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REHVA

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The REHVA European HVAC Journal

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IAQ in workplace in Belgium: alternatives to CO_2 requirement
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Send the manuscripts of articles for the journal
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In the year of CLIMA 2019 also continuing focus on energy, indoor climate

Year 2019 is already on its way when you are reading this editorial. It will be an important year for the REHVA community. The world congress CLIMA2019 will be held May 26-29 in Bucharest, which is a mayor event and excellent opportunity for our professional community to meet. Apart from the very interesting presentations and seminar program many workshops will be organised to stimulate interactions (see on page 87).

JAAP HOGELING
Editor-in-Chief
REHVA Journal

After four years of serving the REHVA Journal as Editor in Chief I looked back to the 24 issues published. It is no surprise that 60% of the articles was dealing with energy and EPBD related issues. A good second place is for articles related to Indoor Air/Environmental Quality. A third place for articles related to Quality assurance and monitoring of our buildings and building systems (related to the Qualicheck project). Finally, several articles related to certification schemes, new standards and new technical solutions and case studies. Additional to these technical articles the REHVA journal has been a great source for news from REHVA, on EU Commission policy issues, events, fairs, products and publications.

We expect a similar picture for the coming years. Realising that all EPB standards have been published we expect articles on the use of these standards in practise. Also, about the way and level of implementation of these EPB standards in the different EU countries. Energy (EPBD), NZEB Uptake and the IEQ will continue our attention but also the role of Smart technology (SRI) and the focus on how to integrate sustainable energy production and storage in our buildings. Smart grids require us to interact with our building systems and when using sustainable energy producing systems (like PV, wind…) how to design and operate energy storage systems (electric, thermal or chemical).

For this issue the focus is on articles based on a selection of papers of the 39th AIVC Conference 'Smart ventilation for Buildings' which conference included also the Tight Vent and Venticool conferences.

The next REHVA journal issue will pay attention to the coming CLIMA 2019 congress May 26-29. The 3rd issue will look back to this CLIMA 2019 Congress and will try to report on the highlights.

The REHVA Journal Editing board welcomes suggestions and reactions from our readers, we also encourage the REHVA members to propose to us technical articles, published in their national member journal, that are expected to be of importance for the REHVA Journal readers. ■

This article is based on a paper presented at the 39th AIVC - 7th TightVent & 5th venticool Conference, 2018 "Smart ventilation for buildings" held on 18-19 September 2018 in Antibes Juan-Les-Pins, France.

Are low-cost sensors good enough for IAQ controls?


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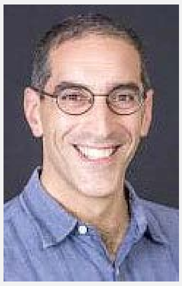
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This study used laboratory testing to evaluate low-cost (about $200 US) IAQ monitors that measured PM2.5 to determine if they are suitable for controlling IAQ for ventilation or air cleaning systems.

Keywords: Sensors, Controls, PM2.5, IAQ, laboratory testing

Current Indoor Air Quality (IAQ) standards and approaches to minimizing pollutants depend almost exclusively on using dilution with outdoor air for some generic, continuously generated contaminant (e.g., ASHRAE Standard 62.2-2016). Some standards include measurement of CO_2 (e.g., EN 13779 standard (CEN, 2007) and NEN 8088 (NEN, 2011)) – however this is not because CO_2 itself is a pollutant of concern, but rather because it can be used as an occupancy indicator or as something that correlates with bioeffluents. Ideally, we would like to measure contaminant concentrations directly and ventilate to control their concentration within acceptable limits. This would ensure that concentrations do not got too high (as they can if emission rates exceed our assumptions) and also allow for ventilation reductions, and resulting energy savings, if concentrations are low. Until recently, it was impractical to consider direct contaminant control in residential (and many commercial) spaces due to the high cost and maintenance requirements for monitoring equipment. In the past couple of years low-cost sensors have been developed for some contaminants of concern – the greatest example of which is for particles. These sensors have been incorporated into low-cost (< $250 US) IAQ monitors. This has opened up the possibility of direct control of ventilation (and filtration systems) by sensing particles. However, it is important to evaluate these monitors to determine if their results are sufficiently good to control a ventilation system.

In this study we performed laboratory experiments to compare the output of seven low-cost monitors to laboratory grade and reference particle measurement methods. The laboratory tests used a range of particle sources to determine if the monitors can reliably detect common household particle emission events. It should be noted that an important aspect of this work is consider particle size. The current state of the art is that particles less than 2.5 microns in diameter (PM2.5) are of the most concern for health. There are some concerns that smaller submicron particles (less than 0.1 microns in diameter) may also be a health hazard, although the evidence for these smaller particles being a significant health hazard is not as strong. Most of the monitors evaluated for this study do not directly have a way of disaggregating results by particle size. For those that do we used the total and did not size disaggregate the results. Instead they employ calibrations or signal conditioning to take the raw output of a particle sensor and translate it into a reported particle concentration. Therefore, our results include both the response of the particle sensor and whatever calibration has been used by the manufacturers of the IAQ monitors. Not all particle emission events emit particles in these ranges (as will be shown in our results). The results can be used to assess the ability of these devices to provide a reasonable control signal for a ventilation system. The results of this study are discussed in more detail in Singer and Delp (2018) together with more information regarding individual sensor performance and discussion of potential indoor particle sources.

Laboratory testing

The experiments were conducted in a 120 m³ laboratory with a 5.8 m by 7.1 m floor plan, as illustrated in (**Figure 1**). The room was continuously mixed with fixed direction and oscillating fans. Consumer and research particle monitors were placed on a wire shelving unit co-located with reference instruments in the central area, sufficiently far from source activities that measurements should reflect average room conditions rather than concentrated plumes. In a subset of experiments, filter samples were collected for time-integrated, gravimetric mass determination. During source activities, outdoor air exchange was provided solely by natural infiltration with no mechanical ventilation systems operating. After the source activity ended, particles were allowed to naturally decay over a period of variable duration. In most experiments, after about one hour of decay exterior doors at opposite ends of the laboratory were opened to rapidly ventilate the room and remove residual particles and co-pollutants. During the experiments, the outdoor air exchange rate was measured by a tracer decay method and varied from 0.5 to 1.1 h^{-1} with a median of 0.7 h^{-1}. Several mixing fans were placed in the test chamber to create uniform particle concentrations. Baseline measurements were taken prior to each source activity. The baseline values were subtracted from the measurements taken during the source activity and integrated over time to calculate mass integration measurements for the source.

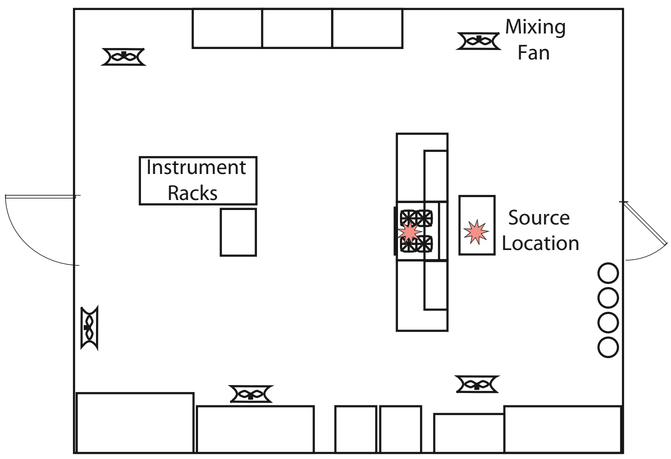

Figure 1. Plan view of test laboratory.

Particle Sources

The purpose of this study was to compare consumer and research monitor response to reference instrumentation for typical indoor-generated aerosols, therefore, we did not try to precisely control the source emissions. Instead, we used sources that might commonly occur in a home. There were 16 distinct sources: recreational combustion included candles, cigarettes, and incense; mineral sources included an ultrasonic humidifier without a filter, Arizona test dust, and shaking of a workshop dust mop; cooking sources included heating oil in a steel wok on gas or electric burners, frying bacon and toasting four slices of bread in a toaster oven, and stir-frying green beans in oil on a gas burner. Cooking sources that produced large numbers of particles with low to moderate mass concentrations and almost all below 0.3 µm included heating water in a covered pot on a gas stove, heating a gas oven, cooking a pizza in the gas oven, cooking pancakes on a lightly oiled pan over medium heat, and toasting bread in a well-used electric toaster oven. Each source was active for about 10–15 minutes.

Table 1. Particle sources.

Source	Description
Humidifier	Ultrasonic humidifier, cleaning cartridge removed
Incense	Incense stick (Shanthimalai Red Ng Champa)
AZ Dust	AZ test dust (0–3 micron) manually puffed from bag
Beans	150 g frozen green beans, 15 g canola oil stir fried in steel wok on gas stove
Toast	Single piece of bread, medium-toasted in used electric coil toaster oven
Bacon+Toast	280 g bacon fried on gas stove; 4 slices bread med-toasted in toaster oven
GB Oil	15 g of canola oil brought to bubble in steel wok on gas stove
Burnt toast	Slice of bread, dark-toasted in used electric coil toaster oven
Dust mop	Aggressive shaking of a 90 cm wide workshop dust mop
Candles	5 unscented dinner candles, lit with butane lighter
Gas+Pots	Two covered 5 L pots, half-filled w/H_2O, heated on gas stove
Oven	Gas oven heated to 400F over 12 min after ~4 y of no use
Pancakes	Two batches pancakes cooked on a lightly oiled fry pan on gas burner
Pizza	Gas oven heated to 400F 14 min; frozen pizza cooked
Cigarettes	3 cigarettes lit with butane lighter, smoldered until self-extinguished
Electric Oil	15 g canola oil brought to bubble in fry pan on an electric coil burner

The highest 5-min baseline-subtracted mass concentrations (adjusted Mini-WRAS data) varied from 21 µm m^{-3} for the pancakes to 721 µm m^{-3} for one of the green-bean stir-fry experiments. The highest number concentrations varied from the AZ test dust and dust mop experiments (at 2–5 x 10^3 cm^{-3}) to the Bacon + Toast experiment at 2 x 10^5 cm^{-3}. The five experiments with the lowest peak mass concentration (Pancakes, Pots on gas burners, Oven, Pizza, Burnt Toast) were in the middle of the distribution of peak number concentrations (6^{th} to 18^{th}).

Particle Monitoring Devices

A Grimm Mini Wide Range Aerosol Spectrometer Model 1.371 (Mini-WRAS) was used as a reference for 1-minute resolved data and also to provide distributions of particle number and mass concentrations. The Mini-WRAS combines an electrical mobility analyzer that counts particles in 10 size bins from 10 to 200 nm with a laser-based optical particle counter that provides particle counts in 15 size bins from 0.2 µm (200 nm) to 2.5 µm plus 16 bins between 2.5 and 35 µm. The Grimm estimates volume concentration from the size-resolved number concentrations by assuming the particles are spheres, then calculates mass assuming a density of 1.68 g cm^{-3}. The density is a user-definable parameter that enables the Mini-WRAS to measure aerosols with varying composition.

Seven consumer grade monitors were selected for testing. All devices were available for retail purchase in the US in early 2017 and had either been tested previously by the US EPA or AQ-SPEC for outdoor use, or the research team had learned of their use in one or more citizen science projects. We also used two research-grade monitors that are often used in field and laboratory studies. Summary information for the monitors is listed in **Table 2**. All of the monitors have a data reporting interval that is reasonable for use as a ventilation controller where we are unlikely to want to make changes on a time scale of less than 5 or 10 minutes.

Example data

Figure 2 presents some example results illustrating the different time and magnitude responses of the monitors. The plot shows two very large sources – candles and oil heated on a gas burner – that produced clear and substantial, though not fully quantitative responses by all

Table 2. Consumer and research grade monitors evaluated in this study.

Device [Code]	Cost ($US)	Data interval	Particle sensor	Notes
AirBeam **[AB]**	$249	1 sec	Shinyei PPD60PV	Full schematics and program available on github https://github.com/HabitatMap/AirCastingAndroidClient/tree/master/arduino/aircasting Web site mentions PM2.5 several times, but does not list the specs
Air Quality Egg **[AQE]**	$280	1 min	Shinyei PPD42	Talks about PM2.5, but lists the operating range 0.5-10 µm
AirVisual **[AVN]**	$200	10 sec	AVPM25b	Sensor developed by AirVisual. Nominally reports PM2.5 for particles 0.3–2.5 µm.
Awair **[AWA]**	$199	10 sec	Sharp GP2Y-1010AU0F	Product lit describes measurement as "PM". Range of 0–500 µm/m^3. (This corresponds to linear range for voltage output as specified on Sharp sensor sheet.)
Foobot **[FOB]**	$199	5 min	Sharp GP2Y-1010AU0F	Proprietary 'learning' algorithm applied to the signal. Product literature describes as PM2.5 covering range of 0.3–2.5 µm 0–1,300 µm/m^3 ±4 µg or ±20%
PurpleAir PA-II **[PA]**	$229	80 sec[1]	Plantower PMS1003	Reports # in 6 size bins; PM1, PM2.5, PM10. Calibrated to ambient PM in Beijing. Counting efficiency: 50% @0.3µm 98% >= 0.5 µm Consistency error: ±10 µg/m^3 @0–100 µg/m^3, ±10% 100–500 µg/m^3
Speck **[SPK]**	$200	1 min	Syhitech DSM501A	Calibrated with AZ dust. Machine learning algorithms applied to sensor signal. Product literature notes range of 0.5–3 µm.
Thermo pDR-1500 **[PDR]**	~$6000	20 sec	Proprietary	Calibrated with SAE Fine AZ dust. Precision: ±0.5% of reading or ±0.0015 mg/m^3, whichever is larger, for 10 sec averaging time. Accuracy: ±5% of reading ±precision
MetOne BT-645 **[BT]**	~$3000	1 min	Proprietary	Calibrated with 0.54 mm diameter polystyrene latex spheres. Accuracy: 5%

analyzers. The Egg, Awair and Speck all reported only a small fraction of the actual mass concentration. Emissions from the dust mop, which were concentrated in the largest particles, produced responses of some but not all devices; though for this source the Speck response was substantially higher than the estimate of actual mass concentration. Using the gas cooktop burners to heat water in covered pots and heating the empty oven produced large numbers of particles below 100 nm and modest mass concentrations as indicated by the Mini-WRAS signal (GRM), but no perceptible response of the other monitors. It is also interesting to note that the Speck baseline appears to have shifted following the candle source event.

Figures 3 through 7 summarize the test results for the monitors, broken down by the type of particle source. The inset plot in each figure shows the particle size distribution. This is important because these results show that the monitors are sensitive to particle size – in particular for the < 0.3 micron particles from combustion & cooking (in **Figure** 7).

Discussion

The results show that the research-grade devices worked well, with the exception of events dominated by small submicron particles. This is expected due to the inability of the light-scattering sensors in these devices to detect such small particles.

Among the consumer grade monitors, the Egg and Speck showed the most problems. The Egg had very low responses across a wide range of events. The Speck had inconsistent correlation. The Awair had decent correlation but also had responses that were consistently low in magnitude. The AirBeam, AirVisual, Foobot, and Purple Air were better at detecting a wide range of sources, with the Foobot and Purple Air generally showing the most accurate responses. The exception for the Purple air was low responses to events dominated by large particles, such as the Arizona dust and the duct mop. For both the Speck and Awair the manufacturer claims to have upgraded the sensor since these experiments were performed.

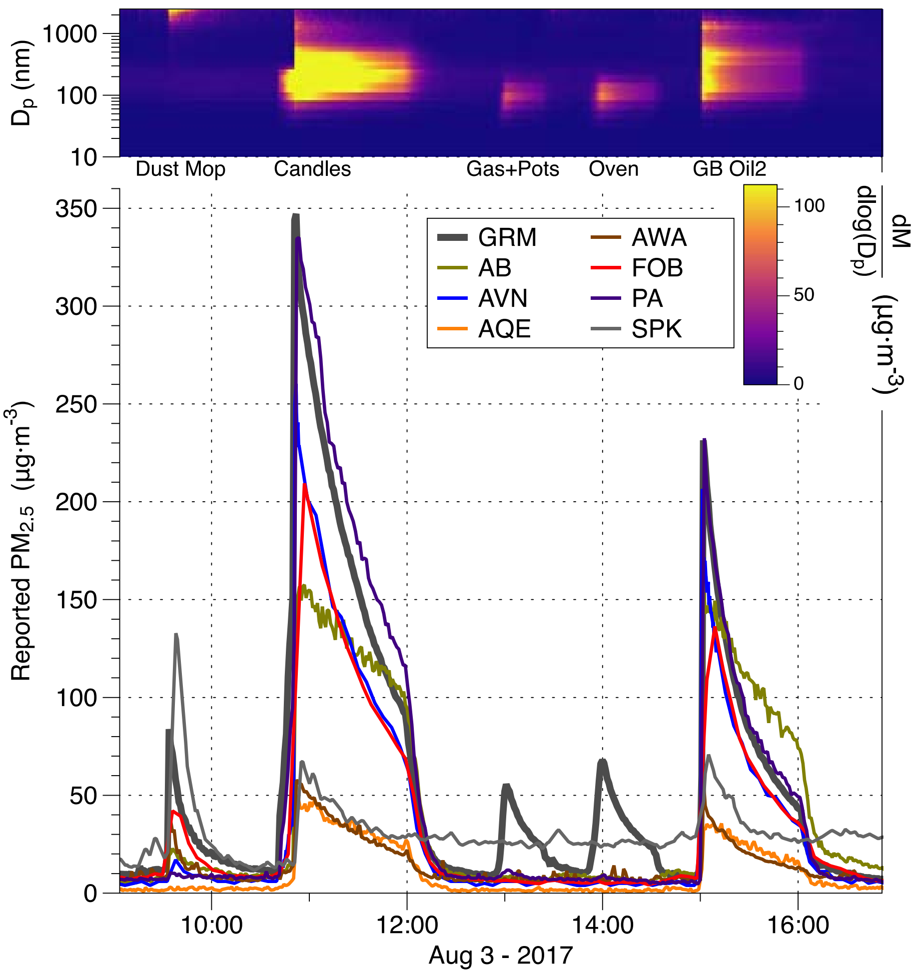

Figure 2. Example results from five source experiments. For devices that sampled more frequently than each minute, data have been averaged for 1-min resolution. The top portion of plot shows the distribution of mass by particle size.

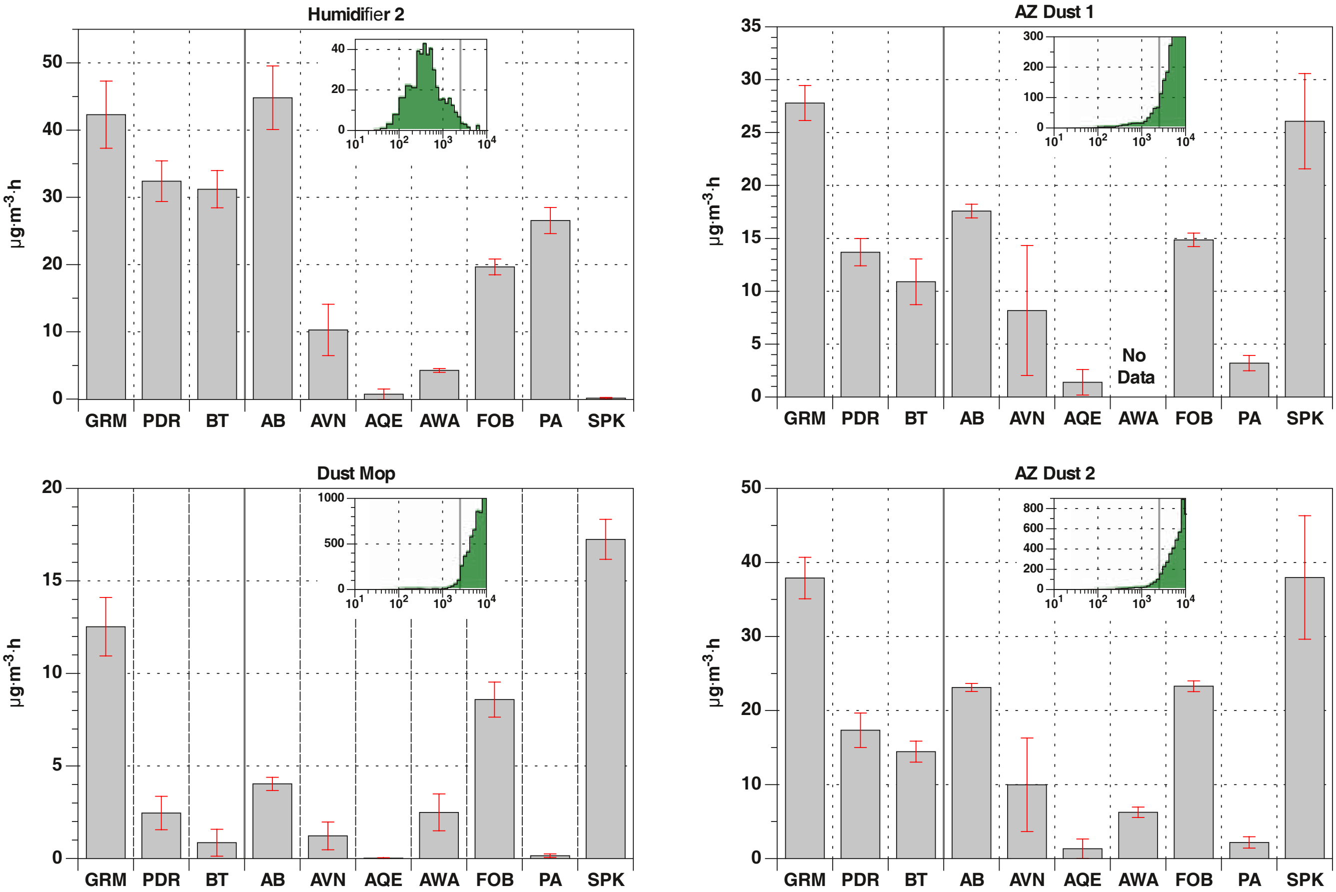

Figure 3. Response to dust and humidifier sources (generally larger particles).

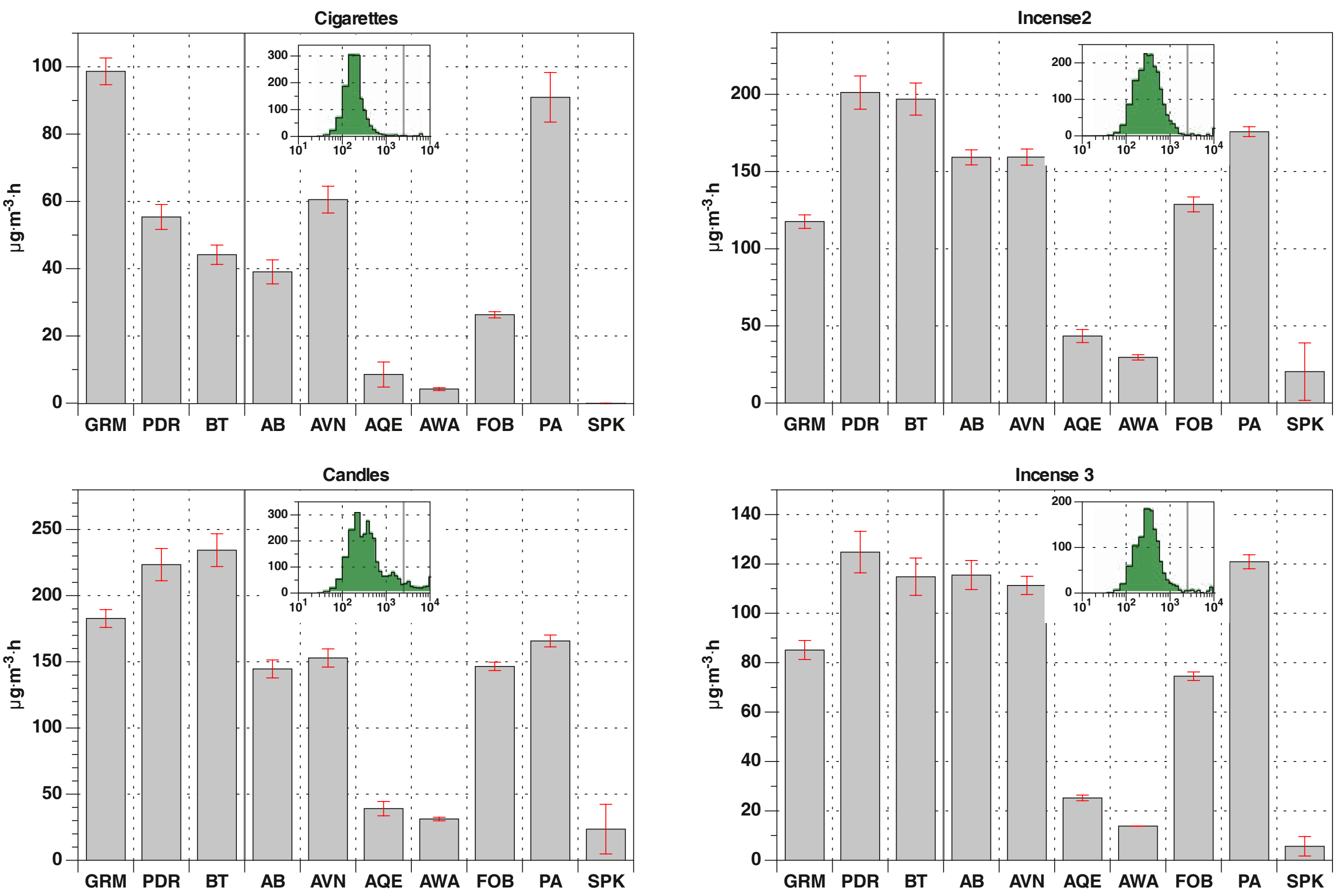

Figure 4. Response to recreational combustion sources.

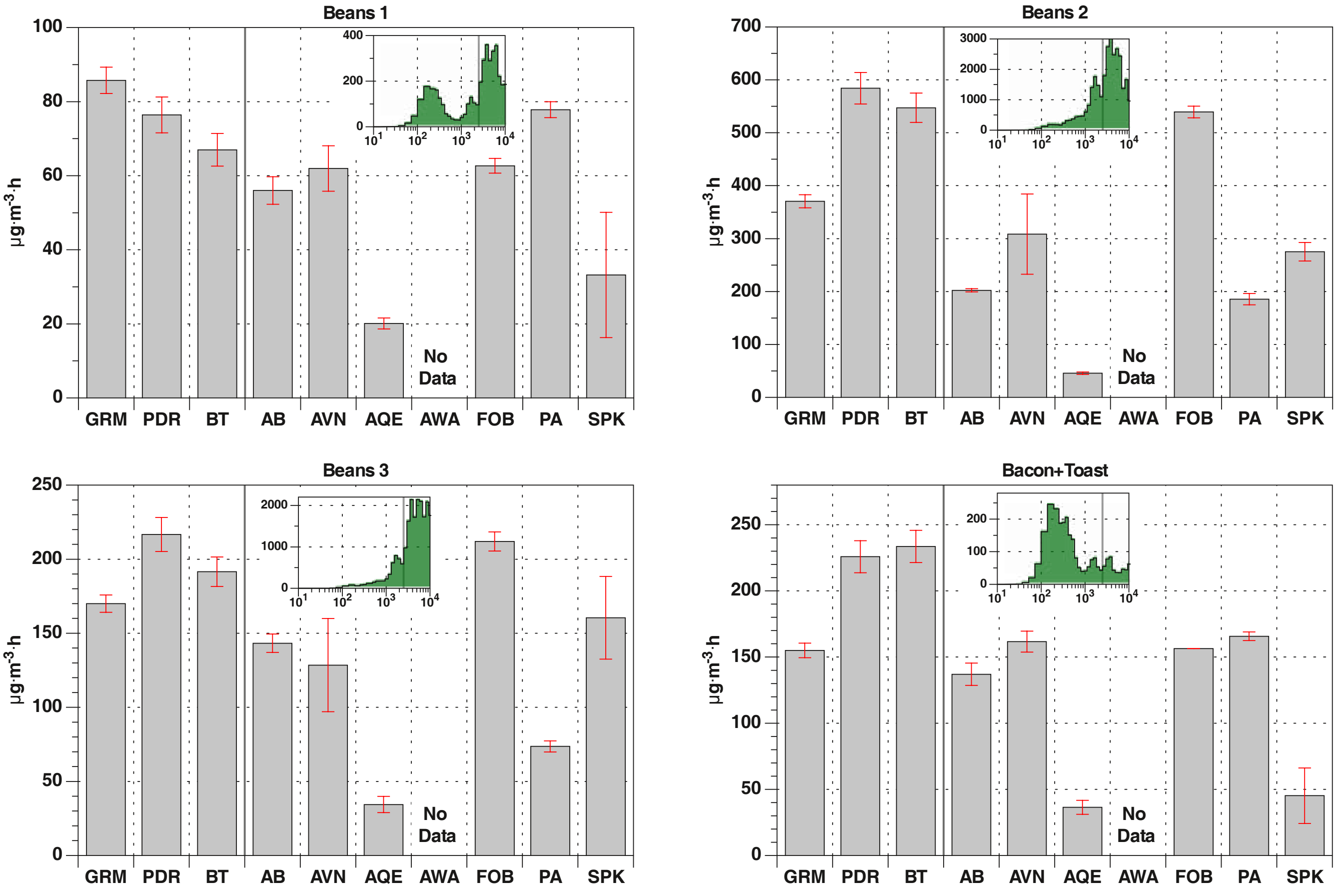

Figure 5. Response to frying and toasting.

