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Standards New Zealand

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Committee representation

This technical report was prepared by the P4097 Light and Lighting – Energy Performance of Lighting in Buildings Committee. Membership of the committee was approved by the Standards New Zealand Standards Approval Board and appointed by the New Zealand Standards Executive, under the Standards and Accreditation Act 2015.

The committee consisted of representatives of the following nominating organisations:

BRANZ (Building Research Association of New Zealand)

Carbon and Energy Professionals New Zealand (CEP)

Energy Efficiency and Conservation Authority (EECA)

Engineering New Zealand

Illuminating Engineering Society of Australia and New Zealand (IESANZ)

International Association of Lighting Designers – Australia and New Zealand division (IALD ANZ)

Lighting Council New Zealand (LCNZ)

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New Zealand Technical Report

Light and lighting

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

Contents

Preface

In 2022, Standards New Zealand Committee P4097 reviewed ISO/CIE 20086:2019, *Light and lighting – Energy performance of lighting in buildings*. A modified adoption of the standard was published as NZS 20086:2022, *Light and lighting − Energy performance of lighting in buildings.*

As of September 2023, ISO/CIE 20086:2019 is now accompanied by ISO/CIE TR 3092:2023 *Light and lighting − Energy performance of lighting in buildings − Explanation and justification of ISO/CIE 20086.* That technical report contains examples for implementing calculations in ISO/CIE 20086:2019.

The requirement to adopt ISO/CIE TR 3092:2023 comes from differences in drafting practice between European standards and New Zealand standards. A New Zealand standard would normally include information and examples for implementing the standard's requirements. As such, this document, SNZ ISO/CIE TR 3092, serves as an informative guide and companion publication to aid understanding and application of NZS 20086:2022 and/or ISO/CIE 20086:2019. It provides informative content to support the correct understanding, use, and national implementation of NZS 20086. It also explains the lighting energy calculation methodology and gives worked examples, including descriptions of integrated lighting control options.

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(a) In the source text, 'this International technical report' should read, 'this New Zealand technical report';
(b) A full point substitutes for a comma when referring to a decimal marker.

The terms 'normative' and 'informative' have been used in this document to define the application of the annex, or appendix, to which they apply. A 'normative' annex, or appendix, is an integral part of a standard, whereas an 'informative' annex is only for information and guidance.

TECHNICAL REPORT

ISO/CIE TR 3092

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2023-09

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).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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_{dir}/H_{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
$P_{j,\mathrm{lx}}$	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
$Q_{\mathrm{LENI,sub}}$	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
$W_{\mathrm{L,t}}$	Total energy for illumination	kWh
W_{mt}	Total metered energy used for electric lighting	kWh
$W_{\mathrm{P,t}}$	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:

a) Method (1): comprehensive;

b) Method (2): quick calculation;

c) 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.

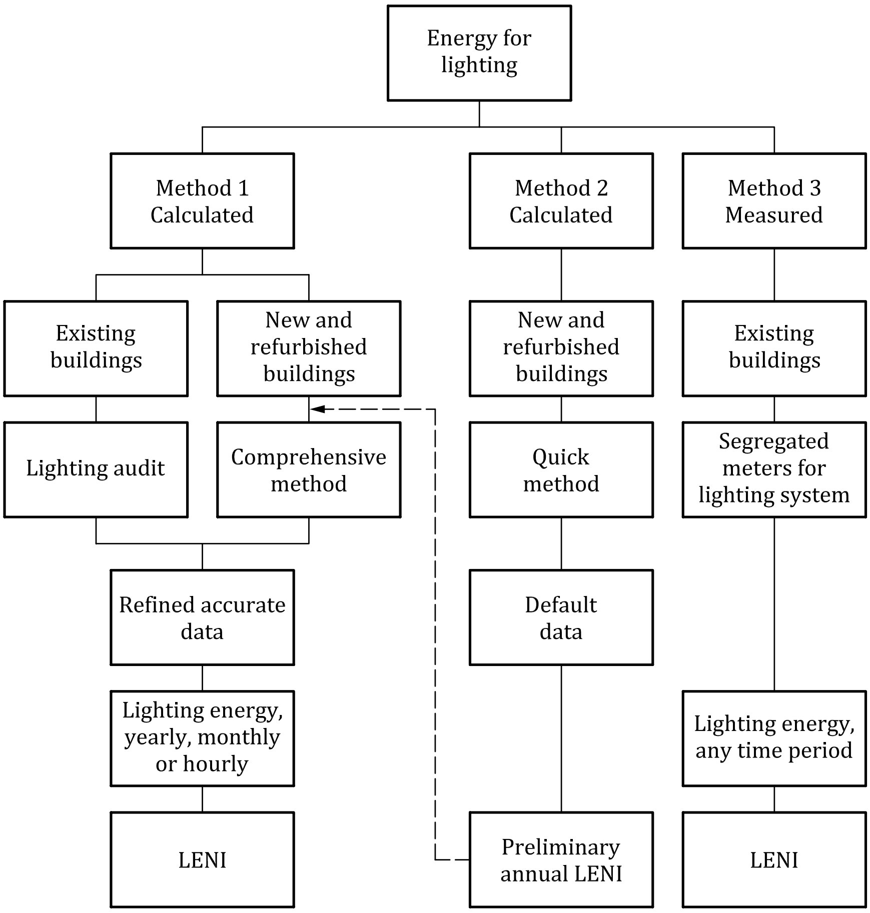


Figure 1 — Flow chart illustrating alternative routes to determine energy use

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/rooflight/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_i) 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_i) 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/m^2) 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):

$$P_i = 1{,}2 \cdot P_r \cdot n_{La} \tag{1}$$

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_O, 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_O	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.

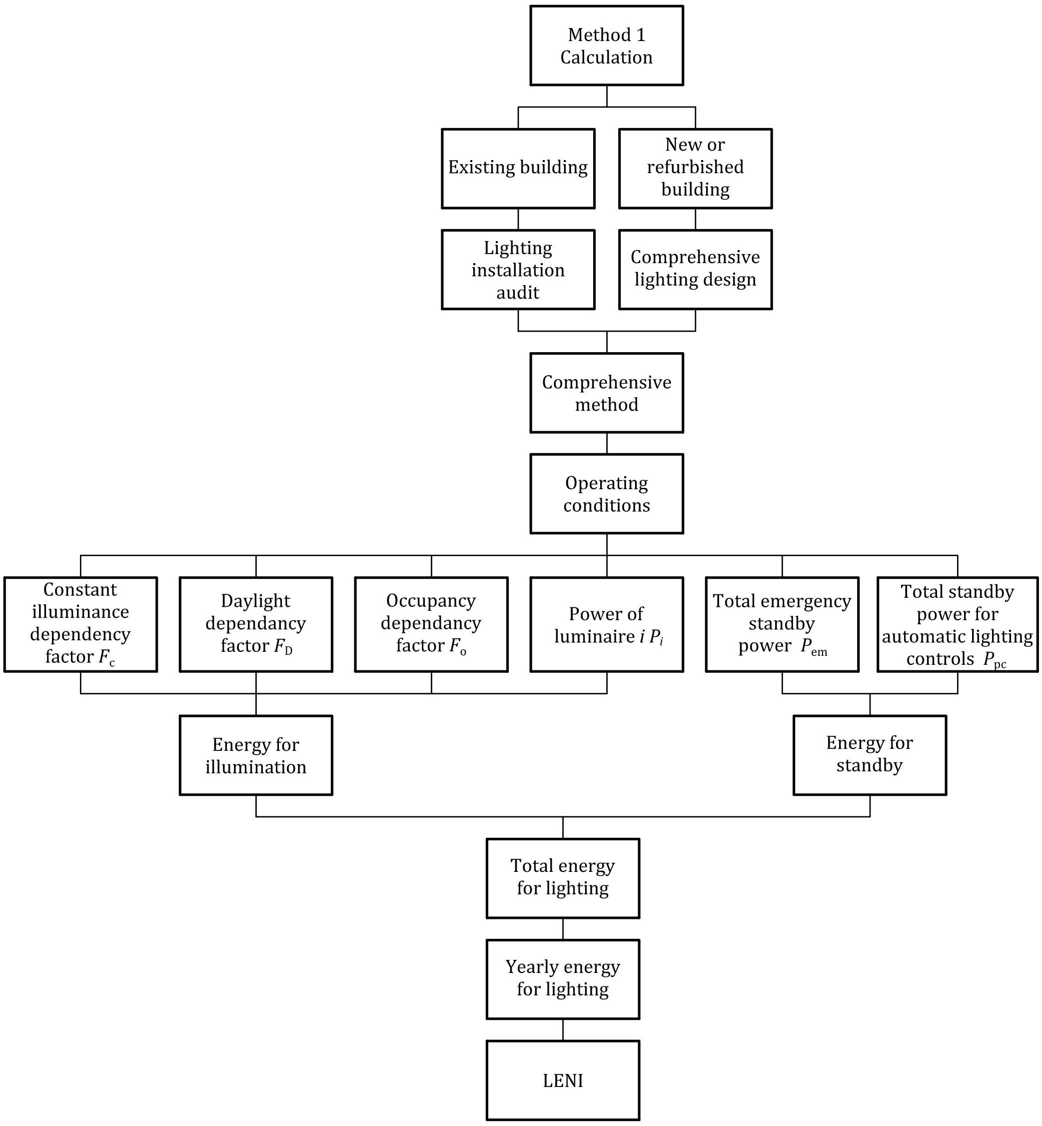


Figure 2 — Flow chart illustrating the calculation of energy for lighting by Method 1

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):

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

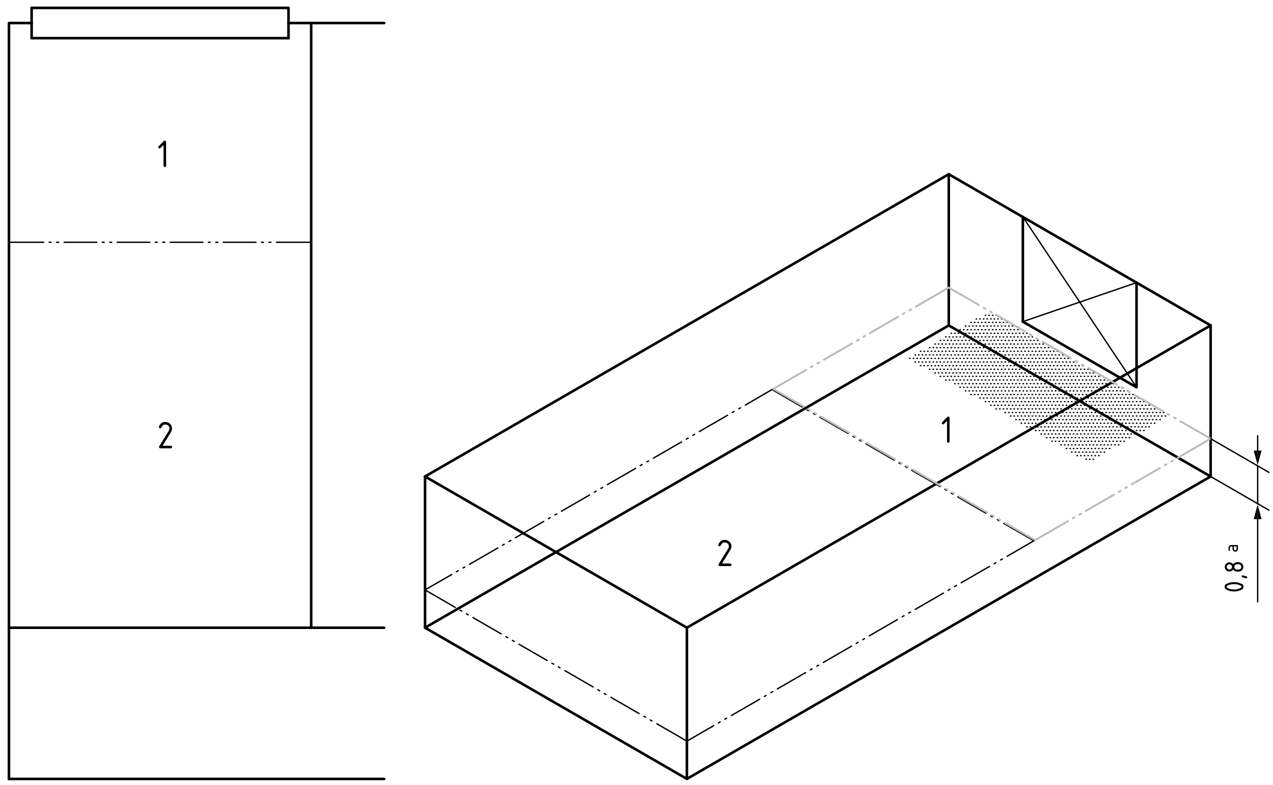
where

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.



a) top view b) 3-D view

Key

1 daylit zone

2 non-daylit zone

—·· daylit zone workplane

—·· non-daylit zone workplane

(shaded) A_D on the workplane

a Height of workplane in m.

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 Σ ($P_{n1} + P_{n2} +...+P_{nm}$).

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):

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

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);

$P_{\text{e},i}$ is the emergency charging power of luminaire i. The $P_{\text{e},i}$ 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):

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

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);

$P_{\text{c},i}$ is the control standby power of luminaire i. The $P_{\text{c},i}$ 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_{0C}) 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 m^2 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 m^2 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 m^2	0,00
			Open plan office > 6 persons sensing/10 m^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

[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):

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

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:

$$A_{D,j} = a_D \cdot b_D \tag{7}$$

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:

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

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

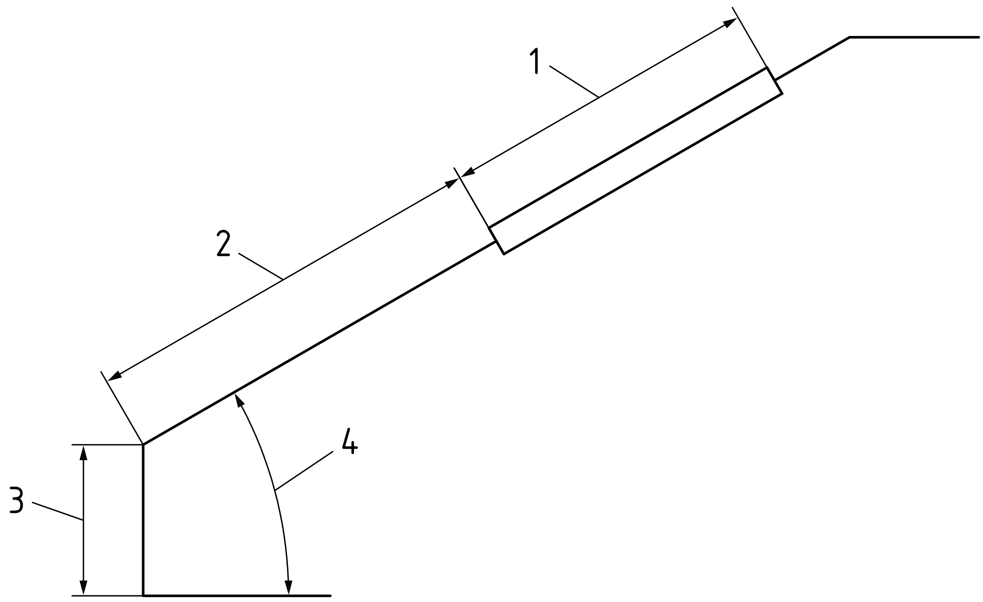
In case of doubt as to whether a specific opening or aperture is evaluated as being a window or a rooflight, all such openings of which the entire glazed areas are above the ceiling of the space under consideration are deemed to be rooflights.

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:

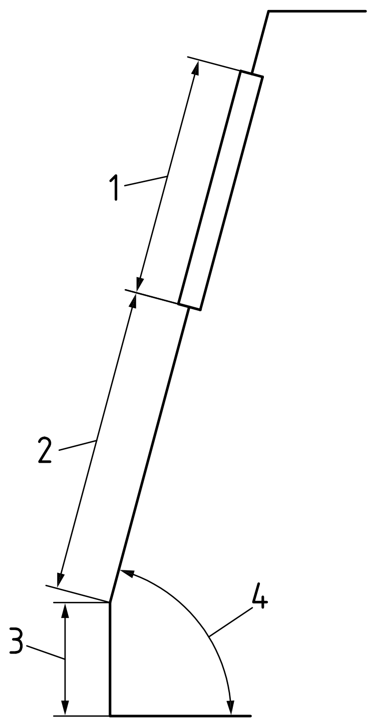
— for roof slope angles larger or equal to 75°, the procedure defined for vertical façade windows is used (see ISO 10916:2014, Clause A.3); such sloped roof windows can be labelled as 'horizontal sloped' windows;

— 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

2 distance from wall

3 height to slope

4 γ ≥ 75°

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:

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

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.

According to ISO 10916:2014, the daylight supply factor for an area under investigation ($F_{D,S,j}$) shall be determined 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 formula provided to determine $F_{D,S,j}$ is:

$$F_{D,S,j} = t_{rel,D,SNA,j} \cdot F_{D,S,SNA,j} + t_{rel,D,SA,j} \cdot F_{D,S,SA,j} \text{ (\%)} \tag{10}$$

where

$t_{rel,D,SNA,j}$ is the relative portion of the total operating time during which the solar and/or glare protection system is not activated;

$t_{rel,D,SA,j}$ is the relative portion of the total operating time during which the solar and/or glare protection system is activated. The following equation can be applied: $t_{rel,D,SA,j} = 1 - t_{rel,D,SNA,j}$

The values of the variables listed above are provided by ISO 10916 through a set of dedicated tables. The following steps need to be followed to eventually calculate the daylight supply factor $F_{D,S}$.

Step 1 Calculation of the luminous exposure ratio H_{dir}/H_{glob} for the site under consideration

The luminous exposure of the site under consideration is introduced to synthetically account for the specific climate and the latitude of the site.

ISO 10916 reports the luminous exposure ratios for a wide range of locations worldwide (see ISO 10916:2014, Table A.2). For other specific locations of interest, the ratio H_{dir}/H_{glob} can be obtained from the corresponding weather data sets (e.g. TRY – weather data sets; alternatively, climate files available on the Energy Plus site can be used to calculate the luminous exposure ratio). The direct and global horizontal illuminances are summed up for daily hours from 8 am to 5 pm over the whole year.

Step 2 Daylight factor for an area under evaluation *D*

The daylight factor D is calculated for each area under evaluation, by correcting $D_{CA,j}$ through the *window effective transmittance* for periods during which the solar and/or glare protection system is not activated. The effective transmittance accounts for the window properties, with regard to both glazing and frame, through the formula:

$$D = D_{CA,j} \cdot \tau_{eff,SNA,j} = D_{CA,j} \cdot \tau_{D65,SNA} \cdot k_1 \cdot k_2 \cdot k_3 \text{ (\%)} \tag{11}$$

where

$\tau_{D65,SNA}$ is the transmittance of the façade glazing for vertical light incidence; ISO 10916 provides typical values of the transmittance $\tau_{D65,SNA}$ of common transparent and translucent building components (ISO 10916:2014, Table A.4);

k_1 is the reduction factor for frames and subdivisions, as calculated as the ratio of the transparent area to the area of raw building carcass opening;

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 adequate).

If the transparent or translucent façade element to be evaluated comprises different components, the effective transmittance is weighted according to the relative proportion of the areas of the respective components.

Step 3 Calculation of $t_{rel,D,SNA,j}$, $F_{D,S,SNA,j}$, and $F_{D,S,SA,j}$ for an area under evaluation

The three parameters can be determined from dedicated following tables given in ISO 10916:2014. In more details:

- $t_{\mathrm{rel,D,SNA},j}$: ISO 10916:2014, Table A.3: three tables are reported, one for façades oriented South, one for façades oriented West or East, and one for façades oriented North (North and South orientation are chosen based on the hemisphere where the location is situated). To enter either one of the three sub-tables, the following parameters are needed:
  - latitude of the site;
  - luminous exposure ratio $H_{\mathrm{dir}}/H_{\mathrm{glob}}$;
- $F_{\mathrm{D,S,SNA},j}$: ISO 10916:2014, Table A.5, Table A.6, Table A.7: three tables are reported, one for façades oriented South (ISO 10916:2014, Table A.5), one for façades oriented West or East (ISO 10916:2014, Table A.6), and one for façades oriented North (ISO 10916:2014, Table A.7). North and South orientation are chosen based on the hemisphere where the location is situated. To enter either one of the three tables, the following parameters are needed:
  - latitude of the site;
  - luminous exposure ratio $H_{\mathrm{dir}}/H_{\mathrm{glob}}$;
  - maintained target illuminance over the workplane $\bar{E}_{\mathrm{m}}$, depending on the visual activity carried in the considered area;
  - daylight factor value D in the considered area;
- $F_{\mathrm{D,S,SN},j}$: ISO 10916:2014, Table A.8: the value is reported as a function of the classification of daylight availability, for 4 different shading systems:
  - 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;
  - 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;
  - light-guiding systems;
  - no protection against solar radiation and shades.

