as a common certification procedure for the WWHR units. The adoption of **WWHR in the Eco-design Directive** could convey the benefits of combining WWHR with water heating systems in an easy and understandable way, through established energy labelling.
- The **WWHR may be included in the EU's toolbox** as an effective measure for energy-efficient renovations and new constructions. As WWHR is in some regions a new technology, it needs to be **promoted** and **professionals need to be trained** on its benefits and planning. Together with further incentives this procedure can be an effective way to overcome the well-known psychological effect of "status quo bias", making the professionals more hesitant about new technologies they are not familiar with yet.
- **Scaling-up** the number of applications shall make the WWHR system more affordable due to higher cost-efficiency in production. Although double-wall heat exchanger construction is currently required by law in Europe, **single-wall designs** could increase cost-effectiveness if sufficient drinking water safety is provided. In the NL and UK an exemption has been granted (status by 04.2022) to the active systems where the heat exchanger is located above tile level with an air brake for drainage (overflow).

Removing the barriers and making the energy efficiency measures more attractive and simpler to apply will decide if every well-done renovation and new construction will bring Europe closer to its goals, or if it will become a missed opportunity that could lock-in untapped energy savings and associated emissions in the coming decades. ■

Appendices

Link to the full article:
https://diglib.uibk.ac.at/7640369

Annotation

45,26 m² living area / person [16]

Abbreviations

COP	Coefficient of performance
EC	European Commission
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificates
EU	European Union
FSE	Final sewage effluent
GHG	Green House Gas
HE	Heat Exchanger
HVAC	Heating, ventilation, and air conditioning
nZEB	nearly-Zero-Energy Building
PHPP	Passive House Planning Package Tool
WWHR	Waste Water Heat Recovery
DVGW	German society for gas and water installations
ZEB	Zero-Emission Building

Table 1. Current standard.

Country	Efficiency	Hygiene
Germany	PHI (Certified Passive House Components); DIN 94678 (in preparation)	DVGW
Netherland	KIWA NEN 7120	
France	CSTB CAPE/RECADO-PQE	Th-BCE/RT2012
UK	CAPE/RECADO-PQE or KIWA NEN 7120	WRAS
Switzerland	KIWA NEN 7120; Minergie	SVGW
EU	EU No 812/2013 (in preparation)	

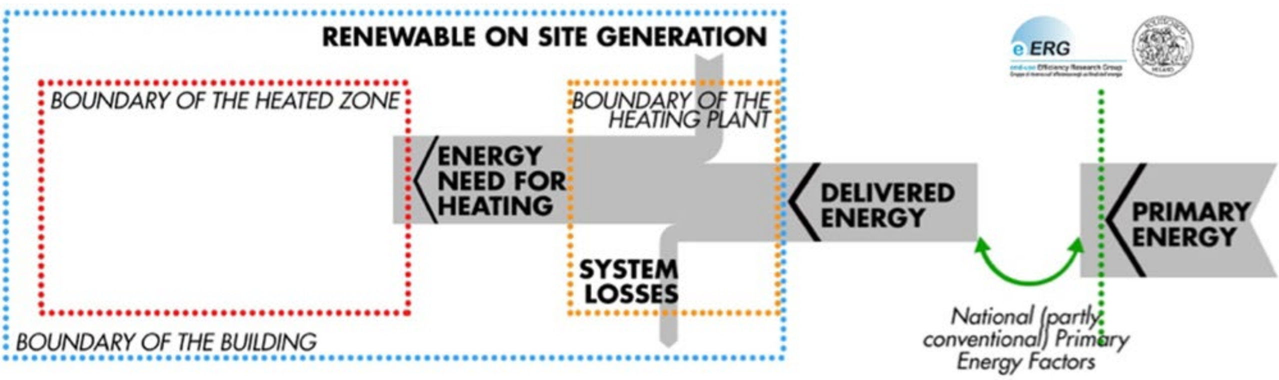


Figure 9. Methodological explanatory to the EPBD. [17]

Data Statement

The team at the University of Innsbruck will be happy to answer further inquiries, share their practical experience and hands on knowledge in WWHR research and development. pavel.sevela@uibk.ac.at

Acknowledgement

This study was commissioned by the European Copper Institute at the University of Innsbruck and the Passive House Institute.

References

[1] European Commission; EPBD-Facts and figures; https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/energy-performance-buildings-directive_en.

[2] Comission to the European parliament; A Renovation Wave for Europe; Brussels 2020.

[3] Eurostat database; https://ec.europa.eu/eurostat/de/data/database.

[4] Roscini et al.; contributions from the building sector to a strengthened 2030 climate target; BPIE 2020.

[5] Anna Marszal-Pomianowska et. al; Comfort of Domestic Water in Residential Buildings: Flow, Temperature and Energy in Draw-Off Points: Field Study in Two Danish Detached Houses; Energies 2021.

[6,7]Bertrand et. al; Characterization of domestic hot water end-uses for integrated urban thermal energy assessment and optimization; Applied Energy 2017.

[8] Passive House Institute; Component Database as of 2021; https://database.passivehouse.com/de/components/list/heat_recovery.

[9] Passive House Planning Package (PHPP) https://passivehouse.com/04_phpp/04_phpp.htm.

[10] Eurostat/size of housing https://ec.europa.eu/eurostat/cache/digpub/housing/bloc-1b.html?lang=en.

[11] A Renovation Wave for Europe - greening our buildings, creating jobs, improving lives; Brussels, 14.10.2020 COM (2020): 662 final.

[12] Eurostat database; https://ec.europa.eu/eurostat/de/data/database.

[13] Commission to the European parliament; A Renovation Wave for Europe; Brussels 2020.

[14] European Commission; EPBD-Facts and figures; https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/energy-performancebuildings-directive_en.

[15] Technical assistance services to assess the energy savings potentials at national and European Level, Member State Annex Report; Yeen Chan et.al; European Commission; 2021.

[16] Eurostat/size of housing https://ec.europa.eu/eurostat/cache/digpub/housing/bloc-1b.html?lang=en.

[17] Explanatory note from eceee regarding the EPBD draft Annex I; European Council for an Energy Efficient Economy; 1 December 2017.

Holistic approach to design healthy and resilient apartments

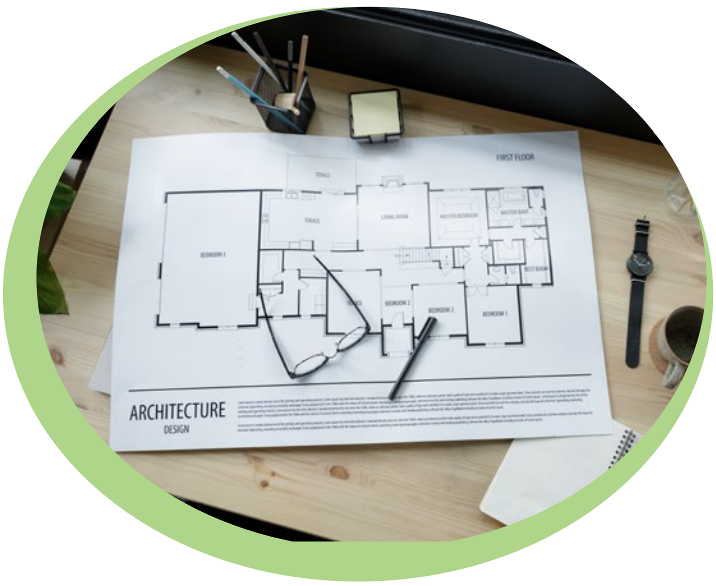
ABEL SEPÚLVEDA
Department of Civil Engineering and Architecture, Tallinn University of Technology
Email: absepu@taltech.ee

ROMAN SMIRNOV
Department of Civil Engineering and Architecture, Tallinn University of Technology

MARÍA DOLORES DONAIRE GALIANO
Department of Architecture, University of Malaga

Designers and practitioners have to face several challenges when designing modern apartments. For current and future climatic conditions, buildings not only must provide to occupants suitable level of comfort but to reach a certain level of energy efficiency and sustainability to make possible the energy transition.

Keywords: energy efficiency, resilience, thermal comfort, visual comfort, daylight, acoustic comfort, indoor air quality, human-centric design, human health, PV generation



In this article, we explain the design process we followed based on a holistic approach to achieve a sustainable, comfortable, and energy-efficient design of a 20-apartment complex called "Vistamadera apartments". This project was one of the finalists of the Healthy Homes Design Competition 2022 held in CLIMA 2022 international conference on May 2022 [1]. The case study is located at one corner surrounded by nature in Pernis, Rotterdam, a suboptimal urban area for new residential developments because of the surrounding industrial zones (i.e. poor outdoor air quality and high noise levels). The realization of a holistic design was possible thanks to the cooperation between different disciplines: architecture, HVAC engineering, and architectural engineering.

Step 1 - Building massing process considering sustainability and view out

For one side, we tried to avoid north-oriented facades because of the lack of daylight. On the hand, pure west orientations were avoided because of the excess of solar heat gains. Therefore, a symmetrical V-shape building was developed (**Figure 1**) with NW-SE and NE-SW orientations.

Regarding view contact with the outside, the V-shape building footprint allows (from each apartment) future occupants to keep an eye to the children park (south side) from each apartment and enjoy the view towards the Nieuwe Maas river (north side). The location of the building footprint is not arbitrary: we wanted to split the original buildable plot in three different green areas that could be used for different communal activities: children park in the heart of the plot, street workout park in the NW part of the plot, and a park for elderly people located in the NE part of the plot.

In order to protect the building against flooding events, the whole original plot terrain was elevated 1 m and the first floor of the lower apartments were located in the second floor. In fact, the uncovered first floor of the building allow: (1) occupants have view contact with all the green areas which are populated by transplanted local trees of the limits of the plot; (2) the pass of local wildlife through the plot. The number of parking lots were limited to 10 and 50 bike parking places were located in the first uncovered floor in order to promote healthy and sustainable way of transport.

Step 2 – Window and shading sizing process considering visual and thermal comfort

Once defined the building volume, the windows were located for each apartment to have at least double orientation. This distribution allows the possibility of use a hybrid ventilation strategy to ensure a good indoor air quality and decrease the overheating risk even in future climatic conditions. For all the rooms, the windows

Figure 1. Top view of the plot (upper left figure), top view of the different floors (upper right figure), perspective rendering view from the south-west side of the plot (bottom left figure), and perspective rendering view from the north-west side of the plot (bottom right figure).

(U-value of 0.6 W/m²K and aluminium frame with U-value of 1 W/m²K) were sized by using novel coupled method based on prediction formulas [2] that allow us to select a suitable combination of g-value (0.3 and 0.4 for south and north orientations, respectively), visible transmittance (Tvis) (60%) and window-to-wall-ratio (WWR) (76-80%) to have enough daylight provision (mean Daylight Factor higher than 2%) and protection against overheating. The size of the windows facing south-east and south-west were increased in order to compensate two design decisions: the high depth and the balconies with PV panels (tittle angle of 45°) of 1 m were installed as passive design solution: they maximize solar heat gains in winter and limit them during summer. Thus, considering a mean urban heat island effect (UHI) between 0.5° and 4° (**Figure 2a**) [3] and future climatic conditions (year 2085), all the rooms will have at least a 93% of annual comfort hours according to the EN 16798-1:2019 Category II (adaptive comfort criterion) (**Figure 2b** and **2c**). Moreover, the building will have an annual energy consumption of 1.84 51.84 kWh/m² (HVAC), 7.3 kWh/m² (artificial lighting), and 17.52 kWh/m² (occupants' appliances). Detailed description of the HVAC systems is explained in Step 4.

