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Daylight in buildings

National foreword

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A list of organizations represented on this committee can be obtained on request to its secretary.

The UK committee draws users' attention to National Annex NA, which provides further recommendations to assist users in the application of this standard.

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European foreword

This document (EN 17037:2018) has been prepared by Technical Committee CEN/TC 169 “Light and Lighting”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2019, and conflicting national standards shall be withdrawn at the latest by June 2019.

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Introduction

Daylight should be a significant source of illumination for all spaces with daylight opening(s). Daylight is strongly favoured by building occupants as a way to adequately illuminate the indoor surfaces, and to save energy for electrical lighting.

Daylight can provide significant quantities of light indoors, with high colour rendering and variability, changing through the day and the seasons. Daylight openings provide views and connection to the outside and contribute to the psychological well-being of occupants. A daylight opening can also provide exposure to sunlight indoors, which is important, for example, in dwellings, hospital wards and nurseries. In a space, where activities comparable to reading, writing or using display devices are carried out, a shading device should be provided to reduce visual discomfort. The standard addresses daylighting performance over the year. Daylight should illuminate spaces during a significant fraction of the annual daylight hours over the year. Daylight provision depends firstly on the availability of daylight outside (i.e. the prevailing climate at the site) and, thereafter, the environment surrounding the building, the components immediate around the daylight opening and the configuration of the interior spaces.

This standard encourages building designers to assess and ensure successfully daylit spaces. It also allows building designers and developers to target ambitions with respect to daylighting, as well as addressing other issues related to daylight design, such as view out, protection against glare, and exposure to sunlight.

1 Scope

This document specifies elements for achieving, by means of natural light, an adequate subjective impression of lightness indoors, and for providing an adequate view out. In addition, recommendations for the duration of sunshine exposure within occupied rooms are given.

This document gives information on how to use daylighting to provide lighting within interiors, and how to limit glare. This document defines metrics used for the evaluation of daylighting conditions and gives principles of calculation and verification. These principles allow to address the issue of variability of daylight over the days and the year.

This document applies to all spaces that may be regularly occupied by people for extended periods except where daylighting is contrary to the nature and role of the actual work done.

The specification of lighting requirements for humans in indoor work places including visual tasks are given in EN 12464-1 and are not part of this document.

2 Normative references

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

EN 12216, *Shutters, external blinds, internal blinds — Terminology, glossary and definitions*

EN 12464-1, *Light and lighting — Lighting of work places — Part 1: Indoor work places*

EN 12665:2018, *Light and lighting — Basic terms and criteria for specifying lighting requirements*

EN 14501:2005, *Blinds and shutters — Thermal and visual comfort — Performance characteristics and classification*

ISO 15469:2004, *Spatial distribution of daylight — CIE standard general sky*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 12665:2018 and the following apply.

3.1
daylight
visible part of global solar radiation

Note 1 to entry: Also defined as part of global solar radiation capable of causing a visual sensation [CIE ILV 278].

[SOURCE: EN 12665:2018, 3.4.7, modified – note to entry added]

3.2
daylight factor
ratio of the illuminance at a point on a given plane due to the light received directly or 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, excluding the contribution of direct sunlight to both illuminances

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

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

Note 3 to entry: The term daylight factor is normally used when considering an overcast sky as sky type 1 or 16 in ISO 15469.

[SOURCE: EN 12665:2018, 3.4.8, CIE ILV 17-279, modified – note 3 to entry added]

3.3
daylight opening
any area in the building envelope that is capable of admitting daylight to an interior

3.4
daylight provision
level of illuminance achieved across a fraction of a reference plane for a fraction of daylight hours within a space

3.5
diffuse horizontal illuminance (from the sky)
illuminance produced by skylight on a horizontal surface on the Earth

[SOURCE: CIE ILV 17-302]

3.6
discomfort glare
glare that causes discomfort without necessarily impairing the vision of objects

[SOURCE: EN 12665:2018, 3.2.23, CIE ILV 17-333]

3.7
glare
condition of vision in which there is discomfort or a reduction in the ability to see details or objects, caused by an unsuitable distribution or range of luminance, or by extreme contrasts

[SOURCE: EN 12665:2018, 3.1.8, CIE ILV 17-492]

3.8
global horizontal illuminance
illuminance produced by daylight on a horizontal surface on the Earth

[SOURCE: CIE ILV 17-495]

3.9
no-ground line for view
divider between the part of the space from which the ground can be seen directly by a sitting person and the part from which it cannot

3.10
no-sky line for view
divider between the part of the space from which the sky can be seen directly by a sitting person and the part from which it cannot

3.11
obstruction
anything outside a building which prevents the direct view of part of the sky

[SOURCE: CIE ILV 17-834]

3.12
outside distance of view
distance from the inner surface of view opening to opposite major obstructions located in front of the opening

3.13
reference plane
plane in a space on which illuminances and/or daylight factors are calculated, specified or measured

3.14
reference point for view
position from which the view is assessed

3.15
skylight
part of sky radiation capable of causing a visual sensation

[SOURCE: CIE ILV 17-1194]

3.16
solar altitude
vertical angle between the line passing through the centre of the solar disc and the horizontal plane measured from the reference/observation point

3.17
solar azimuth
horizontal angle between vertical plane passing through the geographical north and vertical plane passing through the centre of the solar disc

Note 1 to entry: Solar azimuth is measured clockwise from due North from 0° to 360°

3.18
sunlight
part of direct solar radiation capable of causing a visual sensation

[SOURCE: CIE ILV 17-1281]

3.19
sunlight exposure
sum of the time (hours) (e.g. on a given day) within a given period during which the sun is above the actual horizon with a cloudless sky, which may be limited by permanent obstructions like mountains, buildings, etc.

3.20
utilized area
fraction of the space intended to be occupied

3.21
veiling reflections
specular reflections that appear on the object viewed and that partially or wholly obscure the details by reducing contrast

[SOURCE: EN 12665:2018, 3.2.24, CIE ILV 17-1396]

3.22
view
visual contact with the surrounding through an opening in the surface of a building, providing information about the surrounding landscape/cityscape, possibility to experience the weather changes and to follow the time over the day

3.23
view opening
any area in the building envelope admitting a view, including glazed walls, glazed doors, etc

4 Symbols and abbreviations

For the purposes of this document, the specific symbols listed in Table 1 apply.

Table 1 — Symbols and units

Symbol	Name of quantity	Unit
$A_{\text{façade}}$	Area of the façade	m^2
A_{glazing}	Area of the glazing	m^2
D	Daylight factor	%
DGP	Daylight glare probability	-
$DGP_{\text{e} < 5\ \%}$	*DGP*-value, that is not exceeded in more than 5 % of the occupation time	-
DGP_{s}	Simplified *DGP* value	-
DGP_{t}	Threshold *DGP* value for a critical glare situation	-
D_{T}	Target daylight factor	%
D_{TM}	Minimum target daylight factor	%
D_{W}	Distance from daylight opening	m
ET	Equation of time	h
E_{v}	Vertical illuminance at eye level	lx ($lm \cdot m^{-2}$)

Symbol	Name of quantity	Unit
$E_{v,d}$	Diffuse horizontal illuminance (from the sky)	lx (lm·m^{-2})
$E_{v,d,med}$	Median diffuse horizontal skylight illuminance	lx (lm·m^{-2})
$E_{v,g}$	Global horizontal illuminance	lx (lm·m^{-2})
$E_{v,g,med}$	Median global horizontal daylight illuminance	lx (lm·m^{-2})
$F_{DGP,exceed}$	Fraction of reference usage time for which a threshold value DGP_t is exceeded	-
$F_{plane,\%}$	Fraction of the reference plane for target illuminance level	%
$F_{time,\%}$	Fraction of time for which a given value of illuminance is exceeded	%
f_{glaz}	Glazing fraction	%
i	Number of glare sources	-
J	J is the day number of the year (e.g. for 1st January, $J = 1$ and for 31st December, $J = 365$, February is taken to have 28 days)	-
LT	Local clock time	h
L_s	Luminance of glare source	cd/m^2
L_v	Sky luminance	cd/m^2
P	Position index	-
TST	True solar time	h
t_d	Daylight hours	h
t_{end}	Time when the duration of sunlight is ending by the obstruction or when the solar azimuth α_s reaches the end of the acceptance angle α_a	h
t_{start}	Time when the sun rays begin to reach reference point	h
α_a	Acceptance angle	degrees
α_{obs}	Angle of obstruction	degrees
α_s	Solar azimuth (measured clockwise from due North)	degrees
$\alpha_{wn,s}$	Azimuth angle of daylight opening normal, measured from South	degrees
γ_s	Solar altitude	degrees

Symbol	Name of quantity	Unit
$\gamma_{s,min}$	Minimum Solar altitude	degrees
Δ	Declination of the sun	degrees
Λ	Geographical longitude of the site East (+) or West (-) of Greenwich	degrees
λ_s	Longitude of standard meridian	degrees
$\tau_{glazing}$	Normal-hemispherical light transmittance of the glazing	-
$\tau_{v,n\text{-}dif}$	Normal-diffuse light transmittance	-
$\tau_{v,n\text{-}n}$	Normal-normal light transmittance	-
φ	Geographical latitude of the site	degrees
ω_s	Solid angle subtended by the glare source	sr
ω_η	The hour angle ω_η is counted from the meridian as positive towards the afternoon and negative towards the morning.	degrees

5 Assessment of daylight in interior spaces

5.1 Daylight Provision

5.1.1 General

Daylight can contribute significantly to the lighting needs of any type of building. This means that daylight openings should have appropriate areas to provide sufficient daylight throughout the year. Thus, the evaluation of daylight provision should make account of the availability of daylight at the site in addition to accounting for the properties of the space (e.g. external obstruction, glazing transmittance, thickness of walls and roofs, internal partition and surface reflectance, funitures).

5.1.2 Criteria for daylight provision

A space is considered to provide adequate daylight if a target illuminance level is achieved across a fraction of the reference plane within a space for at least half of the daylight hours.

In addition, for spaces with vertical or inclined daylight openings, a minimum target illuminance level is also to be achieved across the reference plane.

The reference plane of the space is located 0,85 m above the floor, unless otherwise specified. A small fraction of the reference plane may be disregarded to account for singularities.

Values for target illuminances, minimum target illuminances and fractions of reference plane are given in Table A.1.

5.1.3 Daylight Provision Calculation Methods

The following methods to assess daylight provision to the interior, using validated software, are possible:

Method 1) Calculation method using daylight factors on the reference plane. Annex A gives values for target daylight factors (D_T) and minimum target daylight factors (D_{TM}) to be achieved depending on the given site.

Method 2) Calculation method of illuminance levels on the reference plane using climatic data for the given site and an adequate time step. Annex A gives values for target illuminances and minimum target illuminances to be achieve.

Annex B describes recommendations for the daylight calculations using the two methods.

5.1.4 Verification of daylight provision

Verification of daylight provision can be determined using either an adequate software or on site measurements.

The procedure by software requires a representative model of the space together with the key parameters (such as any significant nearby obstructions, the assigned surface reflectance values and glazing transmissivity) that are a reasonable representation of those for the actual, completed building. This can be determined using either Method 1 or Method 2 described in 5.1.3.

On site, it can also be verified using illuminance meters, to measure the distribution of the daylight factor in the actual, completed building. It needs to be conducted at grid points of the reference plane (see B.2) Methods for verification are described in Annex B.

5.2 Assessment for view out

5.2.1 General

View to the outside provides visual connection with the surroundings to supply information about the local environment, weather changes and the time of day. This information can relieve the fatigue associated with long periods of being indoors. All occupants of a space should have the opportunity for the refreshment and relaxation afforded by a change of scene and focus. View to the outside should be assessed from selected reference points corresponding to where people are located within the utilized area.

A view is considered to comprise three distinct layers:

— a layer of sky;

— a layer of landscape;

— a layer of ground.

NOTE The ground layer can include information of activities. The landscape layer can be comprised of buildings, nature, and/or the horizon only.

From any specific reference point (Q), the view quality depends on:

— the size of the daylight opening(s);

— the width of the view (horizontal sight angle);

— the outside distance of view;

— the number of layers;

— the quality of the environmental information of the view.

5.2.2 Criteria for view out

The criteria for view out concern the utilized area. In order to ensure an adequate view out, the following criteria should be met:

— the glazing material of the view opening should provide a view that is perceived to be clear, undistorted and neutrally coloured;

— in the utilized area, view opening(s) as seen from the reference point of the view should have a total horizontal sight angle higher than a minimum value;

— the distance to the outside view should be larger than a minimum value;

— in the utilized area a minimum number of layers should be seen.

Recommended values of view out are given in Table A.5 and calculation methods are described in Annex C.

5.2.3 Verification of view out

Two procedures for verification of view out are given in Annex C.

One simplified verification method of the criteria for view out is described in C.4.1.

One advanced verification method for complex shapes of daylight opening and/or multiple openings is described in C.4.2.

5.3 Exposure to sunlight

5.3.1 General

Exposure to sunlight is an important quality criterion of an interior space and can contribute to human well-being. Minimum exposure to sunlight should be provided in patient rooms in hospitals, play rooms in nurseries and at least one habitable space in dwellings. This is achieved through the expression of the minimum number of hours during which this space receives direct sunlight, for a clear cloudless reference day in the year.

5.3.2 Criteria for exposure to sunlight

For a given reference day (see A.4), a space should receive sunlight for at least a predefined number of hours. Recommended values of sunlight exposure (h) are given in A.4 and calculation methods are described in Annex D.

5.3.3 Verification of sunlight duration

Verification of sunlight duration needs to be conducted in a space which receives sun beams. The sunlight duration is to be verified at the reference point *P* described in Annex D, considering as many daylight openings as necessary to reach the recommended value. This can be determined using either a manual procedure or an adequate software. On site, it can also be verified using either geometrical measurements or pictures taken at point *P* using e.g. a camera equipped with a fish eye lens.

Methods for verification are described in Annex D.

5.4 Protection from glare

5.4.1 General

Glare is a negative sensation and the cause is bright areas with sufficiently greater luminance than the luminance to which the eyes are adapted to, producing annoyance, discomfort or loss in visual performance and visibility. Direct sunlight or high luminance differences between bright and dark areas within the field of view can cause risk of glare.

For any space with daylight openings, it is recommended to use shading devices to reduce risk of glare, and direct view to the sun or a reflection of it should be avoided.

Recommendations for glare protection can be found in Annex E.

5.4.2 Criteria for protection from glare

Daylight Glare Probability (*DGP*) is used to assess protection from glare for spaces where the activities are comparable to reading, writing or using display devices and the occupants are not able to choose position and viewing direction. The *DGP*-assessment can be applied to a space with vertical or inclined daylight openings, but is not applicable for a space with horizontal daylight openings.

DGP-threshold values should not be exceeded for a certain fraction of the reference usage time $F_{\mathrm{DGP,exceed}}$ (see A.5). Recommended maximum *DGP* targets can be assessed by the simplified method given in Annex E. Alternative an annual *DGP* calculation can be used.

Ratings of discomfort glare caused from an indoor electric lighting installation (e.g. UGR, see EN 12464-1) cannot be applied to rate discomfort glare from vertical or inclined daylight openings.

5.4.3 Verification for protection from glare

Verification of glare protection can be conducted with two methods. A simplified method verifying shading devices is described in E.3.2, or method for on site measurements to calculate *DGP* values, see E.5.

Methods for verification are described in Annex E.

Annex A
(informative)

Recommendations

A.1 General

This annex gives three levels of recommendation for assessment of daylight in interior spaces, as specified in Clause 5. The three levels are: minimum, medium and high, and the minimum recommendation level should be provided. The recommendations are given for daylight provision (A.2), view out (A.3), sunlight exposure (A.4) and protection from glare (A.5). If activities in the space may benefit for higher levels, then recommendations are given.

A.2 Recommendations for daylight provision in a space

Table A.1 and Table A.2 give recommendations for daylight provision in a space. The tables include levels for target illuminance E_{T} (lx) and target minimum illuminance E_{TM} (lx). A target illuminance level E_{T} (lx) should be achieved across a specified fraction $F_{plane,\%}$ of the reference plane within a space. For a space with vertical and inclined daylight opening(s), a minimum target illuminance E_{TM} (lx) should be achieved across the entire (i.e. 95 %) fraction $F_{plane,\%}$. Horizontal opening areas can provide the target illuminance across the entire (i.e. 95 %) fraction $F_{plane,\%}$ of the reference plane (Table A.2). The fraction, $F_{plane,\%}$, of the reference plane within a space, in percentage, is given in Table A.1 and Table A.2. Table A.1 gives recommendations for a space with daylight openings in a vertical and/or inclined surface, while Table A.2 gives recommendations for a space with openings in a horizontal surface.

In case of doubt as to whether a particular daylight opening is to be evaluated as an opening in a vertical/inclined surface, or a horizontal surface, any opening is considered to be horizontal if the entire opening area is above the reference plane of the space under consideration.

The reference plane of the space is located 0,85 m above the floor, unless otherwise specified.

Table A.1 — Recommendations of daylight provision by daylight openings in vertical and inclined surface

Level of recommendation for vertical and inclined daylight opening	**Target illuminance** E_{T} lx	**Fraction of space for target level** $F_{plane,\%}$	**Minimum target illuminance** E_{TM} lx	**Fraction of space for minimum target level** $F_{plane,\%}$	**Fraction of daylight hours** $F_{time,\%}$
Minimum	300	50 %	100	95 %	50 %
Medium	500	50 %	300	95 %	50 %
High	750	50 %	500	95 %	50 %
NOTE Table A.3 gives target daylight factor (D_{T}) and minimum target daylight factor (D_{TM}) corresponding to target illuminance level and minimum target illuminance, respectively, for the CEN capital cities.					

Table A.2 — Recommendations of daylight provision by daylight openings in a horizontal surface

Level of recommendation for horizontal daylight opening	Target illuminance E_T lx	Fraction of space for target level $F_{plane,\%}$	Fraction of daylight hours $F_{time,\%}$
Minimum	300	95 %	50 %
Medium	500	95 %	50 %
High	750	95 %	50 %
NOTE Tables A.3 and A.4 give target daylight factor (D_T) corresponding to target illuminance level for the CEN capital cities. Note, that for spaces with horizontal daylight openings, there is no minimum target illuminance recommendations. Table A.4 is only for horizontal daylight openings with diffusing material.			

