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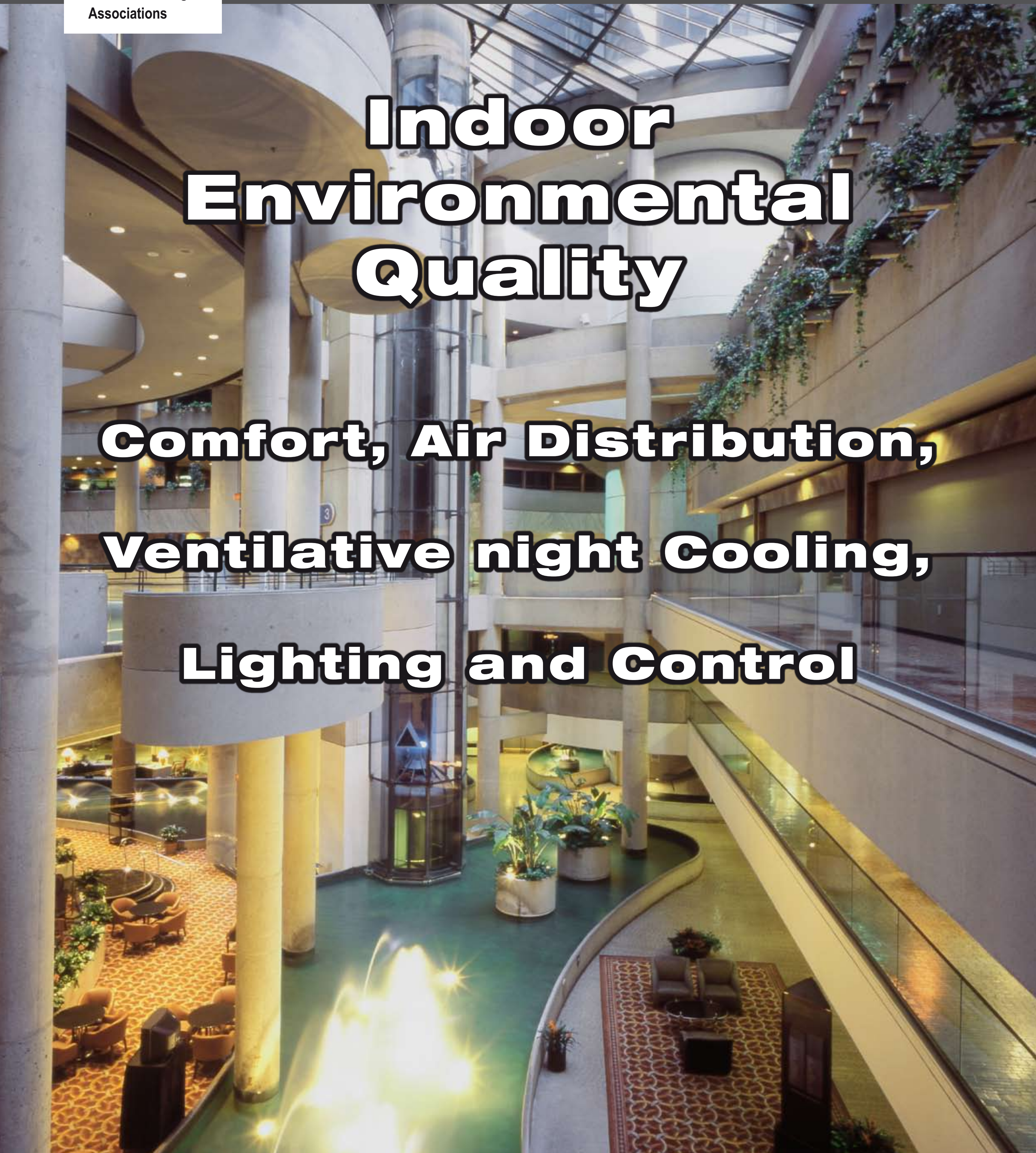

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Indoor Environmental Quality needs a multidisciplinary approach

JAAP HOGELING
Editor-in-Chief

Indoor Environmental Quality (IEQ) is the main theme of this issue. No surprise given the earlier announced participation of REHVA in the new international network organisation Indoor Environmental Quality-Global Alliance (IEQ-GA) (see page 62). The articles in this REHVA Journal reflect that many disciplines are needed to guaranty a high or acceptable IEQ.

The impact of energy saving measures on the IEQ is the main background of several articles. Improved Energy Performance (EP) and improved IEQ can go hand in hand. CO_2 controlled ventilation, better air distribution systems, a design tool for night ventilation are good examples. Two articles on new EPB-standards on emitters ("emitter" efficiency) and control of fans give insight how these standards support both: EP and IEQ.

The article on observed IEQ in Dutch homes shows that we have to invest more in the quality of works and clarity of the building regulation, this was also the main focus of our last REHVA Journal, we as professionals know how to design but are not always able to perform in practise. Better QA and commission are to be required by our clients and should be part of our building regulation.

In more special cases more research in the relation between sleep performance and IAQ (CO_2 related) is needed to support the default requirement as stated in the prEN16798-1 "Indoor environmental input parameters for the design and assessment of energy performance of buildings". This standard indicates that Category I: Design ΔCO_2 concentration for bedrooms of 380 ppm above outdoors, is needed for people in the category of "… recommended for spaces occupied by very sensitive and fragile persons with special requirements like some disabilities, sick, very young children and elderly persons, …". People suffering from Alzheimer, or another form of dementia, may have lost an adaptive response to high CO_2 levels and can react physically more intense and already at relatively low ΔCO_2 levels of about 550 ppm (Bedrooms Class II).

Sometimes reported research may lead to confusion as happened with an article reporting about women requiring higher temperatures when mechanical cooling is effective under summer conditions. A clear reaction from Bjarne Olesen clarifies this being a wrong conclusion. To say it short: there are differences in appreciation of the indoor temperature but they are almost entirely related to the difference in clothing level. Complains from the female population about a low temperature in offices in the summer are not uncommon but can only be avoided if we normalise the clothing levels of both sexes or give the temperature control to the persons with the lowest clo-levels (which might save cooling energy).

Page 71 is reporting the current status of the EPB-standardisation. **Important to read!** Almost all standards passed the enquiry. The Overarching Standard prEN-ISO/DIS 52000-1 "Energy performance of buildings — Overarching EPB assessment — Part 1: General framework and procedures" replacing the prEN15603 is now out for enquiry. This draft has been developed by CEN, and processed under the CEN lead as defined in the Vienna Agreement. This draft is submitted to the ISO member bodies and to the CEN member bodies for a parallel 3 month enquiry. It is important that all National Standard Bodies are aware of this pending enquiry and vote before the closing date of Friday November 27, 2015. ■

Monitoring the energy- & IAQ performance of residential ventilation systems

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Long-term monitoring studies show that there are large differences in the IAQ- and energy performance of code compliant residential ventilation systems. Existing legal framework and assessment tools do not suffice to ensure the IAQ and properly asses the energy performance of ventilation systems.

Keywords: Monitoring, Residential Ventilation Systems, IAQ-performance, Energy performance.

MONICAIR

MONICAIR --MONItoring & Control of Air quality in Individual Rooms-- is a precompetitive field research project of a broad consortium of Dutch ventilation unit manufacturers and research institutes, supported by the Dutch government. The aim is to investigate the indoor air quality (IAQ) performance and energy characteristics of ten different mechanical ventilation solutions in dwellings that meet strict air-tightness standards and comply with current building regulations. Over a full year 62 residential dwellings were monitored, with in each habitable room sensors for occupancy, CO_2, relative humidity and air temperature. The power consumption of the mechanical ventilation units were also continuously monitored.

Key question the MONICAIR-consortium wanted to answer is "How well do code compliant ventilation systems perform in terms of IAQ and energy consumption in well insulated and air tight dwellings *in real life,* and how can their performance be further improved?" Past research has focussed on compliance with standards at nominal conditions -- and improvements are certainly necessary there [1] – but research on IAQ and energy performance of code compliant systems in real life conditions is scarce [2,3]. While housing stock is being improved in terms of insulation and air tightness as we speak, we do not know if ventilations systems perform sufficiently.

Selection of ventilation systems and dwellings

The manufacturing partners in the MONICAIR consortium produce both type C (MEV) and type D (MVHR) ventilation systems. Most commonly used in the Netherlands is ventilation system type C (mechanical extraction in wet rooms combined with natural air supply vents in habitable rooms). Ventilation systems type D (mechanical air extraction and mechanical supply) are applied in the new built sector when the budget allows for more expensive ventilation systems. Both types of ventilation systems are selected for the monitoring study, both with their specific variants and combinations as described in **Table 1**. The table describes per type of ventilation system 1) the air exchange provisions in both the wet rooms (bathroom, kitchen, toilets) as well as the habitable rooms (living room, bedrooms), 2) whether heat recovery is applicable and 3) what type of controls are used for the exhaust and supply provisions. The system type numbers refer to classification used in the Netherlands Standard NEN 8088-1, 2011 [4].

Selecting and finding suitable and comparable dwellings that also comply with the air tightness requirements ($q_{v;10} \leq 1.0$ dm³/s.m²) proved to be challenging and could not have been done without the aid of the housing corporations. Not only the air tightness requirement, but also finding inhabitants that were prepared to allow sensors being installed in all rooms that monitor the IAQ and their behaviour for more than a year was very difficult. Eventually 62 families were prepared to make their dwelling available for the MONICAIR project. Before the start of the actual monitoring, all ventilation systems were checked and adjusted to the latest building code requirements, thus securing correct system specifications and ensuring that possible design- or installation errors do not influence the performance.

Data monitoring system

In every dwelling of the MONICAIR project the following sensors were installed:

- CO_2, RH (Relative Humidity) and air temperature sensors in all habitable rooms (living room, kitchen, bedrooms, study and utility room (if applicable). The sensors were mounted in the middle of the room approximately 1.5 m above the floor, away from doors and windows; the sampling frequency was set at five minutes.
- Occupancy sensors (PIR-type) in all habitable rooms

Table 1. Type of ventilation systems selected for MONICAIR.

System type		Section of house that is served	Air exchange provisions			Controls	
			Exhaust	Supply	Heat Rec.	Exhaust	Supply
	A.	Whole house	Nat. extraction in wet-rooms	Stnrd nat.supply vents in hab.rooms	No	No Control	Manual
Type C Systems	C.1	Whole house	Mech. extraction in wet-rooms	Stnrd nat.supply vents in hab.rooms	No	Manual 3-pos. switch	Manual
Type C Systems	C.2c	Whole house	Mech. extraction in wet-rooms	Wind contrl. nat. supply in hab.rooms	No	Manual 3-pos. switch	Manual
Type C Systems	C.4a	Whole house	Mech. extraction in wet-rooms	Wind contrl. nat. supply in hab.rooms	No	CO_2-sensor in living room	Manual
Type C Systems	C.4c	Whole house	Mech. extraction in all rooms	Wind contrl. nat. supply in hab.rooms	No	CO_2/ RH cntrl in all hab.rooms	Manual
Type D Systems	D.2	Whole house	Mech. extraction in wet-rooms	Mech. supply in hab.rooms	Yes	Manual 3-pos. switch	
Type D Systems	D.5a	Whole house	Mech. extraction in wet-rooms	Mech. supply in hab.rooms	Yes	Manual 3-pos. switch with CO_2-contrl in 2 zones	
Type D Systems	D.5b	Whole house	Mech. extraction in all rooms	Mech. supply in hab.rooms	Yes	CO_2 and RH -controlled ventilation in all rooms	
Type D Systems	D.x	Whole house	Mech. extraction in all rooms	Mech. supply in con.spaces	Yes	CO_2- & RH control in all hab. rooms	
Comb. of systems	X1/C	Living section: D	Mech. extraction in hab.rooms	Mech. supply in hab.rooms	Yes	CO_2 and RH -controlled ventilation in living room	
Comb. of systems		Sleeping section:C.2c	Mech. extraction in wet-rooms	Wind contrl. nat. supply in bedrooms	No	Manual 2-pos. switch	Manual
Comb. of systems	X1/A	Living section: D	Mech. extraction in hab.rooms	Mech. supply in hab.rooms	Yes	CO_2 and RH -controlled ventilation in living room	
Comb. of systems		Sleeping section: A	Nat. extraction in wet-rooms	Wind contrl. nat. supply in bedrooms	No	No control	Manual

- RH-sensor in the bathroom with a sampling frequency of five minutes
- Sensors monitoring the power consumption of the mechanical ventilations units and kitchen hoods.
- Meteorological data on outdoor temperature, relative humidity, wind speed, wind direction and air pressure of the most nearby weather stations was gathered.

Per cluster of dwellings all data of each house is gathered through rf-communication and stored on a local PC. Through an FTP connection the data stored on local PCs is regularly copied onto the centralized MONICAIR SQL database.

Data analyses

For a period of more than a year large amounts of data were gathered about the ventilation systems and their real life performance on indoor air quality and energy consumption, as well as data on consumer behaviour regarding the preferred temperature per habitable room, operation of ventilation units, use of kitchen hoods, and hot water consumption pattern. With these data various angles of data analysis are possible. Given the focus and resources related to the first part (WP1a) of the MONICAIR project, the analysis here is restricted to the IAQ- performance and the energy performance during heating season.

Indicator for the IAQ performance

To assess the IAQ performance of ventilation systems the measured CO_2-concentration in the individual habitable rooms is used as leading parameter. The CO_2-concentration is generally accepted as the key indicator for the existing ventilation rate per person during presence [5] and consequently for the occurring IAQ levels. The following procedure is used to assess the IAQ in the various habitable rooms:

a) Determine for each habitable room in each dwelling the number of hours per day that the CO_2-concentration is above 1200 ppm in unit [hours/day]. The limit value of 1200 ppm corresponds to the IAQ category IV (= the lowest IAQ level) as described in prEN 16798-1:2015 [6].
b) Determine for each habitable room in each dwelling the average concentration with which the CO_2-limit of 1200 ppm is exceeded in unit [ppm/h].
c) Calculate the CO_2-excess dose per heating season in kppmh by multiplying the outcome of a) with the outcome of b) and then multiplying the result with the number of days in a heating season (212) and dividing it by 1000 to convert the ppm-figure to kppm.
d) Sum up all the CO_2-excess doses per habitable room per dwelling and divide it with the number of inhabitants of that specific dwelling to determine the average achieved IAQ level per person.

Indicator for the Energy performance

The indicator for the Energy performance of ventilation systems is obtained using the following procedure:

I) Determine the *hourly* thermal energy losses for mechanical ventilation on the basis of the hourly average ventilation rate and the hourly average differences between indoor and outdoor temperature and humidity. For systems with heat recovery this figure is corrected with an average real-life efficiency of 80%.
II) Calculate the *daily* thermal energy losses by adding up the hourly averages and relate it to the daily av. temperature difference between in- and outdoors ($\Delta T_{in\text{-}out}$) of that specific day.
III) From II) the daily average energy loss is derived for the heating season average temperature difference $\Delta T_{in\text{-}out}$ of 13°C (being the average indoor temperature of 19°C minus average outdoor heating season temperature in the Netherlands of 6°C).
IV) The yearly primary energy consumption is determined by multiplying the outcome of III) with the number of days in an heating season (212), dividing it by the average heating system efficiency of 85% and adding up to this figure the total power consumption of all ventilation units during heating season, after converting it to primary energy.
V) Divide the outcome of IV) with the total heated surface area of the dwelling to obtain the average primary energy consumption of the mechanical ventilation system per m² during heating season.

Note 1: The calculations for a) and b) are made with a resolution of five minutes and then summarised to obtain either the number of hours per day or the excess value per hour.
Note 2: The calculation procedure for the IAQ-performance is comparable to the methodology used in the declaration of equivalence of the VLA [7] for determining the Air Quality Index.
Note 3: Energy consumption related to cross ventilation (air that enters the dwelling through infiltration or airing on one façade and leaves through another façade) is not included; also internal and solar gains are not included in this assessment of the energy performance.

Results

The results on CO_2-concentrations and energy consumption are summarized in **Figure 1**. In the graph the diamond markers represent system averages on CO_2-excess dose per person (product of duration and amount of excess above 1200 ppm during heating season). The vertical lines represent the standard deviation of a group of ventilation systems (both refer to the vertical axis of the graph). On the horizontal axis the system averages for energy consumption of ventilation systems in total primary energy per m² heated surface during heating season is indicated. The standard deviation on energy consumption is limited and therefore not displayed in the graph (see lit.1 for further explanation of ventilation system types).

For further details on the results of the monitoring study see lit. [8] and [9].

Apart from ventilation system A (which was added at the request of housing associations because they represent a significant share of the housing stock) all other ventilation systems are code compliant. The large variations both in CO_2-excess dose per person and in the standard deviation illustrate that there are considerable differences in the IAQ-performance of code compliant ventilation systems. The large extent of these differences in achieved air exchange rates was not fully anticipated, especially given the fact that all ventilation systems achieved overall air exchange rates well above 10 l/s per person, which complies with the highest IAQ category (prEN 16798-1:2015) . The data in fact illustrates to what extent the ventilation systems are capable of achieving the requested air exchange rates per person in the various habitable rooms. Ventilation systems that apply a mechanical component in the air exchange provisions in habitable rooms (either supply, exhaust or both) perform significantly better in that respect than systems with only natural air exchange provision in habitable rooms. Both on CO_2-excess dose per person and on its standard deviation the systems with a mechanical component in the habitable rooms outperform the systems with only natural provisions. The latter systems show large variations in their IAQ-performance due to the fact that they have insufficient control over the air exchange in the habitable rooms. These systems would require frequent and targeted interventions from active occupants, but the monitoring results show that this type of behaviour was not exhibited.

Systems with a mechanical air exchange component in the habitable rooms, to a lesser extent, also vary in their IAQ-performance due to the fact that some units or individual fans are temporary switched off because of noise or draught.

In respect to the energy performance of the investigated ventilation systems, it may be concluded that the real life energy consumption is not in line with the results of the EPBD calculation methods. The real life measurements result in a different relative ranking than according to EPBD assessment methods. This is mainly caused by differences in the assumed and real life system operation. Apart from that, there are ventilation systems with a certain type of automated CO_2-control, that actually perform considerably worse in real life than according the assessment methods. Again, the assumptions on the effect of the concerning CO_2-control on which the EPBD assessment is based, differs from real life operation.

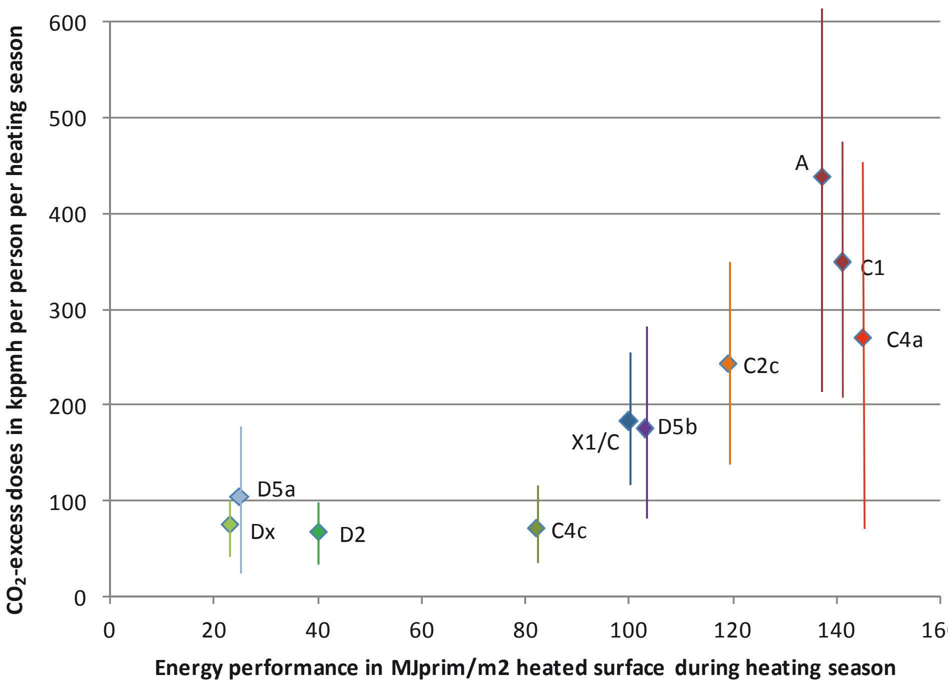

Figure 1. Ventilation system averages and standard deviation on CO_2-excess dose and energy performance.

Conclusions

Clearly the (implicit) assumption that all code compliant ventilation systems perform comparably on IAQ cannot be substantiated by these findings. There are significant differences related to the IAQ-performance that are currently not recognized. The existing legal framework does not require any assessment of the IAQ-performance. Only the energy performance of the ventilation system is assessed. But what is the meaning is of an assessment of the energy performance when the performance on its primary function is not known? On top of that this long-term monitoring study shows that the real life energy-performance of ventilation systems is not in line with the results of the EPBD assessment methods.

Current legal framework and assessment tools therefore give an incorrect representation and ranking of code compliant ventilation systems and unjustly favour certain systems. Further refinement of the legal framework and performance assessment tools will be necessary to correct this. Only with a proper assessment of the IAQ- and energy performance a true representation of the systems can be given. ■

Acknowledgements

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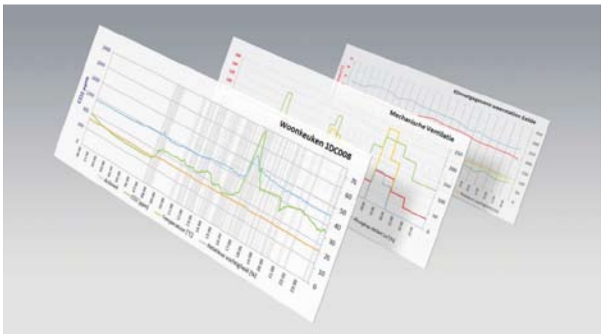

MONICAIR

The following parties participate in the MONICAIR consortium:

Manufacturers:
- Brink Climate Systems BV
- ClimaRad BV
- Honeywell, HCCP
- Itho Daalderop Nederland BV
- Zehnder Group Nederland BV

Research and consultancy agencies:
- Nieman Raadgevende Ingenieurs BV
- VHK (Van Holsteijn en Kemna) BV

Knowledge and research institutes:
- TNO
- TUDelft –OTB

Website : www.monicair.nl
Project leader : Rob van Holsteijn

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Are women feeling colder than men in air-conditioning buildings?

Recently the international media like in USA, Canada, UK, Denmark, Germany etc. has been discussing the issue of differences between men and women regarding thermal comfort and the preferred room temperature. This presentation will discuss the issue of thermal comfort and the existing knowledge on the influence of gender.

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Results

The Dutch study

In their paper, researchers Boris Kingma and Wouter van Marken Lichtenbelt (2015) state, "Indoor climate regulations are based on an empirical thermal comfort model that was developed in the 1960s. Standard values for one of its primary variables—metabolic rate—are based on an average male, and may overestimate female metabolic rate by up to 35 percent". According to their experiment with 16 females performing sedentary work, they measured a significant lower metabolic rate for women than the metabolic rate for a "standard man", which they found in literature. This will, according to the authors, result in a higher preferred room temperature for women.

The existing literature

Fanger (1982), Fanger and Langkilde (1975), and Nevins et al. (1966) used equal numbers of male and female subjects, so comfort conditions for the two sexes can be compared. The experiments show that men and women prefer almost the same thermal environments. Women's skin temperature and evaporative loss are slightly lower than those for men, and this balances the somewhat lower metabolism of women. The reason that women often prefer higher ambient temperatures than men may be partly explained by the lighter clothing normally worn by women.

Looking at the existing literature (Karjalainen 2011) clearly more than half of the laboratory and field studies have found that females express more dissatisfaction than males in the same thermal environments. A Meta-analysis shows that females are more likely than males to express thermal dissatisfaction (ratio: 1.74, 95% confidence interval: 1.61–1.89). Females are more sensitive than males to a deviation from an optimal temperature and express more dissatisfaction, especially in cooler conditions.

Study	Sex	Preferred ambient temp. (°C)	Mean skin temp. at comfort (°C)	Evaporative weight loss during comfort ($g/m^2/hr$)	Number of subjects
Nevins et al. 1966 Fanger 1982 (both studies combined)	*Males*	25.4			488
	Females	25.8			488
Fanger & Langkilde 1975	*Males*	25.0	33.6	19.5	32
	Females	25.1	33.4	16.6	32
Comfort equation Fanger 1982		25.6			

Subjects were tested under the following standardized conditions: sedentary activity: light clothing 0.6 clo, rel. velocity <0.1 m/s, rel. humidity 50%, mean radiant temperature = air temperature.

Figure. Preferred ambient temperatures (air ~operative temperature) in laboratory test with the same sedentary activity level (1-1.1met) and the same clothing (~0.6 clo) for all subjects.

However, most studies found no significant difference in neutral temperatures between the genders as also shown in the basic studies in the table.

The existing standards

Existing international standards like ISO EN7730, EN15251 and ASHRAE 55 are based on the same basic studies described above. These standards do not specify different room temperatures for women and men when doing the same work and dressed in similar clothing.

Contrary to what has been suggested, these standards are not devised exclusively for men. They are based on extensive laboratory studies of both men and women wearing the same clothing, engaged in the same activity, and exposed to a wide variety of thermal conditions (air temperature, surface temperature, humidity and air movement). Metabolic heat production was simply a proxy for the kind of activity. And while it is one of many variables used in an empirical formula, it is not an input to a heat balance equation, as one might find in a thermo-physiological model (which exists, but was not the basis for the standards)

Type of building/ space	Category	Operative temperature for energy calculations °C	
		Heating (winter season), ~ 1,0 clo	Cooling (summer season), ~ 0,5 clo
Offices and spaces with similar activity (single offices, open plan offices, conference rooms, auditorium, cafeteria, restaurants, class rooms, Sedentary activity ~1,2 met)	I	21.0 – 23.0	23.5 – 25.5
	II	20.0 – 24.0	23.0 – 26.0
	III	19.0 – 25.0	22.0 – 27.0
	IV	17.0 – 26.0	21.0 – 28.0

A 2009 study in the journal Indoor Air examined temperatures in 100 office buildings and found the average indoor air temperature in the summer was not only cooler than recommended and cooler than the established comfort zone for office workers about 22.9°C, it was cooler even than the temperature set in the winter to about 23.4°C .

In the main studies, where they did the same sedentary work and wore the same type of clothing, there were no differences between the preferred temperature for men and women. So the researchers' finding of a lower metabolic rate for females will not influence the recommended temperatures in the existing standards. Also their study is not conclusive. They only studied 16 females at a sedentary activity. They should also have studied 16 men at the same activity to be able to compare. The reason why we, in some field studies, find that women prefer higher room temperature than men is attributed to the level of clothing. Women adapt better their clothing to summer conditions while men are still wearing suit and tie. So if the thermostat is set to satisfy the men, the women will complain about being too cold. In the standard, this adaption of clothing to summer is taken into account so if the standard is followed the women would be satisfied; but maybe not the men.

Why are air-conditioned buildings often too cold?

There can be many reasons why buildings are often too cold. Here are some possible explanations:

- Some buildings overcool air to reduce humidity.
- Some Air-Conditioning systems do not work well under part load conditions
- People think the air conditioning isn't working if it's not a little cold
- Being able to make people feel cold in the summer is a sign of power and prestige
- Men stuffed into heavy suits may control the thermostat
- Energy is too cheap giving people little incentive to save on the air conditioning

Conclusions

The extensive studies, which form the basis for existing international standards for the thermal environment (ANSI/ASHRAE Standard 55, ISO EN 7730, EN 15251) included equal amount of male and female subjects and no difference in preference was observed. Despite this fact, we may often find women are colder during summer time in air conditioned offices. This can however, in most cases be attributed to the difference in clothing level between men and women. It seems the thermostat settings in summer in air-conditioned buildings are often too low and below the recommended range in existing standards. ■

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Air distribution in a classroom

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One main factor for inadequate indoor air quality in classrooms is the design of air distribution. This paper presents comparison of the indoor air quality in the classroom in summer and winter conditions with most used mechanical air distribution systems. Indoor air quality in the occupied zone is best with displacement ventilation. Air distribution with supply air grille gives uniform conditions, but it can cause problems due to too high velocities in some locations. Supply air jet from perforated duct diffuser and from ceiling diffuser tends to be carried along thermal plumes from the heat loads.

The performance of four typical air distribution methods in winter and summer conditions with different occupancy ratio was studied in a mock-up classroom (Kosonen and Mustakallio 2010) and was visualized with CFD- simulations (Mustakallio and Kosonen 2011).

The measured mock-up room (6.0 m × 4.4 m × 3.3 m (H)) was half of a actual classroom (floor area 6 × 10 m²). The simulated window size was 4.4 m × 1.4 m (H). The air distribution was identified at three different load conditions: summer conditions with maximum occupancy (cooling load of 54 W/m²) and partly occupied (cooling load of 40 W/m²) and winter conditions with partly occupied room (heating demand of 38 W/m²). The room was ventilated at 6 l/s per person in all cases. In the winter condition, an underneath radiator was introduced to prevent draft risk of cold window surface. The heat balance and breakdown of the loads in the measurement cases are presented in **Table 1**.

Utilizing dynamic energy simulations, room air temperatures in winter and summer are set to be corresponding average conditions in Scandinavian classrooms. In laboratory conditions, heat losses were supplemented by heat losses through structures, if necessary, to attain the room air temperature required.

The performance of four typical air distribution methods was studied: a corridor-wall grille, a ceiling diffuser in the middle of the ceiling, a perforated duct diffuser in the middle of the ceiling, and two displacement ventilation units in the floor corners (**Fig. 1**). The supply units were selected based on the throw pattern analysis. The supply airflow rate was 90 l/s (6 l/s per person) in all cases (half classroom). The supply air temperatures were 17°C and 18°C in summer and winter cases respectively. The room air temperatures were 26°C and 24°C in summer case with full and half occupancy respectively. In winter conditions, the room air temperature was set to be 21°C.

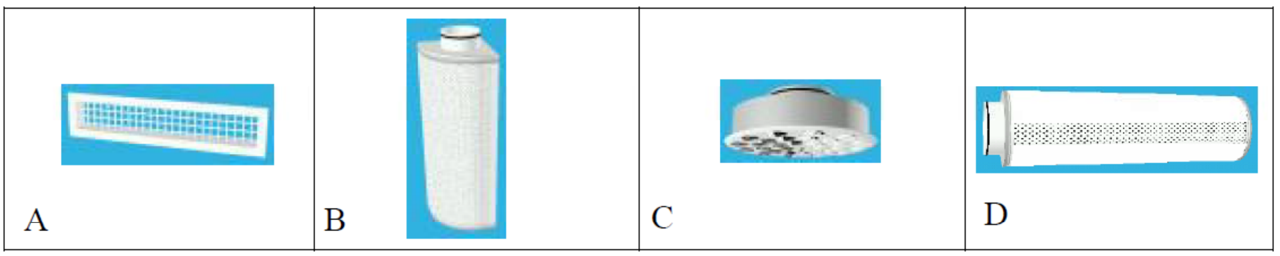

Figure 1. Air distribution schemes: A) Wall grille, B) Displacement ventilation, C) Multi-nozzle ceiling diffuser and D) Perforated duct diffuser.

Air velocity and temperatures were measured at 24 pole locations and at 7 heights (0.1, 0.5, 0.9, 1.3, 1.8, 2.4 and 3.1 m above the floor) at each location, i.e. altogether in 168 points. The classroom and the measurement pole locations are shown in **Fig. 2**.

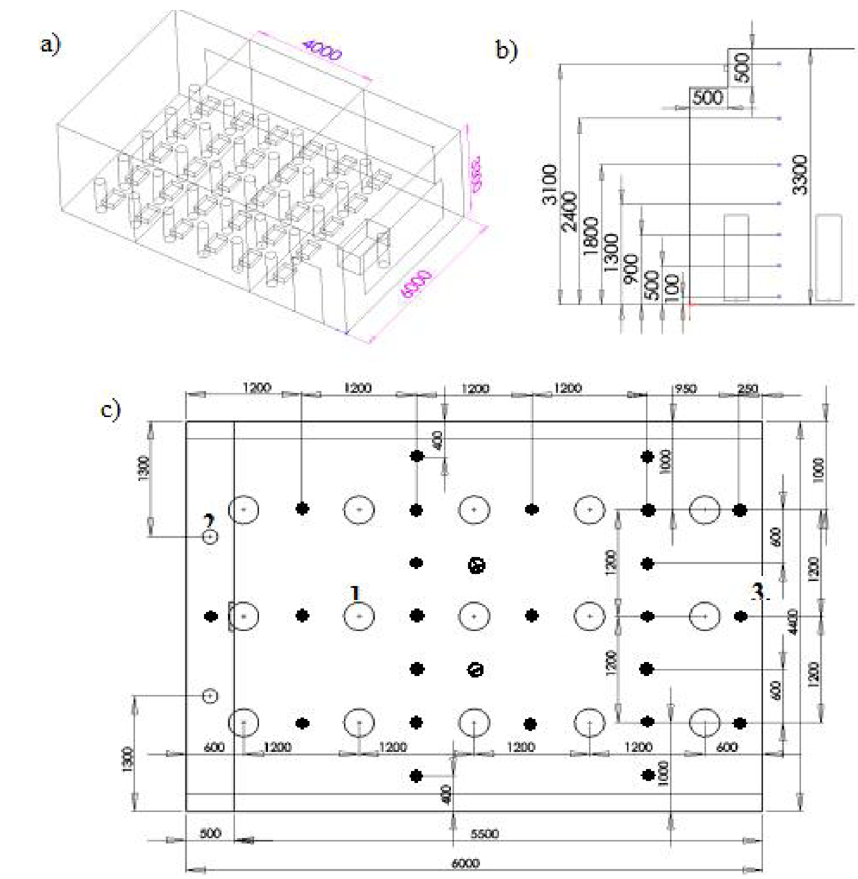

Figure 2. a) The classroom geometry with heat load simulated; b) Measurement pole locations: ● = pole location, ⊗ = black ball temperature at 1.3m from floor, ⊘ room temperature at 1.3 m from floor, 1.=heated cylinder representing occupant heat load, 2.=exhaust valve and 3.=simulation window.

