



BSI Standards Publication

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)

National foreword

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**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)**

Performance énergétique des bâtiments - Ventilation
des bâtiments - Partie 2 : Interprétation des exigences
de l'EN 16798-1 - Données d'entrées d'ambiance
intérieure pour la conception et l'évaluation de la
performance énergétique des bâtiments couvrant la
qualité de l'air intérieur, l'ambiance thermique,
l'éclairage et l'acoustique (Module M1-6)

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Gebäuden - Teil 2: Interpretation der Anforderungen
der EN 16798-1 - Eingangsparameter für das
Innenraumklima zur Auslegung und Bewertung der
Energieeffizienz von Gebäuden bezüglich
Raumluftqualität, Temperatur, Licht und Akustik
(Module M1-6)

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European foreword

This document (CEN/TR 16798-2:2019) has been prepared by Technical Committee CEN/TC 156 “Ventilation for buildings”, the secretariat of which is held by BSI.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

This document is part of the set of standards and accompanying Technical Reports on the energy performance of buildings and has been prepared under the Mandate M 480 given to CEN by the European Commission and the European Free Trade Association, see Bibliographical Reference [35]).

Directive 2010/31/EU recasting the Directive 2002/91/EC on energy performance of buildings (EPBD, [36]) promotes the improvement of the energy performance of buildings within the European Union, taking into account all types of energy uses (heating, lighting, cooling, air conditioning, ventilation) and outdoor climatic and local conditions, as well as indoor climate requirements and cost effectiveness (Article 1).

The directive requires Member States to adopt measures and tools to achieve the prudent and rational use of energy resources. In order to achieve those goals, the EPBD requires increasing energy efficiency and the enhanced use of renewable energies in both new and existing buildings. One tool for this is the application by Member States of minimum requirements on the energy performance of new buildings and for existing buildings that are subject to major renovation, as well as for minimum performance requirements for the building envelope if energy-relevant parts are replaced or retrofitted. Other tools are energy certification of buildings, inspection of boilers and air-conditioning systems.

The use of European standards increases the accessibility, transparency and objectivity of the energy performance assessment in the Member States facilitating the comparison of best practices and supporting the internal market for construction products. The use of EPB-standards for calculating energy performance, as well as for energy performance certification and the inspection of heating systems and boilers, ventilation and air-conditioning systems will reduce costs compared to developing different standards at national level.

The first mandate to CEN to develop a set of CEN EPBD standards (M/343, [34]), to support the first edition of the EPBD ([33]) resulted in the successful publication of all EPBD related CEN standards in 2007-2008.

The Mandate M/480 was issued to review the Mandate M/343 as the recast of the EPBD raised the need to revisit the standards and reformulate and add standards so that they become on the one hand unambiguous and compatible, and on the other hand a clear and explicit overview of the choices, boundary conditions and input data that need to be defined at national or regional level. Such national or regional choices remain necessary, due to differences in climate, culture and building tradition, policy and legal frameworks. Consequently, the set of CEN-EPBD standards published in 2007-2008 had to be improved and expanded on the basis of the recast of the EPBD.

The EPB standards are flexible enough to allow for necessary national and regional differentiation and facilitate Member States implementation and the setting of requirements by the Member States.

Further target groups are users of the voluntary common European Union certification scheme for the energy performance of non-residential buildings (EPBD art.11.9) and any other regional

(e.g. Pan European) parties wanting to motivate their assumptions by classifying the building energy performance for a dedicated building stock.

For the convenience of Standards users CEN/TC 156, together with responsible Working Group Conveners, have prepared a simple table below relating, where appropriate, the relationship between the 'EPBD' and 'recast EPBD' standard numbers prepared by Technical Committee CEN/TC 156 "Ventilation for buildings".

EPBD EN Number	Recast EPBD EN Number	Title
EN 15251	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 M1-6) (revision of EN 15251)
N/A	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)
EN 13779	EN 16798-3	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) (revision of EN 13779)
N/A	CEN/TR 16798-4	Energy performance of buildings – Ventilation for buildings - Part 4: Interpretation of the requirements in EN 16798-3 - For non-residential buildings – Performance requirements for ventilation and room-conditioning systems (Modules M5-1, M5-4)
EN 15241	EN 16798-5-1	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 (revision of EN 15241)

EPBD EN Number	Recast EPBD EN Number	Title
EN 15241	EN 16798-5-2	Energy performance of buildings – Ventilation for buildings - Part 5-2: Calculation methods for energy requirements of ventilation systems (Modules M5-6, M5-8, M6-5, M6-8, M7-5, M7-8) - Method 2: Distribution and generation (revision of EN 15241)
N/A	CEN/TR 16798-6	Energy performance of buildings - Ventilation for buildings – Part 6: Interpretation of the requirements in EN 16798-5-1 and EN 16798-5-2 – Calculation methods for energy requirements of ventilation and air conditioning systems (Modules M5-6, M5-8, M6-5, M6-8, M7-5, M7-8)
EN 15242	EN 16798-7	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) (revision of EN 15242)
N/A	CEN/TR 16798-8	Energy performance of buildings – Ventilation for buildings – Part 8: Interpretation of the requirements in EN 16798-7 – Calculation methods for the determination of air flow rates in buildings including infiltration – (Modules M5-5)
EN 15243	EN 16798-9	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 (revision of EN 15243)
N/A	CEN/TR 16798-10	Energy performance of buildings – Ventilation for buildings – Part 10: Interpretation of the requirements in EN 16798-9 – Calculation methods for energy requirements of cooling systems (Module M4-1, M4-4, M4-9) – General
N/A	EN 16798-13	Energy performance of buildings – Ventilation for buildings - Part 13: - Calculation of cooling systems (Module M4-8) – Generation
N/A	CEN/TR 16798-14	Energy performance of buildings – Ventilation for buildings - Part 14: Interpretation of the requirements in EN 16798-13 – Calculation of cooling systems (Module M4-8) – Generation

