



BSI Standards Publication

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

National foreword

This British Standard is the UK implementation of ISO/CIE 10916:2024. It supersedes [BS ISO 10916:2014](#), which is withdrawn.

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

This first edition of ISO/CIE 10916 cancels and replaces ISO 10916:2014, which has been technically revised.

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 building automation and control system (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 ($\text{lx} = \text{lm} \cdot \text{m}^{-2}$).

[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 ($\text{lx}\cdot\text{s} = \text{lm}\cdot\text{s}\cdot\text{m}^{-2}$) or lux hours ($\text{lx}\cdot\text{h} = \text{lm}\cdot\text{h}\cdot\text{m}^{-2}$).

[SOURCE: CIE S 017:2020, 17-21-072, modified — Notes 1, 2, 3, 5 and 6 deleted, added possibility to express in lux hours.]

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
H	luminous exposure	lx h
h	height	m
I	index	—
$I_{Tr,j}$	Transparency index	—
$I_{RD,j}$	Space depth index	—
$I_{Sh,j}$	Shading index	—
$I_{Sh,lsh}$	Linear shading, correction factor	—
$I_{Sh,hf}$	Horizontal projections, correction factor	—
$I_{Sh,vf}$	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	effective, root-mean-square	Sh	shading, obstruction
eq	equivalent	SNA	sun-shading not activated
ext	external, outdoors	start	start
GDF	glazed curtain wall, glazed double facade	sunrise	sunrise
glob	global	sunset	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	Maximum	v	visual quantity
Month	Month	vf	vertical fin or projection
mth	monthly		

5 Proof calculation method

5.1 Energy demand for lighting as function of daylight

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

$$Q_{l,f} = \sum_{n=1}^N \sum_{j=1}^J Q_{l,f,n,j} \quad (1)$$

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

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

where

$$A_j = A_{D,j} + A_{ND,j} \quad (3)$$

applies to the total area of the respective evaluation area,

and where

$Q_{l,f}$	is the final energy demand for lighting;
N	is the number of zones;
J	is the number of areas;
$F_{c,j}$	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 ;
$A_{D,j}$	is that part of area j which is lit by daylight;
$A_{ND,j}$	is that part of area j which is not lit by daylight;
$t_{\text{eff,Day,D},j}$	is the effective operating time of the lighting system, during day-time, in area j which is lit by daylight;
$t_{\text{eff,Day,ND},j}$	is the effective operating time of the lighting system, during day-time, in area j which is not lit by daylight;
$t_{\text{eff,Night},j}$	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 \(4\)](#).

$$t_{\text{eff,Day,D},j} = t_{\text{Day},n} F_{D,j} F_{O,j} \quad (4)$$

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

$$t_{\text{eff,Day,ND},j} = t_{\text{Day},n} F_{O,j} \quad (5)$$

where

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

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

$F_{\text{O},j}$ 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.

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

where $t_{\text{Night},n}$ 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.

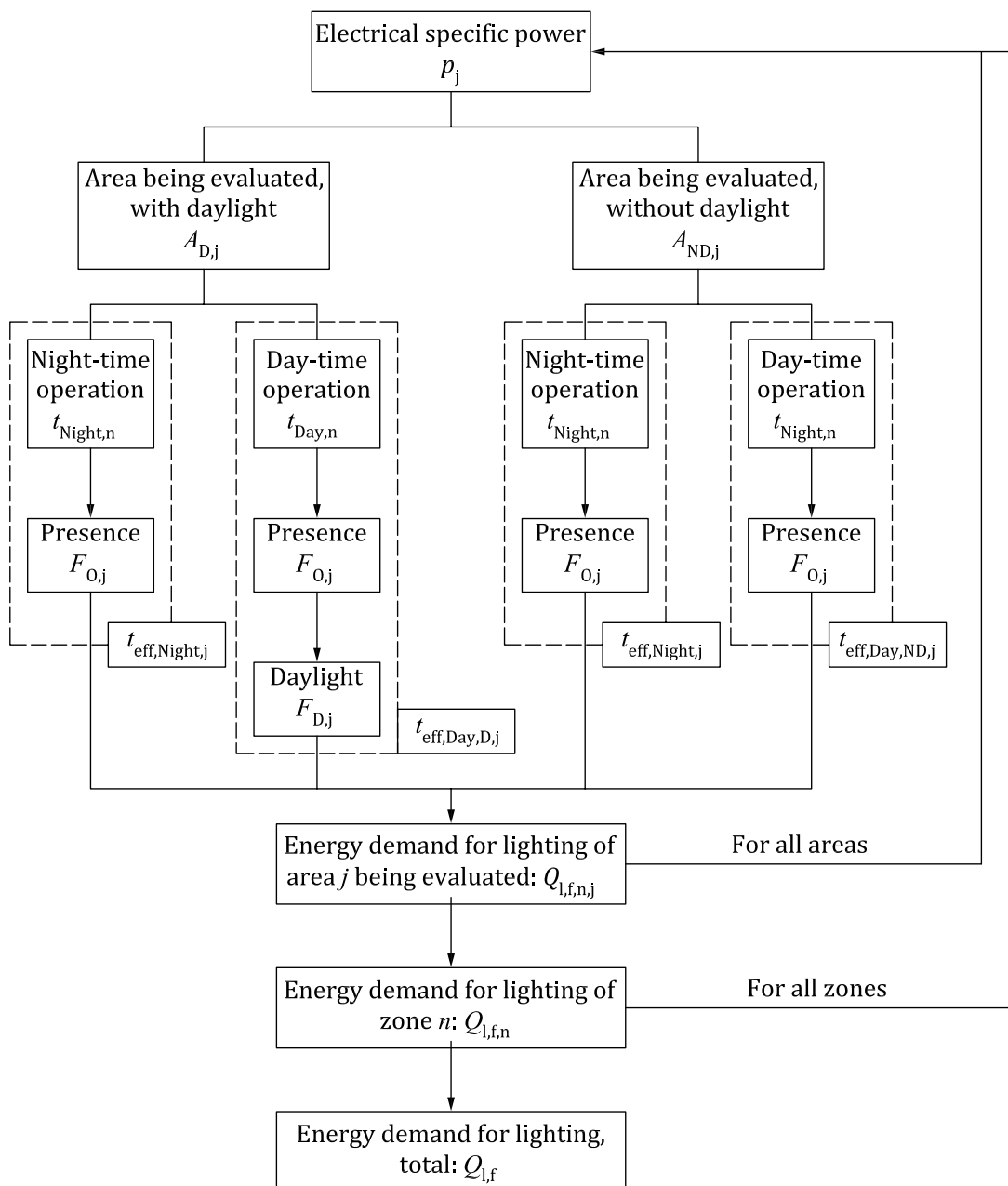


Figure 1 — Flowchart showing calculation of the energy demand for lighting

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 $t_{\text{Day},n}$ during which daylight is available, and intervals $t_{\text{Night},n}$ without daylight. The operating time t_n is equal to $t_{\text{Day},n} + t_{\text{Night},n}$. 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 $F_{D,j}$ used to account for lighting of an area j by daylight is defined as

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

where

$F_{D,s,j}$ is the daylight supply factor;

$F_{D,c,j}$ is the factor representing the effect of the daylight-responsive control system.

