Draft for Public Comment

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BSI Group Headquarters

389 Chiswick High Road London W4 4AL

Tel: + 44 (0)20 8996 9000
Fax: + 44 (0)20 8996 7400
www.bsigroup.com

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Interested committees:

Title: Draft BS EN 15193-1 Energy performance of buildings - Module M9 - Energy requirements for lighting - Part 1: Specifications

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Responsible Committee Secretary: **Ms Sue Barden (BSI)**
Direct tel: **020 8996 7773**
E-mail: **sue.barden@bsigroup.com**

Introduction

This draft standard is based on European discussions in which the UK has taken an active part. Your comments on this draft are welcome and will assist in the preparation of the consequent British Standard. Comment is particularly welcome on national, legislative or similar deviations that may be necessary.

Even if this draft standard is not approved by the UK, if it receives the necessary support in Europe, the UK will be obliged to publish the official English Language text unchanged as a British Standard and to withdraw any conflicting standard.

UK Vote

Please indicate whether you consider the UK should submit a negative (with reasons) or positive vote on this draft.

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: **ISO/DIS xxxx**

1	2	(3)	4	5	(6)	(7)
MB	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/ Table/Note**	**Type of com-ment**	**Commend (justification for change) by the MB**	**Proposed change by the MB**	**Secretariat observations on each comment submitted**
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	

EXAMPLE ONLY

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EUROPEAN STANDARD

NORME EUROPÉENNE

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DRAFT
prEN 15193-1 rev

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Will supersede EN 15193:2007

English Version

Energy performance of buildings - Module M9 - Energy requirements for lighting - Part 1: Specifications

Performance énergétique des bâtiments - Exigences énergétiques pour l'éclairage - Partie 1: Spécifications

Energetische Bewertung von Gebäuden - Modul M9 - Energetische Anforderungen an die Beleuchtung - Teil 1: Spezifikationen

This draft European Standard is submitted to CEN members for enquiry. It has been drawn up by the Technical Committee CEN/TC 169.

If this draft becomes a European Standard, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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Recipients of this draft are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

Ref. No. prEN 15193-1 rev:2014 E

Contents

Foreword

This document (prEN 15193-1:2014) has been prepared by Technical Committee CEN/TC 169 “Light and lighting”, the secretariat of which is held by DIN.

This document is currently submitted to the CEN Enquiry.

This document will supersede EN 15193:2007.

Introduction

This standard is part of a set of standards developed to support EPBD directive implementation, hereafter called "EPB standards".

EPB standards deal with energy performance calculation and other related aspects (like system sizing) to provide the building services considered in the EPBD directive.

TC 169 deals with light and lighting and the subjects covered by committee are:

- Lighting criteria for indoor and outdoor activities;
- Photometry of lighting systems;
- Lighting terminology;
- Energy efficiency of lighting systems.

This standard specifies two methods to take into account the energy performance of lighting systems.

It is of paramount importance that correct lighting is provided in buildings. The convention and procedures in this standard assumes that the designed and installed lighting scheme conforms to good lighting practices. For new and refurbished installations in the tertiary building sector the design of the lighting system should conform to the requirements in the lighting applications standards EN 12464-1 for indoor workplaces, EN 12193 for sports buildings and EN 1838 for emergency escape lighting. For domestic buildings the lighting system should be designed to fulfil the needs of the rooms in the buildings. Guidance on the requirements is provided in the supporting Technical Report CEN/TR 15193-2:2013.

This standard also assumes that the buildings can have access to daylight to provide all or some of the illumination required in the rooms and that in addition there will be an adequate amount of electric lighting installed to provide the required illumination in the absence of daylight.

This standard defines the methods for estimating or measuring the amount of energy required or used for lighting in buildings. The method of separate metering of the energy used for lighting will also give regular feedback on the effectiveness of the lighting control.

The methodology of energy estimation not only provides values for the Lighting Energy Numeric Indicator (*LENI*) but it will also provide input for the heating and cooling load estimations for the combined total energy performance of building indicator.

Figure 1 gives an overview of the methodology and the flow of the processes involved.

NOTE The dotted line linking preliminary annual *LENI* to the comprehensive method indicates the required follow-up of the budget calculation with the comprehensive calculation during the detailed lighting design process.

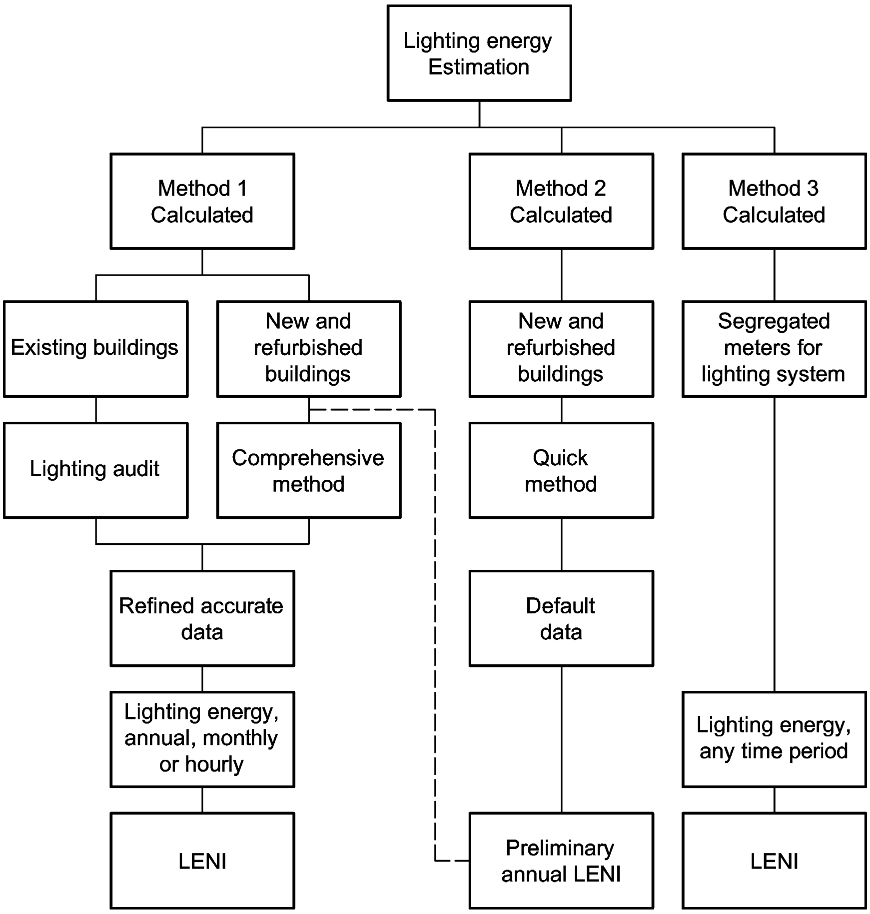


Figure 1 — Flow chart illustrating alternative routes to determine energy use

This standard was developed during the first EPBD mandate and the first version was published in 2007.

The revision for inclusion in the second mandate package was performed during 2013-2014, and was concerned with extension of calculation methods, inclusion of lighting for domestic buildings and substantial editorial changes.

1 Scope

This standard specifies the methodology for evaluating the energy performance of lighting systems for providing general illumination in domestic and tertiary buildings and for estimating or measuring the amount of energy required or used for lighting in buildings.

This standard does not cover lighting requirements, the design of lighting systems, the planning of lighting installations, the characteristics of lighting equipment (lamps, control gear and luminaires) and systems used for display lighting, desk lighting or luminaires built into furniture.

Table 1 shows the relative position of this standard within the EN EPB set of standards.

Table 1 — Position of this standard within the EN EPB set of standards

Overarching		Building (as such)		Technical Building Systems											
	Descriptions		Descriptions		Descriptions	Heating	Cooling	Ventilation	Humidification	Dehumidification	Domestic Hot Water	Lighting	Building Automation & Control	PV, Wind
sub1	M1	sub1	M2	sub1		M3	M4	M5	M6	M7	M8	M9	M10	M11
1	General	1	General	1	General									
2	Common Terms and Definitions; Symbols, Units and Subscripts	2	Building Energy Needs	2	Needs									
3	Applications	3	(Free) Indoor Conditions without Systems	3	Maximum Load and Power									
4	Ways to Express Energy Performance	4	Ways to Express Energy Performance	4	Ways to Express Energy Performance									
5	Building Functions and Building Boundaries	5	Heat Transfer by Transmission	5	Emission and Control									
6	Building Occupancy and Operating Conditions	6	Heat Transfer by Infiltration and Ventilation	6	Distribution and Control									
7	Aggregation of Energy Services and Energy Carriers	7	Internal Heat Gains	7	Storage and Control									
8	Building Partitioning	8	Solar Heat Gains	8	Generation and Control									
9	Calculated Energy Performance	9	Building Dynamics (thermal mass)	9	Load Dispatching and Operating Conditions									
10	Measured Energy Performance	10	Measured Energy Performance	10	Measured Energy Performance									
11	Inspection	11	Inspection	11	Inspection									
12	Ways to Express Indoor Comfort			12	BMS									
13	External Environment Conditions													
14	Economic Calculation													

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

FprEN 15603:2014, *Energy performance of buildings – Overarching Standard EPBD*

EN 12665:2011, *Light and lighting — Basic terms and criteria for specifying lighting requirements*

EN 1838, *Lighting applications — Emergency lighting*

EN 12193, *Light and lighting — Sports lighting*

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

EN 60598 (all parts), *Luminaires*

IEC/PAS 62722-1, *Luminaire performance — Part 1: General requirements*

EN 15251, *Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics*

EN 50470 (all parts), *Electricity metering equipment (a.c.)*

3 Terms and definitions

For the purposes of this standard, the terms and definitions given in FprEN 15603:2014 and EN 12665:2011 and the following specific definitions apply.

3.1
time step
ts
period in which the energy is evaluated

Note 1 to entry: Measured in hours [h].

3.2
standby energy
energy required for charging batteries and/or the energy required for lighting controls during the time the electric lights are switched off

4 Symbols and abbreviations

4.1 Symbols

For the purposes of this standard, the symbols given in FprEN 15603:2014 and the specific symbols listed in Table 2 apply.

Table 2 — Symbols and units

Symbol	Name of quantity	Unit
F	Dependency Factor	-
w	Width	m
k	Room Index	-
W_t	Energy per time step	W / t_s
t_s	Time step	Hour / month / year
F_c	Constant illuminance factor	-
F_o	Occupancy dependency factor	-
F_D	Daylight dependency factor	-
P_i	Luminaire power	W
P_n	Total power of n number of luminaires	W

P_{em}	Total emergency standby power	W
P_{ei}	Luminaire emergency standby power	W
P_{pc}	Total controls standby power	W
P_{ci}	Luminaire control standby power	W
F_{oc}	Controls function factor	-
P_j	Power density of the area	W/m²
F_A	Absence factor	-
$F_{D,S}$	Daylight supply factor	-
$F_{D,C}$	Lighting control factor	-
$W_{L,t}$	Total energy for illumination	W/h
$W_{P,t}$	Total energy for standby	W/h
t_D	Daylight time	h
t_N	Daylight absence time	h
t_y	Annual operating hours	h
t_e	Battery charge time only	h
t_{tot}	Total operating hours	h
W_{mt}	Metered energy	W/h
P_j	Power density	W/m²
$P_{j,lx}$	Power density per lux	W/lm
E_{task}	Maintained illuminance	lux
F_{MF}	Correction factor for *MF*	-
F_{CA}	Factor for reduced power of area	-
F_L	Factor for equipment efficiency	-
L_R	Length of room	m
w_R	Width of room	m
h_m	Mounting height of luminaire	m
E_{SUR}	Illuminance on immediate surround	lux
A_S	Sum of task areas within the room	m²
W_{US}	Energy used for lighting	W/h
W_{nd}	Energy needed for lighting	W/h
e_L	Expenditure factor for lighting systems	-
$e_{L,C}$	Partial expenditure factor for constant illuminance control	-
$e_{L,O}$	Partial expenditure factor for occupancy dependant lighting control	-
$e_{L,D}$	Partial expenditure factor for daylight dependant lighting control	-
$e_{L,ES}$	Partial expenditure factor for the electric lighting system	-
F_{cc}	Factor for the efficiency of the constant illuminance control	-
A_{ND}	The area not lit by daylight	m²

p_e	Electrical evaluation power for determination of the energy use	W
$e_{L,ES,del}$	Partial expenditure factor for delivery of electric light	-
$e_{L,ES,dis}$	Partial expenditure factor for distribution of electric light	-
$e_{L,ES,gen}$	Partial expenditure factor for generation of electric light	-
F_{ue}	Utilization factor for determination of the energy use	-
F_u	Utilization factor of the luminaire	-
η_L	Luminaire luminous efficacy	lm/W
η_{LB}	Luminaire light output ratio	-
f_B	The efficiency of the operating device	-
L_{80}	The elapsed time over which an LED light source will maintain 80 % of its initial output	-
$F_{D,n,j}$	Daylight dependency factor for the area under consideration	-
$t_{Day,nj}$	Daylight time for the area under consideration	h
$t_{eff,Day,nj}$	Daylight effective time for the area under consideration	h
$F_{D,S,nj}$	Daylight supply factor for the area under consideration	-
$F_{D,C,nj}$	Daylight responsive control system factor for the area under consideration	-
$F_{D,mth}$	Monthly daylight dependency factor	-
ρ_F	Reflectance of floor	-
ρ_W	Reflectance of walls	-
ρ_C	Reflectance of ceiling	-
D_{CA}	Daylight factor from carcass opening	-
A_{Dj}	Area receiving daylight	m²
A_{NDj}	Area not receiving daylight	m²
$a_{D,max}$	Maximum depth of the daylight area	m
h_{Li}	Height of the window lintel above the floor	m
h_{Ta}	Height of the task area above the floor.	m
a_D	Depth of the daylight area	m
b_D	Width of the daylight area	m
h_{Rj}	Distance between floor and ceiling height in an area with roof lights	m
$I_{Tr,j}$	Transparency index in the area under consideration	-
$I_{RD,j}$	Space depth index of the area under consideration	-
$I_{Sh,j}$	Shading index of the area under consideration	-
A_{Ca}	Area of the raw building carcass opening of the area under consideration	m²
A_D	Partial area which is lit by daylight	m²

$I_{sh,j}$	Shading index of the area under consideration	-
$I_{Sh,lsh}$	Correction factor for linear obstruction of the area under consideration	-
$I_{Sh,hA}$	Correction factor for overhang shading of the area under consideration	-
$I_{Sh,vA}$	Correction factor for side shading of the area under consideration	-
$I_{Sh,In,At}$	Correction factor for internal courtyard and atrium shading of the area under consideration	-
$I_{Sh,GDF}$	Correction factor for glazed double façades of the area under consideration	-
$\gamma_{Sh,lsh}$	Obstruction altitude angle	degrees
$\gamma_{Sh,hf}$	Horizontal shading angle due to horizontal projection	degrees
$I_{Sh,vf}$	Correction factor for vertical projection	-
$\gamma_{Sh,vf}$	Vertical shading angle due to vertical projection	degrees
wi	Well index	-
$a_{In,At}$	Depth of the courtyard or atrium	m
$b_{In,At}$	Width of the courtyard or atrium	m
$h_{Im,At}$	Height of the courtyard or atrium from floor level to the roof level	m
$\tau_{Sh,In,At,D65}$	Transmittance of the atrium glazing	-
$k_{Sh,In,At,1}$	Reduction factor for the frames or subdivisions in the atrium façade	-
$k_{Sh,In,At,2}$	Reduction factor by pollution of the glazing of the atrium façade	-
$k_{Sh,In,At,3}$	Reduction factor for non-vertical light incidence of the atrium façade	-
$\tau_{Sh,GDF,D65}$	Transmittance of the external layer of glazing of the double glazed façade	-
$k_{Sh,GDF,1}$	Reduction factor for the frames or subdivisions in a double glazed façade	-
$k_{Sh,GDF,2}$	Reduction factor by pollution of the glazing of the double glazed façade	-
$k_{Sh,GDF,3}$	Reduction factor for non-vertical light incidence on the façade glazing	-
$D_{Rb,j}$	Daylight factor for raw carcass opening	%
$t_{rel,D,sNA,j}$	The relative portion of the total operating time during which the solar or glare protection system is not activated	h
$t_{rel,D,aA,j}$	The relative portion of the total operating time during which the solar or glare protection system is activated	h
$F_{D,S,SNA,j}$	Daylight supply factor of the area for when solar or glare protection system is not activated	-
$F_{D,S,SA,j}$	Daylight supply factor of the area when solar or glare protection system is activated	-
H_{dir}	Luminous exposure from direct insolation	

H_{glob}	Luminous exposure from global insolation	
Υ	Latitude angle	degrees
t_{SNA}	Time when solar or glare protection is not activate	h
$\tau_{eff,SNA,j}$	Effective transmittance of the façade glazing when solar or glare protection system is not activated	-
$\tau_{D65,SNA}$	Transmittance of the façade glazing for vertical incident light	-
k_1	Reduction factor for the frames or subdivisions	-
k_2	Reduction factor for pollution of the glazing	-
k_3	Reduction factor of non-vertical light incident upon the glazing	-
H_{dir} / H_{glob}	Ratio for climate characterisation	-
τ_{eff}	Effective transmittance	-
D	Daylight factor	-
$\bar{E}_m$	Maintained illuminance	lux
$\bar{D}_{SNA}$	Mean daylight factor with rooflight, shading not activated	-
$\bar{D}_{SA}$	Mean daylight factor with rooflight, shading activated	-
D_a	External daylight factor	-
$\tau_{D65,SA}$	Transmittance of diffuse rooflight glazing with shading activated	-
η_R	Utilance	-
E_F	Illuminance on the external surface of the skylight from overcast sky	lux
E_A	Horizontal external illuminance from an overcast sky	lux
$k_{Obl,1}$	Reduction factor for the frames or subdivisions in rooflights	-
$k_{Obl,2}$	Reduction factor by pollution of the glazing of rooflights	-
$k_{Obl,3}$	Reduction factor for non-vertical light incidence on the rooflight glazing	-
A_{FS}	Glazed area of a dome or strip skylight	m²
A_{Rb}	Glazed area of a shed rooflight	m²
h_R	Distance between workplane and ceiling	m
$F_{D,s,j}$	Daylight supply factor for a vertical façade	-
$v_{month,j}$	Factor for monthly distribution	-
$\Delta F_{D,s,j}$	Difference of daylight supply factor	
$F_{D,j,i}$	Factor for monthly partial-load daylight operation	-
t_{Day}	Monthly daylight time hours	h
t_{Night}	Monthly night time hours	h
Φ	Latitude	degrees
$t_{start,i}$	Time of the beginning of usage	Real time in h

$t_{end,i}$	Time at the end of usage	Real time in h
$t_{bs,i}$	Time usage before sunrise	h
$t_{as,i}$	Time usage after sunset	h
$t_{sunrise,i}$	Sunrise time	Real time in h
$t_{sunset,i}$	Sunset time	Real time in h
N_i	Number days in the respective month	d
C_{we}	Factor for reduction to take account of weekends	-
ω_i	Hour angle	degrees
t_{eq}	Time difference between apparent solar time and mean solar time (equation of time)	h
J_i	Day of the month	-
δ	Declination of the sun	degrees

4.2 Subscripts

For the purposes of this standard, the subscripts given in FprEN 15603:2014 and the specific subscripts listed in Table 3 apply.

Table 3 —Subscripts

j	Relevant area under consideration				
i	Month number, 1 - 12				

4.3 Abbreviations

For the purposes of this standard, the abbreviations listed in FprEN 15603:2014 and the specific abbreviations given in Table 4 apply.

Table 4 — Abbreviations

Symbol	Name of quantity	Unit
LENI	Lighting Energy Numeric Indicator	kWh / m² year
MF	Maintenance Factor	-
LLMF	Lamp Lumen Maintenance Factor	-
LSF	Lamp Survival Factor	-
LMF	Luminaire Maintenance Factor	-
RSMF	Room Surface Maintenance Factor	-

5 Description of the methods

This standard covers three methods for the assessment of the energy required for electric lighting within a building, either by calculation (method 1 and method 2) or by direct metering of the lighting circuit (method 3). The calculation method 1 offers two options, one for new or refurbished buildings and two for existing buildings. For new and refurbished buildings it also offers a quick calculation method 2 for the annual energy estimation.

5.1 Output of the method 1

This method covers the calculation of the energy requirements of lighting systems in domestic and tertiary buildings where a comprehensive lighting system design has been performed. This calculation method is suitable for use during the design of new or refurbished buildings and for assessing existing buildings.

The method output shall be in terms of kilowatt hours per time step for the building. The yearly output value shall be normalized to square meters of the useful area to give the Lighting Energy Numeric Indicator (LENI).

The time step of the output can be:

- yearly;
- monthly or
- hourly;

in accordance with the time-step of the input data.

5.2 Optional methods

5.2.1 Method 2 – Quick calculation method

This method covers the calculation of the energy requirements of lighting systems for domestic and tertiary buildings where a comprehensive lighting system design has not been performed. The method makes use of quick calculation and default data and the result gives budget values.

The method output shall be in terms of kilowatt hours per year for the building. This yearly output value shall be normalized to square meters of the useful area to give the LENI.

The time step of the output shall be yearly.

This method is suitable for use during the conceptual stage of design of new or refurbished buildings.

5.2.2 Method 3 – Direct metering method

This method covers the direct measurement of the energy used by lighting system in domestic and tertiary buildings by segregated direct metering. This method gives the true value of energy used by the lighting system and can be used to verify the values obtained by the calculated methods.

The method output shall be in terms of kilowatt hours per time step for the building. The yearly output value shall be normalized to square meters of the useful area to give the LENI.

The time step of the output can be:

- yearly;
- monthly; or
- hourly;

in accordance with the time-step of the input data.

This method is suitable for use in existing buildings where the lighting circuit is sufficiently segregated to allow separate metering.

This method is applicable to buildings with facilities for separate metering of the electricity used for all lighting within the building. The metering can alternatively be by a Building Management System (BMS) arrangement.

5.3 Other general topics

The calculated or measured annual energy required for lighting can be normalized to a unit area to generate the *LENI*. The *LENI* indicator provides a comparable measure of the energy performance of the lighting installation in the buildings.

6 Method 1 - Calculation of the energy required for lighting

6.1 Output data

The [t_s].

The (W_t) [kWh / t_s].

The summation of annual energy for electric lighting within the building (W) [kWh / year].

The output data of this method are listed in table 5.

Table 5 - Output data of this method:

Description	Symbol	Unit	Intended destination module
specified time step	*ts*		all
energy used for lighting per time step within rooms or zones	W_t	kWh	MX-X
summation of annual energy for electric lighting within the building	W	kWh	MX-X

The *LENI*, which is the area normalized annual energy used for lighting within the building [kWh / m² year].

6.2 Calculation time steps

The methods described in Clause 6 are suitable for the following calculation time steps:

- Yearly - Taken as 8 760 hours.
- Monthly - Taken as an average of 730 hours.
- Hourly - Taken as (monthly / 730).

6.3 Input data

6.3.1 Lighting system data

For the comprehensive calculation method the energy estimation shall be based upon the electric lighting system that provides lighting in accordance with the requirements for non-domestic buildings of EN 12464-1 for lighting of indoor work places or EN 12193 for lighting of sports facilities. For domestic buildings see recommendations in CEN/TR 15193-2 for the lighting criteria.