EPBD EN Number	Recast EPBD EN Number	Title
N/A	EN 16798-15	Energy performance of buildings – Ventilation for buildings – Part 15: Calculation of cooling systems (Module M4-7) – Storage
N/A	CEN/TR 16798-16	Energy performance of buildings – Ventilation for buildings – Part 16: Interpretation of the requirements in EN 16798-15 – Calculation of cooling systems (Module M4-7) – Storage
EN 15239 and EN 15240	EN 16798-17	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)
N/A	CEN/TR 16798-18	Energy performance of buildings – Ventilation for buildings – Part 18: Interpretation of the requirements in EN 16798-17 – Guidelines for inspection of ventilation and air-conditioning systems (Module M4-11, M5-11, M6-11, M7-11)

Introduction

This document is a guide to EN 16798-1 and can help the user in application of the standard and give additional background information. Besides this document describes and recommends additional topics related to the evaluation of the indoor environmental quality and new possibilities to improve the indoor environmental quality and reduce energy use of buildings like personalized systems, air cleaning technologies, consideration of adapted persons, etc.

This document explains how design criteria can be established and used for dimensioning of systems. It explains how to establish and define the main parameters to be used as input for building energy calculation and long term evaluation of the indoor environment. This document also describes how gas phase air cleaning in the future can improve the indoor air quality and partly substitute for outside air. Finally it will identify parameters to be used for monitoring and displaying of the indoor environment. Different categories of criteria can be used depending on type of building, type of occupants, type of climate and national differences. The report explains how these different categories of indoor environment can be individually selected as national criteria, be used in project agreement for design criteria and for displaying the yearly building performance in relation to indoor environmental quality. The designer can also define other categories using the principles from EN 16798-1 and this document.

1 Scope

This document deals with the indoor environmental parameters for thermal environment, indoor air quality, lighting and acoustic. The document explains how to use EN 16798-1 for specifying indoor environmental input parameters for building system design and energy performance calculations. The document specifies methods for long term evaluation of the indoor environment obtained as a result of calculations or measurements. The document specifies criteria for measurements which can be used if required to measure compliance by inspection. The Document identifies parameters to be used by monitoring and displaying the indoor environment in existing buildings. This document is applicable 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. The document explains how different categories of criteria for the indoor environment can be used.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE The references in EN 16798-1 are also applicable in this document. Additional references are listed in the Bibliography.

EN 12193, *Light and lighting — Sports lighting*

EN 12464-1:2011, *Light and lighting — Lighting of work places — Part 1: Indoor work places*

EN 12464-2, *Light and lighting — Lighting of work places — Part 2: Outdoor work places*

EN 12665, *Light and lighting — Basic terms and criteria for specifying lighting requirements*

EN 12792, *Ventilation for buildings — Symbols, terminology and graphical symbols*

EN 16798-1:2019, *Energy performance of 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*

EN 16798-3, *Energy performance of buildings — Part 3: Ventilation for non-residential buildings — Performance requirements for ventilation and room-conditioning systems*

EN ISO 10052, *Acoustics — Field measurements of airborne and impact sound insulation and of service equipment sound — Survey method (ISO 10052)*

EN ISO 16032, *Acoustics — Measurement of sound pressure level from service equipment in buildings — Engineering method (ISO 16032)*

EN ISO 13731, *Ergonomics of the thermal environment — Vocabulary and symbols (ISO 13731)*

EN ISO 52000-1:2017, *Energy performance of buildings — Overarching EPB assessment — Part 1: General framework and procedures (ISO/FDIS 52000-1:2017)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 16798-1, EN 12792, EN ISO 13731, EN 12464 (all parts), EN 12665 and EN ISO 52000-1 apply.

4 Symbols and abbreviations

4.1 Symbols

For the purposes of this Report, the symbols given in EN ISO 52000-1:2016, Clause 4 and Annex C and the specific symbols listed in Table 1 apply.

Table 1 — Symbols and units

Symbol	Quantity	Unit
θ_o	indoor operative temperature	°C
θ_e	outdoor temperature	°C
Θ_m	running mean outdoor air temperature	°C
θ_{ed-i}	daily mean outdoor temperature	°C
Θ_o	operative temperature, design and energy calculations	°C
Θ_{rm-i}	running mean outdoor temperature	°C
v_a	air speed (average/maximum)	m/s
Θ_f	floor surface temperature	°C
ΔCO_2	Concentration difference	ppm
$\Delta \Theta_{pr}$	radiant temperature asymmetry	K
$\Delta \Theta_a$	vertical air temperature difference	K
α	constant for running mean calculations	
q_{tot}	total ventilation rate	l/s
q_B	ventilation rate for building materials	l/s (m ²)
q_p	ventilation rate for persons	l/s (per person)
q_{tot}	total ventilation rate in occupied zone	l/s (m ²), l/s (person)
n	number of persons	
q_h	ventilation rate required for dilution of pollutant	L/s
G_h	generation of a pollutant	µg/s
C_h	guideline value of a pollutant	µg/L
$C_{h,i}$	guideline value of the substance	µg /m ³
$C_{h,o}$	supply concentration of a pollutant at air intake	µg/L
ε_v	ventilation effectiveness	-

Symbol	Quantity	Unit
A	floor area	m ²
$L_{p,A}$	A-weighted sound pressure level	dB(A)
$L_{eq, nT,A}$	equivalent continuous sound pressure level	dB(A)
D	daylight factor	
$DC_{a,j}$	daylight quotient of the calculated area	
E_m	average maintained illuminance	lx
M	activity level	met
I_{cl}	assumed clothing level winter/summer	clo

4.2 Abbreviations

Table 2 — Abbreviations

Abbreviation	Term
ACH	air changes per hour
DR	draught rate, %
DSNA	daylight quotient sunscreen not activated
IEQ	indoor environmental quality
IEQ _{cat}	indoor environmental quality category for design
LPB ₁₋₃	low polluting building class
PD	percentage dissatisfied for local thermal discomfort
PMV	predicted mean vote
PPD	predicted percentage of dissatisfied, %
RH	relative humidity
WHO	World Health Organization

5 Interactions with other standards and use of categories

The present document interacts mainly with EN 16798-1 and indirectly with the standards that interact with EN 16798-1.

