The Indoor Air Quality Project


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Introduction

Indoor Air Quality (IAQ) has become one of the most pressing public-health and building-performance challenges of our time. While outdoor air pollution has declined across much of Europe, air pollution remains the continent's leading environmental health risk. What is often overlooked is that pollution is not limited to the outdoors – poor IAQ significantly contributes to respiratory and cardiovascular diseases, as well as long-term health impacts.

Although organisations such as ISO, CEN and ASHRAE have developed standards and guidelines for indoor air and ventilation, their impact remains limited due to their non-binding nature. In many European countries, legislation still lacks enforceable requirements for ventilation performance, filtration efficiency, air infiltration, system maintenance, and the control of indoor pollutants such as CO_2, formaldehyde and particulate matter. As a result, building occupants are often unaware of the actual quality of the air they breathe and lack tools to make informed decisions.

To address these gaps, Eurovent Certita Certification, launched the IAQ Project. It started with the development of a certification programme covering Indoor Air Quality and Energy Efficiency of Ventilation Systems (IAQVS) for individual houses (Phase I) and has expanded to a comprehensive methodology applicable to residential and commercial buildings (Phase II). The project was created to move beyond static standards and instead provide a performance-based, scenario-driven evaluation of ventilation systems, which takes into account both IAQ and energy performance. Using advanced numerical simulation tools, the IAQ project assesses how ventilation units and system configurations behave in real operating conditions, considering climate, wind profiles, airtightness, occupancy habits, pollution sources, dwelling layout, and building type.

Evaluating Single-Flow and Balanced Ventilation systems in multifamily residential buildings

The following case study explores the method developed by the IAQ Project for calculating IAQ performance in Phase II. The study is conducted on a two-story multi-family residential building representative of European housing stock. The building is assumed to be in an urban environment in Strasbourg. In addition, two levels of building envelop airtightness are considered: a tight envelope, representative of modern constructions, and a permeable envelope, representative of older or less airtight dwellings. Outdoor particulate pollution is introduced through two boundary conditions for

$PM_{2.5}$ concentration: a low pollution level (annual mean 10 µg/m³) and a high pollution level (annual mean >20 µg/m³) (See **Table 1**).

To evaluate the performance of the ventilation system, simulations are performed with HEAVENLY (Holistic Evaluation tool for Air VENtiLation sYstems) based on a TRNSYS-CONTAM dynamic computations of heat, moisture, and pollutants as described in Kiani et al. [1] (See **Figure 1**).

Indicators

IAQ assessment is based on IAQ indicators for CO_2, used as a proxy for occupancy-related pollution and ventilation effectiveness; Formaldehyde (HCHO), representative of indoor chemical emissions from building materials and furnishings; $PM_{2.5}$, representative of fine particulate matter influenced by outdoor pollution and filtration. Each pollutant assessed on a five-level scale. Based on [2] CO_2 concentration (ppm) is room related, so the IAQ for this room is calculated at each time step in each room and are compared directly with the limit values indicated in **Table 2**.

