The IAQ performance-based regulation in Spain: description, identified problems for its application, and foreseen changes

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ABSTRACT

Efforts must be made to promote the use of efficient ventilation systems in buildings with the aim of reducing energy demand, as ventilation is a major source of energy loss. Nevertheless, the implementation of efficient ventilation systems is frequently constrained by regulations. It is therefore essential that governments and regulatory bodies facilitate and even encourage the use of appropriate solutions through the introduction of performance-based regulations.

Prescriptive regulations establish particular conditions or specifications for deemed-to-satisfy solutions or systems, thereby limiting the utilization of any alternative solution or system. In general, indoor air quality (IAQ) regulatory frameworks worldwide are still mainly based on prescriptive approaches that set fixed requirements for airflows or air change rates (Dimitroulopoulou, C., 2012). This can hinder the implementation of innovative and more efficient ventilation systems.

In contrast, performance-based regulations provide a flexible regulatory framework that can accommodate any solution that meets the specified performance requirements, regardless of whether it is explicitly outlined in the regulations. This approach allows for innovation, promoting the utilisation of novel techniques and building practices that result in enhanced efficiency (IRCC, 1998). Therefore, to promote the use of efficient ventilation systems, it is imperative to develop and implement performance-based IAQ regulations that require IAQ performance indicators during the building design stage. A number of countries have already implemented performance-based IAQ regulations (Guyot, G. et al., 2019) with the intention of encouraging the use of efficient ventilation strategies.

This paper presents a description of the IAQ performance-based regulation in Spain, along with an analysis of the main identified problems for its application and the anticipated changes that are likely to occur in the near future.

KEYWORDS

Ventilation, IAQ, regulations, performance-based, building code, CO_2

1 REGULATORY FRAMEWORK

The primary regulatory framework in Spain for ensuring the quality of buildings is the *Código Técnico de la Edificación* (CTE, 2006). It encompasses a comprehensive range of requirements pertaining to matters including energy efficiency and IAQ. The provisions for regulating IAQ within dwellings are included in Section DB HS3 *Calidad del aire interior*

(Indoor air quality) (Fig. 1). The DB HS3 was originally based on the establishment of minimum constant ventilation flow rates for supply and exhaust air in habitable rooms, which were formulated as deem-to-satisfy solutions. Efficient ventilation systems, such as smart ventilation systems, were not included among the deemed-to-satisfy solutions. Instead, compliance was to be demonstrated through the assessment of a *Documento de Idoneidad Técnica* (Technical Approval Document, DIT).

In response to the growing demand for sustainable policies and regulations that promote the use of more efficient ventilation systems, section DB HS3 was reviewed (Linares, P. et al., 2014) and subsequently enforced in 2017 (DB HS3, 2017). The revised regulations currently adopt a fully performance-based approach, which allows the use of systems that can adjust ventilation rates to meet actual needs. The current requirement is to limit the concentration of CO_2 as an indicator of pollutants related to human activity and to establish a minimum ventilation rate to reduce other pollutants related to the building and its furnishings. These performance-based regulations facilitate the implementation of efficient ventilation systems avoiding the inherent regulatory obstacles associated with prescriptive regulations. Additionally, the 2017 revision retained the constant flow rates as deemed-to-satisfy solutions but optimised them to meet the set performance-based requirements.

This approach enables designers to utilise optimised constant ventilation flow rates, utilising ventilation systems that have already been certified with DIT or assessing the compliance of other systems in real dwellings according to the performance-based requirements. Consequently, it is more straightforward to optimise energy demand by utilising either variable or constant flow ventilation systems.

Figure 1. Left: web page of the *Código Técnico de la Edificación*.
Right: Cover of DB HS3 *Calidad del aire interior*

2 IAQ INDICATOR AND METRICS

The IAQ level is typically determined by the concentration of pollutants generated in buildings that can affect people's health and comfort. A number of common pollutants are found in buildings including fine and coarse particulate matter, NO_2, second-hand smoke, radon, formaldehyde and ozone (Morantes et al., 2023; Logue et al., 2011). Pollutants may be generated by human activity or exhaled from furniture and finishes. It is challenging task to establish a relationship between pollutant concentration and its effect on the health of occupants. Furthermore, the majority of common pollutants are challenging to quantify or assess without the use of sophisticated instrumentation.