The recommendations in Table A.1 and Table A.2 can be expressed in terms of a daylight factor *D*. Table A.3 and Table A.4 provide the corresponding daylight factor (*D*) relative to recommended target illuminance E_T (lx) and target minimum illuminance E_{TM} (lx). The corresponding daylight factors relative to the illuminance levels, to be used in method 1 (see 5.1.3), are given in Table A.3 and Table A.4.

Table A.3 — Values of *D* for daylight openings to exceed an illuminance level of 100, 300, 500 or 750 lx for a fraction of daylight hours $F_{time,\%}$ = 50 % for 33 capitals of CEN national members

Nation	Capital [a]	Geographical latitude φ [°]	Median External Diffuse Illuminance $E_{v,d,med}$	*D* to exceed 100 lx	*D* to exceed 300 lx	*D* to exceed 500 lx	*D* to exceed 750 lx
Cyprus	Nicosia	34,88	18 100	0,6 %	1,7 %	2,8 %	4,1 %
Malta	Valletta	35,54	16 500	0,6 %	1,8 %	3,0 %	4,5 %
Greece	Athens	37,90	19 400	0,5 %	1,5 %	2,6 %	3,9 %
Portugal	Lisbon	38,73	18 220	0,5 %	1,6 %	2,7 %	4,1 %
Turkey	Ankara	40,12	19 000	0,5 %	1,6 %	2,6 %	3,9 %
Spain	Madrid	40,45	16 900	0,6 %	1,8 %	3,0 %	4,4 %
Italy	Rome	41,80	19 200	0,5 %	1,6 %	2,6 %	3,9 %
Former Yugoslav Republic of Macedonia	Skopje	42,00	15 400	0,6 %	1,9 %	3,2 %	4,9 %
Bulgaria	Sofia	42,73	18 700	0,5 %	1,6 %	2,7 %	4,0 %
Romania	Bucharest	44,50	18 200	0,5 %	1,6 %	2,7 %	4,1 %
Croatia	Zagreb	45,48	17 000	0,6 %	1, 8 %	2,9 %	4,4 %
Slovenia	Ljubljana	46,22	17 000	0,6 %	1,8 %	2,9 %	4,4 %
Switzerland	Bern	46,25	16 000	0,6 %	1,9 %	3,1 %	4,7 %

Nation	**Capital** [a]	**Geographical latitude** φ [°]	**Median External Diffuse Illuminance** $E_{v,d,med}$	***D* to exceed 100 lx**	***D* to exceed 300 lx**	***D* to exceed 500 lx**	***D* to exceed 750 lx**
Hungary	Budapest	47,48	18 100	0,6 %	1,7 %	2,8 %	4,1 %
Austria	Wien	48,12	16 000	0,6 %	1,9 %	3,1 %	4,7 %
Slovakia	Bratislava	48,20	16 300	0,6 %	1,8 %	3,1 %	4,6 %
France	Paris	48,73	15 900	0,6 %	1,9 %	3,1 %	4,7 %
Luxembourg	Luxembourg	49,36	16 000	0,6 %	1,9 %	3,1 %	4,7 %
Czech Republic	Prague	50,10	14 900	0,7 %	2,0 %	3,4 %	5,0 %
Belgium	Brussels	50,90	15 000	0,7 %	2,0 %	3,3 %	5,0 %
United Kingdom	London	51,51	14 100	0,7 %	2,1 %	3,5 %	5,3 %
Poland	Warsaw	52,17	14 700	0,7 %	2,0 %	3,4 %	5,1 %
The Netherlands	Amsterdam	52,30	14 400	0,7 %	2,1 %	3,5 %	5,2 %
Germany	Berlin	52,47	13 900	0,7 %	2,2 %	3,6 %	5,4 %
Ireland	Dublin	53,43	14 900	0,7 %	2,0 %	3,4 %	5,0 %
Lithuania	Vilnius	54,88	15 300	0,7 %	2,0 %	3,3 %	4,9 %
Denmark	Copenhagen	55,63	14 200	0,7 %	2,1 %	3,5 %	5,3 %
Latvia	Riga	56,57	13 600	0,7 %	2,2 %	3,7 %	5,5 %
Estonia	Tallinn	59,25	13 600	0,7 %	2,2 %	3,7 %	5,5 %
Sweden	Stockholm	59,65	12 100	0,8 %	2,5 %	4,1 %	6,2 %
Norway	Oslo	59,90	12 400	0,8 %	2,4 %	4,0 %	6,0 %
Finland	Helsinki	60,32	13 500	0,7 %	2,2 %	3,7 %	5,6 %
Iceland	Reykjavik	64,13	11 500	0,9 %	2,6 %	4,3 %	6,5 %

[a] Other cities could be added by countries to take into account more precise role of latitude and climate.

Table A.4 — Values of *D* only for horizontal daylights openings with diffusing material[1)] to exceed an illuminance level of 100, 300, 500 or 750 lx for a fraction of daylight hours $F_{\text{time},\%}$ = 50 % for 33 capital cities of CEN national members

Nation	Capital [a]	Geographical latitude φ [°]	Median External Global Illuminance $E_{\text{v,g,med}}$	*D* to exceed 100 lx	*D* to exceed 300 lx	*D* to exceed 500 lx	*D* to exceed 750 lx
Cyprus	Nicosia	34,88	43 200	0,2 %	0,7 %	1,2 %	1,7 %
Malta	Valletta	35,54	33 600	0,3 %	0,9 %	1,5 %	2,2 %
Greece	Athens	37,90	35 350	0,3 %	0,8 %	1,4 %	2,1 %
Portugal	Lisbon	38,73	38 717	0,3 %	0,8 %	1,3 %	1,9 %
Turkey	Ankara	40,12	31 300	0,3 %	1,0 %	1,6 %	2,4 %
Spain	Madrid	40,45	35 200	0,3 %	0,9 %	1,4 %	2,1 %
Italy	Rome	41,80	30 900	0,3 %	1,0 %	1,6 %	2,4 %
Former Yugoslav Republic of Macedonia	Skopje	42,00	24 300	0,4 %	1,2 %	2,1 %	3,1 %
Bulgaria	Sofia	42,73	22 200	0,5 %	1,4 %	2,3 %	3,4 %
Romania	Bucharest	44,50	28 500	0,4 %	1,1 %	1,8 %	2,6 %
Croatia	Zagreb	45,48	20 300	0,5 %	1,5 %	2,5 %	3,7 %
Slovenia	Ljubljana	46,22	19 800	0,5 %	1,5 %	2,5 %	3,8 %
Switzerland	Bern	46,25	21 700	0,5 %	1,4 %	2,3 %	3,5 %
Hungary	Budapest	47,48	25 100	0,4 %	1,2 %	2,0 %	3,0 %
Austria	Wien	48,12	20 800	0,5 %	1,4 %	2,4 %	3,6 %
Slovakia	Bratislava	48,20	22 600	0,4 %	1,3 %	2,2 %	3,3 %
France	Paris	48,73	20 400	0,5 %	1,5 %	2,5 %	3,7 %
Luxembourg	Luxembourg	49,36	17 100	0,6 %	1,8 %	2,9 %	4,4 %
Czech Republic	Prague	50,10	17 400	0,6 %	1,7 %	2,9 %	4,3 %
Belgium	Brussels	50,90	17 200	0,6 %	1,7 %	2,9 %	4,4 %
United Kingdom	London	51,51	17 650	0,6 %	1,7 %	2,8 %	4, 2 %
Poland	Warsaw	52,17	18 300	0,5 %	1,6 %	2,7 %	4,1 %

1) A diffusing material redistribute transmitted light evenly regardless of the angular distribution of the incident light. The ratio between the internal and external illuminance remains relative constant regardless of the sun and sky conditions.

Nation	**Capital** [a]	**Geographical latitude** φ [°]	**Median External Global Illuminance** $E_{v,g,med}$	***D* to exceed 100 lx**	***D* to exceed 300 lx**	***D* to exceed 500 lx**	***D* to exceed 750 lx**
The Netherlands	Amsterdam	52,30	17 600	0,6 %	1,7 %	2,8 %	4,3 %
Germany	Berlin	52,47	17 100	0,6 %	1,8 %	2,9 %	4,4 %
Ireland	Dublin	53,43	18 200	0,5 %	1,6 %	2,7 %	4,1 %
Lithuania	Vilnius	54,88	18 400	0,5 %	1,6 %	2,7 %	4,1 %
Denmark	Copenhagen	55,63	17 300	0,6 %	1,7 %	2,9 %	4,3 %
Latvia	Riga	56,57	15 000	0,7 %	2,0 %	3,3 %	5,0 %
Estonia	Tallinn	59,25	14 500	0,7 %	2,1 %	3,4 %	5,2 %
Sweden	Stockholm	59,65	15 200	0,7 %	2,0 %	3,3 %	4,9 %
Norway	Oslo	59,90	14 600	0,7 %	2,1 %	3,4 %	5,1 %
Finland	Helsinki	60,32	16 900	0,6 %	1,8 %	3,0 %	4,4 %
Iceland	Reykjavik	64,13	14 000	0,7 %	2,1 %	3,6 %	5,4 %
[a] Other cities could be added by countries to take into account more precise role of latitude and climate.							

A.3 Recommendations for view

View opening(s) should provide a sufficient view. If there are several openings with little distance between them, the sum of openings may be regarded as one opening.

Table A.5 gives recommendations for three levels of view out through vertical, inclined and horizontal openings. These levels depend on the horizontal sight angle, the distance to outside view, and the number of layers (content of the view). These aspects are assessed from reference positions (see Annex C for further details). The highest view levels are specifically important for buildings for people with limited mobility.

Table A.5 — Assessment of the view outwards from a given position

	Parameter [a]		
Level of recommendation for view out	**Horizontal sight angle**	**Outside distance of the view**	**Number of layers to be seen from at least 75 % of utilized area:** **- sky** **- landscape (urban and/or nature)** **- ground**
Minimum	≥ 14°	≥ 6,0 m	At least landscape layer is included
Medium	≥ 28°	≥ 20,0 m	Landscape layer and one additional layer is included in the same view opening
High	≥ 54°	≥ 50,0 m	all layers are included in the same view opening

[a] For a space with room depth more than 4 m, it is recommended that the respective sum of the view opening(s) dimensions is at least 1,0 m × 1,25 m (width × height).

A.4 Recommendation for exposure to sunlight

The recommendation is that a space should receive possible sunlight for a duration according to Table A.6 (supposed to be cloudless) on a selected date between February 1st and March 21st. Table A.6 proposes three levels for sunlight exposure. See Annex D for further details.

When applying the recommendation to a whole dwelling, the proposal is that at least one habitable room in the dwelling should have at least exposure to sunlight after Table A.6.

Table A.6 — Recommendation for daily sunlight exposure

Level of recommendation for exposure to sunlight	Sunlight exposure
Minimum	**1,5 h**
Medium	**3,0 h**
High	**4,0 h**

A.5 Recommendation for glare protection

The Daylight Glare Probability (*DGP*) should not exceed a maximum value for more than the fraction $F_{\mathrm{DGP,exceed}}$ = 5 % of the usage time of the space.

In Table A.7, $DGP_{\mathrm{e} < 5\ \%}$ -threshold values for different levels of glare protection are proposed.

The minimum recommendation for glare protection is that the *DGP* for the occupied space does not exceed a value of 0,45 in more than 5 % of the occupation time of the relevant space.

Table A.7 — Proposed different levels of threshold $DGP_{e\ <\ 5\ \%}$ for glare protection

Level of recommendation for glare protection	$DGP_{e\ <\ 5\ \%}$
Minimum	**0,45**
Medium	**0,40**
High	**0,35**

Annex B
(informative)

Daylight

B.1 General

The daylight in an interior space depends, primarily, on the availability of natural light and, thereafter, the properties of the space and its surroundings. The standard proposes two methods to assess daylight provision in the interior: a calculation method based on daylight factor and cumulative daylight availability data (method 1); or, a calculation method based on the direct prediction of illuminance levels using hourly climate data (method 2).

Both methods apply the annual occurrence of an absolute value for internal illuminance calculated from the availability of external horizontal illuminance as determined from climate data suitable for the site of evaluation.

Calculation method 1 using daylight factors on a reference plane should achieve a target daylight factor (D_{T}) and/or a minimum target daylight factor (D_{TM}) across a fraction of the reference plane for at least half of the daylight hours, where D_{T} and D_{TM} are based on the provision of recommended target illuminance values, (E_{T})and minimum target illuminance (E_{TM}), both in lx.

Calculation method 2 uses the recommended illuminance values E_{T} and E_{TM}. Annex A gives values for respectively D_{T} and D_{TM} respectively as well as E_{T} and E_{TM}. The area in the space being assessed is characterized by a number of grid points detailed described in B.2.

B.2 Calculation grids

To determine target values of illuminances and daylight factors, it is necessary to perform calculations over the entire reference plane, located 0,85 m above the floor of the area to which they apply. The points at which calculations should be carried out are defined in Formula (B.1).

Grid cells approximating to a square are preferred, the ratio of length to width of a grid cell shall be kept between 0,5 and 2. The maximum grid size shall be:

$$p = 0{,}5 \times 5^{\log_{10}(d)} \qquad \text{(B.1)}$$

where

— $P \leq 10$ m,

— d is the longer dimension of the calculation area (m), however if the ratio of the longer to the shorter side is 2 or more then d becomes the shorter dimension of the area, and

— p is the maximum grid cell size (m).

The number of points in the relevant dimension is given by the nearest whole number that is equal to or greater than d/p.

The resulting spacing between the grid points is used to calculate the nearest whole number of grid points in the other dimension. This will give a ratio of length to width of a grid cell close to 1.

The area of the grid points, within a space, should exclude a band of 0,5 m from the walls, unless otherwise specified.

B.3 Calculation methods

B.3.1 General

Daylight calculation should take into account appropriate sky luminance distribution(s), external surroundings, daylight openings (materials and components), and internal reflections (e.g. indoor surfaces and fixed objects). This can be done through performing calculations of either daylight factors or alternatively indoor daylight illuminances on the reference plane over a whole year using a time step of one hour or less. With calculation methodologies, there are always approximations, and uncertainties, moreover the reduction of glazing transmittance due to dirt deposition should be taken into account. If details of the space being assessed are not available, then reasonable assumptions may be employed (e.g reflectance of indoor surfaces, indoor space configurations and furniture, if known). All assumptions made shall be stated.

The reflectance of the main surfaces needs to be considered carefully when assessing daylighting design of a space, and often the recommended values of reflectances for the major interior surfaces would be in the following ranges: ceiling 0,7 to 0,9; interior walls 0,5 to 0,8; floor 0,2 to 0,4; exterior walls 0,2 to 0,4; with exterior ground usually set to 0,2. Deviations from these ranges are of course permitted, but justification should be given, e.g. a high reflectivition (0,6) exterior wall finish applied to a courtyard.

It is recommended to use default reflection of floor 0,2, walls 0,5 and ceiling 0,7 when tested or verified calculations are carried out.

NOTE CIE 16:1970 lists calculation methods and CIE 171:2006 gives test data that can be used to validate the calculation process.

B.3.2 Calculation method using daylight factor (method 1)

The daylight factor method assumes a constant ratio between internal and external illuminance. The daylight factors (D) in the space shall be calculated by any reliable method that is based on the ISO 15469:2004 standard overcast sky (TYPE 1 or TYPE 16). Daylight factors are to be predicted across grid of points according to B.2 on a plane 0,85 m above the floor of the space. Once daylight factors are calculated, ensure that, at least on the required area of the space, the daylight factors equal or exceed the target values (D_{TM} and D_T) given in Tables A.3 and A.4. The parameters of target daylight factor D_T and minimum target daylight factor D_{TM} are:

— D_T is the target daylight factor relative to a given illuminance to be exceeded for more than half of daylight hours, over 50 % of the reference plane. If, for instance, the criterion is to achieve at least 300 lx, then D_T is equal to:

$$D_T = \frac{\text{illuminance level}}{E_{v,d,med}} = \frac{300\ \text{lx}}{E_{v,d,med}} \times 100 \left[\%\right] \qquad \text{(B.2)}$$

where

$E_{v,d,med}$ is the median diffuse horizontal illuminance from the sky. Table A.3 give the value of $E_{v,d,med}$ for each of the 33 capital cities of CEN national members. $E_{v,d,med}$ is the illuminance produced by skylight on a horizontal surface on the Earth achieved for half of the daylight hours (2 190 h) in the year (see B.4)

— D_{TM} is the minimum target daylight factor relative to a given illuminance to be exceeded for more than half of daylight hours, over 95 % of the space. D_{TM} may act a safeguard against poorly illuminated daylit spaces. Similar to D_T, the criterion to achieve, for instance, at least 100 lx, then D_{TM} is equal to:

$$D_{TM} = \frac{\text{illuminance level}}{E_{v,d,med}} = \frac{100\ \text{lx}}{E_{v,d,med}} \times 100 \left[\%\right] \qquad \text{(B.3)}$$

where

$E_{v,d,med}$ is the median diffuse horizontal skylight illuminance (see Table A.3).

NOTE When horizontal diffusing materials are used in a daylight opening, one can consider that sunlight contributes also to daylighting of buildings. In these conditions, daylight factors can be used, but in conjunction with the median external global illuminance $E_{v,g,med}$. Table A.4 give values for horizontal daylight openings with diffusing material, and the values of D can lead to a reduction in sunny climates.

B.3.3 Calculation method using illuminance level (method 2)

This requires the use of a detailed daylight calculation method where hourly (or sub-hourly) internal daylight illuminance values for a typical year are computed using hourly (or sub-hourly) sky and sun conditions derived from climate data appropriate to the site.

This calculation method determines daylight provision directly from simulated illuminance values on the reference plane. If the actual space is expected to contain any moveable shading device (e.g. blinds) then the dynamic modelling of these should be included in the simulation.

For a space with vertical and/or inclined opening with a given target illuminance, e.g. 300 lx, and appropriate reference plane fraction, i.e. 50 %, the criterion is that the target illuminance is achieved across the reference plane fraction for 2 190 h (i.e. half of the daylight hours of the year). For the minimum target illuminance, e.g. 100 lx, the criterion is that the minimum target illuminance is achieved across the entire (i.e. 95 %) reference plane for 2 190 h. Similarly, this detailed calculation method should be applied to spaces with horizontal daylight openings.

