
**Light and lighting — Energy
performance of lighting in buildings**

*Lumière et éclairage — Performance énergétique de l'éclairage des
bâtiments*

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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 documents 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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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.

ISO collaborates closely with the International Commission on Illumination (CIE) on all matters of standardization for light and lighting.

This document was prepared by Technical Committee ISO/TC 274, *Light and lighting*. The document has been jointly prepared with CIE JTC 6, *Energy performance of lighting in buildings*.

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 of paramount importance that correct lighting is provided in buildings. The convention and procedures in this document assumes that the designed and installed lighting scheme conforms to good lighting practices. For new and refurbished installations in the non-residential building sector the design of the lighting system should conform to the requirements in the lighting applications standards ISO 8995-1/CIE S 008 for indoor workplaces and ISO 30061/CIE S 020 for emergency escape lighting. This document also assumes that the buildings can have access to daylight to provide all or some of the illumination required in the rooms or zones and that in addition there will be an adequate amount of electric lighting installed to provide the required illumination in the absence of daylight.

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

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

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

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

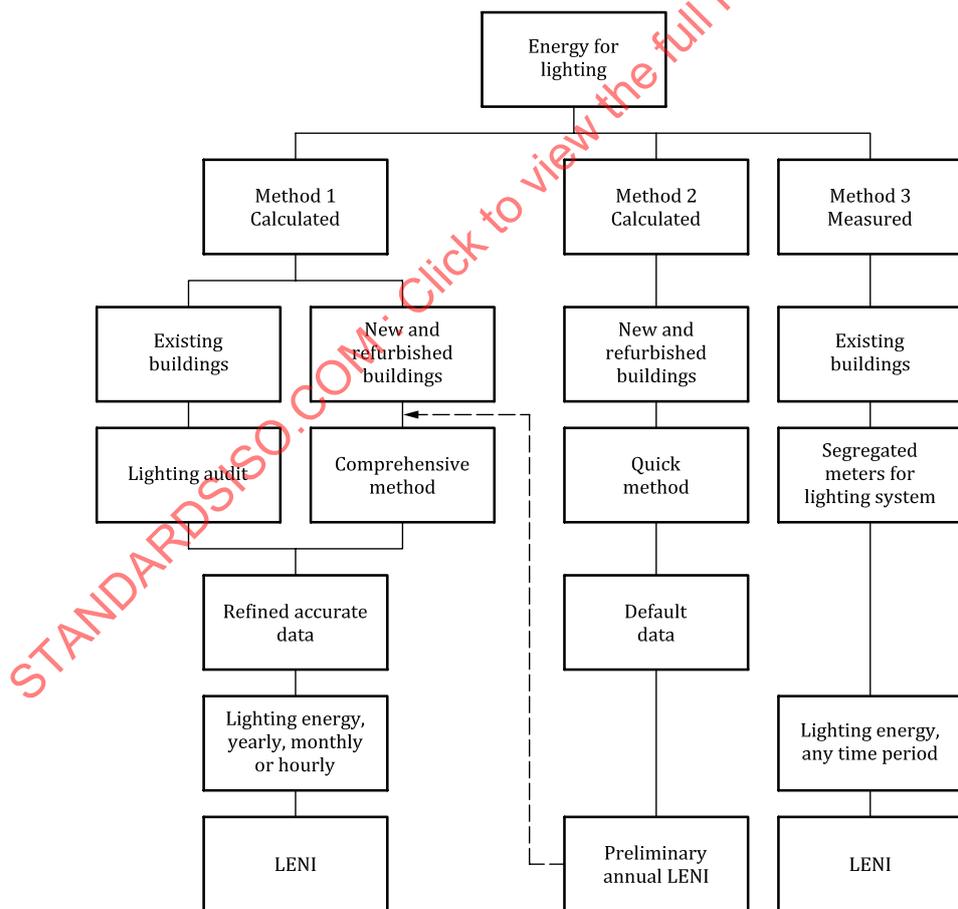


Figure 1 — Flow chart illustrating alternative routes to determine energy use

Light and lighting — Energy performance of lighting in buildings

1 Scope

This document specifies the methodology for evaluating the energy performance of lighting systems for providing general illumination inside non-residential buildings and for calculating or measuring the amount of energy required or used for lighting inside buildings.

This document does not cover lighting requirements, the design of lighting systems, the planning of lighting installations, the characteristics of lighting equipment (lamps, control gear and luminaires) and systems used for display lighting, desk lighting or luminaires built into furniture. This document does not provide any procedure for the dynamic simulation of lighting scene setting.

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 8995-1/CIE S 008, *Lighting of work places — Part 1: Indoor*

ISO 10916, *Calculation of the impact of daylight utilization on the net and final energy demand for lighting*

ISO 30061/CIE S 020, *Emergency lighting*

IEC 60598 (all parts), *Luminaires*

CIE S 017, ILV, *International Lighting Vocabulary*

3 Terms and definitions

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

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

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

3.1 time step

t_s
period in which the energy is evaluated

Note 1 to entry: Measured in hour, month, year.

3.2 standby energy

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

Note 1 to entry: Lighting controls and emergency battery charging circuits are only considered where power is supplied via a luminaire.

3.3 lighting control

device connected to the luminaire to vary the light output

Note 1 to entry: In this document lighting controls are only considered where power is supplied via a luminaire.

3.4 lighting system

set of light sources and/or lamps with luminaires and related equipment, if any, interacting together to satisfy lighting application requirements

Note 1 to entry: The lighting system can be dedicated to:

- a) the support of (a) specified visual task(s) under specified conditions considering other requirements such as human comfort, safety, the appearance of the surrounding environment and energy consumption;
- b) the support of other than human tasks, such as plant growth or breeding of animals.

Note 2 to entry: The lighting system can include physical components, communication protocols, user interfaces, software and networks to provide control and monitoring functions.

[SOURCE: CIE DIS 017:2016; Term 17-29-029]

3.5 expenditure factor

expense factor

effort factor

indicator of the energy efficiency of a given lighting system compared to a reference system

4 Symbols and abbreviations

4.1 Symbols

For the purposes of this document, the specific symbols listed in [Table 1](#) apply.

Table 1 — Symbols and units

Symbol	Name of quantity	Unit
A	Total useful area	m^2
A_D	Partial area which is lit by daylight	m^2
A_{ND}	Area not lit by daylight	m^2
A_s	Sum of task areas within the room	m^2
D	Daylight factor	%
D_{class}	Daylight availability classification	1
e_L	Expenditure factor for lighting systems	1
$e_{L,C}$	Partial expenditure factor for constant illuminance control	1
$e_{L,D}$	Partial expenditure factor for daylight dependant lighting control	1
$e_{L,ES}$	Partial expenditure factor for the electric lighting system	1
$e_{L,ES,del}$	Partial expenditure factor for delivery of electric light	1
$e_{L,ES,dis}$	Partial expenditure factor for distribution of electric light	1
$e_{L,ES,gen}$	Partial expenditure factor for generation of electric light	1
$e_{L,O}$	Partial expenditure factor for occupancy dependant lighting control	1
E_m	Maintained illuminance	lx
E_{sur}	Maintained illuminance on immediate surround of task area	lx
E_{task}	Maintained illuminance on the task area	lx

Table 1 (continued)

Symbol	Name of quantity	Unit
F_A	Absence factor	1
f_B	Factor for the efficiency of the operating device	1
F_C	Constant illuminance factor	1
F_{CA}	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	Factor for light source efficiency	1
f_m	Maintenance factor	1
F_{CMF}	Correction factor for maintenance factor	1
F_O	Occupancy dependency factor	1
F_{OC}	Controls function factor	1
F_U	Utilization factor of the luminaire	1
$F_{U,e}$	Utilization factor for determination of the energy use	1
h_m	Mounting height of luminaire	m
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_i	Number of days in month i	d
n_{La}	Number of lamps in the luminaire	1
P	Installed electric power density	W/m ²
p	Specific electrical evaluation power	W/(m ² lx)
$P_{c,i}$	Control standby power of luminaire i	W
P_e	Electrical evaluation power density for determination of the energy use	W/m ²
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
$P_{j,lx}$	Illuminance-normalized power density of area j	W/(m ² lx)
P_n	Total power of n luminaires	W
P_{pc}	Total controls standby power	W
P_r	Lamp rated power	W
Q_{LENI}	Lighting energy numeric indicator (LENI) for a building	kWh/m ²
$Q_{LENI,sub}$	Lighting energy numeric indicator for an area or relevant zone	kWh/m ²
R_a	General colour rendering index	1
t_D	Daylight time	h
t_N	Daylight absence time	h
t_s	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

Table 1 (continued)

Symbol	Name of quantity	Unit
$W_{L,t}$	Total energy for illumination	kWh
W_{mt}	Metered energy	kWh
$W_{p,t}$	Total energy for standby	kWh
w_R	Width of room	m
W_t	Energy per time step	kWh
W_{us}	Energy used for lighting	Wh
W_{nd}	Energy needed for lighting	Wh
W_{pc}	Standby energy density for automatic lighting controls of the luminaire per year	kWh/m ²
W_{pe}	Standby energy density for battery charging of emergency luminaires per year	kWh/m ²
η_L	Luminaire luminous efficacy	lm/W
η_{LB}	Luminaire light output ratio	1
η_R	Utilance	1

4.2 Subscripts

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

This document covers three methods for the assessment of the energy required for electric lighting within a building, either by calculation (method 1 and method 2) or by direct metering of the lighting circuit (method 3). The calculation method 1 offers two options,

- 1) for new or refurbished buildings, and
- 2) for existing buildings.

For new and refurbished buildings it also offers a quick calculation method 2 for the annual energy estimation.

This document offers calculation methods, with different levels of accuracy for the installed power, occupancy estimation and daylight availability.

Method 1 provides the most accurate calculation procedure and it relies upon a comprehensive lighting scheme design as the main input to the energy calculation.

Method 2 provides a quick estimation aimed for pre-design calculations and employs default values. Default values are provided in [Annex A](#).

Method 3 provides the most accurate energy use for lighting information but can only be used after the building has been commissioned and occupied. This method can also be linked to the Building Management System (BMS) of the building to provide continuous smart metering.

5.2 Output of the method 1— Comprehensive method

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

The method output shall be in terms of kilowatt hours per time step for the building. The output value shall be normalized for the considered time step to square meters of the useful area to give the sub-LENI value. If the time-step is yearly this is the Lighting Energy Numeric Indicator LENI.

The time step of the output can be:

- yearly,
- monthly, or
- hourly,

in accordance with the time step of the input data.

