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Energy performance of buildings — External climatic conditions —

Part 1: Conversion of climatic data for energy calculations

Performance énergétique des bâtiments — Conditions climatiques extérieures —

Partie 1: Conversion des données climatiques pour les calculs énergétiques

Reference number
ISO 52010-1:2017(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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

ISO 52010-1 was prepared by ISO Technical Committee ISO/TC 163, *Thermal performance and energy use in the built environment*, Subcommittee SC 2, *Calculation methods*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 89, *Thermal performance of buildings and building components,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

A list of all the parts in the ISO 52010 series can be found on the ISO website.

Introduction

This document is part of a series aimed at the international harmonization of the methodology for assessing the energy performance of buildings. Throughout, this series is referred to as a “set of EPB standards”.

All EPB standards follow specific rules to ensure overall consistency, unambiguity and transparency.

All EPB standards provide a certain flexibility with regard to the methods, the required input data and references to other EPB standards, by the introduction of a normative template in Annex A and Annex B with informative default choices.

For the correct use of this document, a normative template is given in Annex A to specify these choices. Informative default choices are provided in Annex B.

The main target groups for this document are architects, engineers and regulators.

Use by or for regulators: In case the document is used in the context of national or regional legal requirements, mandatory choices may be given at national or regional level for such specific applications. These choices (either the informative default choices from Annex B or choices adapted to national/regional needs, but in any case following the template of Annex A) can be made available as national annex or as separate (e.g. legal) document (national data sheet).

NOTE 1 So in this case:

— the regulators will specify the choices;

— the individual user will apply the document to assess the energy performance of a building, and thereby use the choices made by the regulators.

Topics addressed in this document can be subject to public regulation. Public regulation on the same topics can override the default values in Annex B. Public regulation on the same topics can even, for certain applications, override the use of this document. Legal requirements and choices are in general not published in standards but in legal documents. In order to avoid double publications and difficult updating of double documents, a national annex may refer to the legal texts where national choices have been made by public authorities. Different national annexes or national data sheets are possible, for different applications.

It is expected, if the default values, choices and references to other EPB standards in Annex B are not followed due to national regulations, policy or traditions, that:

— national or regional authorities prepare data sheets containing the choices and national or regional values, according to the model in Annex A. In this case a national annex (e.g. NA) is recommended, containing a reference to these data sheets;

— or, by default, the national standards body will consider the possibility to add or include a national annex in agreement with the template of Annex A, in accordance to the legal documents that give national or regional values and choices.

Further target groups are parties wanting to motivate their assumptions by classifying the building energy performance for a dedicated building stock.

More information is provided in the technical report (ISO/TR 52010-2[6]) accompanying this document.

The subset of EPB standards prepared under the responsibility of ISO/TC 163/SC 2, *Thermal performance and energy use in the built environment — Calculation methods*, cover *inter alia*:

— calculation procedures on the overall energy use and energy performance of buildings;

— calculation procedures on the internal temperature in buildings (e.g. in case of no space heating or cooling);

— indicators for partial EPB requirements related to thermal energy balance and fabric features; and

— calculation methods covering the performance and thermal, hygrothermal, solar and visual characteristics of specific parts of the building and specific building elements and components, such as opaque envelope elements, ground floor, windows and facades.

ISO/TC 163/SC 2 cooperates with other TCs for the details on, for example, appliances, technical building systems and indoor environment.

This document provides:

— Standard calculation procedures for the conversion of hourly weather data to apply as input for energy performance calculations, in particular calculation of solar irradiance on an arbitrary inclined surface.

— Procedures for the use of (other) output from ISO 15927-1, ISO 15927-2, and ISO 15927-4) as input for the EPB assessment.

Common standard climatic data shall be used for the all relevant EPB modules. Most of the input data are available from ISO 15927-1, ISO 15927-2, ISO 15927-4, ISO 15927-5 and ISO 15927-6.

These data include the variables per time interval, as described in ISO 52000-1:2017, 11.5.

Table 1 shows the relative position of this document within the set of EPB standards in the context of the modular structure as set out in ISO 52000-1.

NOTE 2 In ISO/TR 52000-2[7] the same table can be found, with, for each module, the numbers of the relevant EPB standards and accompanying technical reports that are published or in preparation.

NOTE 3 The modules represent EPB standards, although one EPB standard could cover more than one module and one module could be covered by more than one EPB standard, for instance a simplified and a detailed method respectively. See also Tables A.1 and B.1

Table 1 — Position of this document (in casu M1–13), within the modular structure of the set of EPB standards

		Overarching		Building (as such)		Technical Building Systems									
Submodule		Descriptions		Descriptions		Descriptions	Heating	Cooling	Ventilation	Humidification	Dehumidification	Domestic hot water	Lighting	Building automation and control	PV, wind, ..
sub1			M1		M2		M3	M4	M5	M6	M7	M8	M9	M10	M11
1		General		General		General									
2		Common terms and definitions; symbols, units and subscripts		Building energy needs		Needs								a	
3		Applications		(Free) Indoor conditions without systems		Maximum load and power									
4		Ways to express energy performance		Ways to express energy performance		Ways to express energy performance									
5		Building categories and building boundaries		Heat transfer by transmission		Emission and control									
6		Building occupancy and operating conditions		Heat transfer by infiltration and ventilation		Distribution and control									
7		Aggregation of energy services and energy carriers		Internal heat gains		Storage and control									
8		Building zoning		Solar heat gains		Generation and control									
9		Calculated energy performance		Building dynamics (thermal mass)		Load dispatching and operating conditions									
10		Measured energy performance		Measured energy performance		Measured energy performance									
11		Inspection		Inspection		Inspection									

[a] The shaded modules are not applicable.

Table 1 *(continued)*

		Overarching		Building (as such)		Technical Building Systems										
Submodule		**Descriptions**		**Descriptions**		**Descriptions**	**Heating**	**Cooling**	**Ventilation**	**Humidification**	**Dehumidification**	**Domestic hot water**	**Lighting**	**Building automation and control**	**PV, wind, ..**
sub1			**M1**		**M2**		**M3**	**M4**	**M5**	**M6**	**M7**	**M8**	**M9**	**M10**	**M11**
12		Ways to express indoor comfort				BMS									
13		External environment conditions	ISO 52010-1												
14		Economic calculation													

[a] The shaded modules are not applicable.

Energy performance of buildings — External climatic conditions —

Part 1:
Conversion of climatic data for energy calculations

1 Scope

This document specifies a calculation procedure for the conversion of climatic data for energy calculations.

The main element in this document is the calculation of solar irradiance on a surface with arbitrary orientation and tilt. A simple method for conversion of solar irradiance to illuminance is also provided.

The solar irradiance and illuminance on an arbitrary surface are applicable as input for energy and daylighting calculations, for building elements (such as roofs, facades and windows) and for components of technical building systems (such as thermal solar collectors, PV panels).

Other parameters of climatic data needed to assess the thermal and moisture performance of buildings, building elements or technical building systems [like wind, temperature, moisture and long-wave (thermal) radiation] are to be obtained according to the procedures in ISO 15927-4. These data are listed in this document as input and passed on as output without any conversion.

NOTE 1 The reason for passing these data via this document is to have one single and consistent source for all EPB standards and to enable any conversion or other treatment if needed for specific application.

NOTE 2 Table 1 in the Introduction shows the relative position of this document within the set of EPB standards in the context of the modular structure as set out in ISO 52000-1.

2 Normative references

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

ISO 7345, *Thermal insulation — Physical quantities and definitions*

ISO 9488, *Solar energy — Vocabulary*

ISO 15927-4, *Hygrothermal performance of buildings — Calculation and presentation of climatic data — Part 4: Hourly data for assessing the annual energy use for heating and cooling*

ISO 52000-1, *Energy performance of buildings — Overarching EPB assessment — Part 1: General framework and procedures*

ISO 52016-1, *Energy performance of buildings — Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads — Part 1: Calculation procedures*

NOTE Default references to EPB standards other than ISO 52000-1 are identified by the EPB module code number and given in Annex A (normative template in Table A.1) and Annex B (informative default choice in Table B.1).