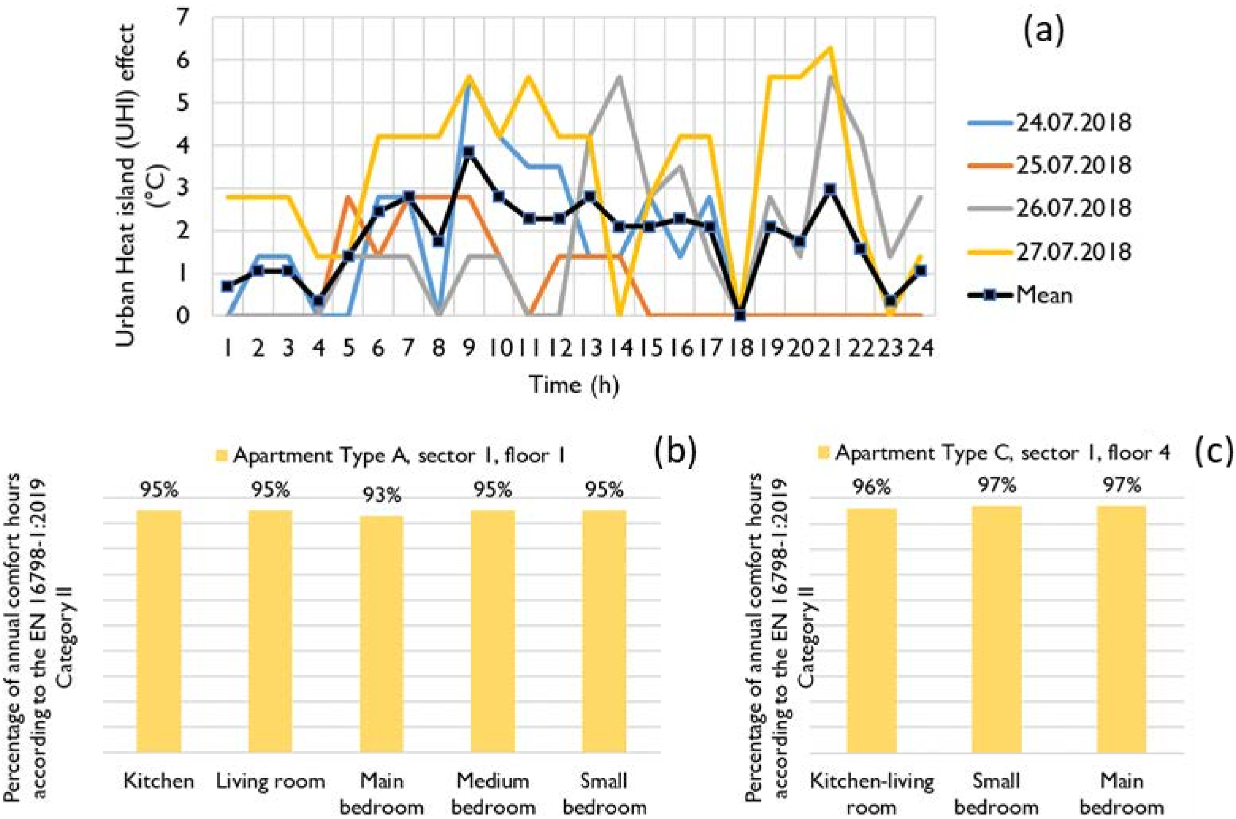


Figure 2. Measured urban heat island effect for different summer days (a) and percentage of annual comfort hours according to the EN 16798-1:2019 Category II for different apartment types: A (b) and C (c).

Step 3 – Construction materials selection considering energy efficiency and acoustic comfort

We selected high quality multi-layer thermal insulation materials for external/interior walls, slabs, and roofs (**Figure 3**). The combination of these materials was inspired by existing modern Estonian buildings, such as the Narva Study Centre of the Estonian Academy of Security Sciences [4]. The finishing materials for interior and exterior were adapted to the residential use (recyclable paints and vertical cladding wood) and the thickness values for each material were modified according to local Dutch practice (reduction of 50% with respect to the Estonian practice). The results were construction elements with suitable thermal insulation for the Dutch context: U-values about 0.1-0.5 W/m²K for exterior walls/roofs-interior walls/slabs. As secondary criterion, we chose at least one material per layer and construction element with high noise reduction coefficients (NRCs between 0.63-0.9) (green coloured layers in **Figure 3**). The acoustic comfort performance of all the apartments was satisfactory: the maximum indoor noise level (airborne and contact noise) was below 30 dB when considering different external noise sources simultaneously:

- Contact noise source from upper floor (55 dB)
- Airborne noise source from upper/lower floor (55/55 dB)
- Airborne noise source from ship engine (173 dB)
- Airborne noise sources from traffic and outdoor activities (55 dB)

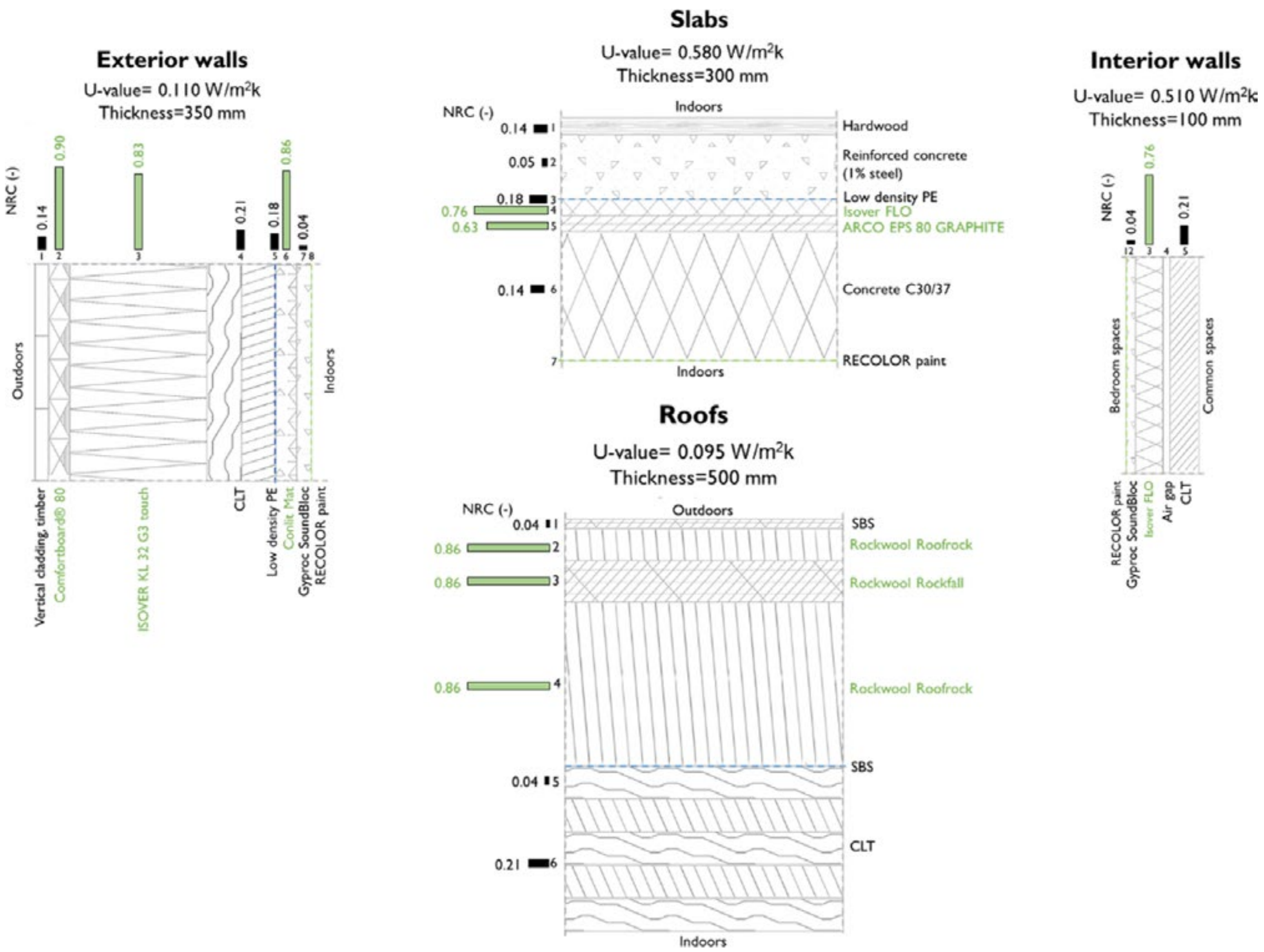


Figure 3. Multi-layer construction elements used, acoustic and thermal properties included.

Step 4 – Selection of HVAC systems considering thermal comfort and energy efficiency

Thermal comfort, efficiency, and flexibility were considered as main criteria to select the HVAC system. Floor heating (capacity of 54.4 kW) and hot water systems were solved by heat from district heating using heat exchangers (**Figure 4**). The main heat sources of the local district heating are waste treatment installation (WIP), residual heat, and biomass power plant. Hot water supply temperature must be 55°C, once a day increasing temperature up to 65°C to prevent risk of salmonella disease. Apartments are equipped with hot water circulation to provide hot water inflow maximum in 10 seconds. Floor heating dimensioning temperature for supply and return water is 40°C and 35°C, respectively. The floor heating system was solved with pipe step of 300 mm and 150 mm near external slabs and bathrooms (to improve operative temperature).

Apartments cooling was solved with VRV cooling system (**Figure 5**). Outside unit is located at the roof of the building. Inside units are located at every bedroom and leaving room. Optimal design temperature is set to 25°C. Supply cooling temperature is 7°C and return is 12°C. R410A refrigerant is the working fluid. Cooling and heating simultaneous working must be forbidden by the help of room automation.

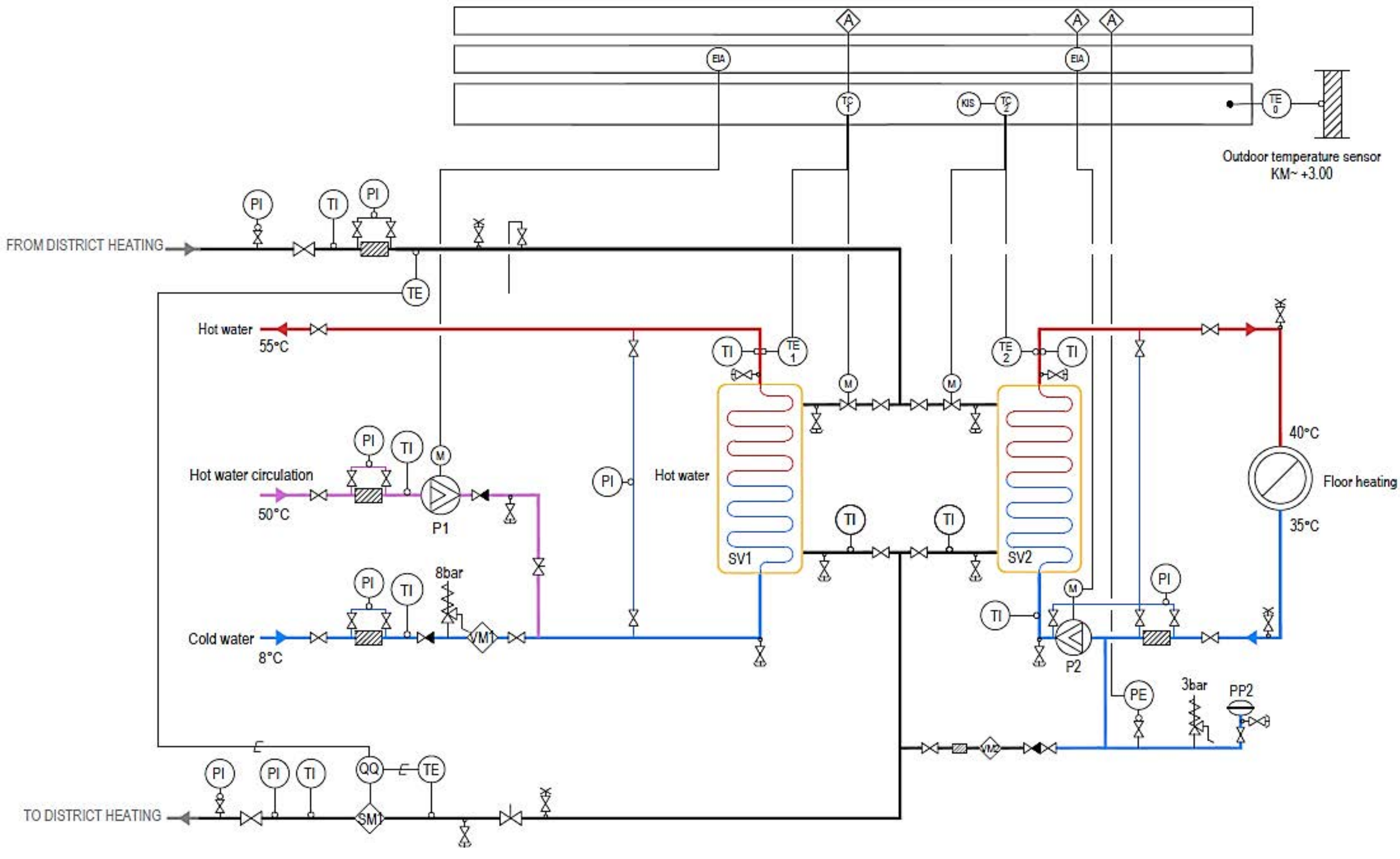


Figure 4. Heating and hot water system.

