Indoor environment for energy performance of buildings – a new European draft standard

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ABSTRACT

European Directive for Energy Performance of Buildings was approved in the beginning of 2003. The transition period is 3-6 years depending of the article. European Standardisation Organisation (CEN) has drafted several standards to help the member countries implementing the directive. One of these is the "Criteria for the indoor environment including thermal, indoor air quality (ventilation) light and noise". The standard specifies design values of indoor environment, values to be used in energy calculations, and methods how to verify the specified indoor environment in the buildings. The paper describes some of the principles used in standards, and gives examples presented in the standard. The standard covers all building types but the paper is focuses on the non-residential buildings, numeric examples are given only for offices. The draft standard is under international review process during writing this paper, and subject to changes.

1. INTRODUCTION

European Parliament and Council approved in December 2002 a directive on the energy performance of buildings (EPDB). The directive requires member countries to (1) develop a comprehensive methodology for calculation of integrated energy performance of buildings and HVAC systems including heating, cooling, ventilation and lighting (2) set minimum requirement of energy performance of new buildings (3) apply requirements in existing buildings (4) develop energy certification system for buildings (5) have boilers and air-conditioning systems inspected regularly.

Energy consumption of buildings depends significantly on the used criteria for the indoor environment which also affects health, productivity and comfort of the occupants. An energy declaration without a declaration related to the indoor environment makes no sense. There is therefore a need to for specifying criteria for the indoor environment for design, energy calculations, performance and operation.

The paper describes how design criteria of indoor environment are set for dimensioning of systems and for energy calculations the draft standard (TC 156 EPBD-WI 31). The paper highlights some of the new principles in the standard such as three categories of indoor environment, difference between target values for dimensioning and energy calculations, principles of defining the ventilation rates, and evaluation of indoor environment.

2. SCOPE OF THE STANDARD

The European Draft Standard specifies the parameters of impact and/or criteria for indoor environment and how they are used to meet the intent in the EPBD. It:

- specifies how to establish indoor environmental input parameters for the building system design and energy performance calculations.
- specifies methods for long term evaluation of the obtained indoor environment as a result of calculations or measurements.
- includes a special section for buildings with-

out mechanical cooling.
- specifies criteria for measurements to be used by inspection or monitoring of the indoor environment in existing buildings.
- is applicable mainly in the non-industrial buildings where the criteria for indoor environment are set by human occupancy and where the production or process does not have a major impact on indoor environment.
- specifies how different categories of indoor environment can be used. But does not does not require the certain criteria to be used. This is up to national or individual project specifications.

The parameters and criteria are based on existing Standards and Guidelines (such as ISO CD16814, EN ISO 7730, EN 13779, CR1752, and existing national standards).

3. DESIGN CRITERIA FOR DIMENSIONING

For design of building and dimensioning of HVAC systems the thermal comfort criteria (minimum room temperature in winter, maximum room temperature in summer) shall be used as input for heating load (EN12831) and cooling load (EPBD WI-16) calculations. This will guarantee that a minimum-maximum room temperature can be obtained at design outdoor conditions and design internal loads. Values are presented for the sizing and dimensioning of the systems and well as for design of buildings without mechanical cooling.

In general nationally specified criteria for design and dimensioning of systems must be used, but the standard gives, in case of no national regulation recommended, design values in informative annexes. The recommended criteria are given for three classes (categories).

Using a higher class with stricter criteria will result in higher calculated design loads and then may result in larger systems and equipment. Design criteria for the indoor environment shall be documented by the designer. An example of thermal design criteria for offices is given in Table 1.

3.1 Buildings without mechanical cooling

For the dimensioning of the heating system the same criteria as for mechanically ventilated, cooled and heated buildings shall be used (Table 1).

Table 1: Recommended design values of the indoor temperature for design of buildings and HVAC systems.