5.3 Optional methods

5.3.1 Method 2 — Quick calculation method

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

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

The time step of the output shall be yearly.

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

5.3.2 Method 3 — Direct metering method

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

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

The time step of the output can be:

- yearly,
- monthly, or
- hourly,

in accordance with the time step of the input data.

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

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

The calculated or measured annual energy required for lighting can be normalized to a unit area to generate the LENI. LENI provides a comparable measure of the energy performance of the lighting installation in the buildings. When the output value is obtained for other time steps it shall be normalised to the unit area to give the sub-LENI value.

6 Method 1 — Calculation of the energy required for lighting

6.1 Output data

The output data of this method are listed in [Table 3](#).

Table 3 — Output data of this method

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

LENI is the area normalized annual energy used for lighting within the building [kWh/m²]. LENI produced by method 1 provides the most accurate calculated Q_{LENI} .

6.2 Calculation time steps

The methods described in [clause 6](#) are suitable for the following calculation time steps:

- Yearly – Taken as 8 760 h;
- Monthly – Taken as an average of 730 h;
- Hourly – 1 h derived from monthly calculated value divided by 730.

NOTE If more accurate data for occupancy and daylight is available for hourly intervals this data can be used.

6.3 Input data

6.3.1 Lighting system data

For the comprehensive calculation method the energy estimation shall be based upon the electric lighting system that provides illumination in accordance with the requirements for non-residential buildings of ISO 8995-1/CIE S 008 for lighting of indoor work places and requirements for emergency lighting according to ISO 30061/CIE S 020.

It is important that for all buildings the lighting solution shall combine daylight, if available, and electric light to fulfil all requirements in accordance with ISO 8995-1/CIE S 008 and the general and specific lighting criteria for the places within the buildings.

6.3.1.1 New or refurbished building lighting system

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

NOTE 1 The comprehensive lighting system design process is not part of this document.

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

- the types of luminaires, identified by a unique product reference code;
- the quantities of each specific type of luminaire;
- the control technique and device types;
- the maintenance factor (f_m) assumed in the design.

NOTE 2 The specific type of the luminaire includes information on the product as well as the lamp and ballast combination if applicable.

All luminaires listed for use shall comply with the requirements specified in IEC 60598 (all parts).

6.3.1.2 Existing building lighting system

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

- the types of luminaires, identified by a unique product reference code;
- the quantities of each specific type of luminaire;
- the control technique and device types;
- the maintenance factor (f_m) defined by the maintenance schedule.

6.3.2 Product data

6.3.2.1 General

Where the comprehensive method is being used, the data in [Table 4](#) to [7](#) shall be specified for each product type given in the product schedule:

Table 4 — Luminaire identification

Code	Description

Table 5 — Power of luminaire i (P_i)

Code	Power W

Table 6 — Control standby power of luminaire i ($P_{c,i}$)

Code	Power W

Table 7 — Emergency charging power of luminaire i ($P_{e,i}$)

Code	Power W

In the case of existing buildings where the luminaire data is not available from the manufacturer the method described in [Annex C](#) shall be used for obtaining the value of the maximum luminaire power.

NOTE In this document product means light sources and/or lighting controls and/or emergency battery charging circuits where power is supplied via a luminaire.

6.3.2.2 Luminaire description data (qualitative)

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

6.3.2.3 Luminaire technical data

The luminaire technical data, in accordance with [Table 4](#) to [7](#), shall be the values declared by the manufacturer in accordance with the certified measurements that are performed in accordance with the relevant product standards. If standby energy density values declared by the manufacturer are not available, then default values are given in [Table A.1](#) for information.

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

6.3.3 System design data

Calculations shall be made for each area of a zone or building to establish the installed lighting power, P_n , P_{em} and P_{pc} , and to estimate the impact of occupancy, daylight and over design/maintenance factors on the lighting controls by determining the values of the dependency factors, F_o , F_D and F_c . These shall be presented as shown in [Table 8](#).

Table 8 — System design data

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

6.3.4 Operating conditions

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

In addition the occupancy and activity patterns shall be defined to allow the evaluation of t_D and t_N for each area of a zone or building. These shall be presented as shown in [Table 9](#).

Table 9 — Times for operating conditions

Area Code	t_D	t_N

6.3.5 Constants and physical data

Number of hours in a standard year (t_y) – defined as 8 760 h.

6.4 Calculation procedure

6.4.1 Applicable time step

This procedure can be used with the following time steps:

- yearly,
- monthly, or
- hourly.

NOTE No dynamic effects are explicitly taken into account because there are no significant time constants. This procedure is not suitable for dynamic simulations.

6.4.2 Operating conditions calculation

If no better values are available the default values of t_D , and t_N as provided in [Table A.2](#) and F_A as provided in [Table A.6](#) shall be used.

The occupancy schedule shall be provided based on documented assumptions.

NOTE Examples are provided in ISO 18523-1 and other national or regional references.

6.4.3 Energy calculation

6.4.3.1 General

The lighting energy calculation method is shown in [Figure 2](#). The procedure represents the principle of the method and needs to be applied for different areas/zones.

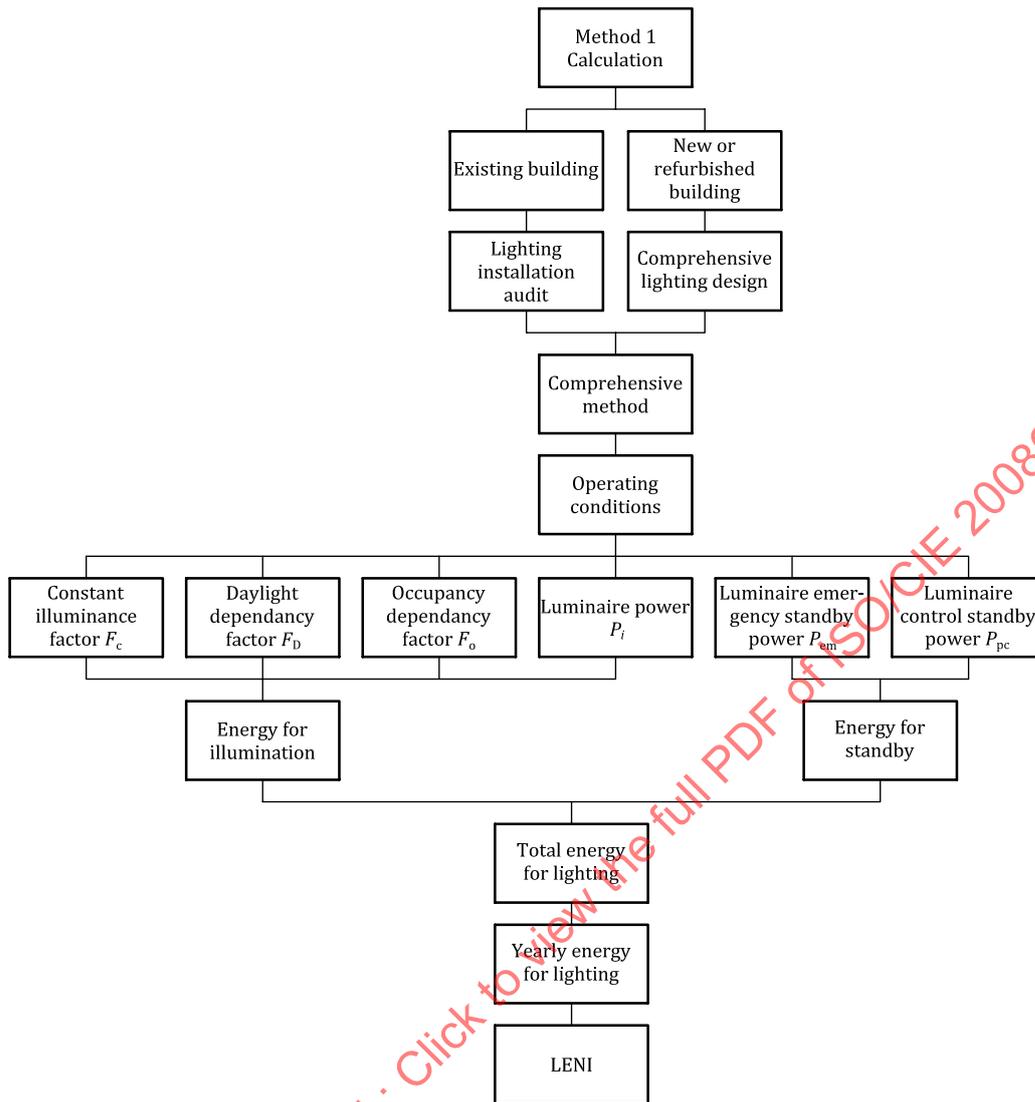


Figure 2 — Flow chart illustrating the calculation of energy for lighting by method 1

6.4.3.2 Installed power calculation

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

The required connected or installed power for the lighting system shall be calculated by summation of the power requirements of the specified luminaires in the lighting scheme within each area of the building by using [Formula \(1\)](#):

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

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

Where available accurate data from installed lighting should be used.

6.4.3.2.1 Assessment of installed power in existing buildings

The assessment of the installed power for the lighting system in existing buildings shall be made by the procedure described in [Annex C](#). The installed power for the lighting system shall be calculated by working out the power supplied to the luminaires within each area of the building by using [Formula \(1\)](#).

6.4.3.3 Standby system power requirements

The required total installed power to charge the batteries in emergency luminaires P_{em} and to provide standby power for the automatic controls in the luminaires when the lamps are not operated P_{pc} shall be calculated and shall be made by summing the standby power $P_{e,i}$ for charging the batteries and the standby power $P_{c,i}$ for the automatic control for each specified luminaire within each area of the building by [Formulae \(2\)](#) and [\(3\)](#):

$$P_{em} = \sum_{i=1}^{i=n} P_{e,i} \quad [\text{W}] \quad (2)$$

$$P_{pc} = \sum_{i=1}^{i=n} P_{c,i} \quad [\text{W}] \quad (3)$$

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

Details of the standby power and energy calculation and requirements are provided in [6.4.3.7](#).

6.4.3.4 Occupancy dependency factor F_o

6.4.3.4.1 General

The occupancy dependency factor F_o shall be calculated by the process shown below.

6.4.3.4.2 Case $F_o = 1$

F_o shall be taken to equal 1,0 when:

- the lighting is switched on 'centrally', i.e. in more than one area at once (e.g. a single automatic system – for instance with timer or manual switch for an entire building, or for an entire floor, or for all corridors etc.). This applies regardless of the type of 'off-switch' (automatic or manual, central or per room etc.);
- multi-occupancy or traffic areas larger than 30 m² are illuminated by a group of luminaires that are (manually or automatically) switched together.

