SUSTAINABILITY AND INDOOR AIR QUALITY IN THE EUROPEAN CONSTRUCTION SECTOR: INSIGHTS FROM TWO NATIONAL SURVEYS IN CROATIA

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Abstract: *The European construction sector plays a critical role in achieving climate neutrality, accounting for nearly 40% of global energy consumption and over one-third of greenhouse gas emissions. EU policy developments – such as the Green Deal, the Climate Law, the Renovation Wave, the EU Taxonomy, and the revised Energy Performance of Buildings Directive (EPBD) – increasingly embed sustainability, life-cycle performance, and Indoor Environmental Quality (IEQ) into mandatory requirements for both new construction and renovation. This paper contextualizes these European trends and presents insights from two national surveys conducted in Croatia: (1) a 2023 survey assessing sustainability awareness among 199 professionals, and (2) a 2025 survey assessing the level of knowledge and implementation readiness regarding Indoor Air Quality (IAQ) and Indoor Environmental Quality (IEQ) among 62 experts. While the EU has established a comprehensive regulatory and financial framework for decarbonizing the built environment, findings reveal significant knowledge gaps in key areas, including sustainability assessment, regulatory familiarity, IAQ provisions, and life-cycle evaluation – challenges that mirror those reported across Europe. The paper discusses how these gaps may hinder alignment with EU sustainability goals, and it identifies priority areas for professional capacity-building, regulatory uptake, and integration of IAQ into sustainable building design. In this context, the identified regulatory and knowledge gaps, together with emerging EU sustainability requirements, also point to new opportunities for a stronger involvement of environmental engineers in the planning, assessment, and implementation of sustainable building practices across the European construction sector.*
Keywords: *sustainability, construction sector, EPBD, IEQ/IAQ, life-cycle assessment*

Received: 16.12.2025. / Accepted: 17.12.2025.
Published online: 18.12.2025.

Professional paper

1. INTRODUCTION: THE EUROPEAN CONTEXT FOR A SUSTAINABLE CONSTRUCTION SECTOR

The built environment is central to the EU's climate, energy, and public health objectives. Buildings are responsible for 40% of final energy use and 36% of EU greenhouse gas emissions in their operational phase, while construction materials contribute an additional share of embodied carbon. Across the EU, the construction sector accounts for 50% of extracted raw materials, 33% of generated waste, and up to 33% of freshwater use. (European Commission, no date; World Green Building Council and Europe Regional Network 2019)

At the EU level, a series of strategic frameworks form an interconnected policy ecosystem:

- European Green Deal (2019), mandating climate neutrality by 2050. (European Commission 2019)
- EU Climate Law (2021), legally binding net-zero targets. (European Union 2021)
- Renovation Wave (2020), aiming to double renovation rates by 2030. (European Commission 2020)
- EU Taxonomy (2020–2023), defining sustainable investments. (European Union 2020)
- Energy Performance of Buildings Directive (EPBD) Recast (2024), integrating life-cycle carbon, energy performance standards, and Indoor Environmental Quality/Indoor Air Quality (IEQ/IAQ) obligations. (European Union 2024)

While these instruments provide clear direction, numerous studies across the EU indicate challenges in practical implementation, including insufficient awareness among practitioners, a lack of methodological tools, and limited consideration of IAQ in design processes.

This paper combines the broader EU perspective with evidence from two Croatian studies, providing insight into how one Member State's construction sector interprets and applies these evolving requirements.

2. SUSTAINABILITY PRINCIPLES AND EU LEGISLATIVE DRIVERS

2.1. Foundations of Sustainability in Construction

The conceptual foundations of sustainability in the construction sector are commonly traced back to the Brundtland definition of sustainable development, which emphasizes meeting present needs without compromising the ability of future generations to meet their own. This concept has been further operationalized in the construction context through Kibert's six principles of sustainable construction: resource reduction, reuse, the use of renewable resources, protection of nature, provision of healthy environments, and quality in the built environment (Kibert 1994). Together, these principles establish a framework that is closely aligned with contemporary European Union sustainability objectives.

