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Filling the Health Gap in Energy Performance Certificates to Reduce Pulmonary Diseases Due to Bad Indoor Air Quality

Alexandre Soares dos Reis, Marta Ferreira Dias, and Alice Tavares

Abstract Good indoor air quality (IAQ) levels in buildings are among the essential benefits and drivers as they lead to better health and comfort of the occupants. However, this research identified a health gap in dwellings' energy performance certificates (EPCs) in Portugal, as IAQ seems not to be appropriately covered. Volatile organic compounds (VOCs) are gases containing various chemicals emitted from liquids or solids. Additionally, biomass-burning stoves are significant contributors to fine particle matter ($PM_{2.5}$) concentrations that may cause cancer and respiratory diseases. Therefore, it is crucial to formulate strategies to control and enhance IAQ. As air pollutants often enter the human body through inhalation, the respiratory system is regularly the main target of Indoor Air Pollution (IAP), resulting in pulmonary diseases and allergies. These facts emphasize the need to track IAQ properly. Depending on indoor air pollutants, several rules and criteria are the basis of the current published work on IAQ indicators. According to our findings, in the planning stage, understandable and straightforward criteria for VOCs, $PM_{2.5}$, and proper ventilation schemes, could help architects and engineers to enhance IAQ. Finally, next-generation EPCs could consider the proposed IAQ score to fill the identified health gap.

Keywords Energy performance certificates · Indoor air quality · VOCs · $PM_{2.5}$ · Ventilation

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1 Introduction

The 2019 United Nations Climate Change Conference (COP25), headed in Madrid, incorporated the 25th Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC), the 15th meeting of the parties to the Kyoto Protocol (CMP15), and the second meeting of the parties to the Paris Agreement (CMA2). The agreement recognized the importance of people in the fight against climate change and that they should inevitably be at the heart of the response to the climate emergency—in short, people first [1].

It is clear the European Union's (EU) commitment to developing an energy system on the track to carbon neutrality as established in the energy performance of buildings directive (EPBD) from 2010 [2] and 2018 [3]. According to the EPBD, it is the exclusive responsibility of Member States (MS) to set minimum requirements for the energy performance of buildings and building components. Improvements should be made in the building stock, bringing them to nearly zero-energy buildings (NZEBs).

The EPBD also refers to good health and wellbeing, which depends on indoor air quality (IAQ) since people spend most of their time indoors [4]. IAQ may determine how comfortable and healthy occupants may be inside buildings [5], especially when sleeping, due to its essential role in human welfare [6]. IAQ refers to the contribution of the building components to the good health and wellbeing of the occupants [7], and enhancing ventilation effectiveness may improve IAQ [8]. In the long term, a weak IAQ may seriously compromise the health and wellbeing of people inside buildings [9], especially children [10]. Sleep disorders, allergies, a dry throat, respiratory problems, eye irritation, headaches, or loss of concentration are possible effects [11], especially for those with existing health issues [12]. Hence, architects and engineers should take additional care in the planning stage [13] to minimize human exposure to contaminants [14], prioritizing people's health instead of energy efficiency as indoor air pollutants are likely to accumulate inside houses due to airtightness [15]. High thermal insulation and insufficient ventilation [16] may become a breeding ground for molds [17], viruses, and bacteria. Among the risks for health are also a variety of volatile organic compounds (VOCs) [18], particulate matter (PM) [19], and carbon dioxide (CO_2), which presence in buildings are extensively described in the literature. Several authors have monitored indoor air pollutants for the characterization of IAQ. PM, formaldehyde [20], CO_2—likely associated with consequent higher emissions through breathing and metabolic processes [21], and carbon monoxide (CO) are among the most referred air pollutants. Additionally, inside buildings, several contaminants can also be found as benzene, toluene [22], nitrogen dioxide (NO_2), ozone (O_3) acetaldehyde [23], siloxanes, flame retardants, synthetic phenolic antioxidants [24], acrolein [25], bioaerosols [26], ethylbenzene and xylenes [27].