6.4.3.4.3 Case $F_o < 1$

F_o shall be taken as less than 1,0:

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

In these instances, F_o shall be determined according to the value of F_A as follows in [Formulae \(4\)](#) to [\(6\)](#):

$$0,0 \leq F_A < 0,2 \quad F_o = 1 - \left[(1 - F_{oc}) \cdot F_A / 0,2 \right] \quad (4)$$

$$0,2 \leq F_A \leq 0,9 \quad F_o = F_{oc} + 0,2 - F_A \quad (5)$$

$$0,9 \leq F_A \leq 1,0 \quad F_o = [7 - (10 \cdot F_{oc})] \cdot (F_A - 1) \quad (6)$$

where

F_A is the proportion of the time that the space is unoccupied;

F_{oc} is determined as a function of the lighting control system.

Details of the estimation of F_o , F_A and F_{oc} are given in [Annex D](#).

6.4.3.5 Daylight dependency factor F_D

The daylight dependency factor F_D shall be calculated for a room or zone in the building as a function of the daylight supply factor $F_{D,S}$ and the daylight dependent electric lighting control factor $F_{D,C}$ by [Formula \(7\)](#):

$$F_D = 1 - (F_{D,S} \cdot F_{D,C}) \quad (7)$$

The method for the determination of the daylight supply factor $F_{D,S}$ and the daylight dependent electric lighting control factor $F_{D,C}$ are given in ISO 10916.

6.4.3.6 Constant illuminance dependency factor F_c

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

The constant illuminance dependency factor F_c shall be calculated by [Formula \(8\)](#):

$$F_c = 1 - \frac{1}{2} F_{cc} (1 - f_m) \quad (8)$$

where

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

f_m is the maintenance factor for the scheme.

For technologies with inbuilt constant light output capabilities used in systems without constant illuminance sensing the F_c value shall be based on the method according to Annex F.

6.4.3.7 Calculation of energy for lighting

The total estimated energy required for lighting for a period in a room or zone of the building shall be estimated by using [Formula \(9\)](#):

$$W_t = W_{L,t} + W_{P,t} \text{ [kWh]} \quad (9)$$

Where $W_{L,t}$ is the estimated lighting energy required to fulfil the illumination function in a room or zone of the building, it shall be established using [Formula \(10\)](#):

$$W_{L,t} = \sum \left\{ (P_n \cdot F_c) \cdot F_o \left[(t_D \cdot F_D) + t_N \right] \right\} / 1\,000 \text{ [kWh]} \quad (10)$$

Where $W_{P,t}$ is the estimated standby energy required during non-lighting periods to provide charging energy for emergency lighting and the activation energy for lighting controls in a room or zone of the building, it shall be established using [Formula \(11\)](#):

$$W_{P,t} = \sum \left\{ (P_{pc} \cdot t_s) + (P_{em} \cdot t_e) \right\} / 1\,000 \text{ [kWh]} \quad (11)$$

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

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

The annual energy for electric lighting within a building shall be calculated using [Formula \(12\)](#):

$$W = 8\,760 / t_s \cdot \sum W_t \text{ [kWh]} \quad (12)$$

summed across all rooms and zones within the building.

Q_{LENI} for the building shall be established using [Formula \(13\)](#):

$$Q_{LENI} = W / A \text{ [kWh/m}^2\text{]} \quad (13)$$

where

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

A is the total useful floor area of the building [m²].

6.5 Expenditure factors for lighting systems

This methodology allows a quick analysis of the energy flows in an electric lighting system.

The expression of energy performance of a given lighting system can be indicated by the expenditure factor, where the higher the expenditure factor the less efficient is the lighting system. It does not affect the determination of the energy required for lighting. Instead it can be derived by correlation of the previously derived values. Applying this methodology allows a quick analysis of the energy flows in an electric lighting system, separately for each of its technical components. As specific conventions are required for the energy assessment of lighting systems, such as luminous efficacy and luminous intensity distribution, the absolute values received for the expenditure factor are specific for lighting and cannot be directly compared with other technical building services.

The expenditure factor for lighting systems is defined according to [Formula \(14\)](#):

$$e_L = \frac{W_{us}}{W_{nd}} \quad (14)$$

where

- e_L is the expenditure factor for lighting systems;
- W_{us} is the energy used for lighting (either calculated or measured);
- W_{nd} is the reference energy needed for lighting.

It can be derived by the following formal separation of the individual influences according to [Formula \(15\)](#):

$$e_L = e_{L,C} \cdot e_{L,O} \cdot e_{L,D} \cdot e_{L,ES} \quad (15)$$

where

- e_L is the expenditure factor for lighting systems;
- $e_{L,C}$ is the partial expenditure factor for constant illuminance control;
- $e_{L,O}$ is the partial expenditure factor for occupancy dependent lighting control;
- $e_{L,D}$ is the partial expenditure factor for daylight dependent lighting control;
- $e_{L,ES}$ is the partial expenditure factor for the electric lighting system.

The partial expenditure factor for constant illuminance control is calculated using [Formula \(16\)](#):

$$e_{L,C} = \frac{1 - \frac{1}{2} F_{cc} (1 - f_m)}{1 - \frac{1}{2} (1 - f_m)} \quad (16)$$

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

The partial expenditure factor for occupancy dependent lighting control is calculated using [Formula \(17\)](#):

$$e_{L,O} = \frac{F_o}{(1 - F_A)} \quad (17)$$

The partial expenditure factor for daylight dependent lighting control is calculated using [Formula \(18\)](#):

$$e_{L,D} = \frac{A_D (t_D \cdot (1 - F_{D,S} \cdot F_{D,C}) + t_N) + A_{ND} (t_D + t_N)}{A_D (t_D \cdot (1 - F_{D,S}) + t_N) + A_{ND} (t_D + t_N)} \quad (18)$$

where

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

The partial expenditure factor for the electric lighting system is calculated using [Formula \(19\)](#):

$$e_{L,ES} = \frac{P}{P_e} \tag{19}$$

It can be derived by the formal separation of the different effects using [Formula \(20\)](#):

$$e_{L,ES} = e_{L,ES,del} \cdot e_{L,ES,dis} \cdot e_{L,ES,gen} \tag{20}$$

where

- P is the installed electric power density [W/m²];
- P_e is the electrical evaluation power density for determination of the energy use [W/m²];
- $e_{L,ES,del}$ is the partial expenditure factor for delivery of electric light;
- $e_{L,ES,dis}$ is the partial expenditure factor for distribution of electric light;
- $e_{L,ES,gen}$ is the partial expenditure factor for generation of electric light.

The partial expenditure factor for delivery of electric light is calculated using [Formula \(21\)](#):

$$e_{L,ES,del} = \frac{F_{u,e}}{F_u} \tag{21}$$

where

- F_u is the utilization factor; based upon reflectances of ceiling 70 %, walls 50 %, floor 20 %;
- $F_{u,e}$ is the reference utilization factor

The utilization factor F_u and the reference utilization factor $F_{u,e}$ can be derived using [Table 10](#) and [Table 11](#), in dependence of the room index (K).

Table 10 — Utilization factor F_u as a function of the room index K

Upward flux fraction (UFF)	Room index K									
	0,6	0,8	1	1,25	1,5	2	2,5	3	4	5
10 % (direct)	0,45	0,52	0,56	0,62	0,64	0,69	0,72	0,76	0,79	0,79
30 % (dir./ind.)	0,39	0,44	0,48	0,51	0,54	0,57	0,60	0,62	0,64	0,67
70 % (ind./dir.)	0,26	0,31	0,36	0,41	0,45	0,51	0,56	0,57	0,64	0,67
90 % (indirect)	0,19	0,24	0,28	0,33	0,36	0,43	0,48	0,52	0,57	0,62

NOTE Intermediate values of the room index can be interpolated.

Table 11 — Reference utilization factor $F_{u,e}$ as a function of the room index K

Room index K	0,6	0,8	1	1,25	1,5	2	2,5	3	4	5
Utilization factor $F_{u,e}$	0,50	0,61	0,69	0,78	0,84	0,90	0,95	0,99	1,03	1,05

NOTE Intermediate values of the room index can be interpolated.

The partial expenditure factor for distribution of electric light is calculated using [Formula \(22\)](#):

$$e_{L,ES,dis} = \frac{1}{\eta_{LB}} \tag{22}$$

where η_{LB} is the luminaire light output ratio.

The partial expenditure factor for generation of electric light is calculated using [Formula \(23\)](#):

$$e_{L,ES,gen} = \frac{\eta_{L,ref} \cdot f_B}{\eta_L} \tag{23}$$

where

$\eta_{L,ref}$ is the reference lamp luminous efficacy and has the value of 140 lm/W;

η_L is the lamp luminous efficacy [lm/W];

f_B is the factor for the efficiency of the operating device.

When applying the method 2, quick calculation method, given in [7.4.3.1](#), the partial expenditure factor for the electric lighting system can simplistically be calculated using [Formula \(24\)](#):

$$e_{L,ES} = 1,75 \cdot \frac{P_{j,lx}}{P_{j,lx,direct}} \cdot F_L \tag{24}$$

where

$P_{j,lx}$ is the power density of the areas (W/m²/lx);

$P_{j,lx,direct}$ is the power density of the area under reference condition;

F_L is the factor for light source efficiency of the equipment relative to the reference equipment (see [Table A.9](#)).

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

7.1 Output data

The output data of this method are listed in [Table 12](#).

Table 12 — Output data of this method

Description	Symbol	Unit
Specified time step	t_s	year
Annual energy required for lighting for an area or a zone	W_{az}	kWh
Summation of annual energy for electric lighting within the building	W	kWh

The preliminary LENI is the area normalized annual energy used for lighting within the building [kWh/m²]. LENI produced by method 2 provides a budget calculated Q_{LENI} .

NOTE This method only applies to annual estimation as default data for other intervals is not available.

7.2 Calculation time steps

The time step is yearly — Taken as 8 760 h.

7.3 Input data

7.3.1 Lighting system data

For the quick calculation method the energy estimation shall be based upon the electric lighting system that provides lighting in accordance with the requirements for non-residential buildings of ISO 8995-1/ CIE S 008 for lighting of indoor work places.

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

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

7.3.2 Luminaire data

7.3.2.1 General

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

7.3.2.2 Product description data (qualitative)

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

7.3.2.3 Product technical data

Default values for standby energy density are given in [Table A.1](#).

