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Light and lighting – Energy performance of lighting in buildings — Calculation of the impact of daylight utilization

Lumière et éclairage — Performance énergétique de l'éclairage des bâtiments — Calcul de l'impact de l'utilisation de la lumière du jour

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Foreword

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This document was prepared by Technical Committee ISO/TC 274, *Light and lighting*, in collaboration with the International Commission on Illumination (CIE), JTC 06, *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

This document is part of a set of standards which allows users to rate the overall energetic performance of buildings. Facades and rooflights have a key impact on the building's energy balance. This document supports daylighting and lighting-energy-related analysis and optimization of facade and rooflight systems. It is specifically devised to establish conventions and procedures for the estimation of daylight penetrating buildings through vertical facades and rooflights, as well as on the energy consumption for electric lighting as a function of daylight provided in indoor spaces.

Light and lighting – Energy performance of lighting in buildings — Calculation of the impact of daylight utilization

1 Scope

This document defines the calculation methodology for determining the monthly and annual amount of usable daylight penetrating non-residential buildings through vertical facades and rooflights and the impact thereof on the energy demand for electric lighting. This document is applicable for existing buildings and the design of new and renovated buildings.

This document provides the overall lighting energy balance equation relating the installed power density of the electric lighting system with daylight supply and lighting controls (proof calculation method).

The determination of the installed power density is not in the scope of this method, neither are controls relating, for instance, to occupancy detection. Provided the determination of the installed power density and control parameters using external sources, the internal loads by lighting and the lighting energy demand itself can be calculated. The energy demand for lighting and internal loads by lighting can then be taken into account in the overall building energy balance calculations:

— heating;

— ventilation;

— climate regulation and control (including cooling and humidification);

— heating the domestic hot-water supply of buildings.

For estimating the daylight supply and rating daylight-dependent electric lighting control systems, a simple table-based calculation approach is provided. The simple method describes the division of a building into zones as required for daylight illumination-engineering purposes, as well as considerations on the way in which daylight supplied by vertical facade systems and rooflights is utilized and how daylight-dependent lighting control systems affect energy demand. Dynamic vertical facades with optional shading and light redirection properties are considered, i.e. allowing a separate optimization of facade solutions under direct insolation and under diffuse skies. For rooflighting systems, standard, static solutions like shed rooflights and continuous rooflights are considered. The method is applicable for different latitudes and climates. For standard building zones (utilizations), operation times are provided.

For detailed analysis an approach to calculate the effect of daylight on the lighting energy demand on an hourly or sub-hourly basis is provided. Unlike the simple table-based annual calculation approach, which is regression based, this method relies on an emulation concept. Relevant quantities are modelled explicitly and are then interacting directly with sensors, actuators and functional elements of the BACS or are triggering user interaction. By this approach, model configuration and parametrization from the design stage can seamlessly be used in the BACS configuration.

To support overall building performance assessment, additional daylight performance indicators on the overall building level are provided.

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.

CIE S 017:2020, *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 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
control system
various types of electrical and electronic systems including the following:

— systems used to control and regulate;

— systems to protect against solar radiation and/or glare;

— electric lighting in relation to the currently available daylight;

— systems used to detect and record the presence of occupants

3.2
daylight factor
D
quotient of the illuminance at a point on a given plane due to the light received directly and indirectly from a sky of assumed or known luminance distribution and the illuminance on a horizontal plane due to an unobstructed hemisphere of this sky, where the contribution of direct sunlight to both illuminances is excluded

Note 1 to entry: Glazing, dirt effects, etc. are included.

Note 2 to entry: When calculating the lighting of interiors, the contribution of direct sunlight has to be considered separately.

Note 3 to entry: CIE S 017:2020 defines the unit as 1. However, daylight factor is in practice, usually presented in percent values.

Note 4 to entry: The term daylight factor is normally used when considering an overcast sky as sky type 1 or 16 in ISO 15469.

[SOURCE: CIE S 017:2020, 17-29-121, modified — Notes 3 to 5 deleted, new Notes to entry 3 and 4 added]

3.3
electrical power of electric lighting system
P
total electrical power consumption of the lighting system in the considered space

3.4
illuminance
E
density of incident luminous flux with respect to area at a point on a real or imaginary surface

$$E = \frac{d\Phi_v}{dA},$$

where

Φ_v is luminous flux;

A is the area on which the luminous flux is incident

Note 1 to entry: The illuminance is expressed in lux ($lx = lm \cdot m^{-2}$).