EXAMPLE EPB module code number: M5–5, or M5–5.1 (if module M5–5 is subdivided), or M5–5/1 (if reference to a specific clause of the standard covering M5–5).

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 7345, ISO 9488, ISO 52000-1 and the following apply.

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

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

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

3.1
EPB standard
standard that complies with the requirements given in ISO 52000-1, CEN/TS 16628 and CEN/TS 16629

Note 1 to entry: These three basic EPB documents were developed under a mandate given to CEN by the European Commission and the European Free Trade Association (Mandate M/480), and support essential requirements of EU Directive 2010/31/EU on the energy performance of buildings (EPBD). Several EPB standards and related documents are developed or revised under the same mandate.

[SOURCE: ISO 52000-1:2017, definition 3.5.14]

3.2
solar declination
angle between direction of the direct solar radiation and the equatorial plane of the earth

3.3
illuminance
<at a point of a surface> quotient of the luminous flux incident on an element of the surface containing the point, divided by the area of that element

Note 1 to entry: This is expressed in lux, 1 lx = 1 lm·m^{-2}.

[SOURCE: ISO 16817:2012, 3.14]

4 Symbols and abbreviations

4.1 Symbols

For the purposes of this document, the symbols from ISO 52000-1 and the following apply.

NOTE If, within this document, a symbol is more or less uniquely linked with a specific subscript, the symbol is shown with the subscript.

Symbol	Name of quantity	Unit
D	wind direction	°
f	brightness coefficients (Perez model)	–
E_{v}	global illuminance	lx
F	coefficient	–
G	irradiance	W/m^2
H	height	m
H	(accumulated, monthly) solar irradiation	kW h/m^2
i	index	–
I	calculated irradiance	W/m^2
K_{v}	Global luminous efficacy	lm/W
k_{T}	clearness index	–
L	distance	m

Symbol	Name of quantity	Unit
m	air mass	–
n	number	–
R_{dc}	earth orbit deviation	°
n	index	–
t	time	min, h
TZ	time zone	h
u_{10}	wind speed	m/s
x	moisture content or mixing ratio	kg/kg
α	angle	°
β	angle	°
γ	angle	°
δ	solar declination	°
ε	clearness parameter (Perez model)	–
θ	Celsius temperature	°C
θ	angle	°
λ	longitude	°
φ	relative humidity	–
φ	angle, latitude	°
ρ	reflectivity	–
ω	hour angle	°

4.2 Subscripts

For the purposes of this document, the subscripts given in ISO 52000-1 and the following apply.

NOTE Relevant subscripts already given in ISO 52000-1 are included if necessary for the understanding of this document.

Subscript	Term	Subscript	Term
a	atmosphere, air	ic	surface of any inclination
an	annual, yearly	l	long-wave
b	beam	m	monthly
c	constant	obst	obstacle
circum	circumsolar	segm	segment
d	day	sol	solar, sun
d	diffuse	sh	shading
dif	diffuse	tot	total
dir	direct	v	visual, light
eq	equation	w	weather station
ext	extra-terrestrial	z	zenith
g	global	0, 1, ...	index
grnd	ground	11, 12, ...	index

5 Description of the methods

5.1 Output of the method

This document covers primarily the generic hourly calculation methodology of the solar irradiance on a surface of any orientation and tilt, optionally including the effect of shading by distant objects.

To avoid serious errors in case of separate calculation of the effect of shading in case of overlapping shading objects, it is recommended that the calculation of the effect of shading by external objects is done in the application standard where the position, location and surroundings of the irradiated surface is known.

For that purpose the output provides the solar irradiance not only as a total, but also as different components. Additional output needed for the calculation of the effect of shading in standards using the output from this document as input is the position of the sun.

The time interval of the output is hourly.

Other data from the climatic data set (not related to solar radiation) do not need any conversion, but can be used directly in the relevant EPB standards. These are also listed in the table with output quantities.

NOTE The reason for passing these data via this document is to have one single and consistent source for all EPB standards and to enable any conversion or other treatment if needed for specific application.

5.2 General description of the method

The method gives procedures to calculate the distribution of solar irradiance on a non-horizontal plane based on hourly solar radiation data on a horizontal surface.

NOTE The explanation and justification is given in ISO/TR 52010-2[6]. The model is named after Mr Perez. Several improvements were made in the course of time, see the list of references in the bibliography of the technical report. The calculation procedure described in this document is based on the “simplified Perez model” proposed in the early 1990s.

Essentially, the model is composed of three different components:

a) a geometric representation of the sky dome;

b) a parametric representation of the insolation conditions, and;

c) a statistic component linking both components mentioned before.

It is a model of anisotropic sky, where the sky dome is geometrically divided into three areas, each of them showing a constant radiance, different from the other two.

These three areas are:

— isotropic diffuse (for the sky hemisphere);

— circumsolar radiation;

— horizon brightness.

For the purposes of this document the following is added:

— isotropic ground reflected radiation.

The diffuse (sky) radiation for the surface uses as input hourly values of diffuse horizontal and direct beam solar radiation. Other inputs to the model include the sun’s incident angle to the surface, the surface tilt angle from the horizontal, and the sun’s zenith angle.

Shading by distant objects is taken into account through a shading correction coefficient for the direct radiation. Shading of diffuse radiation and reflection by distant objects is not taken into account. Shading by fins and overhangs is calculated in ISO 52016-1. In case of a combination of shading objects, specified in different standards (like in this document plus in ISO 52016-1), the calculation of the effect shall not be done separately, because the effects may overlap, leading to double counting. For that reason this document gives as output the choice between unshaded and shaded solar radiation. The (combined) effect of shading objects can be done in the application standard, such as ISO 55016-1 for the heating and cooling needs, design load or indoor temperature; or e.g. in standards assessing the energy performance of thermal solar collectors, photovoltaic panels in the built environment. Such standards contain all the details of the assessed object and of the surroundings.

6 Calculation method

6.1 Output data

The output data of this method are listed in Tables 2 to 4.

The general data needed when the climatic data set is used as input in other standards are given in Table 2.

The calculated total solar irradiance is provided without and with the effect of solar shading by external objects (see 6.4.3).

The solar position (altitude and azimuth) is needed as input for solar shading calculations, after the calculation of the irradiance according to this document. For the same purpose the output is split into direct and diffuse irradiance. The direct and diffuse solar irradiance can be divided in two sets: one set without and one set with a correction for circumsolar irradiance. See Table 3.

Other data from the climatic data set (not related to solar radiation) do not need any conversion, but can be used directly in the relevant EPB standards. These are listed in Table 4.

Table 2 — Output data of this method; climatic data file

Description	Symbol	Unit	Validity interval[a]	Intended destination module[b]	Varying[c]
Identifier for climatic data file	-	(text)	text	M9–2 M2–3, M3–3, M4–3, M5–3, M6–3, M7–3, M9–3 M11-X	No
First day of time series (day of the year)	$n_{day;start}$	-	1 to 366	Same	No
Last day of time series (day of the year)	$n_{day;end}$	-	1 to 366	Same	No

[a] Practical range, informative.

[b] Informative.

[c] “Varying”: value may vary over time: different values per time interval, for instance: hourly values or monthly values (not constant values over the year).

[d] If Yes: additional information to be added.

Table 2 *(continued)*

Description	Symbol	Unit	Validity interval[a]	Intended destination module[b]	Varying[c]
Day of the week for first day		-	Monday to Sunday (day 1 to 7)	Same	No
Daylight saving time in time series? [d]	-	-	Yes/No	Same	No
Leap day included?	-	-	Yes/No	Same	No

[a] Practical range, informative.

[b] Informative.

[c] "Varying": value may vary over time: different values per time interval, for instance: hourly values or monthly values (not constant values over the year).

[d] If Yes: additional information to be added.