7.3.3 System design data

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

Technologies with inbuilt constant light output capabilities used in systems without constant illuminance sensing the F_c value shall be based on the method according to Annex F.

7.3.4 Operating conditions

The operating conditions for the lighting system shall be specified to fulfil the relevant lighting criteria and requirements for the tasks or activity in an area, zone or building and shall be managed by controls. The controls shall be manually or automatically operated.

7.3.5 Constants and physical data

Number of hours in a standard year (t_y) – defined as 8 760 h.

7.4 Calculation procedure

7.4.1 Applicable time step

The time step of the output shall be yearly.

7.4.2 Operating conditions calculation

Default values of t_D and t_N are provided in [Table A.2](#).

7.4.3 Energy calculation

7.4.3.1 General

The quick calculation method is shown in [Figure 3](#).

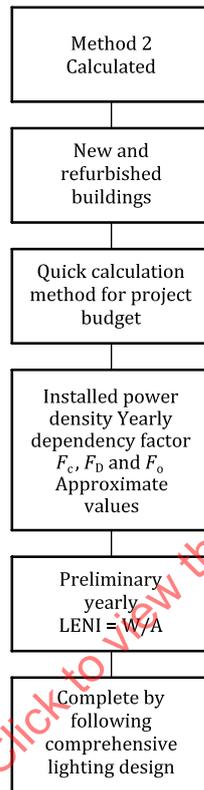


Figure 3 — Flow diagram for quick method of lighting energy calculation

7.4.3.2 Installed power calculation

At the preliminary, conceptual stage for a new design or refurbishment of a building the total installed power P_n (in this case budgeted) required for electric lighting for an area shall be estimated by the procedure according to [Annex B](#).

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

7.4.3.3 Standby system power requirements

Default data for the required standby energy for battery charging of emergency luminaires W_{pe} and for standby energy for automatic lighting controls W_{pc} are provided in [Table A.1](#).

7.4.3.4 Occupancy dependency factor F_o

Default values for the occupancy dependence factor F_o can be obtained in [Table A.7](#).

7.4.3.5 Daylight supply dependency factor F_D

The daylight supply dependency factor F_D shall be calculated according to ISO 10916.

7.4.3.6 Constant illuminance dependency factor F_c

Default values for the constant illuminance dependency factor F_c are provided in [Table A.8](#).

7.4.3.7 Energy calculation

$$Q_{\text{LENI,sub}} = \left\{ F_c \cdot (P_j / 1\,000) \cdot F_o \left[(t_D \cdot F_D) + t_N \right] \right\} + 1 + 1,5 \left[\text{kWh} / \text{m}^2 \right] \quad (25)$$

where

$Q_{\text{LENI,sub}}$ is the Lighting Energy Numeric Indicator for the area [kWh/m²];

F_c is constant illuminance factor;

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

F_o is the occupancy dependency factor;

t_D is daylight time [h];

F_D is the daylight dependency factor for the area;

t_N is the daylight absence time [h] for the area.

NOTE Constants 1,0 and 1,5 are the default standby energy density for battery charging and controls respectively.

If national values are not available the default values for P_n , t_D , t_N , F_c , F_D , F_o , W_{pe} and W_{pc} which are given in [Annex A](#) should be used.

The annual energy required for electric lighting within the area or zone shall be established by [Formula \(26\)](#):

$$W_{\text{az}} = Q_{\text{LENI,sub}} \cdot A_i \left[\text{kWh} \right] \quad (26)$$

where

W_{az} is the total annual energy required for lighting for the zone or area [kWh];

$Q_{\text{LENI,sub}}$ is the Lighting Energy Numeric Indicator for the relevant zone or area [kWh/m²];

A_i is the total useful floor area of the relevant zone or area [m²].

$$Q_{\text{LENI}} = \frac{\sum_{i=1}^{i=n} (Q_{\text{LENI,sub},i} \cdot A_i)}{A} \quad (27)$$

where

Q_{LENI} is the Lighting Energy Numeric Indicator for the building [kWh/m²];

n is the number of areas under consideration;

A_i is the total useful floor area of the relevant space [m²];

A is the total useful floor area of the building [m²].

The annual energy required for electric lighting within the building shall be established by [Formula \(28\)](#):

$$W = Q_{LENI} \cdot A \quad [\text{kWh}] \tag{28}$$

where

W is the total annual energy required for lighting for the building [kWh];

A is the total useful floor area of the building [m²].

7.5 Expenditure factors for lighting systems

For a description of the expenditure factor calculation see [6.5](#).

8 Method 3 — Metered energy used for lighting

8.1 Output data

The output data of this method are listed in [Table 13](#).

Table 13 — Output data of this method

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

The metered LENI is the area normalized annual energy used for lighting within the building [kWh/m²]. LENI produced by method 3 provides the actual Q_{LENI} .

8.2 Calculation time steps

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

The time step of the output can be:

- yearly;
- monthly, or
- hourly.

8.3 Input data

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

8.4 Calculation procedure of annual energy

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

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

$$W_{mt} = \sum W_t \quad [\text{kWh}] \quad (29)$$

The annual energy for electric lighting within a building shall be calculated using the [Formula \(30\)](#):

$$W = 8\,760 / t_s \cdot W_{mt} \quad [\text{kWh}] \quad (30)$$

where t_s is the time step [h].

Q_{LENI} for the building shall be established using [Formula \(13\)](#).

9 Quality control

9.1 Method 1

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

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

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

The calculation report shall include a statement of the calculation method used and the summation of annual energy values for electric lighting within the building W [kWh].

9.2 Method 2

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

The calculation report shall include a statement of the calculation method used and the summation of the annual budget energy values for electric lighting within the building W [kWh].

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

9.3 Method 3

The report shall include a statement of the measurement method used and the summation of the annual metered energy values for electric lighting within the building W [kWh].

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

The energy or power meters shall conform to the requirements for Class C as defined in IEC 50470 (all parts).

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

10 Compliance check

10.1 General

When required compliance shall be checked using one of the procedures given in [10.2](#) to [10.4](#).

10.2 Method 1

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

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

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

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

10.3 Method 2

This method provides a budget energy value. No compliance check can be made until a comprehensive calculation according to method 1 has been performed.

10.4 Method 3

The energy usage of the electric lighting installation shall be verified by metering as described in [Clause 8](#).

Annex A (informative)

Input data sheet with default values and choices

A.1 Introduction

This annex gives informative default values and informative default choices.

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

A.2 Method 2

A.2.1 System design data

A.2.1.1 General

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

A.2.1.2 Standby energy density

Table A.1 — Standby energy density

Purpose	Symbol	Default annual energy density kWh/m ²
Battery charging of emergency luminaires	W_{pe}	1
Standby energy for automatic lighting controls	W_{pc}	1,5

A.2.1.3 Annual operating hours

Table A.2 — Annual operating hours — Building type

Building type	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
Sports facilities	2 000	2 000	4 000
Wholesale and retail services	3 000	2 000	5 000
Manufacturing factories	2 500	1 500	4 000

A.2.1.4 Daylight supply factor for vertical façades

The daylight supply factor for vertical façades is listed in [Table A.3](#).

Table A.3 — Daylight supply factor for vertical façades

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

A.2.1.5 Daylight supply factor for roof lights

The utilisation η_R as function of room index K is listed in [Table A.4](#).

Table A.4 — Utilisation η_R as function of room index K

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

$F_{D,S}$ as function of daylight availability classification D_{class} , where daylight availability is classified in accordance to ISO 10916, see [Table A.5](#).

Table A.5 — Daylight supply factor for roof lights, $F_{D,S}$ as function of D_{class}

D_{class}	None	Low	Medium	Strong
$F_{D,S}$	0	0,68	0,85	0,92

A.2.1.6 Absence factor F_A for rooms and zones in building types

The absence factor for rooms and zones in building types is listed in [Table A.6](#).

Table A.6 — Absence factor 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 2-6 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		

Table A.6 (continued)

Overall building calculation		Room by room calculation	
Building type	F_A	Room type	F_A
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
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

A.2.1.7 Occupancy dependency factor F_0

The F_0 values provided in Table A.7 are a function of F_A and the lighting control system.

Table A.7 — Occupancy dependency factor F_0

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	0,650	0,550	0,450	0,350	0,250	0,000
Auto on/dimmed	1,000	0,975	0,950	0,850	0,750	0,650	0,550	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

A.2.1.8 Example constant illuminance dependency factor F_c

Table A.8 — 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
Factory	Trunking mounted open HF dimmable fluorescent lamp luminaires, dirty environment, biannual bulk lamp change and luminaire clean	0,6	0,80

Table A.9 — Factor for light source efficiency F_L

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

A.3 Method 3

No default data.

Annex B (normative)

Simplified method for installed power estimation

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

Installed power assessment for non-residential buildings

The budget installed power required for an area in the building is estimated using [Formula \(B.1\)](#):

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

where A is the relevant area in the building [m^2].

The power density for the lighting in an area of building may be assessed using [Formula \(B.2\)](#):

$$P_j = P_{j,\text{lx}} \cdot E_{\text{task}} \cdot F_{\text{CMF}} \cdot F_{\text{CA}} \cdot F_{\text{L}} \quad (\text{B.2})$$

where

- P_j is the power density of the area [W/m^2];
- $P_{j,\text{lx}}$ is the power density per lux of the area [$\text{W}/(\text{m}^2\text{lx})$];
- E_{task} is the maintained illuminance that the lighting system will be designed to provide [lx];
- F_{CMF} is the correction factor to account for the maintenance factor that will be used in the lighting system design;
- F_{CA} is the factor to account for the reduced power required if parts of the area are lit to a lower level;
- F_{L} is the correction factor to account for the efficiency of the lighting equipment that will be used in the lighting system.

Evaluation of $P_{j,\text{lx}}$

The value of $P_{j,\text{lx}}$ 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 in accordance with its room index K which may be evaluated using [Formula \(B.3\)](#):

$$K = \frac{L_R \cdot w_R}{h_m (L_R + w_R)} \quad (\text{B.3})$$

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 height of the luminaires above the working plane in the room or zone [m].

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

[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 %.

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

K	Upward Flux Fraction (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

Evaluation of F_{CMF}

The lighting scheme shall be 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 CIE 97. Once the overall maintenance factor f_m for the installation is determined, [Formula \(B.4\)](#) shall be used to calculate the correction factor to account for the maintenance factor f_m :

$$F_{CMF} = \frac{0,8}{f_m} \quad (B.4)$$

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 where it is necessary to consider the depreciation of the luminous flux, the light source survival, the luminaire maintenance factor and the 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.

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.