The document explains how the indoor environmental criteria in EN 16798-1 can be used for the design of building and HVAC systems. The thermal criteria (design indoor temperature in winter, design indoor temperature in summer) are used as input for heating and cooling load calculations and sizing of the installed systems. Ventilation rates are used for sizing ventilation systems, and lighting levels for design of lighting system including the use of day lighting. The design values for sizing the building services are needed to avoid possible negative effect of indoor environment and to give advice in respect of improvement of the energy efficiency of existing buildings as well as of the heating and cooling of buildings.

This document explains how values for the indoor environment (temperature, ventilation, lighting) are used as input to the calculation of the energy demand (building energy demand). Output from measured indoor environmental parameters in existing buildings (temperature, CO₂, ventilation rates, illumination levels) will enable the evaluation of overall annual performance and can be used to display the indoor environmental factors together with data for the energy performance.

Output from room temperature calculations and yearly dynamic building simulations will enable evaluation of the annual performance of buildings at the design stage.

The document describes methods for measurement of the indoor environment and for treating measured data related to the inspection of HVAC systems.

The document will provide a method for categorization of indoor environment (Clause 10). This method can be used to integrate complex indoor environment information to simple classification for a possible indoor environment certificate.

6 How to establish design input criteria for dimensioning of buildings, heating, cooling, ventilation and lighting systems

6.1 Introduction

Recommended input values are given for each of the different categories as shown in Table 3. These categories can be used in different ways. First and foremost they can be used to establish different levels of criteria for the design of buildings and building services. Different countries can standardize one category for design. The consultant and client of a building project can use the categories to agree on a specific design level. The intention is not that a building should be operated strictly in one class the whole year round. Instead the categories can be used to describe the yearly indoor environmental performance of a building by showing the distribution of the parameters in the different categories. It can then, on the national level or in a design/operation contract, be specified how much of the time the categories can be exceeded. This is shown in this report with some examples.

Table 3 — Categories of indoor environmental quality

Category	Level of expectation	Explanation
IEQ _I	High	Should be selected for occupants with special needs (children, elderly, persons with disabilities).
IEQ _{II}	Medium	The normal level used for design and operation.
IEQ _{III}	Moderate	Will still provide an acceptable environment. Some risk of reduced performance of the occupants.
IEQ _{IV}	Low	Should only be used for a short time of the year or in spaces with very short time of occupancy.

Even if a building is designed for category III it can still be operated a greater part of the year in category I or II. When the outdoor conditions are less severe (warmer in winter, colder in summer) than the design day, the capacity of the heating/cooling system will be large enough to keep the indoor environment within a more narrow range.

It can be argued that selecting a higher category can increase the energy consumption. The energy requirement is however regulated by national building codes and cannot be exceeded. The challenge is then for the designer/operator of the building to obtain a high level of indoor environmental quality within the required energy criteria.

For design of buildings and dimensioning of room conditioning systems the thermal comfort criteria (minimum room operative temperature in winter, maximum room operative temperature in summer) will be used as input for heating load and cooling load calculations. The design ventilation rates that are used for sizing the equipment, are also used for energy calculations. The criteria are used as input values for the sizing and dimensioning of the systems as well as for design of buildings (facades, orientation, solar shading, etc.). Using a higher category will result in systems with a higher capacity; but depending on how the system is operated the energy use is not necessarily higher. In the design a design external temperature for heating and a design day (including solar load) for cooling will normally be used.

To protect the designer/installer against complaint for not meeting the design intent, it is very important that the basis for design (boundary conditions, occupant density, etc.) are documented in the design documents. This will avoid discussions when these boundary conditions are changed during the lifetime of the building and the performance criteria cannot be met.

6.2 Thermal environment

6.2.1 General

Field studies in office buildings have shown that people's expectations regarding the thermal environment can be different for buildings with installed mechanical cooling and buildings where the occupants only have the possibility to open windows to influence the thermal environment. Therefore the design criteria are different for the two types of office buildings: mechanical heated and cooled buildings and buildings without mechanical cooling (see definition in EN 16798-1). The decision on which approach to use is taken by the client together with his consultant. It is possible for the consultant to show the difference between the two methods (acceptable indoor temperatures, energy use, etc.)

6.2.2 Mechanically heated and/or cooled buildings

6.2.2.1 General

Criteria for the thermal environment in heated and/or cooled buildings, in EN 16798-1 are based on the thermal comfort indices PMV-PPD (Predicted Mean Vote - Predicted Percentage of Dissatisfied) with assumed typical levels of activity and typical values of thermal insulation for clothing (winter and summer) as described in detail in EN ISO 7730. Assuming different criteria for the PPD, different categories of the indoor environment are established. The PMV-PPD index takes into account the influence of all six thermal parameters (clothing, activity, air temperature, mean radiant temperature, air velocity and humidity) and can be directly used as criteria.