Table 3 — Output data of this method; time series, calculated quantities

Description	Symbol	Unit	Validity interval[a]	Intended destination module[b]	Varying[c]
Day of the year	n_{day}	–	1 to 366	M9–2 M2–3, M3–3, M4–3, M5–3, M6–3, M7–3, M9–3 M11-X	Yes
Actual (clock) hour for the location (counting number of the hour in the day)	n_{hour}	–	1 to 24	Same	Yes
Calculated diffuse solar irradiance	I_{dif}	W/m^2	0 to 1 300	Same	Yes
Calculated diffuse solar irradiance excluding circumsolar irradiance	$I_{dif;tot}$	W/m^2	0 to 1 300	Same	Yes
Calculated direct solar irradiance	I_{dir}	W/m^2	0 to 1 300	Same	Yes
Calculated direct solar irradiance including circumsolar irradiance	$I_{dir;tot}$	W/m^2	0 to 1 300	Same	Yes
Calculated hemispherical solar irradiance	I_{tot}	W/m^2	0 to 1 300	Same	Yes
Calculated global illuminance	E_v	lx	0 to 150 000	Same	Yes

[a] Practical range, informative.

[b] Informative.

[c] "Varying": value may vary over time: different values per time interval, for instance: hourly values or monthly values (not constant values over the year).

[d] Convention in this document: angle from South, eastwards positive, westwards negative.

NOTE For aggregation over a longer period: see 6.2.

Table 3 *(continued)*

Description	Symbol	Unit	Validity interval[a]	Intended destination module[b]	Varying[c]
Calculated hemi-spherical solar irradiance, including effect of shading	$I_{tot;sh}$	W/m^2	0 to 1 300	Same	Yes
Solar altitude angle, from horizontal	α_{sol}	°	0 to 90		
Solar azimuth angle[d]	φ_{sol}	°	−180 to +180		

[a] Practical range, informative.

[b] Informative.

[c] “Varying”: value may vary over time: different values per time interval, for instance: hourly values or monthly values (not constant values over the year).

[d] Convention in this document: angle from South, eastwards positive, westwards negative.

NOTE For aggregation over a longer period: see 6.2.

Table 4 — Output data of this method; time series, other climatic data

Description	Symbol	Unit	Validity interval[a]	Intended destination module[b]	Varying[c]
Dry-bulb air temperature	θ_a	°C	−50 to 50	M9–2 M2–3, M3–3, M4–3, M5–3, M6–3, M7–3, M9–3 M11-X	Yes
Wind speed at 10 m height	u_{10}	m/s	0 to 20	Same	Yes
Wind direction from north	D	°	0 to– 360	Same	Yes
Long-wave irradiance from the atmosphere on a horizontal plane	$G_{l;a}$	W/m^2	0 to 500	Same	Yes
Moisture content or mixing ratio	x	kg/kg	0 to 0,050	Same	Yes
Relative humidity	φ	%	0 to 100	Same	Yes

[a] Practical range, informative.

[b] Informative

[c] “Varying”: value may vary over time: different values per time interval, for instance: hourly values or monthly values (not constant values over the year).

NOTE For aggregation over a longer period: see 6.2.

6.2 Calculation time intervals

The method described in Clause 6 is suitable for hourly time intervals.

If daily, monthly, yearly data are needed they can be aggregated from hourly data by taking the monthly mean or monthly total values and adding the subscript corresponding with the period (d, m, an). The number of hours per month can be aggregated in the same way.

NOTE 1 This corresponds to the time intervals needed for energy calculations and the availability of hourly integrated solar irradiance data. If data on shorter time intervals is available the method can be applied to shorter time intervals.

NOTE 2 ISO 15927-1[1] specifies procedures for calculating and presenting the monthly total or monthly mean values of those parameters of climatic data needed to assess the overall or partial energy performance of buildings. But when hourly data are available, as assumed in this document, such calculation is a trivial summing and averaging.

When the hourly values for the solar irradiance, I_x, in (W/m^2), are summed over a month, they are divided by 1 000 and expressed as the solar irradiation, H_x, in (kWh/m^2), where x is the placeholder for the different irradiance components.

6.3 Input data

6.3.1 General

The basic input data are solar radiation measured at a weather station, coordinates of the weather station and the orientation and tilt angle of the surface of interest, and the date and time for the calculation. For shading the height of the surface, the height of the shading object and the distance of the shading object are also required as input data.

Clause 8 provides procedures for reporting the application range of the time series of climatic data.

The measured solar radiation components that are used in the calculation are the direct beam solar irradiance and the diffuse horizontal solar irradiance. The basic calculation of ground reflection is based on the global horizontal radiation which in this document is calculated from the diffuse and direct beam solar radiance.

When only the global solar radiance is measured at the weather station the diffuse and direct beam radiance can be estimated according to 6.4.2.

The ground reflection from surroundings of the building location is needed as input data for the calculation (see 6.4.3).

6.3.2 Weather station and climatic data set

The climatic data are to be obtained in accordance with the procedures in ISO 15927-4.

NOTE 1 See NOTE 2 in 6.2.

NOTE 2 ISO 15927-1[1] also contains a few conversions, such as conversion between vapour pressure, relative humidity and mixing ratio and conversion between reference hourly mean wind speed and local mean wind speed, that can be of use for specific applications that are described in other EPB standards.

ISO 15927-4 gives a method for constructing a reference year of hourly values of appropriate meteorological data suitable for assessing the average annual energy for heating and cooling. Other reference years representing average conditions can be constructed for special purposes.

Meteorological instrumentation and methods of observation are not covered; these are specified by the World Meteorological Organization (WMO).

The climatic data are measured at main weather stations. Which weather station to use and which time series is described in Table A.2 (normative template).

For each time series of climatic data a reference to documentation is required that provides background information on the selection of the time series and the intended application range. See template in Table A.2.

EXAMPLE Heating and cooling energy (sensible, latent); ventilation and air infiltration; design heating or cooling load; indoor comfort; thermal solar collectors; wind turbines. Where applicable: indication if it intends to represent an average or an extreme year.

The report shall also contain information whether the climatic data consist of measured data, pre-processed measured data or synthetic data, and the method used for pre-processing or constructing the synthetic data. See template in Table A.2.

An informative default choice of weather station and time series, normally for each EPB standard provided in Table B.2, is not applicable, because this choice strongly depends on local conditions. Instead, Table B.2 contains the data from a climatic data set that is internationally widely used for validation tests, such as the validation and verification tests described in ISO 52016-1.

6.3.3 Climatic input data

Table 5 contains data needed for the calculation of the solar irradiance at an inclined surface.

The calculation method comprises different options. Therefore not all the data in Table 5 are necessary in each case.

Table 5 — Climatic input data needed for the calculation

Name	Symbol	Unit	Validity interval[a]	Origin[b]	Varying[c]	Reference
Day of the year	n_{day}	–	1 to 366	Climatic data set	YES	
Actual (clock) hour for the location (counting number of the hour in the day)	n_{hour}	–	1 to 24	Climatic data set	YES	
Diffuse solar irradiance on a horizontal surface	$G_{sol;d}$	W/m^2	0 to 1 000	See 6.4.2	YES	
Direct normal (beam) solar irradiance (normal to the sun)	$G_{sol;b}$		0 to 1 000	Climatic data set	YES	
Global solar irradiance	$G_{sol;g}$		0 to 1 000	Climatic data set	YES	
Ground solar reflectivity	$\rho_{sol;grnd}$	-	0 to 1	See 6.4.2.4	YES	

[a] Practical range, informative.

[b] For instance EPB module or (e.g. product) standard or "local" (type, geometry).

[c] "Varying": value may vary over time: different values per time interval, for instance: hourly values or monthly values (not constant values over the year).

Other data from the climatic data set (not related to solar radiation) do not need any conversion, but can be used directly in the relevant EPB standards. These are listed in Table 4.

6.3.4 Geometrical characteristics

Geometrical data for the inclined surface are listed in Table 6.

Table 6 — Geometric input data, inclined surface

Name	Symbol	Unit	Validity interval[a]	Origin[b]	Varying[c]	Reference
Tilt angle of the inclined surface from horizontal, measured upwards facing	β_{ic}	°	0 to 180	Local	NO	
Orientation angle of the inclined surface, expressed as the geographical azimuth angle of the horizontal projection of the inclined surface normal [d]	γ_{ic}	°	−180 to +180	Local	NO	

[a] Practical range, informative.

