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Calculation of the impact of daylight utilization on the net and final energy demand for lighting

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National foreword

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Calculation of the impact of daylight utilization on the net and final energy demand for lighting

Calcul de l'effet d'utiliser la lumière du jour à la demande énergétique net et finale pour l'éclairage

Reference number
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Contents

Page

Foreword

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The committee responsible for this document is ISO/TC 163, *Thermal performance and energy use in the built environment*, Subcommittee SC 2, *Calculation methods*.

Introduction

This International Standard is part of a set of standards allowing to rate the overall energetic performance of buildings. Facades and rooflights have a key impact on the building's energy balance. This International Standard supports the daylighting and lighting-energy-related analysis and optimization of facade and rooflight systems. It was therefore 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.

Calculation of the impact of daylight utilization on the net and final energy demand for lighting

1 Scope

This International Standard 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 International Standard can be used for existing buildings and the design of new and renovated buildings.

This International Standard 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 artificial 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 effect 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 computer-based analysis (comprehensive calculation), minimum requirements are specified.

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

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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/E:2011, *ILV: International Lighting Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in CIE S 017/E:2011 ILV apply.

3.1
ballast
unit inserted between the supply and one or more discharge lamps, which by means of inductance, capacitance, or a combination of inductance and capacitance, serves mainly to limit the current of the lamp(s) to the required value

3.2
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;

— artificial lighting in relation to the currently available daylight;

— systems used to detect and record the presence of occupants

3.3
daylight factor
D
ratio 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 to 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

[SOURCE: CIE S 017/E:2011 ILV, modified]

Note 1 to entry: CIE S 017/E:2011 defines the unit as 1. However, daylight factor is in practice, usually presented in percent values.

3.4
electrical power of artificial lighting system
P
the total electrical power consumption of the lighting system in the considered space

3.5
illuminance
E
quotient of the luminous flux $d\Phi$ incident on an element of the surface containing the point, by the area dA of that element

[SOURCE: CIE S 017/E:2011 ILV, modified]

Note 1 to entry: Unit: lx = lm × m^{-2}.

3.6
lamp
source made to produce optical radiation, usually visible

3.7
light reflectance
ratio of the reflected luminous flux to the incident luminous flux in the given conditions

Note 1 to entry: Unit: 1.

3.8
light transmittance
ratio of the transmitted luminous flux to the incident luminous flux in the given conditions

Note 1 to entry: Unit: 1.

3.9
luminaire
apparatus which distributes, filters, or transforms the light transmitted from one or more lamps and which includes, except the lamps themselves, all the parts necessary for fixing and protecting the lamps and, where necessary, circuit auxiliaries together with the means for connecting them to the electric supply

[SOURCE: CIE S 017/E:2011 ILV]

3.10
luminous exposure
quotient of quantity of light dQ_v incident on an element of the surface containing the point over the given duration, by the area dA of that element

Note 1 to entry: Unit: lx × s = lm × s × m^{-2}.

3.11
luminous flux
Φ
quantity derived from the radiant flux, Φ_e, by evaluating the radiation according to its action upon the CIE standard photometric observer

Note 1 to entry: Unit: lm.

3.12
maintained illuminance
$\bar{E}_m$
value below which the average illuminance over the specified surface is not allowed to fall

Note 1 to entry: Unit: lx = lm × m^{-2}.

3.13
obstruction
anything outside the window which prevents the direct view of part of the sky

3.14
rooflight
daylight opening on the roof or on a horizontal surface of a building

3.15
task area
partial area in the work plane in which the visual task is carried out

[SOURCE: CIE S 017/E:2011 ILV]

3.16
visual task
visual elements of the work being done

[SOURCE: CIE S 017/E:2011 ILV]

4 Symbols, indices, and abbreviated terms

For the purposes of this document, the following symbols and units apply.

4.1 Symbols

	Quantity	Unit
τ	light transmittance	—
ρ	light reflectance	—
Φ	luminous flux	lm
η	efficiency	—
Q	energy	kWh
γ	angle, geographical latitude	°
δ	declination of the sun	°
a	depth	M
A	area	m^2
b	width	M
bf	occupancy factor	—
C	correction factor	—
D	daylight factor	—
$\overline{D}$	mean daylight factor	—
E	illuminance	lx
$\overline{E}_m$	maintained illuminance	lx
f, F	factors	—
g	g-value	—
H	luminous exposure	lxh
h	height	m
I	index	—
k	space index	—
k	correction factor	—
J	counter for number of areas being evaluated	—
N	counter for number of zones	—
p	area-specific power	W/m^2
t	time	H
U	U-value of glazing system	W/m^2K
v	distribution key	—
wi	light-well index	—

4.2 Indices

A	absence	ND	no daylight
At	atrium	Night	night-time
c	control	O	occupancy
Ca	carcass opening	R	room
D	daylight	rel	relative
Day	day-time	Rd	room depth, space depth
dir	direct	s	transparent or translucent surface of the daylight aperture
D65	standard lightsource D65	s	supply
e	energic quantity	SA	sun-shading activated
eff	effective, root-mean-square	Sh	shading, obstruction
ext	external, outdoors	SNA	sun-shading not activated
GDF	glazed curtain wall, glazed double facade	start	start
glob	global	sunrise	sunrise
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
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:

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

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

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

where

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

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;
$t_{eff,Day,D,j}$	is the effective operating time of the lighting system, during day-time, in area *j* which is lit by daylight;
$t_{eff,Day,ND,j}$	is the effective operating time of the lighting system, during day-time, in area *j* which is not lit by daylight;
$t_{eff,Night,j}$	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).

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

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

$t_{Day,n}$	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.

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

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.

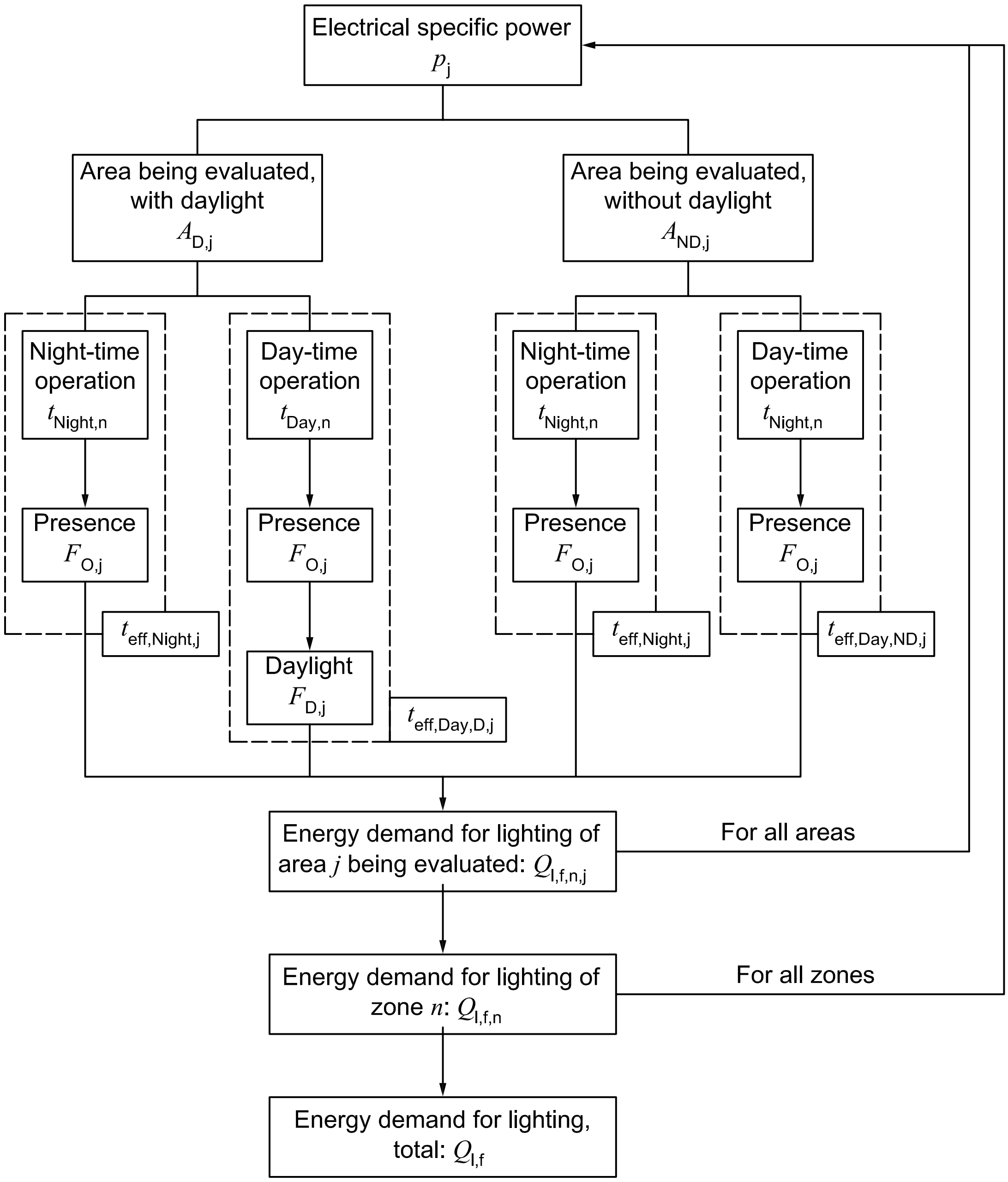


Figure 1 — Flowchart showing calculation of the energy demand for lighting

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 artificial lighting system, lighting control systems, characteristics of the facades).

From practical experience, a simplification rule can be recommended: One and 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 $t_{Day,n}$ during which daylight is available, and intervals $t_{Night,n}$ without daylight. The operating time t_n is equal to $t_{Day,n} + t_{Night,n}$. 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 shall be determined separately.

5.4 Artificial lighting

The specific electrical power of the artificial 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 DIN V 18599-4[2] 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 artificial 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, for instance, defined in DIN 5034-3,[4] 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 calcutate $F_{D,S,j}$ for vertical facades (A.3) and rooflights (A.4) and to obtain tabulated values for $F_{D,c,j}$. Annex B contains specifications for using comprehensive, detailed computer-based tools to calculate $F_{D,j}$.

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 this potential by either manual or automatic switching. Parametrizations of $F_{O,n}$ might, for instance, be found in DIN V 18599-4[2] and EN 15193.[6]

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.

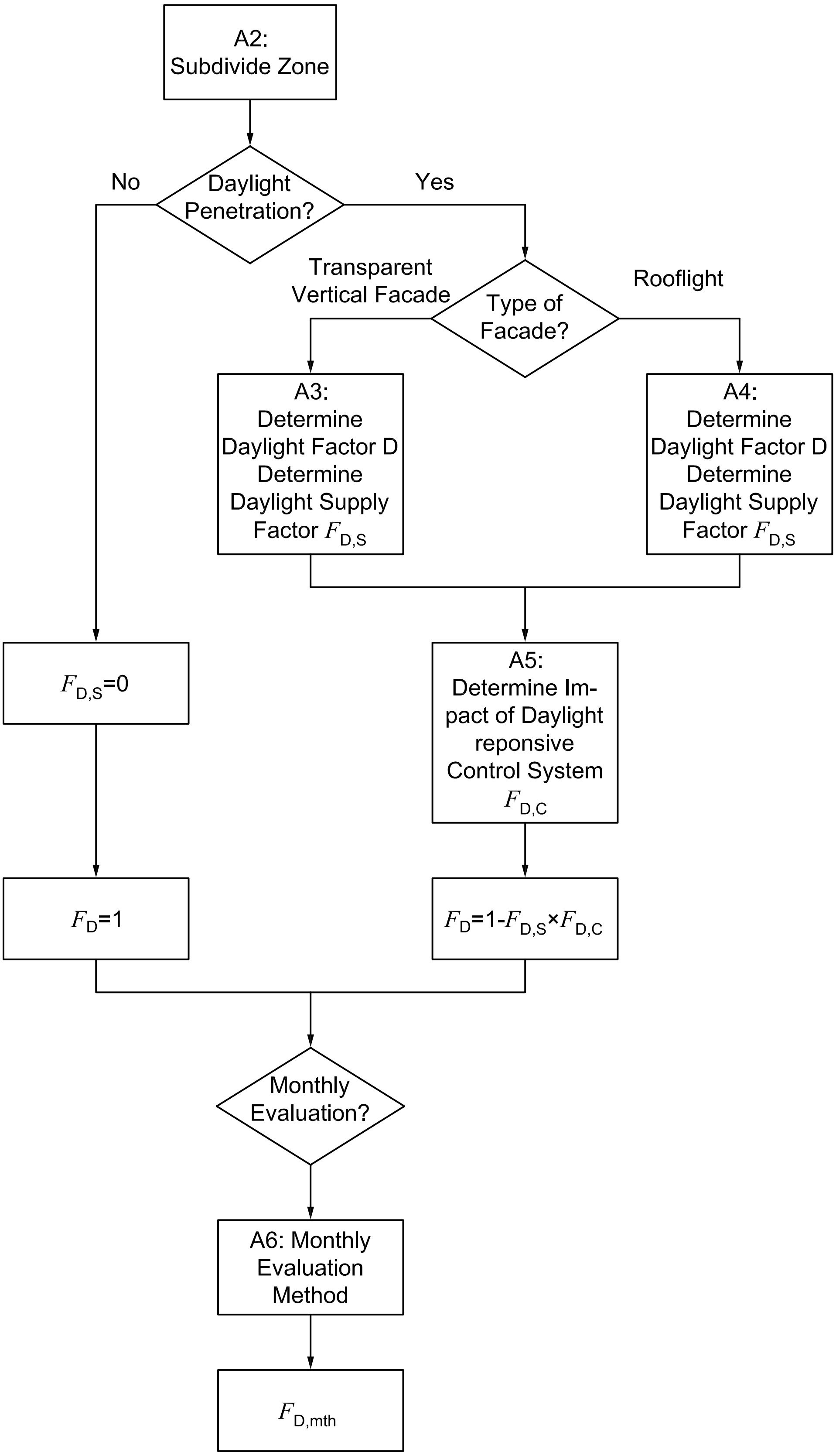


Figure A.1 — Flowchart illustrating the simplified approach

As for the determination of the daylight supply factor $F_{D,S,n,j}$, as well for 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, ρ_F = 0,2 for the floor, ρ_W = 0,5 for the walls, and ρ_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 for instance computer tools.

— 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.

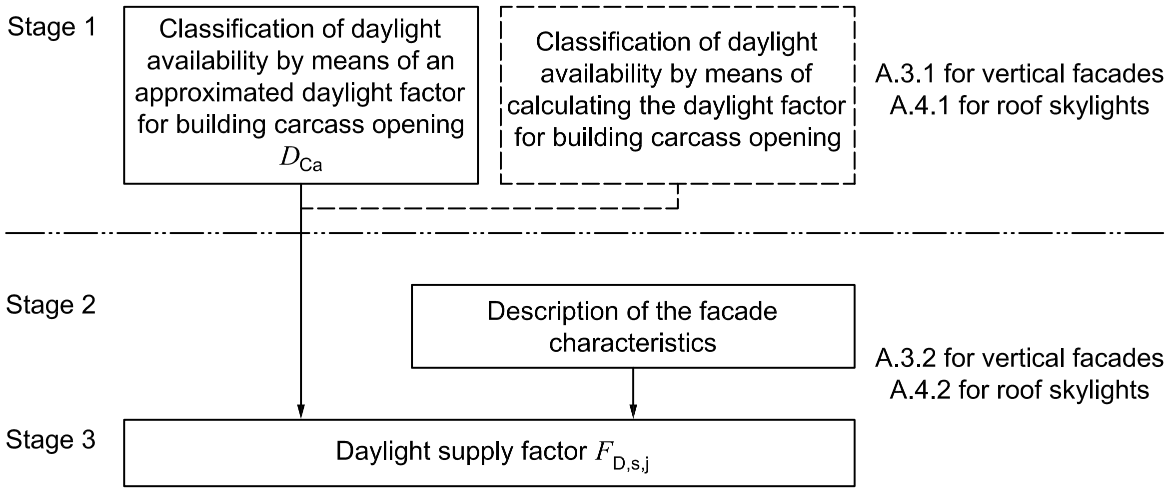


Figure A.2 — Three-stage approach to determining the daylight supply factor $F_{D,s,j}$

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).

Depth and width of the area daylight by vertical facades

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

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

where

$a_{D,max}$ is the maximum depth of the daylight area;

h_{Li} is the height of the window lintel above the floor;

h_{Ta} is the height of the task area above the floor.

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. a_D can also be assumed to be equal to the real depth of the area being evaluated if the real area depth is less than 1,25 times the calculated maximum daylight area depth.