[SOURCE: CIE S 017:2020, 17-21-060, modified — Notes 1, 2, 4 and 5 deleted]

3.5
insolation
incidence of solar radiation on a surface or body

3.6
luminaire
apparatus which distributes, filters or transforms the light transmitted from at least one source of optical radiation and which includes, except the sources themselves, all the parts necessary for fixing and protecting the sources and, where necessary, circuit auxiliaries together with the means for connecting them to the power supply

[SOURCE: CIE S 017:2020, 17-30-001, modified — Notes deleted]

3.7
luminous exposure
H_v
H
density of incident luminous energy with respect to area at a point on a real or imaginary surface

$$H_v = \frac{dQ_v}{dA}$$

where

Q_v is the luminous energy;

A is the area on which the luminous energy is incident.

Note 1 to entry: The luminous exposure is expressed in lux second ($lx \cdot s = lm \cdot s \cdot m^{-2}$).

[SOURCE: CIE S 017:2020, 17-21-072, modified — Notes 1, 2, 3, 5 and 6 deleted]

3.8
luminous flux
Φ
Φ_v
change in luminous energy with time

$$\Phi_v = \frac{dQ_v}{dt}$$

where

Q_v is the luminous energy emitted;

t is time.

Note 1 to entry: The luminous flux is expressed in lumen (lm).

[SOURCE: CIE S 017:2020, 17-21-039, modified— Notes 1, 2, 3, 5 and 6 deleted]

3.9
maintained average illuminance
$\bar{E}_m$
value below which the average illuminance over the specified surface is not allowed to fall

Note 1 to entry: In specific contexts of this document the maintained average illuminance can in limit case be the maintained point illuminance

Note 2 to entry: Unit: lx = lm · m^{-2}.

3.10
shading
anything inside, in between or outside the window which prevents the direct view of part of the sky

Note 1 to entry: Shading can be manually operated or automatic and can as well be moveable or fixed.

Note 2 to entry: For example shutters, external or internal blinds.

3.11
daylight opening
any area in the building envelope that is capable of admitting daylight to an interior

3.12
rooflight
daylight opening (3.11) on the roof or on a horizontal surface of a building

3.13
task area
partial area in the work place in which the visual task is carried out

[SOURCE: CIE S 017:2020, 17-29-171, modified — notes deleted]

3.14
visual task
visual elements of the work being done

[SOURCE: CIE S 017:2020, 17-22-084, modified — notes deleted]

4 Symbols, indices, and abbreviated terms

4.1 Symbols

	Quantity	Unit
Φ	luminous flux	lm
Q	energy	kWh
γ	angle, geographical latitude	°
δ	declination of the sun	°
a	depth	m
A	area	m^2
B	width	m
D	daylight factor	—
$\bar{D}$	mean daylight factor	—
E	illuminance	lx
E_e	irradiance	W/m^2
$\bar{E}_m$	maintained illuminance	lx
f, F	factors	—

	Quantity	Unit
G	*g*-value	—
H	luminous exposure	lx h
H	height	m
I	index	—
$I_{\mathrm{Tr},j}$	Transparency index	—
$I_{\mathrm{RD},j}$	Space depth index	—
$I_{\mathrm{Sh},j}$	Shading index	—
$I_{\mathrm{Sh,lsh}}$	Linear shading, correction factor	—
$I_{\mathrm{Sh,hf}}$	Horizontal projections, correction factor	—
$I_{\mathrm{Sh,vf}}$	Vertical projections, correction factor	—
k_{si}	space index	—
k_{cf}	correction factor	—
T	time	s, h
V	distribution key	—

4.2 Indices and abbreviated terms

A	absence	ND	no daylight
At	atrium	Night	night-time
c	control	O	occupancy
Ca	carcass opening	R, Room	room
D	daylight	rel	relative
Day	day-time	Rd	room depth, space depth
dir	direct	s_t	transparent or translucent surface of the daylight aperture
D65	standard lightsource D65	s_s	supply
e	energy quantity	SA	sun-shading activated
Eff eq	effective, root-mean-square equivalent	Sh	shading, obstruction
ext	external, outdoors	SNA	sun-shading not activated
GDF	glazed curtain wall, glazed double facade	start	start
glob	global	sunrise sunset	sunrise sunset
hf	horizontal fin or projection	t	building use (operating) time
i,j,n	serial counter indices	Ta	task area
In	internal courtyard	Tr	transparency
Li	lintel	u	lower
Lsh	linear shading	usage	usage
Max Month	Maximum Month	v	visual quantity
mth	monthly	vf	vertical fin or projection