[b] For instance EPB module or (e.g. product) standard or “local” (type, geometry).

[c] “Varying”: value may vary over time: different values per time interval, for instance: hourly values or monthly values (not constant values over the year).

[d] Convention in this document: angle from South, eastwards positive, westwards negative.

If the effect of shading by distant objects is taken into account in the calculation (see 6.4.5), the needed input data are given in Table 7.

Table 7 — Geometric input data; shading

Name	Symbol	Unit	Validity interval[a]	Origin[b]	Varying[c]	Reference
Base height of the shaded surface, from ground level	$H_{0;ic}$	m	≥ 0	Local	NO	
Height of the shaded surface, from bottom to top; if tilted: vertical projection [d]	$H_{1;ic}$	m	> 0	Local	NO	
Height of the shading obstacle, from ground level	$H_{sh;obst}$	m	≥ 0	Local	NO	
Horizontal distance between the shaded surface and the shading object (obstacle) in the direction of the sun, measured between their central points	$L_{sh;obst}$	m	≥ 0	Local	NO	
The position of the shading object indicated by the upper boundary of the geographical azimuth angle [e]	$\gamma_{sh;obst;max}$	°		Local	NO	

[a] Practical range, informative.

[b] For instance EPB module or (e.g. product) standard or “local” (type, geometry).

[c] “Varying”: value may vary over time: different values per time interval, for instance: hourly values or monthly values (not constant values over the year).

[d] If horizontal: choose small value, e.g. H_1 = 0,01 m.

[e] Convention in this document: angle from South, eastwards positive, westwards negative, so: North- > East- > South- > West- > North = −180 - > −90 - > 0 - > +90 - > +180 degrees.

6.3.5 Constants and physical data

Values for clearness parameter, ε, and the corresponding index, *Ind*, and brightness coefficient, *f*, are given in Table 8.

Table 8 — Values for clearness index and brightness coefficients as function of clearness parameter

ε	Index, *Ind*	f_{11}	f_{12}	f_{13}	f_{21}	f_{22}	f_{23}
$\varepsilon < 1{,}065$	1 Overcast	−0,008	0,588	−0,062	−0,060	0,072	−0,022
$1{,}065 \leq \varepsilon < 1{,}230$	2	0,130	0,683	−0,151	−0,019	0,066	−0,029
$1{,}230 \leq \varepsilon < 1{,}500$	3	0,330	0,487	−0,221	0,055	−0,064	−0,026
$1{,}500 \leq \varepsilon < 1{,}950$	4	0,568	0,187	−0,295	0,109	−0,152	−0,014
$1{,}950 \leq \varepsilon < 2{,}800$	5	0,873	−0,392	−0,362	0,226	−0,462	0,001
$2{,}800 \leq \varepsilon < 4{,}500$	6	1,132	−1,237	−0,412	0,288	−0,823	0,056
$4{,}500 \leq \varepsilon < 6{,}200$	7	1,060	−1,600	−0,359	0,264	−1,127	0,131
$\varepsilon \geq 6{,}200$	8 Clear	0,678	−0,327	−0,250	0,156	−1,377	0,251

Other constants are listed in Table 9:

Table 9 — Other constants and physical data

Name	Symbol	Unit	Value
pi	π	-	3,14159265359
Solar constant	$G_{sol;c}$	W/m^2	1 370
Constant parameter for clearness formula	K	rad^{-3}	1,014
Luminous efficacy	K_v	lm/W	115[a]
[a] This is the average value for different types of sky.			

6.3.6 Input data from Annex A (see Annex B)

Annex A contains the normative template for choices in references, methods and input data. Informative default choices in references, methods and input data are given in Annex B, respecting the template of Annex A.

All these choices and input data are indispensable for the application of this document.

6.4 Calculation procedure

The calculation procedure consists of several steps. The solar position is determined by solar altitude angle and azimuth (which are dependent on the solar orbit).

NOTE All angles are in degrees

6.4.1 Calculation of the sun path

6.4.1.1 Solar declination

The solar declination, δ, in degrees is determined by the following Formulae (1) and (2):

$$\delta = 0{,}33281 - 22{,}984 \times \cos(R_{dc}) - 0{,}3499 \times \cos(2 \cdot R_{dc}) - 0{,}1398 \times \cos(3 \cdot R_{dc}) + 3{,}7872 \times \sin(R_{dc}) + 0{,}03205 \times \sin(2 \cdot R_{dc}) + 0{,}07187 \times \sin(3 \cdot R_{dc}) \quad (1)$$

with

$$R_{dc} = \frac{360}{365} \times n_{day} \quad (2)$$

where

δ is the solar declination, in degrees;

R_{dc} is the earth orbit deviation as a function of the day, in degrees;

n_{day} is the day of the year, from 1 to 365 or 366 (leap year).

6.4.1.2 Equation of time

The equation of time, t_{eq}, calculated as a function of the day resulting from the elliptic path of the earth around the sun is determined by Formulae (3) to (7):

$$\text{If } n_{day} < 21: \; t_{eq} = 2{,}6 + 0{,}44 \times n_{day} \quad (3)$$

$$\text{If } 21 \le n_{day} < 136: \; t_{eq} = 5{,}2 + 9{,}0 \times \cos\left[(n_{day} - 43) \times 0{,}0357 \times \frac{180}{\pi}\right] \quad (4)$$

$$\text{If } 136 \le n_{day} < 241: \; t_{eq} = 1{,}4 - 5{,}0 \times \cos\left[(n_{day} - 135) \times 0{,}0449 \times \frac{180}{\pi}\right] \quad (5)$$

$$\text{If } 241 \le n_{day} < 336: \; t_{eq} = -6{,}3 - 10{,}0 \times \cos\left[(n_{day} - 306) \times 0{,}036 \times \frac{180}{\pi}\right] \quad (6)$$

$$\text{If } n_{day} \ge 336: \; t_{eq} = 0{,}45 \times (n_{day} - 359) \quad (7)$$

where

t_{eq} is the equation of time, in minutes;

n_{day} is the day of the year, from 1 to 365 or 366 (leap year).

6.4.1.3 Time shift

The time shift, t_{shift}, resulting from the fact that the longitude and the path of the sun are not equal, is determined by the following Formula (8):

$$t_{shift} = TZ - \frac{\lambda_w}{15} \quad (8)$$

where

t_{shift} is the time shift, in h;

TZ is the time zone, the actual (clock) time for the location compared to UTC (Universal Time, Coordinated), according to Table A.2 (template; with informative choice in Table B.2), in h;

λ_w is the longitude of the weather station, in degrees, according to Table A.2 (template; with informative choice in Table B.2).

EXAMPLE 1 Greenwich Mean Time: $TZ = 0$

EXAMPLE 2 $TZ = + 2{,}0$. $\lambda_w = 10$ degrees (East)$t_{shift} = + 2{,}0 - 10/15 = 1{,}33$ h. Meaning: the clock time (disregarding possible daylight saving time) is 1,33 h ahead of the solar time.

NOTE Daylight saving time is disregarded in t_{shift} which is time independent.

6.4.1.4 Solar time

The solar time, t_{sol}, is determined as a function of the equation of time, the time shift and the hour of the day by Formula (9):

$$t_{sol} = n_{hour} - \frac{t_{eq}}{60} - t_{shift} \tag{9}$$

where

t_{sol} is the solar time, in h;

n_{hour} is the actual (clock) time for the location, the hour of the day, obtained from the climatic data set, as chosen in Table A.2 (normative template), with informative choice in Table B.2, in h;

t_{eq} is the equation of time according to Formulae (3) to (7), in minutes;

t_{shift} is the time shift determined in Formula (8).

6.4.1.5 Solar hour angle

The solar hour angle, ω, in the middle of the current hour as a function of the solar time, t_{sol}, is:

$$\omega = \frac{180}{12} \cdot (12{,}5 - t_{sol}) \tag{10}$$

when

$\omega > +180$, $\omega = \omega - 360$;

$\omega < -180$, $\omega = \omega + 360$;

where

ω is the solar hour angle, in degrees;

t_{sol} is the solar time according to Formula (9), in h.