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

$$A_{D,j} = a_D \, b_D \tag{A.2}$$

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

$$a_{D,max} \le 2 \times \left(h_{R,j} - h_{Ta,j} \right) \tag{A.3}$$

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

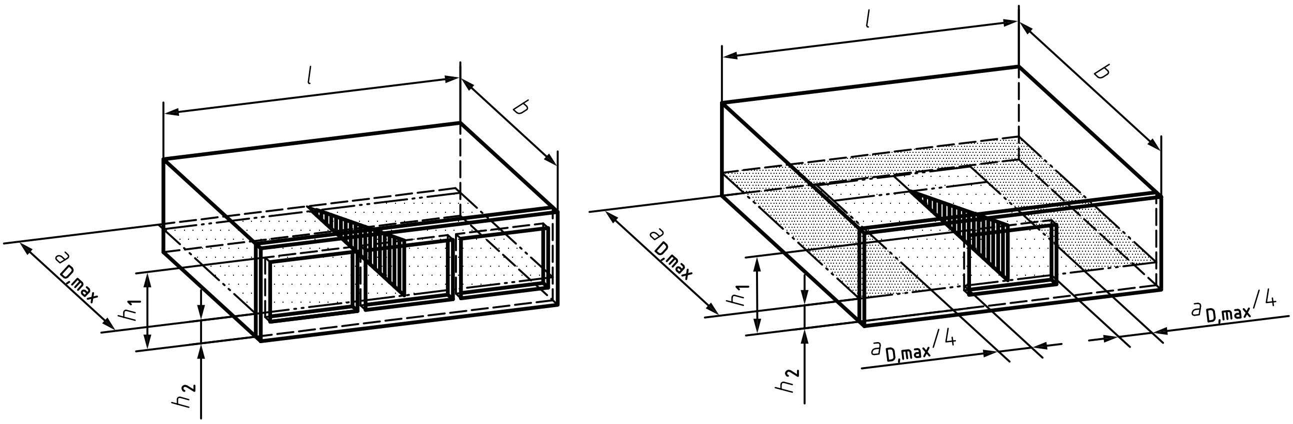
where

$h_{R,j}$ 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.

Distinction between vertical facades and rooflights

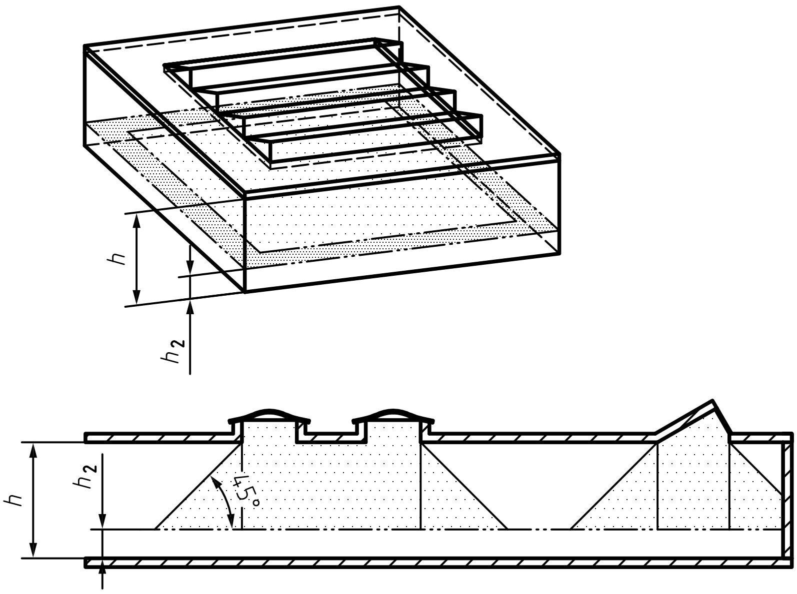
In case of doubt as to whether a specific opening or aperture is to be evaluated as being a window or a rooflight, all such openings of which the entire glazed areas are above the ceiling of the space under consideration are deemed to be rooflights.



Key

- ▭ A_D
- ▭ A_{ND}

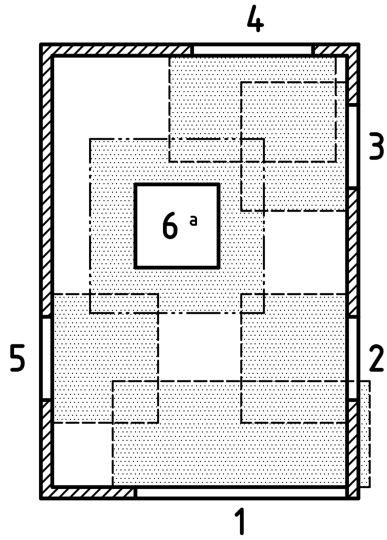
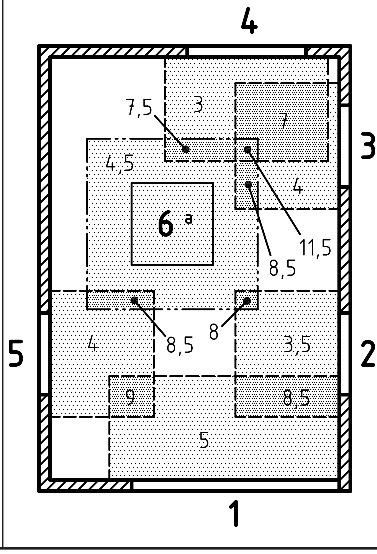
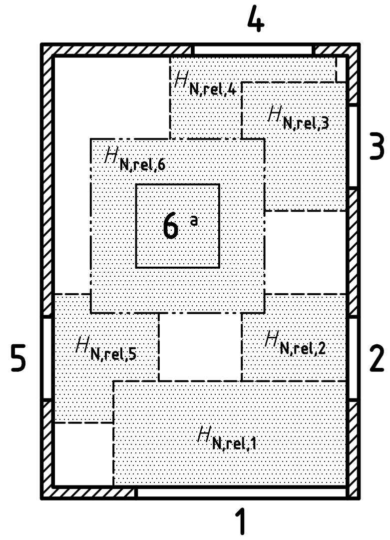
Figure A.3 — Impact of facade opening on daylight area for vertical facades



Key

- ▭ A_D
- ▭ A_{ND}

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

Daylight areas of the different vertical facades (1 – 5) and the rooflight (6)	Approach 1: Superposition of daylight factors in the overlapping daylight areas	Approach 2: The more favourable lighting condition is taken for the respective daylight area: $F_{D,S,1} > F_{D,S,6} > F_{D,S,5} = F_{D,S,3} > F_{D,S,2} > F_{D,S,4}$
		

Key

▭ A_D

▭ A_{ND}

a rooflight

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.

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

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 $I_{RD,j}$.

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

Obstruction 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 might 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).

$$I_{Sh,j} = I_{Sh,lsh} I_{Sh,hf} I_{Sh,vf} I_{Sh,In,At} I_{Sh,GDF} \tag{A.6}$$

where

$I_{Sh,j}$ is the obstruction index of the area j under evaluation;

$I_{Sh,lsh}$ is the correction factor for linear obstruction 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).

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 $I_{Sh,lsh}$

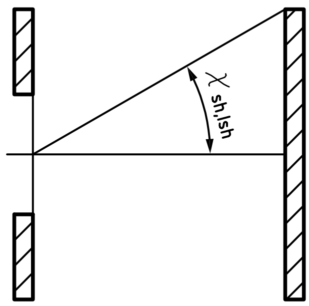


Figure A.6 — Cross-section diagram to illustrate the effect of the linear shading altitude angle $\gamma_{Sh,lsh}$

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.5. Formula (A.7) is used to calculate the correction factor which accounts for linear obstruction.

$$I_{Sh,lsh} = \cos(1{,}5 \times \gamma_{Sh,lsh}) \quad \text{for } \gamma_{Sh,lsh} < 60°$$
$$I_{Sh,lsh} = 0 \quad \text{for } \gamma_{Sh,lsh} \geq 60° \tag{A.7}$$

where

$\gamma_{Sh,lsh}$ is the obstruction altitude angle as shown in Figure A.5.

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

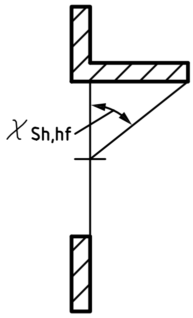


Figure A.7 — Cross-section diagram to illustrate the effect of the horizontal shading angle $\gamma_{Sh,hf}$

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.6. Formula (A.8) is used to calculate the correction factor which accounts for shading by a horizontal projection.

$$I_{Sh,hf} = \cos(1{,}33 \cdot \gamma_{Sh,hf,j}) \quad \text{for } \gamma_{Sh,hf} < 67{,}5°$$
$$I_{Sh,hf} = 0 \quad \text{for } \gamma_{Sh,hf} \geq 67{,}5° \tag{A.8}$$

where

$\gamma_{Sh,hf}$ is the horizontal shading angle due to a horizontal projection as shown in Figure A.6.

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

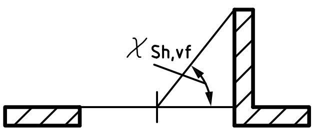


Figure A.8 — Cross-section diagram to illustrate the effect of the vertical shading angle $\gamma_{Sh,vf}$

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.7. Formula (A.9) is used to calculate the correction factor which accounts for shading by a vertical projection.

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

where

$\gamma_{\mathrm{Sh,vf}}$ is the vertical shading angle due to a vertical projection as shown in Figure A.7.

Courtyards and atria (glazed forecourts), correction factor $I_{\mathrm{Sh,In,At}}$

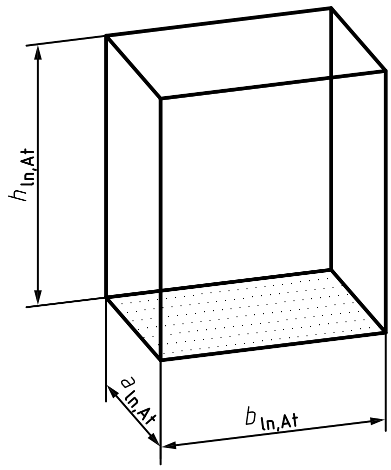
There are very many different design variants for courtyards and atria or glazed forecourts. The calculations are based on an internal courtyard surrounded on all four sides by the building. Better daylight availability can be expected if only three or two sides (linear courtyards) of the courtyard are 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 *wi*:

$$wi = \frac{h_{\mathrm{In,At}} \left(a_{\mathrm{In,At}} + b_{\mathrm{In,At}} \right)}{2 \times a_{\mathrm{In,At}} \, b_{\mathrm{In,At}}} \qquad \text{(A.10)}$$

When determining the well index *wi* 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.

where



$a_{\mathrm{In,At}}$ is the depth of the courtyard or atrium;

$b_{\mathrm{In,At}}$ is the width of the courtyard or atrium;

$h_{\mathrm{In,At}}$ is the height of the courtyard or atrium, measured from the floor of the storey being evaluated;

wi 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 ***wi***

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

$I_{\text{Sh,In,At}} = 1 - 0{,}85\ wi$ for internal courtyards (A.11)

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

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

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:

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

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 $I_{\mathrm{Tr},j}$, $I_{\mathrm{RD},j}$, and $I_{\mathrm{Sh},j}$ 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:

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

For combinations of a larger space depth index value $I_{\mathrm{RD},j}$ and low transparency index values $I_{\mathrm{Tr},j}$, Formula (A.14) might produce negative $D_{\mathrm{Ca},j}$ values. In such cases, $D_{\mathrm{Ca},j}$ 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 $D_{\mathrm{Ca},j}$ of the raw building carcass opening

Daylight factor $D_{\mathrm{Ca},j}$	**Classification of daylight availability**
$D_{\mathrm{Ca},j} \geq 6\ \%$	Strong
$6\ \% > D_{\mathrm{Ca},j} \geq 4\ \%$	Medium
$4\ \% > D_{\mathrm{Ca},j} \geq 2\ \%$	Low
$D_{\mathrm{Ca},j} < 2\ \%$	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

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 $F_{\mathrm{D,s},j}$ 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 availability factor $F_{D,s,j}$.

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

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 availability 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.5. 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 availability 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_{dir}/H_{glob} for representative locations worldwide is given in A.3.2.1.

A.3.2.1 Luminous exposure ratios at different sites (climates and latitudes)

Figure A.9 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_{dir}/H_{glob}. For other specific locations of interest, the ratio H_{dir}/H_{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 to 17:00 h over the whole year.

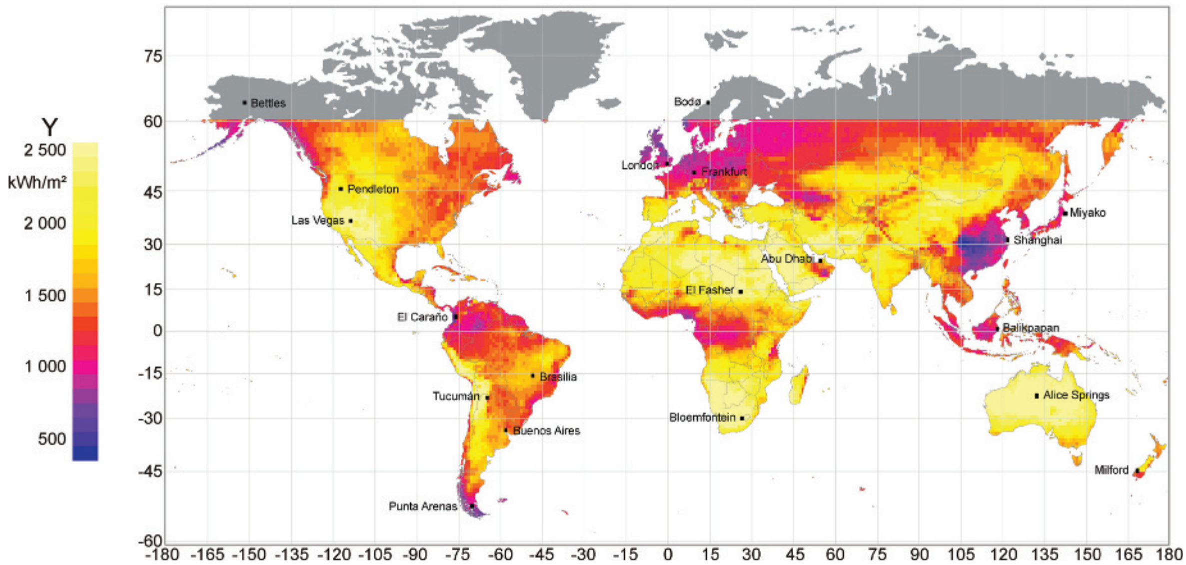


Figure A.10 — Selected sites for which ratios H_{dir}/H_{glob} are provided with assignment of latitude corridors

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

Geographical location				Climate	Representative site	Luminous exposure ratio H_{dir}/H_{glob} [-]
Corridor		Latitude γ	Longitude γ			
Northern hemisphere	60° to 75°	67,3°	14,4°	Cloudy	Bodø, N	0,40
		66,9°	–151,5°	Sunny	Bettles, USA	0,49
	45° to 60°	51,2°	–0,2°	Cloudy	London, GB	0,39
		50,0°	8,7°	Cloudy	Frankfurt, D	0,42
		45,7°	–118,9°	Sunny	Pendleton, USA	0,58
	30° to 45°	39,7°	145,0°	Cloudy	Miyako, J	0,45
		36,1°	–115,2°	Sunny	Las Vegas, USA	0,71
	15° to 30°	31,2°	121,4°	Cloudy	Shanghai, VRC	0,36
		24,4°	54,5°	Sunny	Abu Dhabi, AE	0,58
	0° to 15°	5,7°	–76,6°	Cloudy	El Caraño, CO	0,34
		13,6°	25,3°	Sunny	El Fasher, SUD	0,66
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, RA	0,55
		–30,0°	26,3°	Sunny	Bloemfontein, SA	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.3.2.2 Relative times, shading activated, shading not activated for vertical facades

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

The relative times $t_{rel,D,SNA,j}$ are provided for unobstructed facades. For shading indices $I_{Sh,j}$ of obstructed facades of less than 0,5, especially for higher latitudes $\gamma \geq 45°$, it is recommended to set $t_{rel,D,SNA} = 1$. 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 $I_{Sh,j}$ of a shaded facade is less than 0,5, then the relative times $t_{rel,D,SNA,j}$ and $t_{rel,D,SA,j}$ 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, $t_{rel,D,SNA,j}$ 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]

$t_{rel,D,SNA}$ 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 $t_{rel,D,SNA,j}$ for not activated solar radiation and/or glare protection systems, as a function of the facade orientation, the geographic latitude γ, and the ratio H_{dir}/H_{glob}

t_{SNA} **South**[a]									
H_{dir}/H_{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	—	—	—
t_{SNA} **East/West**									
H_{dir}/H_{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	—	—	—

[a] Corresponds to a north facade in the southern hemisphere.

[b] Corresponds to a north facade in the northern hemisphere.

[c] Corresponds to a south facade in the southern hemisphere.

Table A.3 — *(continued)*

t_{SNA} North[b]/South[c]									
H_{dir}/ H_{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 north facade in the southern hemisphere.

b Corresponds to a north facade in the northern hemisphere.

c Corresponds to a south facade in the southern hemisphere.