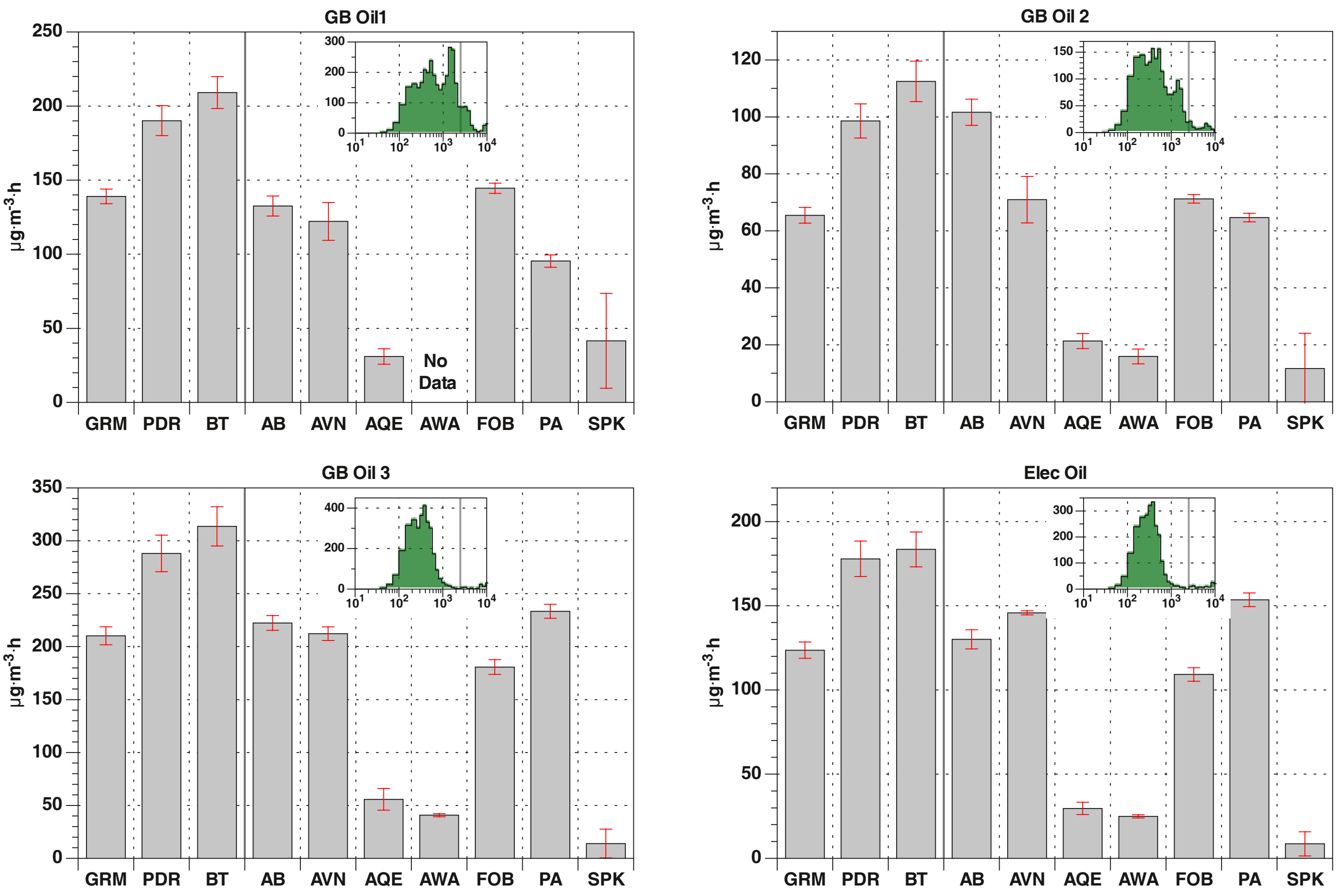

Figure 6. Response to heating oils on gas and electric cooktops.

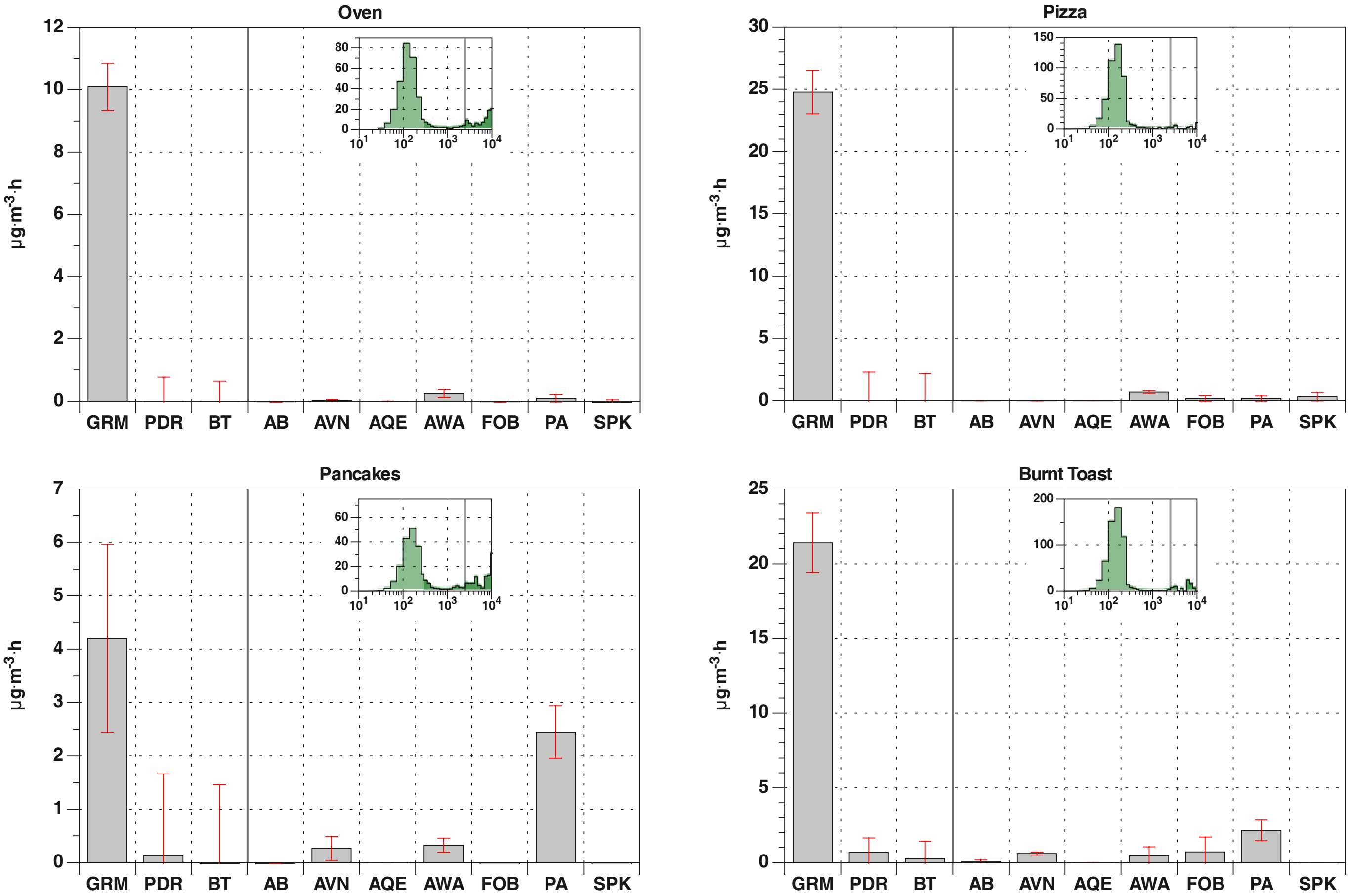

Figure 7. Response to cooking events that mostly emit small particles.

As a group, the monitors generally missed sources that had the vast majority of their mass below 0.3 microns, including use of gas oven or cooktop cooking that did not include frying with oil. The exception was the Purple Air, which had low responses but high correlations, suggesting that it saw the events but not quantitatively. Note that PurpleAir is particle counter, which is more sensitive to low-levels.

Conclusions

Overall, these results suggest that the low-cost monitors will miss important sources of ultrafine particles and sources that may contribute to PM2.5 mass exposures in homes, and therefore we cannot generally say that these devices are suitable for controlling ventilation systems. However, four monitors were acceptable for identifying sources that emitted a lot of PM2.5: AirBeam, AirVisual, Foobot, Purple Air, and may have some value not as a primary control for a ventilation system, but perhaps to control and auxiliary boost function to increase ventilation during high particle events. They could also be used to operate stand alone filter units.

Acknowledgements

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Indoor Air Quality Standardization in Ibero-America[1]

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General public is well aware that outdoor air quality in many European cities is bad and definitively affect our health and wellness, however, unless the well-known fact that urban population spend more than 90% of the time indoors, much less attention has been addressed to indoor air quality compared with outdoor.

We spend time working in commercial buildings, enjoying leisure time in hotels or shopping malls, or using services in hospitals and transportation centres.

Do we know the air quality in those places? Is it under control? Generally speaking most people assume that air quality indoors is good regardless outdoor air quality. Experience shows something quite different.

Countless scientific studies have shown that indoor pollution reflects outdoor, more or less exactly depending on the degree of air ventilation and infiltration, plus a large number of other pollutants added in the indoor air due to the activities, materials, people presence, biological activity, etc. Therefore, typically indoor air tends to be worse than outside.

There is a lot of knowledge about this problem, however, there is a lack of practical application of most of this information in every day's life for general public, the managers of the facilities do not apply, generally speaking, rigorous protocols and maintenance programs intended to enhance indoor air quality in their installations.

Any effort dedicated to control the quality of the indoor air will have undoubtedly enormous social benefits in terms of comfort and health of the population, enhancing productivity and minimizing absenteeism in commercial premises or diminishing nosocomial infections in hospital environments.

[1] This article refers to a pre-standard in Public Review, the pre-number is NIbF 400001 (Norma Ibero-Americana FAIAR) Indoor Air Quality Inspections.

Indoor Air Quality in Spain and Ibero-America

Indoor Air Quality is a relevant topic in Spain. A couple of decades ago media showed a lot of interest in episodes of so called “Sick Building Syndrome”, Legionella outbreaks are, unfortunately, somehow common in Spain, or problems due to presence of *Aspergillus spp* in hospital environments and more recently health effects of asbestos, all these issues created general public awareness.

Probably due to such social awareness, since April 2013 Spanish main legal regulation dealing with HVAC systems established the compulsory obligation of carrying out yearly full inspections of Indoor Air Quality in buildings equipped with thermal installations holding a capacity above 70 kW (either heating or cooling).

The obligation is based on a set of standards previously developed by AENOR through a specific Technical Committee established in 2004 dealing with Indoor Air Quality, (TC171). Most of the effort in developing these standards have been managed by FEDECAI (Spanish Federation of Indoor Air Quality).

Portugal has also been a pioneer in Europe introducing IAQ as one of the topics to consider in Energy Efficiency certifications.

Other countries in South America, like Brazil also count on the obligation of analysing periodically IAQ in their buildings, and Colombia, probably Chile and others will soon follow this path. Representatives of those countries have actively participated in the development of the standard.

FEDECAI in conjunction with ATECYR (Spanish HVAC Association) reached an agreement with FAIAR (Ibero-American Federation of HVAC) in order to develop some harmonized Iberomerican Standards aimed to serve as a model that could be used by all the countries in the development of their own standards and also be used to train professionals specialized in Indoor Air Quality, being able to carry out IAQ inspections and apply solutions to the potential problems that might be found.

General considerations

In the last decades sustainability of buildings is becoming a prerequisite, no new structure is built without considerations of energy use and outdoor environmental impact, however, energy saving and environmental impact must be balanced with the need of a proper IAQ delivery.

The general workflow of the process is described in **Figure 1**.

The initial step is to identify all relevant aspects that may affect Indoor Air Quality in the building, the standard includes a list of some aspects that must be typically considered in a most buildings:

- Location of the building
- Uses and activities
- Construction and decoration materials
- Building Installations
  - HVAC
  - Water
  - Sanitary installations
  - Fuel tanks
  - Lifts and escalators
- Park areas
- Warehouses and special rooms.
- Maintenance of the building
- Refurbishment of the building
- Emergency (water and fire damages)
- Users complaints, epidemiological data, etc.

The objective of the inventory and subsequent assessment is to identify all potential IAQ adverse effect that may arise from different sources, each aspect is evaluated, considering the level of damage a situation may pose (consequences) and the likeliness that such event might happen.

For example, a typical IAQ aspect is the garage, a building having an underground garage indicates a potential serious risk, but the likeliness of fuel exhausts from the vehicles entering the building is low if the garage is properly separated (double access doors) and equipped with well-maintained exhaust fans connected to CO sensors, or it might be high if it is an old building with direct escalators connecting to the garage.

Indoor Air Quality Inspections

The inspection standard establishes a minimum set of parameters that are considered as general indicators of the Indoor Air Quality of any building:

- Inspection of hygiene of HVAC system (including ductwork test: surface microorganisms, gravimetric analysis of settled dust)
- Carbon dioxide and carbon monoxide
- Temperature and relative humidity
- Particle concentration and counting
- Airborne fungi and bacteria
- Carbon dioxide is used as an indicator of the quality of the ventilation.

Particle reading is a good indicator of the quality of the filtration systems, concentration is a health concern, and particle counting is used as an Indoor-Outdoor reference.

Humans are a source of airborne bacteria, so typically indoor airborne concentration is higher than outdoor, this is a good indicator of the general hygiene of the building and also a complementary indicator of the quality of the ventilation.

Fungi is mainly pulled in the building from outdoor and it is a good indicator of the hygiene of the HVAC and the quality of the filtration system.

These parameters must be checked on a yearly basis according to the standard, but apart from this minimum, some other complementary parameters should be analyzed if relevant sources have been identified:

- Formaldehyde
- Ozone
- Volatile organic compounds
- Airborne fibres (asbestos, fiberglass, etc.
- Nitrogen oxides

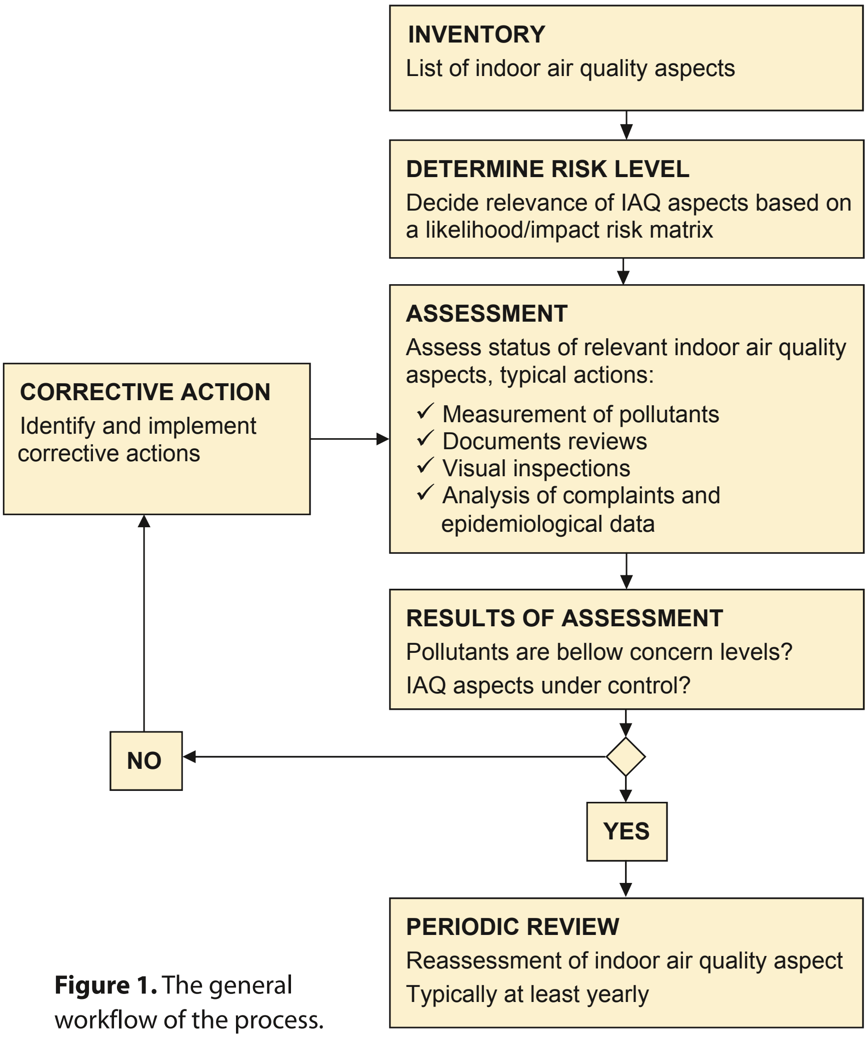

Figure 1. The general workflow of the process.

The inspection standard also establishes the number of sampling points to be taken as a result of the formula:

$$P = 0{,}15 \times \sqrt{A}$$

P = Nº sampling points

A = Area under study

Inspectors must be qualified by fulfilling a specific IAQ training course including at least the following content:

- ventilation and air conditioning systems
- chemical contaminants in indoor environments
- microbiological contaminants in indoor environments
- physical factors in indoor environments
- assessment
- control methods of indoor environmental quality.

The purpose of the inspection is to achieve enough information to be able to declare conformity of the building as a whole. That means that it is not so relevant to find high readings of a specific pollutant in one single point, some basic statistical analysis apply, the building will be declared conform if 75% of the readings are below comfort threshold values, however, the standard specifies that it must be identified the cause of the non-conformities and corrective actions should be implemented.

Conclusion

Implementing IAQ control programs in buildings might suppose a major advance in the quality of the indoor air.

Building managers should ensure that the buildings are environmentally friendly, use energy efficiently and provide a healthy and comfortable indoor environment which is a benefit for the society not only in terms of better quality of life but also as a good economic investment. ■

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Including air-exchange performance in building regulation




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It is generally assumed that compliance with building codes results in an acceptable indoor air quality (IAQ). Field research however clearly demonstrates that this is often not the case. IAQ-levels can be far from adequate and there are large differences in ventilation performance between systems and dwellings. There is a serious need to assess the actual performance of ventilation systems.

Keywords: Residential Ventilation Systems, Ventilation Performance, Assessment method

Up until today the performance of ventilation systems in residential buildings remains largely unaddressed. It is generally assumed that compliance with building codes results in an acceptable indoor air quality (IAQ). It is also assumed that the various types of code-compliant ventilation systems perform comparably. Field research however demonstrates that both assumptions are incorrect: IAQ-levels can be far from adequate and there are large differences in ventilation performance between systems in dwellings [1, 2, 7, 8, 9,10,11]. With energy performance standards demanding increased airtightness levels and reduced natural infiltration [9,10], there is a serious need to assess the actual performance of ventilation systems.

In most countries, building regulations on ventilation are based either on the capacity of the ventilation provisions to be installed, or on a minimum air-flow for the whole building. Air-exchange performance levels in the individual habitable rooms and wet rooms, based on the operating reliability of selected ventilation provisions, their controls, outdoor wind speed, building airtightness and occupant behaviour, are not considered, despite the fact that these parameters are crucial for occurring IAQ-levels.

In the Netherlands, when the Dutch Standard Committee was requested to develop a new ventilation standard for the Dutch building codes, it was decided to include a performance assessment method for ventilation systems. It was also proposed to base this ventilation performance assessment method on the methodology that was developed by VHK and U-Gent in consultation with the Residential Working Group of EVIA. This methodology was presented on the 2017 AIVC conference in Nottingham [5]. The methodology needed adaptations to fit the demands of the Dutch building regulations [12] under public law. This paper describes both the methodology and how it has been adopted for the implementation in the draft new prNEN 1087, Ventilation systems for buildings. This standard will be published for public comments in spring 2019.

Building codes

Fundamentals

Building codes differ significantly where ventilation rates and IAQ-metrics are concerned, even in EU-countries and despite the fact that national standards bodies participate in CEN workgroups and technical committees. Typically, some countries use the number of persons as basis for the ventilation rates, while others use floor-area as a metric or the carbon dioxide-level and/or the RH-level.

The common denominator in the different approaches is the fact that a certain airflow capacity of the ventilation component or -system is to be installed. The assumption is that when code compliant airflow capacities are installed – regardless of the type of system – code compliant air exchange rates are achieved. The logical consecutive assumption is, that all code compliant ventilation systems perform comparably on achieved air exchange rates and consequently on IAQ. However, both field surveys and model research clearly indicate that the impact the type of ventilation provisions and its controls have on the actual occurring air exchange is significant [2,3,9,11] As a result there is a wide range of IAQ-levels that are actually achieved and the IAQ-level is often significantly worse than aimed at in building codes and standards.

On another note, no distinction is made for ventilation needs during absence and presence of inhabitants. During absence ventilation is only required to prevent accumulation of building- and interior products emissions, while during presence ventilation would be aimed at inhabitant-produced emissions. In other words, ventilation during absence or presence of inhabitants has different aims.

IAQ and ventilation rates

Using IAQ directly as a performance indicator requires a clear understanding of what good IAQ actually is. All polluting substances would then have to be defined as well as their allowed threshold values and required ventilation rates.

Recent research, including work in the AIVC-setting, time and again gives new understanding on parameters that define a healthy IAQ [14, 15, 16]. It is often concluded that more research is needed to enlarge the degree of certainty of the advised ventilation-rates. This approach, although in itself valuable, is not expected to lead to new ventilation strategies or largely different ventilation rates than those in the current standards and building codes. Most clearly it is stated by Carrer et. al. [15] that: '*… none of the mentioned standards present a coherent, clear and consistent strategy on how to design ventilation rates that refer to and respect directly health requirements …*'

However, there is consensus that regarding IAQ, source control (or in other words selecting the right building material, furniture and decorative products) is the primary strategy [14, 15]. In addition, ventilation plays a key role in reducing the remaining exposures [14]. In this perspective the most recent recommended ventilation rates must be perceived. It is clear that RH-levels nor CO_2-concentrations match with the complexity of IAQ. But as indicators for the air exchange rates for respectively wet spaces and habitable spaces, the parameters are most adequate and consequently most widely used [13, 14].

Notable in this context is that, in the HealthVent guidelines with regard to the ventilation system, it is emphasised that proper design, operation and maintenance are relevant for compliance of the system to the thus defined ventilation rates [15]. The effectiveness of the system (are the intended air exchanges actually achieved in all wet and habitable spaces) is not mentioned.

Dutch Building Act (Bouwbesluit)

The main document in Dutch building code is Building Act (Bouwbesluit), currently Bouwbesluit 2012, last revised in July 2018 [12]. In this document the ventilation rates for all building types are specified. For all building, excluding residential, the ventilations rates are defined by the number of people the building is designed to use. For residential buildings and single dwellings, the rates depend on the area of 'verblijfsgebied' a difficult to translate typical Dutch conception, which is best referred to as 'habitable space'. In general, it is the total surface of all habitable rooms, without the distinction of the type of use of the rooms. For wet or exhaust spaces it is however possible to differentiate between bathroom, toilet and kitchen.

The Dutch Bouwbesluit gives minimum capacities for ventilation of habitable spaces and exhaust spaces. For schools, office buildings and other utility buildings, the requested capacity depends on the amount of people the building is designed for, as stated in the calculation when applied for a building permit. In this paper we will focus on residential buildings. The ventilation requirements in Bouwbesluit 2012 for all dwellings are (and unchanged since mid-80s) are presented in **Table 1**.

Table 1. Ventilation requirements according Bouwbesluit 2012.

Type of room	Minimum ventilation capacity to be installed
habitable spaces	0,9 l/s·m^2 (with a minimum of 7 l/s per room
toilet	7 l/s
bathroom	14 l/s
kitchen	21 l/s

The capacity should be calculated in accordance with NEN 1087:2001. The Dutch Standard Committee was requested to revise this standard and decided to include a performance assessment method for ventilation systems, based on preliminary research [1, 10].

Consequences for quality-assessment

To actually achieve the requested ventilation rate, all influencing factors which affect air exchange in a room should be evaluated and taken into account. The rate of air exchange is considered to be representative for the amount of fresh air and the transport of pollutants, independent of the nature of the pollutants in a specific situation. Thus, the ventilation system and degree of air exchange it provides, is representative for the probability that a healthy indoor air quality is present during occupation. The 'quality of a ventilation system' is the result of the characteristics of all components including controls, the rate of influence of the building and surroundings and the probability of proper use by the inhabitants.

During the development of the revised Dutch ventilation standard, the authors proposed to base the requested quality assessment method on the methodology that was developed by VHK and U-Gent in consultation with the Residential Working Group of EVIA. This methodology was presented on the 2017 AIVC conference in Nottingham [5]. For this assessment method the following definition is adopted for the air-exchange performance of residential ventilation systems: 'the ability to achieve the requested air exchange in each room of a dwelling for the purpose of extracting and/or diluting concentrations of all hazardous and annoying substances' [5].

Obviously, also this approach has its disadvantages. It will not be possible to predict the exact IAQ in a specific room in a specific building under all circumstances. It is limited to an educated and substantiated expectation of to what extent and with what probability the requested air exchange can be achieved. In that sense, this approach fits with the generally phrased goals for ventilation in the Dutch building act, which states: 'a building has such a provision for air exchange that an unfavourable indoor air quality is prevented'. [13; art 3.29 lid1, translation by the authors].

Assessment method

General overview

The methodology that is developed and proposed [6], assesses the actual occurring air exchange rates on room type level during presence and absence. This specific Air Exchange Performance (AEP) determines to which extent the ventilation system is able to remove and/or dilute pollutant concentrations in the various rooms, especially during presence when exposure occurs. Compared to current practice, where only the air exchange rate over the building is assessed, this represents a major step towards more relevant ventilation performance assessment. Current practice after all does not differentiate between the places in which the air exchanges occur nor between periods of presence or absence. This implies that with current assessment methods, a system that mainly ventilates the corridor, is similarly valued as a system that ventilates the habitable spaces. Likewise, no distinction is made between air exchanges that occur during presence or absence; both are considered equally relevant. Clearly current practice does not lead to a proper assessment of the ventilation performance [14].

Explanation

Based on the principle that is described in the paper 'Methodology for assessing the air-exchange performance of residential ventilation systems' [5], a calculation method is proposed, that assesses the air exchange rates that occur in both habitable spaces and exhaust spaces during periods of absence and presence.

In the assessment method (**Figure 1**), two room types are used, with a matching ventilation strategy:

Habitable Spaces (HS: living rooms, bedrooms, study, etc.), with long exposure of inhabitants to polluting substances in the indoor air during presence. The reference ventilation strategy is to accommodate air-exchange during presence, where supply of sufficient fresh outdoor air is key, and the exhaust is adjusted accordingly. During absence, basic ventilation rates are required to prevent accumulation of building- and interior products emissions.

Exhaust Spaces (ES: kitchen, bathroom, toilet, laundry room), with short exposure of inhabitants, but possibly high humidity levels which are leading. The reference ventilation strategy is the extraction of sufficient air so that moisture/odour is removed. Also, during absence of inhabitant's extraction of air is needed until humidity levels are below threshold values, to be followed basic ventilation rates.

The following technical specifications and parameters of the ventilation system are needed:

- Type of air-exchange provisions (direct/indirect, driving force)
- Installed maximum airflow capacity (limiting factor for achievable air exchange rates)
- Type of operation and/or controls (affects systems ability to achieve requested air-exchanges at the right time in the right place)
- Type of filtration of supply air (indication of filtration performance for situations where quality outdoor air is insufficient).

***Initial focus on residential ventilation* systems**

- *Only applicable to ventilation systems that are properly installed (in accordance with prevailing buildings codes, national practitioner guidelines and manufacturer guidelines)*
- *Air-exchanges for the purpose of extracting cooking fumes are excluded from the assessment (dedicated solution (cooker hood) is default)*
- *Mechanical ventilation systems using continuously alternating flow directions are excluded from the scope (no representative field research available)*
- *Only technical system features will serve as input for the assessment*

Figure 1. Scope of proposed assessment method.

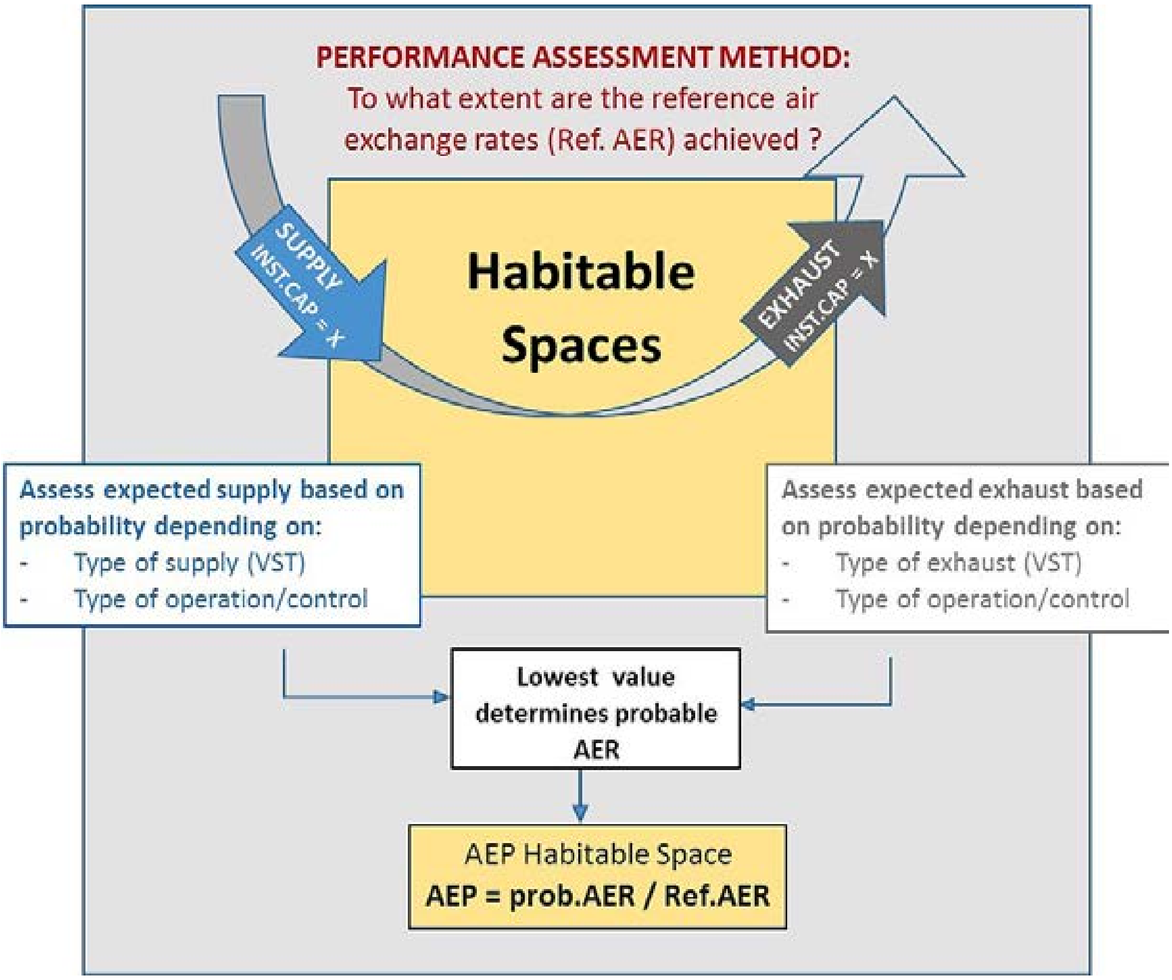

Figure 2. Illustration explaining the ventilation performance assessment method.

The reference air exchange rates (AER) will be based on the air exchange rates that are described in prEN16798-1 [4]

Ventilation system type (VST)

The European Ventilation Industry Association distinguishes seven different ventilation system types in the various European markets. These system types can be identified by the type of air exchange provision they use in habitable spaces and exhaust spaces. The Dutch Standards Committee intends to implement this clear classification in the new Dutch prNEN1087. **Table 2** gives a short overview of the characteristics of these system types by describing the type of the air exchange provisions.

Calculation of Air Exchange Performance

The proposed assessment method distinguishes between periods of occupancy and periods of absence. As a consequence, additional information on occupancy patterns is requested (to be based on typical dwelling occupancy data).

Next, for the air exchange provisions used in the various ventilation system types mentioned in **Table 1**, the controls that are applied determine to what extend ventilation provisions are switched to the requested capacity during periods of occupancy and absence. For ventilation provisions that depend on natural driving forces, the probability of the availability of these driving forces (wind, stack or both) need to be taken

Table 2. Ventilation System Type (VST)VST.