Oil paints and PVC floors are sources of VOCs, and the radiation amount of all pollutants increases with temperature increase [28]. Materials (finishes and furnishing) are one of the primary sources of indoor air pollution (IAP) [29]. IAP is a severe threat to human health, causing millions of deaths each year [30]. Commonly reported plausible health effects associated with IAP are respiratory symptoms, sick building syndrome (SBS) [24], and cancer risk [31]. As the renovation increases, the concentration of formaldehyde, one of the most widespread VOCs, increases significantly due to finishing materials [32]. Formaldehyde and total VOCs (TVOCs) concentrations in apartments may be critical [33]. $PM_{2.5}$ may cause respiratory diseases and affect mental health [34]. Hence, the planning stage plays an essential role in achieving a good IAQ [35].

In Portugal, for non-residential buildings, EPCs consider fresh air flows depending on the number of occupants, interior finishing materials, and activities developed in each space [36]. However, in dwellings' EPCs, the ventilation is based on the air changes per hour (ACH) in the whole house [37], so it does not consider minimum fresh air flows as the methodology for non-residential buildings.

The main objectives of this study are to define clear criteria to reduce the concentration of VOCs and $PM_{2.5}$ and suggest proper ventilation schemes in dwellings to enhance IAQ. The final goal is to propose a score base criteria for IAQ.

This paper is structured as follows. Section 1 introduces the problem and provides a literature review about the health problems related to VOCs and $PM_{2.5}$ as the importance of proper ventilation. The adopted methodology and the discussion of results are described in Sect. 2. Finally, Sect. 3 presents the conclusions.

1.1 VOCs

Nowadays, as people spend most of their time inside buildings, mainly at home or at the workplace [38], researchers started to change the focus from outdoor air quality (OAQ) [39] to IAQ. According to Hanif et al. [40], VOCs are widely recognized to cause significant adverse health effects on humans. Huang et al. [41] have concluded that VOCs concentration indoor may become at least ten times higher than outdoor. One of the most widespread VOC is formaldehyde, a colorless, flammable, strong-smelling chemical used in building materials like varnishes, paints, and glues [42]. They come into the interior of buildings mainly from internal sources due to building materials, flooring, composite wood products, adhesives, brand new furniture [43], cleaning agents, and other consumer products [44]. According to Kotzias [45], VOCs significantly impact IAQ, thus, human health and wellbeing, as they may lead to chronic or severe diseases [46]. Suzuki et al. [47] found a substantial relationship between VOCs concentration and building-related symptoms (BRS). They realized that people with a medical history of allergies and those with a high sensitivity to chemicals tended to experience BRS. Therefore, in the planning stage, architects and engineers should carefully choose interior building components. Liang [48], while assessing VOCs risks to construction workers, found that TVOCs concentration was the highest during the doors and doorframes stage. Formaldehyde constituted 78% and 66% of the cancer risk for painters and carpenters, respectively.

Additionally, Jung et al. [49] measured the concentrations of VOCs and inorganic gaseous pollutants in around 5000 households in Japan, concluding that toluene, formaldehyde, and acetaldehyde were the dominant indoor VOCs. Stamp et al. [50] state that improved guidance and product labeling schemes may be required to achieve the guideline concentrations of formaldehyde and reduce associated health risks. On the other hand, while studying the indoor total volatile organic compound concentrations in densely occupied university buildings, Jia et al. [51] realized that the indoor TVOCs concentration variation was similar to the indoor CO_2 values. However, Liang et al. [52] found that when variations of CO_2 concentrations occur, the levels of CO_2 may not be used as an indicator for formaldehyde, despite their positive correlation. Additionally, according to Persily, there have been many instances in which CO_2 concentration measurements have been misinterpreted and misunderstood [53], stating that an indoor CO_2 limit is not a good indicator of ventilation or IAQ [54].

The focus on energy performance might influence architects and engineers to design airtight buildings that may lead to the accumulation of VOCs indoors, thus changing the philosophy stated in the EPBD for a healthy indoor environmental quality.

1.2 $PM_{2.5}$

PM is a complex mixture of solid and liquid particles suspended in the air [55]. These particles can vary in size, shape, and composition. PM that are 10 μm in diameter or smaller (for instance, $PM_{2.5}$) are inhalable and can affect the lungs, causing acute respiratory disorders [56]. $PM_{2.5}$ may also play a role in mental health conditions, such as major depressive disorder [34].