A.3.2.3 Determination of Daylight supply factor for sunshading not activated $F_{D,s,SNA,j}$

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:

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

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.4 shows typical values of the transmittance $\tau_{D65,SNA}$ for visible light. Standard values of the pollution reduction factor k_2 are given in DIN V 18599-10.[3] More accurate information on various reduction factors to account for the effect of pollution from a lighting aspect can be found in DIN 5034-3.[4] If the reduction factor k_1 for frames and structural divisions is not known, it should be assumed to be 0,7.

Table A.4 — Typical values of the transmittance $\tau_{D65,SNA}$ of transparent and translucent building components

Type	U	$g\perp$	τ_e	$\tau_{D65,SNA}$
Single glazing	5,8	0,87	0,85	0,90
Double glazing	2,9	0,78	0,73	0,82
Triple glazing	2,0	0,70	0,63	0,75
low-e glazing, double glazed	1,7	0,72	0,60	0,74
low-e glazing, double glazed	1,4	0,67	0,58	0,78
low-e glazing, double glazed	1,2	0,65	0,54	0,78
low-e glazing, triple glazed	0,8	0,50	0,39	0,69
low-e glazing, triple glazed	0,6	0,50	0,39	0,69
Solar protection glazing, double	1,3	0,48	0,44	0,59
Solar protection glazing, double	1,2	0,37	0,34	0,67
Solar protection glazing, double	1,2	0,25	0,21	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 de-activated solar and/or glare protection system and of the facade orientation. Estimated values can be taken from Table A.4. For maintained illuminances $\bar{E}_m$ of less than 100 lx, the $F_{D,s,SNA,j}$ values for $\bar{E}_m$ = 100 lx should be used. Correspondingly, for maintained illuminances $\bar{E}_m$ of more than 1 000 lx, the $F_{D,s,SNA,j}$ values for $\bar{E}_m$ = 1 000 lx should be used.

The daylight availability factor $F_{D,S,SNA}$ can be obtained from Table A.5, Table A.6, and Table A.7 as a function of

— the daylight factor D,

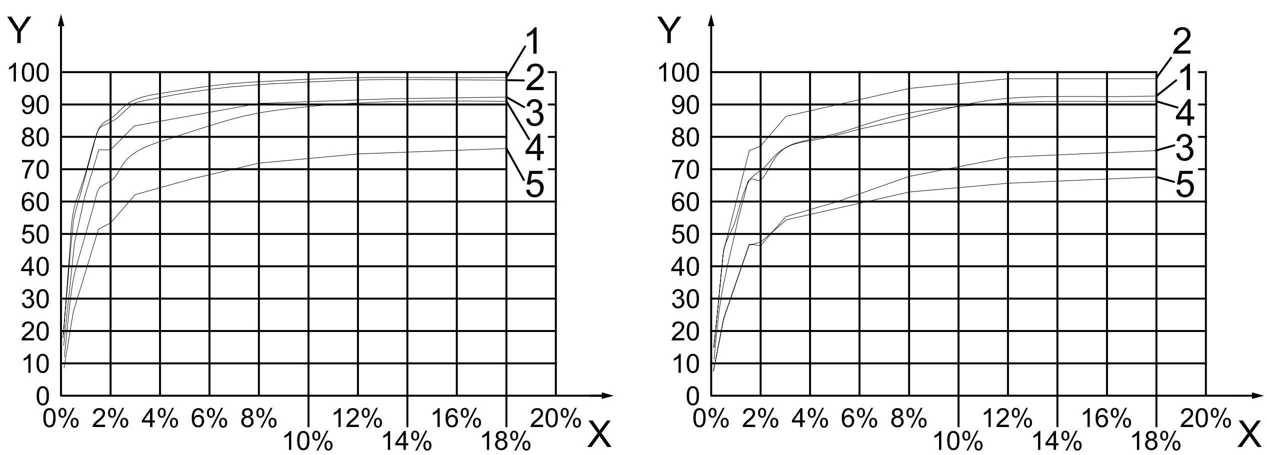
— the geographic location, i. e. latitude γ,

— the climate, characterized by the ratio H_{dir}/H_{glob},

— the maintained illuminance $\bar{E}_m$, and

— the facade orientation.

Figure A.10 provides an exemplarily parametrization for climates with mainly cloudy sky conditions for different locations.



Key

X-axis daylight factor (%)

Y-axis daylight factor, $F_{D,s,SNA,j}$ (%)

1 0° to 15°

2 15° to 30°

3 30° to 45°

4 45° to 60°

5 60° to 75°

Figure A.11 — Example of a set of functions used to determine the daylight supply factor $F_{D,s,SNA,j}$ and $F_{D,s,SA,j}$ as a function of D and γ according to Table (A.5) for $\bar{E}_m$ = 500 lx and a south-facing facade

The relevant D for interpolation in Table A.5, Table A.6, and Table A.7 is obtained from $D = \tau_{eff} \times D_{Ca}$.

Table A.5 — Daylight supply factor $F_{D,s,SNA,j}$ for sun shading not activated parameterized by D, γ, $\bar{E}_m$, climate (H_{dir}/H_{glob}), facade orientation, and geographic location for orientation South

$F_{D,s,SNA,j}$ %												
South facade[a]												
Geo-graphic location γ	$\bar{E}_m$ lx	H_{dir}/H_{glob}	D %									
			0,125	**0,5**	**1,0**	**1,5**	**2,0**	**3,0**	**5,0**	**8,0**	**12,0**	**18,0**
0° – 15°	100	0,34	31,9	95,6	97,9	99,4	99,7	99,9	99,9	100,0	100,0	100,0
		0,66	28,1	84,3	94,0	98,2	98,1	99,3	99,3	100,0	100,0	100,0
	300	0,34	25,1	75,2	83,3	91,9	94,0	96,8	98,0	99,2	99,6	99,6
		0,66	19,9	59,8	67,7	78,3	82,5	88,4	90,5	95,5	98,2	98,3
	500	0,34	18,5	55,6	68,2	82,2	85,7	91,6	94,8	97,2	98,5	98,5
		0,66	14,7	44,0	54,3	65,7	69,3	76,4	80,1	85,6	91,5	92,0
	750	0,34	12,9	38,6	52,6	70,2	75,0	84,4	90,0	94,4	96,6	96,8
		0,66	10,3	30,9	42,4	55,4	58,8	66,6	70,6	76,2	83,1	84,2
	1 000	0,34	9,7	29,1	41,0	59,2	64,7	77,2	85,0	91,4	94,6	94,9
		0,66	7,8	23,3	33,4	47,2	50,7	59,7	64,2	70,0	76,3	77,9
15° – 30°	100	0,36	30,8	92,4	95,9	97,8	97,8	98,7	99,0	99,4	99,6	99,6
		0,58	29,4	88,1	96,6	99,2	98,6	99,6	99,6	100,0	100,0	100,0
	300	0,36	24,3	73,0	83,1	91,1	92,0	95,3	96,7	98,2	98,7	98,8
		0,58	20,6	61,7	76,8	87,8	88,4	94,3	95,9	98,5	99,5	99,5
	500	0,36	17,9	53,7	69,0	82,7	84,8	90,8	93,8	96,6	97,7	97,8
		0,58	14,8	44,3	61,0	75,4	77,0	85,9	89,8	94,6	97,2	97,3
	750	0,36	12,3	36,9	53,5	71,4	75,1	84,5	89,6	94,2	96,2	96,4
		0,58	10,3	30,8	46,9	62,7	65,0	76,3	81,9	89,2	93,6	94,0
	1 000	0,36	9,2	27,7	41,7	60,5	65,1	77,9	85,1	91,5	94,5	94,9
		0,58	7,7	23,2	37,0	52,6	55,4	67,9	74,9	83,8	89,7	90,4

[a] Corresponds to a north facade in the southern hemisphere.

Table A.5 *(continued)*

$F_{D,s,SNA,j}$ %												
South facade[a]												
Geo-graphic location γ	$\bar{E}_m$ lx	H_{dir}/H_{glob}	D %									
			0,125	**0,5**	**1,0**	**1,5**	**2,0**	**3,0**	**5,0**	**8,0**	**12,0**	**18,0**
30° – 45°	100	0,45	26,9	80,6	88,7	92,1	90,7	93,0	93,1	94,5	94,7	95,1
		0,71	17,8	53,3	70,1	80,0	78,4	84,6	85,6	89,5	90,3	90,9
	300	0,45	20,8	62,5	75,4	84,2	83,2	88,4	89,6	92,4	93,3	93,8
		0,71	10,8	32,3	46,6	57,1	56,8	66,4	70,0	77,0	82,4	83,6
	500	0,45	15,4	46,3	62,5	76,0	76,2	83,4	86,1	90,4	91,8	92,4
		0,71	7,6	22,8	36,4	46,6	46,2	55,3	59,5	67,8	73,6	75,4
	750	0,45	10,8	32,3	48,2	65,3	67,1	77,1	81,3	87,2	89,7	90,4
		0,71	5,3	16,0	27,8	38,2	38,2	47,1	51,3	59,6	65,9	68,2
	1 000	0,45	8,3	24,9	37,7	55,4	58,3	71,0	77,2	84,6	87,8	88,6
		0,71	4,1	12,4	21,9	32,0	32,5	41,5	46,0	54,2	60,3	63,0
45°– 60°	100	0,39	25,3	75,8	83,2	88,4	88,5	90,9	92,0	93,4	94,1	94,5
		0,58	24,3	72,8	84,2	90,0	88,2	91,8	92,0	94,1	94,4	94,8
	300	0,39	17,2	51,7	64,0	75,3	76,7	83,7	87,5	91,4	93,1	93,5
		0,58	16,7	50,2	66,5	78,0	77,5	85,0	87,7	92,3	94,0	94,4
	500	0,39	12,0	36,0	49,8	63,7	66,4	75,3	81,1	87,6	90,7	91,3
		0,58	11,5	34,6	51,3	66,0	66,6	76,4	80,7	87,1	90,1	90,8
	750	0,39	8,1	24,3	36,9	51,7	54,5	65,6	73,0	81,6	86,2	87,1
		0,58	8,0	23,9	38,9	54,5	56,0	68,3	74,8	83,0	87,0	87,9
	1 000	0,39	6,1	18,3	28,4	42,4	45,4	57,9	66,5	76,3	82,2	83,3
		0,58	6,0	17,9	30,2	45,1	46,9	60,4	68,5	78,6	83,4	84,5
60°– 75°	100	0,40	20,6	61,7	68,3	72,9	73,0	75,7	76,9	78,3	78,9	80,3
		0,48	17,8	53,4	60,0	64,2	64,2	66,8	68,1	69,7	70,5	72,5
	300	0,40	13,2	39,7	51,3	61,5	62,5	68,3	71,5	75,3	77,1	78,7
		0,48	11,9	35,7	46,1	54,4	54,6	59,9	62,6	66,3	68,0	70,2
	500	0,40	8,6	25,7	38,1	51,4	53,6	61,9	66,7	72,1	74,9	76,5
		0,48	7,9	23,8	35,6	46,3	47,2	54,1	57,9	62,9	65,4	67,6
	750	0,40	5,7	17,1	26,7	39,8	42,6	53,5	60,1	67,3	70,9	72,6
		0,48	5,4	16,1	25,7	37,5	39,3	47,8	52,7	58,9	62,2	64,5
	1 000	0,40	4,3	12,8	20,1	31,4	33,8	46,0	54,3	63,1	67,7	69,5
		0,48	4,0	12,1	19,5	30,1	32,1	42,2	48,2	55,4	59,4	61,8

[a] Corresponds to a north facade in the southern hemisphere.

Table A.6 — Daylight supply factor $F_{D,s,SNA,j}$ for sun shading not activated parameterized by D, γ, $\bar{E}_m$, climate (H_{dir}/H_{glob}), facade orientation, and geographic location for orientations East/ West

$F_{D,s,SNA,j}$ %												
East/West facade												
Geo-graphic location γ	$\bar{E}_m$ lx	H_{dir}/H_{glob}	D %									
			0,125	**0,5**	**1,0**	**1,5**	**2,0**	**3,0**	**5,0**	**8,0**	**12,0**	**18,0**
0° – 15°	100	0,34	31,7	95,1	97,4	98,9	99,2	99,4	99,4	99,5	99,5	99,5
		0,66	26,6	79,9	89,1	93,1	92,9	94,1	94,2	94,8	94,8	94,8
	300	0,34	24,6	73,9	81,8	90,2	92,3	95,0	96,2	97,3	97,8	97,9
		0,66	15,1	45,2	51,1	59,2	62,3	66,8	68,4	72,1	74,2	75,9
	500	0,34	18,0	53,9	66,1	79,7	83,1	88,9	91,9	94,2	95,5	95,8
		0,66	11,7	35,2	43,5	52,6	55,5	61,1	64,1	68,5	73,2	75,0
	750	0,34	12,5	37,5	51,0	68,1	72,7	81,8	87,3	91,5	93,6	94,0
		0,66	6,1	18,4	25,3	33,1	35,1	39,7	42,1	45,4	49,5	53,0
	1 000	0,34	9,4	28,1	39,7	57,3	62,5	74,6	82,2	88,4	91,5	92,0
		0,66	4,5	13,4	19,2	27,1	29,2	34,3	36,9	40,3	43,9	47,7
15° – 30°	100	0,36	30,6	91,8	95,3	97,2	97,2	98,1	98,4	98,7	98,9	99,0
		0,58	28,9	86,6	95,0	97,5	96,9	97,9	97,9	98,3	98,3	98,4
	300	0,36	23,4	70,3	80,1	87,8	88,6	91,8	93,2	94,6	95,1	95,4
		0,58	17,7	53,1	66,2	75,6	76,2	81,2	82,6	84,8	85,7	86,6
	500	0,36	16,8	50,5	64,9	77,7	79,7	85,3	88,2	90,8	91,8	92,3
		0,58	12,4	37,2	51,2	63,4	64,7	72,2	75,4	79,4	81,6	82,8
	750	0,36	11,4	34,1	49,4	66,0	69,5	78,2	82,8	87,1	89,0	89,7
		0,58	7,4	22,1	33,7	45,0	46,7	54,8	58,8	64,0	67,2	69,4
	1 000	0,36	8,4	25,3	38,0	55,1	59,4	71,0	77,6	83,4	86,1	87,1
		0,58	5,3	15,8	25,2	35,9	37,7	46,3	51,0	57,1	61,1	63,8
30° – 45°	100	0,45	26,2	78,6	86,5	89,9	88,5	90,7	90,9	92,2	92,4	92,9
		0,71	16,4	49,3	64,9	74,1	72,6	78,4	79,2	82,8	83,6	84,7
	300	0,45	18,7	56,1	67,6	75,5	74,6	79,2	80,3	82,9	83,7	84,8
		0,71	7,0	21,1	30,4	37,2	37,0	43,3	45,6	50,2	53,7	56,9
	500	0,45	13,6	40,7	55,0	66,9	67,1	73,4	75,7	79,5	80,8	82,1
		0,71	5,8	17,3	27,6	35,4	35,1	42,0	45,2	51,5	55,9	58,9
	750	0,45	8,9	26,7	39,7	53,9	55,3	63,6	67,1	72,0	74,0	75,7
		0,71	2,2	6,7	11,6	15,9	15,9	19,6	21,4	24,8	27,5	32,4
	1 000	0,45	6,7	20,1	30,3	44,6	47,0	57,2	62,2	68,2	70,8	72,8
		0,71	1,5	4,6	8,1	11,9	12,1	15,4	17,1	20,2	22,4	27,7

Table A.6 *(continued)*

$F_{D,s,SNA,j}$ %												
East/West facade												
Geo-graphic location γ	$\bar{E}_m$ lx	H_{dir}/H_{glob}	D %									
			0,125	**0,5**	**1,0**	**1,5**	**2,0**	**3,0**	**5,0**	**8,0**	**12,0**	**18,0**
45° – 60°	100	0,39	25,0	75,0	82,3	87,4	87,5	89,9	91,0	92,4	93,0	93,5
		0,58	23,9	71,6	82,8	88,5	86,8	90,3	90,5	92,5	92,9	93,3
	300	0,39	16,2	48,7	60,2	70,9	72,2	78,8	82,4	86,1	87,6	88,4
		0,58	14,8	44,5	58,9	69,2	68,7	75,4	77,8	81,8	83,3	84,5
	500	0,39	11,0	33,1	45,8	58,6	61,1	69,2	74,6	80,6	83,4	84,5
		0,58	9,8	29,4	43,6	56,1	56,6	65,0	68,6	74,1	76,6	78,2
	750	0,39	7,3	21,9	33,1	46,4	49,0	59,0	65,6	73,3	77,5	79,0
		0,58	6,4	19,2	31,4	43,9	45,1	55,0	60,2	66,8	70,1	72,1
	1 000	0,39	5,4	16,2	25,1	37,6	40,3	51,3	58,9	67,7	72,8	74,7
		0,58	4,7	14,1	23,7	35,4	36,9	47,5	53,8	61,8	65,6	67,9
60° – 75°	100	0,40	20,9	62,8	69,5	74,3	74,3	77,1	78,3	79,7	80,3	81,6
		0,48	16,8	50,3	56,5	60,5	60,5	62,9	64,2	65,7	66,4	68,7
	300	0,40	12,5	37,6	48,6	58,4	59,3	64,8	67,8	71,4	73,2	74,7
		0,48	9,9	29,7	38,4	45,3	45,5	49,8	52,1	55,2	56,6	59,3
	500	0,40	7,9	23,7	35,0	47,3	49,3	57,0	61,3	66,3	68,9	70,9
		0,48	7,1	21,4	32,0	41,7	42,5	48,7	52,1	56,6	58,8	61,6
	750	0,40	5,1	15,3	23,8	35,5	38,0	47,7	53,6	60,0	63,2	65,5
		0,48	4,2	12,5	20,0	29,1	30,5	37,1	40,9	45,7	48,3	51,5
	1 000	0,40	3,7	11,2	17,6	27,5	29,6	40,3	47,6	55,3	59,3	62,0
		0,48	3,1	9,3	15,0	23,2	24,7	32,4	37,1	42,6	45,7	49,3

