
**Light and lighting — Energy
performance of lighting in buildings —
Explanation and justification of
ISO/CIE 20086**



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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 274, *Light and lighting*, in cooperation with CIE Joint Technical Committee 6.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

It is important that lighting schemes are designed appropriately to provide the right light in the right place at the right time, while being energy efficient and conforming to local, regional, and/or national regulations. It is also important that the lighting systems are operated energy efficiently and managed by suitable lighting control systems.

Carrying out a comprehensive lighting design (daylight and electric lighting) for new or refurbished buildings will yield both effective and energy efficient lighting solutions that fulfil the lighting criteria specified in the lighting application standards. The lighting design process will show how much daylight will be available and how much electric lighting is needed and what scheme solutions will satisfy the required lighting conditions during the occupied and unoccupied periods.

ISO/CIE 20086 gives a procedure to estimate the required energy and the energy efficiency of the electric lighting scheme.

There is a risk that the purpose and limitations of ISO/CIE 20086 will be misunderstood, unless the background and context to its content is explained in some detail to users. If this information would have been placed in ISO/CIE 20086, the standard would be overloaded with informative content; and the result is likely to be confusing and cumbersome, especially if ISO/CIE 20086 is referenced in local, regional, or national building codes.

Therefore, this document accompanies ISO/CIE 20086 and provides informative content to support the correct understanding, use and national implementation of the lighting standard. It also provides explanation of the lighting energy calculation methodology and working calculation example of integrated lighting control options. ISO/CIE 20086 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.

LENI represents the absolute amount of energy required for a lighting scheme and does not directly provide indications on the efficiency of the lighting technology employed. Therefore, a concept of expenditure factors intending to render energy flows in lighting systems more transparent is introduced in ISO/CIE 20086:2019, 6.5 and Annex E to complement LENI.

Light and lighting — Energy performance of lighting in buildings — Explanation and justification of ISO/CIE 20086

1 Scope

This document is a technical report supporting ISO/CIE 20086.

2 Normative references

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

ISO/CIE 20086:2019, *Light and lighting — Energy performance of lighting in buildings*

CIE S 017, *ILV: International Lighting Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/CIE 20086, CIE S 017 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

CIE maintains a terminology database for use in standardization at the following address:

- e-ILV: available at <https://cie.co.at/e-ilv>

3.1

useful floor area

total gross floor area of all enclosed spaces, measured to the internal face of the external walls

Note 1 to entry: The total useful floor area can have a different value than the total floor area in the building.

4 Symbols and abbreviations

4.1 General

As given in CIE S 017, considering that LED technology has mostly replaced the conventional form of lamps, the term “lamp” should be replaced with the more general term “light source” to follow changes already introduced in some definitions of terms. However, as this document intends to accompany ISO/CIE 20086, the terms and definitions used in this document are consistent with ISO/CIE 20086 by using the term “lamp”. Still, whenever the term “lamp” is used in this document, it also refers to the term “light source”.

4.2 Symbols and abbreviations

For the purposes of this document, the symbols given in ISO/CIE 20086 and the specific symbols listed in [Table 1](#) apply.

Table 1 — Symbols and units

Symbol	Name of quantity	Unit
A	Total useful floor area in the building	m^2
a_D	Depth of daylight area	m
b_D	Width of the daylight area	m
A_i	Total useful floor area of the relevant zone or area	m^2
A_s	Sum of task areas within the room or zone	m^2
D	Daylight factor	%
D_{CA}	Daylight factor of the raw building carcass opening	%
E_{sur}	Maintained illuminance on immediate surround of task area	lx
E_{task}	Maintained illuminance on the task area	lx
F_A	Absence factor	1
F_c	Constant illuminance dependency factor	1
F_{CA}	Correction factor for reduced power of area	1
F_{cc}	Factor for the efficiency of the constant illuminance control	1
F_D	Daylight dependency factor	1
$F_{D,C}$	Lighting control factor	1
$F_{D,S}$	Daylight supply factor	1
F_L	Correction factor for the light source efficiency	1
f_m	Maintenance factor	1
F_{CMF}	Correction factor for maintenance factor	1
f_{LLM}^a	Lamp luminous flux maintenance factor	1
f_{LS}^a	Lamp survival factor	1
f_{LM}^a	Luminaire maintenance factor	1
f_{RSM}^a	Room surface maintenance factor	1
F_O	Occupancy dependency factor	1
F_{OC}	Controls function factor	1
h_{Li}	Height of the window lintel above the floor	m
h_m	Mounting height of luminaire	m
$H_{\text{dir}}/H_{\text{glob}}$	Luminous exposure ratio	1
h_{Ta}	Height of the task area above the floor	m
I_{RD}	Room depth index	1
I_{Sh}	Shading index	1
I_{Tr}	Transparency index	1
K	Room index	1
L_x	Time period at which x % of the measured initial luminous flux value is maintained	h
L_R	Length of room	m
n_{La}	Number of lamps in the luminaire	1
$P_{c,i}$	Control standby power of luminaire i	W
P_{em}	Total emergency standby power	W
$P_{e,i}$	Emergency charging power of luminaire i	W
P_i	Power of luminaire i	W
P_j	Power density of area j	W/m^2

^a The symbols for lamp luminous flux maintenance factor, lamp survival factor, luminaire maintenance factor and room surface maintenance factor have changed according to CIE S 017 *ILV* and differ from ISO/CIE 20086.

Table 1 (continued)

Symbol	Name of quantity	Unit
$P_{j,lx}$	Illuminance-normalized power density of area j	W/(m ² lx)
P_n	Total power of n luminaires	W
P_{pc}	Total standby power for automatic lighting controls	W
P_r	Declared (marked) lamp rated power	W
Q_{LENI}	Lighting energy numeric indicator (LENI) for a building	kWh/m ²
$Q_{LENI,sub}$	Lighting energy numeric indicator for an area or relevant zone	kWh/m ²
t_e	Battery charge time	h
t_D	Daylight time	h
t_N	Daylight absence time	h
t_s	Specified time step	hour, month, year
t_{tot}	Total operating hours	h
t_y	Number of hours in a standard year	h
W	Total annual energy used for lighting	kWh
W_{az}	Annual energy required for lighting for an area or a zone	kWh
$W_{L,t}$	Total energy for illumination	kWh
W_{mt}	Total metered energy used for electric lighting	kWh
$W_{p,t}$	Total energy for standby	kWh
W_t	Energy used for lighting per time step	kWh
W_{pc}	Standby energy density for automatic lighting controls per year	kWh/m ²
W_{pe}	Standby energy density for battery charging of emergency luminaires per year	kWh/m ²
W_R	Width of the room or zone	m

^a The symbols for lamp luminous flux maintenance factor, lamp survival factor, luminaire maintenance factor and room surface maintenance factor have changed according to CIE S 017 *ILV* and differ from ISO/CIE 20086.

For the purposes of this document, the specific subscripts listed in [Table 2](#) apply.