With a specified combination of activity and clothing, an assumed 50 % relative humidity and low air velocities ($<0,1$ m/s) the criteria can also be expressed as operative temperature as shown in B.2.1. For other air velocities and humidities the corresponding operative temperature will be different. Some examples of recommended design indoor operative temperatures for heating and cooling, derived according to this principle, are presented in B.2, Table B.2. This presents design values for the indoor operative temperature in buildings that have active heating systems in operation during winter season and active cooling systems during summer season, assumed clothing level for winter (1,0 clo) and summer (0,5 clo) and activity level (sedentary, 1,2 met). Note that the operative temperature limits should be adjusted when clothing levels and/or activity levels are different from the values mentioned in the table.

In some types of room there can be mixed type of occupants (sedentary-standing/walking) with different type of clothing (visitor to department store in outdoor clothing and shop assistance in indoor clothing). In these cases a compromise should be found for the design criteria and the boundary conditions and this should be documented in the design documents and agreed by the client.

The temperatures in Table B.2 are operative temperatures (EN ISO 7726) with design loads at the design weather conditions which are specified nationally according to EN ISO 15927-4 and EN ISO 15927-5.

In most cases the average room air temperature can be used as defining the design indoor temperature, but if temperatures of large room surfaces differ significantly from the air temperature (windows in winter and summer) or in situations where building occupants are often exposed to direct sun, the operative temperature should be used. Further information on clothing and activity can be found in EN ISO 9920 and EN ISO 8996. The value of design temperature can vary from the values shown, to take account of e.g. local custom (clothing) or a desire for energy saving so long as the within-day variation from the design temperature is within the given range, and the occupants are given time and opportunity to adapt to the modified design temperature.

The design criteria in this section are both for design of buildings (dimensioning of windows, solar shading, building mass, etc.) and for design of HVAC systems.

6.2.2.2 Local thermal discomfort

Criteria for local thermal discomfort (see EN 16798-1) such as draught, radiant temperature asymmetry, vertical air temperature differences and floor surface temperatures will also have an influence on the design of buildings and systems, and should be taken account of.

6.2.2.3 Personalized systems

Individual preferences regarding the indoor environment can be very different. Therefore there is an increasing interest in using personalized systems for providing thermal comfort at individual work places. With personalized systems it can be possible to satisfy all occupants. Recommended criteria for these types of systems are included in Annex H.

6.2.3 Buildings without mechanical cooling

During the summer season and during the between-seasons (spring and autumn) the so-called adaptive criteria (upper and lower temperature limits that change with the running mean outside temperature) can be applied (see the category I, II and III upper and lower limits in B.2.2, Figure B.1 in EN 16798-1:2019). During the winter season, the same temperature limits should be applied as presented for buildings with mechanical cooling systems.

The adaptive criteria are based on data for office buildings, but could possibly be used for other buildings of similar type used mainly for human occupancy with mainly sedentary activities, where there is easy access to operable windows and occupants can freely adapt their clothing to the indoor and/or external thermal conditions. This method only applies to spaces where occupants during the majority of their time have metabolic rates ranging from 1,0 to 1,3 met. It is also important that strict clothing policies inside the building are avoided and that building occupants are free to adapt their clothing to indoor and/or external thermal conditions within a range of at least 0,4 to 1,0 clo.

The upper and lower limits presented in Figure B.1 in EN 16798-1:2019 only apply when the running mean external temperature is between 10 °C and 30 °C.

The temperature limits for the summer and the in-between-seasons only apply when the thermal conditions in the spaces at hand are regulated (during those seasons) primarily by the occupants through opening and closing of windows. Several field studies have shown that occupants'

thermal responses in such spaces depend in part on the external climate, and differ from the thermal responses of occupants in buildings with mechanical cooling systems, mainly because of differences in thermal experience, presence of adaptive opportunities, differences in perceived control and shifts in occupants' expectations.

In order for this optional adaptive method to apply, the spaces in question should be equipped with operable windows or comparable facade components which open to the externals and which can be readily opened and adjusted by the occupants of the spaces. These operable windows (facade components) should be designed and positioned in such a way that on warmer days they allow occupants to fine tune the (wind pressure driven) air speeds inside.

There should be no mechanical cooling in operation in the space. Mechanical ventilation with unconditioned air (in summer) can be utilized, but opening and closing of windows should be of primary importance as a means of regulating thermal conditions in the space. In addition occupants can have additional options for personal control over the indoor environment such as solar shading, fans, shutters, night ventilation, etc.

The spaces can be provided by a heating system, but this optional method does not apply during times of the year when the heating system is in operation.

In residential buildings the opportunities for (behavioural) adaptation are relatively wide: one is relatively free to adjust metabolism and clothing insulation according to outside weather and momentary indoor temperatures. With an exception for bedrooms, where the lower limit should be lower than in other rooms, as studies have shown that operative temperature in bedrooms have a significant impact on sleep quality and general health.

Note that the field studies on the temperature limits shown in Annex B.2.2 do not take work performance effects into account.

In landscaped (open plan) offices most occupants have only limited access to operable windows and therefore typically reduced personal control over natural ventilation, e.g. if there are work places placed in the middle of the room, away from direct access to operable windows. Therefore the temperature limits established by this method will not always apply in such situations.

EN 16798-1:2019, Figure B.1 includes three categories of temperature limits for use as outlined in the introduction and in EN 16798-1:2019, Clause 5. The allowable indoor operative temperatures of Figure B.1 are plotted against the running mean external temperature θ_{rm} .

The following approximate Formula (1) can be used where records of daily mean external temperature are available:

$$\theta_{rm} = \frac{(\theta_{ed-1} + 0,8\theta_{ed-2} + 0,6\theta_{ed-3} + 0,5\theta_{ed-4} + 0,4\theta_{ed-5} + 0,3\theta_{ed-6} + 0,2\theta_{ed-7})}{3,8} \quad (1)$$

The temperature limits presented in Annex B.2.2 should be used for the dimensioning of passive means to prevent overheating in summer conditions. Some examples are: dimensioning and orientation of windows, dimensioning of solar shading systems and of the thermal capacity of the building. Where the adaptive temperature limits presented in Figure B.1 (upper limits) of EN 16798-1:2019 cannot be guaranteed by passive means, then mechanical cooling should be used. In such cases the design criteria for buildings with mechanical cooling should be used (see summer limits in B.2.1).