Table A.7 — Daylight supply factor $F_{D,s,SNA,j}$ for sun shading not activated, parameterized by D, γ, $\bar{E}_m$, climate (H_{dir}/H_{glob}), facade orientation, and geographic location for orientation North

$F_{D,s,SNA,j}$ %												
North facade[a]												
Geographic location γ	$\bar{E}_m$ lx	H_{dir}/H_{glob}	D %									
			0,125	**0,5**	**1,0**	**1,5**	**2,0**	**3,0**	**5,0**	**8,0**	**12,0**	**18,0**
0° – 15°	100	0,34	31,8	95,4	97,7	99,3	99,5	99,7	99,7	99,8	99,8	99,8
		0,66	27,2	81,6	91,0	95,1	94,9	96,1	96,2	96,8	96,8	96,8
	300	0,34	24,5	73,5	81,4	89,7	91,8	94,6	95,8	96,9	97,3	97,5
		0,66	14,5	43,5	49,2	56,9	59,9	64,2	65,8	69,4	71,4	73,3
	500	0,34	17,8	53,4	65,4	78,9	82,2	88,0	91,0	93,3	94,5	94,9
		0,66	10,6	31,7	39,1	47,3	49,9	55,0	57,6	61,7	65,8	68,2
	750	0,34	12,2	36,5	49,7	66,4	70,9	79,8	85,1	89,2	91,3	91,8
		0,66	5,3	15,9	21,9	28,6	30,3	34,3	36,4	39,3	42,8	46,7
	1 000	0,34	9,2	27,5	38,8	56,0	61,1	72,9	80,3	86,3	89,4	90,1
		0,66	4,0	12,0	17,2	24,3	26,2	30,8	33,1	36,1	39,3	43,5
15° – 30°	100	0,36	30,4	91,2	94,7	96,6	96,6	97,4	97,8	98,1	98,3	98,4
		0,58	28,8	86,4	94,8	97,3	96,7	97,7	97,7	98,1	98,1	98,2
	300	0,36	22,8	68,4	77,9	85,4	86,2	89,3	90,7	92,0	92,5	93,0
		0,58	16,8	50,5	62,9	71,9	72,5	77,2	78,6	80,7	81,5	82,7
	500	0,36	16,1	48,3	62,1	74,4	76,3	81,7	84,4	86,9	87,9	88,7
		0,58	11,5	34,6	47,6	58,8	60,1	67,0	70,0	73,8	75,8	77,4
	750	0,36	10,7	32,0	46,4	62,0	65,2	73,4	77,8	81,8	83,5	84,6
		0,58	6,7	20,0	30,5	40,7	42,3	49,6	53,2	58,0	60,8	63,5
	1 000	0,36	7,8	23,3	35,0	50,8	54,8	65,5	71,6	76,9	79,5	80,9
		0,58	4,7	14,0	22,3	31,7	33,4	40,9	45,1	50,5	54,1	57,2
30° – 45°	100	0,45	25,4	76,3	83,9	87,2	85,9	88,0	88,2	89,5	89,7	83,6
		0,71	16,6	49,9	65,6	74,9	73,4	79,2	80,1	83,7	84,5	85,5
	300	0,45	17,2	51,7	62,3	69,6	68,8	73,0	74,0	76,4	77,1	78,7
		0,71	6,9	20,7	29,8	36,5	36,3	42,5	44,8	49,3	52,7	55,9
	500	0,45	11,7	35,2	47,5	57,8	57,9	63,4	65,4	68,7	69,8	71,8
		0,71	5,8	17,3	27,6	35,4	35,1	42,0	45,2	51,5	55,9	58,9
	750	0,45	7,7	23,2	34,6	46,9	48,2	55,3	58,4	62,6	64,4	66,8
		0,71	2,0	6,1	10,5	14,5	14,4	17,8	19,4	22,5	24,9	30,0
	1 000	0,45	5,7	17,1	25,9	38,0	40,1	48,8	53,0	58,1	60,3	63,0
		0,71	1,4	4,1	7,2	10,5	10,7	13,6	15,1	17,8	19,8	25,3

[a] Corresponds to a south facade in the southern hemisphere.

Table A.7 *(continued)*

Geo-graphic location γ	$\bar{E}_m$ lx	H_{dir}/H_{glob}	$F_{D,s,SNA,j}$ % — North facade[a] — D % 0,125	0,5	1,0	1,5	2,0	3,0	5,0	8,0	12,0	18,0
45° – 60°	100	0,39	24,7	74,2	81,4	86,4	86,5	88,9	89,9	91,3	92,0	92,5
		0,58	23,6	70,8	81,9	87,5	85,7	89,2	89,5	91,4	91,8	92,3
	300	0,39	15,5	46,5	57,5	67,7	68,9	75,3	78,6	82,2	83,6	84,7
		0,58	13,9	41,6	55,1	64,7	64,2	70,4	72,7	76,4	77,9	79,4
	500	0,39	10,3	31,0	42,8	54,8	57,1	64,7	69,8	75,4	78,0	79,4
		0,58	8,4	25,3	37,5	48,1	48,6	55,8	58,9	63,6	65,8	68,1
	750	0,39	6,7	20,1	30,4	42,6	44,9	54,1	60,2	67,2	71,0	73,0
		0,58	5,5	16,6	27,1	38,0	39,0	47,6	52,1	57,8	60,6	63,3
	1 000	0,39	4,9	14,6	22,7	33,9	36,3	46,3	53,1	61,0	65,7	68,0
		0,58	4,0	11,9	20,1	30,0	31,2	40,2	45,5	52,3	55,5	58,5
60° – 75°	100	0,40	21,0	63,1	69,9	74,6	74,7	77,5	78,7	80,1	80,7	82,0
		0,48	17,1	51,3	57,6	61,7	61,7	64,2	65,4	67,0	67,7	69,9
	300	0,40	11,9	35,8	46,3	55,6	56,5	61,7	64,5	68,0	69,7	71,5
		0,48	9,4	28,1	36,3	42,8	43,0	47,1	49,3	52,2	53,6	56,5
	500	0,40	7,3	21,9	32,4	43,7	45,5	52,6	56,7	61,3	63,7	66,0
		0,48	6,5	19,5	29,2	38,0	38,7	44,4	47,5	51,5	53,6	56,7
	750	0,40	4,6	13,8	21,4	32,1	34,3	43,0	48,4	54,1	57,1	59,7
		0,48	3,7	11,0	17,7	25,7	27,0	32,8	36,2	40,5	42,7	46,4
	1 000	0,40	3,3	10,0	15,6	24,4	26,2	35,7	42,1	49,0	52,6	55,7
		0,48	2,7	8,1	13,0	20,0	21,3	28,0	32,0	36,9	39,5	43,5

[a] Corresponds to a south facade in the southern hemisphere.

A.3.2.4 Determination of daylight supply factor for sunshading activated $F_{D,s,SA,j}$

Facade system solutions with an activated solar and/or glare protection can be classified according to Table A.8 in a simplified way.

Table A.8 — System solutions (values to be applied for the period $t_{rel,D,SA,j}$)

System solution (to be used for the period $t_{rel,D,SA,j}$)		$F_{D,S,SA,j}$ — Classification of daylight availability: None	Low	Medium	Strong
1	Glare protection only: Systems which provide glare protection in compliance with the regulations applying to the respective utilization profile, e. g. regulations for computer terminal workplaces.[2] This includes manually operated Venetian blinds[a].	—	0,1	0,2	0,3

[a] Venetian blinds and internal or external louvres are also dealt with in DIN V 18599–2.[1]

Table A.8 *(continued)*

System solution (to be used for the period $t_{rel,D,SA,j}$)		$F_{D,S,SA,j}$ Classification of daylight availability			
		None	Low	Medium	Strong
2	Automatically-operated protection against solar radiation and glare: Devices to protect against solar radiation and/or glare and which can be moved in relation to the amount of daylight available. Venetian blinds which are automatically opened slightly after being lowered, so that transmittance is greater than that of the fully closed blinds.	—	0,2	0,43	0,55
3	Light-guiding systems	—	0,3	0,65	0,8
4	No protection against solar radiation and shades. NOTE Only applicable for areas being evaluated to which no special regulations or provisions such as the regulations for computer terminal workplaces apply.	—	0,6	0,75	0,8
a Venetian blinds and internal or external louvres are also dealt with in DIN V 18599–2.[1]					

Light-guiding system solutions, line 3 of Table A.8, can be assumed to include solutions of type 1 with additional light-guiding functions:

— *Venetian blinds in cut-off operating mode:* In the so-called “cut-off” mode, the louvres of the blinds are directed in relation to the incident sunlight in such a way that direct sunlight is just prevented from passing through, but diffuse daylight can enter. Furthermore, these systems generally permit visual contact to the surroundings for a large part of the operating time. Appropriate control systems which move the louvres in relation to the solar radiation profile angle shall be installed. The sun profile angle is the projection of the altitude angle of the sun onto a vertical plane which is perpendicular to the plane of the facade surface.

— *Light-guiding glass:* Facade systems using glass components which transmit at least 30 % of the incident direct sunlight into the upper quarter of the space when lit under an altitude of 35° (measured from the normal of the facade plane) at a sun facade azimuth of zero. As a general rule, not more than 1/3 of the transparent facade openings should be equipped with such systems to prevent overheating of the respective space. Light-guiding glass shall be combined with other solar radiation protection and/or glare protection systems installed in the lower section of the facade area. However, no solar and/or glare protection devices can be installed in front of the light-guiding components described below.

— *Daylight-guiding external Venetian blinds:* These have diffuse surfaces and the louvres of the upper and lower sections of the blinds are at different angles. The upper section of the blind shall not be higher than 1/3 and not lower than 1/4 of the total blind length and the system shall be equipped with control devices.

— *Daylight-guiding internal Venetian blinds between glazing layers or in the air-space (gap) of glazed double facades:* These have highly reflective or mirror-finished surfaces and the louvres of the upper and lower sections of the blinds are at different angles. The upper section of the blind shall not be higher than 1/3 and not lower than 1/4 of the total blind length and the system shall be equipped with control devices.

No solar and/or glare protection devices can be installed in front of the light-guiding components listed in Table A.8.

A.4 Daylight supply factor for rooflights

As in the method applied for vertical facades, the first evaluation step for rooflights is to classify the daylight availability via the daylight factor. Then the daylight availability factors can be determined for different maintained illuminance values, different orientations and slope angles of the glazed roof openings and locations and climates.

A.4.1 Daylight availability factor

An approximate value of the mean daylight factor of spaces equipped with rooflights can be calculated using Formula (A.17).

$$\bar{D}_j = D_a \tau_{D65} k_1 k_2 k_3 \frac{\sum A_{Ca}}{A_D} \eta_R \text{ in } \% \tag{A.17}$$

where

A_{Ca} is the area of the rooflights (raw roof opening dimensions);

A_D is the floor area which is lit by daylight in the space being evaluated;

D_{ext} is the external daylight factor;

τ_{D65} is the transmittance of the diffusive rooflight glazing;

k_1 is the reduction factor for frames and subdivisions of the glazing;

k_2 is the reduction factor for pollution of the glazing;

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

η_R is the value of utilance as listed in Table A.11 and Table A.12.

Formula (A.17) combines the calculation stages 1 (classification of daylight availability) and 2 (description of the facade characteristics) of the three-stage calculation approach in one single calculation step. This method is also applicable for skylights with transparent glazing. As a supplement to the typical transmittance values given in Table A.4, Table A.9 contains a list of transmittance values of components frequently used in rooflights.

Table A.9 — Typical values of the transmittance τ_{D65}, U, and g of components frequently used in rooflight construction

Type	Construction	Colour	U W/(m2 · K)	$g \perp$	τ_{D65}
Sky dome	Acrylic sheet, single-shell	clear	5,4	0,85	0,92
	Acrylic sheet, single-shell	opal	5,4	0,80	0,83
	Acrylic sheet, double-shell	clear/clear	2,7	0,78	0,80
	Acrylic sheet, double-shell	opal/clear	2,7	0,72	0,73
	Acrylic sheet, triple-shell	clear/clear/clear	1,8	0,66	0,68
	Acrylic sheet, triple-shell	opal/opal/clear	1,8	0,64	0,60
	PMMA, single-shell	clear	5,4	0,88	0,92
	PMMA, single-shell	opal	5,4	0,78	0,79
	PMMA, single-shell	coated	5,4	0,38	0,51
	PMMA, double-shell	clear/clear	2,8	0,77	0,84
	PMMA, double-shell	opal/clear	2,8	0,68	0,71
	PMMA, double-shell	opal/opal	2,8	0,64	0,59
	PMMA, double-shell	coated/clear	2,8	0,32	0,47
	PMMA, triple-shell	clear/clear/clear	1,7	0,70	0,79
Strip sky-light	Polycarbonate multiwall double-wall sheet, 6 mm	clear	3,6	0,86	0,82
	Polycarbonate multiwall double-wall sheet, 6 mm	opal	3,6	0,78	0,64
	Polycarbonate multiwall double-wall sheet, 8 mm	clear	3,3	0,81	0,81
	Polycarbonate multiwall double-wall sheet, 8 mm	opal	3,3	0,70	0,62
	Polycarbonate multiwall double-wall sheet, 10 mm	clear	3,1	0,85	0,80
	Polycarbonate multiwall double-wall sheet, 10 mm	opal	3,1	0,70	0,50
	Polycarbonate multiwall triple-wall sheet, 10 mm	clear	3,0	0,69	0,73
	Polycarbonate multiwall triple-wall sheet, 10 mm	opal	3,0	0,62	0,52
	Polycarbonate multiwall four-wall sheet, 10 mm	opal	2,5	0,59	0,50
	Polycarbonate multiwall triple-wall sheet, 16 mm	clear	2,4	0,69	0,72
	Polycarbonate multiwall triple-wall sheet, 16 mm	opal	2,4	0,55	0,48
	Polycarbonate multiwall five-wall sheet, 16 mm	opal	1,9	0,52	0,45
	Polycarbonate multiwall six-wall sheet, 16 mm	opal	1,85	0,47	0,42
	Polycarbonate multiwall five-wall sheet, 20 mm	clear	1,8	0,70	0,64
	Polycarbonate multiwall five-wall sheet, 20 mm	opal	1,8	0,46	0,44
	Polycarbonate multiwall four-wall sheet, 25 mm	clear	1,7	0,62	0,68
	Polycarbonate multiwall four-wall sheet, 25 mm	opal	1,7	0,53	0,45
	Polycarbonate multiwall six-wall sheet, 25 mm	clear	1,45	0,67	0,62

Table A.9 *(continued)*

Type	Construction	Colour	U $W/(m_2 \cdot K)$	$g\perp$	τ_{D65}
Strip sky-light	Polycarbonate multiwall six-wall sheet, 25 mm	opal	1,45	0,46	0,44
	PMMA multiwall double-wall sheet, 8 mm	clear	3,4	0,82	0,84
	PMMA multiwall double-wall sheet, 8 mm	opal	3,4	0,79	0,80
	PMMA multiwall double-wall sheet, 8 mm	coated	3,4	0,50	0,62
	PMMA multiwall double-wall sheet, 16 mm	clear	2,5	0,82	0,86
	PMMA multiwall double-wall sheet, 16 mm	clear, C-relief	2,5	0,81	0,85
	PMMA multiwall double-wall sheet, 16 mm	opal	2,5	0,73	0,74
	PMMA multiwall double-wall sheet, 16 mm	coated	2,5	0,40	0,50
	PMMA multiwall double-wall sheet, 16 mm	coated	2,5	0,82	0,91
	PMMA multiwall double-wall sheet, 16 mm	coated, brown	2,5	0,63	0,50
	PMMA multiwall four-wall sheet, 32 mm	clear	1,6	0,71	0,76
	PMMA multiwall four-wall sheet, 32 mm	clear, C-relief	1,6	0,69	0,74
	PMMA multiwall four-wall sheet, 32 mm	opal	1,6	0,60	0,64
	PMMA multiwall four-wall sheet, 32 mm	coated, opal	1,6	0,30	0,40
	PMMA multiwall four-wall sheet, 32 mm	coated, clear	1,6	0,50	0,45

