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Performance of ventilation

Zero-emission buildings in EPBD proposal

Aiming at good IEQ in cold climate

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A few words from the Editors

This issue focuses on technologies in the Nordic countries, where much attention has been paid to indoor environmental quality (IEQ) and energy efficiency for a long time. Requirements for indoor environment and ventilation may be high due to cold and dark winters. The principles for ventilation design for good indoor air quality are summarized by Wargocki et al., in a document from the Nordic Ventilation Group. Criteria for ventilation design, installation, and operation are implemented and regularly updated in the building codes of all Nordic countries. The latest update is from Denmark. The standard which is referred to in the Danish regulations is summarized in an article by Olesen et al.

A new proposal for the revision of the EPBD was published at the end of 2021. It includes several new requirements for the improvement of energy efficiency of buildings. The goal is to have only zero-emission buildings in EU by 2050. The draft EPBD suggests zero balance for annual primary energy use. An article by Kurnitski et al. critically reviews the draft and proposes, instead, to use the annual zero energy balance of non-renewable energy use as the criterion. Experimental research on zero-emission buildings through production of renewable energies has been going on also in the Nordic countries. Results from full-scale laboratory measurements used for simulation validation at the Zero emission laboratory in Norway are described by Nocente et al.

The major goal of the EU policy is to slow down the global warming, which, however, is still taking place. An article by Kosonen et al. shows how the predicted warming of the climate influences the future cooling capacity of A/C systems. New design weather data is needed.

Economical and environmental criteria for financing of energy renovations (taxonomy), are needed to ensure that the measures are cost-effective and sustainable. The quality of the indoor environment and the performance of ventilation should be included in these criteria. This has been done already in Estonia and is described in a summary by Kurnitski et al. From the building owner´s point of view the question is how to identify sufficiently profitable measures for energy renovation. The internal rate of return has been used for a long time, although still valid, to evaluate these measures as illustrated in an article by Abel.

The EPBD proposal has more focus on IEQ and ventilation than before. Now the ventilation systems are dealt with as specific technical systems with requirements for regular inspection and monitoring of the performance. Unfortunately, ventilation does not always meet the expectations. Results of a questionnaire on the performance of ventilation systems by Olsson et al. summarizes the opinions of various professionals on the status of ventilation in Sweden. An article by Holopainen et al. shows that inspections are needed not only for energy efficiency but also for the total performance of ventilation systems, with focus on IAQ. The cold climate sets its own requirement to the performance of ventilation equipment. This is well shown in an article by Kempe on frosting and performance of heat exchangers for heat recovery from ventilation air.

Ventilation also affects the spread of airborne infections. New and more effective ventilation systems are needed to meet expanded indoor environmental criteria. An article by Melikov et al. shows, with CFD simulations, how the risk of airborne infection can be reduced by improving room air distribution. However, it is important to check the performance of both new and traditional systems also in practice. The failures in performance of DCV systems in practice are illustrated in an article by Kosonen et al.

An index (TAIL) for evaluation of IEQ in existing buildings was introduced as a result of an EU-project some years ago. Now a method to use a similar index at the design stage of renovations (PredicTAIL) is introduced in an article by Wei et al. ■

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Recommendation from Nordic Ventilation Group*

Principles of ventilation design to achieve high IAQ

Guidelines for design, operation, and maintenance of systems used to supply and extract the air for ventilation

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These principles of ventilation design are based on the results of an EU project "HealthVent". Tentative guidelines were published in the REHVA Journal 2/2021, page 10 in an article by Pawel Wargocki. It was further developed by experts of the Nordic Ventilation Group and edited by Pawel Wargocki and Olli Seppänen.

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These guidelines are for securing high quality of air delivered to spaces by ventilation systems to maintain good and healthy indoor air quality in non-industrial environments (public buildings, dwellings) with human occupancy. Energy efficiency, structural strength, industrial processes, fire/smoke control, equipment, and other important properties of the ventilation system are not dealt with in these guidelines. Portable air cleaners and filters are not dealt with either. The guidelines are based on the documents produced during the EU-funded HealthVent project, which the Nordic Ventilation Group further developed.

The guidance is given in the following two areas:

I. Ventilation system functions and properties
  - I-I Supply and/or extract of the required airflow rate
  - I-II Air distribution
  - I-III System design

II. Commissioning and operation
  - II-I Commissioning and inspection
  - II-II Operation and maintenance

I. Ventilation system functions and properties

I-I Supply of the Required Airflow Rate

The systems should meet ventilation requirements to reduce risk for occupants through the entire lifetime of the building or the entire lifetime of the ventilation system (i.e., from the initiation to demolition). They have to be flexible and adaptable to the changes in the use of spaces or requirements regarding ventilation (demand-controlled).

The ventilation rates should reflect the actual needs and potential demands (based on the risk scenarios) which may change during operation; hence the design parameters should be selected so that reasonable flexibility and resilience would be achieved especially with regard to airflows.

The system should be balanced to prevent unnecessary pressure differences and transmission of air between different zones (spaces).

If a mechanical system is used for ventilation, there should be a contingency plan for ensuring ventilation (e.g., by opening the windows or other measures) in case of system failures. It should also allow blocking and shutting down the systems by the users and operators in the case of sudden severe deterioration of outdoor air.

I-II Air Distribution

Ventilation air should be properly distributed within the space that it is serving.

The systems should be designed to limit spreading of polluted air from less clean areas to areas with expected higher cleanliness. The systems to the extent possible should enhance the removal of pollutants from the source or its proximity.

The systems should minimize the risk of cross-contamination between occupants. The systems should decrease the risk of cross-contamination by ensuring proper ventilation efficiency.

I-III System Design

Low-emitting, certified and durable materials should be used in any system product/component used for ventilation. Emission from fibres and other pollutants from fibrous materials should be reduced to a minimum.

Systems must be properly drained and kept dry. Outdoor air intakes should prevent rain and snow entrainment. Condensation in the systems used for ventilation should be minimized to avoid microbial growth.

Air cleaning, and any products and technologies generating ozone in the systems used for ventilation should be avoided.

All outdoor air intakes, including openings for natural ventilation, should be located to minimize the direct entrainment of pollutants from nearby sources and exhaust openings.

The systems used for ventilation shall not become a source of nuisance and annoyance due to noise, vibration or draft at any time from the commissioning instant through all its service life.

The system used to supply and/or extract the air for ventilation must not create unfavourable or potentially harmful pressure differences over the building envelope or between rooms regarding the moisture and pollutant transfer from and through the structures.

The systems (ductwork) must be sufficiently airtight and controlled so that polluted air does not escape/flow from the system to the room air or the clean supply air. Supply air ducts must be sufficiently airtight so that the intended air quantity reaches the air terminal devices.

The systems must not circulate polluted exhaust air to the rooms or supply air so that air quality requirements in the room air are not met.

II. Commissioning and Operation

II-1 Commissioning and Inspection

The performance of mechanical ventilation systems should be verified at the commissioning phase and shall be granted by the deliverers/building owners throughout the service-life of the systems. This should include balancing in all control modes (e.g. unoccupied, normal and boost), and also the check of airflow balance between the zones to consider possible effects of toilet or kitchen or other separated exhausts.

The systems used for ventilation should be regularly inspected (retrospective commissioning) and maintained during regular operation. The inspections should include at minimum the same aspects as during commissioning and additionally examination of cleanliness, loading of filters, and the need for modifications and rebalancing in case of changing demands, layout, sensor location, zoning, etc. These obligations shall become the exclusive responsibility of the building owner.

Installation of the system and any changes in the existing systems should only be performed by the qualified/authorized personnel, best with the certification to perform such work.

II-2 Operation and Maintenance

Systems used for ventilation should be designed for easy and safe maintenance and operation. Operation instructions have to include advice on adjusting the ventilation rates based on the occupancy and strength of pollution sources. While demand controlled systems with regular and professional maintenance need are essential in non-residential buildings, more robust systems are favourable for residential buildings, typically maintained and operated by non-professional occupants.

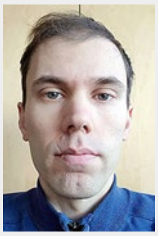
Systems and the components used for ventilation should be kept clean for the whole building lifetime. They should be cleaned regularly using certified products for wet and dry cleaning that do not elevate exposures.

Well-documented operation and maintenance instructions must always be provided for the building owner and user.

The ventilation systems must be operated and maintained by qualified personnel. Qualifications of operation personnel have to correspond to the complexity of the system. Continuous education programs should be implemented for designers, consultants, and facility managers, which besides technical matters, should address the connection between ventilation and exposures. ■

Operational challenges of modern demand control ventilation systems

– a case study

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To maintain proper indoor air quality and increase energy efficiency, a demand control ventilation (DCV) system has become a popular solution. While DCV systems offer benefits over constant air volume (CAV) systems, their technique is more complex than used in CAV systems. To guarantee the proper operation of DCV system, attention needs to be paid to check the performance of systems.

Keywords: demand control, ventilation, public buildings, fault diagnosis, post-occupancy evaluation, field study

Background

Buildings account for approximately 40 % of the world's energy and 36 % of global greenhouse gas emissions in the European Union [1]. To address this, EU directive 2018/844 requires that the whole building stock in the Union must be carbon-free by 2050 [2]. Ventilation accounts 20-40 % of the total energy consumption of a building. Thus, high performing ventilation systems is a key measure to reach the EU targets.

The DCV systems are designed to meet the demand caused by the changing heat gains and indoor air pollutants in the conditioned space [3–5]. By this way, it reduces outdoor airflow rates based on the occupancy, and thus saves heating/cooling energy and fan power.

DCV systems studied with field measurements

To analyze the actual performance of DCV, we performed field measurements in eight public buildings in Southern Finland.

We chose one representative space (**Table 1**) for monitoring from each building and these spaces consisted of meeting rooms (1, 6, and 8), offices (2, 5 and 7) and classrooms (3 and 4). Based on the ventilation design and control strategy, the spaces were classified into four types:

- Type 1 Space 1, 2, 3 and 4: all-air systems with two operation modes (normal and boost modes).
- Type 2 Space 5: all-air system with three operation modes (minimum, normal and boost modes).
- Type 3 Space 6 and 7: air-water systems with two operation modes (normal and boost modes).
- Type 4 Space 8: both all-air and air-water systems with two operation modes (normal and boost modes).

Analysis of airflow rate

The measurements indicate that there are a lot of faults in airflow rate balancing and operation of DCV systems. Almost all the measured ventilation systems have significant faults of the operation that normal facility management has not noticed. Also, there are deficiencies in the technical documentation and for some buildings, the design airflow rates were not available.

In Space 1 with the normal mode (**Table 2**), the measured supply airflow is more than double the design airflow, and it is 3.6 times higher than the exhaust airflow. In the boost mode, airflow rate is lower than the normal mode. Also, the supply airflow is 3.4 times greater than the exhaust airflow. The damper pair was opened in the normal mode but closed in the boost mode. Therefore, the damper pair is operated exactly the opposite way.

In Space 2, the supply airflows are close to the design values in both modes. However, the measured exhaust airflow rate is much higher than the supply airflow.

Table 1. *The control methods of the studied spaces.*

Space/area	Control of damper	Control of ventilation	Supply air temperature controlled based on
1 (meeting room/25 m^2)	ON/OFF	T + CO_2	Exhaust air temperature
2 (office space/25 m^2)	ON/OFF	T + CO_2+ boost button	Outside air temperature
3 (classroom/60 m^2)	Proportion	T + CO_2	Outside air temperature
4 (classroom/18 m^2)	Proportion	T + CO_2+ occupancy	Outside air temperature
5 (office/10 m^2)	Proportion	T + occupancy	Outside air temperature.
6 (meeting room/20 m^2)	Proportion	T + CO_2	Exhaust air temperature
7 (office/20 m^2)	ON/OFF	T + CO_2+ boost button	Exhaust air temperature
8 (meeting room/25 m^2)	Proportion	T + CO_2	Outside air temperature

Table 2. *Measured and design airflows for Type 1 spaces (all-air system).*

Space	Mode	Supply airflow [ℓ/s]		Exhaust airflow [ℓ/s]		Supply/ exhaust ratio
		Measured	Design	Measured	Design	
1 (meeting room)	Normal	118	50	33	50	3.6
	Boost	81	100	24	100	3.4
2 (study space)	Normal	58	50	76	50	0.8
	Boost	105	100	133	100	0.8
3 (classroom)	Normal	56	N/A	36	N/A	1.6
	Boost	143	180	81	180	1.8
4 (classroom)	Normal	102	54	117	54	0.9
	Boost	174	180	200	180	0.9

This lower ratio between supply and exhaust airflows leads to under pressure in the space.

In Space 3, the design values are not available for normal mode in the documentation. In the boost mode, the measured airflow rates are lower than the design values. The measured specific airflow rates are 0.9 ℓ/s/m² and 2.3 ℓ/s/m² in the normal and boost modes. Thus, do not fulfill the airflow requirements for classrooms of 3 ℓ/s/m² [6]. Also, the airflows are not balanced.

In Space 4, the measured supply and exhaust airflows are doubled to the design values in the normal mode. In the boost mode, the measured airflows are close to the design values. In Spaces 3 and 4, the airflows are too low to meet the minimum requirements.

In Space 5 (**Table 3**), the airflow rates are not possible to measure in the minimum mode as being outside the measurement range (<0.9 m/s) for the damper. This measurement clearly indicates that we have the challenge to check the wide range of airflow rates with the existing technology. It is difficult to find any method that makes it possible to measure the range that is nowadays commonly used in commercial buildings.

In Space 6 (**Table 4**), the design values in the normal mode were not available in the design documents. In the normal mode, unbalanced airflows lead to under pressure of 16 Pa. In the boost mode, the airflows are much lower than the designed values. In Space 7, the airflows are similar to the designed airflows in both modes and ventilation works properly in Space 7.

In Space 8 (**Table 5**), the measurements were only performed in the boost mode because the ventilation system constantly works in the boost mode due to the technical fault.

Monitoring during normal operation

As an example, the measured temperature, CO_2 concentration, and automation data were shown in **Figure 1**. When CO_2 concentration is above 750 ppm, other damper pair opens as designed. The dampers have also opened a few times when CO_2 concentration was below 750 ppm and the room air temperature was under 23°C. This is because that the boost mode was activated with the boost mode button by user. However, the measured exhaust airflow is much higher than the supply airflow.

Table 3. *Measured and designed airflows for Type 2 space (all-air system).*

Space	Mode	Supply airflow [ℓ/s]		Exhaust airflow [ℓ/s]		Supply/ exhaust ratio
		Measured	Design	Measured	Design	
5 (office)	Minimum	N/A	6	N/A	6	N/A
	Normal	22	17	16	17	1.4
	Boost	30	25	25	25	1.2

Table 4. *Measured and designed airflows for Type 3 spaces (air-water system).*

Space	Mode	Supply airflow [ℓ/s]		Exhaust airflow [ℓ/s]		Supply/ exhaust ratio
		Measured	Design	Measured	Design	
6 (meeting room)	Normal	38	N/A	49	N/A	0.8
	Boost	44	80	53	80	0.8
7 (office)	Normal	20	20	22	20	0.9
	Boost	38	40	45	40	0.9

Table 5. *Measured and designed airflows for Type 4 space (air water system).*

Space	Mode	Supply airflow [ℓ/s]		Exhaust airflow [ℓ/s]		Supply/ exhaust ratio
		Measured	Design	Measured	Design	
8 (meeting room)	Normal	N/A	N/A	N/A	N/A	N/A
	Boost	78	100	106	100	0.7

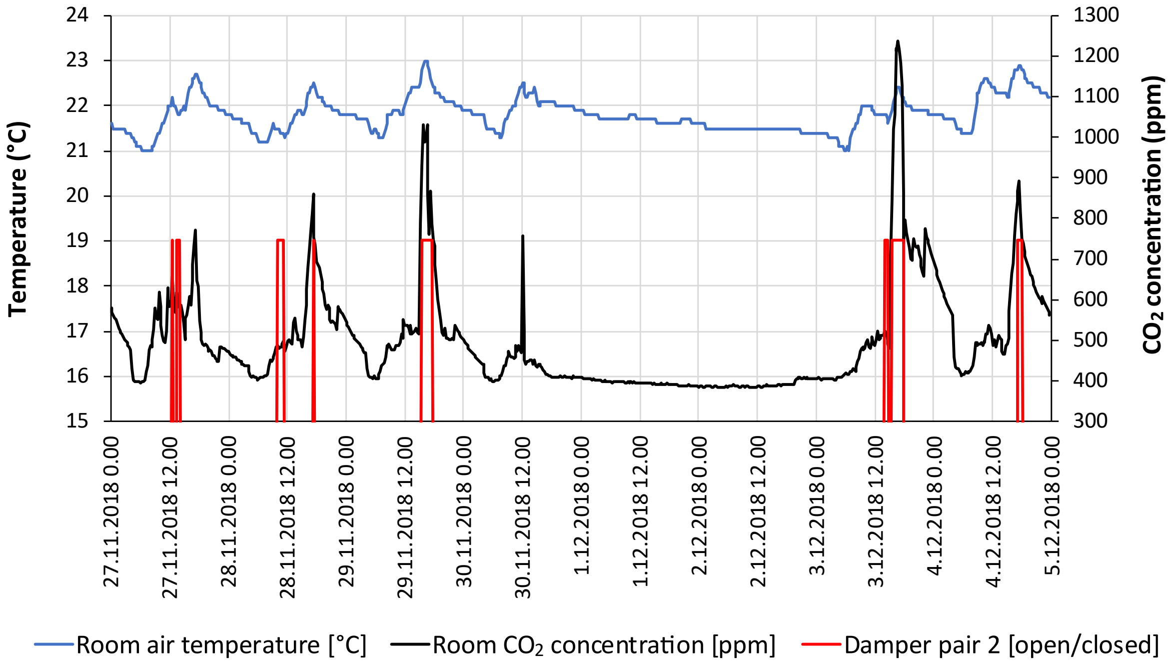

Figure 1. Performance of DCV system in Space 2.

The measurement depicts that only room air temperature and CO_2, it's not possible to determine whether the DCV system works in its design manner. The supply/exhaust airflow rates should be always also measured.

Conclusion

The results show that only one DCV system performs according to design values in eight public buildings. In all the others, either the airflows were wrong or there was technical fault. However, the indoor air temperatures were within design target values in each space and no complaints about IAQ or thermal comfort were reported by the users.

Two major conclusions can be drawn from this result. Firstly, different kinds of faults seem to be common in the DCV systems. Secondly, these faults are not easy to detect only with the automation system. To guarantee the system performance, post-occupancy evaluation of the system performance should be regularly carried out. ■

Acknowledgements

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BIPV in Nordic climate: **the ZEB Laboratory**





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The ZEB Laboratory, designed to be a test environment for building technology, energy use, ventilation, and user-building interaction, is an example of how to reach the ambition of Zero Emission Building (ZEB) through production of renewable energies. After the first year of use, real data are used to validate simulations.

Keywords: Solar Power, Zero Emission Buildings, BIPV, Renewable Energy, Measurement

Introduction

The laboratory/test building ZEB Laboratory [1] is located in Trondheim at the NTNU Gløshaugen campus. It is a 4-storey office building with a total area of 2000 m². The ZEB Laboratory was designed and realised with the aim to be a pilot building used to facilitate the diffusion of new environmentally friendly building components, solutions, and processes and as an arena for national and international research cooperation.

Norway, through the work of the ZEB Research Centre [2], defined five levels of nearly zero energy building as encouraged by the EU Commission [3]. The ZEB Laboratory was built according to the ZEB-COM level. This means that the *in loco* production of renewable energy (hence the reduction of potential emission) must compensate the CO_2 generated by the construction and the use of the building in its planned lifetime, and the CO_2 embodied in the materials. The construction process, the building envelope, building service systems, and materials and components used are selected to ensure very low construction, operational and embodies emissions as well as a highly energy efficient building [4]. The renewable energy production is entirely achieved by Building Integrated Photovoltaic panels (BIPV).

The PV installation in the ZEB Laboratory

BIPV panels constitute most of the building external envelope, as seen in **Figure 1**. The roof, the South façade and the pergola are entirely covered, the East, West and North façade are partially covered. This choice is not only due to the orientation of the building, but rather to the characteristics of the surroundings and their capacity to cast shadow.

The interest towards the use of vertically mounted PV has increased in the last years. They seem to be particularly promising for Northern climates. At these latitudes, in fact, vertical panels can gather solar radiation when the sun is low on the horizon while gravity helps to keep surfaces free from ice and snow. In addition, vertical panels can better capture scattered or reflected radiation that in some condition during the year can be preeminent.

Table 1 gives an overview of the whole installed solar power system in the ZEB Laboratory. A total of 701 monocrystalline panels of different type and shape are installed for a total power of 184 kWp. All the panels are connected in strings and to three inverter units. According to calculations performed in the design phase, the expected yearly PV production is estimated to be 156 MWh.

Table 1. *Overview of the installed PV panels.*

Surface	Panels [pcs.]	Area [m²]	Installed Power [kWp]	Type
Roof	280	456	98	Sunpower 350
North	30	53	11	Sunpower 375
South	132	144	22	Solarlab
West	73	80	12	Solarlab
East	144	156	25	Solarlab
Pergola (mono)	21	37	8	Sunpower 375
Pergola (bi)	21	37	5	Solitek
Total	**701**	**963**	**184**	

Figure 1. The ZEB Laboratory: Southern and Western façade.

The graph in **Figure 2** illustrates the yearly power balance as predicted by simulations during the design phase. As written above, the renewable energy production relies entirely on the PV. The production by the PV covers the heating demand by sustaining a twin heat pump system, and the electricity consumption in the building. The remaining energy is transferred to the local electricity grid, and it should compensate, in terms of equivalent tons of CO_2, the CO_2 emission related to the construction process and the CO_2 embodied in the materials.

The ZEB Laboratory was finished in 2020 and delivered at the beginning of 2021. After that, it went through a commissioning phase. The building is used as office space by NTNU and SINTEF and it has started to gather solar power and to acquire data. The data infrastructure was tested in the autumn, and in the winter started logging the first results.

Results

Winter results are particularly interesting since they constitute the "worst case scenario" and this is especially true for the Nordic climates. The winter season at Trondheim´s latitude offers few hours of daylight, and during these few hours the sun is low on the horizon.

The chosen period of investigation is one month from December 15th to January 14th.

In Trondheim (63°26´N 10°24´E) the day length during the chosen period varies from 4h20 around the solstice to 5h30 (Jan 14th). The sun elevation above the horizon is low, it spans from 3.3° to circa 5.5°. On January 14th the Sun rises at 141° South-East and sets at 219° South-West. To the low elevation and the short azimuth angle are to be added cloud coverage and snow coverage. The panels installed with an inclination can be covered by snow for a certain time. In the considered period, thanks to daily photographic observation (**Figure 3**), we could determine that snow covered totally or mostly the PV surface on the roof from Dec 23rd to Jan 11th. On the other hand, the presence of snow increases the albedo of the surroundings thus increasing the production of vertically mounted BIPV.

Although the worst-case scenario, data reported in **Figure 4** shows how the system can still produce a certain amount of renewable energy, for a total 232 kWh in one month.

Figure 3. Example of daily photographic inspection to evaluate snow coverage on the roof (Dec 15th to Jan 14th).

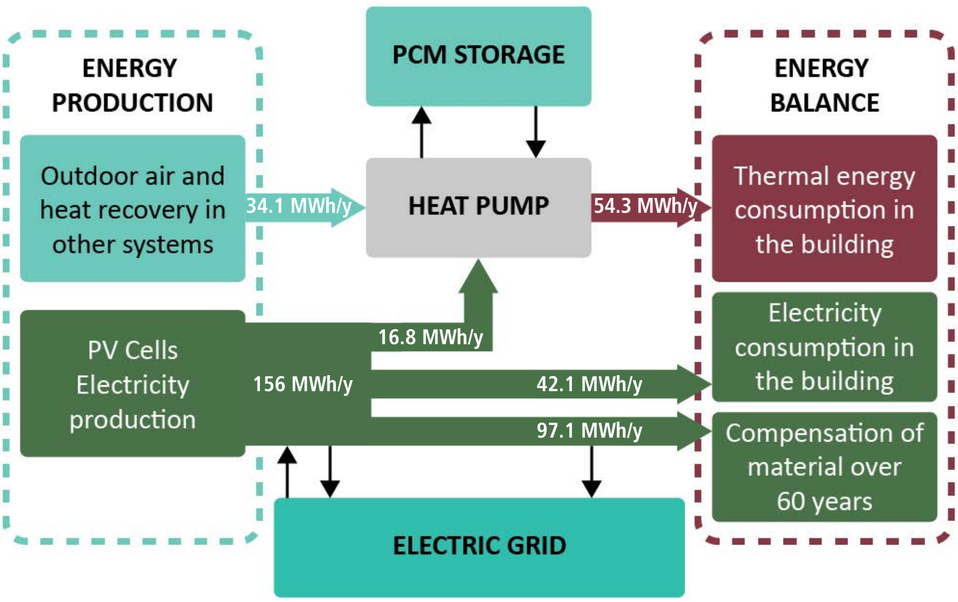

Figure 2. The overall energy balance of the ZEB Laboratory. [5]

The contribution of each surface is reported in **Table 2**. The table presents the percentage of installed power on each surface, the production, and the percentage of production during the investigated period.

It is interesting to look at the production of the North façade, here reported in **Figure 5**.

Although the available solar radiation is very low, and the PV panels of the North façade are those which are in the worst position, still they managed to produce circa 2.6 kWh during the whole period, a value comparable with the production of the monocrystalline elements of the pergola which have a slightly inferior installed power but are oriented towards South.

The first thing that can be observed is that the roof produced 41.3% of the energy despite constituting more than a half of the installed power. On the contrary the South and East façade produced in proportion more than expected from the share of installed power. This is due to the low elevation of the sun. By comparing the daily production data, it is also possible to relate this difference to the period of snow coverage.

Development in the research

This paper presented some preliminary results of the PV production on the ZEB Laboratory. The data acquisition will continue, and a larger amount of data will allow for a validation of the simulations performed in the design phase. During the winter an additional set of sensors was added to the ZEB Laboratory. This mainly consists of a pyranometer per façade and two weather stations: one on the roof and one at ground level. They allow for a better analysis of the solar resources, which in this paper was only based on the energy produced without comparing it to the actual solar energy available.

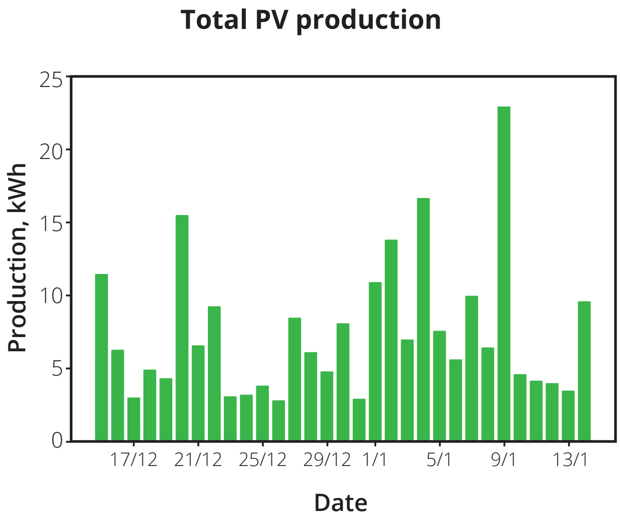

Figure 4. Daily PV production of the whole PV system during the investigated period.

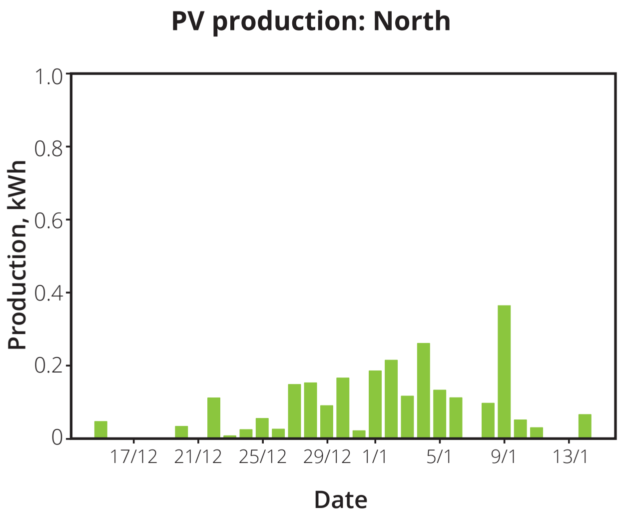

Figure 5. Daily PV production of the North facade during the investigated period.

Table 2. *Absolute and relative production of the PV surfaces in the ZEB Laboratory during the investigated period.*

Surface	Percentage of installed power [%]	Production [kWh]	Percentage of the production [%]
Roof	53.5%	95.8	41.3%
North	6%	2.6	1.1%
South	12%	47.1	20.3%
West	7%	20.6	8.9%
East	14%	52.3	22.5%
Pergola (mono)	4.5%	2.6	1%
Pergola (bi)	3%	0.9	0.39%
Total	–	**231.8**	–

The BIPV installations are part of a ventilated wooden façade structure. The correct ventilation of the structure is needed to keep the correct hygrothermal conditions. These conditions influence the temperature of the panels and consequently, since the efficiency of the solar panels depends on the temperature, on the power production and the reach of the ZEB-COM [2] ambition. On the other hand, PV panels with open joints introduce a challenge with regards to the rain tightness for Norwegian climate. These topics are under study both experimentally and by means of numerical models. ■

Acknowledgements

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Buildings Post Corona

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Buildings Post Corona is a Swedish collaborative research project between Chalmers, KTH Royal Institute of Technology, Lund, and Umeå Universities. The project supports the building sector in designing and maintaining sustainable buildings with a healthy and good indoor environment. The COVID-19 crisis has stressed the importance and urge of this research, which is financially supported by FORMAS*.

Systems approach

Climate change, with increasing periods characterized by extreme cold and extreme heat, place completely new demands on buildings and their systems for indoor climate. Also, the escalating global increase in CO_2 emissions is an aggravating circumstance, calling for a radical reduction of the use of energy within the building sector. At the same time, the COVID-19 pandemic has made it clear that we need to be careful when designing and using buildings in order to reduce disease transmission, hence ensure efficient ventilation performance.

* FORMAS is a governmental research council for sustainable development. https://formas.se

Thus, the building sector faces new challenges when designing, building, and operating buildings that are healthy, use limited resources, and are climate resilient.

The scope of the project is to develop a methodology for the operation and design of buildings with an indoor environment that meets future health and climate challenges. The project's overall goal is to establish an interdisciplinary platform to document existing experiences and knowledge and to gain new knowledge required for good building design and operation.

The project is formed around four sub-goals encompassing networking, methodology development, methodology evaluation and development of guidelines.

A network for collaboration

One of the project's overall goals is to establish an interdisciplinary platform for collaboration that gathers national academic expertise on healthy indoor environments. The idea is that the platform shall support decision-makers and that it will facilitate and promote holistic ways of working with the planning, construction, and maintenance of energy- and resource-efficient buildings with healthy indoor environments. An important task is to identify and open up laboratories and test facilities so that we in the future can do the necessary tests with the most appropriate infrastructures with minimum delays and cost. The idea is also to critically review current guidelines and ways of working related to the indoor climate and suggest updated guidelines and checklists for buildings owners/planners/contractors.

Methodology for design of sustainable buildings

Methodologies are needed to support design of healthy indoor environments and minimize the risk of disease transmission. The work includes demonstrating a combination of models for comprehensive evaluation of indoor climate and airflows to develop and optimize new or existing HVAC systems in terms of relative humidity (RH), temperature, and inlet and outlet specifications. Also introducing a machine learning approach to find optimal combinations of parameters from the perspective of combining the requirements of providing appropriate thermal comfort and reduce the risk of airborne infection and low energy use.

Methodology evaluation

In order to answer the research questions in this study, we will conduct qualitative and quantitative surveys of the effectiveness of solutions implemented to diminish the effects of heatwaves, the spread of airborne diseases, ventilation optimization, and energy minimization. Based on information gathered from the surveys we will choose solutions/scenarios, which according to surveys proved efficient and had positive outcomes. We will develop a test monitoring methodology for assessment of the chosen solutions for indoor air quality, comfort with a minimized spread of airborne diseases. Depending on the solution we will design either a set of measurement tests under controlled laboratory conditions or a methodology that could be applicable for field measurements e.g., in specific indoor environments of interest. A battery of measurement techniques will be used that encompasses measurements of not only the key pollutants of interest e.g., airborne particles (pathogen models), gas pollutants, CO_2 and comfort parameters T, RH, but also environmental parameters such as noise, draught (air velocities), ozone, which may impair the perceived indoor environment quality, but also initiate indoor air chemistry that may have negative health effects. We will perform the measurements of selected solutions and assess their effectiveness from the holistic perspective on indoor environmental quality. Cost and practicality of implementation of assessed solutions will be also evaluated. The outcomes will be

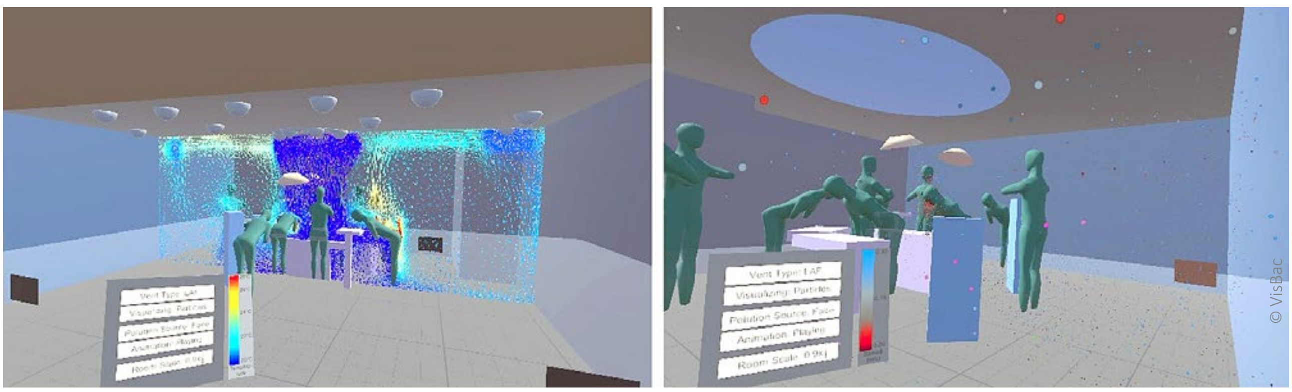

Figure 1. Visualization of airflow field (left) and airborne particle distribution (right) within the enclosed environment.