The daylight supply factor $F_{D,s,j}$ accounts for the amount of lighting of the evaluation area j by daylight. This factor describes the relative proportion of the light needed for the visual task provided by daylight within the reference time interval at the point where the illuminance is measured (control point). When determining this factor, the type of lighting control system shall be taken into consideration. The factor corresponds to the relative luminous exposure as the ratio of luminous flux by daylight up to the required maintained illuminance to the total luminous flux for the required maintained illuminance over operation time.

NOTE The relative luminous exposure is also referred to as “daylight autonomy”.

The factor $F_{D,c,j}$ additionally accounts for the efficiency of the lighting control system in using the available daylight to achieve the required luminous exposure level in the area j . The daylight dependency factor $F_{D,j}$ which takes the daylight illumination into consideration can be determined for any given time interval (e.g. year, month, hour).

[Annex A](#) comprises simplified approaches to calculate $F_{D,s,j}$ for vertical facades ([A.3](#)) and rooflights ([A.4](#)) and to obtain tabulated values for $F_{D,c,j}$. [Annex B](#) contains a methodology for detailed generally computer-based comprehensive calculations to calculate the effect of daylight on the lighting energy demand on an hourly or sub-hourly basis.

A calculation example each for daylight penetration through a vertical facade and a rooflight is given in Annex D.

5.7 Occupancy dependency factor $F_{O,n}$

The occupancy dependency factor $F_{O,n}$ for a room or zone correlates the time when a space is occupied with the efficiency to benefit from potential energy savings by either manual or automatic switching. Parametrizations of $F_{O,n}$ can, for instance, be found in ISO/CIE 20086.

6 Daylight Performance Indicator

To judge the overall daylight performance of a building or a building design and to compare different buildings or building designs, integral daylight performance indicators are helpful. [Annex C](#) gives definitions and explains their application.

Annex A (informative)

Simple calculation method

A.1 General

This Annex specifies a simplified approach to calculate the effect of daylight on the lighting energy demand on monthly and annual bases. The method involves the following stages to obtain, according to [Clause 5](#), the daylight dependent quantities $F_{D,n,j}$, $t_{Day,n,j}$ and as a function thereof $t_{eff,Day,n,j}$, as also depicted in [Figure A.1](#):

- [A.2](#) contains a scheme of how to subdivide the zone to be evaluated into area sections which receive daylight and those which do not;
- [A.3](#) specifies a procedure on how to determine the daylight supply factor $F_{D,S,n,j}$ for spaces lit by vertical facades;
- [A.4](#) specifies a procedure on how to determine the daylight supply factor $F_{D,S,n,j}$ for spaces lit by rooflights;
- [A.5](#) specifies a procedure on how to rate daylight responsive control systems described by the parameter $F_{D,C,n,j}$;
- [A.6](#) describes how to convert annual values into monthly values of $F_{D,n,j}$;
- [A.7](#) provides a procedure to determine day- and night-time hours;
- [A.8](#) provides a list of precalculated day- and night-time hours for 41 different utilization types of building spaces.

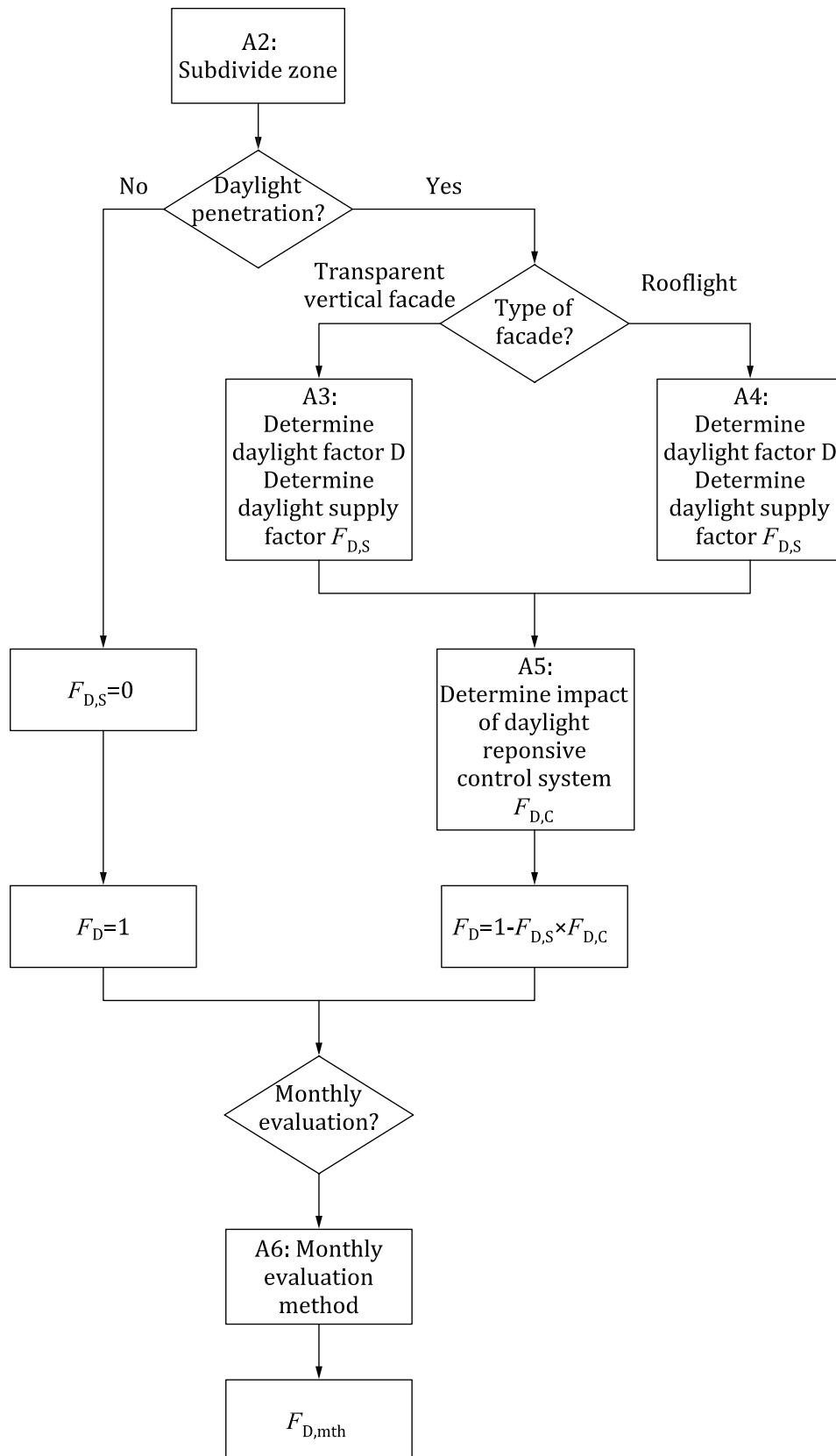


Figure A.1 — Flowchart illustrating the simplified approach

For the determination of the daylight supply factor $F_{D,S,n,j}$ as well for a vertical facade (A.3) as for rooflights (A.4), Figure A.2 shows the applied three-stage approach:

- Stage 1: Use of a simple criterion approximating the daylight factor to classify the type of daylight availability on the basis of the geometrical parameters of the building zone being evaluated. This assumes a combination of standard reflectances, $\rho_F = 0,2$ for the floor, $\rho_W = 0,5$ for the walls, and $\rho_C = 0,7$ for the ceiling. The reflectance of the external surroundings is assumed to be 0,2. Instead of using these approximations, a more detailed determination of the daylight factor can be carried out for more complicated space geometries and other reflectance values using a computer program.
- Stage 2: Describe the facade characteristics.
- Stage 3: Determine the annual amount of daylight available on the basis of the daylight supply classification of the building zone and the facade characteristics as a function of location and climate.