5 Proof calculation method

5.1 Energy demand for lighting as function of daylight

The final energy demand for lighting purposes is $Q_{\mathrm{l,f}}$ to be determined for a total of N building zones which can be subdivided into J evaluation areas:

$$Q_{\mathrm{l,f}} = \sum_{n=1}^{N} \sum_{j=1}^{J} Q_{\mathrm{l,f},n,j} \tag{1}$$

The energy demand of any one evaluation area j is calculated by applying Formula (2) and Formula (3).

$$Q_{\mathrm{l,f},n,j} = p_j \, F_{\mathrm{c},j} \left[A_{\mathrm{D},j} \left(t_{\mathrm{eff,Day,D},j} + t_{\mathrm{eff,Night},j} \right) + A_{\mathrm{ND},j} \left(t_{\mathrm{eff,Day,ND},j} + t_{\mathrm{eff,Night},j} \right) \right] \tag{2}$$

where

$$A_j = A_{\mathrm{D},j} + A_{\mathrm{ND},J} \tag{3}$$

applies to the total area of the respective evaluation area,

and where

$Q_{\mathrm{l,f}}$	is the final energy demand for lighting;
N	is the number of zones;
J	is the number of areas;
$F_{\mathrm{c},j}$	factor relating to the usage of the total installed power when constant illuminance control is in operation in the room or zone;
p_j	is the specific electrical evaluation power of area j;
A_j	is the floor area of area j;
$A_{\mathrm{D},j}$	is that part of area j which is lit by daylight;
$A_{\mathrm{ND},j}$	is that part of area j which is not lit by daylight;
$t_{\mathrm{eff,Day,D},j}$	is the effective operating time of the lighting system, during day-time, in area j which is lit by daylight;
$t_{\mathrm{eff,Day,ND},j}$	is the effective operating time of the lighting system, during day-time, in area j which is not lit by daylight;
$t_{\mathrm{eff,Night},j}$	is the effective operating time of the lighting system, during night-time, in area j.

The effective operating time, during day-time, in an area which is lit by daylight is calculated using Formula (4).

$$t_{\mathrm{eff,Day,D},j} = t_{\mathrm{Day},n} \, F_{\mathrm{D},j} \, F_{\mathrm{O},j} \tag{4}$$

The effective operating time, during day-time, in an area which is not lit by daylight is calculated using Formula (5).

$$t_{\mathrm{eff,Day,ND},j} = t_{\mathrm{Day},n} \, F_{\mathrm{O},j} \tag{5}$$

where

$t_{Day,n}$ is the operating time of zone n during day-time, as defined in 5.3;

$F_{D,j}$ is the part-utilization factor to account for the illumination by daylight in the evaluation area j as defined in 5.6;

$F_{O,j}$ is the part-utilization factor to account for the presence of persons (occupancy) in the evaluation area j as defined in 5.7.

Formula (6) is used to calculate the effective operating time during night-time.

$$t_{eff,Night,j} = t_{Night,n} F_{O,j} \quad (6)$$

where $t_{Night,n}$ is the operating time of zone n during night-time, as defined in 5.3.

Figure 1 illustrates the order in which the individual steps of the calculations are carried out.