Smoke and CFD- visualizations of air distribution in full occupancy summer cases are shown in **Figure 3**. Thermal plumes did not have a significant effect of the performance of a wall- grille: the momentum flux of a wall-grille was strong enough to attain the other side of room. Also, air spread effectively over the whole occupied zone with the low velocity units, whereas supply air from the ceiling diffuser tends to be carried along thermal plumes from heat sources (in the winter case without window heat load and with half occupancy flow pattern was more uniformly). A perforated duct diffuser had a tendency to create unstable flow conditions and varied loads can change unexpectedly thrown pattern.

High velocities (over 0.3 m/s) over the occupied zone were measured in all conditions with a wall-grill. The highest velocities (above 0.2 m/s) were measured near the window (0.25 m distance). In all conditions velocity higher than 0.2 m/s was also measured near the floor, 0.1 m height at distance as far as 3.6 m from the window. A displacement ventilation concept was not sensitive to load variation and air velocities were very low (<0.15 m/s) except measurement points close to the corner-installed supply unit. With a ceiling diffuser, air velocities were reasonable low in all cases (0.19–0.23 m/s). With a perforated duct diffuser relatively high velocity (0.15 – 0.2 m/s) was measured near the floor (0.1 m height). In the two summer conditions the velocity was above 0.2 m/s (up to 0.31 m/s with

Table 1. Heat balance and the breakdown of the loads in the mock-up classroom section.

Heat loads and heat losses of the simulated classroom (half size of the actual classroom)	**Summer Full Occupancy**	**Summer Half Occupancy**	**Winter Half Occupancy**
Room air temperature	26°C	24°C	21°C
Occupants - 58 W/person (total heat load)	15 (870 W)	7 (406 W)	7 (406 W)
Lighting 15 W/m²	360 W	360 W	360 W
Solar load or heat loss from window (surface temperature of window)	197 W (30°C)	296 W (30°C)	–448 W (11°C)
Power of a radiator underneath window	0 W	0 W	250 W
Total heat gains	**1427 W**	**1062 W**	**1016 W**
Supply airflow rate 90 l/s (supply temperature)	–972 W (17°C)	–756 W (17°C)	–324 W (18°C)
Heat loss through structures	–455 W	–306 W	–244 W
Total heat losses	**–1427 W**	**–1062W**	**–1016 W**

full occupancy) close to the floor for the locations 3.6 and 4.8 m from the window, i.e. the increment of heat gain increased air velocities. This depicts more unstable performance with a perforated duct diffuser when higher heat gains are introduced in the classroom.

Air distribution with corridor wall-grille gave high velocities in all load conditions. In winter conditions, air velocities even raised close to the window. In principle, the thrown length could be optimized for winter conditions and thus get lower velocities close to the window workplaces e.g. by selected larger wall-grille. This increases draught risk in summer conditions.

Supply air jet from ceiling diffuser tended to be carried along thermal plumes from the heat loads during summer times. In winter when there was no the effect of window plume, air distribution was more uniform. The function of ceiling diffuser concept is quite appropriate in varied load conditions.

With a perforated duct diffuser, the performance is quite unstable and sensitive when higher heat gains exit. In those conditions, supply air could unexpectedly drop down causing increased draught risk in certain work places.

In mixing ventilation concepts, load conditions have a significant effect on air distribution and when the air distribution strategy is designed the system performance should be analysed in different conditions. In design phase without using CFD- simulation or laboratory mock-ups, it is not possible to analyse the interaction of convection flows and jets.

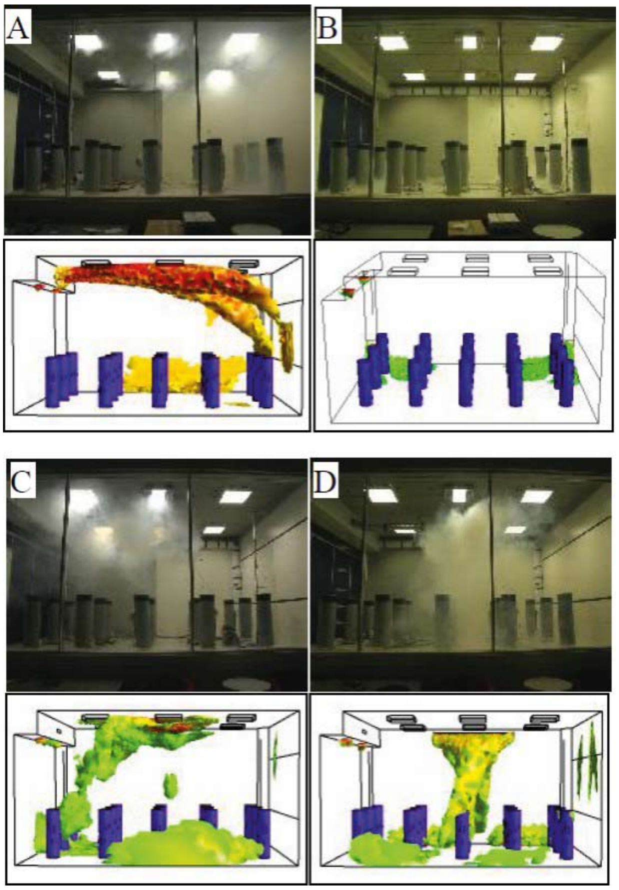

Figure 3. Visualization of air distribution smoke /half classroom) and CFD (in cooling case with full occupancy. Supply air units: a) a wall-grille, b) displacement ventilation with low velocity units, c) a ceiling diffuser and d) a perforated duct diffuser.

Conclusions

The quality of the indoor climate and thermal conditions in schools has been found to be poor in a number of surveys. To analyse thermal comfort conditions in a classroom, measurements were conducted in laboratory conditions. The performance of four typical air distribution methods was studied in a mock-up classroom with different load conditions. The measured air distribution methods were: a corridor-wall grille, a ceiling diffuser, a perforated-duct diffuser and a displacement ventilation concept. From the tested concepts, displacement ventilation is the least sensitive for different load conditions of all studied concepts. Using a ceiling diffuser, air velocities were reasonable low in all cases. Together with displacement ventilation, ceiling diffuser is the other recommended solution for classrooms. A wall grille gave high velocities in both summer and winter conditions. With a perforated duct diffuser, air distribution is quite unstable causing increased draft risk in some load conditions. The performance of a wall-grille and a perforated duct diffuser is sensitive for strength and location of heat gains. ■

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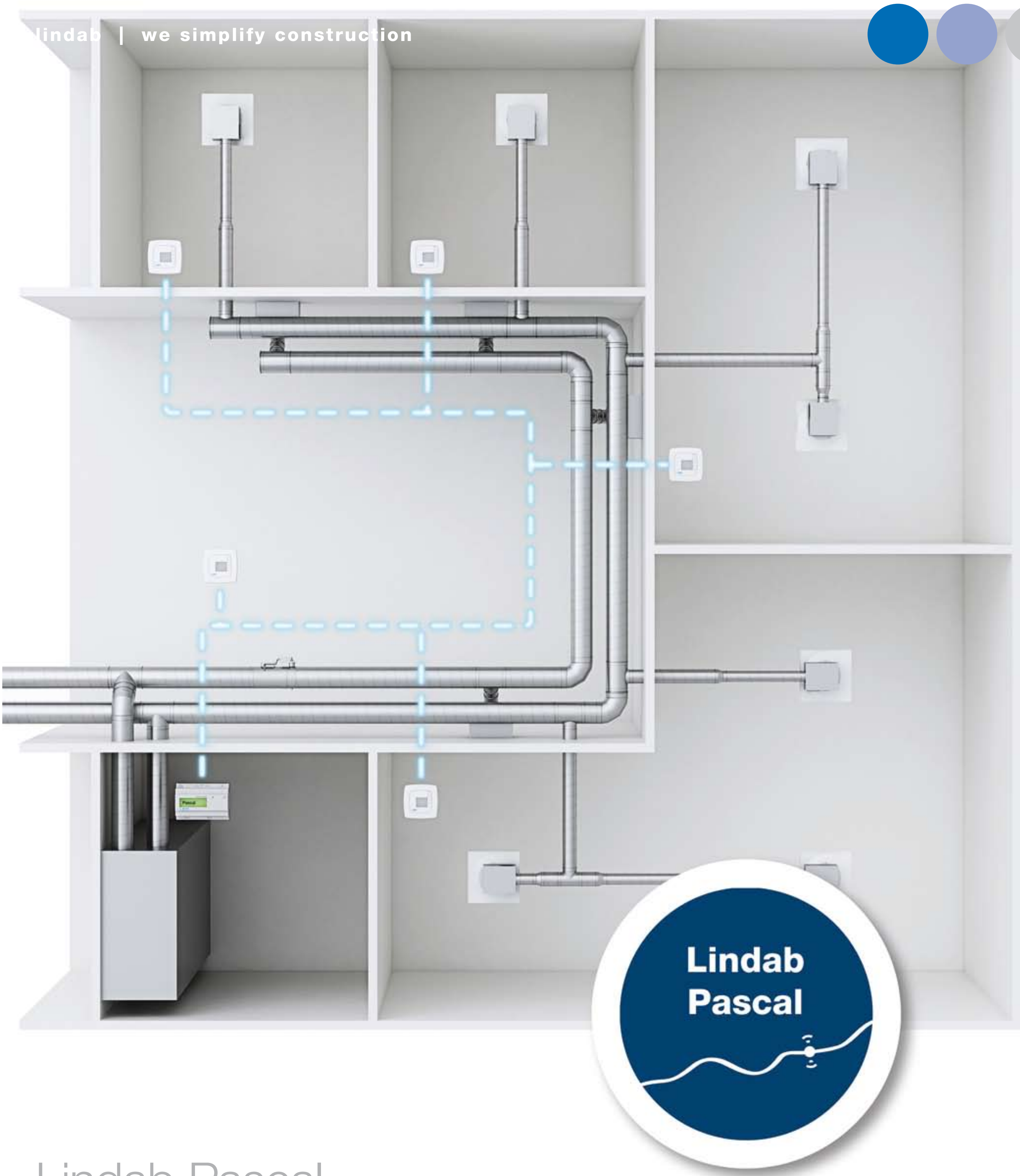

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Model Home 2020 experiment opens new perspectives on home automation – Where technology serves humans

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Buildings can achieve excellent energy performance and still provide an excellent indoor comfort to their residents – as long as their operation is automatically controlled. This was one of the key lessons learned in Model Home 2020 experiment by VELUX. The socio-psychological monitoring of the houses also showed that the test families considered the automation very helpful in their everyday routines, and that they quickly adapted to the operation of the technical systems.

Keywords: Daylight, Thermal Comfort, Indoor air Quality, Dwellings, Post Occupancy Evaluation.

Introduction

During 2009-2011, a demonstration project programme of five model homes were built in Denmark (Home for Life, HFL, 2009), Austria (Sunlighthouse, SLH, 2010), Germany (LichtAktiv Haus, LAH, 2010), France (Maison Air et Lumière, MAL, 2011) and United Kingdom (CarbonLight Homes, CLH, 2011). All houses are designed following the Active House principles [1] with the three main elements: Comfort, Energy and Environment. The houses have been occupied by test families in periods of one year or longer and have been tested and monitored in use, under post occupancy evaluation schemes by national research teams of engineers and / or scientists [2].

Use of natural ventilation for summer comfort is based on ventilative cooling principles, referring to the use of natural or mechanical ventilation strategies to cool indoor spaces. This effective use of outside air reduces the energy consumption of cooling systems while maintaining good thermal comfort [3]. To ensure fresh air supply, the houses use natural ventilation in the warm part of the year and uses mechanical ventilation with heat recovery during cold periods. The exception is LichtAktiv Haus, which is a renovation project, using natural ventilation all year. There is external automatic solar shading on windows towards south and in most cases also towards east and west. Overhangs are used where appropriate. The building occupants can override the automatic controls, including ventilation and solar shading at any time.

Physical Measurements

Measurements of Indoor Environmental Quality (IEQ) include light, thermal conditions, indoor air quality, occupant presence and all occupant interactions with the building installations, including all operations of windows and solar shading. The recorded temperature data is evaluated according to the Active House specification, which is based on the adaptive approach of EN 15251.

Post Occupancy Evaluation Survey

As part of the evaluation, a Post Occupancy Evaluation (POE) survey is carried out seasonally during the test year allowing capturing and exploring variation on a seasonal basis with approximately three months in-between.

It is a set of questions relating statements about satisfaction/dissatisfaction with energy consumption and production, indoor climate and air quality, daylight and electric lighting, house automation, and sustainability. Each family in four of the houses responded to the questionnaire four times during a year (at 3-month intervals) with two additional responses from CLH.

Results

Generally, in the Post Occupancy Evaluation survey the indoor climate is rated as "very important" and the residents state most of the time that it is "good" or "very good" (>90% state "good" or "very good").

Improved sleep, reduced number of sick days and emphasis of view out

The POE survey found that the families experience that their sleep quality compared to their former home is "better" (50%) or "almost the same" (39%), and when rating their children's sleep quality, the tendency is a bit higher ("better" 56%; "almost the same" 44%). Furthermore, they have a significant experience that they have "less" sick days (83%) than in their former home, and they state their general health all in all is "good" or "very good". View to the outside through the window is rated as "very important" (44%) or as "quite important" (50%). Between 72% and 83% of the residents reported that they were "satisfied" or "very satisfied" with the view in the house in general.

High daylight levels without overheating

All of the houses were designed for good daylight conditions, expressed by a target average daylight factor of 5% or higher in the main rooms. This was generally achieved, with only insignificant deviations. In the POE survey, the daylight levels in the houses is rated either as "much higher" (88%) or as "higher" (12%) than their former home. The families report that the daylight level is generally "appropriate" (>75%) in the kitchen, the living room, and the bedroom. Between 89% and 100% of the residents reported that they were "satisfied" or "very satisfied" with the daylight in the house in general. They also state the windows is "about right" for all the rooms (>89%).

Good daylight conditions come with the potential risk of overheating, as plenty of sunlight also provides plenty of solar gains, which can lead to overheating in summer and intermediate seasons. The results from all houses show that overheating has been prevented. That is demonstrated by the fact that the buildings achieve category 1 according to the Active House specification for thermal comfort during summer (in less than 5% of the hours of the year the temperature is above category 1). See example of temperatures in **Figure 1** from Sunlighthouse.

This is well in line with the POE survey, as the residents in all houses are either "very satisfied" or "satisfied" with the temperature conditions in general (90%). Most of the time, the temperature conditions is assessed as about right, but separated into the different season of the year, the winter and the spring/autumn is stated as time of the year when temperature is sometimes evaluated as varying, while few state temperatures as too hot, even in the summer.

Only limited research has been identified on the relation between temperature and sleep quality, but what is known is that the temperature in bedrooms during the

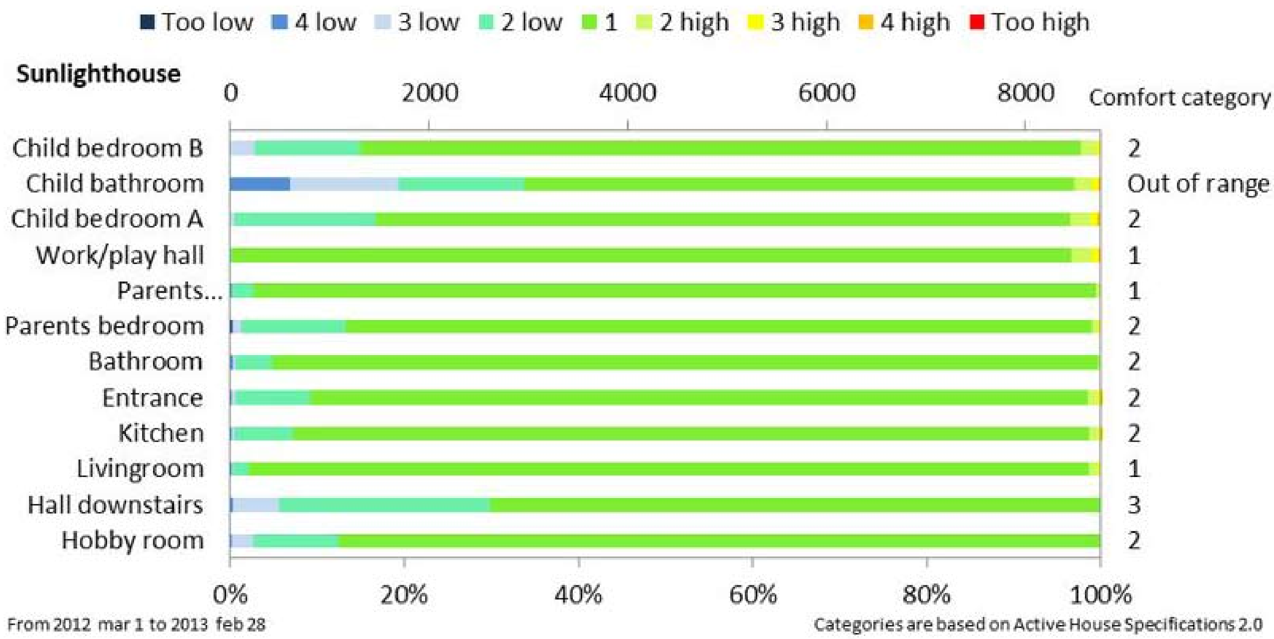

Figure 1. Thermal comfort of Sunlighthouse for each of the rooms evaluated according to Active House specification (based on adaptive method of EN 15251). Criteria are differentiated between high and low temperatures.

night should not be *too high*, to prevent reduction of sleep quality [4]. In lack of a better threshold, category 1 is used as indicator of acceptable temperature for sleeping, and the bedrooms meet this criteria, which means that overheating was prevented particularly in the bedrooms.

Electric light is not used between sunrise and sunset

The families state in the POE survey that they turn the electric light on "less often" (100%) than in their former home, and they evaluate the light levels as "appropriate" (>72%) in the focus rooms.

The measurements support this and show that electric light is generally not used between sunrise and sunset. This is the case not only during summer, but also during the darker winter months. This can be expressed by the term *daylight autonomy* [5]: Rooms can be expected to be daylight autonomous when the average daylight factor in a room is above 5%. The results support this.

Ventilative cooling by natural ventilation prevents overheating. Night cooling is important.

A particular element of the present study is that the actual position of windows and solar shading has been included in the data recording, which provides detailed insights on the role of these components. The use of window openings follows the seasons; during spring and autumn windows are used on most days for approx. 50% of the time during daytime. During summer, windows are used more systematically during daytime hours, and also during the night. There is a correlation between use of windows and hours without overheating. This is an indication that window openings have played an important role in maintaining good thermal comfort. See **Figure 2**.

Open windows during the night (night cooling) cools down the rooms from a temperature at the upper range of the comfort range to a temperature at the lower end of the comfort range, e.g. from 26°C in the evening to 20°C in the morning. The temperature can then rise during the day, in many cases without becoming uncomfortably hot at the end of the day.

The results are supported by tracer gas measurements which were used to investigate the airflow generated by ventilative cooling, and how large a temperature reduction ventilative cooling provided. The results showed that airflow rates of 10–20 air changes per hour could be achieved, and that the indoor temperature could be maintained 5°C lower than if ventilative cooling had not been applied [6].

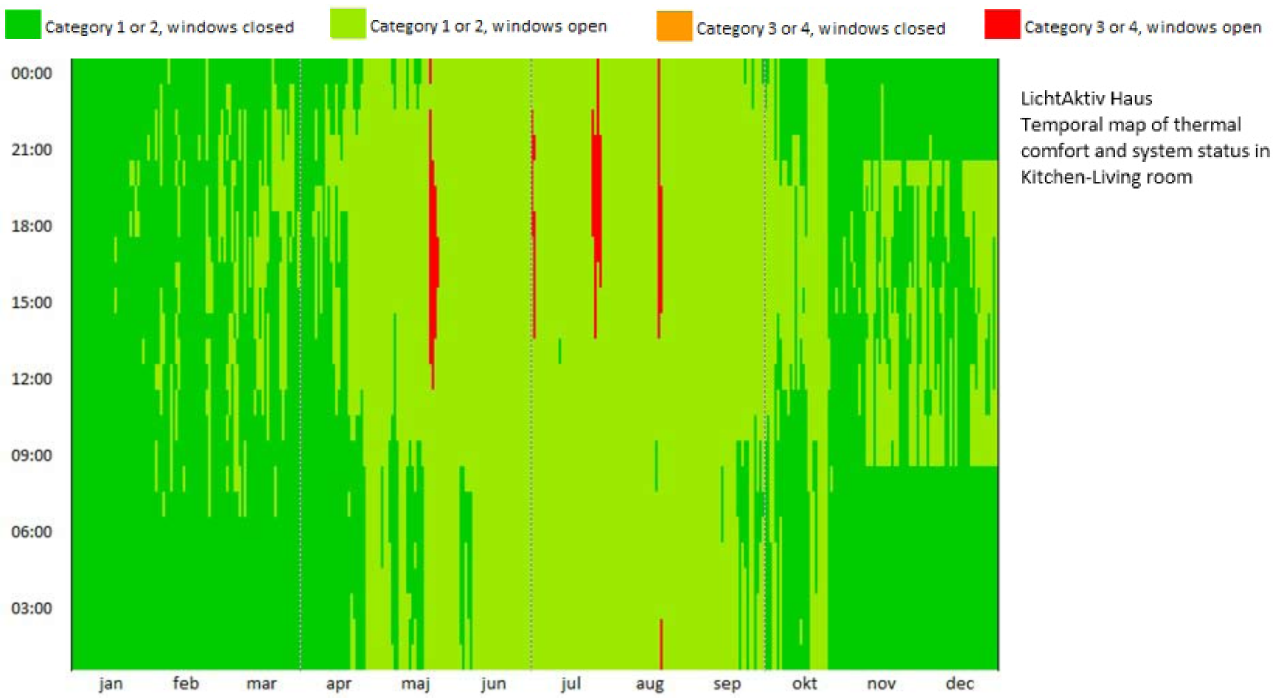

Figure 2. Thermal comfort of the kitchen living room in LichtAktiv Haus, similarly as on Figure 2. On this figure, categories 1 and 2 are bundled, as well as categories 3 and 4. The position of windows is added (open or closed). The result is an illustration of when windows were open, and the relation to the thermal comfort at the same time. The light green squares represent hours when windows were open and good thermal comfort occurred; this happened during daytime in spring and autumn, and during the night in summer.

Solar shading helps prevent overheating

The position of solar shading was recorded just as the position of windows. Awning blinds were the preferred type of external shading used on the houses, and the results show that the awning blinds had a role in providing good thermal comfort. The awning blinds were used the most during the summer, but also during spring and autumn. There is a correlation between use of awning blinds and hours without overheating.

Automation important

Automated control of window openings, solar shading and mechanical ventilation was used in all the investigated buildings. The results show that solar shading and window openings are used frequently during work-hours on weekdays and during the night, e.g. at times when the families cannot be expected to be able to operate the products themselves. The same use of products could not have been achieved with only manual products.

The families respond in the POE survey that they are generally "very satisfied" or "satisfied" (>85%) with the way the house system operates the facade and roof windows, the indoor temperature, internal and external screen, and ventilation system (one house is natural ventilated). They have a clear feeling that the way the control unit operates the house support their needs, and is either "easy" or "very easy" to use. It further shows that they "rarely" or "occasionally" use the control system to manually operate the facade and roof windows, internal temperature, but more frequently use the control system to operate the screening.

Satisfying CO_2-levels during summer

The CO_2 levels are low during the spring, summer and autumn seasons, typically below 900 ppm. Natural ventilation is used in this period as the only mean of ventilation, and the results clearly shows that with limited temperature difference to drive the stack effect, it is still possible to reach a reasonable level. During summer there is no electricity consumption for mechanical ventilation and no heat loss, so high ventilation rates and excellent indoor air quality can be achieved without any use of energy. It is also shown that openable windows were generally able to reduce or maintain low CO_2 levels in all the Model homes 2020.

The most challenging rooms are the bedrooms, as these are small rooms where approximately eight hours are spent each night, often two persons together in the same room. This is longer time than we spend in any other room in the home. Still, the CO_2-levels are maintained at a reasonable level in the bedrooms. **Figure 3** is an example of the CO_2-level in a bedroom in Maison Air et Lumière.

The POE survey indicates that the perceived indoor air quality is good as it is rated as "very acceptable" (78%) or "acceptable" (22%), and the families state that

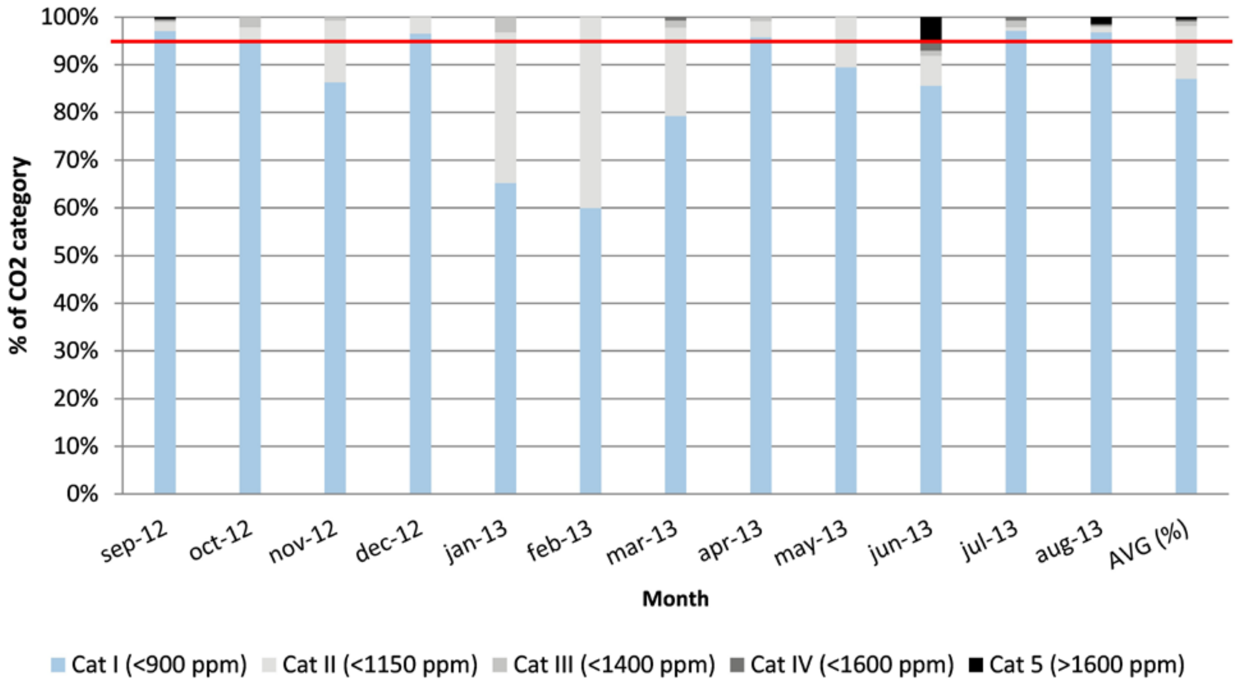

Figure 3. Bedroom in Maison Air et Lumière. Monthly distribution of night time hours in each of five categories for CO_2 level, based on Active House specification. The CO_2-level is lower during the summer than in winter.

they have not experienced any problems at all. If they want to improve the air quality, they open the facade and roof windows, and make airings. In most of the houses there is hybrid ventilation, so that mechanical ventilation with heat recovery is used during the winter to save energy. The mechanical ventilation systems are designed and commissioned to provide the ventilation rates required by the building codes, and they fulfil this requirement flawlessly. However, when the winter CO_2-levels are evaluated according to the Active House specification, particularly bedrooms only achieve a score of 2 or 3.

Conclusions

The five houses have good daylight conditions (DF > 5% in main rooms), and the results show that electric light under these conditions was not used between sunrise and sunset. The measurements show that good daylight conditions can be obtained without causing overheating, when solar shading and window openings are included in the building design and controlled automatically. Night cooling is a particular important aspect. It was found that high ventilation rates can be achieved also during summer with limited temperature difference available as driving force.

The use of ventilative cooling during summer also meant that the ventilation rates were high in this period, and as a consequence the measured CO_2-levels were low. The POE survey indicated that the families show high satisfaction with the indoor environment, that their expectations often are fulfilled, and that house automation is acceptable. Furthermore, combining excellent indoor environment with high quality homes, give clear indication that the residents experience better health and better sleep quality, as well as having less sick days than when living in their former homes. ■

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Summertime overheating prevention requirements and results in Estonia

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Overheating has become a problem even in a cold climate in new airtight and highly insulated buildings with large glazing areas. To avoid such problems, Estonia has launched temperature simulation based procedure and requirements.

One of the aims of the Energy Performance of Buildings Directive (Directive 2010/31/EU) [1] is to reduce cooling energy consumption of buildings and at the same time to improve indoor climate, and prevent overheating. More specifically, EPBD Annex I requires: *"1. The energy performance of a building shall be determined … and shall reflect the … **cooling energy needs (energy needed to avoid overheating)** to maintain the envisaged temperature conditions …"* In Estonia this has addressed in the regulation 'Minimum requirements for energy performance' [2], which besides energy performance also regulates summer thermal comfort since 2008. Estonian regulation sets a limit for maximum indoor temperature excess, expressed in degree-hours (°Ch) over a given base temperature, which is calculated from simulated room temperature values as:

$$DH_{\vartheta_b} = \sum_{i=1}^{j} (\vartheta_i - \vartheta_b)$$

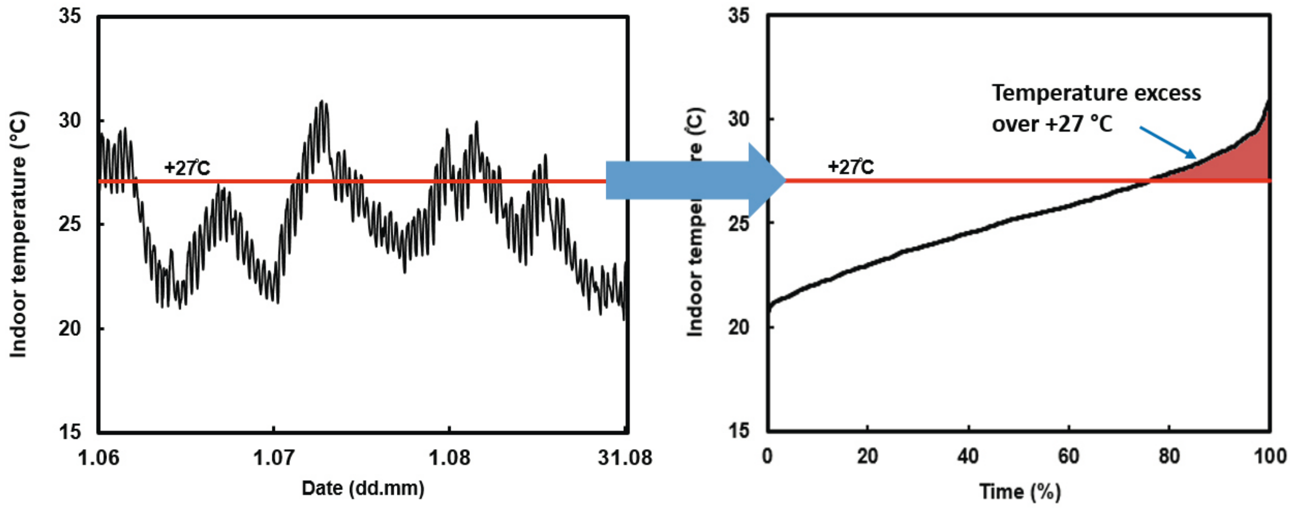
Where DH_{ϑ_b} is temperature excess over base temperature ϑ_b, ϑ_i is hourly mean room temperature and j is the total number of hours in the given period. The "+" sign means that only positive values are summed (**Figure 1**).

