

# From Directive 2002/91/EC to Directive 2024/1275/EC: evolution of design criteria for ventilation systems. Past, present and suggestions for future developments

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**Abstract.** This paper traces a historical route, highlighting the main regulatory and technical changes that have influenced the sector of building ventilation. The aim is to provide a reference guideline for Italian lawmakers, designers, and installers who, due to the rapid evolution of the international framework, find it difficult to manage the complex system of regulatory and legislative documents available. The paper also reports examples of monitoring results intended to guide those involved in technical and legislative discussions in sectors considered to be of primary importance for this issue: school and residential buildings. The paper also refers to the main voluntary sustainability protocols in the field of ventilation systems to evaluate the current criteria and strategies that can be implemented to create more sustainable buildings with better indoor air quality. By comparing the criteria of the leading voluntary schemes with statutory requirements, the work highlights inconsistencies and opportunities for alignment that can accelerate the adoption of high-performance ventilation systems. The paper concludes with an operational road map of indoor air quality, health, and energy consumption.

## 1. Introduction

The main idea of this work was to offer the Italian readers a key to see and analyze how laws and standards on indoor air quality in buildings have changed since the “beginnings”. It can be assumed that knowledge of the specific past, but still relevant, situation may be useful in dealing with the constantly evolving reality in this field. Of course, the same approach can be applied also to other European countries: it could be interesting to see if the final results will be common or not.

As the years go by, especially after 2002, with the enactment of the first EPBD [1], the number of documents (including laws, standards, voluntary protocols, etc.) focusing on several aspects concerning energy saving and indoor air quality, have multiplied. Designers have to spend a lot of time reading and studying pages of long texts that, sometimes, contradict each other.

And yet, even perfectly respecting the law, in many residential buildings severe environmental problems occur. The use of simple airing to renew the air has always been a frequent cause of mould formation, due to excessive internal humidity generated by the presence and activities of people. This phenomenon has become much more pronounced in recent years due to the reduced air permeability of windows and doors as a result of more precise manufacturing and the introduction of gaskets. The presence of moulds, apart from the intrinsic negativity, is a warning of insufficient air renewal and consequently poor air quality.

It is evident that as long as the local building codes require only the presence of a given surface area of openable windows to fulfill the indoor air quality requirements in buildings, the situation is far away from protecting human health and buildings integrity.

A tangible evolution of this situation could happen only when the adoption of specific designed ventilation in buildings would be compulsory. A first step into this direction has been taken by national decree D.M. 23/06/2022 [2] only for public buildings.

In the following paragraphs, starting from 1967, reference documents for designers concerning environmental health are presented. The aims of the work are:

- to provide a historical overview of the regulatory and technical evolution;
- to clarify current design criteria for ventilation used in Italy within the European context;
- to offer recommendations for future developments, with focus on schools and residential buildings.

## **2. Italian regulatory framework**

In the following text the state of the art of the reference documents concerning indoor air quality in Italy is presented starting from 1967. A distinction between mandatory and optional documents is necessary. This is very important because it clearly shows why, presently, mechanical ventilation is not so diffused in Italy, despite the existing of pertaining standards (national since 1995 and European since 2007). Therefore, in many buildings the indoor air quality is quite poor.

In fact, in Italy, in each municipality (more than 8000), the main reference for the design of a building is the municipal regulation (depending on the zones it can be REC, Regolamento Edilizio Comunale or RUE, Regolamento Urbanistico Edilizio). Each individual regulation addresses the designers because it contains the rules to follow and the standards to apply.

It was not possible to analyze all the 8000 building regulations but, concerning residential buildings and schools, for example, it still can be read in many of them that in order to fulfill indoor health requirements, openable windows must be present. Their area must be calculated according to the room's floor surface. Mechanical exhausts must be provided in toilets without windows.

More details concerning air renewal can be found in the documents used for energy calculation, as described in the next paragraphs, and in the standards which are of a voluntary nature. They become compulsory only if a law or regulation explicitly mentions them and requires compliance with their provisions.

### **2.1. Regulatory framework before 2002**

From a legislative point of view, the issue of ventilation as an element of indoor environmental quality has quite distant roots.

The Circolare 22/05/1967 n. 3151 [3] in the section on subsidised civil construction, establishes that every dwelling must be equipped with a forced ventilation system capable of

ensuring an air renewal rate equal to 1 ach. A brief description indicates that this system must be of the extraction type from bathrooms and kitchens. It can be said that this provision has been practically ignored since then until very recently, when some spread of mechanical ventilation began to take hold even in low-cost construction.

The D.M. 18/12/1975 [4], a comprehensive document relating to school buildings, prescribes specific air change values for different categories of schools: 2.5 ach for nursery and primary schools, 3.5 ach for middle schools and 5 ach for upper secondary schools. The exact term used in the decree is “introduction of external air flow”, without specifying whether this is to be achieved by mechanical or natural (but specifically designed) means or by simple airing, i.e. opening the windows. In most cases, the latter has been the interpretation, and in very few cases, in the past, mechanical ventilation systems have been adopted. Here too, the situation has recently evolved. This Decree is still formally in force but has been supplemented and integrated by more recent and specific regulations, such as those on safety [5], which update its application, especially for new buildings, but its principles remain a fundamental reference point, especially for existing schools.