Table 2 — Subscripts

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

5 Description of the methods

5.1 General

ISO/CIE 20086 provides three methods for the assessment of the energy required for electric lighting within buildings:

- Method (1): comprehensive;
- Method (2): quick calculation;
- Method (3): direct metering (see [figure 1](#)).

These methods can provide the information on the electric energy required for lighting in the selected time steps and the Lighting Energy Numeric Indicator (LENI) for the whole building, individual room

or zones. LENI can be used for comparison of similar buildings and as a measure of the lighting energy performance of the building.

Methods (1) and (2) are based on calculations, and Method (3) is based on the direct metering of the lighting circuit. The calculation methods [(1) and (2)] can be used during feasibility studies or detailed design of new or refurbished buildings, and for the assessment of energy use in existing buildings by first performing a lighting installation audit [(1)]. The metered Method (3) can only be used in existing buildings that have segregated lighting circuits that include meters to facilitate direct metering of the energy used for lighting only or a building management system that can measure lighting energy use.

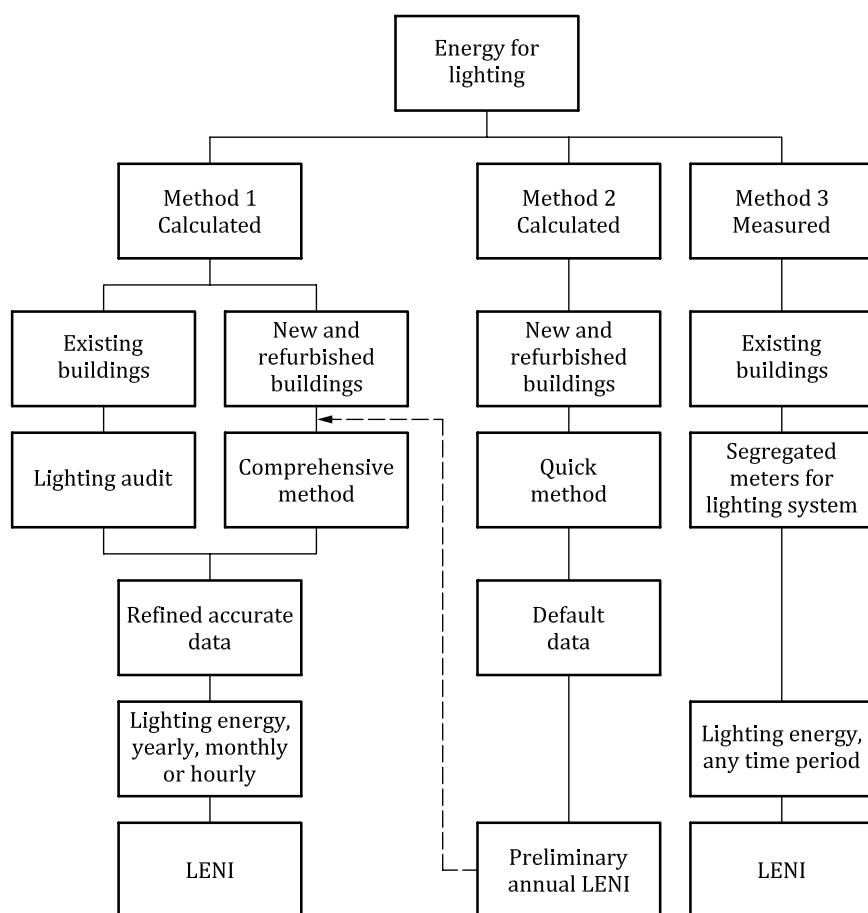


Figure 1 — Flow chart illustrating alternative routes to determine energy use

In terms of the outcome for the installed power, occupancy estimation and daylight availability, Method 1, which relies upon a comprehensive lighting design, is a more accurate calculation procedure than Method 2, which provides a quick estimation based on default values used during pre-design. Method 3 provides the actual energy use for lighting information; however, it can only be used for existing buildings that are lighting end-use metered, commissioned and occupied.

5.2 Method 1 – Comprehensive method

Method 1 provides the most accurate calculation procedure as it relies upon a comprehensive lighting scheme design that is based on real data of the specified products as the main input to the energy calculation. This method can be used for new and refurbished buildings and for assessing existing buildings where it involves a detailed audit of the existing lighting system to establish the installed lighting load. The lighting energy (kWh) per time step (month or hour) normalized to an area unit (m^2) of the useful applicable zone area provides a sub-LENI value for the building zone. In a case of the yearly time step, and for total useful building area, this is the total annual Lighting Energy Numeric Indicator (LENI).

5.3 Optional methods

5.3.1 Method 2 – Quick calculation method

Method 2 is a simplified method that calculates the required lighting load and evaluates an impact of the control's features using an approximation approach and a set of default data for new and refurbished buildings at the conceptual project stage where no comprehensive lighting design has been completed. Therefore, the calculation results in a preliminary lighting energy (kWh) per time step (year) normalized to an area unit (m^2) of the useful applicable building or zone area and gives the budget LENI or sub-LENI value, respectively. This estimated energy budget in general is likely to be higher than those obtained from the comprehensive design process and is recalculated for more accurate results with real data when the more detailed and comprehensive lighting system design has been completed.

5.3.2 Method 3 – Direct metering method

Method 3 relies on the direct measurement of the energy used for lighting in buildings. It is ideal for buildings where segregated lighting power circuits exist and separate energy meter has been installed. This method gives true values of the energy used for lighting at any time intervals and the annual value can also be used to calculate the LENI for the building. This method can be used to verify the values obtained by calculations and to continuously monitor the energy used for lighting. It can also be used where a building management system (BMS) allows energy use for lighting to be measured. It is important that the segregated energy meters only record the energy used for lighting in any parts of the building.

6 Method 1 — Calculation of the energy required for lighting

6.1 Output data

For the purposes of this document, the output data of Method 1 listed in [Table 3](#) apply.

Table 3 — Output data of Method 1

Description	Symbol	Unit
Specified time step, e.g. hourly, monthly or annually	t_s	hour, month, year
Energy used for lighting (kWh) per time step (e.g. hourly, monthly or yearly) within rooms or zones	W_t	kWh

LENI is the area normalized annual energy used for lighting within the building [kWh/m^2]. Method 3 (direct metering) provides the most accurate value of Q_{LENI} , while Method 1 (comprehensive) assesses Q_{LENI} more accurate than Method 2 (quick calculation).

6.2 Calculation time steps

The time step for calculations is chosen consistently for the input and output data and can be:

- yearly – 8 760 h/year,
- monthly – 730 h/month, or
- hourly – 1 h, derived from the monthly calculated value divided by 730,
- with accordance to the time step of the input data.

The provided method for the estimation of the lighting energy demand is based on an annual approach. Seasonal impacts can be considered with monthly correction factors, if available. Hourly values cannot be derived in any correct correlation with climatic data. Accurate hourly calculation of the energy required for lighting is not practical as there is no robust method for the prediction of the values of the dependency factors.