***Buildings Post Corona* -project participants in brief**

The division of Buildings Services Engineering, Chalmers, Gothenburg. This research team builds knowledge of system solutions for ventilation, heating, cooling, as well as control and regulation technology. The goal is to develop and disseminate knowledge about methods that contribute to good indoor environments in energy and resource-efficient buildings. The research is based on a combination of theoretical modeling, experiments in a controlled laboratory environment and field studies.

KTH Live-In Lab at KTH Royal Institute of Technology. A platform with several test beds in real environments for testing and researching new technologies and new methods. Through collaboration projects with industry, academia and society, KTH Live-In Lab shortens the lead times between research results and introduction to the market. KTH Live-In Lab spreads knowledge about technology, methods and systems that enable the smart and sustainable buildings of the future. KTH Live-In Lab accelerates the pace of innovation in the civil engineering sector.

The fluid and Climate research group at KTH conducts rich, interdisciplinary, and broad research with the aim of indoor air quality improvement and promoting occupants' health and wellbeing. Most of the investigation in the group comprises the use of numerical simulations which are a great compliment to KTH Live-In Lab experimental studies.

The aerosol laboratory at Lund University.has an advanced infrastructure for examining airborne particles in different environments. In addition to a wide range of techniques for measuring the biological, physical and chemical properties of pollutants and contaminants in the air, the laboratory also has rooms for controlled simulation of ventilation, climate and exposure. Researchers at the laboratory work, among other things, in close collaboration with healthcare on how infection is spread and can be counteracted.

The Center for Healthy Indoor Environments (CHIE) adds interdisciplinary expertise that combines technical, psychological and medical aspects to create healthy indoor environments. CHIE promotes methods for a holistic view with a focus on the residents' needs, health and well-being.

The energy efficiency group at Umeå University conducts research focusing on the end-use of energy and the indoor environment in buildings. The aim is to develop more powerful methods and methodologies for evaluation, validation, and control towards a better indoor thermal environment and air quality with increased energy efficiency.

The work is based on laboratory investigations and field measurements as well as on simulations of newly built and refurbished buildings. The research group has experimental equipment for field measurements, but also a laboratory at the university with a climate chamber and technical installations for experimental studies. Simulations are performed with both data-driven and physical models. Often, the research projects are interdisciplinary and often involve several different disciplines in energy and building construction technology, ranging from primary energy conversion (production), distribution, and energy end-use.

compared to model simulations where the gathered data and outcomes will be used for models' validation.

In addition, we will use Computational Fluid Dynamics (CFD) technique to predict, and visualize environmental factors, such as temperature, humidity, air motion and airborne particle distributions.

Guidance for best practice

Finally, we aim at packaging the knowledge and results from earlier stages, presenting the material to the network through a series of workshops and seminars. Also developing guidelines and checklists related to new State-of-the-Art building ventilation/geometry/control/sensing capabilities, as well as development of evaluation plans (technical strategy, identification of key actors) for final implementation. The work also includes consideration of societal impact and scrutinizing existing institutional settings (rules, regulations, law, norms).

The work is ongoing, and the scope is big. The project team invites REHVA and REHVA members to connect in order to sharing ideas and searching for opportunities to collaborate You can read more and find contact details at https://www.buildingspostcorona.se/participants. ■

Highlights of EPBD recast proposal – *aspects related to HVAC*

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The proposal introduces zero-emission buildings, deep renovation, minimum energy performance standards, harmonised EPC scale, hourly energy calculation method, monitoring and regulation of indoor air quality, inspection of stand-alone ventilation systems and a new vision to transform European building stock into zero emission buildings by 2050.

Keywords: EPBD recast, zero-emission building, deep renovation, national building renovation plan, minimum energy performance standard, monitoring indoor air quality

Energy Performance of Buildings Directive is in the third revision, the recast proposal (EPBD recast) was published in 15.12.2021, being a part of the "Fit for 55" package. The new directive may be expected by the end of 2022. The main new vision of the recast proposal is to transform all existing buildings into zero emission buildings by 2050. For this purpose, nearly zero energy buildings (NZEB) will be replaced by zero-emission buildings (ZEB) and existing major renovation is complemented with deep renovation, intending to ZEB level. The main new instrument to realize the ambition are *National building renovation plans* that are the next step from the present *long-term renovation strategies*. In these national building renovation plans, Member States (MS) must set targets for 2030, 2040 and 2050, including renovation rates, primary and final energy consumption, GHG emissions and to assure finance for renovation. It is said that the necessary decarbonisation of the EU building stock requires energy renovation at a large scale: almost 75% of today's building stock is inefficient according to current building standards, and 85-95% of the buildings that exist today will still be standing in 2050.

Deadlines for ZEB and improvement of worst-performing buildings

There are clear deadlines in the recast proposal to target new ZEB and for improvement of worst-performing existing building stock by defining minimum energy performance standards (MEPS). New public buildings shall be ZEB from 2027 and all new buildings from 2030. In ZEB, the very low energy demand shall be fully covered by energy from renewable sources. First time, Annex III of the directive sets threshold primary energy values for ZEB in three climate zones, from which national values cannot be higher. It is also required to move to hourly energy calculation that is set in Annex I.

The energy performance certificate (EPC) scale is planned to be harmonised so that class A is ZEB and worst performing 15% of existing buildings will belong to class G. Other classes are proportionally divided in between of these two and the same scale must be used both for new and existing buildings. This means that the major renovation requirements do not need to be class A. It is expected that MS stimulate class A renovation that is called deep renovation by financial incentives. Deep renovation is defined as NZEB before 2030 and ZEB as of 1 January 2030. There is a full article about financial incentives setting that MS have to provide appropriate financing and support measures to stimulate both deep renovation as well as mandatory renovation of worst performing building stock that is targeted with MEPS. MEPS require that public buildings will achieve EPC class F by 2027 and class E by 2030. The same requirement applies for other non-residential buildings. Residential buildings must achieve EPC class F by 2030 and EPC class E by 2033.

Indoor environmental quality and ventilation

Indoor environmental quality is stressed for both new buildings and major renovations by mentioning that the issues of healthy indoor climate conditions shall be addressed. When setting minimum energy performance requirements, taking into account indoor climate conditions, in order to avoid possible negative effects such as inadequate ventilation, was already included in the existing EPBD. There is a new requirement to equip zero emission buildings with measuring and control devices for the monitoring and regulation of indoor air quality. In existing buildings, the installation of such devices shall be required, where technically and economically feasible, when a building undergoes a major renovation. Regular inspection of heating and air conditioning systems is extended to stand alone ventilation systems. Ventilation systems are also specified as part of the EPBD measures aimed at addressing indoor air quality.

Methodology development

Energy performance levels for ZEB and as well as for major renovation requirements will stay to be based on the cost-optimality principle. Next cost-optimal levels calculation round in 2023 will be conducted with existing methodology and NZEB requirements that will stay in use until 2027 in public and 2030 in other new buildings cannot have the lower ambition than the 2023 cost-optimal level. By June 2026, the Commission plans to revise the cost-optimal methodology of minimum energy performance requirements in existing buildings undergoing major renovation, and 2028 cost-optimal calculations are to be done with this revised methodology. A review of the methodology should take into account extension of the emissions trading system (ETS), carbon prices and environmental and health externalities.

Life cycle carbon footprint (GWP with the Level(s) framework) is required to be calculated and reported in EPCs from 2027 for new buildings larger than 2 000 m² and from 2030 for all new buildings. This includes carbon footprint of building materials and products as well as operational energy and is for informing on the whole-life cycle emissions of new construction; there is no mention about possible requirements. Smart readiness of buildings is further developed by a mandate to the Commission to publish a delegated and an implementing act on a common Union scheme for rating the smart readiness of non-residential buildings above 290 kW effective rated output by the end of 2025.

Zero-emission building (ZEB) definition

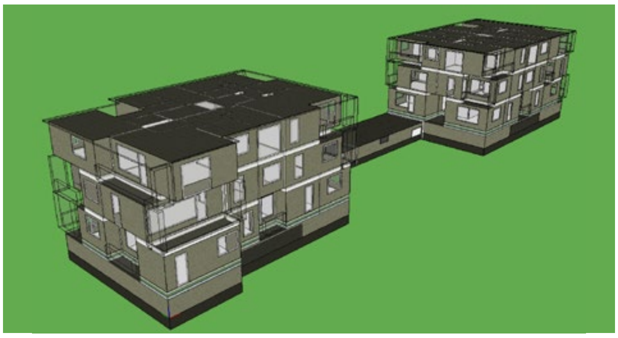
ZEB is perhaps the most fundamental issue defined as "the very low amount of energy still required is fully covered by energy from renewable sources generated on-site, from a renewable energy community or from a district heating and cooling system, in accordance with the requirements set out in Annex III". In Annex III, it is further specified that the energy to be fully covered is the total annual primary energy, for which maximum thresholds are provided in **Figure 1**. So far, the primary energy requirements have been based on non-renewable primary energy, following the cost-optimal regulation (EU) No 244/2012 and Commission Recommendation (EU) 2016/1318. To understand the meaning of the change from non-renewable primary energy to total primary energy, REHVA Technology and Research Committee prepared a calculation example shown in **Figure 1**.

In the example, Annex III ZEB requirements are applied to a NZEB apartment building in Nordic climate to check if and under which conditions these requirements could be fulfilled. The building configuration meets current Estonian NZEB requirements with district heating (DH) and ground source heat pump (GSHP) if PV generation is 16 kWh/(m² a). Air to water heat pump (AWHP) would need some improvement and gas would need major changes. **Figure 1** indicates the primary energy factors and CO_2 emission coefficients of energy carriers and renewable energy from the EN ISO 52000-1 standard, and estimated values for effective district heating.

EPBD Annex III limits the total primary energy in Nordic climate to 75 kWh/(m² a). **Figure 1** line "EPBD No 1" shows that the gas boiler is closest to reach this requirement when calculated without taking PV export into account in the primary energy. Heat pumps show the highest total primary energy values because the heat taken from the environment is included in the total primary energy (EN ISO 52000-1, total primary energy factor 1.0). If the exported PV electricity would be taken into account, the gas boiler total primary energy of 71 kWh/(m² a) will be the only one fulfilling the requirement. This result is not logical and the total primary energy values conflict with CO_2 emissions and non-renewable primary energy which are lower for district heating and heat pumps.

The second requirement in the ZEB definition ask to fully cover, on a net annual basis, the total primary energy use by renewables (without accounting renewables from the electricity grid). In this case, it is impossible to fulfil this requirement even if the maximum size of 24 kWh/(m² a) of PV that is possible to install to the roof is considered and exported PV is taken into account. At the same time, renewable energy covers non-renewable primary energy in the case of district heating and is very close to that with GSHP.

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	Energy use kWh/m² a			
		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	0	0	0	0	0
→	Non-ren. primary energy, kWh/m² a		44.7	72.6	51.7	64.2
EPBD No 1	**Total primary energy[2], kWh/m² a**		**91.9**	**82.0**	**100.9**	**109.0**
EPBD No 2	**Renewable energy[3], kWh/m² a**		**53.8**	**16.0**	**49.5**	**44.1**
→	CO_2 emissions, $kgCO_2$/m² a		8.8	14.4	9.4	11.7
	Energy cost[4], €/m² a		5.6	6.6	4.5	5.6

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. Comparison of NZEB building in Nordic climate and the zero-emission level.

Non-renewable energy and total primary energy calculation

To explain how the values in **Figure 1** were calculated, GSHP case is shown below step by step, all units in kWh/(m² a). Sum of all energy uses (all electrical, blue values in **Figure 1**) is 33.6 and the self-use of PV is 11.2. Delivered energy to the site is thus 33.6-11.2=22.4, **Figure 2**. As exported energy was not accounted, non-renewable primary energy is:

$$EP_{nren} = 22.4 \times 2.3 = 51.5$$

For the total primary energy calculation, also the heat extracted from environment needs to be taken into account, because it has renewable and total primary energy factor of 1.0. This additional energy flow of geothermal energy is shown in **Figure 3**. Because the exported energy was not accounted, only the self-use of PV is calculated in the total primary energy:

$$EP_{tot} = 15.1 + 18.5 + 16.0 - 4.8 + 22.4 \times 2.5 = 100.8$$

Renewable energy in EPBD recast proposal does not include the renewable energy from grid electricity:

$$RE = 15.1 + 18.5 + 16.0 = 49.6$$

It would be logical to account renewable energy from grid electricity, which will increase renewable energy by 22.4 × 0.2=4.5.

This calculation example shows that the details of ZEB definition are either not correctly understood or need some development. The use of total primary energy-based requirements seems not to be sound. Instead, ZEB should be defined based on non-renewable primary energy or CO_2 emissions which provide similar results. Renewable energy compensation calculation works well, but it is unclear why renewable part of grid electricity cannot be taken into account. ■

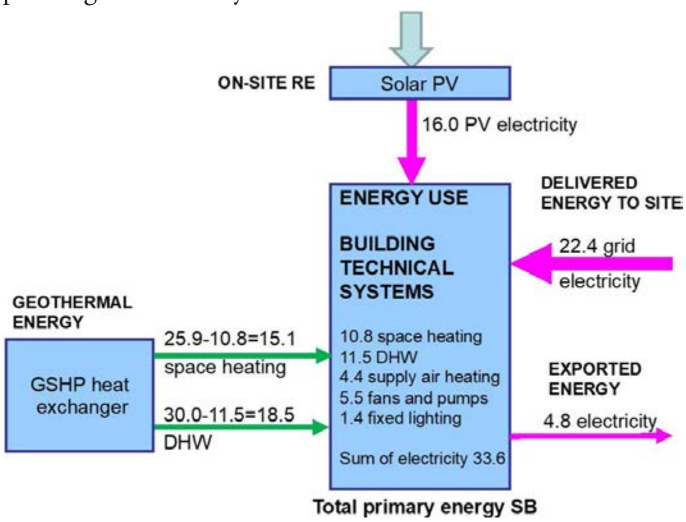


Figure 3. Energy flows for total primary energy calculation.

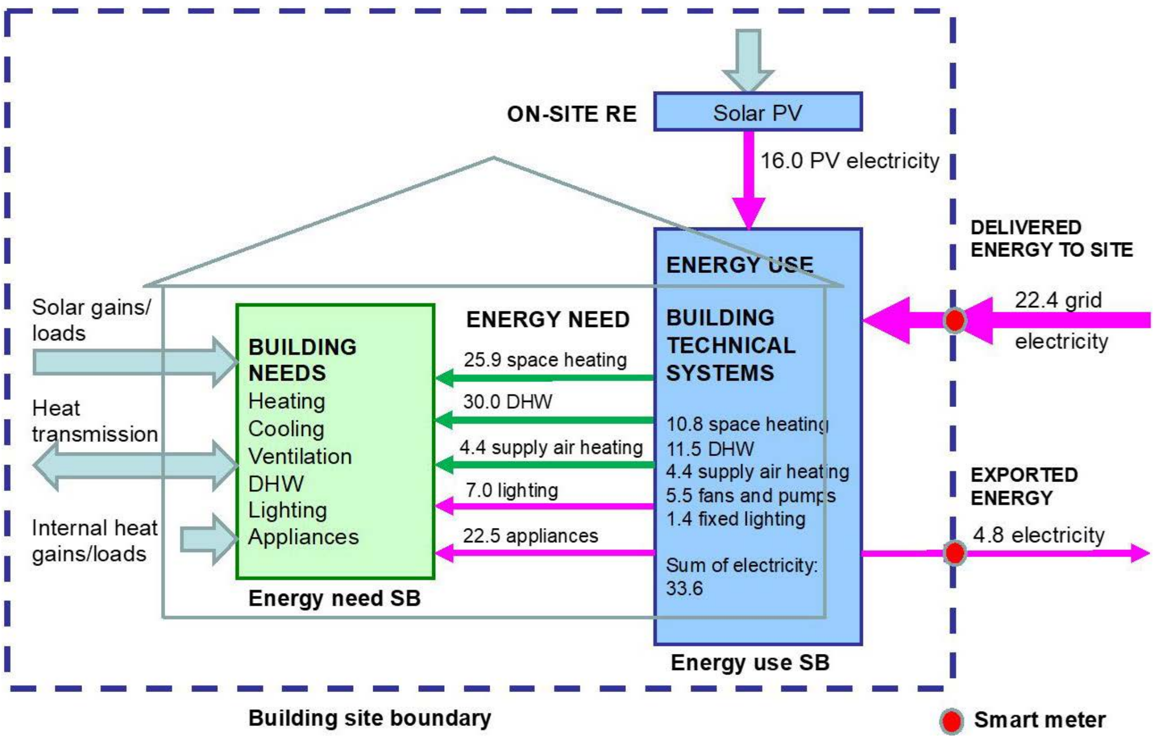


Figure 2. Energy flows for delivered and exported energy calculation. Note that internal heat gains (under energy needs) include the full lighting as well as appliances which are not included in EPB services but are used for PV self-use (otherwise PV self-use of 70% would be impossible).

Energy efficient rebuilding

Nowadays there is a well-motivated focus on the environmental impact of our buildings, the construction of new buildings as well as the operation and maintenance of already existing ones. Even if there is an extensive new construction of buildings going on, this accounts annually only for 1–2% of the building stock already existing.

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In most cases the construction of new buildings does not replace existing buildings, it only increases the building stock. The year 2050, i.e., 30 years from today, about 60–70% of all buildings will be the ones existing today. These will then still dominate the total environmental impact from buildings in operation. Independent of how minimal the impact of new buildings might be, the environmental load from the whole building stock will be decreased only if most of the already existing stock is substantially improved. It is a real challenge to carry out this since the required measures might be costly, and concern millions of buildings with owners willing, or forced, to finance at least a substantial part. A large-scale improvement of the existing building stock can be brought about only if it is economically feasible for the individual property owners.

The environmental impact of a building in operation is almost entirely determined by its need of different forms of energy. Only by carrying out measures to decrease this need, the environmental impact of the building stock can be lowered. However, to bring about a real cut, every measure taken, as well as the measures taken together, must be really energy efficient. This means that the resources used must lead to the greatest possible energy saving and also, what is most important, the function of the building must be preserved or improved. To ensure that, it is advisable to form an optimized package of measures, which, when implemented will result in the greatest possible increase in energy efficiency.

The savings can always be expressed in economic terms as a decrease of annual energy cost. The pricing can also be based on primary energy or energy related CO_2 emissions, but for the property owner, it is the bill to be paid that matters. The investments needed can be linked to the saved energy by established economic methods. In every existing building one can usually identify quite a few more or less efficient energy saving measures. They can be ranked into a package after profitability by the internal rate of return IRR (interest rate). In a graph with investment cost on the x-axis and annual saving on the y-axis, lines from origin represent the IRR, the value given by the slope of the line. By the annual energy cost saved and the investment needed, the energy saving measures identified can be shown in the graph and arranged after their profitability measured by the IRR-value.

Figure 1 shows an example. It is an about 5.000 m² office building. According to the building owner, the profitability of the project should be at least 5%, as applied by this company generally on long term investments.

The energy saving measures might have different economic lifetimes. Insulation of roofs and walls and new windows may last 30 years or more. For ventilation units, lighting systems, measures in the heating and AC systems, it may be about only 15 years. This can be accounted for by adopting the IRR lines to the difference in lifetime of the measures.

In the case shown in **Figure 1**, the building owner accepted that the profitability demand should be valid for the whole package of measures. After being implemented, all measures together, resulted in about 50% annual energy savings. In **Figure 1**, only the part of the package that meets the required profitability of 5% is shown. Other identified measures, as insulation

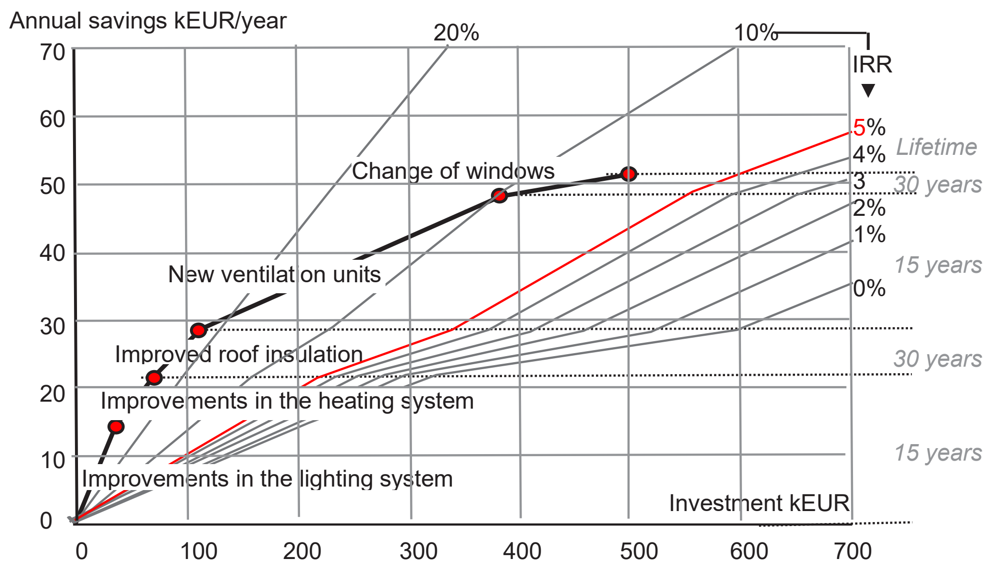

Figure 1. A package of energy saving measures in the IRR graph. The package did lead to 50% annual saving of energy.

of walls, are not shown since they, if included, would result in a package interest rate, IRR, below 5%. Naturally, measures as PV panels, solar collectors, heat pumps, etc., can be included in the package.

The method accounted for above, is nowadays widely applied in Sweden in energy saving projects in non-residential buildings as offices, schools, hospitals, etc. The basic principle is that the rebuilding has to be profitable for the property owner. In Sweden long time investments in the building sector yield a return of 7–8%. It is quite obvious that, at least in Europe, in the future the energy prices will increase noticeably. The refund from energy savings will increase. About 5% return on energy savings is often accepted by dominating Swedish property owners.

A prerequisite is that the package shown in the IRR graph is reliable, i.e., the real savings and the real costs after the rebuilding process will be close to those estimated beforehand. The identification of measures to be included in the package must be unbiassed. The energy savings must be predicted for each measure and in many cases, it must be done by simulations. A problem when simulating energy need of buildings is that some input data may be uncertain. By way of example: how and when are rooms occupied, how are lights used, what is the air infiltration through the building envelope, due to door openings and window openings, etc. Nowadays there is available, at least for commercial buildings, quite comprehensive statistic data about the energy use. These can be used for "tuning-in" the uncertain input data. By this the results from simulations usually become quite well in accordance with the ones obtained after rebuilding.

The reliability of the cost estimation is of course important as well. Experience from realized projects indicate that the real costs often tend to become higher than the estimated ones. This ought to be considered. The build-up of the package is a somewhat demanding task. There are quite a few quite detailed reports and papers about the process*. In Sweden there is also a course available.

The development of the method began about 15 years ago in Sweden, and it has been applied also in other Nordic countries. The method goes under the name The Total Concept and you can read more here: http://totalconcept.se/. ■

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Occupant targeted ventilation brings clean air to occupants

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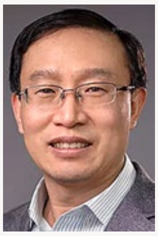

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The primary goal of room ventilation is to provide occupants with clean air for breathing. In this process, the distribution of the supplied clean air in spaces is of major importance. Occupant targeted ventilation, presented in this article, is the next, natural step in the development of room air distribution practice.

Keywords: advanced ventilation, air distribution, inhaled air quality, infection probability, design

Present ventilation practice

At present total volume air distribution (TVAD), primarily mixing ventilation, is most commonly applied in practice. This ventilation is also known as ventilation by dilution. The goal is to mix as completely as possible the supplied clean air with the polluted and most often warm room air and to obtain uniform temperature, humidity and contaminant distribution in the occupied zone of rooms. However, the strategy of TVAD is inefficient. Clean and cool air is supplied far from occupants, typically from diffusers located on the ceiling and is mixed with room air. The supply air becomes warm and polluted and possibly contains infectious agents exhaled by respiration activities of sick people before it reaches the occupants. The air distribution pattern of mixing ventilation enhances the transport of pollution generated outside of the occupied zone (e.g., from wall surfaces, etc.) into the occupied zone (**Figure 1**). Complex interactions of supplied ventilation flow, thermal plumes from occupants and buoyancy flows from cold/warm objects and surfaces (walls, windows) determine temperature, velocity and contaminant distribution in spaces. These interactions have a large impact on indoor air quality. However, it is difficult to control the interactions because they depend on the strength and changes in time of the heat loads distribution, the characteristics of the supplied air jets in their fully developed region (which are not easy to control), etc.

Design aimed at a uniform temperature and velocity in the occupied zone does not respond to the large differences between occupants with regard to the preferred environment. Therefore, occupants report often dissatisfaction with the indoor air quality and thermal conditions, though the recommendation prescribed in the indoor climate standards are met. The supply of large amounts of clean and cool air are needed to maintain temperature and pollution concentration at acceptable levels in the entire space (including unoccupied areas) leading to increased energy consumption and use of large and costly air handling and ducting systems. Flexibility in space use, which is an important requirement in many office buildings, hospitals, etc., is curtailed. Once installed, air supply devices can be difficult to reposition (except for some floor diffusers) in order to generate proper air distribution after the furniture layout is changed.

The stated above disadvantages of mixing ventilation call for the need to develop new ventilation methods able to provide a better indoor environment for occupants at reduced energy consumption. At the same time, the methods should provide efficient and smart control and flexibility in space use. Occupant targeted ventilation has the potential to fulfil these requirements.

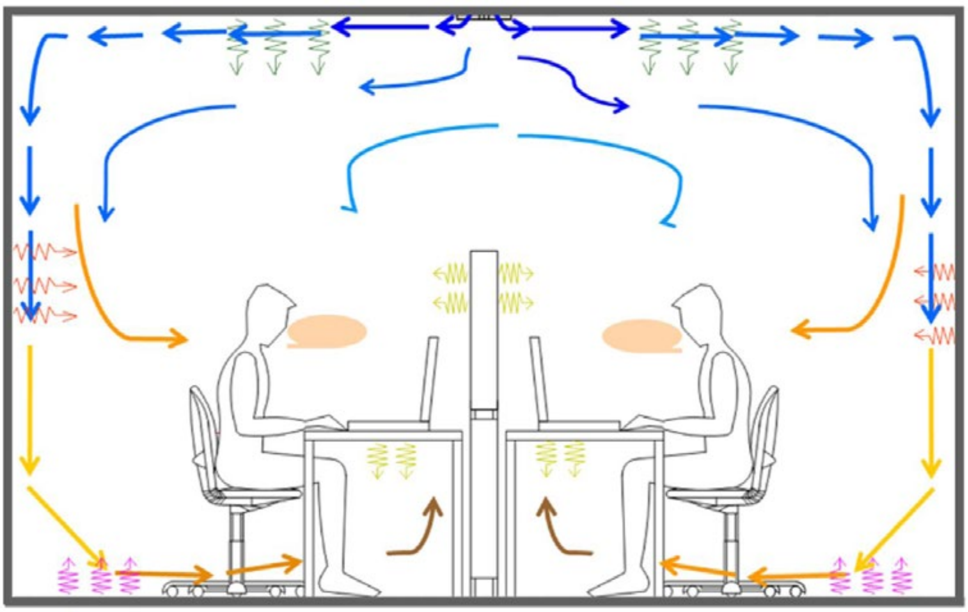


Figure 1. Mixing ventilation. Pollution generated by building materials and office equipment is mixed with the supplied clean air, transported to occupied zone and inhaled by occupants.

Occupant targeted ventilation: advanced air distribution

Occupant targeted ventilation (OTV) is based on the occupant centred principle with advanced clean air distribution [1]. The existing practice of air conditioning and air transportation is applied during the design. The OTV focuses on two important elements – health and comfort for individual and group occupants and non-uniform air distribution. Efficient control of the air distribution is an important advantage of targeted ventilation. OTV can be implemented in different spaces in hospital facilities, public buildings, shops, schools, etc. Two examples of OTV, namely localized chilled beam [2] and wall-attached ventilation [3] are shown in **Figure 2**. The performance of other designs and applications of OTV have been studied and reported in the literature: stratum ventilation [4], protected zone ventilation [5], personalized ventilation [6], localized combined radiant and convective microenvironment systems [7], etc.

Occupant targeted ventilation is the next, natural step in the development of room air distribution practice in occupied spaces after total volume ventilation (mixing and displacement). OTV is based on efficient methods and devices for air distribution to the target area, i.e. as close as possible to the breathing zone of single or group of occupants. Therefore, occupants breathe cleaner air compared to total volume ventilation. OTV has higher potential for reduction of the risk of airborne cross-infection compared to the total volume ventilation as well.

An important advantage of OTV is that its design considers the activities of each occupant or group of occupants, supply air demands, adjustability, functionality and flexibility according to the needs that may change in time and space. As already noted, some OTV methods are known and already used in practice; others are newly developed. Some OTVs utilize the existing design and implementation of air transportation to the spaces as used today for mixing and displacement ventilation. Therefore, its design and implementation in practice is easy for consultants.

Occupant targeted ventilation has the potential to perform better than total volume ventilation with regard to energy consumption. OTV is designed to focus on the changing in time needs and activities of each occupant or group of occupants. Therefore, the ventilation air can be supplied when, where and as much as needed. This principle may lead to a reduction in energy consumption.

Occupant target ventilation is occupant-centred. This allows more sophisticated and efficient control, including smart and intelligent control, compared to the control strategies for mixing ventilation. These control strategies make it possible to improve the micro-environment (inhaled air quality and thermal comfort) for each occupant (e.g., the localized chilled beam shown in **Figure 2**) and a group of occupants as well as to reduce energy use. Intelligent sensing of occupants' body physiological signals and positioning are used as feedback signals to control target ventilation [8, 9].

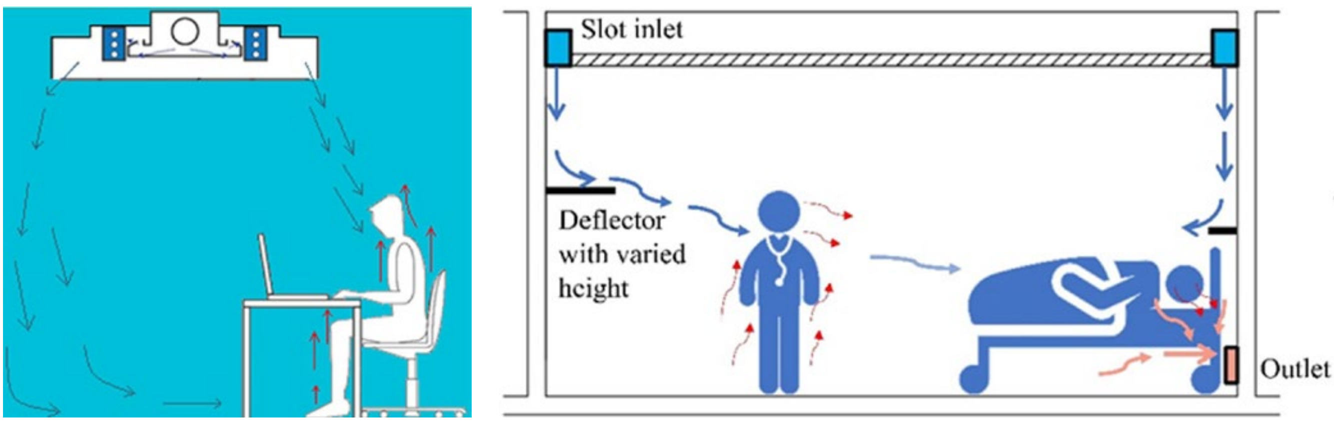


Figure 2. Examples of OTV:

Left: localized child beam with direction and strength of the supplied flow rate under the control of the occupant [2], Right: wall attached ventilation providing clean air to the breathing zone of the two occupants and removing locally the air exhaled by the patient [3].

Several solutions of OTV have already been implemented and performed successfully in practice. The coming soon new REHVA guidebook on Occupant Targeted Ventilation will present new solutions together with numerous case studies to help consultants and designers for the OTV to prevail in practice.

Performance of OTV

Considering the importance of COVID 19 pandemic at present, in the following, the performance of OTV for the reduction of the airborne cross-infection between occupants in an office room (length 10 m × width 5 m × height 2.7 m; 50 m^3) with 10 occupants (one infected occupant and nine susceptible occupants) is presented as an example. The room is ventilated by a supply of 118 ℓ/s (423 m^3/h) outdoor air, i.e., 2.35 ℓ/s m^3 (8.46 m^3/h m^3). The supplied air aims removal of pollution generated by occupants and pollution generated from building materials: 100 ℓ/s (360 m^3/h) corresponding to 2 ℓ/s m^3 (7.2 m^3/h m^3) is supplied for removal of pollution generated by occupants, i.e., 10 ℓ/s per person, and additional 18 ℓ/s (63 m^3/h), corresponding to 0.35 ℓ/s m^3 (1.26 m^3/h m^3), for removal of pollution generated by building materials (very low polluting buildings, category II – EN16798 [10]).