Within the EU construction sector, sustainability is increasingly translated into practice through a set of regulatory and assessment instruments. The revised EPBD in 2024 (European Union 2024) places strong emphasis on energy efficiency, focusing on onsite energy production, the achievement of zero emission buildings, the integration of IEQ, and the introduction of minimum energy performance standards. Complementing this, the EU Taxonomy (European Union 2020) provides technical screening criteria to guide sustainable investment, covering climate change mitigation and adaptation, circular economy principles, pollution prevention, sustainable water use, and biodiversity protection. In parallel, the Level(s) framework offers a harmonized set of indicators for assessing the environmental performance of buildings over their entire life cycle, enabling a more consistent evaluation of sustainability across Member States (European Commission and Directorate-General for Environment 2021). Additionally, the Corporate Sustainability Reporting Directive (CSRD) introduces mandatory sustainability reporting obligations that directly affect construction companies and building material manufacturers, further embedding sustainability considerations into business practices (European Union 2022). Collectively, these policy instruments signal a clear shift in focus from operational energy efficiency alone toward a broader life-cycle perspective that includes embodied carbon, material resource impacts, and health-related aspects of building performance.

2.2. Gaps in EU-wide Implementation

Despite the rapid development of sustainability-oriented legislation and assessment frameworks at the EU level, their implementation remains uneven across Member States. A persistent challenge is the limited understanding of embodied carbon requirements and life-cycle assessment methodologies among construction professionals, alongside the insufficient integration of IEQ considerations into design and decision-making processes, which are often secondary to energy-related criteria.

The uptake of sustainability assessment and certification schemes remains slow, particularly among small and medium-sized enterprises facing financial and knowledge-related constraints. Moreover, sectoral responses to new regulatory requirements are predominantly reactive and compliance-driven rather than proactive, a pattern that mirrors the situation observed in Croatia and points to broader structural challenges across the European construction sector.

3. INDOOR AIR QUALITY AS A SUSTAINABILITY PARAMETER

IAQ is increasingly recognized as a key sustainability and public health concern, with strong evidence linking poor IAQ to adverse respiratory and cardiovascular outcomes, impaired cognitive performance, and reduced well-being (World Health Organization. Regional Office for Europe 2010). As Europeans spend up to 90% of their time indoors, where pollutant concentrations are often significantly higher than outdoors, IAQ represents a substantial health burden (World Health Organization. Regional Office for Europe 2013).

While EU environmental policy has traditionally focused on outdoor air quality, the revised EPBD (EPBD 2024) reflects a shift toward a more holistic understanding of building performance. By integrating IEQ into energy performance requirements, including monitoring, reporting, and Energy Performance Certificate (EPC) recommendations, the EPBD positions IAQ as an essential component of sustainable and energy-efficient buildings (European Union 2024).

Sustainability certification systems increasingly incorporate IAQ criteria within broader building performance assessments. The Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB) framework addresses IAQ as part of its sociocultural and functional quality criteria, linking indoor conditions to occupant health and comfort (Deutsche Gesselschaft für Nachhaltiges Bauen). However, survey results from Croatia indicate limited practical experience with IAQ-related certification criteria, highlighting the need for targeted capacity-building to support their effective implementation in practice.

4. METHODS: TWO COMPLEMENTARY NATIONAL SURVEYS

The first study was conducted in late 2023 and focused on assessing the level of awareness, understanding, and practical experience related to sustainability principles within the construction sector (Zanki et al. 2024). Data were collected through an online questionnaire distributed to professionals active across the building life cycle, including architects, civil, mechanical and electrical engineers, contractors, facility managers, manufacturers of construction products, representatives of public authorities, and academics. A total of 199 valid responses were collected. The survey addressed respondents' familiarity with sustainability concepts, experience with sustainability assessment tools, awareness of key EU regulatory frameworks (such as the EU Taxonomy, EPBD, Level(s), and CSRD), and perceptions of key drivers and motivations for sustainable investment. The objective of this study was to evaluate how sustainability is currently understood and applied in professional practice and to identify gaps that may hinder alignment with EU sustainability and decarbonisation objectives.