6.4.3.10 Daylight supply factor $F_{\mathrm{D,S}}$ for rooflights

6.4.3.10.1 General

A method is provided with ISO 10916:2014, A.4 to determine the daylight supply factor $F_{\mathrm{D,S,n},j}$ for each space lit by rooflights.

The procedure is conceptually similar to the procedure defined for vertical windows (see 6.4.3.9). The first evaluation step for rooflights 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. In more detail, it consists of the following steps:

6.4.3.10.2 Daylight availability factor

An approximate value of the mean daylight factor of spaces equipped with rooflights can be calculated for the two configurations of shading not activated and shading activated [see Formula (12)].

$$\bar{D}_j = D_a \cdot \tau_{D65} \cdot k_1 \cdot k_2 \cdot k_3 \cdot \frac{\sum A_{Ca}}{A_D} \cdot \eta_R \ (\%) \tag{12}$$

where

A_{Ca} is the area of the rooflights (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; it is defined as the ratio of the illuminance on the external surface of the skylight to the horizontal external illuminance, both received from an overcast sky; ISO 10916 contains a table that lists external daylight factors D_a for a ground reflectance ρ_B of 0,2 and various slope angles of the shed-roof glazing (ISO 10916:2014, Table A.10);

τ_{D65} is the transmittance of the diffusive rooflight glazing for daylight D65; ISO 10916:2014 provides a table that contains a list of transmittance values of components frequently used in rooflights (ISO 10916:2014, Table A.9);

k_1 is the reduction factor for frames and subdivisions of the rooflight glazing; ISO 10916:2014 provides a formula to calculate k_1 [ISO 10916:2014, Formula (A.13)];

k_2 is the reduction factor for pollution of the rooflight glazing;

k_3 is the reduction factor for non-vertical light incidence on the rooflight (0,85 is considered adequate);

η_R is the value of utilance; ISO 10916 provides two tables to determine η_R for different types of rooflights and shed-rooflight geometries, as a function of the room index k (ISO 10916:2014,Table A.11 and Table A.12). Table A.11 refers to rooflights that have an annular supports in spaces with dome and strip skylights, while ISO 10916:2014, Table A.12 refers to shed rooflights. ISO 10916:2014, Figure A.12 and Figure A.13 illustrate the geometry parameters of the two systems to be used to enter the corresponding tables.

The room index k can be found through Formula (13):

$$k = \frac{a_R \cdot b_R}{h'_R \cdot (a_R + b_R)} \tag{13}$$

where

a_R is the room depth;

b_R is the room width;

h'_R is the height difference of ceiling and task area height.

$\bar{D}_j$ values are then used to classify the daylight availability for the space under evaluation, as follows:

— $\bar{D}_j \geq 7\ \%$ classification of daylight availability (D_{class}): STRONG;

— $4\ \% \leq \bar{D}_j < 7\ \%$ classification of daylight availability (D_{class}): MEDIUM;

— $2\ \% \leq \bar{D}_j < 4\ \%$ classification of daylight availability (D_{class}): LOW;

— $\bar{D}_j < 2\ \%$ classification of daylight availability (D_{class}): NONE.

Note that according to ISO 10916:2014, values of $\bar{D}_j$ > 10 % should be avoided due to the danger of overheating.

If the daylight factor has been calculated using another validated method (for instance, through validated simulations tools or measurements in situ), it can be used instead of the value calculated through ISO 10916:2014, Formula (A.17) to then classify the daylight availability. According to ISO 10916:2014, in this case, the daylight factor shall be determined as the mean value on the work plane.

6.4.3.10.3 Daylight supply factor $F_{D,s,j}$

ISO 10916:2014, Table A.14 contains a set of values of $F_{D,s,j}$ for rooflights for different locations and climates. $F_{D,s,j}$ values can be determined as a function of: (i) daylight availability classification; (ii) maintained illuminance $\bar{E}_m$; (iii) façade orientation and incline; (iv), location γ; and (v) climate, through the luminous exposure ratio H_{dir}/H_{glob}.

NOTE 1 There are known errors in the values provided in ISO 10916:2014, Table A.14. The values will be corrected in the next edition of the standard, to be published as ISO/CIE 10916.

NOTE 2 Movable shading devices are not taken into consideration.

Note that according to ISO 10916:2014, for maintained illuminances $\bar{E}_m$ of less than 100 lx, the daylight supply factor $F_{D,s,j}$ values for $\bar{E}_m$ = 100 lx should be used; for maintained illuminances $\bar{E}_m$ of greater than 1 000 lx, the daylight supply factor $F_{D,s,j}$ values for $\bar{E}_m$ = 1 000 lx should be used.

6.4.3.11 Factor for daylight responsive control systems $F_{D,C}$

A method is provided with ISO 10916:2014, A.5 to rate daylight responsive control systems described by the parameter $F_{D,C,j}$.

The effect taken into consideration here relates to the characteristics of the electric lighting controls deployed to supplement the available daylight 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:

— the type of control involved;

— the daylight supply classification of the zone ('poor', 'average', 'good');

— the maintained illuminance $\bar{E}_m$.

A series of distinctions are be made:

— where open-loop or closed-loop controls are used, a distinction is made as to whether the controls:

  — operate automatically and autonomously, i.e. without processing information from other systems; or

  — operate in a system network, i.e. can use information from other systems (installation bus systems or building management systems);

— artificial lighting control systems are distinguished according to:

  — whether they are controlled manually; or

  - they are controlled automatically to adjust the artificial light intensity to achieve the specified maintained illuminance;
- an additional distinction is made between:
  - stand-alone systems, of which there are two types:
    - systems which turn off the artificial lighting during operating times (if daylight availability is adequate);
    - systems which dim the artificial lighting system to the lowest possible intensity during operating times without actually switching the system off;
  - installation bus systems and building management systems.

Correction factor $F_{\mathrm{D.C},j}$ to rate daylight responsive control systems are reported in ISO 10916:2014, Table A.15.

6.4.3.12 Calculation of the daylight supply factor F_{D} on an annual or a monthly basis

6.4.3.12.1 Annual daylight supply factor F_{D}

The daylight supply factor F_{D} can be eventually calculated on an annual basis for an area under investigation:

$$F_{\mathrm{D}} = 1 - F_{\mathrm{D,S}} \cdot F_{\mathrm{D,C}} \tag{14}$$

6.4.3.12.2 Monthly daylight supply factor F_{D}

Monthly partial-load daylight supply factors $F_{\mathrm{D,j,i}}$ can be derived from the calculated annual daylight supply factor, through a set of correction factors $\mathrm{v}_{\mathrm{Month,j}}$, named ‘monthly distribution key factors’:

$$F_{\mathrm{D},j,i} = \begin{cases} 1 - v_{\mathrm{Month},i} \cdot F_{\mathrm{D},S,j} \cdot F_{D,C,j} & \text{for } v_{\mathrm{Month},i} \cdot F_{\mathrm{D},S,j} \cdot F_{\mathrm{D},C,j} < 1, \\ 0 & \text{otherwise} \end{cases} \tag{15}$$

The correction factors $v_{\mathrm{Month},j}$ are reported in ISO 10916:2014, for vertical façades (ISO 10916:2014, Table A.16) or for rooflights (ISO 10916:2014, Table A.17). As 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 in ISO 10916:2014, Table A.16 for such systems.

6.4.3.13 Determination of day-time and night-time hours

The number of day-time and night-time hours needs to be known to be able to determine the energy need and energy use for lighting.

ISO 10916:2014 provides a method described to determine the number of day-time hours t_{Day} and night-time hours t_{Night} on a monthly basis for a known latitude γ and a specified beginning of usage t_{start} and end of usage t_{end}. The hours between sunrise and sunset are considered as day-time hours [ISO 10916:2014, Formula (A.21) to Formula (A.31)].

Besides, ISO 10916:2014 also provides a table that reports the two values t_{day} and t_{night} as a function of latitude for typical operating hours from 8 am to 5 pm, weekends excluded (ISO 10916:2014,Table A.18) and a further table that reports operation times (t_{start}, t_{end}, t_{Day}, and t_{Night}) of different building zone for a detailed list of activities (ISO 10916:2014, Table A.19).

6.4.3.14 Constant illuminance dependency factor F_c

Constant illuminance control is a technique employed to cut out the initial excess of light output provided by the new installation to compensate for the expected gradual decay in output over time.

The constant illuminance dependency factor F_c is a ratio of the average input power at the period for one complete maintenance cycle to the initial installed input power of the lighting system in the area and can be calculated by ISO/CIE 20086:2019, Formula (8):

$$F_c = 1 - \frac{1}{2} F_{cc} \cdot (1 - f_m) \tag{16}$$

where

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

f_m is the maintenance factor for the scheme.

The lighting scheme is designed with an overall maintenance factor f_m calculated for the selected lighting equipment, environment and specified maintenance schedule. An over-design of "task illuminance" is necessary and is specified in terms of "maintained illuminance", which has a value the "task illuminance" is not permitted to fall below. The decay in the area illumination is mainly due to a combination of several factors:

— lamp luminous flux maintenance factor, f_{LLM}, considering the depreciation of the luminous flux;

— lamp survival factor, f_{LS}, considering the survival/failure of the lamp;

— luminaire maintenance factor, f_{LM}, considering dirt deposit on luminaire optics;

— room surface maintenance factor, f_{RSM}, accounting for dirt deposit on room surfaces.

The combination of these factors produces the maintenance factor of the installation ($f_m = f_{LLM} \cdot f_{LS} \cdot f_{LM} \cdot f_{RSM}$). Overall maintenance factors are typically in the range 0,6 to 0,9. More information on the derivation of maintenance factors is given in ISO/CIE TS 22012:2019, Clause 6 and 7.4.3.2 for Method 2 of this document.

The factor for the efficiency of the constant illuminance control F_{cc} represents the non-linear relationship between input power and light output of certain light sources. It also represents the magnitude of the impact of the control ripple, bias and deviation characteristics of the control system. The value of F_{cc} can vary between different light products and technologies and information on these can be sought from the product suppliers and their respective product specifications.

6.4.3.15 Calculation of energy for lighting

The energy W_t used for lighting per time step t_s required for lighting in a room/zone can be estimated as the total energy for illumination $W_{L,t}$ and the total energy for standby $W_{P,t}$ in that room/zone of the building by ISO/CIE 20086:2019, Formula (9):

$$W_t = W_{L,t} + W_{P,t} \tag{17}$$

$W_{L,t}$ can be estimated for hourly, monthly, or yearly time step period t_s according to the time period of the dependency factors F_c, F_O and F_D used, by ISO/CIE 20086:2019, Formula (10):

$$W_{L,t} = \frac{\sum\{(P_n \cdot F_c) \cdot F_O [(t_D \cdot F_D) + t_N]\}}{1\,000} \text{ (kWh)} \tag{18}$$

where

P_n is the total power of n luminaires in the room/zone (W),

F_c is the constant illuminance dependency factor,

F_O is the occupancy dependency factor,

t_D is the daylight time (h),

F_D is the daylight dependency factor,

t_N is the daylight absence time (h).

Calculations are based upon an average value across a defined time step, irrespective of any variations within the time step.

The total energy for standby $W_{P,t}$ can be estimated using ISO/CIE 20086:2019, Formula (11):

$$W_{P,t} = \Sigma\left\{\left(P_{pc} \cdot t_s\right) + \left(P_{em} \cdot t_e\right)\right\} / 1\,000 \text{ (kWh)} \tag{19}$$

where

P_{pc} total standby power for automatic lighting controls (W),

P_{em} total emergency standby power (W),

t_e battery charge time (h).

Therefore, the total annual energy used for lighting W for the entire building can be calculated summing across all the rooms/zones within the building, using ISO/CIE 20086:2019, Formula (12):

$$W = \left(\frac{8\,760}{t_s}\right) \cdot \Sigma W_t \text{ (kWh)} \tag{20}$$

Then the Lighting energy numeric indicator (LENI) for the building can be calculated per area unit using ISO/CIE 20086:2019, Formula (13):

$$Q_{LENI} = \frac{W}{A} \text{ (kWh/m}^2\text{)} \tag{21}$$

where A is the total useful floor area of the building (m^2).

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

7.1 General

This method is quick and simple as it employs approximation procedures for the calculation of the required installed load and uses default data for the impact assessment of the lighting controls. The method is particularly useful for new and refurbished buildings during concept design and feasibility study stage.

7.2 Output data

The output of the method will be as in ISO/CIE 20086:2019, Table 12 shown in Table 14 below and provides the budget estimated values that in general are likely to be higher than those obtained from the comprehensive Method 1. It is useful to recalculate the energy requirement values with real data when the comprehensive lighting system design has been completed. The method procedure results in a budget calculated Q_{LENI}, which is the area normalized energy used for lighting within the building annually, measured in kWh/m^2. For the purposes of this document, the output data of Method 2 listed in Table 14 apply.

Table 14 — Output data of Method 2

Description[a]	Symbol	Unit
Specified time step	t_s	year
Annual energy required for lighting for an area or a zone	W_{az}	kWh
Total annual energy used for lighting within the building	W	kWh
[a] Output data according to ISO/CIE 20086:2019, Table 12		

7.3 Calculation time steps

The default data used for the lighting controls' impact assessment are based on the annual estimation and there is no data for other time intervals available; therefore, only the yearly time step t_s (8 760 h) can be utilized by the Method 2 calculations.

7.4 Input data

To estimate the energy required for lighting with the quick calculation method, the intended lighting design solution are identified for all areas within the building; that design scheme becomes a source for the input data for the Method 2 calculations. The input data typically include:

— building information: building type, area types and dimensions, luminaire types and quantities required for the building electrical lighting system to realize the intended lighting design solution;

— luminaire information: luminaire description and identification/catalogue number, unique product characteristics and functional (dimming control, integral detectors, emergency batteries) capabilities, light source type and flux emission, standby energy density (default values are provided in ISO/CIE 20086:2019, Table A.1);

— system design information and operating conditions: maintained illuminance, task area dimensions, method of daylight admittance, occupancy factor, daylight factor, over-design/maintenance factor.

7.5 Calculation procedure

7.5.1 Applicable time step

As noted in 7.2, the only time step that can be utilized and provide meaningful outcomes in the quick calculation method, yearly, is defined as 8 760 h per annum.

7.5.2 Operating conditions calculation

Default values for t_N (daylight absence time) and t_D (daylight time) for the eight most common building type options are provided in the ISO/CIE 20086:2019, Table A.2, shown in Table 15:

Table 15 — Annual operating hours — Building type

Building type[a]	Default annual operating hours		
	t_D	t_N	t_{tot}
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
Sport 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

[a] Building types according to ISO/CIE 20086:2019, Table A.2

7.5.3 Energy calculation

7.5.3.1 General

The steps in the lighting energy calculation in this quick method are shown in Figure 3 below. This shows that the first step is to establish the building type New or Existing and the second step is to estimate the required installed power for lighting followed by the selection and calculation of the dependency factors value, and finish with the calculation of LENI and the yearly energy required for lighting. As the energy values are preliminary, a recalculation of the energy requirements after a comprehensive lighting design has been completed on the project will improve the results.

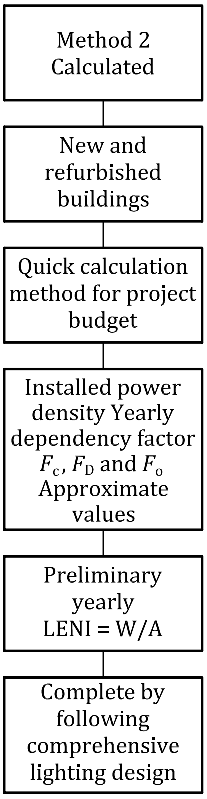


Figure 5 — Flow diagram for quick method of lighting energy calculation

7.5.3.2 Installed power calculation

7.5.3.2.1 General

For non-domestic new or refurbished buildings at the conceptual stage of the design, the total power of n luminaires P_n required for electric lighting to provide lighting to a given area can be estimated by the following procedure (also described in ISO/CIE 20086:2019, Annex B). The method only gives the approximate installed power as it makes several assumptions and there are situations where significant errors can occur. Thus, the method is only suitable for early stage designs and is later followed up with an assessment of the installed power once the lighting equipment for the building has been specified. Also, the method described is not suitable for use for areas that contain specialized application spaces such as operating theatre or special sports playing areas such as badminton and squash courts.

According to ISO/CIE 20086:2019, Formula (B.1), the total power of n luminaires required for an area in the building can be estimated using:

$$P_n = P_j \cdot A \,(\mathrm{W}) \tag{22}$$

where

P_n is the total power of n luminaires in the area (W);

P_j is the power density of area j (W/m²);

A is the total useful floor area in the building (m²).

In turn, the power density is dependent on power density per lux and the required illuminance. ISO/CIE 20086:2019, Formula (B.2) relates the power density to the power density per lux and the required illuminance. There are also correction factors to allow for variation in the maintenance factor, the efficiency of the lighting system and if some areas in the room are being lit to a lower light level.

$$P_j = P_{j,\mathrm{lx}} \cdot E_{\mathrm{task}} \cdot F_{\mathrm{CMF}} \cdot F_{\mathrm{CA}} \cdot F_{\mathrm{L}} \tag{23}$$

where

P_j is the power density of the area j (W/m²);

$P_{j,\mathrm{lx}}$ is the illuminance-normalized power density of area j [W/(m²lx)];

E_{task} is the maintained illuminance on the task area (lx);

F_{CMF} is the correction factor for the maintenance factor;

F_{CA} is the correction factor for the reduced power of area;

F_{L} is the correction factor for the light source efficiency.

Note that ISO/CIE 20086:2019, Formula (B.2) has been set up in such a way that if F_{CMF}, F_{CA} and F_{L} are ignored (i.e. taken to be 1,0), then the formula can be simplified to $P_j = P_{j,\mathrm{lx}} \cdot E_{\mathrm{task}}$. The result will give a slightly less accurate estimate of the lighting power density. The final installed power is re-calculated by using the comprehensive lighting system design process.

7.5.3.2.2 Evaluation of $P_{j,\mathrm{lx}}$

The value of $P_{j,\mathrm{lx}}$ is dependent on the photometric distribution of the luminaires used and the shape of the room or zone that they are illuminating. The shape of the room or zone is classified according to its room index K which is evaluated using ISO/CIE 20086:2019, Formula (B.3):

$$K = \frac{L_R \cdot W_R}{h_m \cdot (L_R + W_R)} \tag{24}$$

where

L_R is the length of the room or zone (m);

W_R is the width of the room or zone (m);

h_m is the mounting height of the luminaires above the working plane in the room or zone (m).

According to ISO/CIE 20086:2019, 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. This is because the room has very unusual proportions and is likely to require a non-standard approach to lighting design. According to ISO/CIE 20086:2019, 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 16:

Table 16 — Values of power density per lux for various photometric distributions and room indices

K	Upward Flux Fraction[a] (description of flux emission)			
	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

[a] Table taken from ISO/CIE 20086:2019, Table B.1

ISO/CIE 20086:2019, Table B.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 %. This is possible that in rooms with a room index of 5 there is very little light that interacts with the walls and the changes in going to a space where the walls make up an even smaller fraction of the room surfaces makes very little difference.

7.5.3.2.3 Evaluation of F_{CMF}

ISO/CIE 20086:2019 requires that the lighting scheme is designed with an overall maintenance factor f_m calculated for the selected lighting equipment, environment and specified maintenance schedule. More information on the derivation of maintenance factors is given in ISO/CIE TS 22012. Once the overall maintenance factor f_m for the installation is determined, ISO/CIE 20086:2019, Formula (B.4) is used to calculate the correction factor F_{CMF} to account for the maintenance factor f_m:

$$F_{CMF} = \frac{0{,}8}{f_m} \tag{25}$$

where

0,8 is the reference maintenance factor;

f_m is the selected maintenance factor.