It is important that for all buildings the lighting solution shall combine daylight, if available, and electric light to fulfil all requirements in accordance with EN 12464-1 and/or EN 12193 and the general and specific lighting criteria for the places within the buildings.

6.3.1.1 New or refurbished building lighting system

The lighting scheme design process of the electric lighting system for all rooms and zones within the building shall deliver as output the required type and number of luminaires and these shall be listed in the product schedule.

NOTE The comprehensive lighting system design process is not part of this standard.

The lighting system design shall give the following input data and details for each room and zone of the building:

- the types of luminaires, identified by a unique product reference code;
- the quantities of each specific type of luminaire;
- the control technique and device types.

All luminaires listed for use shall comply with the requirements specified in EN 60598.

6.3.1.2 Existing building lighting system

The lighting system shall be surveyed to give the following input data and details for each room and zone of the building:

- the types of luminaires, identified by a unique product reference code;
- the quantities of each specific type of luminaire;
- the control technique and device types.

6.3.2 Product data

6.3.2.1 General

Where the comprehensive method is being used the following data shall be specified for each product type given in the product schedule:

- unique product reference code;
- maximum luminaire power (P_i) [W];
- luminaire controls standby power (P_{ci}) [W];
- luminaire emergency battery charging power (P_{ei}) [W].

In the case where the alternative calculation methods are used the data as provided by the optional calculation methods may be applied.

In the case of existing buildings where the luminaire data is not available from the manufacturer the method described in Annex D shall be used for obtaining the value of the maximum luminaire power.

6.3.2.2 Product description data (qualitative)

The product description data shall indicate the product characteristics and state the functional capabilities regarding dimming control, integral detectors and emergency lighting facility.

6.3.2.3 Product technical data

The product technical data shall be the values declared by the manufacturer in accordance with the certified measurements that are performed in accordance with the relevant product standards. If standby energy density values declared by the manufacturer are not available, then default values are given in informative Annex B.

Declared values are given at standard reference test conditions. Declared values shall be adjusted in accordance with the actual operating conditions. This adjustment is part of the calculation procedure. This applies both to standard test values and to field test measurements.

6.3.3 System design data

Calculations shall be made for each room, zone or building to establish the installed lighting power and to estimate the impact of occupancy, daylight and over design/maintenance factors on the lighting controls by determining the values of the dependency factors, F_o, F_D and F_c.

For technologies with inbuilt constant light output capabilities used in systems without constant illuminance sensing, the F_c value shall be based upon *LLMF* as described in Annex G.

6.3.4 Operating conditions

The operating conditions for the lighting system are specified in the design of the lighting system to fulfil the lighting requirements for the tasks or activity in a room, zone or building. The electric lighting system shall be designed to meet all the relevant lighting criteria and the system shall be managed by controls. The controls shall be manually or automatically operated. Details of control types and their operation and effectiveness are given in CEN/TR 15193-2.

Information on default occupancy patterns in buildings are given in EN 15251.

6.3.5 Constants and physical data

Annual operating hours (t_y) – defined as 8 760 hours.

6.4 Calculation procedure

6.4.1 Applicable time step

This procedure can be used with the following time steps:

- yearly;

- monthly; or

- hourly.

No dynamic effects are explicitly taken into account because there are no significant time constants.

This procedure is not suitable for dynamic simulations.

6.4.2 Operating conditions calculation

The default occupancy hours for the building type shall be obtained from EN 15251.

Default values are also provided in Annex A.

6.4.3 Energy calculation

6.4.3.1 General

The lighting energy calculation method is shown in Figure 2.

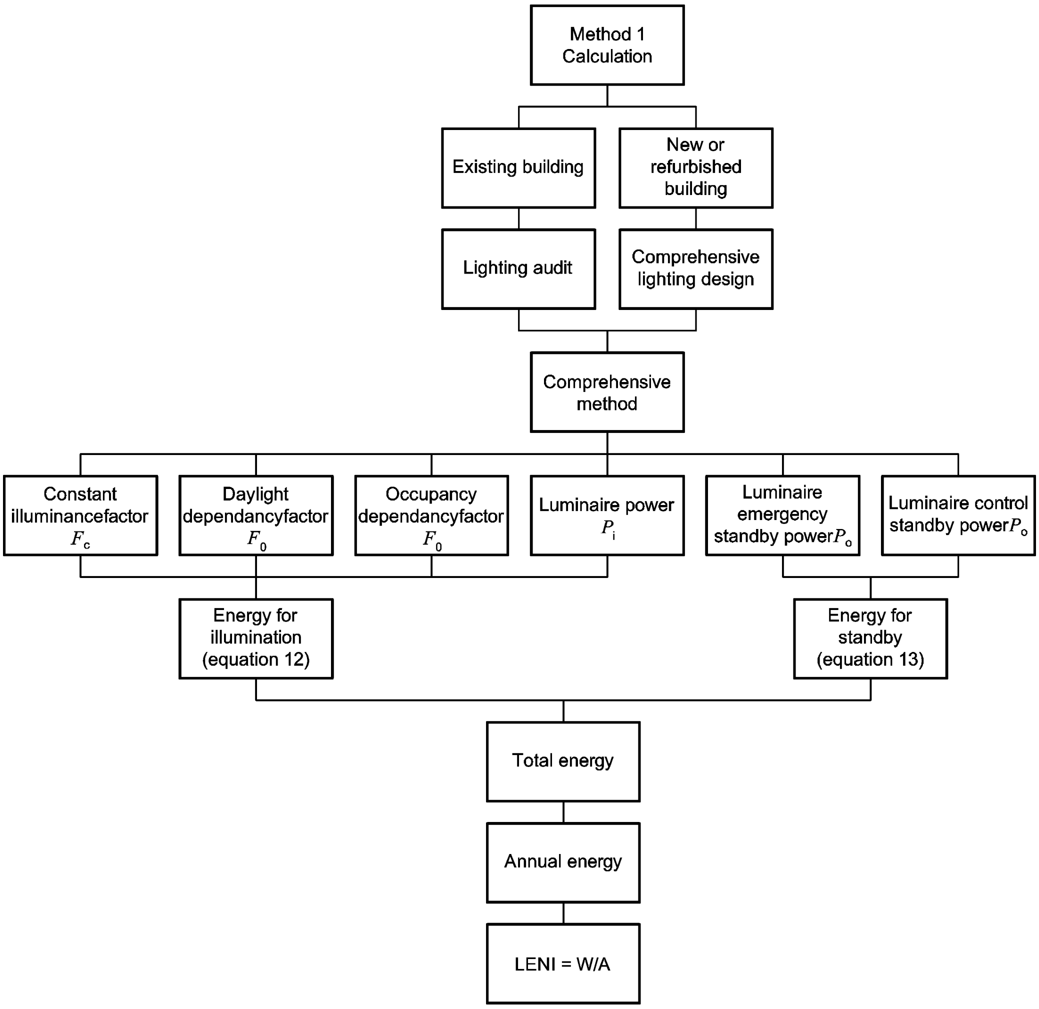


Figure 2 - Flow diagram for lighting energy calculations

6.4.3.2 Installed power calculation

For the comprehensive calculation method the energy estimation shall be based upon the electric lighting system that provides lighting in accordance with the requirements for non-domestic buildings of EN 12464-1 for lighting of indoor work places or EN 12193 for lighting of sports facilities. For domestic buildings consult CEN/TR 15193-2 for the lighting criteria.

The luminaire power P_i shall be the declared circuit power of the luminaire when operating at maximum power. The value of P_i shall include the power supplied to operate all lamp(s), ballast(s) and other component(s) when operating at maximum power.

The required connected or installed power for the lighting system shall be calculated by summation of the power requirements of the specified luminaires in the lighting scheme within each area of the building by using the equation

$$P_n = \sum_{i=1}^{i=n} P_i \, [W] \tag{1}$$

Where

n is the number of individual luminaires in the area defined in the lighting system design.

Default installed power load for domestic buildings is given in Annex B.

6.4.3.2.1 Assessment of installed power in existing buildings

The assessment of the installed power for the lighting system in existing buildings shall be made by the procedure described in Annex D. The installed power for the lighting system shall be calculated by working out the power supplied to the luminaires within each area of the building by using Equation 1.

6.4.3.3 Standby system power requirements

The required total installed power to charge the batteries in emergency luminaires (P_{em}) and to provide standby power for the automatic controls in the luminaires when the lamps are not operated (P_{pc}) shall be calculated. The calculation shall be made by summing the standby power (P_{ei}) for charging the batteries and the standby power (P_{ci}) for the automatic control for each specified luminaire within each area of the building by equations

$$P_{em} = \sum_{i=1}^{i=n} P_{ei}\ [W] \qquad (2)$$

$$P_{pc} = \sum_{i=1}^{i=n} P_{ci}\ [W] \qquad (3)$$

Where

n is the number of individual luminaires in the area defined in the lighting system design.

Details of the standby power and energy calculation and requirements are provided in Annex H.

6.4.3.4 Occupancy dependency factor (F_O)

The occupancy dependency factor F_o shall be calculated by the following process:

$$F_O = 1{,}0 \qquad (4)$$

F_O shall be taken to equal 1,0 when:

- the lighting is switched on 'centrally', i.e. in more than one room at once (e.g. a single automatic system – for instance with timer or manual switch for an entire building, or for an entire floor, or for all corridors etc.). This applies regardless of the type of 'off-switch' (automatic or manual, central or per room etc.).
- multi-occupancy or traffic areas larger than 30 m^2 are illuminated by a group of luminaires that are (manually or automatically) switched together.

$$F_o < 1{,}0 \qquad (5)$$

F_O shall be taken as less than 1,0:

- in meeting rooms (whatever the area covered by one switch and/or by one detector), as long as they are not switched on 'centrally', i.e. together with luminaires in other rooms.
- in other rooms where F_o is not deemed to be equal to 1,0. In the case of systems with automatic presence and/or absence detection the area covered by the detector should closely correspond to the area illuminated by the luminaires that are controlled by that detector.

In these instances, F_o shall be determined as follows:

$$F_o = 1 - [(1 - F_{oc}) \times F_A / 0{,}2] \qquad (6)$$

When $0{,}0 \le F_A < 0{,}2$

$F_o = F_{oc} + 0,2 – F_A$ (7)

When $0,2 \le F_A \le 0,9$

$F_o = [7 - (10 \times F_{oc})] \times (F_A – 1)$ (8)

When $0,9 \le F_A \le 1,0$

Where F_A is the proportion of the time that the space is unoccupied and F_{oc} is determined as a function of the lighting control system.

Details of the estimation of F_o, F_A and F_{oc} are given in Annex E.

6.4.3.5 Daylight dependency factor (F_D)

The daylight dependency factor F_D shall be calculated for a room or zone in the building as a function of the daylight supply factor $F_{D,S}$ and the daylight dependent electric lighting control factor $F_{D,C}$ by the equation:

$F_D = 1 – (F_{D,S} \times F_{D,C})$ (9)

The method for the determination of the daylight supply factor $F_{D,S}$ and the daylight dependent electric lighting control factor $F_{D,C}$ are given in Annex F.

6.4.3.6 Constant illuminance dependency factor (F_C)

The constant illuminance dependency factor (F_C) shall be taken as the ratio of the average input power at a specified time to the initial installed input power to the luminaire. The specified time shall be taken to be the period specified in the maintenance schedule for one complete maintenance cycle.

The constant illuminance dependency factor F_c shall be calculated by the equation:

$$F_c = 1 - \frac{1}{2} F_{cc} (1 - MF)$$ (10)

Where F_{cc} is the efficiency factor of the constant illuminance control;

MF is the maintenance factor for the scheme.

Details of the maintenance factor compensation are provided in Annex G.

For technologies with inbuilt constant light output capabilities used in systems without constant illuminance sensing the F_c value shall be based upon *LLMF* as described in Annex G.

6.4.3.7 Energy calculation

The total estimated energy required for lighting for a period in a room or zone of the building shall be estimated by using the equation:

$W_t = W_{L,t} + W_{P,t}$ [kWh / t_s] (11)

Where $W_{L,t}$ is the estimated lighting energy required to fulfil the illumination function in a room or zone of the building, it shall be established using the following equation:

$W_{L,t} = \Sigma\{(P_n \times F_c) \times F_o [(t_D \times F_D) + t_N]\}/1\,000$ [kWh / t_s] (12)

Where $W_{P,t}$ is the estimated standby energy required during non-lighting periods to provide charging energy for emergency lighting and the activation energy for lighting controls in a room or zone of the building, it shall be established using the following equation:

$W_{P,t} = \Sigma\{\{P_{pc} \times [t_s – (t_D + t_N)]\} + (P_{em} \times t_e)\}/1\,000$ [kWh / t_s] (13)

NOTE 1 The total lighting energy can be estimated for any required time step period t_s (hourly, monthly or yearly) in accordance with the time interval of the dependency factors used.

NOTE 2 This estimation does not include the power consumed by control systems remote from the luminaire and not drawing power from the luminaire.

The annual energy for electric lighting within a building shall be calculated using the equation:

$$W = 8760 / t_s \times \Sigma\, W_t \text{ [kWh / year]} \tag{14}$$

summed across all rooms and zones within the building.

The LENI for the building shall be established using the following equation:

$$LENI = W/A \text{ [kWh / (m}^2\text{ x year)]} \tag{15}$$

where

W is the total annual energy used for lighting [kWh / year];

A is the total useful floor area of the building [m^2].

6.5 Expenditure factors for lighting systems

The efficiency of a given lighting system can be indicated by the expenditure factor. It does not affect the determination of the energy required for lighting. Instead it can be derived by correlation of the previously derived values. Applying this methodology allows a quick analysis of the energy flows in an electric lighting system, separately for each of its technical components. As specific conventions are required for the energy assessment of lighting systems, such as luminous efficacy and luminous intensity distribution, the absolute values received for the expenditure factor are specific for lighting and cannot be directly compared with other technical building services. For further information consult CEN/TR 15193-2.

The expenditure factor for lighting systems is defined as:

$$e_{\mathrm{L}} = \frac{W_{\mathrm{us}}}{W_{\mathrm{nd}}} \tag{16}$$

It can be derived by the following formal separation of the individual influences:

$$e_{\mathrm{L}} = e_{\mathrm{L,C}} \cdot e_{\mathrm{L,O}} \cdot e_{\mathrm{L,D}} \cdot e_{\mathrm{L,ES}} \tag{17}$$

where

W_{us} is the energy used for lighting;

W_{nd} is the energy needed for lighting;

e_L is the expenditure factor for lighting systems;

$e_{L,C}$ is the partial expenditure factor for constant illuminance control;

$e_{L,O}$ is the partial expenditure factor for occupancy dependent lighting control;

$e_{L,D}$ is the partial expenditure factor for daylight dependent lighting control;

$e_{L,ES}$ is the partial expenditure factor for the electric lighting system.

The partial expenditure factor for constant illuminance control is calculated using equation (18):

$$e_{L,C} = \frac{1-\frac{1}{2}F_{CC}(1-MF)}{1-\frac{1}{2}(1-MF)} \tag{18}$$

Where

F_{cc} is the factor for the efficiency of the constant illuminance control.

The partial expenditure factor for occupancy dependent lighting control is calculated using equation (19):

$$e_{L,O} = \frac{F_O}{(1-F_A)} \tag{19}$$

The partial expenditure factor for daylight dependent lighting control is calculated using equation (20):

$$e_{\mathrm{L,D}} = \frac{A_{\mathrm{D}}(t_{\mathrm{Day}} \cdot (1-F_{\mathrm{D,S}} \cdot F_{\mathrm{D,C}}) + t_{\mathrm{Night}}) + A_{\mathrm{ND}}(t_{\mathrm{Day}} + t_{\mathrm{Night}})}{A_{\mathrm{D}}(t_{\mathrm{Day}} \cdot (1-F_{\mathrm{D,S}}) + t_{\mathrm{Night}}) + A_{\mathrm{ND}}(t_{\mathrm{Day}} + t_{\mathrm{Night}})} \tag{20}$$

Where

A_{D} is the area lit by daylight;

A_{ND} is the area not lit by daylight, which can be derived by total area A - A_{D}.

The partial expenditure factor for the electric lighting system is calculated using equation (21):

$$e_{\mathrm{L,ES}} = \frac{P}{P_{\mathrm{e}}} \tag{21}$$

It can be derived by the formal separation of the different effects using equation (22):

$$e_{\mathrm{L,ES}} = e_{\mathrm{L,ES,del}} \cdot e_{\mathrm{L,\,ES,\,dis}} \cdot e_{\mathrm{L,ES,gen}} \tag{22}$$

Where

P is the installed electric power density [W/m²];

P_e is the electrical evaluation power density for determination of the energy use [W/m²];

$e_{\mathrm{L,ES,del}}$ is the partial expenditure factor for delivery of electric light;

$e_{\mathrm{L,ES,dis}}$ is the partial expenditure factor for distribution of electric light;

$e_{\mathrm{L,ES,gen}}$ is the partial expenditure factor for generation of electric light.

The partial expenditure factor for delivery of electric light is calculated using equation (23):

$$e_{\mathrm{L,ES,del}} = \frac{F_{\mathrm{U,e}}}{F_{\mathrm{U}}} \tag{23}$$

Where

F_u is the utilization factor;

$F_{u,\mathrm{e}}$ is the utilization factor for determination of the energy use.

The utilization factor for the determination of the energy use $F_{u,e}$ can be derived using Table 6, in dependence of the room index.

Table 6: Utilization factor for determination of the energy use $F_{u,e}$ as a function of the room index.

Room index *k*	**0,6**	**0,8**	**1**	**1,25**	**1,5**	**2**	**2,5**	**3**	**4**	**5**
Utilization factor $F_{u,e}$	**0,50**	**0,61**	**0,69**	**0,78**	**0,84**	**0,90**	**0,95**	**0,99**	**1,03**	**1,05**
NOTE Intermediate values of the room index can be interpolated.										

The partial expenditure factor for distribution of electric light is calculated using equation (24):

$$e_{\mathrm{L,ES,dis}} = \frac{1}{\eta_{\mathrm{LB}}} \tag{24}$$

Where

η_{LB} is the luminaire light output ratio.

The partial expenditure factor for generation of electric light is calculated using equation (25):

$$e_{\mathrm{L,ES,gen}} = \frac{140 \cdot f_B}{\eta_{\mathrm{L}}} \tag{25}$$

where

140 is the value of the reference lamp luminous efficacy [lm/W];

η_{L} is the lamp luminous efficacy [lm/W];

f_B is the efficiency of the operating device.

When applying the tabular method given in 6.4.3.1, the partial expenditure factor for the electric lighting system can simplistically be calculated using equation (26):

$$e_{\mathrm{L,ES}} = 1{,}75 \cdot \frac{P_{\mathrm{j,lx}}}{P_{\mathrm{j,lx,direct}}} \cdot k_{\mathrm{L}} \tag{26}$$

7 Method 2 - Quick calculation of the energy required for lighting

7.1 Output data

The specified time step (t_s) [yearly].

The preliminary *LENI*, which is the area normalized annual energy used for lighting within the building [kWh / m² year]. The value may also be taken as the annual energy demand for lighting W_L [kWh / m² year].

The summation of annual energy for electric lighting within the building (W) [kWh / year].

7.2 Calculation time steps

The time step is yearly - Taken as 8 760 hours.

7.3 Input data

7.3.1 Lighting system data

For the quick calculation method the energy estimation shall be based upon the electric lighting system that provides lighting in accordance with the requirements for non-domestic buildings of EN 12464-1 for lighting of indoor work places or EN 12193 for lighting of sports facilities and for domestic buildings. See recommendations in CEN/TR 15193-2 for the lighting criteria.

It is important that for all buildings the lighting solution shall combine daylight and electric light to fulfil all legal requirements and the general and specific lighting criteria for the places within the buildings.

The lighting scheme design process of the electric lighting system for all rooms and zones within the building shall deliver as output the required type and number of luminaires and these shall be listed in the product schedule.

In the case where the alternative calculation methods are used the lighting system data, as provided by the optional calculation methods, may be applied.

7.3.2 Product data

7.3.2.1 General

Where the quick method is being used the unique product characteristics shall be specified (e.g. lamp type and flux emission).

7.3.2.2 Product description data (qualitative)

The product description data shall indicate the product characteristics and state the functional capabilities regarding dimming control, integral detectors and emergency lighting facility.

7.3.2.3 Product technical data

Default values for standby energy density are given in Annex B.

7.3.3 System design data

Calculations shall be made for each room, zone or building to establish the installed lighting power and to estimate the impact of occupancy, daylight and over design/maintenance factors on the lighting controls by determining the values of the dependency factors, F_o, F_D and F_c.

Technologies with inbuilt constant light output capabilities used in systems without constant illuminance sensing the F_c value shall be based on *LLMF* as described in Annex G.

7.3.4 Operating conditions

The operating conditions for the lighting system shall be specified to fulfil the relevant lighting criteria and requirements for the tasks or activity in a room, zone or building and shall be managed by controls. The controls shall be manually or automatically operated. Details of control types and their operation and effectiveness are given in CEN/TR 15193-2.

Information on default occupancy patterns in buildings are given in EN 15251 and in Annex B.

7.3.5 Constants and physical data

Annual operating hours (t_y) – defined as 8 760 [h].

7.4 Calculation procedure

7.4.1 Applicable time step

The time step of the output shall be yearly.

7.4.2 Operating conditions calculation

The default occupancy hours for the building type shall be obtained from EN 15251.

Default values are also provided in Annex B.

7.4.3 Energy calculation

7.4.3.1 General

The quick calculation method is shown in Figure 3.

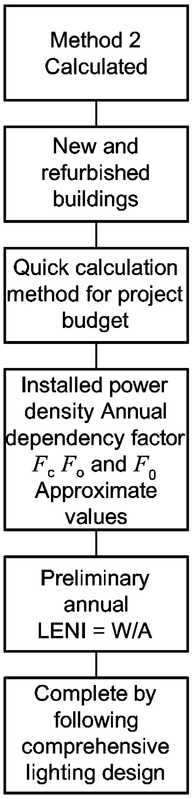


Figure 3 – Flow diagram for quick method of lighting energy calculation

7.4.3.2 Installed power calculation

At the preliminary, conceptual stage for a new design or refurbishment of a building the budget installed power (P_n) required for electric lighting for an area may be estimated by the procedure described in Annex C.

The final installed power shall be calculated by using the comprehensive lighting system design process.

Default installed power load for domestic buildings is given in Annex B.

7.4.3.3 Standby system power requirements

Default data for the required standby energy for battery charging of emergency luminaires (W_{pe}) and for standby energy for automatic lighting controls (W_{pc}) are provided in Annex B.

7.4.3.4 Occupancy dependency factor (F_o)

Default values for F_o can be obtained in Annex B.

7.4.3.5 Daylight supply dependency factor (F_D)

7.4.3.5.1 Vertical façades

The quick method for estimating F_D for vertical façades shall be calculated by selecting the zone segmentation as described in F.2 and use of the following three equations:

$$D = 0,34\ (4,13 + 20\ I_{Tr,j} - 1,36\ I_{RD}) \tag{27}$$

Where

$$I_{Tr,j} = \frac{A_{Ca}}{A_D} \tag{28}$$

and

$$I_{RD,j} = \frac{a_D}{h_{Li} - t_{Ta}} \tag{29}$$

Details for equations (28) and (29) are given in F.3.1.