[Table B.2](#) gives the required background illuminances associated with particular values of task illuminance.

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

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

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

Once the illuminance on the surrounding areas has been determined then F_{CA} can be evaluated by [Formula \(B.5\)](#):

$$F_{CA} = \frac{A_s \cdot E_{\text{task}} + (A - A_s) \cdot E_{\text{sur}}}{E_{\text{task}} \cdot A} \tag{B.5}$$

where

A is the area of the room or zone [m²];

A_s is the sum of the task areas within the room or zone [m²].

Evaluation of F_L

The correction factor to account of the efficiency of the lighting equipment F_L is provided in [Table A.9](#) which gives the values for luminaires with common lamp types. The table is based on a survey of a large number of luminaires and gives the median value for all luminaires surveyed with a particular lamp type.

Annex C (normative)

Assessment of the installed power for lighting systems in existing buildings

In existing buildings where the individual power of a luminaire i , P_i is known the total power P_n can be calculated by the summation of the rated power of each installed luminaire:

$$P_n = \sum_{i=1}^{i=n} P_i \quad [\text{W}] \quad (\text{C.1})$$

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

In existing buildings where the power P_i of the luminaire i , is not known this power can be estimated as:

- a) For lamps operating directly on mains supply voltage e.g. mains voltage incandescent lamps, self-ballasted fluorescent lamps etc.:

$$P_i = P_r \cdot n_{La} \quad (\text{C.2})$$

where

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

P_r is the lamp rated power.

- b) For lamps connected to the mains supply via a ballast or transformer in the luminaire:

$$P_i = 1,2 \cdot P_r \cdot n_{La} \quad (\text{C.3})$$

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

Annex D (normative)

Occupancy estimation

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

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

- in meeting rooms (whatever the area covered by one switch and/or by one detector), as long as they are not switched on ‘centrally’, i.e. together with luminaires in other rooms or zones,
- in other rooms or zones, if the area illuminated by a luminaire or by a group of luminaires that are (manually or automatically) switched together, is not larger than 30 m², and if the luminaires are all in the same room or zone. In addition, in the case of systems with automatic presence and/or absence detection the area covered by the detector should closely correspond to the area illuminated by the luminaires that are controlled by that detector.

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

In the expressions for determining F_o the default value of F_{oc} is fixed as a function of the lighting control system, as given in [Table D.1](#) and the default value of F_A is determined at either building or room level, as given in [Table D.2](#). F_o as a function of F_A for the different control systems is given in [Figure D.1](#) and [Table D.3](#).

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

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

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

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

Table D.1 — F_{oc} values

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

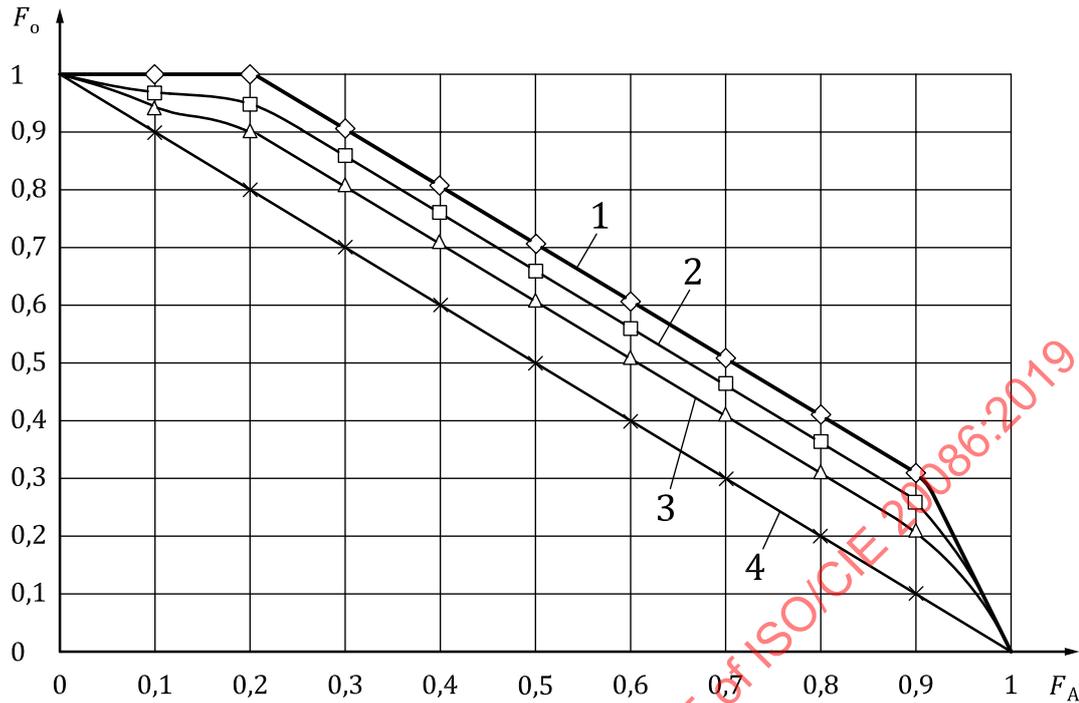
NOTE 1 The value of F_o can range from 0,0 to 1,0. The absence factor corresponds to the fraction of the reference operating time ($t_D + t_N$) that a building, room or zone is not in use. (Sleeping hours can usually be considered equivalent to absence.) When the building, the room or zone is permanently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

Table D.2 — F_A values

Overall building calculation		Room by room calculation		
Building type	F_A	Building type	Room type	F_A
Offices	0,20	Offices	Cellular office 1 person	0,40
			Cellular office 2–6 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	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

Table D.2 (continued)

Overall building calculation		Room by room calculation		
Building type	F_A	Building type	Room type	F_A
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
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
		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



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

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

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

NOTE 2 These include meeting rooms in office buildings and hotels, classrooms, cinemas etc.

NOTE 3 For programming purposes, the F_o value estimation can be rewritten as a single expression:

$$F_o = \min \left\{ 1 - \left[(1 - F_{oc}) F_A / 0,2 \right]; (F_{oc} + 0,2 - F_A); \left[7 - (10 \cdot F_{oc}) \right] \cdot (F_A - 1) \right\} \quad (D.1)$$

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

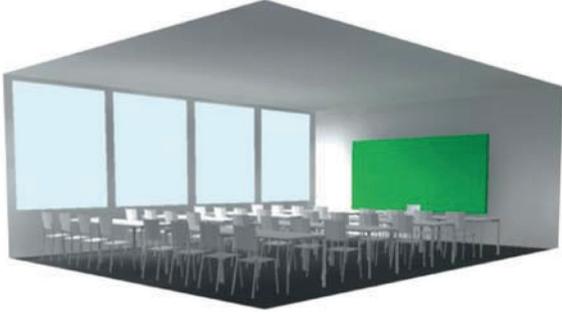
Annex E (informative)

Expenditure factors for lighting systems

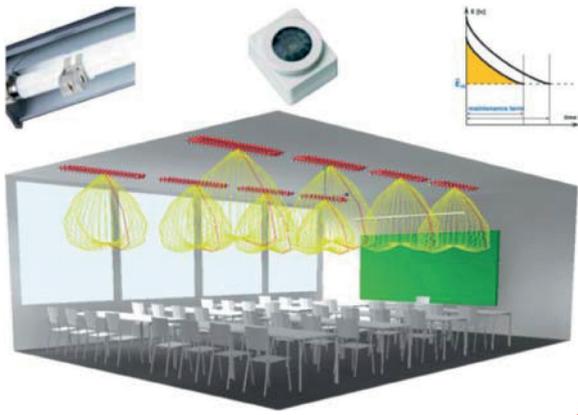
E.1 General

As LENI (Lighting Energy Numeric Indicator), represents the absolute amount of energy required for a lighting scheme it does not directly provide indications on the efficiency of the lighting technology employed. The concept of expenditure factors is therefore introduced to complement LENI, intending to render energy flows in lighting systems more transparent. As the same concept - of with efficiency factors as ratio of energy need to energy used being the inverted of the expenditure factors - are already well known for other building systems like heating and cooling, the concept allows for a uniform and homogeneous rating over all building services systems by differentiating energy need and energy use. The expenditure factor for lighting systems is composed of partial expenditure factors for the respective technical installations. This includes the lighting control systems depending on presence of users and daylight conditions and the electric lighting system. Again, the latter can be broken down into the partial expenditure factors for light generation, distribution, and delivery. The concept of expenditure factors does not represent a new or alternative calculation method. Instead it only relates technical performance parameters of a lighting design to reference values. As it is not possible to assess the energy demand for lighting in general, it was necessary to define a reference lighting system with respective reference values.

[Figure E.1](#) gives a depiction of the influences (a) on the energy need for lighting W_{nd} and (b) of the determination of the expenditure factor for lighting systems by the partial expenditure factors.

	Space geometry: $W_{nd}=f(\dots, \text{room index}, \dots)$
	Reflection: $W_{nd}=f(\dots, \text{reflection coefficient}, \dots)$
	Façade: $W_{nd}=f(\dots, \text{daylight availability}, \dots)$
	Usage: $W_{nd}=f(\dots, E_{\text{task}}, \text{usage time}, \text{absence}, \dots)$

a) Depiction of the influences on the energy need for lighting W_{nd}

	Electric lighting	$e_{L,ES}$
	Occupancy dependent control	$e_{L,O}$
	Daylight dependent control	$e_{L,D}$
	Constant illuminance control	$e_{L,C}$
	Expenditure factor for lighting	e_L

b) Depiction of the expenditure factor for lighting system e_l and of the partial expenditure factors

Figure E.1 — Influences on the energy need for lighting and determination of the expenditure factor for lighting systems

E.2 Energy need and energy use for lighting

In general, the notion of energy need describes the energy a consumer receives from an appliance in the requested form (heat, light, drives, etc.). For lighting it can be described as follows: The energy need for lighting W_{nd} is the energy equivalent of the luminous flux that is required for electric space lighting (on the basis of defined lighting requirements), having been weighted with the total operating time and assuming ideal lighting control (ideal use of appropriate potentials like absence, daylight and compensation for over-dimensioning due to maintenance of the electric lighting system). Whereas the energy use generally describes the amount of energy to be supplied to the corresponding subsystem. For lighting it reflects the electrical energy input to a lighting system.

The energy need for lighting W_{nd} includes all influences, which are not to be attributed to the efficiency of the lighting technology, such as:

- Usage.
 - Requirements pertaining to the visual task: Generally, spaces that have to meet high requirements with regard to the visual task are characterized by higher values of maintained illuminance and by higher requirements to the luminance distribution within the space - these spaces are hence distinguished by higher values of W_{nd} compared to spaces complying with less strict requirements. As a consequence, W_{nd} depends on the requirements for the visual tasks.