Four OTV methods, namely wall attached ventilation (WAV), stratum ventilation (SV), personalized ventilation (PV) and impinging jet ventilation (IJV), are considered (**Figure 3**). The methods employ non-uniform occupant-centred distribution of clean air supplied to spaces. In addition, the used at present mixing (MV), displacement ventilation (DV) and diffuse ceiling ventilation (DCV) are considered as well for the purpose of comparison. The geometry of the room, the layout of the ten workstations and the size and location of supply and exhaust diffusers are presented in detail in [11]. The layout in the simulated room, location of air supply and exhaust terminals and the simulated two positions (1 and 2) of the infected occupant are shown in **Figure 4**.

The Computational Fluid Dynamics (CFD) method, validated with full scale physical measurements, was used to simulate the office, the occupants and the studied air distribution methods. Based on the CFD simulations, the exposure of the susceptible occupants to the infected air exhaled by the sick occupant was calculated. The probability of infection was calculated using the modified Wells-Riley model considering the non-uniformity in the spread of the infectious exhaled air. The details of the applied method are provided in [11].

The simulation results related to the risk of airborne transmission are shown in **Figure 5**. The infection probability for the studied cases, including the two locations of the infected occupant, P1 and P1, for the WAV, SV and DV and one location, P1 (assuming symmetry in the room air distribution) for the IJV, MV, PV and DCV is compared. The median, the 25 and 75 percentiles, and the 5 and 95 percentiles are

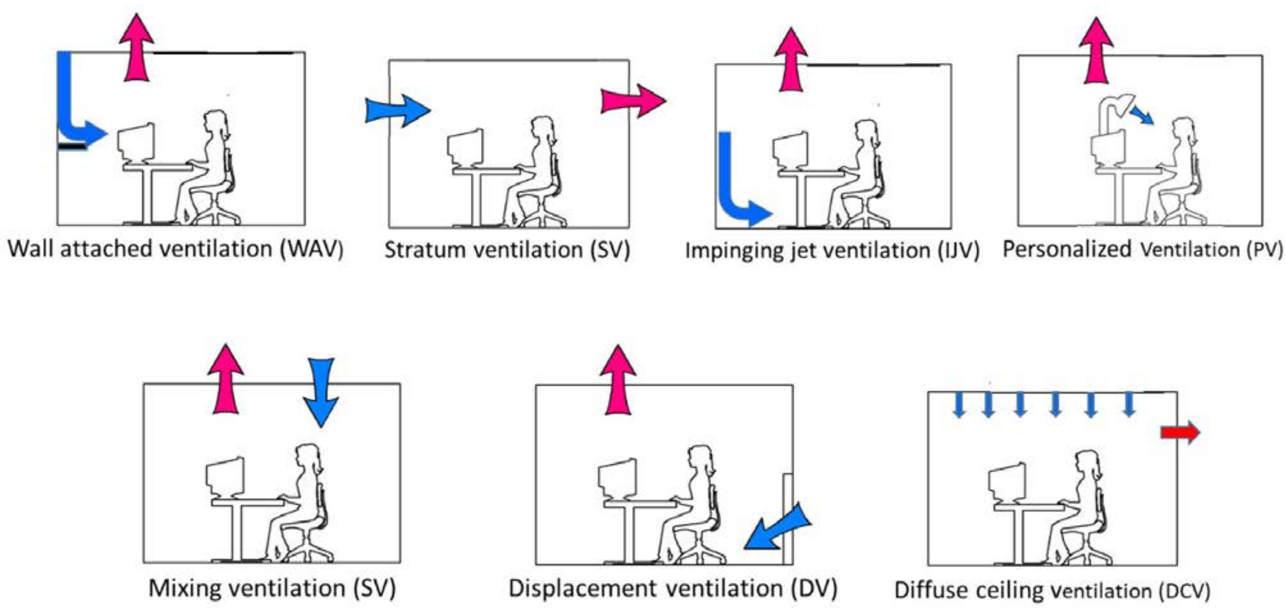
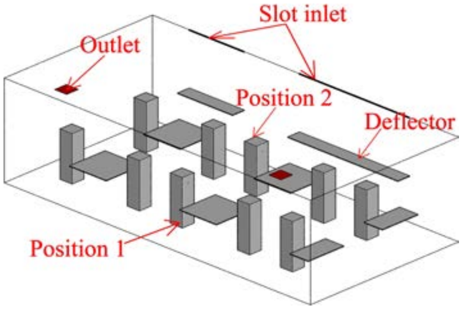
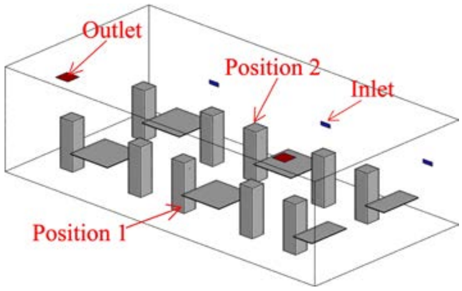


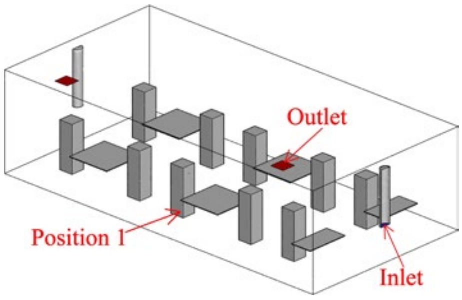
Figure 3. The simulated air distribution methods (blue arrows: supply; red arrows: exhaust).



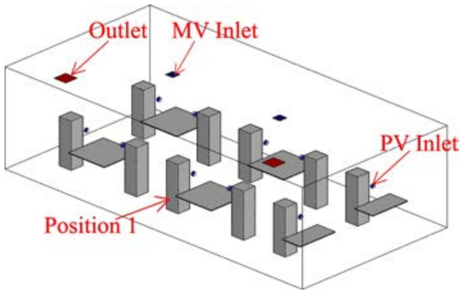
a) Wall attached ventilation (WAV)
Slot inlets 1&2: 1.8 m × 0.02 m & 3.6 m × 0.02 m (L × W)
Deflector 1: 1.8 m × 0.4 m (L × W), 1.2 m above floor
Deflector 2: 3.6 m × 0.4 m (L × W), 1.2 m above floor



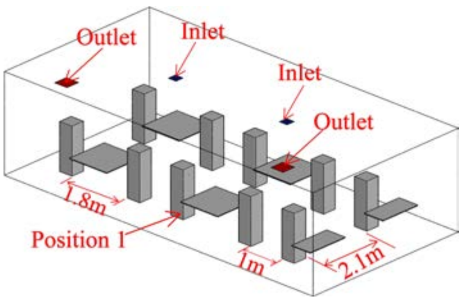
b) Stratum ventilation (SV)
Three inlets: 0.30 m × 0.10 m (L × W), 1.3 m above floor



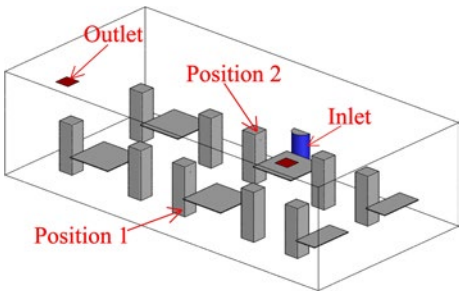
c) Impinging jet ventilation (IJV)
Semi-circular inlet: radius 0.15 m, 0.95 m above floor



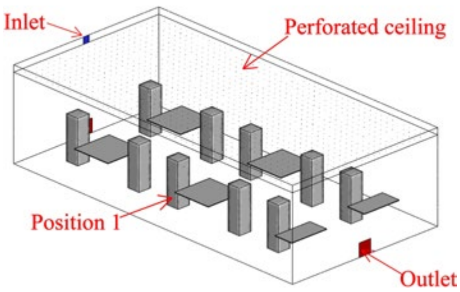
d) Personalized ventilation (PV) combined with MV
MV inlet: 0.25 m × 0.25 m (L × W),
PV inlet: radius: 0.06 m; 0.30 m
(in front of the face of each occupant)



e) Mixing ventilation (MV)
Ceiling inlet 0.25 m × 0.25 m (L × W)



f) Displacement ventilation (DV)
Semi-circular inlet - radius 0.25 m, height 0.97 m



g) Diffuse ceiling ventilation (DCV) with perforated ceiling

Figure 4. The simulated office room. Air supply and exhaust diffusers indicated respectively as "inlet" and "outlet". Outlet size in all cases: 0.2 m × 0.2 m (L × W)

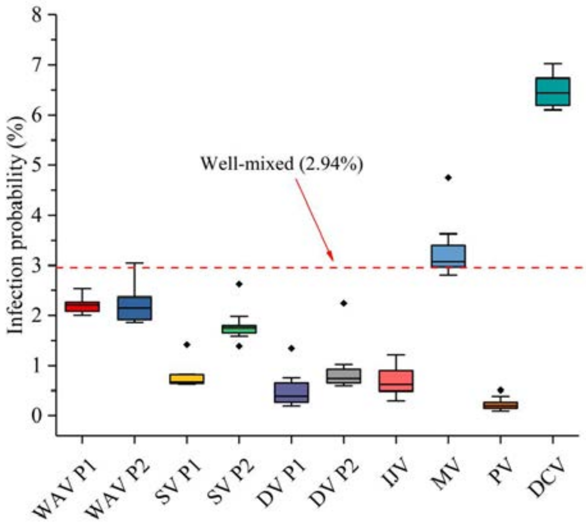


Figure 5. Infection probability at the faces of nine susceptible persons under ten simulation cases (maximum, minimum, quarter, three-quarter and median values are shown).

shown in the figure. The red dotted line indicates the infection risk predicted with the original Wells-Riley model when assuming perfect mixing of the supplied air with the room air [12].

The results in **Figure 5** show the potential of OTV methods for achieving lower infection probability compared to mixing ventilation (MV) and diffuse ceiling (DCV).

REHVA Guidebook on OTV

REHVA Guidebook on design of Occupant Targeted Ventilation is under preparation. The guideline will include design procedure and recommendations as well as cases of design and implementation of OTV in practice. ■

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Dimensioning of the cooling system in Finnish office buildings using the new cooling design days for the current and future climates

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This study aimed to investigate the dimensioning cooling power demand in the current and future climate in office buildings, using the new cooling design days for Finland. The results showed that, depending on future climate scenarios, the dimensioning cooling power demand will increase by about 5–13% and 7–17% with the air-water and all-air system, respectively.

Keywords: Office building, cooling demand, climate change, cooling power, thermal comfort

Climate change is mostly about the gradual increase in ambient temperature which is more serious in the northern areas [1]. Increasing temperature has an adverse impact on health [2]. Additionally, since the selection of outdoor design conditions is an important factor in determining the building cooling loads, changes in HVAC design should be considered due to climate change [3, 4]. In this paper, we investigate the dimensioning cooling power demand of office buildings in the current and future climate using the new cooling design days for Finland.

Methods

Studied building

The example building considered in this study is a six-story office building located in Helsinki. The geometry of the building is shown in **Figure 1**. The heated net floor area of the building is 5 744 m². It is assumed that the example building is located in a neighborhood, where it is surrounded by similar buildings. **Figure 2** shows the neighborhood.

The U-value of the external walls is 0.17 W/m²K. The window U-value is 1 W/m²K, g-value is 0.3 and direct solar transmittance (ST) is 0.35. The window to wall ratio is 50%. It is assumed that the building is occupied 7–18 weekdays. The occupancy density is 1 person per 20 m². Manually controlled blinds between the outer panes are used when solar radiation exceeds 100 W/m² on the window. The presence of the occupants corresponds with the activity in office rooms and meeting rooms.

The total annual electricity consumption of office appliances and indoor lighting are 22.4 kWh/m² and 18.6 kWh/m² per floor area. The space cooling setpoint is 24°C in all the spaces. The supply air temperature is 14°C in the rooms. Ventilation is controlled by CO_2 concentration and temperature in the all-air system and by just the CO_2 concentration of the room in the air-water system (**Table 1**).

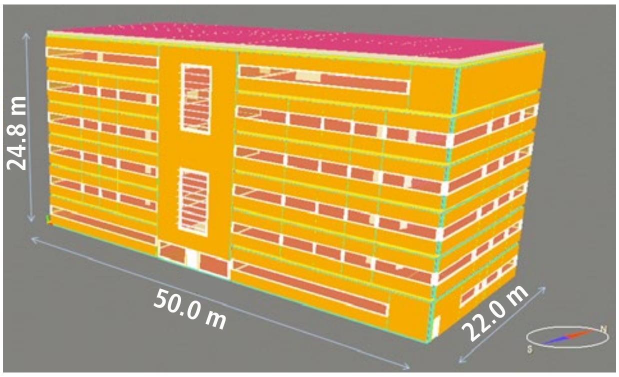

Figure 1. The geometry of the example building.

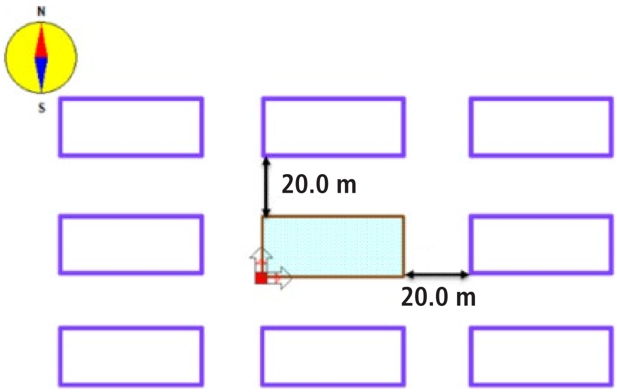

Figure 2. The surroundings of the example building.

Table 1. *Ventilation and cooling systems input data.*

System	Ventilation		Space cooling
	Main AHU	Basic AHU	
All-air	VAV: CO_2 and temperature control	CAV, 0.15 ℓ/s,m² Supply air temperature setpoint in the room: 14°C (Always on)	–
Air-water	VAV: CO_2 control Office rooms: min 1 ℓ/s,m² (if CO_2 < 600 ppm) max 2 ℓ/s,m²(if CO_2 > 900 ppm) Meeting rooms: min 1 ℓ/s,m² (if CO_2 < 600 ppm) max 4 ℓ/s,m²(if CO_2 > 900 ppm)		Radiant cooling panels

The space cooling in the air-water system is provided by radiant cooling panels on the ceiling. The difference between the average room air temperature and average water temperature difference at design condition is 8°C.

Climatic data and simulation tool

The new cooling design day for Finland has been chosen using SFS-EN ISO 15927-2 standard [5]. The design climate imposing a cooling load likely to be exceeded on 1% of the days (1% risk level) was determined for the current climate and for three future scenarios; 2030 under Representative Concentration Pathway RCP 4.5, 2050 RCP 4.5, and 2050 RCP 8.5. **Figure 3** and **Figure 4** show the outdoor temperature and enthalpy in the current and future design days. The maximum outdoor temperature varies from 30°C to 33°C. The maximum enthalpy is 65 kJ/kg on the current design day, and it increases up to 72 kJ/kg on the design day of 2050 under the RCP 8.5 scenario.

Simulation cases

The all-air system (VAV) and the air-water system (ventilation and radiant panels) are simulated using the current and future climate design days and with the test reference year of TRY2012 (June-August) Vantaa. TRY2012 describes the current 30-year average climatic conditions of Southern Finland [6]. The simulation is done using the validated dynamic building simulation tool IDA ICE 4.8.

Results

System dimensioning

The required radiant cooling panel power for each room with the air-water system and the required airflow rates with the all-air system simulated using the current climate design day are shown in **Table 2**.

The peak cooling power demand for the all-air system is higher than the air-water system by 18% with the

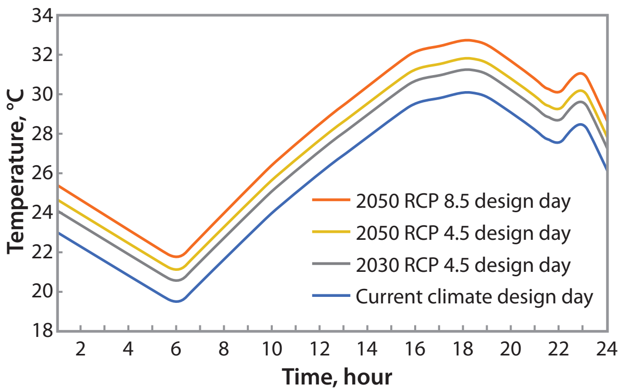

Figure 3. Outdoor temperature on the design days of Vantaa with 1% risk level.

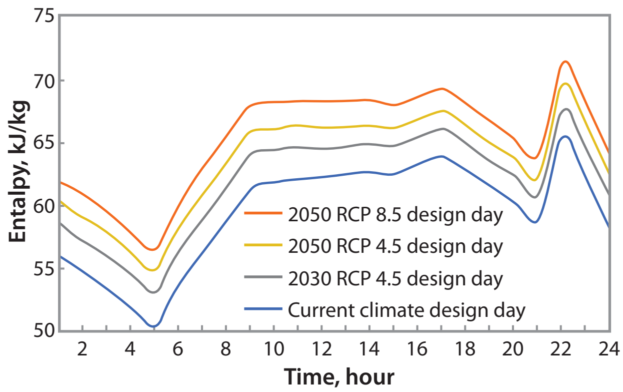

Figure 4. Enthalpy on the design days of Vantaa with 1% risk level.

Table 2. *The system sizing for air-water and all-air system with the current design day.*

Rooms		Air-water system	All-air system
		Power/room area (W/m^2)	Airflow rates
Meeting rooms	Min. power	10.5	VAV (CO_2, Temperature control) min 1 ℓ/s,m^2 (if CO_2 < 600 ppm) max 4 ℓ/s,m^2(if CO_2 > 900 ppm)
	Max. power	34.3	
Office room	Min. power	12.3	VAV (CO_2, Temperature control) min 1 ℓ/s,m^2 (if CO_2 < 600 ppm) max 2.5 ℓ/s,m^2(if CO_2 > 900 ppm)
	Max. power	31.2	

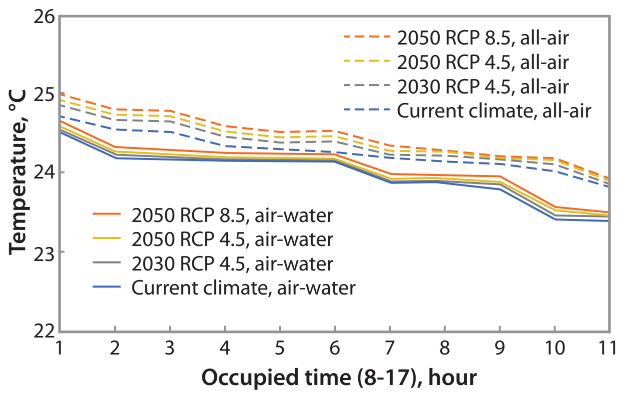

Figure 5. Indoor air temperature in the warmest single office.

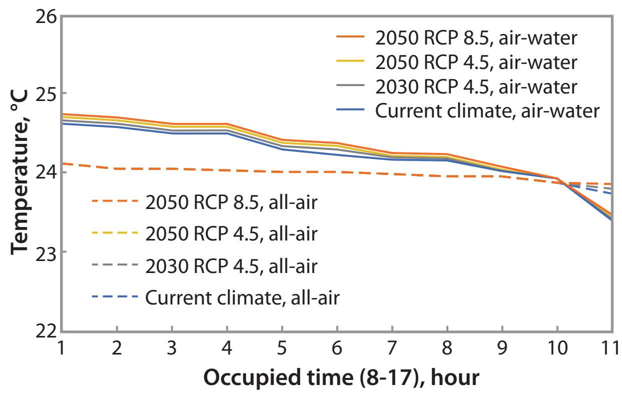

Figure 6. Indoor air temperature in the warmest meeting room.

Table 3. *Peak cooling power demand (kW).*

System		Current climate	2030 RCP 4.5	2050 RCP 4.5	2050 RCP 8.5	Summer (Jun-Aug) TRY 2012
Air-water system	Radiant panel	51.1	51.5	51.7	52.0	47.2
	AHU cooling	253.9	269.7	281.0	294.8	306.1
	Total cooling power	294.1	308.7	319.4	332.3	311.4
	Difference compared to the current climate design day (%)	–	5.0	8.6	13.0	5.9
All-air system	Total cooling power	348.1	371.5	388.2	408.0	329.7
	Difference compared to the current climate design day (%)	–	6.7	11.5	17.2	–5.3

current design day (**Table 3**). Additionally, the peak total cooling power demand of the air-water system increases by 5%, 8.6%, and 13% for 2030 RCP4.5, 2050 RCP 4.5, and 2050 RCP 8.5 (**Table 3**). For the all-air systems, these rises are 6.7%, 11.5%, and 17.2%, respectively.

The peak cooling power happens in August 2012 in both systems. In the first week of August, the enthalpy of outdoor air reaches about 70 kJ/kg. This explains the rise in cooling power demand in comparison to the current climate design day.

Indoor air temperature

Figure 5 and **Figure 6** show the duration curves of indoor air temperature for both systems on the current and future design days in the warmest office and the warmest meeting room. The office is warmer with the all-air system than the air-water system. While in the meeting room, the indoor air temperature is lower with the all-air system. However, the temperature is always below 25°C which was the target temperature of indoor temperature conditions [7], for all the weather conditions and the rise in the peak cooling power demand of the chiller can compensate for the rise of outdoor temperature in the future scenarios and the indoor temperature will be below the target value for future climate scenarios.

Conclusions

The simulated all-air system has higher airflow rates in some rooms compared to the air-water system with radiant cooling panels on the ceiling. This leads to higher peak cooling power in the chiller (18% in the current climate design day) than in the air-water system. The peak cooling power demand increases in the future design days and this increased level is higher for the all-air system. However, the indoor temperature conditions results showed that with the rise in future dimensioning power due to the outdoor temperature increase in future scenarios, the indoor temperature will be below the target value for future climate scenarios. ■

Acknowledgments

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New Danish standard for mechanical, natural and hybrid ventilation systems

Standards for ventilation systems are important for establishing design and dimensioning criteria to be used by consultants, installers, and manufacturing industry. It is important that such standards are up to date regarding technology, building regulations and other standards. Therefore, the Danish Standard DS 447 for ventilation systems in buildings has recently been updated.



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Keywords: ventilation, indoor air quality, standards, mechanical, natural, hybrid

Introduction

The Danish Standard DS 447 "Ventilation in buildings – Mechanical, natural and hybrid ventilation systems" has been revised and a new edition was published in January 2022. DS 447 is the governing system standard for ventilation systems and is referred to in a normative way in the Danish Building Regulations. Even though the building regulations refer to DS 447, the building regulations still contain requirements for ventilation in residential buildings, day care, and classrooms. DS 447 covers standardization on ventilation in buildings and ensures implementation of European standards for building ventilation and indoor climate.

Field of applications

The standard sets requirements for ventilation and ventilation systems in all types of buildings, intended for human occupancy.

The standard consists of the following sections and annexes:

Normative sections:

- Assumptions and input parameters for the indoor environment
- Mechanical ventilation
- Natural ventilation
- Hybrid ventilation
- Testing, balancing, handing over, documentation and operation

Informative annexes:

A. Examples of setting up indoor climate requirements and deviations (residential, office, school)
B. Ventilation efficiency
C. Draught rate
D. Dynamic calculation of concentrations of pollutants
E. Ventilation systems, designs and principles
F. Residential ventilation
G. Ventilation in large kitchens
H. Design methods for natural ventilation
I. Ventilation and spread of infection

The purpose of the standard is to ensure that ventilation systems are designed, installed, and can be operated and maintained in a technically, hygienically, and functionally sound manner, e.g., considering comfort and energy efficiency. The standard contains provisions regarding the design, execution, testing and operation of ventilation systems, as well as provisions for products and components used for the ventilation systems.

The standard includes normative parts, that must be met, and notes that give guidance and recommendations.

Assumptions and input parameters for the indoor environment

For the design the assumptions and requirements for the ventilation system in relation to system selection, atmospheric, thermal, and acoustic indoor environment, the users' ability to influence the conditions, and noise to the environment must be set at room level or room type.

Annex A gives examples of indoor climate requirements and acceptable deviations for typical building types / rooms. The basis for the recommendations is IEQ level II in DS / EN 16798-1: 2019 with the national Annex A (DK-NA: 2022). An example for the recommendations for the atmospheric environment is shown in **Table 1**.

During non-steady conditions like meeting rooms the volume of the room and the duration of the stay may be considered when determining the outdoor air supply (Annex D).

The recommended room temperatures for winter (heating, 1.0 clo) and summer (cooling, 0.5 clo) are based on DS /EN 16798-1 category II both for buildings with mechanical cooling/ventilation and building with natural ventilation and window opening. In the CEN standard there is no guidance for temperature criteria in the shoulder seasons (spring and fall). In DS the shoulder season is defined as periods where the 7-day running mean outdoor temperature is between 10°C and 15°C.

In this period the recommended operative temperatures are 21.5–25°C based on a 0.75 clo clothing. In offices due to a little higher physical activity on arrival at work, it is allowed to start with 1 K lower room temperature the first hour of use. This increases the potential for using night cooling and by night set-back start the heating later.

In the project the agreed deviations from the specified requirements should be documented according to the recommendations in DS /EN 16798-2.

Ventilation technologies

To achieve the requested indoor climate, different principal technological paths are available to the designer. For the former DS 447:2013, also available in English, the Danish standardization committee decided that both mechanical, natural and hybrid ventilation should be allotted equivalent sections of the standard, describing the technological requirements when a principal technological path has been chosen. Furthermore, as the purpose of the ventilation system is to achieve a certain indoor climate, it was decided that the requirements for the indoor climate had to be the same, regardless of technological solution.

This has proven a wise decision, as it gives the designer the freedom to choose type of system, but it has also given the customer the certainty that the system will fulfil the requirements for the indoor climate, regardless of system type. This important principal structure of the standard has been maintained in the new version DS 447:2021.

Design requirements

One key issue in the Danish market is that the design of ventilation systems is increasingly pushed forward in the value chain. Thus, it is often no longer the consulting engineer that design the system – they primarily describe the requirements on the resulting indoor climate and refer to legislation and standards. The actual system design is left for the contractor, who often has more scarce competences and resources for such a task.

Table 1. *Ventilation requirements in an office building. IEQ_{II} for very low polluting building.*

Room	Single	Open plan	Meeting	Source: DS /EN16798-1 & -2	Comment
Occupancy, m^2/pers.	10	15	2	IEQ_{II} Table B.6 /2	
Relative Humidity, %	25 < RH < 60			IEQ_{II} DS /EN 16798-1:2019 DK NA:2021, Table NA.16	Design de- and humidifier. Control of ventilation Absolut humidity < 12 g/kg
Ventilation, ℓ/s m^2	1,1	0,8	3,9	Part 2: IEQ_{II} Table B.6	Ventilation outside occupancy DS /EN 16798-1:2019 DK NA:2021 (NA.3.3.1)
Equivalent, Δ CO_2	529	454	722	Part 2: IEQ_{II} Table B.11	

To improve the quality of the installed systems, the standard has been expanded with the absolute minimum requirements for system design, in particular requirements for the project documentation, e.g., declaration of the design air flows on room level and through air inlets, specification of air distribution principles, heating/cooling capacities, also considering the room usage, geometry, orientation etc. Noise, energy consumption, space for service and maintenance and many more parameters must also be declared in the documentation.

Mechanical Ventilation

The mechanical ventilation chapter is updated and based on European standards.

The chapter on mechanical ventilation has undergone an important revision such that it now focuses entirely on system and product requirements. All requirements on balancing, air tightness testing, hand over etc. has been moved to a new chapter focusing on the handover stage of the project life cycle.

For the mechanical ventilation chapter, European standards form the principal basis for all requirements and key elements are included in tables. It was discussed whether a revised new Danish ventilation standard was at all needed, since we now have relevant European standards for the entire topic. The conclusion was that the stakeholders in the Danish building industry would benefit from a standard in Danish, containing core requirements, tables, and content, and providing an overview and references to all the relevant European standards.

The chapter has been expanded a few places where the technological and market developments has proven this to be necessary, see **Table 2**.

Natural ventilation

Natural ventilation is defined as *ventilation which utilize natural driving forces.*

The main aim of the natural ventilation chapter is to secure that the system is being well designed, installed, operated, and later in chapter 9 maintained properly. The focus for this recent update of this chapter was to implement a set of minimum documentation levels to be full filled.

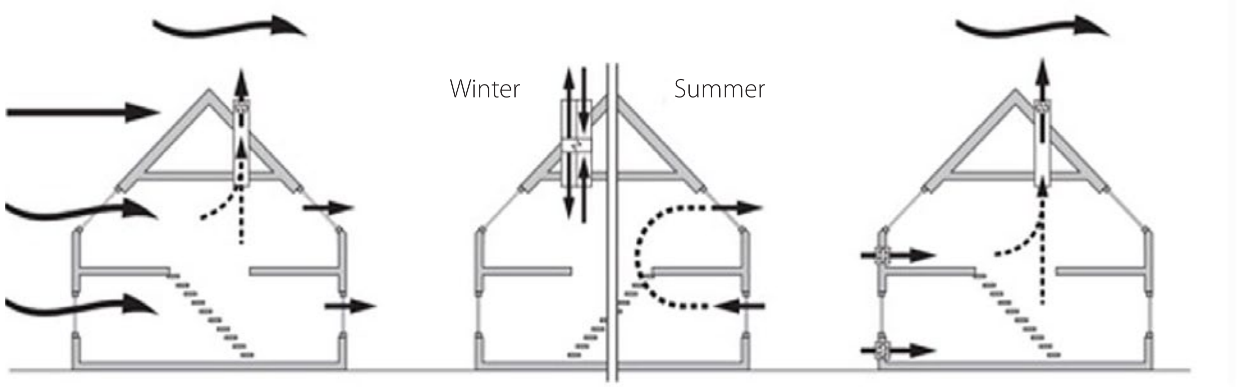
One important aspect is the design stage which now includes methods such as analytic and dynamic simulations. For the specific project calculation, you need to state and include parameters like ventilation principle, pressure coefficients, control of the openings, effective opening areas at maximum and common operating modes etc.

Natural ventilation needs to be automatic controlled to secure the basic ventilation rate. The opening degree of the openings needs as a minimum to be determined based on the wind effect as well as indoor and outdoor temperatures as these are the driving forces. Different operating strategies like nighttime cooling and intermittent ventilation (pulse ventilation) shall be included in the control strategy of the natural ventilation system for winter, summer, and the transition period.

Requirements to components, ducts and shafts, sensors etc. is also an important part of this section.

Table 2. *Some examples of expansions implemented in the new Danish standard, and their motives.*

Expansion implemented	Motives
A more detailed list of requirements for the accessibility and space requirements for components has been included.	Projects often do not assign sufficient space for service and maintenance.
More strict requirements on the exhaust from range hoods have been included for renovation of apartment buildings.	More and more projects see solutions where the exhaust is established through the façade of the building – and thus polluting the air intake of neighbouring apartments.
New classification requirements on small non-ducted single room alternating ventilation units have been included.	Such units are vulnerable to pressure differences on the facades, leakages when not in operation, short-circuit of the air flows - and the heat recovery efficiency needs to be calculated in a special way.
The section on filtration has been updated with the filter classifications in the new EN 16890, and recommendations for filtration efficiencies for a given outdoor air quality (ODA) and a required supply air quality (SUP), based on EN 16798-3, have been included.	A desire and benefit expected from harmonizing with existing European standards; EN 16890 and EN 16798-3.
The sections on humidification and enthalpy heat exchangers are expanded	Dry indoor air during the winter has been identified as an increasing problem in Denmark.



Examples of different hybrid ventilation systems.

Hybrid ventilation

Hybrid ventilation is defined as a combination of natural and mechanical ventilation.

The hybrid ventilation chapter contains additional requirements which isn't described in the natural or mechanical ventilation chapters. The essential of the hybrid section is not only to fulfill requirements in the natural and mechanical ventilation chapter, but to be able to take the interaction of the natural and mechanical ventilation into account. This is especially important in the design stage where the control and operating strategies should be implemented and handled to get a realistic picture of the performance of the system.

Hybrid system can utilize the same air flow path when in natural- as well as mechanical ventilation mode. An example could be a mechanical ventilation component (fan) located in a shaft used when the system runs in mechanical mode. The same shaft is then also being used as the natural air flow path when the system runs in purely natural ventilation mode. Here it is important that the fan doesn't reduce the natural ventilation air flow below acceptable limit. Considerations like these are crucial in the design phase.

System testing, balancing, handover, and service

Unfortunately, Denmark is often the scene for very poor installation of ventilation systems. Some projects end up in public scandals, with project stakeholders fighting each other. There are many erroneous and problematic projects in the field. The revision committee has attempted to build a new chapter for the testing, balancing, hand over, documentation, training, service, and maintenance requirements for ventilation systems. The former standard did include some of the requirements, but they were partitioned over different chapters, resulting in a lack of overview for the contractor.

For air tightness testing of ventilation systems, the standard now includes expanded requirements. Guidance regarding the required documentation, including documentation for the air tightness testing setup, is included. Should the contractor decide to test using samples, it is also described that minimum 25% of the ducts must be tested, and should the samples fail, 100% of the duct system must be tested.

The section on balancing of the systems is also expanded, and now included the maximum allowed measurement uncertainties on the testing equipment (based on EN 12599).

The standard has made a new and much more detailed section on testing of the entire system before handover. The list of activities in this regard follows the description from the REHVA Guidebook No. 29 on Quality Management of Buildings.

A very elaborate list of the required system and user documentation has also been written. A new requirement on system training at handover has been written. Often, in the past there had been no budget left for training in actual projects.