For residential buildings, the base temperature, is t_b = +27°C and the excess limit is 150°Ch, for non-residential buildings the values are +25°C and 100°Ch respectively. The calculation period is set in the summertime from July 1st till August 31st, including only occupied hours of the building – outside those hours the indoor temperature may be higher (in non-residential buildings, as residential buildings are considered to be used 24 h and 7 d). In buildings with cooling system, specific temperature simulation reporting is not required as cooling energy is in any case accounted in dynamic energy simulation. Only exception is for detached houses where temperature simulation is not required if specified requirements for window size, shading and openable windows are fulfilled, and specific form with this data is provided.

Compliance verification process

In the building design process, dynamic indoor temperature simulations are required to produce summer thermal comfort compliance verification certificate as a part of the EPC.

The simulation methodology and standardized input data for the compliance assessment procedure is described in detail in the regulation No. 63, 'Methodology for calculating the energy performance of buildings' [3]. The simulation models use a single zone method, meaning that only selected rooms are modelled individually with no connections to other rooms (**Figure 2**). In case of residential buildings, at least two 'critical' rooms are required to simulate, one bedroom and one living room, which have the biggest potential to score high temperatures, e.g. south or west orientation, higher floor location, relatively large glazed surfaces. The selection of these rooms is up to the energy efficiency specialist, designer or HVAC engineer responsible for the calculations (**Figure 2**).



Date	Time	Temp, °C	Excess, °Ch	
...	...	...	...	
5. July	10:00	26.4	0.0	
5. July	11:00	26.8	0.0	
5. July	12:00	27.3	0.3	
5. July	13:00	27.4	0.4	
5. July	14:00	27.6	0.6	
5. July	15:00	27.8	0.8	4.2°Ch
5. July	16:00	28.6	1.6	
5. July	17:00	27.5	0.5	
5. July	18:00	27.0	0.0	
5. July	19:00	26.8	0.0	
...	...	...	...	Requirement
		Σ	685.0	≤150°Ch

Figure 1. Calculation principle of temperature excess. Hourly mean indoor temperature values are simulated and excess values over the base temperature are summed up for total degree-hours. If the sum is lower than the requirement, the building is considered compliant, otherwise one needs to apply measures to reduce the temperature excess.

Figure 2. Rooms most likely to counter overheating are modeled and simulated. At least two 'critical' rooms – one bedroom and one living room must be analyzed in case of residential buildings.

For the internal heat gains detailed standard use profiles of hourly loads for equipment, occupancy and lighting, depending on the building type are used. Also, depending on the building type, ventilation and infiltration air flows are considered as standard values.

All solar protection solutions, such as solar protection glass or coatings, internal and external window blinds, grates, awnings etc. as provided in the design solution, as well as the surrounding objects that cast shadows on glass surfaces and parts of the building itself, are also included in the building model (**Figure 2**, **Figure 3**).

One of the most important difference between modelling residential and non-residential buildings is the use of window airing. Ventilative cooling through the opening of windows is not taken into account in non-residential buildings. In residential buildings, the opening of windows to the airing position (the use of airing position instead of fully opened window is especially stressed in the regulation) and the air change driven by the difference between outdoor and indoor temperature are taken into account (wind driven air change is not allowed to be simulated). The windows are to be closed when the temperature falls to the heating set-point (**Figure 4**).

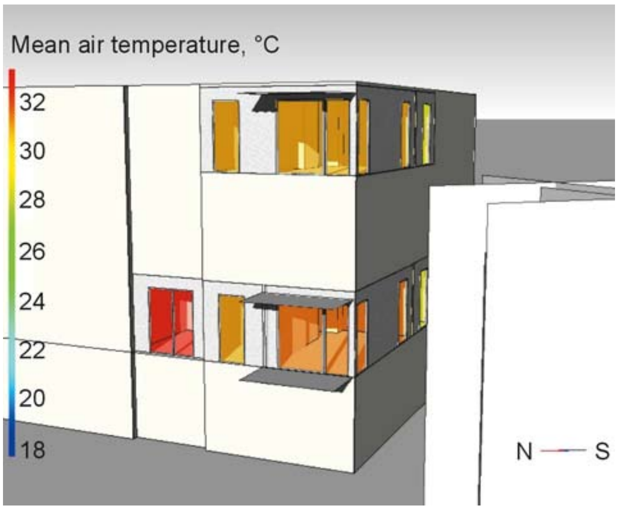


Figure 3. Visualizing simulation results.

The calculations are performed regardless of the building's location on the basis of the data of Estonian Test Reference Year [4], initially built for energy calculations, containing parts of climate data from 30 real years.

The results of the temperature simulations with regard to all calculated rooms are presented as duration curves together with verification results as a mandatory part of the EPC of the building.

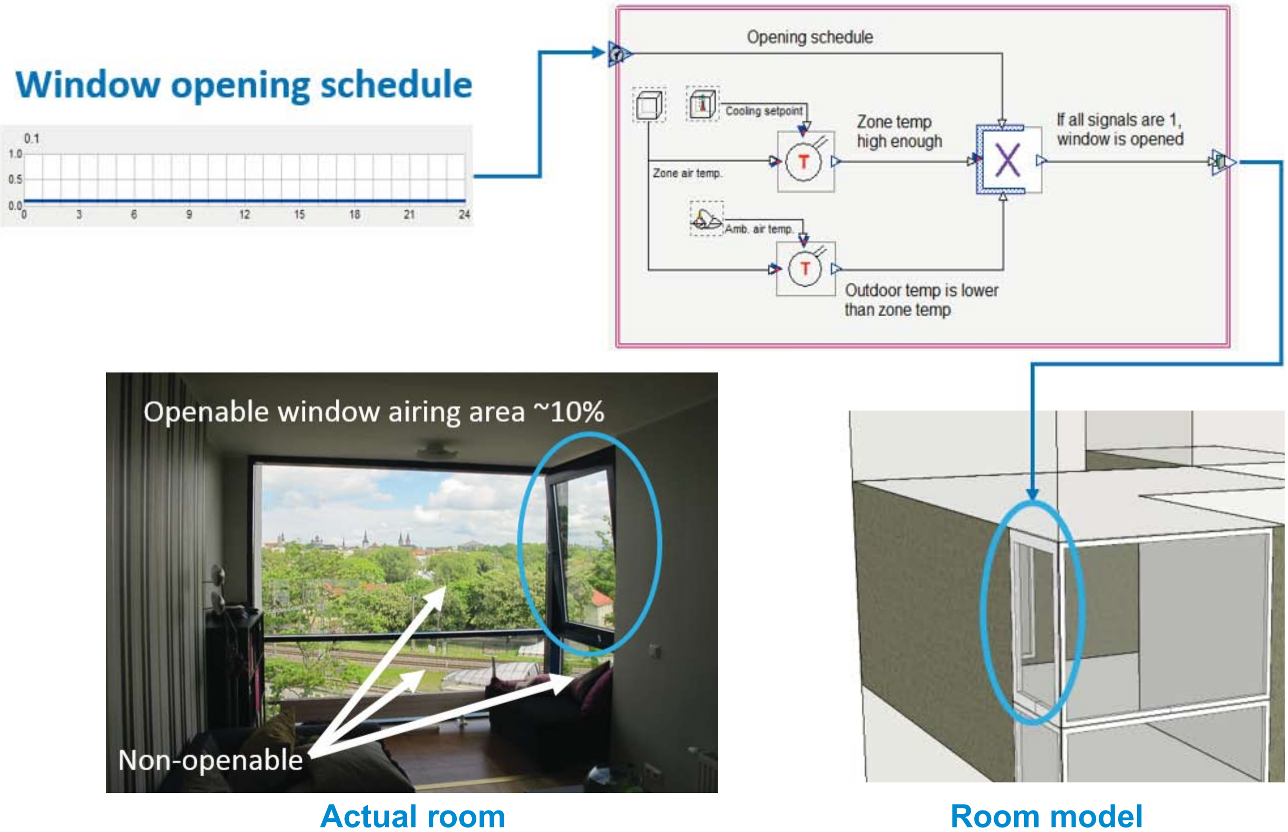


Figure 4. Modeling opening and closing of windows. Window is opened 10%, when room temperature is higher than outdoor temperature and cooling set-point is exceeded, otherwise the window is closed.

National study

During the summer 2014 we conducted a study on summer thermal comfort in new apartment buildings as a part of European QualiCheck project. Using field measurements and simulations we analysed the compliance of buildings, implementation of the relatively new regulation and overheating problems in reality.

For modelling and simulations we used indoor climate and energy simulation software IDA Indoor Climate and Energy (IDA-ICE) [5]. Input data for the buildings in question, including building site surroundings, architecture, floor plans, and specifications for walls, roofs and windows were acquired from the design documentation of the buildings, the Estonian Registry of Buildings database [6], and the Estonian Land Board web map [7]. In total, we simulated room temperature for 158 dwellings from 25 different apartment buildings and took indoor temperature measurements in 18 dwellings of 16 buildings, during the period of July 1 to August 31 2014.

Of the total dwellings that were simulated, 52 reached temperature excess values higher than 150°Ch. The temperature duration curves for all the simulated dwellings are shown in **Figure 5**. As was the case with simulations, also the measurement results showed strong signs of overheating (**Figure 6**). Although most cases that showed overheating risk with simulations, were also over the limit with measurements, the temperature measurement results cannot be used to assess dwelling compliance. This is stated in the methodology that is simulation based at standard use conditions and is also our conclusion based on the comparative analyses. Many factors influence the results and can be different in real operation. These include weather data differences, occupancy density and presence profile, other internal heat gains and window openings.

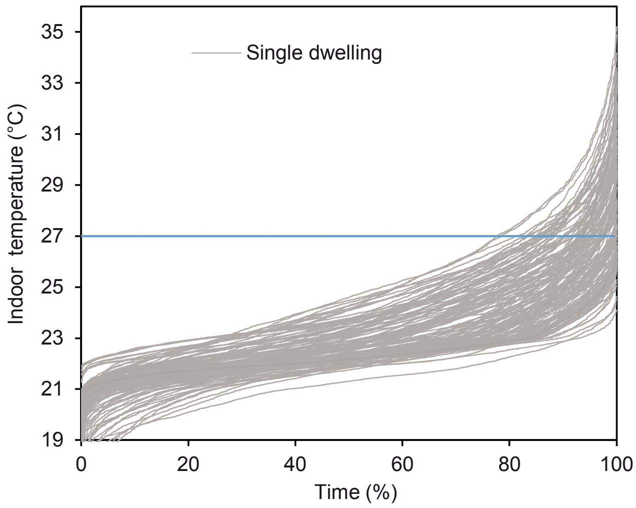


Figure 5. Simulated cumulative indoor air temperature of the studied dwellings.

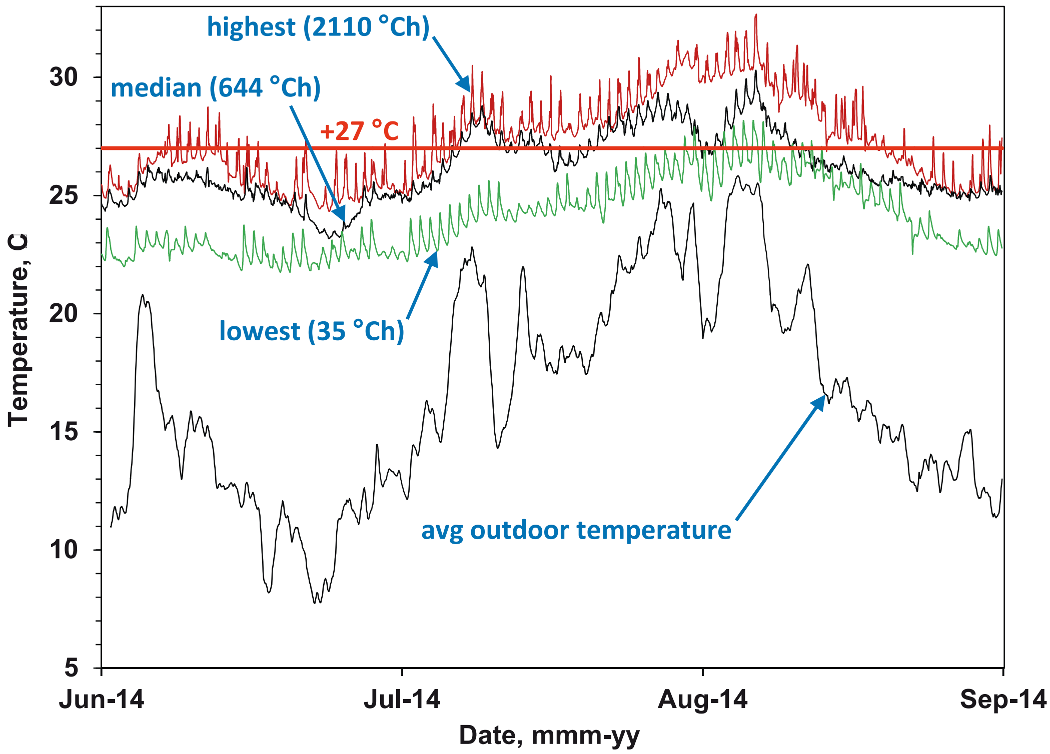


Figure 6. Example of measurement results: dwellings with highest, lowest and median temperature excess. Measured hourly mean indoor temperatures during period of 1. June – 31. August 2014.

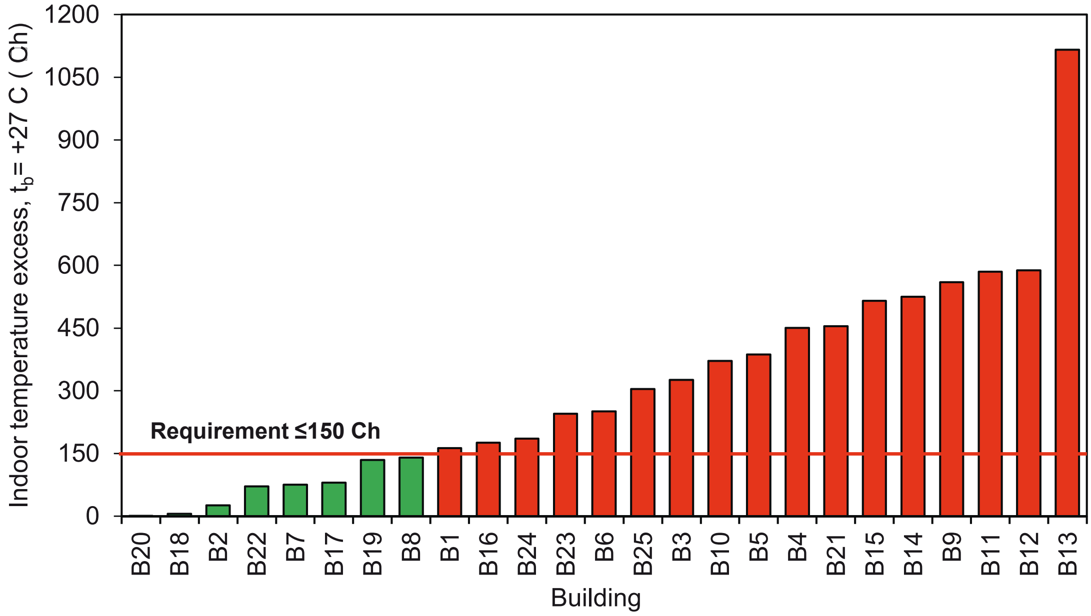


Figure 7. Overall building simulation results: out of the 25 simulated buildings, 17 (68%) did not comply with the requirement.

The overall simulations results showed that 17 out of 25 (68%) of the apartment buildings in this study did not comply with the summer thermal comfort requirements (**Figure** 7).

Conclusion

It may be concluded that this relatively new building code requirement was not fully established in practice; this conclusion is supported also by the fact that only in 8 buildings the required calculations and forms were included in the building permit documentation. Although the methodology for compliance assessment was proven to be sound and robust, the outcomes of the study suggested some minor improvements, such as guidance for selecting 'critical' rooms and combination of measures for avoiding the risk of overheating. Results show that the requirement in apartment buildings is achievable without cooling, if passive measures are properly applied. The regulation has evidently improved the summer thermal comfort in buildings which have conducted temperature simulation and have followed the requirements in the design. It is recommended for authorities to pay more attention for EPC (random) checks and to check also within this process the availability and plausibility of overheating temperature simulation reports. ■

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A design tool for night ventilation

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Dynamic multi-zone energy simulations are required to design and evaluate natural/hybrid night ventilation, but the additional costs are too high, especially for smaller construction projects. That is why Ghent University and consultancy Ingenium designed a simulation tool for ventilation manufacturer Duco Ventilation & Sun Control with which the components of a night ventilation system in an office (building) can be sized and the performance of the system can be evaluated. The tools processes the user input, carries out simulations with Trnsys-Trnflow and shows the performance.

In night ventilation, ventilation will use outside air to cool the building mass that during the day before has stored part of the heat gains. Applying night ventilation reduces the maximum inside temperature and delays the maximum inside temperature to later in the day. Comfort during summer is considerably increased and any cooling installations can be made smaller. That is why night ventilation is garnering quite some attention from clients in Belgium and the Netherlands. Recent projects with night ventilation, especially office buildings, prove this. Architects Stéphane Beel and Xavier De Geyter provided an inspiring example with their design of the University Forum (Ufo for short), a building of Ghent University with offices and an auditorium (**Figure 1**). Outside air enters the offices through open windows and flows back outside via the open stairwell. The new court building in Antwerp by Richard Rogers is another example. The building makes use of a hybrid night ventilation system. In spring and autumn, the ventilation grilles in the outside wall open at night, whilst in summer mechanical ventilation system blows in cold air through floor grates. Building designers who want to incorporate night ventilation in their design have a lot of choices to make. Does natural ventilation suffice or are ventilators required to guarantee the ventilation rate? Which ventilation concept is the best: single-sided ventilation, cross ventilation or stack ventilation? Do the windows have to be opened or will a small grate suffice? Which construction elements must remain thermally accessible? The degree to which designers succeed in coming up with an optimum design largely depends on the design tools used. In large projects, there is enough time and money to carry out advanced simulations. Designers of small buildings, however, have to make do with rules of thumb and conceptual design tools.

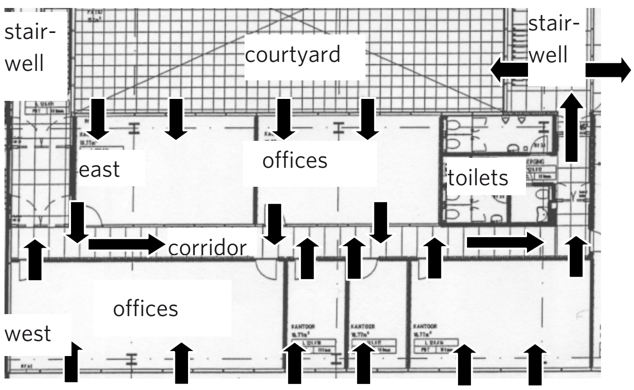
They do not always submit a good design and some of them do not even dare to propose night ventilation. That is why Ghent University and consultancy Ingenium designed a simulation tool for Duco Ventilation & Sun Control, a manufacturer of natural ventilation and sunscreen systems, with which the components of a natural/hybrid night ventilation system by this manufacturer can quickly and easily be sized and the performance of the system evaluated. This article describes the possibilities / shortcomings of the existing simple design tools, explains how the new design tool works, and explains by means of an example.

Development

Due to the larger size of building projects and the increasing complexity of construction, integral design has been on the rise since the beginning of the nineteen nineties. External specialists increasingly assisted the architect with the design. Partly as a result of this, sustainable technologies have become more popular. Various research projects have been launched with the aim of promoting natural ventilation as an alternative to mechanical ventilation and mechanical cooling. The European Pascool project and Annex 28 of the IEA about low-energy cooling were the first reference projects and were quickly followed by the European Joule project NatVent and IEA Annex 35 about hybrid ventilation. People who worked on these and other projects developed different types of design tools, varying from simple guidelines to numerical ventilation models. **Table 1** provides an overview of the main simple design tools that have been developed until now.

Graphic tools and spreadsheets

Chartered Institute of Building Services Engineers designed graphs and spreadsheets that helped to size the ventilation openings of wind-driven ventilation and/or ventilation on the basis of the stack effect [1]. Both the graphs and the spreadsheets were however based on explicit comparisons that did not take the interaction between flow paths into account. Another limitation resulted from the assumption that all the resistance along the flow path was situated at the supply and removal. Input parameters were the local wind speed, the estimated difference between the temperature inside and outside, the resistance along the flow path and the difference in height between the ventilation opening and the neutral pressure zone (the height at which the inside and outside pressure are the same). The graphs and spreadsheets showed the relation between the ventilation rate and the surface area of the opening as a function of the difference in temperature inside and outside and/or the wind speed. One of the results of the NatVent project was the graphic design tool by Van Paassen e.a., that enabled designers to dimension ventilation openings for night ventilation in Dutch buildings (**Figure 2**) [2]. The tool was based on a large number of dynamic simulation results. The simulation model consisted of a three-zone model: two offices with a corridor in the middle. The design tool took the following input parameters into account: two building orientations, three thermal capacities, five levels of internal heat gains, three window surface area to floor surface area ratios, three ventilation strategies, different ventilation opening to floor surface ratios and three settings for night ventilation. Using the tool, designers were able to estimate the necessary surface area of the ventilation openings.



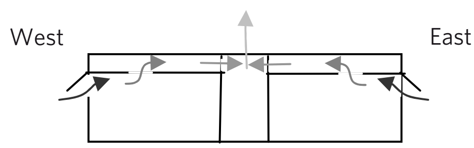


Figure 1. University Forum with natural night ventilation (supply via windows, removal via the stairwell).

Table 1. Overview of design tools for night ventilation

Tool	Tool	Calculation model	Building model	Output
Graphic tools and spreadsheets	CIBSE method	Explicit equations	1 zone	Snapshot
	Graph by Van Paassen ea	Thermal and ventilation model	1 zone	Dimension of ventilation openings
Simulation models	Lesocool	Thermal and ventilation model	Maximum 9 zones (single flow path)	Day profile
	Nitecool	Thermal and ventilation model	1 zone	Week profile
	NatVent	Thermal and ventilation model	1 zone	Year profile
	LoopDA (CONTAM)	Thermal and ventilation model	Multiple zones	Dimensions ventilation openings
	Coolvent	Thermal and ventilation model	Multiple zones	Year profile

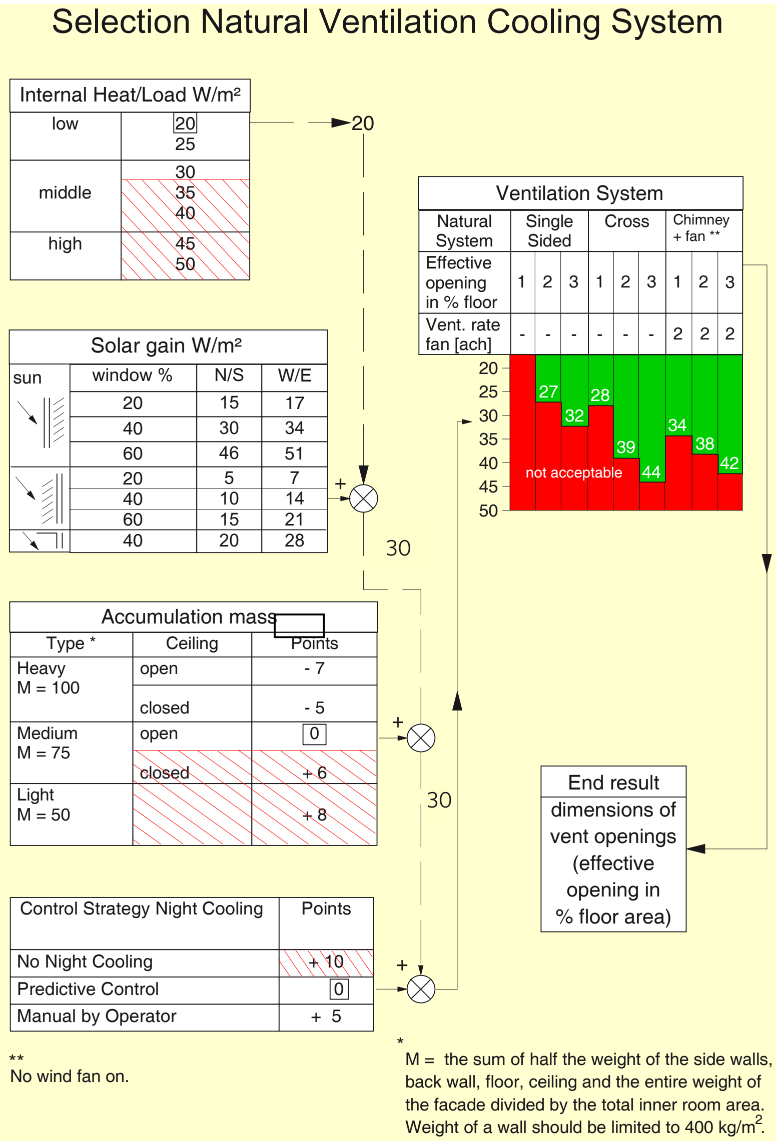


Figure 2. Graphic design tool by Van Paassen e.a.

Simulation models

One of the research results of the Pascool project was Lesocool, a simulation tool that made it possible to evaluate the effect of (natural) night ventilation [2].

The calculation model comprised a stationary thermal model combined with a storage model and a ventilation model for a single ventilation flow through a maximum of nine zones. Lesocool users could adapt the following parameters: the type of ventilation (natural or mechanical), the properties of the openings (e.g. position, size, removal coefficient), the setting (on the basis of temperature or time), the thermal mass of the zone (four standard levels), the construction surface areas, the internal heat gains (three standard levels) and the surface area and U-value of the glazing. The tool offered the variation in the ventilation rate, the inside temperature, the average surface temperature and the cooling capacity for a typical day. The UK Department of the Environment sponsored the development of Nitecool [3]. This simulation tool had to enable the designers of British offices to quickly determine the impact of a number of important parameters on the performance of the night ventilation. The program simulated heat transport in a typical, individual office with a resistance capacity model and air transport with a simple ventilation model. Users could enter the following parameters: site location, building orientation, thermal mass, infiltration rate, glass surface area, internal heat gains, occupancy duration, and sunscreens. In addition, they had a choice of nine cooling system for operation during the day and/or night and three types of setting for the night ventilation system. The results were limited to a week profile of the temperature and the peak capacity / energy consumption for cooling that had been economized. The NatVent tool was developed in the research project of the same name. The thermal calculation model was a first-order system; the ventilation model was a single-zone model that represented an entire building. Users could adapt four categories of input parameters: location, building, ventilation, and windows. Location included the climate and orientation of the building. The building category included the geometrics, the degree of insulation and the airtightness. The ventilation category allowed the size of the openings, the internal heat gains, the ventilation strategy, and the properties of any ventilators to be entered. The windows category comprised the properties of the windows and sunscreens. The result of the tool was the ventilation rate and the inside temperature in summer, winter or during a year. The National Institute of Standards and Technology developed the Loop Design Analysis tool (LoopDA) and integrated it into the multi-zone ventilation model Contam [4].

The accompanying Loop Equation Design Method described the steps required to arrive at a correctly dimensioned ventilation system with the simulation program. The calculation model comprised a stationary heat and mass balance that were calculated successively. Users of the tool had to enter the following parameters: the building's characteristics (such as geometrics, average U-value), the properties of the ventilation system (such as minimum ventilation requirements) and the design preconditions (target inside temperature, wind speed). The tool first provided a rough estimate of the ventilation openings before using the additional preconditions (such as the maximum air speed through the opening) in further calculations with Contam. Coolvent, a multi-zone energy simulation model for natural ventilation in buildings, was developed at the Massachusetts Institute of Technology. It was a user-friendly and robust tool that had an advanced thermal model and ventilation model as its template. In contrast to, for example, LoopDA, it calculated the heat and mass balance simultaneously. The input parameters were limited to those with the most impact and were divided into two categories: general information and detailed building information. The general information included the ventilation concept, building orientation, user profiles, terrain information, and climate data. The building information comprised the size of the building, the size of the windows and openings, the thermal mass and strategies for opening windows. The result of the tool was a profile of the inside temperature and the ventilation rate during the period studied.

Dynamic multi-zone energy simulation

The above overview shows that most of the existing tools are greatly simplified. Either the results of simulations were moulded into a design tool with a limited number of input parameters, or a greatly simplified calculation model was developed that calculated the heat and air flows. The main reason was the limited calculation power of computers. However, for natural/hybrid night ventilation the driving forces vary over time, which makes the performance of such a system highly uncertain. In addition, the temperature differences and ventilation rates depend on each other. The inside temperature affects the natural ventilation rate and the ventilation rate has an impact on the inside temperature. That is why dynamic multi-zone energy simulation programs that are based on linked thermal and ventilation model are required to properly design natural/hybrid night ventilation and correctly evaluate its performance. However, various obstacles hinder the general use of dynamic multi-zone energy simulation programs. It takes a lot of know-how and time to carry out simulations. The calculation algorithms can become very complex and the user environment is not always user friendly. What's more, a simulation model is determined by a large number of parameters, that all have to be entered. Often it is also difficult to convince parties that the higher initial study costs will quickly be recovered, especially if it concerns smaller projects. If a fast assessment of the performance of natural/hybrid ventilation is required there are two possibilities. A simulation expert can carry out an extensive parameter study to then compile the results in a design graph or table. Or a simple, applied interface for controlling an energy simulation program can be developed. The direct control of a template does have advantages over a derived graph/table. The choice of parameter values is not limited to a number of discrete values but can be any numerical value. This makes practically every combination of parameters possible. Ghent University and Ingenium, in consultation with Duco

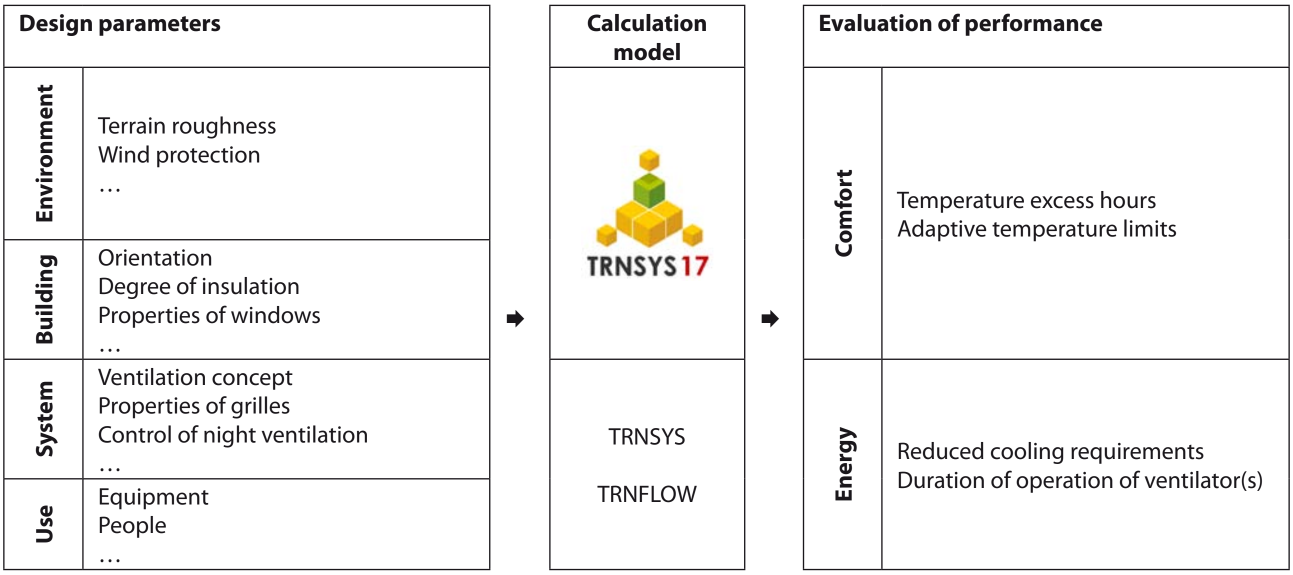


Figure 3. Configuration of the new design tool.

Ventilation & Sun Control, opted to make an interface for an existing commercial simulation program, namely Trnsys-Trnflow [5]. With this tool it was possible to adapt a number of input parameters in order to arrive at a properly predicted performance of the natural/hybrid ventilation system. For example by adapting the type of grate, the intended comfort in summer is achieved. The focus was on office buildings since night ventilation is interesting in this type of building.