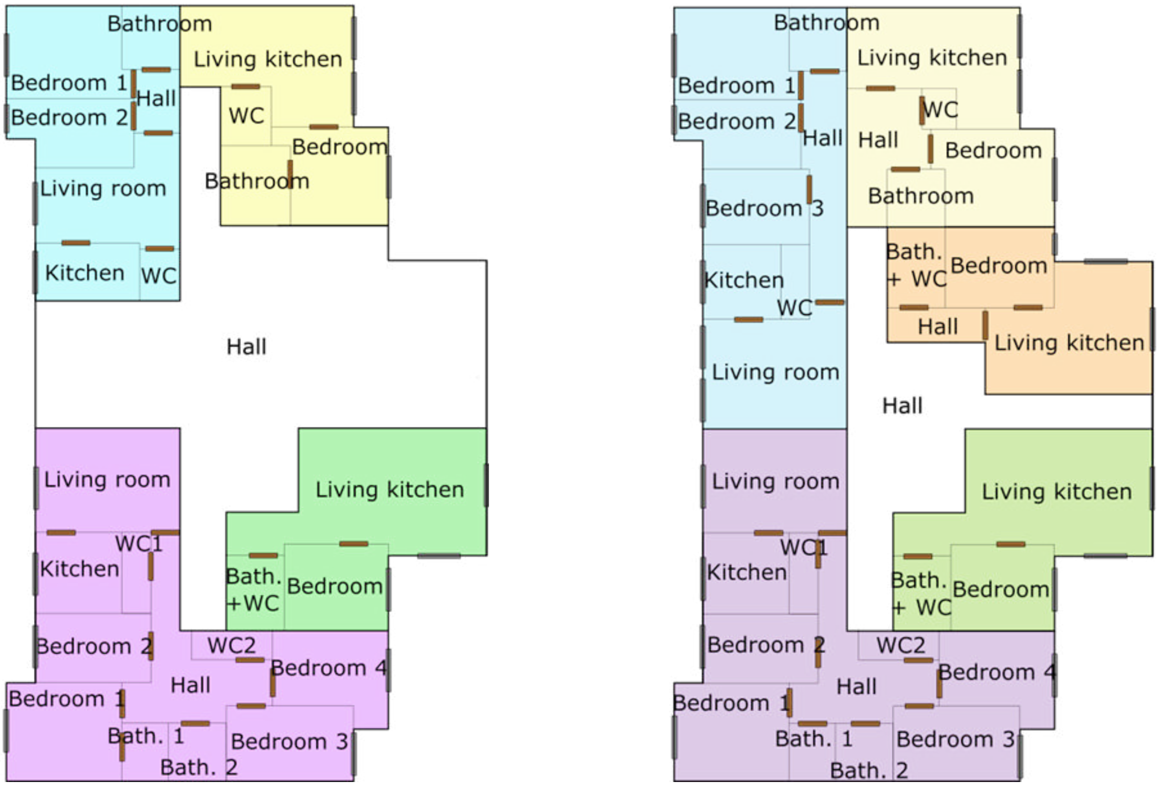
Table 1. *Boundary Conditions. [20]*

Case	Outdoor Environment		Building
Number	Wind Intensity	$PM_{2.5}$ Levels	Tightness
1	Strong	<10	Tight
2	Strong	<10	Permeable
3	Strong	>20	Tight
4	Strong	>20	Permeable

Table 2. *5-level scale for CO_2. [19][20]*

IAQ levels	ΔCO_2 [1]		Acceptable deviation
	Living Room	Bedrooms	
Excellent	<950 ppm	<780 ppm	AD < 3%
Good	<1200 ppm	<950 ppm	AD < 3%
Acceptable	<1750 ppm	<1350 ppm	AD < 3%
Bad	<1750 ppm	<1350 ppm	AD < 5%
Very Bad	<1750 ppm	<1350 ppm	AD > 5%

[1] Concentration above outdoor concentration (400 ppm).



a) b)

Figure 1. Representation of the 1st floor (a) and 2nd floor (b).[20]

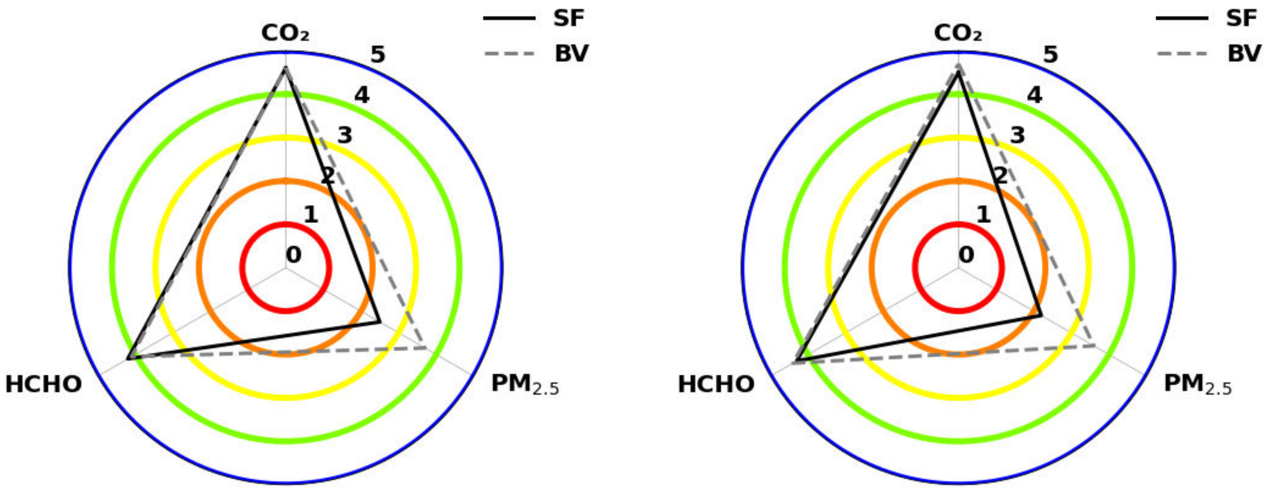
For $PM_{2.5}$ and formaldehyde, it is the average exposure of each occupant over 24 hours for $PM_{2.5}$ and 30 minutes for formaldehyde, which must be compared to the reference value in **Table 3**.