The Italian reference Decree including the main requirements for hygiene and health in residential buildings is D.M. 5/7/1975 [6], still in force and constituting the main reference for minimum health and hygiene requirements for housing in Italy, establishing essential parameters such as heights, surface areas, ventilation and other systems, even if the legislation is supplemented and sometimes mitigated for existing buildings by subsequent legislative measures. According to article 5: “For each living space, the window size must be proportionate to ensure an average daylight factor of no less than 2%, and in any case, the opening window area must not be less than 1/8 of the floor area.”

The approach to express hygiene and health according to a window surface was therefore introduced for all Italian building regulations not only for residential premises, but also for other kinds of building, and it is generally still in force.

Some other important approaches came out from that Decree:

- the use of mechanical centralized ventilation when windows’ surfaces are below the minimum required;
- the use of mechanical exhaust ventilation in bathrooms fitted with non-openable windows;
- the use of mechanical exhaust (cooking hood) above gas stoves if kitchen and living room are in the same room.

All these rules have been used for years and are still copied also in the most recent building regulations. That’s why, for many designers, “natural ventilation” is equivalent to “openable windows”, to ensure indoor hygiene and health.

Concerning energy calculations, the first Italian law on energy saving in buildings is Law 373/1976 [7]. In order to size the heating system, it prescribed to take into account energy losses due to ventilation on the basis of 0.3 ach, but without imposing the implementation of such air renewal.

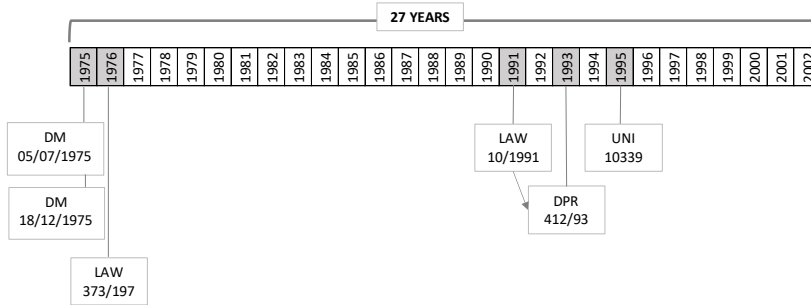
The subsequent law was enacted in 1991. Law 10/1991 [8]: its implementing regulation is Decree DPR 412/1993 [9] which considered a new conventional value equal to 0.5 ach, again without imposing the implementation of such air renewal.

In this context, the first Italian standard on ventilation of buildings is UNI 10339 [10]. It was published in 1995 and has been withdrawn in 2024. The text was short but very effective in addressing designers in:

- calculating the design air flow rate of a mechanical ventilation system for both residential and non residential buildings;
- choosing the air filters according to their classifications;
- taking into account future maintenance actions;
- preparing the technical documentation for a tender.

UNI 10339, being a standard, was not compulsory by itself, but it was mentioned e.g. in the Allegato (Technical Annex) of D.M. 256/2022 on minimum environmental criteria [2] together with UNI EN 16798-1 [11], already in force since 2019, with clear overlap in scope of application. D.M. 256/2022 has been revised by D.M. 283/2025 [12] on the same topic.

As shown in Figure 1 it can be observed that in 27 years of history, from 1975 to 2002, designers had very few reference documents to follow concerning rules for “hygiene and health”.



**Fig. 1.** Regulatory framework and standards concerning ventilation in buildings and energy calculations in Italy before 2002.

## 2.2. Regulatory framework after 2002

In 2002 the first European Directive on Energy Performance of Buildings, 2002/91/EC [1], so called EPBD, was published. According to the European Parliament and the Council, a plan in the building sector was needed to promote efficient energy use. For this reason, a common methodology to calculate the energy performance of buildings together with the application of minimum requirements for both new and existing constructions was needed. In order to support the EPBD requirements, CEN was commissioned to develop specific standards concerning the “different needs” associated with a standardised use of the building, like heating, hot water heating, cooling, ventilation and lighting. As explained in article 3, Member States have to apply the EPBD methodology at national level. The general framework for the calculation of energy performance of buildings is described in the Annex and includes ventilation, including natural ventilation, of buildings. The standards concerning ventilation of buildings developed by CEN to support EPBD and implemented at Italian level are listed in Table 1 [13].

**Table 1.** List of standards on ventilation of buildings, developed by CEN, supporting EPBD 2002/91/EC.

Standard	Title
UNI EN 13779:2005	Ventilation for non-residential buildings - Performance requirements for ventilation and room-conditioning systems
UNI EN 15239:2008	Ventilation for buildings - Energy performance of buildings - Guidelines for inspection of ventilation systems
UNI EN 15240:2008	Ventilation for buildings - Energy performance of buildings - Guidelines for inspection of air-conditioning systems
UNI EN 15241:2008	Ventilation for buildings - Calculation methods for energy losses due to ventilation and infiltration in commercial buildings

UNI EN 15242:2008	Ventilation for buildings - Calculation methods for the determination of air flow rates in buildings including infiltration
UNI EN 15243:2008	Ventilation for buildings - Calculation of room temperatures and of load and energy for buildings with room conditioning systems
UNI EN 15251:2008	Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics

Concerning energy calculations, Italy has implemented the EPBD and the relevant standards. The Legislative Decree D.Lgs. 192/2005 [14] was published in 2005 and it addressed to use the Technical Specifications UNI TS 11300 [15] series which are based on the standards under EPBD mandate, with national deviations (this process is permitted at European level). UNI TS 11300-1 and UNI TS 11300-2 were the first parts published in 2008. Currently UNI TS 11300 series consist of 6 parts that cover the following items:

- Part 1: evaluation of energy need for space heating and cooling;
- Part 2: evaluation of primary energy need and of system efficiencies for space heating, domestic hot water production, ventilation and lighting for non residential buildings;
- Part 3: evaluation of primary energy and system efficiencies for cooling;
- Part 4: renewable energy and other generation systems for space heating and domestic hot water production;
- Part 5: evaluation of energy performance for the classification of buildings;
- Part 6: evaluation of energy need for lifts, escalators and moving walkways.

In order to size the heating system in buildings without mechanical ventilation, UNI TS 11300-1 prescribed to take into account energy losses due to ventilation as follows: for residential buildings on the basis of 0.3 ach and for non residential buildings on the basis of the air flow rates calculated with formula 33 – attributed to UNI 10339 – and corrected by appropriate coefficients reported in a specific annex. Unfortunately, UNI TS 11300-1 mentioned (and still does) formula 33 as belonging to UNI 10339, but in reality it was taken from a revision hypothesis of UNI 10339, which was never published. This situation created many misunderstandings among designers because the binomial approach of formula 33, which consists in adding an air flow rate per person to an air flow rate per surface, never appeared in UNI 10339:1995. In 2026 the misunderstandings prosecute because UNI 10339, as explained in the previous paragraph, has been withdrawn in 2024 with “no replacement”. Considering that UNI TS 11300 series are used only for energy calculations of buildings, and not for design, it is reasonable to say that UNI 10339 can still be used to calculate reference air flow rates for the energy losses due to “airing”. In case of mechanical ventilation, instead, design flow rates calculated with UNI EN 16798-1 (new numbering given to the revision of EN 15251) can be used for energy calculations.

As the years go by, EPBD has been updated by 2010/31/CE [16], 2018/844/CE [17] and 2024/1275/CE [18]. Consequently all EPBD standards have been revised. The status of the set of standards introduced in Table 1 has been modified as shown in Table 2. Some standards, in their revision, changed number. It can be observed that all standards concerning ventilation of buildings belong, now, to a set with the same number: UNI EN 16798, divided into several parts. In this set, all odd parts are standards and all even parts are accompanying Technical Reports CEN/TR 16798-2:2019 [19].

**Table 2.** List of standards on ventilation of buildings, developed by CEN, supporting EPBD in 2025.

<b>First Standard (title in Table 1)</b>	<b>Correspondent revised standard in 2025</b>	<b>Title</b>
UNI EN 13779:2005	UNI EN 16798-3:2025	Energy performance of buildings - Ventilation for buildings - Part 3: For non-residential buildings - Performance requirements for ventilation and room-conditioning systems (Modules M5-1, M5-4)
UNI EN 15239:2008	UNI EN 16798-17:2018	Energy performance of buildings - Ventilation for buildings - Part 17: Guidelines for inspection of ventilation and air conditioning systems (Module M4-11, M5-11, M6-11, M7-11)
UNI EN 15240:2008		
UNI EN 15241:2008	UNI EN 16798—5-1:2018 + NA:2025	Energy performance of buildings - Ventilation for buildings - Part 5-1: Calculation methods for energy requirements of ventilation and air conditioning systems (Modules M5-6, M5-8, M6-5, M6-8, M7-5, M7-8) - Method 1: Distribution and generation
	UNI EN 16798—5-2:2018	Energy performance of buildings - Ventilation for buildings - Part 5-2: Calculation methods for energy requirements of ventilation and air conditioning systems (Modules M5-6, M5-8, M6-5, M6-8, M7-5, M7-8) - Method 2: Distribution and generation
UNI EN 15242:2008	UNI EN 16798-7:2018	Energy performance of buildings - Ventilation for buildings - Part 7: Calculation methods for the determination of air flow rates in buildings including infiltration (Modules M5-5)
UNI EN 15243:2008	UNI EN 16798-9:2018	Energy performance of buildings - Ventilation for buildings - Part 9: Calculation methods for energy requirements of cooling systems (Modules M4-1, M4-4, M4-9) – General
	UNI EN 16798-13:2018	Energy performance of buildings - Ventilation for buildings - Part 13: Calculation of cooling systems (Module M4-8) - Generation
UNI EN 15251:2008	UNI EN 16798-1:2019	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 M1-6