Type of building/space	Category	Operative temperature °C Heating (winter season), ~ 1,0 clo	Operative temperature °C Cooling (summer season), ~ 0,5 clo
Single office	A	21,0	25,5
(cellular office)	B	20,0	26,0
Sedentary ~ 1,2 met	C	19,0	27,0

The criteria for the thermal environment in buildings without mechanical cooling may be specified different from those with mechanical cooling during the warm season due to the different expectations of building occupants and adaptation. The level of adaptation and expectation is strongly related to climatic conditions. As there is no mechanical cooling system to dimension the criteria for the categories of summer temperatures are mainly used for building design to prevent the overheating of the building by using solar shading, thermal capacity of building, design, orientation and opening of windows etc. Based on a mean monthly outside temperature recommended criteria for the indoor temperature are given in Figure 1.

3.2 Indoor air quality and ventilation rates

For design of ventilation systems and calculation of heating and cooling loads the required ventilation rates must be specified in the design documents based on national requirements or using the recommended methods in this standard. In the design and operation the main sources of pollutants should be identified and eliminated or decreased by any feasible means. The remaining pollution is then dealt by local exhausts, and ventilation. Air cleaning devices can also be used to remove the pollutants from the room air to improve the air quality. The ventilation rates for air quality are independent of season.

In the standard the recommended ventilation rates in non-residential buildings are derived taking into account pollutant emission. The calculated design ventilation rate is from two components (a) ventilation for pollution from the occupancy and (b) ventilation for the pollution from the building itself. The ventilation for each category is the sum of these two components as

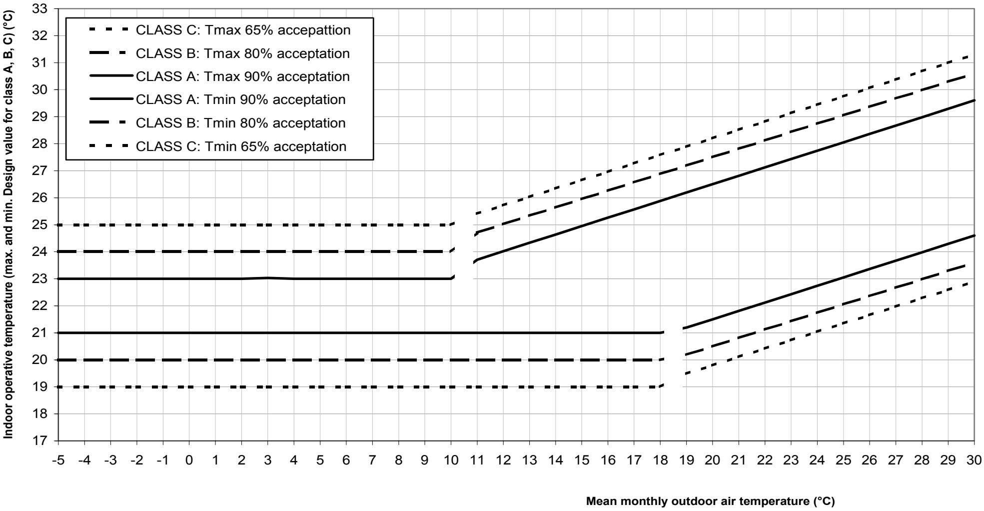

Figure 1: Design values for the indoor operative temperature as a function of mean monthly outdoor air temperature for buildings without mechanical cooling systems.

Table 2: Recommended ventilation rates for non-residential buildings with default occupant density for two categories of pollution from building (from CR 1752) itself. If smoking is allowed the last column gives the additional required ventilation rate.

Type of building or space	Category	Floor area m^2/person	l/s, m^2 for occupancy	q_B l/s,m^2 for low polluted building	q_A l/s,m^2 for non-low polluted building	q_{tot} l/s,m^2 total for low poll building	q_{tot} l/s,m^2 total for non-low poll building	Add when smoking allowed l/s,m^2
Single office	A	10	1,0	1,0	2,0	2,0	3,0	0,7
	B	10	0,7	0,7	1,4	1,4	2,1	0,5
	C	10	0,4	0,4	0,8	0,8	1,2	0,3

illustrated with the equation (1).

The ventilation rates for occupants (q_p) only are: category A: 10 l/s, pers, B: 7 l/s, pers and category C: 4 l/s, pers.