Last years have witnessed a surge in publications about the influence of biomass burning on PM's concentration and chemical composition. Combustion of biomass fuel is among the leading environmental risk factors for preventable disease, as stated by Fandiño-Del-Rio et al. [57]. According to Baris et al. [58], domestic burning of biomass fuel is one of the most critical risk factors for developing respiratory diseases and infant mortality. Especially in areas where the winters are long, and the biomass stove is indoors. Hadeed et al. [59] concluded that dwellings heated with coal or wood had elevated indoor $PM_{2.5}$ concentrations that exceeded both the U.S. Environmental Protection Agency (EPA) ambient standard and the World Health Organization (WHO) guideline. Abdel-Salam [60] observed a robust seasonal variability, with air quality being inferior in winter. Due to increased ventilation rates in summer, indoor air pollutants were less critical. In contrast, indoor concentrations in winter were more strongly affected by indoor sources due to increased human activities and poor ventilation. Fulvio Amato et al. [61] demonstrated that, during the winter period, biomass equipment used for residential heating represents one of the leading PM sources in urban areas, contributing up to over 20% of $PM_{2.5}$ values. OAQ may be directly related to IAQ, as Frasca et al. showed [62]. While studying PM inside two flats with airtight biomass systems, they realized that infiltration from the outdoor is the primary source of fine particles. Furthermore, mainly due to the cleaning operations required to remove residual ash, biomass stoves may be a significant source of indoor pollution. In fact, during regular operation, the combustion products are isolated from the surrounding environment, but the periodical removal of residual ash results in its dispersion inside the flats.

In addition, Zhou et al. [63] have also developed a method that analyses the variation of $PM_{2.5}$ inside dwellings between seasons that suggests significant infiltrations from outside. Rice et al. [64] studied the impact of exposure to secondhand smoke and indoor combustion from gas heaters, wood stoves, and fireplaces on respiratory symptoms in children with bronchopulmonary dysplasia (BPD). They found that 75% of the children were exposed to at least one combustible source of air pollution in the home. This exposure was associated with an increased risk of hospitalization. Their conclusions state that exposure to combustible sources of indoor air pollution was associated with increased respiratory morbidity in a group of high-risk children with BPD. Ventilation frequency and duration, biomass equipment characteristics, design, and location could be essential to improve the IAQ and preserving human health, as de Gennaro et al. [65] stated. Investigations carried out by Carvalho et al. [66] showed that the adjustment of fuel loads to heating requirements could result in a tendency of the efficiency of new biomass stoves to be higher than 80%.

On the other hand, airtight installations may reduce wood consumption by more than 50% compared with fireplaces. PM emissions may be reduced by more than 30% when using automated systems instead of manual control of combustion air inlets. Noonan et al. [67] have made the follow-up of a changeout program of old wood stoves to new lower emission ones and found a 53% reduction of $PM_{2.5}$ emissions. Carvalho et al. [68] developed a system consisting of an outer chimney installed around the existing chimney of a wood stove. In this way, the outgoing air going up preheated the outdoor air coming down through the external chimney before entering the combustion chamber. With this heat transfer system, the thermal efficiency of the wood stove increased from 62% to up to 79%. To sum up, secondary air was supplied to the wood stove reducing the carbon monoxide (CO) emissions by 39%. The two measures resulted in a better heat release from the wood stove, more stability, and reduced the average $PM_{2.5}$ emission factor by 22%. Lai et al. [69] also conclude that to reduce PM emissions associated with biomass stoves in dwellings is essential to study the combustion conditions. Saraga et al. [70] highlighted the increase of PM mass concentration, both outside and inside homes, due to biomass burning. On average, outdoor $PM_{2.5}$ concentration levels were up to two times higher during biomass burning hours. They have also realized that the indoor air was significantly influenced by the burden outdoor atmosphere in flats where no biomass burning occurred. McNamara et al. [71] have proposed air filtration units to reduce $PM_{2.5}$. Vicente et al. [72] tested several fuels in an automatic pellet stove and concluded that the pellet composition greatly influences PM emissions.

This literature review shows that fine particulate matter inside homes may directly contribute to pulmonary diseases, emphasizing the need to establish criteria to minimize the exposure to $PM_{2.5}$.