In this context, the Spanish regulations (DB HS3, 2017) opted to select an easily measurable indicator as a performance-based requirement to represent the state of the IAQ. Although there is no general consensus on the health risks posed by CO_2 at typical indoor concentrations, and the relationship between CO_2 and other important pollutants remains uncertain (Persily, A., 2022), CO_2 concentration can still be considered a reliable indicator of ventilation rate, it is easy to measure and closely related to human activity and bioeffluent emissions. For these reasons, it has traditionally been used as an IAQ indicator and was chosen in DB HS3 as the indicator for pollutants directly related to human activity.

In order to quantify the performance-based requirement two thresholds for CO_2 concentration were established:

- the maximum annual average concentration of CO_2 should not exceed 900 ppm;

- the maximum annual accumulated concentration of CO_2 above 1,600 ppm should not exceed 500,000 ppm per hour. This parameter indicates the relationship between the duration of CO_2 concentrations above a specified limit value over a year. It can be calculated as the sum of the areas (ppm·h) within the limit value of 1,600 ppm and the representation of the CO_2 concentration as a time function (Fig. 2).

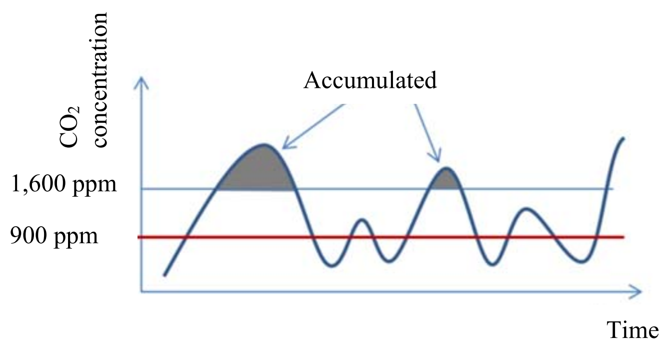

Figure 2. Annual accumulated concentration of CO2 above 1,600 ppm

These thresholds must not be exceeded under the design conditions established in DB HS3, which include occupancy scenarios and CO_2 production rates. These thresholds are considered 'design performance' as it is not possible to measure them on-site under precisely these conditions; they can only be assessed during the design stage.

In addition to the aforementioned performance-based requirement, a minimum constant flow rate of 1.5 l/s was established in order to regulate the concentration of pollutants that are not directly related to human activity, such as those originating from furniture and finishes (for instance formaldehyde).

3 DEEMED-TO-SATISFY SOLUTIONS AND VERIFICATION METHOD

Compliance with performance-based requirements can be achieved either through a deemed-to-satisfy solution or a specialised verification method.

Deemed-to-satisfy solutions are designed with the intention of being user-friendly for non-specialist practitioners, and their use serves as a guarantee of compliance with the performance-based requirements. On the other hand, specialist practitioners may elect to utilise alternative solutions that demonstrate their compliance with the specified verification method.

3.1 Deemed-to-satisfy solutions

The deemed-to-satisfy solutions consist of minimum constant ventilation flow rates, as indicated in Table 1, for the supply and exhaust of air in habitable rooms. The required flow rates depend on the type of dwelling according to the number of bedrooms.

Table 1. Constant ventilation flow rates (l/s)

Number of bedrooms in the dwelling	**Dry rooms**			**Wet rooms**	
	Master bedroom	**Other bedrooms**	**Dining and living rooms**	**Global**	**Each room (1)**
0 or 1	8	-	6	12	6
2	8	4	8	24	7
≥ 3	8	4	10	33	8

(1) Kitchen and bathrooms.

Fresh air must be supplied to dry rooms and stale air must be extracted from wet rooms. Table 1 illustrates the supply and exhaust flow rates for each room.

The total supply flow rate is calculated by adding together the individual supply flow rates for each dry room. In parallel, the total exhaust flow rate is determined by taking the greater of the global flow rate for wet rooms and the sum of the individual exhaust flow rates for each wet room. It is necessary that the total supply and exhaust flows for the entire dwelling are balanced, so that the total ventilation flow rate for the design of the system is equal to the largest of the exhaust and supply flows. Therefore, it may eventually be necessary to increase the flow rate in some rooms (wet or dry) in order to achieve equilibrium within the system. The decision regarding which room(s) to increase the flow rate will be made by the designer.