The ventilation rates (q_B) for the building emissions are:

	Low polluting building	Non low-polluting building
Category A:	1,0 l/s, m^2	2,0 l/s, m^2
Category B:	0,7 l/s, m^2	1,4 l/s, m^2
Category C:	0,4 l/s, m^2	0,8 l/s, m^2

Total ventilation rate for a room is calculated from the following formula

$$q_{tot} = n \cdot q_p + A \cdot q_B \quad (1)$$

where:

q_{tot}: total ventilation rate of the room, l/s,
n: design value for the number of the persons in the room,
q_p: ventilation rate for occupancy per person, l/s, pers,
A: room floor area, m^2,
q_B: ventilation rate for emissions from building, l/s,m^2.

Examples of the total ventilation rates for non-industrial, non-residential buildings based on these values are calculated using the equation (1) with default occupancy densities indicated in the Table 2. The ventilation required for smoking is based on the assumption that 20% of occupants are smokers smoking and smoke 1, 2 cigarettes per hour. For higher rate of smoking the ventilation rates should be increased proportionally. Ventilation rates for smoking are based on comfort, not on health criteria.

3.3 Humidity

Humidification or dehumidification of room air is usually not required. If a humidification or dehumidification system is used the design values for dehumidification are given in Table 3.

3.4 Lighting

Lighting levels for design must be established at national level. Recommended values for design luminance levels that should be used when designing lighting system are for office: luminance level at height of 0,8 m **500 lx, uniform glare index URG<19 and colour rendering index R_a>80** (adapted from EN 12464). When it comes to luminance levels a distinction in class A, B and class C levels seemed less appropriate than e.g. for temperature and fresh air supply. However, for the more *qualitative* aspects of lighting also a separation in class A, B and C demands could be made. The standard gives values for daylight factor (at centre of room), luminance uniformity, control and dimming, uniform glare rating (UGR), ease of modification of lighting, light colour (colour temperature) and colour rendering index R_a.

3.5 Noise

The noise from the energy systems of the building may disturb the occupants and prevent the intended use of the space or building. The noise in a space can be evaluated using A-weighted equivalent sound pressure level (Table 4). These criteria apply to the sources from the building as well as the noise level from outdoor sources. The criteria should be used to limit the sound power level from the mechanical equipment and to set sound insulation requirements for the noise from outdoors and adjacent rooms. The values can be exceeded in the case when the occupant can control the operation of the equipment or the windows. For example a room air conditioner may generate a higher sound pressure level if its operation is controlled by the occupant, but even in this case the rise of the sound pressure level over the values in the Table 4 should be limited to between 5 and 10 dB(A).

It is therefore noted that the ventilation should not rely on operable windows if the building is located in an area with too high outdoor noise level considering the level the designer wishes to achieve in the indoor zone.

Table 3: Recommended criteria for the humidity if humidification or dehumidification is required. Spaces where humidity criteria are set by human occupancy. Special spaces (museums, churches etc) may require other limits.

Category	Design relative humidity for dehumidification, %	Design relative humidity for humidification, %
A	50	40
B	60	30
C	70	20

3.6 Draft

Criteria for maximum mean air velocity is given for summer (cooling season) and winter (heating season) as mean air velocity (Table 4).

4. INDOOR ENVIRONMENT PARAMETERS FOR ENERGY CALCULATIONS

Standardised input values for the energy calculations are needed for calculations specified in article 3 and in the annex of directive. To perform a yearly energy calculation (EPBD WI-14) criteria for the indoor environment must be specified and documented.

4.1 Thermal environment

As the energy calculations may be performed on seasonal, monthly of hourly basis (dynamic simulation) the indoor environment is specified accordingly

4.1.1Seasonal calculations (degree day method)

For seasonal and monthly calculations the same values of indoor temperature as for design (sizing) the heating and cooling systems should be used (Table 1) for each category of indoor environment to calculate energy consumption for heating and cooling respectively.

Table 4: Criteria to evaluate draft and noise criteria of some spaces and buildings.

