Possible guidelines to support the implementation of EPBD Indoor Environmental Quality provisions

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New IEQ provisions in EPBD

EPBD has a **new definition for IEQ** according to which a minimum scope of IEQ addresses thermal comfort and ventilation/indoor air quality domains (Article 2, 66):
"'Indoor environmental quality' means the result of an assessment of the conditions inside a building that influence the health and wellbeing of its occupants, based upon parameters such as those relating to the temperature, humidity, ventilation rate and presence of contaminants."

EPBD introduced a new principle of **optimal indoor environmental quality**. When setting minimum energy performance requirements, Article 5 states that "those requirements shall take account of optimal indoor environmental quality, in order to avoid possible negative effects such as inadequate ventilation…". Revised Articles 7 and 8 for new and existing buildings stress IEQ for both new buildings and major renovations by stating that the issues of optimal indoor environmental quality shall be addressed.

Article 13 calls to establish national IEQ requirements: "Member States shall set requirements for the implementation of **adequate indoor environmental quality standards** in buildings in order **to maintain a healthy indoor climate**." These requirements may be referred to when recommendations to improve IEQ are provided in EPC-s which is a new provision in Article 19 (5).

Article 13 also requires equipping new non-residential ZEBs with IAQ monitoring and regulation capability: "Member States shall require non-residential zero-emission buildings to be equipped with **measuring and control devices for the monitoring and regulation of indoor air quality**."
To fulfil this requirement, demand-controlled ventilation systems (in principle mechanical, hybrid or natural) which have both control and monitoring functions, can be used, which would be needed from 2028 in public and from 2030 in all new non-residential buildings. Demand-controlled operation of ventilation systems is currently not addressed in standards but is considered in the ongoing EN 16798-1:2019 revision, and therefore needs specific attention in national regulation/guidelines.

Summary of possible IEQ parameters and requirements

Indoor environmental quality generally covers four domains, namely indoor air quality (IAQ), thermal comfort, lighting, and acoustic. For the two first domains, EPBD explicitly requires setting minimum requirements in the national regulation or building code for new buildings and major renovations. It can be practical to set these requirements according to measurable indicators based on those of the LEVEL(s) framework. Level(s) is the European framework for sustainable buildings[1], providing IEQ indicators in User Manual 3, under Macro-Objective 4: Healthy and comfortable spaces, where indicators 4.1 to 4.4 can be found for IAQ, thermal comfort, lighting and acoustics. Regarding to numeric values, LEVEL(s) indicators 4.1[2] and 4.2[3] (IAQ and thermal comfort) refer to EN 16798-1:2019 standard which uses Categories I to IV to describe IEQ level. As EPBD refers to 'healthy indoor climate' and 'optimal indoor environmental quality', it can be recommended to use the normal level of Category II specified in EN 16798-1:2019 which values will not only ensure avoiding adverse health effects but also ensure comfort and well-being of occupants.

When setting minimum requirements (design), conducting commissioning (handing over) and continuous monitoring in operation or inspection (regular check), relevant IEQ parameters are different as illustrated in Table 1.
Table 1. An example of the most important IEQ parameters. Minimum requirements specify design targets which compliance can be assessed with commissioning procedures. IEQ and energy performance can be assessed with continuous monitoring and inspection.

[1] https://environment.ec.europa.eu/topics/circular-economy/levels_en

[2] Dodd N., Donatello S. & Cordella.M., 2021. Level(s) indicator 4.1: Indoor air quality user manual: introductory briefing, instructions and guidance (Publication version 1.1)

[3] Dodd N., Donatello S., & Cordella M., 2021. Level(s) indicator 4.2: Time outside of thermal comfort range user manual: introductory briefing, instructions and guidance (Publication version 1.1)

		Design	Commissioning	Monitoring[1)]	Inspection	Comment
Thermal	Operative temperature	x				At representative points in the occupied zone to ensure occupant comfort
	Air velocity	x				At representative points in the occupied zone to ensure the design and control of the HVAC system for occupant comfort
	Air temperature			x		At 1.1 m above the floor in occupied zones
	Relative humidity	x		x		At 1.1 m above the floor in occupied zones
Acoustical	Sound pressure (A- and C-weighted)	x	x			Equivalent continuous sound pressure level (A- and C-weighted) at representative points in the occupied zone
	Sound reverberation time	x	x			Evaluation of noise at the design stage is found in EN 12354-5. Sound insulation parameters are not included in this document
Indoor air quality	Carbon dioxide	x		x		At 1.1 m above the floor in occupied zones, the extracted air
	PM2.5	x[2)]		x[3)]		At 1.1 m above the floor in occupied zones
	Formaldehyde				x	Near potential sources such as furniture and flooring
	Nitrogen dioxide				x	Near potential sources like kitchens and garages
	Carbon monoxide				x	Alarm sensors in buildings with combustion sources
	Radon	x			x	In the lowest occupied level of the building
	Ventilation rate	x	x		x	Outdoor airflow rate supplied and extracted from rooms, typically measured from supply and extract terminals
Light	Daylight provision	x				Daylight can be evaluated in accordance with EN 17037
	Glare probability	x				At workstations and near windows (EN 17037)
	Illuminance	x	x			The quality of lighting can be evaluated in accordance with EN 12464-1