2.2 Verification method

The verification method involves specialised software to assess the CO_2 concentration in each room. While no specific software is designated, the values of the fundamental parameters to be considered are explicitly outlined. The simulation should incorporate these influencing parameters, including the number of occupants, occupancy scenarios, weather conditions, the CO_2 production rate, the annual average outdoor CO_2 concentration, and closed doors.

The aim of the verification method is to verify compliance with performance-based requirements at the design stage. On-site CO_2 monitoring is not required to demonstrate compliance. Performance-based requirements are considered 'design performance' as they cannot be measured in situ under precisely the very same conditions as those used to set the thresholds; they can only be assessed at the design stage.

It is possible to assess any ventilation system for compliance with the performance-based requirements.

4 ENERGY SAVING WITH THE CURRENT APPROACH

The principal advantage of the performance-based approach is that any ventilation system can demonstrate compliance with the performance-based requirements. This allows the utilisation of energy-efficient systems such as demand controlled ventilation (DCV) systems.

Figure 3 illustrates the reduction in demand achieved in 20 case studies when DCV systems that fulfil the performance-based current regulations are employed instead of the constant airflows derived from the application of the old regulations (Linares, P. et al., 2015). A total of five dwellings were studied in two climate zones (D3 and A3) with two orientations (north and south). In all cases, both heating and cooling demands were found to be reduced. Nevertheless, the reduction in heating demand was considerably more pronounced, with figures ranging from 21% to 100%.

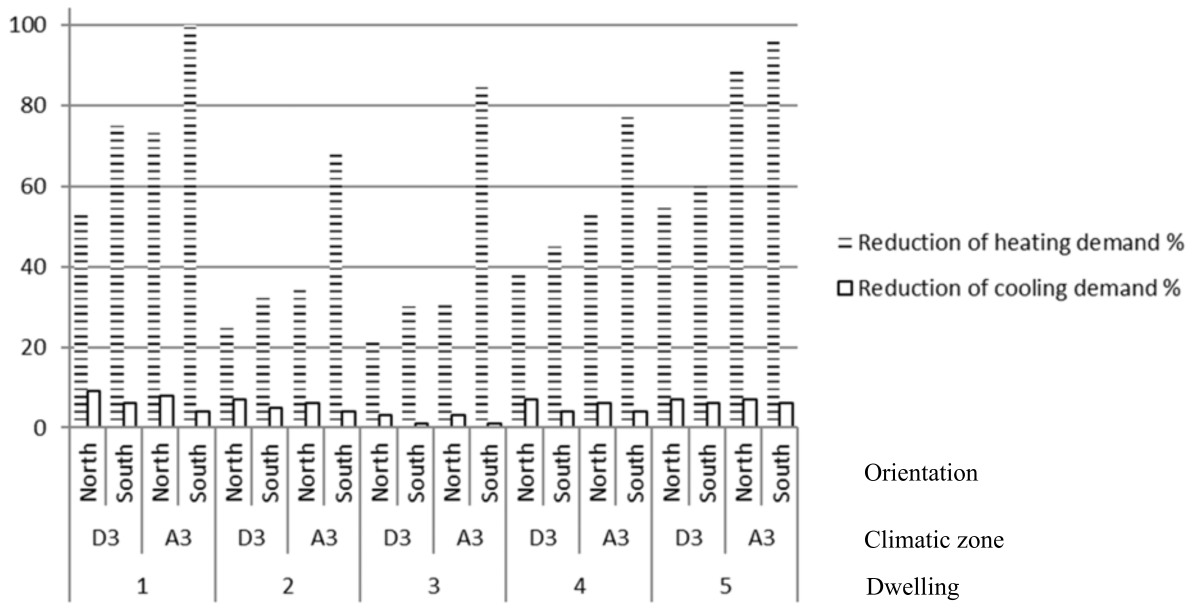

Figure 3. Reduction of demand

5 PROBLEMS IDENTIFIED IN ITS APPLICATION

Following the initial implementation of DB HS3 approximately twenty years ago and the subsequent introduction of the current performance-based version seven years ago, a number of issues have been identified in its application (AIVC VIP 48.1, 2024). These issues primarily relate to the consideration of smart ventilation systems in energy assessment tools and the rise of condensation risk in renovations. Although only the first one is directly related to the new performance-based approach, the other one is also described below because of its relevance.