This document takes an alternative way to link into the hourly calculation scheme of other parts of the energy balance, such as internal loads for heat load calculation, by the average hourly value. The average hourly value is obtained from the monthly calculated value divided by the hours (730) in the month. For each month a constant (not variable) term will therefore be added as lighting energy to the other hourly variable parts of the energy balance.

The reason for this restriction lies in modelling the impact of daylight. This requires a photometrically correct three-dimensional calculation scheme of the light distribution outside entering through the façades into the adjacent indoor spaces. Early simple approaches have been based on the determination of the daylight factor (D) at a given inside position and an hourly multiplication with an estimate of the outside illuminance to obtain the indoor illumination which then serves as the basis for estimating the electric lighting needs. As the daylight factor is defined for a CIE overcast sky only (fixed uncommon outside luminance distribution), multiplication of the daylight factor with general outside illuminance values as derived from real weather data (including clear, sunny and partially overcast conditions) led to significant and not tolerable errors. Moreover, the daylight factor method does not allow accounting for any sun shading devices, which are mandatory in today's rating methods. Simplified methods to cope on an hourly basis – without the use of photometric algorithms – with the versatile outside luminance distribution and complex light transmission through façade elements like different sun-shading systems so far do not exist.

Therefore, rating the impact of daylight nowadays has been accounted for in such a way, that monthly and annual detailed simulation runs with photometrical exact sky and room models have been performed with lighting simulation software for a representative set of room geometries, sun-shading devices and locations. Regression models (analytical and tabular) have been derived from these detailed simulation results, allowing the annual and monthly impact of daylight penetration through the façade to be estimated without the need of using detailed computer tools, and with a higher accuracy than the former D (Daylight Factor) method and allowing to incorporate not only simple glazing systems but also sun-shading and light redirection devices.

Generally, selecting a calculation step that is smaller than necessary, makes application more complicated as the occupation profiles and other input parameters for hourly calculation are considerably more detailed. As monthly or even annual balancing methods would be sufficiently precise for all balancing applications, a monthly balancing procedure approach enhances the acceptance and user-friendliness of ISO/CIE 20086.

Nevertheless, if deemed necessary, the direct usage of detailed lighting simulation software on an hourly basis is always possible but with associated higher expenses (modelling and calculation time).

No reliable method can be recommended to break down the monthly period values into hourly time steps. This implies that the overall general hourly method cannot properly represent energy flows in the building on hourly time steps.

6.3 Input data

6.3.1 Lighting system data

6.3.1.1 General

The comprehensive method (Method 1 of ISO/CIE 20086) makes the energy estimation based upon the lighting design scheme, including lighting controls with their protocols, that is fully developed based on the requirements specified in the lighting application standards (i.e. ISO 8995-1/CIE S 008 for lighting of indoor work places and ISO 30061/CIE S 020 for emergency lighting). ISO/CIE 20086 also highlights the importance of the available daylight and electric light combination for fulfilling the requirements of ISO 8995-1/CIE S 008 and the general and specific lighting criteria for all places within the buildings.

The following relevant input data and details for each room and zone of the building are based on the lighting design scheme (for new or refurbished buildings) or on the lighting survey results (for existing buildings):

- types of luminaires identified by a unique product reference code;
- quantities of each specific type of luminaire;
 - luminaires which respond to daylight (e.g. Manual, Automated/Dimmed, Automated/switched) to control the artificial light, when located in an A_D area (i.e. those close to windows). In these areas the daylight parameter $D_{ca,j}$ is calculated;
 - luminaires which respond to occupancy (e.g. Manual On/Off switch, Manual On/Off switch + additional automatic sweeping extinction signal, Auto on/Dimmed, Auto on/Auto off, Manual on/Dimmed, Manual on/Auto Off);
- control technique and device types;
 - Efficiency Factor of Constant Illuminance Control, F_{CC} (F_C calculated from f_m and F_{CC});
- maintenance factor (f_m) assumed in the design or defined by the maintenance schedule (for each room and/or area);
- dominant building type;
- latitude;
- longitude;
- luminous exposure H_{dir}/H_{glob} ;
- shading system solution (shading type/s) for rooms/areas;
- shading obstructing context (shading index/s);
- daylight time t_D ;
- daylight absence time t_N ;
- maintained illuminance of zone (lx) (E_{task});
- occupancy, F_O (for each room and/or area);
- users absence factor, F_A (for each room and/or area);
- window/rooftlight/atrium properties;
- zone properties: set the properties of the zone.

6.3.1.2 New or refurbished building lighting system

The completion of the lighting design process will produce the lighting solution, the required lighting scheme and the product schedule. The lighting solution will give the specification details of the required luminaire types, including maintenance factors; and the lighting control system. There can be several types of luminaires in the scheme, each performing specific functions from a specific mounting position. The luminaire types could only be used for illumination, but some could also contain components to provide emergency lighting. The luminaires usually have embodied components to make them controllable by receiving signals from remotely mounted or in-built detectors and/or from a central control system. Each luminaire type will have a unique product reference code (luminaire type) for clear identification.

The information on the type and number of luminaires used in a zone, room or building and the type of controls is a prerequisite to form the input data for estimating the energy requirements for lighting. An example of how the lighting system data can be set out is shown in [Table 4](#) below.

Table 4 — Example of the luminaire schedule

Area	Luminaire ID/type	Luminaire product number	Quantity	Control type/Operation technique
Reception/Main Lobby 1011	L1	ABC32830WH	18	DALI Dimmable, Daylight and Occupancy linked
Reception/Main Lobby 1011	L1E	ABC32830WHEM	4	DALI Dimmable, Daylight and Occupancy detectors linked, Emergency battery
Stairways S1-S8	L4E	AABB14D8402EBOS	48	DALI, Integrated occupancy detector, 10-50-100 % step-dimmable driver, Emergency battery
Open office 2012	L12	SSS96W35	60	DALI Dimmable, Daylight and Occupancy detectors linked

6.3.1.3 Existing building lighting system

Method 1 is suitable for existing buildings that already have installed lighting systems. In this method, a lighting audit according to ISO 50001 or ISO 50002 is carried out in the building to establish the type and numbers of luminaires installed and the power rating of each luminaire type.

The audit includes the identification of the luminaire types in use, counting the number of each luminaire type and recording the data information on the product label. Ideally the luminaire label contains the manufacturer's name, luminaire code and the technical information (light source type, number of light sources and their power rating). If the power of luminaire (P_l) is not shown on the label, this ideally can be obtained from the manufacturer's data sheet for the luminaire. If the label is not readable, then the characteristics could be established by noting and recording the number, rating and type of light sources used in the luminaire from which the power of luminaire (P_l) can be calculated.

The information and data obtained will form the input to the energy estimation process. Once the installed lighting load is established, the calculation procedure of the lighting energy requirement described in Method 1 can be followed. The output of Method 1 is

- specified time step, e.g. hourly, monthly or annually,
- energy used for lighting (in kWh) per time step (e.g. hourly, monthly or annually) within rooms or zones,

as described in ISO/CIE 20086:2019, 6.1.