The calculation should be carried out using validated software.

B.4 Daylight availability

When the evaluation is founded on the daylight factor, the daylight provision is based on the availability of diffuse skylight for the particular locale as determined from standardized climate files or equivalent.

Standardized climate files contain an annual time series of 8 760 hourly values for diffuse horizontal illuminance (e.g. EnergyPlus Weather file; Meteonorm weather file; Satel-Light). The hours of daylight are determined by rank-ordering (i.e. from highest to lowest) the 8 760 values for diffuse horizontal illuminance and then extracting the first (i.e. the highest) 4 380 hourly values. Note that the retained (i.e. highest) 4 380 values may include some zero values, or that the discarded 4 380 values may include some non-zero values. This is to be expected given the nature of illuminance data in climate files and does not affect the outcome. The selection of the median value is related to the criterion of 50 % of the daylight hours propose by this standard.

The median diffuse horizontal illuminance value ($E_{v,d,med}$) during daylight hours for each capital of the CEN member countries is given in Table A.3. It is possible to calculate equivalent values for other locations provided suitable data are available.

NOTE 1 If the climate file does not contain an annual time-series for diffuse horizontal illuminance ($E_{v,d}$), then the external median daylight illuminance can be derived from diffuse horizontal irradiance ($E_{e,d}$) using a luminous efficacy model. $E_{v,d}$ can be obtained by multiplying $E_{e,d}$ by the fixed luminous efficacy value. Luminous efficacy of skylight varies, and a reasonable approximation value is 110 lmW^{-1}.

NOTE 2 If diffusing materials in a horizontal daylight opening are used, the median external global illuminance ($E_{v,g,med}$) during daylight hours for each capital of the CEN member countries is given in Table A.4.

B.5 Validation of actual daylighting performance

Evaluation of an actual space against predicted daylight performance using the proposal described above is little different to that required for any 'traditional' daylight factor-based prediction. In principle, predicted daylight factors would be compared to measurements taken in the real space under suitable overcast sky conditions. In practice, however, this may introduce uncertainties due to measurements under real sky conditions include confounding factors, such as if the occurring overcast sky conforms to the CIE standard overcast sky luminance pattern.

In practice, the daylight factor in real spaces is measured directly using paired readings of internal and external illuminance levels. For this, the properties that need to be determined are:

— Geometrical: to confirm that the dimensions and configuration of the space assumed for the prediction stage are a sufficiently close match to the real space.

— Surface properties: to confirm that the reflection/transmission properties assumed for the prediction are realistic representation of those found in the finished space.

Both the geometrical and the surface properties of the real space can be compared against those employed for the prediction with rather more precision and reliability than relying solely on paired measurements of internal and external illuminance.

To minimize the risk of significant discrepancy between the modelled and actual space, any assumptions made at the prediction stage should be 'reasonable' according to normal, professional practice. Specified daylight design criteria need to consider building site characteristics, façade and roof characteristics, size and placement of daylight openings, glazing and shading systems, and geometry and reflectance of interior surfaces. All criteria should be verified by certain assumptions including degree of accuracy made. These assumptions should be declared reasonable and according to normal practice.

Annex C
(informative)

View out

C.1 General

Daylight openings with a view out provide connection with surroundings. The view out should comprise of layers of sky, city or landscape, and ground. A natural view is preferred over a view towards man-made environment, and a wide and distant view is appreciated more than a narrow and near view. A diverse and dynamic view is more interesting than a monotonous view. A view of nature may have positive influence on a person's sense of wellbeing, and job satisfaction, and people generally prefer to sit near a daylight opening and to look outside.

Views are rated 'minimum', 'medium' or 'high' according to criteria given in Table A.5. In addition to the rating in Table A.5, a view opening is generally perceived as good, if it comprises of a sufficiently horizontal width of the opening, a distinct distance to the outside view, and several layers are included.

A view rated minimum contains at least the landscape layer and provides information about the conditions outside, especially about location, time, and weather. Additionally, a view rated medium contains at least two layers, and a view rated high includes all three layers. The rating of the view out includes information about the distance to the outside view and the width of the view opening (i.e. horizontal sight angle). The overall achieved level for view out should be ranked according to the lowest rated criterion. Furthermore, a view opening should have glazing that ensure a view through the glazing is perceived to be clear, undistorted and neutrally coloured.

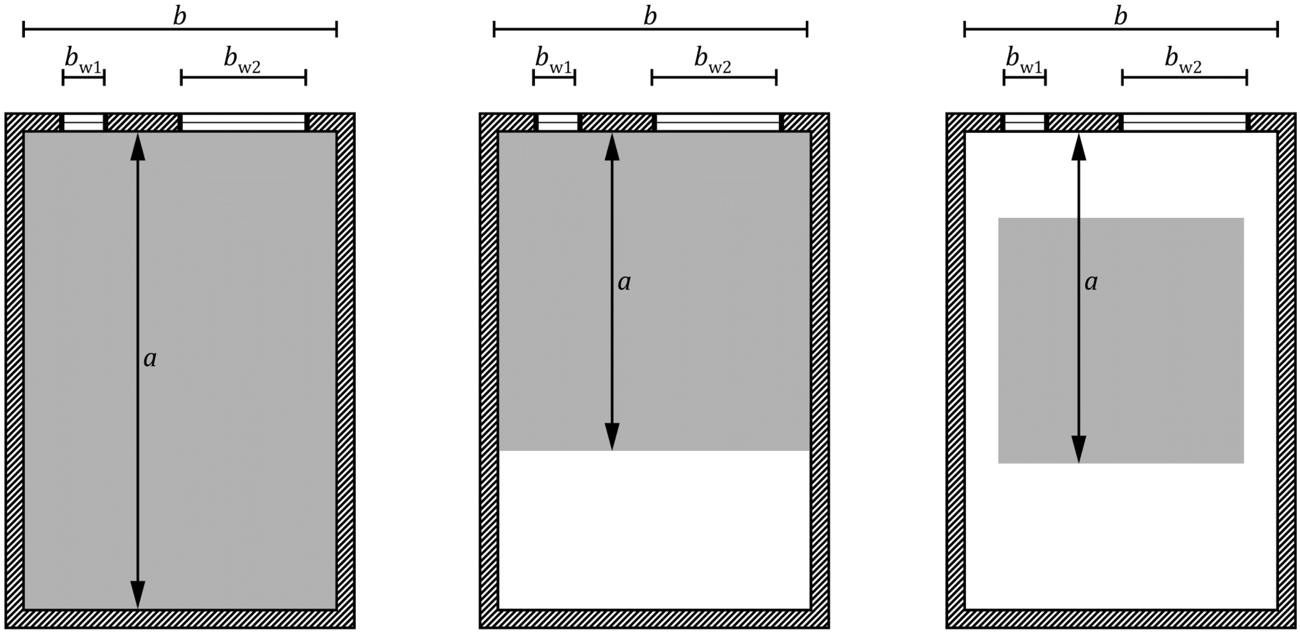
The horizontal sight angle should be sufficiently large to ensure a wide and distant view. For very large spaces (>2000 m^2), a nearby view opening may be difficult to provide; however, a degree of relaxation of the eyes can be achieved with a distant interior view.

C.2 Quality of view out

For daylight opening(s) in a vertical façade or in an inclined surface, the rating parameters and threshold values are specified in Table A.5. In addition to rating parameters, other measures are important when evaluating the view out: the aesthetical value of objects included in the view and the composition of the view. Aesthetical value of the scene within the view is correlated with complexity, maintenance, age, etc. The composition of the view may be examined at the photo of the view out taken from the reference points indoors. For a good composition, the elements generally appreciated should not be fragmented and a balance between left and right side of the picture should be ensured. Furthermore, environmental information, such as location, time, weather, nature, people are also important. One additional subjective rating of environmental information could be: 'minimum' include time, weather and location; 'medium' include additionally information about nature; and 'high' should include all.

C.3 Width of view out

In the case of a medium rated view out, it should be possible, from the reference points, to see through a view opening that covers a horizontal sight angle of at least 28° according to Table A.5. The reference points can be at any potential location within the utilized area of the space. Figure C.1 show examples of view opening(s) in the same façade. For a medium rated view, the view opening(s) (b_W) should have a total width equalling at least half the distance between the façade and the most remote part of the utilized area (a) of the space. To fulfill the recommended level, a should be at least equal to the depth of this area. The total width of the view opening, for a medium rated view, should be equal to or more than half the width of the space. If there are several openings (b_{W1} and b_{W2}) with little distance between them, the sum of openings may be regarded as one (b_W).



$$b_{w1} + b_{w2} \geq \frac{a}{2} \text{ and } b_{w1} + b_{w2} \geq \frac{b}{2}$$

Key

a distance between the façade and the most remote part of the utilized area

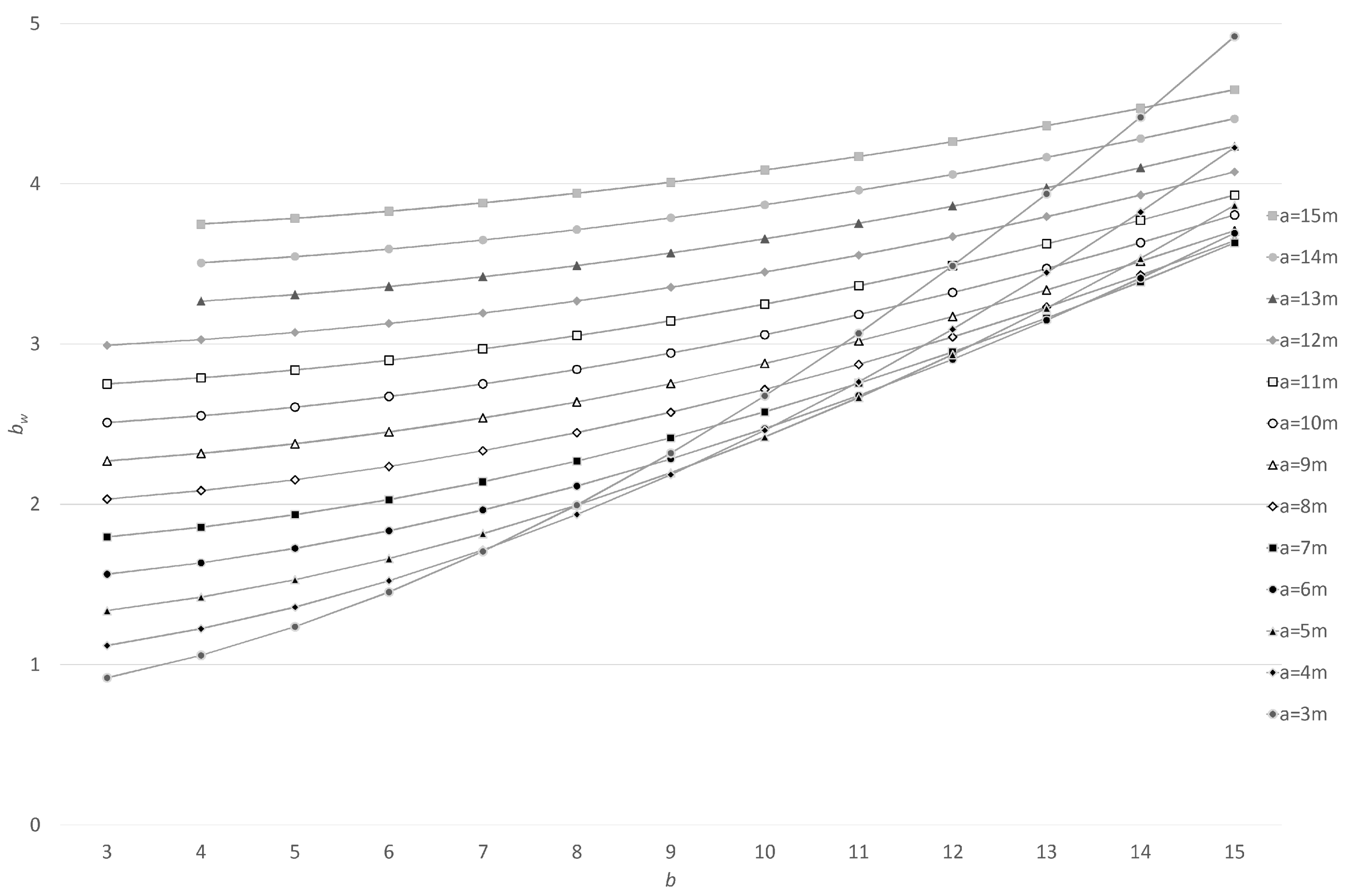
b width of façade between interior walls

b_{W1} width view opening 1

b_{W2} width view opening 2

Figure C.1 — The view opening(s) in the same façade

Figures C.2, C.3 and C.4 provide the width of the view opening(s) in (m) as a function of the depth of the utilized area within a space and a horizontal sight angle of at least 14, 28 and 54 degrees, respectively.



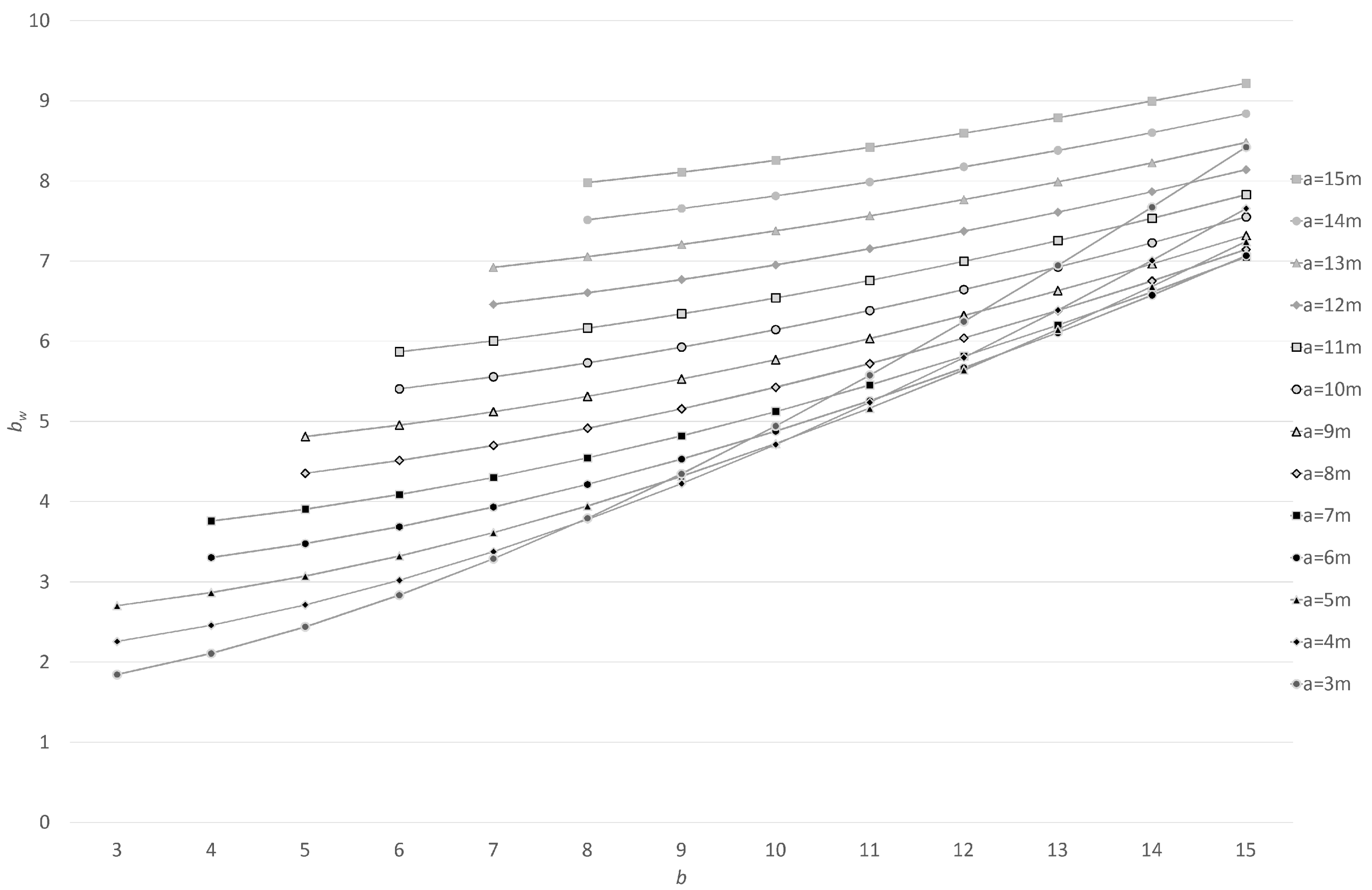
Key

a distance between the façade and the most remote part of the utilized area

b_W width of the view opening(s) (m)

b width of the room (m)

Figure C.2 — Rating of width of view opening(s) as a function of depth of the utilized area for a horizontal sight angle of ≥ 14 degrees