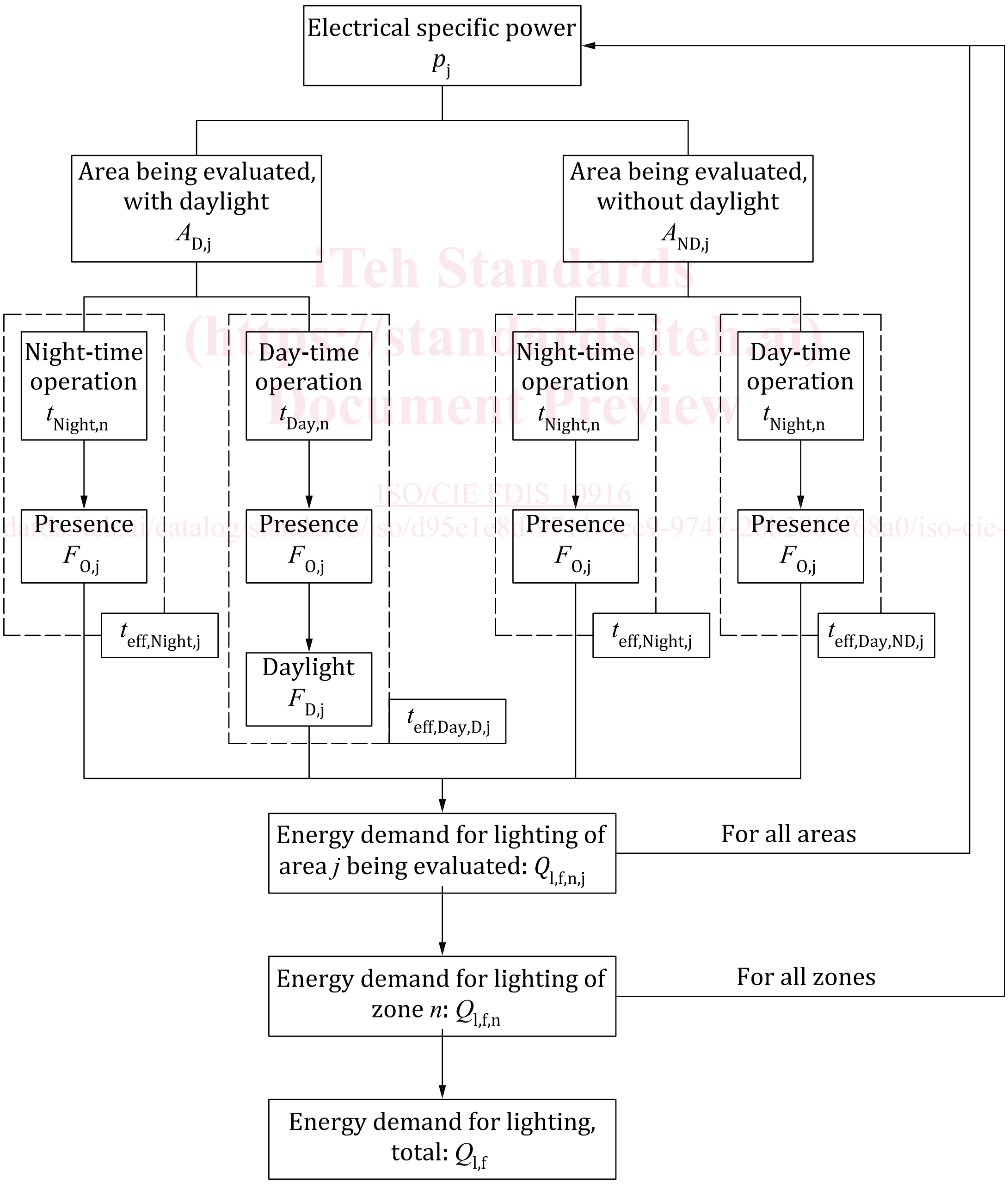

Figure 1 — Flowchart showing calculation of the energy demand for lighting

5.2 Subdivision of a building into zones

The final energy demand for lighting is calculated for all building zones N. The building zones are to be defined in accordance with the zoning boundary conditions as requested by other criteria like utilization of spaces and technical requirements.

It can be necessary to subdivide a building zone n into J evaluation areas to determine the final energy demand for lighting. This subdivision can be necessary due to differences in the boundary conditions (e.g. technical design of the electric lighting system, lighting control systems, characteristics of the facades).

From practical experience, a simplification rule can be recommended: the same boundary condition can be assumed to apply for an entire building zone or an evaluation area if the corresponding input parameter applies to at least 75 % of the area being evaluated. Input parameters of the remaining parts (e. g. window areas) assigned to the dominating areas are not taken into account in the calculations. The specific energy demand is calculated for that part of the evaluation area which occupies at least 75 % of the total area and is then assumed to apply to the total area.

5.3 Operating time

The times during which the areas of a zone being evaluated are used are subdivided into intervals $t_{\mathrm{Day},n}$ during which daylight is available, and intervals $t_{\mathrm{Night},n}$ without daylight. The operating time t_n is equal to $t_{\mathrm{Day},n} + t_{\mathrm{Night},n}$. Day-time is thus the time span between sunrise and sunset. Annual daylight hours and night hours are defined in relation to the different utilization profiles given in Annex A. For operating times which do not match the cases listed in the tables, the values may be determined separately. This may follow the scheme of Table A.21, i.e. specifying the specific data in columns 3, 4, 5 and 6. Data for columns 8 and 9 are separated according to the above described split if the operating time into t_{Day} and t_{Night}.

5.4 Electric lighting

The specific electrical power of the electric light installation p_j can be obtained by, for instance, using standard lighting design software, as provided by luminaire manufacturers. Simplified methods, as defined in ISO/CIE 20086, can as well be employed.

5.5 Constant illuminance control

When constant illuminance control is in operation in the zone or evaluation area, the installed power will be lowered by a factor F_{c}.

5.6 Daylight

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

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

The daylight dependency factor $F_{\mathrm{D},j}$ used to account for lighting of an area j by daylight is defined as

$$F_{\mathrm{D},j} = 1 - F_{\mathrm{D,s},j}\ F_{\mathrm{D,c},j} \quad (7)$$