Correctly deriving the maintenance factor f_m is a complex procedure which requires consideration of the depreciation of the luminous flux, the lamp survival, the luminaire maintenance factor and the surface maintenance factor.

Thus, it can be derived as $f_m = f_{LLM} \cdot f_{LS} \cdot f_{LM} \cdot f_{RSM}$,

where

f_{LLM} is the lamp luminous flux maintenance factor;

f_{LS} is the lamp survival factor (used only if spot-replacement of lamps is not carried out);

f_{LM} is the luminaire maintenance factor;

f_{RSM} is the room surface maintenance factor.

The maintenance factor thus depends on the lighting equipment chosen, the installation and the room or zone being lit together with the maintenance cycle. Overall maintenance factors are typically in the range 0,6 to 0,9.

7.5.3.2.4 Lamp luminous flux maintenance factor, f_{LLM}

The luminous flux output from all lamp types reduces over time of operation. The rate of fall-off varies for different lamp types and it is essential to consult manufacturers' data. From such data it is possible to obtain the lamp luminous flux maintenance factor for a specific number of hours of operation. The lamp luminous flux maintenance factor is therefore the proportion of the initial light output that is produced after a specified time and, where the rate of fall-off is regular, can be quoted as a percentage reduction per thousand hours of operation. Manufacturers' data will usually be based on standard test procedures which specify the ambient temperature in which the lamp will be tested, with a regulated voltage applied to the lamp and, if appropriate, a reference set of control gear. If any of the aspects of the proposed design are unusual, e.g. high ambient temperature, vibration, switching cycle, operating attitude etc., it is advised that the manufacturer is made aware of the conditions and will advise if they affect the life and/or light output of the lamp.

7.5.3.2.5 Lamp survival factor, f_{LS}

For lamp luminous flux maintenance factor, it is essential to consult manufacturers' data. These will give the percentage of lamp failures for a specific number of hours operation and is only applicable where group lamp replacement, without spot replacement, is carried out. These data will also be based on assumptions such as switching cycle, supply voltage and control gear. It is advised that manufacturers are made aware of these aspects and will advise if these will affect the light source life or light source survival. If manufacturers' information is not available, then the values in Table 17 can be used as a guide.

Table 17 — Values of f_{LLM} and f_{LS}

			Burning hours/1 000											
Lamp types[a]		**Differences[c]**	**0,1**	**0,5**	**1**	**2**	**4**	**6**	**8**	**10**	**12**	**15**	**20**	**30**
Incandescent	f_{LLM}	moderate	1,00	0,97	0,93									
	f_{LS}	big	1,00	0,98	0,50									
Halogen	f_{LLM}	big	1,00	0,99	0,97	0,95								
	f_{LS}	big	1,00	1,00	0,78	0,50								
Fluorescent Tri-phosphor (HF gear)	f_{LLM}	moderate	1,00	0,99	0,98	0,97	0,93	0,92	0,90	0,90	0,90	0,90	0,90	
	f_{LS}	moderate	1,00	1,00	1,00	1,00	1,00	0,99	0,98	0,98	0,97	0,94	0,50	
Fluorescent Tri-phosphor	f_{LLM}	moderate	1,00	0,99	0,98	0,97	0,93	0,92	0,90	0,90	0,90	0,90	0,90	
	f_{LS}	moderate	1,00	1,00	1,00	1,00	1,00	0,99	0,98	0,98	0,92	0,50		
Fluorescent halophos-phate	f_{LLM}	moderate	1,00	0,98	0,96	0,95	0,87	0,84	0,81	0,79	0,77	0,75		
	f_{LS}	moderate	1,00	1,00	1,00	1,00	1,00	0,99	0,98	0,98	0,92	0,50		
Compact fluo-rescent	f_{LLM}	big	1,00	0,98	0,97	0,94	0,91	0,89	0,87	0,85				
	f_{LS}	big	1,00	0,99	0,99	0,98	0,97	0,94	0,86	0,50				
Mercury	f_{LLM}	moderate	1,00	0,99	0,97	0,93	0,85	0,82	0,80	0,79	0,78	0,77	0,76	
	f_{LS}	moderate	1,00	1,00	0,99	0,98	0,97	0,94	0,90	0,86	0,79	0,69	0,50	
Metal halide (250 W/ 400 W)[b]	f_{LLM}	big	1,00	0,98	0,95	0,90	0,87	0,83	0,79	0,65	0,63	0,58	0,50	
	f_{LS}	big	1,00	0,99	0,99	0,98	0,97	0,92	0,86	0,80	0,73	0,66	0,50	
Ceramic metal halide (50 W/ 150 W)	f_{LLM}	big	1,00	0,95	0,87	0,75	0,72	0,68	0,64	0,60	0,56			
	f_{LS}	big	1,00	0,99	0,99	0,98	0,98	0,98	0,95	0,80	0,50			
High pres-sure sodium (250 W/ 400 W)	f_{LLM}	moderate	1,00	1,00	0,98	0,98	0,98	0,97	0,97	0,97	0,97	0,96	0,94	0,90
	f_{LS}	moderate	1,00	1,00	1,00	1,00	0,99	0,99	0,99	0,99	0,97	0,95	0,92	0,50

[a] Data for LED is changing rapidly; guidance on values is given in 7.5.3.2.6.

[b] Differences in group of metal halides are significant. Very high and very low wattage lamps live significantly shorter than values given here.

[c] Indicates differences in LLMF and LSF among lamps, which belong to the same lamp type category

7.5.3.2.6 LED Maintenance Factor

According to ISO/CIE TS 22012 and CEN/TR 15193-2, for LED luminaires it is necessary to use different parameters to establish a meaningful maintenance factor f_m for lighting designs. With LEDs the lamp luminous flux maintenance factor and the lamp survival factor can be based on (L_x, B_y), (L_x, C_y) and (L_x, F_y)

where:

L_x is the time period at which x % of the measured initial luminous flux value is maintained;

L_x, B_y is a measure for the age at which a given percentile (y) of LED luminaires no longer meet the lumen depreciation criteria (x). LED luminaires that give a light output lower than the limit set by L_x are considered as a parametric failure. This means that even though the luminaire is still operational (and in most cases still provides substantial amount of light) the luminous flux is lower than the limit set by x. For example, the "L_{80} B_{10}" life is the age at which 10 % of products produce less than 80 % of their initial luminous flux. The age at which 50 % of the items parametrically fail, the "B_{50} life", is called Median Useful Life.

A common misperception is that the "parametrically failed" luminaires produce light far below this threshold. However, in practice a parametrically failed luminaire will provide light "just below" the indicated threshold, where other luminaires in the group will still produce slightly above this threshold;

L_x, C_y is a measure for the lifetime linked to the critical or abrupt failure of a LED luminaire. C_y (equivalent to a lamp failure) is when a failure of the LED module, driver or other component means that a luminaire no longer provides light. It is not usual to include this element of light loss in the maintenance factor as it is assumed that any such failure is replaced, although group replacement is still a valid practice and it could be relevant value for maintenance planning;

L_x, F_y is a measure for the Failure Fraction – The failure rate over the rated life is defined as the failure fraction (F_y) where y is the percentage of LEDs that will have failed at the end of rated life and is a combination of gradual failure (B_y) and critical failure (C_y).

Providing both the useful life and the criteria used (for example, $L_{80}B_{50}$) for each luminaire allows comparison between manufacturers.

A manufacturer will declare values for Useful Life at a specified ambient temperature. For example, $L_{80}B_{50}$ (50 000 h at 25 °C) indicates that after an operating time of 50 000 h, 80 % of the initial luminous flux will be emitted for a luminaire operating in an ambient temperature of 25 °C and by this time 50 % of the LED luminaires could have dropped below this threshold. Using this example, the LED lumen maintenance factor (which is a part of the maintenance factor determination method) is 0,8 at 50 000 h. The gradual loss of light is a specific characteristic of a luminaire and cannot be assumed from knowledge of the performance of a single individual component (such as the performance of the individual LEDs).

7.5.3.2.7 Luminaire Maintenance Factor, f_{LM}

Dirt deposited on or in the luminaire optical surface will cause a reduction in light output from the luminaire. The rate at which dirt is deposited depends on the construction of the luminaire and on the extent to which dirt is present in the atmosphere, which in turn is related to the nature of the dirt generated in the specific environment. Table 18 gives a list of the luminaire classes and Table 19 gives a list of typical locations where the various environmental conditions can be found.

Table 20 shows typical changes in light output from a luminaire caused by dirt deposition, for the various types of luminaire and environment classes at different cleaning intervals.

Table 18 — Luminaire classes

Class	Description
A	Bare lamp batten
B	Open top reflector (ventilated self-cleaning)
C	Closed top housing (unventilated)
D	Enclosed (IP2X)
E	Dustproof (IP5X)
F	Indirect uplighter

Table 18 *(continued)*

Class	Description
G	Air handling and forced ventilated

Table 19 — Locations of environmental conditions

Environment	Typical Locations
Very Clean (VC)	Clean rooms, semiconductor plants, hospital clinical areas, computer centres
Clean (C)	Offices, schools, hospital wards
Normal (N)	Shops, laboratories, restaurants, warehouses, assembly areas, workshops
Dirty (D)	Steelworks, chemical works, foundries, welding, polishing, woodwork

Table 20 — f_{LM} values for indoor use

Elapsed time between cleanings in years	Environment	Luminaire type						
		A	B	C	D	E	F	G
0,5	VC	0,98	0,96	0,95	0,94	0,94	0,94	1,00
	C	0,95	0,95	0,93	0,92	0,96	0,92	1,00
	N	0,92	0,91	0,89	0,87	0,93	0,89	0,99
	D	0,88	0,88	0,85	0,83	0,91	0,85	0,98
1,0	VC	0,96	0,95	0,94	0,94	0,96	0,93	1,00
	C	0,93	0,90	0,89	0,88	0,94	0,86	0,99
	N	0,89	0,86	0,81	0,82	0,90	0,81	0,96
	D	0,83	0,83	0,75	0,77	0,86	0,74	0,93
1,5	VC	0,95	0,94	0,93	0,93	0,92	0,91	0,99
	C	0,91	0,87	0,84	0,85	0,92	0,81	0,97
	N	0,87	0,83	0,74	0,79	0,88	0,73	0,94
	D	0,80	0,79	0,66	0,73	0,83	0,65	0,89
2,0	VC	0,94	0,92	0,91	0,91	0,93	0,88	0,99
	C	0,89	0,84	0,80	0,83	0,91	0,77	0,96
	N	0,84	0,80	0,69	0,77	0,86	0,66	0,92
	D	0,78	0,75	0,59	0,71	0,81	0,57	0,87
2,5	VC	0,93	0,91	0,89	0,90	0,92	0,86	0,98
	C	0,87	0,82	0,77	0,81	0,90	0,73	0,95
	N	0,82	0,76	0,64	0,75	0,85	0,60	0,91
	D	0,75	0,71	0,54	0,68	0,80	0,51	0,86
3,0	VC	0,92	0,89	0,87	0,89	0,92	0,85	0,98
	C	0,85	0,79	0,74	0,79	0,90	0,70	0,95
	N	0,79	0,74	0,61	0,73	0,84	0,55	0,90
	D	0,73	0,68	0,52	0,65	0,79	0,45	0,85

7.5.3.2.8 Room Surface Maintenance Factor, f_{RSM}

Changes in room surface reflectance caused by dirt deposition will cause changes in the illuminance produced by the lighting installation. The magnitude of these changes is governed by the extent of dirt deposition and the importance of inter-reflection to the illuminance produced. Inter-reflection is closely related to the distribution of light from the luminaire. For luminaires which have a strongly downward distribution, i.e. direct luminaires, inter-reflection has little effect on the illuminance produced on the horizontal working plane. Conversely, indirect lighting is completely dependent on inter-reflections. Most luminaires lie somewhere between these extremes so most lighting installations are dependent to some extent on inter-reflection.

Table 21 to Table 23 show the typical changes in the illuminance from an installation that occur with time due to dirt deposition on the room surfaces the environmental conditions given in Table 19. From the tables it is possible to select a room surface maintenance factor appropriate to the circumstances.

Table 21 — Room Surface Maintenance Factor f_{RSM} for direct flux distribution 0 ≤ UFF < 0,25

Reflectance values ceiling/ walls/floor	Time years	0,5	1,0	1,5	2,0	2,5	3,0	3,5	4,0	4,5	5,0	5,5	6,0
	Environment	Room surface maintenance factors											
0,80/0,70/0,20	VC	0,97	0,96	0,95	0,95	0,95	0,95	0,95	0,95	0,95	0,95	0,95	0,95
	C	0,93	0,92	0,91	0,91	0,91	0,91	0,91	0,91	0,91	0,91	0,91	0,91
	N	0,88	0,86	0,86	0,85	0,85	0,85	0,85	0,85	0,85	0,85	0,85	0,85
	D	0,81	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80
0,80/0,50/0,20	VC	0,98	0,97	0,97	0,97	0,97	0,97	0,97	0,97	0,97	0,97	0,97	0,97
	C	0,95	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94
	N	0,91	0,90	0,90	0,90	0,90	0,90	0,90	0,90	0,90	0,90	0,90	0,90
	D	0,86	0,85	0,85	0,85	0,85	0,85	0,85	0,85	0,85	0,85	0,85	0,85
0,80/0,30/0,20	VC	0,99	0,98	0,98	0,98	0,98	0,98	0,98	0,98	0,98	0,98	0,98	0,98
	C	0,97	0,96	0,96	0,96	0,96	0,96	0,96	0,96	0,96	0,96	0,96	0,96
	N	0,94	0,93	0,93	0,93	0,93	0,93	0,93	0,93	0,93	0,93	0,93	0,93
	D	0,91	0,90	0,90	0,90	0,90	0,90	0,90	0,90	0,90	0,90	0,90	0,90
0,70/0,70/0,20	VC	0,97	0,96	0,96	0,96	0,96	0,96	0,96	0,96	0,96	0,96	0,96	0,96
	C	0,94	0,92	0,92	0,92	0,92	0,92	0,92	0,92	0,92	0,92	0,92	0,92
	N	0,89	0,87	0,87	0,87	0,87	0,87	0,87	0,87	0,87	0,87	0,87	0,87
	D	0,83	0,81	0,81	0,81	0,81	0,81	0,81	0,81	0,81	0,81	0,81	0,81
0,70/0,50/0,20	VC	0,98	0,97	0,97	0,97	0,97	0,97	0,97	0,97	0,97	0,97	0,97	0,97
	C	0,96	0,95	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94
	N	0,92	0,91	0,90	0,90	0,90	0,90	0,90	0,90	0,90	0,90	0,90	0,90
	D	0,87	0,86	0,86	0,86	0,86	0,86	0,86	0,86	0,86	0,86	0,86	0,86
0,70/0,30/0,20	VC	0,99	0,98	0,98	0,98	0,98	0,98	0,98	0,98	0,98	0,98	0,98	0,98
	C	0,97	0,96	0,96	0,96	0,96	0,96	0,96	0,96	0,96	0,96	0,96	0,96
	N	0,95	0,94	0,94	0,94	0,93	0,93	0,93	0,93	0,93	0,93	0,93	0,93
	D	0,92	0,91	0,91	0,91	0,91	0,91	0,91	0,91	0,91	0,91	0,91	0,91
0,50/0,70/0,20	VC	0,98	0,97	0,97	0,96	0,96	0,96	0,96	0,96	0,96	0,96	0,96	0,96
	C	0,95	0,94	0,93	0,93	0,93	0,93	0,93	0,93	0,93	0,93	0,93	0,93
	N	0,91	0,89	0,89	0,89	0,89	0,89	0,89	0,89	0,89	0,89	0,89	0,89
	D	0,85	0,84	0,84	0,84	0,84	0,84	0,84	0,84	0,84	0,84	0,84	0,84
0,50/0,50/0,20	VC	0,98	0,98	0,98	0,98	0,97	0,97	0,97	0,97	0,97	0,97	0,97	0,97
	C	0,97	0,96	0,95	0,95	0,95	0,95	0,95	0,95	0,95	0,95	0,95	0,95
	N	0,94	0,92	0,92	0,92	0,92	0,92	0,92	0,92	0,92	0,92	0,92	0,92
	D	0,89	0,89	0,88	0,88	0,88	0,88	0,88	0,88	0,88	0,88	0,88	0,88
NOTE This table is taken from CEN/TR 15193-2:2017, Table C.6													

Table 21 *(continued)*

Reflectance values ceiling/walls/floor	Time years	0,5	1,0	1,5	2,0	2,5	3,0	3,5	4,0	4,5	5,0	5,5	6,0
	Environ-ment	**Room surface maintenance factors**											
0,50/0,30/0,20	VC	0,99	0,99	0,98	0,98	0,98	0,98	0,98	0,98	0,98	0,98	0,98	0,98
	C	0,98	0,97	0,97	0,97	0,97	0,97	0,97	0,97	0,97	0,97	0,97	0,97
	N	0,96	0,95	0,95	0,95	0,95	0,95	0,95	0,95	0,95	0,95	0,95	0,95
	D	0,93	0,92	0,92	0,92	0,92	0,92	0,92	0,92	0,92	0,92	0,92	0,92
NOTE This table is taken from CEN/TR 15193-2:2017, Table C.6													

Table 22 — Room Surface Maintenance Factor f_{RSM} for direct/indirect flux distribution $0,25 \leq UFF < 0,75$

Reflectance values ceiling/walls/floor	Time years	0,5	1,0	1,5	2,0	2,5	3,0	3,5	4,0	4,5	5,0	5,5	6,0
	Environ-ment	**Room surface maintenance factors**											
0,80/0,70/0,20	VC	0,95	0,94	0,93	0,93	0,93	0,93	0,93	0,93	0,93	0,93	0,93	0,93
	C	0,90	0,88	0,87	0,87	0,87	0,87	0,87	0,87	0,87	0,87	0,87	0,87
	N	0,81	0,78	0,77	0,77	0,77	0,77	0,77	0,77	0,77	0,77	0,77	0,77
	D	0,70	0,67	0,67	0,67	0,67	0,67	0,67	0,67	0,67	0,67	0,67	0,67
0,80/0,50/0,20	VC	0,96	0,95	0,95	0,95	0,95	0,95	0,95	0,95	0,95	0,95	0,95	0,95
	C	0,93	0,91	0,90	0,90	0,90	0,90	0,90	0,90	0,90	0,90	0,90	0,90
	N	0,85	0,83	0,82	0,82	0,82	0,82	0,82	0,82	0,82	0,82	0,82	0,82
	D	0,76	0,73	0,73	0,73	0,73	0,73	0,73	0,73	0,73	0,73	0,73	0,73
0,80/0,30/0,20	VC	0,97	0,96	0,96	0,96	0,96	0,96	0,96	0,96	0,96	0,96	0,96	0,96
	C	0,94	0,93	0,92	0,92	0,92	0,92	0,92	0,92	0,92	0,92	0,92	0,92
	N	0,89	0,87	0,86	0,86	0,86	0,86	0,86	0,86	0,86	0,86	0,86	0,86
	D	0,81	0,79	0,78	0,78	0,78	0,78	0,78	0,78	0,78	0,78	0,78	0,78
0,70/0,70/0,20	VC	0,96	0,94	0,94	0,93	0,93	0,93	0,93	0,93	0,93	0,93	0,93	0,93
	C	0,91	0,89	0,88	0,88	0,88	0,88	0,88	0,88	0,88	0,88	0,88	0,88
	N	0,83	0,80	0,79	0,79	0,79	0,79	0,79	0,79	0,79	0,79	0,79	0,79
	D	0,72	0,69	0,69	0,69	0,69	0,69	0,69	0,69	0,69	0,69	0,69	0,69
0,70/0,50/0,20	VC	0,97	0,96	0,95	0,95	0,95	0,95	0,95	0,95	0,95	0,95	0,95	0,95
	C	0,93	0,91	0,91	0,91	0,91	0,91	0,91	0,91	0,91	0,91	0,91	0,91
	N	0,87	0,84	0,84	0,83	0,83	0,83	0,83	0,83	0,83	0,83	0,83	0,83
	D	0,77	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75
0,70/0,30/0,20	VC	0,98	0,97	0,96	0,96	0,96	0,96	0,96	0,96	0,96	0,96	0,96	0,96
	C	0,95	0,93	0,93	0,93	0,93	0,93	0,93	0,93	0,93	0,93	0,93	0,93
	N	0,90	0,88	0,87	0,87	0,87	0,87	0,87	0,87	0,87	0,87	0,87	0,87
	D	0,82	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80
0,50/0,70/0,20	VC	0,97	0,95	0,95	0,95	0,95	0,95	0,95	0,95	0,95	0,95	0,95	0,95
	C	0,93	0,91	0,90	0,90	0,90	0,90	0,90	0,90	0,90	0,90	0,90	0,90
	N	0,86	0,83	0,83	0,83	0,83	0,83	0,83	0,83	0,83	0,83	0,83	0,83
	D	0,76	0,74	0,74	0,74	0,74	0,74	0,74	0,74	0,74	0,74	0,74	0,74
NOTE This table is taken from CEN/TR 15193-2:2017, Table C.7													