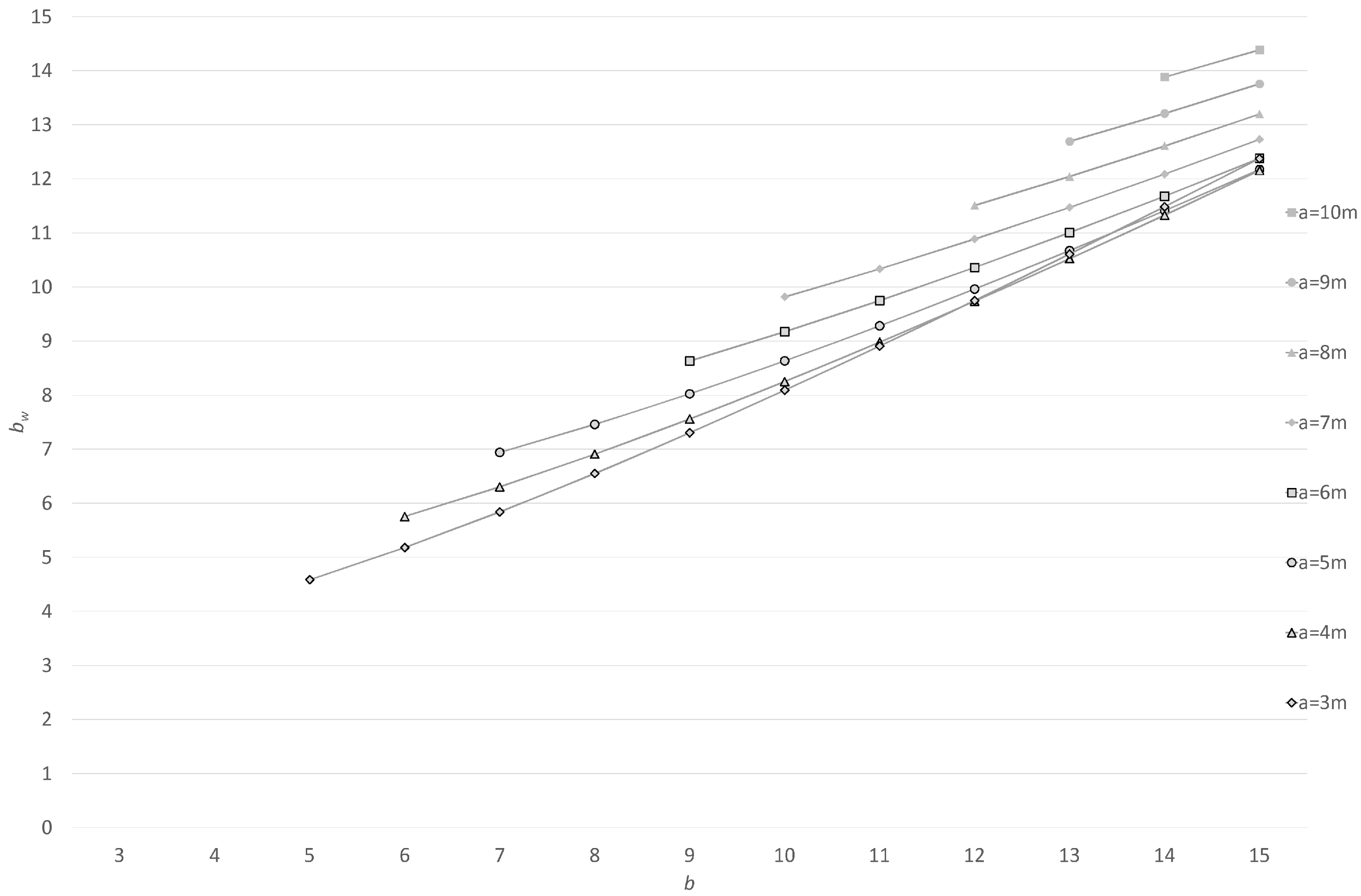
Key

a distance between the façade and the most remote part of the utilized area

b_W width of the view opening(s) (m)

b width of the room (m)

Figure C.3 — Rating of width of view opening(s) as a function of depth of the utilized area for a horizontal sight angle of ≥ 28 degrees



Key

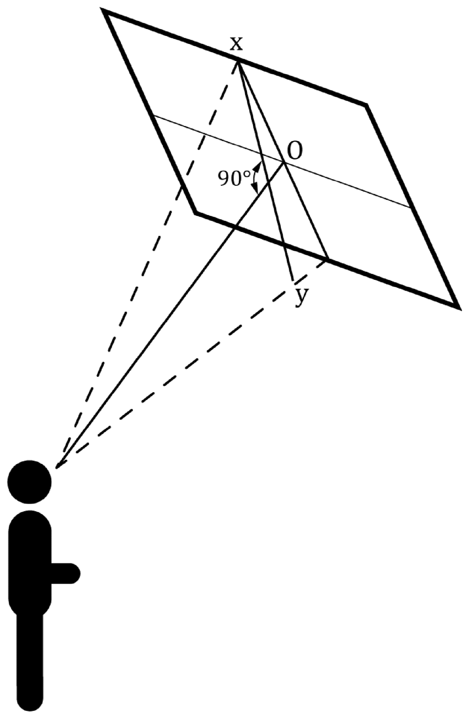
a distance between the façade and the most remote part of the utilized area

b_W width of the view opening(s) (m)

b width of the room (m)

Figure C.4 — Rating of width of view opening(s) as a function of depth of the utilized area for a horizontal sight angle of ≥ 54 degrees

If a space has daylight openings in more than one façade, at least one view opening should comprise a rated view according to Table A.5. The distance *a* should be diagonal line across the utilized area. For a daylight opening with a sill-height above eye-level, the recommended xy projection of the height of the opening, perpendicular to the sight direction of the eye should be used (see Figure C.5). If view to the outside is not possible, the rated view towards an atrium with social interactions and plants can be used. To have a feeling of spaciousness of the view, it is recommended opposite atrium façades should be at a distance of more than 20 m from the daylight opening.



Key

O centre of daylight opening

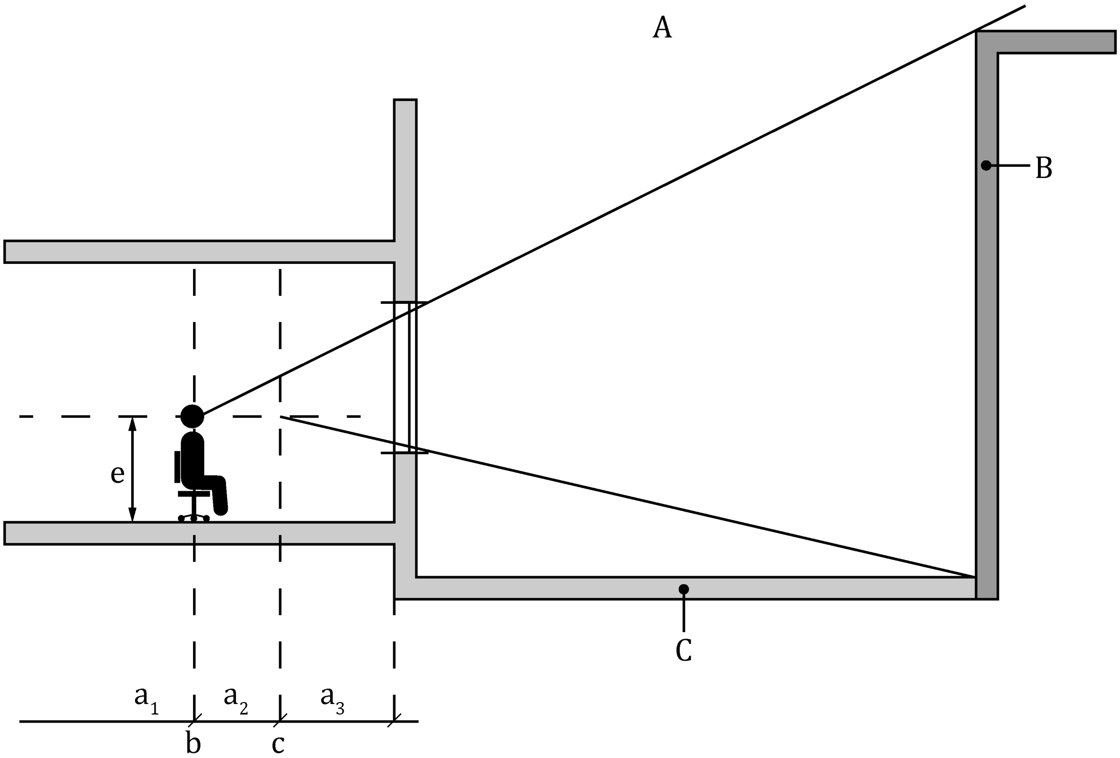
xy perpendicular on the view direction

Figure C.5 — For daylight openings with a sill-height above the eye-level

C.4 Verification of view out

C.4.1 Simplified verification method

A simplified verification method to assess the view out, horizontal sight angle and number of layers is the no-sky line and no-ground line concept combined with the assessment of the view width. The level of view out assumes that the width and outside distance is according to the criteria given in C.3. For minimum rated view out, the number of layers to be seen from 75 % of utilized area should be at least the landscape/cityscape layer. Figure C.6 provide a simplified method to assess the number of layers visible from the position of the occupant. The position marked as line a_1 in Figure C.6 provides the minimum number of layers visible - no-sky line for view. In front of line a_2, it will be possible to see two layers, the sky and the landscape or cityscape - no-ground line for view. Line a_3 provides a view to all three layers. The actually sitting eyelevel is 1,2 m above the floor or for standing the eye level 1,7 m above the floor, unless otherwise specified.



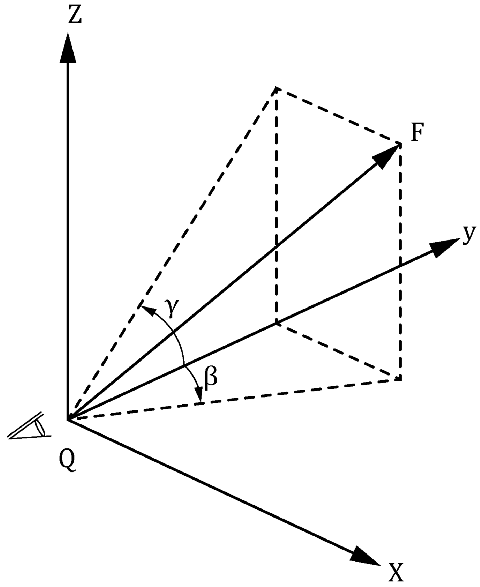
Key

a	visible layers
b	no sky
c	no ground
e	eye-level 1,2 m
A	sky
B	landscape/cityscape
C	ground

Figure C.6 — Cross-section for simplified verification method

C.4.2 Advanced verification method

The advanced method is the projection method. It is recommended to use a projection method for complex shapes of daylight openings and/or multiple openings, as well as components within the daylight openings (e.g shading devices). The projection method uses an equidistant fish-eye projection (see Figure C.8), which can be made with photo camera, computer software or hand drawing, depending on the stage of designing or if it is an existing building, as illustrated in Figure C.9. In Figure C.7, the y-axis is the view direction to the point where the eyes are focussed. F is the location where an object is observed in the total visual field. The vector QF is projected on the yz plane and on the xy plane, which give the angles γ and β between the respective projections of QF and the y-axis. Point Q indicate the eyelevel of a seated (e.g. 1,2 m over the floor) or standing (usually, eye level 1,7 m over the floor) person, unless otherwise specified. Other projection methods, such as projections with cylindrical coordinates can be used.



Key

y viewing direction

Q eye-level

F the location where an object is observed

Figure C.7 — Position of an object F (with angles γ and β) seen by a person from point Q. The y-axis is the viewing direction

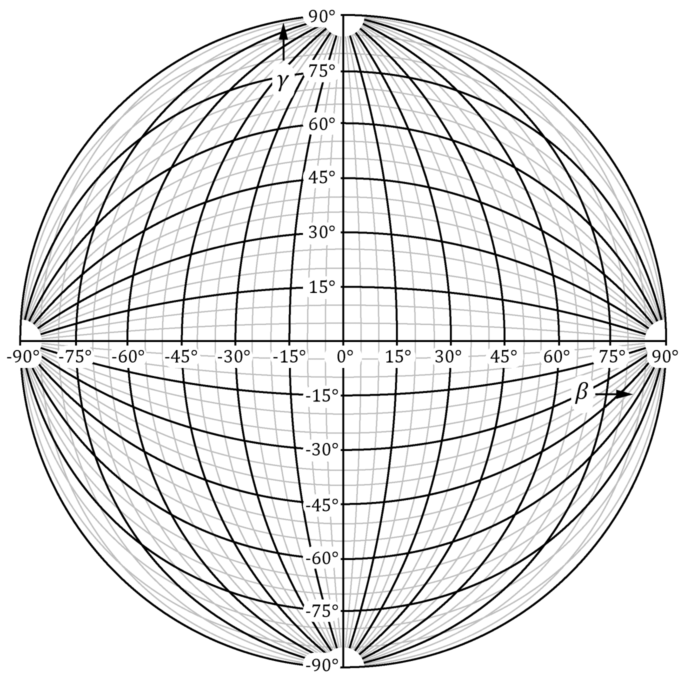


Figure C.8 — Basic diagram for the projection, with axes for angles γ and β (equidistant spherical projection)

Figure C.9 — Photo with a fish-eye lens

Annex D
(informative)

Exposure to sunlight

D.1 General

Evaluation of exposure to sunlight consists of checking if the sun may be visible across the sky on the selected date, and to calculate the duration of the exposure in hours. Sunlight provision is essential for any interior space and depending on the function of the space, it is generally desirable, except during hot climatic conditions. Sunlight duration needs to be linked to appropriate selection of shading systems to minimize possible thermal and/or visual discomfort to the occupants (see recommendations in Annex A and Annex E on glare protection).

Sunlight is also important for building occupants and it enhances overall brightness of the interiors with patches of high illuminance. When properly controlled, sunlight is generally welcome in most buildings throughout Europe, and dissatisfaction can arise from a permanent exclusion of sunlight as much as from its excess.

Considerations of sunlight access will influence the decision about the form of the building itself, the design of the façade and the orientation of the daylight openings. It needs to be achieved by constructing the building appropriate to the climatic conditions through careful planning of the orientation, the disposition of rooms and their openings, which includes the selection of solar shading devices and considers obstructions and surroundings.

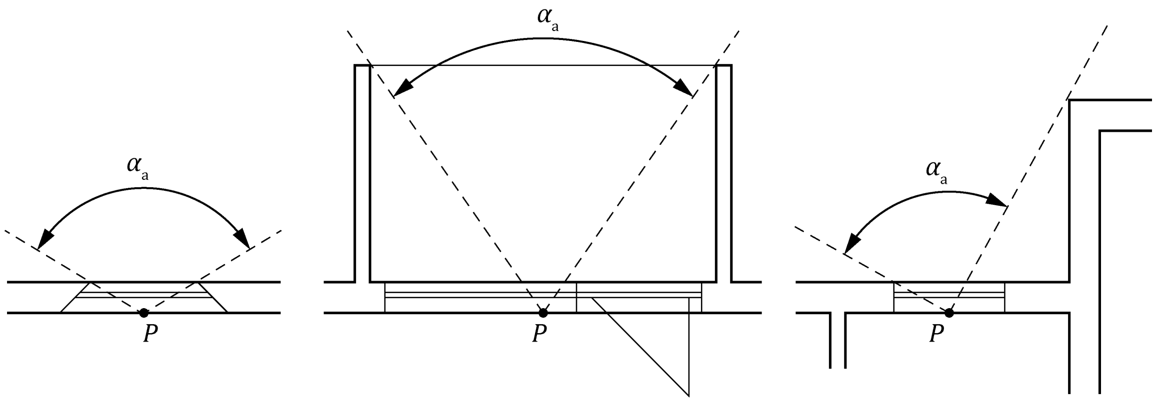
Solar gains can contribute positively to the reduction of energy consumption for heating. In warmer months, sunlight should be restricted by solar shading devices or by strategically constructed shading elements, either as a static or moveable devices. In homes for people with limited mobility, the orientation of openings should take into account periods of occupancy and any preferences for sunlight at particular times of a day.

Daylight opening in interiors, in position where sunlight could cause glare, discomfort or overheating, should be provided with solar shading devices.

D.2 Principle of assessment of hours of sunlight

Annex A presents three values of sunlight exposure in a space for a selected day. Recommended values of sunlight exposure (*h*) are in Table A.6. The selected date for assessments should be between February 1st and March 21st.

The assessment should be conducted for this date, for each opening of the space, from a reference point (point *P*) located on the inner surface of the aperture. Point *P* is located at the centre of the opening width. For multiple apertures in different façades it is possible to cumulate the time of sunlight availability if not occurring at the same time. The reference point is minimum 1,2 m above the floor and 0,3 m above the sill of the daylight opening, if present. If a daylight opening is without a sill, the reference point is located 1,2 m above the floor. The influence of various shapes of opening linings and of the exterior constructions of the building itself is presented in Figure D.1, in top view, while the position of reference point P is presented in Figure D.2 and Figure D.3, in section.”



Key

a) daylight opening with cut lining

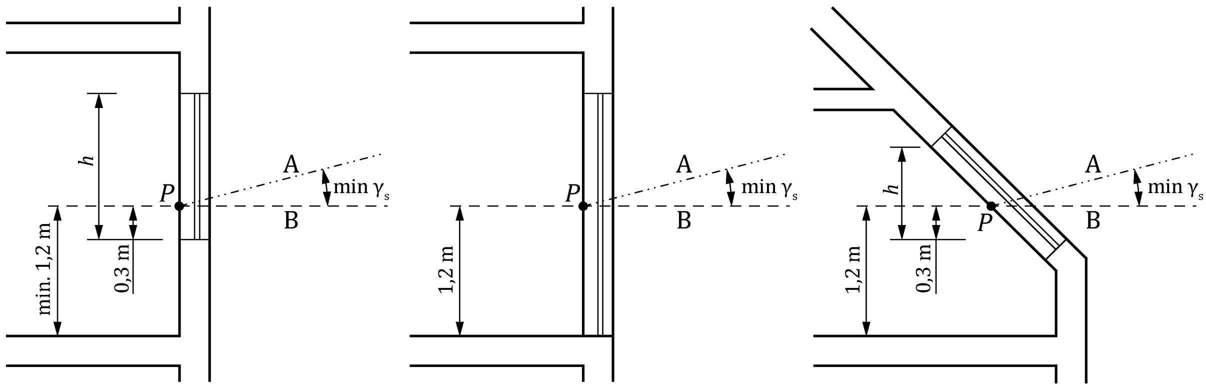
b) daylight opening in a loggia

c) daylight opening shaded by own building construction

α_a acceptance angle

P reference point

Figure D.1 — Relation of acceptance angle α_a to the position of the reference point *P* in plan



Key

a) vertical daylight opening with a sill below 1,2 m above the floor

b) vertical daylight opening starting from the floor level

c) daylight opening located in an inclined surface

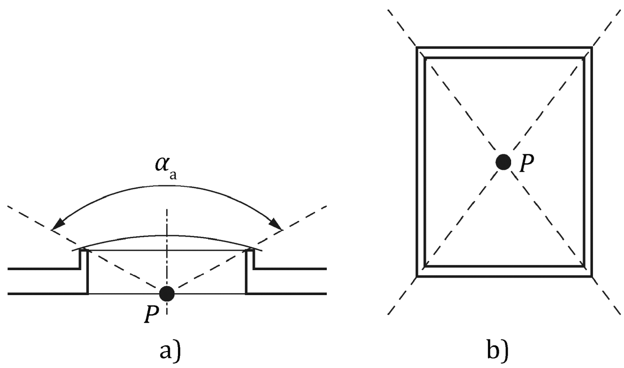
A minimum solar altitude

B horizon

γ_s solar altitude

P reference point

Figure D.2 — Position of the reference point *P* in section



Key

a)	section
b)	plan
α_a	acceptance angle
P	reference point

Figure D.3 — Position of the reference point *P* for a horizontal daylight opening

From this point, it is necessary to identify as precisely the fraction of the sky which is visible, to identify the possibility that the sun can reach reference point *P* on the selected date. This requires describing obstructions due to the external site as well as façade components and details of the façade which are concerned. Two methods are recommended for sun exposure evaluation, one using available software and sun paths diagrams, one using manual geometric constructions.