1.3 Ventilation

The general purpose of ventilation in buildings is to provide healthy air for breathing by diluting the pollutants originating in the building and removing the contaminants [73]. Low ventilation rates are regularly associated with pulmonary diseases, including cancer [74]. Lin et al. [75] concluded that the excess lifetime cancer risk shows a need to lower exposure by reducing or removing VOCs, especially formaldehyde, or increasing ventilation rates. Sun et al. [76] found that low ventilation rates in bedrooms caused elevated concentrations of formaldehyde and an increased prevalence of SBS [76]. Moreover, Bornehag et al. [77] realized that a decrease in the air changes in single-family houses coincides with the increase in allergic diseases among children and adults. Hence, appropriate ventilation regimes are needed. Huang et al. [78] stated that improved ventilation effectively reduced the indoor concentrations of VOCs. Gabriel et al. [23] state that the promotion of ventilation is essential for improving air quality in households and promoting children's health. Burguelle et al. [79] found that mechanical supply and exhaust ventilation yielded an overall improvement of IAQ. However, also natural ventilation may positively impact IAQ. Assuring a continuous entrance of outside air through windows provides to the indoor a feasible and affordable way to regulate and sustain low standards in the VOCs, as stated by Aguillar et al. [80]. They have proposed a method that allows outside air to regulate the VOCs inside buildings effectively. D'amico et al. [81] also highlighted the central role of ventilation in IAQ.

Furthermore, Amira et al. [82] stated that a sound ventilation system and a careful selection of construction materials are crucial for a good IAQ. Yang et al. [83] studied VOCs levels in 169 energy-efficiency dwellings in Switzerland, concluding that thermal retrofit of residential buildings and absence of mechanical ventilation system were associated with high levels of formaldehyde. The results suggest that actions should accompany energy efficiency measures in dwellings to mitigate VOCs exposures and avoid adverse health outcomes. In addition to this, according to Fan et al. [84], diluting indoor air pollutants with fresh outdoor air is the most convenient way to lower VOCs values. While assessing air pollutants in university buildings, Mundackal and Ngole-Jeme [85] observed high VOCs concentrations. They have recommended additional ventilation and frequent monitoring of IAQ. Kraus and Juhasova Senitkova [86] referred to a simulation tool that predicts the emission of VOCs from building surface materials and furnishings, helping to select low-emission materials and effective ventilation strategies.

Yang et al. [87] characterized the indoor environment at facilities for sensitive populations in Korea, investigating the effects of legal regulation on IAQ. They recommend installing efficient ventilation to reduce indoor pollutants concentrations while controlling the primary sources of pollutants. Holos et al. [88] studied the influence of ventilation on VOCs emission rates in newly built and renovated buildings. Their results may be used to assess practical ventilation strategies to keep the concentration of TVOCs within acceptable levels during hours of occupancy after completion of a new or renovated building. However, ventilation for itself might not be enough to ensure a good IAQ [89].

2 Methodology and Results

Existing published work about IAQ indexes is mainly based on real-time data generated by indoor air pollutants, like the one developed by Yuan et al. [90]. Based on the data collected from sensors in a classroom, Rastogi et al. [91] proposed a novel method for the determination of ventilation states using three indoor pollutants, $PM_{2.5}$, PM_{10}, and carbon monoxide (CO), with three levels of alerts: 1) “poor”; 2) “moderate”; and 3) “good”. Balbis-Morejón et al. [92] proposed an Air Conditioning Performance Indicator (ACPI) based on six criteria: energy consumption, IAQ, thermal comfort, carbon emissions, investment costs, and finally, operation and maintenance costs. Piasecki and Kostyrko [93] developed a method based on a decision matrix that includes six attributes: actual indoor air CO_2 concentration, TVOCs, and formaldehyde concentration, and their anthropogenic and construction product emissions to the indoor environment with a combined weighting scheme for an IAQ index equation. Kim et al. [94] suggested an IAQ index which reflects $PM_{2.5}$ and CO_2, divided into five grades from “good” to “hazardous” with a scale of 1 to 100 points, as follows: “good” (0–20); “moderate” (21–40); “unhealthy for a sensitive group” (41–60), “bad” (61–80), and “hazardous” (81–100). Nimlyat [95] developed two indexes for indoor environmental quality (IEQ), the IEQ performance model (IEQ_{PM}), and the IEQ occupants‧ satisfaction (IEQ_{POS}) in hospital ward buildings. The IEQ_{PM} model indicated that thermal, acoustic, visual, and IAQ are significant determinants of IEQ performance. The author found out a substantial relationship between IEQ_{PM} and IEQ_{POS} and proposed the Comprehensive Occupant Satisfaction Index (COS_I), which may be used for the assessment of comfort of the IEQ criteria in Green Building Rating Systems (GBRS), according to the following scale: IEQ performance “above average” (COS_I = 0.90); “average” IEQ performance (COS_I = 0.80); IEQ performance “below average” (COS_I = 0.70). Javid et al. [96] aimed to develop a comprehensive index with fifteen parameters and 108 rules—the Fuzzy-Based Indoor Air Quality Index (FIAQI). Poirier et al. [13] built three emission rates classified for $PM_{2.5}$ and formaldehyde: “high”, “medium,” and “low”, to be selected depending on the available data at the design stage. For instance, a “low” emission rate concerning formaldehyde may be considered only if A-class