[1)] *In addition to indoor values, monitoring of outdoor values for air temperature, humidity, CO_2 and PM2.5 is needed. The importance for IAQ is the difference between indoor-outdoor CO_2 and PM2.5.*

[2)] *For non-residential buildings filters are specified in EN 16798-3.*

[3)] *PM2.5 continuous monitoring is not needed if particulate matter is controlled with filters in the ventilation system, and there is no significant infiltration through the building envelope.*

Indoor air quality (IAQ)

Indoor air pollution originates from both indoor and outdoor sources, and the interaction of pollutants and oxidants from both of these[4]. Indoor sources are building materials or cleaning products emitting volatile organic compounds[5], respiratory effluents and body odours emitted by humans themselves, but also combustion, cooking, products with fragrances and resuspending floor dust[6]. It has been shown that the most harmful contaminants in dwellings are PM2.5, PM10, NO_2, formaldehyde, radon, and ozone[7]. Good IAQ requires controlling indoor emission sources and concurrently reducing the entry of outdoor pollutants indoors which can be done by filtering outdoor air pollutants and reducing infiltration. The remaining pollutants indoors must be ventilated out. Multiple origin of indoor air

[4] Weschler, C. Chemistry in indoor environments: 20 years of research. Indoor Air 2011;21:205-218

[5] Harrison, P.; Crump, D.; Kephalopoulos, S.; Yu, C.; Däumling, C.; Rousselle, C. Harmonised regulation and labelling of product emissions–a new initiative by the european commission. Indoor and Built Environment 2011;20:581-583

[6] Qian, J.; Peccia, J.; Ferro, A.R. Walking-induced particle resuspension in indoor environments. Atmospheric Environment 2014;89:464-481

[7] Morantes, Giobertti and Jones, Benjamin and Molina, Constanza and Sherman, Max Howard, Harm from Indoor Air Contaminants. Available at SSRN: https://ssrn.com/abstract=4409736 or http://dx.doi.org/10.2139/ssrn.4409736

pollutants makes IAQ monitoring complicated. Monitoring for all six pollutants included in WHO AQG[8] has shown to be infeasible because of the cost and complexity of compliance monitors to be deployed to all indoor spaces[9]. In addition to pollutants in WHO AQG many other harmful pollutants are common in the indoor air. Low-cost sensors for routine IAQ monitoring are available for CO_2, RH, particulate matter PM2.5, and CO that originate from combustion.

Direct measurement of all indoor air pollutants is impossible in practice because it generally requires sampling and subsequent chemical analysis. However, CO_2 concentration can be continuously monitored as a proxy for ventilation which is an important factor for good IAQ. With PM2.5 monitoring it can be ensured that outdoor air for ventilation is clean or adequately filtered and indoor sources such as cooking are properly extracted. In the design of buildings, control of pollutant sources and ventilation requirements must be applied for good IAQ. To control particulate matter from outdoor sources, air filtration requirements are also needed. The following minimum requirements can be recommended to be established to control IAQ:

1. Source control must be applied for pollution sources from building materials and interior design through the use of low-polluting building materials as defined in EN 16798-1:2019, which means that the values for very low-polluting materials can be used only in the case of labelled/certified materials;
2. Ventilation rates to maintain an acceptable level of pollutants in the indoor environment are to be specified according to EN 16798-1:2019 requirements;
3. To control particulate matter, ventilation with filters is one way of meeting the requirements in areas where the WHO limits for outdoor air are exceeded. To be effective, the building envelope needs to be airtight. For non-residential buildings filters are specified in EN 16798-3. If no ventilation with filters is used, other measures need to be considered to control PM2.5.

As EPBD requires in Article 13 the installation of measuring and control devices for the monitoring and regulation of indoor air quality, where technically and economically feasible, this requirement shall be included in national regulation. Through this requirement, it is ensured that minimum requirements of ventilation rates can be set and treated as nominal (design) ventilation rates. In the operation, ventilation rates should be controlled according to occupancy to maintain CO_2 and temperature setpoints.

IAQ monitoring means continuous measuring of parameters in spaces designed for human occupancy, such as classrooms, offices, meeting rooms, restaurants, kitchens, shops, gyms, etc., at the relevant unit level. It can be implemented with the capacity of integrated controls of ventilation devices, which include sensors in rooms or through, in particular in the case of complex buildings, centralised BACS. The parameters to be monitored are CO_2, temperature, relative humidity, and if filters are not used in ventilation, also PM2.5.