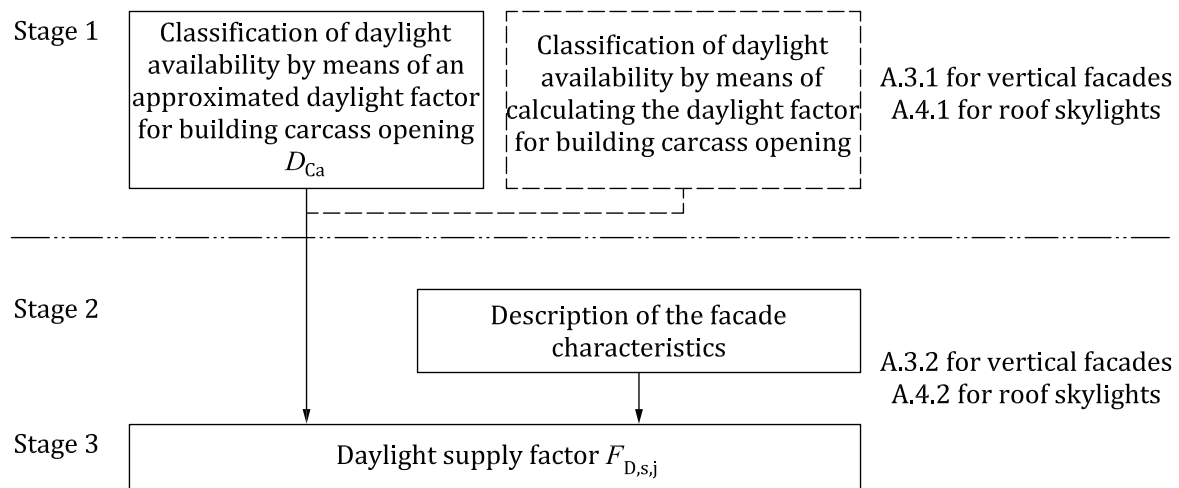


Figure A.2 — Three-stage approach to determining the daylight supply factor $F_{D,s,j}$

A.2 Building segmentation: spaces benefiting from daylight

Evaluation zones which are illuminated by daylight entering via facades or rooflights shall be subdivided into a daylight-lit area $A_{D,j}$ and an area $A_{ND,j}$ which is not illuminated by daylight. For simplified estimate calculations, the more favourable respective lighting conditions can be assumed to apply in cases where one area is illuminated by daylight entering via several facades or via a facade and rooflights. Alternatively, it is also possible in these areas to determine the daylight factor according to A.3 and A.4 by superposition. This can nevertheless only be applied for areas being lit by only one type of daylight aperture (either vertical facade or rooflight). Figure A.3 shows the impact of a facade opening on the daylight area for vertical facades.

- Depth and width of the daylight area lit by vertical facades

The maximum possible depth $a_{D,max,j}$ of the area $A_{D,j}$ lit by daylight entering via a facade is calculated using Formula (A.1).

$$a_{D,max,j} = 2,5 \times (h_{Li} - h_{Ta}) \quad (A.1)$$

where

- $a_{D,max,j}$ is the maximum depth of the daylight area;
- h_{Li} is the height of the window lintel above the floor;
- h_{Ta} is the height of the task area above the floor.

In this case, the maximum depth $a_{D,max}$ of the daylight area is calculated from the inner surface of the external wall and at right angles to the reference facade. If the real depth of the area being evaluated is less than the calculated maximum depth of the daylight area, then the total area depth is considered to be the depth of the daylight area a_D . The a_D value can also be assumed to be equal to the real depth of the area being evaluated if the real area depth is less than 1,25 times the calculated maximum daylight area depth.

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

$$A_{D,j} = a_D b_D \quad (A.2)$$

where

a_D is the depth of the daylight area;

b_D is the width of the daylight area.

The width b_D of the daylight area normally corresponds to the facade width on the inner surface of the building zone or the area being evaluated. Internal walls can be overmeasured (i.e. their thickness ignored) to keep the equations simple. If windows only constitute a part of the facade, then the width of the daylight area associated with this facade is equal to the width of the section which has windows, plus half the depth of the daylight area.

— Depth of the daylight area lit by rooflights

Areas to be evaluated having rooflights evenly distributed all over the roof area are always deemed to be lit by daylight. In the case of individual or single rooflights and at the boundaries of areas which have evenly distributed skylights, those parts of the area which are within a distance of

$$a_{D,max} \leq 2 \times (h_{R,j} - h_{Ta,j}) \quad (A.3)$$

from the edge of the nearest skylight are deemed to be lit by daylight,

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

For all parts of the area under evaluation which are not lit by daylight, the factor $F_{D,j}$ is equal to 1. [Figure A.4](#) shows the impact of a roof opening on the daylight area for rooflights.

— Distinction between vertical facades and rooflights

In case of doubt as to whether a specific opening or aperture is to be evaluated as being a window or a rooflight, all such openings of which the entire glazed areas are above the ceiling of the space under consideration are deemed to be rooflights. [Figure A.5](#) shows the superposition and penetration of daylight areas for vertical facades and rooflights.