The second study was carried out in January 2025 and specifically examined the understanding and interpretation of IAQ and IEQ requirements among experts in the construction sector (Zanki & Erdelj 2025). This survey targeted professionals directly involved in building design, construction, renovation, and operation, including designers, engineers, contractors, manufacturers, DGNB consultants, representatives of non-governmental organisations, and academic experts. A total of 62 responses were collected. The questionnaire focused on respondents' familiarity with IAQ and IEQ concepts, awareness of the revised EPBD provisions related to IEQ monitoring, reporting, and integration into energy performance certification, as well as perceptions of IAQ impacts across different building life-cycle phases. The aim of this study was to assess the sector's readiness to implement new regulatory requirements and to identify knowledge gaps that may affect the integration of health-related parameters into sustainable building design and assessment.

5. RESULTS

5.1. Results of the Sustainability Awareness Survey

This section presents the results of the survey examining awareness, understanding, and practical experience related to sustainability principles and sustainability assessment within the construction sector. The findings highlight the current level of familiarity with key European regulatory and methodological frameworks, as well as the extent to which sustainability concepts are integrated into professional practice.

A limited level of awareness of core EU sustainability-related frameworks was identified among respondents. As shown in **Figure 17**, 43% of respondents reported that they had not heard of the EU Taxonomy, while only 2% stated that they were fully familiar with its content. Similarly, low levels of awareness were observed for other relevant instruments, including the CSRD and the Level(s) framework (70% had not heard). Despite its long-standing application, 48% of respondents indicated that they were unfamiliar with the EPBD. These results indicate that key EU policy instruments related to sustainability are not yet consistently recognized or understood across the construction sector.

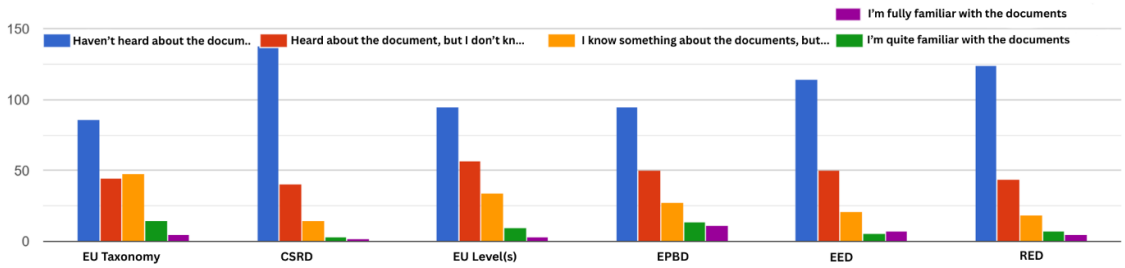

Figure 17. *Level of familiarity with key EU sustainability-related regulatory and assessment frameworks in the construction sector (Zanki et al. 2024)*

As shown in **Figure 18**, only 15.6% of respondents reported having previously conducted a sustainability assessment, indicating that for more than 80% of participants the practical application of sustainability assessment concepts remains unfamiliar. Furthermore, while the majority of respondents associate life-cycle assessment primarily with operational costs during building use (77.4%) and long-term commercial value (45%), 30% do not associate life-cycle assessment with carbon dioxide (CO_2) emissions over the building life cycle, highlighting a limited understanding of whole-life environmental impacts.