D.3 Method using software

This method requires that the appropriate software has a graphical module allowing to generate, from the reference point *P*, images toward the outside, through the daylight opening. For instance, if one uses a software able to produce a 180° angle image (e.g. Fish-eye type, equidistant projection), it is possible to compare the sky area free from obstructions with circular sun path diagrams, Figure D.4 and Figure D.5.

The direction to North when generating the pictures and orienting the sun paths diagrams shall be exactly determined. If a “fish-eye“type of image is to be produced at point *P*, the center of the image should be the point in the sky at the vertical of point *P* (zenith) . Then the sun path diagram should be superimposed to the circular image made by the graphical software at point *P*.

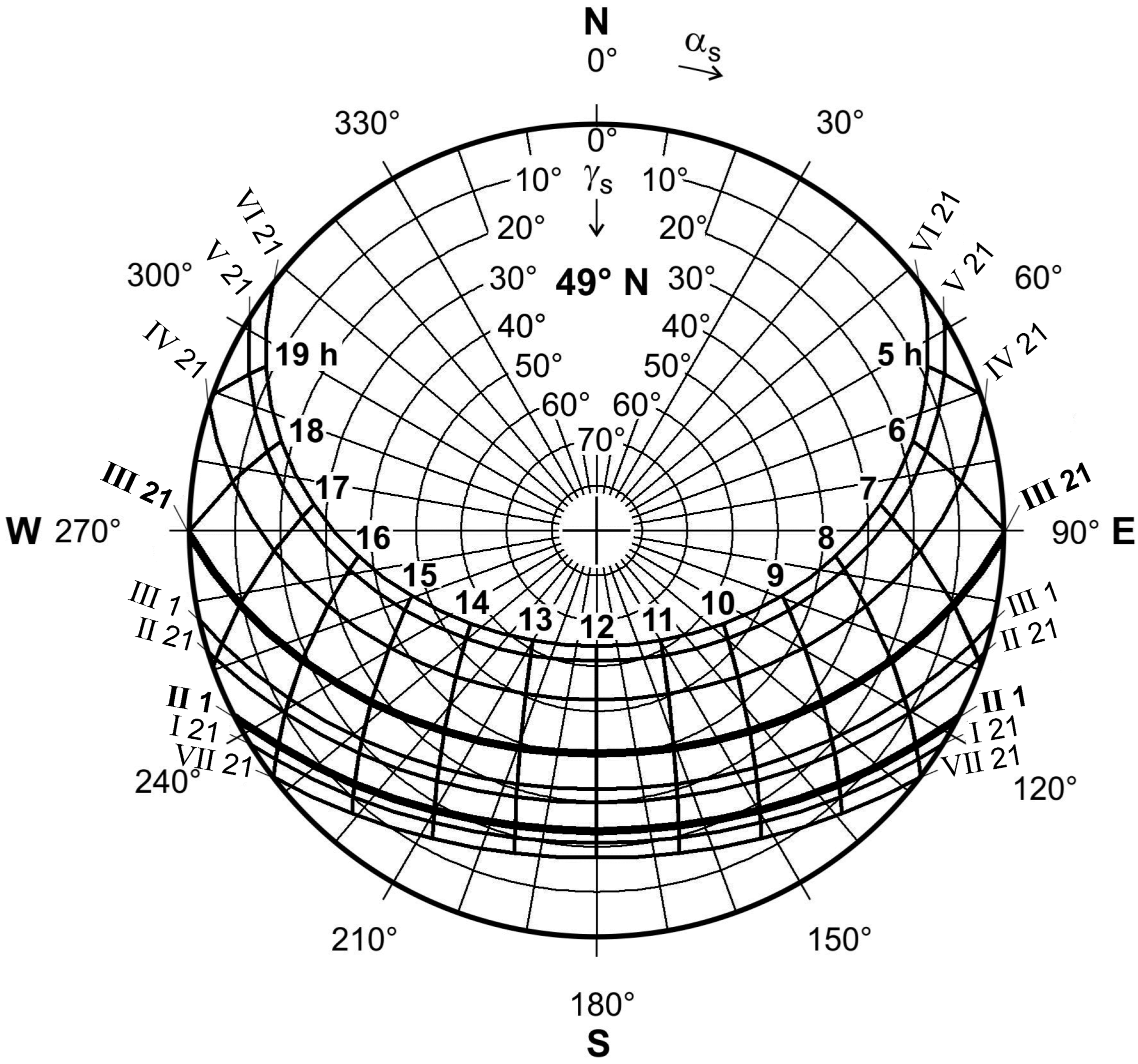


Figure D.4 — Sun path diagram method recommended for evaluation of exposure to sunlight, with North direction located at the top of the diagram

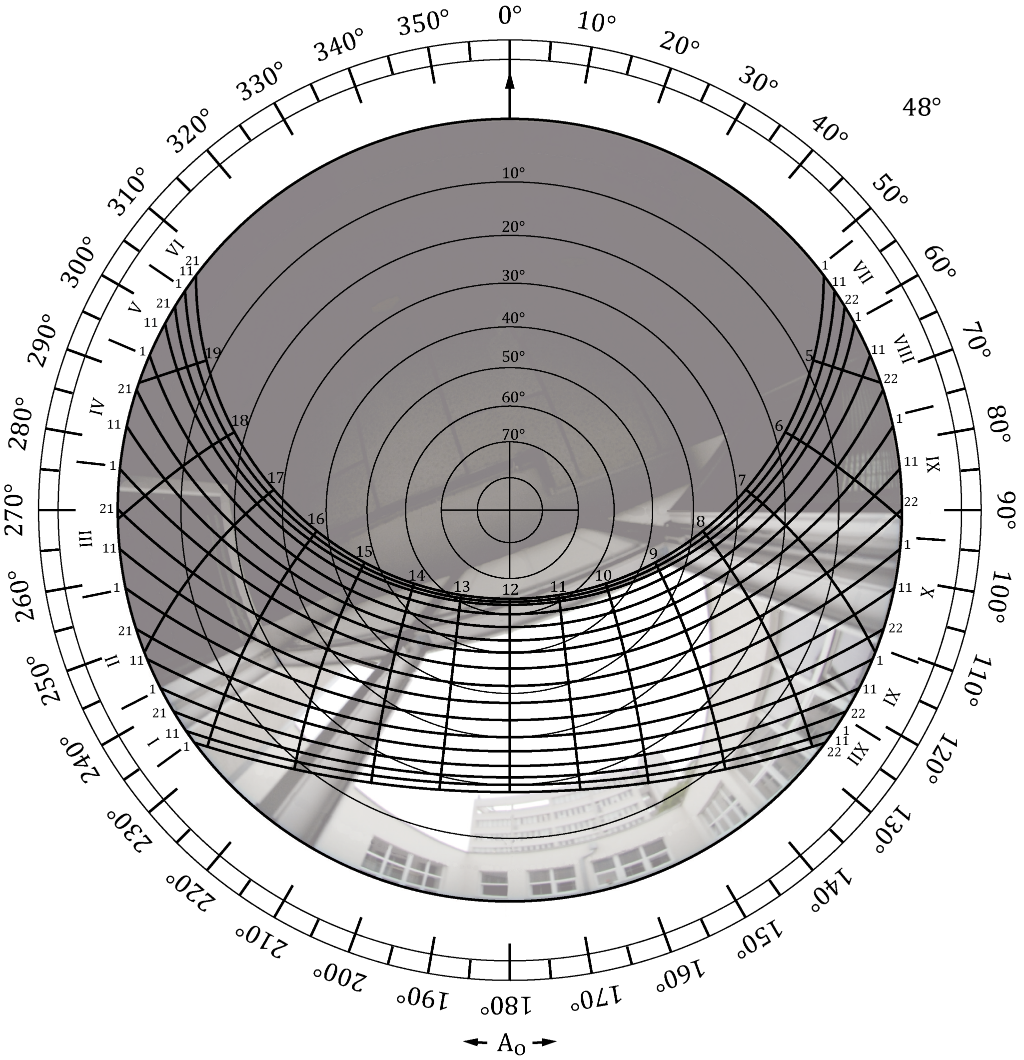


Figure D.5 — Fish eye type image taken from point *P* looking upward, with north orientation located at the top of the image. Shading buildings are overlayed by a stereographic sun path diagram

D.4 Method using manual geometric constructions

The method requires to identify a number of critical azimuthal α_a and elevation γ_a angles of surrounding obstructions. The angle $\gamma_{s,min}$ which is the minimum of solar altitude above the horizon for which sunlight can be taken into account (this depends on latitude, see Table D.1), is applied as a limit for start or end of possible duration of the exposure to sunlight. If values of solar altitude γ_s are higher than elevation of obstruction γ_a at the investigated azimuth α_a then reference point receives sun rays and this time fraction is considered in calculation of duration of sunlight exposure.

D.5 Determination of the position of the sun in the sky

For a given place, the sunlight conditions are determined by the sun position, which is expressed by the altitude of the sun γ_s above the horizon and the solar azimuth α_s which is characterised with respect to the North. These angles can be expressed as a function of a date, time within that day, once the location is known (geographical longitude and geographical latitude) The following formulas refer to the centre of the sun's disc. Normally the calculation is based on the True Solar

Time (TST), excluding the shifts of summer time. For statements in True Solar Time (h) it is necessary to determine the longitude of the standard time meridian λ_S and geographical longitude of the site λ, thus

$$TST = LT + \frac{\lambda - \lambda_s}{15} + ET \quad \text{(D.1)}$$

where

LT is the Local Clock Time

λ is the geographical longitude of the East (+) or West (-) of Greenwich

λ_S is longitude of standard meridian

ET is the equation of time

The equation of time ET and the solar declination δ are changing during the year and can be calculated from Formulae (D.2) and (D.3). In Formulae (D.2) and (D.3), J is the day number of the year (e.g. for 1st January, $J = 1$ and for 31st December, $J = 365$, February is taken to have 28 days), while parameter $J' = 360° J / 365$.

$$ET(J) = 0{,}0066 + 7{,}3525 \times \cos\left(J' + 85{,}9^o\right) + 9{,}9359 \times \cos\left(2 \times J' + 108{,}9^o\right) + 0{,}3387 \times \cos\left(3 \times J' + 105{,}2^o\right) \quad \text{(D.2)}$$

$$\delta(J) = 0{,}3948 - 23{,}2559 \times \cos\left(J' + 9{,}1^o\right) - 0{,}3915 \times \cos\left(2 \times J' + 5{,}4^o\right) - 0{,}1764 \times \cos\left(3 \times J' + 26{,}0^o\right) \quad \text{(D.3)}$$

For calculating the sun position, it is necessary to specify the hour angle ω_η

$$\omega_\eta = \left(12{,}00\,\text{h} - TST\right) \times 15^o \quad \text{(D.4)}$$

The hour angle ω_η is counted from the meridian as positive towards the afternoon and negative towards the morning. The following then applies for solar altitude

$$\gamma_s = \arcsin\left(\cos\omega_h \times \cos\varphi \times \cos\delta + \sin\varphi \times \sin\delta\right) \quad \text{(D.5)}$$

where

φ is the geographical latitude of the site

For the solar azimuth α_S

$$\alpha_s = 180^o - \arccos\frac{\sin\gamma_s \times \sin\varphi - \sin\delta}{\cos\gamma_s \times \cos\varphi} \text{ for } TST \leq 12:00\,\text{h} \quad \text{(D.6)}$$

Or

$$\alpha_s = 180^o + \arccos\frac{\sin\gamma_s \times \sin\varphi - \sin\delta}{\cos\gamma_s \times \cos\varphi} \text{ for } TST > 12:00\,\text{h} \quad \text{(D.7)}$$

The capital directions have the solar azimuth from North as follows:

— North $\alpha_S = 0°$;

— East α_S = 90°;

— South α_S = 180°;

— West α_S = 270°.

To allow flexibility for space orientation, the angle of opening normal $\alpha_{wn,s}$ is 120° measured from the South. The minimum solar altitude $\gamma_{s,min}$ are applied according to Table D.1.

Table D.1 — Minimum solar altitude $\gamma_{s,min}$ on 21st March for 33 capital cities of CEN national members when exposure to sunlight is 1,5 h

Nation	Capital [a]	Geographical latitude φ [°]	Minimum solar altitude $\gamma_{s,min}$ [°]
Cyprus	Nicosia	34,88	23
Malta	Valletta	35,54	22
Greece	Athens	37,90	20
Portugal	Lisbon	38,73	20
Turkey	Ankara	40,12	19
Spain	Madrid	40,45	19
Italy	Rome	41,80	18
Former Yugoslav Republic of Macedonia	Skopje	42,00	17
Bulgaria	Sofia	42,73	17
Romania	Bucharest	44,50	16
Croatia	Zagreb	45,48	15
Slovenia	Ljubljana	46,22	15
Switzerland	Bern	46,25	15
Hungary	Budapest	47,48	14
Austria	Wien	48,12	14
Slovakia	Bratislava	48,20	14
France	Paris	48,73	13
Luxembourg	Luxembourg	49,36	13
Czech Republic	Prague	50,10	13
Belgium	Brussels	50,90	12
United Kingdom	London	51,51	12
Poland	Warsaw	52,17	12
The Netherlands	Amsterdam	52,30	11

Nation	**Capital** [a]	**Geographical latitude** φ **[°]**	**Minimum solar altitude** $\gamma_{s,min}$ **[°]**
Germany	Berlin	52,47	11
Ireland	Dublin	53,43	11
Lithuania	Vilnius	54,88	10
Denmark	Copenhagen	55,63	10
Latvia	Riga	56,57	10
Estonia	Tallinn	59,25	8
Sweden	Stockholm	59,65	8
Norway	Oslo	59,90	8
Finland	Helsinki	60,32	8
Iceland	Reykjavik	64,13	6

[a] Other cities could be added by countries to take into account more precise role of latitude and climate.

NOTE 1 Minimum criteria for evaluation of sunlight duration are specified in Table D.1 at the True Solar Time for the geographical latitude of the CEN capitals. Solar altitudes below those stated in Table D.1 and cloudiness are neglected in the evaluation.

NOTE 2 Direct sunlight cannot be counted below minimum sun altitude.

Normals of openings $\alpha_{wn,s}$ when minimum solar altitude $\gamma_{s,min}$ = 3° for three categories of sunlight exposure are specified in Table D.2.

Table D.2 — Maximum azimuth angle of daylight opening from south, February 1st, to fulfill sunlight recommendation for 33 capital cities of CEN national members when minimum solar altitude $\gamma_{s,min}$ = 3°

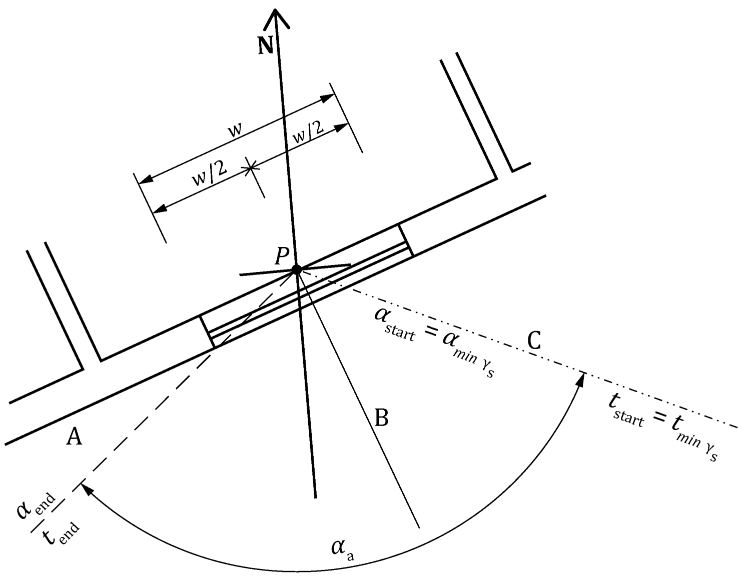
Nation	Capital [a]	Geographical latitude φ [°]	Opening normal measured from South, $\alpha_{wn,s}$ [°]		
			Minimum exposure to sunlight 1,5 h	Medium exposure to sunlight 3 h	High exposure to sunlight 4 h
Cyprus	Nicosia	34,88	117	97	81
Malta	Valletta	35,54	116	97	81
Greece	Athens	37,90	115	95	79
Portugal	Lisbon	38,73	114	94	78
Turkey	Ankara	40,12	113	93	77
Spain	Madrid	40,45	113	92	77
Italy	Rome	41,80	112	91	75
Former Yugoslav Republic of Macedonia	Skopje	42,00	112	91	75
Bulgaria	Sofia	42,73	111	90	75
Romania	Bucharest	44,50	110	89	73
Croatia	Zagreb	45,48	109	88	72
Slovenia	Ljubljana	46,22	108	87	72
Switzerland	Bern	46,25	108	87	72
Hungary	Budapest	47,48	107	86	70
Austria	Wien	48,12	106	85	70
Slovakia	Bratislava	48,20	106	85	70
France	Paris	48,73	106	85	69
Luxembourg	Luxembourg	49,36	105	84	69
Czech Republic	Prague	50,10	104	83	68
Belgium	Brussels	50,90	104	82	67
United Kingdom	London	51,51	103	82	67
Poland	Warsaw	52,17	102	81	66
The Netherlands	Amsterdam	52,30	102	81	65
Germany	Berlin	52,47	102	80	65
Ireland	Dublin	53,43	101	79	64
Lithuania	Vilnius	54,88	99	77	62
Denmark	Copenhagen	55,63	98	76	61
Latvia	Riga	56,57	97	75	60

Nation	Capital [a]	Geographical latitude φ [°]	Opening normal measured from South, $\alpha_{wn,s}$ [°]		
			Minimum exposure to sunlight 1,5 h	Medium exposure to sunlight 3 h	High exposure to sunlight 4 h
Estonia	Tallinn	59,25	92	71	56
Sweden	Stockholm	59,65	92	70	55
Norway	Oslo	59,90	91	70	55
Finland	Helsinki	60,32	91	69	54
Iceland	Reykjavik	64,13	88	60	46

[a] Other cities could be added by countries to take into account more precise role of latitude and climate.