Results

Figure 2 presents the IAQ indicator levels on a five-level scale (1 = *Very Bad* … 5 = *Excellent*) for CO_2, $PM_{2.5}$ and HCHO, comparing Single-Flow (SF) and Balanced Ventilation (BV) for different boundary conditions. Across all boundary conditions, CO_2 and HCHO remain consistently at "Good–Excellent" levels for both systems, whereas $PM_{2.5}$ is the limiting pollutant and drives most of the differences between SF and BV.

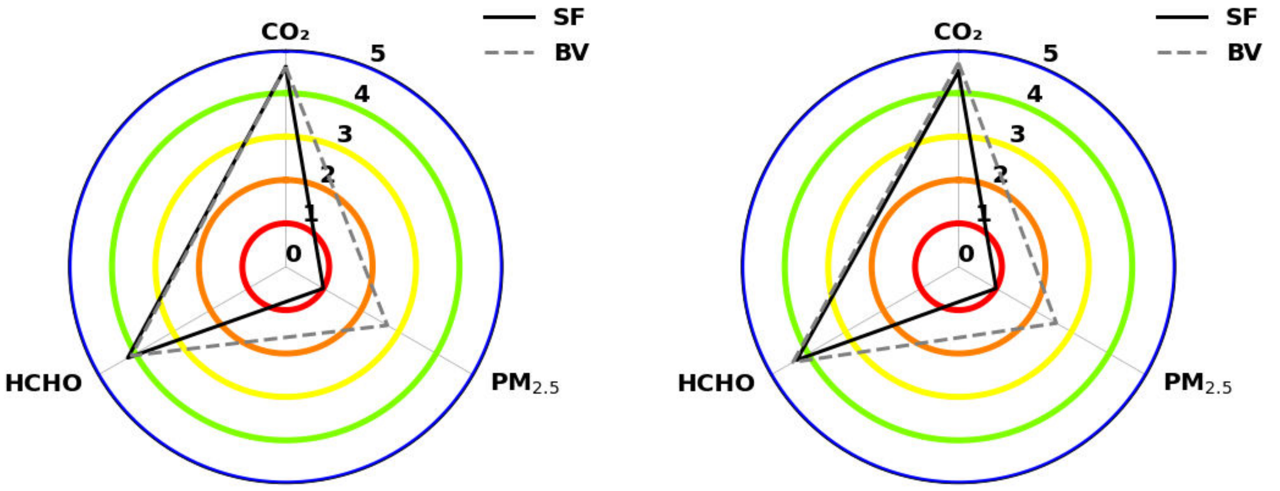
For CO_2, both systems achieve values around 4.5–4.7, corresponding to Good to near-Excellent ventilation effectiveness for occupancy-related pollution. CO_2 is essentially unchanged across boundary conditions and between systems (SF: 4.5–4.6; BV: 4.6–4.7). For HCHO, both systems also remain in the Good range (≈4.1–4.4), with only minor variations between SF and BV, meaning that formaldehyde exposure stays well controlled in all tested cases.

In contrast, $PM_{2.5}$ shows clear and systematic improvement with BV. Under low outdoor $PM_{2.5}$ conditions (**Figure 2.a, b**), SF $PM_{2.5}$ levels are Bad-to-Acceptable (2.2 and 2.5), while BV increases them to Acceptable-to-Good (3.6 and 3.7). Under high outdoor $PM_{2.5}$ conditions (**Figure 2.c, d**, $PM_{2.5}$ >20), SF reaches Very



a) Case1: Strong wind, $PM_{2.5}$ < 10, tight building

b) Case 2: Strong wind, $PM_{2.5}$ < 10, permeable building



c) Case 3: Strong wind, $PM_{2.5}$ > 20, tight building

d) Case 4: Strong wind, $PM_{2.5}$ > 20, permeable building

Figure 2. IAQ indicator levels (five-level scale) comparing SF and BV systems across different boundary conditions.