For south facing façades with shading or glare protection use:

$$F_{D,S} = 0,65\ F_{D,S,SNA} + 0,07 \tag{30}$$

For south facing façades without shading or glare protection, or for east, west and north facing façades use:

$$F_{D,S} = 0,65\ F_{D,S,SNA} + 0,25 \tag{31}$$

Values for $F_{D,S,SNA}$ for various daylight factors (D) are given in Annex B.

Then

$$F_D = 1 - 0,52\ F_{D,S} \tag{32}$$

7.4.3.5.2 Roof lights

The quick method for estimating F_D for vertical façades shall be calculated by selecting the zone segmentation as described in F.2 and use of the following two equations:

Values for η_R for various room indices (k) are given in Annex B.

$$\overline{D}_{SNA} = 0,54 \cdot \tau_{D65} \cdot \frac{\sum A_{Ca}}{A_D} \cdot \eta_R \tag{33}$$

Values for $F_{D,S}$ for various daylight factors (D) are given in Annex B.

Then

$$F_D = 1 - 0,52\ F_{D,S} \tag{32}$$

7.4.3.6 Constant illuminance dependency factor (F_c)

Default values for F_c are provided in Annex B.

7.4.3.7 Energy calculation

$$LENI = \{F_c \times (P_j / 1000) \times F_o [(t_D \times F_D) + t_N]\} + 1 + \{1,5 / t_y \times [t_y - (t_D + t_N)]\} \text{ [kWh / (m}^2\text{ year)]} \quad (34)$$

Where

LENI is the Lighting Energy Numeric Indicator [kWh / m² year]. The value may also be taken as the annual energy demand for lighting W_L [kWh / m² year];

F_c is constant illuminance factor;

P_j is the power density of the area [W/m²];

F_o is the occupancy dependency factor;

t_D is daylight time [h];

F_D is the daylight dependency factor;

t_N is the daylight absence time [h];

t_y are the annual operating hours [h].

NOTE If national values are not available in Annex NA or Annex NB the default values for P_n (domestic), t_D, t_N, F_c, F_D, F_O, W_{pe} and W_{pc} which are given in Annexes B, E, F, G and H should be used.

The annual energy required for electric lighting within the building shall be established using equation (15).

7.5 Expenditure factors for lighting systems

For a description of the expenditure factor calculation see 6.5

8 Method 3 - Metered energy used for lighting

8.1 Output data

The output data of this method are listed in table 7

Table 7 - Output data of this method:

Description	Symbol	Unit	Intended destination module
specified time step	*ts*		all
energy used for lighting per time step within rooms or zones	W_t	kWh	MX-X
summation of annual energy for electric lighting within the building	W	kWh	MX-X

The *LENI*, which is the area normalized annual energy used for lighting within the building [kWh / m² year].

8.2 Calculation time steps

The energy shall be measured in real time intervals in accordance with requirements.

The time step of the output may be:

- yearly;
- monthly; or

- hourly.

8.3 Input data

The segregated energy meters shall only record the energy used for lighting in the various parts of the building.

8.4 Calculation procedure of annual energy

The energy used for electric lighting W_t for time step t_s shall be obtained from the meter reading.

The total metered energy (W_{mt}) used for electric lighting in the building for time step (t_s) [h] shall be calculated by summation of the energy usage reported by each meter for all the meters used for measurement in different parts of the building.

$$W_{mt} = \Sigma\ W_t \text{ [kWh } t_s^{-1}\text{]} \tag{35}$$

The annual energy for electric lighting within a building shall be calculated using the equation:

$$W = 8760 / t_s \times W_{mt} \text{ [kWh year}^{-1}\text{]} \tag{36}$$

where t_s is expressed in hours.

The LENI for the building shall be established using equation (15).

9 Quality control

9.1 Method 1

The quality of the results depends on the accuracy of the input data and the estimation of the dependency factors.

The accuracy of the dependency factors shall be optimized through the use of the comprehensive design method. The tolerances of all factors and assumptions used to derive them shall be declared.

NOTE The precision of the dependency factors are directly related to the prevailing climate conditions and human activity in and around the building.

The calculation report shall include the values of the following data:

Summation of annual energy for electric lighting within the building *W*

9.2 Method 2

This method provides budget energy values. The quality of the results is limited by the accuracy of the assumptions within the input data and the estimation of the default dependency factors.

The calculation report shall include the values of the following data:

Budget energy values *W*

NOTE The precision of the dependency factors are directly related to the variance between the default assumptions and the true prevailing climate conditions and human activity in and around the building.

9.3 Method 3

The calculation report shall include the values of the following data:

Summation of annual energy for electric lighting within the building *W*

The quality of the results depends on the metering circuit integrity and the accuracy of the meter(s).

The energy or power meters shall conform to the requirements for Class C as defined in EN 50470.

NOTE The circuit integrity assumes that all relevant luminaires and components are connected to the measurement meter.

10 Compliance check

10.1 Method 1

Compliance shall be verified by inspection during commissioning and at the planned maintenance cycle, and by measurements.

Inspection shall be made during the commissioning of the lighting scheme, ensuring the correct products have been installed, wiring and interconnections are correct and the system operates and communicates in accordance with the design.

Inspection shall be repeated at each planned maintenance cycle when the lighting components and systems are serviced and maintained to ensure they continue to operate correctly.

Commissioning and inspections in both new and existing buildings will have a major impact upon the efficiency and future energy usage of the installation. Inspections shall be scheduled and structured to ensure the lighting system operates efficiently throughout its working life.

The energy usage of the electric lighting installation shall be verified by metering.

10.2 Method 2

This method provides a budget energy value. For accuracy and to ensure compliance to standards and regulations during detailed design of the building, the comprehensive calculation of method 1 shall be performed.

10.3 Method 3

The energy usage of the electric lighting installation shall be verified by metering as described in Clause 7.

Annex A
(normative)
Input and method selection data sheet

A.1 Method selection

For the correct use of this standard the template given in this Annex shall be used to specify the choices between methods and the required input data.

NOTE 1 Informative default choices are provided in Annex B.

NOTE 2 Following this template is necessary but not enough to guarantee consistency of data.

NOTE 3 In particular for the application within the context of EU Directives transposed into national legal requirements. These choices (either the informative default choices from Annex B or choices adapted to national/regional needs), but in any case following the template of this Annex A) can be made available as National Annex or as separate (e.g. legal) document. The latter implies that the values and choices may be imposed by national/regional regulations for that purpose.

This standard offers calculation methods, with different levels of accuracy for the installed power, occupancy estimation and daylight availability, i.e. input parameters to equation (12) (6.4.3.7) These can be combined in national adaptions in accordance with the accuracy needed for the different influences. Exemplarily the lighting energy demand can be computed with the installed power in accordance with Annex C and the daylight supply factor in accordance with Annex F.

A.2 Default input data

Table A.1 – Default values of parameters of glazings and rooflights

Parameters of glazings and rooflights	Description
$\tau_{D65,SNA}$ (Vertical façades)	is the transmittance of the façade glazing for vertical light incidence;
$\tau_{D65,SNA}$ (roof lights)	is the transmittance of the diffusive roof light glazing when shading is not activated;
$\tau_{D65,SA}$ (roof lights)	is the transmittance of the diffusive roof light glazing when shading is activated;
$\tau_{Sh,In,At,D65}$	is the transmittance of the atrium glazing for vertical light incidence
$\tau_{Sh,GDF,D65}$	is the transmittance of the external layer of glazing of the façade, for vertical light incidence
$\gamma_{Sh,lsh}$	linear shading altitude angle
k_1, $k_{Sh,In,At,1}$, $k_{Sh,GDF,1}$, $k_{Obl,1}$	is the framing factor for frames

Parameters of glazings and rooflights	Description
$\tau_{D65,SNA}$ (Vertical façades)	is the transmittance of the façade glazing for vertical light incidence;
$\tau_{D65,SNA}$ (roof lights)	is the transmittance of the diffusive roof light glazing when shading is not activated;
$\tau_{D65,SA}$ (roof lights)	is the transmittance of the diffusive roof light glazing when shading is activated;
$k_{,2}$, $k_{Sh,In,At,2}$, $k_{Sh,GDF,2}$, $k_{Obl,2}$	is the dirt on glazing factor
$k_{,3}$,$k_{Sh,In,At,3}$, $k_{Sh,GDF,3}$, $k_{Obl,3}$	is the reduction factor for diffuse light incidence (usually 0,85 is considered to be adequate)
$F_{D,s,SA,j}$	system solution for sun shading activated

Annex B
(informative)
Input data sheet with CEN values and choices

B.1 Introduction

All tables in this Annex have the same lay-out as the corresponding tables in the template in Annex A. But in this Annex B these are completed with informative default values and informative default choices.

NOTE 1 In future versions of this standard some of the informative default values and choices may become mandatory.

NOTE 2 Using the default values will not guarantee consistency of data.

NOTE 3 In particular for the application within the context of EU Directives transposed into national legal requirements. These choices (or choices adapted to national/regional needs) can be made available as National Annex or as separate (e.g. legal) document, using the template in Annex A.

B.2 Method 1

B.2.1 Product description data

B.2.2 Product technical data tables

B.2.3 System design data

B.3 Method 2

B.3.1 Product description data

B.3.2 Product technical data tables

B.3.3 System design data

This subclause contains a set of default values for the quick estimation of the energy requirements for lighting within buildings. They are suitable for use in the preliminary design stage for energy estimation. These values may be replaced by alternative national standard values.

B.3.3.1 Standby energy density

Purpose	Symbol	Default annual energy density kWh / m² year]
Battery charging of emergency luminaires	W_{pe}	1
Standby energy for automatic lighting controls	W_{pc}	1,5

B.3.3.2 Annual operating hours

Building type	Default annual operating hours		
	t_D	t_N	t_{tot}
Domestic buildings	1 820	1 680	3 800

Offices	2 250	250	2 500
Education buildings	1 800	200	2 000
Hospitals	3 000	2 000	5 000
Hotels	3 000	2 000	5 000
Restaurants	1 250	1 250	2 500
Sports facilities	2 000	2 000	4 000
Wholesale and retail services	3 000	2 000	5 000
Manufacturing factories	2 500	1 500	4 000

B.3.3.3 Daylight supply factor for vertical façades

D [%]	0,13	0,5	1,0	1,5	2,0	3,0	5,0	8,0	12,0	18,0
$F_{D,S,SNA}$ [%]	12,1	36,1	49,6	63,5	66,4	75,2	81,1	87,7	90,8	91,4

B.3.3.4 Daylight supply factor for roof lights

η_R as function of room index *k*.

k	0,6	0,8	1,0	1,25	1,5	2,0	2,5	3,0	4,0	5,0
η_R	0,4	0,54	0,6	0,69	0,75	0,83	0,88	0,92	0,97	1,00

$F_{D,S}$ as function for D, where D is classified in accordance with Table F.11.

D [%]	None	Low	Medium	Strong
$F_{D,S}$	0	0,68	0,85	0,92

B.3.3.5 Occupancy dependency factor (F_O)

The F_o values provided in the table are a function of F_A and the lighting control system. The calculation of F_A is given in Annex E.

F_A	0,0	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1,0
Manual on/off switch	1,000	1,000	1,000	0,900	0,800	0,700	0,600	0,500	0,400	0,300	0,000
Manual on/off switch + additional automatic sweeping extinction signal	1,000	0,975	0,950	0,850	0,750	0,550	0,650	0,450	0,350	0,250	0,000
Auto on/dimmed	1,000	0,975	0,950	0,850	0,750	0,550	0,650	0,450	0,350	0,250	0,000
Auto on/auto off	1,000	0,950	0,900	0,800	0,700	0,600	0,500	0,400	0,300	0,200	0,000

Manual on/dimmed	1,000	0,950	0,900	0,800	0,700	0,600	0,500	0,400	0,300	0,200	0,000
Manual on/auto off	1,000	0,900	0,800	0,700	0,600	0,500	0,400	0,300	0,200	0,100	0,000

B.3.3.6 Constant illuminance dependency factor (F_c)

Building type	**Lighting system, environment and servicing**	***MF***	F_C
Any building	Non-dimmable lighting system.	Any	1,00
Restaurant	Tungsten halogen spot lamps in dimmable recessed downlights in clean environment, spot replacement of failed lamps.	0,9	0,95
Hospital	Linear fluorescent lamps in open pendant HF dimmable luminaires in very clean environment, luminaires cleaned annually, spot replacement of failed lamps and bulk lamp change at 20 000 h.	0,8	0,90
Office	LED light source (L_{80} at 30 000 h) in surface mounted dimmable enclosed luminaire, clean environment, luminaires cleaned annually.	0,7	0,85
Factory	Trunking mounted open HF dimmable fluorescent lamp luminaires, dirty environment, biannual bulk lamp change and luminaire clean.	0,6	0,80

B.3.3.7 Installed power domestic buildings

			Optimized lighting solution [W]			Standard lighting solution [W]		
		E (lux)	Small	Medium	Large	Small	Medium	Large
Kitchen	General and ambient lighting	150	20	30	40	60	80	120
	Worktop lighting	300	30	30	30	90	90	90
Dining room	General and ambient lighting	150	35	50	75	100	135	200
	Dining table lighting	300	35	35	35	120	120	120
Living room	General and ambient lighting	150	35	50	75	100	135	200
	Reading lights	300	25	25	25	60	60	60
Bathroom and toilets	General and ambient lighting	100	20	30	40	50	70	100
	Mirror lighting	300	25	25	25	70	70	70
Bedroom	General and ambient lighting	100	30	50	70	90	110	140
	Bedside lamps	300	10	10	10	30	30	30
	Desk lamps	300	20	20	20	50	50	50
Entrance hall, corridors and stairs	General and ambient lighting	100	20	30	40	40	60	80
Storeroom, cellar and laundry room	General and ambient lighting	200	25	35	50	60	80	120

Assumed efficacy of the optimized lighting solution is 60 lm/W and the standard lighting solution is 15 lm/W.

For the definition of small, medium and large room see B.2.3.8.

Further information is given in CEN/TR 15193-2.

B.3.3.8 Useful areas in domestic buildings

		Area (m²)		
		Small	Medium	Large
Kitchen	General and ambient lighting	6 - 8	8 - 10	10 - 12
	Worktop lighting	2	2	2
Dining room	General and ambient lighting	8 - 12	12 - 16	16 - 20
	Dining table lighting	3	3	3
Living room	General and ambient lighting	8 - 12	12 - 16	16 - 20
	Reading lights	1	1	1
Bathroom and toilets	General and ambient lighting	4 - 6	6 - 8	8 - 10
	Mirror lighting	1	1	1
Bedroom	General and ambient lighting	6 - 8	8 - 12	12 - 16
	Bedside lamps	1	1	1
	Desk lamps	1	1	1
Entrance hall, corridors and stairs	General and ambient lighting	1 - 3	3 - 5	5 - 7
Storeroom, cellar and laundry room	General and ambient lighting	4 - 6	6 - 8	8 - 10

Further information is given in CEN/TR 15193-2.

B.4 Method 3

No default data.

Annex C
(normative)
Simplified Method for Installed Power Estimation

The budget installed power required for new electric lighting systems shall be estimated using a standard set of assumptions and procedures.

C.1 Installed power assessment for tertiary buildings

The budget installed power required for an area in the building is estimated using equation (C.1):

$$P_n = P_j \times A \text{ [W]} \quad \text{(C.1)}$$

Where

A is the relevant area in the building [m²].

The power density for the lighting in an area of building may be assessed using equation (C.2):

$$P_j = P_{j \cdot lx} \times E_{task} \times F_{MF} \times F_{CA} \times F_L \quad \text{(C.2)}$$

Where:

P_j is the power density of the area [W/m²];

$P_{j.lx}$ is the power density per lux of the area [W/lx];

E_{task} is the maintained illuminance that the lighting system will be designed to provide [lx];

F_{MF} is the correction factor to account for the maintenance factor that will be used in the lighting system design;

F_{CA} is the factor to account for the reduced power required if parts of the area are lit to a lower level

F_L is the correction factor to account for the efficiency of the lighting equipment that will be used in the lighting system.

Evaluation of $P_{j.lx}$

The value of $P_{j.lx}$ is dependent on the photometric distribution of the luminaires used and the shape of the room that they are illuminating. The shape of the room is classified in accordance with its room index (k) which may be evaluated using equation (C.3).

$$k = \frac{L_R \times w_R}{h_m \left(L_R + w_R\right)} \quad \text{(C.3)}$$

Where:

L_R is the length of the room [m];

w_R is the width of the room [m];

h_m is the height of the luminaires above the working plane in the room [m].

If the calculated room index (k) results in a value below 0,6 then the tabular method of estimating installed power should not be used. If the room index is found to be greater than 5,0 then the value for 5,0 should be used in looking up the value of power density per lux in Table C.1.

Table C.1 gives values of the power density per lux for values of room index between 0,6 and 5,0 for luminaires with upward flux fractions (UFF) of 10 %, 30 %,70 % and 90 %.

Table C.1 Values of power density per lux for various photometric distributions and room indices

	Upward Flux Fraction (description of flux emission)			
k	**10 % (direct)**	**30 % (direct / indirect)**	**70 % (indirect / direct)**	**90 % (indirect)**
0,60	0,037	0,043	0,064	0,087
0,80	0,032	0,038	0,053	0,070
1,00	0,030	0,035	0,046	0,060
1,25	0,027	0,033	0,041	0,051
1,50	0,026	0,031	0,037	0,046
2,00	0,024	0,029	0,033	0,039
2,50	0,023	0,028	0,030	0,035
3,00	0,022	0,027	0,029	0,032
4,00	0,021	0,026	0,026	0,029
5,00	0,021	0,025	0,025	0,027

Evaluation of F_{MF}

The lighting scheme shall be designed with an overall maintenance factor (*MF*) calculated for the selected lighting equipment, environment and specified maintenance schedule. More information on the derivation of maintenance factors is given in CIE 97[1]. Once the overall maintenance factor (*MF*) for the installation is determined, equation (C.4) may be used to calculate the correction factor to account for the maintenance factor (F_{MF}).

$$F_{MF} = \frac{0,8}{MF} \tag{C.4}$$

Where 0,8 is the reference maintenance factor;

MF is the selected maintenance factor.

Correctly deriving the maintenance factor (*MF*) is a complex procedure where it is necessary to consider the light source luminous maintenance factor (*LLMF*), the light source survival factor (*LSF*), the luminaire maintenance factor (*LMF*) and the room surface maintenance factor (*RSMF*). The maintenance factor thus depends on the lighting equipment chosen, the installation and the room being lit together with the maintenance cycle. Overall maintenance factors are typically in the range 0,6 to 0,9. The list below gives some examples of installations for particular *MF* values.

0,6 - An open HF luminaire with fluorescent lamps in a dirty factory where the lamps are replaced and the luminaires cleaned every two years (16 000 h).

[1] CIE 97 Guide on the Maintenance of Indoor Electric Lighting Systems

0,7 - A LED closed luminaire in a clean office where the luminaires are cleaned every year and the light sources replaced when they reach L_{80} (typically 30 000 h).

0,8 - A fluorescent open HF luminaire in a clean office where failed lamps are spot replaced and bulk changed every 20 000 h (typically six years) and the luminaires are cleaned every year.

0,9 - Lighting using tungsten halogen spot lamps.

HF denotes high frequency operation.

Evaluation of F_{CA}

Where only part of the area of the room contains task areas then it is possible to reduce the illuminance on the area that does not have defined tasks to the level given in EN 12464-1 for the area immediately surrounding the task.

Table C.2 gives the required background illuminances associated with particular values of task illuminance.

Table C.2 Relationship of illuminances on immediate surroundings to the illuminated task area

Illuminances on the task areas E_{task} [lx]	Illuminances on the immediate surrounding areas E_{SUR} [lx]
≥ 750	500
500	300
300	200
200	150
150	E_{task}
100	E_{task}
< 50	E_{task}
NOTE This table is taken from Table 1 of EN 12464-1:2011	

In many room layouts some areas may be well away from task areas, in some cases it may be permissible to reduce the illuminance below the values given for the immediate surround area. However, it is not possible to assess the additional energy saving in such rooms.

Once the illuminance on the surrounding areas has been determined then F_{CA} can be evaluated by equation (C.5):

$$F_{CA} = \frac{A_s \times E_{task} + (A - A_s) \times E_{sur}}{E_{task} \times A} \qquad \text{(C.5)}$$

Where

A is the area of the room [m^2];

A_s is the sum of the task areas within the room [m^2].

Evaluation of F_L

The correction factor to account of the efficiency of the lighting equipment F_L may be found in Table C.3 which gives the values for luminaires with common lamp types. The table is based on a survey of a large number of luminaires and gives the median value for all luminaires surveyed with a particular lamp type.

Table C.3 – Values for F_L

Lamp Type	F_L
Metal halide	0,99
Compact fluorescent lamp (CFL)	1,56
Light emitting diode (LED)	0,86
T16 linear fluorescent lamp	0,90
T26 linear fluorescent lamp	0,95
Tungsten Halogen	4,49
High pressure sodium	1,01
Tungsten	6,38

C.2 Installed power assessment for domestic buildings

The lighting power required for a domestic building shall be calculated by the summation of the power rating of each lamp installed in a room or area.

Guidance on the installed lighting power requirements is given in CEN/TR 15193-2.

Annex D
(normative)
Assessment of the installed power for lighting systems in existing buildings

In existing buildings where the individual luminaire power (P_i) is known the total power (P_n) can be calculated by the summation of the rated power of each installed luminaire.

$$P_n = \sum_{i=1}^{i=n} P_i \; [W] \qquad \text{(D.1)}$$

Where n is the number of individual luminaires in the area defined in the lighting system.

In existing buildings where the luminaire power (P_i) is not known this power can be estimated as:

a) P_i = (the lamp rated power) × (number of lamps in the luminaire) (D.2)

b) for lamps operating directly on mains supply voltage e.g. mains voltage incandescent lamps, self-ballasted fluorescent lamps etc.

c) P_i = 1,2 × (the lamp rated power) × (number of lamps in the luminaire) (D.3)

d) for lamps connected to the mains supply via a ballast or transformer in the luminaire.

NOTE If emergency lighting and automatic controls are included in the installation the standby power to these can be ignored or the default values used.

Annex E
(normative)
Occupancy Estimation

This annex describes the analyses and rules to be followed to determine F_o. Whatever control system is used, if F_o is taken as 1,0, no further analyses are needed.

In the circumstances described below, F_o shall always be less than 1,0:

- in meeting rooms (whatever the area covered by one switch and/or by one detector), as long as they are not switched on 'centrally', i.e. together with luminaires in other rooms.

- in other rooms, if the area illuminated by a luminaire or by a group of luminaires that are (manually or automatically) switched together, is not larger than 30 m^2, and if the luminaires are all in the same room. In addition, in the case of systems with automatic presence and/or absence detection the area covered by the detector should closely correspond to the area illuminated by the luminaires that are controlled by that detector.

In both cases, also the conditions with respect to timing and dimming level outlined below should be fulfilled. (If these conditions are not satisfied, F_o = 1,0)

In the expressions for determining F_o the default value of F_{oc} is fixed as a function of the lighting control system, as given in Table E.1 and the default value of F_A is determined at either building or room level, as given in Table E.2.

For systems without automatic presence or absence detection the luminaire should be switched on and off with a manual switch in the room.

An automatic signal may also be included which automatically switches off the luminaire at least once a day, typically in the evening to avoid needless operation during the night.