Table A.9 — *(continued "A", individual roof windows, glazed, "B" continuous rooflight, glazed)*

Type	Composition	type	*U* W/(m² · K)	g ⊥	τ_{D65}
A	4 mm float glass 16 mm air 4 mm float glass	clear double pane	2,8	0,79	0,81
A	4 mm toughened glass 16 mm Argon 4 mm float glass w. coating	clear double pane low-e	1,2	0,59	0,76
A	4 mm toughened glass 14 mm Argon 33,1 laminated float glass	clear double pane low-e	1,2	0,54	0,75
A	4 mm toughened 14 mm air 33,1 laminated float glass w. coating	clear double pane low-e, sun protection	1,2	0,27	0,42
B	Laminated glass 6,2 16 mm air, 6 mm float glass	clear	2,7	0,67	0,77
B	Laminated glass 6,2 16 mm air, 8 mm float glass	clear	2,7	0,67	0,77
B	Laminated glass 8,2 16 mm air, 6 mm float glass	clear	2,7	0,65	0,77
B	Laminated glass 8,2 16 mm air, 8 mm float glass	clear	2,7	0,65	0,76
B	Laminated glass 10,2 16 mm air, 6 mm float glass	clear	2,7	0,63	0,76
B	Laminated glass 10,2 16 mm air, 8 mm float glass	clear	2,7	0,63	0,76
B	Laminated glass 6,2 16 mm argon, 6 mm float glass	coated, silver	1,1	0,52	0,72
B	Laminated glass 6,2 16 mm argon, 8 mm float glass	coated, silver	1,1	0,52	0,71
B	Laminated glass 8,2 16 mm argon, 6 mm float glass	coated, silver	1,1	0,51	0,71
B	Laminated glass 8,2 16 mm argon, 8 mm float glass	coated, silver	1,1	0,51	0,70
B	Laminated glass 10,2 16 mm argon, 6 mm float glass	coated, silver	1,1	0,50	0,70
B	Laminated glass 10,2 16 mm argon, 8 mm float glass	coated, silver	1,1	0,49	0,70
B	6 mm toughened glass (extra clear) 18mm Argon, 33,1 laminated float glass	clear double pane	1,5	0,61	0,79
B	6 mm toughened glass (green) 18 mm Argon, 33,1 laminated float glass	clear double pane	1,5	0,38	0,64
B	6 mm toughened glass (grey) 18 mm Argon, 33,1 laminated float glass	clear double pane	1,5	0,34	0,39
B	6 mm toughened glass (extra clear) 18 mm Argon, 44,1 laminated float glass	clear double pane	1,5	0,55	0,78

The external daylight factor D_a is defined as

$$D_a = \frac{E_F}{E_a} \text{ in } \% \quad (A.18)$$

where

E_F is the illuminance on the external surface of the skylight from an overcast sky;

E_a is the horizontal external illuminance from an overcast sky.

The correction factor $k_{Obl,1}$ for frames and subdivisions can be determined using Formula (A.13). The structural parts of dome skylights include the annular supports. Thus, $k_{Obl,1}$ is the ratio of the area $A_{Fs} = a_s \cdot b_s$ through which light can pass, i. e. the top opening of the annular support, minus the area of other opaque parts of the domes or strip skylights, to the area $A_{Rb} = a_{Rb} \cdot b_{Rb}$ of the raw roof opening as shown in Figure A.11.

As opposed to this, the raw roof opening area of shed rooflights does not correspond to the area of the roof plane occupied by the shed structure, as shown in Figure A.12. For these, the raw roof opening area is $A_{Ca} = h_G \cdot b_{Rb}$, where h_G is the height of the skylight opening and b_{Rb} is the width of the skylight opening. The correction factor $k_{Obl,1}$ for frames and subdivisions accounts for the other opaque parts of the skylight structure within the opening defined in this way.

Table A.10 lists external daylight factors D_a for a ground reflectance ρ_B of 0,2 and various slope angles of the shed-roof glazing.

Table A.10 — External daylight factor D_a as a function of the facade slope γ_F for a floor reflectance ρ_B of 0,2 (without building shading)

Slope γ_F degrees	$D_a = E_F/E_a$ %
0	100
30	92
45	83
60	72
90	50

The utilance η_R is calculated on the basis of the space index as determined using Formula (A.19) and the type of rooflight involved. In the calculation of η_R, h'_R is the difference between the ceiling height and the work plane height. The height of the work plane is given for individual utilization profiles in A.8. A distinction is made between the dome skylights shown in Figure A.11 and the shed rooflights shown in Figure A.12. Strip skylights are treated as a special dome skylight design. For strip skylights with a side ratio a_S/b_S of more than 5, the utilance stated for ratio a_S/b_S = 5 should be assumed. The room index is defined as

$$k = \frac{a_R \cdot b_R}{h'_R \cdot (b_R + a_R)} \quad (A.19)$$

where

a_R is the room depth;

b_R is the room width;

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

Table A.11 and Table A.12 show utilance values for different types of dome and shed rooflight geometries.

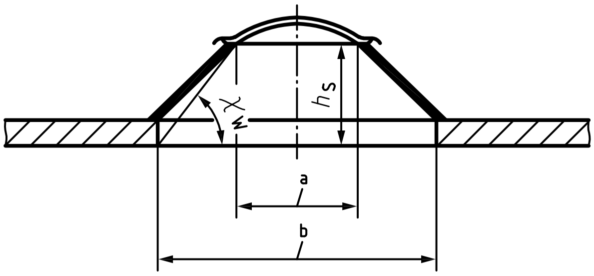


Figure A.12 — Dimensions used to describe the geometry of the annular supports of spaces with dome and strip skylights

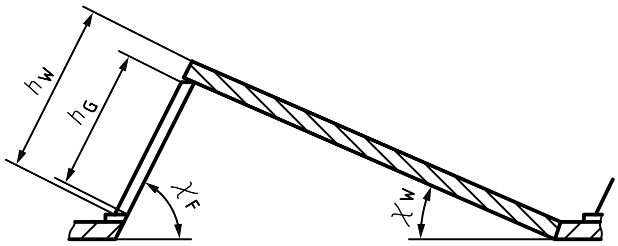


Figure A.13 — Dimensions used to describe the geometry of shed rooflights

Table A.11 — Dome skylight utilances η_R, expressed as a percentage, as a function of the space index k and the geometry parameters of the annular support design

a_S/b_S	1			2			5			1			2			5		
h_S/b_S	0,25			0,25			0,25			0,5			0,5			0,5		
γ_W	30°	60°	90°	30°	60°	90°	30°	60°	90°	30°	60°	90°	30°	60°	90°	30°	60°	90°
k	η_R %																	
0,6	0,40	0,41	0,38	0,40	0,40	0,39	0,41	0,41	0,40	0,40	0,41	0,36	0,40	0,41	0,37	0,42	0,43	0,39
0,8	0,53	0,54	0,50	0,53	0,54	0,51	0,54	0,55	0,52	0,53	0,55	0,46	0,53	0,55	0,49	0,55	0,57	0,51
1,0	0,59	0,60	0,56	0,59	0,60	0,57	0,60	0,61	0,59	0,60	0,61	0,51	0,60	0,61	0,54	0,62	0,66	0,56
1,25	0,68	0,69	0,64	0,68	0,69	0,66	0,69	0,70	0,67	0,69	0,69	0,58	0,69	0,70	0,62	0,71	0,72	0,64
1,5	0,75	0,75	0,69	0,75	0,75	0,71	0,76	0,76	0,72	0,76	0,75	0,63	0,76	0,76	0,67	0,78	0,78	0,69
2,0	0,83	0,83	0,77	0,83	0,83	0,79	0,84	0,84	0,80	0,84	0,82	0,69	0,84	0,83	0,73	0,87	0,85	0,75

Table A.11 *(continued)*

a_s/b_s	1			2			5			1			2			5		
h_s/b_s	0,25			0,25			0,25			0,5			0,5			0,5		
γ_w	30°	60°	90°	30°	60°	90°	30°	60°	90°	30°	60°	90°	30°	60°	90°	30°	60°	90°
2,5	0,89	0,88	0,81	0,89	0,88	0,84	0,90	0,89	0,85	0,90	0,87	0,73	0,90	0,88	0,77	0,92	0,90	0,79
3,0	0,93	0,92	0,85	0,93	0,92	0,87	0,94	0,93	0,88	0,94	0,90	0,76	0,94	0,91	0,81	0,96	0,93	0,86
4,0	0,98	0,96	0,90	0,98	0,97	0,92	0,99	0,98	0,93	0,99	0,95	0,80	0,98	0,96	0,85	1,00	0,98	0,87
5,0	1,02	1,00	0,92	1,02	1,00	0,95	1,03	1,01	0,96	1,02	0,97	0,82	1,02	0,99	0,87	1,04	1,01	0,89

Table A.12 — Shed rooflight utilances η_R, expressed as a percentage, as a function of the space index k and the geometry parameters

h_G/h_W	1													0,5												
γ_F	30				45	60				90				30				45	60				90			
γ_W	30°	45°	60°	75°	45°	30°	45°	60°	75°	30°	45°	60°	75°	30°	45°	60°	75°	45°	30°	45°	60°	75°	30°	45°	60°	75°
k	η_R %																									
0,6	0,39	0,39	0,41	0,40	0,37	0,34	0,35	0,36	0,35	0,29	0,30	0,31	0,31	0,38	0,39	0,39	0,40	0,36	0,33	0,34	0,35	0,36	0,29	0,29	0,30	0,30
0,8	0,51	0,52	0,53	0,50	0,49	0,44	0,45	0,46	0,44	0,37	0,39	0,39	0,38	0,50	0,51	0,52	0,51	0,48	0,43	0,44	0,45	0,44	0,37	0,37	0,38	0,38
1,0	0,57	0,58	0,58	0,55	0,55	0,50	0,52	0,51	0,49	0,44	0,45	0,45	0,44	0,56	0,57	0,57	0,56	0,53	0,49	0,50	0,51	0,50	0,43	0,44	0,44	0,44
1,25	0,66	0,66	0,65	0,62	0,62	0,58	0,59	0,58	0,55	0,51	0,51	0,51	0,49	0,65	0,65	0,65	0,64	0,61	0,57	0,58	0,58	0,56	0,50	0,51	0,50	0,50
1,5	0,72	0,72	0,71	0,67	0,68	0,64	0,64	0,63	0,60	0,56	0,56	0,56	0,54	0,71	0,71	0,71	0,69	0,67	0,62	0,63	0,63	0,61	0,55	0,56	0,55	0,55
2,0	0,80	0,79	0,77	0,73	0,75	0,72	0,71	0,69	0,66	0,64	0,63	0,62	0,60	0,79	0,79	0,78	0,76	0,75	0,71	0,71	0,70	0,68	0,62	0,63	0,62	0,61
2,5	0,85	0,84	0,81	0,77	0,80	0,77	0,76	0,73	0,70	0,69	0,68	0,66	0,64	0,84	0,84	0,83	0,80	0,80	0,76	0,76	0,75	0,72	0,68	0,68	0,67	0,65
3,0	0,88	0,88	0,84	0,80	0,83	0,81	0,79	0,76	0,72	0,72	0,71	0,69	0,67	0,88	0,88	0,86	0,83	0,84	0,80	0,80	0,78	0,75	0,72	0,71	0,70	0,68
4,0	0,94	0,92	0,88	0,84	0,87	0,85	0,83	0,80	0,76	0,77	0,75	0,73	0,70	0,93	0,93	0,91	0,87	0,88	0,85	0,84	0,82	0,79	0,77	0,76	0,75	0,72
5,0	0,97	0,95	0,91	0,87	0,90	0,89	0,86	0,82	0,78	0,80	0,78	0,75	0,73	0,97	0,96	0,93	0,90	0,92	0,89	0,88	0,85	0,81	0,80	0,79	0,77	0,75

Daylight availability is classified according to the criteria shown in Table A.14.

The daylight availability factor $F_{D,s,SNA,j}$ can be calculated using computer-based tools or using the regression-based compound method in 4.2.

Table A.13 — Classification of daylight availability as a function of the daylight factor $\overline{D}_j$

Classification criterion $\overline{D}_j$	Classification of daylight availability
$7 \le \overline{D}_j$ [a]	Good
$4 \le \overline{D}_j < 7$ %	Average
$2 \le \overline{D}_j < 4$ %	Poor
$0 \le \overline{D}_j < 2$ %	None

[a] In accordance with DIN 5034–6,[5] values of $\overline{D}_j > 10$ % should be avoided due to the danger of overheating.

If a daylight factor which has been calculated using another validated method is known, this can be used instead of the value calculated by Formula (A.17) when classifying daylight availability according to Table A.14. In this case, the daylight factor is to be determined as the mean value on the work plane.

A.4.2 Daylight supply factor

Table A.15 provides a set of values of $F_{D,s,j}$ for rooflights for different locations and climates. Movable shading devices are not taken into consideration here. For maintained illuminances $\overline{E}_m$ of less than 100 lx, daylight availability factor $F_{D,s,j}$ values for $\overline{E}_m = 100$ lx should be used, and for maintained illuminances $\overline{E}_m$ of greater than 1 000 lx, the $F_{D,s,j}$ values for $\overline{E}_m = 1\,000$ lx should be used.

Table A.14 — Daylight availability factor $F_{D,s,j}$ of spaces with skylights as a function of the daylight availability classification, the maintained illuminance $\bar{E}_m$, facade orientation and incline, location γ, and climate (H_{dir}/H_{glob})

Geo-graphic location γ	H_{dir}/H_{glob}	Orien-tation	$\bar{E}_m$	Classification of daylight availability								
				Poor[a]			Average[a]			Good[a]		
				300 lx	500 lx	750 lx	300 lx	500 lx	750 lx	300 lx	500 lx	750 lx
			Surface slope	$F_{D,s,j}$								
0° - 15°	0,34	Horizontal	0°	0,88	0,78	0,66	0,95	0,89	0,82	0,97	0,94	0,90
		South	30°	0,85	0,73	0,62	0,94	0,87	0,79	0,96	0,93	0,88
			45°	0,81	0,68	0,57	0,91	0,83	0,74	0,95	0,91	0,84
			60°	0,75	0,61	0,51	0,88	0,77	0,67	0,93	0,86	0,78
			90°	0,56	0,44	0,35	0,72	0,59	0,49	0,83	0,70	0,60
		East/West	30°	0,84	0,71	0,58	0,93	0,86	0,77	0,96	0,93	0,87
			45°	0,78	0,63	0,50	0,91	0,81	0,70	0,95	0,90	0,82
			60°	0,70	0,53	0,41	0,87	0,74	0,60	0,93	0,85	0,75
			90°	0,46	0,33	0,24	0,67	0,50	0,38	0,81	0,65	0,51
		North	30°	0,82	0,69	0,55	0,93	0,85	0,75	0,95	0,92	0,86
			45°	0,76	0,59	0,45	0,90	0,80	0,67	0,95	0,89	0,81
			60°	0,66	0,45	0,31	0,85	0,71	0,54	0,92	0,83	0,72
			90°	0,38	0,23	0,15	0,63	0,41	0,28	0,78	0,60	0,42
	0,66	Horizontal	0°	0,88	0,78	0,66	0,95	0,89	0,82	0,97	0,94	0,90
		South	30°	0,85	0,73	0,62	0,94	0,87	0,79	0,96	0,93	0,88
			45°	0,81	0,68	0,57	0,91	0,83	0,74	0,95	0,91	0,84
			60°	0,75	0,61	0,51	0,88	0,77	0,67	0,93	0,86	0,78
			90°	0,56	0,44	0,35	0,72	0,59	0,49	0,83	0,70	0,60
		East/West	30°	0,84	0,71	0,58	0,93	0,86	0,77	0,96	0,93	0,87
			45°	0,78	0,63	0,50	0,91	0,81	0,70	0,95	0,90	0,82
			60°	0,70	0,53	0,41	0,87	0,74	0,60	0,93	0,85	0,75
			90°	0,46	0,33	0,24	0,67	0,50	0,38	0,81	0,65	0,51
		North	30°	0,82	0,69	0,55	0,93	0,85	0,75	0,95	0,92	0,86
			45°	0,76	0,59	0,45	0,90	0,80	0,67	0,95	0,89	0,81
			60°	0,66	0,45	0,31	0,85	0,71	0,54	0,92	0,83	0,72
			90°	0,38	0,23	0,15	0,63	0,41	0,28	0,78	0,60	0,42

[a] The following daylight factors $D_{RB,j}$ of the raw carcass opening were used to calculate these values:

— poor: 3 %;

— average: 5,5 %;

— good: 8,5 %.