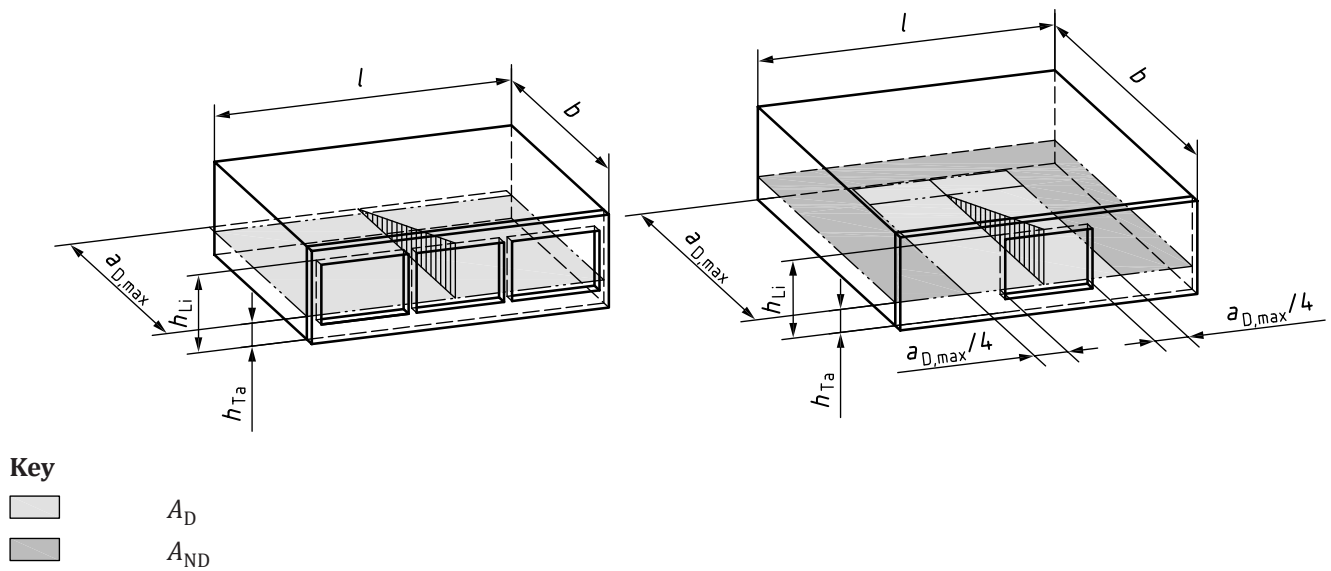


Figure A.3 — Impact of facade opening on daylight area for vertical facades

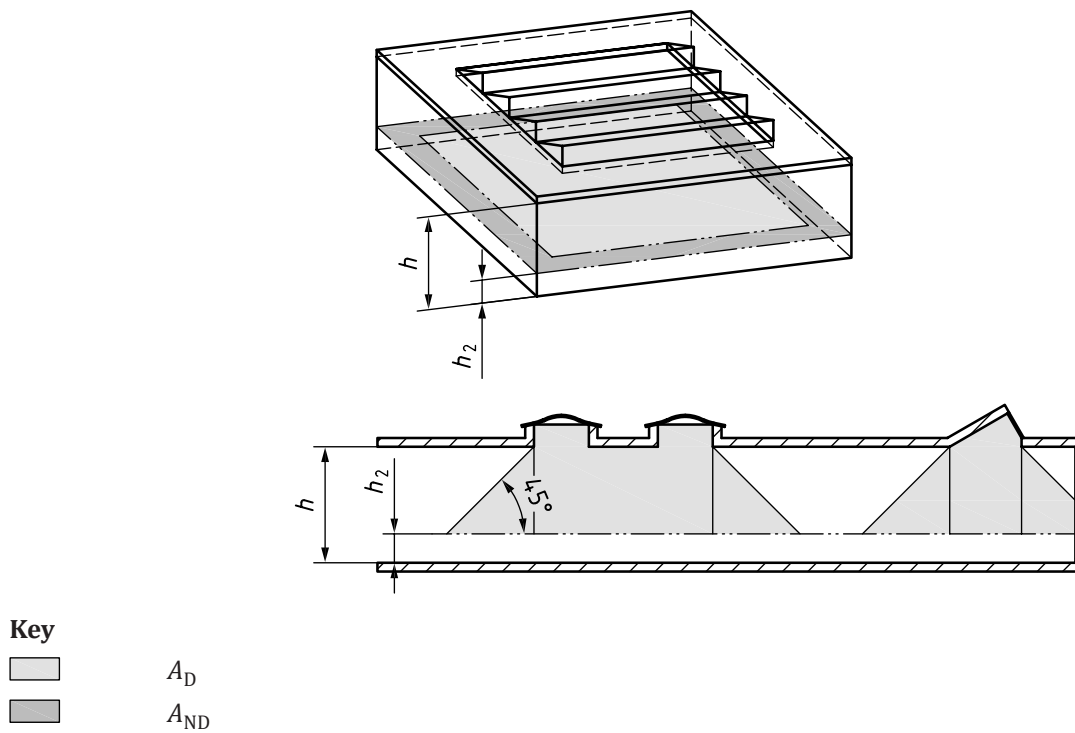


Figure A.4 — Impact of roof opening on daylight area for rooflights

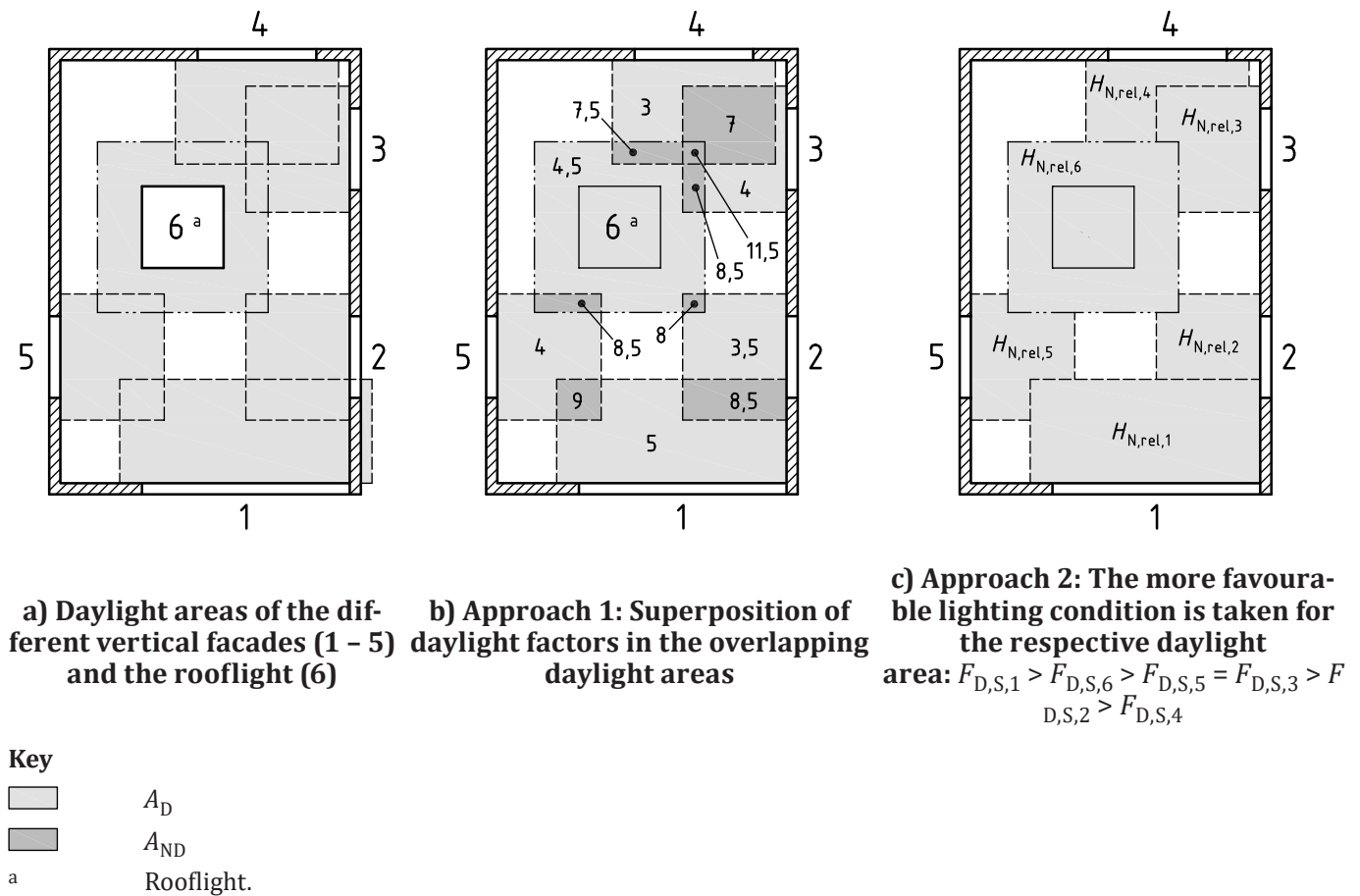


Figure A.5 — Superposition and penetration of daylight areas for vertical facades and rooflights

A.3 Daylight supply factor for vertical facades

A.3.1 Daylight factor classification

The daylight factor for vertical facades can be obtained by several means, e.g. graphical, analytical, or computer-based approaches. Here, a simplified analytical approach allowing to account for the major parameters classifying the daylight availability in vertical lit rooms is provided.