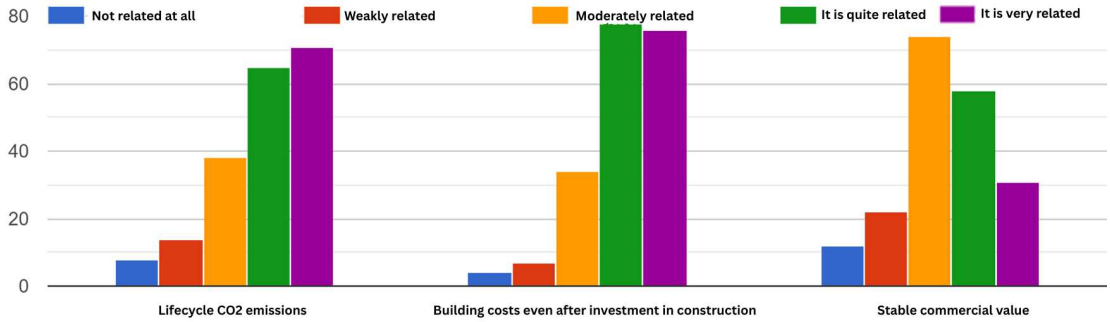

Figure 18. *Perceived association between life-cycle assessment and economic and environmental performance indicators (Zanki et al. 2024)*

5.2. Results of the IAQ and IEQ Awareness Survey

The second part of the results focuses on the level of awareness and understanding of IAQ and IEQ among professionals in the construction sector. Respondents were asked to assess their familiarity with IAQ on a five-point scale, ranging from 1 (not familiar) to 5 (completely familiar).

As shown in **Figure 19**, the majority of respondents reported a moderate level of familiarity with IAQ. The largest shares selected level 3 (32.3%) and level 4 (30.1%), while 22.6% rated themselves as highly familiar with the topic. In contrast, a smaller proportion of respondents reported low or no familiarity, with 9.7% selecting level 2 and 4.8% selecting level 1. These results indicate that IAQ is generally recognized within the professional community; however, in-depth and comprehensive knowledge appears to be limited to a relatively small group of experts.

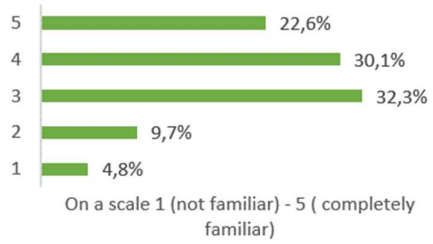

Figure 19. *Self-assessed level of familiarity with indoor air quality (IAQ) among construction sector professionals (Zanki & Erdelj, 2025)*

In addition to general IAQ knowledge, the survey examined awareness of specific regulatory requirements introduced by the revised EPBD. The results reveal a considerably lower level of familiarity with these provisions. As illustrated in **Figure 20**, 25.8% of respondents reported no familiarity with the EPBD obligation to control and monitor IEQ, while only 3.2% indicated that they fully understand the provision and its implications. The largest share of respondents (37.1%) reported partial knowledge and expressed the need for additional information. Similar patterns were observed for other IEQ-related EPBD provisions, including the integration of IEQ recommendations into energy performance certificates and the consideration of IEQ in determining minimum energy performance standards.

Overall, the results suggest a clear distinction between general awareness of IAQ as an important aspect of building performance and limited familiarity with the specific regulatory mechanisms through which IAQ and IEQ are to be implemented in practice. These findings provide a relevant basis for the integrated discussion of systemic knowledge gaps and implementation challenges in the following section.

6. DISCUSSION

The results of both surveys reveal a consistent pattern across different sustainability-related domains in the construction sector. While professionals generally acknowledge the importance of sustainability principles and IAQ, their understanding of the regulatory frameworks, assessment methodologies, and practical implementation mechanisms remains limited. In both surveys, respondents most frequently reported moderate levels of familiarity, indicating awareness of key concepts but uncertainty regarding how these should be systematically applied in professional practice.

A notable similarity between the two datasets is the gap between general recognition and operational readiness. In the sustainability survey, this is reflected in limited familiarity with EU regulatory instruments and life-cycle assessment, despite long-standing policy frameworks. In the IAQ and IEQ survey, a comparable gap emerges between awareness of IAQ as a health-related parameter and low familiarity with specific EPBD provisions governing monitoring and controlling IAQ with minimum performance requirements. Together, these findings suggest that sustainability and health-related criteria are often perceived as abstract objectives rather than as measurable and enforceable components of building performance.