5.1 Lack of consideration of smart ventilation systems in energy assessment tools

The use of efficient ventilation systems can result in significant energy savings. However, the most commonly used building energy assessment tools do not fully account for these benefits due to inaccurate ventilation flow rates used in the energy assessment and suboptimal integration of demand-controlled ventilation systems.

In Spain, the most commonly used tool for assessing the energy performance of buildings is the *Herramienta Unificada Lider-Calener* (HULC). HULC is a whole building energy simulation software that is used to assess energy demand and consumption. It comprises the earlier software tools LIDER and CALENER, allowing both assessment of energy qualification and fulfilment of the energy saving requirements. The software is offered by the *Ministerio de Fomento* and the *Ministerio de Industria, Energía y Turismo - Instituto para la diversificación y ahorro de la energía* (IDAE), having been developed by *Grupo de Termotecnia de la Asociación de Investigación y Cooperación Industrial de Andalucía* (AICIA) from the *Escuela Técnica Superior de Ingenieros* from *Universidad de Sevilla*, in collaboration with the *Unidad de Calidad en la Construcción* from *Instituto Eduardo Torroja de Ciencias de la Construcción* (IETCC-CSIC).

HULC takes into account the constant ventilation flow rate of the entire building and the electrical energy consumption based on the specifications of the ventilation system (ErP technical data, data from fan curves (flow rates and power) or data for heat recovery systems). However, these ventilation flow rates and energy consumption are not optimised to match real needs and are assumed to be constant at all times. The only viable option is to calculate the equivalent average flow over the year under design conditions.

5.2 Rise of condensation risk in renovations

It is probable that surface condensation will occur on the inner side of façade walls during a renovation of a dwelling in which existing windows are replaced by other airtight windows without the provision of additional means of intake of fresh air.

Historically, the ventilation system most commonly employed in Spanish dwellings was based on the occupants' habits of opening windows, high infiltration rates through the building envelope, primarily window frames (Hoek, T., et al., 2022), and the extraction of stale air through thermal buoyancy-based vertical stacks located in wet rooms, mainly bathrooms and toilets, and sometimes kitchens (Linares-Alemparte, P. et al., 2024).

In order to enhance the energy efficiency in renovations, it is frequently the case that existing permeable windows are replaced with airtight ones, which are sometimes equipped with microventilation. The microventilation system is a device integrated into the window frame, usually a tilt-and-turn design, that opens a 4-5mm gap around the perimeter of the active window sash when activated by the window handle. This results in a small but permanent airflow. However, occupants are typically unaware of this possibility.

In the event that microventilation or other means of fresh air intake are not provided, in addition to opening windows, there is a risk of insufficient ventilation, leading to the accumulation of humidity and surface condensation. Despite the current DB HS3 already emphasizes the importance of not compromising performance during renovations, instances of this occurring are still common. A preliminary study has revealed that 50% of existing buildings fail to meet the current CO_2 values established in the IAQ regulations.

6 FORESEEN CHANGES

The plan to revise HULC already includes targets to more accurately account for the energy saving benefits of utilising efficient ventilation systems, including:

- adjusting the ventilation flow rates used in the energy performance assessment to make them more accurate and reflective of actual rates;

- optimising the integration of demand-controlled ventilation systems into the energy performance assessment methodology and simulation tools.

Efforts must be made to ensure that regulations emphasise the need to maintain or improve IAQ performance when replacing existing windows with airtight ones, including the provision of fresh air supplies. There is a need to raise awareness of the issue among designers and to guarantee the implementation of suitable building controls for monitoring compliance.

In the near future, regulations are expected to further embrace a performance-based approach. This may involve a move away from CO_2 as the sole indicator of IAQ and the setting of thresholds levels for other pollutants. A major challenge in implementing this change is to establish the correlation between pollutant concentration and its impact on occupant health. Research is currently underway to investigate the generation of the most common pollutants in dwellings, their concentration and their impact on occupant health in terms of Disability-Adjusted Life Years (DALYs). Other challenges include the lack of accuracy of readily available pollutant detectors for controlling ventilation systems.

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