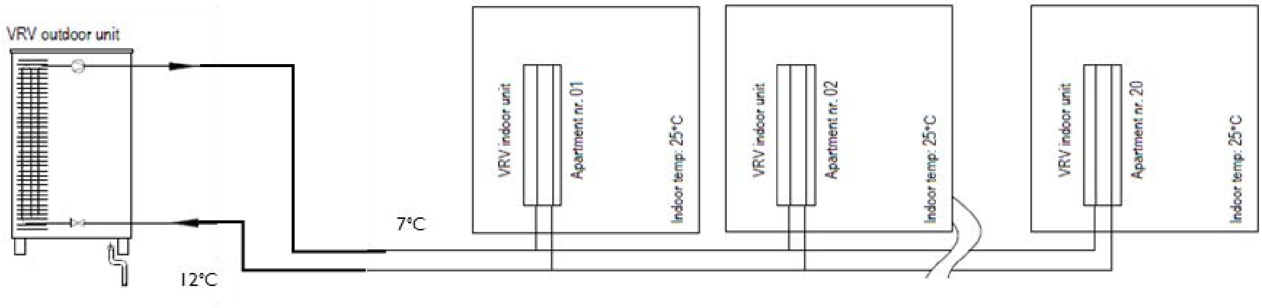


Figure 5. VRV cooling system scheme used for each apartment.

To improve indoor air quality, mechanical ventilation was used (**Figure 6**). A private ventilation unit was designed per each apartment. Every unit is equipped with particle filters (ePM1 55% (F7) for supply air and ePM10 50% (M5) for exhaust air) to protect indoor spaces against dusted air. Rotor enthalpy type of ventilation heat exchanger was used to return humidity from exhaust air. Thanks to that, it was possible to achieve relative humidity level up to 35% during winter. Airflows of ventilation units were dimensioned according to the restriction of CO_2 level concentration (max 550 ppm above outdoor CO_2 level) and not less than 0.7 ℓ/s·m².

Step 5 – On-site energy generation considering PV technology

The on-site energy generation was conducted By the installation of high-efficient PV modules (1.6 × 1,046 m) (total surface of 195 m²) as 45° tilted backwards shading systems of the south-oriented rooms. The PV technology is monocrystalline silicon with a nominal power of 327 W per panel and STC efficiency of 20.07% [5]. There is an inverter per sector, which converts the DC power output of the PV modules to AC power for the occupants' loads. Each sector circuit is connected to the utility service. Thus, each sector can sell the excess of generated electric energy to the grid. Predicted annual electrical energy demand in kWh/y for each sector can be seen in **Table 1**.

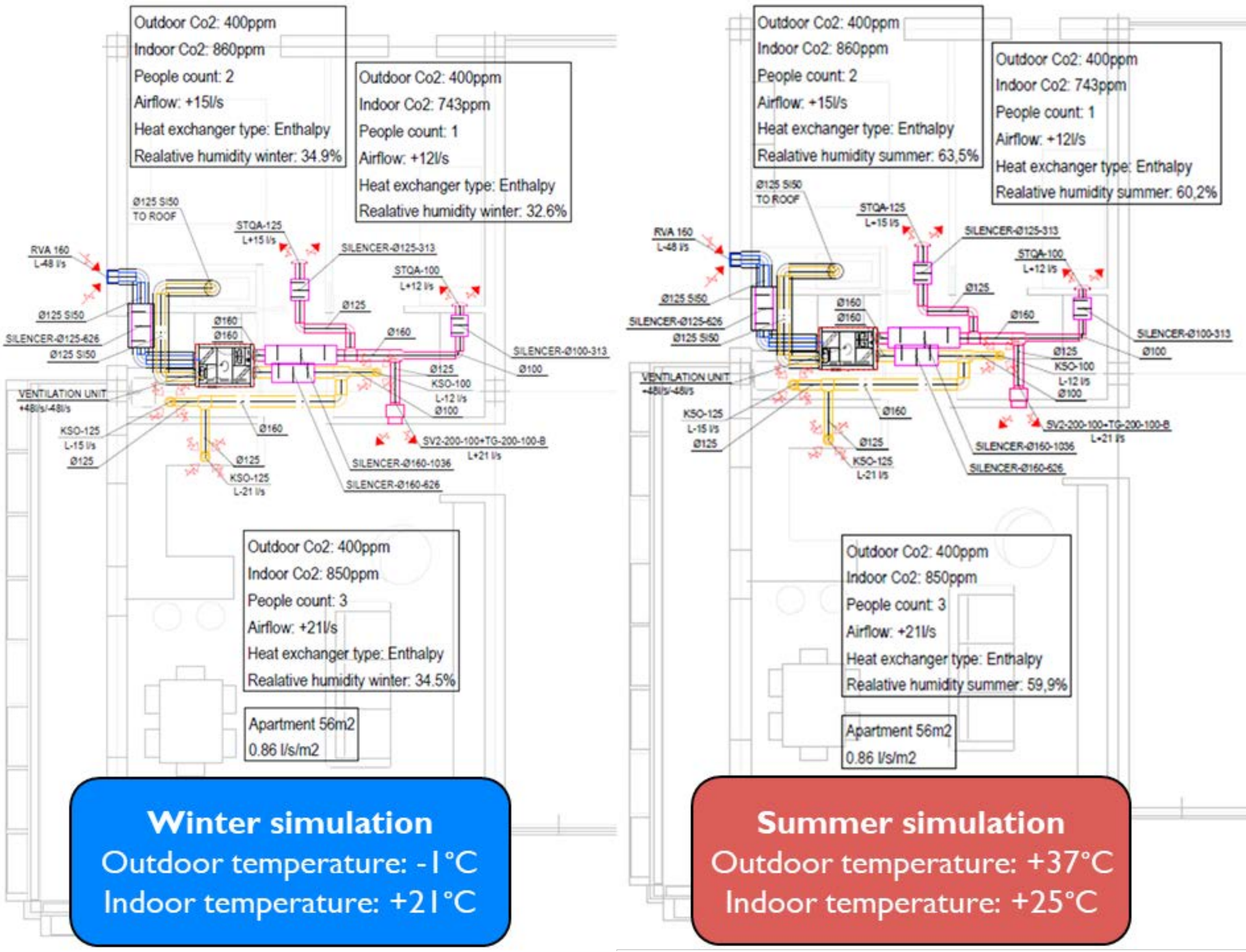


Figure 6. Simulation of the mechanical ventilation system for a critical apartment (type C) under winter and summer climatic conditions.

Table 1. *Predicted and generated annual electrical energy demand per facade and sector (kWh/y).*

Sector ID	Predicted annual electrical energy demand (kWh/y)	Facade orientations	Number of modules per orientation	Generated annual electrical energy demand per facade (kWh/y)	Generated annual electrical energy demand per sector(kWh/y)
1	21480	SW | SE	16 | 16	4600 | 4360	8960
2	20495	SE	28	7600	7600
3	20495	SW	28	8000	8000
4	21480	SW | SE	16 | 16	4600 | 4360	8960

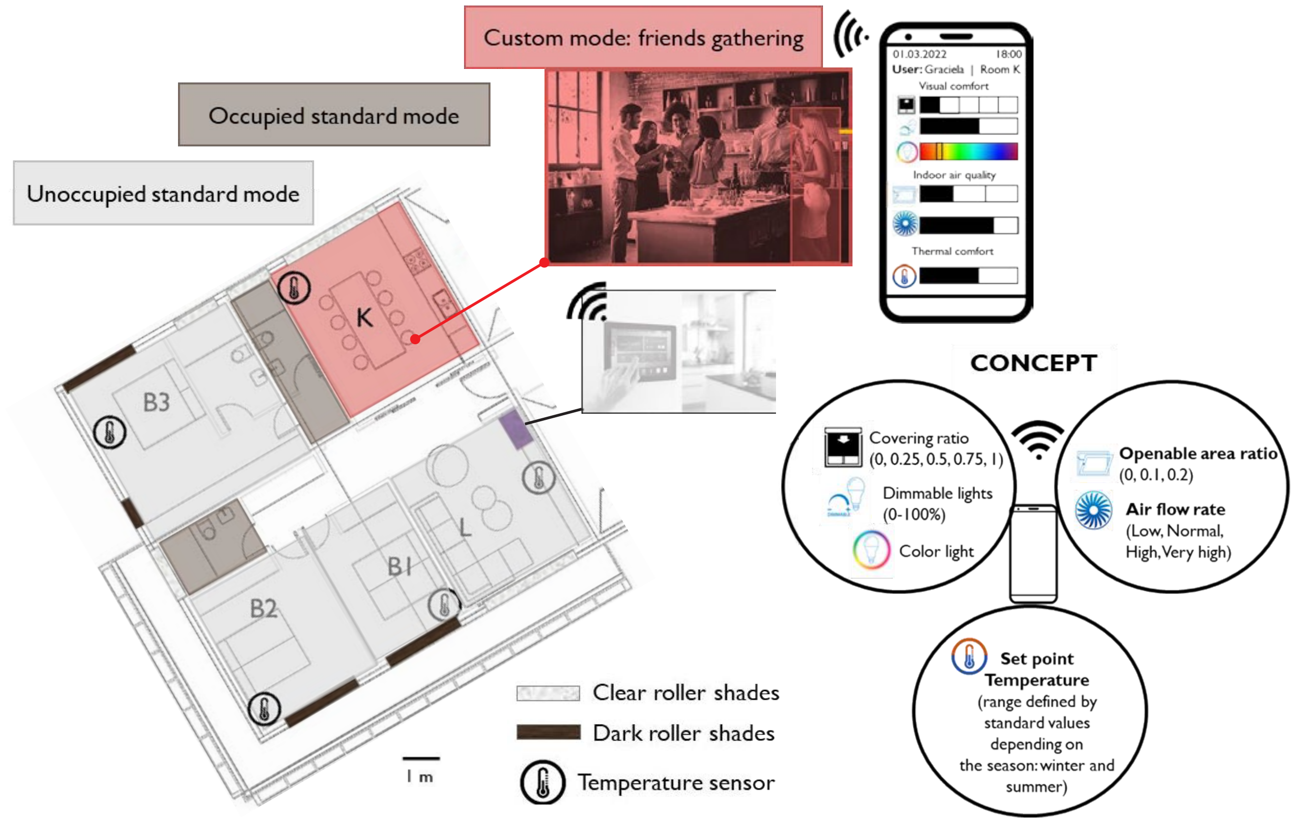


Figure 7. Personal control system concept and example of use.

With this system, sectors 1, 2, 3, and 4 could save a maximum of 41.7%, 37.1%, 39%, and 41.7% of the predicted annual electrical energy.

Step 6 – Personal control of the indoor environment

We made sure that building occupants have adequate options for personal control over their indoor environment: occupants will have available an integrated smart system to control the indoor environment in terms of visual comfort, thermal comfort, and indoor air quality to different levels: apartment and room level (**Figure** 7).

Thus, the variables related to visual comfort that can be controlled are the following: covering ratio (i.e. 0= shades in up position, 1=shades totally lowered), intensity of the dimmable artificial lights (0=completely switch off, 1=switch on to maximum brightness), and colour of the light. The variables related to thermal comfort is the traditional indoor set point, which value range depends on the season. Finally, the indoor air quality could be controlled through two variables: openable area ratio (0= windows closed and 1=openable area represents 20% of the window area) and air flow rate generated by mechanical ventilation system (Low=0.7 $\ell/s{\cdot}m^2$ and Very high= air ventilation rate according to the number of people in the room).

The available control modes at apartment level are: (1) standard mode for occupied/unoccupied apartment (energy efficiency-based criterion, i.e. windows closed and shades lowered) and (2) simulated occupied apartment (security-based criterion considering how occupants normally use the apartment). Finally, there is the possibility to set each of the controlled variables via occupant's smartphone for rooms such as living room, kitchen, and bedrooms. ■

References

[1] Winners of the first edition (2022).URL: https://www.healthyhomesdesigncompetition.com/results/2022.

[2] Sepúlveda, A., De Luca, F., & Kurnitski, J. (2022). Daylight and overheating prediction formulas for building design in a cold climate. Journal of Building Engineering, 45, 103532.

[3] Rotterdam Urban Heat Island Explorer (2022). URL: https://doi.org/10.1016/j.jobe.2021.103532.

[4] Narva Study Centre of the Estonian Academy of Security Sciences / 3+1 Architects (2022). URL: https://www.archdaily.com/957698/narva-study-centre-of-the-estonian-academy-of-security-sciences-3-plus-1-architects.