	Roomtype	Air exchange provision		Abbrev.
1	Habitable spaces	supply	Natural Direct Supply	NDS
		extract	Natural Indirect Extract	NIE
	Habitable spaces	supply	Natural Indirect Supply	NIS
		exhaust	Natural Direct Exhaust	NDE
2	Habitable spaces	supply	Mechanical Indirect Supply	MIS
		exhaust	Natural Direct Exhaust	NDE
	Habitable spaces	supply	Mechanical Indirect Supply	MIS
		exhaust	Natural Direct Exhaust	NDE
3	Habitable spaces	supply	Natural Direct Supply	NDS
		extract	Mechanical Indirect Extract	MIE
	Habitable spaces	supply	Mechanical Indirect Supply	MIS
		exhaust	Mechanical Direct Exhaust	MDE
4	Habitable spaces	supply	Natural Direct Supply	NDS
		exhaust	Mechanical Direct Exhaust	MDE
	exhaust spaces	supply	Mechanical Indirect Supply	MIS
		exhaust	Mechanical Exhaust	MDE
5	habitable spaces	supply	Mechanical Direct Supply	MDS
		extract	Mechanical Indirect Extract	MIE
	exhaust spaces	supply	Mechanical Indirect Supply	MIS
		exhaust	Mechanical Direct Exhaust	MDE
6	habitable spaces	supply	Mechanical Indirect Supply	MIS
		exhaust	Mechanical Direct Exhaust	MDE
	exhaust spaces	supply	Mechanical Indirect Supply	MIS
		exhaust	Mechanical Direct Exhaust	MDE
7	habitable spaces	supply	Mechanical Direct Supply	MDS
		exhaust	Mechanical Direct Exhaust	MDE
	exhaust spaces	supply	Mechanical Indirect Supply	MIS
		exhaust	Mechanical Direct Exhaust	MDE

into account. These are determined, based on physical principles and statistic data.

Finally, the building or dwelling itself has an influence on occurring air exchanges rates, leading to the necessity to incorporate certain building parameters (air tightness and number of habitable- and wet spaces) into the calculation method.

Based on this data, the probable occurring air exchange rate (AER) is determined. By dividing the probable AER by the reference AER (as specified in Building Codes) the Air Exchange Performance is obtained.

Adjustment to the building code

The methodology needed adaptations to fit the demands of the Dutch building Act [12] under public law. Although the method itself is at first a private addition to the national new NEN1087 standard, in coordination with the relevant Department (BZK) the method will hopefully be adapted to fit in the public building code in the future.

Four main adaptations were made:

- Abandonment of the differentiation in type of habitable rooms.
- Adjustment of the reference AER to the requested ventilation according to Bouwbesluit 2012 the removal of the related categories for Air Exchange Performance classes.
- Determination of the occupancy patterns.
- Removal of the ventilation performance label.

The abandonment of the differentiation in type of use (living room, bedroom or study) makes the method less specific for a specific dwelling and specific use, but is essential to accommodate the principles of the Dutch building act.

Forthcoming

Next step will be to fit the first AEP-results of this new assessment method with field research results and the outcome of multi-zone airflow models, thus providing a substantiation for the use of this assessment model and the versatility of the new AEP- and AER parameters. Based on that outcome, the Dutch standard committee will decide on the implementation in the new standard NEN 1087. Furthermore, the results will be presented to CEN-TC 156, for evaluation, comments and possible input for further development, both in the methodology itself as eventually in the EN 13141- and EN 16798-series.

Conclusion

The adjustments that were necessary to make the methodology suitable for use in building regulation, resulted in more generic performance values for habitable spaces, but nevertheless not less valuable. It is therefore essential to point out that the performance assessment method cannot be used to predict the IAQ-levels that can be expected, but that it is intended to compare ventilation systems on their ability to achieve the requested air exchanges in the right place on the right time. With it a relatively simple method will become available within the context of building regulations, making it possible to – apart from ventilation capacity requirements - set limit values for performance indicators. ■

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IAQ in workplace in Belgium: alternatives to CO_2 requirement

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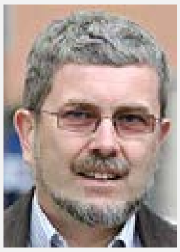

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In March 2016 a new IAQ requirement came into force for workplaces in Belgium with a maximum absolute CO_2 concentration of 800 ppm, leading to a very substantial increase in the required ventilation flowrates.

The proposed alternatives for IAQ requirements take also into account the emissions from materials in order to maximise the final IAQ improvement while assuring an effective implementation in practice.

Keywords: IAQ requirement, working environment, material emission, CO_2 concentration, compliance framework.

Indoor air quality in workplaces is important for comfort, productivity and health of the workers. Requirements are necessary and CO_2 is a common proxy for ventilation in presence of people.

The new requirement, expressed as a maximum **absolute** CO_2 concentration of 800 ppm [1], raises the question of the responsibility of the different involved persons, such as the designer, contractor and owner of the building, the employer but also the employee as end user of the building. Moreover, the stricter requirement remains an economical and technical challenge, especially for existing building without a complete ventilation system. Finally, this higher flow rate is maybe not necessary in all cases, especially if the sources of pollutants from materials have been limited and the persons are the main pollutant source.

For example, the results of the Healthvent project [3] [4] recommends a minimum flow rate, for health, of 4 l/s.pers if the non-human pollutants are limited; and FprEN16798-1:2016 [2] recommends flow rates from 10 l/s.pers to 4 l/s.pers depending on the targeted perceived IAQ.

Our work aimed to identify alternative approaches for the expression of IAQ requirements for working environments in order to maximise the final IAQ improvement for the workers while assuring an effective implementation in practice thanks to a robust compliance framework. Note that the current regulation in Belgium is still based on the requirement of 800 ppm CO_2 and that there is up to now no decision to implement the proposed alternative approaches in the regulation.

Possible approaches

Approach 1 (current regulation in Belgium)

The advantages of the CO_2 requirement are that it is performance based and easily measurable on site. However, the CO_2 requirement focuses only on the persons as source of pollutants and does not consider the possibility to control the other sources of pollutants, such as emissions from materials, by limiting them at the source (for example choosing low emitting materials).

The alternative approaches could then consider the emissions from the material to determine the flow rate required in the working spaces. The draft standard FprEN16798-1:2016 has been used as a basis to identify alternative approaches.

Approach 2

A second (alternative) approach could be two different CO_2 requirements (or flow rate requirements) depending on the level of emission of the materials. In case no attention has been paid to limit emissions from materials, the higher flow rate is required, e.g. minimum 14 l/s.pers or maximum 400 ppm of CO_2 concentration above outdoor (= 800 ppm if outdoor concentration is 400 ppm). On the other hand, if it can be proved that the emissions from the materials are limited by choosing (very) low emitting materials, a less strict requirement applies, e.g. minimum 7 l/s.pers or maximum 800 ppm of CO_2 concentration above outdoor (= 1200 ppm if outdoor concentration is 400 ppm).

Approach 3

A third (alternative) approach is to consider the flow-rate needed for the persons and that needed for material emissions separately in accordance with method 2 described in the standard FprEN16798-1:2016. A first flow rate is calculated for the persons, e.g. 7 l/s.pers (according to class II for the perceived IAQ in the standard). A second flow rate is calculated for the pollutant emissions from the materials, based on different flow rates per m² depending on the level of emission of the building, e.g. 0.35 l/s.m² for very low emissions, 0.7 l/s.m² for low emissions and 1.4 l/s.m² for non-low emissions. Both of these flow rates are calculated for each space and the highest of them is the flow rate to consider as requirement.

Figure 1. Example of a meeting room in a working environment.

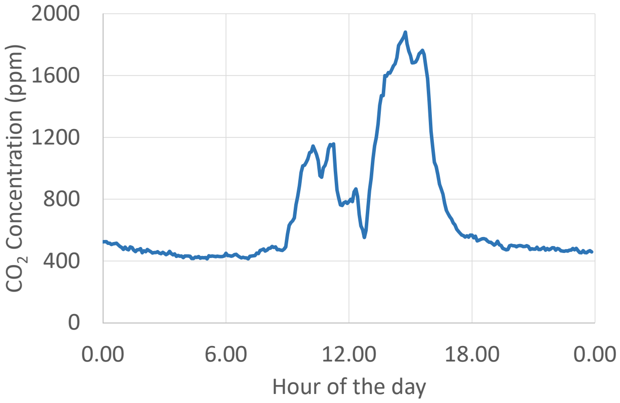

Figure 2. Example of CO_2 measured in an office environment during an occupied day.

For these two alternative approaches, a framework is necessary to classify the type of emissions in a building between very low emissions, low emissions and non-low emissions. For example, this framework could be based on existing framework to classify the emissions from the building materials used for the floor covering, paint and materials for the ceiling and walls, etc. Such a framework exists for example in France [5], with an emission label (with several classes from A+ to C); and in Belgium [6], for floor materials only, with a pass/fail approach.

Table 1. Application of the 3 approaches on 3 typical building spaces and for three levels of emissions from materials. The results are expressed as flow rate per surface area, flow rate per person and CO_2 concentration.

Type of space / building			**Flowrate or [CO_2]**			
	Area per person (m^2/pers)	**Building emission level**		**Approach 1**	**Approach 2**	**Approach 3**
Office	15	Very low	l/s.m^2	0.9	0.5	0.5
			l/s.pers	14	7	7
			ppm	800	1200	1200
		Low	l/s.m^2	0.9	-	0.7
			l/s.pers	14	-	10.5
			ppm	800	-	933
		High/ unknown	l/s.m^2	0.9	0.9	1.4
			l/s.pers	14	14	21
			ppm	800	800	667
Inter-mediate	10	Very low	l/s.m^2	1.4	0.7	0.7
			l/s.pers	14	7	7
			ppm	800	1200	1200
		Low	l/s.m^2	1.4	-	0.7
			l/s.pers	14	-	7
			ppm	800	-	1200
		High/ unknown	l/s.m^2	1.4	1.4	1.4
			l/s.pers	14	14	14
			ppm	800	800	800
Meeting room / school	3.5	Very low	l/s.m^2	4.0	2.0	2.0
			l/s.pers	14	7	7
			ppm	800	1200	1200
		Low	l/s.m^2	4.0	-	2.0
			l/s.pers	14	-	7
			ppm	800	-	1200
		High/ unknow	l/s.m^2	4.0	4.0	2.0
			l/s.pers	14	14	7
			ppm	800	800	1200

Application of the approaches to typical buildings

Methodology

The three approaches described above have been applied to three types of building spaces with different occupation rates: an office with 15 m²/pers, a meeting room with 3.5 m²/pers, and an intermediate space with 10 m²/pers. For each type of space, three different levels of material emissions have been considered: very low emitting, low emitting, non-low emitting.

In these nine configurations, the required flowrates have been calculated according to the three approaches described above and the results are presented in Table 1 in the form of: flow rate per surface area (l/s.m²), flow rate per person (l/s.pers) and absolute CO_2 concentrations (for outdoor concentration of 400 ppm).

Overview of the results

For the first approach (maximum 800 ppm of CO_2), the flow rate per person are the same for all types of spaces and all emission levels. However, because the occupation is different, the flow rate per surface area is lower for the office and higher for the meeting room.

For the second approach (maximum 1200 or 800 ppm of CO_2 depending on emission level), the design flow rate per person depends on the emission level of the building.

For the third approach (flowrate for persons and flowrate for emissions), the final design flow rate of the space depends on the nominal capacity (number of persons) of the space and on the surface area of the space and level of emission of the building.

Comparison of the approaches

With the third approach, based on the standard FprEN16798-1:2016, the design flow rate of a space is determined based on the most limiting pollutant source of this specific room. If the occupation rate of the space is low and the emission level of the building is high, then the limiting factor is the emission. In contrast, if the occupation rate of the space is high and the emission level of the building is low, then the limiting factor is the presence of the persons (bio effluents) and the design flow rate depends only on the number of persons in the room. The design flow rate is thus adapted, case by case, according to the most limiting factor for IAQ.

In contrast to this third approach, the first one requires the same flow rate per person whatever the occupation rate and the emissions from material. For example, in the meeting room, the design flow rate is higher than in the third approach. When low emission materials are used, these higher flow rates are probably unnecessary, causing also unnecessary energy consumption.

For the second approach, the design flow rate of the spaces depends partly on the emission level of the building. In case low emitting material are used, the flow rate per person can be lower while assuring equivalent IAQ and decreasing energy consumption. This is the main advantage of the second approach compared to the first one. However, in case of non-low emitting buildings, the same problems occur for the meeting room: higher design flow rate compared to the third approach based on the standard FprEN16798-1:2016 (method 2).

Discussion of pros and cons of the approaches

Some pros and cons of the different approaches have been identified and listed in Table 2, and a few of them are discussed below.

The approaches can be compared based on the expected impact on the real IAQ in the working environment and their incentives for a better ventilation system on one hand and a better source control on the other hand.

Because the first approach focuses only on a CO_2 requirement and not at all on the source control of material emissions, this approach has absolutely no incentives, for the employers and building designers and contractors, to limit the sources of pollutants by choosing (very) low emission materials. The high level of requirement in this first approach (800 ppm absolute CO_2 concentration) could in theory lead to high IAQ for bio-effluents as well as "indirectly" for other pollutant sources. However, because this higher flow rate has a huge economic impact for the employers as well as for the building owners (larger ductworks and technical rooms, higher energy consumption and operational costs), the true applicability of this first approach in practice is expected to be very poor.

On the other hand, the two alternative approaches allow an effective incentive to control the pollutant emissions at the source, by choosing (very) low emitting materials, and at the same time to adapt the required flow rate for ventilation accordingly. The ambition level of IAQ can then be similar to the first approach but adding two main advantages compared to the first approach: (1) a better incentive for source control, and

Table 2. Comparison of the three approaches in terms of pros and cons.

Comparison Criteria	Approach 1	Approach 2	Approach 3
Expected impact on real IAQ	In theory high but difficult applicability in practice	High and better applicability expected	High and better applicability expected
Incentives for better source control	No	Yes, roughly	Yes, case to case
Incentives for better ventilation system	Yes but high flow rate	Yes, flow rate depends on emissions, but sometimes high flow rate (meeting room)	Yes, flow rate depends on emissions
Ease of conformity control	Easy: CO_2 measurement	Easy for CO_2 measurement + need framework for emissions	Flowrate measurement possible but more difficult + need framework for emissions
Ease of design and installation	Easy to calculate	Easy to calculate flow rates + need framework for emissions	Easy to calculate flow rates + need framework for emissions
Economic impact (for new building)	Very high (higher flow rates)	Choice between effort on materials or flow rates	Choice between effort on materials or flow rates
Applicability for existing buildings	Difficult (higher flow rates)	Ok if low emission	Ok, flow rate depends on emissions

(2) a better expected applicability of the requirement in practice because the flow rate can be lower in case of low emission.

Compared to the second approach, the third one presents an additional advantage: the design flow rate of a space can be fine-tuned in function of the design number of persons in the room and the amount (surface area) and the type of emitting materials in the room. In such way, the third approach is probably more appropriate for some specific cases such as meeting rooms where the occupation rate is high and consequently the flow rate per person can be the limiting factor even if the emission level of the material is high or unknown. This is an important point for this type of space (meeting room, etc.) where the impact of higher flow rate can have high economic consequences.

However, the two alternative approaches also require a framework in order to classify the emission level of a building (or a space) at the design stage as well as for the conformity check. Such an effective framework remains a challenge. One possible approach would be to use existing regulation and framework for material emission, such as the current Belgian regulation on pollutant emission for floor covering materials. ■

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Key findings on Ventilative Cooling

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This paper sums up the key findings on Ventilative Cooling (VC) which has proven a solid and highly energy efficient solution to support summer comfort. It offers detailed insights on VC elements, their application and control strategies linked to well-operating VC systems. Beyond that hands-on information on algorithms for early stage air-flow estimation as well as key performance indicators are stated.

Keywords: Ventilative Cooling, Ventilative Cooling Performance Indicators, Natural Ventilation, Airflow Rate, Summer Comfort, Air Velocity, Operability, Reliability

Over the course of the IEA EBC Annex 62 in depth research on Ventilative Cooling (VC) such as short time performance measurements, user surveys, involvements in VC-building-design, long-term case studies and expert interviews has been carried out. This paper presents a list of key performance-indicators derived from successful VC solutions as well as a list of major challenges and examples of successful practical solutions.

Three qualities turned out to be crucial as regards success or failure of Ventilative Cooling applications:

1. Sufficient **Airflow**
2. Appropriate **Temperatures**
3. **Usability** and Reliability

Airflow

Ensure sufficiently high airflow

Sufficient airflow, whether naturally or mechanically induced is crucial for Ventilative Cooling systems. Design for significant air change rates is necessary in order to get a VC-system working. An air change rate (ACH) of greater 3 h^{-1} is mandatory, whereas an ACH greater 5 h^{-1} is recommended to achieve substantial heat removal and justify noteworthy investments.[1]

The analysis of case studies showed, that the percentage opening area to floor area ratio (POF) has to be around 2–8%, whereas in temperate climates with dry hot summers ratios at the higher end have been recorded.

[1] Holzer, P. et al. (2017), p.3

The analysed case studies show no correlation of building category concerning POFs. These values do not take into account the flow effects of the opening, but may be used as rule of thumb in early design stages.[2]

Favour airflow through architectural apertures

Airflow through architectural apertures is a most effective and most economic technology to achieve sufficient airflow. Simple architectural aperture deliver impressive airflow already at relatively low temperature differences or wind pressure levels. The algorithm proposed by de Gids & Pfaff offers a quick and still reliable estimation for airflow of single sided ventilation through one opening, driven by temperature difference inside/outside as well as wind velocity.

$$U_m = \sqrt{C_1 U_{10}^2 + C_2 h \Delta T + C_3} \quad (1)$$

$$Q = \frac{1}{2} A U_m \quad (2)$$

A	Opening area [m²]
C_1	Wind constant (0.001)
C_2	Buoyancy constant (0.0035)
C_3	Turbulence constant (0.01)
h	Window height [m]
Q	Volume flow rate [m³/s]
U_{10}	Reference wind speed measured at the height of 10 m [m/s]
U_m	Mean velocity [m/s]

E.g., a window of 1 m² (0.5 m width and 2 m height), at a temperature difference of only 2 K and a mean wind velocity of only 0.5 m/s already offers an impressive airflow of 120 m³/h.

Enhance airflow by powerless ventilators

Powerless ventilators generally make use of wind pressure to generate either additional pressure driving supply air flow or – more often – generate a negative pressure driving extract air. The most widely used are Venturi ventilators, powerless rotating ventilators and wind scoops. Powerless ventilators are generally robust, inexpensive and very effective. Again, their effects depend inevitably on the presence of wind.

Industrial Venturi ventilators reach pressure coefficients up to (–1), leading to remarkable negative pressures of:

- 4 Pa at an undisturbed wind speed of 2.5 m/s;
- 60 Pa at an undisturbed wind speed of 10 m/s.

Venturi roofs ventilators and Venturi chimney caps are offered throughout the world as robust and effective air flow enhancing devices for exhaust air (**Figure 1**).

Figure 1. Prefabricated ventilators which utilize the Venturi effect.[3]

Design for very low pressure drops

A very low pressure drop is mandatory for successful VC application:

Buoyancy is widely used as a natural driving force in VC applications. Still, it is important to accept its limitations: If the air driving force is buoyancy, VC shall be designed for pressure drops of less than 5 Pa.

If the air driving force is mechanical ventilation, pressure drop can technically be raised, but economically and ecologically is limited by the call for high power efficiency (COP). COP of VC is defined as the ratio of $P_{thermal}$ / $P_{elecrtical}$. A total pressure drop of 100 Pa will lead to a power efficiency (COP) of ≈ 20, which is a reasonable benchmark, compared to a mechanical chiller. EN 13779 defines the best category of Specific

[2] O'Sullivan, P. O'Donovan, A. (2018), p.24

[3] Passivent Airstract roof ventilation terminals, https://specificationonline.co.uk/directory/passivent/products/airstract-roof-ventilation-terminals (05/06/2018)

Fan Power (SFP) lower than 500 W/(m³·s), equalling a pressure drop of 250 Pa. In Ventilative Cooling this is still too much. VC applications have to be designed within the non-existing category "SFP 1+" with a specific fan power of lower than 200 W/(m³·s), equalling a pressure drop of 100 Pa. [4]

A well performing example of VC exhaust ventilation has been monitored in a Viennese social housing project. The air is drawn in via automated staircase windows, guided through the central aisles, drawn out via <10 m duct length by a central exhaust ventilator on the roof of the building. The monitoring proofed a Specific Fan Power (SFP) lower than 170 W/(m³·s), equalling a total pressure drop of 85 Pa, resulting in COP = 24 at an extract air flow of 22.000 m³/h. [5]

Temperature

Efficient operation of VC is highly dependent on outdoor air temperatures. Natural airflow rates are strongly linked to temperature differences (ΔT) between indoor and outdoor air temperatures. Especially in dense urban areas day night swings might not be sufficient for effective night ventilation. Site specific circumstances however can make a big difference. Green outdoor spaces, like parks with trees and unsealed surfaces, may provide adequate reduction of night temperatures. Orientation of air inlet openings should consider such circumstances.

Exploit available temperature differences, limit VC to periods which physically make sense

VC system should only operate at a sufficient temperature difference potential of indoor to outdoor temperature. A recommendable threshold is $\Delta T \geq 2$ K. In the case of a long term monitored building of the University of Innsbruck the set point for VC operation has even been raised to 3 K, with the benefit of a much more stable and robust operation pattern of VC.

Figure 3 shows short time monitoring results from mechanical ventilative cooling in a Viennese office during a mild summer period. Mechanical ventilation runs from 22:00 to 06:00. Outdoor Air Temperature (green) undergoes the extract air temperature (yellow) at 22:00. The monitoring results show that the start point is well set. As ΔT has its peak in the early morning hours the operation of the operation time should be extended to fully benefit from low outdoor temperatures.[6]

Design the VC system for summer comfort at increased air temperatures

The ability of thermal mass to absorb thermal energy is highly dependent on the prevailing indoor air tempera-

[4] Calculations based on an average ventilator efficiency ratio of 50% and air temperature rising by 3 K.

[5] Holzer, P. et al. (2017), p.2

[6] Holzer, P. et al. (2017), p.4

Figure 2. Air inlet window with chain actuator (left) Exhaust ventilator on roof (right).

ture. Thus, it is mandatory for successful VC application, to allow slightly elevated air temperature in the room. A constantly low air temperature throughout the day will ruin a possible contribution of VC.

Thus, VC has to be safeguarded by indoor climate concepts that secure thermal comfort at elevated levels of air temperature. Elevated air velocity can be an appropriate measure.

Air movement is the most effective mean of extracting heat from the human body, both by convection and evaporation in and ordinary indoor environment. Thus, air movement, hereby addressed as comfort ventilation, is not a measure for extracting heat from houses but of extracting heat from human bodies. The effect of raising the personal neutral temperature by moving air is quantitatively described in many comfort Standards (i.e. ISO 7730:2005, Appendix G).

Air movement may be provided both by natural airflow, whereas heat transfer has to be prevented, and by mechanical fans. Box fans, oscillating fans or ceiling fans are well known and proven for increasing the interior air speed and improving thermal comfort. Higher air speeds permit the buildings to be operated at a higher set-point temperature and thus to reduce its cooling needs. Air circulation fans allow the thermostat to increase by >2°K. Thus, fans can meet up to 40% of the cooling need of buildings.

Usability and reliability

User integration is crucial for a functioning VC system and a well excepted indoor environment. There might be discrepancies concerning the desired operation of VC components (e.g. the scheduled opening and closing of windows) and user preferences, which have to be taken into account. Case study documentations show best results when automated components also allow for manual control. Such implementations prove to be the most adaptable and reliable solutions, where VC systems work well and users are satisfied.[7]

[7] O'Sullivan, P. O'Donovan, A. (2018), p.30

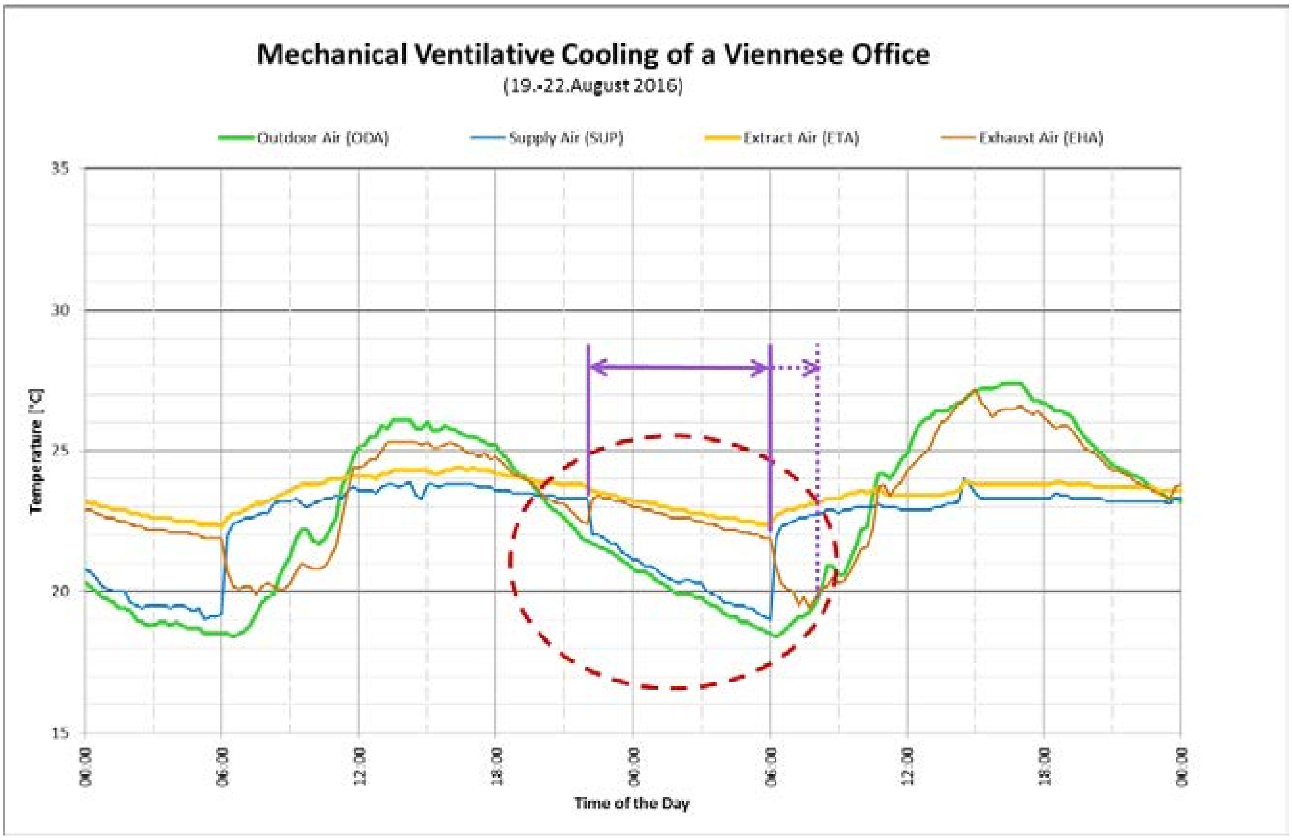

Figure 3. Temperature profile of mechanical Ventilative Cooling system in an office.

One example of such a combination from a Viennese primary school has been documented, where windows (shown in **Figure 4**) are used for night ventilation. They allow users to manually open the window which increases user acceptance, but still are controlled automatically for night ventilation which ensures high efficiency of VC.

Strictly emphasise Operability and Reliability of VC components

The operability of VC components, especially of the airflow guiding and airflow enhancing components, is key to success of the whole VC system. The following aspects are related to previous chapters and offer close links to practical VC application.

Safety and security measures have to be taken into account from early design stages on. They play an important role especially in public buildings where users and visitors might not be that well informed about the building's technical equipment. For automated components, like windows, flaps or louvres, entrapment prevention is mandatory. The best solution comes by making moveable parts of VC components inaccessible for users. If placed at heights above 2 m they are usually save. Another option is to use pressure sensitive sealing as shown in **Figure 4**. This measure needs additional installation care and raises maintenance costs, but allows for placement of VC components in positions reachable by users.

Post occupancy optimisation is mandatory in VC applications: There should be a constant monitoring and parametric optimisation during a period of one year. This cannot be substituted by sophistic building automation. Quite the contrary, post occupancy optimisation turns out most important, for VC systems of high technology levels. It has also been reported, that occupants take less responsibility for maintaining indoor climatic conditions and engage less with the building use over the course of the first months after occupation of the building, which makes well configured automated systems even more vital.

Conclusions

Ventilative Cooling proves to be a robust, cost and highly energy efficient solution to ensure climatic indoor comfort in buildings in both cool and warm temperate climate. Taking on the findings and results from this paper and the Annex 62 will help to make its implementation successful and promote its application on a broad scale. For further results and in depth reading please refer to the official Annex 62 deliverables cited in the references below. ■

Figure 4. Automated window, with optional manual operation and resistance sensitive gasket.

Acknowledgements

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Thermal comfort in operating theatres for different types of ventilation systems

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Thermal comfort in operating theatres is a less addressed research component of the indoor environment in operating theatres. The air quality naturally gets most attention when considering the risk of surgical site infections. However, the importance of thermal comfort must not be underestimated. In this research, the current thermal comfort situation of staff members is investigated. Results show that the thermal comfort for the members of a surgical team is perceived as not optimal. Application of the PMV and DR models needs further attention when applied for operating theatres. For the investigated ventilation systems, the differences in thermal comfort outcomes are small.

Keywords: Operating theatre, thermal sensation, non-uniform thermal comfort, surgical team, HVAC systems, post-operative wound infections, down flow ventilation, mixing ventilation

In an operating theatre, the most important requirement is that the patient receives the best possible care during surgery. The assumption is that by efficiently supplying sufficient clean air into the room the occurrence of post-operative wound infections will be minimized. Therefore, the design of an operating theatre is mainly based on air quality for contamination control (see **Figure 1**). In case of an operating theatre, the possible sources of pollution are the surgical staff, the surgical instruments and the patient itself. Because, based on these sources, the amount of air that needs to be supplied is considerable (in an operating theatre the air change rate is in the order of 15-30 h-1 [1]), theoretically efficient unidirectional downflow (UDF) ventilation systems are often chosen over mixing systems.

Until 2014, The Netherlands prescribed a UDF system for class I operating theatres, i.e. highest air quality requirements. After 2014, a more performance-driven approach was chosen which made it possible to look beyond conventional systems, offering possibilities for new design solutions. In the entire discussion about the quality of an operating theatre, the effect of the work environment of the surgical staff on the result of an operation is generally overlooked. Good lighting is self-evident and translated, e.g., into operating lamps. Sound/speech intelligibility is a point of attention, but also thermal comfort plays an important role in achieving an optimal work environment. This study focused on the latter aspect. Some earlier research is available [2] and literature also shows some numerical analysis of the thermal conditions in an operating theatre [3]. The objective of this research was to analyze the performance of existing operating theatre ventilation systems and new developments in this field with respect to thermal comfort, and identify which system(s) may be preferred from a thermal comfort point-of-view.