- Usage times: Generally, frequently occupied spaces with long usage times are characterized by higher values of W_{nd} (due to the longer total operating time of the lighting system) compared to spaces with shorter usage times. Spaces that are occupied primarily at night (prevailing night-time usage) will be characterized by higher values of W_{nd} than comparable spaces with prevailing day-time usage.
- Relative absence: any long relative absence (i.e. a non-occupied space) will reduce W_{nd} .
- Maintenance of lighting installations: spaces distinguished by high maintenance factors (e.g. due to minor, use-related pollution of luminaires and spaces) require less over-dimensioned new lighting installations; from this, a smaller amount of energy need W_{nd} will result.
- Space geometry.
Due to a relatively higher light absorption of the enclosing surfaces, small compact spaces will need higher luminous fluxes to fulfil the requirements on indoor space illuminances and luminances, which is why they have higher values of W_{nd} than large, wide rooms.
- Reflection coefficients of space enclosing surfaces.
Dark spaces require higher luminous fluxes to meet the requirements on indoor space illuminances and luminances, therefore they are characterized by higher values of W_{nd} than spaces enclosed by bright-coloured surfaces.
- Façade geometry and photometry, location, climate.
Spaces that are poorly supplied with daylight cause higher total operating times (hence, higher values of W_{nd}) than spaces benefitting from good daylight supply. The energy use for lighting W_{us} corresponds to the calculated amount of an energy carrier (usually electricity) that is needed to cover the energy need for lighting.

E.3 Expenditure factor for lighting

E.3.1 General

In general, an expenditure factor describes the ratio between cost (expenditure) and benefit, thus forming the reciprocal value of a utilization factor. According to the above given definitions, it can be written:

$$W_{nd} = p_{Ref} \cdot \left[A_D (t_D \cdot F_{D,Ref} \cdot F_{o,Ref} \cdot F_{c,Ref} + t_N \cdot F_{o,Ref} \cdot F_{c,Ref}) + A_{ND} (t_D \cdot F_{o,Ref} \cdot F_{c,Ref} + t_N \cdot F_{o,Ref} \cdot F_{c,Ref}) \right] \quad [\text{kWh}] \quad (\text{E.1})$$

This amount of energy need will be supplied by the actually installed lighting system, requiring the following energy input or expenditure, termed energy use W_{us} :

$$W_{us} = p \cdot \left[A_D (t_D \cdot F_D \cdot F_o \cdot F_c + t_N \cdot F_o \cdot F_c) + A_{ND} (t_D \cdot F_o \cdot F_c + t_N \cdot F_o \cdot F_c) \right] \quad [\text{kWh}] \quad (\text{E.2})$$

The expenditure factor for lighting systems is obtained as ratio of the two above given energy demands:

$$e_L = \frac{W_{us}}{W_{nd}} \quad (\text{E.3})$$

As said before, it can be derived by formal separation of the individual influences for constant illuminance control, for occupancy dependent and daylight dependent lighting control as well as for the electric lighting system. Each of these influences is described by a partial expenditure factor, whose multiplication result in the expenditure factor for lighting systems [see [Formula \(E.4\)](#)]. These partial factors and their derivation will be described in the following paragraphs. In general, they all account

for the efficiency of the respective component, compared to an ideal system, which is expressed by a ratio, with the ideal system covered in the denominator.

$$e_L = e_{L,C} \cdot e_{L,O} \cdot e_{L,D} \cdot e_{L,ES} \quad (\text{E.4})$$

E.3.2 Partial expenditure factor for constant illuminance control $e_{L,C}$

The partial expenditure factor for constant illuminance control accounts for the efficiency of the constant illuminance control and depends on the maintenance factor. It is calculated by [Formula \(E.5\)](#):

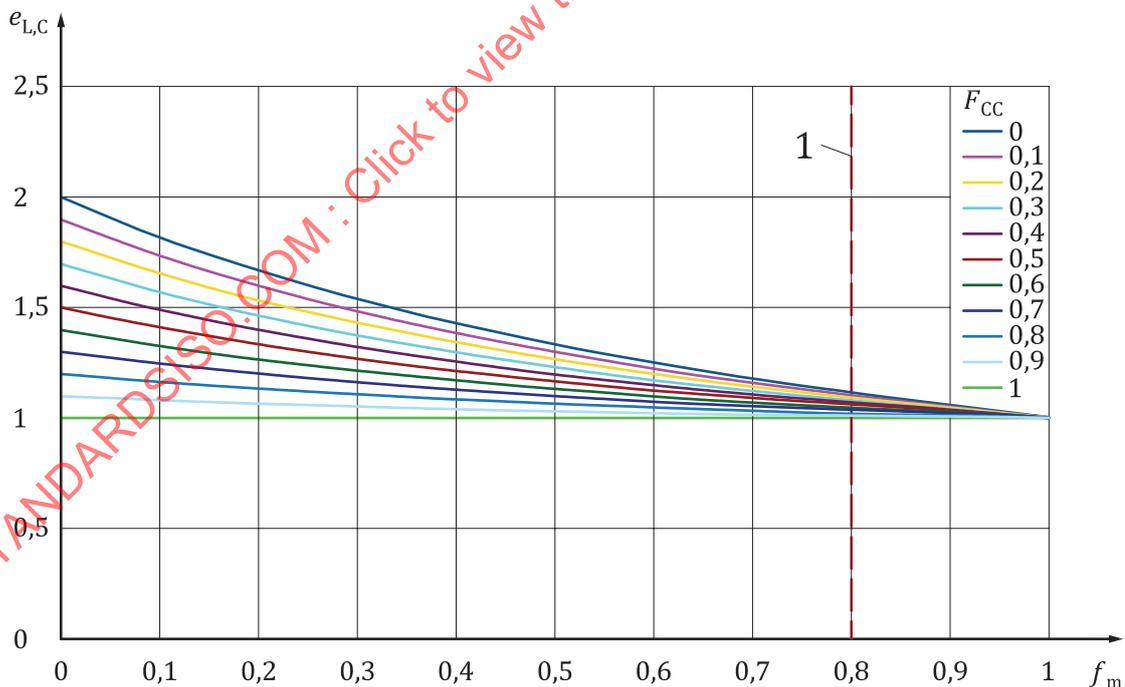
$$e_{L,C} = \frac{1 - \frac{1}{2} F_{CC} (1 - f_M)}{1 - \frac{1}{2} (1 - f_M)} \quad (\text{E.5})$$

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

NOTE The impact of the over-design of schemes (for example modular spacing) is under consideration.

An ideal constant illuminance control with $F_{CC} = 1$ will dim the light exactly at the maintained illuminance, thus resulting in a partial expenditure factor of $e_{L,C} = 1$. The absence of constant illuminance control, i.e. $F_{CC} = 0$ will result in the undimmed operation of the system, thus requiring higher energy inputs. Assuming a maintenance factor f_m of 0,6 and $F_{CC} = 0$, a partial expenditure factor $e_{L,C} = 1,25$ will result; assuming $f_m = 0,9$, the partial expenditure factor will be $e_{L,C} = 1,05$, and for the reference- f_m of 0,8 it will be $e_{L,C} = 1,11$.

The dependency of the partial expenditure factor for constant illuminance control is illustrated in [Figure E.2](#).



Key

1 reference maintenance factor

Figure E.2 — Illustration of the partial expenditure factor for constant illuminance control $e_{L,C}$ as a function of the efficiency factor for constant illuminance control F_{CC} and the maintenance factor f_m

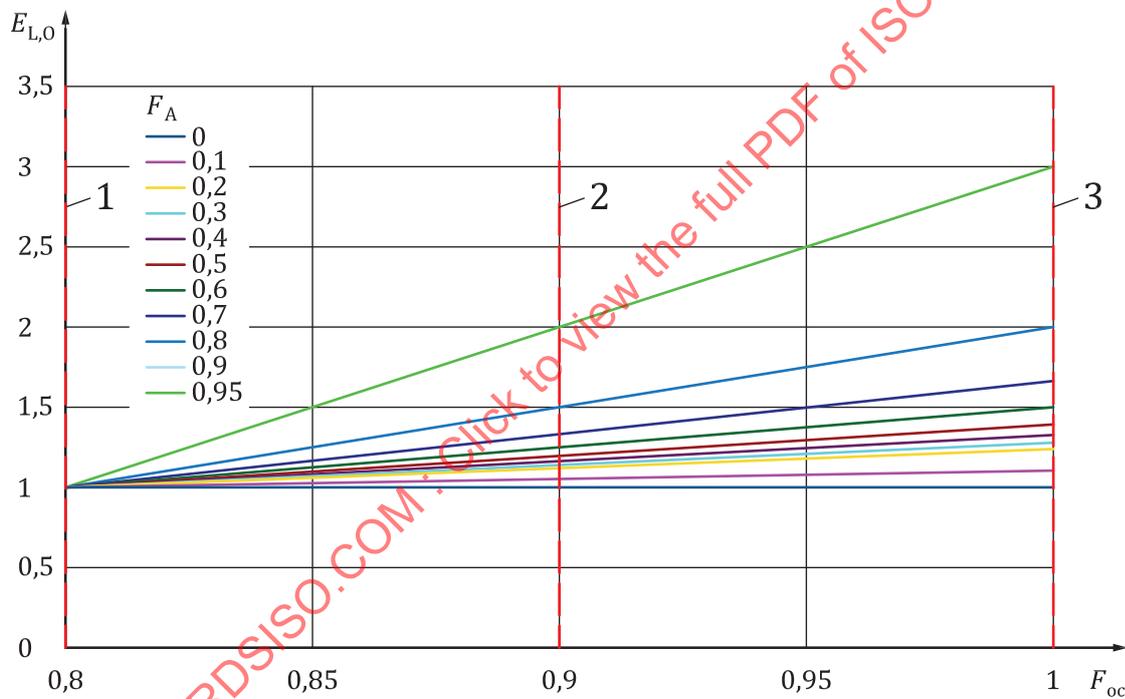
E.3.3 Partial expenditure factor for occupancy dependent lighting control $e_{L,0}$

The partial expenditure factor for occupancy dependent lighting control takes the energy saving potential of occupancy dependent lighting control into account. It is calculated by dividing the occupancy dependency factor F_o , accounting for the type of system and its effect depending on the type of usage, by the relative presence in the area under consideration (derived by $1 - F_A$)

$$e_{L,0} = \frac{F_o}{(1 - F_A)} \tag{E.6}$$

An ideal occupancy detection system will fully recognize the absence of persons and switch off the lights, which will produce a partial expenditure factor equal to 1. Manual switching in response to room or zone occupancy, for instance in a cellular 1 person office ($F_A = 0,4$) with manual switch ($F_o = 0,8$) will result in an expenditure factor of $e_{L,C} = 1,33$. If an automatic presence detection system with $F_{oc} = 0,9$ ($F_o = 0,7$) was installed in the same type of space this would result in a partial expenditure factor of $e_{L,C} = 1,17$

Figure E.3 illustrates the dependency of the partial expenditure factor for occupation control. The normative values for F_{oc} as specified in Annex E have been marked.