[5] https://www.tudelft.nl/en/ewi/over-de-faculteit/afdelingen/electrical-sustainable-energy/photovoltaic-materials-and-devices/dutch-pv-portal/tools-models/detailed-pv-system-design.

Highlights of the 66th REHVA General Assembly

After two years of online meetings, the REHVA Members Associations finally met face-to-face in Woerden and in Rotterdam, the Netherlands on 21-22 May.

Frank Hovorka, the 17th REHVA President opened the first part of the 66th REHVA General Assembly on Saturday 21 May in Woerden in the TVVL offices. The members talked about the issue of the suspension of ABOK's membership in the context of the situation in Ukraine. They unanimously decided to suspend ABOK and to reconsider during a future General Assembly.

The second part of the General Assembly continued the next day in Rotterdam, in the CLIMA 2022 venue.

One of the agenda points of the General Assembly was a presentation of a new potential member from Bulgaria. **Dessislava Petrova** presented BAOVK's application to become a REHVA member. The Bulgarian Association of Heating, Ventilation and Air Conditioning is an NGO that has been established to represent and protect the common interests of the industry and its members before national and international organizations in procedures for drafting and updating regulations and it aims to promote good practices in the industry, to ensure their implementation by its members and to create conditions for improving the quality of trainings. With a unanimous vote, BAOVK has been accepted to the REHVA family.

Lada Hensen Centnerová (TVVL – The Netherlands), Livio Mazzarella (AiCARR - Italy), Pedro Gines Vicente Quiles (ATECYR – Spain) and Johann Zirngibl (AICVF – France) were elected alongside Ivo Martinac (SWEDVAC – Sweden) and Kemal Gani Bayraktar (TTMD -Turkey) who were re-elected from the previous mandate.

Frank Hovorka said his goodbye to REHVA and thanked all the members, board and office team for the last 15 years. He also underlined REHVA's main focus: "supporting knowledge exchange and transfer between members of member associations and facilitating communications between them". The presidency officially changed from Frank Hovorka (France) to Cătălin Lungu (Romania). Before becoming President, Cătălin Lungu was REHVA Vice-President and Treasurer. Standing beside him, the leaving directors, Atze Boerstra, Juan Travesi and Manuel Gameiro da Silva also thanked REHVA and wished good luck to the new board.

The highlight of this year's General Assembly has been the vote of the new REHVA Board of Directors.

Dessislava Petrova presented BAOVK's application to become a REHVA member at the GA.

Three important announcements were made during the meetings:

- REHVA Brussels' Summit, Belgium, 17-18 November 2022
- REHVA Annual Meeting 2023, Brussels, Belgium, or in Istanbul, Turkey, May 2023
- REHVA Annual Meeting & CLIMA 2025, Milan, Italy

Cătălin Lungu, the 18th REHVA President closed the 66th REHVA General Assembly.

The standing Committees (Supporters Committee, Technology and Research Committee, Editorial Board, Publishing and Marketing Committee, Awards Committee, Education and Training Committee and COP) met prior to the General Assembly where REHVA Committees' Chairs presented their reports of activities, outcome, and future goals. The membership of each Committee was updated after the 2 years usual term.

After the REHVA Annual Meeting, all the Members Associations, Office Team and Board Members were invited to attend the 14th REHVA HVAC World Congress organized by our Dutch member TVVL (in cooperation with REHVA, Delft University of Technology and Eindhoven University of Technology) with TU Delft and, in Ahoy Rotterdam. ■

Farewell speech of outgoing REHVA President, Frank Hovorka

At the General Assembly in Rotterdam on 22 May 2022

It started 15 years ago! When, in search of answers on the energy and environmental performance of buildings, I was first invited to an annual conference of the federation in 2007.

I immediately realized that the Federation of European Heating, Ventilation and Air-conditioning Associations is above all a place of excellence and incredible knowledge sharing. Everything you never dared to ask about the genesis of norms, standards and regulations is within reach and open to each other's curiosity and questions.

Indeed, the sum of available knowledge, researchers, experts, and high-level professionals has been fabulous, and the urge to disseminate this knowledge to practitioners and real estate decision-makers (whose field of expertise is not necessarily this one) immediately struck me, for the benefit of our entire profession and the real estate sector.

This is how my mentor within the federation, Maija Virta, convinced me to write a guidebook under her supervision about how to translate system performance into the financial valuation of office buildings.

Then, a fast forward, with the support of AICVF, for which I warmly thank the successive presidents and Francis Allard, I was elected to the REHVA Board in 2012. We lived through very difficult years, questioning our organization and our income sources under the presidency of Karel Kabele, followed by a rebuilding under the presidency of Stefano Corgnati. We have boosted participation in European research projects in cooperation with national member associations and affiliated universities. We have further increased our international recognition by strengthening partnerships with India, China, and Latin America in the context of assumed expansion of our American colleagues. International cooperation is essential to exist in the concert of nations and the visibility of European research and professionals rises through these cooperation and networks.

Still, our main focus has been on supporting knowledge exchange and transfer between members of member associations and facilitating communications between them. All this made it possible to build a strong reputation and credibility within European institutions for the benefit of our industry and gain the weight we have in the EU regulatory field and standardization efforts.

Under my presidency term, we had to face the COVID-19 crisis together, which accelerated the implementation of digital tools, among others our mobile application with the dictionary in 15 languages but it has also increased the frequency of meetings with member associations. And above all, thanks to this solid collaborative organization, we were able to immediately set up a COVID-response task force assessing the impact of airborne transmission in closed premises and providing guidance. We distributed the first reference guide in April 2020 that was translated by most member associations. The COVID-19 task Force has also led us to work with over 250 researchers around the world advocating the recognition of aerosol transmission of the virus, which resulted in the WHO guide on the role of ventilation in April 2021, as well as the creation of a multidisciplinary group where for the first time the HVAC sector is represented by a delegate of the IEQ GA Alliance, of which REHVA is a founding member.

I would like to thank here all the great professionals who I had the honor to meet and the pleasure to work with. All those, who - despite me being an "ignorant" - have supported and trusted me to represent them. And even more thank them for accepting me in the REHVA family, without being an expert in their professional field.

Last but not least, I would like to thank all the past and actual REHVA staff, with a special recognition to Anita and Nathalie who made my task easier! ■

Frank Hovorka
REHVA President
2019 – 2022

From left: Ivo Martinac (Re-elected), Kemal Gani Bayraktar (Re-elected), Livio Mazzarella, Cătălin Lungu (New REHVA President), Lada Hensen Centnerová, Johann Zirngibl and Pedro Vicente-Quiles.

Newly Elected REHVA Board Members

Question 1. **How has your background and experience prepared you to be an effective board member?**
Question 2. **As a board member, what are the main changes you would like to make within REHVA?**
Question 3. **In one sentence, how do you see REHVA in three years' time?**

Lada Hensen Centnerová

- TVVL member
- Vice President and Co-Chair of the CLIMA2022 Scientific Committee
- Operational Director, Smart Buildings and Cities, PDENG program, Eindhoven University of Technology
- Professor and Researcher, department of the built environment, Eindhoven University of Technology

"As a member of two different REHVA Member Associations, it's a shame I couldn't use the REHVA knowledge to my advantage because knowing very little about REHVA. This is why I would like to improve the communication from REHVA to the individual members of the national associations."

1. I am involved in other associations, so I think that I know what it means to do such volunteering job. I am the president of the Dutch chapter of ISIAQ (International Society of Indoor Air Quality and Climate) and I used to be chairman of the Editorial Board of TVVL Magazine (journal of the Dutch national organization) but I stopped to have more time for REHVA Board. In my 'real' job I am the operational director of a post-master program at the Eindhoven University of Technology, so I am used to working with people.

2. With my fresh experience as a CLIMA 2022 vice-president, I would like to initiate setting up a permanent conference committee to improve the organization of CLIMA conferences and help their organizers. I would also like to help to improve communication from REHVA to the members of the national associations and not only to their Board members and so promote REHVA and its activities. All these activities are related to PMC committee, I think.

3. REHVA will have more active members and will be the prime communication partner of the European Commission regarding HVAC issues related to decarbonization, climate change and health in buildings.

Livio Mazzarella

- AiCARR member
- AiCARR past Executive Board Member
- REHVA Fellow, active member since 2011
- Full Professor of Building Physics and Building Energy Systems at Politecnico di Milano

"My aim will be to strengthen the cooperation among REHVA members, through new ways of knowledge sharing. I also want to support the growing of a common European HVAC culture."

1. I'm working as full professor at one of the most important technical universities in Europe, Politecnico di Milano, and such position also involves management activities of groups of people aside from students. I have been dean of the Building Engineering Faculty for 8 years and for three years vice-director of the Energy Department.

   At the same time, since 1993 I have been involved in technical standardization activity through the Italian National Standardization Body, UNI-CTI, managing several working groups in HVAC field till becoming, seven years ago, the President of the Technical Committee on Air Conditioning, Ventilation and Refrigeration.

   I have also specific experience in HVAC&R association management: I have been for four times member of AiCARR board since 2005 for 12 years, and, not least, through my activity in REHVA in the last 15 years.

   I have already served REHVA in different positions as Technology and Research Committee Cochair, Cooperation Group Chair, Award Committee core member, External Relation Committee core member, Supporter Committee core member, active member of COVID-19 task force); thus, it is time to offer my experience to a higher level of management in REHVA as REHVA board member.

2. The main aim of my mandate is to strengthen the cooperation among REHVA members through looking at new ways and to increase knowledge sharing and supporting the growth of a common European HVAC culture not only in EU Countries but also in all other member (and eventually not members) countries. These years, the COVID19 pandemic has shown that cooperation is crucial to create achievable technical solutions able to mitigate the infection effects, for instance developing common free tools, and that no political barrier or state boundary is able to confine its terrible effects. This is the way I would like to pursue building REHVA's new perspectives.

3. A growing worldwide leading role for REHVA without leaving its important role in growing cooperation and cultural exchange among its members

Pedro Vicente-Quiles

- ATECYR member
- President of ATECYR Technical Committee, Board Member since 2005
- Senior Professor at Universidad Miguel Hernández
- Expert in Energy Efficiency in Buildings

"It is gratifying to share experiences with people from all over Europe and learn about the different problems and point of views of different European countries in our sector."

1. I have been a member of Atecyr board for the last 16 years, and I am currently the Chairman of its Technical Committee. For the past several years, I have regularly attended REHVA meetings and know most of the REHVA family members and staff. I know how REVHA works and the important changes that have been made in recent years.

2. REHVA has demonstrated the important role that a Federation of National Associations can play at a European level, providing high technical and scientific knowledge, leading a rapid response to the pandemic and supporting the different member countries.

   Now we have more challenges such as decarbonisation and probably new urgent measures to rapidly reduce fuel consumption in buildings.

   In this sense, from the Board I would like REHVA to have an important weight in giving technical answers and in positioning ourselves so that we are heard and that these regulatory changes are made under reasonable technical criteria, putting air quality and energy efficiency first.

   I would also like REHVA's collaboration and support with all national associations to be as strong as possible.

3. REHVA will be considered throughout Europe as the reference technical association for HVAC.

Johann Zirngibl

- AIVCF member
- Independent expert
- Convenor in CEN and ISO working groups
- Expert for the European Commission

"Within REHVA, I want to use my international political experience to reach decision makers to communicate and discuss technical transposition into building regulations."

1. The French HVAC association is already very active at REHVA level (several past REHVA presidents were French). I am member of the international committee of the AICVF. Therefore, the fruitful exchanges with my colleagues helped to be prepared for the REHVA board. In addition, my professional technical and scientific background as head of division in a public research institute and as convenor of CEN and ISO standardisation working group where the consensus finding is important, are fruitful experiences to contribute to the REHVA board.

2. I think that the orientation and working procedures of REHVA are going already in the right direction. Therefore, I do not think that changes are needed, but that I could contribute to intensify the valorisation of the technical expertise of REHVA in technical rules (e.g., building codes) and to the recognition of HVAC professionals as key actors in the energy transition at European, national, and regional level.

3. REHVA should continue to play, in cooperation with other partners, an active role in the energy transition and CO_2 neutrality, increase its visibility, and transmit the REHVA family spirit to the young generation of HVAC professionals to motivate them to further develop REHVA. ■

Re-elected REHVA Board Members

Ivo Martinac

- SWEDVAC member
- Chair Professor in Building Services Engineering
- Re-elected REHVA Vice President

"My main objective will be to concretize and implement the key goals and activities identified in the recent bilateral discussions with the member associations."