Methodology

As part of the research is perception based, and limitations in the numerical analysis are significant the work is performed experimentally. In the study, in-situ measurements have been performed in several operating theatres with different types of ventilation systems (see **Figure 2** for an impression). The systems studied are UDF (two-temperature [2T] system), Opragon and Halton. The measurements have been carried out in operating theatres in two different hospitals (UDF 2T, Opragon) and in two mock-ups of an operating theatre at the relevant manufacturers of the systems (Avidicare [Opragon] in Sweden; Halton in Finland). Thermal comfort measurements were derived according to ISO 7730 [4] (Predicted Mean Vote [PMV]/ Predicted Percentage of Dissatisfied [PPD]). Additionally, non-uniform thermal comfort conditions (draught, vertical temperature gradients, floor temperature and radiant asymmetry) have been determined. Where possible, the measurements have been carried out for three different use situations:

1. No subjects in the room,
2. Under static conditions (i.e. real persons in fixed positions, or represented as heat sources),
3. Under dynamic conditions (i.e. real persons moving around as if a real surgery is performed).

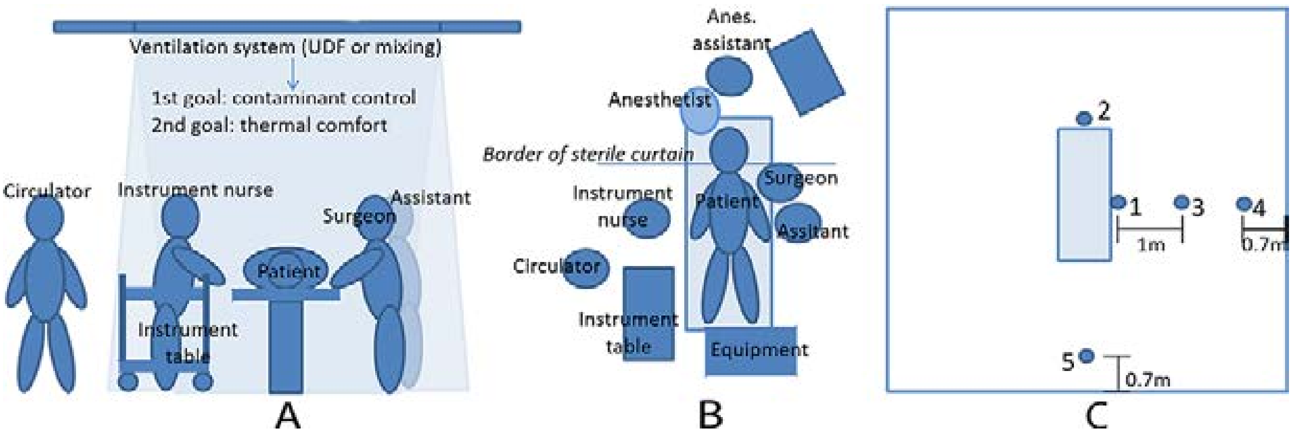

Figure 1. View and plan of a typical operating theatre with a downflow-based ventilation system [1A, 1B]. Figure 1C gives an impression of the typical positions of the surgical team members (1=surgeon/assistant, 2=anesthetist, 3=instrument nurse, 4/5=circulator), where positions 1-3 are often positioned in the direct influence of the downflow system.

Figure 2. UDF (2T) [left] – Opragon [middle] – Halton [right].

Reproducibility of the measurements has been tested by performing similar measurements for equal boundary conditions. The results show that ΔPMV ≤ 0.1 and the draught rate and vertical temperature gradient were within the accuracy level of the applied sensor.

In addition to the objective measurements, subjective analysis has been performed through online surveys on thermal comfort perception of surgical staff members during surgeries. General thermal comfort was examined, but also non-uniform thermal conditions such as draught. For these surveys use has been made of literature [2][5]. This subjective analysis was performed parallel to the experimental research.

For the subjective part of the research, 42 Dutch hospitals (out of 81) were approached to participate in the study. In total, 12 hospitals eventually cooperated and survey results of 341 participants (surgical staff members) were collected. All members of an operating team were represented in the response, while UDF (one-temperature [1T]/2T plenums in particular) was present as a system. For the statistical analysis of the data SPSS Statistics 25 has been used. Significance is assumed at $p < 0.05$. Further details of the research can be found in [6].

Results

Subjective data - An example of the subjective results of the survey is shown in **Figure 3**. There is a difference in perception of the thermal conditions between the members of the surgical team. One can derive that, on average, the staff members are feeling cold, with the anesthesiology assistant being significantly colder than the other members.

In case of non-uniform thermal comfort, the differences are less pronounced (**Figure 4**). In general, hands and arms are often perceived as cold as a result of draught. The surgeon generally has fewer complaints. The anesthesiology assistant has significantly more complaints in comparison to the other members of the surgical team.

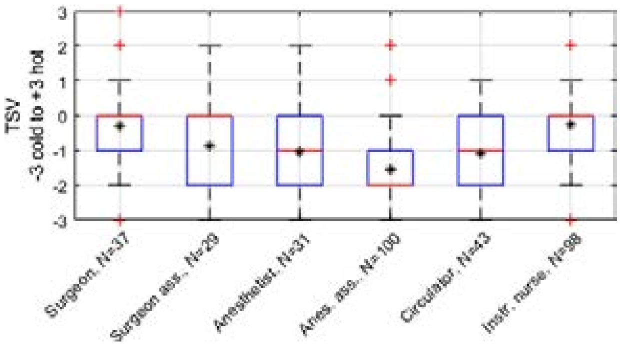

Figure 3. Survey results – uniform thermal comfort. The TSV (Thermal Sensation Vote) is an index on the 7-point thermal sensation scale ranging from -3 (cold) to +3 (hot) with 0 as neutral.

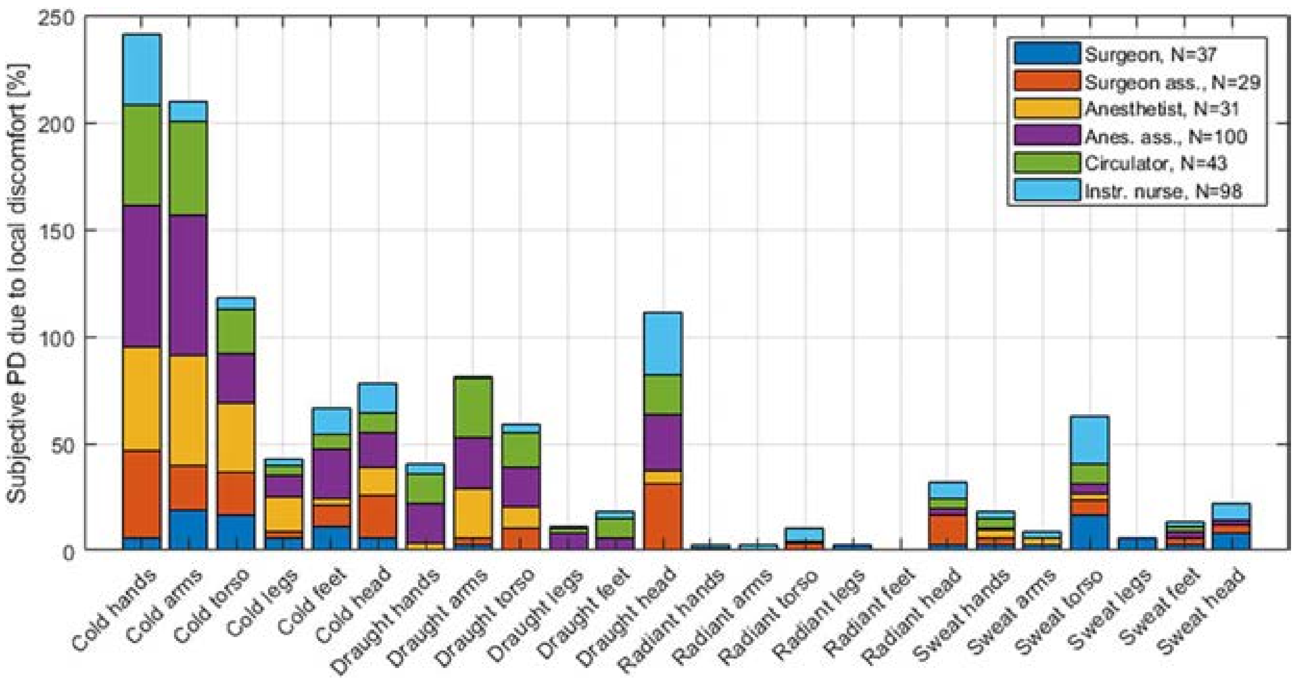

Figure 4. Survey results – non-uniform thermal comfort. The surgical staff members are subdivided per function and were able to give multiple answers regarding local discomfort. Therefore, the total percentage of dissatisfied people can exceed 100%.

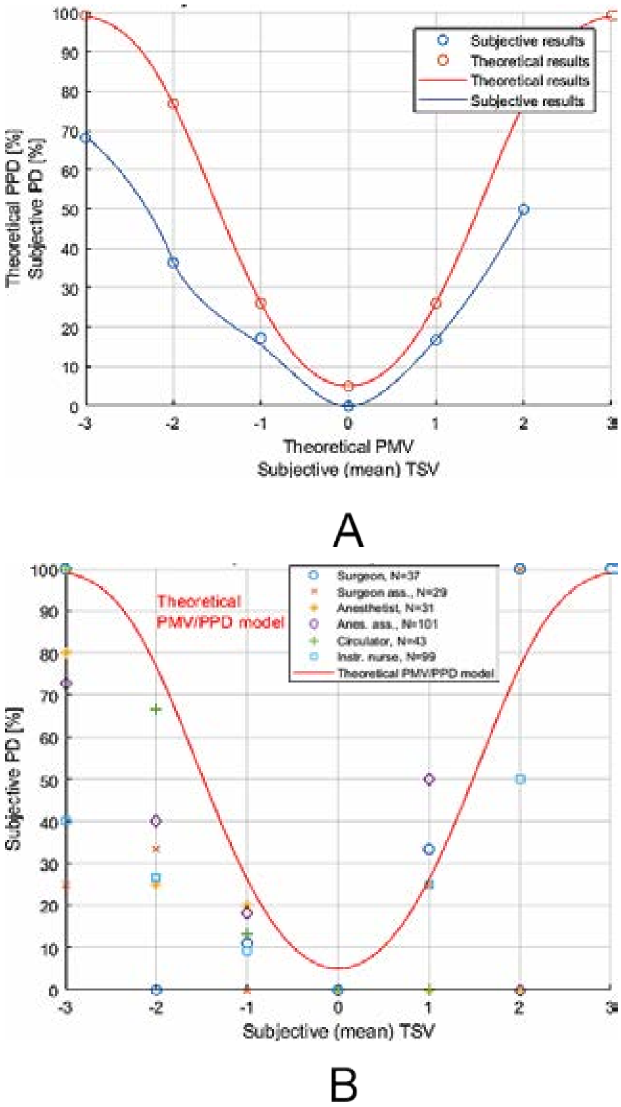

Figure 5. Subjective perception versus the percentage of dissatisfied persons [PD] and a comparison with the theory (A: all members of the surgical team together; B: subdivided by function) [3].

The effect of the type of ventilation system on the assessment of the general thermal sensation and acceptance does not show any significant differences. Every type of ventilation system seems to have its own specific complaints with respect to local discomfort. But these differences are not significant based on the available data. In the survey three different type of ventilation systems were compared: 1T plenum (*N*=72), 2T plenum (*N*=165) and Opragon (*N*=24).

Comparing the subjective data with theory, an assessment can be made of the extent to which the existing ISO7730 standard is applicable to the operating theatre (**Figure 5**). It is assumed that the outcome for the TAV (Thermal Acceptance Vote) is representative for the degree of dissatisfaction (PD: Percentage of Dissatisfied people).

The results show that in case of the operating theatre the theory underestimates the number of satisfied people. The subjective results do show the same trend as the theoretical model. The individual results per team member show that there are clear differences in thermal perception (**Figure 5B**). Preferences are both on the cool and on the warm side. This clearly shows the complexity of the problem in the design of such systems.

Objective data – The comparison of the objective data (measurements) for the different systems (at an average set point temperature of 20°C) shows that the PMV (Predicted Mean Vote) ends up on the cold side (≈−1) of the thermal sensation scale. The systems that are studied show little differences. The variation is also comparable for each position where measurements took place (see **Figure 1C**). The anesthesiology assistant (position 2 and 4) has the worst thermal sensation (lowest PMV value). For the instrument

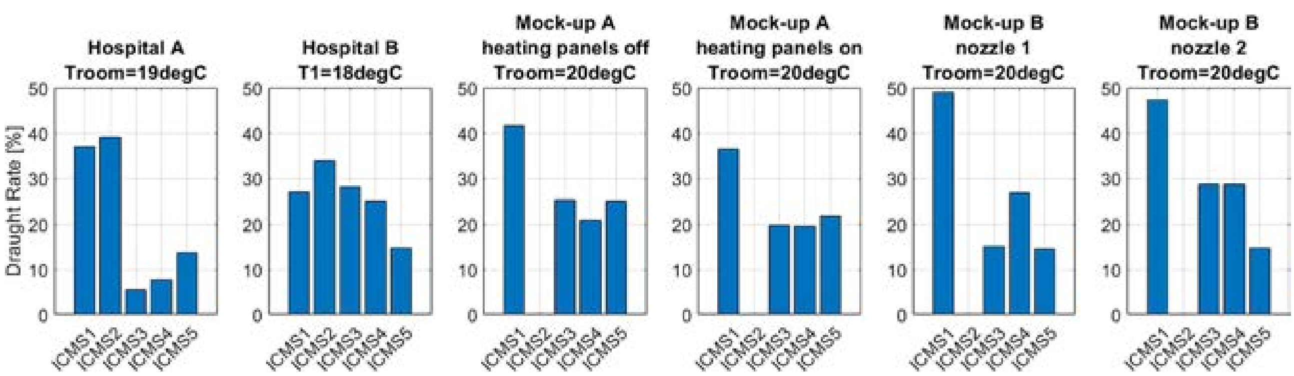

Figure 6. Theoretical percentage of draft complaints (PD) based on objective measurements for the different positions in an operating theatre (see Figure 3) with different types of systems and conditions (For Opragon and Halton it was not possible to measure at position 2 [ICMS2] due to a non-functioning sensor).

nurse (position 3) the situation is somewhat better based on the PMV value. With regard to local discomfort, especially draught is a problem (see **Figure 6**). The positions under the ventilation system are most critical, although at Hospital B the differences with the other positions are not significant. The vertical temperature gradient and floor temperature pose little or no problems.

Comparing the measurements results for the draught rate (DR) with the subjective (survey) data, it is noticed that the surgeon has few draught complaints (position ICMS1), while the measured data indicates otherwise. Referring to the survey results, the Opragon system also shows more draught complaints compared to the other systems (DROpragon = 46% compared to DRUDF_T1 = 36% and DRUDF_T2 = 34%). This is not reflected in the measurement results (DROpragon = 25% compared to DRUDF_T2 = 24%).

Discussion

The results provide interesting insights into the current situation in operating theatres in the Netherlands with regard to thermal comfort of the surgical team. These results show that improvement is possible and desirable for better thermal conditions. Although no statement can be made about the effect on work performance, it may be suspected that in line with what is known about the office environment [7], this performance is affected by thermal comfort. In this case, work performance must be translated in the quality of the execution of the surgery. This could be one of the reasons why, in theory, more efficient systems (based on air quality) perform less than expected [8].

The results of the survey indicate that there are fewer complaints than theory suggests based on the average thermal sensation (PMV). This is not in line with the hypothesis that people would be more critical since the adaption possibilities in an operating theatre are limited. It may be assumed that the focus on the patient makes the own thermal comfort a bit more subordinate. If that is the case, it is questionable whether that is a good choice. However, the PMV model has been developed especially for an office environment [4]. At individual level (member of the surgical team) the agreements are better. This is in line with the results from Van Gaever et al. [2].

Draught perception is experienced differently in an operating theatre than theory indicates. The measurements show high percentages of draught complaints, especially underneath the plenum. The subjective data show, however, that the surgeon has almost no draught complaints. Contrary, other members clearly show more draught complaints than the measurements (and therefore theory) suggest. The different systems show some differences in the evaluation of draught, but generally reveal the same pattern with higher values underneath the plenum.

The limitations in the research must also be mentioned. Clothing and metabolism have an important effect on the PMV values. No specific data were available for surgical staff and, on top of that, the survey showed that there were clear differences in clothing levels between the different hospitals. Additionally, a standard operating theatre with a standard setup has been assumed during the research. In combination with information from literature, clothing insulation (I_{cl}) and metabolism (M) have been set for the different members of the surgical staff (I_{cl} = 0.5 – 0.69 clo; M = 1.5 – 1.6 W/m²). This may not be applicable for specific surgeries. Furthermore, it is assumed that some survey questions were not interpreted correctly in a few cases. If misinterpretation was assumed based on the response to the other questions, the results were excluded from the analysis.

The measurements could not be performed simultaneously with an actual surgery due to hygienic reasons. The location of heat sources and settings of the operating theatre were somewhat limited by the applicable rules. Besides, it was not feasible in this study due to limitations of the reserved research time, to perform measurements for all three use situations in all variants. For those cases where this was possible, measurement situation 2 (static) and situation 3 (dynamic) led to similar conclusions in terms of thermal comfort.

Conclusion

This research shows that the thermal comfort in operating theatres for the members of a surgical team is perceived as not optimal. The distinction in perceived satisfaction for the different members is also evident. Application of the theoretical PMV and DR models needs further attention when applied for operating theatres. Future research may focus on this issue.

The direct effect of thermal (dis)comfort on the outcomes of a surgery is unknown since specific information for the operating theatre is missing. However, it seems appropriate to give this aspect a more prominent role in the development of ventilation systems for operating theatres than has been the case until now. Disconnecting the air quality issue about the thermal issue seems to be an interesting option in order to find an optimal combination about both aspects [9].

Possible improvements can also be found in clothing adjustments. It is expected that the possibility of covering arms, hands and neck against cold and draught will contribute positively to the thermal sensation of the individual staff members. In all cases, the most important goal remains the health and safety of the patient. In an operating theatre, there is little discussion about this. ■

Acknowledgement

This investigation would not have been possible without the hospitals and the operating staff who cooperated in this investigation. This also applies to Avidicare, Optimus and Halton, who made their facilities available for carrying out measurements. Finally, a word of thanks to the BPS laboratory of the TU/e, and especially Wout van Bommel, for preparing the measurements and the associated measuring equipment.

The whole report can be found here: https://pure.tue.nl/ws/portalfiles/portal/108242086/Jacobs_0815645.pdf

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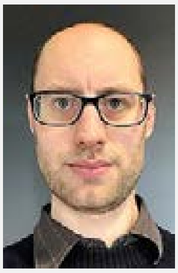
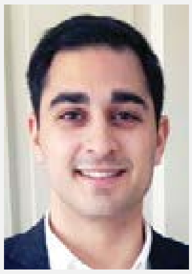
Key Modules and Optimization Approach for hybrid GEOTABS Buildings:

Background and state-of-the-art





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hybrid GEOTABS is an EU H2020 funded research project focusing on the design, development and optimization of the innovative concept combining thermally active building systems (TABS), geothermal, heat pump and model predictive control (MPC). As the first article of a serial of project disseminations, this paper introduces the working principle of hybrid GEOTABS, as well as their main components/modules. The optimization approach of key modules in common practice is also discussed. This article aims at providing a basic knowledge of the concept as a preparation for the up-coming optimization development and integration of the involved key modules.

Keywords: hybridGEOTABS; geothermal heat pump; TABS; radiant heating and cooling

Introduction of hybrid MPC GEOTABS and its key modules

GEOTABS buildings combine an energy efficient heating and cooling system (Thermally Active Building Systems, TABS) with renewable resource (ground, GEO) to heat and cool buildings in a sustainable way. The performance of GEOTABS buildings has been studied thoroughly in an earlier EU project, GEOTABS - Towards Optimal Design and Control of Geothermal Heat Pumps Combined with Thermally Activated Building Systems in Offices [1].

A more recent EU project (HORIZON 2020-10 project EE-04-2016, Model Predictive Control and Innovative System Integration of GEOTABS in Hybrid Low Grade Thermal Energy Systems - hybrid GEOTABS [2]) is taking the analysis that were carried out within the GEOTABS project further. A previous publication has already summarized the project scope, tasks, and goals [3].

Within the scope of this project, hybrid GEOTABS buildings are studied in detail in terms of optimal system design and dimensioning methodology, control, and in other terms, including but not limited to, energy performance, indoor environmental quality (IEQ), costs, environmental impacts, and so forth. Model Predictive Control (MPC) algorithms are being developed and the developed algorithms will be implemented in chosen demonstration buildings. The three demonstration buildings are an office building in Luxembourg, an elderly care home in Belgium, and an elementary school in Czech Republic. All these buildings are equipped with hybrid GEOTABS systems. In addition to these three demonstration buildings, there are also two case study buildings: a residential building and another office building.

In addition to the GEOTABS, the hybridGEOTABS buildings can have "hybrid" heat emission/removal systems and also "hybrid" energy sources. This enables having other room conditioning systems in addition to TABS, and gives the possibility of benefiting from other heat sources and sinks than the ground. MPC ensures the optimal operation of the systems in such buildings.

Previous studies have identified the system concept, individual modules, and the interfaces between system components of hybrid GEOTABS buildings [4], the MPC concept with a focus on hybridgeotabs buildings [5], together with the detailed measurements of thermal indoor environment in the chosen demonstration buildings [6].

As the first article of this serial, this study focuses on introducing the TABS, heat pumps (ground source) and the ground heat exchangers, and their optimization process for the application in hybridGEOTABS buildings.

Hydronic radiant heating and cooling systems

General description

A hydronic (water-based) radiant heating and cooling system refers to a system where water is the heat carrier and more than half of the heat exchange with the conditioned space is by radiation (heat emission to or removal from the space is by a combination of radiation and convection). There are three types of radiant heating and cooling systems [7]:

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hybridGEOTABS

– Model Predictive Control and Innovative System Integration of GEOTABS in Hybrid Low Grade Thermal Energy Systems

hybridGEOTABS is a four-year project started in 2016 by an active team of SMEs, manufacturers and research institutes. The project, led by the University of Gent, is a Research and Innovation Action funded under the EU's Horizon 2020 programme.

The goal of hybridGEOTABS is to optimise the predesign and operation of a hybrid combination of geo-thermal heat-pumps (GEO-HP) and thermally activate building systems (TABS), alongside secondary heating & cooling systems, including automated Model Predictive Control (MPC) solutions.

To know more about the project visit www.hybridgeotabs.eu and contact hybridgeotabs@ugent.be

hybridGEOTABS project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 723649.

- Radiant heating and cooling panels;
- Pipes isolated from the main building structure (radiant surface systems);
- Pipes embedded in the main building structure (Thermally Active Building Systems, TABS)

Hydronic radiant heating and cooling systems are low temperature heating and high temperature cooling systems. Therefore, the heat carrier (water) circulating in the pipes has low temperatures in heating and high temperatures in cooling operation. In some TABS constructions (hollow core concrete decks), also air has been used as a heat carrier, and electricity can also be used in some radiant heating applications [8].

Floor, wall and ceilings can be used as surfaces that provide heating or cooling to the space. Hydronic radiant surface systems can address only sensible heating and cooling loads. Therefore, they require a ventilation system to address the latent loads and to provide the ventilation rates required for indoor air quality concerns [7]

Radiant heating and cooling systems enable lower airflow rates than all-air systems, in which the entire heating and cooling loads are addressed by the ventilation system [9].

TABS and its optimization approach

TABS has emerged as an innovative solution to improve building energy performance and indoor climate. As introduced, TABS combine cooling and heating system in the structural concrete slabs/walls of a multi-storey building, which can operate hydraulic temperature close to ambient temperature from 22–29°C for heating and 16–22°C for cooling [10]

TABS are primary used for sensible cooling and secondarily for base heating. The whole system works with radiant heating and cooling, which is not any air-conditioning or radiators, and does not commonly substitute any ventilation system. Furthermore, TABS stores heat via building structures themselves and can commonly provide upgraded global thermal comfort than conventional convective heating/cooling methods [10]

Due to the reduced draught, noise levels and improved mean radiant temperature through less fluctuated surface temperature, local thermal comfort is commonly high in TABS buildings. All the above advantages have promoted TABS as a competitive heating/cooling emission system in the current EU building markets. TABS-served low-temperature heating (LTH) and high-temperature cooling (HTC) provide wide opportunities for the integrations and applications of renewable energy, such as geothermal energy or ground-source heat pumps (hereafter refer as GEOTABS) [11]

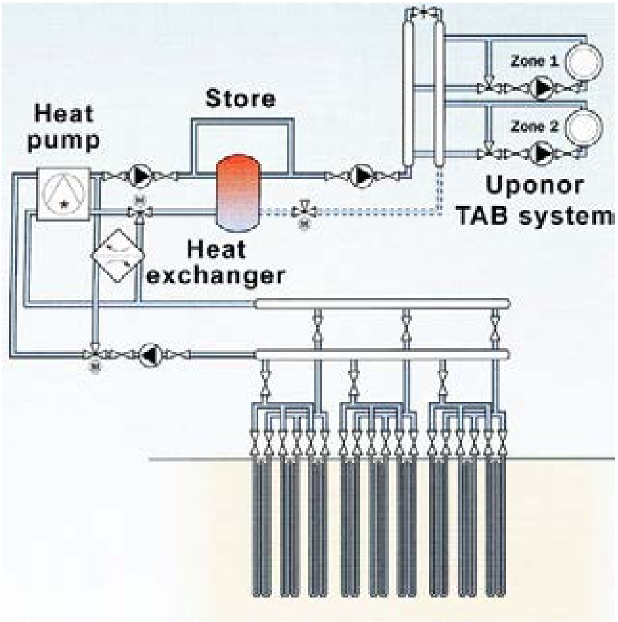


Figure 1. GEOTABS system. [7]

Figure 1 shows a typical GEOTABS system that serves heating and cooling in a building with multi-zones.

TABS as a mature product has been available on the market. The optimization approach of TABS mostly lies in the configuration design of TABS to maximize its outputs based on various construction conditions of the slab/ceiling. In principle, ceiling configurations without insulation or air gap are ideal for maximizing the output of TABS. Five typical optimal methods, used based on ceiling design, have been suggested in **Table 1** [7] [10]

Heat pump and secondary system module and its optimization

The heat pumps are a major component in the hybridGEOTABS concept. The geothermal heat pump serves the upgrade from low temperature geothermal energy to high(er) temperature TABS heating energy. Traditionally geothermal heat pumps are tested following existing standard (EN 14511, EN 14825) for low temperature (35°C) and medium temperature application (55°C). As TABS uses lower supply temperatures than 35°C, (typically 22–29°C, as introduced), it is more interesting to investigate the performance at even lower supply temperatures.

This will be done by a lab test where three parameters will be changed:

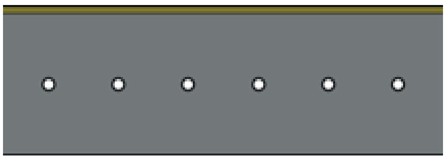
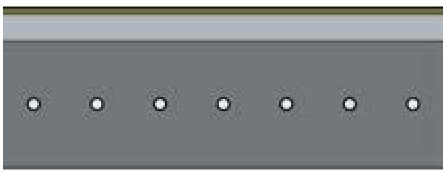
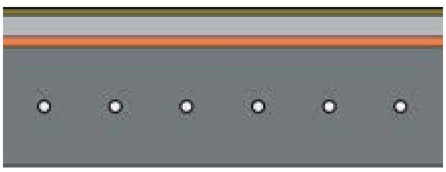
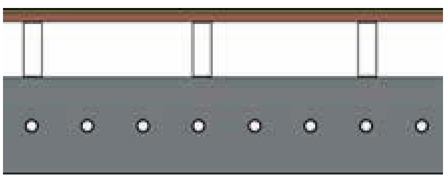
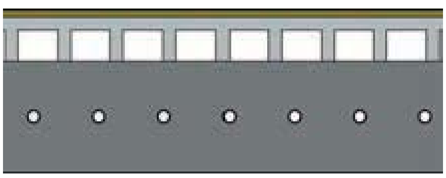
- lowering supply temperature from 35°C to 25°C
- varying the temperature difference at evaporator side
- varying the temperature difference at condenser side.

Last two variables will give information concerning the trade-off between heat pump efficiency (COP-value) and circulation pump energy consumption. Furthermore, the varying primary temperature difference will influence the geothermal bore field performance.

Not only is the performance of the heat pump refrigerant cycle important to improve, but also other parameters of geothermal heat pump system do have an important role in the general system performance (e.g. next generation refrigerants, next advanced circulation pumps, the control of the heat pump). Those parameters will be evaluated together with important market players.

In this hybridGEOTABS project, the geothermal heat pumps deliver the base load in heating and cooling mode. Additional heating and cooling energy are generated by a secondary heating/cooling system. The hydraulic interaction between the base load of the heat pump and the peak load of the bivalent system is very important and will have a big impact on system performance. For all demo buildings in the project, an energy concept is available. In all cases low temperature TABS heating and high temperature top heating were separated from each other. Often fossil boilers were used as the peak load system. Those boilers are less sensible for varying temperatures, temperature differences. Via the hydraulic design, the risk of overruling the heat pump working should be avoided.

Table 1. *TABS based on basic ceiling configurations.*

Slab type	Structure	Optimal application of TABS
Concrete slab with or without bonded screed	 	Concrete slabs with only a thin floor covering or bonded screed deliver heating and cooling into the room
Concrete slab with sound insulation		Sound insulation reduces output via the floor. This design option is acceptable in applications where mainly the effect of cool ceilings is utilized.
Concrete slab with raised floor		For a raised floor, the same considerations apply as for a floor with sound insulation. This type of ceiling construction is popular because power supply and cables can be installed in the void.
Concrete slab with hollow floor		Another variant that is frequently used in office buildings is the hollow floor construction. In terms of performance, it behaves similarly to the false floor. However, because screed (instead of floor panels) is used, inspection openings must be used for the underfloor installations.

Next to hydraulic interaction between base load and peak load, the control between both generators is important. Based on different optimization criteria (e.g., functional cost, energy savings, CO_2-reduction, bore field utilization) both generators will be controlled in a different way.

Available heat pumps in the market have basic input possibilities to communicate with existing Rule Based Controllers (RBC, going from potential free liberation/blocking contact towards 0-10V temperature control). Future Model Predictive Controllers (MPC) may need other data points to write to the future heat pump controller. Additionally, more reading signals can be interesting for future MPC controllers. The wish list of possible reading and writing parameters will get a reality check for current available heat pump and back-up system controllers. Possibilities to develop/extend current controllers will be investigated throughout the project.

Geothermal and renewable supply module optimization

One of the key issues that needs to be optimized for ground heat exchangers (GHEX) is the optimization of borehole field. In order to optimally size the geothermal borehole field, the use of a GRT (Geothermal Response Test) is the most prevalent practice. It is an on-site test to determine the thermodynamic parameters of the subsoil. Its execution allows to know the effective thermal conductivity, which describes the heat transfer through conductivity in the subsoil, and the thermal resistance of the probe. It indicates what should be the thermal leap between the collector circuit and the subsoil for the dissipation of the power applied to the circuit.