- Key**
- 1 manual on/auto off
 - 2 auto off/auto on
 - 3 manual switch

Figure E.3 — Illustration of the partial expenditure factor for occupancy dependent lighting control $e_{L,0}$ as a function of the controls function factor F_{oc} and the absence factor F_A

E.3.4 Partial expenditure factor for daylight dependent lighting control $e_{L,D}$

The partial expenditure factor for daylight dependent lighting control correlates the effect of the actual control system to the ideal case. Formula (E.7) also accounts for the fact that this control system does

neither affect the lighting energy demand in areas not benefitting from daylight nor the one during night time hours.

$$e_{L,D} = \frac{A_D \left[t_D \cdot (1 - F_{D,S} \cdot F_{D,C}) + t_N \right] + A_{ND} (t_D + t_N)}{A_D \left[t_D \cdot (1 - F_{D,S}) + t_N \right] + A_{ND} (t_D + t_N)} \quad (\text{E.7})$$

When applying the document's quick method 2, $F_{D,C} = 0,52$, as manual daylight-responsive control is assumed [see 7.4.3.5, Formula (30)].

An ideal daylight control system will use electric lighting to supplement the available amount of daylight precisely up to the point where the required illuminance is achieved, thus resulting in a partial expenditure factor of 1. For instance, manual daylight-dependent lighting control in a personal office with "strong daylight availability" ($t_D = 2\,250$ h; $t_N = 250$ h and $E_m = 500$ lx with $F_{D,E} = 0$, in a fully daylight-supplied single-occupant office (i.e. $A_D = A$ or $A_{D, \text{normalized}} = 1$) with $F_{D,S} = 0,7$ will result in an expenditure factor of $e_{L,D} = 1,73$. For automated daylight control (dimmed, stand by losses, no switch-on) with $F_{D,C} = 0,8$, a value of $e_{L,D} = 1,34$ will result under the same boundary conditions. If only half of the room or zone is receiving daylight (i.e. $A_D = A_{ND} = A/2$ or $A_{D, \text{normalized}} = 0,5$), the value for the automated system will be $e_{L,D} = 1,09$.

The partial expenditure factor for the daylight-dependent control of electric lighting $e_{L,D}$ is illustrated in Figure E.4 for several typical parameter settings.

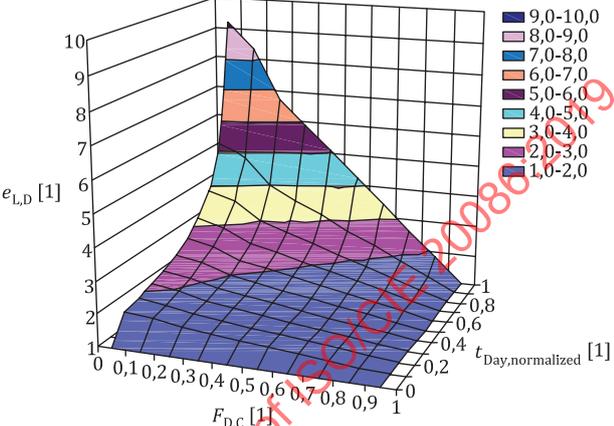
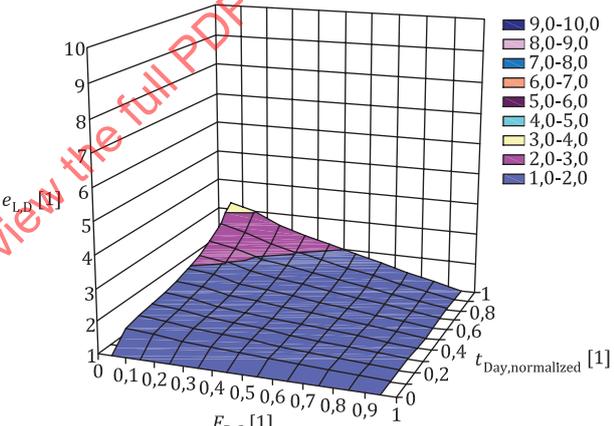
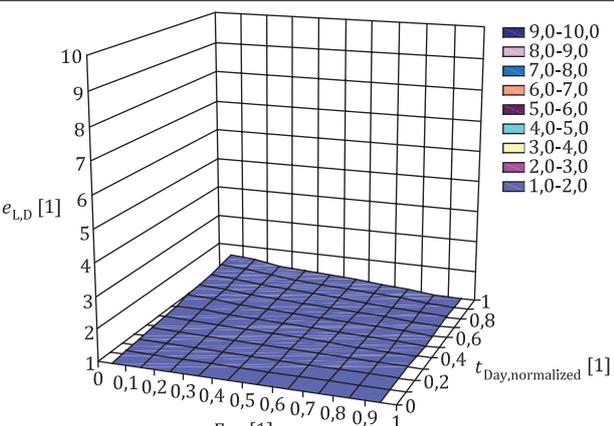
Space type (example)	Normalized area with daylight supply	Typical daylight supply	Partial expenditure factor for daylight-dependent electric lighting control $e_{L,D}$
	$A_{D,normalized}$	$F_{D,S}$	$e_{L,D}$ as a function of $t_{D,normalized}$ and $F_{D,C}$
Manufacturing hall with roof lights	1,0	0,9	
Personal office (single occupant)	1,0	0,7	
Open floor plan office	0,2	0,7	

Figure E.4 — Illustration of the partial expenditure factor for daylight dependent electric lighting control $e_{L,D}$ as a function of the normalized daytime $t_{D,normalized}$ ($t_{D,normalized} + t_{N,normalized} = 1$), the efficiency factor for constant illuminance control $F_{D,C}$ for different values of the normalized area with daylight supply $A_{D,normalized}$ ($A_{D,normalized} + A_{ND,normalized} = 1$), and varying daylight supply factors $F_{D,S}$

E.3.5 Partial expenditure factor for the electric lighting system $e_{L,ES}$

Corresponding to the other partial expenditure factors, $e_{L,ES}$ is an object-related parameter. On the one hand, a luminaire will thus imply two different expenditure factors in two different room or zone situations. On the other hand, this circumstance will also allow to directly compare the energy performance of two different luminaires in one room or zone situation. This approach is similar to the principle of balance calculations used in other evaluation areas (heating, cooling, ventilation).

The partial expenditure factor for the electric lighting system correlates the installed electric power density P with the electrical evaluation power for supplying the luminous flux that is needed to fulfil the use-related requirements, when applying a reference system defined for this purpose. How to determine these power densities and the resulting factor, respectively, depends on the calculation method applied. The determination according to the following three different approaches will be introduced in the following:

- Comprehensive calculation method 1 of the document;
- Simplified utilization factor method¹⁾;
- Quick calculation method 2 of the document (derived from the simplified utilization factor method).

As all approaches rely on the definition of a reference light source, this will be introduced next.

Reference light source: luminous efficacy and luminous intensity distribution

For the determination of expenditure factors, it is necessary to define a reference light source. Analysing the composition of a light source's optical radiation spectrum, the luminous efficacy η_L , the (most similar/close) colour temperature T and the general colour rendering index R_a can be clearly determined. Theoretically, the target function of an ideal light source should ensure the highest possible luminous efficacy ($\eta_L = 683 \text{ lm/W}$), the highest possible general colour rendering index ($R_a = 100$) and the independence of the light colour. Physically such a light source cannot be realized.

Based on the assumptions that fluorescent lamps and discharge lamps can be considered to be fully developed and technically mature and LEDs are expected to become an important light source in future and to be further developed, a reference luminous efficacy of 140 lm/W was chosen. This is estimated to be a realistic, feasible value for LEDs. Further, there is also a relation to natural lighting using daylight. For clear skies, the luminous efficacy of radiation can be found to take on values in this range. The value of 140 lm/W was determined being well aware of the fact that by this convention expenditure factors <1 might occur in selected illumination solutions using specialized lamps (like sodium-vapour lamps).

A reference luminous intensity distribution should meet the lighting requirements in accordance with ISO 8995-1/CIE S 008 in an ideal way with regard to energy performance. As such a luminous intensity distribution curve (I-table) cannot be specified independent of a certain object, it is only possible to make an agreement concerning a real I-table that meets the requirements in good approximation and which should be used as a reference.

In general, the requirements concerning the use of energy can be fulfilled most efficiently by using direct lighting systems. For horizontal work planes as well as regarding further requirements, e.g. concerning the cylindrical illuminance inside the space, the highest room utilization factors will result for light distribution A50²⁾. This type is thus applied as reference luminous intensity distribution. Since luminous intensity distributions (I-table) also vary within one class, exactly one distribution of the type will be selected to satisfy the required uniqueness.

1) A Technical Report as explanatory document to this document is under development explaining the simplified utilization factor method.