Table 22 *(continued)*

Reflectance values ceiling/walls/floor	Time years	0,5	1,0	1,5	2,0	2,5	3,0	3,5	4,0	4,5	5,0	5,5	6,0
	Environment	Room surface maintenance factors											
0,50/0,50/0,20	VC	0,97	0,96	0,96	0,96	0,96	0,96	0,96	0,96	0,96	0,96	0,96	0,96
	C	0,94	0,93	0,92	0,92	0,92	0,92	0,92	0,92	0,92	0,92	0,92	0,92
	N	0,89	0,87	0,86	0,86	0,86	0,86	0,86	0,86	0,86	0,86	0,86	0,86
	D	0,81	0,79	0,79	0,79	0,79	0,79	0,79	0,79	0,79	0,79	0,79	0,79
0,50/0,30/0,20	VC	0,98	0,97	0,97	0,97	0,97	0,97	0,97	0,97	0,97	0,97	0,97	0,97
	C	0,96	0,95	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94
	N	0,92	0,90	0,90	0,90	0,90	0,90	0,90	0,90	0,90	0,90	0,90	0,90
	D	0,85	0,84	0,84	0,84	0,84	0,84	0,84	0,84	0,84	0,84	0,84	0,84
NOTE This table is taken from CEN/TR 15193-2:2017, Table C.7													

Table 23 — Room Surface Maintenance Factor f_{RSM} for indirect flux distribution $0,75 \leq UFF \leq 1,00$

Reflectance values ceiling/walls/floor	Time years	0,5	1,0	1,5	2,0	2,5	3,0	3,5	4,0	4,5	5,0	5,5	6,0
	Environment	Room surface maintenance factors											
0,80/0,70/0,20	VC	0,93	0,91	0,90	0,90	0,90	0,90	0,89	0,89	0,89	0,89	0,89	0,89
	C	0,86	0,82	0,81	0,81	0,81	0,81	0,81	0,81	0,81	0,81	0,81	0,81
	N	0,72	0,67	0,66	0,66	0,66	0,66	0,66	0,66	0,66	0,66	0,66	0,66
	D	0,54	0,50	0,49	0,49	0,49	0,49	0,49	0,49	0,49	0,49	0,49	0,49
0,80/0,50/0,20	VC	0,94	0,93	0,92	0,92	0,92	0,91	0,91	0,91	0,91	0,91	0,91	0,91
	C	0,88	0,85	0,84	0,84	0,84	0,84	0,84	0,84	0,84	0,84	0,84	0,84
	N	0,76	0,72	0,71	0,71	0,71	0,71	0,71	0,71	0,71	0,71	0,71	0,71
	D	0,59	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55
0,80/0,30/0,20	VC	0,96	0,94	0,93	0,93	0,93	0,93	0,93	0,93	0,93	0,93	0,93	0,93
	C	0,90	0,88	0,87	0,87	0,87	0,87	0,87	0,87	0,87	0,87	0,87	0,87
	N	0,80	0,76	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75
	D	0,64	0,60	0,60	0,60	0,60	0,60	0,60	0,60	0,60	0,60	0,60	0,60
0,70/0,70/0,20	VC	0,93	0,91	0,90	0,90	0,90	0,90	0,90	0,90	0,90	0,90	0,90	0,90
	C	0,86	0,83	0,82	0,81	0,81	0,81	0,81	0,81	0,81	0,81	0,81	0,81
	N	0,73	0,68	0,67	0,67	0,67	0,67	0,67	0,67	0,67	0,67	0,67	0,67
	D	0,55	0,51	0,50	0,50	0,50	0,50	0,50	0,50	0,50	0,50	0,50	0,50
0,70/0,50/0,20	VC	0,95	0,93	0,92	0,92	0,92	0,92	0,92	0,92	0,92	0,92	0,92	0,92
	C	0,89	0,86	0,85	0,85	0,84	0,84	0,84	0,84	0,84	0,84	0,84	0,84
	N	0,77	0,73	0,72	0,72	0,72	0,72	0,72	0,72	0,72	0,72	0,72	0,72
	D	0,60	0,56	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55
0,70/0,30/0,20	VC	0,96	0,94	0,94	0,93	0,93	0,93	0,93	0,93	0,93	0,93	0,93	0,93
	C	0,91	0,88	0,87	0,87	0,87	0,87	0,87	0,87	0,87	0,87	0,87	0,87
	N	0,80	0,77	0,76	0,76	0,76	0,76	0,76	0,75	0,75	0,75	0,75	0,75
	D	0,65	0,61	0,60	0,60	0,60	0,60	0,60	0,60	0,60	0,60	0,60	0,60
NOTE This table is taken from CEN/TR 15193-2:2017, Table C.8													

Table 23 *(continued)*

Reflectance values ceiling/walls/floor	Time years	0,5	1,0	1,5	2,0	2,5	3,0	3,5	4,0	4,5	5,0	5,5	6,0
	Environ-ment	Room surface maintenance factors											
0,50/0,70/0,20	VC	0,94	0,92	0,91	0,91	0,91	0,91	0,91	0,91	0,91	0,91	0,91	0,91
	C	0,87	0,84	0,83	0,83	0,83	0,83	0,83	0,83	0,83	0,83	0,83	0,83
	N	0,75	0,70	0,69	0,69	0,69	0,69	0,69	0,69	0,69	0,69	0,69	0,69
	D	0,57	0,52	0,52	0,52	0,52	0,52	0,52	0,52	0,52	0,52	0,52	0,52
0,50/0,50/0,20	VC	0,95	0,93	0,93	0,93	0,92	0,92	0,92	0,92	0,92	0,92	0,92	0,92
	C	0,90	0,87	0,86	0,86	0,85	0,85	0,85	0,85	0,85	0,85	0,85	0,85
	N	0,78	0,74	0,73	0,73	0,73	0,73	0,73	0,73	0,73	0,73	0,73	0,73
	D	0,61	0,57	0,57	0,57	0,57	0,57	0,57	0,57	0,57	0,57	0,57	0,57
0,50/0,30/0,20	VC	0,96	0,95	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94
	C	0,91	0,89	0,88	0,88	0,88	0,88	0,88	0,88	0,88	0,88	0,88	0,88
	N	0,81	0,78	0,77	0,77	0,77	0,77	0,77	0,77	0,77	0,77	0,77	0,77
	D	0,66	0,62	0,61	0,61	0,61	0,61	0,61	0,61	0,61	0,61	0,61	0,61
NOTE This table is taken from CEN/TR 15193-2:2017, Table C.8													

7.5.3.2.9 Evaluation of F_{CA}

Where only part of the area of the room or zone 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 ISO 8995-1/CIE S 008 for the area immediately surrounding the task. Whilst ISO 8995-1/CIE S 008 does not require a whole room to be lit to the value of the surround area it is impractical to estimate exactly how much light will be needed over what area until the final layout of the space is available so for this assessment of power at the early stage of design it is necessary to work on the assumption that the area outside the task areas will be lit to the level for the immediate surrounding area. Table 24 gives the background illuminances associated with the task illuminance values as required by ISO 8995-1/CIE S 008

Table 24 — Relationship of illuminances on immediate surroundings to the illuminated task area

Maintained illuminances on the task areas E_{task} lx	Maintained illuminances on immediate surround of the task areas E_{sur} lx
≥ 750	500
500	300
300	200
200	Same as task illuminance
NOTE This table is taken from ISO 8995-1/CIE S 008:2002, Table 1.	

In some cases, it can 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 or zones. Knowing the area of the room, the area not being lit to the task illuminance, the task illuminance and the surround illuminance, it is possible to calculate the correction factor for reduced power of area, F_{CA}, using the ISO/CIE 20086:2019, Formula (B.5):

$$F_{CA} = \frac{A_S \cdot E_{task} + (A_i - A_S) \cdot E_{sur}}{E_{task} \cdot A_i} \tag{26}$$

where

A_i is the total useful floor area of the room or zone (m^2);

A_S is the sum of the task areas within the room or zone (m^2);

E_{task} is the maintained illuminance on the task area (lx);

E_{sur} is the maintained illuminance on immediate surround of task area (lx).

7.5.3.2.10 Evaluation of F_L

The correction factor for the light source efficiency F_L is provided in Table 25 which gives the values for luminaires with common lamp types. The table is based on a survey of over 23 000 luminaires from 5 major manufacturers and gives the median value for all luminaires surveyed with a particular light source type.

Table 25 — Correction factor for the light source efficiency F_L

Lamp Type	F_L Median	F_L Range
LED Light Emitting Diode	0,86	0,69 to 0,97
T16 linear fluorescent	0,90	0,79 to 1,04
T26 linear fluorescent	0,95	0,84 to 1,11
Metal Halide	0,99	0,93 to 1,10
High Pressure Sodium	1,01	0,94 to 1,06
CFL Compact Fluorescent Lamp	1,56	1,32 to 1,93
TH Tungsten Halogen	4,49	3,27 to 5,39
Tungsten	6,38	6,13 to 6,65
NOTE This table is taken from ISO/CIE 20086:2019, Table A.9		

7.5.3.3 Standby system power requirements from ISO/CIE 20086

For the required standby energy for battery charging of emergency luminaires W_{pe} and for standby energy for automatic lighting controls W_{pc} default values are provided in relation to the zone/room area (m^2) and presented as energy density in Table 26 shown below:

Table 26 — Standby energy density

Purpose	Symbol	Default annual energy density 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
NOTE This table is taken from ISO/CIE 20086:2019, Table A.1		

7.5.3.4 Occupancy dependency factor F_O

The control system dependency is considered through the controls function factor F_{OC}. The absence dependency is considered through the absence factor F_A. The values of F_A provided in Table 27 are defined for the different rooms/functions of each building type. If no information of the room type is available, the absence factor F_A can be determined on building level. The building-based way of determining the F_A value is not so precise compared to those based on the room type. The values in Table 27 have been obtained from results of field studies on occupancy made in several countries.

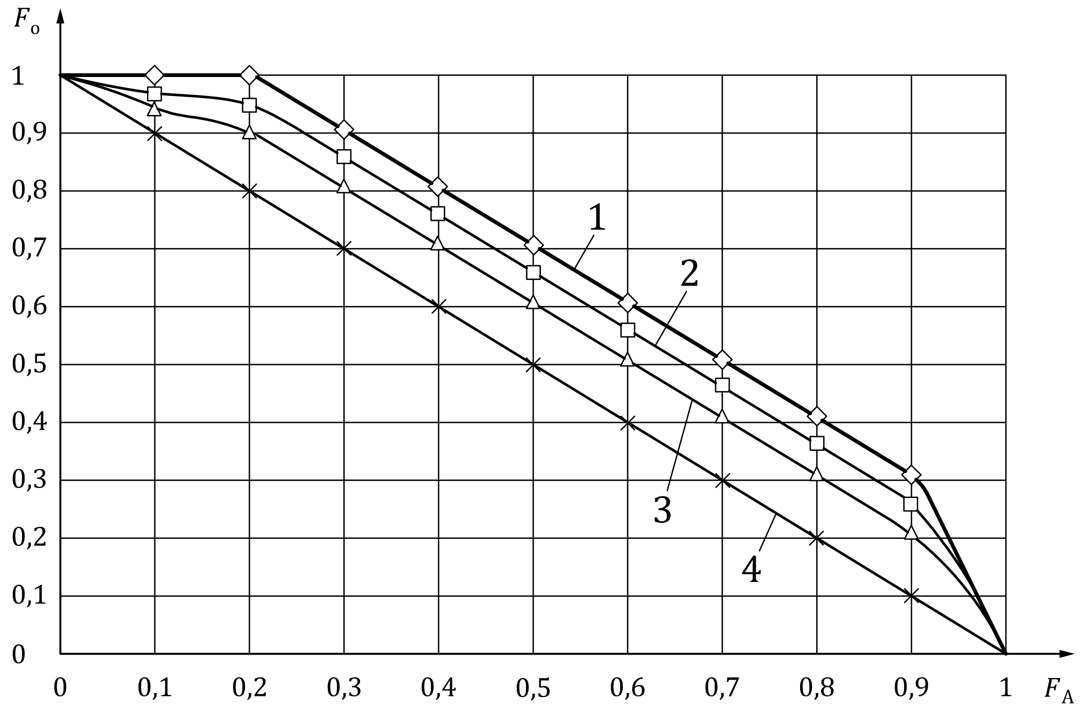
Table 27 — Absence factor F_A for rooms and zones in building types

Overall building calculation		Room by room calculation	
Building type	F_A	**Room type**	F_A
Offices	0,20	Cellular office 1 person	0,40
		Cellular office 2 to 6 persons	0,30
		Open plan office > 6 persons sensing/30 m^2	0,00
		Open plan office > 6 persons sensing/10 m^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	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	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	Assembly hall	0,00
		Smaller assembly room	0,20
		Storage rack area	0,40
		Open storage area	0,20
		Painting room	0,20
NOTE This table is taken from ISO/CIE 20086:2019, Table A.6			

Table 27 *(continued)*

Overall building calculation		Room by room calculation	
Building type	F_A	**Room type**	F_A
Hotels and restaurants	0,00	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	Sales area	0,00
		Store room	0,20
		Store room, cold stores	0,60
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
NOTE This table is taken from ISO/CIE 20086:2019, Table A.6			

The use of an occupancy factor related to the control system in the room allows ranking of the effectiveness of the controls according to the systems in use. It also allows use to derive the data for detailed calculation of energy use for lighting. The relationship between the occupancy dependency factor F_O (Y) and absence factor F_A (X) for various control system regimes is shown in ISO/CIE 20086:2019, Figure D.1, shown here as Figure 6.



Key

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

Figure taken from ISO/CIE 20086:2019, Figure D.1

Figure 6 — F_0 as a function of F_A for the different control systems

Figure 6 shows that there are no differences between systems for F_0 values at the limits.

— For all systems, F_0 is equal to 1 for F_A values of 0.

— For all systems, F_0 is equal to 0 for F_A values of 1.

Between those values the hierarchy of the control systems is shown in Table 28 from the least (1) to the most (4) efficient control system. Table 28 illustrates that the occupancy dependency factor F_0 default values are the function of the lighting control system type and the absence factor F_A.

Table 28 — F_0 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 This table is taken from ISO/CIE 20086:2019, Table D.3											

NOTE The formulae for the determination of F_A and F_O values are based on values and recommendations obtained from several studies carried out in the EU SAVE ENPER Project.

7.5.3.5 Daylight dependency factor, F_D

In zones which have windows or rooflights (skylights), daylight can contribute to the amount of the luminous exposure required. Therefore, this proportion of the required light does not need to be provided by the electric lighting system.

The daylight available from 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 spaces (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 and cooling) of the building.

The daylight dependency factor F_D considers the effect of daylight on the energy required for lighting, by use of the daylight supply factor ($F_{D,S}$) and the lighting control factor ($F_{D,C}$), and can be defined by ISO/CIE 20086:2019, Formula (7)

$$F_D = 1 - F_{D,S} \cdot F_{D,C} \quad (27)$$

For areas with no daylight penetration ($F_{D,S}$ = 0), the daylight dependency factor F_D = 1.

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, the type of lighting control system can be taken into consideration. The factor corresponds to the relative luminous exposure as, for instance, defined in EN 17037, 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 daylight dependency factor F_D which takes the daylight illumination into consideration can be determined for any given time interval (e.g. year, month, hour).

The calculation procedure is provided in ISO 10916 in detail.

A variety of software tools nowadays allow the performance of 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 electric lighting energy demand with a selected number of tools. F_D according to ISO/CIE 20086:2019, Formula (7), can therefore be calculated with these comprehensive approaches.

7.5.3.6 Constant illuminance dependency factor, F_c

Default values for the constant illuminance dependency factor F_c are provided in Table 29.

Table 29 — Example constant illuminance dependency factor F_c

Building type	Lighting system, environment and servicing	f_m	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
NOTE This table is taken from ISO/CIE 20086:2019, Table A.8			

Table 29 *(continued)*

Building type	Lighting system, environment and servicing	f_m	F_c
Factory	Trunking mounted open HF dimmable fluorescent lamp luminaires, dirty environment, biannual bulk lamp change and luminaire clean	0,6	0,80
NOTE This table is taken from ISO/CIE 20086:2019, Table A.8			

7.5.3.7 Energy calculation

The Lighting Energy Numeric Indicator ($Q_{\mathrm{LENI,sub}}$) for the area is calculated by using ISO/CIE 20086:2019 Formula (25):

$$Q_{\mathrm{LENI,sub}} = \left\{F_{\mathrm{c}} \cdot \left(P_j / 1\,000\right) \cdot F_{\mathrm{O}} \left[\left(t_{\mathrm{D}} \cdot F_{\mathrm{D}}\right) + t_{\mathrm{N}}\right]\right\} + W_{\mathrm{pe}} + W_{\mathrm{pc}} \ (\mathrm{kWh/m^2}) \quad (28)$$

where

$Q_{\mathrm{LENI,sub}}$ is the Lighting Energy Numeric Indicator for the area (kWh/m^2);

F_{c} is constant illuminance dependency factor;

P_j is the power density of area j (W/m^2);

F_{O} is the occupancy dependency factor;

t_{D} is daylight time (h);

F_{D} is the daylight dependency factor for the area;

t_{N} is the daylight absence time (h) for the area.

W_{pe} W_{pe} = 1,0, is a constant for the default standby energy for battery charging of emergency luminaires (kWh/m^2),

W_{pc} W_{pc} = 1,5, is a constant for the default standby energy for automatic lighting controls (kWh/m^2).

Then, the annual energy required for lighting within the area or zone can be derived as in ISO/CIE 20086:2019, Formula (26):

$$W_{\mathrm{az}} = Q_{\mathrm{LENI,sub}} \cdot A_i \ (\mathrm{kWh}) \quad (29)$$

where

W_{az} is the annual energy required for lighting for the zone or area (kWh);

$Q_{\mathrm{LENI,sub}}$ is the Lighting Energy Numeric Indicator for the relevant zone or area (kWh/m^2);

A_i is the total useful floor area of the relevant zone or area (m^2).

and the Lighting Energy Numeric Indicator (Q_{LENI}) for the building as in ISO/CIE 20086:2019, Formula (27):

$$Q_{\mathrm{LENI}} = \sum_{i=1}^{i=n} \left(Q_{\mathrm{LENI,sub},i} \cdot A_i\right) / A \ (\mathrm{kWh/m^2}) \quad (30)$$

where

Q_{LENI} is the Lighting Energy Numeric Indicator for the building (kWh/m^2);

n is the number of areas under consideration;

A_i is the total useful floor area of the relevant zone or area (m^2);

A is the total useful floor area of the building (m^2).

The annual energy required for electric lighting within the building is calculated as in ISO/CIE 20086:2019, Formula (28):

$$W = Q_{LENI} \cdot A \ \ (\mathrm{kWh}) \tag{31}$$

where

W is the total annual energy used for lighting for the building (kWh);

A is the total useful floor area of the building (m^2).

7.6 Expenditure factors for lighting systems

The description of the expenditure factors calculation is provided in ISO/CIE 20086:2019, 6.5 and Annex E.

8 Method 3 — Metered energy used for lighting

8.1 General

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 metering has been installed. This method gives true values of the energy used for lighting at any intervals and the annual value can also be used to calculate Q_{LENI} for the building. This method is suitable for use 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 allows energy use for lighting to be measured.