In hybridGEOTABS project, improvements in this process have been achieved by executing more developed, upgraded and detailed GRTs than common practice. In a traditional GRT, only the flow and return temperatures at the top of the borehole are measured, while an Enhanced Geothermal Response Test (EGRT) enable us to obtain a temperature profile at all the levels of the borehole, measuring accurately how the temperature changes with depth as a function of the flow and the thermal stress of the borehole. It allows engineers to understand the optimal areas of the sub-soil are and even, to evaluate the influence of the different materials or groundwater in the case that these exists.

During realization of the EGRT (See **Figure 2**), the temperature of the ground has been obtained, depending on the depth during a heating controlled process. The red curve validates the typical theoretical depth-temperature unaltered profile of the earth. The

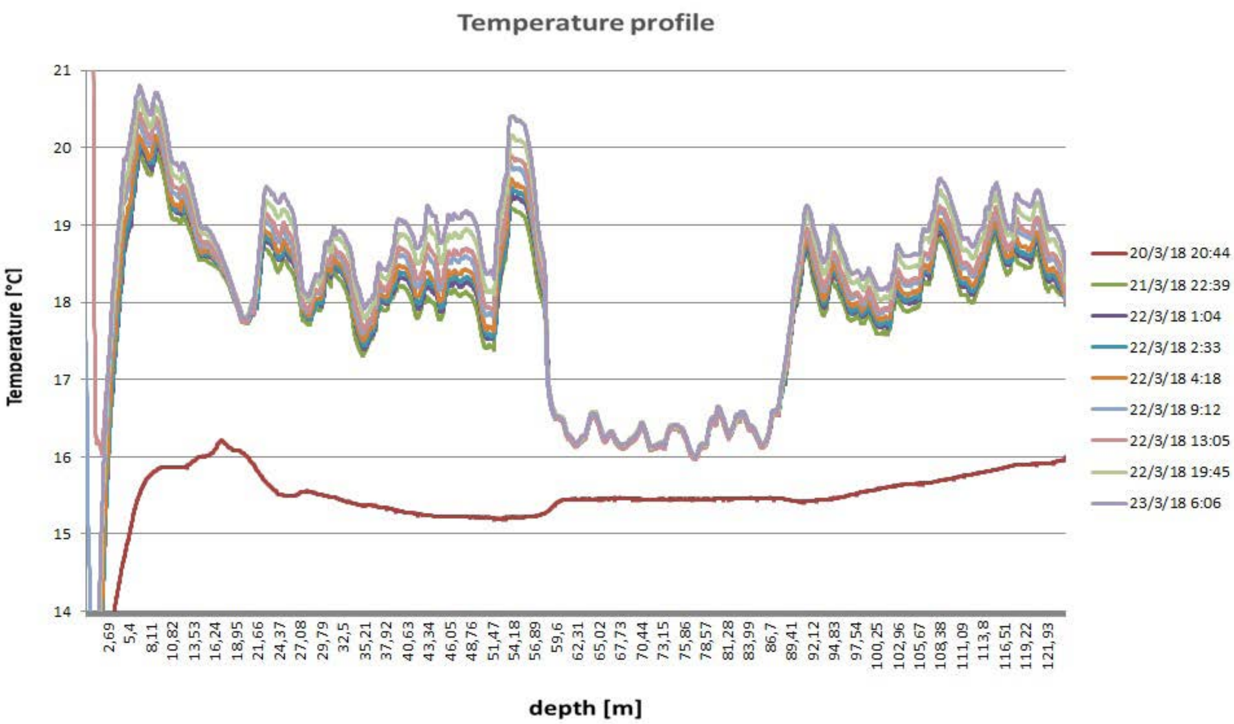


Figure 2. Temperature profile during EGRT execution.

rest colours represent temperature profile along the borehole length, which have been represented as a function of time to verify the temperature changes while a constant heat is injected. With all the information, conductivity along the borehole can be obtained and the optimal depth of the boreholes can be calculated taking into account the thermal loads of the building which we want to provide heating/cooling and DHW. Thermal conductivity differences are explained by the different hydrogeological conditions.

Subsequently, three different simulations were carried out with EED (Earth Energy Designer) software to show the importance of knowing the conductivity along the borehole. In all of them VDI 4640 Guideline has been considered [12] – [16]:

1. Simulations performed by engineering, when the conductivity is estimated based on geological and hydrogeological bibliographic studies as well as on the experience.
2. Simulations performed after performing GRT, when the average conductivity is known.
3. Simulations performed after performing an EGRT, when the conductivity is known throughout the depth.

The required heat exchanger is longer when conductivity has been obtained from engineering than when has been determined by the GRT, due to the oversizing that used to be done for the estimation of conductivity. Similarly, the required exchanger length is higher when conductivity has been obtained from GRT than when has been determined by the EGRT because it is possible to optimize the length of the boreholes. After six different EGRTs executed we can affirm that pre-engineering sizing has a reduction of 4–10% of investment performing a GRT and a reduction of 14–16% performing an EGRT. That means, an EGRT has meant a 7% investment reduction compared to the GRT.

Through an EGRT, areas of high conductivity have been found along the depth, and together with the study through EED software has allowed the optimization of the global geothermal system. Performing an EGRT is possible to analyse the complete information about the subsoil and decide the best solution considering all the project conditions, always optimizing the number of meters to drill. EGRT obtains savings in investment costs without penalizing the optimum functioning of the HVAC installation.

Conclusion

As a renewable source, geothermal is an efficient and abundant energy globally, in this content, it is more important to use this resource efficiently in corrected designed systems. The combination of TABS, heat pumps and GHEX shows to be an efficient solution that has potentials to maximize the advantages of each component. Different approaches of how each module are optimized as common practices have been introduced in this article. However, the challenges lie in the further integration and interactions of the above modules/components by means of, e.g., MPC control system. These aspects will be continuing introduced in the following up articles in the serial. ■

Acknowledgments

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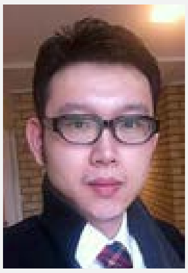
Life Cycle Cost Analysis of Air Preheating Systems using Wastewater and Geothermal Energy



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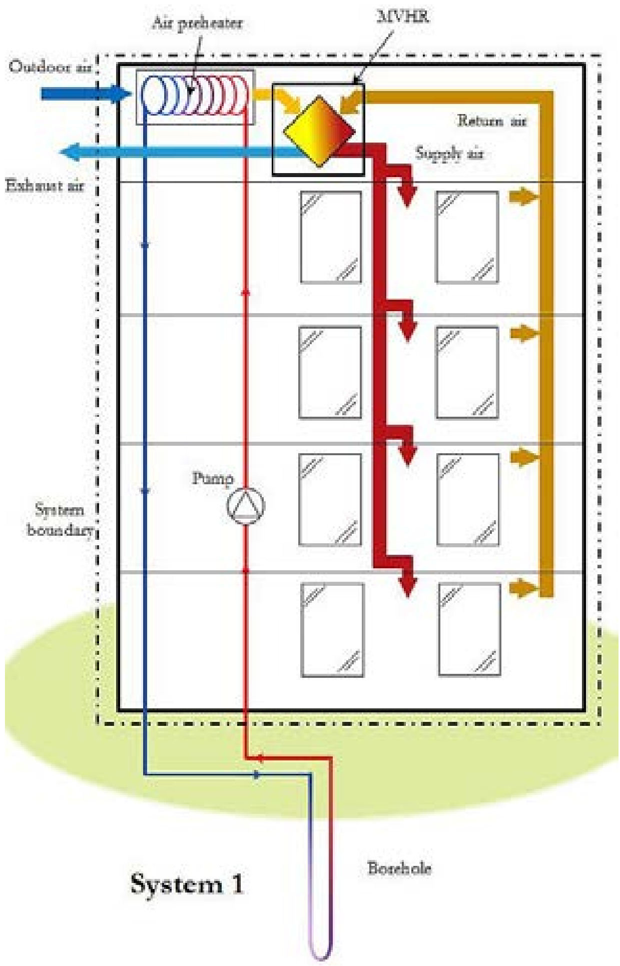
Frosting is a common problem in air handling units in buildings in cold climates. Tackling this problem is so far achieved by using considerable amount of energy while during this process, the indoor air quality is compromised. This article presents the Life Cycle Cost (LCC) assessment of a preventive solution for frosting using two renewable heat sources.

Keywords: wastewater heat recovery, geothermal heating, energy saving, balanced mechanical ventilation, Life Cycle Cost (LCC)

Heat recovery from the return air from buildings has long been carried out in Sweden [1]. Thanks to developments in building insulating materials, the heat losses from building façade have dropped significantly. Therefore, the share of wastewater heat losses has been doubled in modern low-energy buildings compared to the constructions erected between 1940s and 1990s [2]. The present research work explored the potential of residential wastewater as a renewable heat source to improve the performance of mechanical ventilation with heat recovery (MVHR) systems in Sweden. The performance of the suggested wastewater heat recovery system was compared with a passive geothermal system which is already installed and utilized for the same purpose. The air preheating systems were technically assessed and compared in details in previous publications by the authors [3]–[5]. The current study is based on the system presented in [5] which showed that the air preheating systems could reduce the frosting time to 25%. This would maintain the heat recovery efficiency of the MVHR system above 80% for almost 90% of the studied period. The wastewater/brine circulation pumps needed 2%-8% of the recovered heat energy from wastewater or borehole for own operation.



Yet, there is still a lack of knowledge about the financial side for the suggested solutions. To raise awareness for this heat recovery System and establish it in the market, potential customers also need to be familiar with the costs over the complete life-cycle.

Methodology

The simulated building is a multi-family house located in central Sweden and holds a total heated floor area of 876 m² [6]. The base (reference) ventilation system was a common MVHR system. Three outdoor air preheating systems combined with the existing MVHR were compared to the reference system. System 1 used the geothermal energy as the heating source. A vertical U-tube heat collector was inserted in a 250m deep borehole to absorb the heat from the soil. The collected heat was then used to preheat the incoming outdoor air in a heat exchanger placed in front of the MVHR. The other two systems used wastewater as a heat source. System 2 was equipped with a stratified storage tank to utilize a benefit of temperature stratification. System 3 was equipped with an unstratified tank. The studied systems are shown in **Figure 1**. The systems with air preheaters were compared to the reference MVHR system.

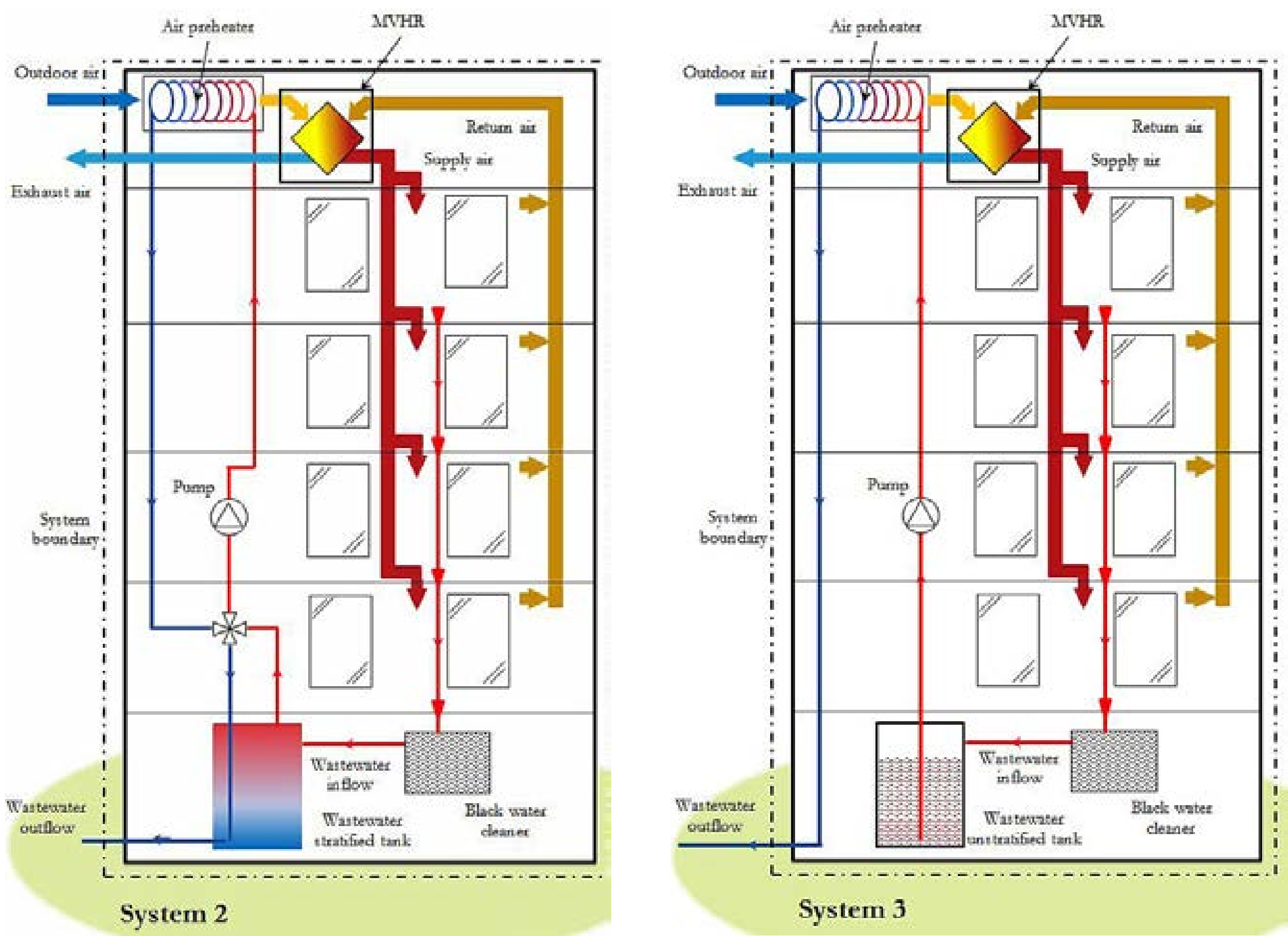


Figure 1. Schematic flow charts of the studied systems, air preheater served by (from left to right) a) borehole (System 1), b) wastewater from the stratified tank (System 2), c) wastewater from the unstratified tank (System 3). [5]

In order to evaluate the cost effectiveness of the studied systems, a Life Cycle Cost Analysis (LCCA) was carried out. The cost factors considered in the financial model are illustrated in **Figure 2**.

Initial investment costs were based on local market prices in Sweden for year 2017. Based on the prices found, maintenance and repair costs were approximated as a percentage share of the initial investment cost. The average for this share was set at 2.4%. Expenditures for the replacement of components were added the year in which its official service life ended. The cost for electricity was predicated on the current market prices, and its development over the following years was estimated with an annual increase of 3%. Total energy usage was calculated using simulation software TRNSYS®. The Net Present Value (NPV) method was applied to compare the systems based on their value at present time. Future costs were therefore discounted with an interest rate of 2.4%, and the total lifespan of 20 years was considered for the suggested heat recovery systems.

The systems exclusively covered ventilation heating demand to reach thermal comfort. This was provided by maintaining a room temperature at 18°C. Since space heating was predominantly active in the cold months, the evaluation period was set from December to March when frosting inside the MVHR system was expected.

Results and Discussion

Figure 3 displays how the cost for each system accumulates over the evaluated lifespan. The base system has the lowest initial cost while its operational cost over 20 years was above the other systems. The operating cost of the reference system increased within three years by 90 000 SEK (≈ 8 800 €) on average, and after a period of 20 years, it had the second highest NPV.

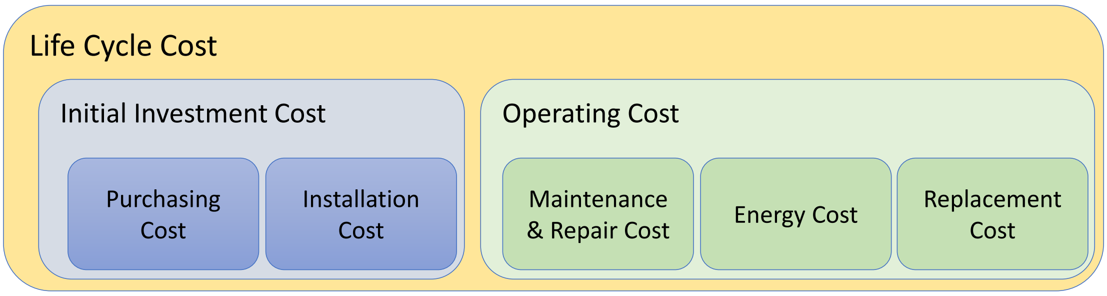


Figure 2. Overview on cost factors considered in the LCCA.

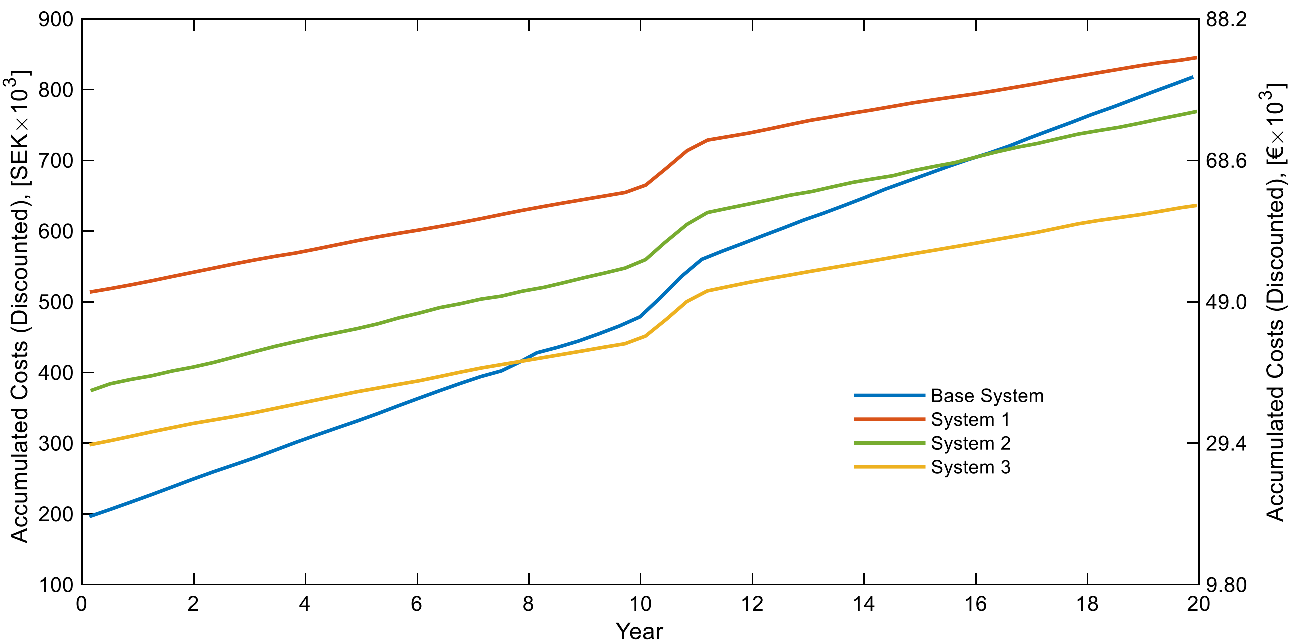


Figure 3. Accumulated cost and the discounted payback period of the studied systems.

System 3 has the shortest payback period, which is about 7.5 years. System 2 pays off the initial investment cost for the outdoor air preheating system 9 years after System 3. This is mainly due to the higher cost for the stratified tank. At the end of the 20-year period, System 3 manages to save about 180 000 SEK (≈ 17 600 €) while the corresponding saving is around 50 000 SEK (≈ 4 900 €) for System 2. System 1 has a steady increase in costs like Systems 2 and 3 with about 40 000 SEK (≈ 3 900 €) every three years on average. Current market prices for borehole drilling are still high. Within the 20-year period, it is not breaking-even with the base system, even though the cost gap at the end of the period closes to about 25 000 SEK (≈ 2 400 €).

Figure 4 demonstrates the total NPV as well as the costs split-up into initial and operating costs at the end of year 20. The graph visualizes the relation between these two costs compared to each other. For the base case, the operating costs exceed the initial costs by around 300%. In other words, most of the costs do not occur in the purchase stage but in the later years during the operation. For System 1, the initial cost dominates over the operational cost with a ratio of about 1.4:1. For the two air preheating systems fed by wastewater, the two costs are roughly equally balanced. Compared to the base (reference) system, the operational costs for other systems were 35% – 45% lower.

Figure 5 depicts the total energy cost of the four systems. The costs in the graph are discounted to NPV. While the costs for the three systems using outdoor air, preheating are on a similar level, the energy cost for the reference system, without an air preheater, is more than three times higher. Therefore, the energy cost can be identified as the critical factor for cost cuts. It is hereby confirmed what was found in the previous studies. Beside the technical potential, frost-avoidance also has a great potential for reducing operational costs of MVHR-units in cold climates. Energy cost can be cut significantly with the suggested systems and eventually compensate for the higher initial investment cost.

Conclusion

In this case study, a multi-family house in central Sweden equipped with a MVHR system and an outdoor air preheating system was considered. Four alternatives were investigated from a financial perspective using the LCCA-method. The system with the lowest life-cycle costs was System 3, see **Figure 1**. According to the results, it saved on average about 180 000 SEK (≈ 17 600 €) after 20 years compared to the MVHR alone (reference system).

The avoidance of frost has proved itself as a significant factor for cutting energy cost. Outdoor air preheating is a practical solution to prevent frost formation inside the MVHR-unit and maintaining a high heat recovery efficiency from the ventilated air during the coldest periods

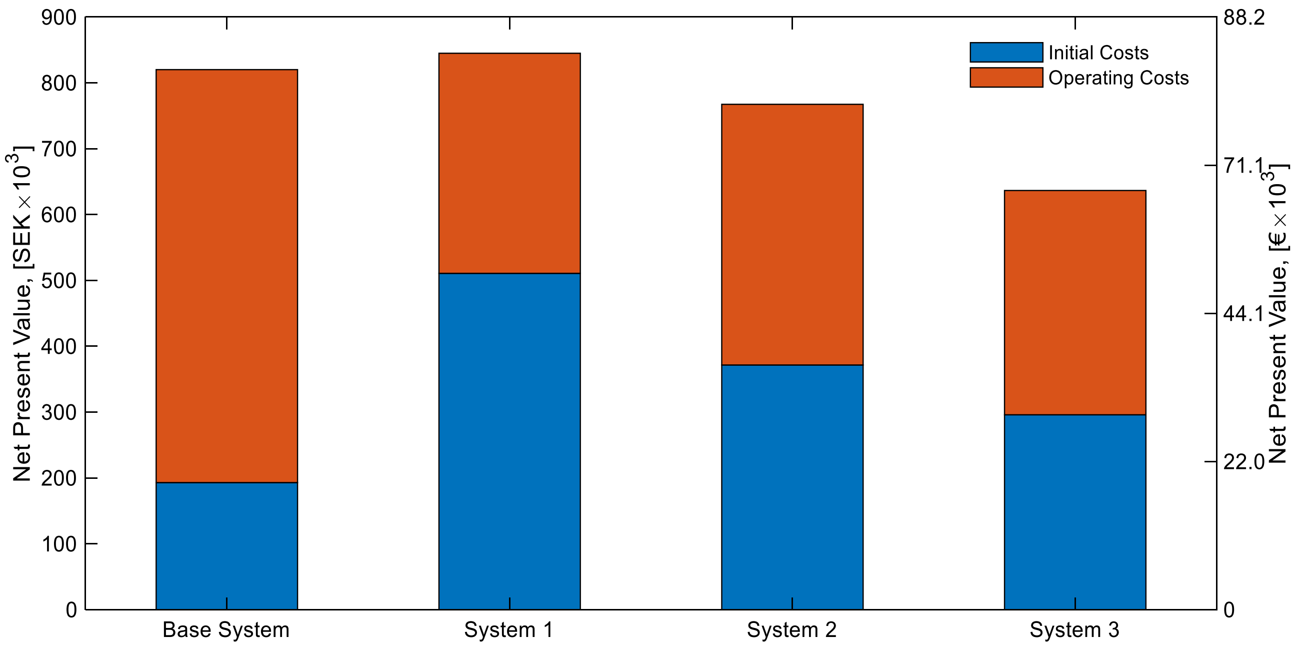


Figure 4. Total NPV of all studied systems.

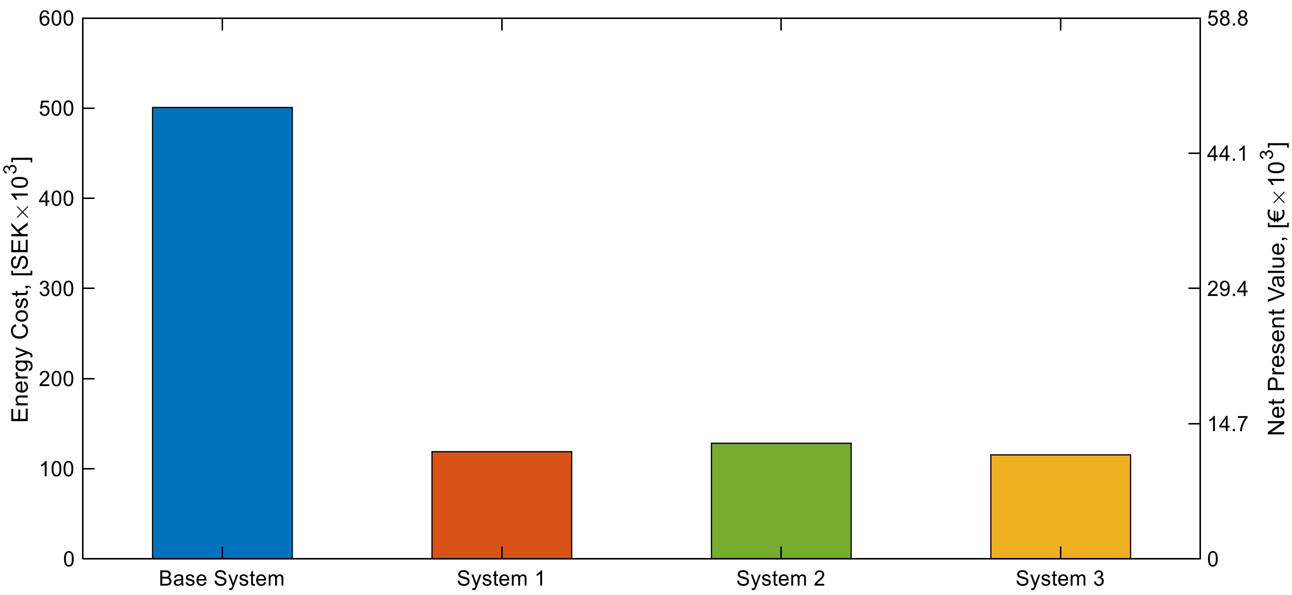


Figure 5. Energy cost per system (discounted).

of the year. While the wastewater system can already generate savings with the state-of-the-art technology, there is still need for improvement in the exploitation of geothermal energy.

Since the operational costs were saved by reducing defrosting time, the suggested outdoor air-preheating systems have even a bigger economic advantage in colder climates where defrosting need is higher. ■

Acknowledgments

This work is financially supported by SBUF (Development Fund of Swedish Construction Industry) and the Swedish Energy Agency. Contributions from SBUF, the Swedish Energy Agency, Bravida Holding AB and Uponor AB, Valvet Förvaltning AB, AB Stockholmshem, WSP Sverige AB and Telge Bostäder in providing valuable information and practical support are acknowledged. The authors would also gratefully appreciate the support from Professor Sture Holmberg from the Division of Fluid and Climate Technology at the KTH Royal Institute of Technology.

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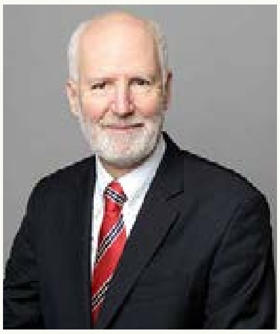
With this special issue of the RHEVA journal, we welcome the opportunity to present our Third-Party performance certification expertise and know-how.



ERICK MELQUIOND
President
Eurovent Certita Certification

Consultants, buyers and contractors benefit from a fair and competitive market, supporting the dimensioning of energy efficient projects

Commercial buildings consume 40% of all electrical energy; with the introduction of the Energy Performance Building Directive (EPBD) in Europe, reducing energy consumption is one of the challenges consultants and contractors have to face. Dimensioning projects that assess the energy consumption of buildings and highlight its true cost quickly illustrate the power and value of certified data.

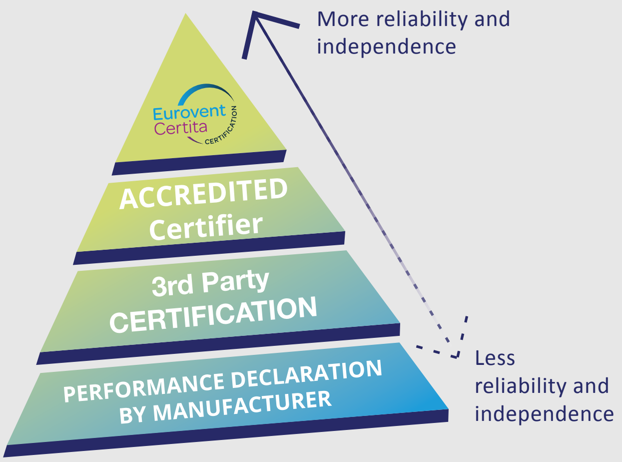
The mission of Eurovent Certita Certification is to create common set of criteria for rating products, that apply to all manufacturers, thus increasing the integrity and accuracy of data while ensuring the needed level of transparency to guarantee a fair and competitive comparison. With over 95,000 models certified, our database provides professionals with all the information needed to dimension equipment and match the technical constraints of the specifications with the financial target of the project.

Third-Party certification enables compliance monitoring to achieve environmental goals

Performance data certified by Eurovent Certita Certification is instrumental for State authorities to enable compliance monitoring. It provides valuable data to document and track market information. Eurovent Certita Certification is an accredited certification body, trusted to deliver a consistently reliable and impartial service which meets the appropriate, internationally recognised standards.

Third-party certification offers more than product testing

Integrity, Independence and Impartiality



- We operate with the commissions responsible for the harmonisation and the integrity of our certification programmes, including authorities, end-user groups, scientific and technical bodies, and manufacturer associations.
- All 30 laboratories and testing agencies that are a part of the Eurovent Certita Certification process are regularly assessed according to ISO 17025. They are located in 11 countries worldwide.
- Our testing protocols include independent tests, manufacturing audits, selection software checks, product sampling, product purchasing, cross data coherence algorithms per product family, and product dismantling after testing.

Product performance certification delivered by Eurovent Certita Certification plays a key role to ensure transparency and deliver high quality and reliable data

Certified data can be used in many instances: tax incentives, national implementation of EPBD, building energy labels, green public procurements, white certificates. As certified performances provides confidence in the quality and the compliance of the products they can be required in voluntary schemes (e. g. building energy labels, green public procurements, white certificates) or being considered with an advantage over non certified products in regulatory schemes (e.g. national implementation of EPBD).