Note that Figure B.1 already accounts for people's clothing adaptation, therefore it is not necessary to estimate the clothing values when using the adaptive method presented in B.2.2 of EN 16798-1:2019. Also it is normally not required that the following parameters be separately evaluated: local thermal discomfort, clothing insulation, metabolic rate, humidity and air speed.

6.2.4 Increased air velocity

Under summer comfort conditions with indoor operative temperatures $> 25\text{ °C}$ increased air velocity can be used to compensate for increased air temperatures. Where there are fans (that can be controlled directly by occupants) or other means for personal air speed adjustment (e.g. personal ventilation systems, or personally operable windows) the upper limits presented in Table B.2 and Figure B.1 in EN 16798-1:2019 can be increased by a 2 ° to 3 ° . The exact temperature correction depends upon the air speed and can be derived from Table B.3. This method can also be used to overcome excessive temperatures in buildings if the local method for controlling air movement (fan, etc.) is available.

Considering the latter: if building occupants have access to fans, personal ventilation systems, personally operable windows etc. that provide them with precise and stepless control over air speed the upper limits of Table B.2 and Figure B.1 can be relaxed. The airspeed – temperature offset relation presented in the table is based upon heat transfer from the skin calculations.

The temperature correction by increased air velocity is assumed to be included in the adaptive method for free running buildings, as a prerequisite for this method is that occupants have access to operable windows under their personal control.

For buildings designed using the PMV-PPD approach, the temperature correction can be applied also if occupants have access to operable windows, and not only if the air velocity is provided from fans, etc.

6.3 Design for indoor air quality (ventilation rates)

6.3.1 General

6.3.1.1 Introduction

The source control strategy together with ventilation (natural, mechanical and hybrid), placement of air intakes and filtration and air cleaning technologies contribute to improve the indoor air quality. The source control strategy is very important since air pollutants often are generated indoors. For residential buildings indoor sources will often be the predominant source of air pollutants.

6.3.1.2 Source control

Source control should as often as possible be the primary strategy for controlling the level of air substances. In many cases the sources will not be known, or little information about emission from building materials and furnishing are known or sources are brought into the space by occupants after the construction of the building. There are several national certification methods for materials that can be used for source control. A local exhaust of a high emitting source (kitchen hood, toilet exhaust, etc.) is also a type of source control.

6.3.1.3 Ventilation

The pollution remaining after source control is dealt with by dilution or displacement with appropriate ventilation air flow rates.

6.3.1.4 Time periods used for determining air flow rates

The methods described in this clause assume that pollutants emissions are constant in each time period considered and lead to a constant design ventilation air flow rate for each time period, therefore it can be a need to look at different time periods with constant values.

6.3.1.5 Building damage

Building damage can occur both at high indoor temperatures (very high room temperatures during warm summer days or if cooling is turned off) or too low temperature due to risk of condensation and resulting mould growth. Therefore some heating, cooling and/or ventilation could also be needed outside the time of occupancy.

6.3.1.6 Design documentation

The design documents are very important to protect both the designer and the owner. During the lifetime of a building the use and loads can change. It is therefore essential that the original design criteria are documented.

6.3.2 Methods

6.3.2.1 General

EN 16798-1 includes three methods for estimating the design air flow rates, which not necessarily will result in the same indoor air quality. The reason for including many methods is to be open for national preferences in choice of method. Again, it should be clearly stated in the design documents which method was used and why the method was chosen.

6.3.2.2 Method 1 based on perceived air quality

The perceived air quality is basically the odour level in the space perceived by the occupants. As odours will consist of emission from occupants (bio effluents) and emission from building materials and furnishing, Formula (2) is recommended.

$$q_{tot} = n \cdot q_p + A_R \cdot q_B \quad (2)$$

As odours from people are added, odours from other sources shall also be added. The knowledge about the people component is relatively well established (9, 10, 22, 23), while the contribution from other sources is less well documented. Because of differences in the building component (selection of indoor materials, etc.) the method includes three different building types (see B.2.2).

Studies (25, 26) have shown that people adapt to the odour from bio effluents, but very little to the emission from building materials and furnishing (reference). This doesn't mean that adapted persons are not subject to fatigue, impaired concentration, etc. that could follow after exposure to excessive concentration of bioeffluents in air over a longer time. However the required minimum ventilation of 4 l/s per person apply also for adapted persons. In EN 16798-1 the perceived air quality levels are set for non-adapted persons. If in special cases the design will be based on adapted persons information is included in B.3.1.2 of EN 16798-1:2019.

6.3.2.3 Method 2 using criteria for individual substances

The ventilation rate required to dilute an individual substance (formaldehyde, other VOCs) can be calculated by a simple steady-state mass balance according to Formula (3):

$$Q_h = \frac{G_h}{C_{h,i} - C_{h,o}} \cdot \frac{1}{\varepsilon_v} \quad (3)$$

NOTE Different units can be used in the formula (see EN 16798-1). The ventilation effectiveness can be found from EN 16798-3 and CEN/TR 16798-4.

Formula (3) applies to steady-state conditions and the method requires that the external pollutant concentration is lower than the indoor. As indicator for human bioeffluents the CO₂ concentration is often used. B.3.1.3 shows examples calculations using CO₂ as an indicator.

6.3.2.4 Method 3 based on pre-defined ventilation air flow rates

An indirect method of expressing intended indoor air quality is to determine a certain minimum ventilation air flow rate estimated to meet requirement for perceived air quality and health in the occupied zone.