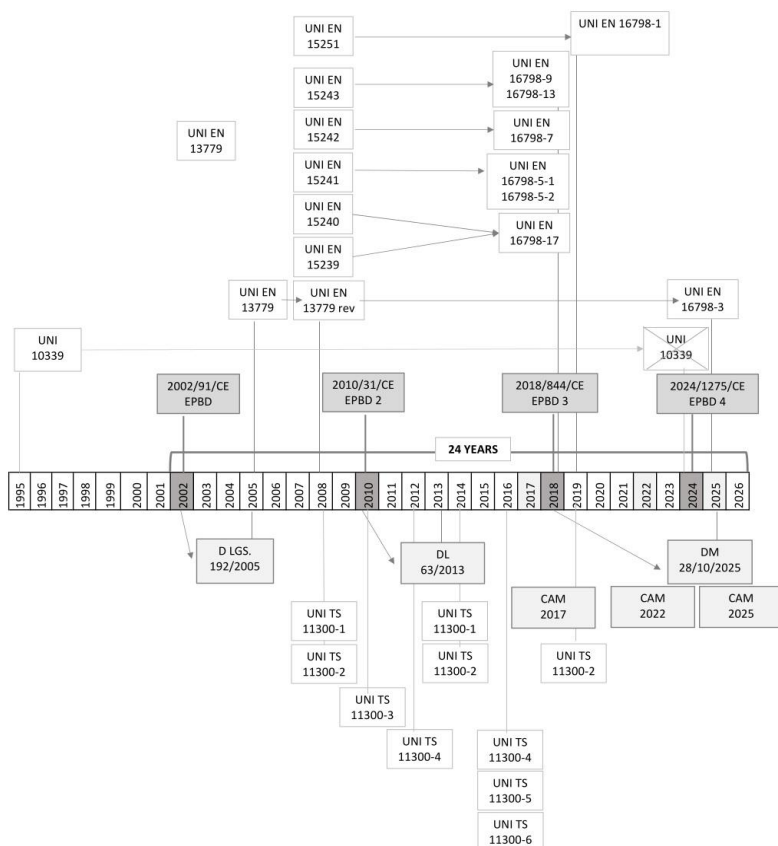
In 2017 the important DM 11/10/2017 [20], limited to sustainable public procurement was published. This was the first version of CAM (Criteri Ambientali Minimi: Minimum Environmental Requirements) whose goal was to promote sustainability in public sector procurements. Concerning indoor environmental quality, paragraph 2.3.5.2 was dedicated to “natural airing and mechanical controlled ventilation” and the general approach was to prescribe opening windows with a surface calculated proportionally to the floor area in line with D.M. 05/07/1975. For residential buildings it was written that “the air changes per hour shall be calculated according to UNI 10339 and UNI 13779”. It should be noted that the standard UNI EN 13779:2008 was in force, at that time, did not contain any reference to air

flow rates, as this information was present only in the 2005 edition. The text referred in a corrected way to the UNI EN 13779:2008 in a subsequent paragraph dedicated to non residential buildings, but again to calculate air flow rates: this item, as said, was not present in the 2008 standard. Only for the design of mechanical ventilation in non residential buildings “UNI 15251:2008, category II and low polluting building from Annex B.1” was mentioned (the correct reference at the time should have been: UNI EN 15251:2008 [21]).

In 2022 a new version of CAM was published in DM 23/06/2022 n.256. The approach concerning the indoor air quality, in the new paragraph 2.4.5 “Airing, ventilation and air quality”, changed completely due to the obligation to design and install mechanical ventilation systems according to the “existing standards” UNI 10339 or UNI EN 16798-1.

In 2025 the last version of CAM was published in DM 24/11/2025. The paragraph 2.3.6 “Airing, ventilation and air quality” confirms the obligation to design and install mechanical ventilation, as in the 2022 version, but according only to UNI EN 16798-1, due to the withdrawn of UNI 10339 in 2024.

As shown in Figure 2 it can be observed that in 24 years of history, from 2002 to 2026, designers had a lot of new reference documents to follow concerning rules for “hygiene and health”.



**Fig. 2.** Regulatory framework and standards concerning ventilation in buildings and energy calculations in Italy after 2002.

Paragraph 3 gives a brief description of the standards above mentioned.

### 2.3. Consequences of the regulatory framework

In the previous paragraphs it was explained that in the last 24 years many standards have been published concerning indoor air quality in buildings. In parallel some other descriptive documents were published, like voluntary sustainability protocols described in next paragraph 4. In Italy, moreover, in 2001 the “Linee-guida per la tutela e la promozione della salute negli ambienti confinati” [22] were diffused to promote strategies aimed to reducing pollutants concentration indoor even through mechanical ventilation.

Nevertheless, many residential buildings and schools, nowadays, have a really poor indoor air quality like it is possible to demonstrate.

In some pictures taken at the beginning of 2026 in two different dwellings mould growth on internal walls is shown. Both buildings are not insulated, and the windows are new and airtight. Italian law was complied with during the renovating process involving changes of windows and heating system only.



**Fig. 3.** Mold growth in a dwelling inside a multifamily building (on the left) and in a single-family house (on the right).

In some other pictures taken at the beginning of 2026 are shown. They refer to a recently renovated single house: all external walls were insulated, all windows were changed and the old heating system (gas boiler and radiators) was replaced by a new heat pump and radiant floor system. Condensations and moulds appear only on the colder surfaces present that are, in this case, windows’ glasses and small walls portion or thermal bridges inadequately insulated. Even in this case the local building regulation was respected because, “in order to ensure a good indoor environment” the openable windows with an adequate surface are present.