NOTE 1 The limitation of angles ranging between −180 and +180 degrees is needed to determine which shading objects are in the direction of the sun; see also the calculation of the azimuth angle of the sun in 6.4.1.7.

NOTE 2 Explanation of "12,5": The hour numbers are actually hour sections: the first hour section of a day runs from 0h to 1h. So, the average position of the sun for the solar radiation measured during (solar) hour section N is at (solar) time = (N −0,5) h of the (solar) day.

6.4.1.6 Solar altitude and solar zenith angle

The solar altitude angle, α_{sol}, is the angle between the solar beam and the horizontal surface, determined in the middle of the current hour as a function of the solar hour angle, the solar declination and the latitude

$$\alpha_{sol} = \arcsin\left[\sin(\delta)\cdot\sin(\varphi_w) + \cos(\delta)\cdot\cos(\varphi_w)\cdot\cos(\omega)\right] \tag{11}$$

when

$\alpha_{sol} < 0{,}0001$, $\alpha_{sol} = 0$

The solar zenith angle, θ_z, is calculated as the complementary angle:

$$\theta_z = 90 - \alpha_{sol} \tag{12}$$

where

α_{sol}	is the solar altitude angle, the angle between the solar beam and the horizontal surface, in degrees;
θ_z	is the solar zenith angle, the angle between the solar beam and the zenith, in degrees;
δ	is the solar declination according to Formula (1), in degrees;
ω	is the solar hour angle of the weather station, obtained according to Formula (10), in degrees;
φ_w	is the latitude of the weather station, according to Table A.2 (template; with informative choice in Table B.2), in degrees.

6.4.1.7 Solar azimuth angle

The following auxiliary variables, determined in Formulae (13) to (15), are needed to calculate the solar azimuth angle, φ_{sol}.

$$\sin(\varphi_{sol;aux1}) = \frac{\cos(\delta)\cdot\sin(180-\omega)}{\cos\{\arcsin[\sin(\alpha_{sol})]\}} \tag{13}$$

$$\cos(\varphi_{sol;aux1}) = \frac{\cos(\varphi_w)\cdot\sin(\delta) + \sin(\varphi_w)\cdot\cos(\delta)\cdot\cos(180-\omega)}{\cos\{\arcsin[\sin(\alpha_{sol})]\}} \tag{14}$$

$$\varphi_{sol;aux2} = \frac{\arcsin(\cos(\delta)\cdot\sin(180-\omega))}{\cos\{\arcsin[\sin(\alpha_{sol})]\}} \tag{15}$$

where

$\varphi_{sol;aux1}$	is a first auxiliary angle to determine the solar azimuth, in degrees;
$\varphi_{sol;aux2}$	is a second auxiliary angle to determine the solar azimuth, in degrees;
δ	is the solar declination according to Formula (1), in degrees;
ω	is the solar hour angle according to Formula (10), in degrees;
α_{sol}	is the solar altitude angle according to n Formula (11), in degrees;
φ_w	is the latitude of the weather station, according to Table A.2 (template; with informative choice in Table B.2), in degrees.

The solar azimuth angle, φ_{sol}, is calculated by Formula (16)

when

$$\sin(\varphi_{\text{sol;aux1}}) \geq 0 \text{ and } \cos(\varphi_{\text{sol;aux1}}) > 0 \quad \varphi_{\text{sol}} = +\left(180 - \varphi_{\text{sol;aux2}}\right)$$

$$\cos(\varphi_{\text{sol;aux1}}) < 0 \quad \varphi_{\text{sol}} = \varphi_{\text{sol;aux2}} \tag{16}$$

$$\text{otherwise} \quad \varphi_{\text{sol}} = -\left(180 + \varphi_{\text{sol;aux2}}\right)$$

where

φ_{sol}	is the solar azimuth angle (angle from South, eastwards positive, westwards negative), in degrees;
$\sin(\varphi_{\text{sol;auxl}})$	is the first auxiliary variable, determined by Formula (13);
$\cos(\varphi_{\text{sol;auxl}})$	is the second auxiliary variable, determined by Formula (14);
$\varphi_{\text{sol;aux2}}$	is the third auxiliary variable, determined by Formula (15), in degrees.

NOTE The azimuth angles range between −180 and +180 degrees; this is needed to determine which shading objects are in the direction of the sun.

6.4.1.8 Solar angle of incidence on inclined surface

The solar angle of incidence, θ_{sol}, is the angle of incidence of the solar beam on an inclined surface and is determined as function of the solar hour angle and solar declination:

$$\theta_{\text{sol;ic}} = \arccos \begin{bmatrix} \sin(\delta)\cdot\sin(\varphi_w)\cdot\cos(\beta_{\text{ic}}) - \sin(\delta)\cdot\cos(\varphi_w)\cdot\sin(\beta_{\text{ic}})\cdot\cos(\gamma_{\text{ic}}) \\ +\cos(\delta)\cdot\cos(\varphi_w)\cdot\cos(\beta_{ic})\cdot\cos(\omega) + \cos(\delta)\cdot\sin(\varphi_w)\cdot\sin(\beta_{\text{ic}})\cdot\cos(\gamma_{\text{ic}})\cdot\cos(\omega) \\ +\cos(\delta)\cdot\sin(\beta_{\text{ic}})\cdot\sin(\gamma_{\text{ic}})\cdot\sin(\omega) \end{bmatrix} \tag{17}$$

where

$\theta_{\text{sol;ic}}$	is the solar angle of incidence on the inclined surface, in degrees;
β_{ic}	is the tilt angle of the inclined surface, obtained according to Table 6, in degrees;
γ_{ic}	is the orientation of the inclined surface, obtained according to Table 6, in degrees;
δ	is the solar declination according to Formula (1), in degrees;
ω	is the solar hour angle of the weather station according to Formula (10), in degrees;
φ_{w}	is the latitude of the weather station, according to Table A.2 (template; with informative choice in Table B.2), in degrees.

6.4.1.9 Azimuth and tilt angle between sun and the inclined surface

The azimuth and tilt angles between sun and the inclined surface are needed as input for the calculation of the irradiance in case of solar shading by objects.

The azimuth angle between sun and the inclined surface, $\gamma_{\text{sol;ic}}$, is calculated by Formula (18)

when

$$(\omega - \gamma_{\text{ic}}) > +180 \quad \gamma_{\text{sol;ic}} = \left(-360 + \omega - \gamma_{\text{ic}}\right)$$

$(\omega - \gamma_{ic}) < -180 \quad \gamma_{sol;ic} = (+360 + \omega - \gamma_{ic})$ (18)

otherwise $\quad \gamma_{sol;ic} = (\omega - \gamma_{ic})$

The tilt angle between sun and inclined surface, $\beta_{sol;ic}$, is calculated by Formula (19)

when

$(\beta_{ic} - \theta_z) > +180 \quad \beta_{sol;ic} = (-360 + \beta_{ic} - \theta_z)$

$(\beta_{ic} - \theta_z) < -180 \quad \beta_{sol;ic} = (+360 + \beta_{ic} - \theta_z)$ (19)

otherwise $\quad \beta_{sol;ic} = (\beta_{ic} - \theta_z)$

where

$\gamma_{sol;ic}$ is the azimuth angle between sun and the inclined surface, in degrees;

$\beta_{sol;ic}$ is the tilt angle between sun and the inclined surface, in degrees;

ω is the solar hour angle of the weather station according to Formula (10), in degrees;

γ_{ic} is the orientation of the inclined surface, obtained according to Table 6, in degrees;

β_{ic} is the tilt angle of the inclined surface, obtained according to Table 6, in degrees;

θ_z is the solar zenith angle, the angle between the solar beam and the zenith according to Formula (12), in degrees.