Method 1 is also applicable for buildings that already have lighting controls or where it is planned to add such controls. The standby power for emergency lighting and/or having lighting controls in the lighting system can similarly be obtained from the manufacturer's data sheets; however, for the case that such data are not available, default values are indicated in ISO/CIE 20086:2019, Table A.1, shown here in [Table 5](#).

Table 5 — Standby energy density

Purpose	Symbol	Default annual energy density ^a kWh/m ²
Standby energy for battery charging of emergency luminaires per year	W_{pe}	1
Standby energy for automatic lighting controls per year	W_{pc}	1,5
^a Default values according to ISO/CIE 20086:2019, Table A.1		

The calculation procedure for lighting energy assessment in existing buildings is described in ISO/CIE 20086:2019, Annex C and the schedule of luminaires can be presented as shown in [Table 4](#) above.

6.3.2 Product data

6.3.2.1 General

See [6.3.2.3](#).

6.3.2.2 Luminaire description data (qualitative)

See [6.3.2.3](#).

6.3.2.3 Luminaire technical data

For each place and for each luminaire type specified in the lighting scheme, the electrical data as shown in the example [Table 6](#) to [Table 9](#) are obtained from the manufacturer's product information sheet or from the lighting audit. The product description provides the information on the luminaire characteristics and functional capabilities regarding dimming control, integral or remotely connected detectors and emergency lighting facility.

Table 6 — Luminaire identification

Code	Description

The power of luminaire i , P_i in [Table 7](#) is the total circuit power supplied to the luminaire with the light source and the controls operating and charge power supplied to the emergency batteries. The control standby power of luminaire i , $P_{c,i}$ in [Table 8](#) and the emergency charging power of luminaire i , $P_{e,i}$ in [Table 9](#) are measured with the light sources in the luminaire switched off. ISO/CIE 20086 requires that all the luminaire power values listed in the [Table 6](#) to [Table 9](#) are declared by the lighting equipment manufacturer based on the certified testing in accordance with the relevant product standard.

Table 7 — Power of luminaire i (P_i)

Code	Power, W

Table 8 — Power of luminaire i ($P_{c,i}$)

Code	Power, W

Table 9 — Emergency charging power of luminaire i ($P_{e,i}$)

Code	Power, W

Alternatively, the required power data can be presented in an assembly way as shown in [Table 10](#).

Table 10 — Luminaire data example table

Luminaire ID/type	Power of luminaire i P_i W	Control standby power of luminaire i $P_{c,i}$ W	Emergency charging power of luminaire i $P_{e,i}$ W
L1	38,4	1,4	0,0
L1E	39,0	1,4	0,6
L4E	19,4	1,4	0,9
L12	49,4	1,4	0,0

If the control standby power of luminaire i and/or the emergency charging power of luminaire i information is not available from the manufacturer, then the default standby energy (kWh/m²) values given in [Table 5](#) (resp. ISO/CIE 20086:2019, Table A.1) can be used in calculations.

For existing buildings, the data gathered during the lighting audit can be organized into [Table 6](#) to [Table 9](#). However, if the power of luminaire i , P_i is not known, then the lamp rated power can be used, but if the lamp use ballasts or drivers, the power of luminaire i is corrected according to ISO/CIE 20086:2019, Formula (C.3):

$$P_i = 1,2 \cdot P_r \cdot n_{La} \quad (1)$$

where

n_{La} is the number of lamps in the luminaire;

P_r is the lamp rated power.

6.3.3 System design data

The required system design data for each zone, room or building will consist of the details, dimensions and function of the building or place and the functional characteristics of the controls and the power ratings of the elements in the electric lighting system. The data permits calculation of the values of the installed lighting power, P_n , P_{em} , and P_{pc} and the various dependency factors: occupancy dependency factor F_0 , daylight dependency factor F_D and constant illuminance dependency factor F_c for the place. The results are presented as shown in the following example in [Table 11](#):

Table 11 — System design data

Area Code	F_0	F_D	F_c	P_n	P_{em}	P_{pc}
Office 202	0,90	0,35	0,91	1 618	22	4,6

The required information and the calculation process involved is provided in detail in ISO/CIE 20086:2019, Annex D, Annex E and Annex F. The results of the calculations will show the amount of energy that can be saved using lighting controls.

6.3.4 Operating conditions

The operating conditions are largely determined by the activity in the space, flexibility of the lighting system and the appropriateness of the lighting controls. Only operating the electric lights when there

are occupants in the area and when there is insufficient daylight available to fulfil the illumination criteria minimizes the amount of energy used for lighting. It is accepted that the electric lighting system has been designed to provide the full lighting requirements in accordance with the relevant lighting application standards (e.g. ISO/CIE 8995-1 and ISO 30061/CIE S 008) for the area without daylight at any time. To then use the electric lighting only to compensate the available daylight to the design conditions and only when the area is occupied, a well-designed lighting control system is an essential part of the lighting solution. The controls are manually or automatically operated. The details of some control types and their operation and effectiveness can be found in CIE 222 and CEN/TR 15193-2:2017, Annex K. In addition, the occupancy and activity patterns are prerequisite as basis to allow the evaluation of t_D and t_N for each area of a zone or building. This information is presented as shown in the example of [Table 12](#) below.

Table 12 — Times for operating conditions

Area Code	t_D	t_N
Office 202	2 271	75

6.3.5 Constants and physical data

The number of hours in a standard year (t_y) is defined as 8 760 h.

6.4 Calculation procedure

6.4.1 Applicable time step

According to ISO/CIE 20086:2019, 6.2, the calculation procedure can be used with the yearly, monthly, or hourly time steps.

The time steps are intended for a procedure which considers steady data for each time interval where each single combination of parameters is used for the calculation (e.g. daylight availability time and daylight absence time, etc.).

6.4.2 Operating conditions calculation

If no accurate data are available for daylight time and daylight absence time, the default values of t_D and t_N as provided in ISO/CIE 20086:2019, Table A.2 and F_A as provided in ISO/CIE 20086:2019, Table A.6 can be used. The occupancy schedules are based on documented assumptions for each space type or activity area (e.g. circulation area, personal office, conference room, kitchen, etc.).

6.4.3 Energy calculation

6.4.3.1 General

The procedure of the lighting energy calculation method needs to be applied for all various areas and zones as specified in ISO/CIE 20086:2019. The calculation of the energy required for lighting involves three basic steps:

- the estimation of the installed power for lighting;
- the estimation of the operating times;
- and the estimation of energy saving impact of lighting controls based on occupancy, daylight availability and lighting system maintenance.

The steps in the lighting energy calculation method are shown in [Figure 2](#).