Configuration

The design tool processes the data entered by the user, carries out simulations with Trnsys-Trnflow and presents the results of the simulations (**Figure 3**). The environment that the user uses is a spreadsheet, Microsoft Excel. The spreadsheet contains codes in Visual Basic for Applications (VBA) and Visual Basic .NET (VB.NET) that carry out the majority of the actions. Excel actions take care of a small part of processing the user data entered and the results. VBA codes do the rest of the user data input; they also make computer files, set up the simulation environment (such as climate data, user profiles) and process the results. The VB.NET codes provide the complex building model. The input parameters are subdivided into properties of the environment, building properties, system properties and building use. The environment in particular determines the wind pressure on the façades. That is why properties such as the roughness of the terrain (countryside, suburb, city) and the degree of screening (open, half screened and completely screened off) must be determined. However, the shape of the building also has an impact, more in particular the height of the building and the relationships of the façades. The latter parameters however fall under the building properties. Other building parameters include: orientation of the building (8 orientations), the geometrics of the room(s) (numerical values), the storey the room is on (numerical value), the degree of insulation (5 insulation levels), the air-tightness (numerical value), the thermal capacity (4 levels), the glazing (numerical values for surface area and g value). System properties include: the ventilation concept (single-sided ventilation, cross or stack ventilation in a room or stack ventilation for an office building with three floors that each consist of two offices with a corridor between them), the properties of the air supply grilles and the extraction ventilator for hygienic ventilation (inc. ventilation rate and heights of the supply grate and extraction ventilator), the properties of the night ventilation grilles and any extraction ventilator (inc. surface area, K factor and height of the supply grate) and the control of the night ventilation system and finally the control of the sunscreens. The use of the building is determined by the internal heat burden (numerical values) and the possibility of extra ventilation during the day. To evaluate the summer comfort, the temperature overshoots and the adaptive temperature limits are selected. In accordance with the temperature limit excess method, the inside temperature may not exceed 25.5°C and 28°C for more than 100 h and 20 h of the occupancy period respectively. The method of the adaptive temperature limits states that a certain ceiling, that varies in function of the outside temperature, may not be exceeded for more than 3% of the occupancy period (in this case in accordance with class B). The viability of the night ventilation system

Figure 4. Supply of fresh air through skylights housed in casing.

is assessed on the basis of the cooling requirement economized and the operating period of the ventilation system. The cooling requirement economized follows from two simulations: one with night ventilation and mechanical cooling and another with only mechanical cooling. The processing time of a ventilation system supported by an extraction ventilator is derived from a simulation with only night ventilation.

Application

Televic, a producer of highly technological communication systems, wanted night ventilation to limit the cooling burden in its new office. The building was designed in such a way that the outside air was brought in through skylights and inside air was removed by natural or mechanical means (**Figure 4**). Televic engaged Duco to dimension and detail various the components. They used the tool to simulate two situations in a typical office space with cross ventilation. In the first situation, night ventilation was only natural. The predetermined number of air exchanges per hour was 7. In the second situation, there was an additional extraction ventilator with a capacity of 2 air exchanges per hour. **Figure 5** shows the parameter input of the ventilation in the tool. Both the natural and the mechanically supported night ventilation yielded a considerable reduction in the cooling requirement: up to 7.5 kWh/m². After all, the building had sufficient thermal mass and the sun-loaded façades had sunscreens. **Figure 6** shows the

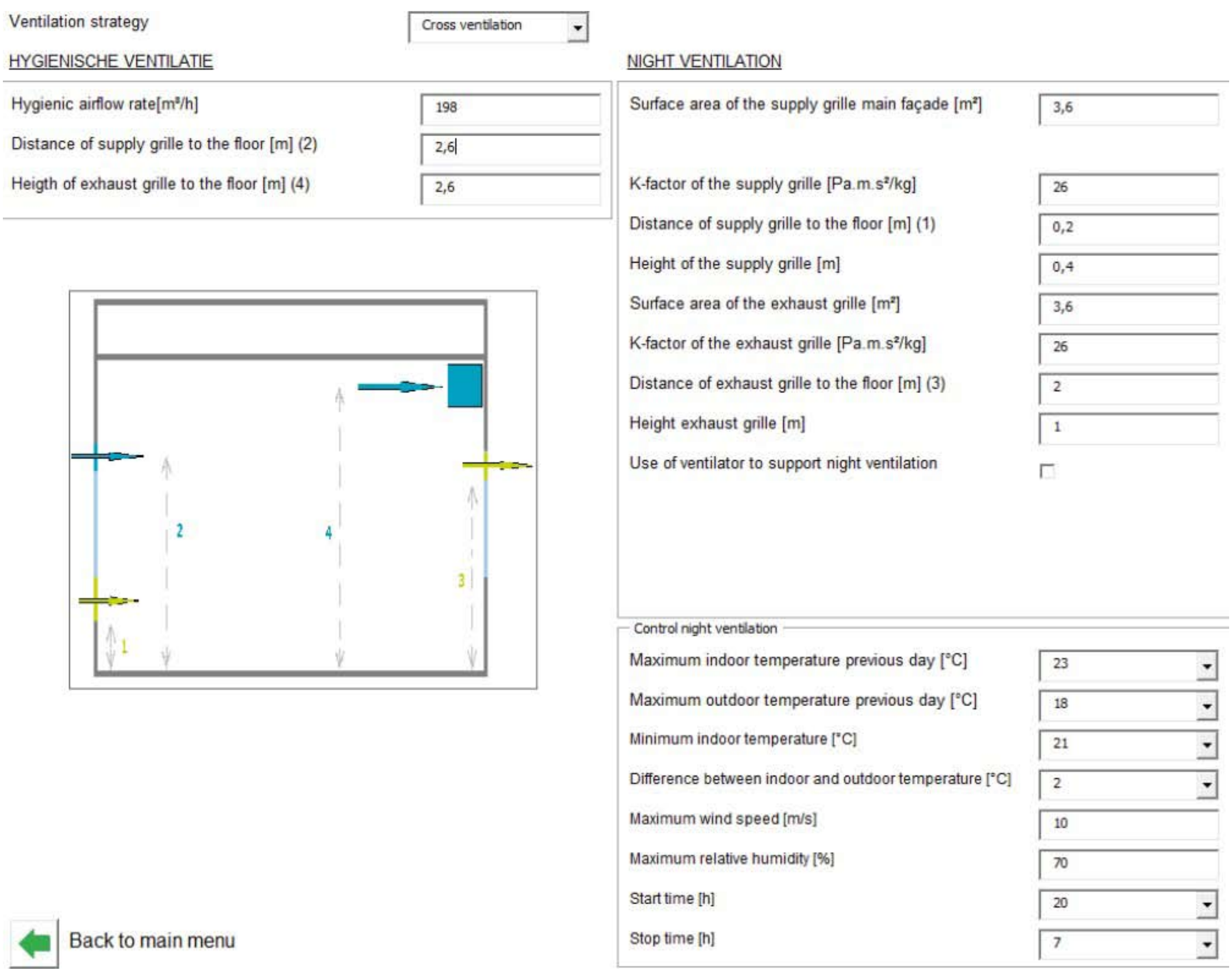
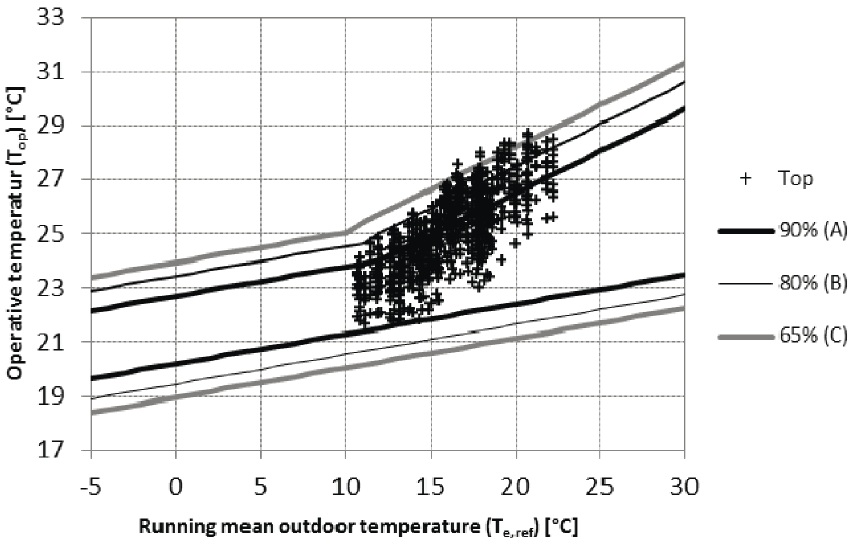


Figure 5. Illustration of the input ventilation in the tool.

COMFORT

TE-METHOD		
boundary	h	%
> 25.5 °C	313	13%
> 28 °C	19	1%

ATG-method		
class	h	%
> A	358	11%
> B	84	3%
> C	12	0%



COOLING

Qc	
	kWh/m²
without night ventilation	10.2
with night ventilation	2.2
saved cooling demand	7.9

PROCESSING TIME

time	
	h
operating hours	1180

Figure 6. Result of the tool

result of the situation with only natural night ventilation. Televic opted for a hybrid night ventilation system. Generally, the outside flowed into the offices through façade grilles to then move on through the (open) doors to the central stairwell. In the stairwell skylights and/or ventilators removed the air.

Conclusion

Night ventilation is a technique with a lot of potential, especially in offices. However, the design is generally so complex that basic know-how or experience is not adequate to evaluate design measures (such as the impact of dimensioning grilles). In these cases, simulations may help, as long as they can be used efficiently. The tool developed by Ghent University and consultancy Ingenium for Duco Ventilation & Sun Control permits to quickly and simply calculate a number of design variants of a night ventilation system in an office (space) using the Trnsys-Trnflow template. This tool has already successfully been used a number of times. ■

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Evaluation of daylight in buildings in the future

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Building regulation requirements and traditional engineering practice for daylight calculations is often outdated and unsynchronized with the advance and needs of modern sustainable building design. State-of-the-art calculation tools provide accurate results on daylight conditions using methods as simple as calculating the useful daylight illuminance. These methods facilitate sustainable building design that also works in practice. This is illustrated with an example where the daylight conditions in an office with solar shading is examined.

The inevitable turn of the building sector to sustainable design techniques has brought daylight analysis to the center of attention. Buildings with an enhanced daylight performance have minimized energy requirements and an improved indoor climate. However, assessing daylight conditions is somewhat adhered to old-fashioned methods, as building regulations and schemes in most countries are not updated to research findings.

Legislation and standards

Daylight Factor is the most widely used method of establishing compliance with building codes and credits within environmental assessment schemes such as BREEAM, DGNB etc. Taking as example the Danish Building Regulation of 2015 the requirement to achieve sufficient daylight conditions in an occupied space is a minimum of 2% daylight factor (DF) covering part of the work plane. This is a typical requirement from Denmark to United Arab Emirates, although the latter almost never experience a standard CIE overcast sky.

Why is the daylight factor method old-fashioned?

As much as the daylight factor method is easy to comprehend and apply, it leaves the designer a lot of space to produce a building with uncomfortable or energy inten-

Daylight factor (DF)

DF is defined as:

$$DF = \frac{E_{inside}}{E_{outside}} \cdot 100\%$$

where E stands for illuminance.

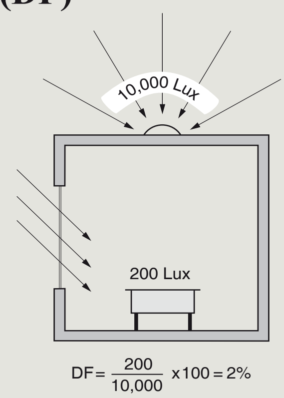


Illustration from By og Byg Anvisning 203 Calculation of daylight in buildings. (2002)

DF is the ratio of the illuminance due to daylight on a surface in a room to the illuminance on an external horizontal surface due to an unobstructed hemisphere of a standard CIE overcast sky. The latter means that direct sunlight to both illuminances is excluded and that orientation and latitude do not affect the value.

sive daylight conditions. That is because DF takes no account of the building location, façade orientation or varying sky conditions. Moreover it provides no indication of glare or visual comfort nor is the solar shading taken into account. The latter is of increasing importance in low energy buildings since the solar shading is more often used and is vital for the expected performance of the building. Several examples show a usage of the solar shading for up to 80% of working hours during the summer in order to maintain a satisfying indoor climate. However, the daylight factor method only evaluates the overcast sky conditions and hence only represents down to 20% of the working hours.

New method - Climate-based daylight metrics

Instead, there are by now several studies1, 2, 3 discussing this exact topic and proving that the introduction of climate-based daylight calculations that rely on hourly meteorological data over the year, form much more accurate and informative, yet simple measures of the daylight conditions in a building compared to the DF and could effectively replace the latter in regulation and scheme requirements.

The *climate-based approach* uses time varying sky and sun conditions, whilst predicting hourly levels of daylight illuminance. This is fully parallel to standard practice for indoor climate simulation. The superiority of the method is thus evident against the daylight factor approach, which is a single number taking no account of orientation and considering only overcast skies, therefore not being meaningful for climates with predominant sun conditions. Moreover the climate-based approach can take solar shading into account.

Indicative calculation metrics of the climate-based method are e.g. the *Daylight Autonomy (DA)* and the *Useful Daylight Illuminance (UDI)*.

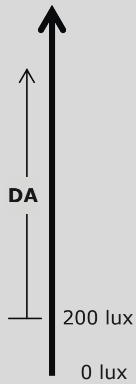
So far the DA and UDI methods are applied by the UK Education Funding Agency for the evaluation of designs submitted for the Priority Schools Building Programme (PSBP)4. Furthermore a variation of DA, the so-called Spatial Daylight Autonomy (sDA) is used in the environmental ration system LEED v45.

Daylight Autonomy

Daylight DA provides the benefit of valuing the contribution of daylight to energy savings; however it is of no value to the occupants' comfort as it does not reflect on the amount of time of extreme illuminance levels causing discomfort or glare. At the same time, the metric ignores illuminances that are below the threshold, which can still be useful to the building users.

Daylight Autonomy (DA)

Daylight Autonomy is defined as the percentage of the working year when a minimum threshold of illuminance can be provided to the work plane by daylight alone – often 200 lux. Thus it is an index directly related to the potential of artificial lighting energy savings.

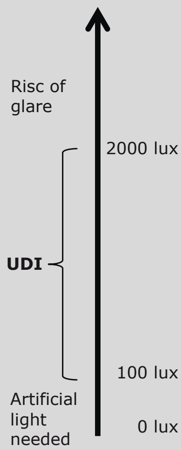


Useful Daylight Illuminance

Useful Daylight Illuminance is more advantageous, because it covers the gaps of DA. The upper and lower threshold of UDI have been defined based on the findings of numerous field studies and surveys in offices[1] indicating that illuminance levels between 100 lux and 2 000 lux are either desirable or tolerable to workers. Hence, UDI informs on how often daylight illuminance is too low, i.e. how often artificial light is needed, how often illuminance is useful to the occupants and how often it is extreme and therefore causes discomfort. Overall, it relies on a detailed method and it gives value to unconventionally useful illuminance levels plus indicating disturbances, whilst giving an impression on the potential for reduced lighting use.

Useful Daylight Illuminance (UDI)

UDI is defined as the percentage of the working year when daylight illuminances on the work plane fall within a certain range – typically 100-2000 lux. Below 100 lux artificial light is needed and above 2000 lux discomfort will occur. Thus UDI stands out as likely the most informative and realistic daylight metric using climate-based data.



How to calculate these metrics?

The daylight factor can be calculated for each evaluation point in the working plane using software that conducts illuminance calculations. These can be simple software packages like Velux Daylight Visualizer or more advanced like Radiance or Daysim.

The calculation of climate-based daylight metrics like UDI requires the use of Climate Based Daylight Modelling (CBDM) programs, e.g. Radiance or Daysim.

Daysim runs annual simulations with detailed climate files by calculating daylight coefficients6. Its simulations give outputs of annual indoor illuminance and luminance profiles. These outputs are combined with a user behavior model and defined illuminance targets, shading controls and lighting controls to predict daylight performance metrics, such as daylight autonomy, useful daylight illuminance as well as artificial lighting energy demand. Daysim uses plug-ins in 3D design tools like SketchUp or Ecotect to import the building's geometry for more accurate simulations. Due to its high accuracy the program requires more simulation time with increasing geometrical details and size of the building model.

A case study with solar shadings

The daylight factor, Daylight Autonomy and Useful Daylight Illuminance was calculated using Daysim for part of an open plan office in Copenhagen oriented south (**Figure 1**).

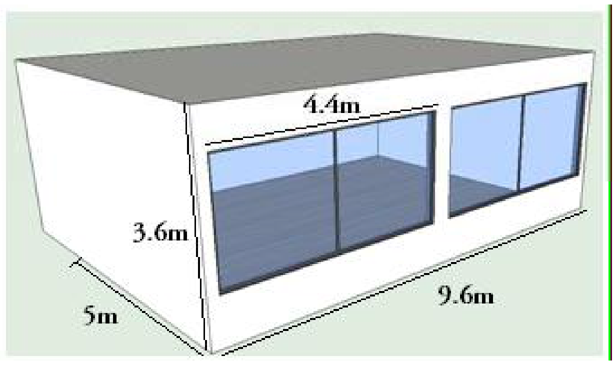


Figure 1. Office in Copenhagen facing south.

The only parameter varying was the solar shading. Five calculations were carried out; a 3-layer low energy glazing without solar shading for reference, a low energy glazing with an external dynamic venetian blind, a solar control glazing (like Pilkington Suncool 40/22), a MicroShade glazing and an external dynamic roller blind.

The control strategy of the external shadings was also energy efficient; the blinds and the external lamellas were set to be drawn whenever direct radiation of 50 W/m² hit the sensors on the façade. Furthermore the control strategy of the external dynamic blind was a cut-off strategy, meaning that according to the sun's position per different periods, e.g. summer-winter, the lamellas were inclined just as much as it was needed to block direct radiation from entering the rooms, thus allowing the maximum daylight possible in the occupied spaces.

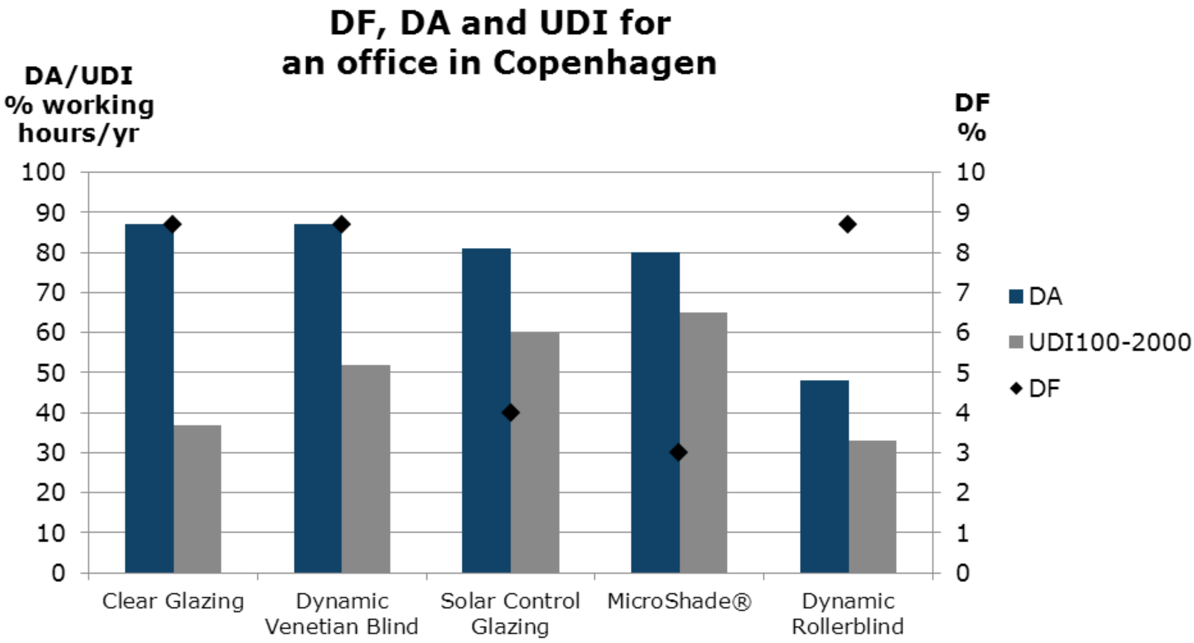


Figure 2. DF, DA and UDI for the five scenarios.

As a threshold for DA 200 lux was used, while threshold values of 100 lux and 2 000 lux was used for UDI. The results can be seen in **Figure 2**.

Looking at the graph above, it is noticeable that the two external dynamic shadings, the roller screens and the venetian blinds, have a DF equal to that of the clear glazing. That is explained by the fact that these blinds are automatically drawn when direct radiation of 50W/m² hits the work plane sensors, so by definition DF is not affected, since the blinds are not used under overcast situations. This is evident especially for the roller blinds, which seem to have a significant shading effect according to DA and UDI, but not according to DF. The latter also highlights that the daylight factor is not an appropriate metric to evaluate daylight when shadings are used.

What is interesting to note is that the application of the solar control and MicroShade glazing seems to level the percentage of daylight autonomy down by less than 10%. This implies that, although the drop in the daylight factor was 54% and 66% respectively from no shading to solar control and no shading to MicroShade, the DA metric shows that this merely affects the percentage of hours per year when the shading allows the room to be sufficiently lit by daylight alone even though they are permanent shadings.

UDI is the only metric that allows for the difference between the venetian blinds and the clear glazing to be evident, highlighting the value of the external lamellas cut-off strategy, which blocks all direct radiation and thus minimizes excessive illuminance levels for the time of year they are in use.

Traditionally external dynamic shading is seen as the best balance between daylight and energy, as they can maximize the utilization of daylight. However, in this example it is the MicroShade glazing and solar control glazing which gives the highest amount of hours with useful daylight. Why?

Figure 4 shows UDI_{100}, $UDI_{100\text{-}2000}$ and UDI_{2000} for the five scenarios.

The reason why MicroShade provides useful daylight for a greater percentage of time compared to e.g. the venetian blinds is due to the increased exposure of the room to excessive illuminance levels with the latter. The illumination level exceeds 2000 lux for 38% of the working hours, while only 20% for the MicroShade glazing.

The chosen control strategy was, as earlier mentioned, a cut-off strategy for allowing maximum daylight. This strategy proved to give too much daylight. In reality it means that it is necessary to close the lamellas

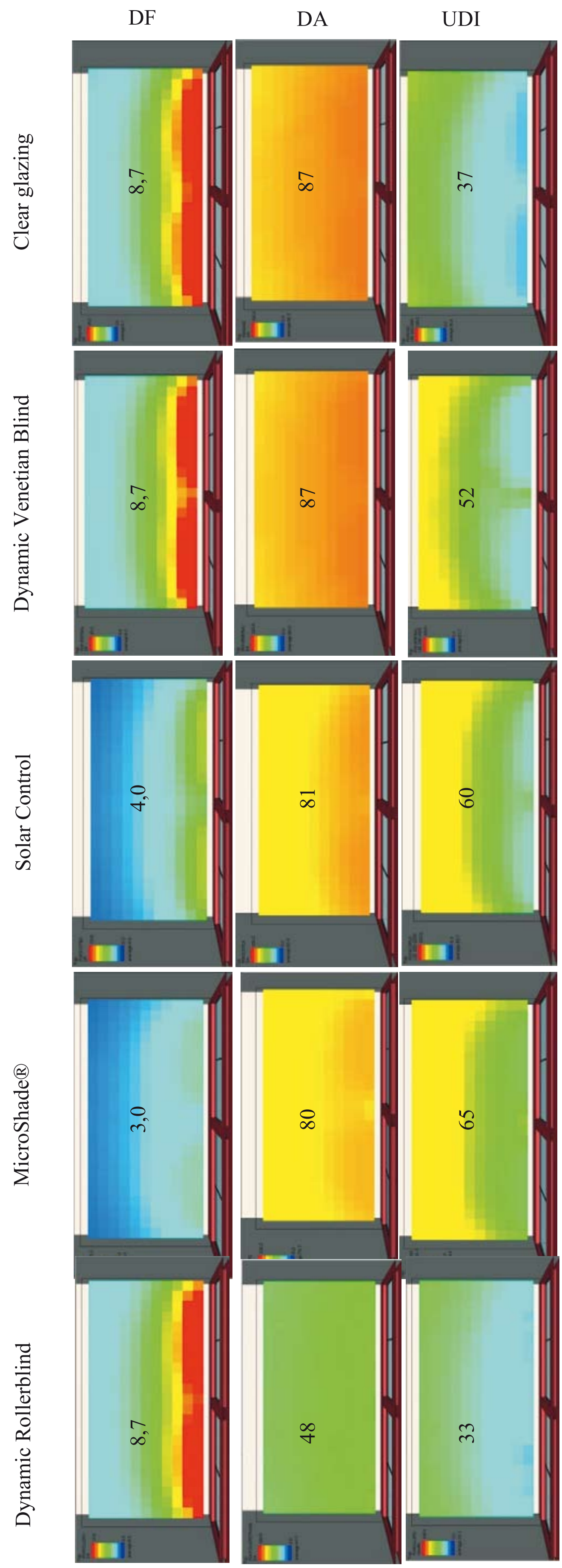


Figure 3. Distribution of DF, DA and UDI in the office.

An overview of the results would conclude the following from the perspective of each daylight metric alone:

DF - The dynamic blinds perform as good as the clear glazing does, whereas the permanent shadings; solar control glazing and MicroShade allows for the lowest illuminance levels in the room.

DA - All of the shading solutions with the exception of the roller blinds provide adequate daylight illuminance levels for a great percentage of the working year. The clear glazing and the dynamic venetian blind provides the highest amount of daylight.

UDI - The MicroShade glazing provides the highest percentage of working time with comfortable illuminance conditions for the occupants, which means adequately day lit and without glare, followed by the solar control coating, the venetian blinds, and the clear glass. The percentage of the clear glass is slightly higher than that of the roller blinds but for the opposite reason; the clear glazing allows for exceeding lux levels, whereas the roller blinds create a rather dark indoor environment.

Similar conclusions can be drawn by looking at the images below, which illustrate the distribution of daylight factor, daylight autonomy and useful daylight illuminance in the examined office space for the five scenarios.

more than just preventing the direct sun to enter. As in the case with the roller blind this can lead to more hours with illuminance levels below 100 lux, while also reducing the view out.

The external dynamic roller blind is the shading providing the most glare-free environment for the users. However, it shades so efficiently that for almost 50 % of the working hours the illuminance level is below 100 lux and there is a need for artificial light. The clear glazing has the exact opposite effect; there is only a need for artificial light in 10% of the working hours, while causing extreme illuminance levels (and a high risk of glare) for more than 50% of the working hours.

Current state of regulations

In the European committee for standardization - CEN – work is ongoing in TG169/WG11 for a proposal for a new standard for daylight in buildings. According to "A proposal for a European Standard for Daylight in Buildings" by J. Mardaljevic et al 7 the method is still based on the daylight factor, however a connection to the actual climate/location is taken into account.

Also in TC156/WG19 work is ongoing to revise EN15251. In the proposal8 a classification system for the daylight availability in a building is being established. The classification method is taken from

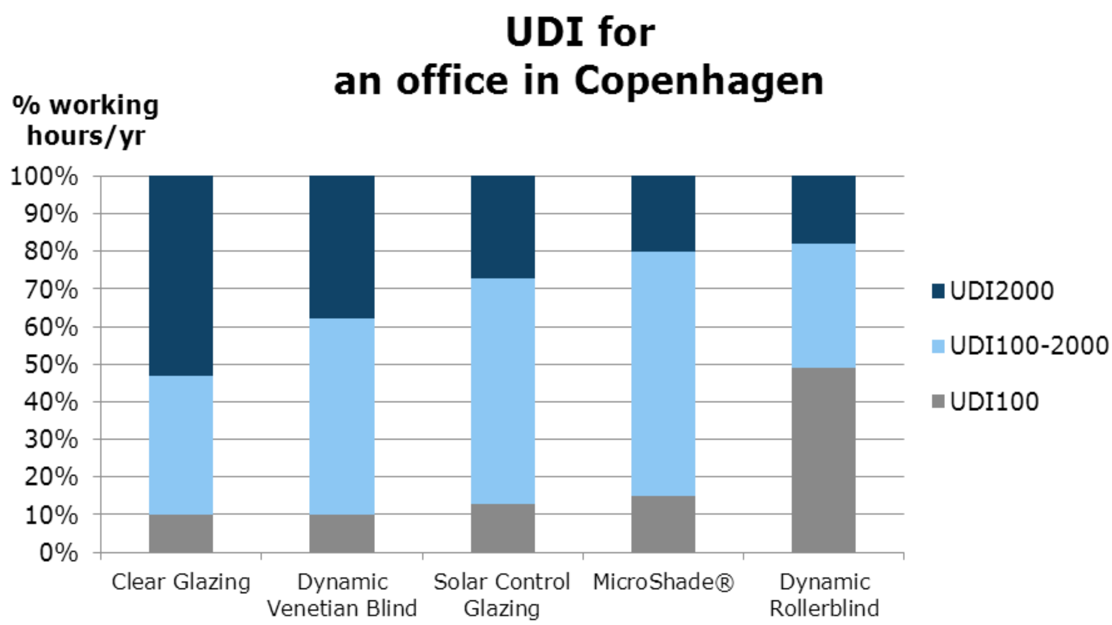


Figure 4. UDI_{100}, $UDI_{100-2000}$ and UDI_{2000} for the five scenarios.

ISO 10916:2014 and corresponds to the German standard DIN V 18599-4 for calculation of the impact of daylight utilization on the energy demand for lighting. The classification is also based on daylight factor.

So even though it is widely recognized by practitioners that the daylight factor method is not up to date it seems like it will take some time before the daylight factor is phased out.

Conclusion

Climate Based Daylight Modeling allows for informative analyses of daylight conditions in spaces by taking in account the location-specific climate characteristics of the building's position and showing the impact of the use of solar shadings. This is a feature lacking from the commonly used daylight factor analysis and it makes daylight assessments tailored to each building, whilst producing information on lighting energy savings, indoor illuminance conditions and occupant comfort.

The daylight investigation among the four shadings showed that the solution achieving the lowest daylight factor in the examined room, in this case the MicroShade, was actually the solution with the most hours/working year of useful illuminance levels and with adequate daylight autonomy. The example showed that accounting for the bespoke climatic annual conditions of the building as well as its location can alter the design decisions for improved daylight. It underlines the importance of using the right criteria in the design phase of a sustainable low energy building.

It is therefore recommended to use climate based daylight modelling in the design phase to secure the optimal utilization of daylight and at the same time secure good indoor climate and low energy consumption.

This requires a revision of the national building codes and international and European standards. ■

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Effect of CO_2 on restlessness of an Alzheimer patient

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Keywords: Indoor air quality, sleep quality, Alzheimer, nocturnal restlessness, ventilation, health, apnoea, CO_2.

The relation between the indoor air quality in buildings and the health of occupants gets more and more attention nowadays. However, it is difficult to point to health effects that have a direct relation to poor indoor air quality. In a risk assessment study Logue (2011) indicated that the risk of indoor air quality on shortened life expectancy is in between the risk of car accidents and the risk of heart diseases.

There may be a stronger relation between the indoor air quality in bedrooms and the sleep quality of inhabitants. Strøm-Tejsen et al. (2014) showed that a higher ventilation rate (open window) had a significant positive effect on sleep latency and the ability to fall asleep. This research reports the measurement of bedroom CO_2 levels and nocturnal restless behavior of an Alzheimer patient as observed by the husband of the patient.

Method

A couple (husband and wife) is living in a naturally ventilated house. Fresh air is provided in a natural way via the envelope of the house, possibly increased by the opening of one or more windows.

Since 2007, the wife is suffering from Alzheimer's disease, with gradual increasing symptoms of dementia. During days, she occasionally suffers from restless behaviour, indicated by periodic introvert behaviour and humming sounds. During the nights, the restless behaviour occasionally shows, indicated by snoring, apnoea, restless sleep and panic when she wakes in the night.

During nights and in the afternoon, the wife, and sometimes the husband, take a sleep in the bedroom (**Figure 1**). The window in the bedroom is a top-hinged turnable window which is occasionally opened according to the wish of the husband. The interior door from the bedroom to the hallway may be opened or closed, as desired by the husband.

Figure 1. The bedroom with a view on the window.

An indicator for the indoor air quality in the bedroom is the CO_2 level, which has been recorded in a 15 minute interval with a CO_2 logger (Wöhler type CDL 210). This logger simultaneously records temperature and relative humidity as well. The logger was placed on a small table next to the bed on the side where the husband sleeps, as far as possible from the direct breathing area.

In order to avoid psychological influence by the indicated CO_2 level, it was proposed to cover the screen with tape, but this was refused by the husband so he could see whether an intervention like opening a window had an effect on the CO_2 level.

The nocturnal behaviour of the wife was described during the night and the day by the husband in a notebook. Incidents of restless behaviour were noted with the specific time. Also, changes in the window position and interior door position were noted. Lastly, the occupation of the bedroom was noted. The indoor air quality and the observed behaviour were recorded during 5 weeks from the 5th of February 2014 until the 13th of March 2014.