Example of such use can be found in the French Building energy efficiency calculation method which applies a penalty for non-certified heat-pumps and air to air heat exchangers. Consultancies use approved software in order to assess the compliance of a building with the French EPB regulation (RT 2012). These softwares are linked to database of products which are fed directly with Eurovent certified performance data.

2019: a new website and a fresh look with our online directory for a fair comparison of certified product performances

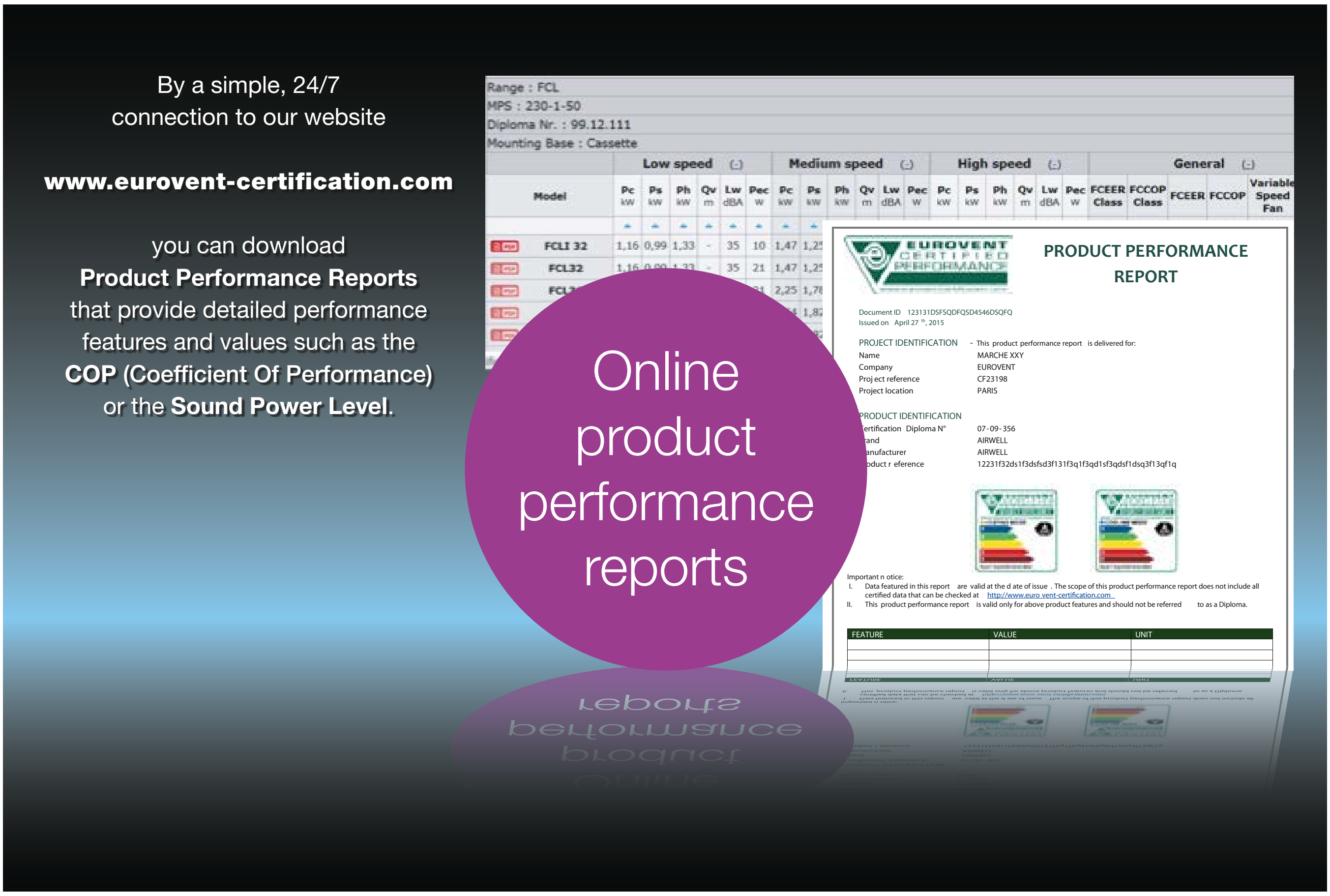
With more than 300 certified trademarks, and 50 000 references, all certified references and performances are listed in our online directory freely available www.eurovent-certification.com. For each product category, characteristics and certified performances are listed according to the same data structure and the latest European and international standards.

Coming soon... New certification programmes

Condensing units

In 2018 we successfully launched our certification programme for condensing units designed for commercial and industrial refrigeration applications. The scope is intended to include air-cooled condensing units as defined in regulation 2015/1095:

- integrating at least one electrically driven compressor
- integrating at least one condenser,
  capable of cooling down and continuously maintaining low or medium temperature inside a refrigerated appliance or system, using a vapour



compression cycle once connected to an evaporator and an expansion device.

All information available soon on our website www.eurovent-certification.com

Beverage coolers and plug-in refrigerated display cabinets

We invite all manufacturers and distributors of refrigerated display cabinets and/or beverage coolers to join our next launching committee where you will contribute to defining the rules to be applied to your equipment.

The **Launching Committee (LC)** oversees the specific requirements for product evaluation by preparing the relevant reference documents as well as guidance on the choice of laboratory.

Should you be interested in participating or just willing to get further information: Please contact us at d.bibalou@eurovent-certification.com ■

Exhibitions in 2019 – Come meet us

28-30 Jan	**HVAC-R expo Saudi**
7 Fev	**EnerJ Meeting**
13-15 Feb	**BePositive**
20-22 Feb-2	**Refrigera**
28 Feb-2 March	**Acrex India**
4-7 March	**Climate World**
11-15 March	**ISH**
12-13 March	**Data Centre World**
9-11 April	**China Refrigeration Expo**
26-29 May	**Clima 2019**
10-13 Sept	**Febrava**
2-5 Oct	**ISK Sodex**
5-8 Nov	**Interclima**
19-21 Nov	**SIFA**

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CERTIFICATION PROGRAMMES

FOR DOMESTIC, COMMERCIAL AND INDUSTRIAL FACILITIES

Indoor Climate

- Chilled Beams (CB)*
- Comfort Air Conditioners (AC)*
- European Heat Pumps
- Fan Coils Units (FCU)*
- Heat Interface Units (HIU)*
- Liquid-to-liquid Plate Heat Exchangers (LPHE)
- Rooftops (RT)*
- Variable Refrigerant Flow (VRF)*

Ventilation & Air Quality

- Air Cleaners (ACL)
- Air Filters Class (FIL)*
- Air Handling Units (AHU)*
- Air to Air Plate Heat Exchangers (AAHE)*
- Air to Air Regenerative Heat Exchangers (AARE)*
- Fans
- Hygienic Air Handling Units (HAHU)
- Residential Air Filters (RFIL)
- Residential Air Handling Units (RAHU)
- Ventilation Ducts (DUCT)

Process Cooling & Food Cold Chain

- Cooling & Heating Coils (COIL)
- Cooling Towers (CT)
- Drift Eliminators (DE)
- Evaporating Cooling
- Heat Exchangers (HE)*
- Heat Recovery Systems with Intermediate Heat Transfer Medium (HRS-coils)
- IT Cooling (ITCU)*
- Liquid Chilling Package & Heat Pumps (LCP-HP)*
- Remote Refrigerated Display Cabinets (RDC)

* All models in the production have to be certified

▼ Indoor Climate

Chilled Beams (CB)

CERTIFY ALL

Scope of certification

This Certification Programme applies to all Active and Passive Chilled Beams. Chilled Beams are presented by ranges but all ranges must be certified. This applies to all product ranges which have either catalogue leaflets with product details including technical data or similar product information in electronic format.

Certification requirements

For the qualification procedure: 3 units are selected from regular production and tested in the independent Laboratory selected by Eurovent Certita Certification.

For the repetition procedures (yearly): the number of units selected is limited to 1 unit/range.

Obtained performances shall be compared with the values presented in the catalogues or electronic selection from manufacturer's website.

Certified characteristics & tolerances

Cooling capacity: 3 conditions are required.

- Active: 80 – 100 – 120% of the nominal air flow rate (for 8°C temperature difference)
- Passive: 6 – 8 – 10°C temperature difference

Tolerance = 12% and +24% for the 3 single values; –6% for the average value.

Water pressure drop: tolerance = maximum (2 kPa; 10%)

ECC Reference documents

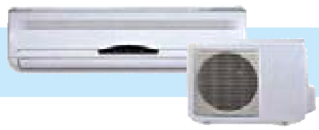
- Certification manual
- Operational Manual OM-12
- Rating Standard RS 2/C/001

Testing standards

- EN 14518: "Testing and rating of Passive Chilled Beams"
- EN 15116: "Testing and rating of Active Chilled Beams"

Comfort Air Conditioners (AC)

CERTIFY ALL



Scope of certification

This certification programme includes:

- AC1: comfort air cooled AC and air to air HP with cooling capacity up to 12 kW, except double duct and single duct units.
- AC2: comfort units with cooling capacity from 12 to 50 kW
- AC3: comfort units with cooling capacity from 50 to 100 kW

This programme applies to factory-made units intended to produce cooled air for comfort air conditioning (AC1, AC2, AC3). It also applies to units intended for both cooling and heating by reversing the cycle. AC1 programme units out of Regulation 206/2012 are excluded. AC2 and AC3 programme units out of Regulation 2016/2281 are excluded.

Participating Companies must certify all production models within the scope of the programme. For multi-split air conditioners, the number of indoor units is limited to 2, with same mounting type and capacity ratio 1±0.05. However, AC2 & AC3 units with 3 or 4 indoor units can be declared as an option.

Certification requirements

For the qualification & yearly repetition procedures: AC1: 8% of the units declared are selected and tested by an independent laboratory, and 30% of the selected units are tested at part load conditions. AC2 & AC3: 10% of the units declared are selected and tested by an independent laboratory.

Certified characteristics & tolerances

- Capacity (cooling and heating) –5%
- Efficiency (EER and COP) at standard rating conditions and part loads: –8%
- AC1 Seasonal Efficiency (SEER and SCOP): –0% (automatically rerated when Part Load efficiency criteria fails)
- AC2 & AC3 Seasonal Efficiency (SEER/η_{sc} and SCOP/η_{sh}): –0% (automatically rerated when Part Load efficiency criteria fails)
- A-weighted sound power level +0 dB (A) Auxiliary power +10%
- Minimum continuous operation Load Ratio: *LRcontmin* [%], COP/EER at *LRcontmin* and Performance correction coefficient at *LRcontmin* *CcpLRcontmin*.

ECC Reference documents

- Certification manual
- Operational Manual OM-1
- Rating Standard RS 6/C/001 • RS 6/C/001A • RS 6/C/006

Testing standards

- EN 14511 • EN 14825 • EN 12102

▼ Indoor Climate

European Heat Pumps

The programmes AC, VRF, RT & LCP-HP also participate to the programme European Heat Pump

Scope of certification

- Electrically driven heat pumps for space heating (incl. cooling function)
- Electrically driven heat pumps used for heating swimming pool water (outdoors or inside)
- Dual-mode heat pumps, i.e. designed for space heating and domestic hot water production,
- Gas absorption heat pumps (incl. cooling function)
- Engine-driven gas heat pumps (incl. cooling function)

Certification requirements

- Qualification campaign: 1 test per range declared + 1 audit/factory
- Repetition campaign: between 1 and 3 machines/ year (depending on the number of certified range) + 1 audit/ year/factory

Main certified characteristics & tolerances

- Heating and/or Cooling capacities P_h and/or P_c [kW], Electrical Power inputs P_e [kW] and Coefficient of performance COP
- Design capacity $P_{designh}$, Seasonal Coefficients of Performance *SCOP*, $SCOP_{net}$ and Seasonal efficiency η_s
- Minimum continuous operation Load Ratio *LRcontmin* [%], COP at *LRcontmin* and Performance correction coefficient at *LRcontmin CcpLRcontmin*
- Temperature stabilisation time t_h [hh:mm], Spare capacity P_{es} [W], Energy efficiency for water heating [COP_{DHW} & WH] or Global performance coefficient for a given tapping cycle COP_{global}, Reference hot water temperature θ'_{WH} and Maximum effective hot water volume V_{MAX} [l]
- Daily consumption for the draw-off cycle in question (Qelec)
- Annual consumption (AEC)
- Sound power levels L_w [dB(A)]

ECC Reference documents

- Certification manual
- Operational manual OM-17
- Rating standard RS 9/C/010

Main testing standards

Thermal performance:

- Heat pumps with electrically driven compressors
- Space heating & cooling: EN 14511-1 to 4; Seasonal performance: EN 14825
- Domestic hot water: EN 16147
- Direct exchange ground coupled heat pumps: EN 15879-1
- Gas-fired heat pump: EN 12309-1 to 5

Acoustics:

- Heat pumps and dehumidifiers with electrically driven compressors: EN 12102
- ISO 3741: Reverberant rooms or ISO 9614-1: Sound intensity, measurements by points

Fan Coils Units (FCU)

CERTIFY ALL

EUROVENT CERTIFIED PERFORMANCE ENERGY EFFICIENCY CHECK ENERGY CLASS ON www.eurovent-certification.com

Scope of certification

This Certification Programme applies to Fan Coil Units using hot or chilled water. It concerns both non ducted and ducted fan coils:

- Non-ducted units: Fan Coil Units with air flow less than 0.7 m³/s and a published external static duct pressure at 40 Pa maximum.
- Ducted units: Fan Coil Units up to 1 m³/s airflow and 300 Pa available pressure.
- District cooling units and 60 Hz units can be certified as an option

Participating companies must certify all production models within the scope of the programme. Selection tools (software) are checked.

Certification requirements

Repetition procedure: the number of units to be tested each year will be proportional to the number of his basic models listed in the Directory, in an amount equal to 17% for Fan Coil Units with a minimum of one test.

Certified characteristics & tolerances

- Sensible capacity* **: –8%
- Total cooling & heating capacity * **: –7%
- Water pressure drop* **: +20%
- Fan power input*: +10%
- A-weighted sound power **: +2 dB(A)
- Air flow rate: –10%
- Available static pressure 0 Pa for medium speed and –5 Pa for other speeds
- FCEER & FCCOP
- Eurovent energy efficiency class

(*) At standard and non-standard conditions

(**) Tolerances for capacities are increased by 2% for variable speed units.

ECC Reference documents

- Certification manual
- Operational Manual OM-1A
- Rating Standard RS 6/C/002
- Rating Standard RS 6/C/002A

Testing standards

- Performance testing: EN 1397:2015
- Acoustic testing: EN 16583:2015

▼ Indoor Climate

Heat Interface Units (HIU)

CERTIFY ALL

Scope of certification

The present certification scheme covers Heat Interface Units, defined as a packaged unit including at least one Domestic Hot Water heat exchanger and control elements.

The HIU may contain:

- An additional heat exchanger for heating
- Balancing elements
- 1 heating pump
- Metering possibilities

The HIU covered by the scheme are 3 pipes configurations. HIU with DHW capacity level above 70 kW are not covered by the certification scope. Only units for single family dwellings use are covered.

The covered technologies are:

- Domestic Hot Water technology only: HIU/DHW
- DHW and direct heating technology: HIU/DHW/DH
- DHW and direct heating mixed technology: HIU/DHW/DHM
- DHW and indirect heating application: HIU/DHW/IH

Certification requirements

The Heat Interface Unit certification program includes:

- Annual random selection of units and tests in an independent and accredited laboratory.
- Annual production site audit
- Unit labelling
- Certify-all principle

Certified characteristics & tolerance

- Maximal DHW capacity (kW)
- Return temperature during normal DHW tapping (°C)
- Minimal DHW flow rate (l/min)
- DHW reaction time (s)
- DHW Standby heat losses (kW)
- Capacity on temperature delta of 20 K (kW)
- Capacity on temperature delta of 10 K (kW)
- Difference between primary return temperature and secondary return temperature at 4kW (°C)
- Heat losses (kW)

ECC Reference documents

- Certification manual
- OM-26
- RS10/C/001

Testing standards

- Tests are conducted in accordance with the Test Regime Technical Specification, Rev-007 by BESA (Building Engineering Services Association), and in complement of testing specifications described in the Rating Standard RS/10/C/001.
- Units are both tested under High Temperature Conditions and Mid Temperature Conditions.

▼ Indoor Climate

Liquid-to-liquid Plate Heat Exchangers (LPHE)

Scope of certification

This certification programme applies to plate heat exchangers designed for liquid/liquid heat exchange (without phase change) applications in the Heating Ventilation and Air Conditioning (HVAC) field and operated with clean water or clean water mixtures (ethylene/propylene glycol but also ethanol aqueous solutions).

The product categories covered are:

- Gasketed plate heat exchangers,
- Brazed plate heat exchangers
- Fusion-bonded plate heat exchangers

Certification requirements

The certification scheme is based on product performance testing by independent testing laboratories as well as manufacturing facility auditing and selection software checking.

For qualification (entry year): 1/4 of the models (4 models minimum) selected for testing + 1 audit/factory.

For the repetition procedure (annually): 1/10 of the models (2 models minimum) selected for testing + 1 audit/factory.

If more than 3 new models are introduced in the range during the declaration file annual update, then 1 extra test will be conducted.

The performances measured by the independent laboratory are compared to the selection software output data.

Certified characteristics & acceptance criteria

Capacity: -(3%+Mu)

Pressure drop on primary fluid circuit: +(10%+Mu), minimum +2kPa

Pressure drop on secondary fluid circuit: +(10%+Mu), minimum +2kPa

With Mu the expanded uncertainty calculated by the laboratory for the test in question (uncertainty analysis as per RS 7/C/010).

ECC Reference documents

- Certification manual
- Operational manual OM-25
- Rating Standard RS 7/C/010

Testing standards

Specific testing method in Rating Standard RS 7/C/010 notably based on, but amending, the following standards:

- EN 1148:1999+A1:2005
- EN 306:1997

Indoor Climate

Rooftops (RT)

CERTIFY ALL

The Eurovent rooftop certification (RT) program covers air-cooled packaged rooftop cooling only and reversible units below 100 kW (in cooling mode), with an option to certify air to air units from 100 kW to 200 kW and water-cooled packages rooftops.

The Rooftop program regroups 11 participants of which the five main European manufacturers.

Eurovent certifies indoor and outdoor sound levels, cooling and heating capacity and efficiency. Certified performances provide transparency and fair comparison between manufacturers. It is also the basis for the reliable study of HVAC system energy performance.

For two years the program has evolved towards tests at part load conditions in order to prepare the certification of seasonal efficiencies (SEER & η_{sc}, SCOP & η_{sh}) of which the publication on the Eurovent Certified Performance (ECP) website is expected for mid-2018.

It was a strong willing of manufacturers involved in the program to be completely in line with the new Eco design Regulation (N° 2016/2281) applicable from 1st of January 2018 for several HVAC products as the rooftop units.

The next challenges of the programme will be the taking into account of the free cooling for the cooling efficiency and the heat recovery mode for the 3 & 4 damper rooftops, but obviously, the software certification will be a key item to comply with existing and coming certification of building energy calculations in the EU countries.

Committee chair:
Mr Alain Compingt
Regulatory and External Relationship, LENNOX EMEA

Mr Arnaud Lacourt
Head of Thermodynamics Department, Eurovent Certita Certification

Scope of certification

- This Certification Program applies to air-cooled packaged rooftop cooling only and reversible units below 100 kW (in cooling mode).
- Air to air units from 100 kW to 200 kW and water-cooled packages rooftops can be certified as an option.

Certification requirements

- For the qualification and repetition procedures (yearly) between 1 & 3 units are selected and tested, depending on the number of products declared.

Certified characteristics & tolerances

- Capacity (Cooling or Heating): –5%
- EER or COP: –8%
- Seasonal Efficiency in cooling: SEER & η_{sc}
  Expected in mid 2018
- Seasonal Efficiency in heating: SCOP & η_{sh}
  Expected in mid 2018
- Condenser water pressure drop: +15%
- A-weighted Sound Power Level: +3 dBA
- Eurovent Energy Efficiency class (cooling and heating)
- Eurovent Energy Seasonal Efficiency class.
  Expected in 2019

ECC Reference documents

- Certification manual
- Operational Manual OM-13
- Rating Standard RS 6/C/007

Testing standards

- EN 14511 for Performance Testing
- EN 14825 for Seasonal Efficiencies
- EN 12102 for Acoustical Testing

Indoor Climate

Variable Refrigerant Flow (VRF)

CERTIFY ALL

Launched in 2013, the VRF programme started with a restricted scope: outdoor units up to 50 kW, testable combinations up to limited number of indoor units (2 cassettes or 4 ducted units). But it was a first step to increase the integrity of the products performances on the market.

From 2015, an annual factory audit has completed the requirements of the VRF programme.

From 2018, an extended scope is proposed:

- Outdoor units up to 100 kW
- Combinations up to 8 indoor units (cassette or ducted) depending of the outdoor unit capacity
- Certified seasonal efficiencies (according to Ecodesign Regulation No 2016/2281, applicable from 2018)

The VRF program has prepared this change during 2017, testing the first units at the part load conditions and extreme ambient temperature (up to –10 kW) in order to be able to publish from Mid-2018:

- certified SEER and η_{sc} for the cooling mode
- certified SCOP and η_{sh} for the heating mode

Early 2018, the VRF program regroups henceforth 15 participants of which the world's leading manufacturers.

Mr Arnaud Lacourt
Head of Thermodynamics Department, Eurovent Certita Certification

Scope of certification

The certification programme for Variable Refrigerant Flow (VRF) applies to:

- Outdoor units used in Variable Refrigerant Flow systems with the following characteristics:
  - Air or water source, reversible, heating-only and cooling-only.

VRF systems with data declared and published as combinations are excluded from the scope.

Heat recovery units are included in the scope but the heat recovery function is not certified.

High ambient systems are included in the scope but tested under standard conditions as specified in RS 6/C/008.

Certification requirements

- Qualification: units selected by ECC shall be tested in an independent laboratory selected by ECC.
- Repetition procedure: units selected from regular production shall be tested on a yearly basis.
- A factory visit is organized every year in order to check the production

Certified characteristics & tolerances

- Outdoor Capacity (cooling and heating): –8%
- Outdoor Efficiency (EER, COP) at standard rating conditions and part loads: –10%
- Seasonal Efficiency (SEER/ηsc and SCOP/ ηsh): –0% (automatically rerated when Part Load efficiency criteria fails)
- A-weighted sound power level: 2 dB

ECC Reference documents

- Certification manual
- Operational manual OM-15
- Rating Standard RS 6/C/008

Testing standards

- EN 14511 • EN 14825 • EN 12102

Ventilation & Air Quality

Air Cleaners (ACL)

Scope of certification

The scope of this new certification programme includes devices for collecting and/or destroying indoor air pollutants for residential or tertiary sector applications, such as:

- Devices equipped with a fan that circulates an air flow of between 15 m³/h and 1,000 m³/h
- Independent electrically-powered devices.
- Residential (domestic) and tertiary sector applications: bedrooms, living rooms, offices, waiting rooms, retail stores, etc.
- All types of technology: mechanical filtration, electrostatic filtration, plasma, ionization, UV-A or UV-C lamp, etc.

Certified characteristics & tolerances

At maximum operating speed:

- Purification efficiency: purified air volume flow rate for each pollutant category treated such as
  - Breathable particles suspended in the air
  - Gaseous pollutants (formaldehyde, toluene, etc.)
  - Microorganisms (bacteria and mould)
  - Cat allergen
- Energy efficiency: (purified air volume flow rate / absorbed electrical power).
- Recommended room area for each pollutant category.

At 1, 2 or 3 operating speeds:

- Device air circulation flow rate.
- **Energy**: absorbed electrical power.
- **Noise impact**: sound power level.

When tested in the laboratory the obtained performance data shall not differ from the declared values by more than the following tolerance values:

- Air circulation flow rate [m³/h]: –5%
- Initial purified air flow rate [m³/h]: –5%
- Sound power level [dB(A)]: +2 dB(A)
- Absorbed electrical power [W]: Maximum [+5%; +1 W]

ECC Reference documents

- Certification manual
- Operational manual OM-20
- Rating Standard RS/4/C/002
- NF-536

Testing standards

- NF B44-200:2016
- XP-B44-013:2009 may notably be used as a supplement in some particular cases identified in the NF-536 reference document.

Air Filters Class (FIL)

CERTIFY ALL

Today, people spend most of the time inside of buildings. Hence, indoor air quality is a key factor to human health. Air filters removing fine dust from the air stream are the key component in building heating, ventilation and air conditioning systems to supply air of the required cleanliness and to ensure a high level of indoor air quality. With the air filter certification program, reliable and transparent filter data are ensured to customers. On a yearly base, four different filters are selected out of the product range of each participant for testing at independent laboratories according to EN ISO 16890: 2016, verifying the initial pressure drop, the filter ISO class rating and the ePM1, ePM1,min, ePM2.5, ePM2.5,min and ePM10 efficiencies, as well as the energy efficiency class to Eurovent document 4/11. Additionally, with the new energy efficiency label, Eurovent provides valuable data to enable users to select the most energy efficient air filters.

Committee chair: Dr. Thomas Caesar
Head of Filter Engineering Industrial Filtration Europe
Freudenberg Filtration Technologies SE & Co. KG

Scope of certification

- This Certification Programme applies to air filters elements rated and sold as ISO ePM1, ISO ePM2.5 and ISO ePM10 according to EN ISO 16890-1:2016 referring to a front frame size of 592x592mm according to standard EN 15805.
- When a company joins the programme, all relevant air filter elements shall be certified.

Certification requirements

- For the qualification procedures: 6 units will be selected and tested by an independent Laboratory selected by Eurovent Certification.
  Then each year 4 units will be selected & tested

Certified characteristics & tolerances

- Filter ISO class rating: no tolerance.
- Initial pressure drop: +10% + 5 Pa (minimum 15 Pa)
- ePM1, ePM1,min, ePM2.5, ePM2.5,min and ePM10 efficiencies: -7%-point
- Annual energy consumption +10% +60 kWh/a

ECC Reference documents

- Certification manual
- Operational Manual OM-11
- Rating Standard RS 4/C/001

Testing standards

- EN ISO 16890: 2016
- Eurovent 4/21

▼ Ventilation & Air Quality

Air Handling Units (AHU)

CERTIFY ALL

Swegon has participated in the program for Air Handling Units from the start. The first priority at that time, and still is, was to find a way for fair competition. This is a long-term struggle were we try to cover all aspects from manufacturing to software performance predictions and its agreement with tests. We discuss and take decisions about mandatory performance in software printout, rules for the energy labelling, how to test and what to apply in the, on site, auditor check. Customers should go for Eurovent certified products, to get reliable data, and then they can cut the main cost and take care of the environment by minimising the use of energy.

Committee chair:
Mr Gunnar Berg
Development Engineer, Swegon

Scope of certification

This Certification Programme applies to ranges of Air Handling Units that can be selected in a software. Each declared range shall at least present one size with a rated air volume flow below 3 m^2/s. For each declared range, all Real Unit Sizes available in the software and up to the maximum stated air flow and all Model Box configurations shall be declared.

Participants shall certify all models in the selected product range up to the maximum stated air flow.

A range to be certified shall include at least one size with a rated air volume flow up to 3 m^3/s.

Certification requirements

For the qualification procedure: the selection software will be verified by our internal auditor. A visit on production site will be organized. During that visit, the auditor will select one real unit per range, as well as several model boxes that will cover all mechanical variations.

The selected units will be tested and performances delivered by the selection software will be compared to the performances measured in an independent laboratory.

For the repetition procedures, the auditor will annually check the software conformity against the production data, and tests will be repeated every 3 to 6 years.

Certified characteristics & tolerances

- External Pressure: 4% or 15 Pa
- Absorbed motor power: 3%
- Heat recovery efficiency: 3%-points
- Heat recovery pressure drop (air side): max. of 10% or 15 Pa
- Water coil performances (heating/cooling): 2%
- Water coil pressure drop (water side): max. of 10% or 2 kPa
- Radiated sound power level casing: 3 dB(A)
- Sound power level unit openings:
  - 5 dB @ 125 Hz
  - 3 dB @ 250 – 8 000 Hz
- Casing Air Leakage: same class or higher

ECC Reference documents

- Certification manual
- Operational Manual OM-5
- Rating Standard RS 6/C/005

Testing standards

- EN 1886: "Ventilation for buildings – Air handling units – Mechanical performance"
- EN 13053: "Ventilation for buildings – Air handling units – Rating & performance for units components and sections"
- RS/6/C/011-2016 Hygienic AHU

▼ Ventilation & Air Quality

Air to Air Plate Heat Exchangers (AAHE)

CERTIFY ALL

Scope of certification

This Certification programme applies to selected ranges of Air to Air Plate Heat Exchangers. Participants shall certify all models in the selected range, including:

- cross flow, counter-flow and parallel flow units
- all sizes
- all materials
- all airflow rates
- all edge lengths
- plate heat exchanger with humidity transfer

Heat Exchangers with accessories such as bypass and dampers shall not be included.

Manufacturers shall declare production places and provenance of products is randomly chosen. The programme does not cover other types of Air to Air Heat Exchangers like Rotary Heat Exchangers or Heat Pipes. Combination of units (twin exchangers) are also included in the scope of the program.

Certification requirements

For each range to be certified, 3 units for qualification and 1 for yearly repetition will be selected by Eurovent Certita Certification and tested in an independent Laboratory.

Certified characteristics & tolerances

- Dimensions: ± 2 mm
- Plate spacing: ± 1% or ± 1 plate
- Temperature efficiency Dry: –3 percentage points
- Temperature efficiency Wet: –5 percentage points
- Humidity efficiency: -5%
- Pressure drop: +10%, minimum 15 Pa

ECC Reference documents

- Certification manual
- Operational Manual OM-8
- Rating Standard RS 8/C/001

Testing standards

- EN 308

Air to Air Regenerative Heat Exchangers (AARE)

CERTIFY ALL

Scope of certification

This Certification Programme applies to all ranges of Air to Air Regenerative Heat Exchangers (RHE) including sealing systems. Units sold without casing and sealing systems are also included. Participants shall certify all models in the ranges, including:

- all classes: condensation (non-hygroscopic, non-enthalpy) RHE, hygroscopic enthalpy RHE, hygroscopic sorption RHE
- all RHE geometry (wave height, foil thickness)
- all sizes (rotor diameters and rotor depths and surface areas of Alternating Storage Matrices - ASM)
- all materials
- all airflow rates
- all different types of sealing (if available)

Certification requirements

For the qualification procedures 1 unit per class of rotor will be selected and tested by an independent laboratory. For yearly repetition, 1 unit will be selected.

Certified characteristics & tolerances

- Temperature Efficiency: –3% points
- Humidity Efficiency: –5% points (min. tolerance 0.2 g/kg in absolute humidity of leaving supply air)
- Pressure Drop: +10% (min 10 Pa)
- Outdoor Air Correction Factor (OACF): 0.05
- Exhaust Air Transfer Ratio (EATR): +1% point

ECC Reference documents

- Certification manual
- Operational Manual OM-10
- Rating Standard RS 8/C/002

Testing standards

- EN 308
- ARI 1060

Fans

Scope of certification

This certification programme applies to the fans types that are intended to be used as Air Handling Units components.