The amount of daylight available in an area j being evaluated depends on the transparency index $I_{Tr,j}$, the space depth index $I_{RD,j}$, and the shading index $I_{Sh,j}$. These index values are determined as follows.

— Transparency index $I_{Tr,j}$

[Formula \(A.4\)](#) is used to calculate the transparency index.

$$I_{Tr,j} = \frac{A_{Ca}}{A_D} \quad (A.4)$$

where

A_{Ca} is the area of the raw building carcass opening of the area under evaluation;

A_D is the partial area which is lit by daylight as calculated by [Formula \(A.1\)](#).

All areas below the work plane (e.g. 0,8 m above floor level in office spaces) are ignored. The height of the work plane is given for individual utilization profiles in DIN V 18599-10[3].

— Space depth index $I_{RD,j}$

[Formula \(A.5\)](#) is used to calculate the space depth index $I_{RD,j}$.

$$I_{RD,j} = \frac{a_D}{h_{Li} - h_{Ta}} \quad (A.5)$$

— Shading index $I_{Sh,j}$

The shading index $I_{Sh,j}$ accounts for all effects which restrict the amount of daylight striking the facade. This includes shading by parts of the building itself, such as those that occur due to horizontal and vertical projections, light wells, courtyards, and atrium arrangements. It also takes into consideration any reduction of incident light by the glazed double facades (GDF — also glazed curtain walls). The shading index $I_{Sh,j}$ is calculated using [Formula \(A.6\)](#).

$$I_{Sh,j} = I_{Sh,lsh} I_{Sh,hf} I_{Sh,vf} I_{Sh,in,At} I_{Sh,GDF} \quad (A.6)$$

where

- $I_{Sh,j}$ is the shading index of the area j under evaluation;
- $I_{Sh,lsh}$ is the correction factor for linear shading of the area under evaluation as calculated using [Formula \(A.7\)](#);
- $I_{Sh,hA}$ is the correction factor for an overhang shading of the area being evaluated, calculated using [Formula \(A.8\)](#);
- $I_{Sh,vA}$ is the correction factor for a side shading of the area under evaluation as calculated using [Formula \(A.9\)](#);
- $I_{Sh,in,At}$ is the correction factor for internal courtyard and atrium shading of the area under evaluation as calculated using [Formula \(A.11\)](#);
- $I_{Sh,GDF}$ is the correction factor for glazed double facades of the area being evaluated, calculated using [Formula \(A.12\)](#).

NOTE A reduction by thick walls in relation to the carcass opening can be approximately described using the factors $I_{Sh,hA}$ and $I_{Sh,vA}$.

To facilitate the calculations, a window located at the centre of the facade area being evaluated can be used as the reference point for which the shading is calculated. If different forms and degrees of shading affect the area being evaluated, the mean value of the respective factors shall be calculated.

$I_{Sh,lsh}$, $I_{Sh,hf}$, $I_{Sh,vf}$, $I_{Sh,in,At}$ and $I_{Sh,GDF}$ can be determined using the following methods:

— Linear shading, correction factor $I_{Sh,lsh}$

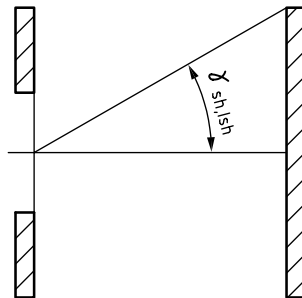


Figure A.6 — Cross-section diagram to illustrate the effect of the linear shading altitude angle $\gamma_{sh,lsh}$

The linear shading altitude angle $\gamma_{Sh,lsh}$ is measured from the centre of the facade section being evaluated for lighting aspects (on the plane of the external wall surface) as shown in [Figure A.6](#). [Formula \(A.7\)](#) is used to calculate the correction factor which accounts for linear shading.

$$I_{Sh,lsh} = \cos(1,5 \times \gamma_{Sh,lsh}) \quad \text{for } \gamma_{Sh,lsh} < 60^\circ$$

$$I_{Sh,lsh} = 0 \quad \text{for } \gamma_{Sh,lsh} \geq 60^\circ \quad (A.7)$$

where $\gamma_{Sh,lsh}$ is the shading altitude angle as shown in [Figure A.6](#).

— Horizontal projections, correction factor $I_{Sh,hf}$

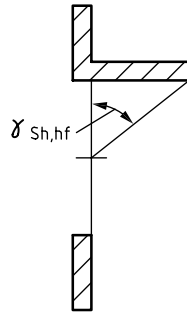


Figure A.7 — Cross-section diagram to illustrate the effect of the horizontal shading angle $\gamma_{Sh,hf}$

The horizontal shading angle $\gamma_{Sh,hf}$ due to a horizontal projection is measured from the centre of the facade section being evaluated for lighting aspects (on the plane of the external wall surface) as shown in [Figure A.7](#). [Formula \(A.8\)](#) is used to calculate the correction factor which accounts for shading by a horizontal projection.

$$I_{Sh,hf} = \cos(1,33 \cdot \gamma_{Sh,hf,j}) \quad \text{for } \gamma_{Sh,hf} < 67,5^\circ$$

$$I_{Sh,hf} = 0 \quad \text{for } \gamma_{Sh,hf} \geq 67,5^\circ \quad (A.8)$$

where $\gamma_{Sh,hf}$ is the horizontal shading angle due to a horizontal projection as shown in [Figure A.7](#).

— Vertical projections, correction factor $I_{Sh,vf}$

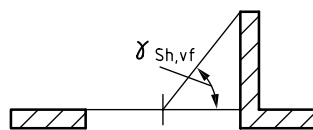


Figure A.8 — Cross-section ("top view") diagram to illustrate the effect of the vertical shading angle $\gamma_{Sh,vf}$

The vertical shading angle $\gamma_{Sh,vf}$ due to a vertical projection is measured from the centre of the facade section being evaluated for lighting aspects (on the plane of the external wall surface) as shown in [Figure A.8](#). [Formula \(A.9\)](#) is used to calculate the correction factor which accounts for shading by a vertical projection.

$$I_{Sh,vf} = 1 - \frac{\gamma_{Sh,vf,j}}{300^\circ} \quad (A.9)$$

where $\gamma_{Sh,vf}$ is the vertical shading angle due to a vertical projection as shown in [Figure A.8](#).

— Courtyards and atria (glazed forecourts), correction factor $I_{Sh,in,At}$

There are very many different design variants for courtyards and atria or glazed forecourts. The calculations are based on an internal courtyard surrounded on all four sides by the building. Better daylight availability can be expected if only three or two sides (linear courtyards) of the courtyard are bordered by the building. This can be calculated and proved using separate, detailed calculation methods.

The geometry of an internal courtyard is characterized by a geometrical index value, the so-called well index I_{well} :

$$I_{\text{well}} = \frac{h_{\text{In,At}} (a_{\text{In,At}} + b_{\text{In,At}})}{2 \times a_{\text{In,At}} b_{\text{In,At}}} \quad (\text{A.10})$$

NOTE In daylight literature wi is used as symbol for the well index.

