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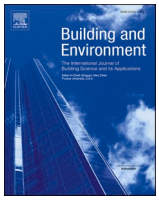

Integrating health and indoor air quality into European building policy: A landmark policy shift

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ABSTRACT

Poor indoor air quality is a common and preventable public health risk that contributes to chronic disease, infectious disease transmission, and economic losses. Europe's updated Energy Performance of Buildings Directive integrates indoor environmental quality into building policy for the first time, representing a major opportunity for Europe to protect the health of building occupants and set an example for the world. With a May 2026 deadline approaching, EU Member States should adopt a health-based framework for indoor air quality and aim to harmonize standards across Europe.

1. Background

1.1. The Energy Performance of Buildings Directive

In 2024, the Energy Performance of Buildings Directive (EPBD) was updated to include, for the first time, requirements for indoor environmental quality (IEQ), including temperature and indoor air quality [1]. The EPBD is a cornerstone of European building policy, setting energy standards of buildings across Europe since 2002. This updated directive is a monumental moment in European energy policy, integrating for the first time health-related IEQ requirements alongside traditional EPBD goals of energy efficiency and decarbonization. As the European Union approaches the EPBD's May 2026 transposition deadline, national policymakers, industry associations, professional associations, and other key stakeholders must capitalize on this political momentum and establish harmonized standards that protect and promote occupants' health, well-being, and comfort.

1.2. Historical neglect of health of building occupants

To date, energy performance policies worldwide have largely treated the health of building occupants as a separate domain or it was not considered at all. The revised EPBD is the first binding energy performance framework at the national or supranational level to explicitly integrate health-relevant indoor environmental quality considerations, marking a global first. This change in the EU's building policy bridges a historical divide between energy efficiency and public health.

Responding to the energy crisis of the 1970s, many buildings were constructed to prioritize energy efficiency, leading to tighter building seals, lower rates of ventilation, and poor indoor air quality. Complaints of what came to be called "sick building syndrome" emerged with symptoms that included eye, nose, and throat irritation; headaches; coughing; and difficulty concentrating, symptoms which typically disappeared when leaving the building [2].

Poor indoor air quality, from stale air, pollutants, dangerous gases, or airborne viruses, can cause heart disease, lung cancer, asthma, infectious disease, and cognitive impairment [3]. Household air pollution alone causes 3.2 million premature deaths annually, but this is a significant undercounting of the total deaths attributable to poor indoor air quality because airborne pathogens and hazardous building materials are not considered, for example [4]. Covid-19 has killed over 7 million people, and seasonal influenza kills, on average, 700,000 people every year, with poor indoor air quality increasing the risk of airborne disease transmission [5,6]. The return on investment for indoor air quality

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improvements when taking into account health and productivity benefits is generally less than two years [7].

Indoor spaces – where people spend up to 90% of their time – represent a largely neglected but important opportunity for public health improvement. Improved ventilation, filtration, and air cleaning offer not only long-term individual health benefits but also societal resilience against future pandemic threats. Momentum is building to prioritize healthy indoor environments: the recently launched *Global Pledge on Healthy Indoor Air* at the United Nations marked the first international commitment declaring healthy indoor air fundamental for human health, with an opportunity for more countries to join this landmark recognition [8]. And dozens of international experts have called for mandating indoor air quality standards in public buildings [9].

Consequently, the inclusion of indoor air quality within the EPBD is a crucial aspect for Member States to consider. By implementing the new requirements of the EPBD, Member States will be prioritizing health and sustainability together. In fact, improving indoor air quality and decarbonization are deeply interconnected goals, with strategies to improve indoor air quality also creating sustainability co-benefits. In this paper, indoor air quality (IAQ) parameters are given special importance due to significant impacts on public health, including impacts from respiratory disease, but we also note that IEQ parameters such as noise, lighting, and temperature are important.