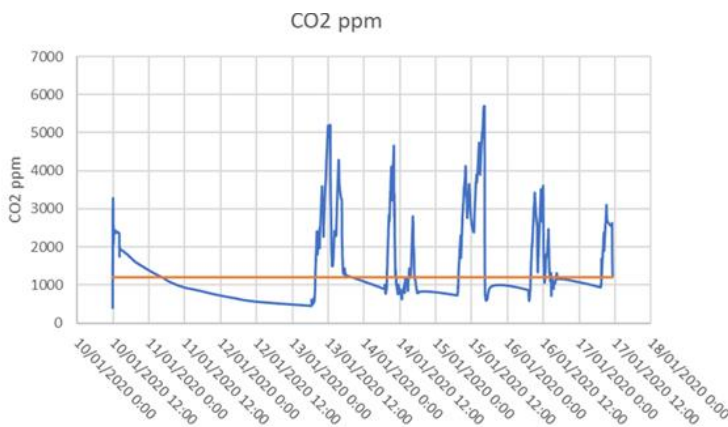
**Fig. 4.** Mold growth in an insulated single-family house renovated in 2025.

It has to be noticed that, at the moment, the regulatory framework described in the previous paragraph and summarized in Figure 2 is known by designers only for the

“compulsory” part. Since most of the standards are of voluntary application, often they are not taken into consideration by the majority of designers.

In other words, the design and installation of mechanical ventilation according to UNI EN 16798-1 series is compulsory in Italy from 2022 in public buildings, according to CAM 2022 [2] and in that kind of buildings problems of poor indoor air quality can be prevented and, eventually, solved. For private buildings problems like the ones shown in the figures above are still expected.

A particularly critical situation concerns school buildings. Although, as already mentioned, the design and installation of mechanical ventilation systems compliant with UNI EN 16798-1 became compulsory in Italy from 2022 for new public buildings and for significant renovations according to CAM 2022, most of the existing school stock was built several decades ago and it is not affected by these obligations. Even recent schools without mechanical ventilation have several air quality issues, including high CO<sub>2</sub> concentrations, as shown in the graph of Figure 5, regarding a building built in 2017.



**Fig. 5.** CO<sub>2</sub> concentration in a school built in 2017 without mechanical ventilation. Results of one week monitoring.

### 3. Evolution of calculation methods and approaches for establishing ventilation flow rates

UNI 10339 was the historic Italian standard for ventilation systems in buildings intended for human comfort. It was developed in a period when the main focus was on thermo-hygrometric comfort, indoor air quality (IAQ) was treated in a simplified way, and energy consumption was not at the centre of the regulatory framework as it is today. In UNI 10339 the amount of outdoor air to supply is calculated using its Table 3 where, according to the intended use and type of room (office, classroom, shop, dwelling, etc.), air flow rates are expressed in litres per second per person. Therefore, the implicit criterion is the perception based on bioeffluents emission. Fixed airflow values per person are assumed (e.g. for dwellings and offices: 11 L/s per person that correspond to 39.6 m<sup>3</sup>/h), with some limited adjustment depending on the type of space. Non-human pollution sources such as emissions from construction materials, furniture, equipment, VOCs and similar contaminants are considered only indirectly, if not completely neglected. The overall setup is strongly prescriptive: the standard provides the table with minimum airflow rates that must be respected, and there is no room for a performance-based design based on explicit air quality levels, categories or detailed usage scenarios. The result is a simple, easy-to-apply approach,

but rather inflexible and not always representative of the real complexity of indoor pollution sources.

Before the implementation of UNI EN 16798-1 in 2019, Europe introduced a set of standards that prepared the paradigm shift from prescriptive rules to performance-based design. EN 13779, focused on ventilation in non-residential buildings, introduced the concept of indoor air quality categories (IDA 1, IDA 2, etc.) and differentiated airflows based on outdoor air quality (ODA 1, ODA 2, etc.) and the desired indoor air quality. This standard started to implement a more performance-oriented view, in which target quality levels are explicitly defined and the ventilation airflow becomes a means to achieve a target of quality, rather than an undifferentiated parameter.

EN 15251:2008 [21], later replaced by EN 16798-1, extended and systematized this approach. It covered input parameters for energy performance calculations and indoor environmental quality in both residential and non-residential buildings. It introduced and formalized comfort and IAQ categories (I, II, III, IV, from very high quality to minimum acceptable), clarified the relationships between ventilation, thermal comfort and energy consumption, and incorporated the idea of different occupancy scenarios and realistic building use profiles.

EN 16798-1 brings to maturity the path started with EN 15251 and places the indoor environment and ventilation firmly within the broader framework of building energy performance. From a conceptual point of view, EN 16798-1 is an overall standard for indoor environmental parameters, covering indoor air quality, thermal comfort, lighting and acoustics. It provides input data and criteria for building energy design, explicitly integrating indoor environmental quality targets with the achievement of energy performance. The standard resumes the concept of quality categories (I, II, III, IV) for thermal comfort and indoor air quality, with corresponding target values, for example, limits on CO<sub>2</sub> concentration above outdoor levels or maximum percentages of dissatisfied occupants.