Conclusions

The Danish Standard DS 447 is applicable for mechanical, natural and hybrid ventilation systems and has just undergone a revision which was published in December 2021. One of the strengths of this standard is to set minimum requirements for each specific ventilation system technology and have some overall requirements to the indoor environment. The requirement to the indoor environment is mainly based on the Danish Building Regulation, DS /EN 16798-1: 2019 and the national Annex A (DK-NA: 2022). To help the user Danish Standard has decided to include the Danish national Annex A, when you buy DS 447. ■

Principles of new Finnish ventilation inspections

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A well-functioning ventilation system supports the conditions for healthy and comfortable indoor air quality. For this reason, it is important that the ventilation system is performing as intended and that it serves the current use of the building. This article presents the content of a walk-through inspection method to check the condition, functioning, and cleanliness of ventilation systems.

Keywords: Certificate, inspector, guideline, report, subscriber, ventilation system, walk-through inspection

Principles of the inspection method

The EU Commission has published a final report (EU 2020) on inspection of the stand-alone ventilation systems in buildings. The report emphasizes the importance of regular inspections of ventilation systems after they are commissioned. According to the Finnish law (ME 1009/2017), air flows and other important parameters of new ventilation systems must be measured before they are handed over to the building owner. Periodic inspections are not mandatory after commissioning.

The request for a new ventilation inspection method came from the Ministry of the Environment in Finland (FINVAC 2021). The need to improve the performance of ventilation systems originated from the common complaints related this. The ministry made a contract with FINVAC for the development of low cost, and quick inspections of ventilation systems. The previously published guides, such as CEN/TR 16798-18 (2017), were considered too expensive to implement as the first stage of inspection. Existing systems such as the Swedish OVK (Boverket 2021, Ekberg 2021) were investigated but they did not meet the identified requirements. The Finnish government preferred also a voluntary inspection, not mandatory inspection as in Sweden. The period between regular inspections was set to three or five years, depending on the type of ventilation system.

Stages of the walk-through inspection are shown in **Figure 1**. The inspection process begins with selecting

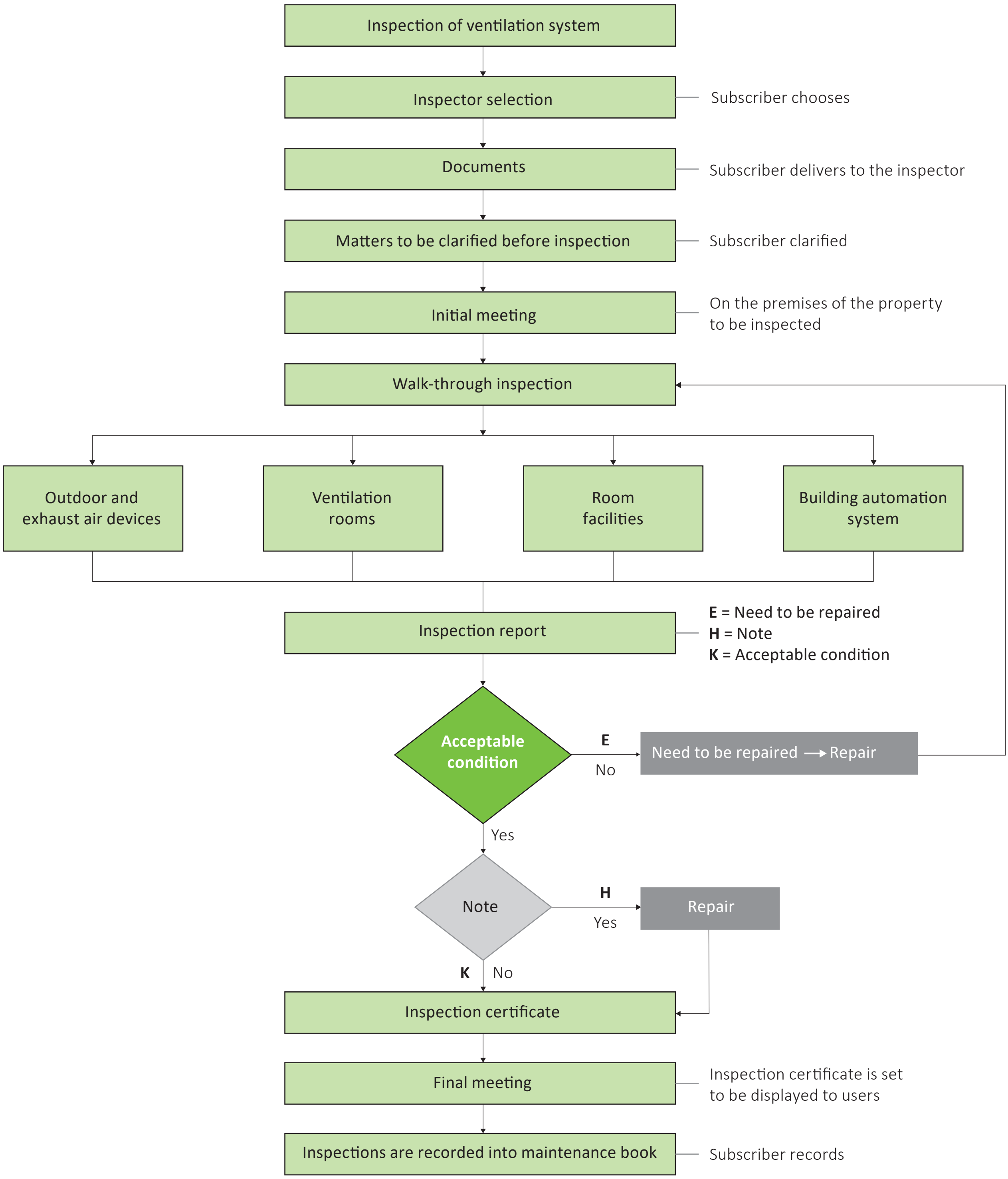


Figure 1. Stages of the walk-through inspection.

a qualified inspector and ordering an inspection. In the beginning, the building owner or its representative (subscriber) collects and submits the necessary documents to the inspector before, or at the latest, in the initial meeting at the building site. It is recommended that the subscriber collects the latest month's trend data on the use of ventilation and indoor air quality from the building automation system for the inspection. This will reduce the inspection time and costs. The ventilation system is examined during a structured walk-through inspection with the service and operational personnel of the building. The condition of the ventilation system is recorded by taking photos during the inspection. The inspection ends with a final meeting and a presentation of the results to the subscriber. The inspection report and the inspection certificate are saved in the building's maintenance book.

Content of the inspection

The walk-through inspection covers the following items: design, operation and maintenance documents of the ventilation system, condition and functioning of the system and its components, air flows in the duct work and to the rooms, balance of the air flows, operation and maintenance of the system and its components, cleanliness and hygiene, fire safety, performance and schedules of building automation system, perceived indoor air quality and environment, and energy efficiency. The inspection is performed mainly using sensory evaluation. Pressure difference is measured for critical components of the system such as fans, and rotary heat recovery units. In addition, the pressure differences over the building envelope are measured. **Table 1** summarizes the content of the inspection.

Table 1. *Items to be inspected in the ventilation system.*

Documents	• Design drawings • Control and operation diagrams • Airflow measurement and reports • Differential pressure measurement and report (buildings with a tight envelope) • Duct cleaning reports • Inspection intervals and maintenance schedule of ventilation system in accordance with maintenance contract of property
Condition and functioning	• Functioning of ventilation components such as fans and dampers • Balance of air flows • Air distribution
Operation and maintenance	• Schedule of ventilation operation • Setpoints of supply air temperature • Maintenance and repairs recorded in maintenance log book
Cleanliness and hygiene	• Cleanliness of air handling unit, components, ducts, and terminal units • Condition of insulated surfaces • Bypasses of supply and exhaust air filters
Fire safety	• Fire dampers and insulation of ventilation ducts
Building automation	• Performance and operation of control system for ventilation and air conditioning processes
Indoor environment	• Air temperature and carbon dioxide concentration • Feedback from occupants
Energy efficiency	• Type and functioning of heat recovery system

Initial meeting

The inspection of the ventilation system begins with the initial meeting, which is attended by an inspector, the property maintenance worker, the person in charge of the building automation system, the subscriber, and a user representative. The initial meeting deals with the deficiencies found in the documents and the facilities to be inspected.

Walk-through inspection

The walk-through inspection covers all rooms with air handling units, roof top units, and exhaust fans in accordance with the safety regulations and rules. Approximately 20% of the rooms in the operation area of each ventilation system are inspected. In buildings with a floor area under 300 m², all the rooms are inspected. The rooms are selected for inspection through an inspection that is carried out on each floor that the ventilation system serves, and the selected rooms must represent typical use. In addition, rooms with several occupants and rooms with complaints about indoor air quality are also selected for the inspection. The inspector checks the condition, functioning and cleanliness of the ventilation system components during the walk-through inspection, takes photos of the faults and records them in the inspection report. The need for further investigations or measurements is added to the report, if the reasons for poor operation or conditions cannot be specified in the sensory inspection.

Assessment of the condition of the system and equipment

The inspector evaluates the ventilation system's condition, functioning and needs to be cleaned using the following scale: E = condition not acceptable (needs to be repaired), H = weak condition (note) and K = acceptable condition (functions as intended). The inspection interval must be taken into account when evaluating the condition of the system, and ventilation must remain in acceptable condition during the inspection period (3–5 years). **Table 2** presents the descriptions and scale used in the evaluation of the system's condition.

Table 2. *Criteria for condition of ventilation system.*

Condition class/mark	Description of condition
E	Condition not acceptable = **Needs to be repaired** • Critical design or operation documents missing • System or its component are defective and must be repaired or replaced • System or its component are dirty and prevent system from operating properly • System or its component must be cleaned The need for further investigation is added to the repair request by the letter **L**, if more detailed measurements are required. Any defects found must be rectified without delay. It is recommended that a re-inspection be carried out within six months of the initial inspection.
H	Weak condition = **Note** • System component has failed or is about to fail, but does not significantly affect the functioning of the ventilation system • Number of people in the room is higher than the design value The notes recorded in the inspection report do not require re-inspection, but defects must be corrected without delay. Correction of defects recorded as a note are checked during the next periodic inspection. If the defects recorded as a note have not been rectified by the next periodic inspection, they are recorded in the inspection report as a correction request at the next inspection.
K	Acceptable condition = **Performs as intended** The condition, functioning and cleanliness of the ventilation system are in an acceptable condition and will remain in order until the next inspection.

Inspection report

The result of the inspection is recorded in the inspection report as E = needs to be repaired or K = acceptable condition. The inspection result of the ventilation system is E if the condition of one or more inspected items condition is not acceptable (**Table 2**). Items with recorded notes do not require re-inspection. The building owner is responsible for repairing ventilation faults without delay and for conducting a re-inspection. It is recommended that a re-inspection is conducted within six months of the previous inspection. The inspection result of the ventilation system is K after the approved inspection or approved re-inspection. The next inspection date is marked in the inspection report and should be conducted within three to five years, depending on the ventilation system.

Final meeting

The inspection is concluded at the final meeting, which is recommended to be held in connection with an approved inspection or an approved re-inspection. The final meeting is attended by the same people who attended the initial meeting. This meeting covers the results of the inspection and the remarks in the inspection report, which must be corrected without delay. The actions taken due to these remarks are checked in the next periodic inspection.

Inspection certificate

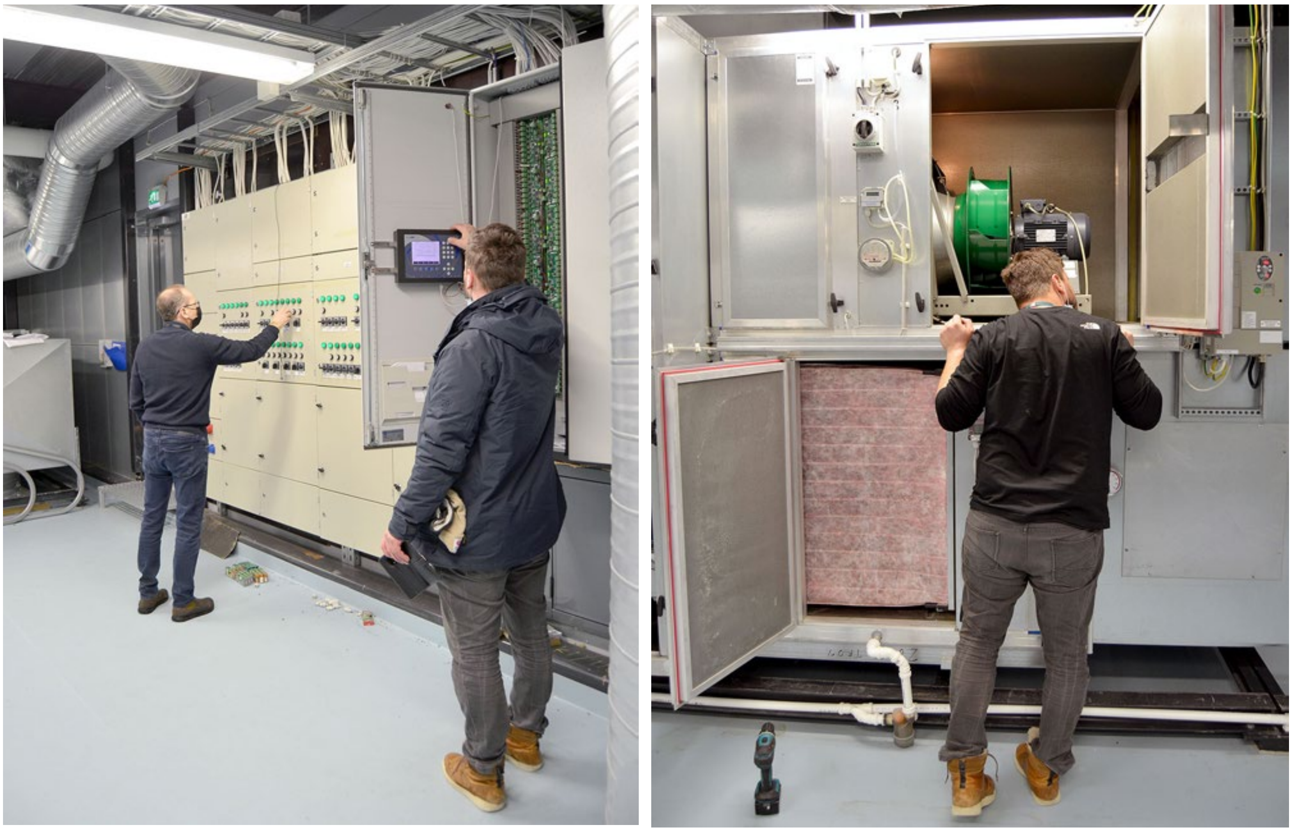
A certificate is drawn up for the approved inspection and is delivered in electronic form to the subscriber signed by the inspector. One copy of the certificate remains in the inspector's archives. The inspection certificate or information on the approved inspection should be available to the users of the building.

Recommended inspection intervals

It is recommended that a ventilation system is inspected every three or five years. Complex and easily defective ventilation systems, such as variable air volume (VAV) systems, should be inspected every three years. Constant air volume (CAV) systems and exhaust ventilation systems should be inspected every five years. Natural ventilation systems should also be inspected every five years.

Competence requirements

The ventilation inspector must be familiar with the legislation on ventilation and indoor air of buildings and the instructions and guides related to this legislation.



Inspection of ventilation system. [© Rauno Holopainen]

The inspector must be familiar with the most common equipment faults in CAV and VAV systems, mechanical exhaust ventilation systems and natural ventilation systems, and able to

- read and understand ventilation system drawings, control diagrams and operating reports
- evaluate the cleanliness of ventilation systems and their need to be cleaned using the visual cleanliness scale as a reference (LVI 39-10409)
- make a sensory evaluation of the adequacy /performance/air quality of the ventilation of the room, the balance of air flows and the room's air distribution using detecting smoke or other methods
- reliably take differential pressure and temperature measurements
- identify the correct and incorrect functioning of ventilation and air conditioning systems as well as building automation systems
- evaluate the importance of regular ventilation maintenance for the condition, functioning and cleanliness of the ventilation system during the inspection interval
- rank the condition of the ventilation system according to **Table 2** (E, H or K)
- evaluate the need for further investigation.

Inspection quality assurance

The ventilation inspection is performed by an inspector whose qualifications meet the competence requirements. Measurements must be made using meters and methods that are suitable for measuring pressure differences and temperatures. The instruments must be sufficiently accurate and have valid calibration. The cleanliness of the ventilation system is evaluated visually using the cleanliness scale as a reference. The content of the inspection report is standardized. The inspector must keep the inspection report and certificate for at least five years.

Summary

The walk-through inspection method was developed in the Inspection of ventilation system project. It is a simpler and faster method than that described in CEN / TR 16798-18. It is intended to be the first stage in evaluating the condition and functioning of ventilation systems and the need to clean them. Further examinations or measurements must be carried out, if the reasons for the poor operation or conditions of the ventilation system cannot be specified in the sensory inspection. A guideline on ventilation inspections has been published, and will be tested during the spring of 2022 in 10–15 municipal buildings in Southern Finland. ■

Acknowledgement

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Status of ventilation in Sweden

  

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A questionnaire survey has been conducted broadly among stakeholders within the Swedish ventilation sector. Representatives of industry, real-estate, consultants, other organizations, academy, authorities etc. participated with the aim to identify important issues and problem areas, and to provide understanding of the needs of development in areas related to ventilation.

The second edition of a knowledge review/compilation commissioned by the Swedish National Board of Housing, Building and Planning was published early 2022 [1]. The compilation comprises:

- Ventilation state of the art
- Legislation & guidelines
- Measurement & verification
- Energy requirements – Eco design
- Fire protection
- Disease transmission prevention
- Mapping of actors/stakeholders

The purpose of this endeavor is to map Swedish stakeholders related to ventilation; industry, real-estate, consultants, other organizations, academy, authorities etc. As a part, a questionnaire survey was conducted broadly among these stakeholders.

The aim was to identify important issues and problem areas related to ventilation, as perceived by the various stake-holders. The intention is to provide a broad and accurate understanding of the needs of development in areas related to ventilation.

A large number of different actors were invited to answer a questionnaire prepared. All in all, the survey was answered by 215 people, of whom 55% were professionals within ventilation inspection, 16% were different types of consultants and the remaining 29% consisted of a total of nine different occupational categories.

The web-based survey was divided into six sub-areas:

1. Identification of the respondent's professional role and experience in ventilation issues
2. The respondent's general experience regarding ventilation
3. Questions regarding ventilation-related complaints from occupants
4. Identification of ventilation-related problems
5. Measures against ventilation-related problems
6. Questions regarding energy efficiency

For each area, a number of claims of the type "*Insufficient airflows in apartment buildings often turn out to be due to…*", followed by a number of response options. For each answer option, the respondent was asked to indicate, using a seven-point scale, the extent to which they agreed with the response options. Furthermore, it was always given the opportunity to comment in free text and/or reply "do not know".

A brief summary of responses

Below are a number of general observations highlighted for some of the questions. A more complete account of the survey responses and the different occupational categories can be found in [2].

- Natural ventilation was typically claimed to perform worse than mechanical ventilation systems, often due to insufficient supply opening areas (See **Figure 2**)
- Mechanical exhaust and supply usually perform well, but are sensitive to poor balancing.
- Ventilation-related complaints often deal with draft, odor from cooking and "stuffy" air.
- Air quality problems in non-residential buildings are often due to changes in the use of the building without implementation of the ventilation adaptations necessary.
- Maintenance and periodic checks are main keys to well-functioning ventilation.
- There are only small possibilities to increase ventilation with existing ventilation systems.
- Schools and preschools in particular have often too low ventilation capacity (under-sized systems).
- Demand-controlled ventilation is claimed to work best when controlled with respect to both room temperature and CO_2-concentration.
- Filters are usually changed according to schedule (not taking into account the filter's pressure drop).
- There are often opportunities to make economically profitable energy saving measures related to ventilation.
- Re-circulation of extract air is generally perceived as a poor option, except in industrial and warehouse premises.

Some reflections on the outcome of the survey

Some of the respondents pointed out that several of the questions were too "narrow" for a justified answer. Indeed, it can be perceived as too generalizing to rank different ventilation principles (natural, mechanical exhaust, mechanical exhaust and supply etc.) in terms of how well they usually work. The fundamental idea emerged that different system solutions have different pros and cons. The important thing is not what type of system is chosen. Instead, the important thing is that

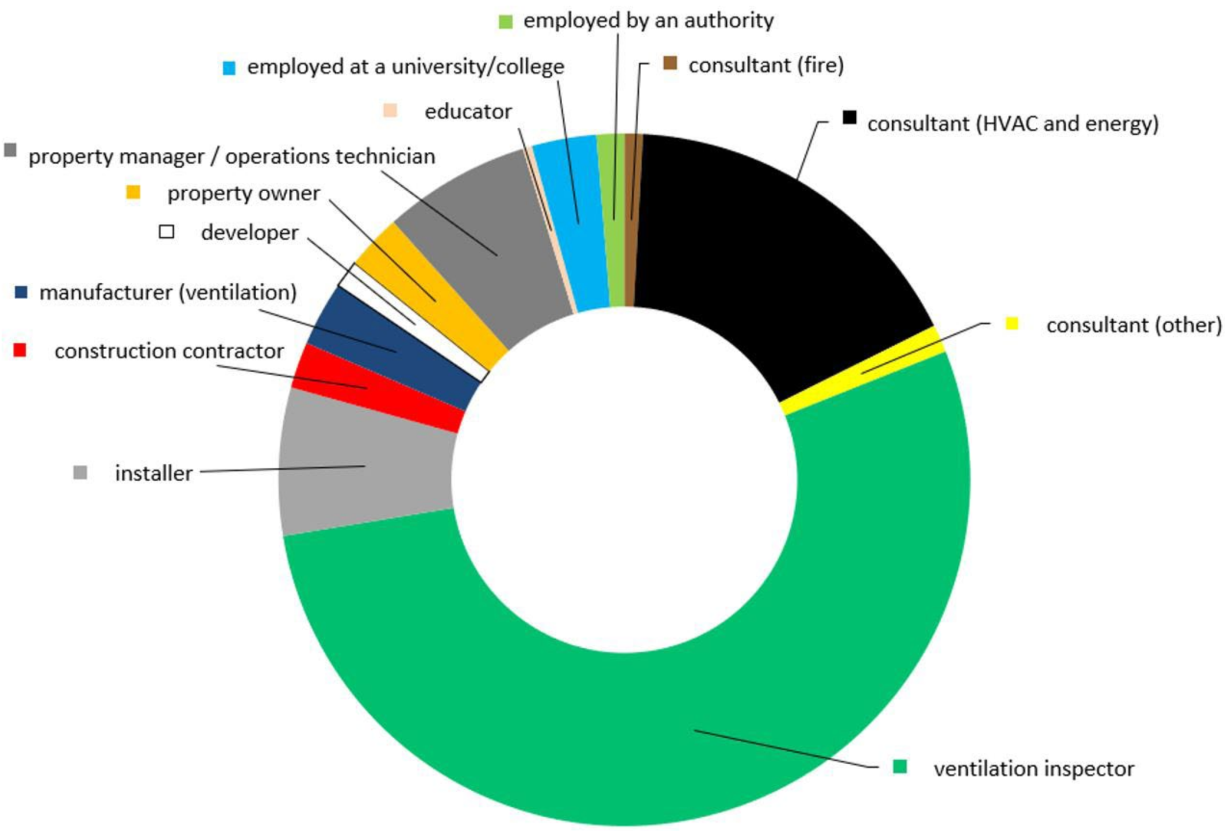

Figure 1. Distribution of the respondents' main professional roles.

the solution chosen must **be designed taking into account the conditions defined** by the building and the operation. For example, a well-designed mechanical exhaust system can work better than a poorly designed system with mechanical supply and exhaust.

Each system must be designed in order to facilitate **efficient inspections and service**. Several respondents pointed out in this context that it is a particularly big challenge to inspect modern systems for demand-controlled ventilation. An important question is which aspects should be included in the inspections. In addition to measuring airflows, more checkpoints may be required to verify the more or less complex control functions. Another question is how to ensure that the checks are carried out under realistic/real conditions.

Overall, the survey responses indicate that ventilation **malfunctions and deficiencies are revealed** roughly to an equal extent through the mandatory ventilation inspections – the OVK-inspections [3] and through complaints from the building users. This is followed by alarms from the building automation system and from visual operational status inspections. This outcome indicates that many respondents see great value in the mandatory OKV-inspections, but that there is a great need for improvements. In an ideal situation, no deficiencies should be identified by complaining tenants. According to the survey responses, the way to get there can be through an improved system for mandatory ventilation inspections together with better utilization of building automation and monitoring and regular operational follow-up.

Several respondents point out that **the ventilation flows** are too often chosen to meet the **authorities' minimum requirements**, without regard to the actual pollution generation from the building itself, the people and the activities in the building. Today, these minimum flows are selected by default and provided that neither operations nor construction equipment emit much pollution. If we instead should really be able to determine the required air flow rate, taking into account the real need from a hygienic point of view, it will be necessary to utilize quality-assured data on the source strength of all relevant sources of pollution. However, such data are generally not available to the building sector.

It must be acknowledged that the standard EN 16798-1:2019 offers a methodology to classify building products with respect to the potential release of pollutants to the air - and to consider this aspect when searching for the dimensioning ventilation rates. At least in Sweden, this way of working has not yet come to use in practice. It might be easy to classify materials

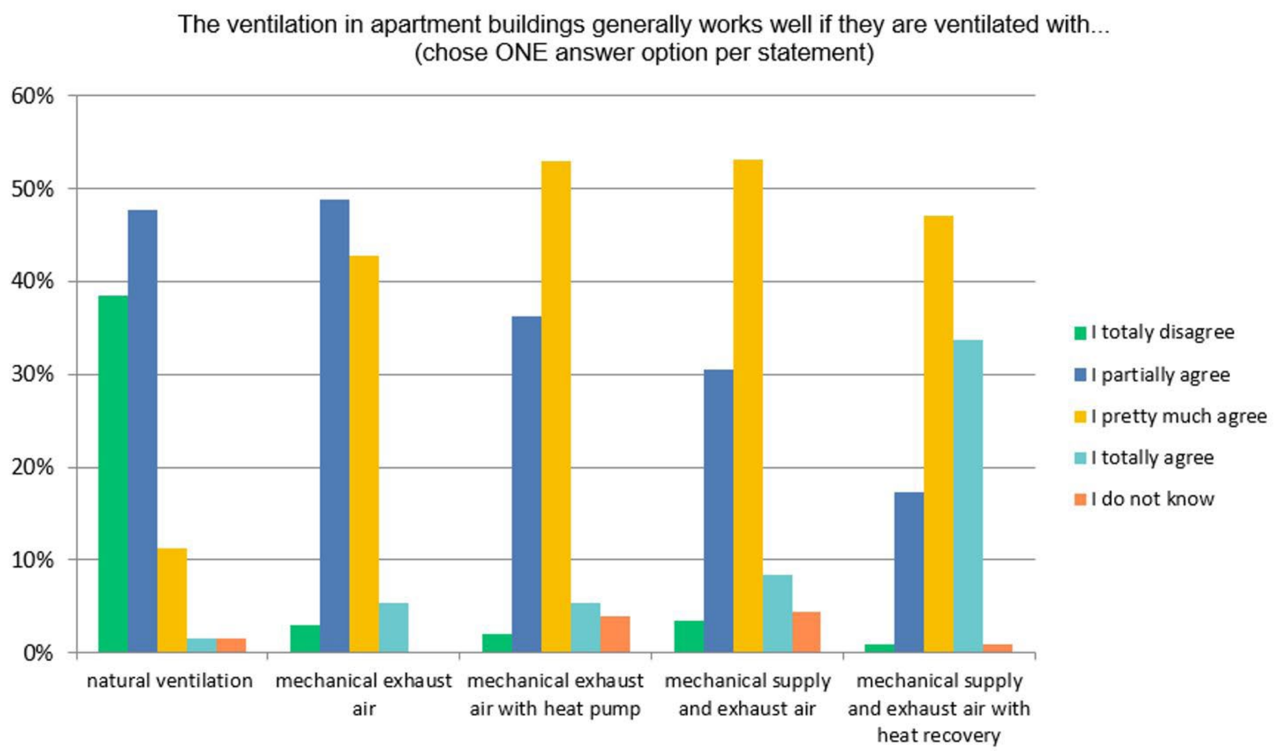

Figure 2. Distribution of the respondents' attitude to the function of different ventilation systems in apartment buildings.

such as glass, stone and metal as low-emitting. It is way harder to find useful data on the rate of pollutant emissions from other materials. Once such data become available, it might be possible to determine the required airflow rate in order to dilute emissions to acceptable levels. However, for many substances the question remains regarding the acceptable concentration level.

Several respondents pointed to a **need for increased competence in the building sector**. It is not just a question of the need for each professional to have sufficient knowledge within their own trade, but about the need to have sufficient understanding of the whole. At least the understanding needs to be sufficient for each professional group to be able to communicate within their own group and with adjacent specialist areas. For example, a ventilation technician needs to have a basic understanding of control and control technology and vice versa; the control specialist needs basic understanding of ventilation technology. Perhaps somewhat surprisingly, this is rarely the case. Basically, it is a question of enduring a holistic approach in a broad sense. It is about everyone applying their own solid knowledge and contributing to wise decisions by communicating effectively. This affects everyone who in one way or another contributes to the creation and maintenance of well-functioning ventilation systems in energy-efficient buildings with a good indoor climate. ■

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Frosting in residential heat recovery units

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During last year, a large number of residential air handling units (AHU) were analysed for both winter and summer periods in two different studies. The analyses of residential AHUs during the winter period showed that some AHUs had problems when frosting. This article shares some of the experiences made.

Keywords: Air handling units, counter flow heat exchanger, moisture generation, moisture content, extract air relative humidity, defrosting function, outdoor air temperature, multifamily buildings

Energy efficient airtight multifamily apartment buildings are increasingly utilizing central air handling units with higher heat exchanger efficiencies typically between 80% and 90% to obtain low energy use for ventilation. However, the moisture generation in homes creates challenges for the function of residential AHUs. This is partly because the air's ability to contain moisture is strongly temperature dependent, which can be seen in **Table 1**. Central AHU is preferred to get substantially fewer maintenance points and less heat loss between outdoor air ducts and exhaust air ducts to surrounding indoor air during the winter period. Total heating use for a new multifamily building in Stockholm area is around 25 kWh/m² floor area, year. In such energy efficient buildings, it is important to ensure high quality in design, production, and operation, because each deviation can increase the energy use with a couple of kWh/m² floor area, year. It is not uncommon that the measured (real) heat use become up to 50% higher than the calculated (expected) heat use in energy efficient buildings.

The moisture generation in Swedish apartments buildings is about 2.0 g / kg air, which is much higher than in office buildings. The moisture generation in apartment buildings comes from people, personal hygiene, potted plants, cooking, clothing care, etcetera. Depending on the behaviour of the resident, the moisture generation can be even greater.

Table 1. *Examples of moisture content in outdoor air at different outdoor temperatures and a moisture generation of 2.0 g/kg air in the building will give a relative humidity for 21°C extract air with corresponding dew point temperature.*

Outdoor air	0°C, 80%RH	–5°C, 80%RH	–10°C, 80%RH	–20°C, 80%RH
Moisture content outdoor air	3.0 g/kg air	2.0 g/kg air	1.3 g/kg air	0.5 g/kg air
Moisture content in extract air with moisture generation 2.0 g/kg air	5.0 g/kg air	4.0 g/kg air	3.3 g/kg air	2.5 g/kg air
Relative humidity 21°C extract air	32.5%RH	26.0%RH	21.5%RH	16.3%RH
Extract air dew point temperature	3.9°C	0.8°C	–1.6°C	–4.9°C

Residential AHUs with heat recovery wheel work "better" in winter, compared to plate heat exchangers, as they have significantly less freezing and a certain moisture return. The indoor air does not get as dry during the winter, but AHUs with heat recovery wheel have a relatively large risk of odours spreading in apartment buildings. Residential AHUs with counter flow heat exchangers are hence preferable in apartment buildings to reduce the risk of odour spread but needs defrosting of the heat recovery when the outdoor temperature is below approximately −2°C.

In **Figure 1**, the heat exchanger is a mix of cross flow and counter flow heat exchanger: We assume that it can be calculated as a counter flow heat exchanger with acceptable accuracy.

During the winter, when the temperature on the surface of the heat exchanger plate is below the extract air dew point temperature, extract air moisture will condense on the heat exchanger plates and freeze if the heat exchanger plates temperature is below 0°C. To prevent the heat exchanger from becoming a lump of ice, a defrost function is needed to melt the ice in the heat exchanger.

The temperature of the heat exchanger plates, T_{plate}, on the exhaust side is about the average between the outdoor air temperature, T_{Out} (marked ① in **Figure 1**), or if preheating is used, the preheated air temperature (marked ② in **Figure 1**), and the exhaust air temperature, T_{Exh} (marked ⑥ in **Figure 1**). Knowing the temperature efficiency, Eff_{ext}, and the extract air temperature, T_{Ext}, equation (1) can be used:

$$T_{plate} = 0.5 \cdot (T_{Exh} + T_{out}) = 0.5 \cdot \left(T_{Ext} \cdot (1 - Eff_{Ext}) + T_{out} \cdot (1 + Eff_{Ext})\right) \quad (1)$$

To be able to calculate at which outdoor temperature the plate temperature is about 0°C we reorganize equation [1] to:

$$T_{out} = \frac{2 \cdot T_{plate} - T_{Ext} \cdot (1 - Eff_{Ext})}{(1 + Eff_{Ext})} \quad (2)$$

Furthermore, **Table 2** shows the counter flow efficiency for supply and extract side at different air flow balances, calculated with equations for counterflow heat exchangers that can be found in literature, for instance (Blomberg, P. 1999).