8.2 Output data

Table 30 — Output data of Method 3

Description	Symbol	Unit
Specified time step	t_s	hour, month, year
Energy used for lighting per time step within rooms or zones	W_t	kWh
Total annual energy used for lighting within the building	W	kWh
NOTE This table is taken from ISO/CIE 20086:2019, Table 13		

The output data of Method 3 is shown in Table 30. The metered LENI is the area normalized annual energy used for lighting within the building (kWh/m^2). LENI produced by Method 3 provides the actual Q_{LENI}.

8.3 Calculation time steps

The energy is measured in real time intervals according to the user's calculation requirements. The time step of the output can be:

— yearly,

— monthly, or

— hourly.

8.4 Input data

ISO/CIE 20086:2019 requires that the segregated energy meters only record the energy used for lighting in the various parts of the building. It is important that only the fixed lighting system in the building is connected to the meter(s).

8.5 Calculation procedure of annual energy

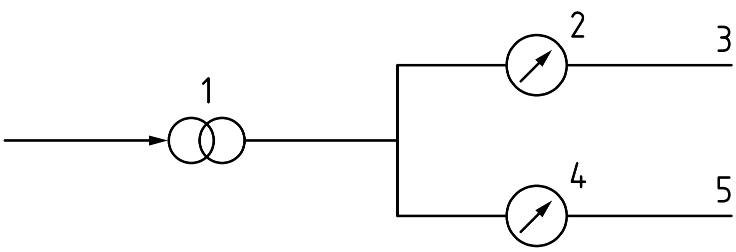
8.5.1 General

The energy used for lighting W_t per specified time step t_s can be obtained from the meter reading.

Volt and ampere meters or watt meters are put on the power input of every lighting controller. The individual lighting controllers calculate the local energy usage by integrating these values over time.

Possible schemes of metering methods are illustrated in Figure 7, Figure 8 and Figure 9 in 8.5.2

8.5.2 Calculation information



Key

1 primary power

2 energy meter - other circuits

3 power circuit

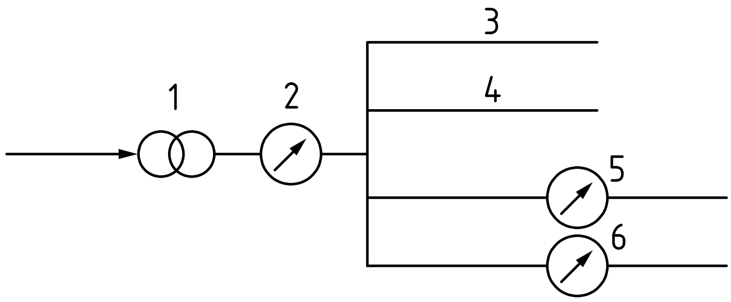
4 energy meter lighting

5 lighting circuit

Figure 7 — energy meters on dedicated lighting circuits in the electrical distribution

In the example of Figure 7, the energy meter for lighting is in parallel to the energy meter for the rest of the electrical installation. The consumption for the total building is in this case the sum of both meters; however, it is intended that energy meters only record the energy used for lighting in the various parts of the building, and the lighting energy consumption is calculated by the following formula:

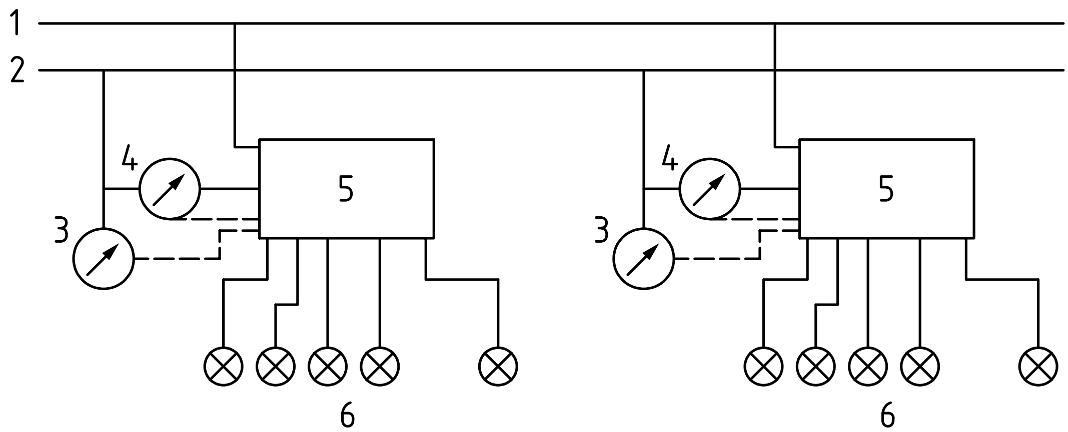
$$W = \sum W_{\text{light metered}} \quad \text{(kWh/year)}$$



Key

1 primary power
2 energy meter – total power
3 power circuit 1
4 power circuit 2
5 energy meter – lighting circuit 1
6 energy meter – lighting circuit 2

Figure 8 — Building with segregation of lighting circuits per floor and separately measured



Key

1 bus line
2 230 volt power
3 volt meter
4 ampere meter
5 light controller
6 luminaires

Figure 9 — Volt and ampere meters coupled to the inputs of the lighting controllers

NOTE 1 Some systems include a power factor meter.

When local power meters are coupled to or integrated in the lighting controllers of a lighting management system, information on the local energy usage is made available via a building management system.

These values are made available via the bus line to either the central computer of the lighting system or the central computer of the building management system. The central computer can process this information and present the consumed energy figures, e.g. per area per month and/or for the total lighting of the building over a period of 12 months in an exportable format, such as a spreadsheet, see CEN/TR 15193-2:2017, Formula (8):

$$W = \sum W_{\text{light metered}} = \sum_{\text{all floors}} \left(\text{kWh}_{@\,\text{date}} - \text{kWh}_{@\,(\text{date}-12\,\text{months})}\right)(\text{kWh}/\text{year}) \tag{31}$$

A lighting management system logs the hours run, the proportionality (dimming level) and relate this to its internal data base on installed load. The lighting management system can make this information available to a BMS for further reporting, or it can give the information in an exportable format.

The lighting controller sums the time per lighting load proportionally per output and makes these values available via the bus line.

NOTE 2 Energy consumption of luminaires not controlled by the lighting control system is not measured.

NOTE 3 Energy consumption of luminaires indirectly controlled via external contactors is measured.

8.5.3 Calculation procedure of annual energy

The total metered energy used for electric lighting W_{mt} in the building for time step t_{s} (h) is calculated by summation of the energy usage by all the meters used for measurement in different parts of the building using ISO/CIE 20086:2019, Formula (29):

$$W_{\text{mt}} = \sum W_{\text{t}} \ \ (\text{kWh}) \tag{32}$$

The annual energy for electric lighting within a building is calculated using ISO/CIE 20086:2019, Formula (30):

$$W = 8\,760 / t_{\text{s}} \cdot W_{\text{mt}} \ \ (\text{kWh}) \tag{33}$$

where t_{s} is a time step in h.

Then the Lighting Energy Numeric Indicator (Q_{LENI}) for the building is calculated by using ISO/CIE 20086:2019, Formula (13):

$$Q_{\text{LENI}} = W / A \ \ (\text{kWh/m}^2) \tag{34}$$

where

W is the total annual energy used for lighting (kWh);

A is the total useful floor area of the building (m^2).

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.

According to ISO/CIE 20086, the accuracy of the dependency factors shall be optimized using the comprehensive design method and the tolerances of all factors and assumptions used to derive them shall be declared.

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

A statement of the calculation method used and the total annual energy used for lighting within the building W (kWh) is provided in the calculation report.

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 for the conditions in the building.

A statement of the calculation method used and the total annual energy used for lighting within the building W (kWh) is provided in the calculation report.

The precision of the dependency factors is 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

A statement of the measurement method used and the total annual energy used for lighting within the building W (kWh) is provided in the report.

The quality of the results depends on the metering circuit integrity and the accuracy of the meter(s). ISO/CIE 20086:2019, requires that the energy or power meters conform to the requirements for Class C as defined in EN 50470 (all parts).

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

10 Compliance check

No additional information beyond ISO/CIE 20086.

Annex A
(informative)

Calculation example for a new design retail store

A.1 Method 1 — Calculation of the energy required for lighting of a new design retail store

A.1.1 Site details

A single level SE corner retail unit located in Shanghai, CN (31,2° N latitude, 121,4° E longitude) consists of the following areas:

— sales floor;

— admin office;

— stock room;

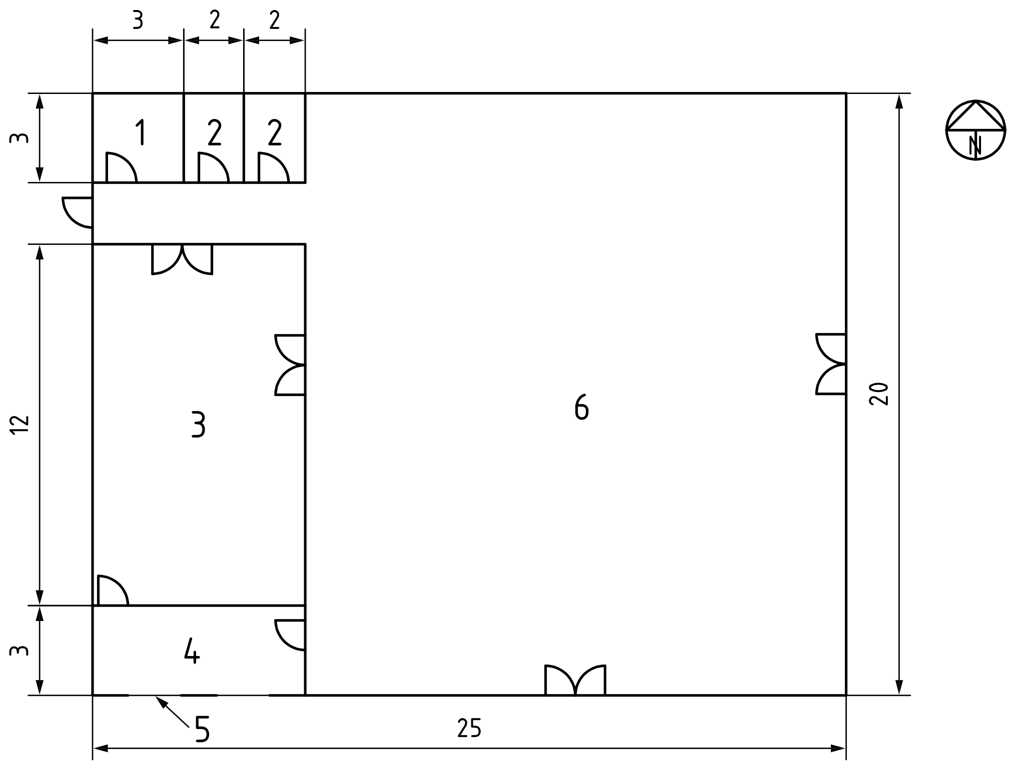
— corridor;

— toilet room;

— fitting rooms;

as shown on the layout plan Figure A.1

Measurements in m



Key

1 toilet
2 fitting rooms
3 stock room
4 office
5 windows
6 sales floor

Figure A.1 — Retail store

A.1.2 Sales floor

A.1.2.1 General

The main sales area provides a place for displaying merchandise, check-out counter, service counters, as well as for sales staff and retail clients' movement.

A.1.2.2 The sales floor details

— Length L = 18 m,

— width W = 20 m,

— wall height H = 3 m.

The window walls on South and East are completed with full height clothing merchandise displays and contain two entry doors to the store.

The other interior walls are light-painted (reflectance ρ = 50 %), white painted plaster ceiling has reflectance of ρ = 80 %, floor is of polished concrete (reflectance ρ = 20 %).

The target illuminance for the general lighting system on the work plane [0,8 m above finished floor (AFF)] is 300 lx; an additional illumination to highlight racks and shelves with merchandise for sale is delivered by a separate lighting setup.

The maintenance factor assumed in the design is f_m = 0,7.

A.1.2.3 Sales floor electric lighting system design data

For each area/space within the building, the design data as shown in ISO/CIE 20086:2019, Table 8 can be specified for the calculations:

Area Code	F_o	F_D	F_c	P_n	P_{em}	P_{pc}

A.1.2.4 System power data

Table A.1 — Luminaires in the sales floor area

Location	Luminaire unique ID	Quantity	Description of luminaire and control type and operation technique	Lighting system operation code[a]
Sales floor	S1	80 (m) or 5 rows	25 W per metre (400 W per row) LED linear indirect/direct luminaire stem-mounted at 2,5 m AFF with low voltage (LV) control, manually dimmable by row (5 rows), on/off schedule control at the lighting panel	System 1
Sales floor	S2	12	14 W LED recessed downlight equipped with emergency battery pack, on/off schedule control at the lighting panel	System 2
Sales floor	S3	45	Track-mounted light adjustable light heads equipped with 15 W LED PAR30 reflector lamps, zoned on/off control at the service desk	System 3
Sales floor	SX	3	3 W LED self-maintained continuous operation emergency exit sign	System 4

[a] The lighting system operation code differentiates between the operating capabilities and original design requirements for the installed luminaires.

Table A.2 — Power data of the luminaires in the sales floor

Luminaire unique ID	Luminaire circuit power P_i W	Luminaire controls standby power P_{ci} W	Luminaire standby emergency battery charge power P_{ei} W	Lighting system operation code
S1	400,0	3,2	0,0	System 1
S2	14,0	0,0	2,0	System 2
S3	15,0	0,0	0,0	System 3
SX	0,0	0,0	3,0	System 4

Based on the information in Tables A.1 and A.2 above,

$$P_n = \sum P_i \cdot n = 400{,}0 \cdot 5 + 14{,}0 \cdot 12 + 15{,}0 \cdot 45 = 2\,843{,}0 \text{ W}$$

NOTE The power of luminaire SX is not included as this is an exit sign that is not intended for general illumination.

$$P_{pc} = 3{,}2 \cdot 5 = 16{,}0 \text{ W}$$

$$P_{em} = 2{,}0 \cdot 12 + 3{,}0 \cdot 3 = 33{,}0 \text{ W}$$

A.1.2.5 Lighting system dependency factors calculation and data

A.1.2.5.1 Lighting controls

Luminaires in the sales floor area are operated by an automated time clock at the electrical lighting panel, which turns ON luminaires of type S1 to 75 % of the full power and luminaires of type S2 to 100 % of the full power one hour before the store opening (at 8:00) and OFF one hour after store closure (at 20:00). In addition, the output of type S1 luminaires can be manually adjustable in the 1 % to 100 % power interval through a wall dimming control device.

Type S3 luminaires are controlled in zones by the manual on/off switches at the service desk.

All the controllable lighting circuits in the retail store are scheduled to completely shut off at 20:00 (one hour after the store closure).

Type SX exit signs are of continuous operation and not controllable.

A.1.2.5.2 Calculation of F_O

From ISO/CIE 20086:2019, Table D.1 of the Manual On/Off Switch + additional automatic sweeping extinction signal F_{OC} = 0,95

From ISO/CIE 20086:2019, Table D.2 for sales area F_A = 0,0

From ISO/CIE 20086:2019, Table D.3 F_O = 1,0

A.1.2.5.3 Calculation of F_C

Luminaires of type S1 and S2 provide average general illumination of 300 lx to the sales floor task level at 0,8 m AFF; however, a constant light output strategy applied to the stem-mounted linear luminaires S1 reducing the luminaire power to the 75 % default level.

System 1. As there is no constant illuminance control, then following ISO/CIE 20086:2019, Clause F.3, for System 1, $F_{COD} = P_{min}/P_{max}$ = 75 %/100 % = 0,75.

Maintenance factor f_m = 0,7, then, following ISO/CIE 20086:2019, Formula (F.2),

F_{CMF1} = (1 + 0,7)/2 = 0,85. Therefore $F_C = F_{COD} \cdot F_{CMF}$ = 0,75 · 0,85 = 0,64.

For Systems 2, 3, and 4, F_C = 1,0 as they are not dimmable.

A.1.2.5.4 Calculation of F_D

Although the sales floor area has the full-length East and South glass walls, both openings are completely blocked from daylight penetration by the floor-to-ceiling height permanent sales displays, therefore, F_D = 1,0.

Determine the luminous exposure ratio H_{dir}/H_{glob}:

Data for sample locations are provided in ISO 10916:2014, Table A.2. Therefore, for Shanghai, CN (31,2° latitude, 121,4° longitude), the ratio H_{dir}/H_{glob} = 0,36.

Determine t_D, $t_{N.}$:

ISO 10916:2014, Table A.18 provides the data for the latitude angle ranges; thus, a linear interpolation is used to calculate the accurate results.

For the latitude angle γ = 31,2°, t_D = 2 343 h and t_N = 2 025 h (based on the annual 4 368 h use with 2 343 h of daytime).

Table A.3 — Sales floor lighting system data summary

Area Code	F_O —	F_D —	F_C —	P_n W	P_{em} W	P_{pc} W	t_D h	t_N h	t_e h	t_y h
Sales – System 1	1,0	1,0	0,64	2 000,0	0,0	16,0	2 343	2 025	—	8 760
Sales – System 2	1,0	1,0	1,0	168,0	24,0	0,0	2 343	2 025	8 760	8 760
Sales – System 3	1,0	1,0	1,0	675,0	0,0	0,0	2 343	2 025	—	8 760
Sales – System 4	1,0	1,0	1,0	0,0	9,0	0,0	—	—	8 760	8 760

A.1.2.5.5 Energy requirement calculations

The total energy required for illumination and for standby requirements during non-lighting periods can be calculated using ISO/CIE 20086:2019, Formula (9), Formula (10) and Formula (11) and the system data.

The annual energy required for illumination in the sales floor is calculated by using ISO/CIE 20086:2019, Formula (10):

$$W_{L,t} = \{(P_n \cdot F_C) \cdot F_O\ [(t_D \cdot F_D) + t_N]\}/1\ 000 = \{(2\ 000{,}0 \cdot 0{,}64 + 168{,}0 + 675{,}0) \cdot 1{,}0 \cdot [(2\ 343 \cdot 1{,}0) + 2\ 025]\}/1\ 000 = 9\ 273$$

$$W_{L,t} = 9\ 273\ \text{kWh}$$

The annual energy required for standby lighting services in the sales floor is calculated by using ISO/CIE 20086:2019, Formula (11):

$$W_P = \{(P_{pc} \cdot t_y) + (P_{em} \cdot t_e)\}/1\ 000 = \{(16{,}0 \cdot 8\ 760) + (33{,}0 \cdot 8\ 760)\}/1\ 000 = 429$$

$$W_P = 429\ \text{kWh}$$

The annual energy W required for the sales floor lighting system is calculated by using ISO/CIE 20086:2019, Formula (9):

$$W = W_L + W_P = 9\ 273 + 429 = 9\ 702\ \text{kWh}$$

Then, for the sales floor $Q_{LENI} = W/A = 9\ 702/(18 \cdot 20) = 26{,}95\ \text{kWh/m}^2$ per year.

A.1.3 Administration office

A.1.3.1 Administration office details

An office provides working place for 4 (four) admin staff members.

— Length L = 7 m;

— Width W = 3 m;

— Wall height H = 3 m.

The south facing façade wall contains two 2 m by 2 m square view windows with a seal at 0,5 m AFF. The interior walls are light-painted (reflectance ρ = 50 %), ceiling is T-bar off-white panels (reflectance ρ = 80 %), floor is of medium-light grey carpet (reflectance ρ = 20 %).

The target general illuminance on the work plane at 0,8 m AFF is 500 lx.

The maintenance factor in the design is assumed as f_m = 0,7.

A.1.3.2 Office electric lighting system

A.1.3.2.1 General

Table A.4 — Luminaires in the office

Location	Luminaire unique ID	Quantity	Description of luminaire and control type and operation technique	Lighting system operation code[a]
Office	A	4	30 W square (0,6 m side) LED panel luminaire recessed at 3 m AFF with LV control, dimmable, daylight sensor and passive infrared (PIR) occupancy sensor linked	System 1
Office	AE	2	30 W square (0,6 m side) LED panel luminaire equipped with emergency battery pack recessed at 3 m AFF with LV control, dimmable, daylight sensor and PIR occupancy sensor linked	System 1
Office door	AX	1	3 W LED self-maintained continuous operation emergency exit sign	System 2

[a] The lighting system operation code differentiates between the operating capabilities and original design requirements for the installed luminaires.