Furthermore, this standard introduces an important concept, namely the influence of the materials constituent of the internal surfaces of rooms in relation to their ability to emit pollutants. Buildings are therefore classified as non-low polluting (NLP), low polluting (LPB) and very low polluting (VLPB). To this end, materials can be classified on the basis of test standards such as UNI EN 16516 [23] or ISO 16000-9 [24] and the criteria set up in UNI EN 16798-1 with regard to Total VOCs, Formaldehyde, C1A or C1B classified carcinogenic VOC. It is worth mentioning that many manufacturers of paints, furniture, carpets and flooring have recently been subjecting their products to these specific tests. It is therefore useful for designers to take this into account when selecting materials and drawing up technical specifications.

The designer, or the applicable regulation, selects the appropriate category based on the building characteristics and use, the sensitivity or vulnerability of occupants (for example schools, hospitals, offices, dwellings) and the project's energy and economic objectives.

The approach is adaptive and flexible. EN 16798-1 allows the designer to assess and compare different ventilation strategies, including natural, mechanical and hybrid systems, as classified in EN 16798-3 according to Ecodesign Regulations. It explicitly supports the modulation of airflows according to actual occupancy and indoor conditions, for example through CO<sub>2</sub> sensors, presence detection or VOC sensors, and recognises intermittent and demand-controlled ventilation as valid options, provided that the required quality levels are met over time.

On 13 November 2025, UNI published the National Annex (Annex A) to UNI EN 16798-1:2019 [24]. Since 2019, designers have become familiar with the European default values of the environmental parameters (Annex B). The Italian version has a different structure. Table 3 describes the main features of the standards and the National Annex.

**Table 3.** Comparison between UNI 10339, UNI EN 16798-1 and the related Italian National Annex.

	<b>UNI 10339 1995 (withdrawn July 2024)</b>	<b>UNI EN 16798-1 2019</b>	<b>National Annex UNI EN 16798-1 2025</b>
<b>Basic logic</b>	Prescriptive: fixed flows by building use	Performance-based: target air quality or comfort levels	
<b>Pollutants considered</b>	Mainly of human origin	Human sources + building and material-related sources	
<b>Design parameters</b>	Mainly l/s per person (alternative: l/(s·m <sup>2</sup> ) in few cases)	3 methods: – l/s per person + l/(s·m <sup>2</sup> ) – CO <sub>2</sub> concentration – Air change per hour	2 methods: – l/s per person + l/(s·m <sup>2</sup> ) – performance based on substances concentration
<b>IAQ quality categories</b>	Implicit or weakly structured	Categories I–IV with explicit performance targets	Categories I–III with explicit performance targets
<b>Role of energy</b>	Secondary	Integrated with building energy performance	
<b>Flexibility/control</b>	Limited, essentially fixed flows	Variable, suited to controlled/demand-based systems	
<b>Choice for the designer</b>	Limited	Choice of calculation methods, choice of category	Choice of calculation methods, choice of category

Over the years, the design approach has evolved from a prescriptive framework to a performance-based logic. UNI 10339 is based on fixed minimum airflows defined by building use, focusing mainly on pollutants of human origin and giving secondary importance to energy and air quality aspects. UNI EN 16798-1, through the intermediate steps of UNI EN 13779 and UNI EN 15251, instead defines explicit performance categories for indoor air quality and thermal comfort, considers both human and building-related pollution sources, and adopts a dual calculation parameter (l/s per person plus l/(s·m<sup>2</sup>)) that is then summed to determine the total design airflow.

In this evolution, the role of energy performance has become central and integrated with IAQ and comfort requirements. Flexibility and controllability have increased, with ventilation systems designed to be variable and responsive to real use, and natural or hybrid ventilation considered on a par with fully mechanical systems, within a coherent and comparable performance framework.

#### 4. Voluntary sustainability protocols and ventilation

Voluntary sustainability protocols, such as LEED, BREEAM, WELL and various national schemes, now play a central role in promoting indoor air quality (IAQ) and advanced design

of ventilation systems. LEED and BREEAM were originally developed with a predominantly energy and overall environmental focus, but they include specific criteria on IAQ, ventilation and material selection; WELL, on the other hand, is explicitly centred on occupants' health and well-being and dedicates considerable attention to air quality, comfort and continuous monitoring.

All these protocols combine minimum requirements for outdoor air supply and pollutant control with advanced performance levels, encouraging solutions that go beyond simple regulatory compliance. In Italy, alongside international schemes, the voluntary sustainability protocols CasaClima Nature and ITACA play an important role in promoting high indoor environmental quality and ventilation.

CasaClima Nature assesses buildings not only in terms of energy performance, but also environmental impacts, occupants' health and comfort, with specific attention to material eco-compatibility, water use and indoor conditions. Indicators include overall energy efficiency, life-cycle impacts of materials, efficient water use, indoor air quality, low-emitting materials, daylight access, acoustic comfort and protection from radon. In this framework, mechanical ventilation and the use of low emission materials are explicit requirements to ensure healthy indoor air and occupant well-being. The certification process covers design, construction and operation, and may include on-site tests such as blower door testing to verify the actual performance of the envelope and systems.