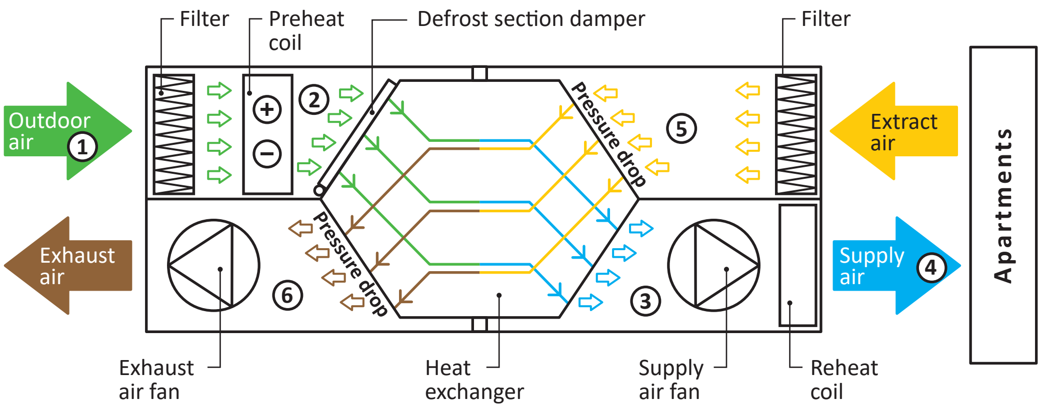

Figure 1. Principle sketch of residential AHU with counter flow heat exchanger: ① Outdoor air temperature (T_{Out}); ② Preheated air temperature (if used); ③ Air temperature after heat exchanger; ④ Supply air temperature; ⑤ Extract air temperature; ⑥ Exhaust air temperature (T_{Exh}).

Table 2. *Calculated ideal counterflow efficiency with different air flow balances.*

Efficiency at balance / Air flow balance		Supply air flow / Extract air flow			
		1.00	0.90	0.80	0.70
70%	Eff_{Sup}	70%	75%	80%	85%
	Eff_{Ext}	70%	67%	64%	60%
80%	Eff_{Sup}	80%	85%	90%	94%
	Eff_{Ext}	80%	76%	72%	66%
90%	Eff_{Sup}	90%	95%	98%	99%
	Eff_{Ext}	90%	85%	78%	70%

The outdoor air temperature to get T_{plate} = 0°C can be seen in **Table 3** and depends on the heat exchanger efficiency on the extract side, Eff_{Ext}, which can be seen in **Table 2** and the extract air temperature.

Table 3. *Outdoor air temperature for ideal counterflow heat exchanger to get T_{plate} = 0°C.*

Eff_{Ext} / T_{ext}	21°C	22°C	23°C
65%	−4.5°C	−4.7°C	−4.9°C
70%	−3.7°C	−3.9°C	−4.1°C
75%	−3.0°C	−3.1°C	−3.3°C
80%	−2.3°C	−2.4°C	−2.6°C
85%	−1.7°C	−1.8°C	−1.9°C
90%	−1.1°C	−1.2°C	−1.2°C

Heat exchangers in energy efficient multifamily buildings have normally an efficiency between 80% and 90% at air flow balance. Given this efficiency the heat exchanger's plate temperature, T_{plate}, will become ±0°C or lower when the outdoor air temperature is below between −1°C to −3°C, mainly depending on the efficiency on the extract air side and the actual air flow balance.

One example with 80% efficiency and air flow balance 0.9 and 21°C extract air temperature the condensation and frosting will begin at −3°C outdoor temperature and extract air relatively humidity 25%.

Conclusions: **Table 4** shows that residential AHU in north and middle of Sweden needs good defrosting functions to work properly and energy-efficiently especially if the moisture generation is high in the apartment building.

Table 4. *Number of hours when the outdoor temperature is below temperatures in Table 3 have been evaluated for a normal weather (typical year) for different Swedish cities (Sveby/SMHI 1981-2010).*

Swedish cities	Outdoor temperature			
	−1°C	−2°C	−3°C	−4°C
Malmo	480	310	190	100
Gothenburg	780	530	340	250
Stockholm	1 300	990	750	590
Orebro	1 730	1 410	1 110	850
Umea	2 400	2 000	1 700	1 500
Kiruna	4 180	3 850	3 510	3 200

Additional comments on air flow balance in buildings

It is important to have a negative pressure in the apartment buildings to reduce the risk of moist indoor air leaking into the building envelope and condensing during the winter with risk for moisture damages. Ten percent lower supply air flow related to extract air flow in each apartment is often sought, which in an apartment building with a high air tightness gives a negative pressure of approximatively 5 Pa. If the deficit becomes larger, the negative pressure increases rapidly and when it exceeds 25 Pa, children, the elderly and others with reduced strength have problems opening doors.

The negative pressure from air flow imbalance causes outdoor air to leak into the apartments, which gives a heat demand, but the negative pressure also reduces the air leaking due to wind (EN ISO 13789, Annex C). So, the total heat demand will be less than the heat demand due to the airflow imbalance.

The under-pressure in the apartments can be determined from the air flow difference (extract air flow – supply air flow) in apartments and the result from blower door test (airflow – pressure relation).

Analysed residential AHU

During the last year approximately 100 residential air handling units, AHU, were analysed in two studies for winter and summer period (Kempe, P. 2021, Kempe, P. 2022). In the analyses, a couple of AHUs were found to have problems with AHU functions when frosting, which is presented below.

Most of the analysed residential AHUs are in Stockholm, Gothenburg and Orebro. Measured data (mainly 5- or 10-minute sampling interval) from AHU and technical documentation were provided by the property owners' operating staff. Sensors vary between different AHUs, so the analyses that can be done varies. Measurements of the extract air relative humidity are not common but were added as desired on a couple of the analysed AHU.

Examples of moisture generation in apartments buildings

In **Figure 2** is shown time series of measured 10-minute data for extract air relative humidity, moisture production (extract moisture content – supply moisture content) and outdoor temperature with cross correlations.

Extract air relative humidity varies between 29–39% RH when outdoor temperature is 0°C and 23–33% RH when outdoor temperature is –5°C and the moisture production is about 1,5 – 2,5 gr/kg air. Other apartment buildings have both higher and lower moisture production depending on resident behaviour.

Examples of defrosting functions

A couple of common defrosting functions

- Preheating the outdoor air to –1°C to –4°C to avoid frosting and the need for defrosting using geothermal energy, district heating or electric heating.
- Section defrosting controlled by the pressure drop over extract air side of the heat exchanger. During defrosting, heat recovery might be halved with increased need for re-heating.
- Section defrosting controlled by outdoor temperature with increased need for re-heating, which can be combined with supply air flow reduction, which increase room heating.
- Section defrosting controlled by outdoor temperature and extract air relative humidity with increased need for re-heating, which can be combined with supply air flow reduction, which increase room heating. Extract air dew temperature is calculated and compared with heat exchanger plate temperature to control defrosting.

At very cold climate, a combination of preheating and section defrosting can be needed.

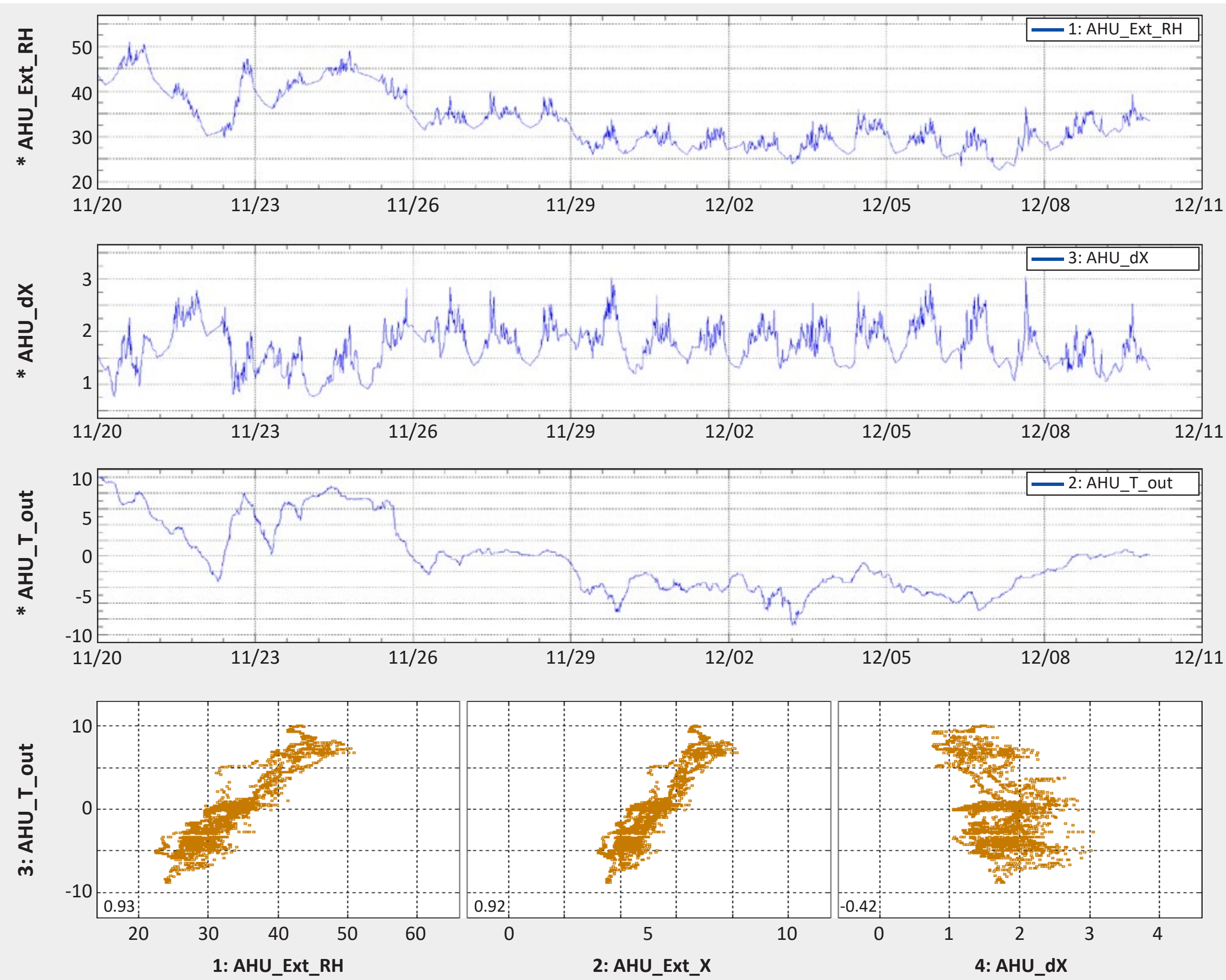

Figure 2. Extract air relative humidity, RH, extract moisture content, X, moisture generation, dX and outdoor temperature for an AHU investigated 20 November – 10 December 2021.

Problems with defrosting of AHU

Below, potential problems with defrosting are illustrated by six examples.

AHU_A has a high moisture load, so it has a lot of defrosting and a very low efficiency, 30 – 40%, for more than half of the period shown in **Figure 3** and the pressure drop is high, 200 – 250 Pa. The temperature, ③ after the heat exchanger is –2°C to +5°C, which is very low and require more reheat energy. A similar AHU also with a high moisture load got a very low return water temperature from the reheating coil, so the AHU stopped to prevent the reheat coil from freezing.

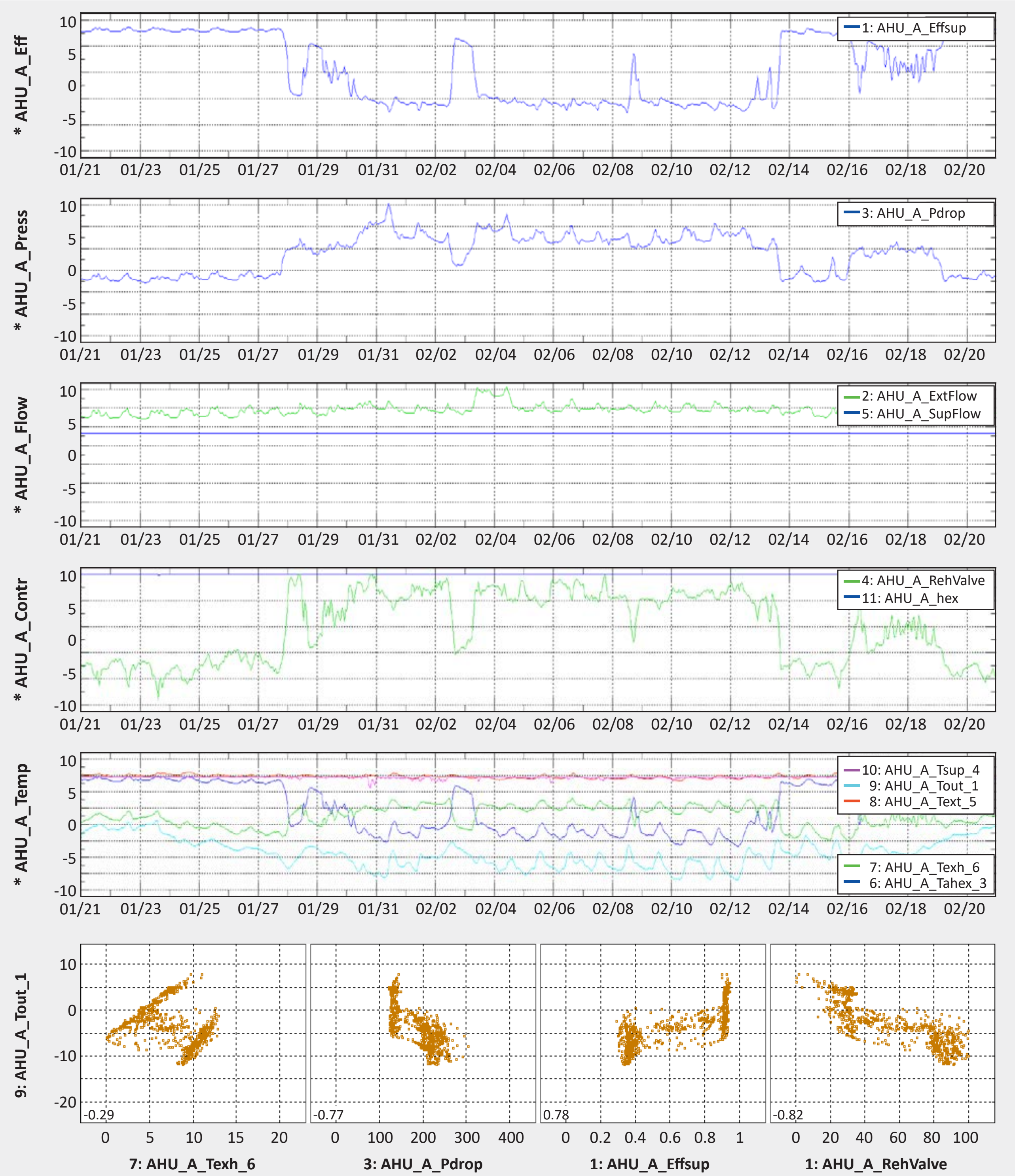

Figure 3. Measurements for AHU_A during 21 January – 21 February 2021.


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AHU_B have low moisture load and for some unknown reason the preheating coil was out of order and the reheat coil was not dimensioned to work without the preheating coil. Hence the valve to the reheat coil was fully open, but still the air supply temperature was too low. When the AHU defrosts, the reheat coil got a very low return water temperature and the AHU stopped prevent the reheat coil from freezing.

Furthermore, two other AHUs that both have a proper defrost function but had too long piping between the reheating valve and the reheat coil. So, when the AHU got several defrost cycles close to each other, the reheat coil system got to long time delays so the reheat coil got to low return water temperature. Therefore, the AHU stopped to prevent the reheat coil to freeze.

There were a couple of other AHUs that have a slightly too small reheating coil, so they could not keep the supply air setpoint during defrosting. As a result, the supply air temperature became a couple of degrees too low.

AHUs with preheating by district heating and no reheat coil used too much heat energy, because they needed to increase the supply air temperature due to heat losses from the extract air duct from the apartments to the AHU. Without a reheat coil and the need to raise the supply air temperature one need approximate 5 times more heat energy to a preheat coil compared to a reheat coil, when the preheated air is above 0°C.

AHU_C has section defrosting that is activated when the outdoor temperature is below 0°C and a reduction of supply air flow when the outdoor temperature is below –2°C. In this case the extract air flow and the efficiency began to decrease because of frosting from 5 February and 8 February as the AHU stopped since the heat exchanger had become a lump of ice. Today the defrosting function has been updated and shall now run smoothly.

Conclusions

High moisture generation can be a challenge for the residential AHU functions in cold climate: Therefore, it is preferable to measure extract air relative humidity as well as analysing timeseries of measurements from the AHU control system (temperature, control signals, air flows, etcetera) and optimize the AHU functions. ■

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Ventilation requirements and results in renovation of Estonian apartment buildings with KredEx scheme

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Renovation grants for deep renovation of apartment buildings have been available in Estonia since 2010. Lessons learnt from the first years helped to develop ventilation requirements and solutions which have led to common application of heat recovery ventilation so that required airflows have been achieved both in commissioning and in operation.

Keywords: Ventilation requirements, deep renovation, renovation grants, apartment buildings, air flow rates, commissioning, heat recovery ventilation, ventilation radiator

When Estonia implemented the first renovation grant scheme 2010-2014 many mistakes have also been made making this experience valuable. It is not a surprise that the lack of ventilation was a major problem at the beginning because the renovation of building fabric stops natural ventilation. It was required in the technical conditions of the renovation grant that EN 16798-1 (EN 15251:2007 at that time) indoor climate category II had to be followed, but ventilation rates were not specified. Commissioning requirement to measure airflow rates was not specified either. This led to the use of a wide variety of ventilation solutions including natural ventilation, single room ventilation units and heat recovery ventilation.

HRV ventilation unit on the roof

Measured air change rates in renovated apartment buildings illustrate the problems at that time, **Figure 1**.

Single room ventilation units (SRVU) and natural ventilation (NV) provided so low air change rate that it may pose a health risk for occupants, and is insufficient for humidity removal and may lead to mould problems. With exhaust heat pump (EAHP) and centralised balanced heat recovery ventilation (HRV) systems, the situation was more complicated. Airflow rate measurement reports available from most of buildings showed that in the commissioning phase these ventilation systems met the design airflow rates. Measurements conducted about one year later show that the airflow rates were reduced in operation that may be due to cold draught or energy saving considerations.

New ventilation requirements from 2015

To ensure adequate ventilation in renovated dwellings, KredEx renovation grant technical conditions require since 2015 that ventilation systems should either be sized according to EN 16798-1:2019 indoor climate category II or with room-based supply and extract air flow rate design values shown in **Table 1**. Supply air flow rate design value is 10 ℓ/s in living rooms and bedrooms. Extract air flow rate design values are 10 ℓ/s in WC, 15 ℓ/s in bathrooms (10 ℓ/s in small apartments) and 8 ℓ/s in kitchens (6 ℓ/s in small apartments). To balance the air flows, supply airflow rates in small apartments and extract airflow rates in large apartments are to be increased, which is marked with "+" in **Table 1**. In kitchens, only general ventilation was required. Additional boost from cooker hoods has not been required, because it might need ducting and remodelling of existing kitchens furniture that is not wanted by occupants.

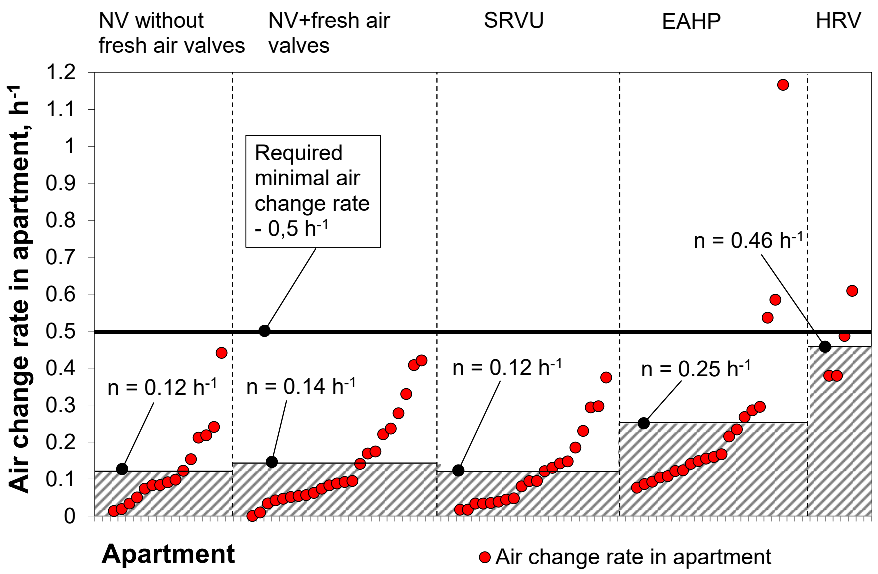

Figure 1. Air change rates measured in apartments renovated 2010-2014. Measurements made after operation for about one year after handing over (Mikola et al. 2022).

Table 1. *Ventilation supply and extract airflow rate requirements applied for ventilation sizing in model dwellings. ACR is the air change rate of the whole dwelling.*

Apartment type	Floor area,	Extract airflow rate, ℓ/s				Supply airflow rate, ℓ/s					ACR
	m^2	WC	Bathroom	Kitchen	Total	Living	Bed1	Bed2	Bed3	Total	h^{-1}
Single room	35	-	10	6	**16**	10+6[1]	-	-	-	**16**	0.63
1 bedroom	55	-	15	8	**23**	10+2[1]	10+1[1]	-	-	**23**	0.58
2 bedrooms	70	10	15	8	**33**	10+2[1]	10+1[1]	10	-	**33**	0.65
3 bedrooms	80	10+2[1]	15+1[1]	8+4[1]	**40**	10	10	10	10	**40**	0.69

[1] values marked with "+" indicate the addition to balance airflows

These new ventilation requirements made it impossible to use natural ventilation and single room ventilation units (SRVU), so these ventilation solutions were practically banned and have not been used after 2015 with KredEx renovation grants. Airflow measurement reports were made mandatory and this together with new ventilation requirements changed the situation radically. Ventilation rates measured in buildings renovated after 2015 are shown in **Figure 2**. In centralized balanced heat recovery ventilation (HRV) in most of the buildings ventilation rates have not been reduced during operation and meet the requirements. In mechanical exhaust ventilation, the airflow rates were achieved in the commissioning according to airflow rate measurement reports, but still have been slightly reduced during operation. It is suspected that this is due to energy saving considerations as housing associations do not understand the operating principle of EAHP where airflow reduction will also reduce the heat source.

Room based ventilation rates were reasonably well met with HRV ventilation where extract airflow rates mostly met the requirements in operation and supply air flow rates were close to the requirement, **Figure 3**.

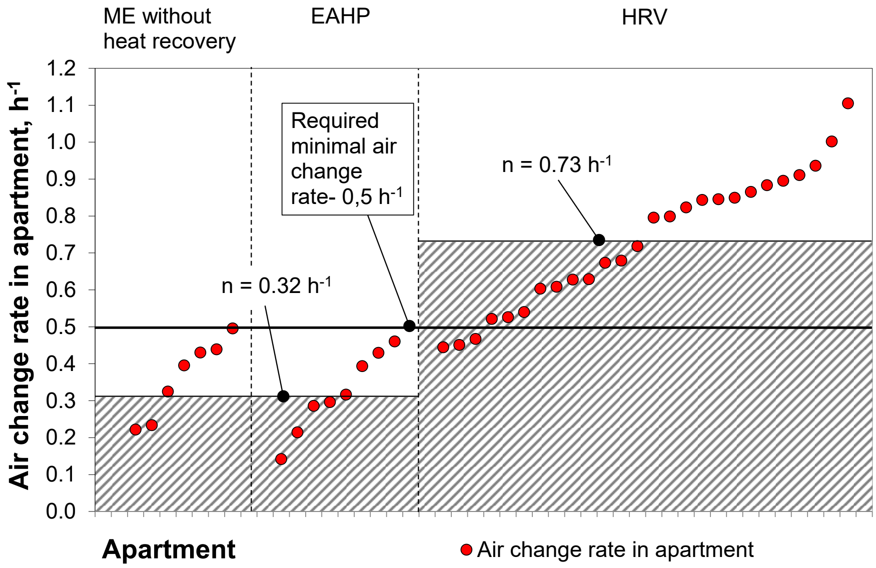

Figure 2. Air change rates measured in apartments renovated after 2015, with new ventilation requirements, in operation about one year after handing over.

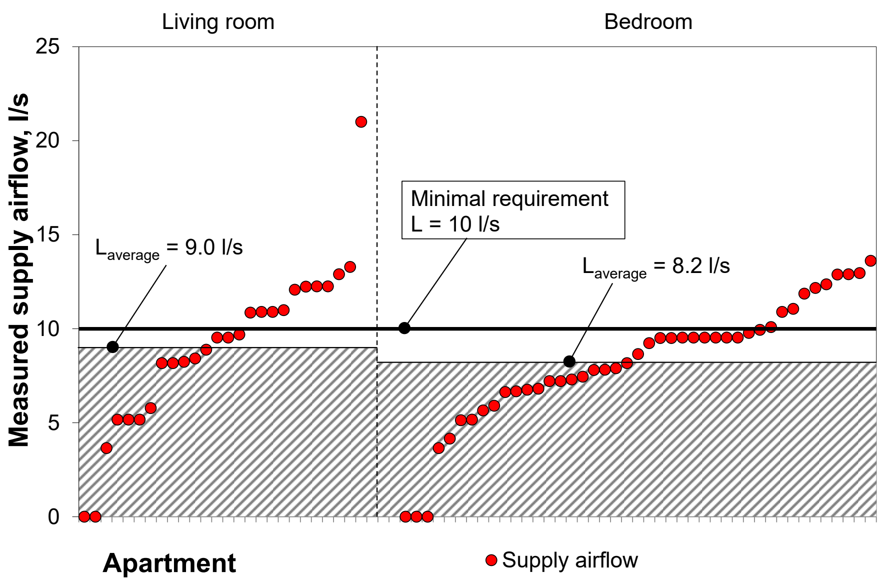

Figure 3. Supply air flow rates measured in bedrooms and living rooms in operation. In five apartments, supply terminals were almost closed or sealed with tape by occupants.

Ventilation systems used from 2015

There are two ventilation solutions that fulfil KredEx requirements for airflow rates and heat recovery and are widely used in practice:

- centralized mechanical supply and exhaust ventilation (balanced ventilation) with heat recovery (HRV);
- mechanical exhaust ventilation with exhaust air heat pump (EAHP) and ventilation radiators.

In HRV, additional insulation of 200 mm allows to install new supply air ductwork on the façade. Heat recovery efficiency is typically ≥ 80% and air handling unit SFP < 1.8 kW/m³/s. Sound attenuation is easy in centralized HRV and there is practically no draught because of heated supply air. The ventilation unit of this system is installed on the roof or in the attic as shown in **Figures 4-5**.

Flat plastic or round-shaped metal sheet supply ducts are installed inside the additional insulation of the external walls and roof. Old ventilation stacks are used to extract air from apartments. Because the air tightness of the stacks is often low, new ventilation ducts are recommended to be installed inside the old stacks. In some cases, exhaust air ductwork has been installed on the façade in a similar fashion to that of the supply air ductwork. The supply air is ducted to the living rooms, and the bedrooms and extracts are from toilets, bathrooms, and kitchens. Installing ventilation ducts inside the additional insulation layer helps to avoid visible ducts inside the apartments. The supply air diffusers are installed on the external wall of the living room and bedroom, and the extract air valves are placed in kitchen, bathroom and toilet. The volume of ventilation installation work inside the apartment

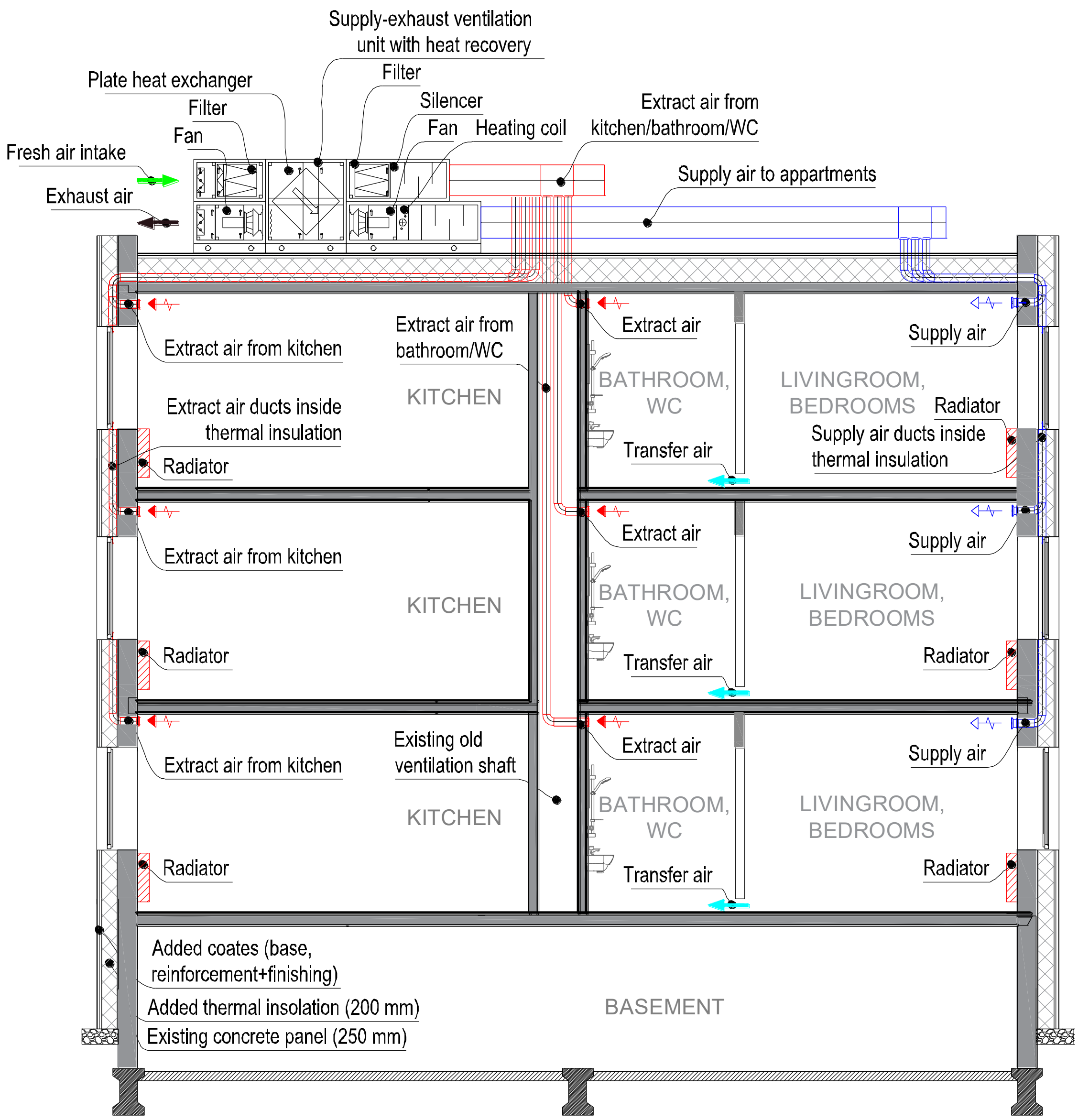

Figure 4. Working principle of centralized HRV renovation solution.

is minimal and does not disturb occupants if properly organised. In AHU, water-based reheating coil after heat recovery to reheat the supply air are used. Frost protection is an important issue, for which preheating coils are not allowed but sectional defrosting with adequate controls is typically used.

Another popular ventilation solution is based on exhaust air heat pump (EAHP) that can be added to any centralized mechanical exhaust ventilation system. Energy analyses conducted with German, Italian and Estonian climate (Kuusk et al. 2020) have shown that EAHP has superior heat recovery performance over HRV in Central European and warmer climates. In this system, it is important to pay attention to adequate intake air solution, because simple air inlets are sensitive to outdoor noise, generate cold draught and have typically poor filtration. KredEx requires to use hydronic ventilation radiators for intake air, which are like common radiators, but have an air intake section with filter (typically ePM1 60% (F7) efficiency) and heat up intake air practically to room temperature. Ventilation radiators are not sensitive to freezing, even if thermostats are closed, that has been demonstrated by laboratory experiments and by wide use in cold climates. Extract air is collected on the roof to an air to brine heat exchanger of the ventilation exhaust unit, where the heat is transferred through a brine loop, to a brine to water heat pump. The heat pump provides heat to space heating and to domestic hot water. The seasonal coefficient of performance (SCOP) is 3.0 – 4.0 depending on the connection scheme and heating curve. The main problem of this renovation solution has been using old natural ventilation stacks without inserting new ducts inside the old stacks. Low airtightness of old stacks may lead to unbalanced air flow rates and noise problems. The main principle of EAHP system is shown in **Figure 6**.