6.4.1.10 Air mass

The air mass, m, expresses the distance the solar beam travels through the earth atmosphere. The air mass is determined as a function of the sine of the solar altitude angle:

If $\alpha_{sol} \geq 10$ then

$$m = \frac{1}{\sin(\alpha_{sol})} \tag{20}$$

If $\alpha_{sol} < 10$ then

$$m = \frac{1}{\sin(\alpha_{sol}) + 0{,}15 \times (\alpha_{sol} + 3{,}885)^{-1{,}253}} \tag{21}$$

where

m is the dimensionless air mass;

α_{sol} is the solar altitude angle according to Formula (11), in degrees.

6.4.2 Split between direct and diffuse solar irradiance

If the direct (beam) solar irradiance, $G_{sol,b}$, is available in the climatic data set, as chosen in Table A.2 (normative template), with informative choice in Table B.2, and if there is a choice between horizontal incidence or normal incidence, the latter shall be used.

If only direct (beam) solar irradiance at horizontal plane is available in the climatic data set, it shall be converted to normal incidence by dividing the value by the sine of the solar altitude, sin(α_{sol}).

NOTE 1 If the solar altitude angle is low, this conversion is very sensitive for tiny errors in the calculation of the solar altitude. Such tiny errors are feasible given the sensitivity for the parameters needed to calculate the solar angle (see 6.4.1) and given the atmospheric refraction of solar radiation near the ground. Therefore the value at normal incidence is preferred.

If the diffuse solar irradiance on a horizontal plane is not available in the climatic data set, it is calculated as the difference of global and direct (beam) irradiance, corrected for the solar altitude:

$$G_{sol;d} = G_{sol;g} - G_{sol;b} \cdot \sin(\alpha_{sol}) \tag{22}$$

where

$G_{sol;d}$ is the diffuse solar irradiance on a horizontal plane, in W/m²;

$G_{sol;g}$ is the global irradiance, obtained from the climatic data set, as chosen in Table A.2 (normative template), with informative choice in Table B.2, in W/m²;

α_{sol} is the solar altitude angle according to Formula (11), in degrees.

If the direct (beam) solar irradiance is not available from the climatic data set, as chosen in Table A.2 (normative template), with informative choice in Table B.2, one of the following two methods shall be chosen.

NOTE 2 Method 1 proved to be the most effective in mid-latitude climates; other models might be more suitable for tropical climates. See ISO/TR 52010-2 for more information.

Method 1, Default method.

The global irradiance, measured on a horizontal plane, is split into the approximate direct and diffuse fractions by calculating the diffuse fraction according to the following empirical correlation with the clearness index:

$$\begin{aligned}
&\text{when } k_T \le 0{,}22: && \frac{G_{sol;d}}{G_{sol;g}} = 1{,}0 - 0{,}09 \times k_T \\
&\text{when } 0{,}22 < k_T \le 0{,}80: && \frac{G_{sol;d}}{G_{sol;g}} = 0{,}9511 - 0{,}1604 \times k_T + 4{,}388 \times k_T^2 - 16{,}638 \times k_T^3 + 12{,}336 \times k_T^4 \\
&\text{when } k_T > 0{,}80: && \frac{G_{sol;d}}{G_{sol;g}} = 0{,}165
\end{aligned} \tag{23}$$

where

$G_{sol;d}$ is the diffuse solar irradiance on a horizontal plane, in W/m²;

k_T is the dimensionless clearness index of the atmosphere related to extra-terrestrial global irradiance, according to Formula (22);

$G_{sol;g}$ is the global irradiance, obtained from the climatic data set, as chosen in Table A.2 (normative template), with informative choice in Table B.2, in W/m².

The clearness index of the atmosphere, k_T, is the ratio of the extra-terrestrial global irradiance on the ground to the measured global irradiance

$$k_T = \frac{G_{sol;g}}{I_{ext}} \tag{24}$$

The extra-terrestrial irradiance is calculated according to Formula (20).

The direct normal (beam) irradiance is calculated as the difference of global and diffuse irradiance (horizontal), corrected for the solar altitude:

$$G_{sol;b} = \frac{G_{sol;g} - G_{sol;d}}{\sin(\alpha_{sol})} \tag{25}$$

where

$G_{sol;b}$ is the direct normal (beam) solar irradiance, in W/m^2;

α_{sol} is the solar altitude angle according to Formula (11), in degrees.

NOTE 3 If the solar altitude angle is low, the conversion from direct horizontal to direct normal beam irradiance is very sensitive for tiny errors in the calculation of the solar altitude (see NOTE 1).

Method 2, Other method.

Any other method

Table A.3 provides the template for the choice between method 1 and method 2, with an informative default choice in Table B.3.

6.4.3 Solar reflectivity of the ground

The solar reflectivity of the ground (Albedo), $\rho_{sol;grnd}$, depends on the surface conditions.

The reflectivity can vary with surface properties but also with climatic conditions like snow coverage.

Options for assessing the solar reflectivity of the ground are provided in Table A.4, Table A.5 and Table A.6 (normative template), with informative default choice in Table B.4, Table B.5 and Table B.6.

6.4.4 Calculation of the total solar irradiance at given orientation and tilt angle

6.4.4.1 Direct irradiance

The direct irradiance on the inclined surface, I_{dir}, is determined as function of cosine of the solar angle of incidence and the direct normal (beam) solar irradiance:

NOTE The solar beam irradiance is defined as falling on an surface normal to the solar beam. This is not the same as direct horizontal radiation.

$$I_{dir} = \max\left[0\,;G_{sol;b} \cdot \cos\left(\theta_{sol;ic}\right)\right] \tag{26}$$

where

I_{dir} is the direct irradiance at the inclined surface, in W/m^2;

$G_{sol;b}$ is the direct beam solar irradiance, obtained according to 6.4.2, in W/m^2.

$\theta_{sol;ic}$ is the solar angle of incidence on the inclined surface according to Formula (17), in degrees.

6.4.4.2 Extra-terrestrial radiation

The extra-terrestrial radiation, I_{ext}, the normal irradiance out of the atmosphere as a function of the day is determined by Formula (20):

$$I_{ext} = G_{sol;c} \cdot \left[1+0{,}033 \times \cos\left(\frac{360}{365} \times n_{day} \right) \right] \tag{27}$$

where

I_{ext}	is the extra-terrestrial radiation, in W/m^2;
n_{day}	is the counting number of the day of the year, obtained from the climatic data set, as chosen in Table A.2 (normative template), with informative choice in Table B.2;
$G_{sol;c}$	is the solar angle of incidence on the inclined surface according to Formula (17), in degrees.

6.4.4.3 Diffuse irradiance

The diffuse part of the irradiance on the surface (without ground reflection), I_{dif}, is determined as function of a number of parameters according to Formulae (28) to (33), see Figure 1. The dimensionless parameters a and b:

$$a = \max\left[0\,;\cos(\theta_{sol}) \right] \tag{28}$$

$$b = \max\left[\cos\left(85^\circ \right); \cos(\theta_z) \right] \tag{29}$$

where

a,b	are dimensionless parameters;
θ_z	is the solar zenith angle according to Formula (12), in degrees;
α_{sol}	is the solar altitude angle according to Formula (11), in degrees;
$\theta_{sol;ic}$	is the angle of incidence on the inclined surface according to Formula (17), in degrees.