For systems with automatic presence and/or absence detection the following situations are valid:

- 'Auto On / Dimmed': the control system automatically switches the luminaire(s) on whenever there is presence in the illuminated area, and automatically switches them to a state with reduced light output (of no more than 20 % of the normal 'on state') no later than 15 minutes after the last presence in the illuminated area. In addition, no later than 15 minutes after the last presence in the room as a whole is detected, the luminaire(s) are automatically and fully switched off.

- 'Auto On / Auto Off': the control system automatically switches the luminaire(s) on whenever there is presence in the illuminated area, and automatically switches them entirely off no later than 15 minutes after the last presence is detected in the illuminated area.

- 'Manual On / Dimmed': the luminaire(s) can only be switched on by means of a manual switch in (or very close to) the area illuminated by the luminaire(s), and, if not switched off manually, is/are automatically switched to a state with reduced light output (of no more than 20 % of the normal 'on state') by the automatic control system no later than 15 minutes after the last presence in the illuminated area. In addition, no later than 15 minutes after the last presence in the room as a whole is detected, the luminaire(s) are automatically and fully switched off.

- 'Manual On / Auto Off': the luminaire(s) can only be switched on by means of a manual switch in (or very close to) the area illuminated by the luminaire(s), and, if not switched off manually, is automatically and entirely switched off by the automatic control system no later than 15 minutes after the last presence is detected in the illuminated area.

Table E.1 — F_{OC} values

Systems without automatic presence or absence detection	F_{OC}
Manual On/ Off Switch	1,00
Manual On/ Off Switch + additional automatic sweeping extinction signal	0,95
Systems with automatic presence and/or absence detection	
Auto On/ Dimmed	0,95
Auto On/ Auto Off	0,90
Manual On/ Dimmed	0,90
Manual On/ Auto Off	0,80

Table E.2 — F_A values

Overall building calculation		**Room by room calculation**		
Building type	F_A	**Building type**	**Room type**	F_A
Domestic buildings	0,00	**Domestic buildings**	Living room	0,30
			Bedroom	0,40
			Room for children or retired persons	0,30
			Dining room	0,70
			Kitchen	0,60
			Bathroom	0,80
			Toilet	0,90
			Entrance hall	0,80
			Corridor, stairs	0,70
			Storeroom	0,90
			Cellar	0,95
			Laundry	0,98
			Larder	0,98
			Workroom	0,60
			Home workshop	0,80
			Garage	0,95
Offices	0,20	**Offices**	Cellular office 1 person.	0,40
			Cellular office 2-6 persons.	0,30
			Open plan office >6persons sensing/30m^2	0,00
			Open plan office >6persons sensing/10m^2	0,20
			Corridor (dimmed)	0,40
			Entrance hall	0,00
			Showroom/Expo	0,60
			Bathroom	0,90
			Rest room	0,50
			Storage room/Cloakroom	0,90
			Technical plant room	0,98
			Copying/Server room	0,50
			Conference room	0,50
			Archives	0,98
Educational buildings	0,20	**Educational buildings**	Classroom	0,25
			Room for group activities	0,30
			Corridor (dimmed)	0,60
			Junior common room	0,50
			Lecture hall	0,40
			Staff room	0,40
			Gymnasium/Sports hall	0,30

			Dining hall Teachers' staff common room Copying/storage room Kitchen Library	0,20 0,40 0,40 0,20 0,40
Hospitals	0,00	**Hospitals**	Wards/Bedroom Examination/Treatment Pre-Operation Recovery ward Operating theatre Corridors Culvert/conduct/(dimmed) Waiting area Entrance hall Day room Laboratory	0,00 0,40 0,40 0,00 0,00 0,00 0,70 0,00 0,00 0,20 0,20
Manufacturing factory	0,00	**Manufacturing factory**	Assembly hall Smaller assembly room Storage rack area Open storage area Painting room	0,00 0,20 0,40 0,20 0,20
Hotels and restaurants	0,00	**Hotels and restaurants**	Entrance hall/Lobby Corridor (dimmed) Hotel room Dining hall/cafeteria Kitchen Conference room Kitchen/storage	0,00 0,40 0,60 0,00 0,00 0,40 0,50
Wholesale and retail service	0,00	**Wholesale and retail service**	Sales area Store room Store room, cold stores	0,00 0,20 0,60
		Other areas	Waiting areas Stairs (dimmed) Theatrical stage and auditorium Congress hall/Exhibition hall museum/ Exhibition hall Library/Reading area Library /Archive Sports hall Car parks office - Private Car parks - Public	0,00 0,20 0,00 0,50 0,00 0,00 0,90 0,30 0,95 0,80

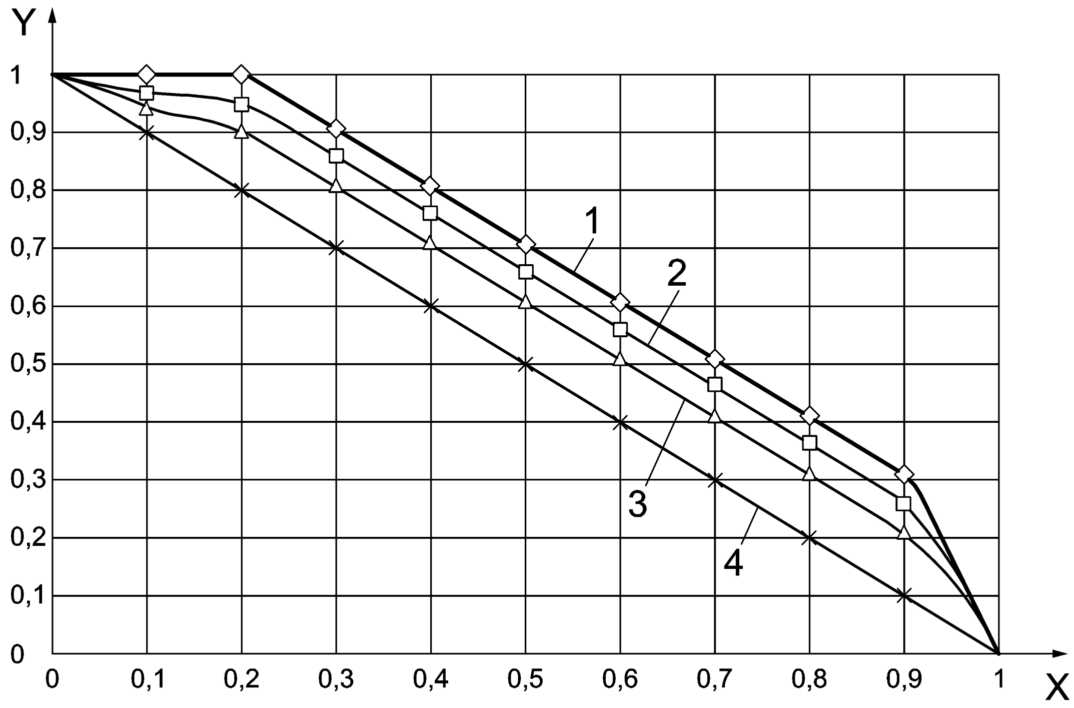


Figure E.1— F_o as a function of F_A for the different control systems

Where X = F_A and Y = F_o and

1. Manual On/ Off switch
2. Manual On/ Off switch + additional automatic sweeping extinction signal, and Auto on/ Dimmed
3. Auto on/ Auto off and Manual on/ Dimmed
4. Manual on/ Auto Off

Table E.3 — F_o values as a function of F_A for the different control systems

F_A	0,0	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1,0
Manual On/ Off switch	1,000	1,000	1,000	0,900	0,800	0,700	0,600	0,500	0,400	0,300	0,000
Manual On/ Off switch + additional automatic sweeping extinction signal	1,000	0,975	0,950	0,850	0,750	0,550	0,650	0,450	0,350	0,250	0,000
Auto on/ Dimmed	1,000	0,975	0,950	0,850	0,750	0,550	0,650	0,450	0,350	0,250	0,000
Auto on/ Auto off	1,000	0,950	0,900	0,800	0,700	0,600	0,500	0,400	0,300	0,200	0,000
Manual on/ Dimmed	1,000	0,950	0,900	0,800	0,700	0,600	0,500	0,400	0,300	0,200	0,000
Manual on/ Auto Off	1,000	0,900	0,800	0,700	0,600	0,500	0,400	0,300	0,200	0,100	0,000

NOTE 1 These include meeting rooms in office buildings and hotels, classrooms, cinemas etc.

NOTE 2 For programming purposes, the F_o value estimation can be rewritten as a single expression:

$$F_o = min\{1 – [(1 – F_{oc}) \times F_A / 0,2]; (F_{oc} + 0,2 – F_A); [7-(10 \times F_{oc})] \times (F_A – 1)\} \quad (E.1)$$

NOTE 3 The value of F_o can range from 0,0, to 1,0. The absence factor corresponds to the fraction of the reference operating time (t_D + t_N) that a building or room is not in use. (Sleeping hours can usually be considered equivalent to absence.) When the building or the room is permanently occupied during the reference time, F_A is 0,0. As a limit value, if a building or room would nearly never ever be entered into, F_A would tend towards 1,0.

NOTE 4 This table gives some values for F_{oc} as a function of the lighting control system. For other types of control systems, other values can be determined; this table is open-ended. The "off-time" of the luminaires with respect to the reference operating time (t_D + t_N) can never be more than F_A. (The "off-state" due to daylight is not considered here but included in F_D.) Therefore F_o can never be more than 1,0 - F_A. This implies that F_{oc} should be at least 0,80.

Annex F
(normative)
Daylight availability

F.1 General

This annex specifies a simplified approach to calculate the effect of daylight on the lighting energy demand on a monthly and annual basis. The method involves the following stages to obtain the daylight dependent quantities $F_{D,n,j}$, $t_{Day,n,j}$ and as a function thereof $t_{eff,Day,n,j}$,. The calculation flow process is depicted in Figure F.1:

- F.2 contains a scheme of how to subdivide the zone to be evaluated into area sections which receive daylight and those which do not;
- F.3 specifies a procedure of how to determine the daylight supply factor $F_{D,S,n,j}$ for spaces lit by vertical façades;
- F.4 specifies a procedure of how to determine the daylight supply factor $F_{D,S,n,j}$ for spaces lit by roof lights;
- F.5 specifies a procedure of how to rate daylight responsive control systems described by the parameter $F_{D,C,n,j}$;
- F.6 describes how to convert annual values into monthly values of $F_{D,n,j}$;
- F.7 provides a procedure to determine day and night time hours;
- F.8 describes requirements for the comprehensive calculation of daylight supply.

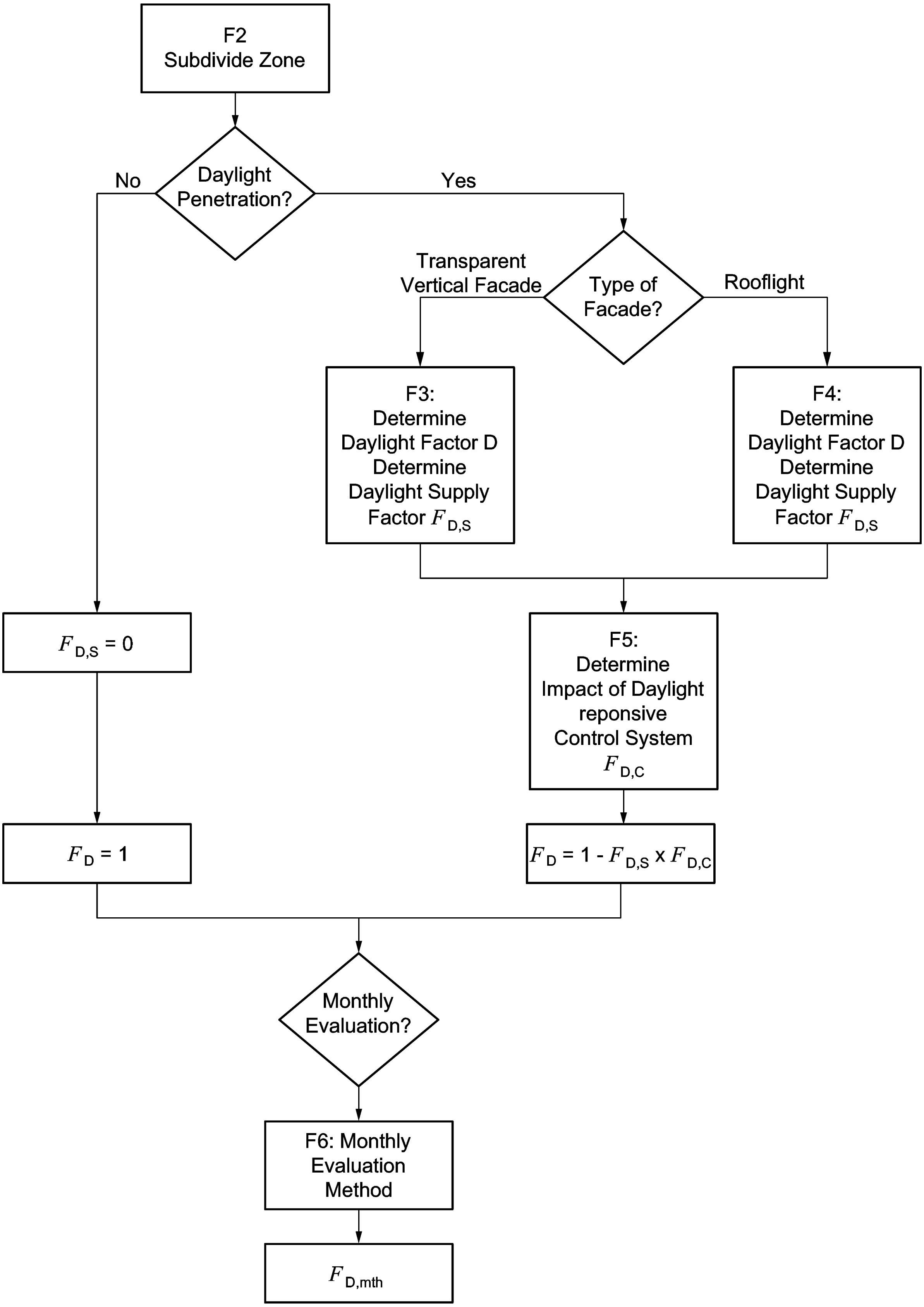


Figure F.1 — Flowchart illustrating the simplified approach

The determination of the daylight supply factor $F_{\mathrm{D,S},j}$ and for a vertical façade (F.3) and for roof lights (F.4). Figure F.2 shows the applied three-stage approach:

- Stage 1: Use of a simple criterion approximating the daylight factor in order to classify the type of daylight availability on the basis of the geometrical parameters of the building zone being evaluated. This assumes a combination of standard reflectances, ρ_{F} = 0,2 for the floor, ρ_{W} = 0,5 for the walls and ρ_{C} = 0,7 for the ceiling. The reflectance of the external surroundings is assumed to be 0,2. Instead of using these approximations, a more detailed determination of the daylight factor can be carried out for more complicated space geometries and other reflectance values using, for instance, computer tools.

- Stage 2: Describe the façade characteristics.

- Stage 3: Determine the annual amount of daylight available on the basis of the daylight supply classification of the building zone and the façade characteristics as a function of location and climate.

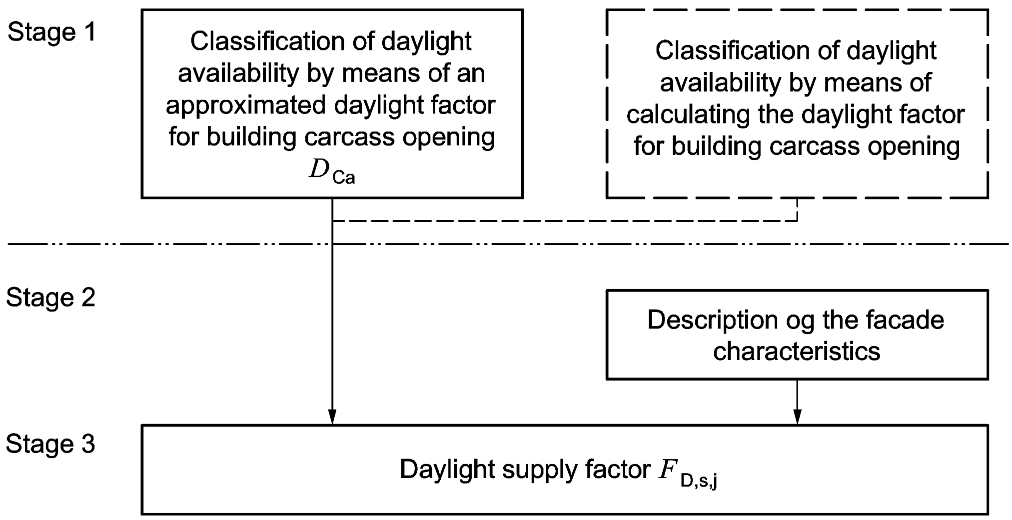


Figure F.2 — Three stage approach to determining the daylight supply factor $F_{\mathrm{D,s},j}$

F.2 Building segmentation: Spaces benefiting from daylight

Evaluation zones which are illuminated by daylight entering via façades or roof lights shall be subdivided into a day lit area $A_{\mathrm{D},j}$ and an area $A_{\mathrm{ND},j}$ which is not illuminated by daylight. For simplified estimate calculations, the more favourable respective lighting conditions can be assumed to apply in cases where one area is illuminated by daylight entering via several façades or via a façade and roof lights. Alternatively, it is also possible in these areas to determine the daylight factor in accordance with F.3 and F.4 by superposition. This may nevertheless only be applied for areas being lit solely by a type of daylight aperture (either vertical façade or roof light).

<u>Depth and width of the daylight area by vertical façades</u>

The maximum possible depth $a_{D,max}$ of the area $A_{\mathrm{D},j}$ lit by daylight entering via a façade is calculated using the following equation:

$$a_{\mathrm{D,max}} = 2{,}5 \cdot (h_{\mathrm{L}\,i} - h_{\mathrm{Ta}}) \tag{F.1}$$

where

$a_{D,max}$ is the maximum depth of the daylight area;

h_{Li} is the height of the window lintel above the floor;

h_{Ta} is the height of the task area above the floor.

In this case, the maximum depth $a_{D,max}$ of the daylight area is calculated from the inner surface of the external wall and at right angles to the reference façade. If the real depth of the area being evaluated is less than the calculated maximum depth of the daylight area, then the total area depth is considered to be the depth of the daylight area a_D. a_D can also be assumed to be equal to the real depth of the area being evaluated if the real area depth is less than 1,25 times the calculated maximum daylight area depth.

The partial area $A_{D,j}$ which is lit by daylight within the area j is calculated as follows:

$$A_{D,j} = a_D \cdot b_D \tag{F.2}$$

where

a_D is the depth of the daylight area;

b_D is the width of the daylight area.

The width b_D of the daylight area normally corresponds to the façade width on the inner surface of the building zone or the area being evaluated. Internal walls thickness may be ignored in order to keep the equations simple. If windows only constitute a part of the façade, then the width of the daylight area associated with this façade is equal to the width of the section which has windows, plus half the depth of the daylight area.

Depth of the daylight area lit by roof lights

Areas to be evaluated that have roof lights evenly distributed all over the roof area are always deemed to be lit by daylight. In the case of individual or single roof lights and at the boundaries of areas which have evenly distributed skylights, those parts of the area which are within a distance of

$$a_{D,max} \leq (h_{R,j} - h_{Ta,j}) \tag{F.3}$$

from the edge of the nearest skylight are deemed to be lit by daylight.

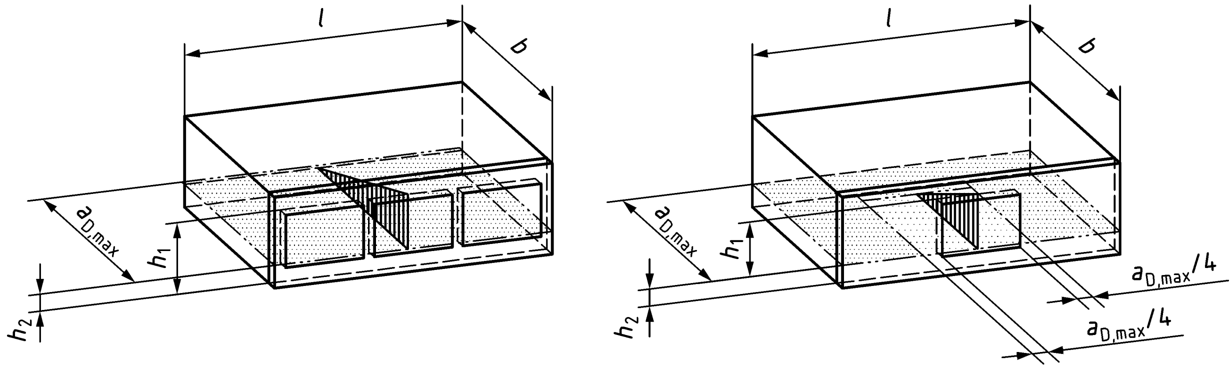
where

$h_{R,j}$ is the clear ceiling height of the area (room) which has a skylight.

For all parts of the area under evaluation which are not lit by daylight, the factor $F_{D,j}$ is equal to 1,0.

Distinction between vertical façades and rooflights

In case of doubt as to whether a specific opening or aperture is to be evaluated as being a window or a roof light, all such openings of which the entire glazed areas are above the ceiling of the space under consideration are deemed to be roof lights.

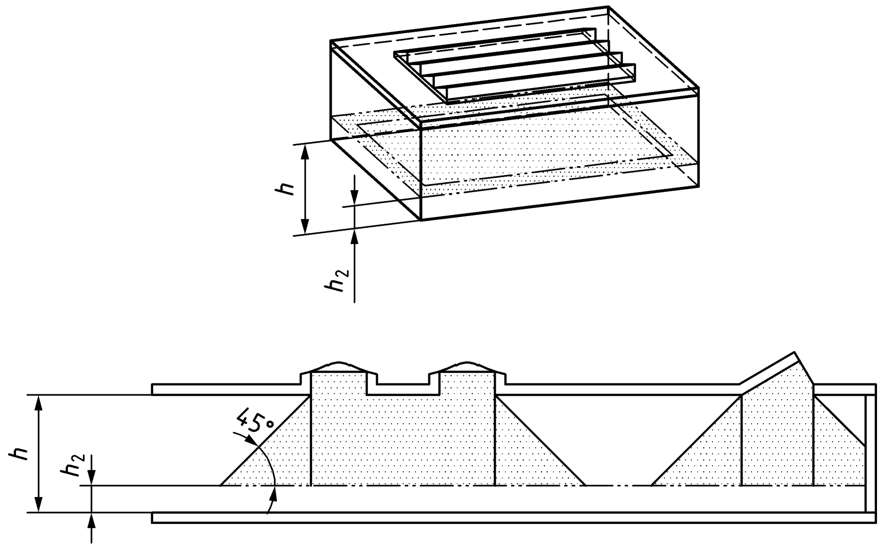


Key

A_D

A_{ND}

Figure F.3 — Impact of façade opening on daylight area for vertical façades



Key

A_D

A_{ND}

Figure F.4 — Impact of roof opening on daylight area for roof lights

F.3 Daylight supply factor for vertical façades

F.3.1 Daylight factor classification

The daylight factor for vertical façades can be obtained by several means, e.g. graphical, analytical or computer based approaches. Here a simplified analytical approach allowing to account for the major parameters classifying the daylight availability in vertically lit rooms is provided.

The amount of daylight available in an area j being evaluated depends on the transparency index $I_{Tr,j}$, the space depth index $I_{RD,j}$ and the shading index $I_{Sh,j}$. These index values are determined as follows.