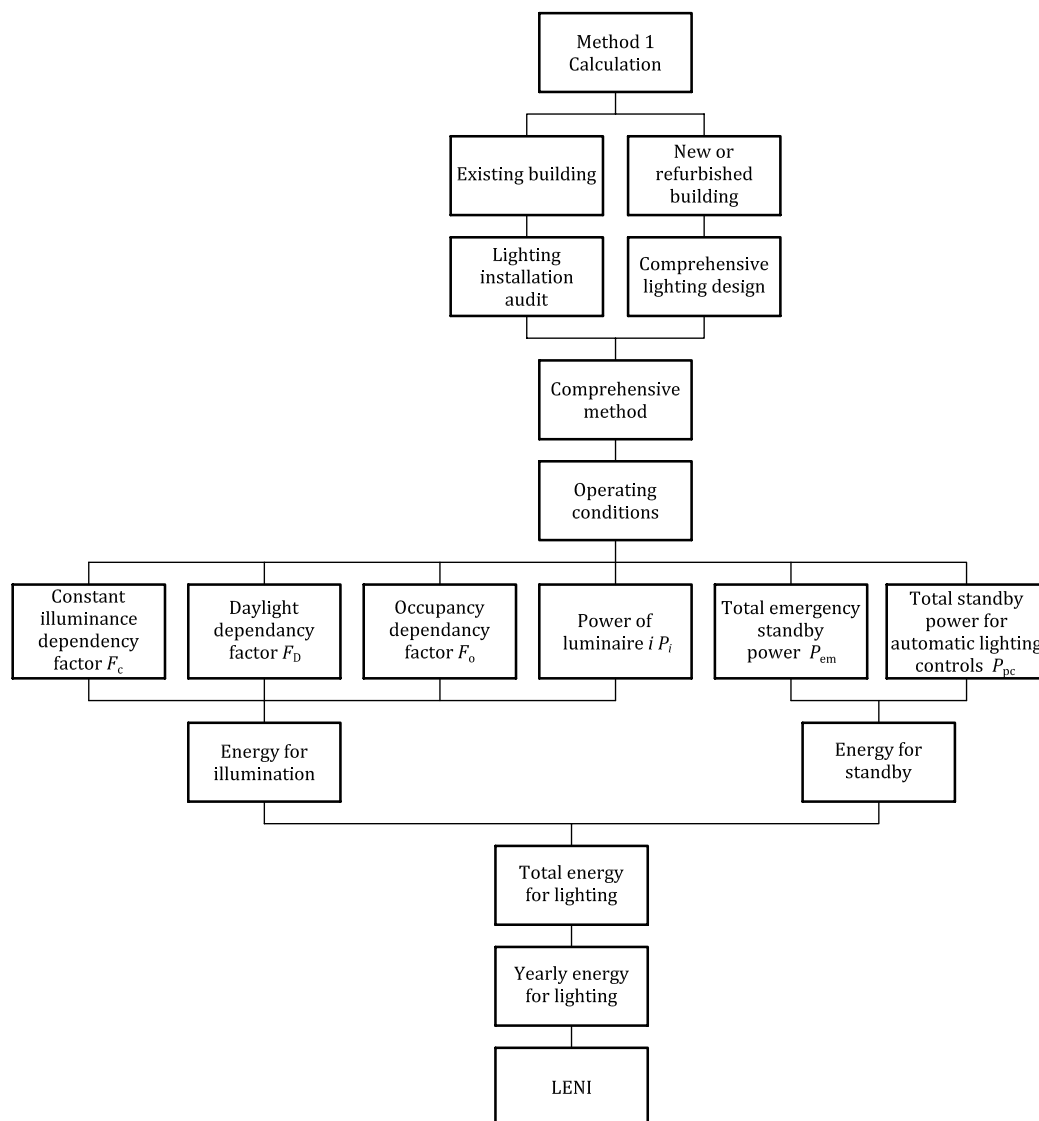


Figure 2 — Flow chart illustrating the calculation of energy for lighting by Method 1

Figure 2 shows that the first step is to establish the building type (existing or new/refurbished) and the second is to assess the lighting solution. From these data, the installed power for lighting and the value of the dependency factors, the energy for illumination, for standby, the total energy and LENI are calculated.

6.4.3.2 Installed power calculation

For new or refurbished buildings, the required connected power for lighting is calculated as a sum of the installed power of the individual luminaires within the lighting system by ISO/CIE 20086:2019, Formula (1):

$$P_n = \sum_{i=1}^{i=n} P_i \text{ (W)} \quad (2)$$

where

- P_n is the total power of n luminaires, (W);
- n is the number of individual luminaires in the area according to lighting design scheme;
- P_i is the power of luminaire i (W).

NOTE The power of an interface control system is not considered in this document and can be an addition to the lighting system power.