Although the Covid 19 pandemic brought about many challenges, including to how we have been able to communicate and work together over the last few years, it has also resulted in opportunities to draw on our joint expertise, enthusiasm and proactivity - and make things happen. Our joint response, at many levels, as REHVA Family to this global challenge gained our organization unprecedented international attention and recognition. Yes, we clearly can – and there is much more we can achieve together!

It has been a particular pleasure and privilege to participate over the past two years in our bilateral meetings and learn in detail about the activities, needs and ambitions of our Member Associations, as well as their visions of our joint goals and continued work.

Kemal Gani Bayraktar

- TTMD member
- TTMD Vice-President, and past President
- Sustainability ambassador
- Re-elected REHVA Vice-President

"I would like to bring my experience with a focus on implementation of a global vision, and contribute with specific actions, specifically transferring research knowledge to action-oriented platforms and programs."

I want to serve for a second term to complete the ongoing and start further important initiatives with and for REHVA. Should I be re-elected, I will continue to help further strengthen our organization with the collaborative activities and responsibilities within REHVA. I would like to bring my experience with a focus on implementation of a global vision, and contribute to the work of REHVA with specific actions in the field of transferring research knowledge to action-oriented platforms and programmes. I would also like to focus on further development and implementation of our offers for young professionals and supporters.

Beyond I will continue to support all promising upcoming initiatives which contribute to strengthen REHVA, increase global footprint and lead towards a Net Zero future. Strengthening REHVA activities globally by developing collaborations with organizations of our industries will be among my priorities as well as contributing to achieve transform and growth in favour of REHVA mission and strategic objectives by working closely with MAs, Supporters and HQ. ■

REHVA Awards and Fellows 2022

REHVA Awards

During the Saturday REHVA Gala Dinner at the Nhow Hotel, REHVA Member Associations have chosen to award their members for their achievements in the field of Education and Science.

Siru Lönnqvist (FINVAC, Finland) and Robert Gavriliuc (AIIR, Romania) received the professional award for Education.

Liviu Drughean (AFCR, Romania) and Francesco Franchimon (TVVL, The Netherlands) received the professional award for Science.

Laure Itard (TVVL, The Netherlands) received a special recognition for her tireless work related to the organisation of the 2022 CLIMA Congress edition (specifically in her role as chair of the CLIMA 2022 scientific committee).

Additionally, TVVL has been awarded the **REHVA Member Association Award** for its active and substantial contribution to the CLIMA Congress over the past 3 years, despite all the turbulences with the pandemic and changes in the events industry. REHVA Board and staff would like to thank them again for their great work and successful Congress.

REHVA Fellows

Three **fellowship awards** were granted for significant contribution to REHVA (board, committees, and task forces) to Gratiela Tarlea (AIIR, Romania), Lada Hensen (TVVL, the Netherlands) and Ole Teisen (Sweco Denmark). REHVA would like to congratulate the two new fellows for their precious time and hard work.

Supporters Awards

This year, REHVA has decided to award 2 of the REHVA Supporters with the Supporters award for longstanding support and collaboration with REHVA. REHVA expresses its heartfelt gratitude to **Purmo Group** and **Lindab** for being a true REHVA supporter for over fifteen years.

The awards were received by John Peter Leesi, CEO of Purmo Group and by Johan Rasmussen on behalf of Lindab AS. We look forward to continuing our precious collaboration to deliver healthy and sustainable indoor climate. ■

Supporters Award: Purmo Group

Supporters Award: Lindab AS

REHVA Member Association Award: TVVL

Professional award for Education: Siru Lönnqvist

Special recognition: Laure Itard

Professional award for Education: Robert Gavriliuc

Fellowship award: Gratiela Tarlea

Professional award for Science: Liviu Drughean

Fellowship award: Lada Hensen

Professional award for Science: Francesco Franchimon


Fellowship award: Ole Teisen

REHVA renewed Memorandum of Understanding with ISHRAE, SAREK and IIR

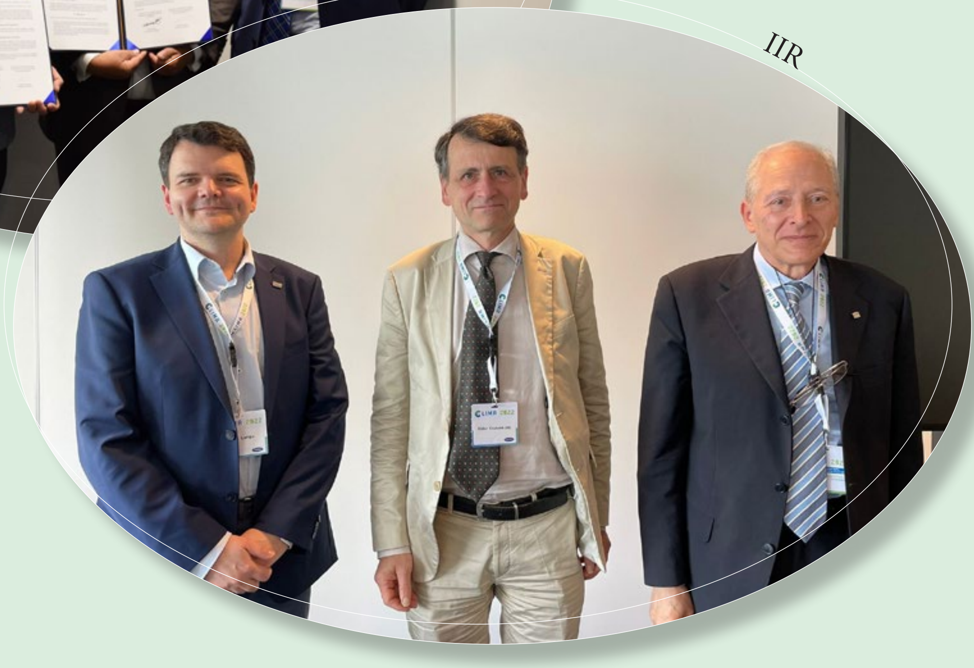
During CLIMA World Congress 2022, REHVA confirmed their cooperation with three international partners and renewed Memorandum of Understanding with the Indian Society of Heating, Refrigerating and Air Conditioning Engineers (ISHRAE), the Society of Air-conditioning and Refrigerating Engineers of Korea (SAREK) and the International Institute of Refrigeration (IIR).

REHVA looks forward to further cooperation with our international partners. ■

ISHRAE

SAREK

IIR



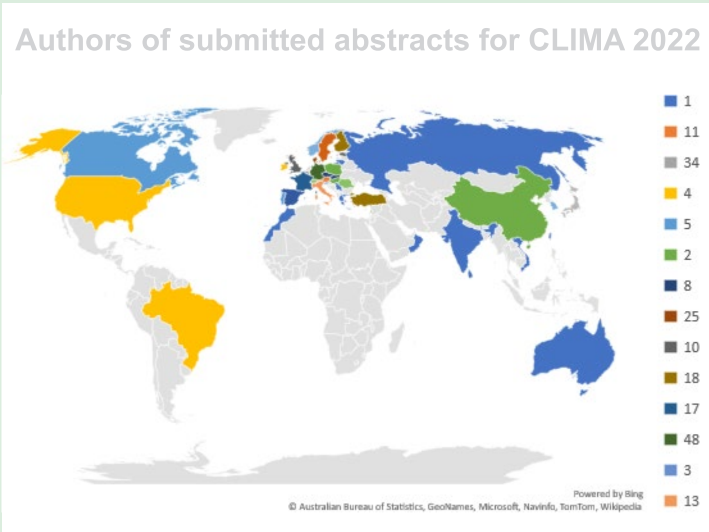
CLIMA 2022: EYE ON 2030

The long-awaited return of physical events, where we can collaborate better, improve the expertise exchange, drive innovation, and network again has finally arrived! During the 3.5 days Congress in May, the REHVA 14th HVAC World Congress has taken place in the "coolest" city of the Netherlands, Rotterdam at the end of May.

This year's edition, for the first time in a hybrid form and have hosted 651 attendees in person in the new Ahoy congress center. Besides the pandemic, the fruitful collaboration between TVVL, REHVA and the Universities of Delft and Eindhoven has ensured that the event has been a great success. "Despite some hurdles during these past few challenging years, we are happy to have delivered a high-quality scientific congress, following the great previous editions of CLIMA. We have put our hearts and souls into making this great congress into reality, and it is very satisfying to see such a result," says Atze Boerstra, president of the 14th CLIMA Congress.

The congress was focusing on 5 different themes; Health & Comfort, Energy, Digitization, Circularity, and Learning & Education, with the first three being the main topics of CLIMA, each featuring one of the days of the congress and each theme being promoted by a sponsor. In addition, CLIMA 2022 landed a great number of additional sponsors, with Carrier being the main sponsor of the whole congress.

Securing the quality of the whole congress was an amazing line up of inspiring keynotes, a total of 40 interactive sessions and 481 scientific papers. "We've had so plenty interesting discussions on different themes. A big thanks goes as well to the high-level keynote speakers who have shown us how we can go towards a sustainable and healthy future." says



KEYNOTE SESSIONS / OPENING CEREMONY

Laure Itard, congress Vice-President. In this 2022 edition we have received 481 contributions with 344 presenters and 228 reviewers from all over the world.

Together with our partners, we are proud of this excellent event. A big thanks goes to all the participants without whom we wouldn't be able to make this edition a success. And with this, we say *vaarwel* to Rotterdam, and *ci vediamo* in Italy for CLIMA 2025!

SCIENTIFIC HIGHLIGHTS

Health & Comfort

- Re-thinking ventilation/cleaning from air room ventilation rates to exposure prevention and cleaning
- Occupant-centric design and control: from ventilating space to delivering comfort to occupants
- Cooperation with different disciplines is indispensable
- The combat against future diseases should be taken up hand in hand with the climate change challenges

Energy

- Re-focus from zero-energy to zero-emission
- It is not only about energy/emissions but about material resources as well
- We have to work together - and time is of the essence
- Increasing interest in operational optimization making use of digitalization

Digitization

- Machine learning shows ample opportunities for improving control and simulation processes
- Information models to be combined with data streams
- Performance gap to be bridged using co-simulation approaches
- Work to be done in connecting devices and software real-time together (computation ability)

Circularity

- Few papers but huge interest in circularity in HVAC
- Case-studies are essential for 'cross-pollination' between theory and practice

Learning & education

- Leaning communities show potential for scaling-up professional education without compromising company activities
- Novel teaching material: interactive worksheets (Jupyter) for integration of classic textbook with visual and interactive content
- Technological Innovation Systems for the development of cross-sectoral knowledge ■

Keynote: Lieve Helsen

Keynote: Pau Garcia Audi

Workshop Report: Sustainable Finance – The EU Taxonomy & Building Performance Gap

The QUEST project organised a session on sustainable finance in the building sector, specifically about how quality management services can help building owners & investors to meet the Taxonomy requirements and de-risk investments by closing the building performance gap. The first half of the workshop focused on the impact of the EU Taxonomy and the need for reliable building data for investors to know if they're meeting the requirements, while the second part covered the impact of the building performance gap and how QUEST has been working to mitigate this.

JASPER VERMAUT, EU Policy & Project Officer at REHVA

Frank Hovorka, who just became Past President of REHVA after handing the position over to Catalin Lungu a few days prior, delivered the keynote speech. The presentation focused on the need for accurate, reliable and transparent building data to enable in-depth digitalisation of the construction sector which is a key factor for creating trust between quality of building units and its value. Building passports were mentioned as a key tool to provide owners & investors a good overview of the performance of buildings in different indicators throughout its lifecycle, not just in terms of energy consumption but also in regards to IEQ indicators. These passports have to be able to provide dynamic data of measured performance, which can be fed into by open BIM tools and digital twinning that allows for simulation and real-time asset management tools.

This was followed with a presentation by the QUEST project coordinator Dr. Stefan Plesser (synavision GmbH) on why Quality Management Services (QMS) are essential to effectively transform Europe's building stock to become green. From construction to decommissioning, a building goes through several of stages of renovations which contain technical risks each time that can prevent optimal gains from the renovation. These technical risks can be mitigated by managing the quality of the works through dedicated services. The QUEST toolbox provides support to integrate several such services in building projects, i.e. Technical Monitoring, Building Commissioning and Green Building Certification, to help to de-risk green investments by mitigating the technical risks involved.