Transparency index $I_{\mathrm{Tr},j}$

The following equation is used to calculate the transparency index:

$$I_{\mathrm{Tr},j} = \frac{A_{\mathrm{Ca}}}{A_{\mathrm{D}}} \quad \text{(F.4)}$$

where

A_{Ca} is the area of the raw building carcass opening of the area under evaluation;

A_{D} is the partial area which is lit by daylight as calculated by equation (F.1).

All areas below the work plane (e. g. 0,8 m above floor level in office spaces) are ignored. The height of the work plane is given for individual utilization profiles in EN 12464-1 and EN 12193.

Space depth index $I_{\mathrm{RD},j}$

The following equation is used to calculate the space depth index $I_{\mathrm{RD},j}$:

$$I_{\mathrm{RD},j} = \frac{a_{\mathrm{D}}}{h_{\mathrm{Li}} - h_{\mathrm{Ta}}} \quad \text{(F.5)}$$

Shading index $I_{\mathrm{Sh},j}$

The shading index $I_{\mathrm{Sh},j}$ accounts for all effects which restrict the amount of daylight striking the façade. This includes shading by parts of the building itself, such as may occur due to horizontal and vertical projections, light wells, courtyards and atrium arrangements. It also takes into consideration any reduction of incident light by the glazed double façades (GDF — also glazed curtain walls). The shading index $I_{\mathrm{Sh},j}$ is calculated using the following equation:

$$I_{\mathrm{Sh},j} = I_{\mathrm{Sh,lsh}} \cdot I_{\mathrm{Sh,hf}} \cdot I_{\mathrm{Sh,vf}} \cdot I_{\mathrm{Sh,In,At}} \cdot I_{\mathrm{Sh,GDF}} \quad \text{(F.6)}$$

where

$I_{\mathrm{Sh},j}$ is the shading index of the area j under evaluation;

$I_{\mathrm{Sh,lsh}}$ is the correction factor for linear obstruction of the area under evaluation as calculated using equation (F.7);

$I_{\mathrm{Sh,hf}}$ is the correction factor for an overhang shading of the area being evaluated, calculated using equation (F.8);

$I_{\mathrm{Sh,vf}}$ is the correction factor for a side shading of the area under evaluation as calculated using equation (F.9);

$I_{\mathrm{Sh,In,At}}$ is the correction factor for internal courtyard and atrium shading of the area under evaluation as calculated using equation (F.11);

$I_{\mathrm{Sh,GDF}}$ is the correction factor for glazed double façades of the area being evaluated, calculated using equation (F.12).

To facilitate the calculations, a window located at the centre of the façade area being evaluated can be used as the reference point for which the shading is calculated. If different forms and degrees of shading affect the area being evaluated, the mean value of the respective factors shall be calculated.

$I_{\mathrm{Sh,lsh}}$, $I_{\mathrm{Sh,hf}}$, $I_{\mathrm{Sh,vf}}$, $I_{\mathrm{Sh,In,At}}$ and $I_{\mathrm{Sh,GDF}}$ can be determined using the following methods:

Linear shading, correction factor $I_{Sh,lsh}$

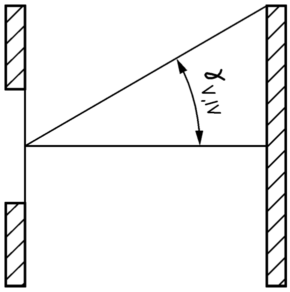


Figure F.5 — Cross section diagram to illustrate the effect of the linear shading altitude angle $\gamma_{V,lV}$

The linear shading altitude angle $\gamma_{Sh,lsh}$ is measured from the centre of the façade section being evaluated for lighting aspects (on the plane of the external wall surface) as shown in Figure F.5. The following equation is used to calculate the correction factor which accounts for linear obstruction:

$I_{Sh,lsh} = \cos(1,5 \cdot \gamma_{Sh,lsh})$ for $\gamma_{Sh,lsh} < 60°$ (F.7)

$I_{Sh,lsh} = 0$ for $\gamma_{Sh,lsh} \geq 60°$

where

$\gamma_{Sh,lsh}$ is the obstruction altitude angle as shown in Figure F.5. as $\gamma_{V,lV}$

Horizontal projections, correction factor $I_{Sh,hf}$

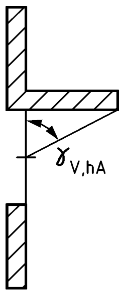


Figure F.6 — Cross section diagram to illustrate the effect of the horizontal shading angle $\gamma_{V,hA}$

The horizontal shading angle $\gamma_{Sh,hf}$ due to a horizontal projection is measured from the centre of the façade section being evaluated for lighting aspects (on the plane of the external wall surface) as shown in Figure F.6. The following equation is used to calculate the correction factor which accounts for shading by a horizontal projection:

$I_{Sh,hf} = \cos(1,33 \cdot \gamma_{Sh,hf,j})$ for $\gamma_{Sh,hf} < 67,5°$ (F.8)

$I_{Sh,hf} = 0$for $\gamma_{Sh,hf} \geq 67,5°$

where

$\gamma_{Sh,hf}$ is the horizontal shading angle due to a horizontal projection as shown in Figure F.6.as $\gamma_{V,hA}$

Vertical projections, correction factor $I_{Sh,vf}$

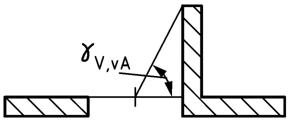


Figure F.7 — Cross section diagram to illustrate the effect of the vertical shading angle $\gamma_{V,vA}$

The vertical shading angle $\gamma_{Sh,vf}$ due to a vertical projection is measured from the centre of the façade section being evaluated for lighting aspects (on the plane of the external wall surface) as shown in Figure F.7. The following equation is used to calculate the correction factor which accounts for shading by a vertical projection:

$$I_{Sh,vf} = 1 - \gamma_{Sh,vf,j} / 300° \tag{F.9}$$

where

$\gamma_{Sh,vf}$ **is the vertical shading angle due to a vertical projection as shown in Figure F.7.as $\gamma_{V,vA}$**

Courtyards and atria (glazed forecourts), correction factor $I_{Sh,In,At}$

There are very many different design variants for courtyards and atria or glazed forecourts. The calculations are based on an internal courtyard surrounded on all four sides by the building. Better daylight availability can be expected if only three or two sides (linear courtyards) of the courtyard are bordered by the building. This can be calculated and proved using separate, detailed calculation methods.

The geometry of an internal courtyard is characterized by a geometrical index value, the so-called well index *wi*:

$$wi = \frac{h_{In,At} \cdot (a_{In,At} + b_{In,At})}{2 \cdot a_{In,At} \cdot b_{In,At}} \tag{F.10}$$

When determining the well index *wi* for an area being evaluated, the height measured from the floor of the respective area is considered to be the height of the courtyard, or atrium.

where

$a_{In,At}$ is the depth of the courtyard or atrium;

$b_{In,At}$ is the width of the courtyard or atrium;

$h_{In,At}$ is the height of the courtyard or atrium, measured from the floor of the storey being evaluated;

wi is the well index used to account for the geometry of the courtyard or atrium.

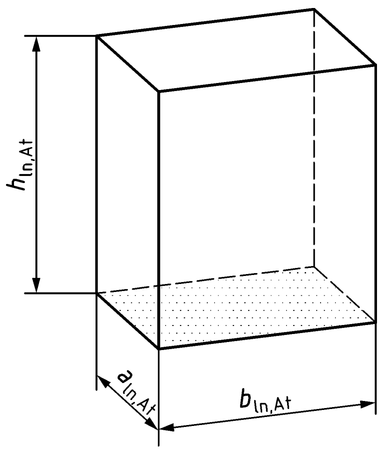


Figure F.8 — Illustration of the geometrical parameters used to define the well index *wi*

The correction factor for taking into consideration building shading in internal courtyards, light wells or atria is:

$I_{Sh,In,At} = 1 - 0{,}85\ wi$ for internal courtyards (F.11)

$I_{Sh,In,At} = \tau_{Sh,In,At,D65} \cdot k_{Sh,In,At,1} \cdot k_{Sh,In,At,2} \cdot k_{Sh,In,At,3} \cdot (1 - 0{,}85\ wi)$ for atria

$I_{Sh,In,At} = 0$ for $wi > 1{,}18$.

where

$\tau_{Sh,In,At,D65}$ is the transmittance of the atrium glazing for vertical light incidence;

$k_{Sh,In,At,1}$ is the reduction factor for frames and subdivisions in the atrium façade;

$k_{Sh,In,At,2}$ is the reduction factor for pollution of the atrium glazing;

$k_{Sh,In,At,3}$ is the reduction factor for non-vertical light incidence on the atrium glazing (0,85 is considered to be adequate).

Glazed double façade (glazed curtain wall), correction factor $I_{Sh,GDF}$

The correction factor for glazed double façades or curtain walls bounding on the space being evaluated is directly deduced from the parameters of the additional glazing layer:

$$I_{Sh,GDF} = \tau_{Sh,GDF,D65} \cdot k_{Sh,GDF,1} \cdot k_{Sh,GDF,2} \cdot k_{Sh,GDF,3} \quad \text{(F.12)}$$

where

$\tau_{Sh,GDF,D65}$ is the transmittance of the external layer of glazing of the façade, for vertical light incidence;

$k_{Sh,GDF,1}$ is the reduction factor for frames and subdivisions in the double-glazed façade;

$k_{Sh,GDF,2}$ is the reduction factor for pollution of the glazing of the double-glazed façade;

$k_{Sh,GDF,3}$ is the reduction factor for non-vertical light incidence on the façade glazing (0,85 is considered to be adequate).

The effects of vertical and horizontal subdivisions in the space between the two façade layers can be approximated by treating these as vertical and horizontal projections with the index values $I_{Sh,vA}$ and $I_{Sh,hA}$. In glazed double façades, it is assumed that pollution of the space between the outer glazing and the space wall is negligible, so that it is usually adequate to take only the dirt deposited on the actual façade surface into consideration (also refer to equation (F.12**Fehler! Verweisquelle konnte nicht gefunden werden.**)). In this case, $k_{Sh,GDF,2} = 1$. The correction factor for frames and subdivisions is calculated as follows:

$$k_{Sh,GDF,1,j} = 1 - \frac{\text{area of structural components}}{\text{area of raw building carcass opening}} = \frac{\text{transparent area}}{\text{area of raw building carcass opening}} \quad \text{(F.13)}$$

Only that part of the external façade glazing which is projected onto the transparent portions of the inner façade is taken into consideration when calculating the factor $k_{Sh,GDF,1}$.

Daylight factor of the raw building carcass opening

The index values $I_{Tr,j}$, $I_{RD,j}$ and $I_{Sh,j}$ can be used to calculate an approximate value for the daylight factor of the area being evaluated on the basis of the raw opening dimensions:

$$D_{Rb,j} = (4{,}13 + 20{,}0 \cdot I_{Tr,j} - 1{,}36 I_{RD,j})\ I_{Sh,j}, \text{in } \% \quad \text{(F.14)}$$

For combinations of a larger space depth index value $I_{\mathrm{RD},j}$ and low transparency index values $I_{\mathrm{Tr},j}$, equation (F.14) might produce negative $D_{\mathrm{Ca},j}$ values. In such cases $D_{\mathrm{Ca},j}$ shall be assumed to be zero or shall be calculated by a more detailed method. For simple estimates, daylight availability can be grouped into four classes as shown in Table F.1.

Table F.1 — Daylight availability classification as a function of the daylight factor $D_{\mathrm{Ca},j}$ of the raw building carcass opening

Daylight factor $D_{\mathrm{Ca},j}$	**Classification of daylight availability**
$D_{\mathrm{Ca},j} \geq 6$ %	Strong
6 % > $D_{\mathrm{Ca},j} \geq 4$ %	Medium
4 % > $D_{\mathrm{Ca},j} \geq 2$ %	Low
$D_{\mathrm{Ca},j} < 2$ %	None

If a daylight factor which has been calculated using another validated method is known, then this can be used instead of the value calculated by equation (F.14) when classifying the daylight availability in accordance with Table F.1. In this case, the daylight factor shall have been determined on the basis of the mean value of the daylight measured on the axis running parallel to the respective façade section and at a distance of half the space depth from the façade.

F.3.2 Daylight supply factor

The following section first explains how the façade characteristics shall be described and then how the daylight availability is determined on the basis of the correlation of the daylight availability (daylight factor) of the building area, as defined in F.3.1, with the façade characteristics. The light passing through façade systems and the associated illumination of the adjacent space depends on the spatial and temporal distribution of the external illuminance conditions in relation to the façade element and the spatial distribution of the light by the façade system (i.e. its optical and control-technological characteristics). From the lighting-engineering aspect, two façade states shall be distinguished for façades with variable solar light shading systems and/or glare-protection systems:

— solar and/or glare protection system not activated, i.e. the sun is not shining on the façade;

— solar and/or glare protection system activated, i.e. the sun is shining on the façade.

The daylight supply factor $F_{\mathrm{D,s},j}$ shall be determined using equation (F.15) to achieve temporal weighting of the orientation-dependent occurrence of two different façade states, i.e. either with activated solar and/or glare protection or with de-activated solar and/or glare protection. The protection against solar radiation and/or glare is activated as soon as direct sunlight shines on the façade.

The daylight supply factor $F_{\mathrm{D,s},j}$ is calculated using:

$$F_{\mathrm{D,s},j} = t_{\mathrm{rel,D,SNA},j}\ F_{\mathrm{D,s,SNA},j} + t_{\mathrm{rel,D,SA},j}\ F_{\mathrm{D,s,SA},j} \tag{F.15}$$

where

$t_{\mathrm{rel,D,SNA},j}$ is the relative portion of the total operating time during which the solar and/or glare protection system is not activated as given in Table F.3 in F.3.2.2. It is a function of the latitude γ of the considered site, $H_{\mathrm{dir}}/H_{\mathrm{glob}}$ representing the climate and façade orientation.

$t_{\mathrm{rel,D,SA},j}$ is the relative portion of the total operating time during which the solar and/or glare protection system is activated. $t_{\mathrm{rel,D,SA}}$ can be obtained by $t_{\mathrm{rel,D,SA}} = 1 - t_{\mathrm{rel,D,SNA}}$.

$F_{D,s,SNA,j}$ is the daylight availability factor of the area j being evaluated at times when the solar and/or glare protection system is not activated, as given in Table F.4 in F.3.2.3. It is a function of the latitude γ of the considered site, H_{dir}/H_{glob} representing the climate, the façade orientation, daylight availability (daylight factor) and the maintained illuminance.

$F_{D,s,SA,j}$ is the daylight availability factor of the area j being evaluated at times when the solar and/or glare protection system is activated, as given in Table F.7 in F.3.2.4

A set of ratios H_{dir}/H_{glob} for representative European locations is given in F.3.2.1

F.3.2.1 Luminous exposure at different sites (climates and latitudes)

Table F.2 contains representative European locations with the relevant data on geographical location and luminous exposure (H_{dir}/H_{glob}). For other specific locations of interest, the ratio H_{dir}/H_{glob} can be obtained by evaluation of the corresponding weather data sets (e.g. TRY – weather data sets). The direct and global horizontal illuminances are summed up for daily from 8:00 to 17:00 hours over the whole year.

Table F.2 — Representative locations in Europe with geographical data and luminous exposure H_{dir}/H_{glob}.

Location	Latitude γ [°]	Longitude φ [°]	Luminous Exposure H_{dir}/H_{glob} [-]
Athens, Gr	37,9	−23,7	0,56
Bodø, N	67,3	14,4	0,40
Bratislava, SK	48,2	−17,2	0,46
Frankfurt, D	50,0	−8,7	0,41
London, GB	51,2	−0,2	0,39
Lyon, Fr	45,7	−5,1	0,43
Stockholm, S	59,7	−18,0	0,42

F.3.2.2 Relative times, shading activated, shading not activated for vertical façades

Table F.3 holds the relative times $t_{rel,D,SNA,j}$ as a function of the latitude γ of the considered site, H_{dir}/H_{glob} representing the climate and façade orientation.

The relative times $t_{rel,D,SNA,j}$ are provided for unobstructed façades. For shading indices $I_{Sh,j}$ of obstructed façades of less than 0,5, especially for higher latitudes $\gamma \geq 45°$, it is recommended to set $t_{rel,D,SNA}$ as 1. This nevertheless shall not give reason to assume that glare protection for the façade is unnecessary. Such protection can be necessary due to individual types of usage.

If the shading index $I_{Sh,j}$ of a shaded façade is less than 0,5 then the relative times $t_{rel,D,SNA,j}$ and $t_{rel,D,SA,j}$ for a north-facing façade should be used. Depending on the operating times of the area being evaluated, even north-facing façades can receive direct sunlight for limited periods. However, for simplified calculations $t_{rel,D,SNA,j}$ is assumed to be 0, but this shall not give reason to assume that glare protection for north-facing façades is unnecessary. Such protection can be necessary due to individual types of usage.

$t_{rel,D,SNA}$ has been calculated for office conditions, but can be used for other user profiles generally with sufficient accuracy as well.

Table F.3 — Relative times $t_{rel,D,SNA,j}$ for non-activated solar radiation and/or glare protection systems, as a function of the façade orientation, the geographic latitude γ and the ratio H_{dir}/H_{global}

t_{SNA} South									
H_{dir}/H_{glob}	γ								
	0°	10°	20°	30°	40°	50°	60°	70°	80°
0,0	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
0,1	0,99	0,97	0,94	0,93	0,96	0,98	0,98	0,93	0,88
0,2	0,94	0,91	0,86	0,84	0,86	0,87	0,86	0,80	0,72
0,3	0,89	0,86	0,79	0,75	0,75	0,76	0,75	0,69	0,61
0,4	0,83	0,80	0,71	0,65	0,64	0,65	0,65	0,60	0,53
0,5	0,71	0,67	0,57	0,50	0,49	0,50	0,51	0,47	0,40
0,6	0,55	0,51	0,41	0,33	0,32	0,34	0,36	0,32	0,23
0,7	0,47	0,43	0,32	0,24	0,23	0,26	—	—	—
0,8	—	0,42	0,32	0,24	0,23	0,26	—	—	—
0,9	—	0,42	0,32	0,24	0,23	0,26	—	—	—
t_{SNA} East/West									
H_{dir}/H_{glob}	γ								
	0°	10°	20°	30°	40°	50°	60°	70°	80°
0,0	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
0,1	0,99	0,98	0,97	0,97	1,00	1,00	0,99	0,95	0,92
0,2	0,95	0,94	0,92	0,92	0,94	0,94	0,93	0,88	0,85
0,3	0,91	0,89	0,87	0,86	0,88	0,88	0,87	0,83	0,79
0,4	0,84	0,83	0,80	0,79	0,81	0,82	0,82	0,80	0,78
0,5	0,74	0,73	0,70	0,70	0,73	0,76	0,77	0,77	0,76
0,6	0,64	0,63	0,61	0,61	0,65	0,69	0,72	0,72	0,73
0,7	0,59	0,58	0,56	0,56	0,61	0,65	—	—	—
0,8	—	0,58	0,56	0,56	0,61	0,65	—	—	—
0,9	—	0,58	0,56	0,56	0,61	0,65	—	—	—
t_{SNA} North									
H_{dir}/H_{glob}	γ								
	0°	10°	20°	30°	40°	50°	60°	70°	80°
0,0	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
0,1	0,99	0,99	0,99	1,00	1,00	1,00	1,00	1,00	1,00
0,2	0,97	0,97	0,98	1,00	1,00	1,00	1,00	1,00	1,00
0,3	0,92	0,92	0,94	0,98	1,00	1,00	1,00	1,00	1,00
0,4	0,84	0,85	0,89	0,94	1,00	1,00	1,00	1,00	1,00
0,5	0,77	0,79	0,83	0,91	0,98	1,00	1,00	1,00	1,00
0,6	0,73	0,75	0,80	0,89	0,98	1,00	1,00	1,00	1,00
0,7	0,71	0,73	0,79	0,88	0,98	1,00	—	—	—
0,8	—	0,73	0,79	0,88	0,98	1,00	—	—	—
0,9	—	0,73	0,79	0,88	0,98	1,00	—	—	—

F.3.2.3 Determination of daylight supply factor for sun shading not activated $F_{D,s,SNA,j}$

Equation (F.16) is used to calculate an approximate value of the effective transmittance for periods during which the solar and/or glare protection system is not activated:

$$\tau_{eff,SNA,j} = \tau_{D65,SNA} \cdot k_1 \cdot k_2 \cdot k_3 \quad \text{(F.16)}$$

where

$\tau_{D65,SNA}$ is the transmittance of the façade glazing for vertical light incidence;

k_1 is the reduction factor for frames and subdivisions, as calculated using equation (F.13);

k_2 is the reduction factor for pollution of the glazing;

k_3 is the reduction factor for non-vertical light incidence on the façade glazing (0,85 is considered to be adequate).

If the transparent or translucent façade element to be evaluated comprises different components, the effective transmittance shall be weighted in accordance with the relative proportion of the areas of the respective components. When determining the shading index by applying equation (F.6) and (F.12), the effect of the outer glazing of glazed double façades shall be calculated separately.

Typical values of the transmittance $\tau_{D65,SNA}$ for visible light and standard values of the pollution reduction factor k_2 are given in the Technical Report. If the reduction factor k_1 for frames and structural divisions is not known, it should be assumed to be 0,7.

The daylight supply factor $F_{D,s,SNA,j}$ is a function of the daylight availability, the maintained illuminance $\bar{E}_m$, the effective transmittance of the façade $\tau_{eff,SNA,j}$ with deactivated solar and/or glare protection system and of the façade orientation. The daylight availability factor $F_{D,S,SNA}$ can be obtained from Table F.4, Table F.5 and Table F.6 as a function of:

- the daylight factor D;
- the geographic location, i. e. latitude γ;
- the climate, characterized by the ratio H_{dir}/H_{glob};
- the maintained illuminance $\bar{E}_m$;
- the façade orientation.

For maintained illuminances $\bar{E}_m$ of less than 100 lx, daylight availability factor $F_{D,s,SNA,j}$ values for $\bar{E}_m$ = 100 lx should be used. For maintained illuminances $\bar{E}_m$ of more than 1 000 lx, the $F_{D,s,SNA,j}$ values for $\bar{E}_m$ = 1 000 lx should be used.

The relevant D for interpolation in Table F.4, Table F.5 and Table F.6 is obtained from $D = \tau_{eff} * D_{Ca}$.