D.6 Evaluation rules for sunlight duration

Orientation of rooms and design of apertures in the building envelope should ensure the sunlight duration of the evaluated interior. The reference point for evaluation of the sunlight duration is placed according to the rule presented in Figure D.1 - Figure D.3. Sunshine is determined if the reference point is insolated within the acceptance angle α_a in plan. This acceptance angle is limited in the morning and afternoon by the azimuths of minimum solar altitude $\gamma_{s,min}$. A case of the morning situation is shown in Figure D.6. The sunlight duration shall be calculated by any reliable method that assumes the cloudless conditions and correct room orientation.



Key

A envelope wall

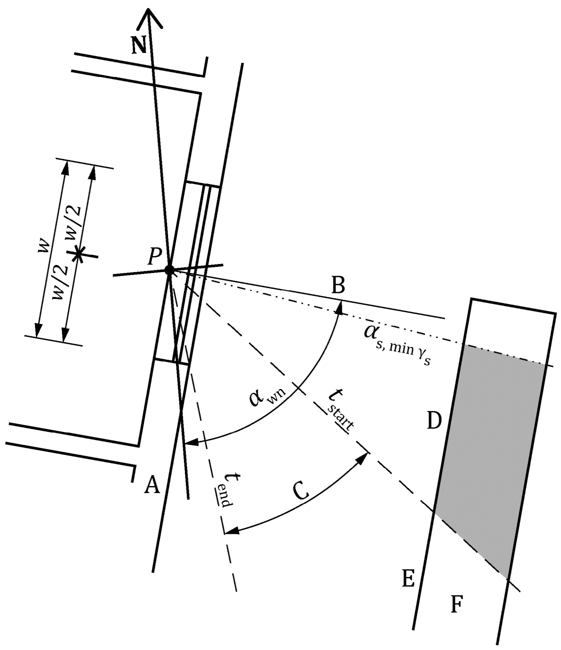
B opening normal

C minimum sun height in the morning

P reference point

Figure D.6 — Position of the reference point *P* in plan and rule for determination of sunlight duration if sun is free of obstructions

Sunlight duration is estimated by the time period $t_{end} - t_{start}$ and considers external obstructions, see Figure D.7. Depending on the geographical latitude, t_{start} is given by the time when the sun rays begin to reach the reference point *P* while t_{end} is ending by the obstruction or is finalized by the time when the solar altitude γ_S reaches the solar azimuth angle α_{end}. Total sunlight duration on referenced day is calculated by the summation of partial sunlight duration periods if sunshine is broken by several obstructions. A case of the shaded reference point *P* by a building façade is presented in Figure D.7.



Key

A	envelope wall
B	opening normal, n
C	sunlight duration
D	shading façade
E	obstruction too low to cause shading
F	building
P	reference point

Figure D.7 — Relation between reference point *P* and solar azimuth respecting a shading building

D.7 Sunlight duration in the reference point *P*

D.7.1 Example

Calculate sunlight duration on 21st March at reference point *P*. Room is on the 1st floor of the residential building. Obstructing building is located on the right side as is shown in Figure D.8. Its height is 28 m above level of the reference point. The geographical latitude $\varphi = 49°$ N and geographical longitude $\lambda = 17{,}06°$ E of the locality was chosen.

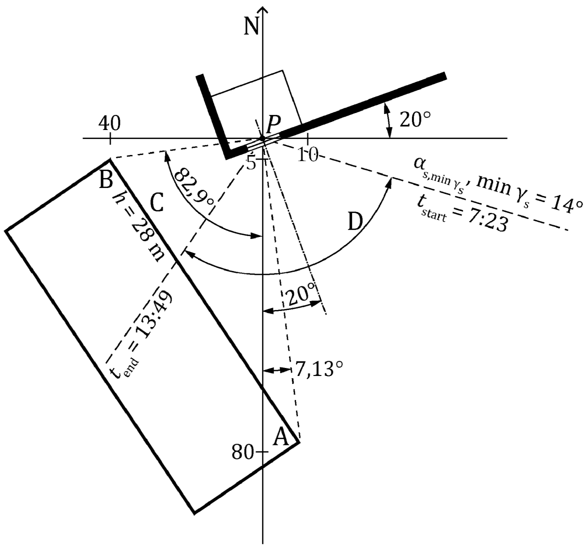
D.7.2 Calculation

From the plan situation, Figure D.8, the orientation of shading building with respect to the critical daylight opening is determined by the range of building corner azimuths $\alpha_A = 180 - 7{,}13° = 172{,}87°$ and

α_B = 180 + 82,9° = 262,9°. Reference point is insolated from 7:23 to 13:49, i.e. 6 h and 26 min. There are several possibilities to document and present sunlight duration assessment using a graphical tool, e.g. cylindrical sun path diagram (see Figure D.9).

D.7.3 Result

The reference point *P* in Figure D.8 is insolated for 6 h and 26 min on 21st March.



Key

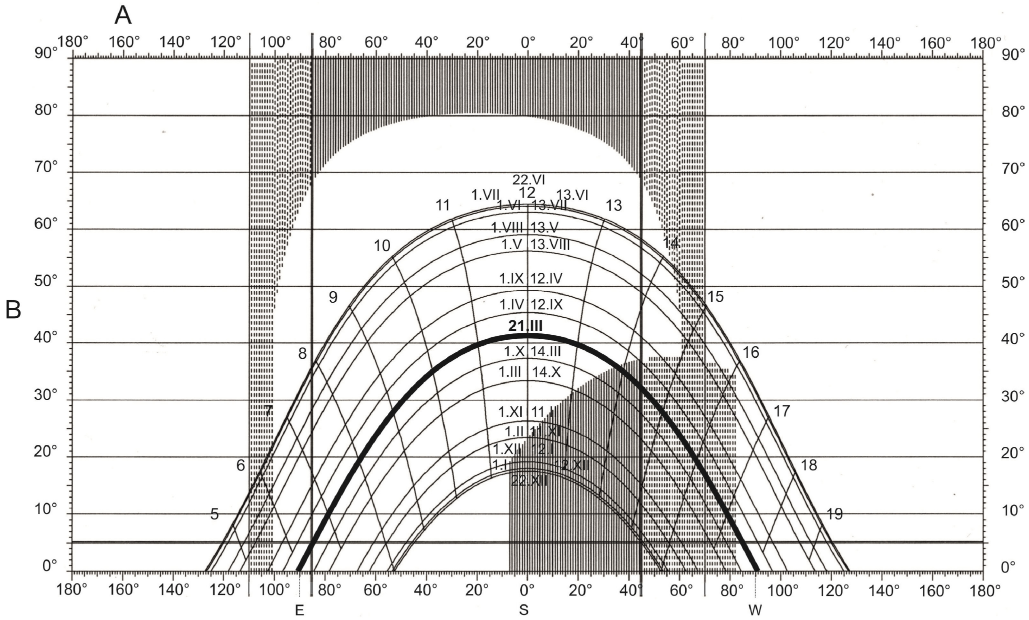
A corner of obstruction

B corner of obstruction

C obstruction

D 6 h and 26 min

Figure D.8 — Situation plan



Key

A Solar azimuth α_S

B Solar altitude γ_S

Figure D.9 — Presentation of sunlight duration assessment using a cylindrical sun path diagram (for a geographical latitude φ of 49°)

D.8 On-site verification of duration of exposure to sunlight

The duration of sunlight exposure can be verified on the site. The simplest approach is to use a camera equipped with a fish-eye lens with equidistant projection to allow superposition with solar diagram. A picture needs to be taken in locating the camera at the point *P* for relevant daylight opening of the critical room, with the camera looking upward (see Figure D.10). The direction toward the North has to be recorded and noted later on the picture.

The procedure is then identical as the one described in the D.3. The picture has to be matched with the circular sun path diagram in matching the North orientation and the duration of sunlight exposure can be extracted in the reference date of the year on the diagram.

The sunlight duration from 8:51 to 13:46, i.e. 4 h and 55 min, is counted in the bedroom of hospital located at the geographical latitude 48° N on 21st March as is shown in Figure D.10.

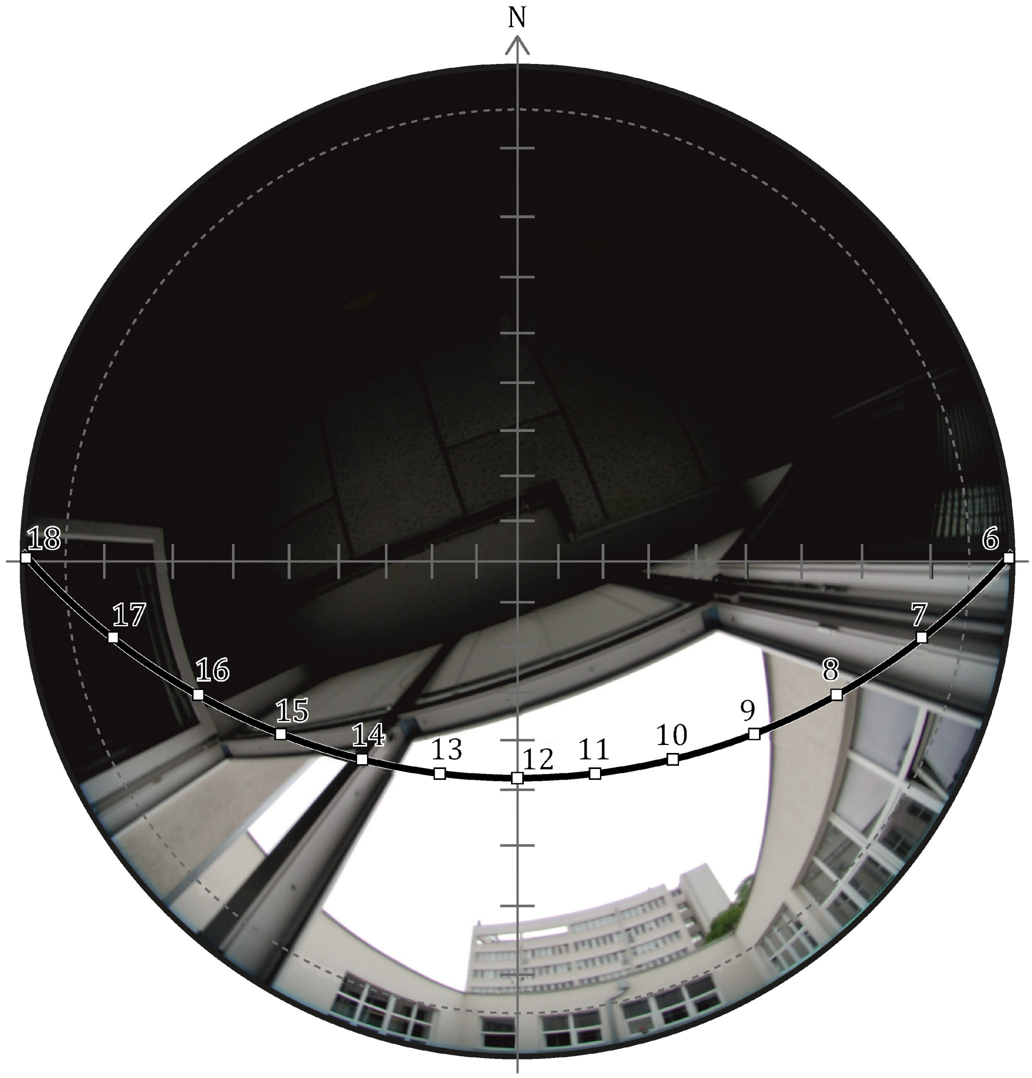


Figure D.10 — Testing of the sunlight duration by a camera equipt with a fish-eye lens. Selected sun path on 21st March with time scale

Annex E
(informative)

Glare

E.1 General

Glare is produced when too bright areas are located within the visual field or when the contrast ratio is reduced due to veiling reflections. The perception of glare is dependent on the luminance distribution in the field of view and is therefore strongly dependent on the spatial position and the line of sight of the occupant. Glare is dependent on individual perception and may cause side or after effects in the form of headaches or fatigue.

Glare perception increases when the size and/or luminance of the source(s) increases and/or when the total amount of light reaching the eyes increases. Larger angular distance of the glare source to the line of sight of the occupant decreases glare perception. Perceived glare increases when the contrast ratio between foveal and central or peripheral vision increases. Usually the foveal vision is directed towards the visual task.

A glare assessment is suggested in spaces, where the expected activities are comparable to reading, writing or using display devices and the user is not able to choose freely his position and viewing direction. For glare protection, a movable or retractable solar protection device can individually be adjusted while fixed devices may need additional shading devices to support individual needs. Note that glare caused by daylight differs from glare caused by electric light sources regarding size of the glare sources, complex luminance distribution and acceptance of the users.

E.2 Daylight Glare Probability

To assess glare from daylight, the complex luminance distribution within the field of view and the size, intensity and location of the glare source(s) in regard to the line of sight have to be taken into account.

The daylight glare probability *DGP* is an approach to consider both the illuminance at eye level and individual glare sources of high luminance to estimate the fraction of dissatisfied persons. *DGP* is a glare metric developed under real daylight conditions in a side-lit space.

The *DGP* is defined in an empirical formula connecting measurable physical quantities (e.g. luminance of glare sources, illuminance at eye level, solid angle of the glare source) with the glare experienced by subjects:

$$DGP = 5,87 \times 10^{-5} \times E_{\mathrm{v}} + 9,18 \times 10^{-2} \times \log\left(1 + \sum_{i} \frac{L_{\mathrm{s},i}^{2} \times \omega_{\mathrm{s},i}}{E_{\mathrm{v}}^{1,87} \times P_{i}^{2}}\right) + 0,16 \quad \text{(E.1)}$$

where

— E_{V} is the illuminance at eye level (lx), measured on a plane perpendicular to the line of sight. This value plays the main role in experiencing glare at daylight orientated positions in a space. In addition, this value is also used as adaptation level;

— L_{S} is the luminance of glare source (cd/m^2), (e.g. in the case of daylight openings, it is the luminance of the sky and/or sun as seen through the opening);

— *P* is the position index (-), it describes the reduction of the glare perception by the angular displacement of the source from the occupant's line of sight. In the case of daylight openings, the position of the visible sky within the field of view describes the magnitude of the position index; the further from the centre of vision, the lower the position index;

— ω_S is the solid angle subtended by the glare source (sr). In the case daylight openings, the apparent size of the visible area of sky at the observer's eyes describes the magnitude of the solid angle; the larger the area, the higher is the solid angle;

— *i* is the number of glare sources.

Table E.1 — *DGP* values can be categorized in following ranges

Criterion	***DGP***
Glare is mostly not-perceived	$DGP \leq 0,35$
Glare is perceived but mostly not disturbing	$0,35 < DGP \leq 0,40$
Glare is perceived and often disturbing	$0,4 < DGP \leq 0,45$
Glare is perceived and mostly intolerable	$DGP \geq 0,45$

In cases of multiple possible positions of activities, the expected worst case position should be investigated. These positions are usually close to the façade and/or where you can expect view connection to a low sun position. If the glare criteria are fulfilled for the worst case position(s) within a space, they are fulfilled within the utilized area of space.

NOTE 1 *DGP* can be applied to any daylight oriented indoor space which is mainly side-lit and where the expected activities are comparable to reading, writing or using display devices. *DGP* is not applicable to assess daylight glare for spaces with horizontal daylight openings.

NOTE 2 *DGP* cannot be applied to situations, where it can be expected that the vertical illuminance is not a good indicator for the glare perception; such situations include for example vending areas of shops, sport halls and deep or dark spaces with very small openings. Furthermore, the *DGP* method cannot be applied to positions in a space, which are far away from the daylight openings or which have low daylight levels.

E.3 Annual evaluation

E.3.1 General

For an overall glare investigation, it is necessary to investigate the temporal behaviour of the occurrence of glare. Critical glare situations exceeding a threshold value DGP_t should be limited to a certain fraction of the reference usage time $f_{DGP,exceed}$

$$f_{DGP,exceed} = \frac{\text{glare exceedance time}}{\text{reference usage time}} = \frac{t_{glare}}{t_{ref}} \quad \text{(E.2)}$$

The reference usage time t_{ref} is defined as the total time throughout the year, where the investigated space is possibly used. The reference usage time is set as the time between 8 h and 18 h on Monday to Friday throughout the year and is used as reference, although the real usage might differ.

Alternative usage times can be applied, when they differ significantly from the reference usage time and when it can be assumed that the space is always used in the same way. Achieved results with different usage times cannot be compared to results gained with the default reference usage time.

The glare exceedance time t_{glare} is the amount of time throughout the reference usage time when the *DGP* exceeds the threshold DGP_{t}.

A *DGP*-value, that is not exceeded in more than 5 % of the occupation time is defined as $DGP_{\mathrm{e} < 5\,\%}$. In Table A.6 proposals for the threshold values for $DGP_{\mathrm{e} < 5\,\%}$ are given.

E.3.2 Simplified annual glare evaluation

E.3.2.1 General

For side-lit spaces and following solar protection devices defined in EN 12216 a simplified annual glare evaluation method may be applied for:

— Solar protection device being opaque in the extended and closed position: e.g. Venetian blinds, plantation shutters, roller shutters…;

— Solar protection device where the curtain is made of textile, film or perforated opaque material: e.g roller blinds, vertical blinds, roller shutters…;

— non-diffusing glazing with a low or variable light transmittance (e.g. electrochromic glazing).