Certification requirements

The certification scheme is based on product performance testing by independent testing laboratories as well as manufacturing facility auditing and selection software checking.

Two sub-programmes enable distinguishing performances certified for an impeller basic assembly on the one hand (sub-programme FAN-I) and for a complete assembly on the other hand (sub-programme FAN-C). In both cases, the fan assembly is evaluated in accordance with a wire-to-air approach. This approach consists in assessing the fan performance from the electric wire to the air discharge, accounting for all the components involved in the air stream generation that affect the performance data.

- For qualification (entry year) and repetition procedures (annually): 2 models (+ 1 extra model in case of confirmed failure) are selected from regular production and tested in independent laboratory + N aerodynamic test reports are provided by the applicant/participant.
- For qualification (entry year): N = Max ($N_{impeller}$; N_{motor}; N_{drive}) with $N_{impeller}$ the number of impeller sizes; N_{motor} the number of motor sizes and N_{drive} the number of drive types available in the range.
- For the repetition procedure (annually): $N = N_{factories}$ with $N_{factories}$ the number of factories involved in the certified range production.

The performances measured by the independent laboratory (or available in the reports) are compared to the selection software output data.

Certified characteristics & tolerances

- Static pressure difference (–4% or –15 Pa)
- Shaft power, including bearings (FAN-I) (+3%)
- Impeller efficiency (FAN-I) (–5 percentage points)
- Maximum fan speed (FAN-I) (–5%)
- Motor (electrical) input power (FAN-C) (+3%)
- Drive/control (electrical) input power (FAN-C) (+3%)
- Overall (static) efficiency (FAN-C)(–5 percentage points)
- Inlet/outlet LWfc by octave bands at 125 Hz (FAN-C) (+5 dB)
- Inlet/outlet LWfc by octave bands for 250 Hz - 8000 Hz (FAN-C) (+3 dB)

ECC Reference documents

- Certification manual
- Operational manual OM-22
- Rating standard RS 1/C/001

Testing standards

- ISO 5801:2007
- ISO 13347-2:2004

▼ Ventilation & Air Quality

Hygienic Air Handling Units (HAHU)

Scope of certification

This programme applies to hygienic ranges of Air Handling Units. As an option of the Certification programme for Air Handling Units, only an already ECP certified range is eligible for the hygienic option.

The hygienic aspect of the AHU is certified based on a 3 levels classification, each level declaring an AHU suitable for different application:

- Level 1: Offices, commercial buildings, schools, hotels
- Level 2: Hospitals
- Level 3: Pharmaceutical, food processes, white rooms

The previous list is not exhaustive and must be used as a reference only. Final customer/user who has complete and detailed knowledge of the building application shall decide which Hygienic rating level is appropriate.

Certification requirements

Same as in the Air Handling Unit programme.

Certification characteristics & tolerances

Services characteristics:
The following services characteristics are certified.

1. Manufacturing
2. Maintenance
3. Quality Management System
4. IOM (Installation and Operational Manual)
5. Shipment

Hygienic characteristics:
The following hygienic characteristics are certified:

1. Materials
2. Casing performance
3. Components arrangement and performances (filters, coils, heat recovery systems, fans, humidifiers, dehumidifiers and silencers)

ECC reference documents

Certification manual

- OM-5-2016-rev1
- RS/6/C/011-2016 Hygienic AHU

Testing standards

- RS 6/C/005-2016
- EN ISO 846:1997
- EN ISO 2896:2001
- EN 10088-3:2014
- EN 1993-1-2:2005
- DIN 1946/4-6.5.1:2008
- EN 779:2012
- EN 1822:2010
- EN ISO 12944-2:1998

Residential Air Filters (RFIL)

Scope of certification

The programme scope covers the particulate and combination (particulate and gas) filters used in a residential ventilation unit and for which the following applies:

- the rated maximum air flow rate is comprised between 70 and 1000 m³/h included;
- the initial efficiency ePM10 is higher than or equal to 50%;
- the initial efficiency ePM1 is strictly lower than 99%;
- the ratio between effluent and influent concentrations measured at time zero is strictly lower than 20% (for combination filters only, see Rating Standard RS/4/C/003 for further details).

The programme scope covers filters for which the face area is lower than or equal to 300 mm x 600 mm. For the RFIL programme, the certify-all requirement as defined in the Certification Manual is applicable from January 1st of 2020 (see Operational Manual OM-21 for further details).

Certified characteristics & tolerances

When tested in the laboratory the obtained performance data shall not differ from the declared values by more than the following tolerance values:

- Initial pressure drop values: +10%+Mt or +10 Pa +Mt
- Initial efficiency values: –5 percentage points (absolute deviation)
- Minimum efficiency values: –5 percentage points (absolute deviation)
- Filter ISO ePMx class reporting value: –5 percentage points (absolute deviation)
- Adsorption capacity: –10%

Nota : Mt means "measuring tolerance"

ECC Reference documents

- Certification manual
- Operational manual OM-21
- Rating standard RS/4/C/003

Testing standards

- Eurovent 4/22:2015 (particulate filters and combination filters)
- SO 11155-2:2009 (combination filters only)

Ventilation Ducts (DUCT)

Scope of certification

The programme scope covers rigid and semi-rigid ventilation ductwork systems divided into the following sub-programmes:

- Rigid metallic ductwork systems with circular cross-section (DUCT-MC);
- Rigid metallic ductwork systems with rectangular cross-section (DUCT-MR);
- Semi-rigid non-metallic ductwork systems predominantly made of plastics (DUCT-P)

Each sub-programme applies to ductwork systems fitted with integrated sealing solution as described in relevant Rating Standard.

Certification requirements

The certification programme is based on product performance testing by independent testing laboratories as well as production sites auditing.

Certification characteristics & tolerances

The product performance testing will enable the verification of the following ratings accuracy:

- Air tightness class (all sub-programmes)
- Positive and negative pressure limits (all sub-programmes)
- Dimensions (DUCT-MC and DUCT-MR)
- Minimum and maximum service temperatures (DUCT-P)
- Resistance to external pressure (DUCT-P)

ECC reference documents

- OM-19
- RS/2/C/002MC
- RS/2/C/003MR
- RS/2/C/004P

Testing standards

- Air leakage and strength testing:
  – EN 12237:2003 (DUCT-MC and DUCT-P)
  – EN 1507:2006 (DUCT-MR)
- Service temperature and resistance to external pressure
- (DUCT-P):
  – RS 2/C/004P-2016

▼ Ventilation & Air Quality

Residential Air Handling Units (RAHU)

CERTIFY ALL

The objective of the Eurovent RAHU certification programme is, through tests performed by a third-party, to verify the performance of a unit bought somewhere on the open European market. It is important for the RAHU certification to use a unit out of the serial production – no special samples. For us, as a manufacturer, it pays to develop good products that deliver what we promise. By utilizing certified products, the designers' task is easier as they do not need to make detailed comparisons or perform advanced tests. Consultants, engineers and users can select a product and be assured that the catalog data is accurate.

Certification is important for a designer/consultant/end user:

- No unnecessary risks – they can only use products that deliver what they promise "Eurovent certified".
- Well-functioning systems – the product delivers the promised capacity and performance
- Safer calculations on energy consumption is expected

Mr. Tobias Sagström
Global Product Manager Residential at Systemair AB

Scope of certification

This programme applies to balanced residential AHUs (supply and exhaust) with heat recovery sys-tems such as:

- Air-to-air **plate** heat exchangers
- Air-to-air **rotary** heat exchangers
- **Heat-pumps** with a nominal airflow below 1 000 m³/h.

Certification requirements

- Qualification test campaign: 1 test per heat recovery type.
- Repetition test campaign: 1 test every 2 years for each heat recovery type.
- Units are sampled directly from selling points.

Certified performances

- Leakage class
- Aeraulic performances:
- Airflow/pressure curves
- Maximum airflow [m³/h]
- Electrical consumption [W]
- Specific Power Input SPI [W/(m³/h)]
- Temperature efficiency / COP
- Performances at cold climate conditions
- SEC (Specific Energy Consumption) in [kWh/(m².an)]
- A-weighted global sound power levels [dB(A)]

Tolerances

- Leakage class 0
- Airflow –10%
- Temperature efficiency –3%-point
- Temperature efficiency at cold climate –6%-point
- COP / EER –8%
- A-weighted global sound power levels +2dB(A)
- Electrical consumption +7%
- Specific Power Input SPI +7%
- Disbalance ratio 0

ECC Reference documents

- Certification manual
- Operational manual OM-16
- Rating standard RS 15/C/001

Testing standards

- European standard EN 13141-7:2010

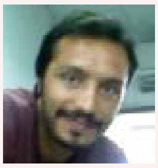
▼ Process Cooling & Food Cold Chain

Cooling & Heating Coils (COIL)

Heating Cooling Coils (HCCs) which enable the conditioning of different zones and flexibility in application in buildings are generally employed in compact and central station AHU. To meet the required extra capacity in various processes, they are also used as heating or cooling devices.

With the application of these coils to high energy efficient heat recovery systems, the entire system becomes more compact as well as it avoids occupation of large spaces. Besides, they can be applied to Variable Air Volume (VAV) systems used for conditioning of hospitals, shopping centers and convention facilities.

The Certification programme for the HCCs has increased integrity and accuracy of the industrial performance ratings which provides clear benefits for end users who can be confident that the product will operate in accordance with design specifications. Also, by means of this certification programme users can collect reference data on the fundamental characteristics of the HCCs, such as capacity, pressure drop, mass flow complying with the standard of EN 1216.



Engin Söylemez, R&D
Test Engineer, Friterm A.Ş

Scope of certification

The rating standard applies to coils operating:

– with water or with a 0–50% ethylene-glycol mixture, acting as cooling or heating fluid.

– and without fans.

Certification requirements

- Qualification and repetition procedures: units declared will be selected and tested by an independent laboratory.
- The number of units will depend on the variety of coil material configurations and their applications for the applied range.
- The selection software will be verified in comparison with the test results.
- On-site audits (checking of software)

Certified characteristics & tolerances

- Capacity: –7%
- Air side pressure drop: +20%
- Liquid side pressure drop: +20%

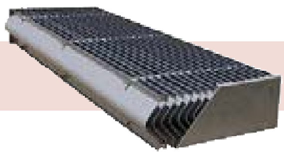
ECC Reference documents

- OM-9
- RS 7/C/005

Testing standards

- EN 1216:1998+A1/2002

Drift Eliminators (DE)



Scope of certification

The Certification Programme for Drift Eliminators applies to Drift Eliminators used for evaporative water-cooling equipment.

Certified characteristics & tolerances

The following characteristics shall be certified by tests:

- For counter-flow and cross-flow film fill, the average drift losses of the two tests at 3.5 m/s are less than 0.007% of circulating water flow rate.
- For cross-flow splash fill, the average drift losses of the two tests at 3 m/s are less than 0.007% of circulating water flow rate.

No tolerance will be applied on the average drift losses.

ECC Reference documents

- Certification manual
- Operational Manual OM-14
- Rating Standard RS 9/C/003

Testing standards

- CTI ATC-140

Cooling Towers (CT)

The importance of air conditioning and industrial cooling is constantly increasing in modern architecture and industrial process cooling. The human perception of comfort and the new challenges to reduce the electrical power consumption and CO_2 foot-print have designers striving for optimal system performances with the highest possible efficiencies. Reliable thermal performances are crucial to ensure these best efficiencies which are typical for cooling circuits driven by evaporative cooling equipment. On a yearly basis, one random picked cooling tower of each Eurovent-CTI certified product line will be full scale thermal tested by applying the CTI standard 201.

Eurovent Certita Certification guarantees the consistency of thermal testing and manufacturing of European and non-European companies that subscribe to the program.

Committee chair:
Mr Rob Vandenboer
Product Manager, Quality Manager
Evapco Europe, BVBA

The first ECC / CTI collaborative certification program for Cooling Towers

The Eurovent Certification Company (ECC, Brussels, Belgium) is pleased to announce the Certification programme for cooling tower thermal performance developed in cooperation with the Cooling Technology Institute Est.1950 (CTI, Houston, Texas, USA). The scope of the program includes standardized model lines for open circuit cooling towers, typically factory assembled. Standardized model lines are composed of individual models that are required to have published thermal rating capacities at corresponding input fan power levels.

Thermal performance certification via this program offers a tower buyer assurance that the capacity published for the product has been confirmed by the initial and on-going performance testing per the requirements of the program using CTI STD-201. It also offers for regulators of energy consumption related to cooling towers, that the capacity of the towers has been validated. Mini-mum energy efficiency standards such as the Eurovent Industry Recommendation / Code of Good Practice Eurovent 9/12-2016 and ASHRAE 90.1, which requires cooling tower energy

efficiency validation by the CTI certification process, are used by governments and by green building certification programs such as LEED™.

Scope of certification

This Certification Programme for Cooling Towers applies to product ranges (or product lines) of Open-Circuit series and Closed Circuit Cooling Towers that:

- Are manufactured by a company whose headquarter or main facility are located in Europe, Middle-East, Africa or India. After getting the Eurovent Certification, the CTI certificate could be requested.
- Have already achieved and hold current certification by the Cooling Technology Institute (CTI) according to CTI STD-201.

Certification requirements

For the qualification & yearly repetition procedures our internal auditor visits the production place and reviews the conformity of Data of Records. One unit per range is selected and tested by an independent test agency.

Certified characteristics & tolerances

- Certified characteristic shall be per CTI STD-201
- Entering wet bulb temperature: 10°C to 32.2°C (50°F to 90°F)
- Cooling range > 2.2°C (4°F)
- Cooling approach > 2.8°C (5°F)
- Process fluid temperature < 51.7°C (125°F)
- Barometric pressure: –91.4 to 105.0 kPa (27” to 31” Hg)

ECC Reference documents

- Certification manual
- Operational Manual OM-4
- Rating Standard RS 9/C/001

Testing standards

- CTI STD-201 RS
- ECC OM-4-2017

Evaporating Cooling

Scope of certification

The programme for Evaporative Cooling is divided in three sub-programmes, as it applies to Evaporative Cooling units in the following groups:

- Direct Evaporative Cooling (DEC)
  - Indirect Evaporative Cooling (IEC)
  - With primary outside air
  - With separation of external and room air
- Evaporative Cooling Equipment (ECE)
  - Water spray system
  - Wet media
  - Ultrasonic unit

Certification requirements

All products of a declared range that fall into the relevant sub-programme scope and are promoted by the Applicant/Participant shall be certified. This is a certification by range.

The certification programme is based on product performance testing by independent laboratories as well as manufacturing facility auditing. In the case of the IEC sub programme, the tests will be performed in the laboratory of the manufacturer supervised by an expert from an independent laboratory.

Certified characteristics & tolerances

- Cooling Capacity (all sub-programmes)
- Air flow (all sub-programmes)
- Efficiency (all sub-programmes)
- Water consumption (all sub-programme)
- Wet and dry pressure drop (ECE only)

ECC Reference documents

- Certification manual
- Operational Manual OM
- Rating Standard RS 9/C/004-005-006

Testing standards

- For direct evaporating cooling
  AS 2913-2000 standard RS9/C/004
- For indirect evaporating cooling
  ANSI/ASHRAE Standard 143-2015 RS9/C/005
- For evaporating cooling equipment
  ASHRAE 133-2015 RS9/C/006

Heat Recovery Systems with Intermediate Heat Transfer Medium (HRS-COIL)

Scope of certification

This certification programme covers the heat recovery exchangers with intermediate heat transfer medium corresponding to the category IIa ("without phase change") of the EN 308:1997 standard, that is Run Around Coils systems.

Certification requirements

Qualification procedure

- Product performance testing:
  - 1 coil per BMG to be selected
  - Selected coils paired into systems (1 "exhaust" coil + 1 "supply" coil)
- Operating software checking
- Audit of the manufacturing facilities

Repetition procedure:

- Product performance testing: 1 system to be selected (1 "exhaust" coil + 1 "supply" coil)
- Operating software checking
- Audit of the manufacturing facilities

Certification characteristics & tolerances

- Dry heat recovery efficiency [%]
- Air side pressure drop at standard conditions for each coil [Pa]
- Fluid side pressure drop for each coil [kPa]

When tested in the laboratory the obtained performance data shall not differ from the recalculated values ("test-check") by more than the following tolerance values:

- Dry heat recovery efficiency: –3 percentage points (abs. deviation)
- Air side pressure drop: Maximum [+10%; +15 Pa]
- Fluid side pressure drop: Maximum [+10%; +2 kPa]

ECC reference documents

- Certification manual
- OM-18
- RS 7/C/009

Testing standards

- EN 308:1997

Process Cooling & Food Cold Chain

Heat Exchangers (HE)

CERTIFY ALL

The purpose of the Eurovent "Certify-All" certification programme for heat exchangers is to encourage honest competition and to assure customers that equipment is correctly rated.

The programme covers 3 product groups:

- Unit Air Coolers
- Air Cooled Condensers
- Dry Coolers

The "Certify-All" principle ensures that, for heat exchangers, all models in the three product categories are submitted for certification, not just some models chosen by the manufacturer.

A product energy class scheme has been incorporated into the certification program, based on 6 classes from "A+" to "E" in order to provide a guide to the best choice of product: this enables the user to minimize life-cycle costs, including running costs which account for a much superior sum than the initial investment cost.

EVOLUTIONS OF THE PROGRAMME:

Extension of the scope of certification programme for Heat Exchangers

- to CO_2 applications. Implementation in 2019
- to NH_3 applications

Committee chair: Stefano Filippini
Technicalmanager - LUVE

Air coolers for refrigeration

Dry coolers

Air cooled condensers

Scope of certification

The Eurovent Certification Programme for Heat Exchangers applies to products using axial flow fans. The following products are excluded from the Eurovent Certification Programme for Heat Exchangers:

- Products units using centrifugal type fans.
- Units working at 60 Hz

In particular, the following products are also excluded from the certification programme for Dx Air Coolers and Air Cooled Condensers:

- Product ranges of Dx Air Coolers with maximum standard capacity SC2 below 1.5 kW
- Product ranges of Air Cooled Condensers with maximum standard capacity under TD1 15 K is below 2.0 kW

Certification requirements

- Qualification: units selected by Eurovent Certita Certification shall be tested in an Independent Laboratory selected by ECC
- Repetition procedure: units selected from regular production shall be tested on a yearly basis.

Certified characteristics & tolerances

- Standard capacity –8%
- Fan power input +10% with a minimum of 3 W
- Air volume flow ±10%
- Dimensions and number of fins: Finned length ±0,5%, with a minimum of 5 mm
  - Height of the coil ±5 mm
  - Depth (width) of the coil ±5 mm
  - Total number of fins* ±4%, at least 2 fins
  - Diameter of (expanded) tube outside the coil* ±1 mm

  (*) except for the micro-channels
- Energy ratio R
- Energy class

For Dry Coolers:

- Liquid side pressure drop +20%

For Air Cooled Condensers and Dry Coolers:

- A-weighted sound power level: +2 dB(A)

ECC Reference documents

- Certification manual
- Operational Manual OM-2
- Rating Standard RS 7/C/008

Testing standards

- Thermal Performance EN 328
- Thermal Performance EN 327
- Thermal Performance EN1048
- Acoustics EN 13487

▼ Process Cooling & Food Cold Chain

IT Cooling Units (ITCU)

CERTIFY ALL

Scope of certification

The present certification programme covers IT Cooling Units specifically designed and used to regulate air temperature and optionally air humidity of an enclosed space containing critical equipment such as IT equipment or telecommunication equipment.

The IT Cooling technologies considered in the scheme are Computer Room Air Conditioners Direct Expansion (CRAC) and Computer Room Air Conditioner Chilled Water (CRAH). HYBRID technologies pairing these technologies are also covered by the scope as an option.

The IT cooling units must be factory made units designed as a single packaged unit or a single split unit. Units must be 50 Hz frequency units, optionally 60 Hz units can be declared in addition to the 50 Hz. The units can be ducted or non-ducted units, as well on the air return or on the air supply. Floating floors air return or supply are considered as a duct.

Certification requirements

- Annual random selection of units and tests in an independent and accredited laboratory
- Annual production site audit
- Software certification extending the certification from standard functioning conditions to non-standard conditions

Certified characteristics & tolerances

- Net Total Cooling Capacity (kW)
- Net Sensible Cooling Capacity (kW)
- Power input (kW)
- Net EER Energy Efficiency Ratio (%)
- Net SHR Sensible Heat Ratio (%)
- Water pressure drop (Pa)
- Supply Air Flow (m3/h)
- A-weighted sound power indoor side (dB(A))
- A-weighted sound power radiated by duct (dB(A))
- A-weighted sound power outdoor side (dB(A))

ECC Reference documents

- Certification manual
- OM 23
- RS/C/012

Testing standards

- EN 1451:2018
- EN 1397:2015
- ANSI/ASHRAE Standard 127-2012
- ASHRAE Standard 37
- EN 12102:2013
- EN 16583:2015

▼ Process Cooling & Food Cold Chain

Liquid Chilling Package & Heat Pumps (LCP-HP)

CERTIFY ALL

The historical ESEER, first seasonal efficiency for cooling, created in 2007 by Eurovent Certita Certification, and deeply recognized on the European Market is living its last moments.

With the implementation of the new Ecodesign Regulation No 2016/2281, the year 2018 will be a crucial year for the chillers industry. The European Market has to change its reference efficiency and turn towards SEER and ηsc, the new seasonal efficiencies for cooling mode.

The LCP-HP program has prepared this change since 2 years, testing yearly a significant number of units at the new part load conditions in order to be able to publish from January 2018, certified SEER and ηsc. The SEER has to become the new reference also for the certification program.

Moreover, the scope of the program has been extended for 2018:

- Previously limited to 1500 kW, the water-cooled chillers above 1500 kW can be henceforth certified in option, up to the maximum capacity of the manufacturer laboratory.
- The 4 pipe units can be certified also in option.

Although the program was originally attended for comfort chillers, it is important to remind that process chillers and their SEPR can also be certified as an option.

Lastly, face to these recently regulatory changes for the industry, the certification will be always a strong way to guaranty the reliability of our declared performances to our clients.

Committee chair:
Mr Rafael Berzosas
Water Cooled Chillers Product Manager
Trane Europe, Middle East & Africa

According to the last Ecodesign Regulations (No 811/2013 - No 813/2013 – No 2016/2281) the programme proposes the certification of Seasonal efficiency for heating (ηs & SCOP) for Chillers & Heat pumps with a design capacity below 70kW, Seasonal efficiency for cooling (ηsc & SEER) for all comfort chillers and the seasonal energy performance ratio (SEPR) for process chillers.

Scope of certification

- This programme applies to standard chillers and hydronic heat pumps used for heating, air conditioning and refrigeration.
- They may operate with any type of compressor (hermetic, semi-hermetic and open) but only electrically driven chillers are included.
- Only refrigerants authorized in EU are considered. Chillers may be air cooled, liquid cooled or evaporative cooled.

Can be certified as an option:

- Heating-only hydronic heat pumps, 60 Hz units, 4-pipe units, Air-cooled units between 600 kW and 1500kW,
  Water-cooled units above 1500 kW.

Certification requirements

Qualification and repetition: a certain number of units will be selected by Eurovent Certita Certification and tested every year, based on the number of ranges and products declared.

Certified characteristics & tolerances

- Cooling & heating capacity, EER & COP at standard rating conditions, TER : < –5%
- Seasonal efficiencies SCOP & η_s: automatically rerated when Part Load efficiency criteria fails
- Seasonal efficiencies SEER & η_{sc}: automatically rerated when Part Load efficiency criteria fails
- Seasonal efficiency SEPR: automatically rerated when Part Load efficiency criteria fails
- A-weighted sound power level: > +3 dB(A) (> +2 dB(A) for units with *Pdesignh* below 70 kW)
- Water pressure drop: +15%

Testing standards

- Performance testing: EN 14511
- Seasonal Performance testing: EN 14825
- Sound testing: EN 12102

ECC Reference documents

- Certification manual
- Operational Manual OM-3
- Rating Standard RS 6/C003 – RS 6/C/003A

▼ Process Cooling & Food Cold Chain

Remote Refrigerated Display Cabinets (RDC)

Remote refrigerated display cabinets (RRDC) are the appliances for selling and displaying chilled and/or frozen foodstuff to be maintained within prescribed temperature limits.

Typically, food and beverage retailers are the direct customers of the refrigeration industry while the supermarket's customers are the end users of food and beverage retailers.

Food and beverage retailers ask for food safety and also for appliances with high-energy efficiency, supermarket's customers ask for food safety. Refrigeration industry has to face the hard challenge of satisfying both needs.

How is it possible to assure that the refrigeration appliances perform accurately and consistently to the reference standards? How is it possible to assure that what is rated by the manufacturer is properly rated?

There is only one way: It is necessary to join a globally recognized and industry respected certification program.

Eurovent Certita Certification program for RRDC is the only certification program in Europe that can assure that performance claims have been independently measured and verified. The factory audits and the product's performances tested in an independent and third-party laboratory make the difference!

Since 2011, Eurovent Certita Certification has also launched a voluntary energy label certification scheme, anticipating what only nowadays EC DG Energy is doing in the framework of Ecodesign and Energy Label Regulations. What better way to rate RRDC's energy consumption and to promote their energy efficiency?

What would you trust more: a self-declaration by the Manufacturer or what an independent, globally recognized and forerunner certification program is able to assure? Which one is better?

Maurizio Dell'Eva
Project manager
EPTA S.p.A. – MILANO (ITALY)

Scope of certification

- 100 basic model groups divided in 5 categories of remote units: semi-verticals and verticals (with doors); multi-deckers; islands; service counters; combi freezers.
- At least two references per basic model group representing 80% of sales shall be declared.
- One Bill of Material for each declared reference.

Certification requirements

- Qualification: sampling and test of one unit & Audit of one factory.
- Repetition test of one unit per brand every 6 months & Annual audit of each factory.

Certified characteristics & tolerances

- Warmest and coldest product temp. ±0.5°C
- Refrigeration duty (kW) 10%
- Evaporating temperature –1°C
- Direct elec. Energy Consumption (DEC) +5%
- Refrigeration elec. Energy Cons (REC) +10%
- M-Package T_{class}: ±0.5°C
- Total Display Area (TDA) –3%

ECC Reference documents

- Certification manual
- Operational Manual OM-7
- Rating Standard RS 14/C/001

Testing standards

- EN ISO 29953 and amendments

Belimo Headquarters, CH-8340 Hinwil, Switzerland, www.belimo.com

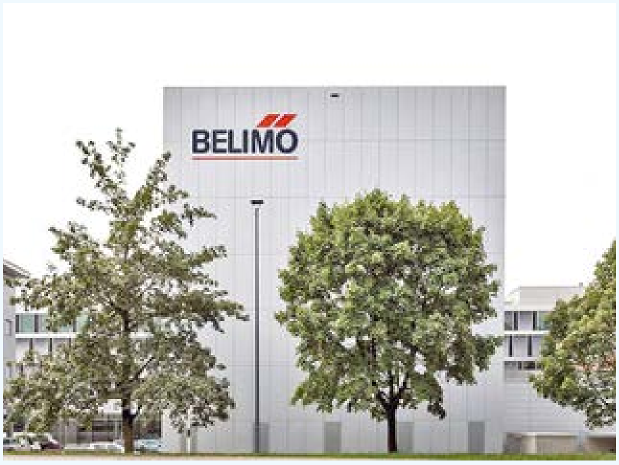
Belimo at ISH 2019, Hall 10.2, Booth C75

Applications that you can touch and try out

Humans spend around 90% of their lifetimes inside closed rooms, so a good room climate is important. Air quality in particular has a huge impact on our health and well-being. Air tight building shells may well be superior in terms of energy, but they prevent natural air exchange. However, they can be fully automated using appropriate ventilation systems and sensors.

HINWIL/SWITZERLAND – Under the motto "Small devices, big impact", Belimo's trade fair exhibition booth at the ISH 2019 from 11.03.2019 to 15.03.2019 in Frankfurt am Main is all about products and solutions for the areas of heating, ventilation and air conditioning. Innovations and further developments from the Belimo product range will, of course, also be presented. Clearly, however, the focus this year will be on cross-sector applications that you can touch. In five different subject areas, visitors can integrate or exchange individual Belimo components and, with support from Belimo experts, experience which effects they have on the particular application.

The "air handling" application wall is all about optimum room air conditioning. Corresponding actuators, valves and sensors ensure precise control of ventilation systems, which reduces noise emissions and allows significant energy savings. "Water control" shows solutions for controlled water distribution and transparent monitoring in heating and cooling systems. In the field of "connectivity & air flow", visitors can obtain information on various options for connecting the Belimo components to a higher-level control and instrumentation system. Personal protection and the protection of material assets in buildings is demonstrated practically in an application with fire protection and the new smoke control damper actuators. The "room comfort" application wall shows how the sensors from Belimo rule out the over- or undersupply of terminal devices, guarantee the desired room comfort and thus have a great effect on peoples' well-being and productivity.



All products and HVAC applications from Belimo shown are future-orientated and fit perfectly together. They guarantee comfort, save energy and protect lives and property in case of fire. Intelligent and extremely easy to use, they also reduce installation and maintenance costs. ■

About Belimo: **www.belimo.com**

REHVA congratulates Jarek Kurnitski for his election as a Member of the Estonian Academy of Sciences!

REHVA would like to congratulate our Technology and Research Committee chair, **Jarek Kurnitski**, Professor of Energy Efficiency and Indoor Climate of Buildings and Director of the TalTech Department of Civil Engineering and Architecture. 20 researchers applied for the seven positions of academicians, and REHVA is very proud to have Jarek Kurnitski, as one of their elected members.

Having received an Estonian Science award, Jarek Kurnitski's research consists of finding solutions to building nearly zero-energy buildings by using old construction for renovation to be not only energy-efficient, but NZEB. Jarek Kurnitski was also the scientific leader of a family dorm renovation at the TalTech campus, as well as being named as the "TalTech researcher of the year".

The tasks of the elected academicians of the Estonian Academy of Sciences, are to represent important fields of science in public life in Estonia.

Changes in the REHVA Office staff

In 2019, REHVA says farewell to some colleagues and welcomes new ones. The responsibilities of our colleagues will also change. See below a summary of changes in our task and activities.