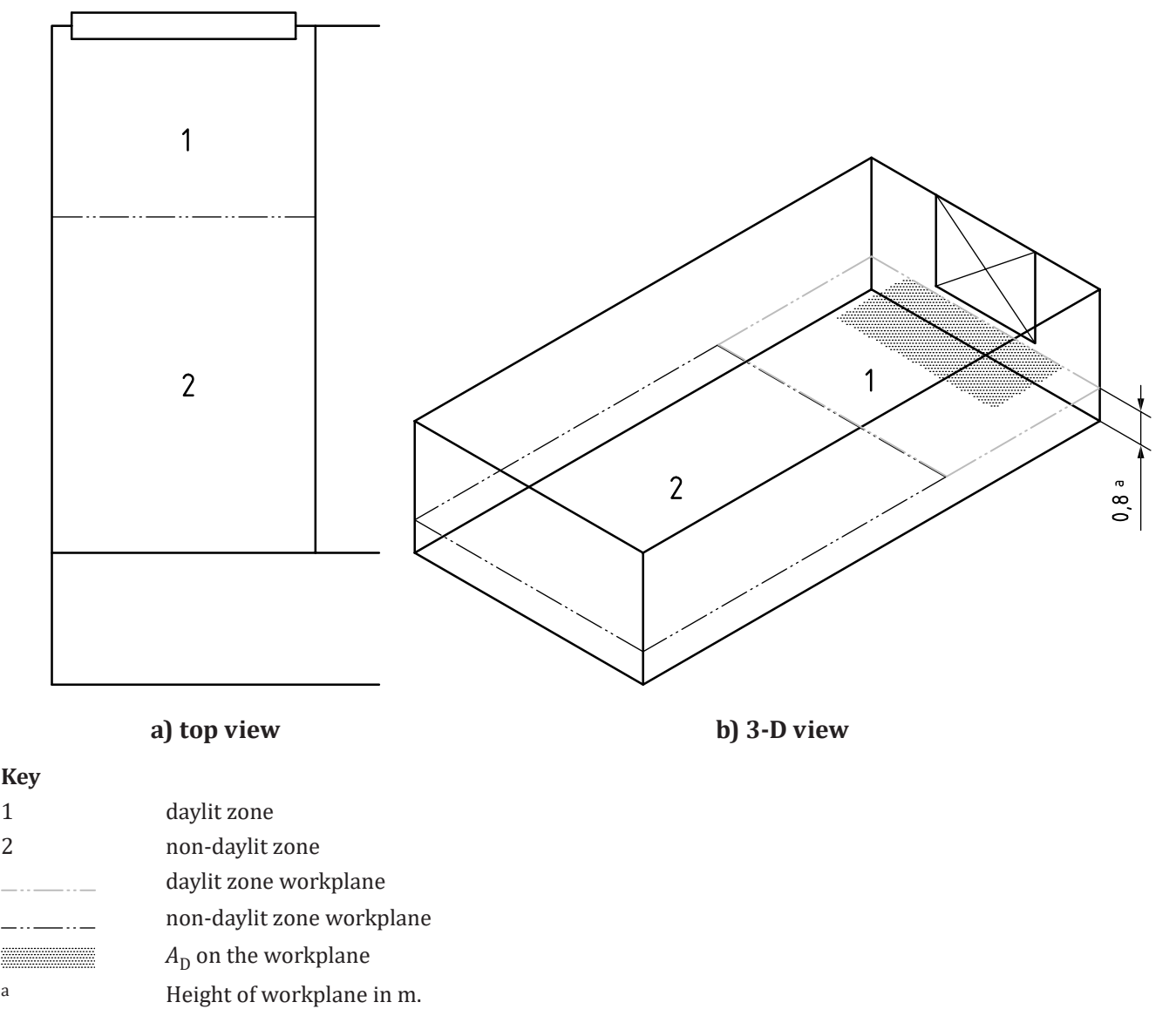


Figure 3 — Multi-zone room

When a room consists of A_D and A_{ND} , as shown in [Figure 3](#), the calculations run by zones with the lighting power and control factors associated to a particular zone, and then the energy results are summed up.

6.4.3.3 Assessment of installed power in existing buildings

To calculate the total power of n luminaires (P_n) in existing buildings, it is necessary to carry out a survey of the lighting system and assess the power rating and number of luminaires in the scheme. The total luminaire power can be calculated by the summation of the rated power of each installed luminaire

as shown in ISO/CIE 20086:2019, Formula (1), but in this case, n is the number of the same luminaires in the area of the lighting system. If there are several (m) types in the area, then the calculation by ISO/CIE 20086:2019, Formula (1) is repeated for each type and the total power of n luminaires P_n is calculated by the summation $\Sigma (P_{n1} + P_{n2} + \dots + P_{nm})$.

The detailed assessment procedure and information on the topic are provided in ISO/CIE 20086:2019, Annex C.

6.4.3.4 Standby system power requirements from ISO/CIE 20086

Some luminaires within the lighting installation are equipped with backup batteries to power luminaires during emergency situations when normal electrical supply is interrupted by a utility outage, a fire, or failure within the building, but a minimum illumination is still required for safety reasons. These batteries need to be fully charged continuously and consume power even when the lighting sources are not in operation. Similarly, lighting controls devices powered through the luminaire require power during the luminaire "off-time". The electrical power drawn by the emergency backup batteries and lighting controls in standby mode are included in the assessment of the installed power.

Thus, the total emergency standby power is calculated by ISO/CIE 20086:2019, Formula (2):

$$P_{em} = \sum_{i=1}^{i=n} P_{e,i} \text{ (W)} \quad (3)$$

where

- n is the number of luminaires equipped with an emergency battery within each area of the building according to lighting design scheme (new or refurbished buildings) or per the lighting survey results (for existing lighting systems);
- $P_{e,i}$ is the emergency charging power of luminaire i . The $P_{e,i}$ values can be found in the manufacturer (battery or luminaire) product specifications.

The required total standby power for automatic lighting controls in non-lighting periods P_{pc} is calculated by ISO/CIE 20086:2019, Formula (3):

$$P_{pc} = \sum_{i=1}^{i=n} P_{c,i} \text{ (W)} \quad (4)$$

where

- n is the number of individual luminaires equipped with the automated lighting controls powered through the luminaire in the area according to the lighting design scheme (new or refurbished buildings) or per the lighting survey results (for existing lighting systems);
- $P_{c,i}$ is the control standby power of luminaire i . The $P_{c,i}$ values can be found in the manufacturer (lighting controls or luminaire) product specifications.

The power drawn by remote controls that are not supplied with electrical power from the luminaire is not a part of this calculation.

6.4.3.5 Occupancy dependency factor F_0

6.4.3.5.1 General

The occupancy dependency factor F_0 for a room or zone correlates the time when a space is occupied with the efficiency to benefit from this potential by either manual or automatic switching. This factor is a function of the control system type (valued by the controls function factor F_{OC}) and the area/zone absence (valued by the absence factor F_A). The value of F_0 can range from 0,0 to 1,0. There are two main scenarios for the value of F_0 to consider: $F_0 = 1$ and $F_0 < 1$.

6.4.3.5.2 Case $F_0 = 1$

ISO/CIE 20086 requires the value of F_0 to be 1,0.

- For an area or zone where lighting is turned “ON” from a “central” control point along with other areas or zones by the same control signal at once, regardless of the turning “OFF” option. The examples of this case can be:
 - lighting in all stairways and corridors in a building controlled by the building automation system (BAS) based on the pre-defined schedule;
 - lighting for the entire floor switched “ON” with a manual switch at the floor electrical panel or with a time-switch;
- for a common use/traffic area larger than 30 m² where lighting provided by a group of luminaires that are (manually or automatically) switched together.

6.4.3.5.3 Case $F_0 < 1$

ISO/CIE 20086 requires the value of F_0 to be less than 1,0.

- For an area/zone/room used for meetings where the lighting is triggered by one switch or occupancy detector, as long as the lighting within this area is not be controlled by any “central” controls (BAS, BMS, DDC, etc.) together with other areas/zones/rooms,
- for any other area/zone/room of 30 m² or less in the floor area where the lighting system is locally controlled with a switch or occupancy detector where the occupancy dependency factor F_0 is considered different than 1,0.

For the case $F_0 < 1$, the calculation of the occupancy dependency factor can be performed according to the value of the absence factor F_A . The absence factor corresponds to the fraction of the reference operating time ($t_D + t_N$) that a building, room or zone is not in use. (Sleeping hours can usually be considered equivalent to absence.) When the building, the room or zone is permanently occupied during the reference time, F_A is 0. As a limit value, if a building, room or zone would rarely ever be entered, F_A would tend towards 1,0.

ISO/CIE 20086:2019, Table D.2 shown here in [Table 13](#) provides values of F_A based on the building and room type.