Ole Teisen (Sweco Denmark) continued with a demonstration on how QMS can help investors to align their building portfolios with the EU Taxonomy requirements. Technical Monitoring is a digital service that monitors if the target values, made during the design

Figure 1. Explanation about Quality Management Services by Ole Teisen (Sweco Denmark).

phase, are met during a trial period in the construction phase through logged data from the building's automation system. The Building Commissioning process goes deeper and covers all stages of a building process, with an in-person assessment by a third-party expert to assess if all requirements during the pre-design phase are met. This process can help investors to align with the Taxonomy since its requirements can be used as the basis for setting up the Building Commissioning process during the pre-design phase. The commissioning process will then ensure that during the construction phase the requirements are met by the time it goes into operation.

During the workshop's first panel discussion, on the topic of the EU Taxonomy, the barriers for the

Figure 2. Panel Discussion on Impact of Performance Gap with Frank Hovorka (Past REHVA President).

Figure 3. The QUEST Consortium at CLIMA 2022.

implementation of the Taxonomy were discussed. Two key barriers were highlighted during the discussions, both by the panel and the audience, which were:

- Uncertainty with financial investors on how to meet the Taxonomy requirements.
- Lack of reliable (accurate & transparent) building data.

The second part on Building Performance Gap started of with a presentation by Prof. Dr. Ivo Martinac (Royal Institute of Technology – KTH) on what this gap exactly was and which indicators this could impact (higher energy consumption than expected, higher operational costs, not meeting legal requirements, …) which all could have an influence on the financial value of building units. QUEST aims to provide a better overview of these issues through the QUEST Data Engine, which is a data set that collects building data that measures the performance of different indicators.

Cormac Ryan (COPILOT – Building Commissioning Certification) presented the QUEST Tool which is an easy-to-use tool that helps investors to calculate the financial added value of QMS into building projects and can help de-risk green building investments by ensuring that the pre-design requirements by investors/owners are met in building projects. ■

Workshop Report: Trigeneration systems based on Heat Pumps with natural refrigerants and multiple renewable sources

In this workshop the TRI-HP project aimed to bring together expertise from different areas with a focus on more technical discussions on trigeneration systems innovations, followed by a more social & policy level debate on the uptake of heat pumps. The first part were 7 short presentations which provided an overview of the TRI-HP objectives and innovations. This was followed by a discussion with two jury members who provided their feedback on the innovations and discussed them with the TRI-HP consortium members. The final session of the workshop focused more on the social and policy aspects of the market uptake of heat pumps with short statements from invited EU associations and comments this by the TRI-HP partners.

JASPER VERMAUT, EU Policy & Project Officer at REHVA

When providing an overview of the TRI-HP objectives, project coordinator Dr. Daniel Carbonell (SPF-OST) explained that the project aims to develop trigeneration systems that are based on electrically driven natural refrigerant heat pumps coupled with PV to provide heating, cooling and electricity to multi-family buildings. The technologies are currently still in a research phase which finishes in early 2023, after that they will be ready to be demonstrated at a larger scale before being ready to go to market in several years.

The two main systems that are under development were introduced. The first being a dual source/sink system that provides heating & cooling from ground- and air-sources for the Mediterranean climatic zone. The second is a solar-ice slurry system which is more focused on central Europe for heating with cooling as an add-on feature. This uses solar collectors as the only renewable heat source, combining it with ice-slurry as an intermediate storage when there's not enough solar. Both systems use an 'Advanced Energy Management System' which provides smart controls to ensure that energy costs are minimized and renewable share is optimised through a management algorithm based on model predictive control.

Figure 1. Presentation of the Solar-Ice-Slurry Heat Pump Systems by Maike Schubert (SPF-OST).

After the presentations the technologies were discussed with the jury who were Sylvain Courtey (President at Eurovent Certita Certification) and Zhecho Bolashikov (Environmental Research Engineer at Daikin Europe). The discussion covered different parts of the innovations:

- It was discussed that the ice-slurry system as a storage medium for heating has a potential cost reduction of 10% as it doesn't have the need for heat exchangers within the ice storage, as opposed to conventional ice storage tanks technologies.
- In terms life-cycle cost analysis it was mentioned that the ice slurry system was compared to a ground source heat pump system achieving same cost and efficiency with the added benefits of not needing space in the ground and not being regulated by water protection laws.
- The importance of awareness of the advantages compared to the barriers of such systems by local & national stakeholders was discussed as well. Where the high upfront investment costs, combined with the complexity of the systems, make the need for information towards investors a key component in the medium- to long term.

In the final part statements were made by Folker Franz (EPEE), Jozefien Vanbecelaere (EHPA) and Davide Sabbadin (EEB) on what is needed for the market uptake of heat pumps in Europe. It was stressed that with the raised ambitions by the EU there is an increased interest among the population and governments in support of heat pumps. This increases the need for policy support in terms of regulations and price control on one hand, and innovations that can accelerate the uptake on the medium and longer term on the other. The major barrier identified on the short term by both the presenters and the audience was the "lack of skills" among installers on heat pumps and the link towards other systems in the building. There is a need for a more structured plan from the EU on addressing the training needs in the different Member States for a smoother transition. ■

Figure 2. Presentation of Development of Natural Refrigerant Heat Pumps within TRI-HP by Dr. Alireza Zendehboudi (NTNU).

Figure 3. TRI-HP Consortium at CLIMA 2022.

Healthy Homes Design Competition Jury and Students.

First edition of the Healthy Homes Design Competition has been a great success!

This year marks the first edition of the Healthy Homes Design Competition. The competition, born out of the collaboration between VELUX and REHVA, encourages and challenges students within the field of building and buildings service systems, operation and construction to explore the theme of healthy living – and to create a deeper understanding of indoor environmental qualities as well as exploring the impact of future climate changes. The award celebrates and promotes excellence in projects with focus on people's health and indoor climate solutions in their living environments and at the same time balancing energy use.

The first edition was already a success; 18 teams submitted their great projects. The jury members, Karel Kabele, Jelle Laverge, Susan Roaf, Jakob Strømann-Andersen, Mieke Weterings, and Stefano Corgnati, selected 4 finalist teams. These teams were invited to the 14th HVAC CLIMA World Congress to present

Team LKMH, Levin Kümmerle and Martina Heilig, University of Applied Sciences Augsburg (Hochschule Augsburg) with Thorbjørn Færing Asmussen (VELUX representative).

Team re²THINK tank, Caroline Reich and Amelie Reiser, University of Applied Sciences Augsburg (Hochschule Augsburg) with Stefano Corgnati (chair of the Jury) and Thorbjørn Færing Asmussen (VELUX representative).

their work out of which then the jury selected the winner.

The winning team was announced during the closing ceremony of CLIMA World Congress 2022, on Wednesday 25 May and was awarded 5.000€. Congratulations to Martina Heilig and Levin Kümmerle, students from the University of Applied Sciences Augsburg.

The team that received the second prize and 3.000€ was from Aalborg University: Christian Rasmussen, Julian Graf, Nikolai Donskov Iversen, Mie Jansen, Mathias Vig. They were awarded 3.000€.

The third prize went to Caroline Reich and Amelie Reise, from the University of Applied Sciences Augsburg. They were awarded 2 000€.

The fourth finalist team was: Abel Sepúlveda Luque, Roman Smirnov, and María Dolores Donaire Galiano from Tallinn University of Technology.

Laura Denoyelle, from the Technical University of Denmark, received an honourable mention from the jury members for the out-of-the-box thinking she demonstrated in her project.

All the projects are available on the Healthy Homes Design Competition website (www.healthyhomes-designcompetition.com).

REHVA would like to congratulate all the students for their great work and wish them good luck in their future professional endeavours. A major thank you goes to VELUX for this great cooperation and sponsorship of the future minds in our field. ■

Team AAU Group 5, Mathias Vig, Christian Rasmussen, Nikolai C.D. Iversen, Julian Graf, Mie Jansen, Aalborg University with Stefano Corgnati (chair of the Jury) and Thorbjørn Færing Asmussen (VELUX representative).

The REHVA student competition and the HVAC World student competition

The REHVA student competition and the HVAC World student competition took place in Ahoy, Rotterdam on 21 May and 22 May during CLIMA Congress 2022. Seventeen students presented their work (the outcome of their bachelor or master's thesis). The event was hybrid as some students and juries could not travel to The Netherlands.

REHVA Student competition

On Monday 23 May, in Rotterdam, the students of the REHVA Student Competition presented their work to the jury members; Manuel Gameiro da Silva (Portugal – OdE), Francis Allard (France – AICVF), Robert Gavriliuc (Romania – AIIR), Pedro Vicente Quiles (Spain – Atecyr), Livio Mazzarella (Italy – AICARR), and Uwe Schultz (Switzerland – Die Planner).

From left to right: Rick Cox, Viktoria Nadas, Íñigo Martín Melero, Sylvain Courtey (Eurovent Certita Certification), Manuel Gameiro Da Silva

After careful examination of the students' work, the jury members deliberated and announced the winners: **Íñigo Martín Melero** (Spain) for his thesis on "Numerical Modelling of an Ultrasonic Evaporative Precooling Process of the Inlet Air of the Condenser for a Vapour Compression Refrigeration System". Congratulations to him! He was awarded 1400€.

The second place goes to **Amila Strikovic**, (France) for her thesis on "Reuse-LCA: Identification of the reduction potential of the environmental impacts of Swiss buildings through material reuse". She was awarded 800€.

The third place goes to **Viktoria Nadas** (Finland), for her thesis on "Advanced Design and Control Strategies to Optimize a Deep Borehole Field as Long-Term Thermal Storage". She was awarded 500€.

The 'Best poster' prize was awarded to: **Rick Cox** (The Netherlands), for his poster on "Forecast Driven Building Energy Flexibility using Battery Electrical Storage System". He was awarded 300€.

The Winner of the REHVA Student competition represented REHVA at the HVAC World Competition the next day.

HVAC World Student competition

On Tuesday 24 May, students from all over the world, winners of their national competition, presented their work to the jury members; Prof. William P. Bahnfleth (ASHRAE, USA), Prof. Jinqing Peng (CAHVAC – China), Prof. Manuel Gameiro da Silva (REHVA – Europe), Prof. Jin Hwa Jung (SAREK – Korea), and Prof. Junta Nakano (SHASE -Japan).

The winner is **Íñigo Martín Melero** (REHVA, Europe), for his thesis on "Numerical Modelling of an Ultrasonic Evaporative Precooling Process of the Inlet Air of the Condenser for a Vapour Compression Refrigeration System". He was awarded 1 400€

The second place goes to **Brett Stinson** (ASHRAE, USA), for his thesis on "Determining Airflows and Volatile Organic Compound Source Strengths for an Occupied School". He was awarded 800€.

The third place goes to **Mizuho Akimoto** (SHASE, Japan), for her thesis on "Effects of Bedroom Ventilation and Thermal Environment on Sleep Quality 2". She was awarded 500€.

Congratulations to all the students, we wish them the best for the future and for their career in the HVAC field.■

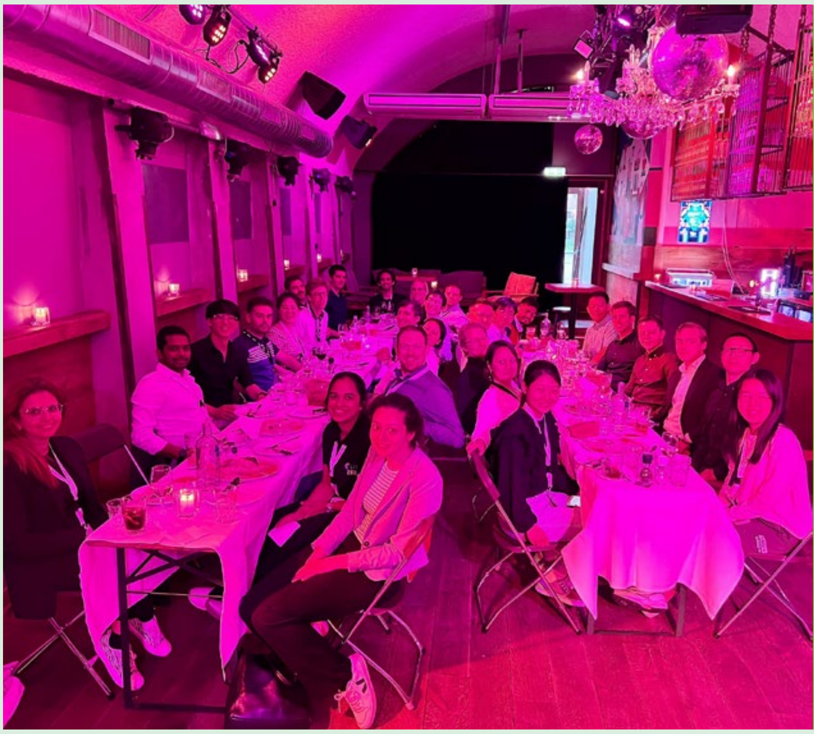
From left to right: Mizuho Akimoto, Brett Stinson, Íñigo Martín Melero, Sylvain Courtey (Eurovent Certita Certification), Manuel Gameiro Da Silva

The REHVA Community of Young Professionals met for the first time!