Table F.4 — Daylight supply factor $F_{D,s,SNA,j}$ for sun shading not activated parameterized by D, γ, $\overline{E}_m$, climate (H_{dir}/H_{glob}), façade orientation, and geographic location for orientation South

$F_{D,s,SNA,j}$ [%]												
South façade												
Geo-graphic location γ	$\overline{E}_m$ [lx]	H_{dir}/H_{glob}	D [%]									
			0,125	**0,5**	**1,0**	**1,5**	**2,0**	**3,0**	**5,0**	**8,0**	**12,0**	**18,0**
0° – 15°	100	0,34	31,9	95,6	97,9	99,4	99,7	99,9	99,9	100,0	100,0	100,0
		0,66	28,1	84,3	94,0	98,2	98,1	99,3	99,3	100,0	100,0	100,0
	300	0,34	25,1	75,2	83,3	91,9	94,0	96,8	98,0	99,2	99,6	99,6
		0,66	19,9	59,8	67,7	78,3	82,5	88,4	90,5	95,5	98,2	98,3
	500	0,34	18,5	55,6	68,2	82,2	85,7	91,6	94,8	97,2	98,5	98,5
		0,66	14,7	44,0	54,3	65,7	69,3	76,4	80,1	85,6	91,5	92,0
	750	0,34	12,9	38,6	52,6	70,2	75,0	84,4	90,0	94,4	96,6	96,8
		0,66	10,3	30,9	42,4	55,4	58,8	66,6	70,6	76,2	83,1	84,2
	1 000	0,34	9,7	29,1	41,0	59,2	64,7	77,2	85,0	91,4	94,6	94,9
		0,66	7,8	23,3	33,4	47,2	50,7	59,7	64,2	70,0	76,3	77,9
15° – 30°	100	0,36	30,8	92,4	95,9	97,8	97,8	98,7	99,0	99,4	99,6	99,6
		0,58	29,4	88,1	96,6	99,2	98,6	99,6	99,6	100,0	100,0	100,0
	300	0,36	24,3	73,0	83,1	91,1	92,0	95,3	96,7	98,2	98,7	98,8
		0,58	20,6	61,7	76,8	87,8	88,4	94,3	95,9	98,5	99,5	99,5
	500	0,36	17,9	53,7	69,0	82,7	84,8	90,8	93,8	96,6	97,7	97,8
		0,58	14,8	44,3	61,0	75,4	77,0	85,9	89,8	94,6	97,2	97,3
	750	0,36	12,3	36,9	53,5	71,4	75,1	84,5	89,6	94,2	96,2	96,4
		0,58	10,3	30,8	46,9	62,7	65,0	76,3	81,9	89,2	93,6	94,0
	1 000	0,36	9,2	27,7	41,7	60,5	65,1	77,9	85,1	91,5	94,5	94,9
		0,58	7,7	23,2	37,0	52,6	55,4	67,9	74,9	83,8	89,7	90,4
30° – 45°	100	0,45	26,9	80,6	88,7	92,1	90,7	93,0	93,1	94,5	94,7	95,1
		0,71	17,8	53,3	70,1	80,0	78,4	84,6	85,6	89,5	90,3	90,9
	300	0,45	20,8	62,5	75,4	84,2	83,2	88,4	89,6	92,4	93,3	93,8
		0,71	10,8	32,3	46,6	57,1	56,8	66,4	70,0	77,0	82,4	83,6
	500	0,45	15,4	46,3	62,5	76,0	76,2	83,4	86,1	90,4	91,8	92,4
		0,71	7,6	22,8	36,4	46,6	46,2	55,3	59,5	67,8	73,6	75,4
	750	0,45	10,8	32,3	48,2	65,3	67,1	77,1	81,3	87,2	89,7	90,4
		0,71	5,3	16,0	27,8	38,2	38,2	47,1	51,3	59,6	65,9	68,2
	1 000	0,45	8,3	24,9	37,7	55,4	58,3	71,0	77,2	84,6	87,8	88,6
		0,71	4,1	12,4	21,9	32,0	32,5	41,5	46,0	54,2	60,3	63,0
45°– 60°	100	0,39	25,3	75,8	83,2	88,4	88,5	90,9	92,0	93,4	94,1	94,5
		0,58	24,3	72,8	84,2	90,0	88,2	91,8	92,0	94,1	94,4	94,8

	300	0,39	17,2	51,7	64,0	75,3	76,7	83,7	87,5	91,4	93,1	93,5
		0,58	16,7	50,2	66,5	78,0	77,5	85,0	87,7	92,3	94,0	94,4
	500	0,39	12,0	36,0	49,8	63,7	66,4	75,3	81,1	87,6	90,7	91,3
		0,58	11,5	34,6	51,3	66,0	66,6	76,4	80,7	87,1	90,1	90,8
	750	0,39	8,1	24,3	36,9	51,7	54,5	65,6	73,0	81,6	86,2	87,1
		0,58	8,0	23,9	38,9	54,5	56,0	68,3	74,8	83,0	87,0	87,9
	1 000	0,39	6,1	18,3	28,4	42,4	45,4	57,9	66,5	76,3	82,2	83,3
		0,58	6,0	17,9	30,2	45,1	46,9	60,4	68,5	78,6	83,4	84,5
60°– 75°	100	0,40	20,6	61,7	68,3	72,9	73,0	75,7	76,9	78,3	78,9	80,3
		0,48	17,8	53,4	60,0	64,2	64,2	66,8	68,1	69,7	70,5	72,5
	300	0,40	13,2	39,7	51,3	61,5	62,5	68,3	71,5	75,3	77,1	78,7
		0,48	11,9	35,7	46,1	54,4	54,6	59,9	62,6	66,3	68,0	70,2
	500	0,40	8,6	25,7	38,1	51,4	53,6	61,9	66,7	72,1	74,9	76,5
		0,48	7,9	23,8	35,6	46,3	47,2	54,1	57,9	62,9	65,4	67,6
	750	0,40	5,7	17,1	26,7	39,8	42,6	53,5	60,1	67,3	70,9	72,6
		0,48	5,4	16,1	25,7	37,5	39,3	47,8	52,7	58,9	62,2	64,5
	1 000	0,40	4,3	12,8	20,1	31,4	33,8	46,0	54,3	63,1	67,7	69,5
		0,48	4,0	12,1	19,5	30,1	32,1	42,2	48,2	55,4	59,4	61,8

Table F.5 — Daylight supply factor $F_{D,s,SNA,j}$ for sun shading not activated parameterized by D, γ, $\overline{E}_m$, climate (H_{dir}/H_{glob}), façade orientation, and geographic location for orientations East/ West

$F_{D,s,SNA,j}$ [%]												
East/West façade												
Geo-graphic location γ	$\overline{E}_m$ [lx]	H_{dir}/H_{glob}	D [%]									
			0,125	**0,5**	**1,0**	**1,5**	**2,0**	**3,0**	**5,0**	**8,0**	**12,0**	**18,0**
0° – 15°	100	0,34	31,7	95,1	97,4	98,9	99,2	99,4	99,4	99,5	99,5	99,5
		0,66	26,6	79,9	89,1	93,1	92,9	94,1	94,2	94,8	94,8	94,8
	300	0,34	24,6	73,9	81,8	90,2	92,3	95,0	96,2	97,3	97,8	97,9
		0,66	15,1	45,2	51,1	59,2	62,3	66,8	68,4	72,1	74,2	75,9
	500	0,34	18,0	53,9	66,1	79,7	83,1	88,9	91,9	94,2	95,5	95,8
		0,66	11,7	35,2	43,5	52,6	55,5	61,1	64,1	68,5	73,2	75,0
	750	0,34	12,5	37,5	51,0	68,1	72,7	81,8	87,3	91,5	93,6	94,0
		0,66	6,1	18,4	25,3	33,1	35,1	39,7	42,1	45,4	49,5	53,0
	1 000	0,34	9,4	28,1	39,7	57,3	62,5	74,6	82,2	88,4	91,5	92,0
		0,66	4,5	13,4	19,2	27,1	29,2	34,3	36,9	40,3	43,9	47,7
15° – 30°	100	0,36	30,6	91,8	95,3	97,2	97,2	98,1	98,4	98,7	98,9	99,0
		0,58	28,9	86,6	95,0	97,5	96,9	97,9	97,9	98,3	98,3	98,4
	300	0,36	23,4	70,3	80,1	87,8	88,6	91,8	93,2	94,6	95,1	95,4
		0,58	17,7	53,1	66,2	75,6	76,2	81,2	82,6	84,8	85,7	86,6
	500	0,36	16,8	50,5	64,9	77,7	79,7	85,3	88,2	90,8	91,8	92,3
		0,58	12,4	37,2	51,2	63,4	64,7	72,2	75,4	79,4	81,6	82,8
	750	0,36	11,4	34,1	49,4	66,0	69,5	78,2	82,8	87,1	89,0	89,7
		0,58	7,4	22,1	33,7	45,0	46,7	54,8	58,8	64,0	67,2	69,4
	1 000	0,36	8,4	25,3	38,0	55,1	59,4	71,0	77,6	83,4	86,1	87,1
		0,58	5,3	15,8	25,2	35,9	37,7	46,3	51,0	57,1	61,1	63,8
30° – 45°	100	0,45	26,2	78,6	86,5	89,9	88,5	90,7	90,9	92,2	92,4	92,9
		0,71	16,4	49,3	64,9	74,1	72,6	78,4	79,2	82,8	83,6	84,7
	300	0,45	18,7	56,1	67,6	75,5	74,6	79,2	80,3	82,9	83,7	84,8
		0,71	7,0	21,1	30,4	37,2	37,0	43,3	45,6	50,2	53,7	56,9
	500	0,45	13,6	40,7	55,0	66,9	67,1	73,4	75,7	79,5	80,8	82,1
		0,71	5,8	17,3	27,6	35,4	35,1	42,0	45,2	51,5	55,9	58,9
	750	0,45	8,9	26,7	39,7	53,9	55,3	63,6	67,1	72,0	74,0	75,7
		0,71	2,2	6,7	11,6	15,9	15,9	19,6	21,4	24,8	27,5	32,4
	1 000	0,45	6,7	20,1	30,3	44,6	47,0	57,2	62,2	68,2	70,8	72,8
		0,71	1,5	4,6	8,1	11,9	12,1	15,4	17,1	20,2	22,4	27,7
$F_{D,s,SNA,j}$ [%]												

East/West façade												
Geo-graphic location γ	$\overline{E}_m$ [lx]	H_{dir}/H_{glob}	D [%]									
			0,125	**0,5**	**1,0**	**1,5**	**2,0**	**3,0**	**5,0**	**8,0**	**12,0**	**18,0**
45° – 60°	100	0,39	25,0	75,0	82,3	87,4	87,5	89,9	91,0	92,4	93,0	93,5
		0,58	23,9	71,6	82,8	88,5	86,8	90,3	90,5	92,5	92,9	93,3
	300	0,39	16,2	48,7	60,2	70,9	72,2	78,8	82,4	86,1	87,6	88,4
		0,58	14,8	44,5	58,9	69,2	68,7	75,4	77,8	81,8	83,3	84,5
	500	0,39	11,0	33,1	45,8	58,6	61,1	69,2	74,6	80,6	83,4	84,5
		0,58	9,8	29,4	43,6	56,1	56,6	65,0	68,6	74,1	76,6	78,2
	750	0,39	7,3	21,9	33,1	46,4	49,0	59,0	65,6	73,3	77,5	79,0
		0,58	6,4	19,2	31,4	43,9	45,1	55,0	60,2	66,8	70,1	72,1
	1 000	0,39	5,4	16,2	25,1	37,6	40,3	51,3	58,9	67,7	72,8	74,7
		0,58	4,7	14,1	23,7	35,4	36,9	47,5	53,8	61,8	65,6	67,9
60° – 75°	100	0,40	20,9	62,8	69,5	74,3	74,3	77,1	78,3	79,7	80,3	81,6
		0,48	16,8	50,3	56,5	60,5	60,5	62,9	64,2	65,7	66,4	68,7
	300	0,40	12,5	37,6	48,6	58,4	59,3	64,8	67,8	71,4	73,2	74,7
		0,48	9,9	29,7	38,4	45,3	45,5	49,8	52,1	55,2	56,6	59,3
	500	0,40	7,9	23,7	35,0	47,3	49,3	57,0	61,3	66,3	68,9	70,9
		0,48	7,1	21,4	32,0	41,7	42,5	48,7	52,1	56,6	58,8	61,6
	750	0,40	5,1	15,3	23,8	35,5	38,0	47,7	53,6	60,0	63,2	65,5
		0,48	4,2	12,5	20,0	29,1	30,5	37,1	40,9	45,7	48,3	51,5
	1 000	0,40	3,7	11,2	17,6	27,5	29,6	40,3	47,6	55,3	59,3	62,0
		0,48	3,1	9,3	15,0	23,2	24,7	32,4	37,1	42,6	45,7	49,3

Table F.6 — Daylight supply factor $F_{D,s,SNA,j}$ for sun shading not activated, parameterized by D, γ, $\overline{E}_m$, climate (H_{dir}/H_{glob}), façade orientation, and geographic location for orientation North

$F_{D,s,SNA,j}$ [%]												
North façade												
Geo-graphic location γ	$\overline{E}_m$ [lx]	H_{dir}/H_{glob}	D [%]									
			0,125	**0,5**	**1,0**	**1,5**	**2,0**	**3,0**	**5,0**	**8,0**	**12,0**	**18,0**
0° – 15°	100	0,34	31,8	95,4	97,7	99,3	99,5	99,7	99,7	99,8	99,8	99,8
		0,66	27,2	81,6	91,0	95,1	94,9	96,1	96,2	96,8	96,8	96,8
	300	0,34	24,5	73,5	81,4	89,7	91,8	94,6	95,8	96,9	97,3	97,5
		0,66	14,5	43,5	49,2	56,9	59,9	64,2	65,8	69,4	71,4	73,3
	500	0,34	17,8	53,4	65,4	78,9	82,2	88,0	91,0	93,3	94,5	94,9
		0,66	10,6	31,7	39,1	47,3	49,9	55,0	57,6	61,7	65,8	68,2
	750	0,34	12,2	36,5	49,7	66,4	70,9	79,8	85,1	89,2	91,3	91,8
		0,66	5,3	15,9	21,9	28,6	30,3	34,3	36,4	39,3	42,8	46,7
	1 000	0,34	9,2	27,5	38,8	56,0	61,1	72,9	80,3	86,3	89,4	90,1
		0,66	4,0	12,0	17,2	24,3	26,2	30,8	33,1	36,1	39,3	43,5
15° – 30°	100	0,36	30,4	91,2	94,7	96,6	96,6	97,4	97,8	98,1	98,3	98,4
		0,58	28,8	86,4	94,8	97,3	96,7	97,7	97,7	98,1	98,1	98,2
	300	0,36	22,8	68,4	77,9	85,4	86,2	89,3	90,7	92,0	92,5	93,0
		0,58	16,8	50,5	62,9	71,9	72,5	77,2	78,6	80,7	81,5	82,7
	500	0,36	16,1	48,3	62,1	74,4	76,3	81,7	84,4	86,9	87,9	88,7
		0,58	11,5	34,6	47,6	58,8	60,1	67,0	70,0	73,8	75,8	77,4
	750	0,36	10,7	32,0	46,4	62,0	65,2	73,4	77,8	81,8	83,5	84,6
		0,58	6,7	20,0	30,5	40,7	42,3	49,6	53,2	58,0	60,8	63,5
	1 000	0,36	7,8	23,3	35,0	50,8	54,8	65,5	71,6	76,9	79,5	80,9
		0,58	4,7	14,0	22,3	31,7	33,4	40,9	45,1	50,5	54,1	57,2
30° – 45°	100	0,45	25,4	76,3	83,9	87,2	85,9	88,0	88,2	89,5	89,7	83,6
		0,71	16,6	49,9	65,6	74,9	73,4	79,2	80,1	83,7	84,5	85,5
	300	0,45	17,2	51,7	62,3	69,6	68,8	73,0	74,0	76,4	77,1	78,7
		0,71	6,9	20,7	29,8	36,5	36,3	42,5	44,8	49,3	52,7	55,9
	500	0,45	11,7	35,2	47,5	57,8	57,9	63,4	65,4	68,7	69,8	71,8
		0,71	5,8	17,3	27,6	35,4	35,1	42,0	45,2	51,5	55,9	58,9
	750	0,45	7,7	23,2	34,6	46,9	48,2	55,3	58,4	62,6	64,4	66,8
		0,71	2,0	6,1	10,5	14,5	14,4	17,8	19,4	22,5	24,9	30,0
	1 000	0,45	5,7	17,1	25,9	38,0	40,1	48,8	53,0	58,1	60,3	63,0
		0,71	1,4	4,1	7,2	10,5	10,7	13,6	15,1	17,8	19,8	25,3
45° – 60°	100	0,39	24,7	74,2	81,4	86,4	86,5	88,9	89,9	91,3	92,0	92,5
		0,58	23,6	70,8	81,9	87,5	85,7	89,2	89,5	91,4	91,8	92,3
	300	0,39	15,5	46,5	57,5	67,7	68,9	75,3	78,6	82,2	83,6	84,7
		0,58	13,9	41,6	55,1	64,7	64,2	70,4	72,7	76,4	77,9	79,4

	500	0,39	10,3	31,0	42,8	54,8	57,1	64,7	69,8	75,4	78,0	79,4
		0,58	8,4	25,3	37,5	48,1	48,6	55,8	58,9	63,6	65,8	68,1
	750	0,39	6,7	20,1	30,4	42,6	44,9	54,1	60,2	67,2	71,0	73,0
		0,58	5,5	16,6	27,1	38,0	39,0	47,6	52,1	57,8	60,6	63,3
	1 000	0,39	4,9	14,6	22,7	33,9	36,3	46,3	53,1	61,0	65,7	68,0
		0,58	4,0	11,9	20,1	30,0	31,2	40,2	45,5	52,3	55,5	58,5
60° – 75°	100	0,40	21,0	63,1	69,9	74,6	74,7	77,5	78,7	80,1	80,7	82,0
		0,48	17,1	51,3	57,6	61,7	61,7	64,2	65,4	67,0	67,7	69,9
	300	0,40	11,9	35,8	46,3	55,6	56,5	61,7	64,5	68,0	69,7	71,5
		0,48	9,4	28,1	36,3	42,8	43,0	47,1	49,3	52,2	53,6	56,5
	500	0,40	7,3	21,9	32,4	43,7	45,5	52,6	56,7	61,3	63,7	66,0
		0,48	6,5	19,5	29,2	38,0	38,7	44,4	47,5	51,5	53,6	56,7
	750	0,40	4,6	13,8	21,4	32,1	34,3	43,0	48,4	54,1	57,1	59,7
		0,48	3,7	11,0	17,7	25,7	27,0	32,8	36,2	40,5	42,7	46,4
	1 000	0,40	3,3	10,0	15,6	24,4	26,2	35,7	42,1	49,0	52,6	55,7
		0,48	2,7	8,1	13,0	20,0	21,3	28,0	32,0	36,9	39,5	43,5

F.3.2.4 Determination of daylight supply factor for sun shading activated $F_{D,s,SA,j}$

Façade system solutions with an activated solar and/or glare protection can be classified in a simplified way as shown in Table F.7.

Table F.7 — System solutions (values to be applied for the period $t_{rel,D,SA,j}$)

System solution (to be used for the period $t_{rel,D,SA,j}$)		$F_{D,s,SA,j}$			
		Classification of daylight availability			
		None	Low	Medium	Strong
1	Glare protection only: systems which provide glare protection in compliance with the regulations applying to the respective utilization profile, e. g. regulations for computer terminal workplaces. This includes manually operated venetian blinds and semi-transparent fabric sun-screens.	—	0,1	0,2	0,3
2	Automatically-operated protection against solar radiation and glare: devices to protect against solar radiation and/or glare and which can be moved in relation to the amount of daylight available. Venetian blinds which are automatically opened slightly after being lowered, so that transmittance is greater than that of the fully-closed blinds.	—	0,2	0,43	0,55
3	Light-guiding systems.	—	0,3	0,65	0,8
4	No protection against solar radiation and shades. NOTE Only applicable for areas being evaluated to which no special regulations or provisions such as the regulations for computer terminal workplaces apply.	—	0,6	0,75	0,8

Light-guiding system solutions, line 3 of Table F.7, can be assumed to include solutions of type 1 with additional light-guiding functions:

- **Venetian blinds in cut-off operating mode**: In the so-called 'cut-off' mode, the louvres of the blinds are directed in relation to the incident sunlight in such a way that direct sunlight is just prevented from passing through, but diffuse daylight can enter. Furthermore, these systems generally permit visual contact to the surroundings for a large part of the operating time. Appropriate control systems which move the louvres in relation to the solar radiation profile angle shall be installed. The sun profile angle is the projection of the altitude angle of the sun onto a vertical plane which is perpendicular to the plane of the façade surface.

- **Light-guiding glass**: Façade systems using glass components which transmit at least 30 % of the incident direct sunlight into the upper quarter of the space when lit under an altitude of 35° (measured from the normal of the façade plane) at a sun façade azimuth of zero. As a general rule, not more than 1/3 of the transparent façade openings should be equipped with such systems in order to prevent overheating of the respective space. Light-guiding glass shall be combined with other solar radiation protection and/or glare protection systems installed in the lower section of the façade area. However, no solar and/or glare protection devices may be installed in front of the light-guiding components described below.

- **Light-guiding external venetian blinds**: These have diffuse surfaces and the louvres of the upper and lower sections of the blinds are at different angles. The upper section of the blind shall not be higher than 1/3 and not lower than 1/4 of the total blind length and the system shall be equipped with control devices.

- **Light-guiding internal venetian blinds between glazing layers or in the air-space (gap) of glazed double façades**: These have highly-reflective or mirror-finished surfaces and the louvres of the upper and lower sections of the blinds are at different angles. The upper section of the blind shall not be higher than 1/3 and not lower than 1/4 of the total blind length and the system shall be equipped with control devices.

No solar and/or glare protection devices may be installed in front of the light-guiding components listed in Table F.7.

F.4 Daylight supply factor for roof lights

F.4.1 General

As in the method applied for vertical façades, the first evaluation step for roof lights is to classify the daylight availability via the daylight factor. Then the daylight availability factors can be determined for different maintained illuminance values, different orientations and slope angles of the glazed roof openings and locations and climates. When movable shading devices exist, this needs to be done for the two different states, when shading is activated and when it is not.

F.4.2 Daylight availability factor

An approximate value of the mean daylight factor of spaces equipped with roof lights can be calculated using equations (F.17) and (F.18).

When shading is not activated:

$$\overline{D}_{SNA} = D_{\mathrm{a}} \cdot \tau_{D65,SNA} \cdot k_{Obl,1} \cdot k_{Obl,2} \cdot k_{Obl,3} \cdot \frac{\sum A_{\mathrm{Ca}}}{A_{\mathrm{D}}} \cdot \eta_{\mathrm{R}} \text{ [\%]} \tag{F.17}$$

When shading is activated:

$$\overline{D}_{SA} = D_{\mathrm{a}} \cdot \tau_{D65,SA} \cdot k_{Obl,1} \cdot k_{Obl,2} \cdot k_{Obl,3} \cdot \frac{\sum A_{\mathrm{Ca}}}{A_{\mathrm{D}}} \cdot \eta_{\mathrm{R}} \text{ [\%]} \tag{F.18}$$

where

A_{Ca} is the area of the roof lights (raw roof opening dimensions);

A_{D} is the floor area which is lit by daylight in the space being evaluated;

D_{a} is the external daylight factor;

$\tau_{\mathrm{D65,SNA}}$ is the transmittance of the diffusive roof light glazing when shading is not activated;

$\tau_{\mathrm{D65,SA}}$ is the transmittance of the diffusive roof light glazing when shading is activated;

$k_{\mathrm{Obl,1}}$ is the reduction factor for frames and subdivisions of the roof light glazing;

$k_{\mathrm{Obl,2}}$ is the reduction factor for pollution of the roof light glazing;

$k_{\mathrm{Obl,3}}$ is the reduction factor for non-vertical light incidence on the roof light (0,85 is considered to be adequate);

η_{R} is the value of utilance as listed in Table F.9 and Table F.10.