Table A.5 — Power data of the luminaires in the office

Luminaire unique ID	Luminaire circuit power P_i W	Luminaire controls standby power P_{ci} W	Luminaire standby emergency battery charge power P_{ei} W	Lighting system operation code
A	30,0	0,2	0,0	System 1
AE	30,0	0,2	2,0	System 1
AX	0,0	0,0	3,0	System 2

Based on the information in the tables above,

$$P_n = P_i \cdot n = 30{,}0 \cdot 6 = 180\ \text{W}$$

NOTE The power of luminaire AX is not included as this is an exit sign not intended for general illumination.

$$P_{\text{pc}} = 0{,}2 \cdot 6 = 1{,}2\ \text{W}$$

$$P_{\text{em}} = 2{,}0 \cdot 2 + 3{,}0 \cdot 1 = 7{,}0\ \text{W}$$

Open office lighting system — Lighting controls

Recessed luminaires in the office are controlled through a manual wall switch and a low-voltage control system which allows an automatic combined constant illuminance control by dimming of the general lighting system (Systems 1) based on a signal from photocell to conform to the design illuminance of 500 lx, and PIR presence detection in the centre of the room, responding to vacancy of the room.

Exit sign (System 2) is on continuous operation and non-controllable.

A.1.3.2.2 Calculation of F_O

The lighting control system in the office consists of automatic dimming to photocell response, manual wall on/off switch and activated by PIR presence detection power switch off.

From ISO/CIE 20086:2019, Table D.1 the automatic presence detection and Manual ON/Auto OFF option, F_{OC} = 0,80.

From ISO/CIE 20086:2019, Table D.2 for a cellular office 2 to 6 persons, F_A = 0,30.

Now F_O using ISO/CIE 20086:2019, Formula (D.1), $F_O = \{1 - [(1 - F_{OC}) \cdot F_A/0,2]\} = 1,0 - 0,3 = 0,7$.

The same result can be found using ISO/CIE 20086:2019, Table D.3.

A.1.3.2.3 Calculation of F_C

Over-design savings. To maintain a uniformity of illumination ratio E_{ave}/E_{min} as 2:1, the layout arrangement requires 2 rows of 3 luminaires. Thus, the general lighting will provide 560 lx on average on the office task level of 0,80 m AFF. This 12 % overdesign can be reduced by dimming to the set design illuminance value of 500 lx. Therefore, the energy saving benefit for the general lighting (systems 1) will be $F_{COD} = E_{ave\ target}/E_{ave\ design}$ = 500/560 = 0,89 of the installed power.

Maintenance factor compensation saving. Maintenance factor f_m = 0,7, then, following ISO/CIE 20086:2019, Formula (F.2), F_{CMF} = (1 + 0,7)/2 = 0,85.

Therefore $F_C = F_{COD} \cdot F_{CMF} = 0,89 \cdot 0,85 = 0,76$.

For System 2, F_C = 1,0 as emergency exit lighting sign is not dimmable.

A.1.3.2.4 Calculation of F_D

The office has unobstructed south facing two 2-metres square low-e double glazed (U-value = 1,7) windows in 50 mm wide metal frames with one 50 mm wide mullion at the centre of each window; manually operated venetian blinds are installed for solar shielding at each window.

Table A.6 — Boundary conditions for the office

Parameter		Value
Space geometry	Length	7,0 m
	Width	3,0 m
	Height (walls)	3,0 m
	Reflectance ρ, work plane – 0,8 m AFF	20 %
	Reflectance ρ, walls	50 %
	Reflectance ρ, ceiling	80 %
Façade	Orientation	South
	Obstruction	No obstructions, 0°
	Light transmission τ_{D65} glazing	0,74[a]
	Framing ratio k_1	1 – [(2 · 5 · 2 · 0,05)/(2 · 2 · 2)] = 0,875[b]
	Pollution of glazing factor k_2	(Workgroup office) 0,92[c]
	Shading system	Interior venetian blinds manually operated

NOTE For the calculation of specific installed power density luminaire EX is not included as this is an exit sign not intended for general illumination.

[a] obtained from ISO 10916:2014, Table A.4

[b] derived with ISO 10916:2014, Formula (A.13)

[c] obtained from DIN V 18599-10:2018,Table A.2

Table A.6 *(continued)*

<table>
<tr><th colspan="2">Parameter</th><th>Value</th></tr>
<tr><td rowspan="4">Lighting system</td><td>Specific installed power density</td><td>$(6 \cdot 30,0)/(7 \cdot 3) = 8,57$ W/m^2</td></tr>
<tr><td>Maintained average illuminance</td><td>500 lx</td></tr>
<tr><td>Control strategy</td><td>Continuous dimming with manual ON and PIR switching OFF</td></tr>
<tr><td>Control point, position</td><td>Control point in the centre of the room</td></tr>
<tr><td colspan="2">Working hours</td><td>8:00 to 17:00, Monday through Friday, no shut down holiday</td></tr>
<tr><td colspan="3">NOTE For the calculation of specific installed power density luminaire EX is not included as this is an exit sign not intended for general illumination.
[a] obtained from ISO 10916:2014, Table A.4
[b] derived with ISO 10916:2014, Formula (A.13)
[c] obtained from DIN V 18599-10:2018,Table A.2</td></tr>
</table>

Estimation of the daylight supply factor $F_{D,s}$

According to ISO 10916:2014, Formula (A.15), $F_{D,S} = t_{relD,SNA} \cdot F_{D,s,SNA} + t_{relD,SA} \cdot F_{D,s,SA}$

As determined in A.1.2.5.4 above:

$H_{dir}/H_{glob} = 0,36$,

$t_{day} = 2\ 343$ h,

$t_{night} = 2\ 025$ h.

Determine the relative time $t_{rel,D,SNA}$

$t_{rel,D,SNA}$ for the non-activated protection systems is a function of the façade orientation, the latitude γ°, and the ratio of H_{dir}/H_{glob}; it can be determined from the data of ISO 10916:2014, Table A.3 using linear interpolation.

For $H_{dir}/H_{glob} = 0,36$ and $\gamma = 31,2°$ in table South, $t_{rel,D,SNA} = 0,68$

A solar shielding would be required for $2\ 343 \cdot (1 - 0,68) = 750$ h. Therefore, $t_{SNA} = 1\ 593$ h; $t_{SA} = 750$ h

Determine D_{CA}, $\tau_{eff,SNA}$ and D

The daylight factor produced by the raw building carcass opening D_{CA} is calculated according to ISO 10916:2014, Formula (A.14), where $D_{CA} = (4,13 + 20,0\ I_{Tr} - 1,36\ I_{RD}) \cdot I_{Sh}$

The transparency index I_{Tr} is calculated using ISO 10916:2014, Formula (A.4):

$I_{Tr} = A_{CA}/A_D$, where

The carcass opening $A_{CA} = 2\ \text{m} \cdot 2\text{m} \cdot 2 = 8\ \text{m}^2$,

The daylit area $A_D = a_D \cdot b_D$, where $a_D = 2,5 \cdot (h_{Li}-h_{Ta})$

As the windows constitute only a part of the façade, b_D is calculated as a sum of the windows' width plus ½a_D.

Then, $A_D = 2,5 \cdot (2,5 - 0,8) \cdot (2,0 \cdot 2 + 2,5 \cdot (2,5 - 0,8)/2) = 26,03\ \text{m}^2$,

Therefore, $I_{Tr} = 8/26,03 = 0,31$.

The space depth index is calculated by ISO 10916:2014, Formula (A.5): $I_{RD} = a_D/(h_{Li} - h_{Ta}) = 2,5 \cdot (2,5 - 0,8)/(2,5 - 0,8) = 2,5$

The shading index $I_{Sh} = 1$ as there is no exterior shading designed for the building.

Thus, $D_{CA} = (4,13 + 20,0 \cdot 0,31 - 1,36 \cdot 2,5) \cdot 1 = 6,93$ %. This D_{CA}-value classifies the daylight availability for the office as strong based on the ISO 10916:2014, Table A.1.

The effective transmittance is calculated by ISO 10916:2014, Formula (A.16):

$$\tau_{\text{eff,SNA}} = \tau_{\text{D65,SNA}} \cdot k_1 \cdot k_2 \cdot k_3 = 0,74 \cdot 0,875 \cdot 0,92 \cdot 0,85 = 0,51,$$

Where $k_3 = 0,85$ according to ISO 10916:2014, A.3.2.3.

Then, $D = D_{CA} \cdot \tau_{\text{eff,SNA}} = 6,93 \cdot 0,51 = 3,53$ %.

Determine $F_{D,s,SNA}$

The daylight supply factor can be determined using linear interpolation of the data from ISO 10916:2014, Table A.5 — South façade for the latitude 31,2°, $H_{dir}/H_{glob} = 0,36$, $D = 3,53$ %, and the maintained task illuminance value of 500 lx.

The daylight supply factor is found $F_{D,s,SNA} = 91,6$ %.

Determine $F_{D,s,SA}$

According to ISO 10916:2014, Table A.8 for strong daylight availability and manually operated venetian blinds, $F_{D,s,SA} = 0,3$.

Then, following ISO 10916:2014, Formula (A.15), $F_{D,S} = 0,68 \cdot 0,916 + (1 - 0,68) \cdot 0,3 = 0,72$.

Determine $F_{D,C}$ and F_D

The lighting control factor can be obtained in ISO 10916:2014, Table A.15; for the office lighting controllability level and strong availability of daylight the $F_{D,C}$ factor is 0,81.

Then, according to ISO 10916:2014, Formula (7), the daylight dependence factor:

$$F_D = 1 - (F_{D,S} \cdot F_{D,C}) = 1 - (0,72 \cdot 0,81) = 0,42$$

Table A.7 — Office lighting system data summary

Area Code	F_O —	F_D —	F_C —	P_n W	P_{em} W	P_{pc} W	t_D h	t_N h	t_e h	t_y h
Office – System 1	0,70	0,42	0,76	180,0	4,0	1,2	2 343	2 025	8 760	8 760
Office – System 2	1,0	1,0	1,0	0,0	3,0	0,0	—	—	8 760	8 760

A.1.3.2.5 Energy requirement calculations

Annual energy required for illumination in the office using ISO/CIE 20086:2019, Formula (10):

$$W_L = \{(P_n \cdot F_C) \cdot F_O\, [(t_D \cdot F_D) + t_N]\}/1\,000$$
$$= \{180 \cdot 0,76 \cdot 0,70 \cdot [(2\,343 \cdot 0,42) + 2\,025]\}/1\,000 = 288,15$$

W_L = 288,15 kWh

Annual energy required for standby lighting services in the office using ISO/CIE 20086:2019, Formula (11):

$$W_P = \{(P_{pc} \cdot t_y) + (P_{em} \cdot t_e)\}/1\,000 = \{(1{,}2 \cdot 8\,760) + (7{,}0 \cdot 8\,760)\}/1\,000 = 72$$

W_P = 72 kWh

The annual energy W required for the office lighting system is calculated by using ISO/CIE 20086:2019, Formula (9):

$$W = W_L + W_P = 288{,}15 + 72 = 360{,}15 \text{ kWh}$$

Then, for the open office Q_{LENI} = W/A = 360,15/(7 · 3) = 17,15 kWh/m^2 per year

A.1.4 Fitting rooms

A.1.4.1 General

Two identical fitting rooms provide space to try on clothes before deciding whether to purchase them.

A.1.4.2 Fitting room details

— Length L = 3 m;

— Width W = 2 m;

— Wall height H = 3 m.

The interior walls are neutral beige (reflectance ρ = 50 %), except of the back wall with a full-size mirror (reflectance ρ = 100 %), ceiling is white painted (reflectance ρ = 80 %), floor is grey carpet (reflectance ρ = 20 %).

The target general illuminance on work plane at 0,8 m AFF is 300 lx.

The maintenance factor in the design is assumed as f_m = 0,7.

A.1.4.3 Fitting room electric lighting system

A.1.4.3.1 General

Table A.8 — Luminaires in the fitting room

Location	Luminaire unique ID	Quantity	Description of luminaire and control type and operation technique	Lighting system operation code[a]
Fitting room	F	1	30 W square (0,6 m side) LED panel luminaire equipped with emergency battery pack recessed at 3 m AFF with PIR occupancy sensor linked (on/off)	System 1
Fitting room	F1	2	25 W linear LED luminaire wall-concealed along the mirror, manual ON/dimmable wall switch, PIR occupancy sensor linked to turn OFF	System 2

[a] The lighting system operation code differentiates between the operating capabilities and original design requirements for the installed luminaires

Table A.9 — Power data of the luminaires in the fitting room

Luminaire unique ID	Luminaire circuit power P_i W	Luminaire controls standby power $P_{c,i}$ W	Luminaire standby emergency battery charge power $P_{e,i}$ W	Lighting system operation code
F	30,0	0,2	2,0	System 1
F1	25,0	0,2	0,0	System 2

Based on the information in the tables above,

$$P_n = P_i \cdot n = 30{,}0 \cdot 1 + 25{,}0 \cdot 2 = 80 \text{ W}$$

$$P_{\text{pc}} = 0{,}2 \cdot 3 = 0{,}6 \text{ W}$$

$$P_{\text{em}} = 2{,}0 \cdot 1 = 2{,}0 \text{ W}$$

Fitting room lighting system - lighting controls.

A fix-output recessed luminaire type F is on auto on/off controlled by a ceiling mounted PIR occupancy sensor.

Two vertically wall-recessed LED strips are controlled by a wall on/dimming switch and linked to a ceiling mounted PIR occupancy sensor to turn them off.

A.1.4.3.2 Calculation of F_O

From ISO/CIE 20086:2019, Table D.1 for automatic presence detection (Auto On/Off or Manual On/Dim) F_{OC} = 0,90

From ISO/CIE 20086:2019, Table D.2 for a sales area F_A = 0,0

From ISO/CIE 20086:2019, Table D.3 F_o = 1,0

A.1.4.3.3 Calculation of F_C

Luminaire type F is not dimmable, therefore, for System 1 F_{C1} = 1,0.

For luminaires type F1 maintenance factor f_m = 0,7, then, following ISO/CIE 20086:2019, Formula (F.2), F_{CMF2} = (1 + 0,7)/2 = 0,85.

Therefore, $F_{C2} = F_{COD2} \cdot F_{CMF2}$ = 1,0 · 0,85 = 0,85

A.1.4.3.4 Calculation of F_D

Fitting room have no openings for daylight penetration, therefore, F_D = 1,0.

Table A.10 — Fitting room lighting system data summary

Area Code	F_O —	F_D —	F_C —	P_n W	P_{em} W	P_{pc} W	t_D h	t_N h	t_e h	t_y h
Fitting room – System 1	1,0	1,0	1,0	30,0	2,0	0,2	2 343	2 025	8 760	8 760
Fitting room – System 2	1,0	1,0	0,85	50,0	0,0	0,4	2 343	2 025	—	8 760

A.1.4.3.5 Energy requirement calculations

The annual energy required for illumination in the fitting room is calculated by using ISO/CIE 20086:2019, Formula (10):

$$W_L = \{(P_n \cdot F_C) \cdot F_O\ [(t_D \cdot F_D) + t_N]\}/1\ 000 = \{[30{,}0 \cdot 1{,}0 \cdot 50{,}0 \cdot 0{,}85] \cdot 1{,}0 \cdot [(2\ 343 \cdot 1{,}0) + 2\ 025]\}/1\ 000 = 316{,}68$$

W_L = 316,68 kWh

The annual energy required for standby lighting services in the fitting room is calculated by using ISO/CIE 20086:2019, Formula (11):

$$W_P = \{(P_{pc} \cdot t_y) + (P_{em} \cdot t_e)\}/1\ 000 = \{(0{,}6 \cdot 8\ 760) + (2{,}0 \cdot 8\ 760)\}/1\ 000 = 22{,}78$$

W_P = 22,78 kWh

The annual energy W required for the fitting room lighting system is calculated by using ISO/CIE 20086:2019, Formula (9):

$W_1 = W_L + W_P = 316{,}68 + 22{,}78 = 339{,}46$ kWh for one room, and for both fitting rooms,

$W = W_1 \cdot 2 = 339{,}46 \cdot 2 = 678{,}92$ kWh

$Q_{LENI} = W/A = 678{,}92/(3 \cdot 2 \cdot 2) = 56{,}58$ kWh/m^2 per year

A.1.5 Toilet

A.1.5.1 Toilet details

— 3 m by 3 m windowless toilet room;

— length L = 3 m;

— width W = 3 m;

— wall height H = 3 m.

The interior walls reflectance ρ = 50 %, ceiling ρ = 70 %, floor reflectance ρ = 20 %.

The target general illuminance on work plane at 0,8 m AFF is 200 lx.

The maintenance factor in the design is assumed as f_m = 0,7.

A.1.5.2 Toilet electric lighting system

Table A.11 — Luminaires in the toilet

Location	Luminaire unique ID	Quantity	Description of luminaire and control type and operation technique	Lighting system operation code[a]
Toilet room	T	2	15 W LED recessed downlight, PIR occupancy sensor linked for on/off control	System 1
Toilet room	TE	1	15 W LED recessed downlight equipped with emergency battery pack, PIR occupancy sensor linked for on/off control	System 1

[a] The lighting system operation code differentiates between the operating capabilities and original design requirements for the installed luminaires

Table A.12 — Power data of the luminaires in the toilet

Luminaire unique ID	Luminaire circuit power P_i W	Luminaire controls standby power P_{ci} W	Luminaire standby emergency battery charge power P_{ei} W	Lighting system operation code
T	15,0	0	0,0	System 1
TE	15,0	0	2,0	System 1

Based on the information in the tables above,

$P_n = P_i \cdot \text{n} = 15{,}0 \cdot 3 = 45$ W

$P_{\text{pc}} = 0{,}8$ W (The standby power for the remote PIR occupancy sensor in the room)

$P_{\text{em}} = 2{,}0 \cdot 1 = 2{,}0$ W

Toilet room lighting controls.

Luminaires in the toilet rooms are switching on/off based on the room entry/occupancy.

A.1.5.3 Calculation of F_{O}

From ISO/CIE 20086:2019, Table D.1 the automatic presence detection (Auto On/Off) $F_{\text{OC}} = 0{,}90$

From ISO/CIE 20086:2019, Table D.2 for a restroom $F_{\text{A}} = 0{,}50$.

Now F_{O} using ISO/CIE 20086:2019, Formula (D.1) is $F_{\text{O}} = (0{,}90 + 0{,}2 - 0{,}50) = 0{,}60$.

A.1.5.4 Calculation of F_{C}

$F_{\text{C}} = 1{,}0$ as luminaires in toilet are not dimmable.

A.1.5.5 Calculation of F_{D}

The toilet room has no openings for daylight penetration, therefore, $F_{\text{D}} = 1{,}0$

Table A.13 — Toilet room lighting system data summary

Area Code	F_O —	F_D —	F_C —	P_n W	P_{em} W	P_{pc} W	t_D h	t_N h	t_e h	t_y h
Toilet room – System 1	0,60	1,0	1,0	45,0	2,0	0,8	2 343	2 025	8 760	8 760

A.1.5.6 Energy requirement calculations

The annual energy required for illumination in the toilet room is calculated by using ISO/CIE 20086:2019, Formula (10):

$$W_L = \{(P_n \cdot F_C) \cdot F_O\ [(t_D \cdot F_D) + t_N]\}/1\ 000 = \{45 \cdot 1{,}0 \cdot 0{,}6 \cdot [(2\ 343 \cdot 1{,}0) + 2\ 025]\}/1\ 000 = 118$$

$$W_L = 118 \text{ kWh}$$

The annual energy required for standby lighting services in the toilet is calculated by using ISO/CIE 20086:2019, Formula (11):

$$W_P = \{(P_{pc} \cdot t_y) + (P_{em} \cdot t_e)\}/1\ 000 = \{(0{,}8 \cdot 8\ 760) + (2{,}0 \cdot 8\ 760)\}/1\ 000 = 24{,}5$$

$$W_P = 24{,}5 \text{ kWh}$$

Annual energy W required for the toilet lighting system is calculated by using ISO/CIE 20086:2019, Formula (9):

$$W_1 = W_L + W_P = 118 + 24{,}5 = 142{,}5 \text{ kWh}$$

Then, for the toilet $Q_{LENI} = W/A = 142{,}5/(3 \cdot 3) = 15{,}83$ kWh/m^2 per year

A.1.6 Stock room

A.1.6.1 Stock room details

Stock room is an 84 m^2 storage windowless space that provides place for storing merchandise in the retail store.