1.3. A new era of healthy and energy efficient buildings is unfolding in Europe

The accelerating factor that convinced EU Member States of the importance of IEQ as a health issue was the Covid-19 pandemic. European civil society organizations (CSOs) and industry associations were key champions of indoor air quality during the pandemic and later advocated for its inclusion as part of the EPBD. The EPBD serves as the EU's primary legislative tool for driving energy efficiency and decarbonization, guiding national frameworks for certifying energy performance, planning renovations, and upgrading the EU's building stock.

IEQ provisions in the 2024 recast of the EPBD represent a formal acknowledgment that energy efficiency cannot come at the expense of building occupants' health. Importantly, these provisions make it clear that IEQ considerations matter not only in the design of the building but throughout a building's lifecycle (**Box 1**). This unified framework from the EU contrasts with approaches in other jurisdictions, such as the United States, where fragmented leadership and dispersed authority have contributed to slower and more uneven progress on IAQ policy [10].

Box 1: Key indoor environmental quality provisions in the 2024 recast of the Energy Performance of Buildings Directive

Under the 2024 EPBD recast, all Member States must:

1. Establish national standards for indoor environmental quality (includes temperature, humidity, ventilation rate, and presence of contaminants) in order to maintain a healthy indoor climate. *(Article 13)*
2. Require indoor air quality monitoring and control systems in new non-residential zero-emission buildings (such as offices, hospitals, and schools). From 2030, all new buildings constructed in the EU are required to be zero-emission buildings. For existing non-residential buildings, air monitoring and control systems are required, where economically and technically feasible, when a building undergoes a major renovation. *(Articles 7 & 13)*
3. Take into account optimal indoor environmental quality when setting minimum energy performance requirements, "in order to avoid possible negative consequences such as inadequate ventilation." *(Article 5)*
4. As part of energy performance certificates, include recommendations to building owners on improvements of IEQ. *(Article 19)*

Since the EPBD is a directive and not a regulation, it is the responsibility of Member States to transpose and implement IEQ standards into national law by May 2026. Additionally, the EU Commission does not have the legal authority to mandate exact metrics for IEQ, since competencies relating to building code and health policy are retained at the national level [11]. Many EU Member states do not have existing standards for indoor air quality established within national legislation or building codes, so the EPBD will require new obligations of these states. With the EPBD now entering national transposition across 27 Member States, the EU faces a critical inflection point: coordinated guidance could enable harmonized implementation, while the absence of such alignment risks a fragmented landscape of national standards. The EU has the opportunity to be a global leader and provide a framework for the world to follow.

2. Evidence-based indoor air quality frameworks

To guide Member States, the European Commission published an annex summarizing IEQ provisions of the EPBD recast and providing example IEQ parameter ranges [12]. In addition, the Federation of European Heating, Ventilation and Air Conditioning Associations (REHVA); EUROVENT; and the Nordic Ventilation Group released a model IEQ regulation that serves as a baseline for Member States to adopt within national legislation [13]. This guidance is an evidence-based consensus from researchers and industry experts and references the TAIL rating scheme [14]. A product of an EU Horizon-funded project, the TAIL rating scheme provides standardized values for the thermal, acoustic, indoor air quality, and luminous environment. The EU Commission annex, the REHVA Model IEQ Regulation, and the TAIL rating scheme, along with other internationally recognized parameters for indoor air quality, are summarized in Table 1. All three of these frameworks are based on World Health Organization guidelines, the core European building ventilation standard (EN16798–1), and/or the European Commission's sustainability framework for buildings (Level(s)) [15–17].

Which indoor air quality standards should Member States adopt? The answer is not as simple as one might hope. Overall, the REHVA Model IEQ Regulation provides the best ready-to-adopt framework, but the EU Commission annex and other frameworks provide important supplements. Setting IAQ standards requires defining: 1) which parameters to measure, 2) what values to aim for, and 3) at what frequency to measure the parameters. Parameters can be measured at different times in the building lifecycle – during design and construction, continuously, or at regular inspection intervals.