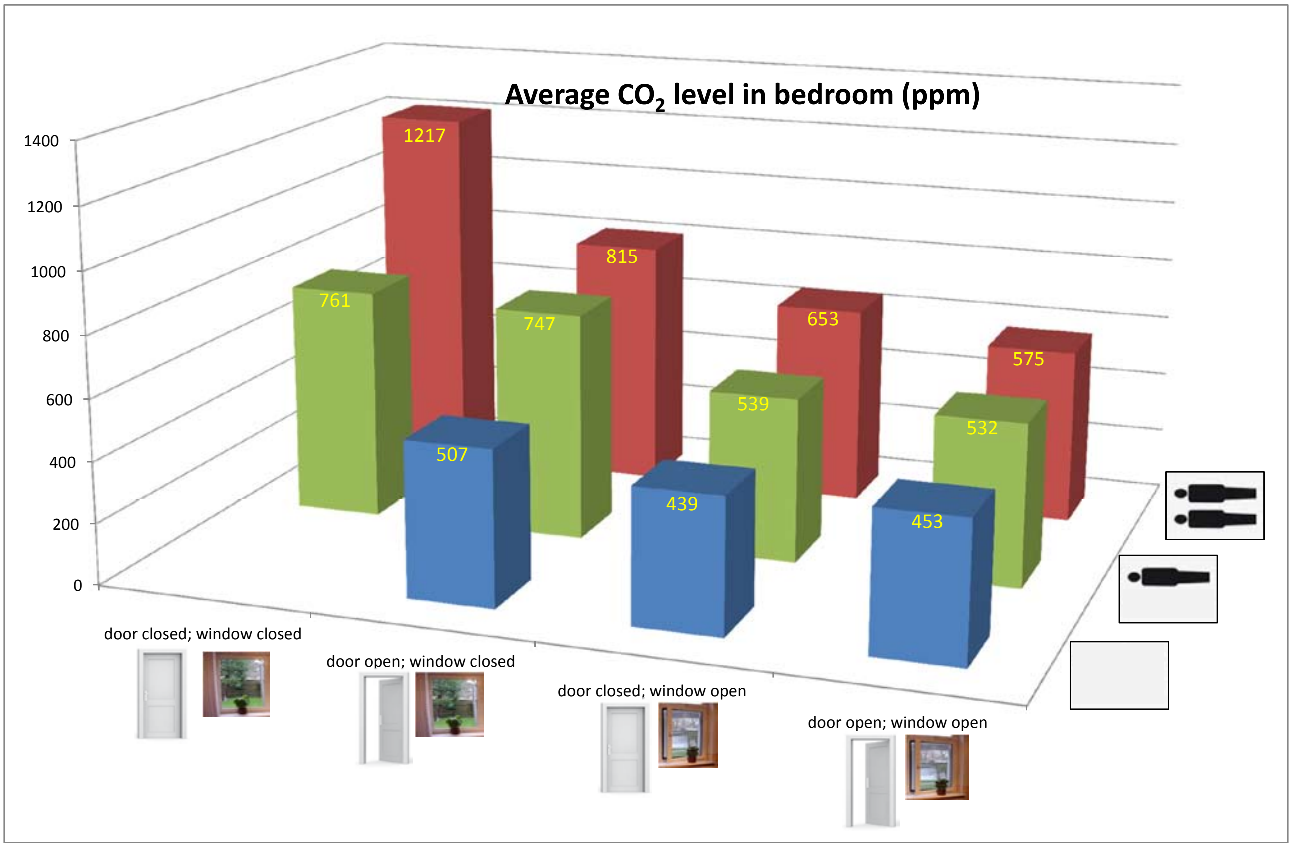

Figure 2. The effect of occupation, window and door position on the average CO_2 level in the bedroom. Left to right: door & window closed, door open & window closed, door closed & window open, door & window open.

Influence of window and door position on CO_2 level

In order to give an idea how the bedroom CO_2 level was dependent on occupation and on window/door position, the average CO_2 level was evaluated in categories. **Figure 2** shows columns in the front row for an unoccupied bedroom, the middle row columns for one person and columns in the back row when two persons are in the bedroom. Furthermore, the horizontal axis shows the positions of window and interior door (closed or open).

As expected, the CO_2 level rises with the number of people in the room. The results also show that the largest reduction of CO_2 can be achieved by opening the window and leaving the door open to the hallway also help to reduce the CO_2 level. Obviously, opening the window increases mixing of indoor air with fresh outdoor air, while opening the door increases mixing with indoor air from the hallway. There is one exception to this last effect: when the bedroom is unoccupied, an open door to the hallway leads to a slightly higher CO_2 value, because CO_2 level from the hallway can be larger than CO_2 level from the bedroom.

The average values of CO_2 level in the bedroom are for a 5 week period, so they cannot be regarded as statistical. Moreover, the number of recordings for each situation is not comparable. There were a lot of recordings with window and door both open, while only a few short periods with window and door both closed. In spite of this, the effect of occupation and window and door position on the CO_2 level is logical and gives guidance to keep the indoor air quality to a certain level.

Influence of CO_2 level on restlessness of Alzheimer patient

Figure 3 shows the first 5 days of the recording period, where the husband experimented a lot with opening and closing of windows and doors in the bedroom. The observed restless behavior of his wife as described in the notebook coincides with peaks in the bedroom CO_2 level. Whenever this behavior was apparent, the window and/or door were opened in order to lower the CO_2 level again. According to the observations, approximately 30 to 45 minutes after this intervention (also indicated in the graph), his wife was breathing and sleeping normally again.

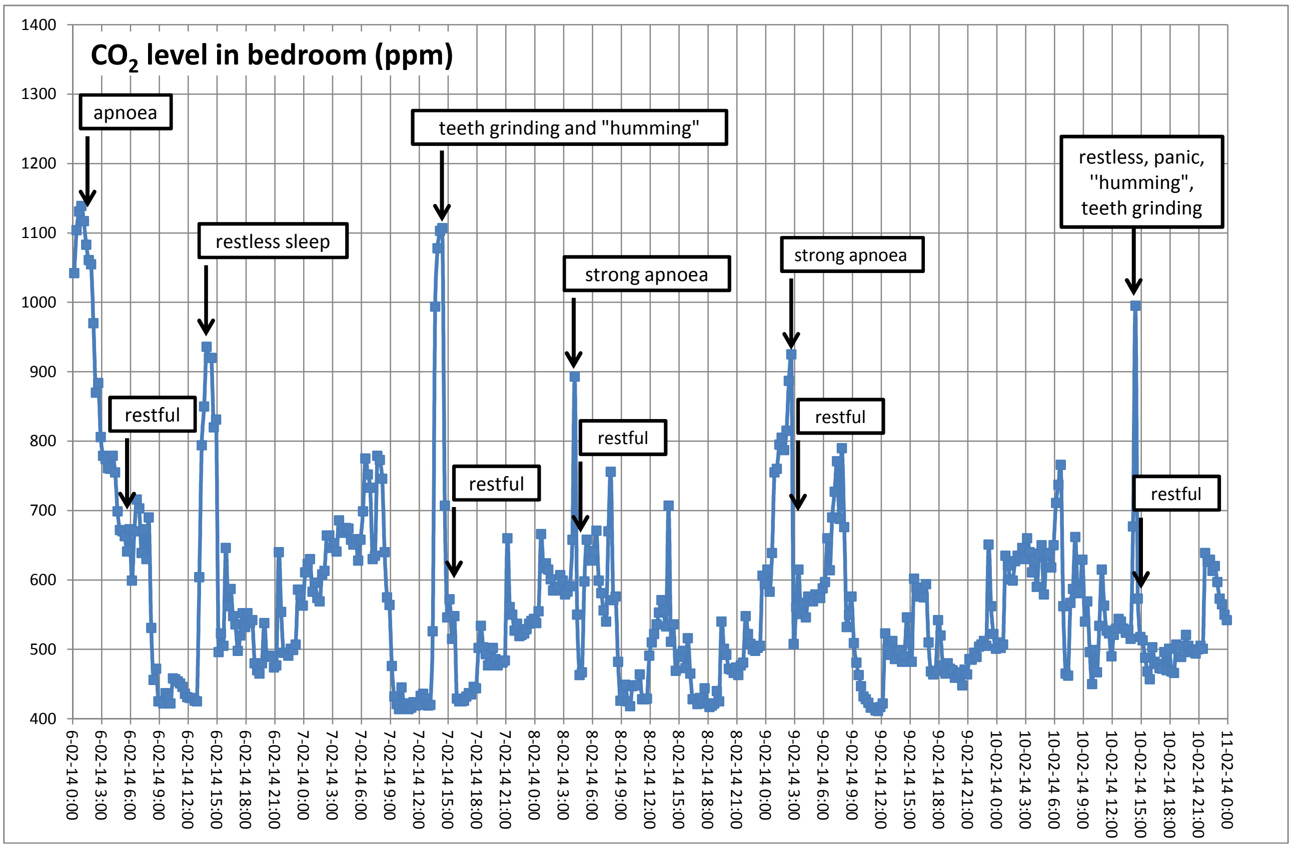

Figure 3. The bedroom CO_2 level and the observed behavior of the Alzheimer patient during a five day experimental period.

After a couple of nights of experimenting, the husband of the Alzheimer patient decided to keep an eye on the CO_2 level and intervene with window and door opening in a more anticipating way. **Figure 4** shows that the restless behavior during sleeping has decreased in occurrences, except for some nights when CO_2 levels were quite high where window or door was left closed.

From the recorded period and the noted observations, the data seems to indicate that the restless sleep behaviour is not observed when CO_2 levels are kept below approximately 800 ppm.

Discussion

The restlessness during the sleep of the Alzheimer patient in this research seems to be coincident with high levels of CO_2 in the bedroom. According to the observations of her husband during the recording period, but also afterwards, the restless behavior has not been observed anymore when the CO_2 levels are kept below 800 ppm. The temperature and relative humidity recordings were also available, but they had no clear deviating pattern coinciding with the restless behavior of the Alzheimer patient.

From the average CO_2 levels recorded in the bedroom, the advice is given to at least open the window of the bedroom in order to keep the CO_2 level below 800 ppm when the bedroom is occupied with one or two persons.

Following this strategy, the husband decided to place two CO_2 loggers permanently, one for the bedroom and one for the living room. Also daytime restless behavior seems to have been decreased since the time that living room CO_2 levels are kept below 800 ppm by opening windows and doors occasionally. Before this knowledge, it was concluded that the restless behavior during for instance birthday parties was originating from the larger number of people in the living room, bringing stress signals to the Alzheimer patient. But this research and the observations may indicate that the elevated CO_2 level itself is responsible for the restless behavior. Nowadays, people are welcome to the house again, without restless behavior, as long as open windows and door keep the CO_2 level low.

The recordings and observations in this research are for one patient only. But following this research, a couple of initiatives have been started to monitor the indoor

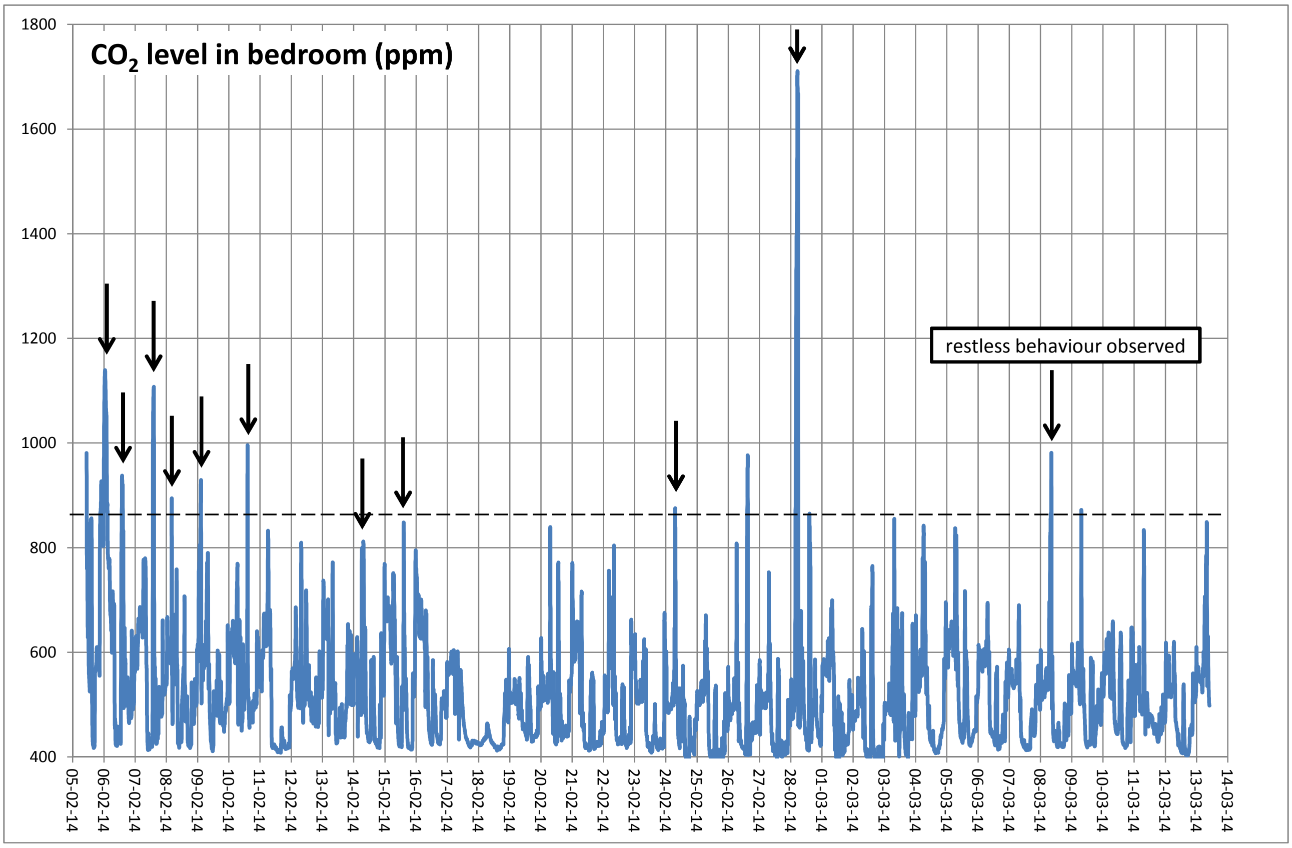

Figure 4. The CO_2 level and the occurrences of restless behavior (arrows) during the 5 week recording period.

air quality and the nocturnal restlessness of Alzheimer patients in care facilities. Only after this larger research these early observations can be substantially backed up by more scientific evidence.

The question arises whether the relation between CO_2 level and restless behavior can be broadened to a larger group like people suffering from dementia, or even healthy people. The author of this article postulates that healthy people have an adaptive response to higher CO_2 levels, meaning they can cope with elevated levels, both physically and mentally, without suffering restless behavior. But people suffering from Alzheimer, or another form of dementia, may have lost this adaptive response to high CO_2 levels and can react physically more intense and already at relatively low CO_2 levels of about 800 ppm. Extensive observational and medical studies have to be carried out to prove if this is the case.

Conclusions

This research shows that the restless behavior of an Alzheimer patient coincides with peaks of the bedroom CO_2 level above 800 ppm. The observed restless sleeping behavior like snoring, teeth-grinding, apnea and panic were not observed anymore when CO_2 levels are kept below 800 ppm. After a peak of CO_2 level and coincident restless behavior, a window was opened so that CO_2 level decreased and after 30 to 45 minutes the sleep of the Alzheimer patient was observed to be restful again.

Much more research should be carried out in the near future if the relation between CO_2 level and restlessness also exists for a larger group of Alzheimer patients or wider for a group of people suffering from dementia or even for healthy people. ■

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The new EN 15316-2*

– a standard for calculating the additional energy use of emission systems

* In this draft standard and this article we still use the terminology "emission" in the future version of the EPB standards we will replace the word "emission" by "emitter". This will be done to avoid the negative connotation of word "emission" which is mainly used in the context of pollutants.

The European Commission asked CEN (mandate M480) to develop standards supporting the application of recast EPBD in the Member States.

This standard constitutes the specific part related to space heating and cooling emission. It specifies the structure for calculating the additional energy use of an emission system.

The new standard supersedes EN 15316-2-1:2007.The main changes compared to EN 15316-2-1:2007 are:

- the two calculation methods have been removed from the standard. Now only one calculation method is in the standard;
- the standard covers also cooling emission systems;
- the standard was updated to cover hourly and monthly time-step.

In the present paper, a short introduction of the new calculation approach of prEN 15316-2 is given.

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This new standard has been prepared by Technical Committee CEN/TC 228 "*Heating systems and water based cooling systems in buildings*". It is part of a package developed to support the Energy Performance of Buildings Directive (EPBD) implementation.

The actual European standard EN 15316-2.1 [1] from 2007 includes two methods for the calculation of the additional energy use for heat emission systems [2, 3]. The new standard draft prEN 15316-2 (as expected to go out for Formal Vote by the end of 2015) provides only one calculation method. In addition, the new prEN15316-2 determines also the additional energy use of water based cooling emission systems. A fundamental point is that the calculation procedure should also be based on tested and certified product values.

Calculation principles

The influences of various phenomena are taken into account in prEN 15316-2 for the calculation of the additional energy use due to often called emission losses. Although these are sometimes not real losses but additional energy use, it is a convention to speak of emission losses. Some come from the physics:

- Embedded emission in the building structure (e.g. floor heating);
- Radiation (e.g. meaning air temperature can be lowered due to radiation effects);
- The stratification (higher air temperatures in the near of the ceiling for convective dominated systems);
- Intermittency.

Some others also based on physics and are additionally influenced by the behavior of the user related to the quality of:

- The building automation and control;
- The hydraulic balance;
- The building management systems (BMS).

It is observed that if the quality of control is low, the user will compensate by increasing the set point temperature in order to obtain the desired comfort. This is modeled by acting on the set point temperature.

prEN 15316-2 proposes to represent all the phenomena by the temperature difference in order to get a unique performance indicator for the classification of the products.

The temperature variation based on all influencing factors can be calculated with Equation (1). For some cases (e.g. for $\theta_{room\ aut}$) also negative values of the temperature variations are possible.

$$\Delta\theta_{int;inc} = \Delta\theta_{str} + \Delta\theta_{ctr} + \Delta\theta_{emb} + \Delta\theta_{rad} + \Delta\theta_{im} + \Delta\theta_{hydr} + \Delta\theta_{room\ aut} \quad (1)$$

With:

$\Delta\theta_{str}$ = spatial variation of temperature due to stratification (K);

$\Delta\theta_{ctr}$ = temperature variation based on control variation (K);

$\Delta\theta_{emb}$ = temperature variation based on an additional heat loss of embedded emitters (K);

$\Delta\theta_{rad}$ = temperature variation based on radiation by type of the emission system (K);

$\Delta\theta_{im}$ = temperature variation based on intermittent operation and based on the type of the emission system (K);

$\Delta\theta_{hydr}$ = temperature variation based on not balanced hydraulic systems (K);

$\Delta\theta_{room\ aut}$ = temperature variation based on stand alone or networked operation room automatization of the system (K)

The calculation of the thermal input for the cooling/heating emission system can be performed on a monthly or on an hourly basis.

Depending on the calculation interval two possibilities are given to calculate the emission sub-system:

- The emission loss approach for a monthly method. The energy needs are calculated with the initial set point temperature according to EN/ISO 13790. The energy needs are then increased by the emission losses (see Equation (2));
- The holistic approach for an hourly method. The energy needs are calculated with the initial set point temperature plus the temperature increase due to the characteristics of the emission subsystem (the emission losses are taken into account directly in the energy need calculation).

In the monthly method the emission losses are calculated as follows (Equation 2). Equation 2 does not apply if there is no thermal output of the emission system (e.g. in the heating case, if the external temperature is equal or higher than the internal temperature).

$$Q_{em;ls} = Q_{em;out} \cdot \left(\frac{\Delta\theta_{\text{int};inc}}{\theta_{\text{int};inc} - \theta_{e;comb}} \right) \quad (2)$$

with

$\Delta\theta_{int;inc}$ = temperature variation based on all influencing factors (K);

$\theta_{int;inc}$ = initial internal temperature (operative temperature) (°C);

$\theta_{e;comb}$ = fictive external temperature during the calculation period (°C);

$Q_{em;ls}$ = additional energy use (heat / cooling losses) of emission (kWh);

$Q_{em;out}$ = thermal output of the heat emission system (kWh)

For heating systems $\theta_{e;comb}$ is the average external temperature during the calculation period.

For cooling systems the fictive external temperature is corrected in the following way:

$$\theta_{e;comb} = \theta_{e;avg} + \Delta\theta_{e;sol} \quad (3)$$

The temperature difference $\Delta\theta_{e;sol}$ represents additional heat gains (e.g. solar heat gains). Default values of $\Delta\theta_{e;sol}$ are tabulated in prEN15316-2.

In the hourly calculation method the user behavior related to the set point temperature can be represented as such. In this case, the additional losses are determined by the simplified hourly energy needs calculation in EN ISO 13790 with the corresponding modified set point temperature.

Input data

Default values for the temperature variations are given in the annexes of the prEN15316-2. For the controller **Table 1** shows the relevant values.

These values could be used if only the product group is known (e.g. during the first design of a HVAC – system). If the products are known and certified then the certified values should be used.

For controllers the temperature variation $\Delta\theta_{ctr}$ is the CA-value (Control accuracy) from EN15500 [5].

For thermostatic valves $\Delta\theta_{ctr}$ -values are from EN215 [6] with is under revision now. The link to the product standard EN215 is in the normative part of the standard. In the informative Annex of the prEN 15316-2 a calculation equation for the CA-values is given as follows:

$$\Delta\theta_{ctr} = \text{CA-value} = 0.45\cdot(\theta_W + \theta_H) \qquad (4)$$

With
θ_W = water temperature influence of the controller
θ_H = hysteresis

This equation can be used during the revision period of the EN 215 and when no other calculation formula is available. It should be noted that the CA-value according EN 15500 and the CA-value calculated on products values based on EN 215 [6] are not completely comparable because of different test procedures. It would be useful to develop a generally applicable test procedure for controllers and thermostatic valves. An additional point is that the Equation (4) is a well-used formula in France but without any scientific background. Therefore, many investigations were carried out in the early past to the topic of CA-value s for TRV systems. In [7] results are presented which are shows that many parameters have an influence on the thermal behavior of TRV-Systems. Especially the

- water temperature influence,
- hysteresis,
- proportional band,
- size of the radiator,
- valve authority,
- supply temperature,
- differential pressure,
- and the flow field around the TRV.

Not all the parameters were investigated very well in the past. But the investigations in [7] can by a starting point of a new discussion. **Figure 1** and **2** show some results.

The printed out curves shows the that the CA-value equation in the present EN 15316-2 represent only in the case of a supply temperature based on the external temperature the behavior of TRV approximately. In the special case of constant supply temperature, the equation fails. Therefore additional investigations are needed.

The same comment applies to the heat and cooling emission system itself. The product standards EN 1264 [8] for embedded heating and cooling systems and the EN 442 [9] for radiator systems do not provide infor-

Table 1. Default values for temperature variation on control.

Product group	$\Delta\theta_{ctr;1}$
Unregulated, with central supply temperature regulation	2.5
Master room space or one-pipe heating	2
Room temperature control (electromechanical / electronic)	1.8
P-controller (before 1988)	1.4
P-controller	1.2
PI-controller	1.2
PI-controller (with optimisation function, e.g. presence management, adaptive controller)	0.9

Note:
P controller (proportional controller)- typically thermostatic controlled valves (TRV)
PI- controller (proportional integral controller)– typically electronic controller

P-controllers are usually directly placed on the emitter (e.g. radiator), PI-controller and "room temperature controlled" in accordance to table 1 can also be installed on a surrounding wall of the room.

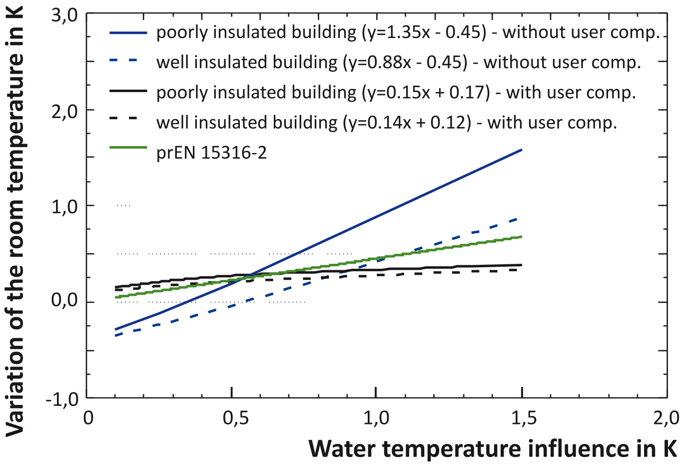

Figure 1. Variation of the room temperature based on the water temperature influence [7] (supply temperature depend on the external temperature).

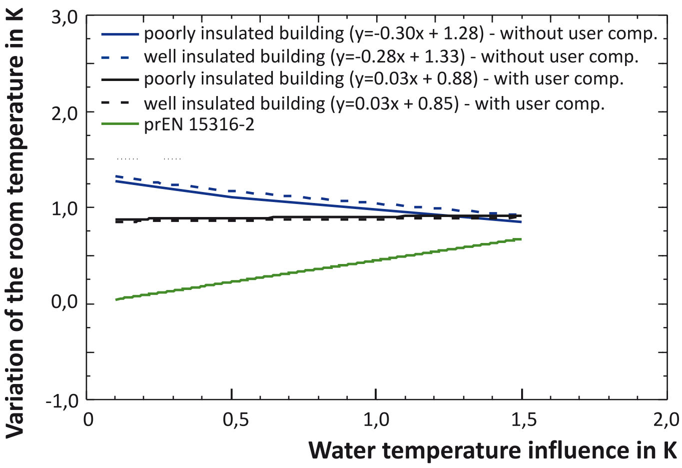

Figure 2. Variation of the room temperature based on the water temperature influence [7] (constant supply temperature).

mation about energy relevant values to be directly used in the calculation method of prEN 15316-2 (temperature variation $\Delta\theta_{rad}$ and $\Delta\theta_{im}$).

prEN 15316-2 has a strong link to the building automation standards (TC247). Work is still needed to harmonize the default product groups in **Table 1** with the classification of the controllers in relation to EN 15232 [10] (e.g. EN 15232 BACS functions, identifiers). It is important for the European industry that there is a common and continuous chain of product testing and standardization, certification, building regulation.

Conclusions

prEN 15316-2 is now under public enquiry until march 2015. prEN 15316-2 is a further step for the harmonization of the energy calculation of buildings. Compared to the existing EN 15316-2.1 there is now only one calculation method in the standard. The method is based on temperature differences. Also cooling emission systems are taken into account in the new standard.

The new prEN 15316-2 has a strong link with product testing. Certified product values can be used directly in the standard. Conservative default values are provided in the annex of the standard.

It should be noticed, that not all the necessary values are already based on product testing. Thus the product standards should be revised in the near future. ■

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The impact of control on the energy use of fans in building ventilation systems

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It is often claimed, or implicitly assumed, that the energy use of controlled fans in ventilation systems decreases in part load conditions by the cube (3rd power) of the load. That means that the energy use decreases from 100% to 12.5% if the air volume flow rate of the ventilation system decreases from full to half load. An analysis ([1], [2] and [3]) based on a mathematical model leads to the conclusion, that there are in fact some cases for which this "cube law" is nearly valid, but also, that in other cases it is far from being valid. Formula and diagrams have been derived that show how the energy consumption reduces with decreasing load, in dependence of the chosen control function type and other decisive influencing factors. Additionally to this insight in the validity of the cube law and the mentioned formulae and diagrams, which also are useful instruments for the control designer, the analysis resulted in new hourly calculation procedures to calculate the energy need for fans, which will be used in the future EN 16798-5-1 (draft [4]) and EN 16798-6-1 (draft [5]), belonging to the calculation standards in the new set of CEN/EPBD standards [6].

The article gives

- In the 1st part an overview of the analysis carried out to study the impact of control on the energy use for fans in ventilation systems
- and in the 2nd part the details to one of the results, i. e. the diagrams which supports the designer of control in the selection of a suitable fan control function type for a multi zone ventilation system.

Key words: Energy performance of buildings, ventilation, fan, single zone ventilation systems, multi zone ventilation systems, control, BAC (Building Automation and Control), constant pressure control, minimum pressure control, part load conditions

Overview of the analysis

The cube law

Under the "cube law" or the "cube law for fans" we understand here the idea that the energy use of a fan is proportional to the cube of the air volume flow rate or of the part load ratio of the ventilation system. We distinguish between two cube laws, the cube law for the fan gas power

$$P_{F,Gas} = R \cdot q_V{}^3 \qquad (1)$$

and the cube law for the electrical power use of the fan

$$P_{F,el} = \frac{1}{\eta_F} R \cdot q_V{}^3 \qquad (2)$$

where (cf. **Figure 1**)

q_V = air volume flow rate
R = flow resistance
η_F = efficiency factor of the fan and its drive
$P_{F,el}$ = electrical power use of the fan, i.e. the power input to the drive of the fan.
$P_{F,Gas}$ = $P_{F,el}$ (according to [7] defined by (5)) if there were no losses in the fan and its drive, that means, if the efficiency factor η_F was equal to 1.

The cube law can be derived directly from the following equations (cf. **Figure 1**)

$$\Delta p_R = R \cdot q_V{}^2 \qquad (3)$$

$$\Delta p_F = \Delta p_R \qquad (4)$$

$$P_{F,Gas} = q_V \cdot \Delta p_F \qquad (5)$$

$$P_{F,el} = \frac{1}{\eta_F} \cdot P_{F,Gas} \qquad (6)$$

where
Δp_R = pressure difference over the flow resistance R
Δp_F = pressure difference over the fan

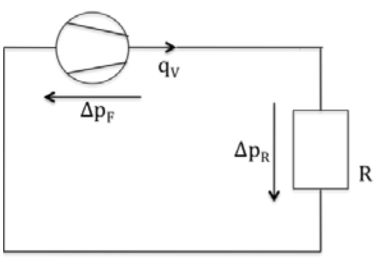

Figure 1. Node model, that is under lied to the cube law for the fan power use.

The cube law for $P_{F,Gas}$ can also be formulated with dimensionless quantities

$$\frac{P_{F,Gas}}{P_{F,Gas,Fld}} = \left(\frac{q_V}{q_{V,Fld}}\right)^3 = f^3 \qquad (7)$$

where

$\frac{P_{F,Gas}}{P_{F,Gas,Fld}}$ = normalized fan gas power
$q_{V,Fld}$ = q_V at full load = design value for q_V
$P_{F,Gas,Fld}$ = $P_{F,Gas}$ for $q_V = q_{V,Fld}$
$f = \frac{q_V}{q_{V,Fld}}$ = part load ratio of the air volume flow rate

This cube law (7) is visualized as dashed curve in **Figure 7**, and repeated also as dashed curve in **Figure 8** and as solid curve in **figures 9–11**.

The cube law is an ideal law. In practice there are always more or less strong deviations from this ideal law. These deviations depend on the operation conditions, on the installed fan and its drive and on the applied fan control function type.

Some findings of the analysis:

- It is important to distinguish between
  - Single zone ventilation systems, where the fan controls directly the air flow rate through the zone
  - Multi zone ventilation systems, for which the air flow rate through a zone is controlled by dampers (often as part of VAV-boxes). The fan control allows to reduce the pressure in the air distribution network and by this to reduce the energy use of the fan
- For single zone ventilation systems it is important to distinguish between
  - Continuous and staged (on-off, 2- stage, etc.) control
  - Open loop and closed loop control
- For multi zone ventilation system it is important to distinguish the following fan control function types
  - Control function type 0: No control
  - Control function type 1: Constant pressure control over the fan
  - Control function type 2: Constant pressure control over the air distribution network
  - Control function type 3: Minimum pressure control

- For multi zone ventilation systems it was possible to develop a relative simple mathematical model that allows deriving formulae that give for all control function types the normalized fan gas power as a function of a few parameters summarizing the main influencing factors.
- The main reasons for the deviations from the ideal cube law are
  - The fan efficiency factor η_F (fan inclusive its drive) is not constant. It generally decreases with reducing part load ratio.
  - The air volume flow rate q_V in single zone ventilation systems with on/off or multi stage fan drives is for commonly used open loop fan control functions, in contrast to closed loop control, usually higher than needed.
  - The pressure drops over not completely open zone control dampers in multi zone ventilation systems causes in part load operation deviations from the cube law.
- It is important to distinguish between the part load conditions of the ventilation system and that of the fan.
- The results of the analysis are valid also for pump control in hydraulic systems.

Results of the analysis:

- **New hourly calculation procedures** to calculate the energy use of fans (This result was the original motivation for the analysis)
- Simple **instruments for the control designer**, supporting him in selecting a suitable fan control function type: Formula and diagrams that show how the energy use of the fan reduces with decreasing load, in dependence of the chosen control function type and other decisive influencing factors
- **Insight** in the validity of the cube law

Application of the results:

- The results will be applied in the future EN 16798-5-1 (draft [4]) and EN 16798-6-1 (draft [5]), belonging to the calculation standards in the new set of CEN/EPBD standards [6]. The standard EN 16798-5-1 will replace EN 15241:2007 [8].
- The results will be applied in the **revision of the SIA 2044** standard [9].

Mathematical models underlying the analysis:

Figure 2 shows the node model on the 'volume flow rate'-pressure- level, underlying the analysis for the case of a multi zone ventilation system with two zones.

An important assumption in the derivation of the hourly method is that the fan control loops converge to a steady state, or to a quasi steady state in the case of staged control, within one calculation time interval of one hour. More details to the mathematical models and the assumptions underlying the analysis are given in [1] and partially also in [2], [3] and [5].