Table 3. *5-level scale for $PM_{2.5}$ and Formaldehyde. [19], [20]*

IAQ levels	$PM_{2.5}$ (µg/m³)		HCHO (µg/m³)		Acceptable deviation
	Long term	Short term	Long term	Short term	
Excellent	Cm,a < 5	Cm,24h < 10	Cm,a < 30	Cm, 30 min < 80	Not permissible
Good	Cm,a < 5	Cm,24h < 15	Cm,a < 30	Cm, 30 min < 100	Not permissible
Acceptable	Cm,a < 5	Cm,24h < 15	Cm,a < 30	Cm, 30 min < 100	AD < 3%
Bad	Cm,a > 5	Cm,24h < 15	Cm,a < 30	Cm, 30 min < 100	AD < 5%
Very Bad	Cm,a > 5	Cm,24h < 15	Cm,a < 30	Cm, 30 min < 100	AD > 5%

Bad particle performance (1.0 in both cases), whereas BV $PM_{2.5}$ is Bad-to-Acceptable (2.6 and 2.7). This confirms that the BV system provides more robust particle-related IAQ, especially when outdoor $PM_{2.5}$ is elevated.

A global IAQ index was computed as the average of the three pollutant indicator levels (CO_2, $PM_{2.5}$, HCHO), and the standard deviation (SD) across pollutants describes how balanced performance is across contaminants. For SF, the global IAQ ranges from 3.3 to 3.8, corresponding overall to Acceptable–Good, but systematically downgraded by the $PM_{2.5}$ indicator. For BV, the global IAQ ranges from 3.8 to 4.2, corresponding overall to Good performance, with smaller imbalance between pollutants. Specifically (mean ±SD across pollutants), global IAQ increases from 3.8 ±0.9 to 4.1 ±0.4 in Case 1, 3.7 ±1 to 4.2 ±0.5 in Case 2, 3.3 ±1.6 to 3.8 ±0.8 in Case 3, and 3.3 ±1.6 to 3.9 ±0.9 in Case 4 when moving from SF to BV. Overall, BV achieves a more consistently "Good" IAQ level, while SF remains more sensitive to outdoor particle pollution because $PM_{2.5}$ frequently falls into Bad or Very Bad levels.

Conclusion

Using a five-level scale for CO_2, PM2.5 and formaldehyde, results show that both systems maintain consistently good-to-near-excellent CO_2 levels (≈4.5–4.7) and good formaldehyde levels (≈4.1–4.4) across all cases. In contrast, $PM_{2.5}$ is the main differentiator between ventilation strategies: BV systematically improves $PM_{2.5}$ indicator levels relative to SF, with the largest gains observed under high outdoor $PM_{2.5}$ conditions. Consequently, the global IAQ index (mean of the three pollutant indicators) is higher and more balanced for BV than for SF in every case, confirming that balanced ventilation provides more robust IAQ performance when outdoor particle pollution increases and/or envelope characteristics vary.

Overall, the IAQ Project has created a standards-based, indicator-driven assessment to reliably evaluate the IAQ performance of ventilation systems. For Phase II, the proposed indicator framework enables an interpretable, comparative evaluation of systems and highlights the importance of particle-related indicators when assessing IAQ performance in multifamily residential buildings.

The IAQVS certification programme combines thousands of simulations, certified product performances, and dynamic modelling, to identify mechanical ventilation systems for single-family homes and apartments that improve IAQ and optimise energy consumption. Find out more about the IAQVS certification programme at www.eurovent-certification.com

References

[1] Z. Kiani, A. Eddine, K. Taurines, K. Mendonça, and M. Abadie, "Evaluating the IAQ and energy performance of ventilation systems in multifamily buildings," E3S Web Conf., vol. 523, May 2024, doi: 10.1051/e3sconf/202452301003.

[2] CEN, NF EN 16798-1 – Energy performance of buildings – Ventilation for buildings – Part 1: Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics – Module M1, May 2019. ■