The REHVA Model Regulation recommends continuous monitoring of two key parameters, $PM_{2.5}$ and CO_2. These are prioritized because $PM_{2.5}$ directly reflects exposure to health-relevant fine particles and CO_2 is a real-time proxy for ventilation adequacy and airborne infection risk. Both can be measured with easily available low-cost monitors. Further, regular inspection (but not continuous monitoring) is recommended for parameters including ventilation rate, formaldehyde, radon, nitrogen

dioxide, and carbon monoxide. The REHVA Model Regulation is missing some values for parameters, so either the TAIL rating scheme or the EU Commission annex can be used as a supplement. While the REHVA Model Regulation offers a more detailed breakdown for different room types, the EU Commission annex (especially Tables 10 and 11) can be a helpful starting point for Member States, providing a summary of single value parameters to use.

The EPBD's May 2026 transposition deadline is approaching quickly, and the coming months will be decisive for indoor air quality standards for the following decades. Each Member State must determine how ambitiously to implement the directive's requirements. Some national governments may only meet the bare minimum requirements of the EPBD, while others already have comprehensive policies for IAQ that prioritize health. In the EU, Belgium and France serve as models for states that have taken comprehensive action on IAQ:

- Belgium has a history of IAQ legislation dating back to 1946, and in 2022 established a comprehensive legal framework for indoor air quality monitoring, certification, and labelling that positions IAQ as a public right-to-know issue [20].
- France recognizes indoor air quality as a public health issue by requiring monitoring in indoor spaces that receive a sensitive public, such as schools and nurseries [21].

3. Call to action for EU member states and civil society

EU Member States and civil society organizations have the opportunity between now and May 2026 to capitalize on the momentum created by EPBD to drive action towards healthy indoor air. Importantly, there is an opportunity to create transparency and awareness of indoor air pollutants in public spaces through the indoor air quality monitoring requirements, creating a new era of healthy buildings. Below are recommended actions for policymakers, public health officials, and other key stakeholders:

1. Take Advantage of this Opportunity to Protect Health: Member States have a minimum legal obligation to establish IAQ standards but can go a step further to establish a health-based framework for indoor air and environmental quality. EU Member States have the opportunity to integrate indoor air quality into building design, maintenance, and operation; establish enforcement and verification mechanisms; develop the new generation of IAQ and IEQ standards for the world to follow; and educate the public about the importance of healthy indoor air. The EU has the unique opportunity to be the global leader in setting a framework for indoor air that prioritizes public health.
2. Establish a Community of Practice: EU Member States, CSOs, industry, and other key stakeholders should establish a community of practice to share best practices and build consensus for indoor air quality parameters among Member States. Entities like REHVA, EUROVENT, and the European Public Health Alliance have an important role to play as convenors that bring in outside perspectives on how to best adopt a comprehensive, health-based framework for indoor air quality.
3. Implement a Consistent Framework Across Member States, Based on REHVA Recommendations: Member States should adopt consistent numbers for key indoor air quality parameters to enable harmonization across all European buildings and avoid patchwork implementation. The REHVA Model IEQ Regulation serves as the best ready-to-adopt framework for Member States to follow. More iteration may be needed through the Community of Practice, outlined above, to weave in considerations from other indoor air quality frameworks. Critically, CO_2 and $PM_{2.5}$ should be integrated into continuous monitoring and control systems, and other parameters should be measured during regular inspections. The ultimate goal is a new-generation of performance-based IAQ standards.
4. Develop Template Legislative Language: In order to avoid a patchwork legal environment, European CSOs can develop template legislative language that provides a cohesive set of policies for countries to adopt.

The 2024 recast of the EPBD is an important step forward in recognizing that energy performance goals should not compromise the health of building occupants. The EPBD represents a major opportunity for EU Member States to take coordinated action to enshrine the right to a healthy indoor environment as part of national legislation and building codes. All people should have access to healthy IEQ, regardless of where they live and which building they occupy briefly or at length. As the European Union renovates its built environment for a zero-emissions future, it must also ensure that the places where people live, work, heal, learn, and sleep actively support their well-being and health. Now is the time for coordinated action across Member States while the window for national implementation remains open.