Equations (F.17) and (F.18) combine the calculation stages 1 (classification of daylight availability) and 2 (description of the façade characteristics) of the three-stage calculation approach in one single calculation step. This method is also applicable for skylights with transparent glazing. Typical transmittance values of components frequently used in roof lights are given in the CEN/TR 15193-2.

The external daylight factor D_{a} is defined as:

$$D_{\mathrm{a}} = \frac{E_{\mathrm{F}}}{E_{\mathrm{a}}} \text{ [\%]} \tag{F.19}$$

where

E_F is the illuminance on the external surface of the skylight from an overcast sky;

E_a is the horizontal external illuminance from an overcast sky.

The reduction factor $k_{Obl,1}$ for frames and subdivisions can be determined using equation (F.13). The structural parts of individual roof lights include the annular supports. Thus $k_{Obl,1}$ is the ratio of the area $A_{Fs} = a_s \cdot b_s$ through which light can pass, i.e. the top opening of the annular support, minus the area of other opaque parts of the domes or strip skylights, to the area $A_{Rb} = a_{Rb} \cdot b_{Rb}$ of the raw roof opening as shown in Figure F.9.

As opposed to this, the raw roof opening area of shed roof lights does not correspond to the area of the roof plane occupied by the shed structure, as shown in Figure F.10. For these, the raw roof opening area is $A_{Rb} = h_G \cdot b_{Rb}$, where h_G is the height of the roof light opening and b_{Rb} is the width of the roof light opening. The correction factor $k_{Obl,1}$ for frames and subdivisions accounts for the other opaque parts of the roof light structure within the opening defined in this way.

Table F.8 lists external daylight factors D_a for a floor reflectance ρ_F of 0,2 and various slope angles of the shed roof light glazing.

Table F.8 — External daylight factor D_a as a function of the façade slope γ_F for a floor reflectance ρ_F of 0,2 (without building shading)

Slope γ_F degrees	$D_a = E_F/E_a$ %
0	100
30	92
45	83
60	72
90	50

The utilance η_R is calculated on the basis of the room index as determined using equation (F.4) and the type of roof light involved. In the calculation of η_R, h'_R is the difference between the ceiling height and the work plane height. A distinction is made between the roof lights shown in Figure F.9 and the shed roof lights shown in Figure F.10. Continuous roof lights are treated as a special roof light design. For continuous roof lights with a side ratio a_s/b_s of more than five, the utilance stated for ratio $a_s/b_s = 5$ should be assumed.

Table F.9 and Table F.10 show utilance values for different types of roof lights and shed-roof light geometries.

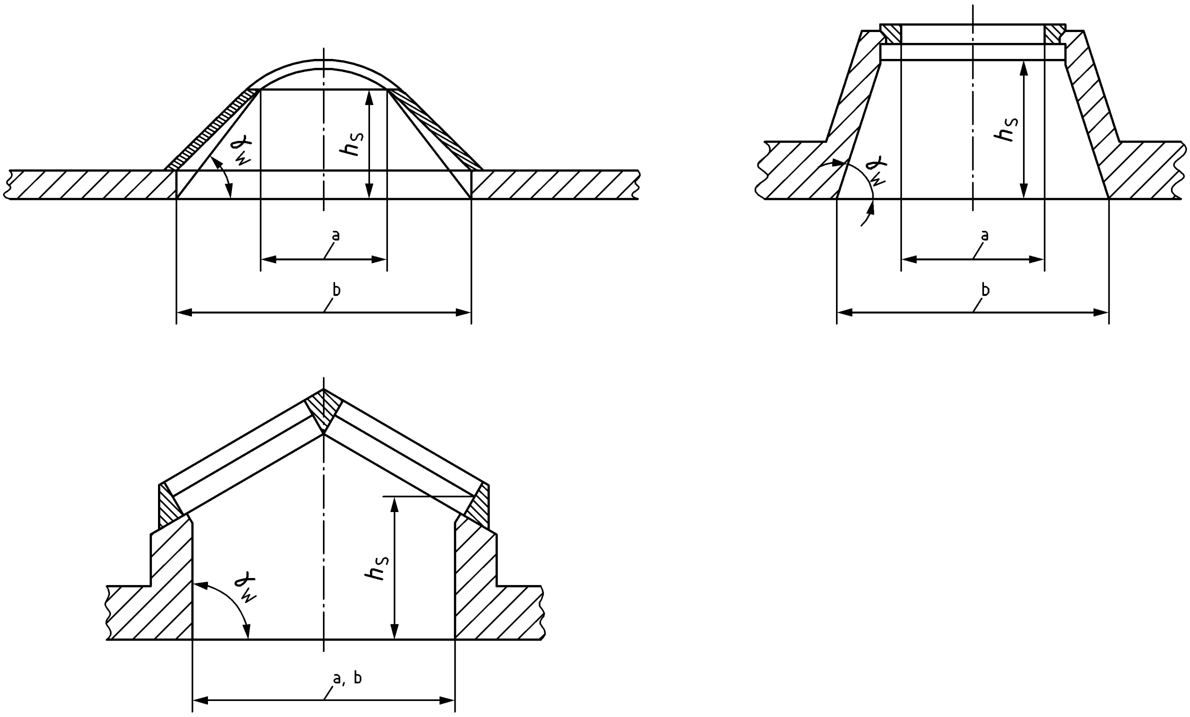


Figure F.9 — Dimensions used to describe the geometry of the annular supports of spaces with individual and continuous roof lights

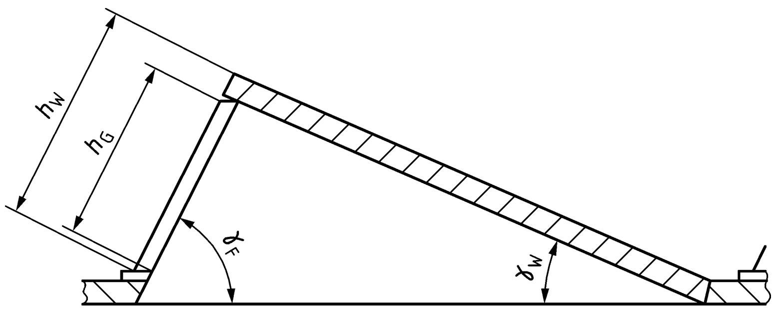


Figure F.10 — Dimensions used to describe the geometry of shed roof lights

Table F.9 — Roof light utilances η_R, expressed as a percentage, as a function of the room index k and the geometry parameters of the annular support design

a_s/b_s	1			2			5			1			2			5		
h_s/b_s	0,25			0,25			0,25			0,5			0,5			0,5		
γ_w	30°	60°	90°	30°	60°	90°	30°	60°	90°	30°	60°	90°	30°	60°	90°	30°	60°	90°
k	η_R %																	
0,6	0,40	0,41	0,38	0,40	0,40	0,39	0,41	0,41	0,40	0,40	0,41	0,36	0,40	0,41	0,37	0,42	0,43	0,39
0,8	0,53	0,54	0,50	0,53	0,54	0,51	0,54	0,55	0,52	0,53	0,55	0,46	0,53	0,55	0,49	0,55	0,57	0,51
1,0	0,59	0,60	0,56	0,59	0,60	0,57	0,60	0,61	0,59	0,60	0,61	0,51	0,60	0,61	0,54	0,62	0,66	0,56
1,25	0,68	0,69	0,64	0,68	0,69	0,66	0,69	0,70	0,67	0,69	0,69	0,58	0,69	0,70	0,62	0,71	0,72	0,64
1,5	0,75	0,75	0,69	0,75	0,75	0,71	0,76	0,76	0,72	0,76	0,75	0,63	0,76	0,76	0,67	0,78	0,78	0,69
2,0	0,83	0,83	0,77	0,83	0,83	0,79	0,84	0,84	0,80	0,84	0,82	0,69	0,84	0,83	0,73	0,87	0,85	0,75
2,5	0,89	0,88	0,81	0,89	0,88	0,84	0,90	0,89	0,85	0,90	0,87	0,73	0,90	0,88	0,77	0,92	0,90	0,79
3,0	0,93	0,92	0,85	0,93	0,92	0,87	0,94	0,93	0,88	0,94	0,90	0,76	0,94	0,91	0,81	0,96	0,93	0,86
4,0	0,98	0,96	0,90	0,98	0,97	0,92	0,99	0,98	0,93	0,99	0,95	0,80	0,98	0,96	0,85	1,00	0,98	0,87
5,0	1,02	1,00	0,92	1,02	1,00	0,95	1,03	1,01	0,96	1,02	0,97	0,82	1,02	0,99	0,87	1,04	1,01	0,89

Table F.10 — Shed roof light utilances η_R, expressed as a percentage, as a function of the room index k and the geometry parameters

h_G/h_W	1													0,5												
γ_F	30				45	60				90				30				45	60				90			
γ_W	30°	45°	60°	75°	45°	30°	45°	60°	75°	30°	45°	60°	75°	30°	45°	60°	75°	45°	30°	45°	60°	75°	30°	45°	60°	75°
k	η_R %																									
0,6	0,39	0,39	0,41	0,40	0,37	0,34	0,35	0,36	0,35	0,29	0,30	0,31	0,31	0,38	0,39	0,39	0,40	0,36	0,33	0,34	0,35	0,36	0,29	0,29	0,30	0,30
0,8	0,51	0,52	0,53	0,50	0,49	0,44	0,45	0,46	0,44	0,37	0,39	0,39	0,38	0,50	0,51	0,52	0,51	0,48	0,43	0,44	0,45	0,44	0,37	0,37	0,38	0,38
1,0	0,57	0,58	0,58	0,55	0,55	0,50	0,52	0,51	0,49	0,44	0,45	0,45	0,44	0,56	0,57	0,57	0,56	0,53	0,49	0,50	0,51	0,50	0,43	0,44	0,44	0,44
1,25	0,66	0,66	0,65	0,62	0,62	0,58	0,59	0,58	0,55	0,51	0,51	0,51	0,49	0,65	0,65	0,65	0,64	0,61	0,57	0,58	0,58	0,56	0,50	0,51	0,50	0,50
1,5	0,72	0,72	0,71	0,67	0,68	0,64	0,64	0,63	0,60	0,56	0,56	0,56	0,54	0,71	0,71	0,71	0,69	0,67	0,62	0,63	0,63	0,61	0,55	0,56	0,55	0,55
2,0	0,80	0,79	0,77	0,73	0,75	0,72	0,71	0,69	0,66	0,64	0,63	0,62	0,60	0,79	0,79	0,78	0,76	0,75	0,71	0,71	0,70	0,68	0,62	0,63	0,62	0,61
2,5	0,85	0,84	0,81	0,77	0,80	0,77	0,76	0,73	0,70	0,69	0,68	0,66	0,64	0,84	0,84	0,83	0,80	0,80	0,76	0,76	0,75	0,72	0,68	0,68	0,67	0,65
3,0	0,88	0,88	0,84	0,80	0,83	0,81	0,79	0,76	0,72	0,72	0,71	0,69	0,67	0,88	0,88	0,86	0,83	0,84	0,80	0,80	0,78	0,75	0,72	0,71	0,70	0,68
4,0	0,94	0,92	0,88	0,84	0,87	0,85	0,83	0,80	0,76	0,77	0,75	0,73	0,70	0,93	0,93	0,91	0,87	0,88	0,85	0,84	0,82	0,79	0,77	0,76	0,75	0,72
5,0	0,97	0,95	0,91	0,87	0,90	0,89	0,86	0,82	0,78	0,80	0,78	0,75	0,73	0,97	0,96	0,93	0,90	0,92	0,89	0,88	0,85	0,81	0,80	0,79	0,77	0,75

Daylight availability is classified in accordance with the criteria shown in Table F.11 and Table F.12.

Table F.11 — Classification of daylight availability when shading is not activated as a function of the daylight factor $\overline{D}_{SNA}$

Classification criterion $\overline{D}_{SNA}$	Classification of daylight availability
7 % ≤ $\overline{D}_{SNA}$ [a]	Strong
4 % ≤ $\overline{D}_{SNA}$ < 7 %	Medium
2 % ≤ $\overline{D}_{SNA}$ < 4 %	Low
0 % ≤ $\overline{D}_{SNA}$ < 2 %	None
[a] Values of $\overline{D}_j$ > 10 % should be avoided due to the danger of overheating.	

Table F.12 — Classification of daylight availability when shading is activated as a function of the daylight factor $\overline{D}_{SA}$

Classification criterion $\overline{D}_{SA}$	Classification of daylight availability
2,5 % ≤ $\overline{D}_{SA}$ [a]	Strong
1,5 % ≤ $\overline{D}_{SA}$ < 2,5 %	Medium
0,5 % ≤ $\overline{D}_{SA}$ < 1,5 %	Low
0 % ≤ $\overline{D}_{SA}$ < 0,5 %	None

If a daylight factor which has been calculated using another validated method is known, this can be used instead of the value calculated by equation (F.17) and (F.18) when classifying daylight availability in accordance with Table F.11 and Table F.12. In this case, the daylight factor shall be determined as the mean value on the work plane.

The daylight availability factor $F_{\mathrm{D,s,SNA},j}$ can be derived by the tables given in the following section. Alternatively it can be calculated using computer based tools or using the regression based compound method described in CEN/TR 15193-2.

F.4.3 Daylight supply factor

As in the method applied for vertical façades, the daylight supply factor $F_{\mathrm{D,s},j}$. is derived by the following equation

$$F_{\mathrm{D,s},j} = t_{\mathrm{rel,D,SNA},j}\ F_{\mathrm{D,s,SNA},j} + t_{\mathrm{rel,D,SA},j}\ F_{\mathrm{D,s,SA},j} \qquad \text{(F.20)}$$

where

$t_{\mathrm{rel,D,SNA},j}$ is the relative portion of the total operating time during which the shading system is not activated, as given in Table F.13, depending on the considered location.

$t_{\mathrm{rel,D,SA},j}$ is the relative portion of the total operating time during which the shading system is activated. $t_{\mathrm{rel,D,SA}}$ can be obtained by $t_{\mathrm{rel,D,SA}} = 1 - t_{\mathrm{rel,D,SNA}}$.

$F_{D,s,SNA,j}$ is the daylight availability factor of the area j being evaluated at times when the shading system is not activated. It depends on the considered location and is given in Table F.14 for Frankfurt (Germany).

$F_{D,s,SA,j}$ is the daylight availability factor of the area j being evaluated at times when the shading system is activated. It depends on the considered location and is given in Table F.15 for Frankfurt (Germany).

F.4.4 Relative times, shading activated/ not activated for roof lights

Table F.13 holds the relative times $t_{rel,D,SNA,j}$ and $t_{rel,D,SA,j}$ for the given European locations.

Table F.13 — Relative times $t_{rel,D,SNA,j}$ and $t_{rel,D,SA,j}$ for not activated and activated shading systems for the given locations, as a function of the façade orientation and the slope of the surface

Orientation	Surface slope	Athens		Bratislava		Frankfurt		London		Lyon		Stockholm	
		$t_{rel,D,SNA,j}$	$t_{rel,D,SA,j}$	$t_{rel,D,SNA,j}$	$t_{rel,D,SA,j}$	$t_{rel,D,SNA,j}$	$t_{rel,D,SA,j}$	$t_{rel,D,SNA,j}$	$t_{rel,D,SA,j}$	$t_{rel,D,SNA,j}$	$t_{rel,D,SA,j}$	$t_{rel,D,SNA,j}$	$t_{rel,D,SA,j}$
		Shading not activated	Shading activated	Shading not activated	Shading activated	Shading not activated	Shading activated	Shading not activated	Shading activated	Shading not activated	Shading activated	Shading not activated	Shading activated
Horizontal	0°	0,61	0,39	0,62	0,38	0,67	0,33	0,69	0,31	0,65	0,35	0,67	0,33
South	30°	0,61	0,39	0,62	0,38	0,67	0,33	0,69	0,31	0,65	0,35	0,67	0,33
	45°	0,61	0,39	0,62	0,38	0,67	0,33	0,69	0,31	0,65	0,35	0,67	0,33
	60°	0,61	0,39	0,62	0,38	0,67	0,33	0,69	0,31	0,65	0,35	0,67	0,33
	90°	0,59	0,41	0,62	0,38	0,67	0,33	0,69	0,31	0,65	0,35	0,67	0,33
South-east / South-west	30°	0,61	0,39	0,62	0,38	0,67	0,33	0,69	0,31	0,65	0,35	0,67	0,33
	45°	0,60	0,40	0,63	0,37	0,68	0,32	0,71	0,29	0,66	0,34	0,68	0,32
	60°	0,56	0,44	0,65	0,35	0,70	0,30	0,72	0,28	0,68	0,32	0,69	0,31
	90°	0,45	0,55	0,70	0,30	0,75	0,25	0,75	0,25	0,73	0,27	0,73	0,27
East / West	30°	0,58	0,42	0,64	0,36	0,70	0,30	0,72	0,28	0,67	0,33	0,70	0,30
	45°	0,51	0,49	0,69	0,31	0,74	0,26	0,76	0,24	0,71	0,29	0,74	0,26
	60°	0,44	0,56	0,73	0,27	0,78	0,22	0,79	0,21	0,75	0,25	0,77	0,23
	90°	0,32	0,68	0,81	0,19	0,83	0,17	0,85	0,15	0,82	0,18	0,83	0,17
North-east / North-west	30°	0,56	0,44	0,66	0,34	0,72	0,28	0,75	0,25	0,68	0,32	0,75	0,25
	45°	0,47	0,53	0,74	0,26	0,79	0,21	0,81	0,19	0,75	0,25	0,82	0,18
	60°	0,35	0,65	0,82	0,18	0,85	0,15	0,87	0,13	0,82	0,18	0,88	0,12
	90°	0,18	0,82	0,91	0,09	0,92	0,08	0,94	0,06	0,91	0,09	0,94	0,06
North	30°	0,54	0,46	0,68	0,32	0,74	0,26	0,77	0,23	0,69	0,31	0,76	0,24
	45°	0,44	0,56	0,75	0,25	0,79	0,21	0,82	0,18	0,75	0,25	0,83	0,17
	60°	0,33	0,67	0,85	0,15	0,89	0,11	0,90	0,10	0,84	0,16	0,96	0,04
	90°	0,03	0,97	0,99	0,01	1,00	0,00	1,00	0,00	1,00	0,00	1,00	0,00

F.4.5 Daylight supply factors as function of the daylight availability classification

Tables F.14 and F.15 provide values of $F_{D,SNA,j}$ and $F_{D,SA,j}$ for roof lights. The values presented are based on the data of Frankfurt (Germany). The corresponding tables and values of the other five given European locations can be found in the Technical Report.

For maintained illuminances $\overline{E}_m$ of less than 100 lx, daylight availability factor $F_{D,s,j}$ values for $\overline{E}_m$ = 100 lx should be used. For maintained illuminances $\overline{E}_m$ of greater than 1 000 lx, the $F_{D,s,j}$ values for $\overline{E}_m$ = 1 000 lx should be used.

Table F.14 —Daylight supply factor $F_{D,SNA,j}$ for rooflights when shading is not activated as a function of the classification of daylight availability and of the maintained illuminance for different orientations and surface slopes, for Frankfurt (Germany).

Orientation	Surface slope	Classification of daylight availability														
		Low*					Medium*					Strong*				
		100 lx	300 lx	500 lx	750 lx	1 000 lx	100 lx	300 lx	500 lx	750 lx	1 000 lx	100 lx	300 lx	500 lx	750 lx	1 000 lx
Horizontal	0°	0,95	0,83	0,68	0,52	0,40	0,97	0,92	0,85	0,75	0,65	0,98	0,95	0,92	0,86	0,79
South	30°	0,95	0,81	0,66	0,50	0,38	0,97	0,92	0,84	0,73	0,62	0,98	0,95	0,91	0,84	0,77
	45°	0,94	0,79	0,62	0,46	0,35	0,97	0,90	0,81	0,69	0,59	0,98	0,94	0,90	0,82	0,74
	60°	0,94	0,75	0,57	0,41	0,31	0,96	0,89	0,78	0,65	0,53	0,97	0,93	0,87	0,79	0,70
	90°	0,91	0,64	0,44	0,30	0,22	0,95	0,82	0,67	0,52	0,40	0,97	0,90	0,80	0,68	0,58
South-east / South-west	30°	0,95	0,81	0,66	0,49	0,38	0,97	0,91	0,83	0,72	0,62	0,98	0,94	0,91	0,84	0,77
	45°	0,94	0,78	0,61	0,45	0,34	0,97	0,90	0,81	0,69	0,58	0,98	0,94	0,89	0,81	0,74
	60°	0,94	0,75	0,56	0,40	0,30	0,96	0,89	0,78	0,64	0,53	0,97	0,93	0,88	0,79	0,70
	90°	0,92	0,66	0,45	0,30	0,23	0,95	0,83	0,69	0,53	0,41	0,97	0,91	0,82	0,70	0,59
East / West	30°	0,95	0,80	0,64	0,48	0,36	0,97	0,91	0,82	0,71	0,60	0,98	0,95	0,90	0,83	0,76
	45°	0,95	0,78	0,60	0,43	0,33	0,97	0,90	0,80	0,67	0,56	0,98	0,94	0,89	0,81	0,73
	60°	0,94	0,75	0,56	0,39	0,29	0,97	0,89	0,78	0,64	0,52	0,98	0,94	0,88	0,79	0,69
	90°	0,92	0,66	0,45	0,30	0,23	0,96	0,84	0,70	0,53	0,41	0,97	0,91	0,83	0,71	0,60
North-east / North-west	30°	0,95	0,79	0,63	0,47	0,35	0,97	0,91	0,82	0,70	0,59	0,98	0,95	0,90	0,83	0,75
	45°	0,95	0,78	0,59	0,42	0,32	0,97	0,91	0,80	0,67	0,55	0,98	0,95	0,90	0,81	0,72
	60°	0,95	0,75	0,55	0,38	0,29	0,97	0,90	0,78	0,63	0,51	0,98	0,94	0,88	0,79	0,69
	90°	0,93	0,67	0,45	0,30	0,23	0,96	0,85	0,71	0,54	0,42	0,97	0,92	0,83	0,72	0,61
North	30°	0,95	0,79	0,62	0,46	0,35	0,97	0,91	0,81	0,69	0,58	0,98	0,95	0,90	0,82	0,74
	45°	0,95	0,76	0,57	0,41	0,31	0,97	0,90	0,79	0,65	0,54	0,98	0,94	0,89	0,80	0,71
	60°	0,95	0,75	0,55	0,38	0,28	0,97	0,89	0,78	0,63	0,51	0,98	0,94	0,88	0,79	0,69
	90°	0,93	0,68	0,46	0,31	0,23	0,96	0,86	0,72	0,55	0,42	0,97	0,92	0,84	0,73	0,61

* The classification is based on the following daylight factors of the raw building carcass opening $D_{Ca,j}$: Low: 3 %; Medium: 5,5 %; Strong: 8,5 %.

Table F.15 —Daylight supply factor $F_{D,SA,j}$ for roof lights when shading is activated as a function of the classification of daylight availability and of the maintained illuminance for different orientations and surface slopes, for Frankfurt (Germany).