The pre-defined ventilation air flow rates can be expressed by a combination of one or more of the following components: total design ventilation for people and building components (q_{tot}); design ventilation per unit floor area (q_{m^2}); design ventilation per person (q_{p}); design air change rates (ACH); design opening areas (A_{tot}). Default values are presented in B.3.1.4 in EN 16798-1:2019.

6.3.3 Non-residential buildings

6.3.3.1 Applicable methods

Determining the design ventilation rate is the first step in the process of designing a ventilation system. The design ventilation air flow rates are used for designing any type of ventilation system, including mechanical, natural, hybrid ventilation systems.

6.3.3.2 Ventilation air flow rates during unoccupied periods

To avoid building damage (condensation, mould growth) and too high a level of pollutant concentrations at the start of the occupied hours it can be necessary to have basic ventilation during unoccupied hours. It is appropriate to use a ventilation rate corresponding to the building component (pollution from the construction materials). Alternatively, full ventilation can be started at a given time before occupation, as described in B.3 in EN 16798-1:2019.

6.3.4 Residential buildings

6.3.4.1 General

In residential buildings, the occupants can in most cases be considered as adapted to the perceived air quality as they occupy the house for a longer time. Unlike other types of buildings, there is no need to maintain a situation where the indoor air quality is perceived as fresh by non-adapted persons entering the building, as this is an unusual situation for everyday use of the residential building. It is of course also possible to design the ventilation rate in residential buildings for non-adapted people. The main priority in residential buildings is to ensure a healthy indoor environment, and a secondary priority is to prevent damages to the building from excess of moisture.

6.3.4.2 Applicable methods

When dealing with ventilation rates, it should be taken into consideration that dwellings have scenario, patterns of use and characteristics different from non-residential buildings (offices, schools, cinemas, bars or restaurants, etc.).

Concerning the scenarios, it's easy to realize that occupation is completely different from non-residential buildings, in fact:

- occupancy of a dwelling can be strongly variable during the different moments of the day;
- activities can be much different from one another: sleeping, cooking, having a shower, cleaning, watching television, etc.
- in residential buildings, the concept of “adapted” people has a great importance: in fact a dwelling is, for the largest part of the time, a private space where the adaptation is practically general, differently e.g. from shops, restaurants and similar, where the first impact on incoming people is essential.

In residential buildings, ventilation systems should take into account flexibility of use of different rooms: typically e.g. bedrooms are scarcely occupied during daytime and occupied during night time, contrary to living rooms.

EN 16798-1:2019, B.3.2 gives methods and details for a suitable design of ventilation systems in residential buildings. B.3.2 explains further, with some examples, how to implement the methods proposed in EN 16798-1 and how they impact on some types of ventilation systems available on the market.

6.3.4.3 Ventilation air flow rates during non-occupied periods

If the ventilation rate is lowered or stopped during unoccupied hours it is recommended that the ventilation system starts before the building is occupied again or airing by window opening is done (see B.3.2.9).

6.3.5 Access to operable windows

To allow the building occupants to air their rooms and to provide contact to the outside it is recommended to include operable windows. This applies to bedrooms and living rooms in dwellings and other buildings with rooms intended for sleeping, e.g. elderly homes. It also applies in offices, schools and child care facilities.

6.3.6 Filtration and air cleaning

To limit the indoor concentration and ingress of outdoor air pollutants one or more of the following methods should be considered:

- placement of air intakes in less polluted areas of the building (e.g. towards courtyards instead of towards roads);
- filtration;
- air cleaning.

Design guidelines on air cleaning (filtration and gas phase) are given in EN 16798-3 and ISO 16814. How to substitute outside air by air cleaning is described in Annex I.

In order to choose appropriate air filtration and air cleaning solutions, ambient air quality at building location can be considered. When the building is located in an area where the national standard or WHO guideline values for PM₁₀ or PM_{2,5} are exceeded, particle fine filters (plus a pre-filter when appropriate) evaluated according to EN 16798-3, or air cleaning devices can be provided to clean the external air at any location prior to its introduction to occupied spaces. It can also be possible for a limited time to close the outside air intakes and use recirculation combined with appropriate air cleaning.

When the building is located in an area where the national standard/WHO guideline value for one or more gaseous contaminants is exceeded such as ozone, NO_x, SO_x, PAH (poly aromatic hydrocarbons), gaseous filtration can be implemented as such or in combination with particle air filtration.

EN 16798-3 provides guidelines for filters performance and filters stage design according to the external air particles levels and the expected indoor air quality.

Air filters and air cleaning devices are selected and installed to protect ventilation system components and ducts from dust fouling as well. Dust fouling can reduce energy performance of heat exchanges of heating/cooling batteries and heat recovery systems. Note that humidity and temperature conditions combined with dust accumulation can lead to additional load by harmful substances of organic contaminants (microorganisms proliferation and their metabolites).

It is important to avoid that air filters themselves do not become a source of harmful or odorous substances. Regular maintenance, inspections and air filters change minimize the carryover of microorganism and keep supply air clean. EN 16798-3 and inspection standards provide recommendations and good practices for air filters maintenance and inspection.

6.4 Humidity

The humidity criteria depend partly on the requirements for thermal comfort and indoor air quality and partly on the physical requirements of the building (condensation, mould, etc.). For special buildings (museums, historical buildings, churches) particular humidity requirements will exist. For buildings with no other humidity requirements than human occupancy (e.g. offices, schools and residential buildings), humidification is usually not needed and dehumidification is usually only needed in geographical areas with high outside humidity levels. Short-term exposure to very low or high values can be accepted.

6.5 Lighting

6.5.1 General

Windows are strongly favoured in buildings for the daylight they deliver and for the visual contact they provide with the outside environment. However, it is also important to ensure windows do not cause visual or thermal discomfort, or a loss of privacy.