The 2020 born community of the Young Professionals of REHVA was finally able to meet for the first time in Rotterdam during CLIMA 2022! Some very cool activities happened for this special occasion.

On Monday, 23 May, the young professionals have met for dinner and drinks, following the Halton Band concert. While the day after, the RCYP has been sent off to the city to find the architectural jewels of Rotterdam in walking tour! Arash Rasooli, the coordinator of the RCYP said, "What a great first meet up we've had. It is refreshing to meet after the pandemic, considering we were born as a REHVA pandemic project. I am looking forward to see what's coming next for the RCYP."

We are excited that we could finally meet in person and see such an interest the RCYP. REHVA hopes that this community will continue to grow and help young professionals build their professional foundations and career. ■



The REHVA Community of Young Professionals is a community facilitating professional activities and knowledge exchange between young professionals (below 35 years old) in the fields of indoor climate management, HVAC and building services.

Are you…

- younger than 35 years old?
- experienced within the fields of indoor climate management, HVAC, building services, and other areas alike?
- a former REHVA student competition participant or active in a REHVA member association?

Make sure to join the community! https://www.rehva.eu/join-the-rehva-community-of-young-professionals.

Overview of REPowerEU Actions impacting HVAC & Buildings

In light of the Russian invasion to Ukraine the European Commission released an outline of the REPowerEU plan on 8 March 2022 to make Europe independent from Russian fossil fuels *well before* 2030. Two months later, on 18 May, they published more concrete proposals, guidelines and actions on how to implement this objective, which include a range of measures impacting the building sector. In this article you can find overview of the different proposed measures that impact the building sector within the REPowerEU publications.

JASPER VERMAUT, EU Policy & Project Officer at REHVA

Photos: shutterstock.com

Proposal to amend key Directives: EPBD, EED & REDII [1]

The Commission has proposed new amendments to these three key legislative acts as part of REPowerEU. This new (and smaller) set of amendments are in addition to what was proposed last year and are currently being negotiated under Fit for 55. The main rational behind them is to greatly accelerate the deployment of renewable energy and in particular solar installations in buildings. The Commission bases itself on a technical study ("RES Simplify") that was coordinated by DG ENER which identified the most common barriers in the administrative process of renewable energy projects.[2]

Energy Performance of Buildings Directive (EPBD)

Only one addition was made to the EPBD which was inserting a new article 9a on '*Solar energy in buildings*'. According to this new article Member States *shall* ensure to deploy solar energy installations on all **new public & commercial buildings** with useful floor area larger than 250 square meters 31 December 2026 and the same on **existing buildings of the same type & size** by 31 December 2027. From 2030 *all* **new residential buildings** should have such installations as well. The process for the installation of solar energy equipment, including solar installations in buildings, shall not exceed three months provided that their primary aim is not solar energy production.

To implement this the Member States shall define criteria at national level for the practical implementation of these obligations and establish possible exemptions for specific types of buildings. Meaning that this article will force Member States to accelerate solar installations but there is still a lot of leeway on how to implement this.

Energy Efficiency Directive (EED)

Within the EED the energy efficiency target for 2030 is increased from 9% to 13% compared to the projections of the 2020 Reference Scenario.[3] For more context on

this target, a technical study coordinated the Commission on energy savings potentials, published in August 2021, states that the EU's technical potential is up to 19% in comparison to the REF 2020.[4] On the other side, at the end of 2021 some Member States stated that they were already "extremely worried" about the 9% target proposed under Fit for 55 on July 2021.[5]

In the "Staff Working Document: Implementing REPowerEU"[6] it is stated that this increase of the energy efficiency target also impacts the scenario of the annual renovation rate, which would increase from 2% under the Fit for 55 scenario, to 2.25% in the REPowerEU scenario.

Renewable Energy Directive 2018 (RED II)

There are multiple amendments proposed to RED II. First, the **2030 target of share energy from renewable sources** in the gross final consumption has been **raised to 45%**, compared to the 40% that was proposed under Fit for 55 in July 2021. This target is put into more perspective in the abovementioned "Staff Working Document" where it's stated that the increase from 40% to 45% would also increase the following targets (that are related to HVAC & buildings, see full document for all targets):*

- **Heating & Cooling**: Average yearly increase of renewables for 2020 – 2030: from 1.5 percentage points to 2.3 percentage points;
- **District Heating & Cooling**: Average yearly increase of renewables for 2020 – 2030: from 2.1 percentage points to 2.3 percentage points;
- **Buildings**: Increase of RES share by 2030 from 49% to 60%.

* These targets show the needed increase between what was proposed under Fit for 55 in 2021 and now under the new RES target under REPowerEU.

To realise this target an acceleration of the uptake of renewable energy generation will be needed, which is why the other amendments focus on trying to remove **administrative barriers and simplifying the permit-granting process** for renewable energy projects. It is proposed that these types of projects receive the status of ***'overriding public interest'*** when balancing the different interest during legal cases over the permit-granting, meaning that they are seen as projects that contribute to "serving public health and safety".

To implement this, Member States shall establish dedicated **'go-to' areas for renewables** where the permit-granting process is simplified and shortened (the process cannot exceed 1 year). Also permit-granting processes outside these areas should not exceed 2 years. These amendments are complemented by a Recommendation for Member States on "speeding up permit-granting procedures for renewable energy projects".[7]

EU Save Energy Communication [8]

As a 'Communication' this document provides on one hand suggestions to Member States on how they could potentially cut up to 5% of gas and oil demand through short-term behavioural changes. On the other hand, and potentially much more impactful, it also provides an outline of **policy intentions regarding the phase-out of fossil fuel-boilers**.

It is mentioned that the ecodesign limits for heating systems will be made stricter which would result in the **phase-out of 'stand-alone' fossil-fuel boilers on the market by 2029**. In parallel the energy labels would be re-scaled **by 2025/2026** which will put **boilers and other fossil-fuel based appliances in the bottom energy classes**.

This can be strengthened by the **introduction of national bans for fossil-fuel boilers in existing and new buildings** by setting **requirements for heat generators based on GHG emissions**.

To tackle the financing of such systems the document mentions to **phase-out subsidies for fossil-fuel boilers in buildings as of 2025** as a minimum, while encouraging support schemes for heat pump systems instead. This would also impact the ongoing EPBD revision, where it's currently proposed by the Commission (in Art. 15) to phase-out financial incentives for fossil-fuel boilers from 2027 onwards.[9]

EU Solar Energy Strategy [10]

For the building industry it's important to note the "European Solar Rooftops Initiative" in this document, which sums amendments to the EPBD and RED II impacting solar rooftop installations. In addition, it encourages Member States to setup support frameworks for rooftop systems based on predictable payback times that are shorter than 10 years and that priority should be given to the most suitable buildings (EPC A to D) for quick interventions on the short term. This can be funded through the proposed new funding opportunities within the Recovery & **Resilience** Plans.[11]

Next Steps

These new proposals will need to be discussed between the European Parliament and the Member States in the Council in the coming months. Most of the REPowerEU proposals impact the ongoing negotiations for the Fit for 55 package and they will be integrated into this. This might extend the timeline of the current negotiations slightly but agreements are expected by the end of this year, especially on the package that was released in July 2021.[12] ■

References

[1] Proposed amendments to EPBD, EED & RED II: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2022%3A222%3AFIN&qid=1653033811900

[2] Technical Study "RES Simplify: https://op.europa.eu/en/publication-detail/-/publication/0e9db9fa-d653-11ec-a95f-01aa75ed71a1/language-en

[3] 2020 Reference Scenario: https://energy.ec.europa.eu/data-and-analysis/energy-modelling/eu-reference-scenario-2020_en

[4] Technical Study on Energy Savings Potential: https://op.europa.eu/en/publication-detail/-/publication/511bb328-f8b9-11eb-b520-01aa75ed71a1/language-en

[5] EURACTIV press release about EED and worries of Member States: https://www.euractiv.com/section/energy/news/energy-efficiency-law-too-ambitious-for-some-eu-member-states/

[6] Staff Working Document on Implementation REPowerEU Actions: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=SWD%3A2022%3A230%3AFIN&qid=1653033922121

[7] Recommendations for Member States on "speeding-up permit granting process for renewable energy projects": https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=PI_COM%3AC%282022%293219&qid=1653033569832

[8] EU Save Energy Communication: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2022%3A240%3AFIN&qid=1653033053936

[9] EPBD recast proposal by the Commission under Fit for 55: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021PC0802&qid=1641802763889

[10] EU Energy Solar Strategy: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2022%3A221%3AFIN&qid=1653034500503

[11] Proposed new chapters for the Recovery & Resilience Plans under REPowerEU: https://ec.europa.eu/info/system/files/com-2022-231_en.pdf

[12] Fit for 55 press conference in July 2021: https://ec.europa.eu/commission/presscorner/detail/en/ip_21_3541

EPBD Negotiations: Updates from the European Parliament

In December 2021 the proposal by the Commission for a recast of the Energy Performance of Buildings Directive (EPBD) was released in the second part of the Fit for 55 package. Since the publication stakeholders had the opportunity to provide their feedback until 1 April (see REHVA's feedback & proposed amendments to the proposal[1]) and the Council and Parliament have been preparing for the inter-institutional dialogues. Both the rapporteurs of ENVI (as advisory committee) and ITRE (as responsible committee) have released their draft reports on the proposal of which we give an overview here, going more in-depth on the latter report.

JASPER VERMAUT, EU Policy & Project Officer at REHVA

PHOTOS: SHUTTERSTOCK.COM

Draft opinion ENVI-rapporteur [2]

In early May rapporteur Radan Kanev released his draft for the advisory report of the ENVI committee, which ITRE as the responsible committee can take into consideration while drafting the position of the Parliament. The most notable proposed amendments were:

- A "pay-as-you-save financial scheme" which means a loan that guarantees that the repayment costs never exceed the energy saving on a monthly or yearly average (Recital, Art. 2, 8, 9 & 15).
- Changing the definition of 'deep renovation' as of 2030: It should either transform a building to a 'zero-emission building' or the best results that a renovation costing up to 50% of the value of the respective building could provide for (Art. 2).

Draft report ITRE-rapporteur [3]

The draft report of rapporteur Ciaran Cuffe was published early June and has not gone unnoticed with many ambitious amendments for a more comprehensive and rapid transformation of Europe's building stock compared to what was proposed by the Commission. Here follows a non-exhaustive overview of which we've noted as most noteworthy for the REHVA network. Consult the full document to see all amendments, in particular on social safeguards and how to protect the most vulnerable households.

Introduction of IEQ minimal standards

In Art. 1, on the subject matter of the Directive, the focus in the report is changed from "*indoor climate*" to "*indoor environmental quality*", showing a stronger commitment to health and comfort. This is strengthened by the addition of a new article 11a on IEQ which states that Member States shall ensure to set requirements for adequate IEQ standards, while the Commission is empowered to adopt a delegated act to establish a methodology for calculating the IEQ standards. Once these standards have been set at EU-wide level, Member States will have to ensure that buildings undergoing major renovation comply with minimal IEQ standards.

This strongly aligns with REHVA's earlier comments to the EPBD for the need for minimum IEQ requirements to be implemented at Member State level for which standard EN-16798-1 could be used as the basis.

In Annex V fixed sensors for monitoring the levels of IAQ also becomes mandatory to report on EPCs, if they're available. This is similarly in line with what REHVA asked for during the feedback round.

'Zero-emission building' requirement moved to 2025 + introduction of 'energy plus buildings'

In Art. 2 (§1, 19a) The rapporteur proposes to move the date for the deep renovation requirement to be turned into a zero-emission building to 2025 instead of 2030. In Art. 2 (§1, 3b) a definition for 'energy plus buildings' has been added which shall correspond to EPC Class A+ and with energy needs for heating, cooling, ventilation and hot water no higher than 15 kWh/m²/year.

