Indoor Environmental Criteria for Design and Calculation of Energy Performance of Buildings – EN15251

B. W. Olesen
International Center for Indoor Environment and Energy, Institute of Mechanical Engineer, Technical University of Denmark

ABSTRACT
European Directive for Energy Performance of Buildings (EPBD) 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 standard includes methods for long term evaluation of the indoor environment. The paper describes some of the principles used in standards, and gives examples presented in the standard. A draft standard has been under the international review process and is now being issued for final approval.

INTRODUCTION
The energy consumption of buildings depends significantly on the criteria used for the indoor environment, which also affect health, productivity and comfort of the occupants. An energy declaration without a declaration related to the indoor environment makes no sense. The indoor environment is mentioned several times in the EPBD. First of all energy-saving measures should not sacrifice people's comfort and health. Secondly, besides the energy certificate and actual values for the energy consumption, it is recommended to display in the building the design values for the indoor environment and indicators for the environmental comfort. There is therefore a need to specify criteria for the indoor environment for design, energy calculations, performance evaluation and display of operation conditions.
The paper describes how design criteria of the indoor environment are set for dimensioning of systems and for energy calculations in the standard (prEN15251-2006). The paper highlights some of the new principles in the standard such as several categories of indoor environment, the difference between target values for dimensioning and energy calculations, principles of defining the ventilation rates, and evaluation of the indoor environment. For dimensioning and energy calculations, different approaches are introduced for mechanically cooled buildings and buildings without mechanical cooling. Finally, the paper will discuss some of the issues raised during the public review.

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

- Specifies the indoor environment parameters that have an impact on energy performance of buildings, and 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.
- Identifies parameters to be used by monitoring and displaying the indoor environment in existing buildings.
- Is applicable mainly in non-industrial buildings where criteria for the indoor environment are set by human occupancy and where the production or process does not have a major impact on the indoor environment. The

standard is thus applicable to the following building types: single-family houses, apartment buildings, offices, educational buildings, hospitals, hotels and restaurants, sports facilities, wholesale and retail trade service buildings.

Several of the criteria are given in different categories as shown in table 1.

Table 1: Description of the applicability of the categories used.

Category	Explanation
I	High level of expectation and is recommended for spaces occupied by very sensitive and fragile persons with special requirements like handicapped, sick, very young children and elderly persons
II	Normal level of expectation and should be used for new buildings and renovations
III	An acceptable, moderate level of expectation and may be used for existing buildings
IV	Values outside the criteria for the above categories. This category should only be accepted for a limited part of the year

DESIGN CRITERIA FOR DIMENSIONING

For the design of buildings 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 and cooling load calculations. This will guarantee that a minimum-maximum room temperature can be obtained under design outdoor conditions and design internal loads.

In general national specified criteria for design and dimensioning of systems must be used, but in case of no national regulations, the standard gives recommended design values in informative annexes. The recommended criteria are given for three categories. Using a higher class with stricter criteria will result in higher calculated design loads and may then result in larger systems and equipment... As an example, thermal design criteria for different types of space are given in Table 2 for buildings with mechanical cooling.

Especially the criteria for kindergartens and department stores are under discussion. In these types of building, activity will not be uniform as some people will be sedentary, children will be playing and people walking. Also the clothing may vary between the different groups of occupancy (sales people, customers). Other types of building like hospitals, restaurants, sports facilities, and warehouses will have similar problems regarding variations in activity and clothing between different types of occupant. The temperature ranges are based on a general comfort criteria using the PMV-PPD index of $\pm$ 0,5 for category A ($\pm$ 0,2 for category A and $\pm$ 0,7 for category C).

Buildings without mechanical cooling

The criteria for the thermal environment in buildings without mechanical cooling may be specified differently 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 categories of summer temperatures are mainly used for building design to prevent the overheating of the building by using solar shading, thermal capacity of the building, design, orientation and opening of windows etc. Based on a weekly running average outside air temperature, recommended criteria for the indoor temperature are

given in Figure 1. This diagram has been validated only for office buildings with operable windows under occupant control.

Table 2. Recommended design values of the indoor temperature for the design of buildings and HVAC systems.