In residential buildings, monitoring and regulation of all IAQ parameters is not economically feasible. If the requirement is extended to cover residential buildings (EPBD does not require the monitoring and regulation of IAQ in residential buildings) it would be meaningful to monitor CO_2 in living rooms and bedrooms, and relative humidity in wet rooms such as toilets and bathrooms.

Indoor air quality and ventilation in non-residential buildings

To set ventilation airflow rate requirements as outdoor air flow rates, the first method (6.3.2.2 Method 1) in EN 16798-1:2019 based on perceived air quality can be used. This method is applicable in indoor spaces where the criteria for indoor environments are set by human occupancy and where the production or process does not have a significant impact on the indoor environment.

As an alternative to ventilation airflow rates, IAQ and ventilation requirements can be set with CO_2 values. Threshold CO_2 concentrations can be calculated from ventilation airflow rate requirements at typical occupancy.

[8] WHO Global Air Quality Guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. World Health Organization. Geneva, Europe; 2021c

[9] Salthammer, T. TVOC-revisited. Environment International 2022:107440

To make it possible to assess compliance with IAQ requirements, acceptable deviation from airflow rates or CO_2 requirements shall be specified for instance as a percentage of occupancy hours out of the accepted range.

Indoor air quality and ventilation in residential buildings

Ventilation requirements for residential buildings may be set by following B.3.2.2 in EN 16798-1:2019 which specifies how much total ventilation of a whole residence and how many litres per person of outdoor air is needed, and also to cover the requirement of kitchen cooker hood extract demand. It is useful to specify in addition to these general requirements a room-based supply and extract airflow requirements as recommended in the REHVA Guidebook[10].

The ventilation supply airflows to the bedrooms and living rooms should be expressed as outdoor airflow rates which shall be supplied primarily to living rooms and bedrooms. The ventilation air for the kitchen, bathroom and toilet has to transfer air from the bedrooms and living rooms. Doors or specific openings must allow transfer air flows without significant pressure loss. From wet rooms extract airflows shall be used to remove pollutants and humidity.

Demand-controlled ventilation systems regulating the airflow to maintain acceptable CO_2 and humidity levels can be recommended. It is possible to locate CO_2 and relative humidity sensors in the rooms or, alternatively, inside the ventilation unit or extract ductwork. The latter option enables to detection of occupancy and for instance operate a ventilation unit in 'at home'/'out of the home' mode.

Thermal comfort

Indoor environmental parameters for thermal comfort are specified in EN 16798-1:2019 standard. These include parameters for general thermal comfort and local thermal discomfort (draught, radiant temperature asymmetry, floor temperatures, vertical air temperature differences). The minimum requirements in the regulation shall include at least acceptable room temperature[11] ranges for winter and summer. Requirements may be split between non-residential and residential buildings where higher adaptation is possible.

Summer thermal comfort requirements may be specified as overheating prevention requirements. For compliance assessment, it is important to specify during how many per cent of the occupancy time the temperature can be out of the required range (excess hours) and which climatic data and internal heat gains this is evaluated with.

Humidity

For relative humidity (RH) in buildings with no other humidity requirements than human occupancy (e.g., offices, schools and residential buildings), EN 16798-1:2019 states that humidification or dehumidification of room air is usually not required. Examples of recommended design criteria for the humidity in occupied spaces are given if the humidification and dehumidification systems are installed. This illustrates the complexity of regulating RH values because the humidity criteria depend on many factors: health, thermal comfort, indoor air quality, condensation, mould growth etc. Poor ventilation and excess humidity can create ideal conditions for microbial growth, especially in kitchens and bathrooms as well as on surfaces cooled by thermal bridges. Microbial growth, in turn, can provoke respiratory or allergenic health issues, while very low RH (< 20%) can irritate the eyes, nose and throat[12]. It is also recommended to avoid RH below 20% because the respiratory tract and mucous membranes are then more sensitive to infections[13].

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[10] REHVA Guidebook No 25, Residential Heat Recovery Ventilation. www.rehva.eu

[11] In EN 16798-1:2019 room temperature is specified as operative temperature that is calculated based on air temperature, mean radiant temperature and air velocity. In new and deeply renovated buildings, the operative temperature is almost equal to the air temperature.

[12] Dodd N., Donatello S. & Cordella.M., 2021. Level(s) indicator 4.1: Indoor air quality user manual: introductory briefing, instructions and guidance (Publication version 1.1)

[13] Kurnitski J, Wargocki P, Aganovic A. Relative humidity effects on viruses and human responses. REHVA Journal, December 2021 https://www.rehva.eu/rehva-journal/chapter/relative-humidity-effects-on-viruses-and-human-responses

Thus, there are two possible options to deal with RH requirements, either not to set at all or to set a lower limit following LEVEL(s) or EN 16798-1 values. The upper limit can be relevant in summer in southern humid climates where a requirement can be set following EN 16798-1 values. If requirements leading to humidification will be used it should be noted that the humidifier itself can be a source of pollution (microbial and chemical) if not properly maintained. If the lower limit requirements of RH are set, they should be specified by the use of the building/building type.