NOTE For diffusing glazing or skylights, the glare protection properties strongly depend on the bidirectional transmission distribution function (BTDF), defining direction and intensity of the transmitted light. Diffusing glazing and skylights exist with a large variety of material properties and therefore no general simplified method can be applied. Systems with a high normal-normal transmission or with narrow scattering properties could cause glare problems, when in the field of view of the occupants. A high direct-diffuse transmission leads to a high luminance and can cause glare for multiple viewing directions and positions, even when the sun disk is not visible.

The simplified assessments are different for each of the above mentioned systems and described in E.3.2.2 to E.3.2.4. To support the assessments, the Tables E.4 to E.8 provide data based on the annual sunshine hours and the corresponding sunshine zones (see E.3.2.5). For each of the sunshine zones, the assessments can be made for two sizes of daylight openings, for three different distances from the observer to the opening and for two different viewing directions. These parameters are described as follows:

— sunshine zone: Locations with more or equal to 2 100 annual sunshine hours are considered as sunshine zone H, and below is sunshine zone L;

— size of daylight opening: A large opening corresponds to a glazing, where the sum of the width of the glazing is larger than 50 % of the façade width and the fraction of the glazing area to the façade area is larger than 50 % and the upper border of the glazing is higher than 2 m above the floor. A small opening corresponds to all other glazing configurations;

— the distance to the daylight opening d_W is the distance between the observer and the solar protection device, in meter.

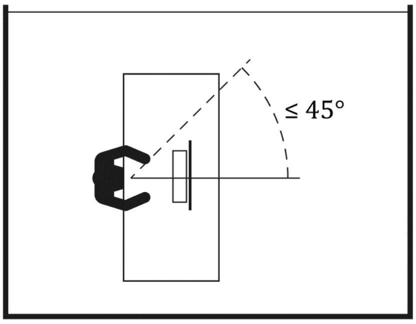


Figure E.1 — The viewing directions VD_p (viewing direction parallel to the façade with a maximum viewing angle to the façade of 45°)

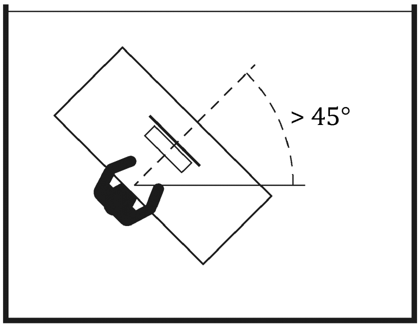


Figure E.2 — The viewing directions VD_f (viewing direction towards the façade and with a viewing angle to the façade greater than 45°)

E.3.2.2 Solar protection device being opaque in the extended and close position

Solar protection devices where the curtain is made of opaque material provide the highest glare criterion $DGP_{e < 5\ \%} \leq 0{,}35$, where:

— the device can be operated by the occupant

and

— there is no view towards all occurring sun positions in the fully closed and extended position.

A typical venetian blind would fulfil these conditions if:

— holes where inner cords are passing through are hidden, and

— there is no disturbing reflection between the slats in closed position, and

— there is no direct view of the sun through peripheral gaps.

E.3.2.3 Solar protection device where the curtain is made of textile, film or perforated opaque material

The occurrence of glare when using this type of solar protection devices is dependent on many design factors – the most important being:

— material optical properties;

— location and sunshine probability;

— viewing direction;

— façade orientation;

— glazing fraction of the façade;

— glazing transmittance;

— distance of the user to the façade.

The material properties and glare protection classes of this type of solar protection devices are defined in EN 14501. See Table E.2 for the classification.

Table E.2 — The material properties and glare protection classes

Class	**Influence on visual comfort**				
	0	1	2	3	4
	very little effect	little effect	moderate effect	good effect	very good effect

Table E.3 — Glare control classification given in EN 14501 according to the visual transmittance properties $\tau_{v,n\text{-}n}$ and $\tau_{v,\ n\text{-}diff}$

$\tau_{v,\ n\text{-}dif}$ [b]	$\tau_{v,\ n\text{-}n}$ [a]					
	$\tau_{v,\ n\text{-}n} = 0{,}00$	$0{,}00 < \tau_{v,\ n\text{-}n} \le 0{,}01$	$0{,}01 < \tau_{v,\ n\text{-}n} \le 0{,}02$	$0{,}02 < \tau_{v,\ n\text{-}n} \le 0{,}03$	$0{,}03 < \tau_{v,\ n\text{-}n} \le 0{,}05$	$\tau_{v,\ n\text{-}n} > 0{,}05$
$\tau_{v,\ n\text{-}dif} \le 0{,}03$	4	4	3	3	1	0
$0{,}03 < \tau_{v,\ n\text{-}dif} \le 0{,}06$	4	3	2	2	1	0
$0{,}06 < \tau_{v,\ n\text{-}dif} \le 0{,}10$	4	3	2	1	0	0
$0{,}10 < \tau_{v,\ n\text{-}dif} \le 0{,}15$	3	2	1	1	0	0
$0{,}15 < \tau_{v,\ n\text{-}dif} \le 0{,}20$	2	2	1	1	0	0
$0{,}20 < \tau_{v,\ n\text{-}dif} \le 0{,}25$	1	1	0	0	0	0
$0{,}25 < \tau_{v,\ n\text{-}dif}$	0	0	0	0	0	0

[a] $\tau_{v,\ n\text{-}n}$ is the normal/normal light transmittance

[b] $\tau_{v,\ n\text{-}dif}$ is the normal/diffuse light transmittance

NOTE 1 $\tau_{v,\ n\text{-}n} = 0{,}00$ means that the openness factor is equal to zero.

NOTE 2 Solar protection devices that are inside the grey area of Table E.3 can gain an additional class, in the case they can justify a cut-off angle less or equal to 65° (e.g. a class 3 product will become class 4 in this specific case).

In Tables E.4 to E.6 the recommended glare protection classes according to EN 14501 are given according to level of glare protection in Table A.7. The classes are given for the two viewing directions VD_p and VD_f and two different glazing transmissions.

Table E.4 — Recommended glare classes according to EN 14501 to fulfil the glare criteria of $DGP_{\mathrm{e}<5\,\%} \le 0,45$

		Sunshine Zone L				Sunshine Zone H			
		orientation S, S-E, S-W		orientation E, W, N-E, N-W		orientation S, S-E, S-W		orientation E, W, N-E, N-W	
		τ_{glazing}		τ_{glazing}		τ_{glazing}		τ_{glazing}	
		≤ 0,60	> 0,60	≤ 0,60	> 0,60	≤ 0,50	> 0,50	≤ 0,50	> 0,50
	d_{w}	VD_{p} / VD_{f}	VD_{p} / VD_{f}	VD_{p} / VD_{f}	VD_{p} / VD_{f}	VD_{p} / VD_{f}	VD_{p} / VD_{f}	VD_{p} / VD_{f}	VD_{p} / VD_{f}
small opening	1 m	1 / 3	2 / 3	1 / 3	1 / 3	1 / 3	1 / 4	1 / 3	1 / 3
	2 m	1 / 1	1 / 1	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2
	3 m	1 / 1	1 / 1	1 / 1	1 / 1	1 / 1	1 / 1	1 / 1	1 / 1
large opening	1 m	1 / 3	2 / 4	1 / 3	2 / 3	1 / 3	2 / 4	1 / 3	2 / 3
	2 m	1 / 2	1 / 3	1 / 2	1 / 3	1 / 3	1 / 3	1 / 3	1 / 3
	3 m	1 / 1	1 / 1	1 / 1	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2

Table E.5 — Recommended glare classes according to EN 14501 to fulfil the glare criteria of $DGP_{\mathrm{e}<5\,\%} \le 0,40$

		Sunshine Zone L				Sunshine Zone H			
		orientation S, S-E, S-W		orientation E, W, N-E, N-W		orientation S, S-E, S-W		orientation E, W, N-E, N-W	
		τ_{glazing}		τ_{glazing}		τ_{glazing}		τ_{glazing}	
		≤ 0,60	> 0,60	≤ 0,60	> 0,60	≤ 0,50	> 0,50	≤ 0,50	> 0,50
	d_{w}	VD_{p} / VD_{f}	VD_{p} / VD_{f}	VD_{p} / VD_{f}	VD_{p} / VD_{f}	VD_{p} / VD_{f}	VD_{p} / VD_{f}	VD_{p} / VD_{f}	VD_{p} / VD_{f}
small opening	1 m	2 / 4	2 / 4	2 / 4	2 / 4	2 / 4	2 / 4	2 / 4	2 / 4
	2 m	1 / 4	1 / 4	1 / 4	1 / 4	1 / 4	2 / 4	1 / 4	1 / 4
	3 m	1 / 1	1 / 1	1 / 1	1 / 2	1 / 1	1 / 1	1 / 2	1 / 2
large opening	1 m	2 / 4	3 / 4	2 / 4	3 / 4	2 / 4	3 / 4	2 / 4	3 / 4
	2 m	1 / 4	1 / 4	1 / 4	2 / 4	2 / 4	2 / 4	2 / 4	2 / 4
	3 m	1 / 1	1 / 4	1 / 2	1 / 4	1 / 4	2 / 4	1 / 4	1 / 4

Table E.6 — Recommended glare classes for fabric or non-fabric curtains according to EN 14501 to fulfil the glare criteria of $DGP_{e < 5\,\%} \leq 0{,}35$

		Sunshine Zone L				Sunshine Zone H			
		orientation S, S-E, S-W		orientation E, W, N-E, N-W		orientation S, S-E, S-W		orientation E, W, N-E, N-W	
		$\tau_{glazing}$		$\tau_{glazing}$		$\tau_{glazing}$		$\tau_{glazing}$	
		≤ 0,60	> 0,60	≤ 0,60	> 0,60	≤ 0,50	> 0,50	≤ 0,50	> 0,50
	d_w	VD_p / VD_f	VD_p / VD_f	VD_p / VD_f	VD_p / VD_f	VD_p / VD_f	VD_p / VD_f	VD_p / VD_f	VD_p / VD_f
small opening	1 m	4 / 4	4 / 4	3 / 4	4 / 4	4 / 4	4 / 4	4 / 4	4 / 4
	2 m	1 / 4	2 / 4	1 / 4	2 / 4	2 / 4	3 / 4	2 / 4	2 / 4
	3 m	1 / 1	1 / 2	1 / 2	1 / 4	1 / 1	1 / 1	1 / 4	1 / 4
large opening	1 m	4 / 4	4 / 4	4 / 4	4 / 4	4 / 4	4 / 4	4 / 4	4 / 4
	2 m	3 / 4	4 / 4	2 / 4	4 / 4	4 / 4	4 / 4	3 / 4	4 / 4
	3 m	1 / 4	1 / 4	1 / 4	1 / 4	2 / 4	2 / 4	2 / 4	2 / 4

E.3.2.4 Non-diffusing glazing device with a low variable light transmittance (e.g. electrochromic glazing)

The occurrence of glare when using a non-diffusing glazing device with a low or variable light transmittance is mainly dependent on two factors:

— transmittance properties of the glazing;

— frequency of the occurrence of the sun in the field of view.

NOTE Low transmittance glazing and solar protection devices can compromise the provision of daylight.

In Tables E.7 and E.8, the pre-calculated $DGP_{e < 5\,\%}$ -values for low transmission glazing or electrochromic glazing are given for a parallel viewing direction VD_p (maximum viewing angle to the façade plane is 45°).

Table E.7 — Pre-calculated $DGP_{e < 5\ \%}$ - values for low transmission glazing or electrochromic glazing for sunshine zone L and VD_p

		Sunshine Zone L																			
		orientation S, S-E, S-W										orientation E, W, N-E, N-W									
		$\tau_{glazing}$										$\tau_{glazing}$									
	d_w	**0,01**	**0,02**	**0,03**	**0,04**	**0,05**	**0,06**	**0,08**	**0,10**	**0,15**	**0,20**	**0,01**	**0,02**	**0,03**	**0,04**	**0,05**	**0,06**	**0,08**	**0,10**	**0,15**	**0,20**
small Opening	1 m	< 0,20	0,36	0,45	0,48	0,50	0,52	0,54	0,55	0,60	0,64	< 0,20	0,41	0,47	0,49	0,51	0,52	0,54	0,56	0,61	0,67
	2 m	< 0,20	< 0,20	< 0,20	0,26	0,36	0,41	0,45	0,46	0,49	0,51	< 0,20	< 0,20	0,29	0,41	0,46	0,48	0,49	0,51	0,53	0,56
	3 m	< 0,20	< 0,20	< 0,20	< 0,20	< 0,20	< 0,20	< 0,20	< 0,20	0,22	0,24	< 0,20	< 0,20	< 0,20	< 0,20	< 0,20	< 0,20	0,22	0,24	0,28	0,33
large Opening	1 m	< 0,20	0,42	0,46	0,49	0,51	0,52	0,55	0,57	0,63	0,71	< 0,20	0,43	0,47	0,49	0,51	0,52	0,54	0,57	0,63	0,70
	2 m	< 0,20	0,22	0,40	0,44	0,47	0,48	0,50	0,51	0,55	0,59	< 0,20	0,36	0,45	0,48	0,49	0,50	0,52	0,54	0,58	0,62
	3 m	< 0,20	< 0,20	< 0,20	0,21	0,31	0,36	0,41	0,42	0,45	0,46	< 0,20	< 0,20	0,25	0,38	0,44	0,45	0,47	0,49	0,51	0,54

Table E.8 — Pre-calculated $DGP_{e < 5\ \%}$ - values for low transmission glazing or electrochromic glazing for sunshine zone H and VD_p

		Sunshine Zone H																			
		orientation S, S-E, S-W										orientation E, W, N-E, N-W									
		$\tau_{glazing}$										$\tau_{glazing}$									
	d_w	0,01	0,02	0,03	0,04	0,05	0,06	0,08	0,10	0,15	0,20	0,01	0,02	0,03	0,04	0,05	0,06	0,08	0,10	0,15	0,20
small opening	1 m	< 0,20	0,36	0,45	0,48	0,50	0,52	0,54	0,55	0,60	0,64	< 0,20	0,41	0,47	0,49	0,51	0,52	0,54	0,56	0,61	0,67
	2 m	< 0,20	< 0,20	< 0,20	0,26	0,36	0,41	0,45	0,46	0,49	0,51	< 0,20	< 0,20	0,29	0,41	0,46	0,48	0,49	0,51	0,53	0,56
	3 m	< 0,20	< 0,20	< 0,20	< 0,20	< 0,20	< 0,20	< 0,20	< 0,20	0,22	0,24	< 0,20	< 0,20	< 0,20	< 0,20	< 0,20	< 0,20	0,22	0,24	0,28	0,33
large opening	1 m	< 0,20	0,42	0,46	0,49	0,51	0,52	0,55	0,57	0,63	0,71	< 0,20	0,43	0,47	0,49	0,51	0,52	0,54	0,57	0,63	0,70
	2 m	< 0,20	0,22	0,40	0,44	0,47	0,48	0,50	0,51	0,55	0,59	< 0,20	0,36	0,45	0,48	0,49	0,50	0,52	0,54	0,58	0,62
	3 m	< 0,20	< 0,20	< 0,20	0,21	0,31	0,36	0,41	0,42	0,45	0,46	< 0,20	< 0,20	0,25	0,38	0,44	0,45	0,47	0,49	0,51	0,54

E.3.2.5 Sunshine zones

Table E.9 gives the annual sunshine hours and the corresponding sunshine zones to be used in Table E.4 to Table E.8.

Table E.9 — Assessment of sunshines zone for 33 capital cities of CEN national members to be used in Table E.4 to Table E.8. Locations with more or equal 2 100 annual sunshine hours are considered as sunshine zone H

Nation	Capital	Geographical latitude φ [°]	Annual sunshine hours	Sunshine Zone
Cyprus	Nicosia	34,88	3 400	H
Malta	Valletta	35,54	3 600	H
Greece	Athens	37,90	3 050	H
Portugal	Lisbon	38,73	3 200	H
Turkey	Ankara	40,12	2 450	H
Spain	Madrid	40,45	3 150	H
Italy	Rome	41,80	3 150	H
Former Yugoslav Republic of Macedonia	Skopje	42,00	2 900	H
Bulgaria	Sofia	42,73	1 800	L
Romania	Bucharest	44,50	2 400	H
Croatia	Zagreb	45,48	2 100	H
Slovenia	Ljubljana	46,22	1 950	L
Switzerland	Bern	46,25	1 950	L
Hungary	Budapest	47,48	2 100	H
Austria	Wien	48,12	1 850	L
Slovakia	Bratislava	48,20	2 250	H
France	Paris	48,73	1 700	L
Luxembourg	Luxembourg	49,36	1 850	L
Czech Republic	Prague	50,10	1 700	L
Belgium	Brussels	50,90	1 550	L
United Kingdom	London	51,15	1 600	L
Poland	Warsaw	52,17	1 750	L
The Netherlands	Amsterdam	52,30	1 850	L
Germany	Berlin	52,47	1 950	L
Ireland	Dublin	53,43	1 650	L

Nation	**Capital**	**Geographical latitude** φ **[°]**	**Annual sunshine hours**	**Sunshine Zone**
Lithuania	Vilnius	54,88	1 750	L
Denmark	Copenhagen	55,63	2 000	L
Latvia	Riga	56,57	2 000	L
Estonia	Tallinn	59,25	2 050	L
Sweden	Stockholm	59,65	2 000	L
Norway	Oslo	59,90	1 950	L
Finland	Helsinki	60,32	2 150	H
Iceland	Reykjavik	64,13	1 850	L

E.4 Reflections or veiling glare

Reflections on display screen equipment or on other task materials (e.g. paper) reduce the contrast between background and foreground for the visual task and therefore reduce the readability. Reflections occur, when bright light sources (e.g. openings) are in the reflected field of view of the screen. The size, amount and significance depend on the luminance of the source, reflection properties of the screen and background and foreground luminance of the display. The occurring contrast should be high enough in order that the task can be fulfilled without errors (e.g. for reading a text on the screen). Therefore, the contrast should exceed a minimum required contrast level. Details can be found in EN ISO 9241-303.