2) A50 characterizes the luminous intensity distribution of a luminaire with an upward flux fraction (UFF) of 0 % and a direct flux fraction (DFF) onto the utilization plane between 60 % and 70 %.

a) **Determination of $e_{L,ES}$ when applying the document’s method 1 (comprehensive calculation)**

Within method 1, the installed power and resulting therefrom the installed power density is derived by simulation of the lighting situation, during the comprehensive lighting system design. In consequence, the power density of the reference lighting system needs to be calculated accordingly. This means, a respective lighting situation with the reference light source as defined above in the area under consideration needs to be computed.

b) **Determination of $e_{L,ES}$ when applying the simplified utilization factor method**

The power densities and thus the partial expenditure factor for the electric lighting system can be determined from the luminous efficacy, the energy expenditure factor of the lamp operating device and the light output ratio (luminaire efficiency) as well as the room utilization factor, as demonstrated in the following [Formula \(E.8\)](#). These parameters are generally available. The formula can be further rearranged corresponding to the influences of delivery, distribution and generation of electric light. Consequently also the partial expenditure factor can be derived by formal separation of these different effects, for which partial expenditure factors ($e_{L,ES,del}$, $e_{L,ES,dis}$, $e_{L,ES,gen}$) were introduced.

$$e_{L,ES} = \frac{P}{P_{Ref}} = \frac{\frac{\Phi}{F_{u,e} \cdot \eta_{LB,Ref} \cdot \eta_{L,Ref} \cdot \frac{1}{f_{B,ref}}}}{\frac{\Phi}{F_u \cdot \eta_{LB} \cdot \eta_L \cdot \frac{1}{f_B}}} = \tag{E.8}$$

$$\frac{F_{u,e}}{F_u} \cdot \frac{\eta_{LB,Ref}}{\eta_{LB}} \cdot \frac{\eta_{L,Ref}}{\eta_L} \cdot \frac{f_B}{f_{B,ref}} = e_{L,ES,del} \cdot e_{L,ES,dis} \cdot e_{L,ES,gen}$$

Partial expenditure factor for delivery of electric light

The partial expenditure factor for delivery of electric light describes the emission of the luminous flux emitted from luminaires to the inside of the space (work plane). It establishes an object-specific relation (i.e. taking into account the space geometry and the respective space reflection coefficients) between the actual room utilization factor for the luminous intensity distribution of the selected luminaire and for a reference luminous intensity distribution. It is calculated using [Formula \(E.9\)](#):

$$e_{L,ES,del} = \frac{F_{u,e}}{F_u} \tag{E.9}$$

For rectangular rooms, the utilization factor F_u can simplified be determined as a function of the room index and upward flux fraction (UFF) using [Table E.1](#). This table also includes the reference utilization factor, which represents the values of a direct A50-system with a UFF of 0 %.

Table E.1 Utilization factors (actual and reference) as a function of the room index K and the upward flux fraction

Upward flux fraction (UFF)	Room index K									
	0,6	0,8	1	1,25	1,5	2	2,5	3	4	5
10 % (direct)	0,45	0,52	0,56	0,62	0,64	0,69	0,72	0,76	0,79	0,79
30 % (dir./ind.)	0,39	0,44	0,48	0,51	0,54	0,57	0,60	0,62	0,64	0,67
70 % (ind./dir.)	0,26	0,31	0,36	0,41	0,45	0,51	0,56	0,57	0,64	0,67
90 % (indirect)	0,19	0,24	0,28	0,33	0,36	0,43	0,48	0,52	0,57	0,62
0 % (reference case)	0,50	0,61	0,69	0,78	0,84	0,90	0,95	0,99	1,03	1,05

NOTE Intermediate values of the room index can be interpolated.

For the determination of the values given in the table the following typical reflection coefficients were applied: ceiling: 70 %, walls: 50 %, floor: 20 %.

Partial expenditure factor for distribution of electric light.

The partial expenditure factor for distribution of electric light relates the actual luminaire efficiency to the ideal luminaire efficiency ($\eta_{LB,Ref} = \eta_{LB,ideal} = 1$). It thus describes the luminaires' light distribution efficiency, i.e. the distribution efficiency of the light emitted from the lamps through the luminaires. In consequence, this factor is equivalent to the reciprocal of the luminaire light output ratio η_{LB} .

Partial expenditure factor for generation of electric light

The partial expenditure factor for generation of electric light relates the actual luminous efficacy and the efficiency of the light source's operating device to a reference luminous efficacy and an ideal operation of the light sources ($f_{B,Ref} = f_{B,ideal} = 1$). Information on the reference light source are given below.

c) Determination of $e_{L,ES}$ when applying the document's method 2 (quick calculation)

Like the calculation procedure of method 2 is derived from the simplified utilization factor method, this also applies for the determination of the partial expenditure factor for the electric lighting system. Applying the formulation of the installed power, according to the simplified method from [Annex B, Formula \(E.9\)](#) can be rearranged and simplified as shown below, when the design influences of the maintained illuminance, the maintenance factor and the surrounding area are regarded to be equal in both cases (reference and actual situation). In addition, the ratio of the power density values can be replaced by the above given quotient of the utilization factors, which depends on the room index:

$$e_{L,ES} = \frac{P}{P_{Ref}} = \frac{P_{j,lx} \cdot E_{task} \cdot F_{CMF} \cdot F_{CA} \cdot F_L}{P_{j,lx,Ref} \cdot E_{task} \cdot F_{CMF} \cdot F_{CA} \cdot F_{L,Ref}} = \frac{P_{j,lx} \cdot F_L}{P_{j,lx,Ref} \cdot F_{L,Ref}} = 2,33 \frac{P_{j,lx}}{P_{j,lx,Ref}} \cdot F_L = 2,33 \frac{F_u}{F_u} \cdot F_L \quad (E.10)$$

with

$$F_{L,Ref} = \frac{60 \text{ lm/W}}{140 \text{ lm/W}} = \frac{3}{7} = \frac{1}{2,33}$$

E.4 Application of expenditure factors

E.4.1 General

Besides rating the efficiency of the lighting situation, the application of expenditure factors allow an easy and at the same time very meaningful comparison of old and new systems. In offices, for instance, the expenditure factors for common electric lighting systems vary between values close to 2 for efficient (newly installed) lighting systems and frequently >6 for old installations. If new systems are provided with appropriate light management systems, overall expenditure factors between 2 and 3 will result, while manually operated lighting systems will produce factors close to 7. For existing systems, which are rarely equipped with light management components, even expenditure factors >10 can occur. [Figure E.5](#) presents an example of the energy flow density defined on the basis of expenditure factors for a personal office lit by an existing system. In [Figure E.6](#) an old and a new system are compared.

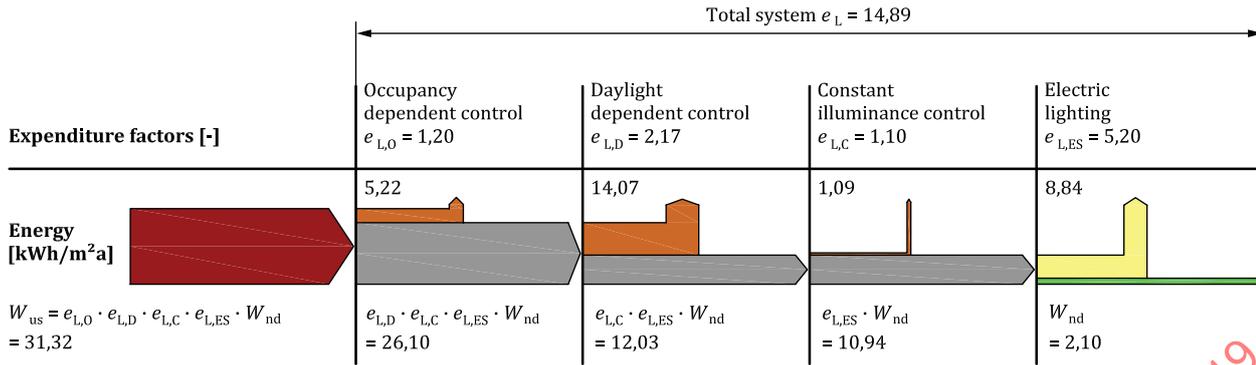


Figure E.5 — Example of the energy flows in a single-occupant office with an existing lighting system

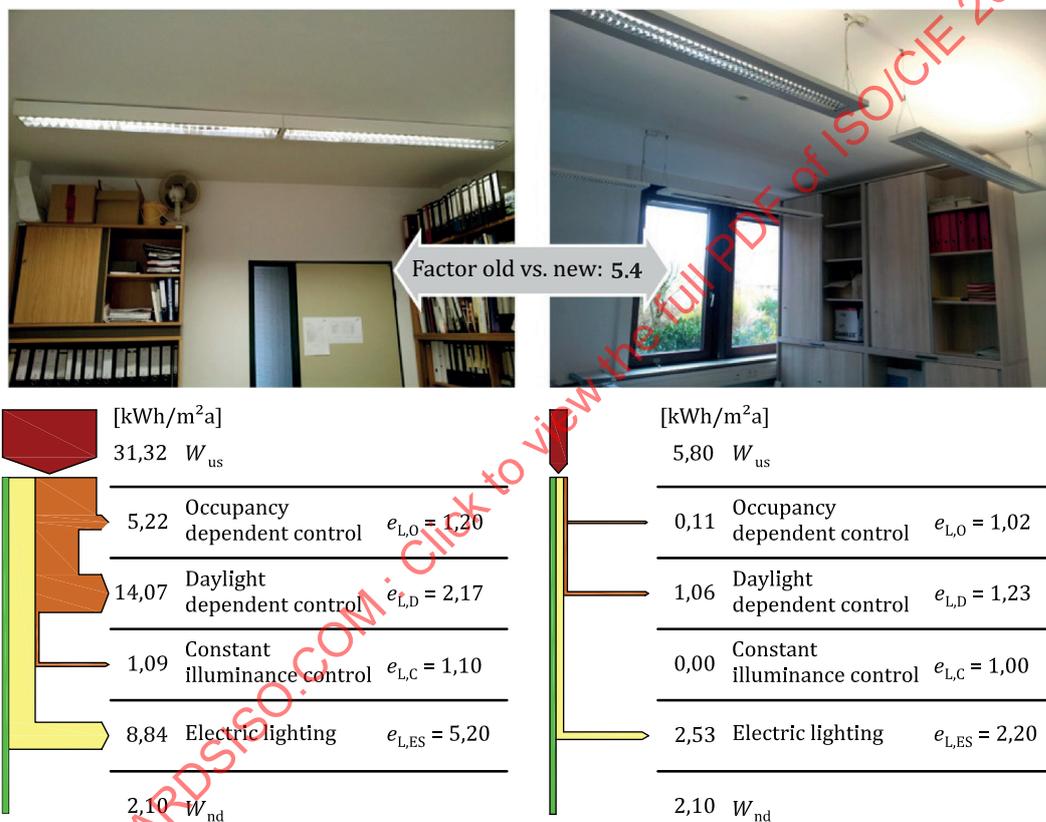


Figure E.6 — Comparable example of the energy flows in a single-occupant office with an old and a new system

E.4.2 Example calculation of expenditure factors for lighting systems

In the following, example calculations for several cases are presented. In a first step, seven different space types will be defined and parameterized. Then, the partial expenditure factors for the electric lighting system will be determined for various system configurations used in practice. As considered most illustrating, this will be done according to the determination of $e_{L,ES}$ following method b, applying the simplified utilization factor method. Lastly, the associated energy need, the expenditure factor, and the energy use for lighting will be determined and discussed for the typical variations of the space types, the electric lighting systems, and the lighting control solutions.