Light is a necessary part to people's health and wellbeing. Light affects the mood, emotion and mental alertness of people. It can also support and adjust the circadian rhythms and influence people's physiological and psychological state.

For reasons of comfort and energy in most cases the use of daylight is preferred.

6.5.2 Non-residential buildings

The degree of visibility and comfort is wide ranging, and governed by activity type and duration of required lighting criteria for work places as specified in EN 12464-1 and for sports lighting in EN 12193. For some visual tasks in buildings and spaces examples of required lighting criteria are presented in Table B.28.

According to EN 12464-1:2011, 4.1, the main lighting requirements are determined by the satisfaction of three basic human needs: visual comfort, visual performance and visual safety.

In order to meet the illumination required in the rooms, buildings should have access to daylight to provide all or some of the illumination and during absence of daylight adequate amount of electric lighting should be installed to provide the required illumination. EN 15193-1 provides details about the effect of daylight on the lighting energy demand (monthly and annual basis) and daylight availability classification as a function of the daylight factor.

Too small windows might provide too little daylight, while too big unprotected windows might lead to overheating.

6.5.3 Residential buildings

Daylight in residential buildings can enter the space by façade and roof light openings or a combination of both. The contribution of daylight will vary in level, direction and spectral composition with time and provides variable modelling and luminance patterns, which is perceived as being beneficial for people in indoor environments. Good daylight provision depends on the size of the area lit by daylight compared to an area, which is not illuminated, by daylight.

6.6 Noise

The Equivalent Continuous Sound Level ($L_{eq,A}$) is the preferred single value parameter to describe noise. It is the constant sound pressure level which would produce the same sound energy, at a given point, over the same period of time T , as the considered variable sound pressure level.

$L_{eq,A}$ is a very good descriptor of noise due to sources active under operating conditions in a medium-long time span. It is widely used as descriptor of equipment noise in continuous operation (e.g. ventilation, air conditioning, etc.) in most of the regulations and national standards.

To adequately assess a noise with respect to requirements, it is necessary to normalize the equivalent continuous level with respect to reverberation time ($L_{eq,nT,A}$) to take into account the sound absorption of the room. $L_{eq,nT,A}$ is defined in EN ISO 16032 and EN ISO 10052.

EN 16798-1 is provided for design and assessment of energy efficiency of buildings, therefore, with respect to noise, only HVAC systems are fully relevant. Nevertheless these systems are usually strictly connected to plumbing, therefore also the contribution of these shall be considered to better achieve comfort conditions. Moreover other sources of noise are important for a comfortable use of the buildings such as lifts and motorized systems for opening doors, gates and similar and should be taken into account in the design of buildings. The use of L_{max} (FAST) instead of L_{max} (SLOW) allow to better include the effect of impulsive phenomena and description of discontinuous noise source functioning (see EN ISO 16032). Some values of acceptable noise from the most common service equipment in buildings are given in B.6.

7 Indoor environment parameters for energy calculation

7.1 General

The input values for energy calculations are based on the same concepts as the criteria for design. The criteria presented in EN 16798-1 are then also reflected in the occupant schedules.

7.2 Thermal environment

7.2.1 General

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

7.2.2 Seasonal and monthly calculations

During the between-seasons (with θ_{rm} between around 10 °C and 15 °C) adjusted upper and lower temperature limits that lie in between the winter and summer values mentioned in Table B.2 can be used.

7.2.3 Hourly calculations or dynamic building simulation

The indoor temperatures can be calculated by dynamic building simulations. Recommended values for the acceptable range of the indoor temperature for heating and cooling are presented in Annex B.2. The midpoint of the temperature range should be used as a target value but the indoor temperature can fluctuate within the range according to the energy saving features or control algorithm. If the cooling power is limited (mixed mode buildings) the excess indoor temperatures can be estimated using one of the methods described in Clause 8 of this document.

Assumptions related to allowable exceedance is described in Clause 8.

7.3 Indoor air quality and ventilation

7.3.1 Generals

An acceptable level of ventilation is required in both non-residential and residential buildings to achieve good indoor air quality.

7.3.2 Non-residential buildings

The recommended ventilation rates for energy calculations are basically the same as used for design of systems. In systems with variable air flow control and demand controlled ventilation the ventilation rate can vary between maximum, for full occupancy, and minimum, when the considered space is unoccupied. In case of CO₂-controlled ventilation the CO₂-concentration values in Annex B.2 can be used. Recommended values for the excess of CO₂ concentration above outdoors CO₂ concentration are listed in Annex B.3.1.2.

7.3.3 Residential buildings

The concept of design ventilation rates and the use of demand controlled ventilation are similar to offices (7.3.2).

7.4 Humidity

The same criteria used for design are also used for energy calculations.

7.5 Lighting

The same criteria used for design are also used for energy calculations.

8 Evaluation of the indoor environment and long term indicators

8.1 General

As the loads of any building vary from place to place and from time to time, the designed system might 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 (Articles 6 and 7 of the Energy Performance Building Directive). This clause 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 is based on the following activities: design (8.2), calculations (8.3), measurements (8.4) or questionnaires (8.5).

8.2 Design indicators

Evaluation of the category of indoor environment of a building is based on the categories of the following indoor environmental factors:

- a) thermal criteria for winter: specified design values for indoor temperature during heating are in 6.2.2;
- b) thermal criteria for summer: specified design values for indoor temperatures during cooling are in 6.2.2 and 6.2.3;
- c) air quality and ventilation criteria: design values for ventilation are in 6.3.3 for non-residential buildings, and in 6.3.4 for residential buildings;
- d) humidity criteria: design values for humidity are in 6.4;

- e) lighting criteria: design values for lighting are in 6.5;
- f) noise criteria: design values for noise are given in 6.6.

