TECHNICAL REPORT

ISO/CIE TR 3092

First edition
2023-09

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

Reference number
ISO/CIE TR 3092:2023(E)

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Published in Switzerland

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Foreword

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

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

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

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

Introduction

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

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

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

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

Therefore, this document accompanies ISO/CIE 20086 and provides informative content to support the correct understanding, use and national implementation of the lighting standard. It also provides explanation of the lighting energy calculation methodology and working calculation example of integrated lighting control options. ISO/CIE 20086 defines the methods for estimating or measuring the amount of energy required or used for lighting in buildings. The method of separate metering of the energy used for lighting will also give regular feedback on the effectiveness of the lighting control. The methodology of energy estimation not only provides values for the Lighting Energy Numeric Indicator (LENI) but it will also provide input for the heating and cooling load estimations for the combined total energy performance of building indicator.

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

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

1 Scope

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

2 Normative references

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

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

CIE S 017, *ILV: International Lighting Vocabulary*

3 Terms and definitions

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

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

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

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

3.1
useful floor area
total gross floor area of all enclosed spaces, measured to the internal face of the external walls

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

4 Symbols and abbreviations

4.1 General

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

4.2 Symbols and abbreviations

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

Table 1 — Symbols and units

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

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

Table 1 *(continued)*

Symbol	Name of quantity	Unit
$P_{j,\text{lx}}$	Illuminance-normalized power density of area *j*	W/(m²lx)
P_n	Total power of n luminaires	W
P_{pc}	Total standby power for automatic lighting controls	W
P_{r}	Declared (marked) lamp rated power	W
Q_{LENI}	Lighting energy numeric indicator (LENI) for a building	kWh/m²
$Q_{\text{LENI,sub}}$	Lighting energy numeric indicator for an area or relevant zone	kWh/m²
t_{e}	Battery charge time	h
t_{D}	Daylight time	h
t_{N}	Daylight absence time	h
t_{s}	Specified time step	hour, month, year
t_{tot}	Total operating hours	h
t_{y}	Number of hours in a standard year	h
W	Total annual energy used for lighting	kWh
W_{az}	Annual energy required for lighting for an area or a zone	kWh
$W_{\text{L,t}}$	Total energy for illumination	kWh
W_{mt}	Total metered energy used for electric lighting	kWh
$W_{\text{P,t}}$	Total energy for standby	kWh
W_{t}	Energy used for lighting per time step	kWh
W_{pc}	Standby energy density for automatic lighting controls per year	kWh/m²
W_{pe}	Standby energy density for battery charging of emergency luminaires per year	kWh/m²
W_{R}	Width of the room or zone	m

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

For the purposes of this document, the specific subscripts listed in Table 2 apply.

Table 2 — Subscripts

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

5 Description of the methods

5.1 General

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

a) Method (1): comprehensive;

b) Method (2): quick calculation;

c) Method (3): direct metering (see figure 1).

These methods can provide the information on the electric energy required for lighting in the selected time steps and the Lighting Energy Numeric Indicator (LENI) for the whole building, individual room or zones. LENI can be used for comparison of similar buildings and as a measure of the lighting energy performance of the building.