Table 1
Parameter levels for key indoor air quality metrics.

Source	Parameter	Levels	Notes
REHVA Model IEQ Regulation [13]	CO_2 (above ambient)	< 500 ppm	Rooms where the floor area is > 6 m^2 per person
		<600 ppm	Classrooms
		<800 ppm	Rooms where the floor area is < 3 m^2 per person
	$PM_{2.5}$	< 10 μg/m^3	Based on WHO Global Air Quality Guidelines 2021, which specify annual mean of 5–10 μg/m^3 and 24-hour mean of 15–25 μg/m^3
	Ventilation	7 L/s per person + 0.7 L/s per m^2	Non-residential buildings
		7 L/s per person + 0.42 L/s per m^2	Residential buildings (specific ventilation levels per room type are further defined in the guidance)
EU Commission Annex [12]	CO_2 (above ambient)	≤ 800 ppm	Threshold not to be exceeded
	$PM_{2.5}$	< 10 μg/ m^3	Annual mean
		< 25 μg/ m^3	24-hour mean
	Ventilation	7 L/s per person + 0.7 L/s per m^2	Non-residential buildings
		7 L/s per person + 0.15 L/s per m^2	Residential buildings

(continued on next page)

Table 1 (*continued*)

Source	Parameter	Levels	Notes
Global Open Indoor Air Quality Standards [18]	CO_2 (absolute value)	800 ppm	Threshold not to be exceeded
	$PM_{2.5}$	15 μg/m^3	1-hour average limit
	CO	9 mg/m^3	8 h averaging time
International Expert Recommendations [9]	CO_2	800 ppm (absolute value) 350 ppm (delta)	Threshold not to be exceeded, assuming outdoor CO_2 concentration is 450 ppm Threshold not to be exceeded, delta between actual CO_2 concentration and CO_2 concentration in the supply air
	$PM_{2.5}$	15 μg/m^3	1-hour average limit
	Ventilation	14 L/s per person	When the space is occupied
	CO	100 mg/m^3	15 min averaging time
		35 mg/m^3	1 h averaging time
		10 mg/m^3	8 h averaging time
TAIL [19]	CO_2 (above ambient)	≤ 550 ppm	Green TAIL rating
		≤ 800 ppm	Yellow TAIL rating
		≤ 1350 ppm	Orange TAIL rating
		If other quality levels can't be reached	Red TAIL Rating
	$PM_{2.5}$	< 5 μg/m^3	Green TAIL rating
		≥ 5 μg/m^3	Yellow TAIL rating
		No criteria	Orange TAIL rating
		≥ 15 μg/m^3	Red TAIL Rating
	Ventilation	≥ (10 L/s per person + 2.0 L/s per m^2)	Green TAIL rating
		≥ (7 L/s per person + 1.4 L/s per m^2) and < (10 L/s per person + 2.0 L/s per m^2)	Yellow Tail Rating
		≥ (4 L/s per person + 0.8 L/s per m^2) and < (7L/s per person + 1.4 L/s per m^2)	Orange TAIL rating
		If other quality levels can't be reached	Red TAIL Rating

4. Declaration of generative AI and AI-Assisted technologies in the writing process

During the preparation of this work the author(s) used ChatGPT 5 in order to refine sentence structure and enhance readability. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the published article.

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Georgia K. Lagoudas: Writing – review & editing, Writing – original draft, Project administration, Formal analysis, Conceptualization. **Skandan Ananthasekar:** Writing – review & editing, Writing – original draft, Conceptualization. **Porter Culp:** Writing – original draft. **Pawel Wargocki:** Writing – review & editing.

Declaration of competing interest

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Data availability

No data was used for the research described in the article.

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