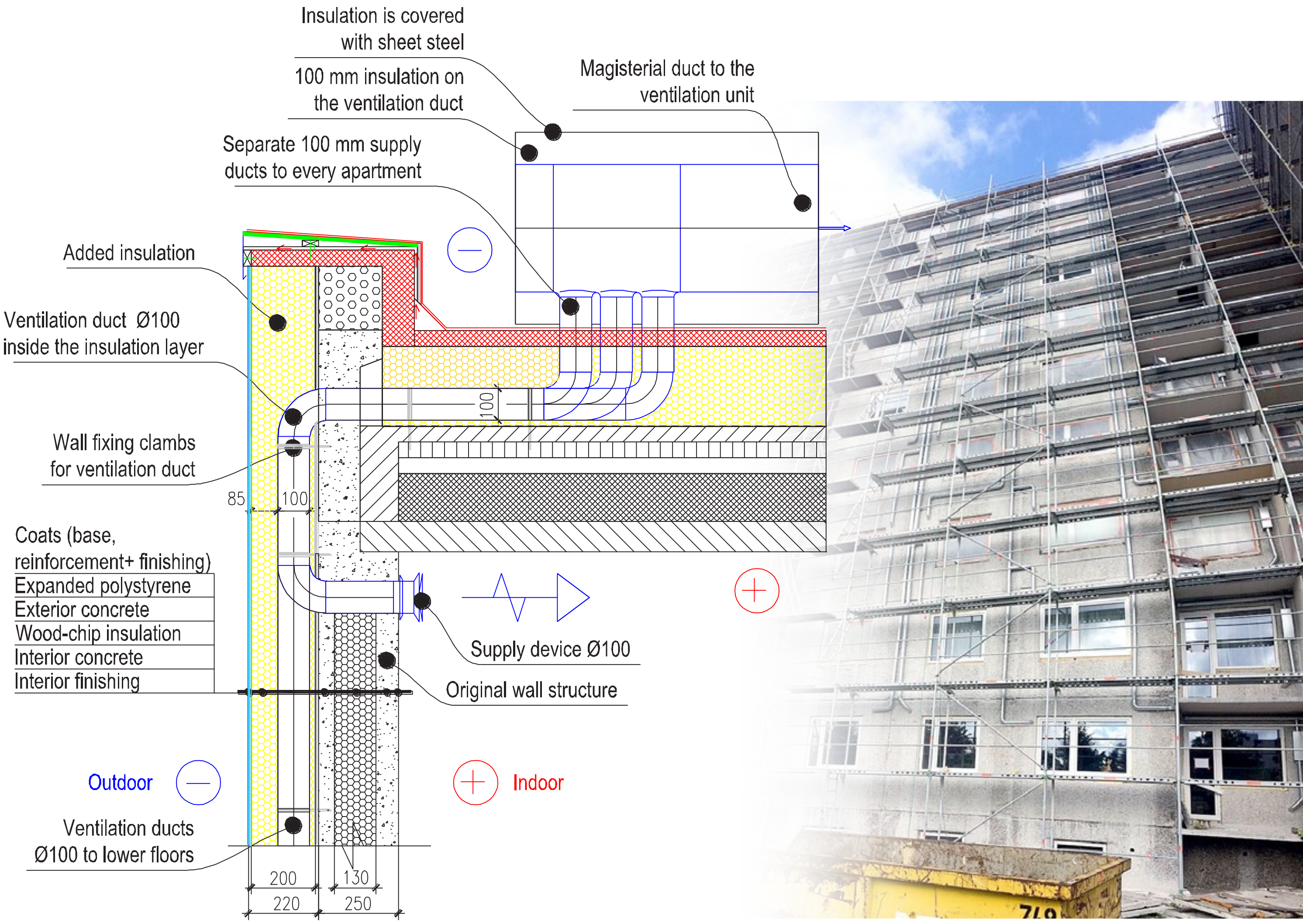

Figure 5. Ventilation ductwork installation on the wall.

There are many possible connection schemes for EAHP; operation with space heating priority has been preferred to maximise the cooling of district heating return. A schematic connection is shown in **Figure 7**.

Conclusions

Estonian renovation experience shows that it is possible to achieve heating energy savings up to 70% together with good indoor climate while adequate heat recovery ventilation solutions are used. In renovation the extent of the installation work needed inside apartments has been critical. Strict ventilation requirements with room-based airflow rates were necessary to mainstream heat recovery ventilation solutions in practice. Both centralized mechanical supply and exhaust ventilation and mechanical exhaust ventilation with exhaust air heat pump and ventilation radiators have been used as standard solutions since 2015. It was also necessary to develop model design drawings and to make ventilation airflow measurement reports mandatory to push towards following the new requirements.

Economic analyses have shown that the grants given by the government are budget neutral, because of average tax return of 32% from renovation projects (Pikas et al. 2015). Renovation has a positive reputation and is seen

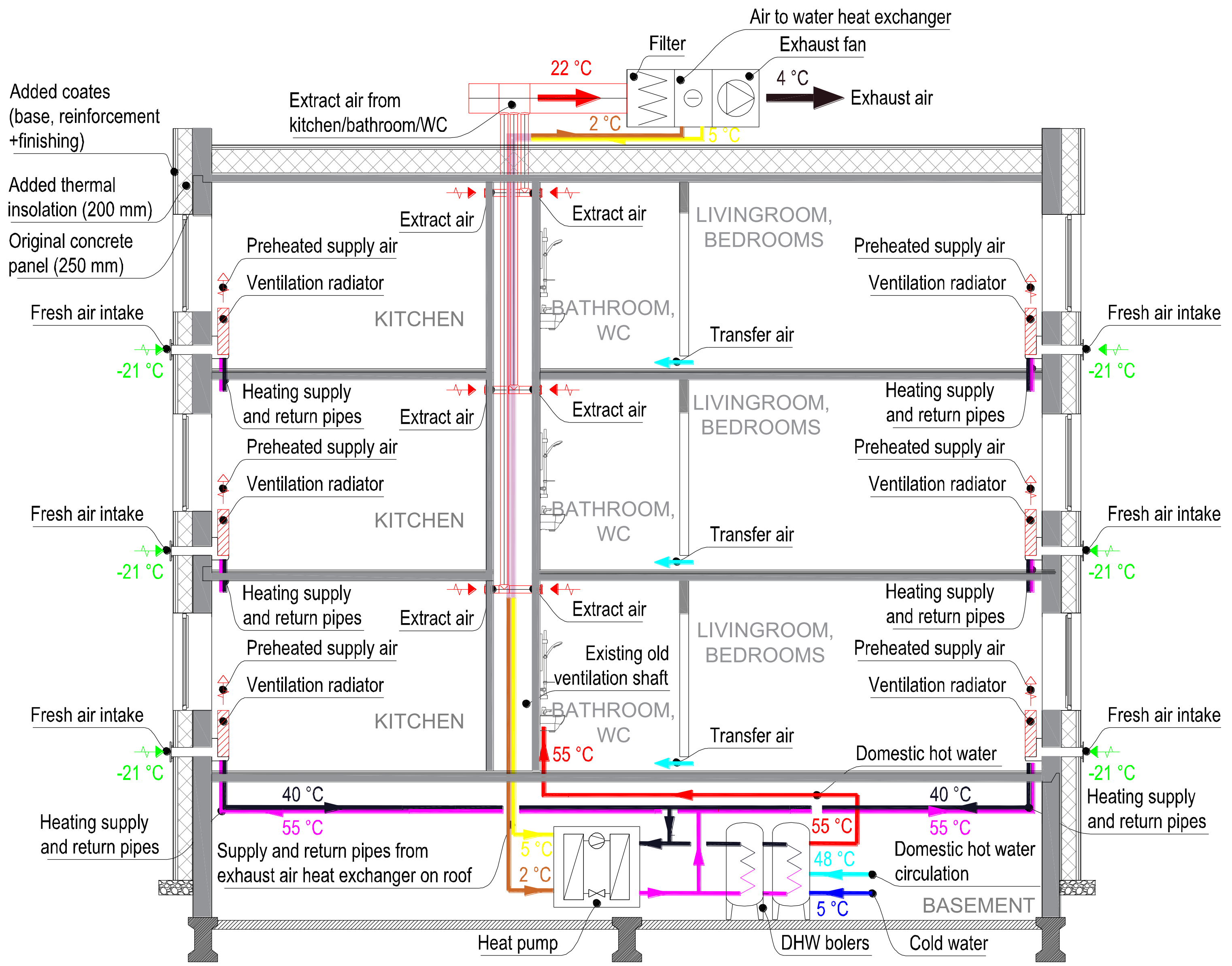

Figure 6. Ventilation radiators with exhaust heat pump heat recovery.

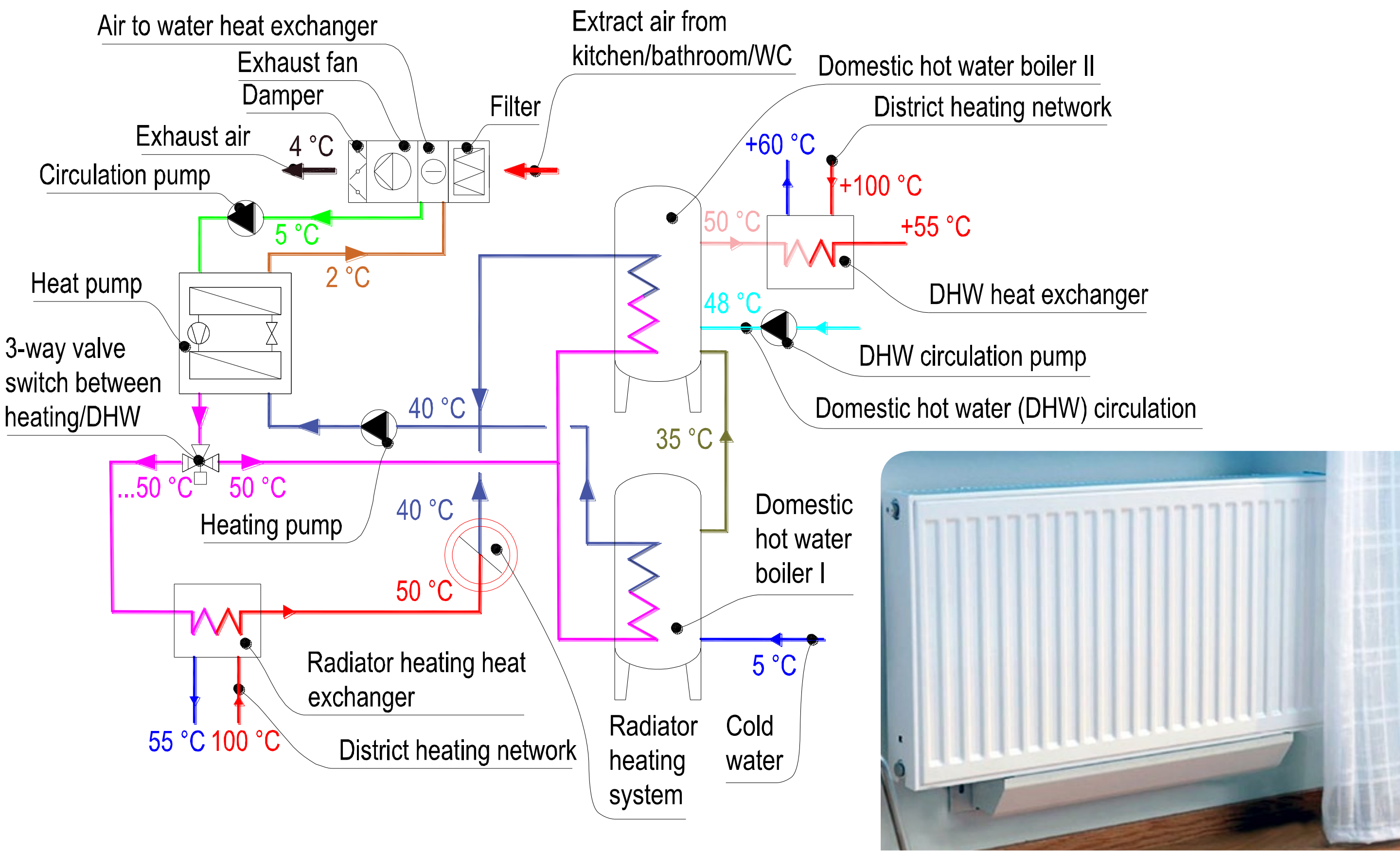

Figure 7. Exhaust air heat pump connection scheme and ventilation radiator.

beneficial for homeowners through improved indoor climate and general condition of the property, and increased real estate value. To date, about 3 000 apartment buildings are renovated, and it is planned to renovate all the rest of apartment buildings constructed before 2000, all together 14 000 buildings, by 2050 according to the Estonian long term renovation strategy. Typically, the renovation grant provides 30% financial support of the total renovation cost in large cities and 40-50% in periphery. ■

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TAIL and PredicTAIL

– the tools for rating and predicting the indoor environmental quality in buildings

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In the absence of a standard rating scheme for indoor environmental quality (IEQ), we propose a scheme that provides a rating of the quality of the thermal, acoustic, and luminous environment, indoor air quality, and the overall IEQ, for buildings under regular use (TAIL) and under renovation design (PredicTAIL).

Keywords: IEQ, health, well-being, rating, thermal, acoustic, IAQ, visual

To ensure that occupants' health and well-being are not compromised in energy-efficient buildings, the EU Directive on the energy performance of buildings (EPBD) states that

> ***"the energy needs for space heating, space cooling, domestic hot water, ventilation, lighting, and other technical building systems shall be calculated in order to optimize health, indoor air quality and comfort levels".***

To ensure that this guidance is observed, indoor environmental quality (IEQ) in buildings undergoing energy renovation must be monitored before and after the renovation process. This requires standard methods for rating the overall IEQ in buildings and the quality of the thermal, acoustic, and luminous environment and indoor air quality (IAQ). No agreed, and standard method exists at the moment to provide such a rating. Consequently, a rating scheme called TAIL has been developed (Wei et al., 2020a, Wargocki et al., 2021). The TAIL (**Figure 1**) allows assessment of the four IEQ components: thermal environmental quality (T), the acoustic environmental quality (A), the indoor air quality (I), and the luminous (visual) environmental quality (L), as well as the overall IEQ.

The quality of the TAIL components is determined by evaluating twelve parameters in buildings under regular use (**Table 1**). Ten of them are measured, one is inspected, and one is modelled. These parameters were selected to describe components of IEQ adequately, based on a literature review of existing IEQ standards, green building certification schemes, European ▶

Figure 1. Graphical presentation of the TAIL rating scheme including four IEQ components: thermal environmental quality (T), the acoustic environmental quality (A), the indoor air quality (I), and the luminous (visual) environmental quality (L), as well as the overall IEQ in the centre.

Table 1. Environmental parameters included in the TAIL rating scheme.

Parameter	Threshold value			
	Quality level: I	**Quality level: II**	**Quality level: III**	**Quality level: IV**
Thermal environment (T)				
Air temperature	**Building with mechanical cooling**			
	Heating season: 22 ± 1°C Non-heating season: 24.5 ± 1°C	Heating season: 22 ± 2°C Non-heating season: 24.5 ± 1.5°C	Heating season: 22 ± 3°C Non-heating season: 24.5 ± 2.5°C	If other quality levels cannot be achieved
	Building without mechanical cooling			
	Heating season: 22 ± 1°C Non-heating season: upper limit 0.33 θ_{rm} + 18.8 + 2°C, lower limit 0.33 θ_{rm} + 18.8 – 3°C	Heating season: 22 ± 2°C Non-heating season: upper limit 0.33 θ_{rm} + 18.8 + 3°C, lower limit 0.33 θ_{rm} + 18.8 – 4°C	Heating season: 22 ± 3°C Non-heating season: upper limit 0.33 θ_{rm} + 18.8 + 4°C, lower limit 0.33 θ_{rm} + 18.8 – 5°C	If other quality levels cannot be achieved
Acoustic environment (A)				
Sound pressure level	Small office: 30 dB(A) Landscape office: 35 dB(A) Hotel: 25 dB(A)	Small office: 35 dB(A) Landscape office: 40 dB(A) Hotel: 30 dB(A)	Small office: 40 dB(A) Landscape office: 45 dB(A) Hotel: 35 dB(A)	If other quality levels cannot be achieved
Indoor air quality (I)				
Air relative humidity	Office: 30 – 50% Hotel: 30 – 50%	Office: 25 – 60% Hotel: 25 – 60%	Office: 20 – 70% Hotel: 20 – 60%	If other quality levels cannot be achieved
Ventilation rate	≥ (10 ℓ/s/p + 2.0 ℓ/s/m² floor)	≥ (7 ℓ/s/p + 1.4 ℓ/s/m² floor) and < (10 ℓ/s/p + 2.0 ℓ/s/m² floor)	≥ (4 ℓ/s/p + 0.8 ℓ/s/m² floor) and < (7 ℓ/s/p + 1.4 ℓ/s/m² floor)	If other quality levels cannot be achieved
CO_2 concentration	550 ppm above outdoor concentration	800 ppm above outdoor concentration	1350 ppm above outdoor concentration	If other quality levels cannot be achieved
Formaldehyde concentration	< 30 µg/m³	≥ 30 µg/m³	No criteria	≥ 100 µg/m³
Benzene concentration	< 2 µg/m³	≥ 2 µg/m³	No criteria	≥ 5 µg/m³
$PM_{2.5}$ concentration	< 10 µg/m³	≥ 10 µg/m³	No criteria	≥ 25 µg/m³
Radon concentration	< 100 Bq/m³	≥ 100 Bq/m³	No criteria	≥ 300 Bq/m³
Visible mould area	No visible mould	Minor moisture damage, minor areas with visible mould (< 400 cm²)	Damaged interior structural component, larger areas with visible mould (< 2500 cm²)	Large areas with visible mould (≥ 2500 cm²)
Luminous environment (L)				
Illuminance	Office: ≥ 60% and ≤ 100% of the time with measured illuminance between 300 and 500 lux Hotel: 0% of the time with measured illuminance ≥ 100 lux	Office: ≥ 40% and < 60% of the time with measured illuminance between 300 and 500 lux Hotel: > 0% to ≤ 50% of the time with measured illuminance ≥ 100 lux	Office: ≥ 10% and < 40% of the time with measured illuminance between 300 and 500 lux Hotel: > 50% to ≤ 90% of the time with measured illuminance ≥ 100 lux	If other quality levels cannot be achieved
Daylight factor	Office: ≥ 5.0% Hotel: no criteria	Office: ≥ 3.3% Hotel: no criteria	Office: ≥ 2.0% Hotel: no criteria	If other quality levels cannot be achieved

θ_{rm}: outdoor running mean temperature research projects, and scientific publications (Wei et al., 2020b). Their ranges were defined based on recommendations and prescriptions in the current standards (EN 16798-1, 2019) and air quality guidelines (WHO, 2005, 2010), as well as other relevant documents (Level(s), 2017). According to the protocols defined by TAIL, these parameters should be evaluated at least in one season.

The quality of each of the parameters determines the quality of the four TAIL components and is presented by one of the four colours:

- Green describing a high (desired) quality level,
- Yellow describing a medium (refined) quality level,
- Orange describing a moderate (ordinary) quality level,
- Red describing a low (undesirable) quality level.

The overall IEQ level of the indoor environment is then determined based on the quality of TAIL components, where the worst quality level among the four TAIL components determines the overall IEQ in a building. This is done to ensure that none of the IEQ components is compromised. The overall IEQ level is indicated by a Roman numeral between I and IV:

- I indicating a high (desired) IEQ,
- II indicating a medium (refined) IEQ,
- III indicating a moderate (ordinary) IEQ,
- IV indicating a low (undesirable) IEQ.

The colours, Roman numerals, and levels of IEQ were selected to follow the indoor environmental categories defined by the standard EN 16798-1 (2019), one of the standards supporting the EPBD.

The TAIL rating scheme is a performance metric; it was examined in several buildings (Wargocki et al., 2021). It describes the actual IEQ in a building that is in regular use. It was developed especially for offices and hotels, but the activities are ongoing to assess whether it can also be used for other building types; this is expected to be likely. It was also defined with the premise of use in buildings undergoing energy renovations to determine IEQ before and after renovation.

However, it is expected that it can also be used to characterize IEQ in buildings that do not undergo energy renovation.

Because TAIL provides the rating of IEQ in buildings during regular use, it cannot be used during the design process to determine the consequences of different renovation options for IEQ; such as a tool was developed recently in Denmark for dwellings (Larsen et al., 2020). Therefore, TAIL was supplemented by a method that allows predicting its parameters during design; the method is called PredicTAIL (Wei et al., 2022). In the method, one-year simulations of ten of the twelve TAIL parameters are conducted to predict the quality level of the TAIL indicators and subsequently the overall IEQ level. The ten parameters that can be predicted by the PredicTAIL method are indoor air temperature, relative humidity, sound pressure level, daylight factor, illuminance, and concentrations of carbon dioxide (CO_2), formaldehyde, benzene, radon, and $PM_{2.5}$; mould cannot be predicted, and ventilation design should follow the codes so is prescribed.

To test the feasibility of the PredicTAIL method, predictions of the TAIL parameters were conducted in two buildings, an office and a hotel, located in two European cities (Wei et al., 2022). The results of only the office building are presented in this paper as an illustration of the PredicTAIL method. The building was a two-floor concrete structure building constructed in 1900 in an urban environment; the four rooms selected for the simulations were considered representative of the office rooms. Simulations of the TAIL parameters considered a base-case scenario (current state) and four renovation scenarios: two scenarios considered renovation actions expected to impact the IEQ, and the other two addressed renovation actions expected to reduce energy use in buildings. These scenarios were selected to examine whether the method would be sensitive to detect changes in IEQ due to the changes defined by the scenarios. Simulations were conducted using TRNSYS for the indoor air temperature and relative humidity, ACOUBAT for the sound pressure level, MATHIS-QAI for the indoor pollutants, and PHANIE for the illuminance and daylight factor. However, it is expected that any other validated and relevant simulation tools can be used to perform these calculations.

Figure 2 shows the results of the predicted TAIL rating for the office building.

The overall IEQ level was red (level IV, undesirable IEQ) in the base-case (current state) scenario. The thermal environment was poor due to large variations in indoor air temperatures in the shoulder season (spring/fall) (min: 16.3°C, max: 27.7°C).

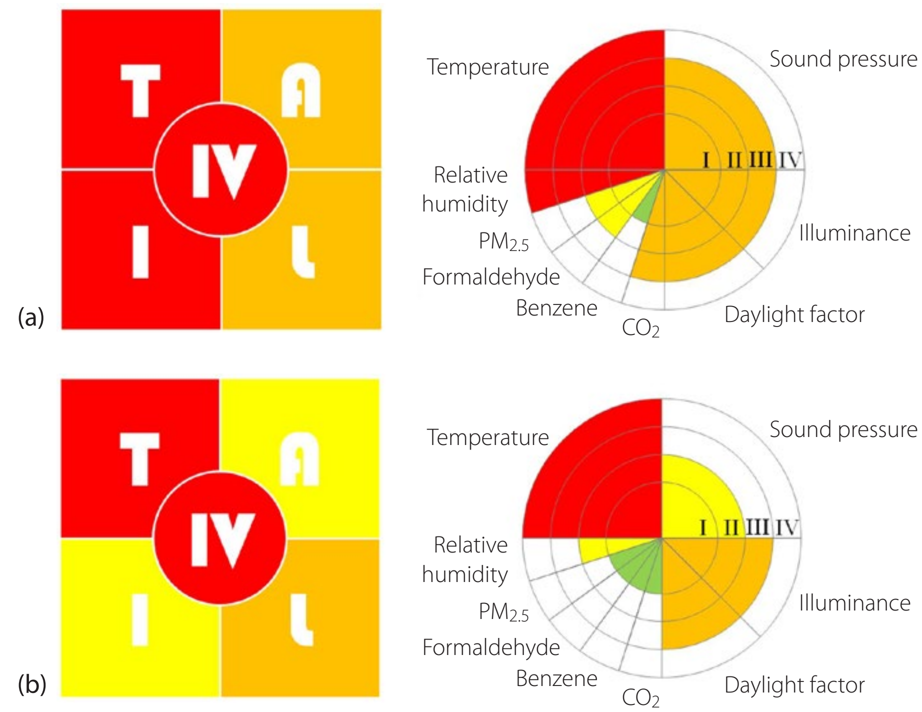

Figure 2. Predicted TAIL rating for the office building for
(a) current state (T: red, A: orange, I: red, L: orange),
(b) IEQ renovation (T: red, A: yellow, I: yellow, L: orange).

The acoustic environment was orange (moderate quality) because the building was located in an urban environment with high outdoor noise. The IAQ level was rated as undesirable due to large variations in the indoor air relative humidity (min: 10% for a few hours in the heating season, max: 92% for a few hours in the shoulder season), particularly in the shoulder season. The ventilation rate was too low, and consequently, the CO_2 concentration was rated as orange in the shared office rooms. The predicted TAIL rating for the base-case scenario indicated that apart from $PM_{2.5}$, formaldehyde and benzene, other parameters had high improvement potential because of their critical ratings for the base-case scenario. The renovation scenarios showed that increasing the ventilation rate to 10 ℓ/s/person according to the standard EN 16798-1 (2019) and installing an F7 filter on the outdoor air inlet could reduce indoor pollutant concentrations, and as a result, the green level could be reached. Improved insulation of the walls and installing double-glazed windows could improve the acoustic environment of the office building located in the urban area to the yellow level (medium quality). Moreover, the predicted TAIL rating showed that the glass curtain wall at the west facade could cause high solar gains and high illuminance levels during the daytime, resulting in moderate and low levels of the luminous and thermal environmental qualities for the office rooms oriented toward the west. As a result, specific actions not considered in the examined scenarios would be needed to improve further the hygro-thermal and luminous parameters for these office rooms next to the glass curtain wall. The prediction results showed that the PredicTAIL method was very useful in guiding design decisions that would lead to improved IEQ. It could identify the changes in IEQ as a result of renovation actions, which means that it was sufficiently sensitive within the IEQ boundaries set by the TAIL rating scheme.

Conclusions

TAIL and PredicTAIL provide a complete tool allowing characterization of IEQ in buildings. It is expected that they will become a standard method of benchmarking IEQ in buildings when applied. This requires however further validation. It is also expected that they will stimulate actions leading to the general improvement of the IEQ in buildings. ■

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QUEST

QUEST TECHNICAL MANUAL

Quality Management: De-Risking Green Investments in Building Projects

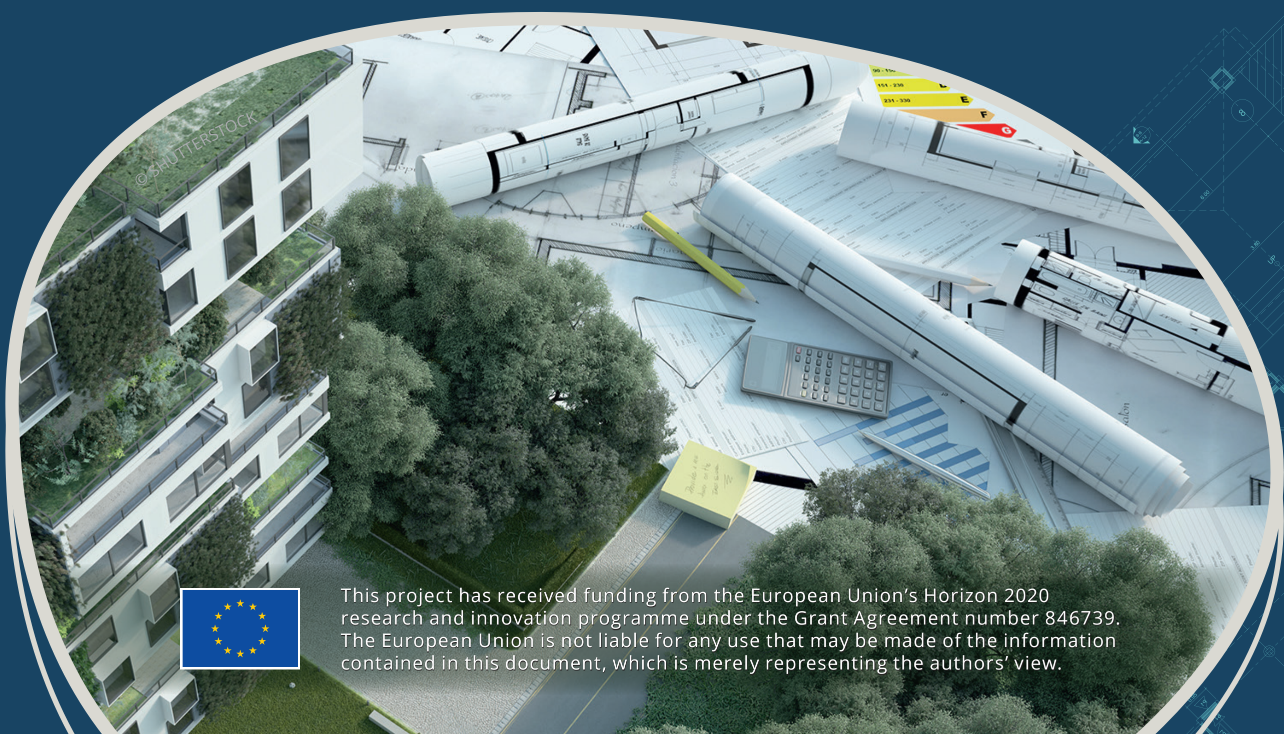
One of the biggest **RISKS** for investments in building projects is the performance gap. This gap signifies a disparity between predicted building performance estimated during the design phase and the actual performance when the building is operational.

One of the most common **CAUSES** for this gap is a lack of quality management during the early stages of the building projects. For building owners & investors it's often hard to keep track of the technical risks and how they can be mitigated.

SOLUTIONS to decrease the risk of this gap happening already exist. Quality Management Services aim to ensure that buildings meet the predefined sustainability requirements placed on them and can help building investments to be Taxonomy-aligned.

The QUEST consortium has developed a **TOOLBOX** to facilitate the integration of various Quality Management Services into building projects. An easy-to-understand technical manual has been developed that helps building owners, investors and real estate developers to apply this toolbox in their own projects to integrate Quality Management Services and ensure that that the investments bring the building performance that is expected.

The QUEST Technical Manual is available for FREE at: https://project-quest.eu/technical-manual-applying-quest



This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement number 846739. The European Union is not liable for any use that may be made of the information contained in this document, which is merely representing the authors' view.

Healthy Homes Design Competition 2022

This project born out of the collaboration of VELUX and REHVA encourages and challenges the young working 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.

After closing the submissions, the Jury now evaluates all submitted projects and the nominees will be announced 15 April 2022. Finalists will be invited to CLIMA 2022 to present their projects on 24 May 2022. After further jury deliberation, the winning teams will be announced at in the closing ceremony of 25 May.

The winner of the competition will be winning a prize of 5 000 €.

REHVA

VELUX®

Meet The Jury

Stefano Cognati (jury chair)
Associate professor at Politecnico di Torino, Italy

Karel Kabele
Vice Dean, Czech Technical University in Prague, Czech Republic

Jelle Laverge
Associate Professor at Ghent University

Susan Roaf
Professor at Heriot-Watt University in Edinburgh

Jakob Strømann-Andersen
Director of Innovation and Sustainability at Henning Larsen

Mieke Weterings
Sustainable and healthy urban planning Consultant at Rotterdam Municipality

The project

Imagine you have a plot in Rotterdam, on the edge of the city, close to an industrial area; but still, you and your teammates are determined to create an above-average healthy & comfortable apartment complex for 20 households, that tunes in with present-day challenges. What would you build on that plot? How would you shape a new way of living at this suboptimal location? How will you make the best out of it? And how would you make this dwelling complex healthy and comfortable but also energy-efficient and climate-resilient?

As a healthy home, the focus of the project is on the indoor environment – the health and well-being of the occupants. The indoor air quality, as well as thermal, acoustical and visual comfort, play an important role in the design. The project should present the solutions applied to achieve the best level of comfort, in terms of indoor climate and daylight. A specific focus should be set on the contemporary and future challenges faced by both designers and end-users e.g., related to climate change. Also, the design should tune in with the specifics of the (virtual) building site.

The future healthy homes are as well expected to be sustainable and resilient to climate change. Sustainability can be seen in many different aspects, mainly related to the environment, economy and society. The project should use the most appropriate level of technologies according to the building use, considering hybrid ventilation, active and passive solutions where possible and have a clear sustainable direction in its energy consumption while maintaining high indoor climate quality. The buildings and systems should also be ready to adapt or resist the climate challenges of tomorrow.

CLIMA 2022

REHVA Annual Meeting Programme

Day 1 - Friday 20 May 2022

REHVA Annual Meeting 2022
Woerden, 20-23 May
Hosted by TVVL

15:00-16:00
COP Meeting

16:00-19:00
Board Meeting (1)

Day 2 - Saturday 21 May 2022

10:00-12:00
Technology and Research Committee Meeting

10:00-11:30
Education and Training Committee Meeting

12:00-13:00 **Lunch**

13:00-14:30
Publishing and Marketing Committee Meeting

13:00-14:00
Awards Committee Meeting

14:30-15:30
REHVA Journal Editorial Board Meeting

14:00-15:30
SCANVAC/BALTVAC Meeting

15:30-16:00 **Coffee break**

16:00-17:30
Quaterly Plenary Meeting
(for Presidents, Directors and delegates of REHVA Member Associations)

20:00 -23:00
REHVA Dinner and professional awards

Day 3 - Sunday 22 May 2022

11:30-12:00 **Brunch**

12:30-15:30
General Assembly
(for delegates of REHVA Member Associations)

13:00-15:30
REHVA Courses (?)

16:00-20:00
CLIMA 2022: opening ceremony, keynotes and walking food & drinks reception

Day 4 - Monday 23 May 2022

10:30-11:00
Board Meeting (2)

12:30 — 13:30 **Supporter's Lunch** *(upon invitation)*

14:15-15:45
Supporters Committee Meeting

All locations of the Annual Meeting program: TBC

REHVA Expert Talks

At the REHVA Annual Meeting 2021, REHVA organized the Expert Talk: Circular Economy in the HVAC Industry. Members of the Supporter Committee meeting and their colleagues joined this exclusive event. The theme was developed by presentations by actors of the field and institutional representatives: Josefina Lindblom of the European Commission, Mirko Sauvan of SWEGON Group, Olaf Oosting of TVVL and Juan Travesi, REHVA Vice-President. A moderated discussion allowed to wrap up the event and to answer questions from attendees. This theme was dear to our Supporters as demonstrated in the 2020 survey efforts made by REHVA.