Type of building/ space	**Category**	**Operative temperature °C**	
		Heating (winter season), ~ 1,0 clo	**Cooling (summer season), ~ 0,5 clo**
Residential buildings: living spaces (bed rooms, drawing room, kitchen etc) Sedentary ~ 1,2 met	A	21,0	25,5
	B	20,0	26,0
	C	18,0	27,0
Residential buildings: other spaces: storages, halls, etc) Standing-walking ~ 1,6 met	A	18,0	
	B	16,0	
	C	14,0	
Single and Landscaped office Conference room Auditorium Sedentary ~ 1,2 met	A	21,0	25,5
	B	20,0	26,0
	C	19,0	27,0
Cafeteria/Restaurant Sedentary ~ 1,2 met	A	21,0	25,5
	B	20,0	26,0
	C	19,0	27,0
Classroom Sedentary ~ 1,2 met	A	21,0	25,0
	B	20,0	26,0
	C	19,0	27,0
Kindergarten Standing/walking ~ 1,4 met	*A*	*19,0*	*24,5*
	B	*17,5*	*25,5*
	C	*16,5*	*26,0*
Department store Standing-walking ~ 1,6 met	*A*	*17,5*	*24,0*
	B	*16,0*	*25,0*
	C	*15,0*	*26,0*

Indoor air quality and ventilation rates

For the design of ventilation systems and the calculation of heating and cooling loads, the required ventilation rate 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. Local exhausts and ventilation then deal with the remaining pollution. Air cleaning devices can also be used to remove pollutants from the room air in order to improve the air quality. The ventilation rates for air quality are independent of season.

In the standard different methods for calculating the recommended ventilation rate are included. As a minimum it must be ventilated to dilute the bioeffluents from the occupants (people component, q_p). In addition the rate is increased to take into account the emissions from the building and systems (q_B). One method is ad these values as shown in table 3 for the different categories. The people part depends on the density and the building part depends on the type of building. Another method is to choose a value between the people's part and the total.

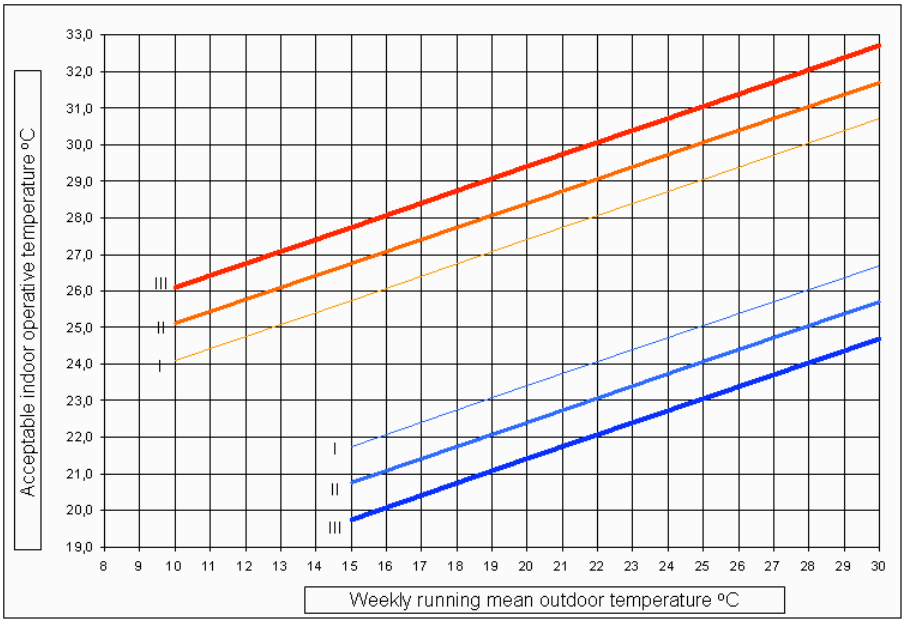

Figure 1. Design values for the indoor operative temperature for buildings without mechanical cooling systems as a function of the exponentially-weighted running mean of the outdoor temperature . Category I ~ 90 % Category II ~ 80 % Category III ~ 65 % satisfaction.

INDOOR ENVIRONMENT PARAMETERS FOR ENERGY CALCULATIONS

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

Thermal environment in mechanically cooled buildings

As the energy calculations may be performed on a seasonal, monthly or hourly basis (dynamic simulation), the indoor environment is specified accordingly.
For seasonal and monthly calculations the same values of indoor temperature as for design (sizing) the heating and cooling systems should be used (Table 2) for each category of indoor environment to calculate energy consumption for heating and cooling respectively.
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 based on a range for the PMV-index. An example is shown in table 4. 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 using one of the methods in the standard

Thermal environment in buildings without mechanical cooling

For heating, the same lower temperature limits apply as for mechanically cooled buildings. As there is no mechanical cooling, there will not be any energy use for

Table 3. Recommended ventilation rates for non-residential buildings with default occupant density for two categories of pollution from the building itself. If smoking is allowed the last column gives the additional required ventilation rate.

