Performance-based approaches to residential smart ventilation

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Energy-efficient homes require rethinking the ventilation and the air change rates, because of their increased impact on thermal losses. For these high performance homes, envelope airtightness treatment becomes crucial (Erhorn et al., 2008) and should be combined with efficient ventilation technologies.

Indoor air quality is another major area of concern in buildings which is influenced by ventilation. Because people spend most of the time in residential buildings (Klepeis et al., 2001), especially in their bedrooms (Zeghnoun et al., 2010), and 60–90% of their life in indoor environments (homes, offices, schools, etc.) (Klepeis et al., 2001; European commission 2003; Brasche and Bischof, 2005; Zeghnoun et al., 2010; Jantunen et al., 2011), indoor air quality is a major factor affecting public health. Logue et al. (2011b) estimated that the current damage to public health from all sources attributable to IAQ, excluding second-hand smoke (SHS) and radon, was in the range of 4,000–11,000 µDALYs (disability-adjusted life years) per person per year. By way of comparison, this means that the damage attributable to indoor air is somewhere between the health effects of road traffic accidents (4,000 µDALYs/p/yr) and heart disease from all causes (11,000 µDALYs/p/yr). According to the World Health Organization (WHO, 2014), 99,000 deaths in Europe and 81,000 in the Americas were attributable to household (indoor) air pollution in 2012. Health gains in Europe (EU-26) attributed to effective implementation of the energy performance building directive, which includes indoor air quality issues, have been estimated at more than 300,000 DALYs per year.

In order to conciliate energy saving and indoor air quality issues, interest in a new generation of smart ventilation systems, including demand-controlled ventilation (DCV), has been growing for 30 years. A number of ventilation standards and national regulations have progressively integrated an allowance for smart ventilation strategies and/or DCV systems in residential buildings. Simultaneously, progressively energy performance regulations include the opportunity to claim credit in energy calculations for savings from such systems. In Europe, several countries enable the use of DCV systems in ventilation codes, including Belgium, France, Spain, Poland, Switzerland, Denmark, Sweden, the Netherlands, Germany (Savin and Laverge, 2011; Kunkel et al., 2015; Borsboom, 2015). The corresponding energy regulations are more or less recent.

Thanks to "performance-based approaches", such systems must often be compared either to constant-airflow systems ("equivalence approaches") or to fixed IAQ metrics thresholds. Given these opportunities, DCV strategies have been used at massive scale, notably in France and in Belgium, for more than 30 years. On August 1st, 2016, 23 DCV systems in France, 34 in Belgium, 37 in the Netherlands have received an agreement. Most of them are CO_2 or humidity-based strategies.

IAQ performance-based approaches could be used in many ways. Table 1 gives an overview of the performance-based approaches used in 5 standards and regulations. Each country uses different IAQ indicators, calculated through different methodologies and compared to different thresholds. The common thread in all of these methods is the use at a minimum, of the exposure to a pollutant generated indoors (very often the CO_2), sometimes combined with the condensation risk. A minimum airflow rate for unoccupied periods is also often required.

Pushed by the international movement toward nearly-zero energy buildings, smart ventilation system success is not about to end. In Europe, two recently published directives n°1253/2014 regarding the eco-design requirements for ventilation units and n°1254/2014 regarding the energy labelling of residential ventilation

Overview of performance-based approaches to residential smart ventilation in 5 standards and regulations.