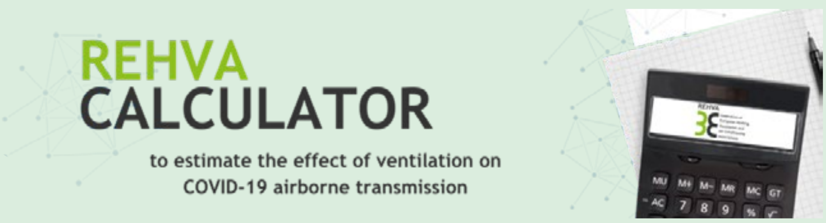
In December 2021, at the REHVA Brussels Summit, the second Expert Talk: Deep energy renovation with the new EPBD was organized for attendees to the Supporter Committee. The speakers were Pau Garcia Audi from the European Commission, Mikko Iivonen from Purmo Group, Jarek Kurnitski, REHVA Vice-President and Claus Händel from EVIA. The speaker's presentations were followed by a Q&A session with the attendance.

REHVA Calculator Update 2.1

This calculator was developed by Prof. **Jarek Kurnitski** and the REHVA COVID-19 Task Force for specialists with at least a minimum understanding of ventilation and air distribution. The tool is available for download for experts who have read and understood the related COVID-19 guidance document, as well as the explanation on the use of the tool or are enrolled in the REHVA COVID-19 course.

This latest update 2.1, published in early 2022 on the REHVA Website has been specifically thought out to account for the Omicron variant of the COVID-19 virus.

It adds to the previous update 2.0 that had considered the Alpha & Delta variants on top of other changes regarding the quanta emission rate representative values, complementary measures (portable air cleaners & facial masks) and probability of infection calculation.



REHVA CALCULATOR

Download the Calculator

In memoriam Ferenc Maszaros

REHVA is sad to announce that Ferenc Meszaros passed away. He was REHVA Vice-President for 9 years, a REHVA Honorary Fellow since 2003, a REHVA fellow since 2011, a proud member of ETE, the Scientific Society for Building (Hungary) and the editor-in chief for the Hungarian HVAC Journal between 1992-2007.

Ferenc passed before of his 90th birthday and enjoyed a full life, with many accomplishments in our industry.

We offer our condolences to his family, colleagues and friends. ■

NEW

REHVA Supporters

E.E.B.C. | Romania | eebc.ro

EEBC is a new supporter of REHVA since 2022.

The approach of the East European Business Center is to constantly improve the quality of services in the field of constructions and installations in any industry.

Whether about consulting and expertise at the highest level, or about execution, the East European Business Center will always deliver integrated solutions and services for installations in any industry at national and international level. Their services are available to clients in areas such as civil and industrial installations and constructions, real estate developments, industry, medical installations and equipment.

Their specialized team with extensive experience in each field, know-how, partnerships with world-renowned manufacturers and suppliers and the experience gained guarantee customers, partners and collaborators that East European Business Center ensures the success of each project.

EVIA | Belgium | evia.eu

EVIA, The European Ventilation Industry Association is a new supporter of REHVA since 2022.

The European Ventilation Industry Association (EVIA) was established in Brussels in July 2010. EVIA's mission is to represent the views and interests of the ventilation industry and serve as a platform between all the relevant European stakeholders involved in the ventilation sector, such as decision-makers at the EU level as well as partners in EU Member States. Membership is composed of more than 45 member companies and 6 national associations across Europe, realising an annual turnover of over 7 billion euros and employing more than 45,000 people in Europe.

EVIA aims to promote highly energy efficient ventilation applications across Europe, with high consideration for health and comfort aspects. Fresh and good indoor air quality is a critical element of comfort and contributes to keeping people healthy in buildings.

Testo | Romania | testo.com

TESTO Romania is a new supporter of REHVA since 2022 and celebrates their 10 year anniversary in this year, congratulations!

Testo, based in Lenzkirch in the Black Forest, Germany, is a world leader in portable and stationary measurement technology. Worldwide, 3,200 employees are involved in research, production and marketing for the company. They help to identify innovative measurement solutions in areas such as air conditioning and ventilation, food quality, construction technology and emission control.

In 2012, TESTO Romania started its activities in Cluj and are planning to expand their service in Bucharest. In 2017, a metrology laboratory was added to the Cluj office.

The laboratory is certified by the Romanian Bureau of Legal Metrology and has traceability to the ISO 17025: 2005 standard applicable to testing and calibration laboratories and use a quality management system that is certified by DEKRA according to the ISO 9001: 2015 standard.

BECOME A REHVA SUPPORTER

REHVA, the Federation of European HVAC Associations represents more than 120.000 building services engineers from 27 countries. **REHVA** is dedicated to the improvement of health, comfort and energy efficiency in all buildings and communities.

REHVA supporter companies share the mission of REHVA: promoting latest HVAC technologies and advocating for energy efficient buildings with high indoor environmental quality. The benefits of REHVA Supporters are multiple: they range from increased European visibility, through networking with experts and HVAC engineers from across Europe, till the access to latest research outcomes and educational materials in the HVAC field.

Services to REHVA Supporter Companies

- EU level networking opportunities with engineers, HVAC designers, researchers and stakeholders in the field of building services
- The Supporters' Bulletin focusing on EU directives, regulations and standards tailored for supporters (bi-monthly)
- Promotion in the REHVA Journal six times a year
- REHVA Journal in paper copy
- Access to restricted online services: eGuidebooks, HVAC Terminology, EU Policy Tracking, REHVA Committee documents, workshops and courses videos.
- Up to 60% discount for REHVA Guidebooks' orders
- Promotion on the REHVA website - www.rehva.eu
- Up to 40% discount advertisements in the REHVA Journal
- REHVAClub events (at Annual Conference, REHVA seminars, cocktails, etc.) organized for Supporters with speakers from the European Commission and EU level stakeholder organizations
- Free copy of new REHVA Guidebooks and 20% discount on list price for extra copies

Pricing

- The annual fee for REHVA Supporters is only 3.000 €!
- Additionally, REHVA offers Platinum, Gold, Silver and Bronze Supporter Packages wich offer complementary promotion opportunities to its Supporters.
- For more information visit www.rehva.eu/about-us/join-rehva or contact us at info@rehva.eu.

NEW

REHVA Associate Organisations

enerbrain
For an intelligent use of energy

Enerbrain srl | Italia | enerbrain.com

Enerbrain is a REHVA Associate Organisation since 2020.

The Enerbrain system is an IoT solution based on innovative algorithms and Artificial Intelligence, which radically improves the energy management in buildings resulting in high energy savings and better indoor comfort levels for their customers.

ENVIROMECH

Enviromech | United Kingdom | enviromech.co.uk

Enviromech is a REHVA Associate Organisation since 2021.

Enviromech is a young dynamic building services company specialising in design, installation & facility management services. Enviromech is renowned for delivering quality Mechanical and Electrical solutions across projects in the United Kingdom. They operate in a variety of sectors including commercial, residential, railway, hospitality and education.

European Copper Institute
Copper Alliance

European Copper Institute (ECI) | Belgium | copperalliance.org

The European Copper Institute, ECI is a REHVA Associate Organisation since 2022.

Based in Brussels, the European Copper Institute (ECI) is the leading advocate for the copper industry in Europe. Through a team of policy, industry and scientific experts, ECI acts to support copper's role in achieving the EU's policy goals. Part of the International Copper Association (ICA), ECI promotes copper's crucial role in the energy transition, electromobility, and the building or renovation of sustainable, energy-efficient buildings.

ISIB TURKISH HVAC-R

ISIB | Turkey | isib.org.tr

ISIB, The Turkish HVAC&R Exporters Association is a REHVA Associate Organisation since 2021.

They are celebrating their 10th anniversary in 2022, congratulations!

The Turkish HVAC&R Exporters Association (ISIB) is the exporter association in the Turkish HVAC&R sector. Established in 2012, ISIB works towards bringing together all the exporter companies active in the Turkish HVAC&R sector under one roof and increasing the export potential of the sector.

Romanian Chamber of Energy Auditors (OAER)

OAER | Romania | oaer.ro

The Romanian Chamber of Energy Auditors, OAER is a REHVA Associate Organisation since 2021.

The purpose of establishing the association Romanian Chamber of Energy Auditors (OAER) is to create the organizational framework in order to promote measures, concepts and actions that lead to the support of professional interests as well as to increase and improve the activity of long-term graduates and research specialists, project execution and operation, for the realization of energy efficient buildings. OAER also provides the appropriate institutional, material and social framework for the manifestation of its members, representing and protecting the interests of energy auditors for buildings.

BECOME A REHVA ASSOCIATE ORGANISATION

REHVA, the Federation of European HVAC Associations represents more than 120.000 building services engineers from 27 countries. **REHVA** is dedicated to the improvement of health, comfort and energy efficiency in all buildings and communities.

REHVA Associate Organisations are associations, institutions, NGOs and other organisations related to the field of building technologies and HVAC that share our vision and pursue the same mission as REHVA: promoting the science and practice of HVAC and building engineering services to achieve high indoor climate quality and building performance levels.

Benefits of a REHVA Associate Organisation

- Be part of the REHVA community of leading HVAC experts and indoor climate engineering professionals from academia and industry
- Join a common European voice promoting healthy buildings, indoor climate quality, safety and energy efficiency in all buildings and communities
- Gain visibility and reputation in the international professional community
- Profit from our interdisciplinary REHVA knowledge platform and shared excellence
- Join our international events and EU level professional networking opportunities with engineers, HVAC designers, researchers, manufacturers, and other stakeholders including high-level speakers from the European institutions and leading industry representatives
- Engage with the REHVA Community of Young Professionals, exchange with your peers and hire your new colleagues
- Follow and engage with our online REHVA information and knowledge sources & social media
- Benefit from our tailored information services and the international knowledge exchange on technological trends, research results and innovations, national engineering practices and EU policy implementation
- Read our bi-monthly REHVA Newsletter
- Get free or advantageous access to REHVA services and publications
- Benefit from the REHVA partnership for webinars, events & knowledge dissemination

PRICING

We offer 3 different fee levels to associated organisation depending on the size of the organisation:

- NGOs, non-profit organisations and micro enterprises: 500 €
- Small size companies: 1.000 €
- Medium size compagnies: 1.500 €
- For more information visit www.rehva.eu/about-us/join-rehva or contact Nicoll Marucciova at nm@rehva.eu.

The REHVA Community of Young Professionals is meeting for the first time!

In May 2022, the RCYP, led by the 2016 winner of the REHVA Student competition Arash Rasooli is organizing social activities for their members in Rotterdam during REHVA 14th HVAC World Congress, CLIMA 2022.

This is the first time the members will be able to meet in person. RCYP was born at the beginning of 2020 and due to the pandemic and its consequences, we never got the chance to have the members socialize. The social events take place during REHVA 14th HVAC World Congress, CLIMA 2022, at AHOY Rotterdam.

The social event will include a dinner & drinks gathering in one of the nicest areas of Rotterdam. This will give us an opportunity to get to know each other for the first time and talk about our work and our history in the field.

The second social activity planned is a Rotterdam walking tour which will include some famous site known for their modern unique Dutch architecture. This architectural & sustainability themed tour of Rotterdam will allow to explore the city with an expert eye. We will be visiting a number of urban areas and learn about their history and the future and their sustainability aspects.

More details will be provided on the website:

The REHVA Knowledge Hub

The REHVA Knowledge Hub is your digital platform offering independent, high quality, trustable information about building services and indoor climate.

Subscribe today to access exclusive benefits and insights! Here is some of the recently uploaded content you can find inside:

The **EU Policy Tracking** has been continuously updated with the latest insights from REHVA and its network. Within the section you can find regularly updated Policy Strategies: *Fit for 55, Renovation Wave and EU Green Deal* as well as Policy Issues both ongoing and closed: *SRI, EPBD revision, EEF, RED II revision 2021, EED revision 2021, Built4People.*

The REHVA policy team keeps you updated on the latest developments and activities in these dossiers and lets you know how they can impact the sector. This is a must have for actors in the field and business leaders.

The **REHVA Academy** content has been updated with the *Brussels Summit 2021 recordings*. This highlight REHVA event saw a panel of experts come together to the Policy Conference to present their views on the current and future landscape of the HVAC sector. The first session presents the building decarbonisation related aspects of the Fit for 55 package and provide updates about the key EU directives under revision and the second session discusses how the existing frameworks and tools to assess building performance and sustainability can work together to foster and deliver building decarbonisation in practice, having an eye and the Renovation Wave.

New content under the REHVA Academy, recordings from the exclusive *Expert Talk* can be found. This REHVA supporters live event brought together experts and representatives. Our Expert Talk discussed how the revised EPBD can help creating the necessary policy environment and how HVAC designers, manufacturer and solution providers can make this massive scale renovation happen at high quality and efficiency delivering also good indoor climate quality with deep energy renovation.

New content has also been added to the **EPB Standards** section including four videos on *zoning principles & example for lighting, Cooling systems calculations, overview & generation*, *cooling systems calculations, generation performance map* and *cooling systems calculations, air-to-air generation & performance map.* Other updated content includes new spreadsheets, information about the elevation of BACS standards to ISO level, webinar content and specific ISO update content.■

REHVA KNOWLEDGE HUB

EXCLUSIVE CLIMA 2022 PROMOTION!

Subscribe to the Knowledge Hub between 22.05.2022 and 31.05.2022 to enjoy 1 year at the REHVA Members' rate!

Use the code "CLIMA2022" in the "REHVA-member / National HVAC association name" section when subscribing to enjoy this limited offer

Pricing		
Non-REHVA Members	REHVA Members	Students
120€	100€	60€

All prices incl. VAT

New REHVA Guidebook No. 32: Energy efficient renovation of existing buildings for HVAC professionals

REHVA is proud to present its new **Guidebook n°32: Energy efficient renovation of existing buildings for HVAC professionals**. This Guidebook was created by a REHVA Task Force, which includes members from 9 European countries, including Estonia, Finland, France, Greece, Italy, Poland, Romania, Serbia and Turkey.

The modernization of Heating, Ventilation and Air Conditioning (HVAC) systems can play a very important role during deep renovations of existing buildings in order to achieve in practice the calculated energy savings by operating the existing installations.

Therefore, the aim of the Guidebook is to provide strategies and recommendations for supporting practising professionals in the field of energy renovation of existing buildings, focusing on HVAC systems. Although this Guidebook does not address in detail the role of the building envelope, it is an essential part of the initial efforts for reducing the energy demand.

The Guidebook shows the baseline for specific energy efficiency and other renovation measures in existing buildings for which the HVAC systems play an important role. Emphasis is given on market ready and technically mature solutions that have been proven in practice in order to increase the building renovation rates and facilitate the energy renovation process of existing buildings. The Guidebook presents results from field studies with quantified energy savings that are complemented with estimates of the payback time to document the overall benefits resulting from different renovation measures that can be implemented by HVAC professionals and practitioners.

Focusing only on the energy renovation of the building envelope, instead of the building as a whole, will often limit the potential energy savings and may significantly increase the payback time. Emphasis should also be placed on the renovation of HVAC systems and foster for the energy education of the building occupants in order to fully exploit the anticipated benefits from the various implemented technologies. In addition, the adaptation of HVAC systems to the different building energy demand will further improve the indoor environmental quality (IEQ) and overall occupant satisfaction.

For the transformation of existing buildings from high energy consumption and high carbon to carbon neutral buildings, professionals can use the general energy renovation concept proposed in this Guidebook. The information presented herein is applicable to different specific renovation concepts that can be adapted to various, regional renovation projects. This holistic approach takes into account all the main factors that may affect energy consumption, IEQ, carbon footprint, costs and future application of Renewable Energy Sources (RES) at all stages of the energy renovation process of existing buildings (i.e. from planning, to construction, and finally monitoring).

The priority to improve and maintain the desirable IEQ should be complemented by technically and economically justified measures that increase energy efficiency of existing buildings. A complete plan should account for the energy renovation of the building's envelope and all the HVAC installations with the use of low embodied energy (carbon) materials, as well as for the user education. Reducing the building's energy demand and final energy consumption, will also facilitate the selection of the appropriate RES and the cost effectiveness for the use of the appropriate technologies to cover the remaining low energy needs for a nearly zero energy building or even a carbon neutral building.

The Guidebook presents the best available techniques and solutions that can be used as part of the energy modernization of the HVAC systems. They are usually characterized with a life cycle analysis to have a low carbon footprint, low payback time, short implementation time, while minimizing disruption for building's occupants and offering a high potential for repeatability to other buildings and widespread use. The information contained in this Guidebook should inspire and motivate professionals to achieve better project results, high performance buildings, satisfied building owners and occupants.

This Guidebook was developed by a working group of the following experts:

Tomasz Cholewa , Chair (Lublin University of Technology, Poland), Constantinos A. Balaras (National Observatory of Athens , Greece), Jarek Kurnitski (Tallinn University of Technology, Estonia), Livio Mazzarella (Politecnico di Milano, Italy), Alicja Siuta-Olcha (Lublin University of Technology, Poland), Elena Dascalaki (National Observatory of Athens , Greece), Risto Kosonen (Aalto University, Finland), Catalin Lungu (Technical University of Civil Engineering of Bucharest, Romania), Marija Todorovic (Academy of Engineering Sciences of Serbia, Serbia), Ilinca Nastase (Technical University of Civil Engineering of Bucharest, Romania), Mihnea Sandu (Technical University of Civil Engineering of Bucharest, Romania), Cécile Jolas (AICVF, France), Murat Çakan (Istanbul Technical University, Turkey)

BELIMO AT MCE 2022

Thermal energy management and metering, through a single device!

Belimo, the leading manufacturer of damper actuators, control valves and sensors for HVAC technology for heating, ventilation and air conditioning, now combines the worlds of "energy control" and "certified energy measurement and metering".

Belimo, the leading manufacturer of damper actuators, control valves and sensors for HVAC technology for heating, ventilation and air conditioning, now combines the worlds of "energy control" and "certified energy measurement and metering".

At **Mostra Convegno Expocomfort 2022**, scheduled to take place from 28 June to 1 July in Milan, numerous new products will be presented at the exhibition stand (Hall 15 - Stand A31-A35), with particular focus on the most important innovation of recent years: the first series of **MID-certified Thermal Energy Meters** developed and produced by Belimo. This new range is available in two versions: **TEM - Thermal Energy Meter**, designed for metering only, and **EV - Energy Valve™**, designed for both metering and thermal energy control.

The two worlds of "energy control" and "certified energy measurement and metering" are finally united in a single device: **the new Belimo Energy Valve™** instantly measures, monitors and regulates the flow rate and energy consumption in heating and cooling systems with direct cost accounting. The new Belimo Thermal Energy Meters are certified according to EN1434/MID for direct metering and heat measurement in pure water systems. Their constant glycol monitoring enables an alarm to be triggered when glycol is present in the water, as this would otherwise adversely affect the energy readings. For non-MID-certified meter models, on the other hand, Belimo's patented glycol monitoring and automatic compensation ensure that the measurement remains accurate, regardless of the concentration or type of glycol in the system.

Thanks to integrated IoT functions, all products in the new range are "remotely readable" as required by EU Directive 2018/2002. The data is available free of charge and for life at the Belimo Cloud, so the end user, building administrator or maintainer can access historical or real-time data of the system at any time, without any cost or service fee. In addition, connecting the devices to the Belimo Cloud extends the warranty to 7 years and offers a number of additional benefits.

Indoor Air Quality & Belimo: more than 45 years of experience.

In order to safeguard our health, the healthiness of our environments, the comfort and well-being of individuals, and to promote energy efficiency and energy savings in buildings, it is becoming increasingly important to pay attention to Indoor Air Quality (IAQ). Since its foundation in 1976, the Swiss company has been dealing with these issues and today the new range of Room Panels represents the ideal complement to Belimo valves and actuators to optimise the performance of systems and improve their energy efficiency.

Belimo Room Panels, also available with Display and characterized by a high precision in the measurement of the fundamental quantities for comfort (Temperature, Humidity, CO2, VOC ...), are able to offer not only energy efficiency and air quality, but also the possibility to measure and monitor all these parameters. ■

REHVA

Federation of European Heating, Ventilation and Air Conditioning Associations

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www.atic.be

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www.ekvy.ee

FINVAC – Finland
www.finvac.org

AICVF – France
www.aicvf.org

VDI–e.V. – Germany
www.vdi.de

ÉTÉ – Hungary
www.eptud.org

MMK – Hungary
www.mmk.hu

AiCARR – Italy
www.aicarr.org

AHGWTEL/LATVAC – Latvia
www.lsgutis.lv

LITES – Lithuania
www.listia.lt

AIIRM – Republic of Moldova
www.aiirm.md

TVVL – The Netherlands
www.tvvl.nl

NEMITEK – Norway
www.nemitek.no

PZITS – Poland
www.pzits.pl

ORDEM DOS ENGENHEIROS – Portugal
www.ordemengenheiros.pt

AIIR – Romania
www.aiiro.ro

AFCR – Romania
www.criofrig.ro

AGFR – Romania
www.agfro.ro

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

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

Exhibitions, Conferences and Seminars in 2022

April			
6-8	World Sustainable Energy Days 2022	Wels, Austria	https://www.wsed.at/
21-22	CIBSE Technical Symposium 2022	London, United Kingdom	https://www.cibse.org/technical-symposium/about
May			
4-6	CIAR Lisboa 2022	Lisbon, Portugal	http://www.ciar2022.com./
4-6	IAQ 2020: Indoor Environmental Quality Performance Approaches	Athens, Greece	https://www.ashrae.org/conferences/topical-conferences/indoor-environmental-quality-performance-approaches
20-23	REHVA Annual Meeting 2022	Rotterdam, the Netherlands	https://www.rehva.eu/events/details/rehva-annual-meeting-2022
22-25	CLIMA 2022	Rotterdam, the Netherlands	https://clima2022.org/
June-July			
12-16 June	Indoor Air 2022	Kuopio, Finland	https://indoorair2022.org/
22-24 June	Ventilation 2022: 13th International Industrial Ventilation Conference For Contaminant Control	Toronto, Canada	https://www.ashrae.org/conferences/topical-conferences/ventilation-2022
25-29 June	2022 ASHRAE Annual Conference	Toronto, Canada	https://www.ashrae.org/conferences/2022-annual-conference-toronto
28-1 July	Mostra Convegno Expocomfort 2022	Milano, Italy	https://www.mcexpocomfort.it
August			
22-23	BuildSim Nordic 2022	Copenhagen, Denmark	https://ibpsa-nordic.org/
September			
16-19	ROOMVENT 2022	Xi'an, China	https://www.roomvent2022.com/
October			
2-6	Light + Building	Frankfurt am Main, Germany	https://light-building.messefrankfurt.com/frankfurt/en.html
5-6	42 AIVC Conference	Rotterdam, the Netherlands	https://www.aivc.org/news/42-aivc-conference-october-2022-netherlands
20-21	The Fifth International Conference on Efficient Building Design	Beirut, Lebanon	https://www.ashrae.org/conferences/topical-conferences/the-fifth-international-conference-on-efficient-building-design

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

REHVA Annual Meeting 2022
Woerden, 20-23 May
Hosted by TVVL

REHVA is pleased to invite its Members and Supporters to the 2022 REHVA Annual Meeting on Friday 20 – Monday 23 May 2022. This year, the Annual Meeting will be hosted by this edition's CLIMA organiser, TVVL in Rotterdam.

Program:

May 20-21 ...... Standing Committee Meetings
May 22 .... General Assembly
May 23 .... Supporters Lunch & Committee Meeting

After the Annual Meeting, REHVA welcomes all its members to participate in the CLIMA congress. For any questions or additional information, please contact info@rehva.eu

CLIMA is coming home

May 22-25 we can finally meet again in person. During the 14th CLIMA HVAC World Congress that will be held in The Netherlands. A historical event, in more than one way. On behalf of the CLIMA organizing committee, **John Lens** and **Olaf Oosting** of TVVL and my two congress vice-presidents **Laure Itard** and **Lada Hensen** I warm-heartedly invite you all to come to Rotterdam and enjoy CLIMA 2022.

In 1996 football was coming home. Back home to England, to be more precise. That year the FIFA World cup was organized in that country. The 'three lions' team beat the Germans in the final and brought the World Cup home to where modern football was invented. What does this have to do with the CLIMA HVAC World Congress?? Well… CLIMA as you know, is the flagship event of REHVA; and REHVA was legally established on the 27th of September 1963 in The Hague, upon the initiative of 9 countries including TVVL.

It has happened before that the REHVA general assembly was held in The Netherlands (e.g. in 2009 in Amsterdam). But now, from May 22nd till May 25th 2022, for the first time also the CLIMA congress will be held here. So, one can truly say that, after 13 CLIMA congresses elsewhere in Europe, CLIMA is coming home. CLIMA congress number 14 (by change the number of our football hero Johan Cruyff) is organized by TVVL, in close cooperation with representatives of both the Eindhoven and the Delft Universities of Technology.

Core themes at our event in Rotterdam won't be 'total football strategies', instead come to this beautiful city on the shores of the Nieuwe Maas river and enjoy presentations and discussions related to one of the 5 congress themes: Health & Comfort, Energy, Circularity, Digitization and innovative Learning & Education. The program includes a whirlwind opening session on Sunday, close to 400 scientific presentations, 30 interactive sessions & workshops, 4 courses, 9 inspiring keynote presentations and vibrant night activities. Make sure not to miss it!

Let's enjoy each other's company again after two rather difficult years and together work out, pro-actively, where we should be heading with our field of expertise, already with a sharp eye on 2030 and beyond.

Don't wait till tomorrow, book your trip and hotel today and register for the congress via the congress website www.clima2022.org.

See you in Rotterdam!

ATZE BOERSTRA
CLIMA congress president

CLIMA 2022

EYE ON 2030 | Towards digitalized, healthy, circular and energy efficient HVAC

REHVA 14th HVAC World Congress

22nd - 25th May, Rotterdam, The Netherlands

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BBA Binnenmilieu – The Netherlands
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Clockworks Analytics – USA
www.clockworksanalytics.com

Arcelik A.S. – Turkey
www.arcelikglobal.com

CLIMA PRELIMINARY PROGRAM CLIMA 2022

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<tr><td>10:00</td><td></td><td rowspan="4">COMMITTEE
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(TRC, ETC)*</td><td rowspan="4">EXCURSIONS</td></tr>
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& REHVA COURSES</td></tr>
<tr><td>13:00</td><td></td><td rowspan="5">COMMITTEE
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<tr><td>16:30</td><td rowspan="5">CLIMA OPENING EVENT

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<tr><td>19:00</td><td></td><td></td><td rowspan="6">WALKING
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<tr><td>20:00</td><td></td><td rowspan="6">REHVA DINNER AND
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<tr><td>20:30</td><td></td></tr>
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CLIMA 2022 14TH HVAC WORLD CONGRESS

THEME HEALTH & COMFORT	THEME ENERGY | LEARNING & EDUCATION	THEME DIGITIZATION | CIRCULARITY
MONDAY 23 May	TUESDAY 24 May	WEDNESDAY 25 May
MORNING SPORT	MORNING SPORT	MORNING SPORT
REGISTRATION	REGISTRATION	REGISTRATION
KEYNOTES	KEYNOTE	KEYNOTE
BREAK	PARALLEL SESSIONS WORKSHOPS	PARALLEL SESSIONS WORKSHOPS
PARALLEL SESSIONS WORKSHOPS	BREAK	BREAK
LUNCH	PARALLEL SESSIONS WORKSHOPS	PARALLEL SESSIONS WORKSHOPS
KEYNOTE	LUNCH	LUNCH
PARALLEL SESSIONS WORKSHOPS	KEYNOTE	PARALLEL SESSIONS WORKSHOPS
BREAK	PARALLEL SESSIONS WORKSHOPS	KEYNOTE
PARALLEL SESSIONS WORKSHOPS	BREAK	CLIMA CLOSING EVENT
	PARALLEL SESSIONS WORKSHOPS	
EXHIBITION	EXHIBITION	EXHIBITION
REHVA PRESIDENTS DINNER* AND STUDENT EVENT	CONFERENCE DINNER**	

* upon invitation only

** tickets possible to buy during registration

List of CLIMA 2022 Interactive Sessions & Workshops

	ORGANISER(S)/CHAIR	TITLE	SPEAKERS	RELATED TO	TIME
HEALTH & COMFORT	Marcel Schweiker, Ardeshir Mahdavi, Andreas Wagner	How to assess multi-domain exposure situations in indoor environments? Discussing new research approaches for comfort and behavior	Marcel Schweiker, Ardeshir Mahdavi, Andreas Wagner	IEA-Annex 79	
	Runa Hellwig, Andreas Wagner, Fatih Topak, Romana Markovic	Accounting for occupants in building design and operation	Runa Hellwig; Andreas Wagner; Fatih Topak; Romana Markovic	IEA-Annex 79	
	Ongun Berk Kazanci, Bjarne W. Olesen	New IEA EBC Annex on Personalized Environmental Control Systems (PECS)	Ongun Berk Kazanci, Bjarne W. Olesen, Mariya P. Bivolarova	REHVA TRC & IEA-Annex 87	
	Peter Holzer, Shady Attia	IEA EBC Annex 80 - Resilient Cooling of Buildings	Peter Holzer	IEA-Annex 80	
	Pawel Wargocki, Jelle Laverge	Bedroom ventilation & sleep quality	Pawel Wargocki, Jelle Laverge		
	Jarek Kurnitski, Atze Boerstra	COVID-19 implications on ventilation criteria and design	Bjarne Olesen, Jarek Kurnitski, Pawel Wargocki, Amar Aganovic	REHVA COVID-19 Task Force	Monday 14:15-15:45
	Risto Kosonen, Arsen Melikov	Advanced airflow distribution methods for reduction of cross infection and exposure to indoor pollution	Arsen Melikov, Guangyu Cao, Bin Yang, Angui Li, Xianting Li, John Zhang Lin	SCANVAC & TVOC Task Force	Monday 16:15-17:45
	Pawel Wargocki	Low relative humidity in indoor air - an important element of indoor air quality	Timo Schreck, Pawel Wargocki, Mikael Börjesson	Swegon	Tuesday 14:15-15:45
	BELIMO	7 Essentials of Healthy Indoor Air	M. George Hoekstra, Martyn Wyss, Mikko Gisin	BELIMO	Monday 16:15-17:45
	Faruk Bayraktar	Rise of Allergies - How do allergen detection affect everyday life?	Faruk Bayraktar, İhsan Ozan Yıldırım (+2 TBC)	Arcelik	
	Panu Mustakallio	Safety in Indoor Settings	Kamal Moumen, Kim Hagström, Ismo Grönvall, Piia Sormunen	Halton	
ENERGY	Hilde Breesch, Jelle Laverge	"Towards Smart Ventilation" in Mid-sized buildings	Hilde Breesch, Louis Cony, Sandy Jorens, Eugene Mamulova	IEA-Annex 86	
	Alexandra Tudoroiu Lukavice	Stationary Fuel Cells for Green Buildings	Alexandra Tudoroiu-Lakavice, Alexander Dauensteiner, Lisa Ruf, Ben Bowler	PACE project	
	Karel Kabele, Zuzana Veverková	Energy performance and comfort of intelligent buildings - where is the limit of automation of building management processes?	Karel Kabele, Zuzana Veverková	TRIO - Czech subsidy program	
	Frank Mills	Nearly Zero Energy Hospitals		REHVA TRC & ASHRAE TC 9.6	
	Daniel Carbonell	Trigeneration systems based on heat pumps with natural refrigerants and multiple renewable sources	Daniel Carbonell, Maike Schubert, Alireza Zendehboudi, Laura Alonso, Thibault Péan, Thomas Friedrich	TRI-HP project - EU-H2020	Tuesday 11:00-12:30
	Stefan Plesser	Sustainable Finance in Building Projects: The EU Taxonomy & Financial Risks of the Performance Gap	Frank Hovorka, Cormac Ryan, Ole Teisen, Ivo Martinac	QUEST project - EU-H2020	Tuesday 14:15-15:45
	Jaap Hogeling	Support, consultancy and services for the implementation and practical use of the set of Energy Performance of Buildings standards	Pau Garcia Audi, Xu Wei, Dick van Dijk, Andrei Litiu	EPB Center	Tuesday 16:15-17:45
	Tomasz Cholewa, Ilinca Nastase	Deep energy renovation of buildings for HVAC professionals	Jarek Kurnitski, Marija S. Todorovic, Tomasz Cholewa, Ilinca Nastase	REHVA TRC TF	Tuesday 16:15-17:45
	Xu Wei, Catalin Lungu	Future ventilation solutions and indoor environment	Li Xianting, Li Angui, Liu Xiaohua, Wu Jianlin	REHVA & CCHVAC	Monday 10:30-12:00
	Mikko Iivonen	Deep Renovation Concepts	Jarek Kurnitski, Clemens Felsmann, Michele De Carli	PURMO Group	Tuesday 14:15-15:45
DIGITIZATION	Mirjam Harmelink, Olivia Guerra-Santin, Marleen Spiekman	Smart buildings & interfaces for managers of buildings and facilities & Seminar Topic: Intelligence needed for occupant-HVAC interfaces at room level	Frans Joostens, Sander van der Harst	Brains4Building	
	Gabriek Fierro	An Introduction to Semantic Metadata for Data-Driven Buildings	Gabriek Fierro, Pieter Pauwels	IEA - Annex 81	
	Andrei Litiu	Digital transformation facilitating building performance convergence and enabling operational rating	Peter op't Veld, Jan Cromwijk, Dick van Dijk, Pablo Carnero	U-CERT project- EU-H2020	Wednesday 11:00-12:30
	Pierre-Thomas Louis de Soultrait	The Future of HVAC as a Service	Pierre-Thomas Louis de Soultrait	LG Electronics	Wednesday 11:00-12:30
	Tiziana Buso	Efficiency beyond the building: the leverage of advanced HVAC control systems in the management of Energy Communities	Tiziana Buso , Attilio Di Sabato	Enerbrain	Wednesday 11:00-12:30
CIRCULARITY	Bob Geldermans, Tillmann Klein, Olaf Oosting	Masterclass Circularity		GF Piping Systems	
LEARNING & EDUCATION	Laure Itard, Christian Struck	Education & Learning in the HVAC sector: what's next? Session 1: sharing experiences with invited speakers from companies and educative bodies	Laure Itard, Christian Struck	TVVL & REHVA	
	Ivo Martinac, Christian Struck	Education & Learning in the HVAC sector: what's next? Session 2: shaping the future: blue print for professional continuous education		TVVL & REHVA	
	Andrei Litiu	CEN-CE scheme roll-out: harmonised training and certification of experts on EPB standards	Johann Zirngibl, Laurent Socal, Catalin Lungu	EPB Center	Tuesday 11:00-12:30

CLIMA 2022 Keynote speakers

Roland Bal, Professor at Erasmus School of Health Policy & Management

Date: Sunday, May 22nd

Professor **Roland Bal**'s main research interest lies in the building, functioning and consequences of knowledge infrastructures for the governance of healthcare. He currently focuses on organisational infrastructures for quality and safety in healthcare, such as studies on the regionalisation of elderly and mental healthcare and a study task differentiation of nursing care. Professor Bal has specialised in qualitative, mainly ethnographic research methods. He is a member of the Dutch research school of Science, Technology & Modern Culture and of the Society for the Social Study of Science. He also participates in the European Health Policy Group, a group of political scientists and economists studying (comparative) health policy.