Table 13 — F_A values

Overall building calculation		Room by room calculation		
Building type	F_A^a	Building type	Room type	F_A
Offices	0,20	Offices	Cellular office 1 person	0,40
			Cellular office 2 to 6 persons	0,30
			Open plan office > 6 persons sensing/30 m²	0,00
			Open plan office > 6 persons sensing/10 m²	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
^a Values according to ISO/CIE 20086:2019, Table D.2				

Table 13 (continued)

Overall building calculation		Room by room calculation		
Building type	F_A ^a	Building type	Room type	F_A
			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	0,20
			Teachers' staff common room	0,40
			Copying/storage room	0,40
			Kitchen	0,20
			Library	0,40
Hospitals	0,00	Hospitals	Wards/Bedroom	0,00
			Examination/Treatment	0,40
			Pre-Operation	0,40
			Recovery ward	0,00
			Operating theatre	0,00
			Corridors	0,00
			Culvert/Conduct/(dimmed)	0,70
			Waiting area	0,00
			Entrance hall	0,00
			Day room	0,20
			Laboratory	0,20
Manufacturing factory	0,00	Manufacturing factory	Assembly hall	0,00
			Smaller assembly room	0,20
			Storage rack area	0,40
			Open storage area	0,20
			Painting room	0,20
Hotels and restaurants	0,00	Hotels and restaurants	Entrance hall/Lobby	0,00
			Corridor (dimmed)	0,40
			Hotel room	0,60
			Dining hall/Cafeteria	0,00
			Kitchen	0,00
			Conference room	0,40
			Kitchen/Storage	0,50
Wholesale and retail service	0,00	Wholesale and retail service	Sales area	0,00
			Store room	0,20
			Store room, cold stores	0,60

^a Values according to ISO/CIE 20086:2019, Table D.2

Table 13 (continued)

Overall building calculation		Room by room calculation		
Building type	F_A^a	Building type	Room type	F_A
		Other areas	Waiting areas	0,00
			Stairs (dimmed)	0,20
			Theatrical stage and auditorium	0,00
			Congress hall/Exhibition hall	0,50
			Museum/Exhibition hall	0,00
			Library/Reading area	0,00
			Library/Archive	0,90
			Sports hall	0,30
			Car parks office – Private	0,95
			Car parks – Public	0,80
^a Values according to ISO/CIE 20086:2019, Table D.2				

According to the value of F_A the occupancy dependency factor can be calculated by the following formulae:

When $0,0 \leq F_A < 0,2$ then $F_O = 1 - [(1 - F_{OC}) \cdot F_A / 0,2]$ ISO/CIE 20086:2019, Formula (4),

When $0,2 \leq F_A < 0,9$ then $F_O = F_{OC} + 0,2 - F_A$ ISO/CIE 20086:2019, Formula (5),

When $0,9 \leq F_A < 1,0$ then $F_O = [7 - (10 \cdot F_{OC})] \cdot (F_A - 1)$ ISO/CIE 20086:2019, Formula (6),

where

F_A is the absence factor;

F_{OC} is the controls function factor.

Further details of the estimation of F_O , F_A and F_{OC} are provided in ISO/CIE 20086:2019, Annex D.

6.4.3.6 Overview of calculation of the daylight dependency factor F_D

In areas/zones which have windows and/or rooflights, daylight can contribute to the amount of the levels of illumination within the space required. Therefore, this proportion of the required light does not need to be provided by the electric lighting system.

The daylight available in the outdoor environment depends on the geographical location, the climatic boundary conditions, the time of day, and the season. Furthermore, the daylight availability in a building also depends on the external building structure and surrounding buildings, spatial orientation, and the technical specifications of the façades and internal areas/zones/rooms. Since the available daylight varies with the time of day and the season, the lighting energy substitution potential is dynamic and therefore has a dynamic effect on the overall energy balance (for heating, cooling, and air-conditioning) of the building.

The daylight dependency factor F_D takes into account the effect of daylight illumination on the energy required for lighting for any given time interval (e.g. year, month, hour), by use of the daylight supply factor $F_{D,S}$ and the lighting control factor $F_{D,C}$ and can be calculated by ISO/CIE 20086:2019, Formula (7):

$$F_D = 1 - (F_{D,S} \cdot F_{D,C}) \quad (5)$$

The daylight supply factor $F_{D,S}$ accounts for the amount of lighting of the evaluation area by daylight. This factor describes the relative proportion of the light needed for the visual task provided by daylight within the reference time interval at the point where the illuminance is measured (control point).

When determining this factor, it is important to consider the type of lighting control system. The factor corresponds to the relative luminous exposure as also referred to as “daylight autonomy”.

The lighting control factor $F_{D,C}$ additionally accounts for the efficiency of the lighting control system in using the available daylight to achieve the required luminous exposure level in the area.

The detail information on the method for the determination of the daylight supply factor $F_{D,S}$ and the daylight dependent electric lighting control factor $F_{D,C}$ can be found in ISO 10916.

In short, the procedure for the calculation of F_D according to ISO 10916:2014 consists of the following steps:

- a) building segmentation: spaces benefiting from daylight, see 6.4.3.7;
- b) distinction between vertical facades and rooflights and how to consider sloped windows, see 6.4.3.8;
- c) determination of the daylight supply factor $F_{D,S}$ for vertical facades, see 6.4.3.9;
- d) determination of the daylight supply factor $F_{D,S}$ for rooflights, see 6.4.3.10;
- e) determination of the factor for daylight responsive control systems $F_{D,C}$, see 6.4.3.11;
- f) determination of the daylight supply factor F_D on an annual or a monthly basis, see 6.4.3.12;
- g) determination of day-time and night-time hours, see 6.4.3.13.

6.4.3.7 Building segmentation: spaces benefiting from daylight

A method is provided with ISO 10916:2014, A.2 to subdivide each zone under evaluation into two areas:

- area sections that receive daylight, called ‘daylit areas’, with symbol A_D ;
- area sections that do not receive daylight, called ‘non-daylit areas’, with symbol A_{ND} .

Evaluation zones which are illuminated by daylight entering via façades or rooflights are subdivided into a daylit area $A_{D,j}$ and an area $A_{ND,j}$ which is not illuminated by daylight. For simplified estimate calculations, for cases where one area is illuminated by daylight entering via several façades or via a façade and rooflights, the more favourable respective lighting conditions can be assumed as unique source of daylight.

An analytical method is given to determine the extent of the daylit area A_D (depth and width) in the presence of vertical windows or rooflights:

Depth and width of areas A_D lit by vertical façades

For every window, the maximum possible depth $a_{D,max}$ of the area $A_{D,j}$ lit by daylight entering via a façade is calculated using the following [Formula \(6\)](#):

$$a_{D,max} = 2,5 \times (h_{Li} - h_{Ta}) \quad (6)$$

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.

If the real depth of the area being evaluated is less than the calculated $a_{D,max}$, then the total area depth is considered to be the depth a_D of the daylight area A_D . The depth 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 $a_{D,max}$.

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

Daylit area A_D

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

$$A_{D,j} = a_D \cdot b_D \quad (7)$$

where

a_D is the depth of the daylight area;

b_D is the width of the daylight area.

Depth of areas A_D lit by rooflights

For areas to be evaluated that have rooflights evenly distributed all over the roof area, those parts of the area which are within a distance of $a_{D,max}$ from the edge of the nearest skylight are deemed to be lit by daylight as follows:

$$a_{D,max} \leq 2 \cdot (h_{R,j} - h_{Ta,j}) \quad (8)$$

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

NOTE For all parts of the area under evaluation which are not lit by daylight (so they belong to the non-daylit area A_{ND}), the factor F_D is equal to 1.