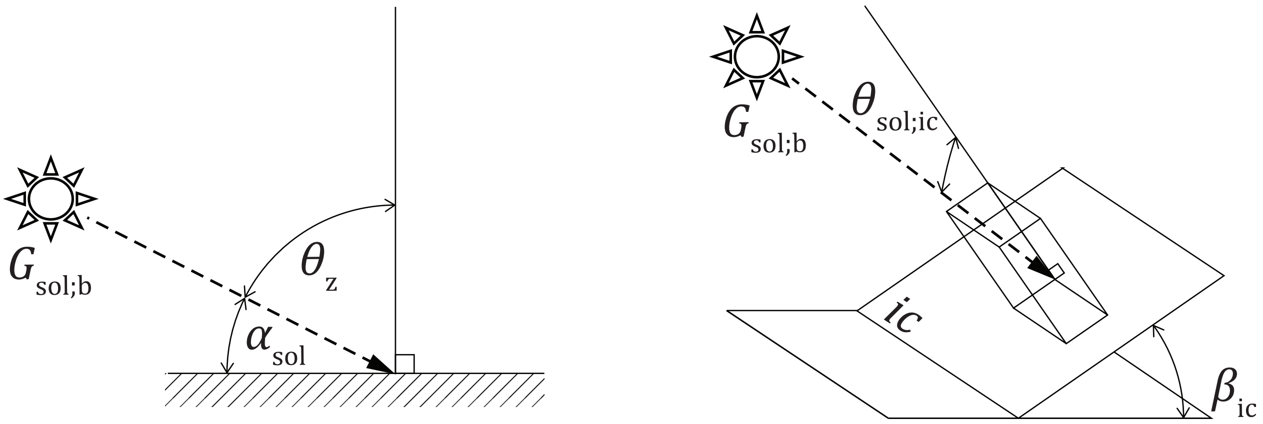

Figure 1 — Beam radiation on an inclined surface

The dimensionless clearness parameter, ε:

$$\varepsilon=\frac{\left[\frac{G_{\mathrm{sol;d}}+G_{\mathrm{sol;b}}}{G_{\mathrm{sol;d}}}+K\cdot\left(\frac{\pi}{180}\cdot\alpha_{\mathrm{sol}}\right)^{3}\right]}{1+K\cdot\left(\frac{\pi}{180}\cdot\alpha_{\mathrm{sol}}\right)^{3}} \tag{30}$$

where

ε	is the dimensionless clearness parameter, anisotropic sky conditions (Perez model);
$G_{\mathrm{sol;d}}$	is the diffuse horizontal irradiance, obtained according to 6.4.2, in W/m²;
$G_{\mathrm{sol;b}}$	is the direct solar beam irradiance, obtained according to 6.4.2, in W/m²;
α_{sol}	is the solar altitude angle according to Formula (11), in degrees;
K	is a constant, obtained according to Table 9, in rad^{-3}.

with

if $G_{\mathrm{sol;d}} = 0$, $\varepsilon = 999$

The circumsolar brightness coefficient, F_1, and horizontal brightness coefficient, F_2:

From Table 8 obtain the brightness coefficients, $f_{i,j}$, that correspond to the value of ε calculated according to Formula (30).

The circumsolar brightness coefficient, F_1, and horizontal brightness coefficient, F_2, are obtained from Formulae (31) to (33):

$$\Delta=m\cdot\frac{G_{\mathrm{sol;d}}}{I_{\mathrm{ext}}} \tag{31}$$

$$F_1=\max\left[0;f_{11}(\varepsilon)+f_{12}(\varepsilon)\cdot\Delta+f_{13}(\varepsilon)\cdot\left(\frac{\pi\,\theta_z}{180}\right)\right] \tag{32}$$

$$F_2=f_{21}(\varepsilon)+f_{22}(\varepsilon)\cdot\Delta+f_{23}(\varepsilon)\cdot\left(\frac{\pi\,\theta_z}{180}\right) \tag{33}$$

with these parameters, the diffuse irradiance is calculated in Formula (34):

$$I_{\mathrm{dif}}=G_{\mathrm{sol;d}}\cdot\left\{(1-F_1)\cdot\frac{\left[1+\cos(\beta_{\mathrm{ic}})\right]}{2}+F_1\cdot\frac{a}{b}+F_2\cdot\sin(\beta_{\mathrm{ic}})\right\} \tag{34}$$

where

Δ	is the dimensionless sky brightness parameter;
m	is the dimensionless air mass according to Formulae (20) and (21);
$G_{\mathrm{sol;d}}$	is the diffuse horizontal irradiance, obtained in accordance with 6.4.2, in W/m²;
I_{ext}	is the extra-terrestrial solar irradiance according to Formula (27), in W/m²;
F_1	is the circumsolar brightness coefficient;
F_2	is the horizontal brightness coefficient;

ε	is the dimensionless clearness parameter anisotropic sky conditions (Perez model) according to Formula (30);
$f_{i,j}$	is the brightness coefficient, anisotropic sky conditions (Perez model) as function of ε;
β_{ic}	is the tilt angle of inclined surface, according to Table 6, in degrees;
θ_z	is the solar zenith angle according to Formula (12), in degrees;
a	is a dimensionless parameter according to Formula (28).
b	is a dimensionless parameter according to Formula (29);
I_{dif}	is the diffuse irradiance, in W/m^2.

6.4.4.4 Diffuse solar irradiance due to ground reflection

The contribution of the ground reflection to the irradiance on the inclined surface, $I_{dif;grnd}$, is determined as function of global horizontal irradiance, which in this case is calculated from the solar altitude, diffuse and beam solar irradiance and the solar reflectivity of the ground:

$$I_{dif;grnd} = \left[G_{sol;d} + G_{sol;b} \cdot \sin\left(\alpha_{sol}\right)\right] \cdot \rho_{sol;grnd} \cdot \frac{\left[1 - \cos\left(\beta_{ic}\right)\right]}{2} \quad (35)$$

where

$I_{dif;grnd}$	is the calculated diffuse solar irradiance on the inclined surface due to ground reflection, in W/m^2;
$G_{sol;d}$	is the diffuse solar irradiance on a horizontal surface, obtained in accordance with 6.4.2, in W/m^2;
$G_{sol;b}$	is the direct normal (beam) solar irradiance, obtained in accordance with 6.4.2, in W/m^2;
α_{sol}	is the solar altitude angle according to Formula (11), in degrees;
β_{ic}	is the angle of slope of inclined surface, according to Table 6, in degrees;
$\rho_{sol;grnd}$	is the solar reflectivity of the ground, obtained in accordance with 6.4.3.

6.4.4.5 Circumsolar irradiance

The circumsolar irradiance, I_{circum}, is calculated from the diffuse irradiance:

$$I_{circum} = G_{sol;d} \cdot F_1 \cdot \frac{a}{b} \quad (36)$$

where

I_{circum}	is the circumsolar irradiance, in W/m^2;
$G_{sol;d}$	is the diffuse radiation on a horizontal plane, obtained in accordance with 6.4.2, in W/m^2;
F_1	is the circumsolar brightness coefficient according to Formula (32);
a, b	are coefficients calculated according to Formulae (28) and (29).

6.4.4.6 Calculated total direct solar irradiance

The total direct irradiance on the inclined surface including circumsolar irradiance, $I_{dir;tot}$, is determined from the direct irradiance plus the circumsolar term of the diffuse irradiance:

$$I_{dir;tot} = I_{dir} + I_{circum} \tag{37}$$

where

$I_{dir;tot}$ is the total direct irradiance on the inclined surface, in W/m²;

I_{dir} is the direct irradiance on the inclined surface according to Formula (26), in W/m²;

I_{circum} is the circumsolar irradiance according to Formula (36), in W/m².

6.4.4.7 Calculated total diffuse solar irradiance

The total diffuse irradiance on the inclined surface excluding circumsolar, $I_{diff;tot}$, and including ground reflected irradiance is the diffuse irradiance minus the circumsolar term plus the diffuse irradiance by ground reflection:

$$I_{dif;tot} = I_{dif} - I_{circum} + I_{dif;grnd} \tag{38}$$

where

$I_{dir;tot}$ is the total diffuse irradiance on the inclined surface, in W/m²;

I_{dif} is the diffuse irradiance on the inclined surface according to Formula (34), in W/m²;

I_{circum} is the circumsolar irradiance according to Formula (36), in W/m²;

$I_{diff;grnd}$ is the irradiance on the inclined surface by ground reflection according to Formula (35), in W/m².

6.4.4.8 Calculated total solar irradiance

The hemispherical or total solar irradiance on the inclined surface without the effect of shading, I_{tot}, is the sum of the calculated total diffuse solar irradiance and the total direct solar irradiance:

$$I_{tot} = I_{dir;tot} + I_{dif;tot} \tag{39}$$

where

I_{tot} is the hemispherical or total solar irradiance on the inclined surface, in W/m²;

$I_{dir;tot}$ is the total direct solar irradiance according to Formula (37), in W/m²;

$I_{dif;tot}$ is the total diffuse solar irradiance according to Formula (38), in W/m².