When determining the well index I_{well} for an area being evaluated, the height measured from the floor of the respective area is considered to be the height of the courtyard or atrium ([Figure A.9](#)).

where

- $a_{\text{In,At}}$ is the depth of the courtyard or atrium;
- $b_{\text{In,At}}$ is the width of the courtyard or atrium;
- $h_{\text{In,At}}$ is the height of the courtyard or atrium, measured from the floor of the storey being evaluated;
- I_{well} is the well index used to account for the geometry of the courtyard or atrium.

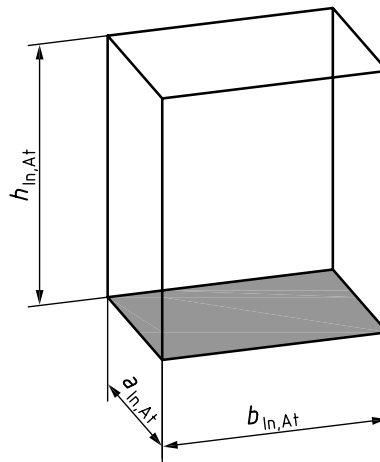


Figure A.9 — Illustration of the geometrical parameters used to define the well index I_{well}

The correction factor for taking into consideration building shading in internal courtyards, light wells, or atria is:

$$I_{\text{Sh,In,At}} = 1 - 0,85 I_{\text{well}} \quad \text{for internal courtyards}$$

$$I_{\text{Sh,In,At}} = \tau_{\text{Sh,In,At,D65}} k_{\text{Sh,In,At,1}} k_{\text{Sh,In,At,2}} k_{\text{Sh,In,At,3}} (1 - 0,85 I_{\text{well}}) \quad \text{for atria} \quad (\text{A.11})$$

$$I_{\text{Sh,In,At}} = 0 \quad \text{for } I_{\text{well}} > 1,18$$

where

- $\tau_{\text{Sh,In,At,D65}}$ is the transmittance of the atrium glazing for vertical light incidence;
- $k_{\text{Sh,In,At,1}}$ is the framing factor for frames in the atrium facade;
- $k_{\text{Sh,In,At,2}}$ is the dirt on glazing factor of the atrium glazing;
- $k_{\text{Sh,In,At,3}}$ is the reduction factor for diffuse light incidence on the atrium glazing (usually, 0,85 is considered to be adequate).

— Glazed double facade (glazed curtain wall), correction factor $I_{\text{Sh,GDF}}$

The correction factor for glazed double facades or curtain walls bounding on the space being evaluated is directly deduced from the parameters of the additional glazing layer:

$$I_{\text{Sh,GDF}} = \tau_{\text{Sh,GDF,D65}} k_{\text{Sh,GDF,1}} k_{\text{Sh,GDF,2}} k_{\text{Sh,GDF,3}} \quad (\text{A.12})$$

where

- $\tau_{\text{Sh,GDF,D65}}$ is the transmittance of the external layer of glazing of the facade, for vertical light incidence;
- $k_{\text{Sh,GDF,1}}$ is the reduction factor for frames in the double-glazed facade;
- $k_{\text{Sh,GDF,2}}$ is the reduction factor for pollution of the glazing of the double-glazed facade;
- $k_{\text{Sh,GDF,3}}$ is the reduction factor for non-vertical light incidence on the facade glazing (usually, 0,85 is considered to be adequate).

The effects of vertical and horizontal subdivisions in the space between the two facade layers can be approximated by treating these as vertical and horizontal projections with the index values $I_{\text{Sh,vA}}$ and $I_{\text{Sh,hA}}$. In glazed double facades, it is assumed that pollution of the space between the outer glazing and the space wall is negligible, so that it is usually adequate to take only the dirt deposited on the actual facade surface into consideration [also refer to [Formula \(A.21\)](#)]. In this case, $k_{\text{Sh,GDF,2}} = 1$. The correction factor for frames and subdivisions is calculated as follows:

$$k_{\text{Sh,GDF,1},j} = 1 - \frac{\text{area of structural components}}{\text{area of raw building carcass opening}} = \frac{\text{transparent area}}{\text{area of raw building carcass opening}} \quad (\text{A.13})$$

Only that part of the external facade glazing which is projected onto the transparent portions of the inner facade is taken into consideration when calculating the factor $k_{\text{Sh,GDF,1}}$.

— Daylight factor of the raw building carcass opening

The index values $I_{\text{Tr},j}$, $I_{\text{RD},j}$ and $I_{\text{Sh},j}$ can be used to calculate an approximate value for the daylight factor of the area being evaluated on the basis of the raw opening dimensions:

$$D_{\text{Ca},j} = (4,13 + 20,0 \times I_{\text{Tr},j} - 1,36 \times I_{\text{RD},j}) I_{\text{Sh},j} \text{ in \%} \quad (\text{A.14})$$

For combinations of a larger space depth index value $I_{\text{RD},j}$ and low transparency index values $I_{\text{Tr},j}$, [Formula \(A.14\)](#) can produce negative $D_{\text{Ca},j}$ values. In such cases, $D_{\text{Ca},j}$ shall be assumed to be zero or shall be calculated by a more detailed method. For simple estimates, daylight availability can be grouped into four classes as shown in [Table A.1](#).

Table A.1 — Daylight availability classification as a function of the daylight factor $D_{Ca,j}$ of the raw building carcass opening

Daylight factor $D_{Ca,j}$	Classification of daylight availability
$D_{Ca,j} \geq 6 \%$	Strong
$6 \% > D_{Ca,j} \geq 4 \%$	Medium
$4 \% > D_{Ca,j} \geq 2 \%$	Low
$D_{Ca,j} < 2 \%$	None

If a daylight factor which has been calculated using another validated method is known, then this can be used instead of the value calculated by [Formula \(A.14\)](#) when classifying the daylight availability according to [Table A.1](#). In this case, the daylight factor shall have been determined on the basis of the mean value of the daylight measured on the axis running parallel to the respective facade section and at a distance of half the space depth from the facade.

A.3.2 Daylight supply factor

A.3.2.1 General

The following section first explains how the facade characteristics are to be described and then how the daylight availability is determined on the basis of the correlation of the daylight availability (daylight factor) of the building area as defined in [A.3.1](#) with the facade characteristics. The light passing through facade systems and the associated illumination of the adjacent space depends on the spatial and temporal distribution of the external illuminance conditions in relation to the facade element and the spatial distribution of the light by the facade system (i.e. its optical and control-technological characteristics). From the lighting-engineering aspect, two facade states shall be distinguished for facades with variable solar light shading systems and/or glare-protection systems:

- solar and/or glare protection system not activated, i.e. the sun is not shining on the facade;
- solar and/or glare protection system is activated, i.e. the sun is shining on the facade.

The daylight supply factor $F_{D,s,j}$ shall be determined using [Formula \(A.15\)](#) to achieve temporal weighting of the orientation-dependent occurrence of two different facade states, i.e. either with activated solar and/or glare protection or with de-activated solar and/or glare protection. The protection against solar radiation and/or glare is activated as soon as direct sunlight shines on the facade.