Table A.14 *(continued)*

Geo-graphic location γ	H_{dir}/H_{glob}	Orien-tation	Classification of daylight availability									
			$\overline{E}_m$	Poor[a]			Average[a]			Good[a]		
				300 lx	500 lx	750 lx	300 lx	500 lx	750 lx	300 lx	500 lx	750 lx
			Surface slope	$F_{D,s,j}$								
15° – 30°	0,36	Hori-zontal	0°	0,88	0,78	0,66	0,95	0,89	0,82	0,97	0,94	0,90
		South	30°	0,85	0,73	0,62	0,94	0,87	0,79	0,96	0,93	0,88
			45°	0,81	0,68	0,57	0,91	0,83	0,74	0,95	0,91	0,84
			60°	0,75	0,61	0,51	0,88	0,77	0,67	0,93	0,86	0,78
			90°	0,56	0,44	0,35	0,72	0,59	0,49	0,83	0,70	0,60
		East/ West	30°	0,84	0,71	0,58	0,93	0,86	0,77	0,96	0,93	0,87
			45°	0,78	0,63	0,50	0,91	0,81	0,70	0,95	0,90	0,82
			60°	0,70	0,53	0,41	0,87	0,74	0,60	0,93	0,85	0,75
			90°	0,46	0,33	0,24	0,67	0,50	0,38	0,81	0,65	0,51
		North	30°	0,82	0,69	0,55	0,93	0,85	0,75	0,95	0,92	0,86
			45°	0,76	0,59	0,45	0,90	0,80	0,67	0,95	0,89	0,81
			60°	0,66	0,45	0,31	0,85	0,71	0,54	0,92	0,83	0,72
			90°	0,38	0,23	0,15	0,63	0,41	0,28	0,78	0,60	0,42
	0,58	Hori-zontal	0°	0,88	0,78	0,66	0,95	0,89	0,82	0,97	0,94	0,90
		South	30°	0,85	0,73	0,62	0,94	0,87	0,79	0,96	0,93	0,88
			45°	0,81	0,68	0,57	0,91	0,83	0,74	0,95	0,91	0,84
			60°	0,75	0,61	0,51	0,88	0,77	0,67	0,93	0,86	0,78
			90°	0,56	0,44	0,35	0,72	0,59	0,49	0,83	0,70	0,60
		East/ West	30°	0,84	0,71	0,58	0,93	0,86	0,77	0,96	0,93	0,87
			45°	0,78	0,63	0,50	0,91	0,81	0,70	0,95	0,90	0,82
			60°	0,70	0,53	0,41	0,87	0,74	0,60	0,93	0,85	0,75
			90°	0,46	0,33	0,24	0,67	0,50	0,38	0,81	0,65	0,51
		North	30°	0,82	0,69	0,55	0,93	0,85	0,75	0,95	0,92	0,86
			45°	0,76	0,59	0,45	0,90	0,80	0,67	0,95	0,89	0,81
			60°	0,66	0,45	0,31	0,85	0,71	0,54	0,92	0,83	0,72
			90°	0,38	0,23	0,15	0,63	0,41	0,28	0,78	0,60	0,42

[a] The following daylight factors $D_{RB,j}$ of the raw carcass opening were used to calculate these values:

— poor: 3 %;

— average: 5,5 %;

— good: 8,5 %.

Table A.14 *(continued)*

Geo-graphic location γ	H_{dir}/ H_{glob}	Orien-tation	Classification of daylight availability									
			$\bar{E}_m$	Poor[a]			Average[a]			Good[a]		
				300 lx	500 lx	750 lx	300 lx	500 lx	750 lx	300 lx	500 lx	750 lx
			Surface slope	$F_{D,s,j}$								
30° – 45°	0,45	Hori-zontal	0°	0,88	0,78	0,66	0,95	0,89	0,82	0,97	0,94	0,90
		South	30°	0,85	0,73	0,62	0,94	0,87	0,79	0,96	0,93	0,88
			45°	0,81	0,68	0,57	0,91	0,83	0,74	0,95	0,91	0,84
			60°	0,75	0,61	0,51	0,88	0,77	0,67	0,93	0,86	0,78
			90°	0,56	0,44	0,35	0,72	0,59	0,49	0,83	0,70	0,60
		East/ West	30°	0,84	0,71	0,58	0,93	0,86	0,77	0,96	0,93	0,87
			45°	0,78	0,63	0,50	0,91	0,81	0,70	0,95	0,90	0,82
			60°	0,70	0,53	0,41	0,87	0,74	0,60	0,93	0,85	0,75
			90°	0,46	0,33	0,24	0,67	0,50	0,38	0,81	0,65	0,51
		North	30°	0,82	0,69	0,55	0,93	0,85	0,75	0,95	0,92	0,86
			45°	0,76	0,59	0,45	0,90	0,80	0,67	0,95	0,89	0,81
			60°	0,66	0,45	0,31	0,85	0,71	0,54	0,92	0,83	0,72
			90°	0,38	0,23	0,15	0,63	0,41	0,28	0,78	0,60	0,42
	0,71	Hori-zontal	0°	0,88	0,78	0,66	0,95	0,89	0,82	0,97	0,94	0,90
		South	30°	0,85	0,73	0,62	0,94	0,87	0,79	0,96	0,93	0,88
			45°	0,81	0,68	0,57	0,91	0,83	0,74	0,95	0,91	0,84
			60°	0,75	0,61	0,51	0,88	0,77	0,67	0,93	0,86	0,78
			90°	0,56	0,44	0,35	0,72	0,59	0,49	0,83	0,70	0,60
		East/ West	30°	0,84	0,71	0,58	0,93	0,86	0,77	0,96	0,93	0,87
			45°	0,78	0,63	0,50	0,91	0,81	0,70	0,95	0,90	0,82
			60°	0,70	0,53	0,41	0,87	0,74	0,60	0,93	0,85	0,75
			90°	0,46	0,33	0,24	0,67	0,50	0,38	0,81	0,65	0,51
		North	30°	0,82	0,69	0,55	0,93	0,85	0,75	0,95	0,92	0,86
			45°	0,76	0,59	0,45	0,90	0,80	0,67	0,95	0,89	0,81
			60°	0,66	0,45	0,31	0,85	0,71	0,54	0,92	0,83	0,72
			90°	0,38	0,23	0,15	0,63	0,41	0,28	0,78	0,60	0,42

[a] The following daylight factors $D_{RB,j}$ of the raw carcass opening were used to calculate these values:

— poor: 3 %;

— average: 5,5 %;

— good: 8,5 %.

Table A.14 *(continued)*

Geographic location γ	H_{dir}/ H_{glob}	Orientation	$\bar{E}_m$	Classification of daylight availability								
				Poor[a]			Average[a]			Good[a]		
				300 lx	500 lx	750 lx	300 lx	500 lx	750 lx	300 lx	500 lx	750 lx
			Surface slope	$F_{D,s,j}$								
45° – 60°	0,39	Horizontal	0°	0,88	0,78	0,66	0,95	0,89	0,82	0,97	0,94	0,90
		South	30°	0,85	0,73	0,62	0,94	0,87	0,79	0,96	0,93	0,88
			45°	0,81	0,68	0,57	0,91	0,83	0,74	0,95	0,91	0,84
			60°	0,75	0,61	0,51	0,88	0,77	0,67	0,93	0,86	0,78
			90°	0,56	0,44	0,35	0,72	0,59	0,49	0,83	0,70	0,60
		East/ West	30°	0,84	0,71	0,58	0,93	0,86	0,77	0,96	0,93	0,87
			45°	0,78	0,63	0,50	0,91	0,81	0,70	0,95	0,90	0,82
			60°	0,70	0,53	0,41	0,87	0,74	0,60	0,93	0,85	0,75
			90°	0,46	0,33	0,24	0,67	0,50	0,38	0,81	0,65	0,51
		North	30°	0,82	0,69	0,55	0,93	0,85	0,75	0,95	0,92	0,86
			45°	0,76	0,59	0,45	0,90	0,80	0,67	0,95	0,89	0,81
			60°	0,66	0,45	0,31	0,85	0,71	0,54	0,92	0,83	0,72
			90°	0,38	0,23	0,15	0,63	0,41	0,28	0,78	0,60	0,42
	0,58	Horizontal	0°	0,88	0,78	0,66	0,95	0,89	0,82	0,97	0,94	0,90
		South	30°	0,85	0,73	0,62	0,94	0,87	0,79	0,96	0,93	0,88
			45°	0,81	0,68	0,57	0,91	0,83	0,74	0,95	0,91	0,84
			60°	0,75	0,61	0,51	0,88	0,77	0,67	0,93	0,86	0,78
			90°	0,56	0,44	0,35	0,72	0,59	0,49	0,83	0,70	0,60
		East/ West	30°	0,84	0,71	0,58	0,93	0,86	0,77	0,96	0,93	0,87
			45°	0,78	0,63	0,50	0,91	0,81	0,70	0,95	0,90	0,82
			60°	0,70	0,53	0,41	0,87	0,74	0,60	0,93	0,85	0,75
			90°	0,46	0,33	0,24	0,67	0,50	0,38	0,81	0,65	0,51
		North	30°	0,82	0,69	0,55	0,93	0,85	0,75	0,95	0,92	0,86
			45°	0,76	0,59	0,45	0,90	0,80	0,67	0,95	0,89	0,81
			60°	0,66	0,45	0,31	0,85	0,71	0,54	0,92	0,83	0,72
			90°	0,38	0,23	0,15	0,63	0,41	0,28	0,78	0,60	0,42

[a] The following daylight factors $D_{RB,j}$ of the raw carcass opening were used to calculate these values:

— poor: 3 %;

— average: 5,5 %;

— good: 8,5 %.

Table A.14 *(continued)*

Geo-graphic location γ	H_{dir}/ H_{glob}	Orien-tation	$\bar{E}_m$	Classification of daylight availability								
				Poor[a]			Average[a]			Good[a]		
				300 lx	500 lx	750 lx	300 lx	500 lx	750 lx	300 lx	500 lx	750 lx
			Surface slope	$F_{D,s,j}$								
60° – 75°	0,40	Hori-zontal	0°	0,88	0,78	0,66	0,95	0,89	0,82	0,97	0,94	0,90
		South	30°	0,85	0,73	0,62	0,94	0,87	0,79	0,96	0,93	0,88
			45°	0,81	0,68	0,57	0,91	0,83	0,74	0,95	0,91	0,84
			60°	0,75	0,61	0,51	0,88	0,77	0,67	0,93	0,86	0,78
			90°	0,56	0,44	0,35	0,72	0,59	0,49	0,83	0,70	0,60
		East/ West	30°	0,84	0,71	0,58	0,93	0,86	0,77	0,96	0,93	0,87
			45°	0,78	0,63	0,50	0,91	0,81	0,70	0,95	0,90	0,82
			60°	0,70	0,53	0,41	0,87	0,74	0,60	0,93	0,85	0,75
			90°	0,46	0,33	0,24	0,67	0,50	0,38	0,81	0,65	0,51
		North	30°	0,82	0,69	0,55	0,93	0,85	0,75	0,95	0,92	0,86
			45°	0,76	0,59	0,45	0,90	0,80	0,67	0,95	0,89	0,81
			60°	0,66	0,45	0,31	0,85	0,71	0,54	0,92	0,83	0,72
			90°	0,38	0,23	0,15	0,63	0,41	0,28	0,78	0,60	0,42
	0,48	Hori-zontal	0°	0,88	0,78	0,66	0,95	0,89	0,82	0,97	0,94	0,90
		South	30°	0,85	0,73	0,62	0,94	0,87	0,79	0,96	0,93	0,88
			45°	0,81	0,68	0,57	0,91	0,83	0,74	0,95	0,91	0,84
			60°	0,75	0,61	0,51	0,88	0,77	0,67	0,93	0,86	0,78
			90°	0,56	0,44	0,35	0,72	0,59	0,49	0,83	0,70	0,60
		East/ West	30°	0,84	0,71	0,58	0,93	0,86	0,77	0,96	0,93	0,87
			45°	0,78	0,63	0,50	0,91	0,81	0,70	0,95	0,90	0,82
			60°	0,70	0,53	0,41	0,87	0,74	0,60	0,93	0,85	0,75
			90°	0,46	0,33	0,24	0,67	0,50	0,38	0,81	0,65	0,51
		North	30°	0,82	0,69	0,55	0,93	0,85	0,75	0,95	0,92	0,86
			45°	0,76	0,59	0,45	0,90	0,80	0,67	0,95	0,89	0,81
			60°	0,66	0,45	0,31	0,85	0,71	0,54	0,92	0,83	0,72
			90°	0,38	0,23	0,15	0,63	0,41	0,28	0,78	0,60	0,42

[a] The following daylight factors $D_{RB,j}$ of the raw carcass opening were used to calculate these values:

— poor: 3 %;

— average: 5,5 %;

— good: 8,5 %.

A.5 Daylight Responsive Control Systems

The effects taken into consideration here relate to the characteristics of the artificial lighting controls deployed to supplement the available daylight to achieve the required illuminance. Control systems which control or regulate the transmission of light through the facades are not discussed here. The approximate effects of the latter type of system are included in the evaluations described in Table A.8.

The correction factor $F_{\mathrm{D,c},j}$ for daylight-responsive control systems is a function of

a) the type of control involved and

b) the daylight availability classification of the area being evaluated.

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

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

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

Artificial lighting control systems are distinguished according to

— whether they are controlled manually or

— controlled automatically to adjust the artificial light intensity to achieve the specified maintained illuminance.

An additional distinction is made between

i) stand-alone systems, of which there are two types:

 — systems which turn off the artificial lighting during operating times (if daylight availability is adequate);

 — systems which dim the artificial lighting system to the lowest possible intensity during operating times without actually switching the system off.

ii) Installation bus systems and building management systems.

Table A.15 provides correction factors $F_{\mathrm{D,c},j}$ to rate daylight responsive control systems.

Table A.15 — Correction factor $F_{\mathrm{D,c},j}$ to account for the impact of daylight responsive control systems in a zone n, as a function of the maintained illuminance $\bar{E}_{\mathrm{m}}$ and the daylight availability classification

Type of control			$F_{\mathrm{D,c},j}$ as a function of daylight availability								
			Poor			Average			Good		
			300 lx	500 lx	750 lx	300 lx	500 lx	750 lx	300 lx	500 lx	750 lx
Manual			0,33	0,30	0,27	0,38	0,35	0,32	0,43	0,40	0,37
Automatic	Stand-alone	No total switch-off	0,65	0,70	0,73	0,70	0,73	0,75	0,73	0,75	0,76
		Total switch-off	0,71	0,74	0,76	0,77	0,78	0,79	0,81	0,81	0,81
	Bus systems		0,76	0,81	0,83	0,83	0,85	0,86	0,87	0,87	0,87

A.6 Monthly evaluation method

The distribution key factors $v_{\mathrm{Month,i}}$ for vertical facades are given in Table A.16. Since light-guiding systems are based on the deflection or guidance of direct light, which is more available in the summer months, separate distribution key factors as a function of the orientation are given for such systems. Table A.17 shows the values for spaces equipped with rooflights. In the summer months, daylight availability can account for 100 % of the required lighting. This means that no supplementary artificial lighting is required during this period. Since the product $F_{\mathrm{D,s},j}\,F_{\mathrm{D,c},j}$ is weighted by monthly key factors, the differences between ($v_{\mathrm{Month,l}}\,F_{\mathrm{D,s},j}\,F_{\mathrm{D,c},j} - 1$) and $\Delta F_{\mathrm{D,s},j}$ shall be added together for all months during which $v_{\text{Month,l}}\ F_{\text{D,s},j}\ F_{\text{D,c},j}$ is greater than 1. $\Delta F_{\text{D,s},j}$ shall be equally divided up among all months during which $v_{\text{Monat,l}}\ F_{\text{D,s},j}\ F_{\text{D,c},j}$ is less than 1. Where necessary, an iteration procedure shall be applied.

Table A.16 — Monthly distribution key factors $v_{\text{Month},i}$ for vertical facades

Facade system	Month, *i*											
	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	March	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
	$v_{\text{Month},i}$											
Light-guiding systems according to Table A.8, South-facing	0,67	0,89	1,06	1,18	1,25	1,28	1,26	1,20	1,08	0,92	0,72	0,46
Light-guiding systems according to Table A.8, facing East or West	0,74	0,92	1,06	1,16	1,22	1,24	1,22	1,16	1,06	0,93	0,75	0,54
Others	0,85	0,97	1,06	1,12	1,16	1,17	1,15	1,11	1,04	0,94	0,81	0,66

Table A.17 — Monthly distribution key factors $v_{\text{Month},i}$ for rooflights

	Month, *i*											
	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	March	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
	$v_{\text{Month},i}$											
Northern Hemi-sphere	0,74	0,92	1,06	1,16	1,22	1,24	1,22	1,16	1,06	0,93	0,75	0,54
Southern Hemi-sphere	1,22	1,16	1,06	0,92	0,74	0,54	0,75	0,93	1,06	1,16	1,22	1,24

Monthly partial-load daylight operation factors $F_{\text{D},j,i}$ can be derived from the calculated annual daylight availability factor.

$$F_{\text{D},j,i} = \begin{cases} 1 - v_{\text{Month},i}\ F_{\text{D,s},j}\ F_{\text{D,c},j} & \text{for } v_{\text{Month,l}}\ F_{\text{D,s},j}\ F_{\text{D,c},j} < 1 \\ 0 & \text{otherwise} \end{cases} \tag{A.20}$$

where

$v_{\text{Month},i}$ is the monthly distribution key for weighting the value of $F_{\text{D,s},j}$.