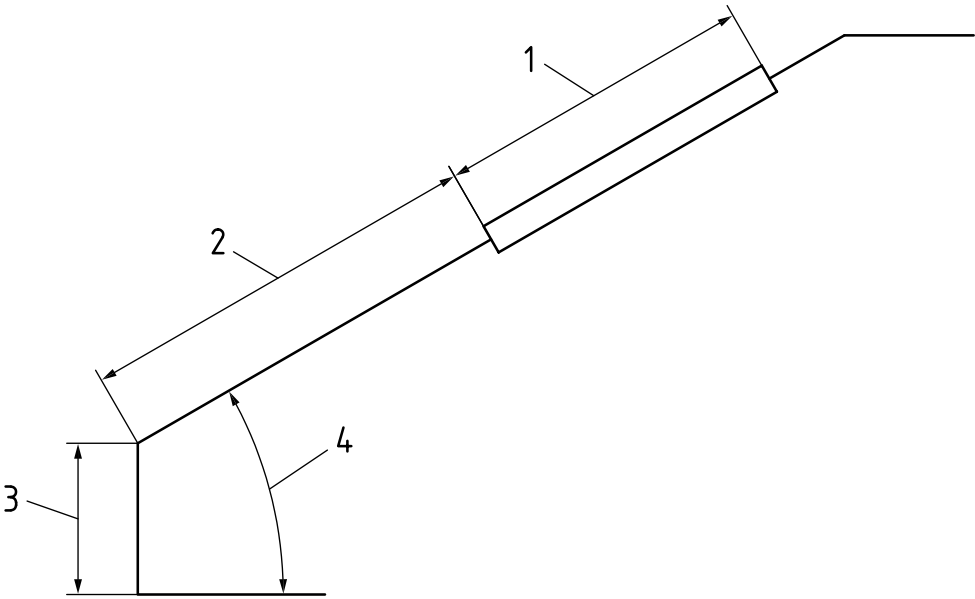
6.4.3.8 Distinction between vertical façades and rooflights and how to consider sloped windows

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

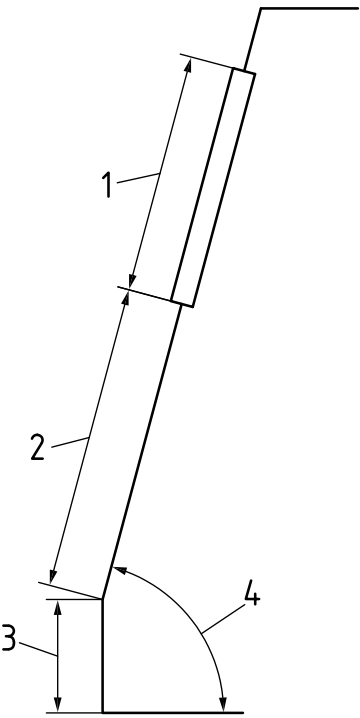
In spite of this, doubts can remain considering the tilt angle of apertures: a horizontal aperture is typically assumed as 'rooflight', whilst a vertical aperture is typically assumed as a 'vertical window'. Doubts can arise for those apertures that are located in sloped roofs. The following rules are therefore adopted:

- for roof slope angles larger or equal to 75°, the procedure defined for vertical façade windows is used (see ISO 10916:2014, Clause A.3); such sloped roof windows can be labelled as 'horizontal sloped' windows;
- for slope angles smaller than 75°, the procedure for rooflights is used (see ISO 10916:2014, A.4) such sloped roof windows can be labelled as 'vertical sloped' windows.

[Figure 4](#) shows how sloped windows are assumed to be 'vertical' or 'horizontal' 'sloped windows'.



a) horizontal orientation



b) vertical orientation

Key

- | | | | |
|---|--------------------|---|------------------------|
| 1 | length | 3 | height to slope |
| 2 | distance from wall | 4 | $\gamma \geq 75^\circ$ |

NOTE Both settings can be described with the same set of parameters. The only difference can be found in the description of the effective transmittance.

Figure 4 — Sloped windows that are considered as ‘horizontal’ [4a)] (and therefore addressed as horizontal rooflights) or ‘vertical’ [4b)] (and therefore addressed as vertical windows)

6.4.3.9 Daylight supply factor $F_{D,S}$ for vertical façades

6.4.3.9.1 General

A method is provided with ISO 10916:2014, A.3 to determine the daylight supply factor $F_{D,S,n,j}$ for each space lit through vertical façades.

The procedure was developed for the following standard reflectances of room surfaces: floor: 0,2; walls: 0,5; ceiling: 0,7; exterior (Ground, obstruction): 0,2. It relies on the following steps:

6.4.3.9.2 Daylight factor classification

The daylight factor for the raw building carcass opening $D_{CA,j}$ is calculated for each area under evaluation:

$$D_{CA,j} = (4,13 + 20,0 \cdot I_{Tr,j} - 1,36 \cdot I_{RD,j}) \cdot I_{Sh,j} (\%) \quad (9)$$

where

$I_{Tr,j}$ is the transparency index, a factor that accounts for the opening area in the space considered, as a function of the area of the raw building carcass opening (A_{Ca}) and of the daylit area (A_D); the calculation formula can be found in ISO 10916:2014, Formula (A.4);

$I_{RD,j}$ is the space depth index, a factor that accounts for the room depth of the space considered, as a function of a_D , h_{Li} , and h_{Ta} ; the calculation formula can be found in ISO 10916:2014, Formula (A.5);

$I_{Sh,j}$ is the shading index, a factor that accounts for all architectural elements that restrict the amount of daylight striking the façade. This includes shading by parts of the building itself, such as can occur due to: a) horizontal projections (such as overhangs, protruding roof etc); b) vertical projections (such as vertical fins, side buildings etc); c) light wells; d) courtyards; and e) atrium arrangements. The calculation formulae can be found in ISO 10916:2014, Formula (A.6) to Formula (A.13).

Based on the $D_{CA,j}$ value obtained for an area under evaluation, the area is classified in terms of daylight availability in the following way (see ISO 10916:2014, Table A.1):

- $D_{CA,j} \geq 6$ % daylight availability: STRONG;
- $4 \% \leq D_{CA,j} < 6$ % daylight availability: MEDIUM;
- $2 \% \leq D_{CA,j} < 4$ % daylight availability: WEAK;
- $D_{CA,j} < 2$ % daylight availability: NONE.

If a daylight factor value has been calculated using another validated method (for instance: validated software or through measurements), then this can be used instead of the value calculated analytically through [Formula \(9\)](#) to classify the daylight availability in the considered space (according to ISO 10916:2014, Table A.1). ISO 10916:2014 requires that in this case, the daylight factor was 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.

6.4.3.9.3 Daylight supply factor $F_{D,S}$

The daylight supply factor is calculated as an average of two partial daylight supply factors:

- $F_{D,S,SNA}$: partial daylight supply factor that is calculated to account for all the conditions when solar and/or glare protection system not activated, i.e. the sun is not shining on the façade;
- $F_{D,S,SA}$: partial daylight supply factor that is calculated to account for all the conditions when solar and/or glare protection system activated, i.e. the sun is shining on the façade.