— Length L = 12 m;

— width W = 7 m;

— wall height H = 3 m.

The interior walls are light-painted (reflectance ρ = 40 %), ceiling is T-bar off-white panels (reflectance ρ = 80 %), floor is of medium-light grey carpet (reflectance ρ = 20 %). The stock room can be accessed from the office, sales floor, and corridor.

The target general illuminance on the task level 0,8 m AFF is 300 lx.

The maintenance factor in the design is assumed as f_m = 0,7.

A.1.6.2 Stock room electric lighting system

Table A.14 — Luminaires in the stock room

Location	Luminaire unique ID	Quantity	Description of luminaire and control type and operation technique	Lighting system operation code[a]
Stock room	M	9	35 W LED recessed luminaire, on-board PIR occupancy sensor for on/off control	System 1
Stock room	ME	3	35 W LED recessed luminaire equipped with an emergency pack, on-board PIR occupancy sensor for on/off control	System 1
Stock room above the exit doors	MX	2	3 W LED self-maintained continuous operation emergency exit sign	System 2

[a] The lighting system operation code differentiates between the operating capabilities and original design requirements for the installed luminaires.

Table A.15 — Power data of the luminaires in the stock room

Luminaire unique ID	Luminaire circuit power P_i W	Luminaire controls standby power $P_{c,i}$ W	Luminaire standby emergency battery charge power $P_{e,i}$ W	Lighting system operation code
M	35,0	0,3	0,0	System 1
ME	35,0	0,3	2,0	System 1
MX	0,0	0,0	3,0	System 2

Based on the information in the tables above,

$$P_n = P_i \cdot n = 35{,}0 \cdot 12 = 420 \text{ W}$$

NOTE Luminaires MX power is not included as this is an exit sign not intended for general illumination.

$$P_{pc} = 0{,}3 \cdot 12 = 3{,}6 \text{ W}$$

$$P_{em} = 2{,}0 \cdot 3 + 3{,}0 \cdot 2 = 12{,}0 \text{ W}$$

Stock room lighting system – lighting controls

The type M luminaires in the in the stock room have occupancy detectors on-board switching a luminaire on immediately upon sensing a presence in the zone of coverage and off after 5 min of no sensing.

Exit signs (System 2) is on continuous operation and non-controllable.

A.1.6.3 Calculation of F_O

From ISO/CIE 20086:2019, Table D.1 for automatic presence detection (Auto On/Off) F_{OC} = 0,90

From ISO/CIE 20086:2019, Table D.2 for a retail storage F_A = 0,20.

Now F_O using ISO/CIE 20086:2019, Formula (D.1) is F_O = (0,90 + 0,2 − 0,20) = 0,90

A.1.6.4 Calculation of F_C

F_C = 1,0 for both, system 2 (exit signs) and system 1 (general lighting), as they are not dimmable.

A.1.6.5 Calculation of F_D

The stock room has no openings for daylight penetration, therefore, daylight factor F_D = 1,0.

Table A.16 — Stock room lighting system data summary

Area Code	F_O	F_D	F_C	P_n W	P_{em} W	P_{pc} W	t_D h	t_N h	t_e h	t_y h
Stock room – System 1	0,90	1,0	1,0	420,0	6,0	3,6	2 343	2 025	8 760	8 760
Stock room – System 2	1,0	1,0	1,0	0,0	6,0	0,0	—	—	8 760	8 760

A.1.6.6 Energy requirement calculations

The annual energy required for illumination in the stock room is calculated by using ISO/CIE 20086:2019, Formula (10):

$$W_L = \{(P_n \cdot F_C) \cdot F_O\ [(t_D \cdot F_D) + t_N]\}/1\ 000 = \{420 \cdot 1{,}0 \cdot 0{,}90 \cdot [(2\ 343 \cdot 1{,}0) + 2\ 025]\}/1\ 000 = 1\ 651{,}1$$

$$W_L = 1\ 651{,}1 \text{ kWh/year}$$

The annual energy required for standby lighting services in the stock room is calculated by using ISO/CIE 20086:2019, Formula (11):

$$W_P = \{(P_{pc} \cdot t_y) + (P_{em} \cdot t_e)\}/1\ 000 = \{(3{,}6 \cdot 8\ 760) + (12{,}0 \cdot 8\ 760)\}/1\ 000 = 136{,}7$$

$$W_P = 136{,}7 \text{ kWh/year}$$

The annual energy W required for the stock room lighting system is calculated by using ISO/CIE 20086:2019, Formula (9):

$$W = W_L + W_P = 1\ 651{,}1 + 136{,}7 = 1\ 787{,}8 \text{ kWh/year}$$

Then, for the stock room $Q_{LENI} = W/A$ = 1 787,8/(12 · 7) = 21,28 kWh/m^2 per year

A.1.7 Corridor

A.1.7.1 General

Corridor provides a connection between sales floor, fitting rooms, toilet room, stock room, and an emergency path to the back of the house.

A.1.7.2 Corridor details

— Length L = 7 m;

— width W = 2 m;

— wall height H = 3 m.

The interior walls are light-painted (reflectance ρ = 50 %), ceiling is T-bar off-white panels (reflectance ρ = 80 %), floor is of grey polished concrete (reflectance ρ = 20 %).

Target general illuminance on the floor is 200 lx.

Maintenance factor assumed in the design f_m = 0,7

A.1.7.3 Corridor electric lighting system

Table A.17 — Luminaires in the corridor

Location	Luminaire unique ID	Quantity	Description of luminaire and control type and operation technique	Lighting system operation code[a]
Corridor	C	2	15 W LED recessed downlight, on/off schedule control at the lighting panel	System 1
Corridor	CE	1	15 W LED recessed downlight equipped with emergency battery pack, on/off schedule control at the lighting panel	System 1
Corridor above the exit door	CX	1	3 W LED self-maintained continuous operation emergency exit sign	System 2

[a] The lighting system operation code differentiates between the operating capabilities and original design requirements for the installed luminaires

Table A.18 — Power data of the luminaires in the corridor

Luminaire unique ID	Luminaire circuit power P_i W	Luminaire controls standby power P_{ci} W	Luminaire standby emergency battery charge power $P_{e\mathrm{i}}$ W	Lighting system operation code
C	15,0	0,0	0,0	System 1
CE	15,0	0,0	2,0	System 1
CX	0,0	0,0	3,0	System 2

Based on the information in the tables above,

$$P_n = P_i \cdot n = 15{,}0 \cdot 3 = 45 \text{ W}$$

NOTE Luminaires CX power is not included as this is an exit sign not intended for general illumination.

$$P_{\mathrm{pc}} = 0 \text{ W}$$

$$P_{\mathrm{em}} = 2{,}0 \cdot 1 + 3{,}0 \cdot 1 = 5{,}0 \text{ W}$$

Corridor lighting system - lighting controls.

The downlight luminaires in the corridor are controlled by a time clock/scheduler at the electrical panel turning on 1 h before store opening and off 1 h after store closing.

Exit sign (System 2) is on continuous operation and non-controllable.

A.1.7.4 Calculation of F_{O}

From ISO/CIE 20086:2019, Table D.1 for no automatic presence detection (Manual On/Off Switch + additional automatic sweeping extinction signal) F_{OC} = 0,95.

From ISO/CIE 20086:2019, Table D.2 for a corridor with no dimming F_{A} = 0,00.

From ISO/CIE 20086:2019, Table D.3 is F_{O} = 1,0.

A.1.7.5 Calculation of F_{C}

F_{C} = 1,0 for both, system 2 (exit sign) and system 1 (general lighting), as they are not dimmable.

A.1.7.6 Calculation of F_D

The corridor has no openings for daylight penetration, therefore, daylight factor F_D = 1,0

Table A.19 — Corridor lighting system data summary

Area Code	F_O	F_D	F_C	P_n	P_{em}	P_{pc}	t_D	t_N	t_e	t_y
				W	W	W	h	h	h	h
Corridor – System 1	1,0	1,0	1,0	45,0	2,0	0,0	2 343	2 025	8 760	8 760
Corridor – System 2	1,0	1,0	1,0	0,0	3,0	0,0	—	—	8 760	8 760

A.1.7.7 Energy requirement calculations

The annual energy required for illumination in the corridor is calculated by using ISO/CIE 20086:2019, Formula (10):

$$W_L = \{(P_n \cdot F_C) \cdot F_O\ [(t_D \cdot F_D) + t_N]\}/1\ 000 = \{45 \cdot 1{,}0 \cdot 1{,}0 \cdot [(2\ 343 \cdot 1{,}0) + 2\ 025]\}/1\ 000 = 196{,}56$$

$$W_L = 196{,}56 \text{ kWh/year}$$

The annual energy required for standby lighting services in the corridor is calculated by using ISO/CIE 20086:2019, Formula (11):

$$W_P = \{(P_{pc} \cdot t_y) + (P_{em} \cdot t_e)\}/1\ 000 = \{(0{,}0 \cdot 8\ 760) + (5{,}0 \cdot 8\ 760)\}/1\ 000 = 43{,}8$$

$$W_P = 43{,}8 \text{ kWh/year}$$

The annual energy W required for the corridor lighting system is calculated by using ISO/CIE 20086:2019, Formula (9):

$$W = W_L + W_P = 196{,}56 + 43{,}8 = 240{,}36 \text{ kWh/year}$$

Then, for the corridor $Q_{LENI} = W/A = 240{,}36/(2 \cdot 7) = 17{,}17$ kWh/m^2 per year.

A.1.8 Retail store annual energy requirements

The annual energy W required for the store is calculated by summing up the energy required for the lighting system in each specified areas of the unit.

Energy required for lighting of:

Sales floor = 9 702 kWh

Office = 360,15 kWh

Fitting rooms = 678,92 kWh

Toilet room = 142,5 kWh

Stock room = 1 787,8 kWh

Corridor = 240,36 kWh

Building = 12 912 kWh

Then, LENI for the unit is $Q_{LENI} = W/A = 12\ 912/(25 \cdot 20) = 25{,}82$

$Q_{LENI} = 25{,}82$ kWh/m^2 per year

A.2 Method 2 — Quick calculation of the energy required for lighting of a new design retail store

A.2.1 Site details

A small single level SE corner retail unit located in Shanghai, CN (31,2° S latitude, 121,4° E longitude) consists of the following areas:

— sales floor;

— admin office;

— stock room;

— corridor;

— toilet room;

— fitting rooms

as shown on the layout plan Figure A.1

A.2.2 Sales floor

A.2.2.1 General

The main sales area provides a place for displaying merchandise, check-out counter, service counters, as well as for sales staff and retail clients' movement.

A.2.2.2 The sales floor details

Room dimensions: L = 18 m, W = 20 m, H = 3 m.

There is no daylight penetration into the space.

Surface reflectance values: ceiling ρ = 80 %, walls ρ = 50 %, floor ρ = 20 %.

Maintained illuminance: 300 lx on the task level (0,8 m AFF).

Maintenance factor f_m = 0,7.

A.2.2.3 Sales floor electric lighting system design data

A.2.2.3.1 General

General illumination in the sales floor will be provided by stem-mounted 0,5 m from the ceiling 25 W/m LED linear indirect/direct dimmable luminaires with an emergency lighting as required by the local safety standard.

A.2.2.3.2 Calculation of P_n

According to ISO/CIE 20086:2019, Formula (B.1) and Formula (B.2), $P_n = P_j \cdot A$ and $P_j = P_{j,\mathrm{lx}} \cdot E_{\mathrm{task}} \cdot F_{\mathrm{CMF}} \cdot F_{\mathrm{CA}} \cdot F_{\mathrm{L}}$

$P_{j,\mathrm{lx}}$ = 0,025 W · m^{-2} · lx^{-1} is dependent on the room index

$$K = \frac{L_R \cdot W_R}{h_m (L_R + W_R)} = \frac{20 \cdot 18}{(3 - 0{,}5 - 0{,}8) \cdot (20 + 18)} = 5{,}57$$

and UFF (Upward Flux Fraction), and can be found in ISO/CIE 20086:2019, Table B.1.

E_{task} = 300 lx

$F_{\mathrm{CMF}} = \frac{0{,}8}{f_m} = \frac{0{,}8}{0{,}7} = 1{,}14$ according to ISO/CIE 20086:2019, Formula (B.4)

F_{CA} = 1,0 as the whole area is taken to be task area

F_L = 0,86 according to ISO/CIE 20086:2019, Table A.9 for LED.

Therefore, P_j = 0,025 · 300 · 1,14 · 1,0 · 0,86 = 7,35 W/m^2,

And P_n = 7,35 · 360 = 2 646 W

A.2.2.3.3 Calculation of standby system power

According to ISO/CIE 20086:2019, Table A.1, the standby energy for automatic lighting controls:

W_{pc} = 1,5 kWh/m^2 · 360 m^2 = 540 kWh per year,

and the standby energy for battery charging of emergency luminaires:

W_{pe} = 1,0 kWh/m^2 · 360 m^2 = 360 kWh per year.

A.2.2.3.4 Calculation of F_O

ISO 10916:2014, Table A.18 provides the data for the latitude angle ranges; thus, a linear interpolation is used to calculate the accurate results.

For the latitude angle γ = 31,2°, t_D = 2 343 h and t_N = 2 025 h (based on the annual 4 368 h use with 2 343 day-hours).

From ISO/CIE 20086:2019, Table D.2 for a sales area F_A = 0,0.

From ISO/CIE 20086:2019, Table D.3, for F_A = 0,0, F_o = 1,0.

A.2.2.3.5 Calculation of F_C

From ISO/CIE 20086:2019, Table A.8 for LED dimmable circuit F_C = 0,85, assuming this value for an “office” type in Table A.8 is the closest F_C value to the “Sales Floor” type in the example.

A.2.2.3.6 Calculation of F_D

As there is no daylight availability for the sales floor, F_D = 1,0.

A.2.2.3.7 Energy requirement calculations

According to ISO/CIE 20086:2019, Formula (25):

$$Q_{\mathrm{LENI,sub}} = \left\{ F_C \cdot \left(P_j / 1\,000 \right) \cdot F_O \left[\left(t_D \cdot F_D \right) + t_N \right] \right\} + 1{,}0 + 1{,}5 \ (\mathrm{kWh/m^2})$$

$Q_{\mathrm{LENI,\,sub}}$ = {0,85 · (7,35/1 000) · 1,0 · [(2 343 · 1,0) + 2 025]} + 1,0 + 1,5 = 29,79 kWh/m^2

Then, according to ISO/CIE 20086:2019, Formula (26), the annual energy required for electric lighting in the entrance lobby:

$W = Q_{\mathrm{LENI,sub}} \cdot A_{\mathrm{j}}$ = 29,79 · 360 = 10 724,4 kWh/year

A.2.3 Administration office

A.2.3.1 General

An office provides working place for 4 (four) admin staff members.

A.2.3.2 Administration office details

Room dimensions: L = 7 m, W = 3 m, H = 3 m.

The south facing façade wall contains 2 (two) 2 m by 2 m square view windows with a seal at 0,5 m AFF, evenly distributed along the wall.

Surface reflectance values: ceiling ρ = 80 %, walls ρ = 50 %, floor ρ = 20 %.

Maintained illuminance: 500 lx on at the desk level (0,8 m AFF).

Maintenance factor f_{m} = 0,7.

A.2.3.3 Office electric lighting system

A.2.3.3.1 General

General illumination in the office will be provided by recessed LED direct dimmable luminaires with an emergency lighting as required by the local safety standard. Lighting is controlled by photosensors responding to daylighting and occupancy detectors in the office.

A.2.3.3.2 Calculation of P_n

According to ISO/CIE 20086:2019, Formula (B.1) and Formula (B.2), $P_n = P_j \cdot A$ and $P_j = P_{j,\mathrm{lx}} \cdot E_{\mathrm{task}} \cdot F_{\mathrm{CMF}} \cdot F_{\mathrm{CA}} \cdot F_{\mathrm{L}}$

$P_{j,\mathrm{lx}}$ = 0,030 is dependent on the room index $K = \dfrac{\mathrm{L_R} \cdot W_{\mathrm{R}}}{h_{\mathrm{m}}\,(L_{\mathrm{R}} + W_{\mathrm{R}})} = \dfrac{7 \cdot 3}{2{,}2 \cdot (7+3)} = 0{,}95$ and UFF (Upward Flux Fraction) and can be found from ISO/CIE 20086:2019, Table B.1.

E_{task} = 500 lx

$F_{\mathrm{CMF}} = \dfrac{0{,}8}{f_{\mathrm{m}}} = \dfrac{0{,}8}{0{,}7} = 1{,}14$ according to ISO/CIE 20086:2019, Formula (B.4)

F_{CA} = 1,0 as the whole area is taken to be task area

F_{L} = 0,86 according to ISO/CIE 20086:2019, Table A.9 for LED.

Therefore, P_j = 0,030 · 500 · 1,14 · 1,0 · 0,86 = 14,71 W/m^2,

And P_n = 14,71 · 21 = 308,9 W

A.2.3.3.3 Calculation of standby system power

According to ISO/CIE 20086:2019, Table A.1, the standby energy for automatic lighting controls:

W_{pc} = 1,5 kWh/m^2 · 21 m^2 = 31,5 kWh per year,

And the standby energy for battery charging of emergency luminaires:

W_{pe} = 1,0 kWh/m^2 · 21 m^2 = 21 kWh per year.

A.2.3.3.4 Calculation of F_O

From ISO/CIE 20086:2019, Table D.2 for a workgroup office F_A = 0,30.

From ISO/CIE 20086:2019, Table D.3, for F_A = 0,30, F_o = 0,70.

A.2.3.3.5 Calculation of F_C

From ISO/CIE 20086:2019, Table A.8, for LED dimmable circuit F_C = 0,85, assuming this value for an "office" type in Table A.8 is the closest F_C value to the "Sales Floor" type in the example.

A.2.3.3.6 Calculation of F_D

To find F_D using ISO 10916:2014, Formula (7), values for D, $F_{D,S,SNA}$, $F_{D,S}$, and $F_{D,C}$ are determined as follows:

$D = D_{CA} \cdot \tau_{eff,SNA}$

From ISO 10916:2014, Formula (A.14) $D_{CA} = (4{,}13 + 20{,}0\ I_{Tr,j} - 1{,}36\ I_{RD,j}) \cdot I_{Sh,j}$

From ISO 10916:2014, Formula (A.4), $I_{Tr,j} = A_{CA}/A_D$, A_{CA} is the carcass opening 2 · 2 m · 2 m = 8 m^2 and $A_D = a_D \cdot b_D$, in which $a_D = 2{,}5 \cdot (h_{Li} - h_{Ta}) = 2{,}5 \cdot (2{,}5 - 0{,}8) = 4{,}25$ m and $b_D = 2 + 2 + a_D/2 = 6{,}125$ m; then $A_D = 4{,}25 \cdot 6{,}125 = 26{,}03$ m^2

Therefore $I_{Tr,j} = 8/26{,}03 = 0{,}31$

From ISO 10916:2014, Formula (A.5), $I_{RD,j} = a_D/(h_{Li} - h_{Ta}) = 4{,}25/(2{,}5 - 0{,}8) = 2{,}5$

The shading index I_{Sh} = 1,0 as in this project there are no shading for the carcass opening in the space.

Thus, $D_{CA} = (4{,}13 + 20{,}0 \cdot 0{,}31 - 1{,}36 \cdot 2{,}5) \cdot 1{,}0 = 6{,}93$ %.

This D_{CA}-value classifies the daylight availability for the office as strong based on the ISO 10916:2014, Table A.1.

From ISO 10916:2014, Formula (A.16), $\tau_{eff,SNA} = \tau_{D65,SNA} \cdot k_1 \cdot k_2 \cdot k_3 = 0{,}74 \cdot 0{,}7 \cdot 0{,}92 \cdot 0{,}85 = 0{,}40$

Where a glazing option assumed to be "low-e double glazed" with $\tau_{D65,SNA}$ = 0,74 per ISO 10916:2014, Table A.4, k_1 = 0,7, k_3 = 0,85 – per ISO 10916:2014, A.3.2.3, k_2 = 0,92 from DIN V 18599-10:2018, Table A.2.