[Formula \(A.15\)](#) is used to calculate the daylight supply factor $F_{D,s,j}$.

$$F_{D,s,j} = t_{rel,D,SNA,j} F_{D,s,SNA,j} + t_{rel,D,SA,j} F_{D,s,SA,j} \quad (A.15)$$

where

- $t_{rel,D,SNA,j}$ is the relative portion of the total operating time during which the solar and/or glare protection system is not activated as given in [Table A.3](#). It is a function of the latitude γ of the considered site, H_{dir}/H_{glob} representing the climate and facade orientation;
- $t_{rel,D,SA,j}$ is the relative portion of the total operating time during which the solar and/or glare protection system is activated. $t_{rel,D,SA}$ can be obtained by $t_{rel,D,SA} = 1 - t_{rel,D,SNA}$;
- $F_{D,s,SNA,j}$ is the daylight supply factor of the area j being evaluated at times when the solar and/or glare protection system is not activated, as given in [Table A.7](#). It is a function of the latitude γ of the considered site, H_{dir}/H_{glob} representing the climate, the facade orientation, daylight availability (daylight factor), and the maintained illuminance;
- $F_{D,s,SA,j}$ is the daylight supply factor of the area j being evaluated at times when the solar and/or glare protection system is activated, as given in [Table A.8](#).

A set of ratios $H_{\text{dir}}/H_{\text{glob}}$ for representative locations worldwide is given in [A.3.2.1](#).

A.3.2.2 Luminous exposure ratios at different sites (climates and latitudes)

[Figure A.10](#) shows the segmentation of locations worldwide according to 15° latitude corridors. For each of the latitude corridors, [Table A.2](#) contains a representative cloudy and sunny location with the ratio $H_{\text{dir}}/H_{\text{glob}}$. For other specific locations of interest, the ratio $H_{\text{dir}}/H_{\text{glob}}$ can be obtained by evaluation of the corresponding weather data sets (e.g. TRY – weather data sets). The direct and global horizontal illuminances are summed up daily from 8:00 h to 17:00 h over the whole year.

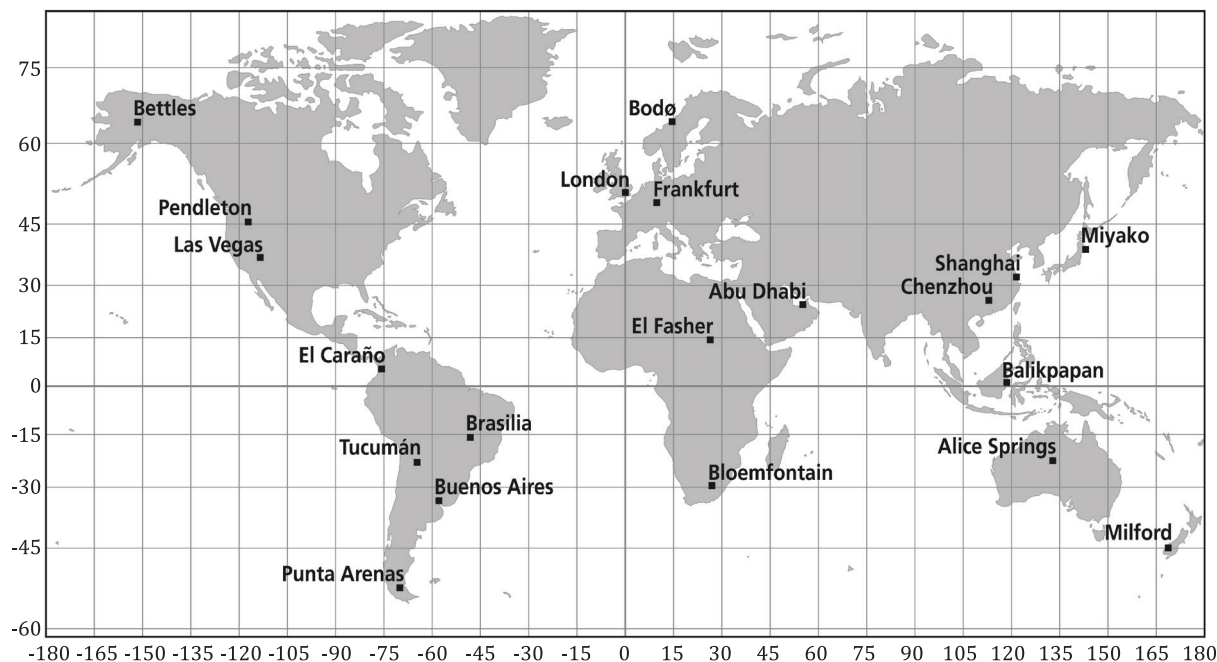


Figure A.10 — Selected sites for which ratios $H_{\text{dir}}/H_{\text{glob}}$ are provided with assignment of latitude

Table A.2 — Representative locations on the northern and southern hemispheres with the corresponding luminous exposure ratios $H_{\text{dir}}/H_{\text{glob}}$

Geographical location			Climate	Representative site	Luminous exposure ratio $H_{\text{dir}}/H_{\text{glob}}$ [–]
Corridor	Latitude γ	Longitude γ			
Northern hemisphere	60° to 75°	67,3°	Cloudy	Bodø, N	0,40
		66,9°	Sunny	Bettles, USA	0,49
	45° to 60°	51,2°	Cloudy	London, GB	0,39
		50,0°	Cloudy	Frankfurt, D	0,42
		45,7°	Sunny	Pendleton, USA	0,58
		31,2°	Cloudy	Shanghai, VRC	0,36
	30° to 45°	39,7°	Cloudy	Miyako, J	0,45
		36,1°	Sunny	Las Vegas, USA	0,71
	15° to 30°	25,8°	Cloudy	Chenzhou, VRC	0,34
		24,4°	Sunny	Abu Dhabi, AE	0,58
	0° to 15°	5,7°	Cloudy	El Caraño, CO	0,34
		13,6°	Sunny	El Fasher, SUD	0,66

Table A.2 (continued)

Geographical location				Climate	Representative site	Luminous exposure ratio $H_{\text{dir}}/H_{\text{glob}}$ [–]
Corridor		Latitude γ	Longitude γ			
Southern hemisphere	0° to 15°	–1,3°	116,9°	Cloudy	Balikpapan, RI	0,38
		–15,8°	–47,9°	Sunny	Brasilia, BR	0,53
	15° to 30°	–26,8°	–65,2°	Cloudy	Tucumán, RA	0,54
		–23,8°	133,9°	Sunny	Alice Springs, AUS	0,67
	30° to 45°	–34,8°	–58,5°	Cloudy	Buenos Aires, AR	0,55
		–30,0°	26,3°	Sunny	Bloemfontein, RSA	0,68
	45° to 60°	–53,0°	–70,9°	Cloudy	Punta Arenas, RCH	0,39
		–44,7°	167,9°	Sunny	Milford Sound, NZ	0,50

A.3.2.3 Relative times, shading activated, shading not activated for vertical facades

Table A.3, Table A.4 and Table A.5 hold the relative times $t_{\text{rel,D,SNA},j}$ as a function of the latitude γ of the considered site, $H_{\text{dir}}/H_{\text{glob}}$ representing the climate and facade orientation.

The relative times $t_{\text{rel,D,SNA},j}$ are provided for unobstructed facades. For shading indices $I_{\text{Sh},j}$ of obstructed facades of less than 0,5, especially for higher latitudes $\gamma \geq 45^\circ$, it is recommended to set $t_{\text{rel,D,SNA}} = 1$. This nevertheless shall not give reason to assume that glare protection for the facade is unnecessary. Such protection can be necessary due to individual types of usage.