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

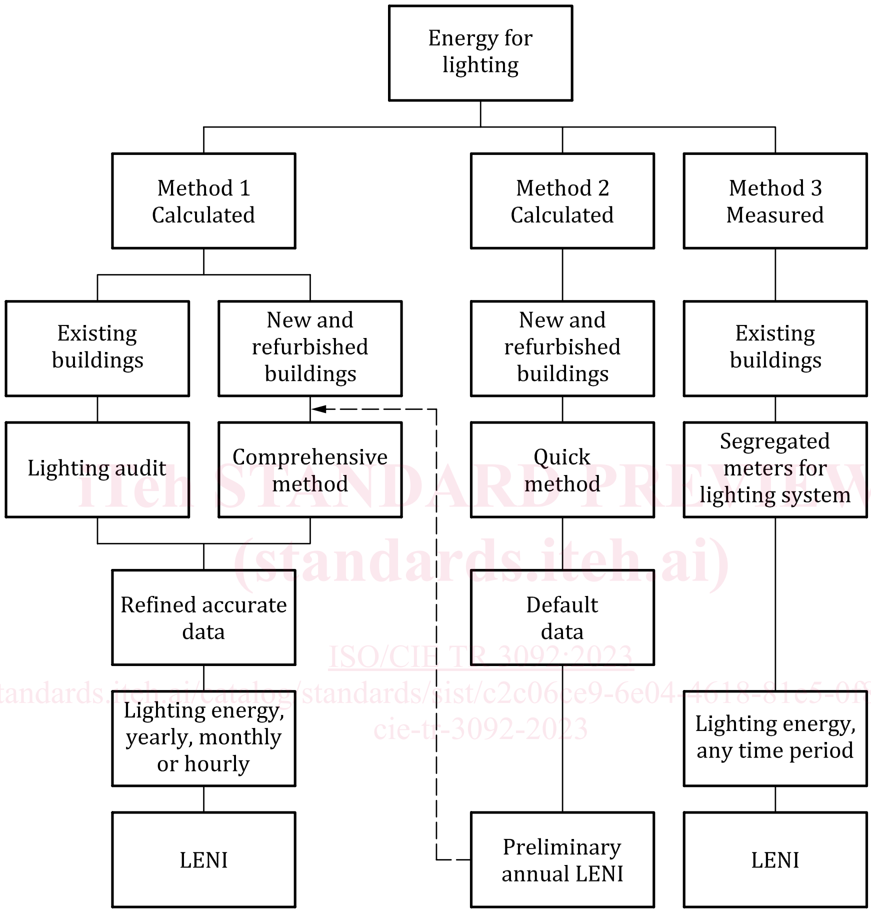

Figure 1 — Flow chart illustrating alternative routes to determine energy use

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

5.2 Method 1 – Comprehensive method

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

5.3 Optional methods

5.3.1 Method 2 – Quick calculation method

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

5.3.2 Method 3 – Direct metering method

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

6 Method 1 — Calculation of the energy required for lighting

6.1 Output data

For the purposes of this document, the output data of Method 1 listed in Table 3 apply.

Table 3 — Output data of Method 1

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

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

6.2 Calculation time steps

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

— yearly – 8 760 h/year,

— monthly – 730 h/month, or

— hourly – 1 h, derived from the monthly calculated value divided by 730,

— with accordance to the time step of the input data.

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

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

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

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

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

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

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

6.3 Input data

6.3.1 Lighting system data

6.3.1.1 General

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

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

— types of luminaires identified by a unique product reference code;

— quantities of each specific type of luminaire;

  — luminaires which respond to daylight (e.g. Manual, Automated/Dimmed, Automated/switched) to control the artificial light, when located in an A_D area (i.e. those close to windows). In these areas the daylight parameter $D_{ca,j}$. is calculated;

  — luminaires which respond to occupancy (e.g. Manual On/Off switch, Manual On/Off switch + additional automatic sweeping extinction signal, Auto on/Dimmed, Auto on/Auto off, Manual on/Dimmed, Manual on/Auto Off);

— control technique and device types;

  — Efficiency Factor of Constant Illuminance Control, F_{CC} (F_C calculated from f_m and F_{CC});

— maintenance factor (f_m) assumed in the design or defined by the maintenance schedule (for each room and/or area);

— dominant building type;

— latitude;

— longitude;

— luminous exposure H_{dir}/H_{glob};

— shading system solution (shading type/s) for rooms/areas;

— shading obstructing context (shading index/s);

— daylight time t_D;

— daylight absence time t_N;

— maintained illuminance of zone (lx) (E_{task});

— occupancy, F_O (for each room and/or area);

— users absence factor, F_A (for each room and/or area);

— window/rooflight/atrium properties;

— zone properties: set the properties of the zone.

6.3.1.2 New or refurbished building lighting system

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

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

Table 4 — Example of the luminaire schedule

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

6.3.1.3 Existing building lighting system

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

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

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

— specified time step, e.g. hourly, monthly or annually,

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

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

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

Table 5 — Standby energy density

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

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

6.3.2 Product data

6.3.2.1 General

See 6.3.2.3.

6.3.2.2 Luminaire description data (qualitative)

See 6.3.2.3.

6.3.2.3 Luminaire technical data

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

Table 6 — Luminaire identification

Code	Description

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

Table 7 — Power of luminaire *i* (P_i)

Code	Power, W

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

Code	Power, W