IAQ-labelled materials are used. Sérafin et al. [97] present an original method for IAQ in office buildings by calculating a hazard quotient (HQ) and a hazard classification (CMRE). Based on the ventilation rate (VR) and on the Predicted Mean Vote (PMV), Rastogi et al. [98] developed an indicator for IAQ and thermal comfort, the Air Quality and Comfort Indicator (AQCI), with a three level scale: 1) "good"; 2) "moderate; and 3) "poor".

The literature review, the current published work about IAQ scores, and the Active House Specifications [99] inspired the adopted methodology. Active House Specifications have nine areas of performance indicators, graded on a four-level scale [100]. Bringing complicated and ambiguous scenarios is not the way to move forward [101], as this may negatively influence decision-makers, architects, and engineers [102]. As the weighting methods are regularly subjective [103], with essential differences between existing schemes [104], this research intends to give the same weight [105] to all criteria under a four-level scale from 1) "better" to 4) "worst" [100].

Measuring the concentrations of indoor air pollutants is the primary strategy used in the identified published work about IAQ indexes. According to the present knowledge, there is a gap in IAQ indexes to be followed in the planning stage. The proposed methodology will allow making essential decisions at the earliest level of a project: first, reducing the source of pollutants—VOCs and $PM_{2.5}$; second, enhancing ventilation. The final IAQ score would be the average of each score proposed, from 1 to 4, for VOCs, $PM_{2.5}$, and ventilation.

2.1 VOCs

The adopted approach to minimize the risk of VOCs inside homes was to follow the French guidelines *Étiquetage des émissions en polluants volatiles des produits de construction* [106] and the Portuguese Ministerial Order Nº353-A/2013 [36], with the criteria and scores showed in Table 1.

Table 1 Criteria and scores to minimize the risk of VOCs inside homes

VOCs	Score
By area, $\geq$75% of paints and varnishes used follow the guidelines of *Étiquetage des émissions en polluants volatils des produits de construction* that leed to class A+	1
By area, $\geq$75% of paints and varnishes used follow the guidelines of *Étiquetage des émissions en polluants volatils des produits de construction* that leed to class A+ or A	2
By area, 50–74% of paints and varnishes used follow the guidelines of *Étiquetage des émissions en polluants volatils des produits de construction* that leed to class A+ or A	3
Paints and varnishes used do not follow the guidelines of *Étiquetage des émissions en polluants volatils des produits de construction* that leed to class A+ or A	4

2.2 $PM_{2.5}$

Reducing indoor $PM_{2.5}$ levels may offer a more feasible and immediate way to save substantial lives and economic losses attributable to $PM_{2.5}$ exposure [92]. The main objective is to minimize the risk of releasing and spreading $PM_{2.5}$ inside homes. Hence, the proposed criteria aim to reduce the risk of $PM_{2.5}$ moving inside dwellings. The following Table 2 gives information about the proposed score for each criterion.

2.3 Ventilation

As ventilation plays a significant role in IAQ, the proposed criteria follow the recommendations of the Portuguese Ministerial Order N.º297/2019 [107] and the book *Manual de Apoio ao Projecto de Reabilitação de Edifícios Antigos* [108], defining simple and understandable criteria—Table 3.

For an air pollutant, the concentration is the amount of contaminant present in each unit volume or unit mass of air. Exposure usually refers to the product of pollutant concentration in the breathing zone of a room and the time the person spends in that room. For some indoor-generated pollutants, as VOCs and $PM_{2.5}$, outdoor exposures can become negligible compared to indoor exposures. A broad range of health effects may result from indoor pollutant exposures. Some pollutants increase the risk of cancers or other severe health effects. The evidence of health risks is sufficient to justify taking precautionary measures to limit VOCs and $PM_{2.5}$ inside homes. Nowadays, we spend most of our time inside buildings, especially inside our homes, so much of our exposure to air pollutants, as VOCs present in building materials or $PM_{2.5}$ released from wood-burning devices, occurs indoors.