Country	Person in charge	Ventilation Equivalence method	Calculated IAQ indicators
USA and Canada (ASHRAE 62.2 2016)	The manufacturer, specifier or designer is supposed to certify that the calculation meets the requirements.	Single zone modelling, $\Delta t < 1$ h, constant pollutant emission rate.	No specifically defined pollutant. Yearly average relative exposure R<1. At each time-step $R_i<5$.
France	The manufacturer for each (humidity) DCV system shall pass through an agreement procedure.	Multizone modelling with MATHIS, $\Delta t = 15$ min, Conventional entry data.	**Per room, over the heating period:** 1/CO_2 cumulative exposure indicator $E_{2000} < 400{,}000$ ppm.h. 2/Number of hours $T_{RH>75\%}$ <600 h in kitchen, 1000 h in bathrooms, 100 h in other rooms.
Spain (<2017)	The manufacturer for each DCV system shall pass through an agreement procedure.	Multizone modelling with CONTAM, $\Delta t = 40$ s, Conventional entry data.	**Per room, over the year:** 1/ Yearly average CO_2 concentration < 900 ppm. 2/ Yearly cumulative CO_2 exposure over 1600 ppm $E_{1600} < 500{,}000$ ppm.h.
Spain (summer 2017)	The designer of the building, of the base of information given by the manufacturer.	A performance-based approach for all ventilation systems is going to be implemented, using a software and conventional data at the design stage of each building.	**Per room, over the year:** 1/ Yearly average CO_2 concentration < 900 ppm. 2/ Yearly cumulative CO_2 exposure over 1600 ppm $E_{1600} < 500{,}000$ ppm.h.
Belgium (<2015)	The manufacturer for each DCV system shall pass through an agreement procedure.	Multizone modelling with CONTAM, $\Delta t = 5$ min, conventional entry data both deterministic and stochastic.	**Per room, over the heating period:** 1/CO_2 cumulative exposure indicator E'_{950}. 2/Monthly average RH> 80% on critic thermal bridges from December 1st to March 1st. 3/Exposure to a tracer gas emitted in toilets and in bathrooms. They must be at least equal that the worst performing reference system.
Belgium (since 2015)	The person involved in EP-calculation and manufacturer for each DCV system.	No-more existing. An advanced equivalence method has been performed by (Caillou et al., 2014) on all the systems having an agreement.	No-more existing.
The Netherlands	The person involved in EP-calculation (standard approach) OR he manufacturer for each DCV system (equivalence approach).	Even if correction factors are given in the standard, a complementary equivalence approach can be performed, using the multizone pressure code COMIS, in a semi-probabilistic approach.	**Per person, over the heating period:** Cumulative CO_2 exposure over 1200 ppm: $LKI_{1200} < 30{,}000$ ppm.h.

units (European Parliament and the Council, 2014) are moving toward a generalization of low-pressure systems, DCV systems and balanced heat recovery systems at the 2018 horizon.

The common thread in all of these performance-based approaches is the use, at a minimum, of the exposure to a pollutant generated indoors (very often the CO_2) and condensation risk. Such approaches and corresponding selected IAQ indicators could be criticized in many ways but they exist and have been tested for few years. They could be considered as an interesting background for future IAQ performance-based approaches at the design stage of every new residential building. ■

	Credit in EP-calculation	Minimum airflow
	No.	Can be null if the total airflow rate equivalence is required over any 3-hour periods.
	Average equivalent exhausted airflow (m^3/h) can be implemented in the EP-calculation.	Switch off not allowed, minimum airflow is 10-35 m^3/h according to the number of rooms in the building.
	Yearly average ventilation airflow could be implemented in the EP-calculation.	
	Yearly average ventilation airflow could be implemented in the EP-calculation.	The minimum airflow during unoccupied periods is set to 1.5 $l.s^{-1}$ in each room.
	An energy saving coefficient f_{reduc} is extrapolated and can be implemented in the EP-calculation.	
	Published conventional energy saving coefficients can be used directly in the EP-calculation. They depend on the sensing type, type of spaces and the regulation type	Minimum airflows over 10% of the minimum constant airflow for each room. An intermittent ventilation is allowed if the average on 15 minutes enables to comply with this 10%.
	Either, correction factors given in the standard for quite a few DCV systems, are used directly in the EP-calculation, OR Correction factors from the equivalence procedure can be used.	A function of the number of type of occupants.

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