Type of building/space	Category	Maximum mean air velocity, m/s Summer (cooling season)	Maximum mean air velocity, m/s Winter (heating season)	Sound press. dB(A)
Single office (cellular office)	A	0,18	0,15	30
	B	0,22	0,18	35
	C	0,25	0,21	40

4.1.2 Hourly calculations (dynamic simulation)

In dynamic simulation the energy consumption is calculated on an hourly basis. Recommended values for the acceptable range of the indoor temperature for heating and cooling are presented in Table 5. The midpoint of the temperature range should be used as a target value but the indoor temperature may fluctuate within the range due to the energy saving features or control algorithm.

If the cooling power is limited (mixed mode buildings) the excess indoor temperatures must be estimated. It may also be considered to allow the indoor temperature to increase above the recommended values in Table 1 by 1/3 of the difference between the actual outdoor temperature and the upper end of the indoor temperature range for cooling (Example: in a category A office building the indoor temperature may be 27,5, when outdoor temperature is 31,5 °C).

4.2 Indoor air quality and ventilation

The ventilation rates during the operation hours of the ventilation rates for energy calculations are usually the same as specified for design load calculations and dimensioning of the ventilation system. To guarantee good indoor air quality in the beginning of the occupancy the ventilation shall start before the occupancy. The operation hours of ventilation shall also be longer than the occupation hours to flush out the pollutants generated during operation of the building. Outdoor air flow corresponding to 2 air volumes of ventilated space should be delivered to the space before occupancy (e.g. if the ventilation rate is 2 ach the ventilation is started one hour before the occupancy). Infiltration can be calculated as a part of the ventilation (leakage assumptions should be described).

Table 5: Temperature ranges for hourly calculation of cooling and heating energy in three categories of indoor environment. Offices and spaces with similar activity (single offices, open plan offices, conference rooms, auditorium, cafeteria, restaurants, class rooms, sedentary activity ~1,2 met.

Category	Temperature range for heating, °C Clothing ~ 1,0 clo	Temperature range for cooling, °C Clothing ~ 0,5 clo
A	21,0 – 23,0	23,5 - 25,5
B	20,0 – 24,0	23,0 - 26,0
C	19,0 – 25,0	22,0 - 27,0

It is recommended also to ventilate buildings during the unoccupied periods, usually with lower ventilation rate than during the occupied period. The minimum ventilation rate shall be defined based on building type and pollution load of the spaces. A minimum value of 0,1 to 0,2 l/s,m^2 is recommended if national requirements are not available.

In systems with variable air flow control and demand controlled ventilation the ventilation rate may vary between maximum for full occupancy or demand and minimum for non occupied space.

4.3 Natural ventilation

Ventilation rates in naturally ventilated buildings are calculated based of building construction, location and weather conditions. During the unoccupied periods minimum is ventilation for the buildings shall be provided. A value between 0,05 and 0,1 l/s,m^2 can be used if national regulations and codes are not available. National codes may allow complementary ventilation by airing to achieve this requirement in mild season if acoustic requirements can be achieved.

5. EVALUATION OF INDOOR ENVIRONMENT

5.1 Methods

As the loads of the building vary spatially and temporally the designed system may not be able to fulfil the design intent in all rooms during all hours. There is a need to evaluate the long-term performance of building in respect of indoor environment. This evaluation is necessary for the display of the climatic factors (indoor environment) in the energy performance certificate (a requirement of directive in articles 6 and 7). The standard also presents indicators for such evaluation and their use. The evaluation of indoor environment of a building is done by evaluating the indoor environment of typical rooms representing different zones in the building. Evaluation can be based on **design, measurements or calculations**. Evaluation includes (1) thermal criteria for winter (2) thermal criteria for summer (3) air quality and ventilation criteria (4) lighting criteria (5) acoustic criteria (6) draft criteria.

5.2 Criteria

The criteria are described for different categories. For example thermal environment of the building meets the criteria of category A when the room temperature in the rooms representing 95% of the occupied space is not more than 3% of occupied hours a year outside the temperature limits of category A building (Table 5)

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REFERENCES

The paper is based on the Draft standard European standard TC 156 EPBD-WI31 which was in the international review process during the writing process of the paper.