The ITACA protocol, developed at national level, is based on a matrix of environmental and social indicators grouped into categories such as indoor environmental quality, resources, environmental loads, service quality and site-related aspects. Indoor air quality and ventilation are addressed through parameters such as ventilation rates, filtration, low-emitting materials and monitoring strategies. The ITACA protocol has evolved over time into the reference practice UNI/PdR 13 (first published in 2015) [25], providing a structured framework of criteria and indicators that is now widely used as a benchmark for the assessment of building sustainability in Italy.

In general, it can be said that the main indicators used in voluntary sustainability protocols are:

- ventilation flow rates per person or per unit area;
- filtration efficiency;
- heat recovery efficiency;
- the presence of monitoring systems for CO<sub>2</sub> and pollutants;
- testing and commissioning of ventilation systems;
- maintenance checks over time.

With respect to ventilation, differences between protocols emerge mainly in the level of detail of the requirements, the weight attributed to IAQ in the overall score, and the emphasis on monitoring, perceived comfort and long-term management. At design level, these schemes promote optimised air distribution, zoning according to use, high-efficiency heat recovery units and integration with advanced HVAC systems, renewable energy sources and smart controls. At the operational level, they encourage continuous performance measurement, adaptive control of air changes based on occupancy and structured maintenance plans.

Looking ahead, voluntary protocols act as regulatory laboratories: they anticipate trends, test innovative ventilation and IAQ solutions, and provide a technical reference that is often incorporated, directly or indirectly, into the future evolution of mandatory regulations.

## 5. Conclusions

Improving ventilation in Italian buildings requires a shift toward simpler, more practical and performance-based rules. First, the regulatory framework on ventilation should be

streamlined into a clear, unified reference, reducing the current fragmentation of documents and cross-references so that designers can apply requirements more easily and consistently. Especially local regulations must stop referring to DM 07/07/1975 in relation to indoor air quality. Within this framework, the design of ventilation – especially mechanical, with heat recovery in colder climate – should become mandatory in all new residential and non-residential buildings, as well as in major refurbishments, in line with energy efficiency goals and the need for good indoor air quality in airtight envelopes.

Ventilation rates are now defined quite precisely for different building types and uses – for example schools, offices, healthcare facilities, dwellings and sports buildings – based on scientific evidence for health, comfort and cognitive performance, but further measurements and scientific analysis could help to improve the relevance of the standards to the many cases and situations that may arise.

Ventilation systems should be conceived as versatile and easily adjustable, able to modulate airflow according to actual occupancy, indoor pollutant levels such as VOCs and particulate matter, and outdoor conditions, with the support of smart controls. To ensure that design intentions are truly met in practice, in-situ verification should become a central requirement: periodic monitoring campaigns of airflows and key pollutants, with clear alert thresholds and predefined corrective actions, need to be embedded in regulations. For sensitive buildings such as schools, care homes, hospitals and high-density offices, a minimum level of continuous monitoring, with data accessible to users and stored for assessment and research purposes, would further support transparency and ongoing improvement.

More generally, the focus of regulations should move away from a purely prescriptive approach towards a performance-oriented model based on functional testing, proper balancing of airflow and systematic commissioning of ventilation systems. Financial incentives could support the upgrade of ventilation in the existing building stock, prioritizing compact, easily retrofittable solutions also applicable to light renovation projects. Finally, ventilation requirements should be explicitly coordinated with energy and acoustic criteria to avoid conflicting prescriptions and to encourage balanced design solutions. This evolution should be accompanied by practical national guidelines and case studies that translate standards into concrete examples of design, installation and operation, facilitating the spread of good practices among designers, contractors and facility managers.

## References

1. European Parliament. 2002. Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings. Official Journal of the European Union.
2. Ministero della Transizione Ecologica. 2022. Decreto 23 giugno 2022. Criteri ambientali minimi per l'affidamento del servizio di progettazione di interventi edilizi, per l'affidamento dei lavori per interventi edilizi e per l'affidamento congiunto di progettazione e lavori per interventi edilizi. (22A04307) (GU Serie Generale n.183 del 06-08-2022).
3. Ministero dei Lavori Pubblici. 1967. Circolare 22 luglio 1967 n. 3151 - Criteri di valutazione delle grandezze atte a rappresentare le proprietà termiche, igrometriche, di ventilazione e di illuminazione nelle costruzioni edilizie. Gazzetta Ufficiale della Repubblica Italiana.
4. Ministero della Sanità. 1975. Decreto Ministeriale 5 luglio 1975. Modificazioni alle istruzioni ministeriali 20 giugno 1896, relativamente all'altezza minima ed ai requisiti