If the shading index $I_{\text{Sh},j}$ of a shaded facade is less than 0,5, then the relative times $t_{\text{rel,D,SNA},j}$ and $t_{\text{rel,D,SA},j}$ for a north-facing facade should be used. Depending on the operating times of the area being evaluated, even north-facing facades can receive direct sunlight for limited periods. However, for simplified calculations, $t_{\text{rel,D,SNA},j}$ is assumed to be 0, but this shall not give reason to assume that glare protection for north-facing facades is unnecessary. Such protection can be necessary due to individual types of usage^[2].

$t_{\text{rel,D,SNA}}$ has been calculated for office conditions but can be used for other user profiles generally with sufficient accuracy as well.

Table A.3 — Relative times $t_{\text{rel,D,SNA},j}$ for not activated solar radiation and/or glare protection systems, as a function of the facade orientation (south), the geographic latitude γ , and the ratio $H_{\text{dir}}/H_{\text{glob}}$

t_{SNA} South ^a									
$H_{\text{dir}}/H_{\text{glob}}$	γ								
	0°	10°	20°	30°	40°	50°	60°	70°	80°
0,0	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
0,1	0,99	0,97	0,94	0,93	0,96	0,98	0,98	0,93	0,88
0,2	0,94	0,91	0,86	0,84	0,86	0,87	0,86	0,80	0,72
0,3	0,89	0,86	0,79	0,75	0,75	0,76	0,75	0,69	0,61
0,4	0,83	0,80	0,71	0,65	0,64	0,65	0,65	0,60	0,53
0,5	0,71	0,67	0,57	0,50	0,49	0,50	0,51	0,47	0,40
0,6	0,55	0,51	0,41	0,33	0,32	0,34	0,36	0,32	0,23
0,7	0,47	0,43	0,32	0,24	0,23	0,26	—	—	—
0,8	—	0,42	0,32	0,24	0,23	0,26	—	—	—
0,9	—	0,42	0,32	0,24	0,23	0,26	—	—	—

^a Corresponds to a north facade in the southern hemisphere.

Table A.4 — Relative times $t_{\text{rel,D,SNA},j}$ for not activated solar radiation and/or glare protection systems, as a function of the facade orientation (east/west), the geographic latitude γ , and the ratio $H_{\text{dir}}/H_{\text{glob}}$

t_{SNA} East/West									
$H_{\text{dir}}/H_{\text{glob}}$	γ								
	0°	10°	20°	30°	40°	50°	60°	70°	80°
0,0	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
0,1	0,99	0,98	0,97	0,97	1,00	1,00	0,99	0,95	0,92
0,2	0,95	0,94	0,92	0,92	0,94	0,94	0,93	0,88	0,85
0,3	0,91	0,89	0,87	0,86	0,88	0,88	0,87	0,83	0,79
0,4	0,84	0,83	0,80	0,79	0,81	0,82	0,82	0,80	0,78
0,5	0,74	0,73	0,70	0,70	0,73	0,76	0,77	0,77	0,76
0,6	0,64	0,63	0,61	0,61	0,65	0,69	0,72	0,72	0,73
0,7	0,59	0,58	0,56	0,56	0,61	0,65	—	—	—
0,8	—	0,58	0,56	0,56	0,61	0,65	—	—	—
0,9	—	0,58	0,56	0,56	0,61	0,65	—	—	—

Table A.5 — Relative times $t_{\text{rel,D,SNA},j}$ for not activated solar radiation and/or glare protection systems, as a function of the facade orientation (north/south), the geographic latitude γ , and the ratio $H_{\text{dir}}/H_{\text{glob}}$

t_{SNA} North ^a									
$H_{\text{dir}}/H_{\text{glob}}$	γ								
	0°	10°	20°	30°	40°	50°	60°	70°	80°
0,0	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
0,1	0,99	0,99	0,99	1,00	1,00	1,00	1,00	1,00	1,00
0,2	0,97	0,97	0,98	1,00	1,00	1,00	1,00	1,00	1,00
0,3	0,92	0,92	0,94	0,98	1,00	1,00	1,00	1,00	1,00
0,4	0,84	0,85	0,89	0,94	1,00	1,00	1,00	1,00	1,00
0,5	0,77	0,79	0,83	0,91	0,98	1,00	1,00	1,00	1,00
0,6	0,73	0,75	0,80	0,89	0,98	1,00	1,00	1,00	1,00
0,7	0,71	0,73	0,79	0,88	0,98	1,00	—	—	—
0,8	—	0,73	0,79	0,88	0,98	1,00	—	—	—
0,9	—	0,73	0,79	0,88	0,98	1,00	—	—	—

^a Corresponds to a south facade in the southern hemisphere.

A.3.2.4 Determination of daylight supply factor for sunshading not activated $F_{\text{D},s,\text{SNA},j}$

Formula (A.16) is used to calculate an approximate value of the effective transmittance for periods during which the solar and/or glare protection system is not activated:

$$\tau_{\text{eff,SNA},j} = \tau_{\text{D65,SNA}} k_1 k_2 k_3 \quad (\text{A.16})$$

where

- $\tau_{D65,SNA}$ is the transmittance of the facade glazing for vertical light incidence;
- k_1 is the reduction factor for frames and structural divisions, as calculated using [Formula \(A.13\)](#);
- k_2 is the reduction factor for pollution of the glazing;
- k_3 is the reduction factor for non-vertical light incidence on the facade glazing (usually, 0,85 is considered to be adequate).

If the transparent or translucent facade element to be evaluated comprises different components, the effective transmittance shall be weighted according to the relative proportion of the areas of the respective components. When determining the shading index by applying [Formulae \(A.6\)](#) and [\(A.12\)](#), the effect of the outer glazing of glazed double facades shall be calculated separately. [Table A.6](#) shows typical values of the transmittance $\tau_{D65,SNA}$ for visible light. If the reduction factor k_1 for frames and structural divisions is not known, it should be assumed to be 0,7.

Table A.6 — Typical values of the transmittance $\tau_{D65,SNA}$ of transparent and translucent building components

Type	Thermal transmittance of glazing unit U (W·m ⁻² ·K)	Total solar energy transmittance of glazing unit $g_{\perp}$	$\tau_{D65,SNA}$
Single glazing	5,8	0,87	0,90
Double glazing	2,9	0,78	0,82
Triple glazing	2,0	0,70	0,75
low-e glazing, double glazed	1,7	0,72	0,74
low-e glazing, double glazed	1,4	0,67	0,78
low-e glazing, double glazed	1,2	0,65	0,78
low-e glazing, triple glazed	0,8	0,50	0,69
low-e glazing, triple glazed	0,6	0,50	0,69
Solar protection glazing, double	1,3	0,48	0,59
Solar protection glazing, double	1,2	0,37	0,67
Solar protection glazing, double	1,2	0,25	0,40

The daylight supply factor $F_{D,s,SNA,j}$ is a function of the daylight availability, the maintained illuminance $\bar{E}_m$, the effective transmittance of the facade $\tau_{eff,SNA,j}$ with deactivated solar and/or glare protection system and of the facade orientation. Estimated values can be taken from [Table A.7](#).

The daylight supply factor $F_{D,s,SNA}$ can be obtained from [Table A.7](#), [Table A.8](#), and [Table A.9](#) as a function of:

- the daylight factor D ;
- the geographic location, i.e. latitude γ ;
- the climate, characterized by the ratio H_{dir}/H_{glob} ;
- the maintained illuminance $\bar{E}_m$; and