Table 2 Proposed scores for each criterion to minimize the risk of release and spreading $PM_{2.5}$ inside homes

PM	Score
Air for biomass stoves comes from the outside, and the kitchen exhaust fan is not in the same room. Or no biomass stoves installed inside the house	1
Air for biomass stoves does not come from the outside, and the kitchen exhaust fan is not in the same room	2
Air for biomass comes from the outside, and the kitchen exhaust fan is in the same room	3
Air for biomass stoves does not come from the outside, and the kitchen exhaust fan is in the same room	4

Table 3 Proposed criteria and scores for ventilation

Ventilation	Score
Fresh air (at least 30 m^3/h in bedrooms and 60 m^3/h in living rooms) with self-regulating flap ventilators. Discharge of polluted air achieved mechanically, with variable flow units, at least in bathrooms. Or centralized mechanical ventilation system that assures fresh air (at least 30 m^3/h in bedrooms and 60 m^3/h in living rooms) and discharge of polluted air	1
Fresh air (at least 30 m^3/h in bedrooms and 60 m^3/h in living rooms) with self-regulating flap ventilators. Discharge of polluted air achieved through natural ventilation with static ventilators Class B—NF P 50 413	2
Fresh air in bedrooms and living rooms with self-ventilating flap ventilators or infiltrations through windows with airtightness class 2 or less	3
No fresh air in bedrooms and living rooms	4

Ventilation is an option for reducing existing indoor VOCs and $PM_{2.5}$ concentrations. Providing outdoor air will decrease the indoor air concentrations of pollutants released from indoor sources. However, considering a strategy to minimize the indoor pollutant sources would be crucial, as ventilation alone cannot optimize health conditions in homes. Hence, eliminating or limiting the indoor sources of VOCs and $PM_{2.5}$ should be the first option to consider. Reducing the sources of indoor pollutants, for example, by selecting low emitting building materials and the proper use of wooden stoves, diminishes the amount of ventilation needed to maintain low indoor pollutant concentrations. Pollutant source control often does not affect building energy use, while increasing ventilation increases energy consumption.

The proposed IAQ score, based not only on increasing ventilation but mainly on reducing the internal sources of VOCs and $PM_{2.5}$, would give precise information, on an early stage, to architects, engineers, builders, and building owners. From 1 to 4, score-based criteria for selecting materials that emit VOCs at a lower rate, properly installing wood-burning equipment and ventilation systems could contribute to a practical and straightforward way to a better IAQ in dwellings.

3 Conclusions

Poor indoor air quality negatively impacts occupants' health, as highlighted in this paper. In Portugal, due to the air changes per hour ventilation criteria in dwellings (Order Nº 15,793-K/2013), there might not be sufficient fresh air to dilute pollutants like VOCs and $PM_{2.5}$. Besides ventilation, it is also vital to reduce finishing materials that may spread VOCs like formaldehyde inside homes. The integration of biomass stoves should be carefully thought, in the planning stage, to avoid high concentrations of $PM_{2.5}$. Adequately ventilated rooms may minimize the high concentrations of VOCs, and $PM_{2.5}$ inside homes, reducing the risk of pulmonary diseases. Still, it is essential to mitigate the sources—as fewer VOCs and $PM_{2.5}$, better. A crucial need is to inform decision-makers and occupants of how proper ventilation, a good choice of finishing materials, and properly installing biomass stoves may contribute to a healthier indoor environment. Complicated and too detailed criteria might not be helpful for this purpose.

This research proposes an accessible and understandable criterion rated on a four-level scale from 1) "better" to 4) "worst". For VOCs, based on the French guidelines for paints and varnishes. For $PM_{2.5,}$ according to the literature review. Finally, for ventilation considering the Portuguese Ministerial Order Nº 297/2019 and the the book *Manual de Apoio ao Projecto de Reabilitação de Edifícios Antigos*.

The aim is to avoid inappropriate interventions during building renovation that could compromise the purpose of having healthy indoor conditions for a better life inside buildings, now more than ever, because people spend much time at home.

For better consumer understanding, future developments should consider applying a certification scale from A ("better") to G ("worst"), similar to the energy performance certificates. This health rating could also be part of the next-generation energy performance certificates, side by side with the energy rating.

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