These results point to systemic challenges that extend beyond the national context examined. Similar patterns of reactive compliance, fragmented knowledge across disciplines, and insufficient methodological guidance have been reported in other European Member States. Addressing these challenges will require a shift toward earlier and more integrated consideration of sustainability and IAQ criteria, supported by targeted education, clearer assessment frameworks, and stronger links between regulatory requirements and everyday design, construction, and renovation practices.

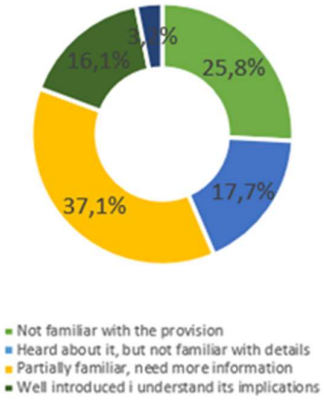

Figure 20 *Awareness of Energy Performance of Buildings Directive (EPBD) provisions related to indoor environmental quality (IEQ) (Zanki & Erdelj 2025)*

7. CONCLUSION AND RECOMMENDATIONS

The European construction sector is undergoing a significant transition driven by climate, energy, and public health objectives. The two national surveys conducted in Croatia and analysed in this paper indicate that, although professionals generally recognize the importance of sustainability and IAQ, substantial gaps remain in knowledge, regulatory familiarity, and practical implementation. These findings suggest that the challenges identified are not specific to a single Member State but reflect broader structural issues within the European construction sector.

The surveys reveal a disconnect between the strategic ambitions of EU policies and their translation into everyday professional practice. Sustainability assessment, life-cycle thinking, and IAQ-related requirements are often perceived as abstract or secondary, rather than as integral components of building quality and performance. At the same time, recent regulatory developments increasingly introduce environmental requirements – such as life-cycle-based environmental impacts, IEQ, and pollution prevention – that have not traditionally been central to engineering practice in the building sector. This situation may hinder the effective implementation of EU objectives related to decarbonisation, circularity, and occupant health, particularly in the context of accelerating renovation rates and tightening minimum performance standards.

To address these challenges, several priority actions can be identified. First, professional education and continuous training should be strengthened through mandatory and voluntary programmes, particularly focusing on life-cycle assessment (LCA), IEQ, and IAQ-related design and monitoring requirements. Professional chambers, universities, and certification bodies play a key role in building these competencies. Second, the development of clear methodological guidelines at the national level is essential to support consistent sustainability and IAQ assessment aligned with EU Taxonomy criteria and the Level(s) framework. Such guidance would reduce uncertainty and facilitate practical uptake among designers, engineers, and contractors.

Furthermore, IAQ considerations should be systematically integrated into permitting procedures, energy performance certification, and renovation strategies, supported by clearly defined threshold values, measurement protocols, and documentation requirements. Promoting genuinely multidisciplinary design processes—bringing together architects, HVAC (Heating, Ventilation and Air Conditioning) engineers, material experts, sustainability consultants and environmental engineers from early project stages – would further enhance the integration of health and environmental criteria into building performance. In this context, the evolving regulatory framework creates a clear opportunity and growing demand for environmental engineers to contribute their expertise in assessing environmental impacts, air quality, and life-cycle-based performance of buildings. Finally, EU funding

mechanisms and public procurement can play a catalytic role by linking financial support to demonstrable sustainability and IAQ performance outcomes, thereby accelerating market adoption.

In conclusion, bridging the identified gaps requires coordinated action across education, regulation, and professional practice. Strengthening the integration of sustainability principles and indoor air quality considerations is essential for delivering climate-neutral, resource-efficient, and healthy buildings, and for ensuring that the European construction sector can effectively meet current and future policy objectives.

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