A method to obtain the distribution key factors $v_{\text{Month},i}$ for vertical facades is provided in A.8.

A.7 Determination of day-time and night-time hours

The number of day-time and night-time hours needs to be known to be able to determine the energy need and energy use for lighting. The approximate method described below can be used in cases where the day-time and night-time hours for the types of usage listed in Table A.19 are to be determined due to deviating operating times or when a totally different type of usage is specified.

The method described below can be used to determine the number of day-time hours t_{Day} and night-time hours t_{Night} on a monthly basis for a known latitude γ and a specified beginning of usage t_{start} and end of usage t_{end}. The hours between sunrise and sunset are considered to be day-time hours.

The times $t_{Day,i}$ and $t_{Night,i}$ for each month are calculated using Formulae (A.21) and (A.22).

$$t_{Day,i} = N_i\, C_{we}\, [(t_{end} - t_{start}) - (t_{bs,i} + t_{as,i})] \tag{A.21}$$

$$t_{Night,i} = N_i\, C_{we}\, (t_{bs,i} + t_{as,i}) \tag{A.22}$$

where

N_i is the number of days in the respective month:

N_i = [31, 28, 31, 30, 31, 30, 31, 31, 30, 31, 30, 31] with i = 1 to 12;

C_{we} is the reduction factor to account for weekends (the value of C_{we} to account for all weekends is 5/7; if no weekends are taken into consideration, C_{we} is equal to 1);

t_{start} is the time of the beginning of usage;

t_{end} is the time of the end of usage;

$t_{bs,i}$ is the usage time before sunrise;

$t_{as,i}$ is the usage time after sunset.

The times before sunrise $t_{bs,i}$ and after sunset $t_{as,i}$ are determined using Formulae (A.23) and (A.24).

$$t_{bs,i} = \begin{cases} t_{sunrise,i} - t_{start,i}, & \text{if } t_{sunrise,i} > t_{start,i} \\ 0 & \text{otherwise} \end{cases} \tag{A.23}$$

$$t_{as,i} = \begin{cases} t_{ende,i} - t_{sunset,i}, & \text{if } t_{ende} > t_{sunset,i} \\ 0 & \text{otherwise} \end{cases} \tag{A.24}$$

where

t_{sunset} is the sunset time;

$t_{sunrise}$ is the sunrise time.

The time of sunrise $t_{sunrise}$ and the time of sunset t_{sunset} are calculated using Formulae (A.25) and (A.26):

$$t_{sunrise,i} = (12 - \omega_i / 15°) - \mathrm{teq}(J_i)/60 \tag{A.25}$$

$$t_{sunset,i} = (12 + \omega_i / 15°) - \mathrm{teq}(J_i)/60 \tag{A.26}$$

where

ω_i is the hour angle;

teq is the formula of time, Formula (A.29).

Formula (A.27) is used to calculate the hour angle, ω_i.

$$\omega_i = \arccos\left\{-\frac{\sin(\phi)\sin\left[\delta(J_i)\right]}{\cos(\phi)\cos\left[\delta(J_i)\right]}\right\} \tag{A.27}$$

where

ϕ is the geographical latitude of the location;

J_i is the day of the month; in this case, the 15th day of each month is used as a reference: J_i = [15, 46, 74, 105, 135, 166, 196, 227, 258, 288, 319, 349];

δ is the declination of the sun.

Formula (A.28) is used to calculate the declination of the sun.

$$\delta(J) = 0{,}394\,8 - 23{,}255\,9 \times \cos(J + 9{,}1°) - 0{,}391\,5 \times \cos(2 \times J' + 5{,}4°) - 0{,}176\,4 \times \cos(3 \times J' + 26{,}0°) \tag{A.28}$$

Formula (A.29) is used to determine the formula of time.

$$teq(J) = 0{,}006\,6 + 7{,}352\,5 \times \cos(J + 85{,}9°) + 9{,}935\,9 \times \cos(2 \times J + 108{,}9) + 0{,}338\,7 \times \cos(3 \times J + 105{,}2) \tag{A.29}$$

with

$J = J \times 360°/365$

The annual day-time and night-time hours are the sum totals of the monthly values as expressed by Formulae (A.30) and (A.31) respectively:

$$t_{Day} = \sum_{i=1}^{12} t_{Day,i} \tag{A.30}$$

$$t_{Night} = \sum_{i=1}^{12} t_{Night,i} \tag{A.31}$$

Table A.18 holds for typical office operating hours precalculated times t_{Day} and t_{Night} as a function of latitude.

Table A.18 — t_{day} and t_{night} as a function of latitude for typical operating hours from 8 am – 5 pm, weekends excluded

Latitude	t_{day} h	t_{night} h
0°	2,346	0
7,5°	2,346	0
22,5°	2,346	0
37,5°	2,341	5
52,5°	2,271	75
67,5°	1,881	465
75,0°	1,629	717

A.8 Exemplary operation times of different building zone

Table A.19 — Data for usage of boundary conditions for non-residential buildings

1	2	3	4	5	6	7	8	9
Numbering	Usage	Usage and operating times						
		Beginning of usage	End of usage	Daily usage time	Annual usage days	Annual usage days per annum	Night-time usage hours per annum	Height of the work plane
		—	—	$t_{usage,d}$	$d_{usage,a}$	t_{Day}	t_{Night}	h_{Ta}
		hrs	hrs	h/d	d/a	h/a	h/a	M
1	Personal office (single occupant)	07:00	18:00	11	250	2 543	207	0,8
2	Workgroup office (two to six workplaces)	07:00	18:00	11	250	2 543	207	0,8
3	Landscaped office (seven or more workplaces)	07:00	18:00	11	250	2 543	207	0,8
4	Meeting, conference, and seminar room	07:00	18:00	11	250	2 543	207	0,8
5	Booking hall	07:00	18:00	11	250	2 543	207	0,8
6	Retail shop/department store	08:00	20:00	12	300	3 009	591	0,8
7	Retail shop/department store (food department with refrigerated products)	08:00	20:00	12	300	3 009	591	0,8
8	Classroom (school and nursery school)	08:00	15:00	7	200	1 400	0	0,8
9	Lecture room, auditorium	08:00	18:00	10	150	1 408	92	0,8
10	Hospital ward or dormitory	00:00	24:00	24	365	4 407	4 353	0,8
11	Hotel bedroom	21:00	08:00	11	365	743	3 272	0,8
12	Canteen	08:00	15:00	7	250	1 750	0	0,8
13	Restaurant	10:00	00:00	14	300	2 411	1 789	0,8
14	Kitchens in non-residential buildings	10:00	23:00	13	300	2 411	1 489	0,8
15	Kitchen – preparation room or storeroom	10:00	23:00	13	300	2 411	1 489	0,8
16	Toilets and sanitary facilities in non-residential buildings	07:00	18:00	11	250	2 543	207	0,8
17	Other habitable rooms	07:00	18:00	11	250	2 543	207	0,8
18	Auxiliary spaces (without habitable rooms)	07:00	18:00	11	250	2 543	207	0,8
19	Traffic/circulation areas	07:00	18:00	11	250	2 543	207	0
20	Storeroom, technical equipment room, archive	07:00	18:00	11	250	2 543	207	0,8
21	Server room, computer centre	00:00	24:00	24	365	4 407	4 353	0,8
22.1	Workshop, assembly, manufacturing, heavy duty work, standing work	07:00	16:00	9	230	2 018	52	0,8
22.2	Workshop, assembly, manufacturing, medium duty work, mainly standing work	07:00	16:00	9	230	2 018	52	0,8
22.3	Workshop, assembly, manufacturing, simple work, mainly standing work, mainly seated work	07:00	16:00	9	230	2 018	52	0,8
23	Spectator and audience areas (theatres and event locations)	19:00	23:00	4	250	59	941	0,8
24	Foyer (theatres and event locations)	19:00	23:00	4	250	59	941	0,8
25	Stage (theatres and event locations)	13:00	23:00	10	250	1 259	1 241	0,8
26	Fair/congress building	09:00	18:00	9	150	1 258	92	0,8
27	Exhibition rooms and museums with conservation requirements	10:00	18:00	8	250	1 846	154	0,8
28	Library – reading rooms	08:00	20:00	12	300	3 009	591	0,8
29	Library – open stacks area	08:00	20:00	12	300	3 009	591	0,8

Table A.19 *(continued)*

1	2	3	4	5	6	7	8	9
		Usage and operating times						
Numbering	**Usage**	**Beginning of usage**	**End of usage**	**Daily usage time**	**Annual usage days**	**Annual usage days per annum**	**Night-time usage hours per annum**	**Height of the work plane**
		—	—	$t_{usage,d}$	$d_{usage,a}$	t_{Day}	t_{Night}	h_{Ta}
		hrs	hrs	h/d	d/a	h/a	h/a	M
30	Library – magazine and stores	08:00	20:00	12	300	3 009	591	0,8
31	Sports hall (without public viewing area)	08:00	23:00	15	250	2 509	1 241	1
32	Garage buildings (for offices and private use)	07:00	18:00	11	250	2 543	207	0,2
33	Garage buildings (public use)	09:00	00:00	15	365	3 298	2 177	0,2
34	Sauna	10:00	22:00	12	365	2 933	1 447	0
35	Gym	08:00	23:00	15	365	3 663	1 812	0
36	Laboratory	07:00	18:00	11	250	2 543	207	1,0
37	Surgery	07:00	18:00	11	250	2 543	207	0,8
38	Special care area	00:00	24:00	24	365	4 407	4 353	0,8
39	Hallways in general nursery areas	00:00	24:00	24	365	4 407	4 353	0,2
40	Medical and therapeutical practice	08:00	18:00	10	250	2 346	154	0,8
41	Storehouses, logistic places (high-rack warehouses)	00:00	24:00	24	365	4 407	4 353	0

Annex B
(normative)

Comprehensive calculation

A variety of software tools nowadays allows the performance of radiosity and/or raytracing-based computations of daylight propagation into indoor spaces. By this means, it is also possible to calculate the impact of daylight utilization on artificial lighting energy demand with a selected number of tools. $F_{D,n}$, according to Formula (4), can therefore be calculated with these comprehensive approaches. For this, the following boundary conditions have to be met:

— The algorithm has to take into account the climatic conditions at the considered location.

— The (eventually variable) photometry of the facade and the control (which has an impact) of the facade are to be regarded. If the facade incorporates movable shading systems, e.g. movable Venetian blinds, the calculation has to take this into account. The supposed control scheme for the facade (when and how is shading triggered, e.g. cut-off Control of Venetian blinds, if sun is on facade) has to be modelled within the calculation process.

— The relative luminous exposure $F_{D,S,n}$ (daylight supply factors) has to be evaluated based on an hourly basis at the control point of the artificial lighting system. Results from this can be aggregated to a monthly or annual basis.

— Over a building, comprehensive calculations and simple calculations can be mixed.

Annex C
(informative)

Daylight performance indicator

To rate the overall daylight performance of the building, the indicators defined in Formula (C.1) can be applied.

Average daylight supply factor

$$\bar{F}_{\mathrm{D,S}} = \sum_{n=1}^{N}\sum_{j=1}^{J}\frac{F_{\mathrm{D,S},j,n}\,A_{\mathrm{D},j,n}}{A_{D,j,n}+A_{\mathrm{ND},j,n}} \tag{C.1}$$

The average daylight supply factor relates the sum of the product of the zones daylight supply factor weighed with the area benefitting from daylight to the total area of the building. It therefore represents the average maximum daylight autonomy, which can be allocated by the control.

Average daylight dependency factor

$$\bar{F}_{\mathrm{D}} = \sum_{n=1}^{N}\sum_{j=1}^{J}\frac{F_{\mathrm{D},j,n}\,A_{\mathrm{D},j,n}}{A_{\mathrm{D},j,n}+A_{\mathrm{ND},j,n}} \tag{C.2}$$

This factor, in addition, also includes the impact of the control system.

Annex D
(informative)

Examples

An example each for daylight penetration through a vertical facade and a rooflight are given in this annex.

D.1 Space with vertical facade

The following example illustrates the application of the model for vertical facades. The geometry of the space under consideration and the corresponding artificial lighting installation are defined in Table D.1 and depicted in Figure D.1. Evaluation is exemplarily performed for two locations. The location of Brussels (altitude: 50.8°; longitude: 4.3°) experiences an oceanic climate (Cfb) according to the Köppen-Geiger climate classification, whereas Rio de Janeiro (altitude: –22.9°; longitude: –43.3°) represents a tropical savanna climate (Aw).

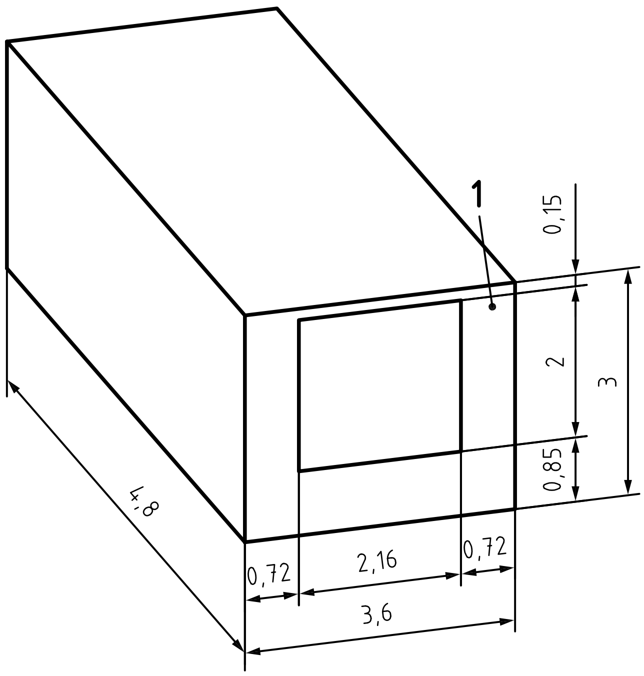


Figure D.1 — Geometry of the example with vertical facade

Table D.1 — Boundary conditions for the example with vertical facade

Parameter		Variation
Space geometry	Width	3,60 m
	Depth	4,80 m
	Height	3,00 m
	Reflectance ρ, ambient	0,2
	Reflectance ρ, ground	0,2
	Reflectance ρ, walls	0,5
	Reflectance ρ, ceiling	0,7
Facade	Orientation	South
	Obstruction	0°
	Light transmission τ_{D65} glazing	0,74
	Framing ratio k_1	0,9
	Dirt on glazing factor k_2	0,9
	Construction	40 % standard window/facade ratio
	System	Blinds, reference system
Lighting system	Specific installed power	12 W/m^2
	Maintained illuminance	500 lx
	Control strategy	Continuous dimming
	Control point, position	1 control point in the centre of the room
Working hours		8 am to 5 pm, Monday through Friday, no vacation

Step 1: Determination of ratio H_{dir}/H_{glob}

The ratios of direct and global outside relative usable luminous exposure are calculated from the corresponding weather data sets as described in A.3.2.1:

— Brussels: H_{dir} = 30,45 Mlxh; H_{glob} = 86,00 Mlxh = > H_{dir}/H_{glob} = 0,35;

— Rio de Janeiro: H_{dir} = 72,42 Mlxh; H_{glob} = 149,60 Mlxh = > H_{dir}/H_{glob} = 0,48.

Step 2: Determination of t_{day} (astronomic model)

The time t_{day}, which represents “sun up”, and the time t_{night}, which represents “sun down”, during working hours, are determined from Table A.18 by linear interpolation for the two locations. The corresponding values are the following:

— Brussels: t_{day} = 2 278 h; t_{night} = 68 h;

— Rio de Janeiro: t_{day} = 2 346 h; t_{night} = 0 h.

Step 3: Determination of t_{SNA} and t_{SA} (regression model)

t_{SNA} is determined from Table A.3. t_{SA} is then obtained by subtracting t_{SNA} from t_{day}.

— Brussels: t_{SNA} = 1 595 h; t_{SA} = 684 h;

— Rio de Janeiro: t_{SNA} = 1 257 h; t_{SA} = 1 089 h .