MATTEO URBANI – Assistant Project Engineer

- EU project implementation and management
- EU proposal writing
- Supporting REHVA technical seminars
- Technology and Research Committee (TRC) secretary, support of Task Forces, and technical publications

GIULIA MARENGHI – Project Communication Officer

- Financial and administrative management of EU projects
- EU project implementation - communication activities
- Events management
- Advertisements (phased out by 06/2019)
- REHVA promotional services (phased out by 06/2019)
- Secretarial support

REHVA

Federation of European Heating, Ventilation and Air Conditioning Associations

FATIMA AHMED – Publications, Marketing & Communication Officer

- REHVA website development, content and & social media management
- Events management and promotion
- REHVA Journal and publications - editorial assistance, production and marketing
- REHVA visual identity development and communication
- Publishing and Marketing Committee (PMC), Cooperation Group (COP) secretary

ANITA DERJANECZ – Managing Director

- REHVA office executive management
- REHVA legal representative
- Business development
- EU public affairs and advocacy
- REHVA Supporters' Liaison
- EU project development and implementation
- Supporters Committee (SC) secretary

REBEKA MARŠNJAK – EU Policy and International Relations Officer

- EU policy monitoring and analysis
- REHVA membership activities
- REHVA international relations, IEQ-GA secretariat
- MoUs follow-up coordination
- External Relations Committee (ERC) secretary

NATHALIE WOUTERS – Office and Membership Manager

- Office management, HR
- Membership liaison
- REHVA Student competition
- REHVA Awards
- REHVA Board meetings' secretary
- REHVA Annual meetings, General Assembly secretary
- Education and Training Committee (EC), REHVA Awards Committee secretary

Off the gas while maintaining existing CV installations, how?

The Netherlands, politics and, increasingly, the consumer is now also considering the above question. The current earthquake situation in Groningen due to the natural gas exploration has only accelerated this question. As a result, a natural gas connection for new homes was even banned as of 1 July 2018. This development has also ensured that the heat pump training courses are now overcrowded. Stichting MOED joined hands with Woonstichting Tiwos, entrepreneurs Durocan and The Netherlands knowledge institute ISSO is in cooperation with several partners and the social housing cooperation working to give a valid answer to the question 'How do we get rid of the gas while retaining existing heating installations'.

Solutions

For new construction projects, replacement techniques can be perfectly integrated, but for existing buildings this becomes more problematic. Installers have to deal with preconditions of the existing building. These are, for example, inadequate insulation, too small heating radiators, lack of underfloor heating, inadequate ventilation systems. It is often not financially and structurally possible to adjust these preconditions. Which solutions are achievable?

The rules of the game are to fit in the new installation as best as possible in the house with the existing installation with as few adjustments as possible. This means that the gas fired boiler is exchanged for the alternative heating system. The radiators, piping and ventilation remain intact. The goal of this project is to investigate which solutions there are more than to rigorously tackle a home.

Measurements

Social housing co-operation Tiwos has made three similar apartments available in Tilburg. In two of the homes two entrepreneurs will realise an alternative heating installation to get rid of the gas. The third home with a conventional combi boiler serves as a reference home. Foundation MOED takes care of the coordination and ISSO carries out measurements in collaboration with the Helicon Energy & Water program. They carry out measurements in every home measuring comfort, gas and electrical energy consumption.

Results

The project runs until the end of February 2019. The results will be published in April 2019 at www.isso.nl (in Dutch, but google translate could assist)

JAAP HOGELING
Manager, International standards at ISSO

Announcement for special Annual English Issue

A REHVA member from Czech Republic, Society of Environmental Engineering (STP, www.stpcr.cz/en), has published a special English Issue of their society professional Journal VVI of *Heating, ventilation and Sanitation*.

Within this journal issue, you can read detailed and updated news about the latest trends in HVAC as well as any new products, technology and other styles and techniques for efficient operations of buildings. You will also have the chance to gain knowledge and learn about the types of testing and measures needed to be analysed to "improve the quality of domestic production" and to push the profit of domestic products within foreign markets. The journal will also provide an insight of computer technology and the different types of methods to be used in environmental engineering.

Due to the high quality of the STP articles and their detailed news on the latest trends on HVAC, the REHVA Journal has published several translated STP articles within the last couple of years, therefore, we would strongly encourage our RJ readers to download this special issue.

For full-text PDF versions of the papers published in the journal, you can find this at the following link: http://www.stpcr.cz/?download=_/special/vvi_6_2018.pdf

Send information of your event to Ms Giulia Marenghi gm@rehva.eu

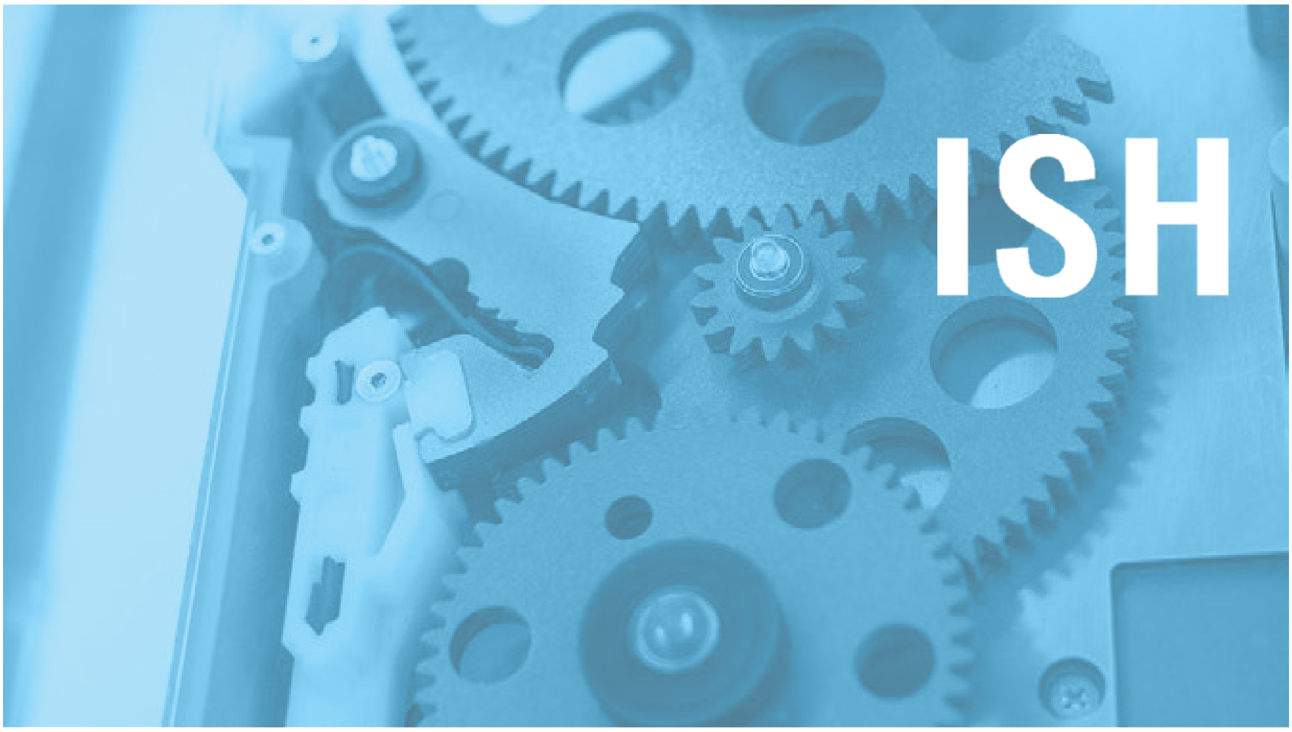
Events & fairs in 2019

Exhibitions 2019

27 February - 1 March	WSED 2019	Wels, Austria	www.wsed.at/en
28 February - 2 March	ACREX 2019	Mumbai, India	www.acrex.in
5-7 March	Futurebuild	London, UK	www.futurebuild.co.uk
1-5 April	BET - Building Energy Technologies 2019	Berlin, Germany	
17-20 April	teskon+SODEX 2019	Izmir, Turkey	http://www.teskonsodex.com/en
6-8 May	ISH China & CIHE	Beijing, China	https://ishc-cihe.hk.messefrankfurt.com/beijing/en.html
3-5 September	ISH Shanghai & CIHE	Shanghai, China	https://www.hk.messefrankfurt.com/content/ishs_cihe/shanghai/en/visitors/welcome.html
2-5 October	ISK-SODEX 2019	Istanbul, Turkey	www.sodex.com.tr/en

Conferences and seminars 2019

27 February - 1 March	WSED 2019 - European Energy Efficiency Conference	Wels, Austria	www.wsed.at/en/programme/european-energy-efficiency-conference.html
27-28 March	AIVC workshop	Dublin, Ireland	
8-10 May	CIAR - Congreso Iberoamericano de Aire condicionado y Refrigération	Santiago de Chile, Chile	
24-25 May	International Buildair Symposium	Hannover, Germany	
26-29 May	CLIMA 2019	Bucharest, Romania	www.clima2019.org/congress/
17-21 June	EUSEW	Brussels, Belgium	https://www.eusew.eu/
12-15 July	ISHVAC 2019 - 11th International Symposium of Heating, Ventilation and Air-Conditioning	Harbin, China	
24-30 August	ICR 2019 - 25th IIR International Congress of Refrigeration	Montreal, Canada	https://icr2019.org/
2-4 September	Building Simulation Conference 2019	Rome, Italy	www.buildingsimulation2019.org
5-7 September	IAQVEC 2019	Bari, Italy	www.iaqvec2019.org
26-28 September	Annual Meeting of VDI-Society for Civil Engineering and Building Services	Dresden, Germany	
15-16 October	AIVC 2019 Conference - From energy crisis to sustainable indoor climate	Ghent, Belgium	https://www.aivc2019conference.org/



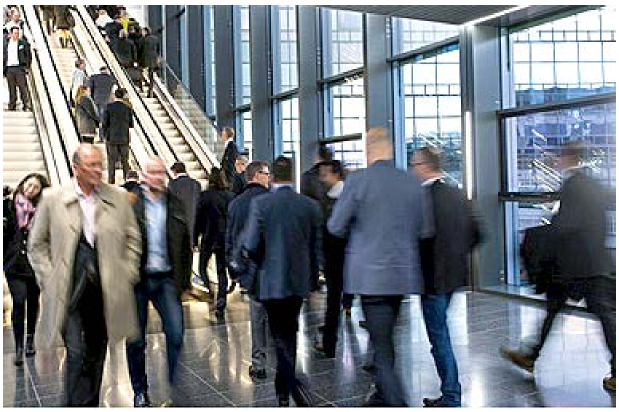
https://ish.messefrankfurt.com/

ISH 2019: the world's leading trade fair focusing on the responsible management of water and energy in buildings

ISH sets trends for sustainable heating and air-conditioning technology as well as intelligent home systems. ISH meets the growing demand for comfort, convenience, individualisation, well-being and aesthetics. Integrated solutions are able to cover all these requirements and make a decisive contribution to energy efficient and resource-friendly building systems.

Over 2,400 exhibitors, including all market leaders from home and abroad, launch their latest products, technologies and solutions onto the world market at ISH. ISH has, therefore, a leading role worldwide as the occasion per se when the sector comes together – 64 percent of the exhibitors and 40 percent of the around 200,000 visitors come from outside Germany.

From 2019 ISH is changing its sequence of days. In future, the event will begin on Monday. Next ISH will be held from **11 to 15 March 2019 (Monday to Friday)**.



ISH Energy: major platform for the groundbreaking building services technologies of tomorrow

The efficient use of energy is one of the most important topics of our times. ISH will be presenting the latest technologies and solutions for the challenges that arise from the need to protect both the climate and our natural resources. The **ISH Energy section of the show is the leading industrial exhibition for efficient heating and air-conditioning technology, combined with renewable energies**, and is thus the major platform for the groundbreaking building services technologies of tomorrow.

As the major vehicle for stimulus in the sector, ISH showcases the future developments in the **heating market**. In Halls 11 and 12, exhibitors will be showcasing their state-of-the-art modern heating technology and heating systems, from efficient heat generation to heat circulation and transfer. The 'Pumps' product group, together with other components of the central heating system – expansion vessels, stop-cocks, fittings and heating units - are all grouped together under the heading of 'Heat Distribution', in Halls 9.0 and 9.1.

The area covering **cooling and refrigeration, air-conditioning and ventilation technology** is showcased all together in the one place, in Hall 8. The focus, here, is on future-proof solutions for greater automation and convenience – with, at the same time, improvements in energy efficiency and increased use of renewable energies.

Intelligent building services technology is the key to improving energy efficiency, whilst at the same time increasing the degree of convenience and comfort. Home and building automation, energy management, together with monitoring, control and regulation technology, as well as testing equipment, are all located in Halls 10.2 and 10.3. This means that they are right at the heart of the ISH Energy section, since this is the segment that links all the technical trades.

REHVA at ISH 2019: come join our events and secure your free entrance ticket

REHVA will be present at ISH 2019 on Thursday, 14 March 2019, at hall 10.3– System Room, Building Automation and Energy Management for a **"REHVA-day"** rich of events: in the framework of the "Skills@ISH" events programme, REHVA invites you to attend its QUANTUM Project Workshop, a REHVA Seminar and a networking reHVAClub cocktail reception. Secure your free one-day ticket to come join us at ISH: contact Giulia Marenghi, Project Communication Officer (gm@rehva.eu), to obtain your free entrance voucher. ■

ISH World's leading trade fair
HVAC + Water
Frankfurt am Main, 11.–15. 3. 2019

futurebuild
05-07 March 2019 / ExCeL, London

REHVA is attending Futurebuild: join us in London

The future of **Energy**

REHVA is attending **Futurebuild** (**ExCel, London, 5-7 March 2019**): the exhibition, issued from the former Ecobuild Conference brand, is focused on showcasing the latest innovations, products and materials and sharing unrivalled insights to help building services professionals to tackle the biggest challenges facing the built environment industry.

You will find REHVA at the Knowledge Forum, a dedicated central forum that will bring together academia, universities, key professional bodies, partners and associations, across all built environment industries, with a common purpose of sharing knowledge. The Knowledge Forum is also the perfect venue to showcase the results of REHVA's European R&I projects: the QUANTUM Project workshop "**Quality management for building performance - Lighthouse examples and tools from the QUANTUM methodology**" will be held there on Tuesday, 5th March, from 15.00 to 16.10.

We are looking forward to meeting you at our booth, stand **D133** at the **Knowledge Forum**, from 5 to 7 March.

@FuturebuildNow /FuturebuildNow /FuturebuildNow /FuturebuildNow FuturebuildNow

CLIMA 2019

Built environment facing climate change

INVITATION

REHVA 13th HVAC World Congress
26 - 29 May, Bucharest, Romania

CLIMA 2019 organisers are very devoted to welcome you all in a wonderful Eastern Europe country-Romania, with very nice and talented people, eager to offer you an outstanding experience of lively and fresh "Carpathian Garden" feeling!

CLIMA 2019 organisers invite you to participate in this 13th REHVA World Congress, the leading international scientific congress in the field of Heating, Ventilating and Air-Conditioning.

Under the heading "BUILT ENVIRONMENT FACING CLIMATE CHANGE", the proposed main topics for the 13th CLIMA Congress will offer answers on the main challenges for the Building and HVAC&R industry and research communities.

How to:

- reduce the CO_2 emission due to the energy use of buildings and their systems,
- improve energy efficiency and energy production
- use of sustainable energy sources
- maintain or improve the indoor environmental quality in buildings.

Which concluded to the main topics:

1. Advanced HVAC&R&S Technology and Indoor Environment Quality
2. High Energy Performance and Sustainable Buildings
3. Information and Communication Technologies (ICT) for the Intelligent Building Management
4. Sustainable Urbanization and Energy System Integration

Some expected figures of CLIMA 2019 congress:

- up to **1000 attendees** (researchers, engineers, architects, students);
- up to **750 papers** (with a special care for the selection of those to be published in like Scopus or Web of Science indexed journals);
- more than **20 technical and scientific workshops**.

Early Birds do register before March 1st (early bird fee for total congress 396 € + VAT (students 144 € +VAT) see for details: www.clima2019.org/registration-fees ■

REHVA
Federation of European Heating, Ventilation and Air Conditioning Associations

UTCB Universitatea Tehnică de Construcții București

Asociația Inginerilor de Instalații din România AIIR

CLIMA 2019
Built environment facing climate change
REHVA 13th HVAC World Congress
26 - 29 May, Bucharest, Romania

The first set of CLIMA 2019 Workshops announced!

CLIMA 2019 continues with the longstanding tradition to offer several practical, interactive workshops beside the plenary paper sessions. The workshops are organised by REHVA and its international sister associations, European research and innovation projects, as well as REHVA supporter companies representing leading HVAC manufactures and service providers. We are happy to announce the first set of interesting workshops awaiting our CLIMA 2019 participants.

Title: NZEB concepts in Europe and Japan

Organisers: REHVA & SHASE

Chairs: Jarek Kurnitski, REHVA; Gyuyoung Yoon, SHASE

Speakers: Jarek Kurnitski, REHVA and Gyuyoung Yoon, SHASE (Chairs); Hideharu Niwa, SHASE

Short description: Recent developments of nearly zero and zero energy requirements in EU and Japan are discussed and possibilities to benchmark NZEB performance levels in different climates and countries will be analysed in more general. The aim is to show how energy performance requirements are set and how these can be compared so that climatic differences, national input data and calculation rules are taken into account.

Title: Evidence-based ventilation needs and development process of future standards

Organiser: REHVA & ISIAQ

Chairs: Jarek Kurnitski, REHVA; Pawel Wargocki, ISIAQ

Speakers: Jarek Kurnitski, REHVA and Pawel Wargocki, ISIAQ; Bjarne Olesen, William Bahnfleth

Short description: Recent research findings, their interpretation and meaning for ventilation system sizing is discussed with the aim to establish evidence-based design criteria of ventilation rates for residential and non-residential buildings. The workshop attempts to summarize existing evidence, possible knowledge gaps and to specify further actions what are needed to implement evidence-based ventilation rate values into future indoor climate standards such as EN 16798-1:2019 and possibly some other ventilation standards.

Title: Dissemination and roll-out of the set of EPB standards. Asking feedback from practitioners

Organiser: REHVA & EPB Center

Chairs: Jaap Hogeling, Dick van Dijk

Short description: The EPB Center (www.epb.center) has been set up to support the uptake of the (CEN and CEN ISO) Energy Performance of Buildings standards developed under EC Mandate M/480, by providing tailored information, technical assistance and capacity building services for involved stakeholders. The purpose of this workshop is to inform the participants about the ongoing activities, more importantly to interact and obtain feedback from professionals involved or interested in the EPB assessment and in the implementation of the related articles of the recently revised EPBD.

Title: From regular inspection to BACS supported HVAC system technical monitoring, commissioning and certification

Organiser: REHVA & eu.bac

Chairs: Atze Boerstra, REHVA; Peter Hug, eu.bac

Speakers: DG ENERGY (tbc); Bonnie Brooks - Siemens/eu.bac; Stefan Plesser, synavision; Cormac Ryan, CoPilot

Short description: This workshop will present the wide spectrum of tools supported by BACS to improve and optimize HVAC systems' performance and make it transparent to building owners and operators. Speakers will present requirements of the revised EPBD, discuss the role of BACS in ongoing commissioning with outlook to the future, present BACS supported technical monitoring tools and introduce the COPILOT commissioning certification scheme developed with contribution of REHVA Member Associations and other partners.

Title: Towards optimized performance, design, and comfort in hybridGEOTABS buildings

Organiser: hybridGEOTABS

Chair: Lieve Helsen, KULeuven

Speakers: Lieve Helsen, KULeuven; Eline Himpe, UGent; Ongun Berk Kazanci, DTU; Qian Wang, Uponor/KTH; Wim Boydens, Boydens Engineering.

Short description: HybridGEOTABS refers to the integration of GEOTABS (Geothermal heat pumps in combination with Thermally Activated Building Systems) with secondary heating and cooling systems. This technology offers huge potential to meet heating and cooling needs throughout Europe in a sustainable way, while providing a very comfortable conditioning of the indoor space. This workshop will discuss the effects of radiant heating and cooling systems on IEQ, as well as the proper design of hybridGEOTABS buildings.

Title: Building commissioning in Europe

Organiser: QUANTUM

Chairs: Stefan Plesser, Ole Teisen

Speakers: Stefan Plesser, IGS TU Braunschweig; Jan Mehnert, IGS; Ole Teisen, Sweco; Margot Grim, E7; Cormac Ryan, CoPilot

Short description: New buildings and deep retrofits with their sophisticated systems for heating, cooling and air conditioning are rather complicated technical systems. Especially, building automation and control systems have added complexity to building projects. As a consequence, the performance gap appeared. Quality management, a process of supporting the fulfilment of requirements, can solve this problem. The workshop will present the current stage of quality management for building performance. This workshop is part of the project '*QUANTUM - Quality management for building performance*' and has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 680529.

Title: Why people matter? Exploitation strategies for people-centred design

Organiser: TripleA-reno & MOBISTYLE projects

Chair: Dr. Simona D'Oca, Huygen Engineers & Consultants

Speakers: Dr. Simona D'Oca, Huygen Engineers & Consultants; Dr. Dan Podjed, Institute for Innovation and Development of the University of Ljubljana; Ana Tisov, Huygen Engineers & Consultants

Short description: the workshop is organised by the H2020 projects TripleA-reno and MOBISTYLE, which both adopted a people-centred approach to improve the performance of the European building stock reaching beyond the focus on technology-driven solutions. The workshop will introduce the TripleA-reno and MOBISTYLE open ICT solutions, followed by a dynamic interactive brainstorm session around the following questions: What problems can the gamified platforms and ICT solutions solve for the engineering branch? Why these open platforms are better than the existing ones? What results do these projects offer for engineers and manufacturers? Who are the users of these innovative solutions and how can we better deliver the tools to them?

Title: The Power of the Cloud

Organiser: Belimo Automation AG

Chair: Dr. Marc Thuillard

Speakers: Dr. Marc Thuillard, Dipl. Ing. Marc Steiner, Dipl. Ing. Forest Reider

Short description: This workshop presents how the power of the cloud can benefit the HVAC industry, by facilitating the exchange of information between stakeholders, it can affect the entire lifecycle of a building. The design, commissioning, operation and maintenance can leverage the cloud as a medium to store and share information, configure and monitor devices, and provide a gateway to integrate technologies. It provides a medium for transparency, intelligent monitoring, and optimization.

Title: The Value of Good Performance - How High-Performance Buildings Protect the Asset value and Increase your Bottom Line

Organiser: BRE- Building Research Establishment (BRE) UK Ltd.

Sponsor: BRE Global

Speakers: Dr. Andy Lewry and James Fisher, presenters of case studies (TBC)

Short description: The discussion would address questions such as: we have the ability to design good buildings and the knowledge to operate them in an effective and efficient manner – so why doesn't it happen? Why doesn't the design feed through to performance-in-use? "The performance gap", with increased energy usage of between 200-450%: what are causes and how can this be remedied? What is the effect on the asset and its value from poor performance? The second session will be a showcase for high performance buildings in Romania – Where 4 cases where presented and then the discussion on how the sustainable performance and certification was achieved.

Title: Costs and benefits of antibacterial filter and its effects on energy saving, human health and worker productivity

Organiser: Rhoss S.p.A

Sponsor: Rhoss S.p.A

Speakers: Leonardo Prendin - Marketing Director, Micaela Ranieri – Product Manager

Short description: The discussion would present *the results of a literature review aimed at exploring how to integrate the health and performance effects on building occupants into the economic benefits of the antibacterial filter. In detail, the research focuses on the methods used to evaluate costs and benefits produced by the application of a biocidal filter, comparing it with a traditional one, by means of computing both direct costs (related to hospitalization and antibiotic treatment) and indirect costs (mainly identified with the loss of working days). Therefore, this workshop will try to enhance the focus on energy technology developing an analysis of the impact on human health and employee performance*.

Title: Third-party confidence for building projects: Eurovent tools to deliver value

Organiser: EUROVENT CERTITA CERTIFICATION, PRODBIM, COPILOT

Sponsor: EUROVENT CERTITA CERTIFICATION

Speakers: Erick Melquiond - President of Eurovent Certita Certification; Thibaud De Loynes -Project Director of Prodbim; Cormac Ryan -Project Director of Copilot

Short description: As quality is critical to risk management, Eurovent Certita Certification have developed a portfolio of solutions to help you derisk your products and projects. Third party certification provides the best assurance that "you get what it says on the box". This reassurance adds value as it de-risks products and projects. Eurovent offers third party certification of HVAC products and projects. They cover the entire lifecycle of HVAC from manufacture to installed operation.

The workshop will introduce you to:

1. ECP certification programme: focus on Indoor Air Quality
2. HVAC Products data from PIM to BIM: PRODBIM
3. The installation and operation of HVAC equipment: COPILOT Building Commissioning Solutions

Title: Energy renovation of building stock towards nZEB levels: How to prepare the market for the challenge?

Organiser: Fit-to-nZEB and iBRoad projects, Grundfos Pompe Romania

Sponsor: Fit-to-nZEB and iBRoad projects, Grundfos Pompe Romania

Speakers: Horia Petran, INCD URBAN-INCERC & Cluster Pro-nZEB
Dragomir Tzanev (Eneffect), Octavian Serban (Grundfos Pompe Romania)

Short description: *The workshop is organised by the H2020 projects iBRoad (Individual Building Renovation Roadmaps) and Fit-to-NZEB (…) together with Grundfos Romania representing the BetterHome initiative. The workshop focuses on developing and combining effective tools to facilitate deep energy renovation of existing building stock at high performance levels in order to support the achievement of decarbonising targets for 2050.*

CLIMA 2019 - Important dates and deadlines

REHVA Annual Meeting	May 24-26 2019
REHVA World Congress CLIMA 2019 & Exhibition	May 26-29 2019
Additional social programme	May 29-31 2019

You can find more details on the event website www.clima2019.org

or ask for more information at our e-desk: info@clima2019.org.

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EUROPEAN GUIDEBOOKS

VISIT REHVA eSHOP

No.01: DISPLACEMENT VENTILATION IN NON-INDUSTRIAL PREMISES
Håkon Skistad (ed.)
Elisabeth Mundt, Peter V. Nielsen, Kim Hagström, Jorma Railio

No.02: VENTILATION EFFECTIVENESS
Elisabeth Mundt (ed.)
Hans Martin Mathisen, Peter V. Nielsen, Alfred Moser

No.03: ELECTROSTATIC PRECIPITATORS FOR INDUSTRIAL APPLICATIONS
Kjell Porle (ed.)
Steve L. Francis, Keith M. Bradburn

No.04: VENTILATION AND SMOKING
Håkon Skistad, Ben Bronsema (eds.)

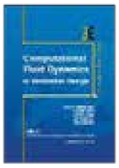
No.05: CHILLED BEAM APPLICATION GUIDEBOOK
Majia Virta (ed.)
David Butler, Jonas Gräslund, Jaap Hogeling, Erik Lund Kristiansen, Mika Reinikainen, Gunnar Svensson

No.06: INDOOR CLIMATE AND PRODUCTIVITY IN OFFICES
Pawel Wargocki, Olli Seppänen (eds.)
Johnny Andersson, Atze Boerstra, Derek Clements-Croome, Klaus Fitzner, Sten Olaf Hanssen

No.07: LOW TEMPERATURE HEATING AND HIGH TEMPERATURE COOLING
Jan Babiak, Bjarne W. Olesen, Dušan Petráš

No.08: CLEANLINESS OF VENTILATION SYSTEM
Pertti Pasanen (ed.)
Birgit Müller, Rauno Holopainen, Jorma Railio, Harry Ripatti, Olle Berglund, Kimmo Haapalainen

No.09: HYGIENE REQUIREMENT FOR VENTILATION AND AIR CONDITIONING
Based on VDI 6022



No.10: COMPUTATIONAL FLUID DYNAMICS IN VENTILATION DESIGN
Peter V. Nielsen (ed.)
Francis Allard, Hazim B. Awbi, Lars Davidson, Alois Schälin

No.11: AIR FILTRATION IN HVAC SYSTEMS
Jan Gustavsson (ed.)
Alain Ginestet, Paolo Tronville, Marko Hyttinen

No.12: SOLAR SHADING
Wouter Beck (ed.)
Dick Dolmans, Gonzague Dutoo, Anders Hall, Olli Seppänen

No.13: INDOOR ENVIRONMENT AND ENERGY EFFICIENCY IN SCHOOLS - PART 1 PRINCIPLES
Francesca R. d'Ambrosio Alfano (ed.)
Laura Bellia, Atze Boerstra, Froukje van Dijken, Elvira Ianniello, Gino Lopardo, Francesco Minichiello, Piercarlo Romagnoni, Manuel C. Gameiro da Silva

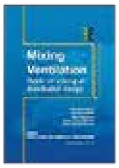
No.14: INDOOR CLIMATE QUALITY ASSESSMENT
Stefano P. Corgnati, Manuel C. Gameiro da Silva (eds.)

No.15: ENERGY EFFICIENT HEATING AND VENTILATION OF LARGE HALLS
Karel Kabele (ed.)
Ondřej Hojer, Miroslav Kotrbatý, Klaus Sommer, Dušan Petráš

No.16: HVAC IN SUSTAINABLE OFFICE BUILDINGS
Majia Virta (ed.)
Frank Hovorka, Andrei Litiu, Jarek Kurnitski

No.17: DESIGN OF ENERGY EFFICIENT VENTILATION AND AIR-CONDITIONING SYSTEMS
Nejc Brelih (ed.)
Olli Seppänen, Thore Bertilsson, Mari-Liis Maripuu, Hervé Lamy, Alex Vanden Borre

No.18: LEGIONELLOSIS PREVENTION IN BUILDING WATER AND HVAC SYSTEMS
Sergio La Mura, Cesare M. Joppolo, Luca A. Piterà (eds.)
Jean Pierre Angermann, Mark Izard



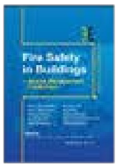
No.19: MIXING VENTILATION
Dirk Müller (ed.)
Claudia Kandzia, Risto Kosonen, Arsen K. Melikov, Peter V. Nielsen

No.20: ADVANCED SYSTEM DESIGN AND OPERATION OF GEOTABS BUILDINGS
Franziska Bockelmann, Stefan Plesser, Hanna Soldaty

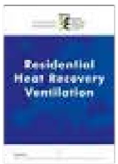
No.21: ACTIVE AND PASSIVE BEAM APPLICATION DESIGN GUIDE
REHVA-ASHRAE joint publication

No.22: INTRODUCTION TO BUILDING AUTOMATION, CONTROLS AND TECHNICAL BUILDING MANAGEMENT
Andrei Litiu (ed.)
Bonnie Brook, Stefano P. Corgnati, Simona D'Oca, Valentina Fabi, Markus Keel, Hans Kranz, Jarek Kurnitski, Peter Schoenenberger, Roland Ullman

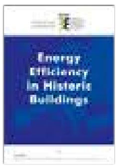
No.23: DISPLACEMENT VENTILATION
Risto Kosonen (ed.)
Arsen K. Melikov, Elisabeth Mundt, Panu Mustakallio, Peter V. Nielsen



No.24: FIRE SAFETY IN BUILDINGS
Othmar Brändli, Rainer Will (eds.)
Thomas Winkler, Bernd Konrath, Jörg Reintsema, Frank Lucka, Paul White, Grzegorz Sypek, Valery V. Kholshchevnikov, Dmitry Samoshin



No.25: RESIDENTIAL HEAT RECOVERY VENTILATION
Jarek Kurnitski (ed.)
Martin Thalfeldt, Harry van Weele, Macit Toksoy, Thomas Carlsson, Petra V. Bednarova, Olli Seppänen



No.26: ENERGY EFFICIENCY IN HISTORIC BUILDINGS
Francesca R. d'Ambrosio Alfano, Livio Mazzarella (eds.)