Thus, $D = 6{,}93 \cdot 0{,}40 = 2{,}77$ %

From ISO 10916:2014, Table A.5 by interpolation for the building location, E_{task} = 500 lx, and D = 2,77 % find $F_{D,S,SNA}$ = 87,6 %

ISO 10916:2014, Formula (A.15) $F_{D,S} = t_{rel,D,SNA} \cdot F_{D,S,SNA} + t_{rel,D,SA} \cdot F_{D,S,SA}$, Where $t_{\text{rel,D,SNA}} = 0{,}68$ from ISO 10916:2014, Table A.3 values interpolation for $H_{\text{dir}}/H_{\text{globe}}$ = 0,36 and y = 31,2°,

$t_{\text{rel,D,SA}} = 1 - t_{\text{rel,D,SNA}} = 1 - 0{,}68 = 0{,}32$,

$F_{\text{D,S,SA}} = 0{,}3$ from ISO 10916:2014, Table A.8 for strong daylight availability (D_{CA} = 6,93 % above and ISO 10916:2014, Table A.1) and interior manually operated venetian blinds.

Thus, $F_{\text{D,S}} =$ 0,68·87,6+0,32 · 30 = 69,2 %

$F_{\text{D,C}}$ = 0,81 can be obtained from ISO 10916:2014, Table A.15 assuming that an “automatic, independent” daylight-responsive control system with total switch-off is installed.

Then, from ISO 10916:2014, Formula (7), $F_{\text{D}} = 1 - F_{\text{D,S}} \cdot F_{\text{D,C}} = 1 - 0{,}692 \cdot 0{,}81 = 0{,}44$, or F_{D} = 44 %.

A.2.3.3.7 Energy requirement calculations

According to ISO/CIE 20086:2019, Formula (25):

$$Q_{\text{LENI,sub}} = \left\{ F_{\text{C}} \cdot \left(P_j / 1\,000 \right) \cdot F_{\text{O}} \left[\left(t_{\text{D}} \cdot F_{\text{D}} \right) + t_{\text{N}} \right] \right\} + 1{,}0 + 1{,}5 \ (\text{kWh/m}^2)$$

$$Q_{\text{LENI, sub}} = \{0{,}85 \cdot (14{,}71/1\,000) \cdot 0{,}7 \cdot [(2\,343 \cdot 0{,}44) + 2\,025]\} + 1{,}0 + 1{,}5 = 29{,}25 \text{ kWh/m}^2$$

Then, according to ISO/CIE 20086:2019, Formula (26), the annual energy required for electric lighting in the office:

$W = Q_{\text{LENI,sub}} \cdot A_{\text{j}} = 29{,}25 \cdot 21 = 614{,}25$ kWh/year

A.2.4 Fitting rooms

A.2.4.1 General

Two identical fitting rooms provide space to try on clothes before deciding whether to purchase them.

A.2.4.2 Fitting room details

Room dimensions: L = 3 m, W_{R} = 2 m, H = 3 m.

Surface reflectance values: ceiling ρ = 80 %, walls ρ = 50 %, floor ρ = 20 %.

Maintained illuminance: 300 lx on work plane at 0,8 m AFF.

Maintenance factor f_{m} = 0,7.

A.2.4.3 Fitting room electric lighting system

Lighting will be provided by LED recessed luminaires controlled by an occupancy sensor; emergency features will follow local electric code requirements.

A.2.4.4 Calculation of P_n

According to ISO/CIE 20086:2019, Formula (B.1) and Formula (B.2), $P_n = P_j \cdot A$ and $P_j = P_{j,\text{lx}} \cdot E_{\text{task}} \cdot F_{\text{CMF}} \cdot F_{\text{CA}} \cdot F_{\text{L}}$.

$P_{j,\mathrm{lx}}$ = 0,037 is dependent on the room index $K = \frac{L_R \cdot W_R}{h_m (L_R + W_R)} = \frac{3 \cdot 2}{2{,}2 \cdot (3+2)} = 0{,}55$ and UFF (Upward Flux Fraction) and can be found from ISO/CIE 20086:2019, Table B.1.

E_{task} = 300 lx

$F_{\mathrm{CMF}} = \frac{0{,}8}{f_m} = \frac{0{,}8}{0{,}7} = 1{,}14$ according to ISO/CIE 20086:2019, Formula (B.4)

F_{CA} = 1,0 as the whole area is taken to be task area.

F_L = 0,86 according to ISO/CIE 20086:2019, Table A.9 for LED.

Therefore, P_j = 0,037 · 300 · 1,14 · 1,0 · 0,86 = 10,88 W/m^2.

And P_n = 10,88 · 6 = 65,28 W.

A.2.4.5 Calculation of standby system power

According to ISO/CIE 20086:2019, Table A.1, the standby energy for automatic lighting controls:

W_{pc} = 1,5 kWh/m^2 · 6 m^2 = 9,0 kWh per year

And the standby energy for battery charging of emergency luminaires:

W_{pe} = 1,0 kWh/m^2 · 6 m^2 = 6,0 kWh per year

A.2.4.6 Calculation of F_O

From ISO/CIE 20086:2019, Table D.2 for a sales area F_A = 0,0.

From ISO/CIE 20086:2019, Table D.3, F_O = 1,0.

A.2.4.7 Calculation of F_C

According to ISO/CIE 20086:2019, Table A.8., as luminaires in the fitting rooms are not dimmable, F_C = 1,0.

A.2.4.8 Calculation of F_D

Fitting room have no openings for daylight penetration, therefore, F_D = 1,0.

A.2.4.9 Energy requirement calculations

According to ISO/CIE 20086:2019, Formula (25):

$$Q_{\mathrm{LENI,sub}} = \{F_C \cdot (P_j / 1\,000) \cdot F_O [(t_D \cdot F_D) + t_N]\} + 1{,}0 + 1{,}5 \ (\mathrm{kWh/m^2})$$

$$Q_{\mathrm{LENI,sub}} = \{1{,}0 \cdot (10{,}88/1\,000) \cdot 1{,}0 \cdot [(2\,343 \cdot 1{,}0) + 2\,025]\} + 1{,}0 + 1{,}5 = 50 \ \mathrm{kWh/m^2}$$

Then, according to ISO/CIE 20086:2019, Formula (26), the annual energy required for electric lighting in the fitting room $W_1 = Q_{\mathrm{LENI,sub}} \cdot A_j$ = 50 · 6 = 300 kWh/year for one fitting room, and for the both identical fitting rooms $W = W_1 \cdot 2$ = 600 kWh/year.

A.2.5 Toilet

A.2.5.1 General

3 m by 3 m windowless toilet room.

A.2.5.2 Toilet details

Single room dimensions: L_R = 3 m, W_R = 3 m, H = 3 m.

Surface reflectance values: ceiling ρ = 70 %, walls ρ = 50 %, floor ρ = 20 %.

Maintained illuminance: 200 lx on the task level at 0,8 m AFF.

Maintenance factor f_m = 0,7.

A.2.5.3 Toilet electric lighting system

The lighting will be recessed LED downlight luminaires controlled by occupancy detectors and with emergency lighting to comply with the local building code requirements.

A.2.5.4 Calculation of P_n

According to ISO/CIE 20086:2019, Formula (B.1) and Formula (B.2), $P_n = P_j \cdot A$ and $P_j = P_{j,\mathrm{lx}} \cdot E_{\mathrm{task}} \cdot F_{\mathrm{CMF}} \cdot F_{\mathrm{CA}} \cdot F_{\mathrm{L}}$.

$P_{j.lx}$ = 0,035 is dependent on the room index $K = \dfrac{L_R \cdot W_R}{h_m (L_R + W_R)} = \dfrac{3 \cdot 3}{2,2 \cdot (3+3)} = 0,68$ and UFF (Upward Flux Fraction) and can be found from ISO/CIE 20086:2019, Table B.1.

E_{task} = 200 lx

$F_{\mathrm{CMF}} = \dfrac{0,8}{f_m} = \dfrac{0,8}{0,7} = 1,14$ according to ISO/CIE 20086:2019, Formula (B.4)

F_{CA} = 1,0 as the whole area is taken to be task area

F_{L} = 0,86 according to ISO/CIE 20086:2019,Table A.9 for LED

Therefore, P_j = 0,035 · 200 · 1,14 · 1,0 · 0,86 = 6,86 W/m^2,

And P_n = 6,86 · 9 = 61,74 W.

A.2.5.5 Calculation of standby system power

There is no control device on-board, but a free-standing occupancy sensor requires some standby power, so W_{pc} = 1,5 kWh/m^2 · 9 m^2 = 13,5 kWh per year.

And the standby energy for battery charging of emergency luminaires W_{pe} = 1,0 kWh/m^2 · 9 m^2 = 9,0 kWh per year.

A.2.5.6 Calculation of F_O

From ISO/CIE 20086:2019, Table D.2 for a restroom/toilet F_A = 0,50.

From ISO/CIE 20086:2019, Table D.3 for auto on/off F_O = 0,60.

A.2.5.7 Calculation of F_C

According to ISO/CIE 20086:2019, Table A.8., F_C = 1,0 as luminaires in toilet are not dimmable.

A.2.5.8 Calculation of F_D

The toilet room has no openings for daylight penetration, therefore, F_D = 1,0.

A.2.5.9 Energy requirement calculations

According to ISO/CIE 20086:2019, Formula (25):

$$Q_{\mathrm{LENI,sub}} = \left\{F_{\mathrm{C}} \cdot \left(P_j / 1\,000\right) \cdot F_{\mathrm{O}}\left[\left(t_{\mathrm{D}} \cdot F_{\mathrm{D}}\right) + t_{\mathrm{N}}\right]\right\} + 1{,}5 \ \ [\mathrm{kWh/m^2}]$$

$$Q_{\mathrm{LENI,\,sub}} = \{1{,}0 \cdot (6{,}86/1\,000) \cdot 0{,}60 \cdot [(2\,343 \cdot 1{,}0) + 2\,025]\} + 1{,}0 + 1{,}5 = 20{,}48\ \mathrm{kWh/m^2}$$

Then, according to ISO/CIE 20086:2019, Formula (26), the annual energy required for electric lighting in the toilet:

$$W = Q_{\mathrm{LENI,sub}} \cdot A_{\mathrm{j}} = 20{,}48 \cdot 9 = 184{,}3\ \mathrm{kWh}$$

A.2.6 Stock room

A.2.6.1 General

Stock room is an 84 m^2 storage windowless space that provides place for storing merchandise in the retail store.

A.2.6.2 Stock room details

Room dimensions: L_R = 12 m, W_R = 7 m, H = 3 m.

Surface reflectance values: ceiling ρ = 80 %, walls ρ = 40 %, floor ρ = 20 %.

Target general illuminance on the task level 0,8 m AFF is 300 lx.

Maintenance factor assumed in the design f_m = 0,7.

A.2.6.3 Stock room electric lighting system

General illumination in the stock room will be provided by LED ceiling-recessed luminaires with an emergency lighting as required by the local safety standard. Lighting is controlled by on-board PIR occupancy detectors for automated ON and OFF switching.

A.2.6.4 Calculation of P_n

According to ISO/CIE 20086:2019, Formula (B.1) and Formula (B.2), $P_n = P_j \cdot A$ and $P_j = P_{j,\mathrm{lx}} \cdot E_{\mathrm{task}} \cdot F_{\mathrm{CMF}} \cdot F_{\mathrm{CA}} \cdot F_{\mathrm{L}}$

$P_{j,\mathrm{lx}}$ = 0,024 is dependent on the room index $K = \dfrac{L_{\mathrm{R}} \cdot W_{\mathrm{R}}}{h_{\mathrm{m}}\left(L_{\mathrm{R}} + W_{\mathrm{R}}\right)} = \dfrac{12 \cdot 7}{2{,}2 \cdot (12+7)} = 2{,}01$ and 10 % UFF (Upward Flux Fraction), and can be found from ISO/CIE 20086:2019, Table B.1.

E_{task} = 300 lx

$F_{\mathrm{CMF}} = \dfrac{0{,}8}{f_{\mathrm{m}}} = \dfrac{0{,}8}{0{,}7} = 1{,}14$ according to ISO/CIE 20086:2019, Formula (B.4)

F_{CA} = 1,0 as the whole area is taken to be task area

F_{L} = 0,86 according to ISO/CIE 20086:2019, Table A.9 for LED

Therefore, $P_j = 0{,}024 \cdot 300 \cdot 1{,}14 \cdot 1{,}0 \cdot 0{,}86 = 7{,}06$ W/m², and $P_n = 7{,}06 \cdot 12 \cdot 7 = 593$ W.

A.2.6.5 Calculation of standby system power

According to ISO/CIE 20086:2019, Table A.1, the standby energy for automatic lighting controls:

$W_{pc} = 1{,}5$ kWh/m² · 84 m² = 126 kWh per year

And the standby energy for battery charging of emergency luminaires:

$W_{pe} = 1{,}0$ kWh/m² · 84 m² = 84 kWh per year

A.2.6.6 Calculation of F_O

From ISO/CIE 20086:2019, Table D.2 for store room in Retail, $F_A = 0{,}20$.

From ISO/CIE 20086:2019, Table D.3, for $F_A = 0{,}0$ and $F_o = 0{,}9$.

A.2.6.7 Calculation of F_C

According to ISO/CIE 20086:2019, Table A.8., as luminaires are not dimmable, $F_C = 1{,}0$.

A.2.6.8 Calculation of F_D

There is no daylight opening in the stock room, therefore, $F_D = 1{,}0$

A.2.6.9 Energy requirement calculations

According to ISO/CIE 20086:2019, Formula (25)

$$Q_{\mathrm{LENI,sub}} = \left\{ F_C \cdot \left(P_j / 1\,000 \right) \cdot F_O \left[\left(t_D \cdot F_D \right) + t_N \right] \right\} + 1{,}0 + 1{,}5 \ \ (\mathrm{kWh/m^2})$$

$$Q_{\mathrm{LENI,\,sub}} = \{1{,}0 \cdot (7{,}06/1\,000) \cdot 0{,}9 \cdot [(2\,343 \cdot 1{,}0) + 2\,025]\} + 1{,}0 + 1{,}5 = 30{,}25 \ \mathrm{kWh/m^2}$$

Then, according to ISO/CIE 20086:2019, Formula (26), the annual energy required for electric lighting in the stock room, $W = Q_{\mathrm{LENI,sub}} \cdot A_\mathrm{j} = 30{,}25 \cdot 84 = 2\,541$ kWh/year

A.2.7 Corridor

A.2.7.1 General

Corridor provides a connection between sales floor, fitting rooms, toilet room, stock room, and an emergency path to the back of the house.

A.2.7.2 Corridor details

Room dimensions: $L_R = 7$ m, $W_R = 2$ m, $H = 3$ m.

Surface reflectance values: ceiling $\rho = 80$ %, walls $\rho = 50$ %, floor $\rho = 20$ %.

Maintained illuminance: 200 lx on the floor.

Maintenance factor $f_m = 0{,}7$.

A.2.7.3 Corridor electric lighting system

The lighting system will be recessed LED downlight luminaires with emergency lighting to comply with the local building code requirements turning on/off through a time schedule device at the electrical panel.

A.2.7.4 Calculation of P_n

According to ISO/CIE 20086:2019, Formula (B.1) and Formula (B.2), $P_n = P_j \cdot A$ and $P_j = P_{j,\mathrm{lx}} \cdot E_{\mathrm{task}} \cdot F_{\mathrm{CMF}} \cdot F_{\mathrm{CA}} \cdot F_{\mathrm{L}}$.

$P_{j,\mathrm{lx}}$ = 0,037 is dependent on the room index $K = \dfrac{L_\mathrm{R} \cdot W_\mathrm{R}}{h_\mathrm{m}\,(L_\mathrm{R} + W_\mathrm{R})} = \dfrac{7 \cdot 2}{3{,}0 \cdot (7+2)} = 0{,}52$ and UFF (Upward Flux Fraction) and can be found from ISO/CIE 20086:2019, Table B.1.

E_{task} = 200 lx

$F_{\mathrm{CMF}} = \dfrac{0{,}8}{f_\mathrm{m}} = \dfrac{0{,}8}{0{,}7} = 1{,}14$ according to ISO/CIE 20086:2019, Formula (B.4)

F_{CA} = 1,0 as the whole area is taken to be task area

F_L = 0,86 according to ISO/CIE 20086:2019, Table A.9 for LED

Therefore, P_j = 0,037 · 200 · 1,14 · 1,0 · 0,86 = 7,25 W/m^2,

And P_n = 7,25 · 14 = 101,5 W

A.2.7.5 Calculation of standby system power

According to ISO/CIE 20086:2019, Table A.1, the standby energy for automatic lighting controls:

W_{pc} = 1,5 kWh/m^2 · 14 m^2 = 21 kWh per year

And the standby energy for battery charging of emergency luminaires:

W_{pe} = 1,0 kWh/m^2 · 14 m^2 = 14 kWh per year

A.2.7.6 Calculation of F_O

From ISO/CIE 20086:2019, Table D.2 for a corridor with no dimming F_A = 0,0.

From ISO/CIE 20086:2019, Table D.3 F_O = 1,0.

A.2.7.7 Calculation of F_C

According to ISO/CIE 20086:2019, Table A.8, as luminaires are not dimmable, F_C = 1,0.

A.2.7.8 Calculation of F_D

There is no opening for daylight penetration, therefore, F_D = 1,0.

A.2.7.9 Energy requirement calculations

According to ISO/CIE 20086:2019, Formula (25)

$$Q_{\mathrm{LENI,sub}} = \left\{F_\mathrm{C} \cdot \left(P_j / 1\,000\right) \cdot F_\mathrm{O}\left[\left(t_\mathrm{D} \cdot F_\mathrm{D}\right) + t_\mathrm{N}\right]\right\} + 1{,}0 + 1{,}5 \ \ (\mathrm{kWh/m^2})$$

$$Q_{\mathrm{LENI,\,sub}} = \{1{,}0 \cdot (7{,}25/1\,000) \cdot 1{,}0 \cdot [(2\,343 \cdot 1{,}0) + 2\,025]\} + 1{,}0 + 1{,}5 = 34{,}17\ \mathrm{kWh/m^2}$$

Then, according to ISO/CIE 20086:2019, Formula (26), the annual energy required for electric lighting in the corridor:

$$W = Q_{\mathrm{LENI,sub}} \cdot A_{\mathrm{j}} = 34{,}17 \cdot 14 = 478{,}4\ \mathrm{kWh}$$

A.2.8 Retail store annual energy requirements

The annual energy W required for lighting the store is calculated by summing up the energy required for the lighting system in each specified areas of the unit.

Energy required for lighting of:

sales floor = 10 724,4 kWh;

office = 614,25 kWh;

fitting rooms = 600 kWh;

toilet room = 184,3 kWh;

stock room = 2 541 kWh;

corridor = 478,4 kWh;

building = 15 142,35 kWh.

Then, LENI for the unit is $Q_{\mathrm{LENI}} = W/A = 15\,142{,}35/(25 \cdot 20) = 30{,}28$

$Q_{\mathrm{LENI}} = 30{,}28\ \mathrm{kWh/m^2}$ per year.

A.3 Method 3 – Metered lighting energy used for of existing retail store

A.3.1 Site details

A retail 500 m^2 unit for selling apparel located at the ground level corner of the multi-story building consists of sales area, admin office, stock room, fitting rooms, toilet room, and corridor spaces as shown on the layout plan Figure A.1.

A.3.2 Building electrical metering

Lighting energy consumption is metered by 2 class C [see EN 50470 (all parts)] electrical meters. The electrical meter registers the lighting energy supplied to the entire unit.

A.3.3 Annual meter readings

The electrical meter registers the lighting energy consumption during the one-year period:

$$W_{\mathrm{t}} = 9\,470\ \mathrm{kWh}$$

Therefore, according to ISO/CIE 20086:2019, Formula (29), the annual metered energy used for electric lighting in the building is

$$W_{\mathrm{mt}} = \sum W_{\mathrm{t}} = 9\,470\ \mathrm{kWh}$$

And according to ISO/CIE 20086:2019, Formula (30), $W = 8\,760/t_{\mathrm{s}} \cdot W_{\mathrm{mt}} = 8\,760/8\,760 \cdot 9\,470 = 9470\ \mathrm{kWh}$

A.3.4 Building metered Q_{LENI}

According to ISO/CIE 20086:2019, Formula (13), LENI for the building is

Q_{LENI} = W/A = 9 470/500 = 18,94 kWh/m^2 per year

Q_{LENI} = 8,94 kWh/m^2 per year

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1) Under revision, next edition will be published as ISO/CIE 8995-1.

2) Under revision, next edition will be published as ISO/CIE 10916.

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