Some design instruments for multi zone ventilation system control

The considered fan control function types:

Four different fan control function types are considered. **Figures 3–6** show their control schematics for the case of two zones (each one with one room) and the case of the supply air fan. For all types the air volume flow rates of the zones are controlled by the local controllers CR1 and CR2 acting on zone control dampers. Shown is the case where these controllers serve to keep the CO_2 concentration in the zone air close to a set-point value, but they could also be zone temperature controllers.

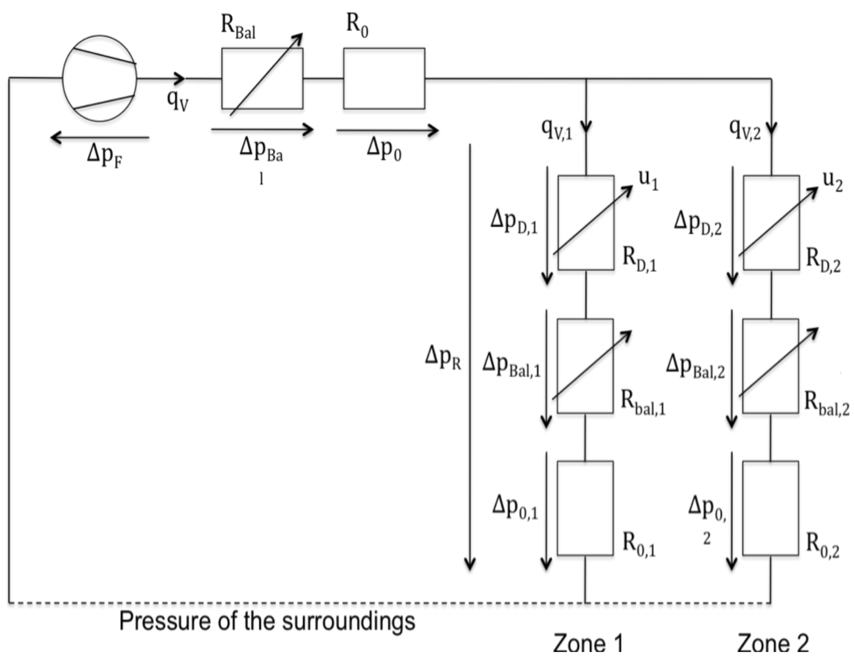

Figure 2. Node model underlying the analysis, shown for a multi zone ventilation system with two zones.

The four considered fan control function types are:

- Control function type 0: No control of the fan (cf. **Figure 3**)
- **Control function type 1: Constant pressure control over the fan** (cf. **Figure 4**): The fan controller C1 controls the pressure difference over the fan on a constant set-point value
- **Control function type 2: Constant pressure control over the air distribution network** (cf. **Figure 5**): The fan controller C1 controls the pressure difference between the distribution network and the surroundings on a constant set-point value.

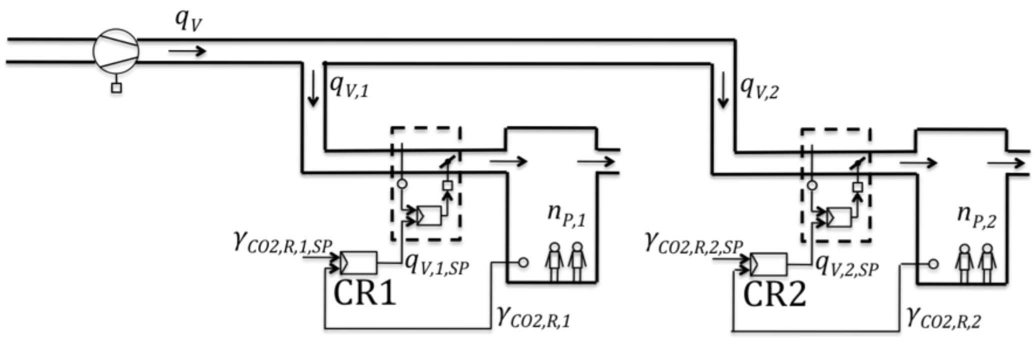

Figure 3. Control function type 0: No control of the fan.

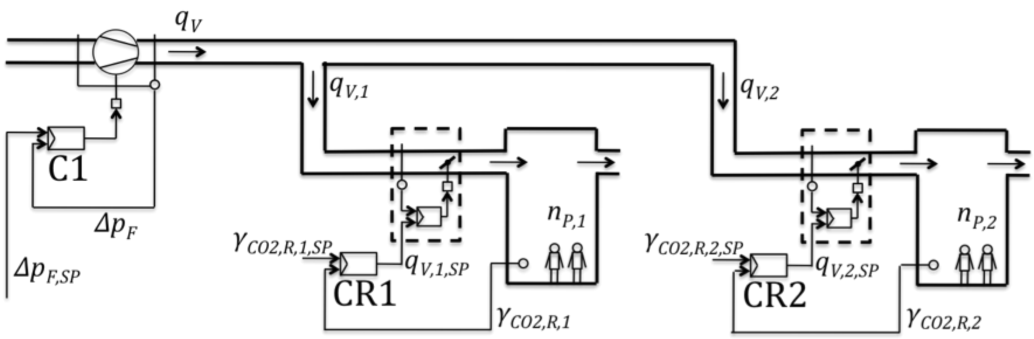

Figure 4. Control function type 1: Constant pressure control over the fan.

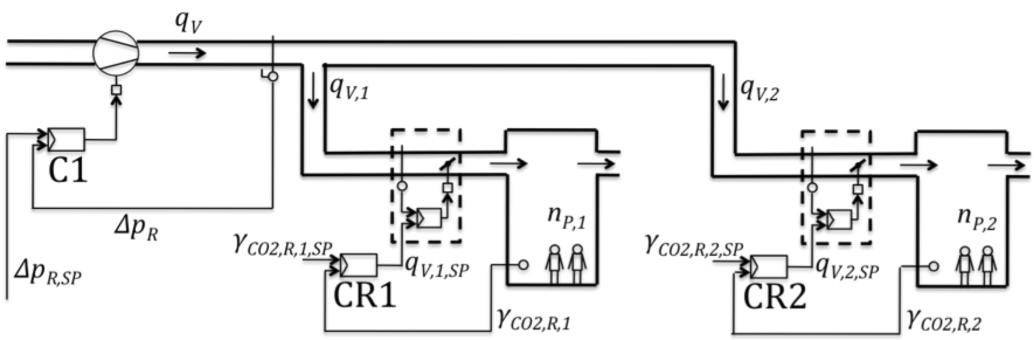

Figure 5. Control function type 2: Constant pressure control over the air distribution network.

- **Control function type 3: Minimum pressure control** (cf. **Figure 6**): The fan controller C1 controls the pressure difference between the distribution network and the surroundings close to the smallest possible set-point value. The smallest possible set-point value is determined by an overlaying control loop with the controller C2, which controls the pressure difference over the distribution network such that the zone damper with the maximum opening will be close to completely open (in the model 100%, in practice e.g. 90%). There are three possible versions of this control function type: In the 1st version the controller C2 acts on the control loop for the pressure over the distribution network, as shown in figure 6, in the 2nd version the controller C2 acts on a control loop for the pressure over the fan and in the 3rd version it acts directly on the fan drive (C1 is no more necessary). **Figure 6** shows that this control function type requires an information link between the zone controller and the central fan controller. Usually the communication network of the building automation system is used for this link. Simulation based investigations to this control function type can be found in [10] and [11].

Formula showing the relation between the fan gas power and its main influencing factors

It was possible to derive for each control function type a formula that give the normalized fan gas power as a function of a few parameters summarizing the main influencing factors.

For the control function type 1 it is

$$P_{F,Gas} / P_{F,Gas,Fld} = f \qquad (8)$$

for $0 \leq f \leq 1$

for the control function type 2

$$P_{F,Gas} / P_{F,Gas,Fld} = f \cdot \left((1-c) \cdot f^2 + c\right) \qquad (9)$$

for $0 \leq f \leq 1$

and for the control function type 3

$$P_{F,Gas} / P_{F,Gas,Fld} = f \cdot \left((1-c) \cdot f^2 + c \cdot f_{\max}{}^2\right) \qquad (10)$$

for $0 \leq f \leq f_{max}$

where

$f =$	part load ratio of the total volume flow through the fan as defined above
$c =$	$\Delta p_{R,Fld} / \Delta p_{F,Fld}$
$f_{\max} =$	$\max_i (f_i)$
$=$	maximum part load factor f_i of the zone air volume flows (maximum over zones)
$=$	$f + \Delta f$ if part load diversity Δf is the given input parameter
$f_i =$	$q_{V,i} / q_{V,Fld,i}$ = part load factor of the zone air volume flow of zone i
$q_{V,i}$ =	volume flow rate in zone i
$q_{V,Fld,i} =$	$q_{V,i}$ at full load = design value for $q_{V,i}$
$\Delta f =$	$f - f_{\max}$ = part load diversity = a scale to measure the diversity of the part loads over the zones

The formulae are valid for any number of zones.

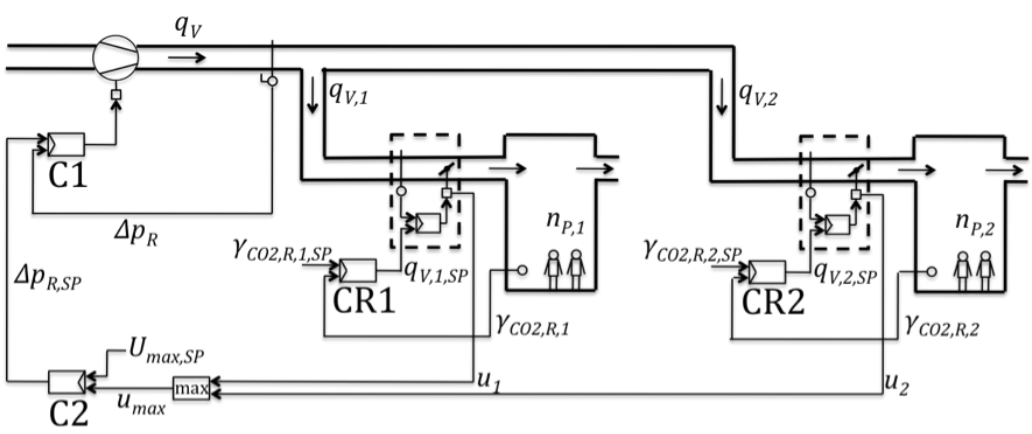

Figure 6. Control function type 3: Minimum pressure control – version 1.

Diagrams supporting the designer in selecting a suitable fan control function type

The formulae (8)–(10) allow to draw the diagrams shown in **figures 7–11**. The parameter $\Delta p_{R,Fld}/\Delta p_{F,Fld}$ is the ratio of the design pressure difference over the zone branches to that over the fan. The curve parameter for the control function type 3 is the maximum part load factor f_{max} (left side of the figure), or alternatively the part load diversity Δf (right side of the figure).

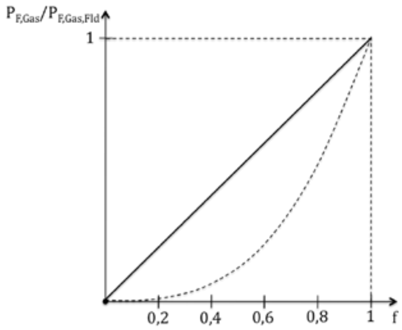

Figure 7. Control function type 1: Load dependency of the fan gas power.

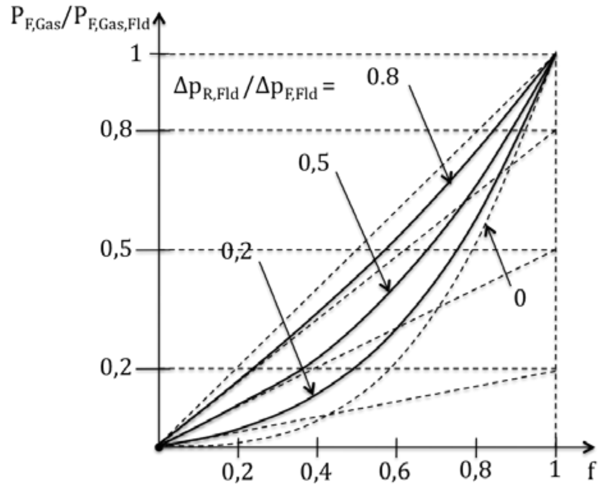

Figure 8. Control function type 2: Load dependency of the fan gas power for different ratios of the design pressure difference over the zone branches to that over the fan.

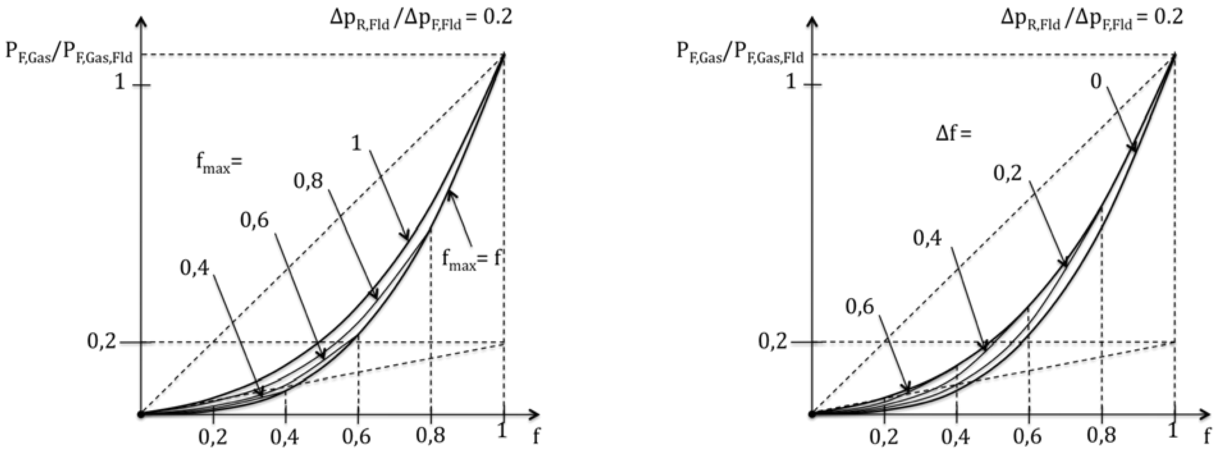

Figure 9. Control function type 3: Load dependency of the fan gas power for the case where the design pressure difference over the zone branches is small compared to that over the fan.

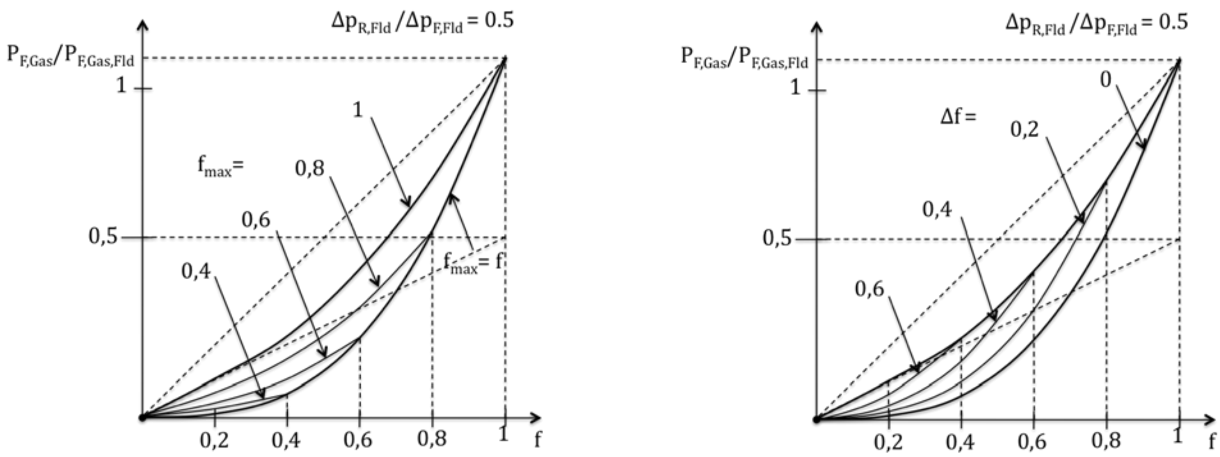

Figure 10. Control function type 3: Load dependency of the fan gas power for the case where the design pressure difference over the zone branches is medium sized compared to that over the fan.

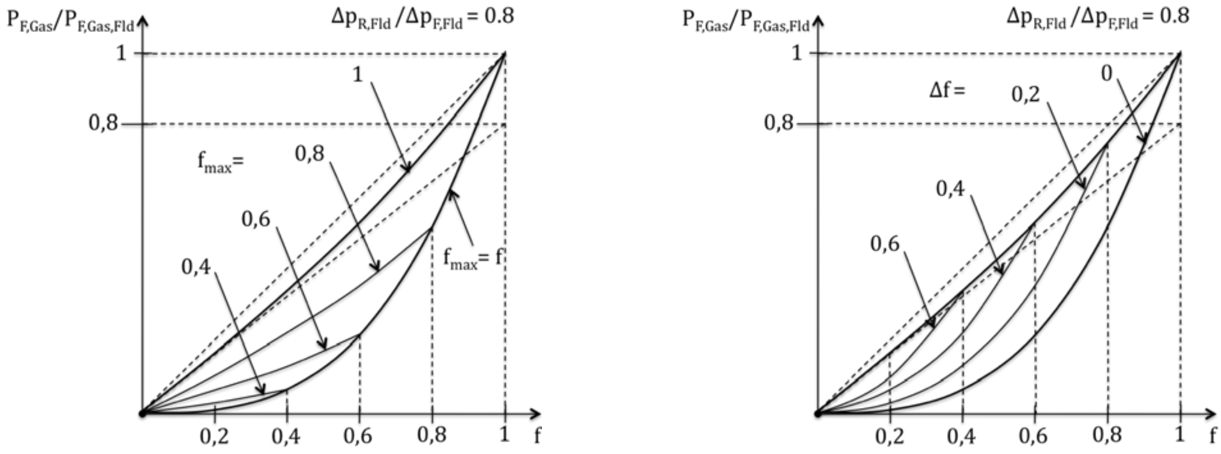

Figure 11. Control function type 3: Load dependency of the fan gas power for the case where the design pressure difference over the zone branches is large compared to that over the fan.

The diagrams in **figures 7–11** show in which cases the cube law for the fan gas power is valid or nearly valid:

- For control function type 2 and 3, if the ratio of the design pressure difference over the zone branches to that over the fan is small. Type 3 does not bring a substantial improvement compared to type 2 in this case.
- For control function type 3, if the part load diversity is small (the cube law is exactly valid if the part load diversity is zero).

The diagrams in **figures 7–11** serve as a useful instrument for the control designer, by supporting him in selecting a suitable control function type. Some rules for the selection from an energy point of view can directly been derived from the diagrams:

- For a ventilation system with a small ratio $\Delta p_{R,Fld}/\Delta p_{F,Fld}$ i.e. for a ventilation system for that the design pressure difference over the zone branches is small compared to that over the fan (typically for the supply air pipe with a central air handling unit with a high flow resistance and short zone branches) the control function type 2 leads in part load operation to a fan energy need that is substantially lower than that of type 1. Control function type 3 does not bring a substantial improvement.
- For a ventilation system with a large ratio $\Delta p_{R,Fld}/\Delta p_{F,Fld}$ i.e. for a ventilation system for that the design pressure difference over the zone branches is large compared to that over the fan (typically for the exhaust/extract air pipe and long zone branches) the advise for a selection depends on how often the system is in which part load and in which part load diversity. The more frequently the system is in part load operation with a small load diversity the more rewarding is it to prefer type 3 to type 2 or 1. If the part load diversity is at most time large, then type 1 is sufficient. Type 2 and 3 does not bring a substantial improvement.

Whether type 1 should be preferred to type 0 cannot be found out from the shown diagrams. That depends on the characteristic curves of the fan. If the curves in the operation area are flat, then the advantage of type 1 compared to type 0 is not substantial.

A final selection of the fan control function type should also take into account other criteria as cost or for example the auto-tuning capability of the control function type 3, which can compensate for bad manual balancing of the pipe network. ■

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US DOE launched a common definition for Zero Energy Buildings

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Chair of CENTC 371 Program Committee on EPBD
Fellow of ASHRAE and REHVA

DOE launched ZEB definition which is very similar to REHVA definition and relies on site boundary being exactly the same as REHVA's system boundary. DOE definition provides valuable input to European discussion in exported energy issues and for instance by addressing Renewable Energy Certificates.

Primary energy commonly used in Europe is called Source Energy (Renewable & Non-Renewable) in DOE definition [1] being a major difference in terminology. The system boundary for zero energy accounting follows exactly the REHVA's one [2] and addresses energy need, energy use, and delivered and exported energy accounted on *site boundary*, **Figure 1**. If compared to the REHVA's system boundary, **Figure 2**, one can see that even the same terms have been used – reflecting the same basic understanding by European and US energy experts. Regarding to the European regulators discussion, should lighting and appliances be accounted in energy performance or not, DOE clearly states that all energy used in the building, including lighting, plug loads and even processes, is considered as energy performance of a building, fully supporting REHVA's previous proposal.

DOE defines Zero Energy Building (ZEB) as "An energy-efficient building where, on a source energy basis, the actual annual delivered energy is less than or equal to the on-site renewable exported energy." Therefore, the definition is based on annual balance of delivered and exported primary energy. This definition equals to REHVA net Zero Energy Building (net ZEB) definition "Non-renewable primary energy of 0 kWh/(m² a)." Both DOE and REHVA provide an explanation that ZEB (net ZEB by REHVA) is typically a grid-connected building that is very energy efficient. "The premise is that ZEBs use the electric grid or other energy networks to transfer any surplus of on-site renewable energy to other users."

The site boundary is defined as a meaningful boundary that is functionally part of the building(s). "For a single building on a single property, the site boundary is typically the property boundary. The site boundary should include the point of utility interface". Definitions for zero energy campus, portfolio and community would allow to extend the site boundary and to include for instance the site energy centers.

In zero energy campus, portfolio or community definitions a word "building" is just replaced by campus, portfolio or community. For example, Zero Energy Community: "An energy-efficient community where, on a source energy basis, the actual annual delivered energy is less than or equal to the on-site renewable exported energy."

DOE definition has no limitations for exported energy and the same primary energy factors are used both for delivered and exported electricity. US primary energy factor for electricity of 3.15 is somewhat higher than European one of 2.3. It is considered that exported on-site renewable electricity displaces electricity that would be required from the grid. "In ZEB accounting, the exported energy is given the same source energy conversion factor as the delivered energy to appropriately credit its displacement of delivered electricity", that is also a default choice in REHVA definition. The source energy conversion factors utilized are from ASHRAE Standard 105, and they are summarized in **Table 1**.

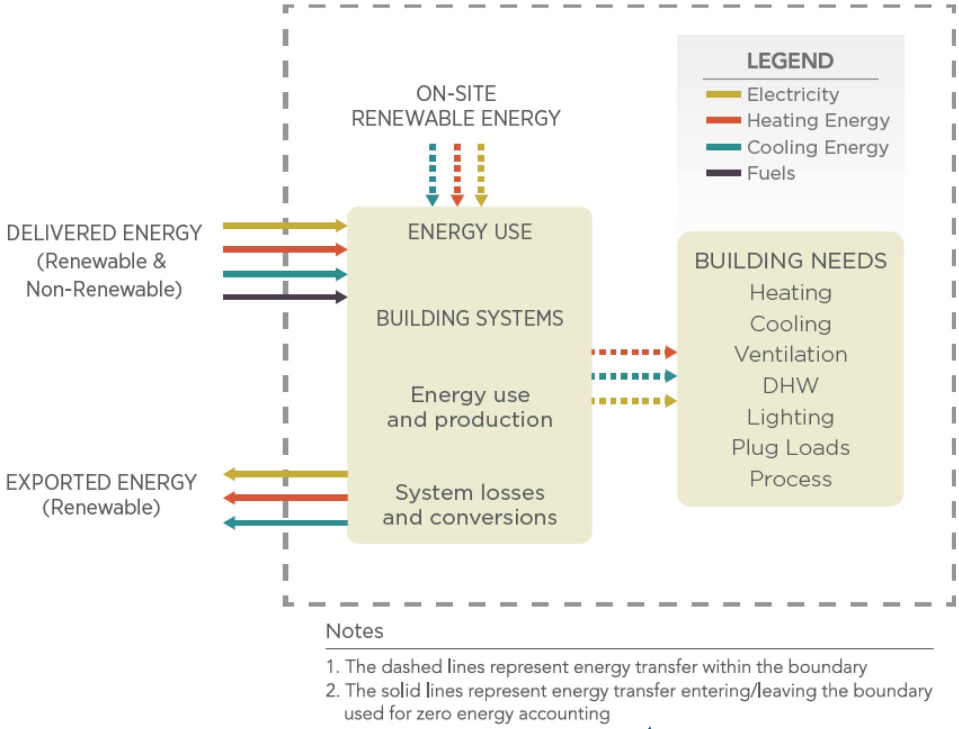

Figure 1. DOE Site Boundary of Energy Transfer for Zero Energy Accounting.

The situation at CEN and ISO standardisation:

The current Overarching Standard the prEN ISO 52000-1 (former prEN15603) offers via the Annex A-B approach all required flexibility to follow the REHVA and DOE approach.

In Europe it is the wish of the EU-Member States to choose their own default parameters to handle imported, exported and primary energy and building- site and nearby boundary.

It is expected that non-EPB use is not included in the equation, however the standard can also support a ZEB definition where this is included.

The added value of the DOE approach is that clear choices have been made. This DOE statement doesn't imply a federal regulation in the USA but may lead the discussion in the right direction.

The EU Commission will require the use of the EPBD-standards inclusive the annex B as required option in the framework of the Voluntary Certification Scheme for Non-Residential buildings. This is similar to, or perhaps even more regulatory, compared with this DEO initiative which will encourage all US stakeholders to act accordingly.

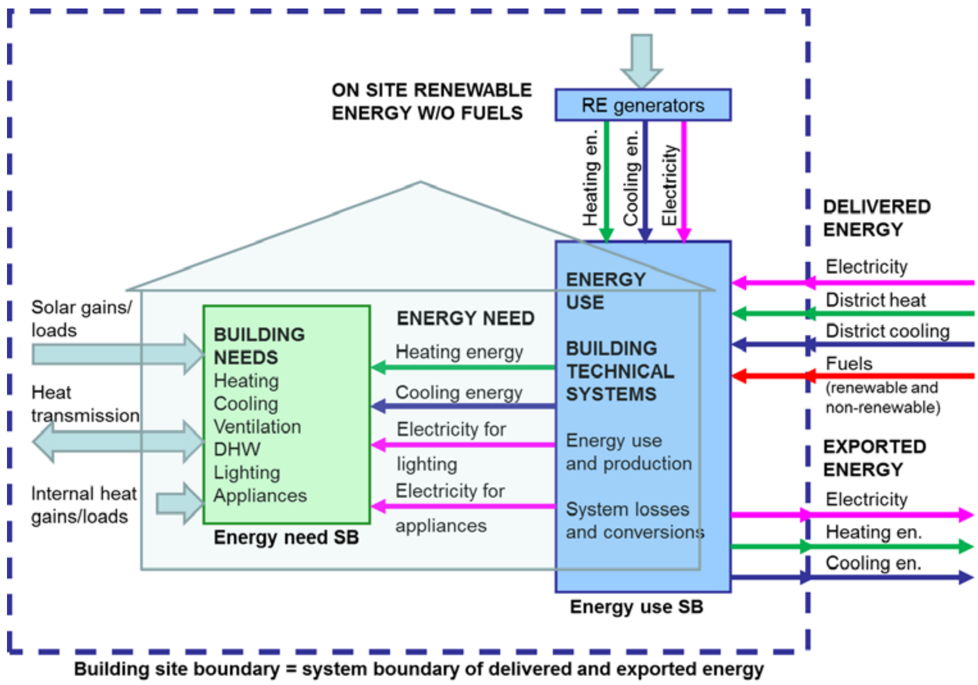

Figure 2. REHVA system boundary from 2013 [2].

Table 1. US National Average Source Energy (primary energy) Conversion Factors.

Energy Form	Source Energy Conversion Factor (r)
Imported Electricity	3.15
Exported Renewable Electricity	3.15
Natural Gas	1.09
Fuel Oil (1,2,4,5,6,Diesel, Kerosene)	1.19
Propane & Liquid Propane	1.15
Steam	1.45
Hot Water	1.35
Chilled Water	1.04
Coal or Other	1.05

DOE definition addresses the use of Renewable Energy Certificates (REC) which are tradable instruments that can be used to meet voluntary renewable energy targets. "Once a buyer makes an environmental claim based on a REC, the buyer can no longer sell the REC and the REC is considered permanently "retired"." The ZEB definition and its variations (Campus, Portfolio, Community) require **on-site renewable energy to be used to fully offset** the actual annual delivered energy. Therefore these definitions **do not allow** renewable electricity purchased through the use of renewable energy certificates (RECs) to be used in the ZEB energy accounting.

High rise buildings in dense urban areas or buildings with high process loads may choose to have off-site renewable electricity utilizing RECs to help balance the annual delivered energy. Special REC-ZEB definition is provided to allow RECs to be used to supplement, after on-site renewable energy sources have been employed, and balance the annual delivered energy to the building. Renewable Energy Certificate - Zero Energy Building (REC-ZEB) is defined as "An energy-efficient building where, on a source energy basis, the actual annual delivered energy is less than or equal to the on-site renewable exported energy plus acquired Renewable Energy Certificates (RECs)".

REC-ZEB is an interesting approach that can be seen as one possible solution for European "nearby generation", having so far no common grounds and not yet implemented into regulation by any MS. ■

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International Conference

World Sustainable Energy Days **2016**

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CONFERENCES:

- European Nearly Zero Energy Buildings Conference
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- Smart Facade Materials Conference
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9 October 2015

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6 specialised conferences offer the opportunity to learn about current trends in the sustainable energy world and interactive events provide valuable networking possibilities. The conference is held in parallel with the Energiesparmesse, a major tradeshow on energy efficiency and renewable energy, with more than 1,600 exhibitors and 100,000 visitors annually.

The European Nearly Zero Energy Buildings Conference, along with the Young Researchers Conference and Award, focus on high energy efficiency buildings supplied by renewable energy.

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Indoor Environmental Quality – Global Alliance

Background

Today energy consumption and energy efficiency of buildings is a very hot topic in most developed countries. This is exemplified by the increased amount of research, buildings codes, standards related to energy compared to a much lower activity level in relation to the indoor environment. There exist several international organisations dealing fully or partly with the indoor environment; but their voice is often neglected. As the indoor environmental quality is a multidisciplinary issue involving architects, engineers, health specialist, occupational health specialist etc. there is not one organisation/society, which in a significant way can make sure that all parties in the chain for providing the indoor environmental quality will do the work.

Vision

The vision of the Indoor Environmental Quality-Global Alliance (IEQ-GA) is to be the world's primary source for information, guidelines and knowledge on the indoor environmental quality in buildings and places of work around the world

Mission

The mission of IEQ-GA is to provide an acceptable indoor environmental quality, to occupants in buildings and places of work around the world. Another mission is to make sure the knowledge from research on IEQ get to be implemented in practice.

Objective

The objective of the alliance is to get the organizations to think together, work together and speak with the same voice. The alliance is formed as an interdisciplinary, international working group of organizations interested in indoor environmental quality (thermal comfort, air quality, acoustic, lighting) science, technology, and applications to stimulate activities that will help in a significant way to improve the actual, delivered indoor environmental quality in buildings.

BJARNE W. OLESEN
ASHRAE Treasurer
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The alliance will consider research, design, commissioning, operations, and standards. The alliance will engage all segments of the indoor environmental community, including research, manufacturing, design, assessment and remediation, government, and others as determined by the alliance.