- igienico-sanitari principali dei locali di abitazione. Gazzetta Ufficiale della Repubblica Italiana.
5. Ministro della Pubblica Istruzione. Decreto Ministeriale 26 giugno 1992. (in GU 30 ottobre 1992, n. 256). Criteri per la costituzione dei gruppi di lavoro provinciali interistituzionali a nomina del provveditore agli studi, ai sensi dell'art. 15 della legge-quadro 5 febbraio 1992, n. 104 , sull'assistenza, l'integrazione sociale e i diritti delle persone handicappate
  6. Ministero dei Lavori Pubblici. 1975. Decreto Ministeriale 18 dicembre 1975. Norme tecniche aggiornate relative all'edilizia scolastica, ivi compresi gli indici di funzionalità didattica, edilizia ed urbanistica, da osservarsi nella esecuzione di opere di edilizia scolastica. Gazzetta Ufficiale della Repubblica Italiana.
  7. Presidenza della Repubblica Italiana. 1976. LEGGE 30 marzo 1976, n. 373. Norme per il contenimento del consumo energetico per usi termici negli edifici. (GU Serie Generale n.148 del 07-06-1976).
  8. Parlamento Italiano. 1991. Legge 9 gennaio 1991, n. 10. Norme per l'attuazione del Piano energetico nazionale in materia di uso razionale dell'energia, di risparmio energetico e di sviluppo delle fonti rinnovabili di energia. Gazzetta Ufficiale della Repubblica Italiana.
  9. Presidenza della Repubblica Italiana. 1993. Decreto del Presidente della Repubblica 26 agosto 1993, n. 412. Regolamento recante norme per la progettazione, l'installazione, l'esercizio e la manutenzione degli impianti termici degli edifici ai fini del contenimento dei consumi di energia, in attuazione dell'art. 4, comma 4, della legge 9 gennaio 1991, n. 10. Gazzetta Ufficiale della Repubblica Italiana.
  10. UNI. 1995. UNI 10339. Impianti aeraulici ai fini di benessere. Generalità, classificazione e requisiti. Regole per la richiesta d'offerta, l'offerta, l'ordine e la fornitura. UNI 10339 Standard. Milano: Ente Nazionale Italiano di Unificazione.
  11. CEN. 2019. 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 MI-6. Bruxelles: European Committee for Standardization.
  12. Ministero dell'ambiente e della Sicurezza Energetica. 2025. Decreto 28 ottobre 2025 Aggiornamento del decreto 26 giugno 2015, recante «Applicazione delle metodologie di calcolo delle prestazioni energetiche e definizione delle prescrizioni e dei requisiti minimi degli edifici». (25A06487) (GU Serie Generale n.283 del 05-12-2025).
  13. Raisa V., Schiavon S., Zecchin R. 2010. Teoria e tecnica della ventilazione. Soluzioni per l'edilizia residenziale e per il piccolo terziario. Editore Delfino.
  14. Presidenza della Repubblica Italiana. 2005. Decreto Legislativo 19 agosto 2005, n. 192. Attuazione della direttiva (UE) 2018/844, che modifica la direttiva 2010/31/UE sulla prestazione energetica nell'edilizia e la direttiva 2012/27/UE sull'efficienza energetica, della direttiva 2010/31/UE, sulla prestazione energetica nell'edilizia, e della direttiva 2002/91/CE relativa al rendimento energetico nell'edilizia. Gazzetta Ufficiale della Repubblica Italiana.
  15. UNI. 2010–2023. UNI/TS 11300-3/4/5/6. Prestazioni energetiche degli edifici – Serie UNI/TS 11300, Parti 3–6. Ente Nazionale Italiano di Unificazione.
  16. European Parliament. 2010. Directive 2010/31/CE of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings. Official Journal of the European Union.

17. European Parliament. 2018. Directive 2018/844/CE of the European Parliament and of the Council of 9 July 2018 on the energy performance of buildings. Official Journal of the European Union.
18. European Parliament. 2024. Directive 2024/1275/CE of the European Parliament and of the Council of 28 May 2024 on the energy performance of buildings. Official Journal of the European Union.
19. CEN, 2019. CEN/TR 16798-2. Energy performance of buildings - Ventilation for buildings - Part 2: Interpretation of the requirements in EN 16798-1 - Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics. Module M1-6. Bruxelles: European Committee for Standardization
20. Ministero dell'ambiente e della Tutela del Territorio e del Mare. 2017. 11 ottobre 2017 Criteri ambientali minimi per l'affidamento di servizi di progettazione e lavori per la nuova costruzione, ristrutturazione e manutenzione di edifici pubblici. (17A07439) (GU Serie Generale n.259 del 06-11-2017).
21. CEN. 2008. EN 15251. Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics. Bruxelles: European Committee for Standardization.
22. Ministero della Salute, 2001. Linee-guida per la tutela e la promozione della salute negli ambienti confinati (Guidelines for the protection of health and safety in indoor spaces).
23. CEN. 2017. EN 16516:2017 Construction products: Assessment of release of dangerous substances - Determination of emissions into indoor air. Bruxelles: European Committee for Standardization.
24. ISO. 2004. ISO 16000-9. Indoor air – Part 9: Determination of the emission of volatile organic compounds from building products and furnishing – Emission test chamber method. Geneva: International Organization for Standardization.
25. UNI. 2025. UNI EN 16798-1:2019/NA:2025. Criteri per l'ambiente interno – Scelte italiane.
26. UNI. 2025. UNI/PdR 13-0:2025. Sostenibilità ambientale nelle costruzioni – Strumenti operativi per la valutazione della sostenibilità – Inquadramento generale e principi metodologici.