Phase out of fossil fuel based technical building systems by 2035

In Art. 3(§1, 3d) Cuffe proposes that Member States should describe, within their 'national building renovation plans', phase-out plans of fossil fuel based technical building systems in existing building by 2035. This is repeated in Art. 11(§1, 3) that Member States shall set requirements of technical building systems *"… in line with phasing out fossil fuels in heating and cooling by 2035 at the latest."*

To impact the market on the short term already he also proposes new paragraphs in Art. 7 (§4a) and Art. 8 (3a) which state that Member States shall introduce national measures to prohibit fossil fuel based technical building systems in new buildings or those undergoing major renovations from the moment the EPBD recast would enter into force.

Stronger focus on embodied carbons & circular use

In addition, it's also proposed that Member States have to set national targets for circular use of materials, recycled content and secondary materials in their national renovation plans (Art. 3 (§1, 3b)). For new buildings also EU-wide targets are introduced in Art. 7(§4b), stating that by 2025 at least 15% of secondary locally sourced materials are used with the aim to double this by 2030.

Integrated district approach to building renovation

In a new Art. 3a Cuffe proposes to oblige Member States to provide more incentives to local & regional authorities to identify districts to roll-out Integrated Renovation Programmes (IRPs) at district level. Member States shall carry out comprehensive heating & cooling assessments & plans, in accordance with the EED, by 1 January 2025. In this assessment they have to include the refurbishment or construction of efficient heating & cooling systems and the required infrastructure as part of their district level IRPs. To facilitate the roll-out of district level solutions, Member States shall setup one-stop-shops that will coordinate the analysis of the district's social fabric and inform the design of IRPs with a view to revitalize, target and support communities.

Harmonised calculation methodology for life-cycle GWP

In a new paragraph proposed under Art. 7 (§2a) the Commission is empowered to adopt a delegated act by 31 December 2026 to setup a harmonized methodology for the calculation of life-cycle Global Warming Potential, building on the existing Level(s) framework, as well as the EU-wide life-carbon roadmap and Bill of Materials.

Stronger links with the New European Bauhaus initiative

In the new Art. 7a it's proposed that Member States shall empower local authorities to develop support instruments for reference buildings that are culturally enriching and are in line with the New European Bauhaus. These instruments may encompass financial schemes for renovations to showcase how individual buildings or whole neighbourhoods can be transformed into zero-emission buildings or districts in an affordable, sustainable and socially inclusive way.

More ambitious Minimum Energy Performance Standards (MEPS)

The ambition of MEPS are proposed to be increased:

- For both publicly-owned and non-residential buildings to have at least EPC D from 2027 (instead of F) and C from 2030 (instead of E) onwards;
- For residential buildings to have at least EPC D from 2030 (instead of F) and C from 2033 (instead of E) onwards.

Portfolio Mortgage Standards

New paragraph in Art. 15 (§4a) which empowers the Commission to adopt delegated acts to establish a common methodology for mortgage portfolio standards to align energy and emission performance of the portfolios with the EU's climate goals. This should provide stronger guidance for investments into a zero-emission building stock by 2050.

ZEB thresholds split into existing & new buildings

In Annex III the ZEB thresholds for existing building remain the same but for new buildings the thresholds are made significantly stricter in order to be considered as a ZEB. ■

References

[1] REHVA's feedback & comments to the EPBD Proposal, submitted during the feedback round: https://www.rehva.eu/fileadmin/user_upload/Policy_Tracking/EPBD_Revision_2021/REHVA_comments_on_the_EPBD_Recast_Proposal_March_2022.pdf.

[2] Draft opinion from ENVI Rapporteur Radan Kanev: https://www.europarl.europa.eu/doceo/document/ENVI-PA-731545_EN.pdf.

[3] Draft report from ITRE Rapporteur Ciaran Cuffe: https://www.europarl.europa.eu/doceo/document/ITRE-PR-732742_EN.pdf.

How does the Handheld Thermal Camera work in HVAC?

InfiRay® is committed to providing global customers with professional and competitive infrared thermal imaging products and solutions.

IRay Technology Co., Ltd, as known as **InfiRay®**, is the leading manufacturer of uncooled VOx thermal sensors. The company is headquartered in Yantai city, Shandong province, China, with over 1 500 employees and R&D staff more than 48%.

InfiRay® released the world's 1st 8μm 1920×1080 uncooled thermal detector. InfiRay® concentrates on developing infrared thermal imaging technologies and manufacturing relevant products, with completely independent intellectual property rights. Main products include VOx uncooled thermal detectors, thermal modules, and finished thermal cameras.

Thermal imaging cameras produced by InfiRay® have been applied in various fields, including epidemic prevention and control, industrial thermography, security surveillance, fire alarm and prevention, night vision and hunting, ADAS, AI, UAV, and machine vision, etc.

InfiRay® provides various products for different thermal imaging application scenarios in HVAC.

Air Tightness Detection of Buildings

On cold winter days, the air tightness of the house is of great importance. If there are gaps in the windows, doors or walls, the chill wind will blow into the house along the gaps, plummeting indoor temperature. InfiRay® handheld thermal camera can quickly locate the gaps in the walls, doors or windows by thermal imaging to figure out where the chill wind comes from, thus solving the problem of wind leakage and wind pouring in of the house caused by poor sealing, and timely blocking the cold wind outside to ensure the warmth inside. Thanks to the clear thermal imaging, InfiRay® handheld thermal camera can also inspect whether the thermal insulation layer in the professional refrigerated warehouse works normally, so as to prevent cold air leakage and the lowering cooling efficiency.

HVAC Operation Monitoring

Since it is difficult to monitor the temperature and airflow at the air conditioning outlet, the existing method is to measure the temperature on site. The real-time temperature of the outlet varies from the temperature change of the whole ambient, so it is necessary to grasp the temperature of the outlet in real time. InfiRay® handheld thermal camera can monitor the temperature of the air outlet of HVAC devices or wall by thermal imaging in real time, and the handheld thermal camera can monitor the wind direction and intensity from the HVAC devices.

Electrical Device Security Monitoring

As temperatures drop, there will be an increase in electricity consumption in both enterprises and communities. Whether power supply devices and electrical devices in the distribution stations work properly affects the production operations of the livelihood of the community residents. Once a possible accident happened, it can easily lead to power failure, voltage instability, and other electrical accidents. InfiRay® handheld thermal camera can timely discover a thermal defect and hidden thermal danger of electrical devices with the assistance of thermal imaging, thus preventing thermal accidents of the circuits and ensuring the security of electricity.

HVAC leakage inspection

As a nondestructive testing tool that visualizes temperature data by thermal imaging, InfiRay® handheld thermal camera can visualize the ground heat distribution, clearly observe the temperature of pipelines on the ground by thermal conduction of floor heating system, and quickly and precisely locate the leakage point once an abnormal temperature area is found. With the functions of thermal imaging and temperature measurement, handheld thermal camera can conduct regional scanning of leakage points, accurately and quickly locate underground leakage parts, and facilitate maintenance to reduce energy loss, ensuring normal heating in winter.

Pipe network/pipe leakage inspection

Pipe failures mainly include corroded pipe leakage and weld cracking, and corrosion leakage accounts for 98% of pipe failures. In case of failure, the location and construction will be very difficult, leading to huge economic losses. With the non-contact thermal imaging detection mode of InfiRay® handheld thermal camera, the steam pipe corrosion can be monitored in real time around the clock without interrupting the operation of heating equipment. Handheld thermal camera can visualize the thermal information on the inspected target surface instantly, and quickly locate faults, completing pipe inspection in a quick manner. It assists the maintenance personnel in completing the preventive maintenance of electrical equipment to reduce the threat of major leakage accidents in heat distribution/heating pipes.

Inspection for user-end heating equipment

The inspection mainly includes effect test/assessment/abnormal spot inspection for user radiators and floor heating system. The user-end heating equipment of the pipe network operates according to the seasonal cycle, and the equipment is idle for a large amount of time, which is prone to problems such as pipe damage and valve blockage. The Engineering Department of the heating company inspects the heating equipment by means of pressure test, temperature test and other methods before starting up, but the fault point and fault cause cannot be determined. With the temperature measurement and thermal imaging detection mode of InfiRay® handheld thermal camera, it is not necessary to contact the heating equipment, but the fault point is clearly displayed, realizing a simpler detection process. According to the temperature distribution of infrared images, abnormal temperature points can be accurately located, which is convenient for workers to investigate the fault points of heating equipment and improves the efficiency of investigation. With professional analysis software, the operators can conduct secondary analysis on the pictures of the scene, and save the temperature data; in addition, the software shows color alarms in high-temperature areas to help operators improve the investigation records.

Inspection for heat-exchange equipment in heating stations

Main heat supply sources are provided by the heating station where there are a large number of heat supply and exchange equipment, making it necessary to regularly maintain temperature control and heat exchange equipment. Damages and blockage of the pump body will seriously lead to the collapse of the heat supply network and a display of abnormal temperature points on the pump body. It can detect the heating equipment of heating stations in real time, and the linkage alarm mode can quickly find faults and offer timely maintenance.

Defect detection of valves in heating stations

Valve failure accounts for about 65% and compensator failure accounts for about 35%. Valve failures mainly include flange leakage, valve corrosion, switch failure, and poor closing, while flange leakage and valve corrosion are the main causes of valve damages. InfiRay® handheld thermal camera can be used to quickly obtain thermal images of the detection area and visually analyze the temperature of the area by accurate and clear thermal imaging. The infrared images of valves and heat pumps can be recorded according to the label number, and the infrared images can be subject to secondary analysis and intelligent data analysis. ■

Exhibitions, Conferences and Seminars in 2022

Conferences and fairs in 2022

July		
18-22 Jul	Smart and Sustainable Planning for Cities and Regions Conference (sspcr.eurac.edu)	Bolzano, Italy
August		
22-23 Aug	BuildSim Nordic (ibpsa-nordic.org)	Copenhagen, Denmark
September		
16-19 Sep	ROOMVENT (roomvent2022.com)	Xi'an, China
26-30 Sep	European Sustainable Energy Week (www.eusew.eu)	Brussels, Belgium
October		
2-6 Oct	Light + Building (light-building.messefrankfurt.com)	Frankfurt am Main, Germany
5-6 Oct	42 AIVC Conference (aivc.org)	Rotterdam, the Netherlands
11-13 Oct	Chillventa (chillventa.de)	Nuremberg, Germany
20-21 Oct	The Fifth International Conference on Efficient Building Design (ashrae.org)	Beirut, Lebanon
November-December		
17-18 Nov	REHVA Brussels Summit 2022	Brussels, Belgium
30 Nov - 2 Dec	53rd International HVAC&R Congress and Exhibition (kgh-kongres.rs)	Belgrade, Serbia

Seminars in 2022

July		
6 Jul	U-CERT & X-tendo final conference: enhanced and future-proof EPCs (rehva.eu)	Brussels, Belgium
September		
20 Sep	EUSEW extended session - Making building performance assessment transparent & holistic: ensuring a reliable and level playing field (rehva.eu)	**Online**
28 Sep	EUSEW session - Zero Emission Buildings: Climate neutral heating and cooling from Nuorgam to Rizokarpaso (eusew.eu)	Brussels, Belgium

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

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

AFCR – Romania
www.criofrig.ro

AGFR – Romania
www.agfro.ro

AIIR – Romania
www.aiiro.ro

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

Daikin Europe – Belgium
www.daikin.eu

EPEE – Belgium
www.epeeglobal.org

EVIA – Belgium
www.evia.eu

Velux – Denmark
www.velux.com

Granlund – Finland
www.granlund.fi

Halton – Finland
www.halton.com

Uponor – Finland
www.uponor.com

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

LG Electronics – France
www.lgeaircon.com

Viega – Germany
www.viega.com

Aermec – Italy
www.aermec.com

Evapco Europe – Italy
www.evapco.eu

Rhoss – Italy
www.rhoss.com

Purmo Group – The Netherlands
www.purmogroup.com

Royal Haskoning DHV – The Netherlands
www.royalhaskoningdhv.com

SMAY – Poland
www.smay.eu

E.E.B.C. – Romania
www.eebc.ro

Dosetimpex – Romania
www.dosetimpex.ro

Testo – Romania
www.testo.com

Camfil – Sweden
www.camfil.com

Fläkt Group – Sweden
www.flaktgroup.com

Lindab – Sweden
www.lindab.com

Swegon – Sweden
www.swegon.com

Systemair – Sweden
www.systemair.com

Belimo Automation – Switzerland
www.belimo.com

Arçelik – Turkey
www.arcelikglobal.com

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

REHVA Associate Organisations:

Enerbrain srl – Italia
www.enerbrain.com

Enviromech – United Kingdom
www.enviromech.co.uk

ISIB – Turkey
www.isib.org.tr

ECI – Belgium
copperalliance.org

OAER – Romania
www.oaer.ro

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