Type of memberships

The founding members are:

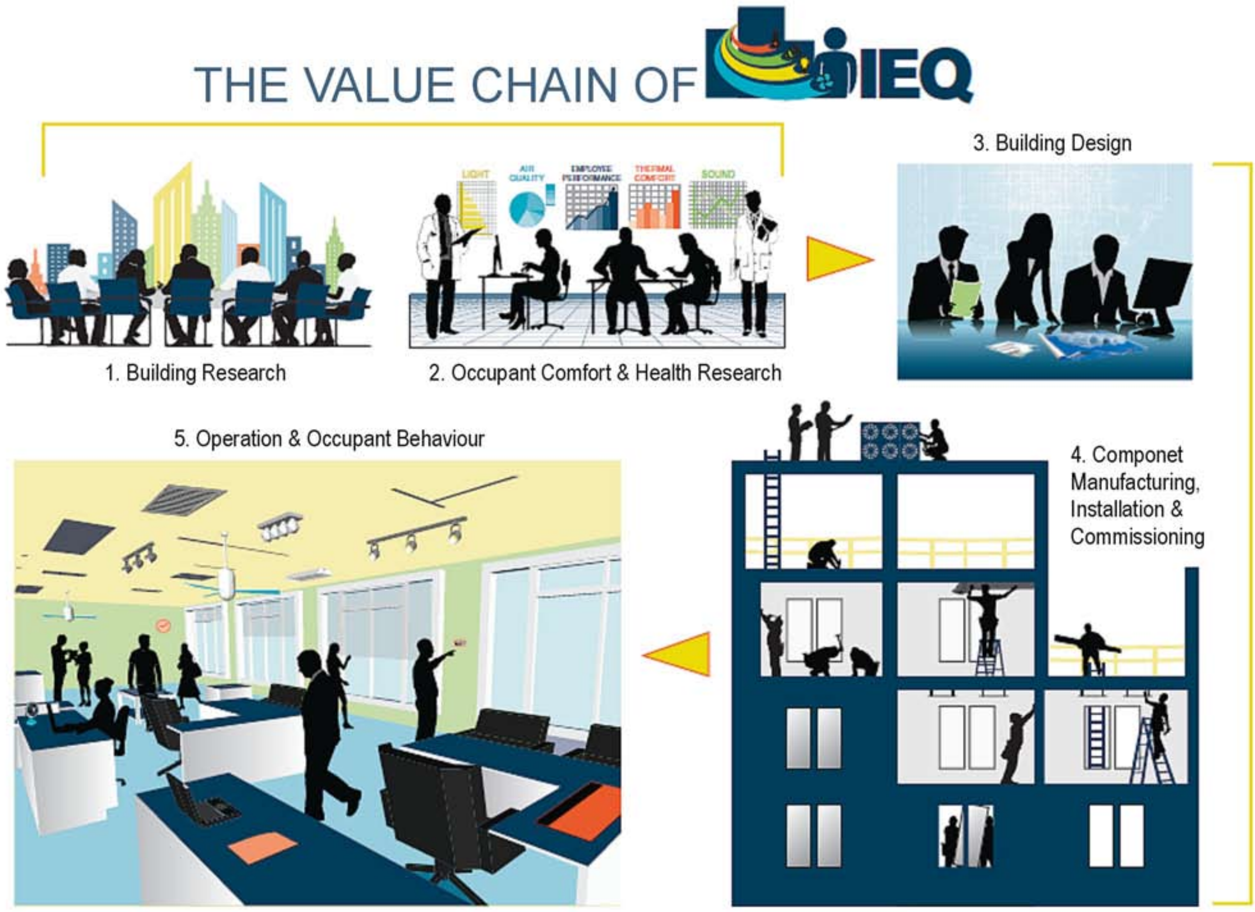
- AIHA- American Industrial Hygiene Association
- AIVC-Air Infiltration and Ventilation Centre
- ASHRAE
- AWMA- Air and Waste Management Association
- IAQA-Indoor Air Quality Association
- REHVA- Federation of European Heating, Ventilation and Air Conditioning Associations

There is a need also to include societies that represent acoustic, lighting and societies that work more on health. These organisations are all non-profit and with members not representing a special product or product group. Besides the alliance have also affiliate members that can be trade organisations or governmental organisations that are dealing with the indoor environment.

Activities

Issues that are addressed by the alliance are:

- How can we involve and work with government bodies?
- What are the research needs?



- Reduction of science to practice in design, assessment, and remediation
- Tools for evaluating indoor environmental quality as a design parameter.
- Integration of IEQ with other building design and operation considerations such as energy and water use
- The economic case for better IEQ.

The possible outcome of the activities can be

- Research recommendations
- Proposals for publications and educational courses.
- Influencing and/or propose standards.
- Common position documents
- Combined conferences

Until now the IEQ-GA has organised several seminars at different conferences. It has also been decided to develop a guide "Review of international standards and guidelines for Indoor Environmental Quality". Standards and guidelines concerning indoor environmental quality are developed and used around the world by a variety of organizations without a high degree of coordination. Some are the product of international standards organizations for global use, while others have been developed using a more limited national or regional perspective but have been more widely adopted over time. As a preliminary step toward the development of a consistent global approach to all aspects of IEQ, this guide will contain a review of these existing documents.

The value chain of indoor environmental quality

The intend is that the alliance shall cover all partners involved in the value chain of IEQ from research, design, manufacturing, construction (building properties), installation (building service systems), operation, inspection to the behaviour of the occupants (see figure).

Future outlook

The alliance is still working on procedures on how to run the alliance and get new memberships to cover all parts of the indoor environment. At the moment we are looking for international organization representing lighting and acoustic. It is possible to follow the IEQ-GA on the web-site: www.ieq-ga.net . Here it is also possible to sign up for a newsletter. ■

Chiller seasonal energy consumption in historical buildings

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A plenty of studies are devoted to estimation methods of seasonal energy consumption of cooling equipment. Several computing instrument give the ability to calculate or simulate chiller's electricity consumption at variable conditions. Using European Seasonal energy efficiency ratio (ESEER), provided by equipment suppliers, engineers and project developers can make fast and rather rough calculations on annual cost in order to determine the economic feasibility for choosing the particular type of cooling equipment. And the question is, how precise those calculations could be for temperate and northern climates?

As a part of the research on evaporative cooling appliance in temperate climate of Baltic States, conducted in Latvia in 2011–2014 [1], an analytical research made in recently restored 19th century historical building, The Art Museum Riga Bourse.

Restoration of old buildings is a complex construction process, in which engineers and architects need to solve many atypical tasks concerning not only the structural stability of the building, but also the recovery of cultural—historical appearance of the building. Necessity of harmonious integration of modern HVAC devices in the historical interior also enforces limits to the equipment selection. The successful solving these and construction tasks results in a balanced and sustainable restoration of the building.

Figure 1. The Riga Bourse building in 19th century and nowadays after reconstruction.

The analytical research overtakes the results of water cooling system operation for one year cooling period. The data of electricity and water consumption, chiller operation modes and cooling system temperature data were logged with one-minute interval. The duration of analysis period was chosen, based on the building cooling demand. The data obtained were converted to average hour values after the analysis of errors. The calculated cooling output depending on the outdoor air (OA) temperature is displayed on **Figure 2**.

The information on equipment efficiency that is necessary for seasonal energy consumption calculations is limited. Usually, energy efficiency ratio and the seasonal efficiency of the device are available. The industry has implemented ESEER (European Seasonal Efficiency Ratio), recently published regulations or those in the process of being published talk about seasonal coefficient of performance (SCOP) in heating mode, and its equivalents SEER and SEPR in cooling mode. Seasonal energy efficiency, in accordance with EN14511:3 – 2013 and [2] is calculated according to the Equation (1) explained below:

$$ESEER = A \times EER_A + B \times EER_B + C \times EER_C + D \times EER_D, \quad (1)$$

Where:

EER = ratio of the total cooling capacity to the effective power input of the unit, Watt/Watt.

In authors' opinion ESEER introduction to the market was a great achievement within the equipment assessment principles, which is likely to reflect accurately the effectiveness of Central Europe or the Mediterranean part of Europe. On the other hand, when in Latvian climate conditions the building cooling load is traditionally calculated using an outdoor air temperature of +27°C (Riga), ESEER test parameters are quite distant from the real situation. Practice shows that the cooling demand in many objects occurs at much lower outdoor temperatures such as +15°C or even +10°C. Such objects may include: office premises with large amount of office equipment, facilities with high human density, retail spaces with great light intensity, and rooms with large windows surfaces and no shadows. The location of ventilation diffusers does not always provide cooling in the most comfortable way such as displacements ventilation, for people in the premises. In those cases the air cooling is carried out with chillers and the room terminal units like chilled beams or fan-coils. Sonderegger (1998), based on a number of energy efficiency project analysis pointed to a large inaccuracies in heating / cooling system energy savings estimates, if they are performed only based on the weather data [3].

The values of cooling energy produced at a certain temperature ranges with a step of 2.0°C are presented

Table 1. ESEER components description.

Conditions	Load ratio, %	Weighing coefficient	Air temperature at condenser inlet (air cooled chillers), °C	Water temperature at condenser inlet (water cooled chillers), °C
A	100	0.03	35	30
B	75	0.33	30	26
C	50	0.41	25	22
D	25	0.23	20	18

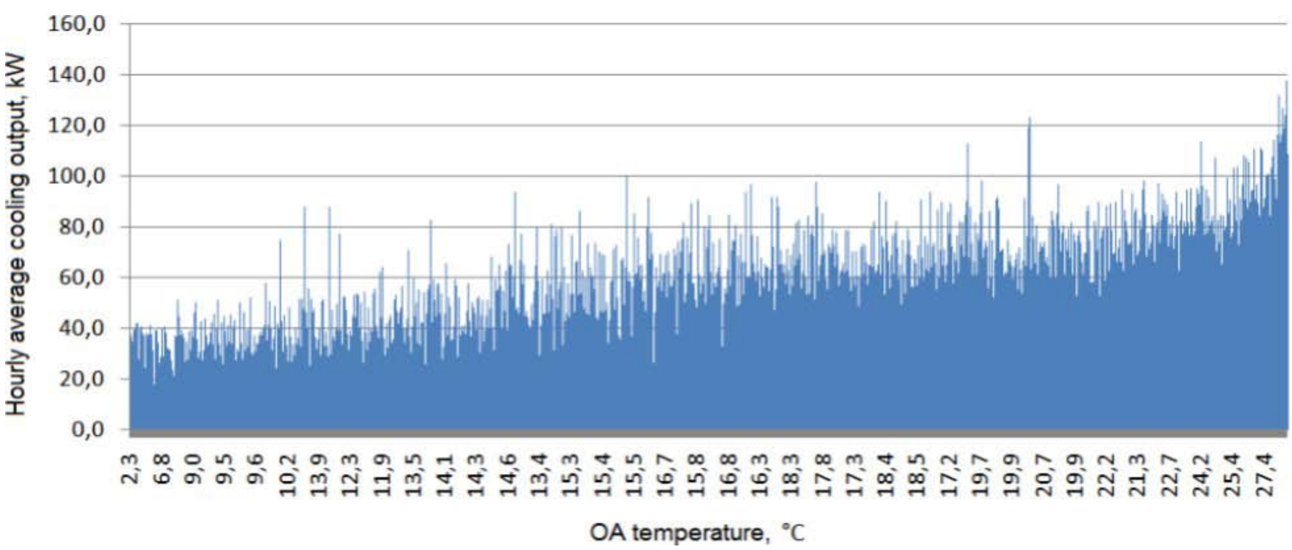

Figure 2. The calculated cooling output depending on the outdoor air (OA) temperature.

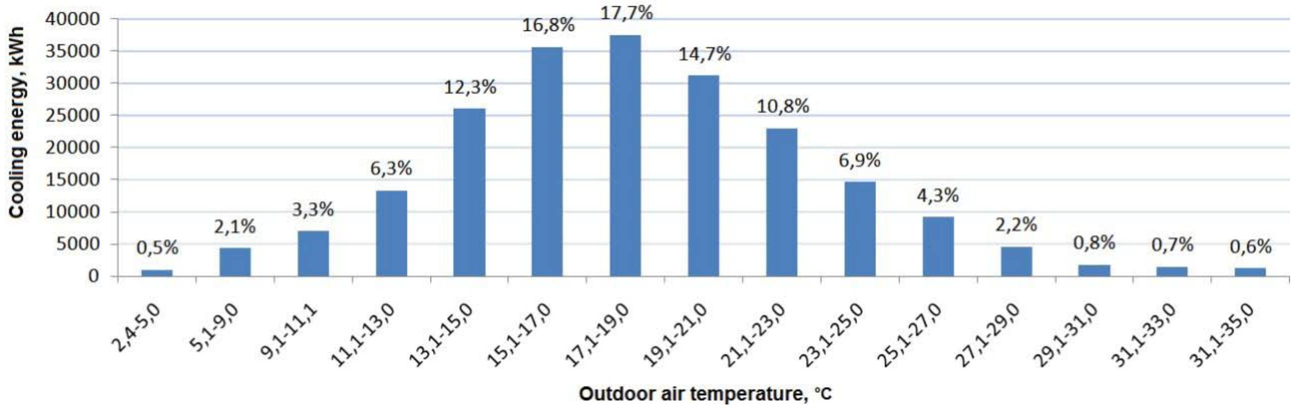

Figure 3. Cooling energy produced at outdoor air temperature diapasons.

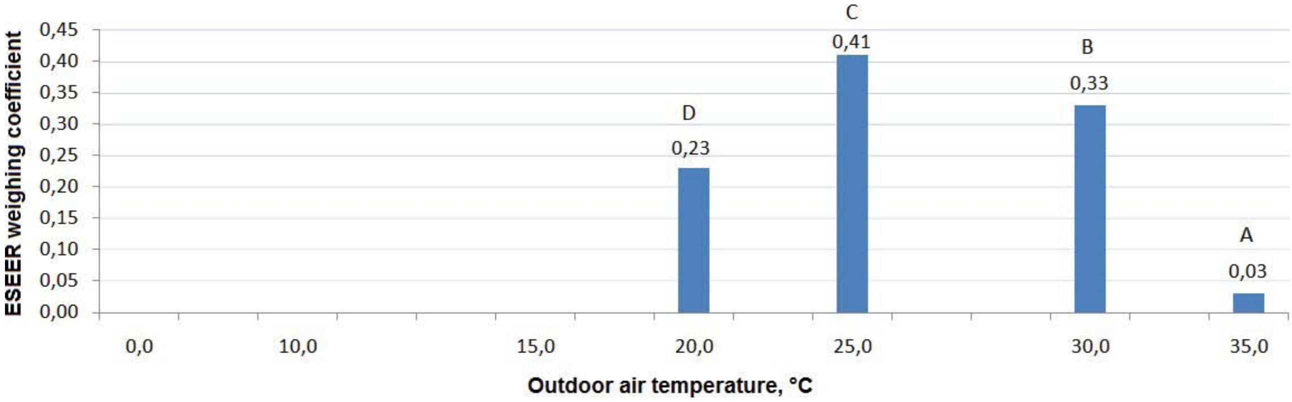

Figure 4. ESEER impact factors at the same outdoor (condenser inlet) temperature distribution for comparison.

in **Figure 3**. The vast majority or about 67% of cooling energy during the cooling period was produced when the outside temperature was in the range from 10 to 20°C. According to the generally accepted practice, the cooling is required when ϑ_{OA} is higher than 18–19°C, (which is also generally accepted base temperature for cooling degree-hour calculation). Within the particular building non-weather dependent cooling accounts for more than half of the total annual cooling energy. This characterizes the objects with high heat gains, and / or high microclimate requirements.

ESEER impact factors at the same outdoor (condenser inlet) temperature distribution for comparison are shown in **Figure 4**.

The acquired data in art museum showed cooling system showed significant difference on cooling energy produced on site and ESEER weighing methodology. Due to that, the more precise coefficient distribution method is offered. The calculation principle can be expressed as follows:

$$Q_{el.seas.} = \sum \Delta\vartheta_n \left(\frac{Q_{c.nom.}}{EER_{\Delta T_n}} \cdot DS_{\Delta\vartheta_n} GS_{\Delta T_n} \right) + Q_{el.st.} \tag{2}$$

Where:

$Q_{el.seas.}$ = electricity consumption during cooling season, kWh

$\Delta\vartheta_n$ = outdoor air temperature interval

$Q_{c.nom.}$ = nominal cooling load of the device in standard conditions, kW

EER = energy efficiency ratio at a given interval

CL = cooling load at a given temperature interval, % or part of 1, from nominal device capacity

GS = the number of cooling degree hours at a given temperature interval, h

$Q_{el.st.}$ = standby electricity consumption, kWh

Using the proportional distribution method, seasonal energy consumption calculations are performed for combined compression cycle – evaporative chiller (KKCD). For comparison, one calculation is done for close to the ESEER temperature / load intervals. Cooling degree hours (CDH) was taken, using Latvian Typical Meteorological year data in temperature diapason ±2°C. We can see that it overtakes outdoor air temperatures from 18 to 37°C and the total electric energy consumed is 24 128 kWh for the chiller with maximum cooling capacity 320 kW (**Table 2**):

However, the actual yearly electricity consumption of the chiller, logged by electricity meters is 62 000 kWh. Using the above mentioned formula (2), proportional method calculation has been performed for 7 outdoor temperature / load intervals. EER data which was out of ESEER conditions was executed from laboratory experiments on the similar chiller. The portion of cooling energy at ϑ_{OA} less than 10°C, which was produced at the investigated site during the cooling season accounted for 5.9% of the total energy produced. This part of the calculation is added to the calculation due to the equipment operating efficiency drawbacks within this range (**Table 3**).

The results showed much higher precision when using 7 interval proportional methods for the investigated building. It could be proposed to extend the ESEER part load test methods to wider TOA and cooling load ranges. Surely, further investigations on real cooling load should be made in different types of buildings to increase the amount of trustable data. These factors could help to increase the accuracy of economic and energy consumption calculations, taking into consideration peculiarities of various object types and conditions of northern climate. ■

Table 2. Seasonal energy calculation using ESEER values and summarized CDH.

Condition	ϑ_{OA} interval, °C	CDH	Load ratio, %	KKCD EER	Yearly electrical energy consumption, kWh
A	33 – 37	2	100%	3,6	178
B	28 – 32	24	75%	4,2	1 371
C	23 – 27	288	50%	5,1	9 035
D	18 – 22	965	25%	5,7	13 544
				Total	**24 128**

Table 3. Seasonal energy calculation using 7 intervals with summarized CDH.

ϑ_{OA} interval, °C	CDH	Load ratio, %	KKCD EER	Yearly electrical energy consumption, kWh
27 – 33	49	90%	4,2	3 360
24 – 26	150	75%	5,1	7 059
20 – 23	580	50%	5,7	16 281
17 – 19	804	30%	6,0	12 864
14 – 16	964	15%	6,3	7 345
10 – 13	1 276	10%	7,0	5 833
0 – 10	5,9% of the overall kWh consumed			3 112
			Total	**55 853**

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M1-classification systems support each other

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Several labelling schemes for low emitting products exist in Europe and each has its own specific requirements for testing and criteria for product evaluation. There is an exceptional way of improving Indoor Air in Finland. There is a classification system for both HVAC components and building materials that support each other when building new premises.

The Emission Classification of Building Materials (M1) and The Cleanliness Classification of Air-handling Components are part of Classification of Indoor Environment 2008, which is intended to be used in the design and construction of healthier and more comfortable buildings and their mechanical systems. Both systems are operated by The Building Information Foundation RTS; the classification systems already provide a good tool to improve IAQ. However, there is a necessity to improve both classification systems continuously. The recent inclusions to the Emission Classification of Building Materials, fixture and furniture without padding or textile coverings are a remarkable step for future improvements for good IAQ. There is a necessity to widen the scope of classified materials in the future as well. The next step is to classify furniture with padding, including office chairs, armchairs, sofa, folding screens and other chairs.

The furniture has high emissions especially after the manufacturing process because of the emissions from not only from the frame but from lacquering, paints, varnishes, padding and textiles. It is typical that the furniture is wrapped almost instantly after manufacturing and emissions are encased inside the wrapping. The installation process will release the emissions into indoor air and it may, depending on ventilation conditions, take months to descend the emissions to the acceptable level.


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Because of the challenges in ventilation, there is a possibility to test also HVAC components as ducts and fittings, air and fire dampers, terminal devices, silencers and air filters. M1 labelled air-handling component shall fulfil both general and product-group-specific requirements. The objective of the Cleanliness Classification of air-handling Components is to ensure the good quality of the supply air flowing through a new air-handling system. It is a voluntary system open to all manufacturers, importers and exporters of air-handling components and systems. Cleanliness Classification of Air-handling Components is based on general and component-group-specific requirements. The general requirements for a classified component are:

- a classified component shall not increase the concentration of contaminants that are detrimental to health or comfort in the air handling system or supply air
- a classified component shall not produce odours, or gaseous or particulate contaminants that decrease the quality of supply air
- a classified component shall be easy to clean

More information about the classification systems can be found from the new Internet-pages in English: http://m1.rts.fi/en/

Eurovent Certita Certification contributes to the COP21 – 2015 Paris Climate Conference – environmental goals

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With more than 6 million units installed in Europe, heat pump's renewable energy from air, water and ground can be used efficiently to provide 100% of a building's heating, cooling and hot water demand and reduce GHG emission. Estimates show that heat pumps could save 50% of the building sector's CO_2 emissions for heating and cooling and 5% for the industrial sector, corresponding to nearly 8% of total global CO_2emissions(*).

In 2015, **COP21**, also known as the **2015 Paris Climate Conference**, will aim to achieve a legally binding and universal agreement on climate, with the aim of keeping global warming below 2°C. In that context, the impact of the heating/cooling demand of buildings will be significant, and the heat pump industry needs to prepare now. This is where product performance certification delivered by Eurovent Certita Certification will add a considerable value and play a key role to ensure transparency and deliver high quality and reliable data.

Our commitment in adding value along the renewable energy decision chain goes one step further and extends to **installers**, **household buyers or contractors** for whom we are implementing on-line tools to support them at every stage of their projects, from the quotation to the filing for local incentives or tax rebates. By a simple, 24/7 connection to our website – www.eurovent-certification.com, it is now possible to upload Product Performance Reports that provide detailed performances features and values such as the COP (Coefficient Of Performance) or the Sound Power Level.

Today, we **exclusively** present you the results of the study carried out by **Eurovent Market Intelligence**, the European statistics office on the Heat, Ventilation, Air-Conditioning and Refrigeration market (HVAC-R). Based on 2014 sales data collected from 280 manufacturers, it shows the penetration rate in Europe of the Eurovent Certified Performance mark for the Heat Pump and Chillers units <100 kW (pls. see the following table.).

Eurovent certified performance penetration rate	HP - Chillers 0...100 kW
Belgium	67%
Czech Republic	25%
Denmark	38%
Finland	49%
France	90%
Germany	55%
Italy	59%
Netherlands	49%
Norway	37%
Portugal	43%
Russia	87%
Slovenia	82%
Spain	48%
Sweden	45%
Switzerland	45%
Turkey	37%
United Kingdom	30%
UE 28	**66%**
© Eurovent Market Intelligence Sales data 2014	

Since the first certification program for heat pumps launched in1994, Eurovent Certita Certification has confirmed a proven track record of its strong contribution to a transparent and fair Heat Pump market, where its expertise applies to all heat pump applications: air to water, brine to water, direct expansion, domestic hot water, air to air. Our milestones:

- **Air to Air** heat pump and comfort application for <100 kW units:
  Certification program started in 1995. Currently 2 835 certified products from17 manufacturers.
- **Air to Water** heat pump and comfort application for <100 kW units:
  Certification program started in 1994. Currently 3 357 certified products from 60 manufacturers
- **Water to Water** heat pump and comfort application for <100 kW units:
  Certification program started in 1994. Currently 818 certified products from 35 manufacturers.

Eurovent Certita Certification also certifies Heat Pumps up to 2 MW.

(*) Source: EPEE

Moisture and mould programme involved in constructing healthier houses in Finland

In Finland, the *Moisture and mould programme* (2009–2015) is working for healthy houses and better indoor air. The objective of the national programme coordinated by the Ministry of the Environment is to initiate work on improving the health of Finnish building stock against moisture and mould damages, which are very often the reason for indoor air problems.

In Finland, the value of the renovation backlog for the current building stock is estimated at EUR 30–50 billion *(Rakennetun omaisuuden tila report 2013)*. As the renovation backlog increases, the health effects caused by damaged buildings also increase. Increasing the energy efficiency of old buildings is essentially connected to renovation construction, and it causes additional concern in terms of the health of buildings.

"It is estimated that about 600,000–800,000 Finns suffer daily from the ill effects caused by indoor air problems in buildings. Due to the climate in our country, Finns spend a lot of time indoors, which increases the health effects of any indoor air problems on people," says **Katja Outinen**, the Programme Director of the Moisture and mould programme.

Largest worksite in Finland

Started in 2009, the Moisture and mould programme aims to reduce health effects and their substantial economic consequences by influencing the whole chain of construction and property maintenance. The objective of the programme is to halve the amount of moisture and mould damage in buildings in our country by 2020. An important achievement is a report by the Finnish Parliament's Audit Committee published in May 2013 that requires significant actions in order to tackle the moisture and mould problem. The implementation of the report is overseen by a monitoring group assembled across ministries set by the Parliament.

"The most important tool and impact method of the programme has been communication throughout the project. The programme talks about the moisture and mould problem, what everyone can do personally, what various organisations can do together, and how a change can be achieved. The programme focuses on offering solutions, and instead of campaign-like attention, the goal is to achieve a permanent social change in attitudes, structures and operations," describes Katja Outinen.

Towards healthier houses

The Moisture and mould programme has succeeded in starting extensive and target-oriented operations and discussions in Finland in order to solve problems related to indoor air and improve the condition of buildings. Work has been carried out by operators across organisations and administrations, educational institutions, researchers, associations, citizens, and the media. A unified programme network of hundreds of experts has produced numerous new tools and operating models in order to solve the moisture and mould problems. During the operation of the programme, about 100 subprojects have been implemented and more than 300 experts have participated in them.

The professional qualification and training path constructed as part of the programme has offered supplementary training and open training events or public lectures that have gathered more than 10,000 participants throughout Finland. The number of people who have participated in the supplementary trainings has exceeded all expectations. A new employment sector of special expertise has formed in Finland.

The Moisture and mould programme has significantly advanced the implementation of Finland's Strategy for Renovation (2007–2017). With the help of the operation of a versatile and uniform group of participants and active communication, the programme has been able to influence all target groups from decision-makers at the national level to ordinary property owners. The programme will extend to the end of 2015, and the goal is to continue the target-oriented work further.

Further information:

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Status of the EN and EN-ISO standards on EPB

CEN/TC371: Current status of the Overarching Standard (OAS) the draft prEN-ISO/DIS 52000-1 (replaces the prEN15603) and connected TR

This prEN-ISO is at enquiry stage till 27-November 2015; After this expected to be ready for Formal Vote around April 2016. Expected to be ready for publication (after FV) October 2016. The Technical Report: revisions TR follow changes in EN constantly, current Draft is available at CEN and ISO Committee level, expected draft TR out for enquiry & vote (=TCA) April 2016 and to be ready for publication (after TCA) in October 2016. Be aware that, given the required time for translation and processing, this will probably result that the standard will be available at national level by the beginning of 2017.

DRAFT INTERNATIONAL STANDARD
ISO/DIS 52000-1

ISO/TC **163**	Secretariat: **SIS**
Voting begins on: **2015-08-27**	Voting terminates on: **2015-11-27**

Energy performance of buildings — Overarching EPB assessment —

Part 1:
General framework and procedures

CEN/TC 89 Energy performance of the building and building components

All CEN/TC 89 related standards planned to be submitted for formal vote before the end of 2015. The two "end of pipeline" EPB standards, EN ISO 52003-1 and EN ISO 52018-1, dealing with indicators, requirements, ratings and certification are planned to be submitted for formal vote during the first quarter of 2016. (EN ISO 52003-1, Energy performance of buildings – Indicators, requirements, ratings and certification – Part 1: General aspects and application to the overall EPB and EN ISO 52018-1, Energy performance of buildings – Indicators for partial EPB requirements related to thermal energy balance and fabric features – Part 1: Procedures)

CEN/TC156 Ventilation Systems

The drafts of TC 156 were all published for enquiry and all finished enquiry .In the TC156 meeting end of November it is expected that all standards will be acceptance for Formal Vote to be ready for submission by end of 2015. EN 16798-1 may have some delay given the relation with the OAS.

CEN/TC 169 – Light and Lighting

The prEN 15193-1: Energy performance of buildings - Module M9 - Energy requirements for lighting - Part 1: Specifications and prCEN/TR 15193-2: Energy performance of buildings - Module 9 - Accompanying Technical Report on Energy requirements for lighting standard are expected to be ready for FV and 2nd TCA for TR by end of 2015.

CEN/TC228 Heating Systems

All prEN's of TC 228 finished the enquiry; comments and revisions in process; after the meeting TC end of September 2015 all standards are expected to become ready for FV before end of 2015 or some at the latest before end March 2016, including draft TR's for TCA and connected Excels.

CEN/TC247 Contribution of Building Automation, Controls and Building Management

All seven standards on Contribution of BAC/BM and their accompanying TR are to be published for enquiry; expected start of enquiry: 3 December 2015. Closing of enquiry: 3 March 2016. TR's and FV versions are expected to be ready by April 2016, with possible short delay due to interrelation other EPB standards and OAS.

JAAP HOGELING
Chair CENTC371 program committee on EPBD

ANITA DERJANECZ, Policy and Project Officer

New Horizon 2020 Energy calls launched with more focus on buildings, heating and cooling

The Horizon 2020 Energy Challenge is designed to support the transition to a secure, clean and efficient energy system for Europe for a seven-year period (2014-2020). The second Horizon2020 Work Programme (2016–2017) on Secure, Clean and Efficient Energy was launched on 14 September 2015 with a €1 000 Million total budget supporting research, demonstration and innovation projects as well as actions promoting market uptake in the next two years. The draft work programme and the first calls were presented at a high level Information Day organised by the Commission Services on 14–15 September in Brussels. The final work programme will be adopted mid-October..

The new draft Horizon 2020 work programme on Secure, Clean and Efficient Energy for the years 2016–2017 was published on 14 September and presented on a two-day Information Day 14–15 September 2015 in Brussels. The Information Day provided essential information on the calls for proposals, which will be open in the next two years. The new work programme is streamlined according to the EU Energy Union strategy and contains two major calls: Energy efficiency and Competitive law carbon energy.

Energy efficiency – stronger focus on buildings and HVAC

The Energy efficiency call (budget: €194M) has an even stronger focus on buildings and HVAC than in the previous years with 2 focus areas dedicated to Heating and cooling and Buildings beside consumer engagement, industrial energy efficiency and financing energy efficiency investments. The most relevant call topics are the following:

Heating and cooling:	Buildings:
• Waste heat recovery in district or individual H/C systems • Improving the performance of inefficient district heating networks • Standardised installation packages integrating renewable and energy efficiency solutions for heating, cooling and/or hot water preparation • New heating and cooling solutions using low grade sources of thermal energy	• Supporting accelerated and cost-effective deep renovation of buildings through Public Private Partnership (EeB PPP) • Overcoming market barriers and promoting deep renovation of buildings • Integration of Demand Response in Energy Management Systems while ensuring interoperability through Public Private Partnership (EeB PPP) • Cost reduction of new Nearly Zero-Energy buildings • Construction skills

Law carbon energy – RES in heating and cooling, system integration, smart grids and storage

The Competitive law carbon energy call (budget: €717M) supports among others the integration of the energy systems, the development of next generation RES technologies, and the demonstration and market uptake of renewable electricity, heating and cooling solutions.

Renewable energy technologies:

- Developing the next generation technologies of renewable electricity and heating/cooling
- Easier to install and more efficient geothermal systems for retrofitting buildings
- Market uptake of renewable energy technologies (heat pumps, PV, etc.)

The submission deadline for the first round of calls is in 21 January 2016 and there will be a second round with the deadline 15 September 2016. More information about the calls is available in the H2020 calls portal. The presentations of the Information day are available at: https://ec.europa.eu/inea/en/H2020-Energy-Infoday-presentations

New Strategic Energy Technology Plan (SET Plan) approved

The European Commission adopted also the new Strategic Energy Technology Plan (C/2015 6317) for Europe on 15 September defining the main research priorities that will supported by European funding mid- and long term. The upgraded SET Plan fits to the Energy Union strategy following a more targeted focus and an integrated approach. Strategic actions will be grouped around 4 core priorities: renewables, consumer, energy efficiency, and transport. The strategic plan will move away from a vertical and technology-specific focus towards a horizontally integrated approach profiting from the innovative technologies that enable increased flexibility and resilience in the energy system.

IAQVEC 2016

October 23–26, 2016, Seoul, Korea

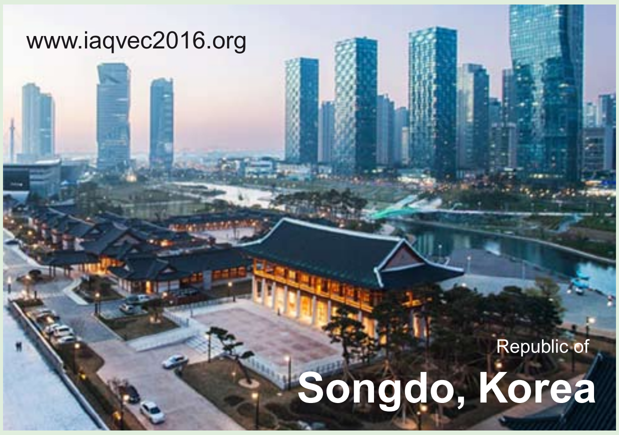
IAQVEC2016, the 9th International Conference on Indoor Air Quality, Ventilation and Energy Conservation in Buildings, will be held in Seoul (Songdo), Korea on October 23–26, 2016 (http://www.iaqvec2016.org).

The conference will be organized by AIK (Architectural Institute of Korea) in co-operation with KIAEBS (Korean Institute of Architectural Sustainable Environment and Building systems), and KICT (Korea Institute of Civil Engineering and Building Technology).