8.3 Calculated indicators of indoor environment

8.3.1 General

Building simulation is a cost effective way to analyse the expected performance of buildings. The computer programs used can be validated according to EN 15265 and EN 15255. Various indicators of indoor environment can be calculated for different purposes. In the following four methods are presented for the thermal evaluation.

8.3.2 Simple indicator

To evaluate the performance of the whole building, representative rooms or spaces shall be simulated. The building meets the criteria of a specific category if the rooms representing 95 % of building volume meet the criteria of the selected category.

8.3.3 Hourly criteria

Performance of the buildings or rooms with different mechanical or electrical systems can be evaluated by calculating the number of actual hours or the percentage of time when the criteria is met or not.

This procedure is described with an example in Annex D.

8.3.4 Degree hours criteria

In respect of the thermal environment the degree hours outside the upper or lower boundary can be used as a performance indicator of building for warm or cold season.

This procedure is described with an example in Annex D.

8.3.5 Overall thermal comfort criteria (weighted PMV criteria)

This procedure is described with an example in Annex D.

8.4 Measured indicators

8.4.1 General

Deviations from the selected criteria should be allowed. Some national criteria express 'acceptable deviations' as an acceptable number of hours or percentage of occupancy time outside the criteria based on a yearly evaluation (like 100 to 150 h assuming 2 000 occupancy hours; or 3 % of the occupancy time). This can also be given as weighted hours, where the level of deviation also is taken into account.

If no national criteria for deviations are available the recommended criteria in Annex E can be used. These criteria can be given on a weekly, monthly and yearly basis.

The weather data file used in the building simulation to design the performance of the ventilation system might differ from the actual weather data. A heat wave might influence on the actual performance of the building and cause e.g. overheating. In this matter a longer period of time where the building is outside the designed category can occur.

8.4.2 Thermal environment

The measurements should be taken in representative rooms at different zones, orientations, with different loads during representative operation periods. The evaluation of the category of indoor environment is based on temporal and spatial distribution of the room temperature.

Measurements points and instruments should fulfil the requirements in EN ISO 7726 (see also EN 12599).

8.4.3 Indoor air quality and ventilation

8.4.3.1 General

Indoor air quality and ventilation of building is evaluated with representative samples taken from different zones of the building.

8.4.3.2 Ventilation method

Ventilation of buildings can be evaluated by measuring air flows in ducts or by tracer gas measurements or by using e.g. CO₂ as an indicator.

8.4.3.3 Air quality method

Air quality of building can be evaluated in buildings where people are the main pollution source by measuring the average CO₂ concentration in the building, when building is fully occupied. This can be done either with representative samples of room air or by measuring the concentration at the exhaust air.

8.4.4 Lighting

Lighting quality is evaluated by measurements of illuminances on task areas, on surrounding areas and on walls and ceiling. Illuminance uniformity should be greater or equal than the recommended values reported in EN 12464-1 for each kind of surface. The verification procedure in Clause 6 of EN 12464-1 can be followed.

The main parameters determining the luminous environment with respect to electric light and daylight are:

- luminance distribution;
- illuminance;
- uniformity of illuminance;
- glare;
- daylight factor;
- directionality of light;
- lighting in the interior space;
- variability of light (levels and colour of light);
- colour rendering and colour appearance of the light;
- flicker.

8.4.5 Noise

Noise is evaluated with a representative sample from rooms and spaces served by different air handling systems, zones, windows and orientation. Normally the criteria for noise do not influence the energy performance of buildings. It could, however, occur in naturally ventilated buildings, that the required amount of outside air cannot be obtained by opening of windows because noise from outside service equipment would violate the noise criteria – unless special

measures are taken, e.g. intelligent placement or sound attenuation of air intakes – or the user control of the system. Also in the case of mechanical ventilation and cooling, providing the required amount of air could result in unacceptable noise levels from fans.

If adequate ventilation depends on the opening of the windows the equivalent sound pressure level (including the periods the windows are open and room is exposed to the external noise from outside service equipment) should be used to evaluate the noise. The criteria for noise are given in B.7.

This statement of EN 16798-1 assumes knowledge in the design phase of the actual level of external noise. These data are often not available or can be influenced by the presence of the building itself. It can be difficult to fix design values when the noise level is dependent not only on the operating conditions of the equipment. Many national regulations define criteria for the evaluation of external noise and depend on considerations related to the local use.

8.5 Subjective evaluations

The direct subjective reaction of the occupants can be used for overall evaluation of the indoor environment. Daily, weekly, monthly evaluations using questionnaires for general acceptance of the indoor environment, thermal sensation, perceived air quality can be used. In Annex F recommended procedures and questionnaires are given for the systematic registration of subjective reactions of building occupants.

9 Inspections and measurement of the indoor environment in existing buildings

9.1 General

Often it is necessary to perform measurements of the indoor environment of the building during inspection to be able to give advice regarding heating loads and system size and operation (Article 8 of EPBD) and the cooling loads and system size (Article 9 of EPBD).

Requirements for inspection can be found at national level or in the standards; see also EN 15378:2007, 6.2.

If the inspection requires measurement of the indoor environment the following procedures should be followed.

9.2 Measurements

9.2.1 General

In existing buildings measurements should be used to check whether the performance of the building and its building service systems (ventilation system, heating and cooling devices, artificial lighting) meets the design requirements. 9.2.2 to 9.2.3 indicate how such measurements can be conducted for each indoor environmental quality parameter.

9.2.2 Thermal environment

The measurement instrumentation used for evaluation of the thermal environment should meet the requirements given in EN ISO 7726.

The recommendations given in EN ISO 7726 should be followed as far as the location of measurement instrumentation within the spaces is concerned.

Measurements should be made where occupants are known to spend most of their time and under representative weather conditions of the cold and warm season. For the winter (heating season) measurements at or below mean outside temperatures for the three coldest months of