Orientation	Surface slope	Classification of daylight availability														
		Low*					Medium*					Strong*				
		100 lx	300 lx	500 lx	750 lx	1 000 lx	100 lx	300 lx	500 lx	750 lx	1 000 lx	100 lx	300 lx	500 lx	750 lx	1 000 lx
Horizontal	0°	0,98	0,91	0,83	0,69	0,54	0,99	0,96	0,93	0,88	0,83	0,99	0,98	0,96	0,93	0,90
South	30°	0,99	0,96	0,91	0,80	0,66	0,99	0,99	0,97	0,95	0,91	0,99	0,99	0,98	0,97	0,96
	45°	0,99	0,97	0,92	0,81	0,67	0,99	0,99	0,98	0,96	0,92	0,99	0,99	0,99	0,98	0,96
	60°	0,99	0,97	0,91	0,79	0,64	0,99	0,99	0,98	0,96	0,91	0,99	0,99	0,99	0,98	0,97
	90°	0,99	0,94	0,83	0,63	0,48	0,99	0,99	0,97	0,91	0,83	0,99	0,99	0,99	0,97	0,93
South-east / South-west	30°	0,99	0,94	0,86	0,75	0,62	1,00	0,98	0,95	0,91	0,86	1,00	0,99	0,98	0,95	0,93
	45°	0,99	0,92	0,85	0,74	0,61	1,00	0,97	0,94	0,90	0,85	1,00	0,99	0,97	0,94	0,91
	60°	0,99	0,94	0,86	0,75	0,60	1,00	0,98	0,96	0,91	0,86	1,00	0,99	0,98	0,96	0,93
	90°	0,99	0,93	0,84	0,66	0,50	0,99	0,98	0,95	0,90	0,84	1,00	0,99	0,98	0,95	0,92
East / West	30°	0,99	0,91	0,81	0,68	0,54	1,00	0,98	0,94	0,87	0,81	1,00	0,99	0,97	0,94	0,89
	45°	0,99	0,91	0,81	0,68	0,54	1,00	0,98	0,94	0,87	0,81	1,00	0,99	0,98	0,94	0,90
	60°	0,99	0,92	0,81	0,67	0,53	1,00	0,98	0,95	0,88	0,81	1,00	0,99	0,98	0,95	0,90
	90°	0,99	0,89	0,75	0,58	0,44	0,99	0,98	0,92	0,84	0,75	0,99	0,99	0,97	0,92	0,87
North-east / North-west	30°	0,98	0,87	0,75	0,57	0,43	0,99	0,96	0,90	0,83	0,75	1,00	0,98	0,95	0,90	0,85
	45°	0,98	0,86	0,71	0,52	0,39	0,99	0,96	0,90	0,81	0,71	0,99	0,98	0,95	0,90	0,84
	60°	0,97	0,85	0,68	0,49	0,36	0,99	0,95	0,89	0,79	0,68	0,99	0,97	0,95	0,89	0,83
	90°	0,96	0,80	0,57	0,38	0,29	0,98	0,94	0,85	0,71	0,57	0,99	0,96	0,93	0,85	0,76
North	30°	0,99	0,91	0,75	0,52	0,39	1,00	0,98	0,93	0,86	0,75	1,00	0,99	0,97	0,93	0,89
	45°	0,99	0,84	0,58	0,38	0,29	1,00	0,98	0,90	0,74	0,58	1,00	0,99	0,97	0,90	0,80
	60°	0,99	0,68	0,41	0,27	0,20	0,99	0,97	0,79	0,54	0,41	0,99	0,99	0,95	0,79	0,61
	90°	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

* The classification is based on the following daylight factors of the raw building carcass opening $D_{Ca,j}$: Low: 1 %; Medium: 2 %; Strong: 3 %.

F.5Daylight Responsive Control Systems

The effect taken into consideration here relates to the characteristics of the electric lighting controls deployed to supplement the available daylight in order to achieve the required illuminance. Control systems which control or regulate the transmission of light through the façades are not discussed here.

The correction factor $F_{D,c,j}$ for daylight-responsive control systems is a function of:

a) the type of control involved;

b) the daylight supply classification of the zone;

c) the maintained illuminance Ēm.

Electric lighting control systems are distinguished in accordance with whether they are:

- controlled manually; or

- controlled automatically in order to adjust the electric light intensity depending on the daylight supply.

A distinction is made between the following:

I. Manual control.

II. Systems which are daylight-responsive (“on/off”): the electric lighting is automatically switched off when the maintained illuminance is achieved by daylight at the point where the illuminance is measured. The electric lighting is switched on again automatically when the maintained illuminance is no longer achieved by daylight.

III. Systems which are daylight-responsive and turn on or off in stages (“on/off in stages”): The electric lighting is switched off in stages until the maintained illuminance is achieved by daylight at the point where the illuminance is measured. The electric lighting is switched on again automatically in stages when the maintained illuminance is no longer achieved by daylight.

IV. Systems which are daylight-responsive and turn off the electric lighting (“daylight-responsive off”): The electric lighting is switched off when the maintained illuminance is achieved by daylight at the point where the illuminance is measured. The electric lighting has to be turned on again manually.

V. Systems which are daylight-responsive and dim the electric lighting without switching it off, then turn on again (“dimmed, stand-by losses, switch-on”): The electric lighting is dimmed to the lowest level during usage periods (periods with adequate daylight) without being switched off (i.e. it uses electrical power (“stand-by losses”)). The electric lighting system is turned on again automatically.

VI. Systems which are daylight-responsive, and dim the electric lighting: The electric lighting is switched off and turned on again (“dimmed, no stand-by losses, switch-on”). The electric lighting is dimmed to the lowest level during usage periods (periods with adequate daylight) and switched off (i.e. no electrical power is used). The electric lighting system is turned on again automatically.

VII. Systems which are daylight-responsive and dim the electric lighting but do not switch it off nor turn it on again (“dimmed, stand-by losses, no switch-on”): As system V, except that the electric lighting system is not turned on again automatically.

VIII. Systems which are daylight-responsive and dim and switch off the electric lighting (“dimmed, no stand-by losses, no switch-on”): As system VI, except that the electric lighting system is not turned on again automatically.

The types of control can be operated as stand-alone systems or integrated in installation bus systems or building management systems. Correction factors $F_{D,c,j}$ are given in Table F.16.

Table F.16 — Correction factor $F_{D,c,j}$ to account for the effect of daylight-responsive control systems in a zone *n*, as a function of the maintained illuminance $\bar{E}_m$ and the daylight supply classification

Type of control			Type of system	$F_{D,c,j}$ as a function of daylight supply								
				Classification of daylight availability								
				Low			Medium			Strong		
				$\bar{E}_m$								
				300 lx	500 lx	750 lx	300 lx	500 lx	750 lx	300 lx	500 lx	750 lx
Manual			I	0,50	0,47	0,44	0,55	0,52	0,49	0,60	0,57	0,54
Automated	Switched	On/off	II	0,58	0,59	0,59	0,63	0,63	0,62	0,67	0,66	0,65
		On/off in stages	III	0,65	0,70	0,73	0,70	0,73	0,75	0,73	0,75	0,76
		Daylight responsive off	IV	0,65	0,70	0,73	0,70	0,73	0,75	0,73	0,75	0,76
	Dimmed	Stand-by losses, switch-on	V	0,65	0,70	0,73	0,70	0,73	0,75	0,73	0,75	0,76
		No stand-by losses, switch-on	VI	0,71	0,74	0,76	0,77	0,78	0,79	0,81	0,81	0,81
		Stand-by losses, no switch-on	VII	0,72	0,77	0,80	0,77	0,80	0,83	0,80	0,83	0,84
		No stand-by losses, no switch-on	VIII	0,78	0,81	0,84	0,85	0,86	0,87	0,89	0,89	0,89

It is recommended not to use in spaces like offices "on/off" systems (II) and in parts "on/off in stages" (III) as they are usually not well accepted by users and are often deactivated after a short period of time. However, switching the light "on/off" in e.g. hallways, toilets, stairs, rest and utility rooms is generally accepted. In addition, switching the electric lighting on and off in stages (III) may be particularly suitable for large interior spaces such as those in factory buildings, for example.

F.6 Monthly evaluation method

The distribution key factors $v_{Month,i}$ for vertical façades are given in Table F.17. Since light-guiding systems are based on the deflection or guidance of direct light, which is more available in the summer months, separate distribution key factors as a function of the orientation are given for such systems. Table F.18 shows the values for spaces equipped with roof lights. In the summer months, daylight availability can account for 100 % of the required lighting. This means that no supplementary artificial lighting is required during this period. Since the product $F_{D,s,j}$ $F_{D,c,j}$ is weighted by monthly key factors, for all months during which $v_{Month,I}\,F_{D,s,j}\,F_{D,c,j}$ is greater than 1, the difference ($v_{Month,I}\,F_{D,s,j}\,F_{D,c,j} - 1$) shall be added up to $\Delta F_{D,s,j}$. $\Delta F_{D,s,j}$

shall be equally divided up among all months during which $v_{Month,I}$ $F_{D,s,j}$ $F_{D,c,j}$ is less than 1. Where necessary, an iteration procedure shall be applied.

Table F.16 — Monthly distribution key factors $v_{Month,i}$ for vertical façades

Façade system	Month, i											
	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	March	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
	$v_{Month,i}$											
Light-guiding systems according to Table F.7 South-facing	0,67	0,89	1,06	1,18	1,25	1,28	1,26	1,20	1,08	0,92	0,72	0,46
Light-guiding systems according to Table F.7, facing East or West	0,74	0,92	1,06	1,16	1,22	1,24	1,22	1,16	1,06	0,93	0,75	0,54
Others	0,85	0,97	1,06	1,12	1,16	1,17	1,15	1,11	1,04	0,94	0,81	0,66

Table F.17 — Monthly distribution key factors $v_{Month,i}$ for roof lights

Month, i											
1	2	3	4	5	6	7	8	9	10	11	12
Jan	Feb	March	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
$v_{Month,i}$											
0,74	0,92	1,06	1,16	1,22	1,24	1,22	1,16	1,06	0,93	0,75	0,54

Monthly partial-load daylight operation factors $F_{D,j,i}$ can be derived from the calculated annual daylight availability factor.

If $v_{\text{Month},i} \cdot F_{\text{D,s},j} \cdot F_{\text{D,c},j}$ <1

$$F_{\text{D},j,i} = 1 - v_{\text{Month},i} \cdot F_{\text{D,s},j} \cdot F_{\text{D,c},j} \qquad \text{(F.21)}$$

otherwise $F_{\text{D},j,i} = 0$

where

$v_{\text{Month},i}$ is the monthly distribution key for weighting the value of $F_{D,s,j}$.

F.7 Determination of daytime and night time hours

The number of daytime and night time hours needs to be known in order to be able to determine the energy need and energy use for lighting. The approximate method described below can be used in cases where the daytime and night time hours for the types of usage listed in Table F.19 are to be determined due to deviating operating times or when a totally different type of usage is specified.

The method described below can be used to determine the number of daytime hours t_{Day} and night time hours t_{Night} on a monthly basis for a known latitude φ and a specified beginning of usage t_{start} and end of usage t_{ende}. The hours between sunrise and sunset are considered to be daytime hours.

The times $t_{Day,i}$ and $t_{Night,i}$ for each month are calculated using equations (F.22) and (F.23):

$$t_{Day,i} = N_i \times C_{we} \left((t_{ende} - t_{start}) - (t_{bs,i} + t_{as,i}) \right) \tag{F.22}$$

$$t_{Night,i} = N_i \times C_{we} \left(t_{bs,i} + t_{as,i} \right) \tag{F.23}$$

where

N_i is the number of days in the respective month; N_i = [31, 28, 31, 30, 31, 30, 31, 31, 30, 31, 30, 31] with i = 1 to 12;

C_{we} is the reduction factor to account for weekends; the value of C_{we} to account for all weekends is 5/7, if no weekends are taken into consideration C_{we} is equal to 1;

t_{start} is the time of the beginning of usage;

t_{ende} is the time of the end of usage;

$t_{bs,i}$ is the usage time before sunrise;

$t_{as,i}$ is the usage time after sunset.

The times before sunrise $t_{bs,i}$ and after sunset $t_{as,i}$ are determined using equations (F.24) and (F.25).

If $t_{sunrise,i} > t_{start,i}$

$$t_{bs,i} = t_{sunrise,i} - t_{start,i} \tag{F.24}$$

otherwise $t_{bs,i} = 0$

If $t_{ende} > t_{sunset,i}$

$$t_{as,i} = t_{ende,i} - t_{sunset,i} \tag{F.25}$$

otherwise $t_{as,i} = 0$

where

t_{sunset} is the sunset time;

$t_{sunrise}$ is the sunrise time.

The time of sunrise $t_{sunrise}$ and the time of sunset t_{sunset} are calculated using equations (F.26) and (F.27):

$$t_{sunrise,i} = (12 - \omega_i / 15°) - \text{teq}(J_i)/60 \tag{F.26}$$

$$t_{sunset,i} = (12 + \omega_i / 15°) - \text{teq}(J_i)/60 \tag{F.27}$$

where

ω_i is the hour angle;

teq is the equation of time (F.28).

Equation (F.28) is used to calculate the hour angle, ω_i:

$$\omega_i = \arccos\left(-\frac{\sin(\varphi)\sin(\delta(J_i))}{\cos(\varphi)\cos(\delta(J_i))}\right) \qquad \text{(F.28)}$$

where

φ is the geographical latitude of the location;

J_i is the day of the month: in this case, the 15th day of each month is used as a reference: J_i = [15, 46, 74, 105, 135, 166, 196, 227, 258, 288, 319, 349];

δ is the declination of the sun.

Equation (F.29) is used to calculate the declination of the sun:

$\delta(J) = 0{,}394\,8 - 23{,}255\,9 \times \cos(J + 9{,}1°) - 0{,}391\,5 \times \cos(2 \times J' + 5{,}4°) - 0{,}176\,4 \times \cos(3 \times J' + 26{,}0°)$ (F.29)

Equation (F.30) is used to determine the equation of time:

$\text{teq}(J) = 0{,}006\,6 + 7{,}352\,5 \times \cos(J + 85{,}9°) + 9{,}935\,9 \times \cos(2 \times J + 108{,}9) + 0{,}338\,7 \times \cos(3 \times J + 105{,}2)$ (F.30)

with

$J = J \times 360°/365$.

The annual daytime and night time hours are the sum totals of the monthly values as expressed by equations (F.31) and (F.32) respectively:

$$t_{\text{Day}} = \sum_{i=1}^{12} t_{\text{Day},i} \qquad \text{(F.31)}$$

$$t_{\text{Night}} = \sum_{i=1}^{12} t_{\text{Night},i} \qquad \text{(F.32)}$$

Table F.19 shows pre-calculated times t_{Day} and t_{Night} as a function of latitude for typical office operating hours.

Table F.18 — t_{day} and t_{night} as a function of latitude for typical operating hours from 8 am – 5 pm, weekends excluded

Latitude	t_{day} [h]	t_{night} [h]
0,0°	2 346	0
7,5°	2 346	0
22,5°	2 346	0
37,5°	2 341	5
52,5°	2 271	75
67,5°	1 881	465
75,0°	1 629	717

F.8 Comprehensive calculation

A variety of software tools nowadays enables radiosity and/or raytracing based computations of daylight propagation into indoor spaces. By this means it is also possible to calculate the impact of daylight utilization on artificial lighting energy demand with a selected number of tools. $F_{D,n}$ in accordance with equation (F.4) can therefore be calculated with these comprehensive approaches. For this the following boundary conditions shall be met:

- The algorithm shall take into account the climatic conditions at the considered location.
- The (eventually variable) photometry of the façade and the control (which has an impact) of the façade are to be regarded. If the façade incorporates movable shading systems, e.g. movable venetian blinds, the calculation shall take this into account. The supposed control scheme for the façade (when, and how is shading triggered, e.g. cut-off control of venetian blinds, if sun is on façade) shall be modelled within the calculation process.
- The relative luminous exposure $F_{D,S,n}$ (daylight supply factors) shall be evaluated based on an hourly basis at the control point of the artificial lighting system. Results from this can be aggregated to a monthly or annual basis.
- Over a building, comprehensive calculations and simple calculations can be mixed.

Annex G
(normative)
Constant illuminance

All lighting installations, from the instant they are installed, start to decay and reduce their output. In the design of the lighting scheme the decay rate is estimated and applied in the calculations known as the maintenance factor (*MF*). The *MF* is the ratio between maintained illuminance and initial illuminance.

As the task illuminance is specified in terms of maintained illuminance, to assure conformity the scheme should provide higher initial illuminance by a factor 1/*MF*. The *MF* is made up of multiples of factors such as *LLMF, LSF, LMF, and RSMF*. Full details of the derivation of the *MF* can be found in CIE 97.

In installations where a dimmable lighting system is provided, it is possible to automatically control and reduce the initial luminaire output to just provide the required maintained illuminance. Such schemes are known as “controlled constant illuminance" system and provide a reduction in energy use. As the light output decays with time, the controls raise the input power to the luminaire to raise the light output and compensate for the light loss. When the power demand equals the installed power the lighting system will need servicing as it completed the maintenance cycle. In accordance with the schedule, the maintenance will include cleaning luminaires, change lamps, clean room surfaces. Figure G.1 illustrates the impact of the variable power supply to compensate for the declining maintenance factor to hold the constant maintained illuminance in one maintenance cycle.

Power for constant illuminance factor

The power for the constant illuminance factor is the ratio of the actual input power at a given time to the initial installed input power to the luminaire.

G.1 Constant illuminance factor (Fc)

The constant illuminance factor is the ratio of the average input power over a given time to the initial installed input power to the luminaire. Normally the time is taken to be the period of one complete maintenance cycle.

Therefore:

$$F_c = 1 - \frac{1}{2} F_{cc} (1 - MF) \qquad \text{(G.1)}$$

Where F_{cc} is the efficiency factor of the constant illuminance control;

MF is the maintenance factor for the scheme.

In situations where F_{cc} is unknown equation (G.2) may be used. This is a simplified version of equation (G.1) where $F_{cc} = 1$.

$$F_c = (1 + MF)/2 \qquad \text{(G.2)}$$

Where *MF* is the maintenance factor for the scheme.

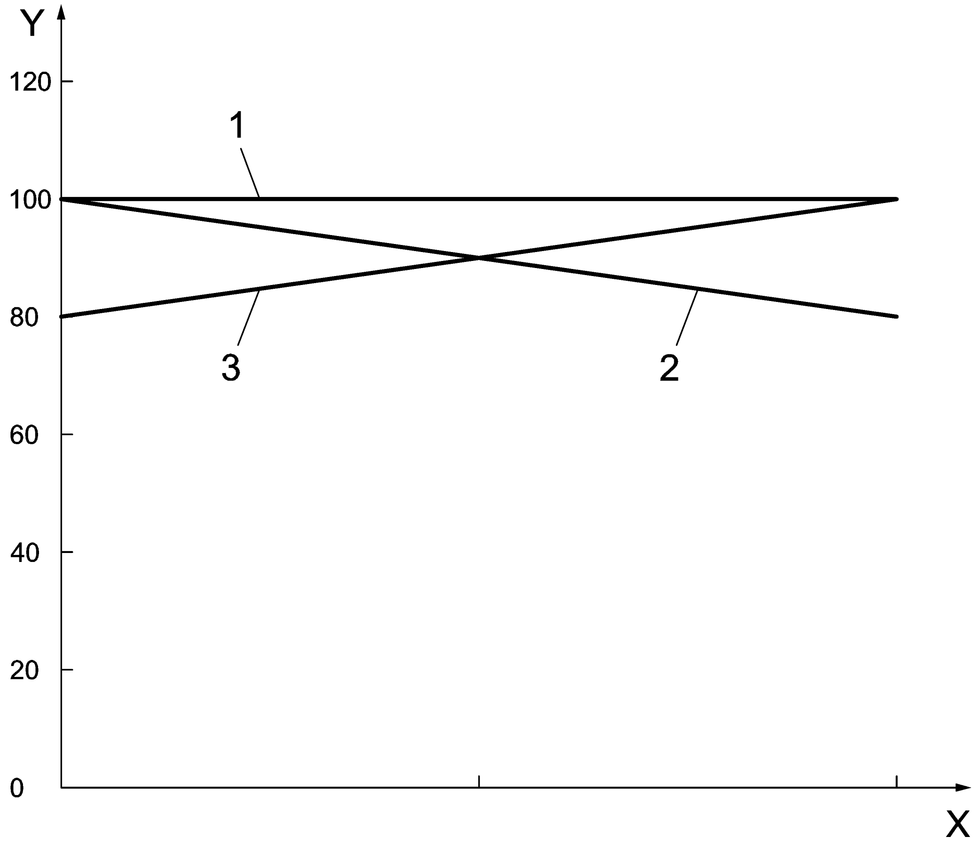


Figure G.1 – Constant illuminance diagram **Key**

1 illuminance
2 maintenance factor
3 power
X time in use
Y % relative values

G.2 Constant lumen output system (CLO)

This feature is driver/luminaire based and over time increases the power to keep the luminous flux constant based upon the known lumen depreciation of the light source (no external sensors involved). This means that the initial flux will be lower (compared to its none CLO equivalent), but will stay constant over its lifetime.

For systems with inbuilt constant light output capabilities having no constant illuminance controls the F_c value shall be based upon equation (G.3).

$$Fc = (1 + LLMF)/2 \quad \text{(G.3)}$$

Annex H
(normative)
Standby system energy requirements

H.1 Emergency lighting luminaire standby charging power (P_{ei})

The emergency lighting luminaire standby charging power P_{ei}, required for trickle charging the batteries in self-contained emergency luminaires with lamps off shall be the declared rated power of the luminaire. This power is for the self-contained emergency luminaires operating in battery charge mode only. The total emergency lighting luminaire charging power P_{em} for luminaires in a room, zone or building shall be summed with equation (H.1):

$$P_{em} = \sum_i P_{ei} \quad [W] \tag{H.1}$$

H.2 Lighting controls standby power (P_{ci})

The luminaire standby power P_{pc} required for standby operation of the lighting controls and detectors in the luminaire without operating the lamps shall be the declared rated standby power of the controlled luminaires. The total controls standby power of luminaires in a room, zone or building shall be calculated using equation (H.2):

$$P_{pc} = \sum_i P_{ci} \quad [W] \tag{H.2}$$

$W_{P,t}$ is the estimated standby energy required during non-lighting periods to provide charging energy for emergency lighting. The activation energy for lighting controls in a room or zone of the building shall be established using equation (H.3):

$$W_{P,t} = \Sigma\{\{P_{pc} \times [t_s - (t_D + t_N)]\} + (P_{em} \times t_e)\}/1\,000 \ [kWh / t_s] \tag{H.3}$$

NOTE 1 The total standby lighting energy can be estimated for any required time step period t_s (hourly, monthly or yearly) in accordance with the time interval of the dependency factors used.

NOTE 2 This estimation does not include the power consumed by control systems remote from the luminaire and not drawing power from the luminaire.

An estimate of the annual standby energy ($W_{P,t}$) required to provide charging energy for emergency lighting and standby energy for automatic lighting controls in the building shall be established using:

$$W_{P,t} = \Sigma\{\{P_{pc} \times [t_y - (t_D + t_N)]\} + (P_{em} \times t_e)\}/1\,000 \ [kWh] \tag{H.4}$$

NOTE 3 For existing buildings, $W_{P,t}$ and $W_{L,t,}$ can be established more accurately by directly and separately metering the energy supplied to the lighting.

NOTE 4 This estimation does not include the power consumed by control systems remote from the luminaire and not drawing power from the luminaire. Where known this should be added.

NOTE 5 The equation does not include the power consumed by a central battery emergency lighting system.

Bibliography

[1] CEN/TR 15193-2, *Energy performance of buildings — — Energy Requirements for lighting – Part 2:*

[2] CIE 97, *Maintenance of indoor electric lighting systems*