Topics

The conference scope encompasses IAQ and ventilation for creating energy efficient, healthy and productive environments in an environmentally sustainable manner in all types of buildings. Topics to be covered in the conference:

- Indoor Environment Quality & Climate
- Ventilation & Airtightness
- Ventilation in relation to IAQ & Health Aspects
- Smart Technologies for Building Performance
- HVAC Systems
- Building System Integration and Optimization
- Sensors, Controls and Information Management
- Modeling and Simulation Tools



Venue: Seoul (Songdo), Korea
Songdo International City, well known as a model city for Ecopolis, is located just besides of Seoul. It only takes about 20 minutes from Incheon international airport to Songdo.
Contact: www.iaqvec2016.org; Info@iaqvec2016.org
Important dates: Deadline for Abstracts submission: November 13 2015, Abstract acceptance December 18, 2015. Deadline for Full papers: March 25, 2016; Acceptance notification: May, 2016

46th KGH HVAC&R Congress and Exhibition

December 2–4, 2015, Belgrade, Serbia

This is the largest HVAC&R congress and exhibition in this part of Europe. The aim of the exhibition is to present and inform the professional community on new products used in buildings and used for energy supply of buildings. The exhibition is an opportunity for designers, constructors, manufacturers, scientists and company representatives, all those dedicated to the same task - energy efficiency in buildings, to meet one another at the same time and at the same place. Among others the 46th KGH HVAC&R Congress will cover topics such as thermal comfort coupled with energy consumption, HVAC&R systems in industrial, residential, public and other buildings, and air distribution in air-conditioned rooms.

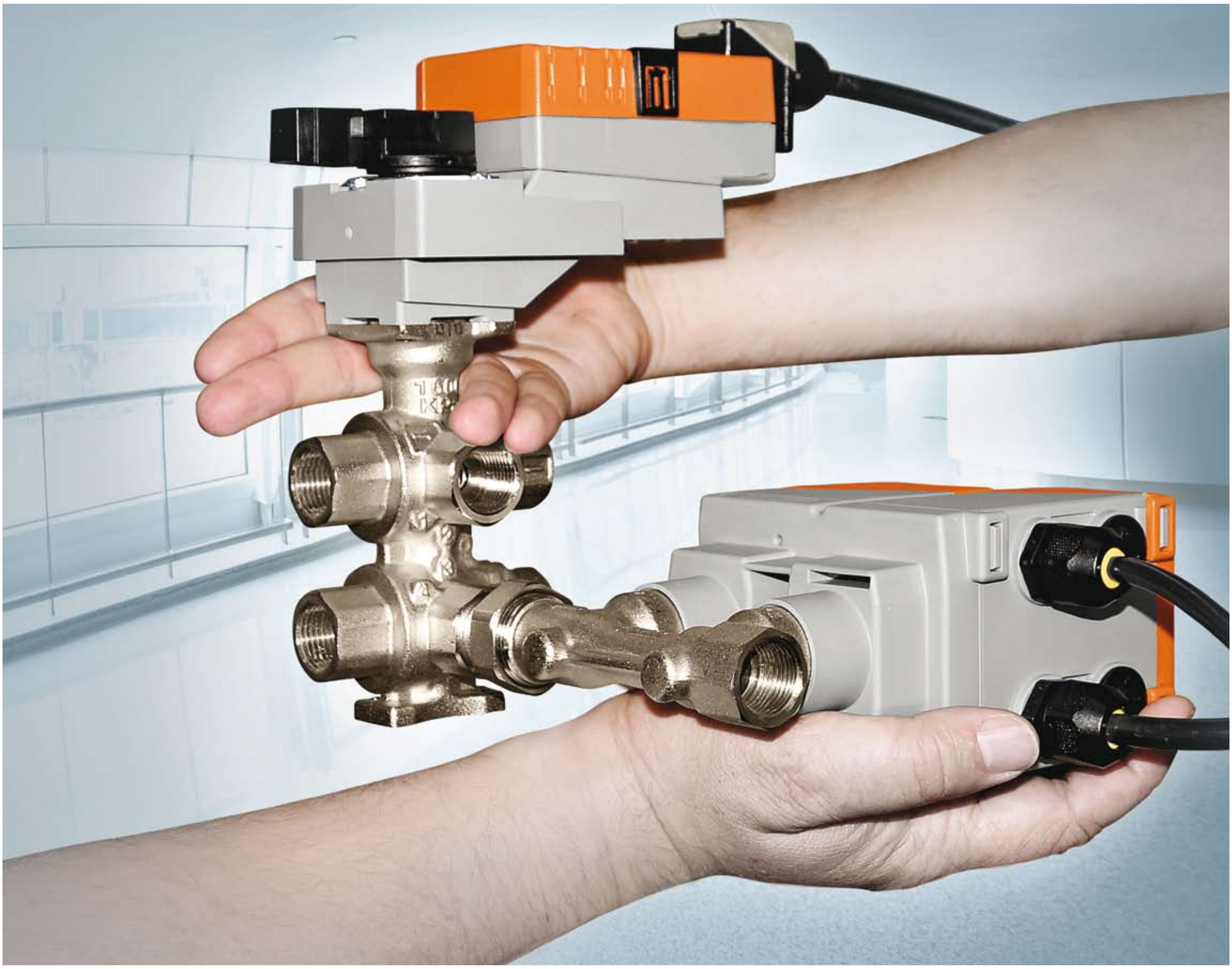
The congress main thematic fields

- Energy problems, challenges and solutions of the project "Belgrade Waterfront"
- The use of renewable energy sources in new and renovated buildings
- HVAC&R systems in industrial, residential and general purpose buildings
- Economic solutions for district heating and cooling
- The buildings of the future, intelligent buildings. The path to "zero" energy buildings.
- Energy for lighting and vertical transport, apparatus and household appliances
- Energy upgrade of old buildings, especially the buildings of historical and cultural significance
- Energy efficiency of buildings during their life-cycle
- The relation of the architectural solution of the building with mechanical, HVAC&R and lighting systems
- Harmonization of the electricity use in the network
- Zero CO_2 emission buildings– zero energy and energy-plus buildings. The present refrigeration systems, heat pumps, new construction of the refrigeration machines. The current state and perspectives for further development
- The most recent realized projects worldwide and in Serbia as the examples of approaching "zero" energy buildings

Programme for Students and Young Engineers

In order to mark 111 years of university education on heating and ventilation, i.e. the introduction of the course Heating and Ventilation as an academic course in Serbia, the 46th international HVAC&R congress will have a special Programme for Students and Young Engineers intended for undergraduate and graduate students, Master and Ph.D. students as well as young engineers who have started their careers in manufacturing companies or in design and engineering offices, and who are under 35.

For more information, please visit the conference website at http://kongres.kgh-kongres.rs/index.php?lang=en.



BELIMO ZoneTight™

Two become one for increased efficiency

BELIMO

The electronic pressure-independent 6-way zone valve from the Belimo ZoneTight™ product family combines two tried and tested valves in one unit. It brings together the good planning reliability and efficiency of the electronic pressure-independent EPIV valve and the ease of installation of the 6-way characterised control valve.

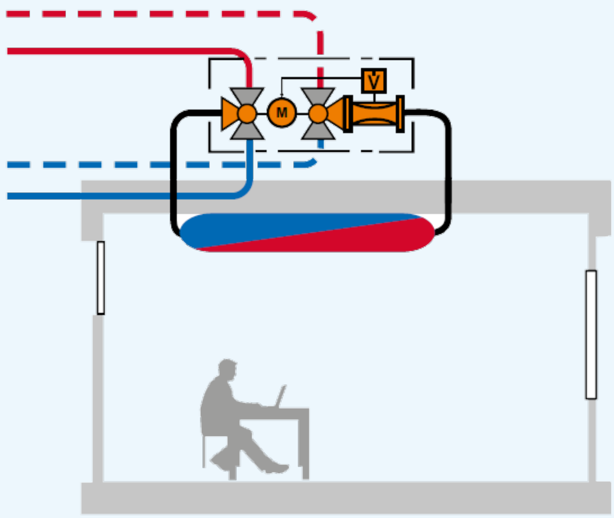
The electronic pressure independence allows the consulting engineer to quickly and easily configure the valve to the volumetric flow required. There is no need to calculate the k_{VS} value, which gives a high level of certainty during planning.

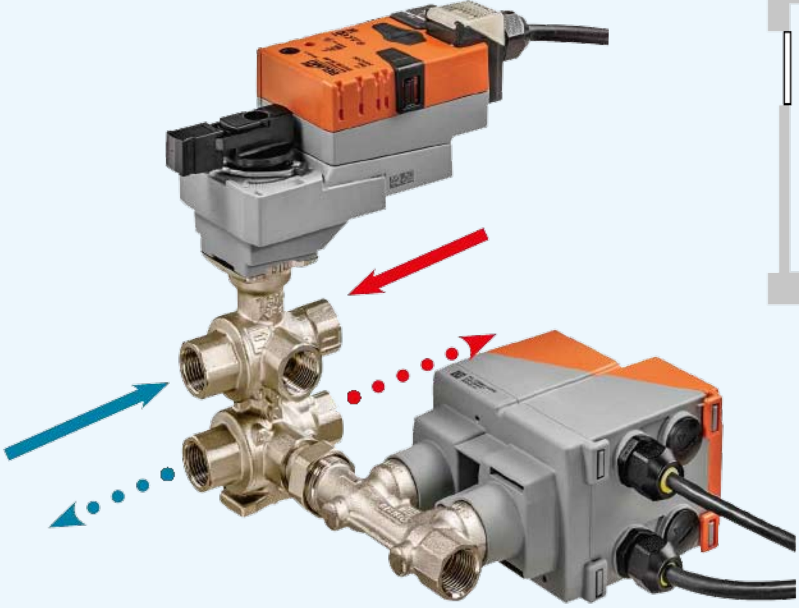
During installation, the electronic pressure-independent 6-way zone valve takes over the function of up to four 2 port valves. No balancing valves need to be fitted. What's more, installation errors are practically eliminated, as it is impossible to mix up the valves and/or control units.

The integrated flow rate measurement and the electronic flow rate control allow the desired amount of water to be ensured for both sequences during full load and partial load. The respective measured values can also be called up as real time information, producing optimum operating conditions.

The characterised control valve closes with absolutely no leaks (leakage rate A according to EN12266-1), preventing energy losses, and the integrated pressure relief function of the electronic pressure-independent 6-way zone valve ensures maximum system safety.

More information: www.belimo.eu



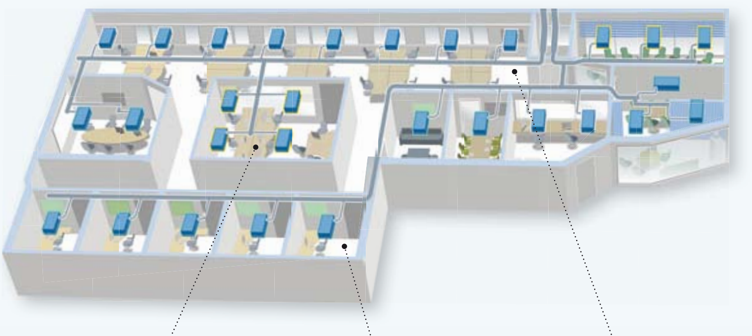


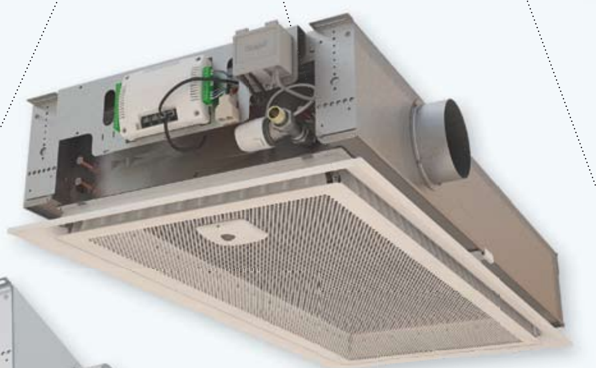
The electronic pressure-independent 6-way zone valve from the Belimo ZoneTight™ product range replaces up to four conventional change-over valves and ensures reliable control of cooling and heating ceilings.

Room for changes

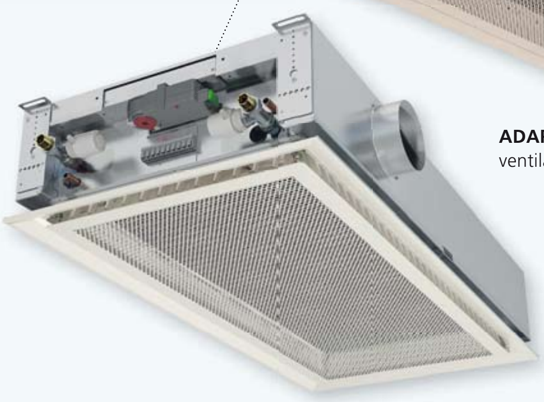
The PARASOL family of comfort modules provides cooling, heating and ventilation with unique flexibility. From basic constant air volume systems, to energy saving demand controlled ventilation. Always quiet, draught free and with perfectly balanced temperature and fresh air supply.

Make every breath count.





ADAPT PARASOL. Demand controlled ventilation for cell office.

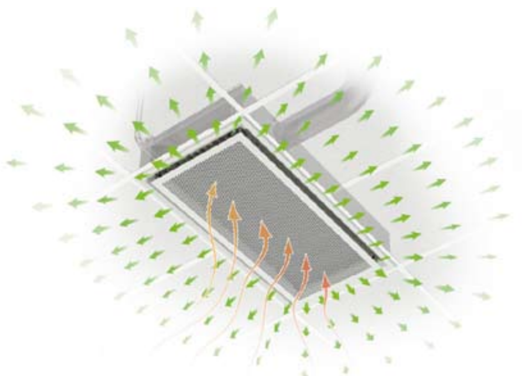


PARASOL VAV. Variable air volume for large conference room.

PARASOL. Constant air volume for open plan office.

Swegon PARASOL VAV – flexible controls, great indoor climate

TONY PETTERSSON
Director Marketing & Business Development
Swegon

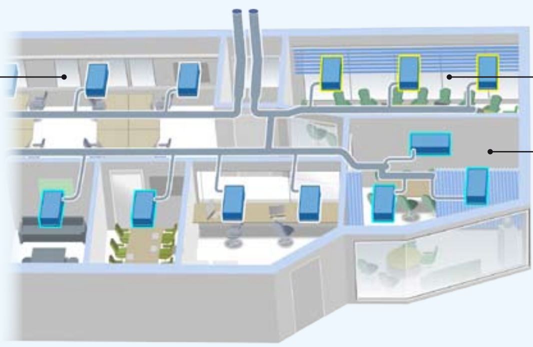


The PARASOL comfort module for ventilation and waterborne heating and cooling, was first introduced in 2005, and is still one of Swegon's bestsellers. Providing high cooling and heating capacity, fully adjustable 360° air spread pattern, and a very low noise level, this combination has proven to be a perfect solution for offices, conference rooms and many other applications, appreciated by tenants and property owners alike.

An addition to the product family, called ADAPT Parasol, was introduced in 2013. Based on the PARASOL platform, but equipped with a unique integrated damper solution, it not only regulates the air flow level, adapting to the actual demand in the room, but also makes sure the cooling and heating output is optimized accordingly. Together with its presence detecting control unit, fitted to each comfort module for independent regulation, the ADAPT Parasol is unbeatable for Demand Controlled Ventilation applications. With plug & play connection to higher-level controls, such as Swegon's own WISE system, the ADAPT Parasol also provides great energy saving potential.

Now Swegon is introducing the PARASOL VAV – still taking advantage of the integrated damper solution of the ADAPT Parasol, but with a somewhat different controls solution. Product Manager Jonas Åkesson explains; "For typical applications such as offices or larger conference rooms, up to eight PARASOL VAV units can be connected to one common control unit. This provides excellent comfort for Variable Air Volume applications in a highly cost efficient way."

Jonas Åkesson continues;"The PARASOL family now provides even more options, always creating a great indoor climate with high energy efficiency, and now with a great flexibility when it comes to control options. Just let the building requirements decide what product to use!"



An example of how you can use different Parasol products in the same building.

VDI- Standards published in September and October 2015

September:

VDI 6040 part 2. Air-conditioning; Schools; Practical guidance (VDI Ventilation Code of Practice, VDI Code of Practice for School Buildings), German/English

During the renovation of schools often only energetic aspects are considered. The result is the deterioration of air quality in schools. The application of the standard helps to improve the indoor air quality in schools. It provides concrete requirements and instructions for implementation and guidance for architects and planners. It provides guidance on planning and operation of ventilation systems in schools with the aim of complying with the requirements specified in VDI 6040 Part 1. Information on non-mechanical ventilation as well as for mechanical ventilation is given. Described solutions are to be considered as examples, and do not release designers and operators of the responsibility to develop an optimal solution for individual cases.

VDI 4710 part 4. Meteorological data for the building services; t,x correlations and wind statistics for 122 European cities, German/English

This standard allows to specify design points (summer and winter) for air temperature, water vapour content, and enthalpy, to be used in the calculation of heating, ventilating and air-conditioning (HVAC) systems in Europe, and can serve as a basis for the analysis of annual energy consumption according to the individual-frequency method. In addition to information regarding the correlations between the air temperature and the water vapour content, a wind statistic including wind speeds and wind directions is provided for each.

October:

VDI 2083 part 16.2. Draft Cleanroom technology; Barrier systems; Mini-environments, German

This standard applies to all types of mini-environments for the separation of defined clean environments in technical areas. This standard applies but to gaseous media such as air and inert gases in a mini-environment. It does not apply to vacuum processes or liquid process media. Only airborne contamination is addressed, i.e. the carrier medium is, as a rule, air (or, in special cases, a protective atmosphere, like an inert gas). The growth of contaminants through leaks or weaknesses is not considered.

VDI 2083 part 7. Cleanroom technology; Ultrapure media; Quality, supply, distribution, German/English

The standard deals with the specification of ultrapure media (steam, gases, chemicals) for contamination-controlled processes and with the distribution systems for such media. The standard provides a summary of knowledge regarding the design, construction, operation and monitoring of high purity supply systems, and supports planners, system suppliers and operators in their work. It is intended to supersede and replace VDI 2083 Part 7 and Part 10.

VDI 2166 part 2. Planning of electrical installations in buildings; Advice for electric mobility, German/English

Individual mobility is changing, in addition to pure combustion vehicles the number of electrically chargeable hybrid vehicles, electric vehicles and electrically powered two-wheelers increases. Electric vehicles can make a significant contribution to reach the climate and energy policy goals. Building installations are planned to represent the state of the art for a long term, thus this standard helps planners, architects and builders to integrate the charging infrastructure for aforementioned vehicles into the planning process for buildings and/or surrounding areas. The standard supplements the given requirements in VDI 2050 Part 5 to accommodate electric mobility.

VDI 4700 part 1. Terminology of civil engineering and building services, German

The standard defines terms from the fields of architecture, civil engineering, building services and facilities management, listed in alphabetical order and written according to the rules applicable to international terminology standards. The standard is intended as a source of information for all persons who are required to consider technical rules in the planning, execution, evaluation and operation of the technical building services or its scientific debate. The standard facilitates the understanding of contents of technical rules for users such as consulting engineers, planners, exporting companies, operators and possibly lawyers.

VDI/BV-BS 6206 part 2. Draft Buildings constructed with reusable pre-assembled room units in steel frame construction; Transportation and construction, German

Buildings constructed with room units in steel frame construction can be used in technically different building configurations. They can be disassembled several times and can be reused with different functions at other locations. The lifetime of these buildings is always limited to a specific period. Special requirements regarding structural integrity, building physics, energy efficiency and deconstructability are to be considered in planning as well as construction and operation. This series of standards covers the basics of planning, construction and deconstruction of buildings constructed with room units in steel frame construction. This standard covers transportation and installation.

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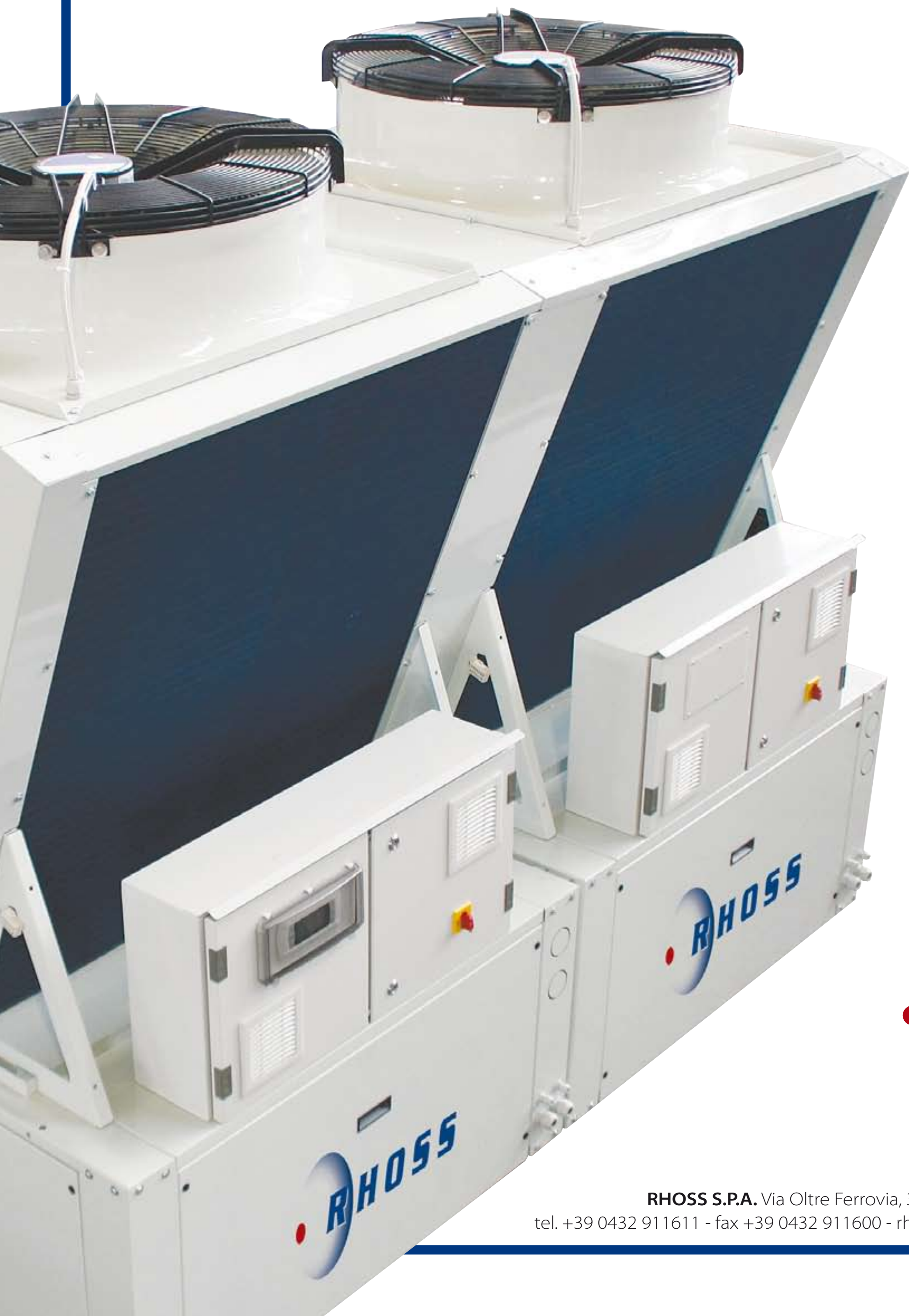

POKER is the innovative range of Rhoss modular heat pumps, which combines key features like silent operation, flexibility and efficiency.
The units can match the requirements of all plant types, minimizing, in every architectural context, noise issues and granting unique performance.

POKER is composed by independent modules with 34 kW heating capacity each, which can be connected together to reach 137 kW maximum total heating capacity.
Each module is a reversible heat pump for outdoor installation, equipped with tandem scroll compressors with liquid injection, hydrofilic treated coils and R410A refrigerant.

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Send information of your event to Ms Cynthia Despradel cd@rehva.eu

Events in 2015 - 2016

Conferences and seminars 2015

October 20–23	Cold Climate HVAC	Dalian, China	www.coldclimate2015.org
October 26–28	11th International Conference on Industrial Ventilation	Shanghai, China	www.ventilation2015.org
December 2–4	46th International HVAC&R Congress and Exhibition	Belgrade, Serbia	http://kongres.kgh-kongres.rs/index.php?lang=en

Exhibitions 2015

November 2–6	Interclima+Elec	Paris, France	www.interclimaelec.com

Conferences and seminars 2016

Jan 23–27	ASHRAE Winter Conference	Orlando, Florida, USA	www.ashrae.org/orlando
Feb 24–26	World Sustainable Energy Days	Wels, Austria	www.wsed.at/en/world-sustainable-energy-days/
March 8–11	Sustainable Built Environment – SBE 2016	Hamburg, Germany	www.sbe16hamburg.org
Mar. 31–Apr. 2	12th International HVAC+R Technology Symposium	Istanbul, Turkey	www.ttmd.org.tr/sempozyum2016/eng/
May 22–25	12th REHVA World Conference – CLIMA 2016	Aalborg, Denmark	www.clima2016.org
May 30–June 3	CIB World Building Congress 2016 Intelligent built environment for life	Tampere, Finland	http://wbc16.com
June 22–24	Central Europe towards Sustainable Building Prague 2016	Prague, Czech Republic	www.cesb.cz
July 3–8	Indoor Air 2016	Ghent, Belgium	www.indoorair2016.org
August 21–24	12th IIR Natural Working Fluids Conference	Edinburgh, United Kingdom	www.ior.org.uk
October 23–26	IAQVEC 2016: international conference on indoor air quality, ventilation & energy conservation in buildings	Seoul, South Korea	www.iaqvec2016.org

Exhibitions 2016

January 25–27	2016 AHR Expo	Orlando, Florida, USA	www.ahrexpo.com
February 2–5	Aqua-Therm Moscow	Moscow, Russia	www.aquatherm-moscow.ru/en
February 24–26	Aqua-Therm Novosibirsk	Novosibirsk, Russia	http://www.aquatherm-novosibirsk.ru/en
March 1–4	AQUATHERM Prague	Prague, Czech Republic	www.aquatherm-praha.com/en/
March 13–18	Light and Building	Frankfurt, Germany	http://ish.messefrankfurt.com
March 15–18	Mostra Convegno Expocomfort	Milan, Italy	www.mcexpocomfort.it/
April 5–8	Nordbygg	Stockholm, Sweden	www.nordbygg.se
April 20–22	Aqua-Therm St-Petersburg	St-Petersburg, Russia	www.aquatherm-spb.com/en
May 4–7	ISK-SODEX 2016	Istanbul, Turkey	www.sodex.com.tr/
October 12–14	FinnBuild	Helsinki, Finland	www.messukeskus.com/Sites1/FinnBuild/

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Register now!

As of January 2015, there is a new private area in the website. REHVA has decided to develop this section progressively. On the first phase, the **REHVA Journal** has been made available to download and read online. All the issues (full articles) are now available in this private section. REHVA is now ready to add new services in this section.

These services are now added in the private area!

⇒ EU policy tracking – **new**

⇒ HVAC terminology – **new**

⇒ eBooks - **4 new books are available online!**
GB1/Displacement ventilation in non-industrial premises
GB4/Ventilation and smoking
GB5/Chilled Beam Applications
GB6/Indoor Climate and Productivity in Offices

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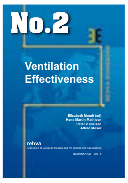
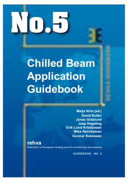
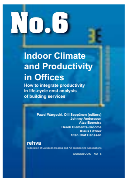


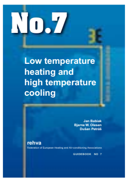
Ventilation Effectiveness. Improving the ventilation effectiveness allows the indoor air quality to be significantly enhanced without the need for higher air changes in the building, thereby avoiding the higher costs and energy consumption associated with increasing the ventilation rates. This Guidebook provides easy-to-understand descriptions of the indices used to measure the performance of a ventilation system and which indices to use in different cases.



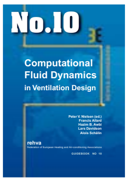
Chilled Beam Cooling. Chilled beam systems are primarily used for cooling and ventilation in spaces, which appreciate good indoor environmental quality and individual space control. Active chilled beams are connected to the ventilation ductwork, high temperature cold water, and when desired, low temperature hot water system. Primary air supply induces room air to be recirculated through the heat exchanger of the chilled beam. In order to cool or heat the room either cold or warm water is cycled through the heat exchanger.



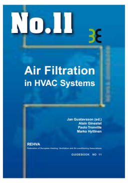
Indoor Climate and Productivity in Offices. This Guidebook shows how to quantify the effects of indoor environment on office work and also how to include these effects in the calculation of building costs. Such calculations have not been performed previously, because very little data has been available. The quantitative relationships presented in this Guidebook can be used to calculate the costs and benefits of running and operating the building.



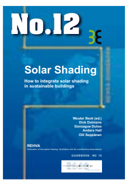
Low Temperature Heating And High Temperature Cooling. This Guidebook describes the systems that use water as heat-carrier and when the heat exchange within the conditioned space is more than 50% radiant. Embedded systems insulated from the main building structure (floor, wall and ceiling) are used in all types of buildings and work with heat carriers at low temperatures for heating and relatively high temperature for cooling.



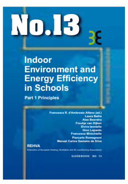
Computational Fluid Dynamics in Ventilation Design. CFD-calculations have been rapidly developed to a powerful tool for the analysis of air pollution distribution in various spaces. However, the user of CFD-calculation should be aware of the basic principles of calculations and specifically the boundary conditions. Computational Fluid Dynamics (CFD) – in Ventilation Design models is written by a working group of highly qualified international experts representing research, consulting and design.



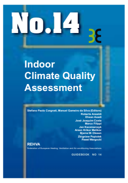
Air Filtration in HVAC Systems. This Guidebook will help the designer and user to understand the background and criteria for air filtration, how to select air filters and avoid problems associated with hygienic and other conditions at operation of air filters. The selection of air filters is based on external conditions such as levels of existing pollutants, indoor air quality and energy efficiency requirements.



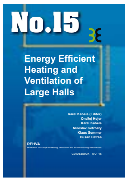
Solar Shading – ***How to integrate solar shading in sustainable buildings.*** Solar Shading Guidebook gives a solid background on the physics of solar radiation and its behaviour in window with solar shading systems. Major focus of the Guidebook is on the effect of solar shading in the use of energy for cooling, heating and lighting. The book gives also practical guidance for selection, installation and operation of solar shading as well as future trends in integration of HVAC-systems with solar control.



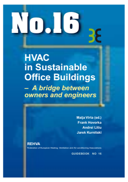
Indoor Environment and Energy Efficiency in Schools – *Part 1 Principles.* School buildings represent a significant part of the building stock and also a noteworthy part of the total energy use. Indoor and Energy Efficiency in Schools Guidebook describes the optimal design and operation of schools with respect to low energy cost and performance of the students. It focuses particularly on energy efficient systems for a healthy indoor environment.



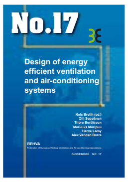
Indoor Climate Quality Assessment. This Guidebook gives building professionals a useful support in the practical measurements and monitoring of the indoor climate in buildings. Wireless technologies for measurement and monitoring have allowed enlarging significantly number of possible applications, especially in existing buildings. The Guidebook illustrates with several cases the instrumentation.



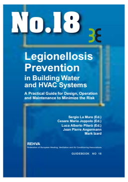
Energy Efficient Heating and Ventilation of Large Halls. This Guidebook is focused on modern methods for design, control and operation of energy efficient heating systems in large spaces and industrial halls. The book deals with thermal comfort, light and dark gas radiant heaters, panel radiant heating,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



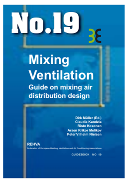
HVAC in Sustainable Office Buildings – ***A bridge between owners and engineers.*** This Guidebook discusses the interaction of sustainability and heating, ventilation and air–conditioning. HVAC technologies used in sustainable buildings are described. This book also provides a list of questions to be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



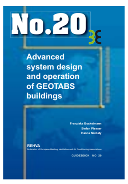
Design of energy efficient ventilation and air-conditioning systems. This Guidebook covers numerous system components of ventilation and air-conditioning systems and shows how they can be improved by applying the latest technology products. Special attention is paid to details, which are often overlooked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



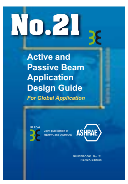
Legionellosis Prevention in Building Water and HVAC Systems. This Guidebook is a practical guide for design, operation and maintenance to minimize the risk of legionellosis in building water and HVAC systems. It is divided into several themes such as: Air conditioning of the air (by water – humidification),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



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



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



Active and Passive Beam Application Design Guide is the result of collaboration by worldwide experts. It provides energy-efficient methods of cooling, heating, and ventilating indoor areas, especially spaces that require individual zone control and where internal moisture loads are moderate. The systems are simple to operate and maintain. This new guide provides up-to-date tools and advice for designing, commissioning, and operating chilled-beam systems to achieve a determined indoor climate and includes examples of active and passive beam calculations and selections.

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