E.5 Verification of the glare protection capability of shadings

To verify the glare protection properties on site in more detail than specified in E.4 the *DGP* value for a critical situation should be determined by the following procedure:

Testing position: The testing position should be either a current used position of a person (activity area or often used position) or a position, which might be used and which might have a glare problem. Such positions are usually close to the façade and/or facing façade orientations, where low sun positions often occur (east or west facing façades).

Testing boundary condition: There should be a clear sky condition and the sun should cause high luminance within the field of view. If possible and known, the solar altitude should be chosen to be a critical position, when glare might be expected. For most systems, a low sun position is most critical and might cause glare situations to be more probable then high sun positions.

Shading state: If the shading has a manual control or an automated control with user override, then the shading should be tested in closed position. In case of an automated control without or minor user override option, then the shade should be tested in automatic mode.

Measurement or approximation of the *DGP*:

> To determine the *DGP* for a critical situation, the viewing direction of the measurement devices should face towards the façade parallel to the floor and towards the azimuth direction of the sun. The camera/sensors should be mounted on a tripod. The height of the measurement devices should be either in 1,2 m height (typical eye level of a seated person) or in the eye level of the specific investigated task.

High Dynamic Range camera (HDR camera) using a fish eye lens

The *DGP* can be measured directly with a HDR camera using a fish eye lens (full 180° or more) or by a HDR camera with a non-fish eye lens and an additional illuminance meter. Commercial calibrated HDR cameras might calculate the *DGP* directly. The *DGP* can be also calculated by free available software (e.g. evalglare) by the use of the hdr format. In case the lens does not cover a full 180° view, an additional illuminance meter is needed to measure the vertical eye illuminance. In that case this value has to be provided to the evaluating software in addition to the hdr image.

Approximation using an illuminance meter and a spot luminance meter

Approximation can be used when sun disk is invisible or specular reflectance not occurring or both are negligible (small size and luminance < 50 000 cd/m²): The *DGP* can be calculated using the simplified DGP formula and the vertical illuminance measurement value. The simplified DGP_S is given by following formula:

$$DGP_s = 6,22 \times 10^{-5} \times E_v + 0,184 \quad \text{(E.3)}$$

where

E_V is vertical illuminance at eye level.

Approximation can be used when the sun disk is visible or specular reflectance might cause glare (luminance of the potential glare source > 50 000 cd/m²): For this approach, the solid angle Ω can be assessed by Formula (E.4) and E.5 (see Figure E.3 for the assessment of the solid angle Ω).

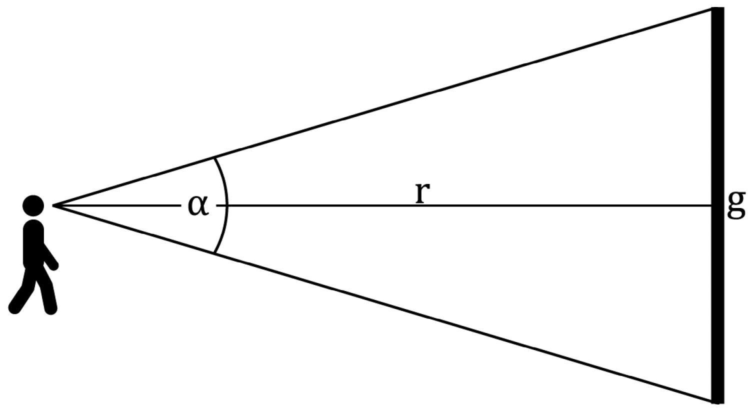


Figure E.3 — Approximation of the solid angle *Ω*

$$\frac{\alpha}{2} = \arctan\left(\frac{g}{2r}\right) \quad \text{(E.4)}$$

$$\Omega = 2\pi\left(1 - \cos\left(\frac{\alpha}{2}\right)\right)) \quad \text{(E.5)}$$

where

α is the angle of glare source, seen by a person;

r is the distance between the person and the glare source in m;

g is the diameter of the glare source in m;

Ω is the solid angle.

In case the sun disk can be seen from the observer's point of view and the size of it is not changed by the shading device (e.g. by scattering of fabric material), a solid angle of 7×10^{-5} sr should be used for this glare source.

The approximate position index can be derived from Figure E.4. The graph covers the vertical half hemisphere in a fish-eye projection.

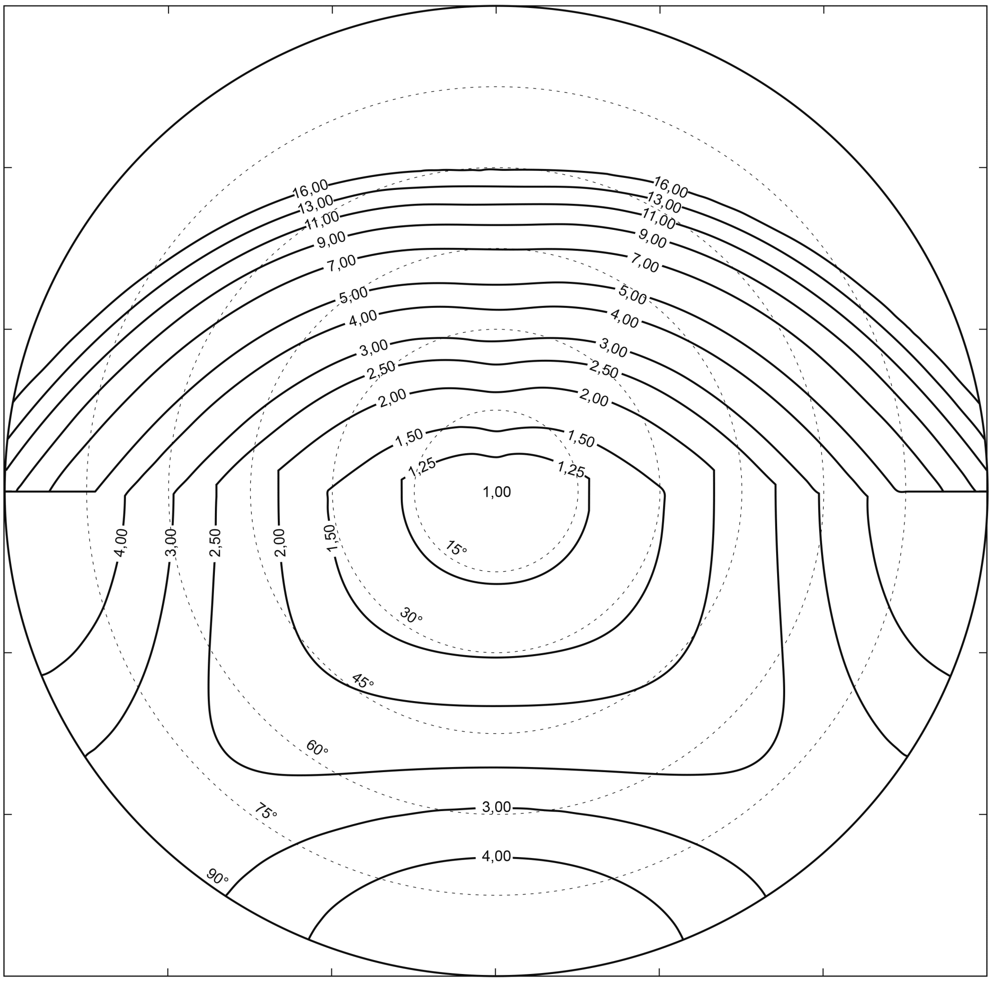


Figure E.4 — ISO-lines of the position index. The centre of the image is the viewing direction where the position index equals 1. The maximum value is 16

Annex F
(informative)

A–deviations

A- deviation: National deviation due to regulations, the alteration of which is for the time being outside the competence of the CEN/CENELEC member.

This **European standard** does not fall under any Directive of the EU.

In the relevant CEN/CENELEC countries these A- deviations are valid instead of the provisions of the **European standard** until they have been removed.

Slovakia

Clause	Deviation
B.3.1	In accordance with the Slovak Regulations No. 259 Coll., §4 of the Ministry of Health of the Slovak Republic and mandatory requirements in the referenced standard STN 73 0580–1 the perimeter of the grid area in a room or part of a room distant 1 m from the walls is included in the calculation area
D.3	In accordance with the Law Act No. 532/2002 Coll., §17 and mandatory requirements in the referenced standard STN 73 4301 the minimum of exposure to sunlight is at least 1 h in historical parts of cities in particularly justified cases.

Bibliography

EN ISO 9241-303, *Ergonomics of human-system interaction — Part 303: Requirements for electronic visual displays (ISO 9241-303:2011)*

CIE S 017/E:2011, *ILV: International Lighting Vocabulary*

CIE 16:1970, *Daylight*

CIE x005-1992, *Proceedings of the CIE Seminar 1992 on Computer Programs for Light and Lighting*

National Annex NA
(informative)

Further recommendations and data for daylight provision in the UK and Channel Islands

NA.1 Introduction

The UK committee supports the recommendations for daylight in buildings given in BS EN 17037:2018; however, it is the opinion of the UK committee that the recommendations for daylight provision in a space (see Clause A.2) may not be achievable for some buildings, particularly dwellings. The UK committee believes this could be the case for dwellings with basement rooms or those with significant external obstructions (for example, dwellings situated in a dense urban area or with tall trees outside), or for existing buildings being refurbished or converted into dwellings. This National Annex therefore provides the UK committee's guidance on minimum daylight provision in all UK dwellings.

This National Annex also provides additional information on glazing maintenance factor, so that users may calculate daylight factor while taking dirt deposition on glazing into account.

BS EN 17037:2018 also provides data on daylight factor (Tables A.3 and A.4), minimum solar altitude (Table D.1) and maximum azimuth angle (Table D.2) for 33 capital cities of CEN national members. This National Annex provides corresponding data for 10 UK and Channel Islands locations, so that users may identify daylight provision based on localized data.

The UK committee notes that the daylight recommendations in BS EN 17037:2018 are based on daylight hours, while daylight provision guidance for schools in the UK is based around the school day. Detailed recommendations for daylight provision in schools, together with guidance on how to meet them, is given in the Society of Light and Lighting's *Lighting Guide 5: Lighting for education*[1)].

NA.2 Minimum daylight provision in UK dwellings

Even if a predominantly daylit appearance is not achievable for a room in a UK dwelling, the UK committee recommends that the target illuminance values given in Table NA.1 are exceeded over at least 50 % of the points on a reference plane 0.85 m above the floor, for at least half of the daylight hours.

Table NA.1 — Values of target illuminance for room types in UK dwellings

Room type	**Target illuminance** E_T (lx)
Bedroom	100
Living room	150
Kitchen	200

Where one room in a UK dwelling serves more than a single purpose, the UK committee recommends that the target illuminance is that for the room type with the highest value – for example, in a space that combines a living room and a kitchen the target illuminance is recommended to be 200 lx.

NOTE The Clause NA.2 information above is derived from BS 8206-2:2008 *Lighting for buildings – Part 2: Code of practice for daylighting*, Subclause 5.6.

1) Society of Light and Lighting (2011) *Lighting Guide 5: Lighting for education*; available from www.cibse.org/Society-of-Light-and-Lighting-SLL/Lighting-Publications [accessed 7 May 2019]

It is the opinion of the UK committee that the recommendation in Clause A.2 – that a target illuminance level should be achieved across the entire (i.e. 95 %) fraction of the reference plane within a space – need not be applied to rooms in dwellings.

The UK committee notes that very high values of daylight illuminance in a room may indicate that the room is likely to be at risk of summer-time overheating; this is particularly likely with single aspect flats, in which cross ventilation is not possible. The UK committee therefore recommends that any room in a dwelling where a daylight illuminance of 500 lx is exceeded on 50 % of the grid points for more than half of the daylight hours is checked for overheating.

NA.3 Glazing maintenance factor

The glazing maintenance factor allows for the reduction of daylight transmittance due to so-called dirt effects, where the amount of light passing though a given element of glazing decreases over time due to the accumulation of dirt.

To determine the glazing maintenance factor for a particular situation it is necessary to first find the value for the percentage loss of light in the particular building type from Table NA.2, and then multiply it by the special factors given in Tables NA.3 and NA.4 if necessary, and subtract the result from 100 %.

Table NA.2 — Percentage losses of light in particular types of buildings

Building type	Percentage loss of daylight compared with clean glazing (%)	
	Rural/suburban	Urban
Residential: private and communal. Rooms with few occupants, good maintenance	4	8
Commercial, educational. Rooms used by groups of people, office equipment	4	8 to 12
Polluted atmosphere. Gymnasia, swimming pools	12 to 24	12 to 24

Table NA.3 — Exposure multiplying factors

Exposure	Exposure multiplier		
	Vertical glazing	Inclined glazing	Horizontal glazing
Normal exposure for location	×1	×2	×3
Exposed to heavy rain	×0.5	×1.5	×3
Exposed to snow	×1	×3	×4

Table NA.4 — Special exposure multiplying factors

Condition	Multiplying factor
Vertical glazing sheltered from rain	×3
Weathered or corroded glazing	×3 (no correction for rain exposure)
Leaded glazing	×3

For example, considering vertical leaded glazing in a rural house. The loss of light will be 4 % × 1 × 3 = 12 %. The glazing maintenance factor will be 100 % − 12 % = 88 % = 0.88.

NOTE [SOURCE: BS 8206-2:2008, Subclause A.1.3]

NA.4 Additional daylight provision data for selected UK and Channel Islands locations

The following tables provide data for selected UK and Channel Islands locations as supplementary information to Tables A.3, A.4, D.1 and D.2.

NOTE 1 The additional values of daylight factor '*D* to exceed 150 lx' and '*D* to exceed 200 lx' in Tables NA.5 and NA.6 are provided so that users may facilitate the assessment of daylight to the recommendation in Table NA.1.

NOTE 2 All UK and Channel Islands locations may be classed within Sunshine Zone L.

Table NA.5 — Supplement to Table A.3 for 10 UK and Channel Islands locations

Location	Geographical latitude φ [°]	Median External Diffuse Illuminance $E_{v,d,med}$	*D* to exceed 100 lx	*D* to exceed 150 lx	*D* to exceed 200 lx	*D* to exceed 300 lx	*D* to exceed 500 lx	*D* to exceed 750 lx
St Peter (Jersey Airport)	49,22	16 600	0,6 %	0,9 %	1,2 %	1,8 %	3,0 %	4,5 %
London (Gatwick Airport)	51,15	14 100	0,7 %	1,1 %	1,4 %	2,1 %	3,5 %	5,3 %
Birmingham	52,45	16 300	0,6 %	0,9 %	1,2 %	1,8 %	3,1 %	4,6 %
Hemsby	52,68	15 800	0,6 %	0,9 %	1,3 %	1,9 %	3,2 %	4,7 %
Finningley	53,48	14 900	0,7 %	1,0 %	1,3 %	2,0 %	3,4 %	5,0 %
Aughton (Lancashire)	53,55	14 200	0,7 %	1,1 %	1,4 %	2,1 %	3,5 %	5,3 %
Belfast	54,65	14 500	0,7 %	1,0 %	1,4 %	2,1 %	3,4 %	5,2 %
Leuchars	56,38	14 000	0,7 %	1,1 %	1,4 %	2,1 %	3,6 %	5,4 %
Oban	56,42	13 100	0,8 %	1,1 %	1,5 %	2,3 %	3,8 %	5,7 %
Aberdeen	57,20	14 100	0,7 %	1,1 %	1,4 %	2,1 %	3,5 %	5,3 %

Table NA.6 — Supplement to Table A.4 for 10 UK and Channel Islands locations

Location	Geographical latitude φ [°]	Median External Global Illuminance $E_{v,g,med}$	*D* to exceed 100 lx	*D* to exceed 150 lx	*D* to exceed 200 lx	*D* to exceed 300 lx	*D* to exceed 500 lx	*D* to exceed 750 lx
St Peter (Jersey Airport)	49,22	21 800	0,5 %	0,7 %	0,9 %	1,4 %	2,3 %	3,4 %
London (Gatwick Airport)	51,15	17 650	0,6 %	0,8 %	1,1 %	1,7 %	2,8 %	4,2 %
Birmingham	52,45	19 700	0,5 %	0,8 %	1,0 %	1,5 %	2,5 %	3,8 %
Hemsby	52,68	19 600	0,5 %	0,8 %	1,0 %	1,5 %	2,6 %	3,8 %
Finningley	53,48	17 600	0,6 %	0,9 %	1,1 %	1,7 %	2,8 %	4,3 %
Aughton (Lancashire)	53,55	17 000	0,6 %	0,9 %	1,2 %	1,8 %	2,9 %	4,4 %
Belfast	54,65	17 200	0,6 %	0,9 %	1,2 %	1,7 %	2,9 %	4,4 %
Leuchars	56,38	17 200	0,6 %	0,9 %	1,2 %	1,7 %	2,9 %	4,4 %
Oban	56,42	15 200	0,7 %	1,0 %	1,3 %	2,0 %	3,3 %	4,9 %
Aberdeen	57,20	16 600	0,6 %	0,9 %	1,2 %	1,8 %	3,0 %	4,5 %

Table NA.7 — Supplement to Table D.1 for 10 UK and Channel Islands locations

Location	Geographical latitude φ [°]	Minimum solar altitude $\gamma_{s,min}$ [°]
St Peter (Jersey Airport)	49,22	13
London (Gatwick Airport)	51,15	12
Birmingham	52,45	11
Hemsby	52,68	11
Finningley	53,48	11
Aughton (Lancashire)	53,55	11
Belfast	54,65	10
Leuchars	56,38	10
Oban	56,42	10
Aberdeen	57,20	9

Table NA.8 — Supplement to Table D.2 for 10 UK and Channel Islands locations

Location	**Geographical latitude** φ [°]	**Opening normal measured from South,** $\alpha_{wn,s}$ [°]		
		Minimum exposure to sunlight 1,5 h	**Medium exposure to sunlight 3 h**	**High exposure to sunlight 4 h**
St Peter (Jersey Airport)	49,22	105	84	69
London (Gatwick Airport)	51,15	103	82	67
Birmingham	52,45	102	80	65
Hemsby	52,68	102	80	65
Finningley	53,48	101	79	64
Aughton (Lancashire)	53,55	101	79	64
Belfast	54,65	99	78	63
Leuchars	56,38	97	75	60
Oban	56,42	97	75	60
Aberdeen	57,20	96	74	59

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