Roland Bal is also connected to the Dutch Pandemic & Disaster Preparedness Center.

Marjan Minnesma, Director Urgenda

Date: Sunday, May 22nd

Marjan Minnesma is director of the Urgenda Foundation, an organization that successfully realized a ruling by the Dutch Supreme Court, finding that the Dutch government is required to take faster and more drastic measures to combat climate change. Marjan has been named the most influential person working in the field of sustainability in the Netherlands three years in a row. In 2015 she was declared to be a 'leading global thinker' by the authoritative American magazine Foreign Policy. "Marjan Minnesma wrote the report and agenda for the Netherlands: "100% sustainable energy in the Netherlands in 2030; It is possible, if we really want to" including all figures and pathways for the next fifteen years. Therefore, we feel she is the best person to open the scientific programme of CLIMA 2022 and introduce our overall theme: EYE ON 2030.

Arsen Melikov, Professor at the International Centre for Indoor Environment and Energy, Technical University of Denmark

Date: Monday, May 23rd
Theme: Health & Comfort

Arsen Melikov, Fellow ASHRAE, Fellow ISIAQ, is professor at the International Centre for Indoor Environment and Energy, Technical University of Denmark. His teaching and research areas cover advanced air distribution in rooms and vehicle compartments, airborne cross-infection, impact of indoor environment on people's health, comfort and performance, personally controlled environment, heat and mass transfer, indoor climate measurements and instruments. Dr. Melikov will give a presentation with the title: Focus on occupants, energy and airborne cross-infection: paradigm shift in ventilation is needed!

Lidia Morawska, Director of the International Laboratory for Air Quality and Health and Queensland University of Technology

Date: Monday, May 23rd
Theme: Health & Comfort

Lidia Morawska is physicist and Distinguished Professor at the School of Earth and Atmospheric Sciences, at the Queensland University of Technology and director of the International Laboratory for Air Quality and Health at Queensland University of Technology (QUT). She was recently named one of the 100 most influential people worldwide by TIME Magazine for her publications and activities on air quality and the transmission of infectious diseases. Lidia Morawska will give a keynote speech about the airborne route transmission of the Coronavirus and the importance of ventilation in the issue at hand. In her presentation she will explain, among other things, how she, in cooperation with colleagues, managed to convince the World Health Organisation (WHO) to include ventilation as a standard Covid measure.

Ben van Berkel, Founder and principal Architect of UNStudio and UNSense

Date: Monday, May 23rd
Theme: Health & Comfort

Ben van Berkel is a Dutch architect; the founder and principal Architect of the international architecture firm UNStudio and UNSense, an Arch Tech company based in Amsterdam that designs and integrates human-centric tech solutions for the built environment. With his studio he designed, among others, the Erasmus Bridge in Rotterdam, the Mercedes-Benz Museum in Stuttgart, Germany, the Singapore University of Architecture and Design, Raffles City in Hangzhou, China and numerous other buildings. In 2017, he gave a TEDx presentation about health and architecture, and is currently a member of the Taskforce Team/Advisory Board Construction Industry for the Dutch Ministry of Economic Affairs.

Pau Garcia Audi, Policy officer DG Energy

Date: Tuesday, May 24th
Theme: Energy

Pau Garcia Audi has worked for the European Commission for twelve years. As policy officer in the field of energy efficiency in buildings, he works on the Energy Performance Buildings Directive. The Directorate General for Energy deals with support for the digitisation and modernisation of buildings in the European Union (EU), from the revised directive on the energy efficiency of buildings. As representative of the European Commission, Audi has stated that we need to address climate and energy issues urgently.

Lieve Helsen, Professor in Mechanical Engineering at KU Leuven & Energyville

Date: Tuesday, May 24th
Theme: Energy

Lieve Helsen is Professor in Mechanical Engineering (KU Leuven & EnergyVille), leading the Thermal Systems Simulation (The SySi) research group, focusing on modelling, optimal control and optimal design of thermal systems in the built environment. System integration over multiple building types, multiple energy services, multiple energy vectors and multiple sectors is key to provide low-carbon services. As chairwoman Lieve established the Flanders Heat Pump Platform in 2008 and organised multiple highly-attended local Heat Pump Symposia that stimulated interaction between researchers and practitioners. The subject of Helsen's speech will be: Towards net zero CO_2 emission in the built environment – a system of systems approach.

Clayton Miller, Assistant Professor at the National University of Singapore in the Department of the Built Environment

Date: Wednesday May 25th
Theme: Digitization

Clayton Miller is an Assistant Professor at the National University of Singapore (NUS) in the Department of the Built Environment. He is the creator of the EDx MOOC Course – Data Science for Construction, Architecture and Engineering that has more than 20,000 participants worldwide since April 2020. He is also the leader of the Building and Urban Data Science (BUDS) Lab at NUS and the Co-Leader of Subtask 4 of the IEA Annex 79 Occupant-Centric Building Design and Operation. Dr. Miller will discuss the importance of open data for the development of robust machine learning in the building industry and how we can catch up to other sectors that have transformed due to data science. He will discuss his mission to introduce basic data science skills to built environment professionals and help steer the two domains towards each other.

Thomas Auer, Managing Director of Transsolar

Date: Wednesday, May 25th
Theme: Circularity

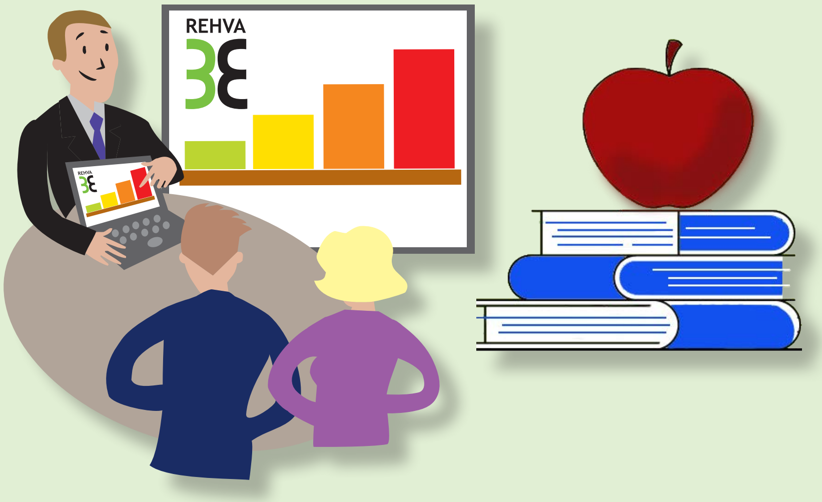
Thomas Auer is Professor and managing director of Transsolar, Stuttgart. The Climate Engineering practice has received international attention over the last three decades and is working on all scales from single buildings to urban neighbourhoods. As Professor and Chair of Building Technology and Climate Responsive Design at the Department of Architecture of TU Munich, he focuses on a holistic design approach. For buildings and cities, it is crucial to recognize the sustainability goals of the EU as well as the reduction of substantial CO_2 emissions in the building sector, as defining parameter. Prof. Auer works in interdisciplinary teams and has established a three-step approach comprising space design, building performance design and infrastructure design.

REHVA Courses

REHVA is always on a path to share best-practices among peers in the HVAC sector and to bring knowledge to all. For this reason, REHVA organizes two courses on Sunday 22 May 2022 from 13.00 to 14.30 on specific topics of interest, prior to the opening ceremony of CLIMA 2022.

Course 1: In-Situ Monitoring of Transmission and Solar Heat Exchange Through Building Envelope

Course 2: NZEB Design Strategies-Systems for Residential Buildings in Mediterranean Regions, principles and best practices



Teachers of Course 1: In-Situ Monitoring of Transmission and Solar Heat Exchange Through Building Envelope

Arash Rasooli

- Dr. Ir., REHVA, EKO Instruments, Delft University of Technology
- Coordinator of REHVA Community of Young Professionals
- R&D Specialist on thermal analysis and monitoring instruments
- Guest researcher and lecturer at TU Delft

Arash Rasooli is an R&D specialist at EKO Instruments. His work is related to heat flux and thermal conductivity measurement instrumentation. After obtaining his MSc in mechanical engineering at Delft University of Technology (TU Delft), he obtained his PhD in chair Building Energy Epidemiology, also at TU Delft. His PhD research was on in-situ determination of buildings' thermo-physical characteristics related to theoretical, computational, and experimental investigation of heat transfer in building components. In 2016, Arash won the national TVVL, REHVA International, and HVAC world student competitions with 1st place. Today, he is also the coordinator of RCYP (REHVA Community of Young Professionals) and a guest researcher and lecturer at Delft University of Technology.

Mario Po’

- Dr. Ir., EKO Instruments
- R&D Specialist on solar and meteorological monitoring instruments at EKO Instruments.

Mario Po’ is an R&D specialist at EKO Instruments His work focuses on solar radiation monitoring instruments and the performance assessment of solar photovoltaic devices. In 2011 he graduated from the Faculty of Sciences of the University of Lisbon with an MSc in Energy and Environment Engineering. In 2017 received his PhD in Sustainable Energy Systems from the MIT-Portugal doctoral program at the University of Lisbon; the thesis topic addressed a novel method of manufacturing silicon sheets for solar cells at a lower cost. At EKO Instruments he has been active in research projects concerning solar energy metrology and forecasting.

Laure Itard

- Prof. Dr. , Delft University of Technology
- Chair Building Energy Epidemiology at TU Delft
- Vice President of CLIMA 2022 World Congress

Laure Itard is Professor of Building Energy Epidemiology at the faculty of Architecture and the Built Environment, Department AE+T. She has a background in thermodynamics and has been working since 2004 at Delft University of Technology (TU Delft). She studied in France and got her PhD in 1998 at the faculty of Mechanical Engineering of TU Delft on research on high efficiency wet-compression-resorption heat pumps. In between she has worked for several years as consulting engineer and software developer at Deerns B.V. in the field of energy and buildings. She was also Professor of applied sciences at The Hague University of Applied Sciences, research group Energy in the Built Environment for 8 years. Her field of expertise is performance analysis, diagnose and optimization of energy systems in operation, at the level of buildings and the building stock and the combination of systems’ engineering and modelling with data-driven approaches. She is a REHVA fellow, and the vice president of CLIMA 2022 World Congress.

Introduction to the training

During Course #1, after an introduction of the building as an energy system, the theoretical aspects of each topic such as the relevant heat transfer phenomena are introduced. Then, the science behind and the technical specifications of the instrumentation required tow monitor and measure the relevant parameters are explained. Finally, during a practical demonstration, the most important methods, procedures, and challenges to monitor those parameters are shown, using the relevant measurement instrumentation.

Target audience of the training

Building Engineers, Energy Auditors, Energy Advisors, Architects, Consultants, MSc and PhD Students, Researchers, Professionals, Home IoT System Companies, Home Energy Management Companies.

Teachers of Course 2: NZEB Design Strategies-Systems for Residential Buildings in Mediterranean Regions, principles and best practices

Murat Çakan

- Asst. Prof., Istanbul Technical University

Murat Çakan graduated from ITU Faculty of Mechanical Engineering in 1992. He, then worked at the von Karman Institute for Fluid Dynamics turbomachinery department and finished his Ph.D. on gas turbine cooling at Université Louvain-la-Neuve in 2000. He teaches fluid mechanics, turbomachinery, engineering ethics, linear algebra and power generation. He acts as the head of TTMD Foreign Affairs Committee and has recently become a REHVA fellow in 2021. His research interests range from experimental fluid dynamics, including building aerodynamics to heat transfer enhancement strategies. Between 2007-2015 he worked as the director of Istanbul Technical University Science Center whose aim was to foster science education among youngsters. He is the co-author of two REHVA guidebooks: NZEB Design Strategies for Residential Buildings in Mediterranean Regions – Part I (No:28) and NZEB Design Strategies for Residential Buildings in Mediterranean Regions – Part II (No: 31). Currently Dr. Çakan is leading a Solar Decathlon team (Team Deeply-High) which is composed of two universities: Istanbul Technical University and Technical University of Applied Sciences Lübeck. They will participate in SDE 2022 which will be held in Wuppertal in May-June 2022.

Ziya Haktan Karadeniz

- Associate Professor, İzmir Kâtip Çelebi University

Ziya Haktan Karadeniz was born in 1980, İzmir, Turkey. He graduated from Dokuz Eylül University, Department of Mechanical Engineering in 2002, and he graduated from the Energy MSc and PhD Programs of the Institute of Natural and Applied Sciences of the same university. He worked as a research assistant at Dokuz Eylül University Department of Mechanical Engineering between 2002 and 2013. He has been working in İzmir Kâtip Çelebi University Department of Mechanical Engineering as a faculty member since 2013. He continues his research in the fields of additive manufacturing of HVAC components, indoor air quality, wind energy, and nanofluids' convective heat transfer. He has more than a hundred scientific papers presented and/or published at national and international meetings and/or journals. He is the co-author of the REHVA guidebook: NZEB Design Strategies for Residential Buildings in Mediterranean Regions – Part II (No: 31). He is a board member at the Chamber of Mechanical Engineers (MMO) İzmir Branch, a substitute board member of Turkish Society of HVAC and Sanitary Engineers (TTMD) which is the REHVA member association of Turkey.

Introduction to the training

The aim of this course is to present and to promote the use of equipment, technology and mechanical systems appropriate to the cooling-demand-dominated requirements of the Mediterranean climate. The course covers the design of Heating, Ventilation and Air-Conditioning systems, energy recovery and free cooling aspects, renewable energy adaptation and innovative system design approaches. The Med-NZEB axiom (very low energy use, high system efficiency, lowest possible non-renewable primary energy use) requires that the system must be selected for performance evaluation in terms of cost-benefit analysis.

The training is structured in the framework of a number of basic criteria which take into account the following statements:

a) Since energy strategies are closely linked to indoor conditions, IEQ strategies must be considered at the same time.
b) Passive heating and cooling strategies must be combined to achieve optimum results and to minimise excessive heating or cooling.
c) Energy strategies must consider all seasons.
d) Existing strategies for colder regions should not be adapted before evaluating their benefits and drawbacks.
e) An analysis of local renewable energy sources is required in order to make the most appropriate choices for their exploitation.

Target audience of the training

The target group of the training are professionals and Master and Ph.D. students who are willing to understand the fundamentals of designing systems for NZEB buildings in the Mediterranean basin countries.

Sponsored by: Eurovent Certita Certification

REHVA STUDENT COMPETITION & HVAC WORLD STUDENT COMPETITION

The REHVA Student Competition takes place on Monday 23 May 2022, starting at 10h30 and showcases the talent of students in the field of HVAC from all over Europe.

They present their Bachelor or Master's thesis, linked to REHVA activities areas such as heating, ventilation, air conditioning, refrigeration, indoor environmental quality, energy balance, energy efficiency and sustainability, building services and more. Each student participant produces: a copy of the paper, an A1 poster and finally a presentation in front of the Jury.

Each student's presentation takes approximately twelve minutes plus three minutes of Q&A to present their work to the Jury that will then select three awardees and one best poster awardee.

The HVAC World Student Competition (HWSC) is organized by REHVA in cooperation with ASHRAE, CAHVAC, FAIAR, ISHRAE, SAREK and SHASE and takes place on Monday 23 May 2022 starting at 14h00 during CLIMA 2022. It will showcase talented student's work from the partner's associations and the winner will be crowned as HVAC World Student Winner.

All student participants produce: a copy of the paper, an A1 poster and finally a presentation in front of the Jury. Each student's presentation takes approximately twelve minutes plus three minutes of Q&A to present their work to the Jury that will then select three awardees and one best poster awardee.

The HVAC World Student Competition Jury is composed by persons nominated by **HWSC partners**. Each partner nominates only one member for the jury.

Juries of The REHVA Student Competition and The HVAC World Student Competition (HWSC) will make a decision based on the following criteria.

- The relevance and technical feasibility of the topic
- A clear statement of the objective of the work
- The adequacy of the used methods
- The validity and reliability of achieved results
- The innovative character of the work carried out
- The accuracy of the explanation of the work in written material and in oral presentation
- The graphical quality of the summary and the presentation
- The candidate's ability to argue during the discussion
- The scientific content and the graphical quality of the poster
- For the Best Poster award, the criterion will be the scientific content and the graphical quality of the Poster

HWSC partners

ASHRAE, CAHVAC, FAIAR, ISHRAE, SAREK, SHASE

Prizes for both competitions

All participants receive a certificate for their participation and the winners will be awarded in the closing session of the CLIMA 2022 Congress on Wednesday 25 May 2022. On top of this, first, second and third place awardees will win 1400 €, 800 € and 500 € respectively. The award for best poster comes with a 300 € prize.

CLIMA 2022 – Theme: Learning & Education

LAURE ITARD & **CHRISTIAN STRUCK**

An unusual theme for a CLIMA Congress, generally striving to technical advances. A focus on education, though, has always been present at CLIMA congresses with REHVA courses, student competitions and attention to new handbooks and guidelines. For CLIMA2022 we have chosen to also include dedicated sessions about learning and education, as we feel the societal challenges are becoming urgent, think about the energy transition, digitization, lack of workforce and the potential impact of online learning.

The HVAC sector changes rapidly

The European targets with respect to the energy transition in the built environment are huge. To realize the transition towards and CO_2 neutral and circular build environment by 2050, upscaling of solutions is urgently needed. Dissemination of technical innovations and proven knowledge and approaches is needed. The building services sector is a main sector to realize this transition: next to delivering the workforce for designing, placing and maintaining all energy and indoor climate equipment in buildings and neighbourhoods, the sector also acts as innovator and as a pivot between the sectors of construction, energy, health and IT & data analytics, integrating knowledge from these fields. Rapid changes in energy and HVAC engineering techniques and systems and in business models, contracts and processes make it necessary to accelerate the uptake of knowledge in these areas. Continuous professional development of the current workforce and the education of new employees is therefore necessary.

Data science workshop. (CC BY-NC-SA 2.0) [https://www.flickr.com/photos/armgov/38569449151]

Educational challenges in the HVAC Sector are broad

Educational challenges have been identified in several studies like the European BuildUpSkills project [1]. Dealing with these challenges have become even more important because they are decisive in realizing the targets of the energy transition. In detail relevant challenges include the following:

- Increased need for professional workforce: There are too few people working in the sector to realize the energy transition. In [2], a shortage of 3 000 workers per year is given for the Dutch sector. This has implications related to the education of new employees, mainly having no background in building or energy engineering services.
- Slow uptake of basic and integrated knowledge: the main challenges here relate to previous point and are how to accelerate and improve the uptake of knowledge inside the company. For instance from senior to junior and vice-versa; cross-specialism (e.g. from electrical to mechanical; from design departments to maintenance departments), balancing between innovation, risk management, lack of time and workforce.
- There are a few domains where in-depth knowledge has shifted from designers to producers of components, like is the case with hydraulic appendages, hydraulic design or system controls. How to take care that knowledge at the system level increases?
- Rapid change of technologies and related knowledge: The sector is facing rapid changes in energy

An example of digital education. (CC BY-NC-SA 2.0) [https://www.flickr.com/photos/agirregabiria/9726981010]

techniques (e.g. all electric instead of gas-driven; low temperature heating networks, integration of heating and electrical networks, NZEB buildings); engineering methods (e.g. digitization, circularity, design for maintenance); types of contracts (e.g. performance contracts including maintenance; lease); and processes (e.g. industrialization, prefab, turnkey, circular businesses). These changes are driven by societal needs while only a few innovators and early adopters develop and master solutions, leaving the question open how to accelerate further uptake.

- Competition between companies: although companies are generally specialized in market segments like residential, offices, schools, hospitals, heating networks etc.. most companies are competing with each other's in the same markets, which hinders open innovation and knowledge sharing. There seems therefore to be a need for in-company learning, as well as sectoral and cross-sectoral innovation learning. CLIMA congresses, REHVA and its country members are however excellent example of stakeholders joining forces.
- Maintenance engineers traditionally focus on solving immediate failure problems or system alarms, or complaints from users and facility management. A new business is arising around energy optimization using the 'big-data' from Building Management Systems, but to do this, knowledge of data handling and machine learning is needed. This is not offered in current curricula. To solve this problem, data analysts are involved, but they lack knowledge of HVAC systems and cannot interpret the data correctly.
- Installers sometimes do the detailed design, install HVAC systems and do physical repairs when needed. They bear most legal and financial responsibility when something goes wrong. However, very often they are not aware of the general idea behind the design and tend to focus on components more than on the whole system. However, with performance contracting, their work is also changing.

This long list of challenges emphasizes the growing need for in-company, sectoral and cross-sectoral learning and also questions the role of regular academic, higher professional and vocational education.

Advancing Learning & Education is essential

CLIMA 2022 considers advances in learning & education as being essential to the sector and therefore showcases original contributions from academia and practice demonstrating novel approaches and good practices for sectoral education. We put particular emphasis on training experienced practitioners by for example developing learning communities and online courses to allow learning on the job. Furthermore, we focus on developing new curricula to attract and educate young professionals. We will address in particular:

- Learning communities: Experiences and challenges in integrating research, education and practice; Novel concepts for faster and more efficient learning on the job; Replicability and potential for up-scaling; Maintenance of learning communities
- Digital education: Massive open online courses; Integration of alternative educational concepts such as flipped-classroom & blended learning; Digital support for learning on the job; Digital education for young professionals; Digital education for experts;
- Development of curricula: Gateways between vocational and higher education; Knowledge integration & cross sectoral curricula; Gateways between operation and design; Sectoral developments; Role of living-labs.

Finally, there will be an interactive session in which we hope to sketch together with companies and REHVA a possible pathway for future professional education of HVAC engineers.■

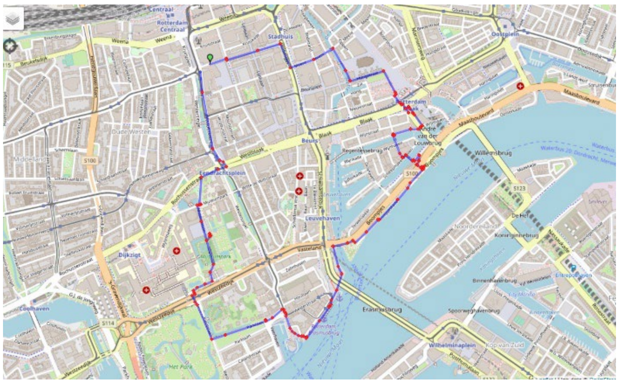
[1] https://buildupskills.eu/,access23-01-2022

[2] Interview Terpstra D., Techniek NL https://www.nu.nl/ondernemen/4476618/installatiebranche-tekort-15000-vakmensen-komende-vier-jaar.html

Social program update CLIMA 2022

CLIMA 2022 is a great place to meet peers, socialize and discover new parts of the world. We have arranged an exciting social program which will give you a full experience of everything Rotterdam has to offer. You can join us on an arranged tour past some of the Netherlands' famous deltaworks, or experience Rotterdam in one of our other social events.

Discover Rotterdam and connect with peers while working a sweat…



Start your day right with an energizing 6 kilometres run through the vibrant city of Rotterdam, without the risk of getting lost or being late to one of our great workshops. In our guided group-run, you will be led along Rotterdam's amazing attractions and hidden gems. On this run you will see popular icons such as Rotterdam's first skyscraper, the Erasmus bridge and, of course, the Euromast. Naturally, our guide is happy to tell you all about the sights you will see during this healthy start of the day. The group-run can be joined freely and takes place every morning during the congress.

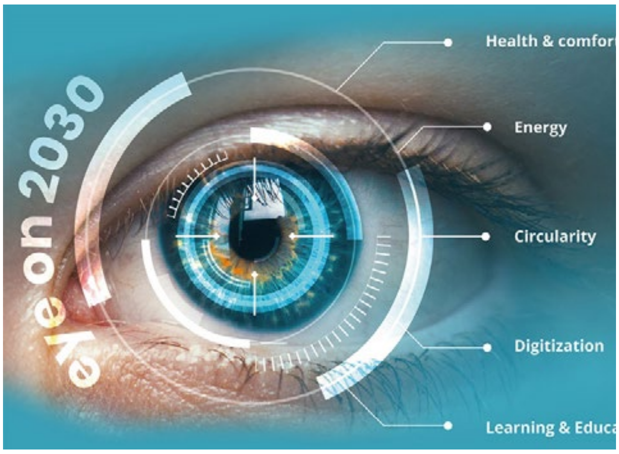
… or while enjoying a great meal

For an extra special experience during CLIMA 2022, reserve your seat at the conference dinner on Tuesday May 24th. This dinner is hosted in one of the most atmospheric establishments in Rotterdam: the Rotterdam World Museum. This venue is located directly by the river Maas in the heart of the historic centre of Rotterdam. To take part in this culinary delight, be sure to book your tickets fast, since there is a limited supply.

CLIMA 2022 in numbers

- 400 papers in review
- 35 workshops and interactive sessions
- 14th edition
- 9 keynote speakers
- 5 themes

Join us at CLIMA 2022



Don't miss out on this great event! CLIMA 2022 is your opportunity to reconnect with peers, stay updated on the latest developments in HVAC, and join the effort in realizing the massive transformation that is on the horizon regarding energy, circularity, digitization, health & comfort, and learning & education. CLIMA 2022 offers a platform where scientific research and developments in HVAC designing and manufacturing can meet and strengthen each other to face the challenges of a sustainable built environment.

Get your tickets today

CLIMA 2022 takes place 22nd – 25th of May 2022 both in Ahoy Rotterdam in the Netherlands as well as online. Book your tickets now, either for the live or online experience.

In person tickets are limited, so make sure you book your tickets in time. Those who choose the online experience of CLIMA 2022 will have access to our livestream and will be able to catch the official opening ceremony with inspiring key-notes online. Join us at CLIMA 2022, whichever way suits you best.

clima2022.org/register/

REHVA
Federation of European Heating, Ventilation and Air Conditioning Associations

REHVA's booth at CLIMA 2022

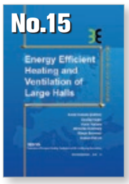
REHVA has a booth set up at CLIMA 2022, come and meet us! We will be more than happy to meet you and discuss, don't be shy, come and say hi!

We will be showcasing our Guidebook catalogue and all our services! Don't miss out on exclusive CLIMA 2022 deals on our products! Find out more in the REHVA Activity & Services section of this Journal!

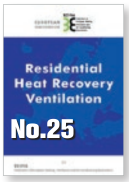
CLIMA 2022
EYE ON 2030 | Towards digitalized, healthy, circular and energy efficient HVAC
REHVA 14th HVAC World Congress
22nd - 25th May, Rotterdam, The Netherlands

REHVA EUROPEAN GUIDEBOOKS

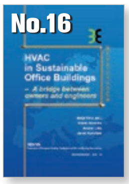
REHVA Guidebooks are written by teams of European HVAC experts



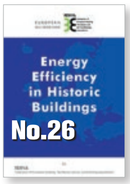
Energy Efficient Heating and Ventilation of Large Halls. This Guidebook is focused on modern methods for design, control and operation of energy efficient heating systems in large spaces and industrial halls. The book deals with thermal comfort, light and dark gas radiant heaters, panel radiant heating, floor heating and industrial air heating systems. Various heating systems are illustrated with case studies.



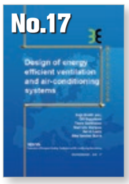
Residential Heat Recovery Ventilation. Heat recovery ventilation is expected to be a major ventilation solution while energy performance of buildings is improved in Europe. This European Guidebook prepared by REHVA and EUROVENT experts includes the latest ventilation technology and knowledge about the ventilation system performance, intended to be used by HVAC designers, consultants, contractors, and other practitioners.



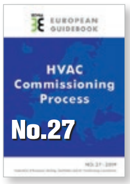
HVAC in Sustainable Office Buildings – A bridge between owners and engineers. This Guidebook discusses the interaction of sustainability and heating, ventilation and air–conditioning. HVAC technologies used in sustainable buildings are described. This book also provides a list of questions to be asked in various phrases of building's life time. Different case studies of sustainable office buildings are presented.



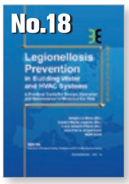
Energy Efficiency in Historic Buildings. These guidelines provide information to evaluate and improve the energy performance of historic buildings, fully respecting their significance as well as their cultural heritage and aesthetic qualities. The guidelines are intended for both design engineers and government agencies.



Design of energy efficient ventilation and air-conditioning systems. This Guidebook covers numerous system components of ventilation and air-conditioning systems and shows how they can be improved by applying the latest technology products. Special attention is paid to details, which are often overlooked in the daily design practice, resulting in poor performance of high quality products once they are installed in the building system.

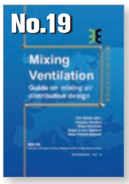


HVAC Commissioning Process. This Guidebook describes the HVAC Commissioning Process compatible with the routines in the building sector almost everywhere around the world. This is the first work that both describes the process in a very hands-on manner and details the commissioning activities for various types of systems, complete with theoretical background, guidance & checklists.

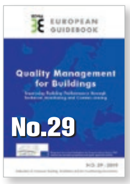


Legionellosis Prevention in Building Water and HVAC Systems. This Guidebook is a practical guide for design, operation and maintenance to minimize the risk of legionellosis in building water and HVAC systems. It is divided into several themes such as: Air conditioning of the air (by water – humidification), Production of hot water for washing (fundamentally but not only hot water for washing) and Evaporative cooling tower.

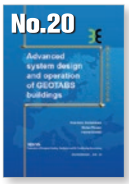
NZEB Design Strategies for Residential Buildings in Mediterranean Regions - Part 1. The aim of this Guidebook is to develop a basic framework of a design guideline for planners, designers and engineers involved in the passive/architectural design of buildings and the selection process of the HVAC systems to deliver the most appropriate and cost-effective solutions for NZEB in Mediterranean climates.



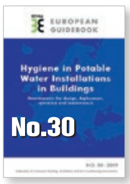
Mixing Ventilation. In this Guidebook most of the known and used in practice methods for achieving mixing air distribution are discussed. Mixing ventilation has been applied to many different spaces providing fresh air and thermal comfort to the occupants. Today, a design engineer can choose from large selection of air diffusers and exhaust openings.



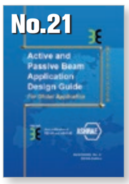
Quality Management for Buildings. This Guidebook gives a brief overview on quality management services Technical Monitoring (TMon) and Commissioning (Cx) to building owners, developers and tenants. Avoiding technical details, it shows the tremendous economic potential, gives insights on the most important technical aspects and provides hands-on advice for application in projects.



Advanced system design and operation of GEOTABS buildings. This Guidebook provides comprehensive information on GEOTABS systems. It is intended to support building owners, architects and engineers in an early design stage showing how GEOTABS can be integrated into their building concepts. It also gives many helpful advices from experienced engineers that have designed, built and run GEOTABS systems.

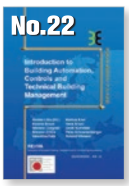


Hygiene in Potable Water Installations in Buildings. This REHVA Guidebook provides information on the design, installation, commissioning, use, operation and maintenance of all water installations in buildings. Central waterworks supply over 95% of the population with potable water round the clock and with virtually no interruptions.

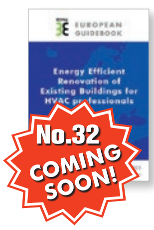


Active and Passive Beam Application Design Guide. is the result of collaboration by worldwide experts. It provides energy-efficient methods of cooling, heating, and ventilating indoor areas, especially spaces that require individual zone control and where internal moisture loads are moderate. The systems are simple to operate and maintain.

NZEB Design Strategies for Residential Buildings in Mediterranean Regions - Part 1. The main objective behind this Guidebook is to present and promote the use of equipment, technology and systems appropriate to the cooling-demand–dominated requirements of the Mediterranean climate.



Introduction to Building Automation, Controls and Technical Building Management. This Guidebook aims to provide an overview on the different aspects of building automation, controls and technical building management and steer the direction to further in depth information on specific issues, thus increasing the readers' awareness and knowledge on this essential piece of the construction sector puzzle.



Energy Efficient Renovation of Existing Buildings for HVAC professionals. This Guidebook shows the baseline for specific energy efficiency and other renovation measures in existing buildings for which the HVAC systems play an important role. It presents the best available techniques and solutions that can be used as part of the energy modernization of the HVAC systems.