Step 4: Determination of daylight factors

The daylight factor is determined by means of a detailed simulation in the middle of the room (at the control point position of the artificial lighting system for the room). A daylight factor of D_{Ca} = 6,81 % for the building carcass opening is obtained. For the glazed facade without shading activated, the effective transmission $\tau_{eff,SNA}$ is calculated with τ_{D65} = 74 %, k_1 = 0,9; k_2 = 0,9; k_3 = 0,85:

$$\tau_{eff,sna} = k_1 k_2 k_3 \tau_{D65} = 0{,}51$$

From this, the daylight factor with the glazed facade is determined:

$$D = \tau_{eff,sna} D_{RB} = 0{,}1 \times 6{,}81\ \% = 3{,}47\ \%$$

Step 5: Determination of Daylight supply factors $F_{D,s,SNA,j}$, $F_{D,s,SA,j}$

From the geographical location, H_{dir}/H_{glob} (step 2), D (step 4), and E_m, the quantities $F_{D,s,SNA,j}$, $F_{D,s,SA,j}$ are determined (using linear interpolation). In the following substeps, the procedure is demonstrated for standard Venetian blinds (system solution 1 according to Table A.8). The resulting values for the other systems considered can be obtained in the same manner. System 2 corresponds to a Venetian blind system operated in cut-off mode. System 3 represents sun protection glazing with internal roller blinds for glare protection.

a) $F_{D,s,SNA,j}$ for system solution 1, using Table A.6:

— Brussels: $F_{D,s,SNA,j}$ (3.47 %; 0,35) = 76,9 %;

— Rio de Janeiro: $F_{D,s,SNA,j}$ (3,47 %; 0,48) = 89,6 %;

b) $F_{D,s,SA,j}$ for system solution 1, using Table A.8:

— Brussels: $F_{D,s,SA,j}$ (6,81 %; 0,35) = 25,3 % ;

— Rio de Janeiro: $F_{D,s,SA,j}$ (6,81 %; 0,48) = 27,9 % ;

c) $F_{D,s,j}$ for system solution 1, using Formula (A.15):

— Brussels:

$$F_{D,S,j} = \frac{1595\ \text{h}}{(1595\text{h}+684\text{h})} \times 76{,}9\ \% + \frac{684\ \text{h}}{(1595\ \text{h}+684\ \text{h})} \times 25{,}3\ \% = 61{,}4\ \%\ ;$$

— Rio de Janeiro:

$$F_{D,S,j} = \frac{1\,257\ \text{h}}{(1\,257\ \text{h}+1\,089\ \text{h})} \times 89{,}6\ \% + \frac{1\,089\ \text{h}}{(1\,257\ \text{h}+1\,089\ \text{h})} \times 27{,}9\ \% = 61{,}0\ \%\ .$$

Table D.2 — $F_{D,s,SNA,j}$, $F_{D,s,SA,j}$, $F_{D,s,j}$, and $Q_{L,f}$ for system solutions 1, 2, 3 at the locations under investigation

Location	System solution	$F_{D,s,SNA,j}$ %	$F_{D,s,SA,j}$ %	$F_{D,s,j}$ %	$Q_{L,f}$ kWh/m²a
Brussels	System 1	76,9	25,3	61,4	11,4
	System 2	76,9	88,1	80,3	6,2
	System 3	65,7	24,9	53,5	13,6
Rio de Janeiro	System 1	89,6	27,9	61,0	11,0
	System 2	89,6	89,1	89,4	3,0
	System 3	83,0	15,7	51,8	13,6

Step 6: Determination of $Q_{l,f}$

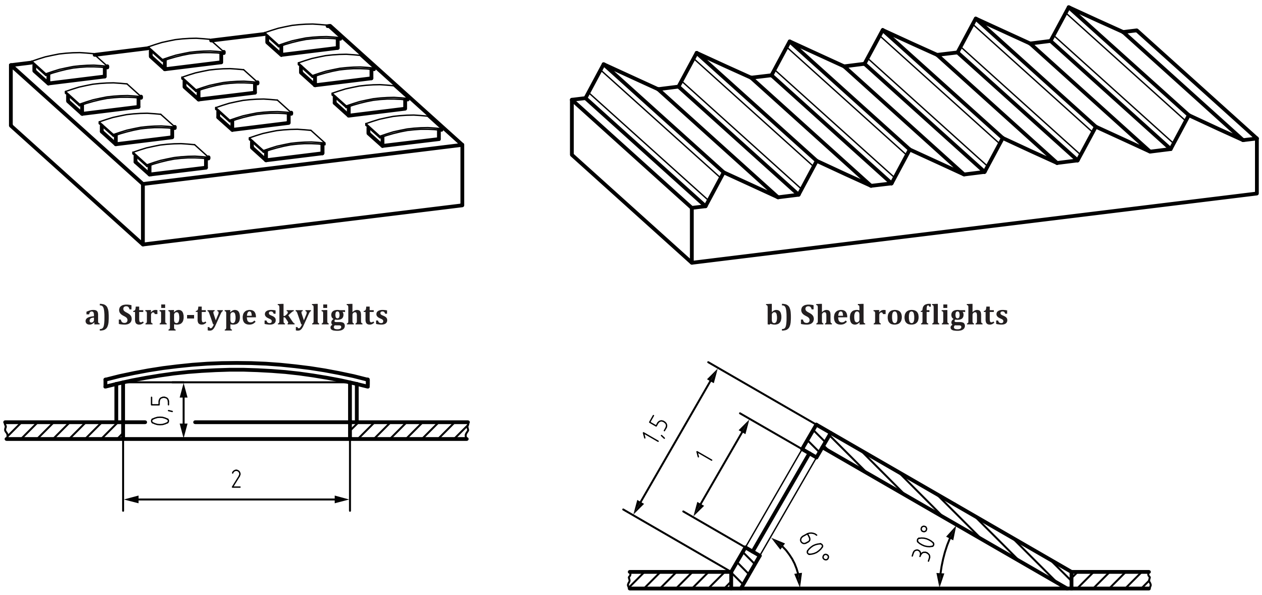
From Formula (2), the annual energy demand for lighting is obtained for a system potential = 1, i. e. ideal continuous dimming and an installed power of the artificial lighting system of 12 W/m^2. The resulting values are displayed in Table A.18.

D.2 Space with rooflights

D.2.1 General

This example describes how the annual and monthly final energy demand for lighting of a production hall receiving daylight only through rooflights is calculated. Two different skylight solutions are discussed. One of the variants involves roof openings fitted with strip-type skylights; shed rooflights are used in the other variant. The entire hall floor area is considered to be lit by daylight. It is therefore assumed that there is only one area to be evaluated.

Dimensions in metres



a) Strip-type skylights

b) Shed rooflights

c) Cross-section of strip-type skylight

d) Cross-section of shed rooflight

Figure D.2 — Rooflights

D.2.2 Determination of the daylight availability factor $F_{D,S}$

Mean daylight factor for strip-type rooflights

The daylight factor shall be calculated using Formula (A.17). The following values apply to the glazing of the strip skylight:

— transmittance of glazing: τ_{D65} = 0,64 [double-wall (PC) polycarbonate multiwall sheets];

— reduction factor for frames and subdivisions of the glazing: $k_{Obl,1}$ = 0,92;

— reduction factor for pollution of the glazing: $k_{Obl,2}$ = 0,9;

— reduction factor for non-vertical light incidence: $k_{Obl,3}$ = 0,85.

The strip-skylight geometry has the following characteristics:

— height of the supporting frame: h_S = 0,5 m;

— slope of the supporting frame: γ_W = 90°; (vertical);

— width of a strip skylight: b_S = 2 m;

— length of a strip skylight: a_S = 10 m.

By inserting the geometry data of the strip skylight and the previously determined space index to obtain the input values for a_S/b_S = 5, h_S/b_S = 0,25; γ_W = 90° and k = 2,93, the space utilance η_R value listed in Table A.11 is found to be 0,88 (interpolated). Since the roof is horizontal, the external daylight factor D_a is 100 %. The total raw roof opening area A_{rb} of the 12 skylights is 240 m². The hall floor area A_{Ca} is 1 350 m². The mean daylight factor is therefore

$$\bar{D} = D_a \, \tau_{D65} \, k_{Obl,1} \, k_{Obl,2} \, k_{Obl,3} \frac{\sum A_{Rb}}{A_{RG}} \eta_R \quad \text{in } \% \tag{D.1}$$

$$\bar{D} = 1 \times 0{,}64 \times 0{,}92 \times 0{,}9 \times 0{,}85 \times \frac{240 \text{ m}^2}{1\,350 \text{ m}^2} \times 0{,}88 = 7{,}05\,\% \tag{D.2}$$

The daylight availability as given is classified as being strong.

Mean daylight factor for shed rooflights

The following values apply to the glazing of the long rectangular skylight:

— transmittance of glazing: τ_{D65} = 0,7;

— reduction factor for frames and subdivisions of the glazing: $k_{Obl,1}$ = 0,88;

— reduction factor for pollution of the glazing: $k_{Obl,2}$ = 0,90;

— reduction factor for non-vertical light incidence: $k_{Obl,3}$ = 0,85.

The shed rooflight geometry has the following characteristics:

— slope of the glazed shed area: γ_F = 60°;

— slope of the opaque shed area: γ_F = 30°;

— height of the total area containing the light-transmitting opening: h_W = 1,5 m;

— height (raw roof opening) of the opening through which light enters: h_g = 1 m;

— width (raw roof opening) of the opening through which light enters: b_{RB} = 30 m.

By inserting the geometry data of the shed-rooflight and the previously determined space index to obtain the input values hg/hw = 0,67, γw = 60°, and k = 2,93, the space utilance γR value listed in Table A.12 is found to be 0,8 (interpolated). For a 60° slope of the area through which the daylight enters, Table A.10 gives an external daylight factor of 0,72 %. The total raw roof opening area A_{rb} of the eight skylights is 240 m². The mean daylight factor is therefore

$$\bar{D} = D_a \, \tau_{D65} \, k_{Obl,1} \, k_{Obl,2} \, k_{Obl,3} \frac{\sum A_{Rb}}{A_{RG}} \eta_R \quad \text{in } \% \tag{D.3}$$

$$\bar{D} = 0{,}72 \times 0{,}7 \times 0{,}88 \times 0{,}9 \times 0{,}85 \times \frac{240 \text{ m}^2}{1350 \text{ m}^2} \times 0{,}8 = 4{,}83\,\% \tag{D.4}$$

The daylight availability according to Table A.13 is classified as being “medium”.

Daylight availability factor $F_{D,s}$ for strip-type rooflights

Table A.14 gives a value of 0,94 for the daylight availability factor $F_{D,s}$ for the respective set of table input values: daylight availability class “strong”, orientation “horizontal” and maintained illuminance $\bar{E}_m$ = 500 lx.

Daylight availability factor $F_{D,s}$ for shed rooflights

Table A.14 gives a value of 0,71 for the daylight availability factor $F_{D,s}$ for the respective set of table input values: daylight availability class “good”, orientation “north-facing” and maintained illuminance $\bar{E}_m$ = 500 lx.

D.2.3 Determination of the annual and monthly final energy demand for lighting

Annual final energy demand for strip-type rooflights

Formula (2) is used to determine the annual final energy demand for lighting. Assuming that an “automatic, independent” daylight-responsive control system without total switch-off is installed, the correction factor $F_{D,c}$ stated in Table A.15, is found to be 0,75. This results in a daylight partial-load factor of 0,295, calculated using Formula (7), i. e. $F_{TL} = 1 - F_{D,s}\ F_{D,c}$ of $F_{TL} = 1 - 0{,}94 \times 0{,}75 = 0{,}295$. According to DIN V 18599-10,[3] the utilization profile for usage type “industrial activities and crafts” does not assume absences during operating times, so that no presence sensor system is installed. This means that $F_O = 1$ so that the following annual operating times as defined in DIN V 18599-10[3] can be assumed: t_{day} = 2 192 h, t_{Night} = 58 h. The effective operating times during daylight hours is therefore calculated as follows:

$$t_{eff,Day,D} = t_{Day}\ F_D\ F_O = 2\,192\,\text{h} \times 0{,}295 \times 1 = 646{,}6\ \text{h} \tag{D.5}$$

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

$$t_{eff,Night} = t_{Night}\ F_O = 58\,\text{h} \times 1 = 58\,\text{h} \tag{D.6}$$

The annual final energy demand for lighting is thus determined by assuming, for instance, an installed electrical power of 11,7 W/m^2 using the following formula.

$$Q_{l,f} = p\left[A_D\left(t_{eff,Day,D} + t_{eff,Night}\right)\right] = 11{,}7\frac{W}{m^2}\left[1\,350\,\text{m}^2\left(646{,}6\,\text{h} + 58\,\text{h}\right)\right] = 11\,130\,\text{kWh}$$

which corresponds to a specific final energy demand, in relation to the floor area, of 8,2 kWh/(m^2·a).

Annual final energy demand for shed rooflights

The final energy demand for lighting by illumination solutions using shed rooflights is calculated in a similar manner. Assuming that an “automatic, independent” daylight-responsive control system without total switch-off is installed, the correction factor $F_{D,c}$ stated in Table A.15 is found to be 0,73. This results in a daylight partial-load factor of 0,482, calculated using Formula (7), i. e. $F_D = 1 - F_{D,s}\ F_{D,c}$ of $F_{TL} = 1 - 0{,}71 \cdot 0{,}73 = 0{,}482$. According to DIN V 18599-10,[3] the utilization profile for usage type “industrial activities and crafts” does not assume absences during operating times, so that no presence sensor system is installed. This means that $F_O = 1$ so that the following annual operating times as defined in DIN V 18599-10[3] can be assumed: t_{Day} = 2 192 h, t_{Night} = 58 h. The effective operating times during daylight hours are therefore calculated as follows:

$$t_{eff,Day,D} = t_{Day}\, F_D\, F_O = 2192\,h \times 0{,}48 \times 1 = 1\,052{,}12\ h \qquad (D.7)$$

Formula (D.8) is used to calculate the effective operating time during night-time.

$$t_{eff,Night} = t_{Night}\, F_O = 58\,h \times 1 = 58\,h \qquad (D.8)$$

The annual final energy demand for lighting is thus determined using Formula (D.9).

$$Q_{l,f} = p\left[A_D\left(t_{eff,Day,D} + t_{eff,Night}\right)\right] = 11{,}7\frac{W}{m^2}\left[1\,350\,m^2 \times \left(1\,052{,}12\,h + 58\,h\right)\right] = 17\,534\,kWh \qquad (D.9)$$

which corresponds to a specific final energy demand, in relation to the floor area, of 13,0 kWh/(m^2·a).

Monthly energy demand for strip-type rooflights

The distribution key factors given in Table A.17 are applied to the product $F_{D,s}$ $F_{D,c}$ = 0,70, which was calculated on the basis of one year's operation, to determine the values for the individual months. By applying the monthly partial-load factors $F_{TL,i}$, the monthly final energy demand values $Q_{l,f,i}$ can then be calculated. The annual operating time is evenly distributed among the individual months.

Table D.3 — Monthly final energy demand for strip-type rooflights

Month	$v_{Month,i}$	$v_{Month,I}\, F_{D,s}\, F_{D,c}$	$F_{TL,i}$	$Q_{l,f,i}$ kWh	$q_{l,f,i}$ kWh/(m² · a)
January	0,74	0,52	0,48	1 456	1,08
February	0,92	0,65	0,35	1 090	0,81
March	1,06	0,75	0,25	805	0,60
April	1,16	0,82	0,18	602	0,45
May	1,22	0,86	0,14	480	0,36
June	1,24	0,87	0,13	439	0,33
July	1,22	0,86	0,14	480	0,36
August	1,16	0,82	0,18	602	0,45
September	1,06	0,75	0,25	805	0,60
October	0,93	0,66	0,34	1 070	0,79
November	0,75	0,53	0,47	1 436	1,06
December	0,54	0,38	0,62	1 863	1,38

Monthly final energy demand for shed rooflights

The distribution key factors given in Table A.17 are applied to the product $F_{D,s}$ $F_{D,c}$ = 0,482, which was calculated on the basis of one year's operation, to determine the values for the individual months. By applying the monthly partial-load factors $F_{TL,i}$, the monthly final energy demand values $Q_{l,f,i}$, $q_{l,f,i}$ can then be calculated. The annual operating time is evenly distributed among the individual months.

Table D.4 — Monthly final energy demand for shed rooflights

Month	$v_{Month,i}$	$v_{Month,I}\, F_{D,s}\, F_{D,c}$	$F_{TL,i}$	$Q_{l,f,i}$ kWh	$q_{l,f,i}$ kWh/(m² · a)
January	0,74	0,38	0,62	1 851	1,37
February	0,92	0,48	0,52	1 581	1,17
March	1,06	0,55	0,45	1 371	1,02
April	1,16	0,60	0,40	1 221	0,90
May	1,22	0,63	0,37	1 131	0,84
June	1,24	0,64	0,36	1 101	0,82
July	1,22	0,63	0,37	1 131	0,84
August	1,16	0,60	0,40	1 221	0,90
September	1,06	0,55	0,45	1 371	1,02
October	0,93	0,48	0,52	1 566	1,16
November	0,75	0,39	0,61	1 836	1,36
December	0,54	0,28	0,72	2 151	1,59

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