Type of building or space	**Ca-te-go-ry**	**Floor area m^2/per-son**	q_p	q_B	q_{tot}	q_B	q_{tot}	q_B	q_{tot}
			l/s, m^2 people	**l/s,m^2 very low-polluted building**		**l/s,m^2 low-polluted building**		**l/s,m^2 non-low polluted building**	
Single office	I	10	1,0	0,5	1,5	1,0	2,0	2,0	3,0
	II	**10**	**0,7**	**0,3**	**1,0**	**0,7**	**1,4**	**1,4**	**2,1**
	III	10	0,4	0,2	0,6	0,4	0,8	0,8	1,2
Landscaped office	I	15	0,7	0,5	1,2	1,0	1,7	2,0	2,7
	II	**15**	**0,5**	**0,3**	**0,8**	**0,7**	**1,2**	**1,4**	**1,9**
	III	15	0,3	0,2	0,5	0,4	0,7	0,8	1,1
Conference room	I	2	5,0	0,5	5,5	1,0	6,0	2,0	7,0
	II	**2**	**3,5**	**0,3**	**3,8**	**0,7**	**4,2**	**1,4**	**4,9**
	III	2	2,0	0,2	2,2	0,4	2,4	0,8	2,8
Auditorium	I	0,75	15	0,5	15,5	1,0	16	2,0	17
	II	**0,75**	**10,5**	**0,3**	**10,8**	**0,7**	**11,2**	**1,4**	**11,9**
	III	0,75	6,0	0,2	0,8	0,4	6,4	0,8	6,8
Restaurant	I	1,5	7,0	0,5	7,5	1,0	8,0	2,0	9,0
	II	**1,5**	**4,9**	**0,3**	**5,2**	**0,7**	**5,6**	**1,4**	**6,3**
	III	1,5	2,8	0,2	3,0	0,4	3,2	0,8	3,6
Classroom	I	2,0	5,0	0,5	5,5	1,0	6,0	2,0	7,0
	II	**2,0**	**3,5**	**0,3**	**3,8**	**0,7**	**4,2**	**1,4**	**4,9**
	III	2,0	2,0	0,2	2,2	0,4	2,4	0,8	2,8

Table 4. Temperature ranges for hourly calculation of cooling and heating energy in three categories of indoor environment.

Type of building or space	Category	Temperature range for heating, °C Clothing ~ 1,0 clo	Temperature range for cooling, °C Clothing ~ 0,5 clo
Offices and spaces with similar activity (single offices, open-plan offices, conference rooms, auditorium, cafeteria, restaurants, classrooms (activity ~1,2 met)	I	21,0 – 23,0	23,5 – 25,5
	II	20,0 – 24,0	23,0 – 26,0
	III	19,0 – 25,0	22,0 – 27,0

cooling and the upper limit in Figure 1 have really no impact. It may, however, be recommended to calculate energy demand as if cooling were installed or calculate how often and how much the recommended temperature range is not fulfilled. The calculated energy demand in summer for a fictive cooling may be added to the

overall energy demand as a penalty, bearing in mind that people may at a later stage want to install mechanical cooling.

Indoor air quality and ventilation

For energy calculations, the ventilation rates during the operation hours of the ventilation system 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 occupancy, the ventilation shall start prior to 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 occupancy). Infiltration can be calculated as a part of the ventilation (leakage assumptions should be described).

It is recommended also to ventilate buildings during unoccupied periods, usually with a 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,m2 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 a non-occupied space. The standard includes recommended CO_2 levels for demand control.

EVALUATION OF INDOOR ENVIRONMENT

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 a building in respect to indoor environment. The standard also presents indicators for such an evaluation and their use. The evaluation of the indoor environment of a building is made by evaluating the indoor environment of typical rooms representing different zones in the building. Evaluation can be based on design, measurements or calculations. As the criteria are based on instantaneous values variations outside the recommended range should be acceptable for short periods during a day. Therefore it is recommended that for 3-5% of the time (working hours) the calculated or measured values can be outside the range. The 3-5% is to be used for daily (meaning 15-25 minutes during a working day), weekly (24-120 working minutes) and yearly (50-100 working hours) periods.

Finally, the standard is discussing methods to give an overall evaluation of the indoor environment, which in the future could be used for an indoor environmental certificate.

ACKNOWLEDGEMENTS

This work was supported by the European Organisation for Standardization (CEN) with a grant from the European Commission, and reviewed by a CEN working group TC 156 WG12, as well as national organisations. Especially I want to thank the task group (Olli Seppanen, Anne-Marie Bernard and Atze Boerstra)

REFERENCES

CEN EN15251, 2006 “Indoor environmental input parameters for design and assessment of energy performance of buildings- addressing indoor air quality, thermal environment, lighting and acoustics”. Document for formal vote.