6.4.5 Calculation of shading by external objects

6.4.5.1 General

Objects in the environment may block part of the solar irradiance on a surface (e.g. hills, trees, other buildings).

The same or other objects may also reflect solar radiation and consequently lead to a higher irradiance.

NOTE 1 For example, on the northern hemisphere, a highly reflecting surface (e.g. glazed adjacent building) in front of the North facing façade of the assessed building.

In order to avoid that for those objects specific solar reflectivity data should be gathered, it is an option, as a simplification, to assume that:

a) The direct radiation (including circumsolar irradiance) is partially blocked, if the object is in the path between sun and surface;

b) the diffuse irradiance (including irradiance from ground reflectance) remains unaffected.

NOTE 2 This is physically equal to the situation where the radiation reflected (and/or transmitted) by the objects in the environment is equal to the diffuse radiation blocked by these objects.

Because different shading objects in the same direction may overlap, serious errors may be introduced due to double counting if the effect of shading objects is calculated separately, by first calculating the irradiance for one set of (e.g. distant) shading objects and then use the output as input to calculate the effect of another set of (e.g. nearby or on site) shading objects.

Therefore, it is recommended that the shading calculation is done in the application standard where the position, location and all surroundings of the irradiated surface are known.

This leads to the following options:

Option 1:

No shading calculation for the irradiance calculated with this document, to avoid double counting.

Option 2:

The shading coefficient by distant objects is calculated as given by one of the following two methods. The choice between option 1 and option 2, and in case of option 2, between method 1 and method 2, is indicated in Table A.7 (template), with informative default choice provided in Table B.7.

— Method 1, Simplified method (shading of direct radiation), see 6.4.5.2.

— Method 2, Detailed method (shading of direct and diffuse radiation), see 6.4.5.3.

ISO 52016-1 contains detailed shading calculation procedures for shading on building elements, including shading from overhangs. The calculation procedure in ISO 52016-1 can also be applied to calculate the effect of shading on solar irradiated system components, such as thermal solar collectors and photovoltaic panels.

6.4.5.2 Method 1, Simplified method (shading of direct radiation)

6.4.5.2.1 General

The total solar irradiance on the inclined surface, $I_{tot;sh}$, is the sum of the calculated total diffuse solar irradiance and the total direct solar irradiance, with the total direct solar irradiance corrected for shading by distant objects by means of the shading coefficient including the effect of shading:

$$I_{tot;sh} = F_{dir} \cdot I_{dir;tot} + I_{dif;tot} \qquad (40)$$

where

$I_{tot;sh}$ is the total solar irradiance on the inclined surface including the effect of shading, in W/m2;

F_{dir} is the shading coefficient for direct irradiance, determined according to 6.4.5.2.2;

$I_{dir;tot}$ is the total direct solar irradiance according to Formula (37), in W/m2;

$I_{dif;tot}$ is the total diffuse solar irradiance according to Formula (38), in W/m2.

6.4.5.2.2 Calculation of the shading coefficient by distant objects

The direct shading coefficient, F_{dir}, is determined by the solar altitude angle and the geometry of the shaded surface and the shading object, see Figure 2.

For the specification of the shading objects, the skyline is divided into a number of segments, $n_{sh;segm}$, each characterized by the upper boundary of the azimuth angle, $\gamma_{sh;obst;max}$, using the convention in this document: angle from South, eastwards positive, westwards negative.

NOTE 1 North- > East- > South- > West- > North = −180 - > −90 - > 0 - > +90 - > +180 degrees.

The choice in the number of segments, and whether the size of the segments are fixed or flexible, is given in Table A.8 (template), with informative default choice provided in Table B.9.

For the shading object in the segment that matches the azimuth of the sun, φ_{sol} determined in 6.4.1.7, the direct shading coefficient is determined with Formula (41):

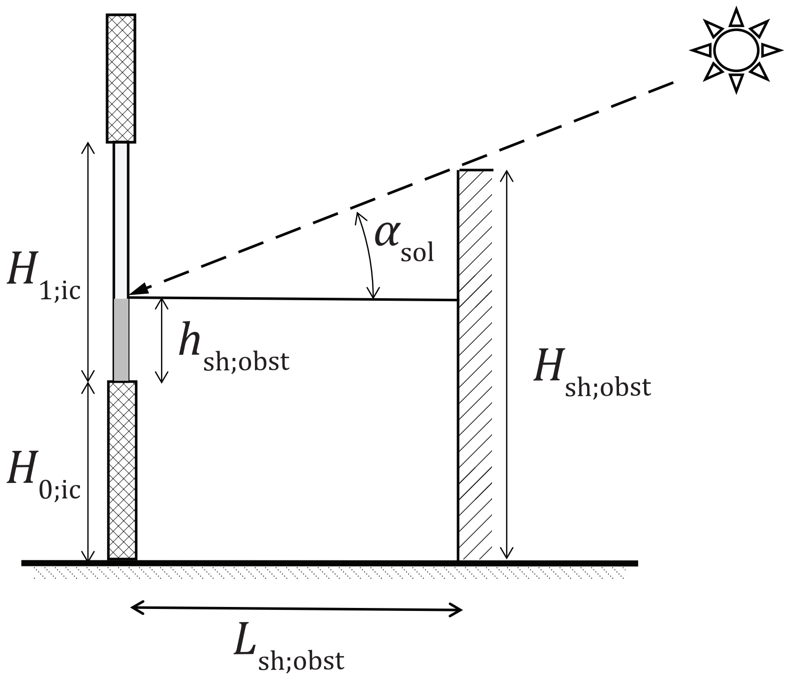

Figure 2 — Shading of the direct solar beam due to distant shading objects (Vertical cross-section)

$$F_{dir} = \max\left[0; \frac{H_{1;ic} - h_{sh;obst}}{H_{1;ic}}\right] \tag{41}$$

with

$$h_{sh;obst} = \max\left[0, H_{sh;obst} - H_{0;ic} - L_{sh;obst} \cdot \tan(\alpha_{sol})\right] \tag{42}$$

where

F_{dir} is the dimensionless direct shading coefficient of the shaded surface;

$H_{0;ic}$ is the base height of the shaded surface, from ground level, obtained according to Table 7, in m;

$H_{1;ic}$ is the height of the shaded surface, from bottom to top(if tilted: vertical projection), obtained according to Table 7, in m;

$h_{sh;obst}$ is the height of the shade on the shaded surface; if tilted: vertical projection, in m;

$H_{sh;obst}$ is the height of the shading obstacle, from ground level, obtained according to Table 7, in m;

$L_{sh;obst}$ is the horizontal distance to the shading object in the direction of the solar beam, obtained according to Table 7, in m;

α_{sol} is the solar altitude angle according to Formula (11), in degrees.

If the vertical cross section of the shaded object is not constant, the vertical cross section shall be assessed in the middle of the object.

The calculation procedures in which the calculation of shading by external objects is applied, may comprise rules for the subdivision of the shaded object.

NOTE 2 For instance: per window or per façade or ...; per PV module, or per array of modules or ...; etc.

6.4.5.3 Method 2: Detailed method (shading of direct and diffuse radiation)

In this method shading by diffuse solar radiation is also taken into account.

The diffuse shading coefficient, F_{dif}, is determined using the detailed calculation procedures of ISO 52016-1:2017, F.2. In that Annex the obstacles are on the building or close by. These are called “remote objects”. The method is however the same in case of external objects.

For this method sky view factors should be calculated. This can be simplified by dividing the skyline in a number of segments and calculate the sky view factors for each segment separately assuming an equal skyline height over the segment.

6.4.6 Calculation of illuminance

For the luminance distribution of the sky and ground the irradiance is converted into illuminance by one of the following two methods:

Method 1, Default method: Multiplication with the global luminous efficacy. Value without taking into account solar shading:

$$E_v = K_v \cdot I_{tot} \tag{43}$$

where

E_v is the global illuminance of a surface, in lx;

K_v is the global luminous efficacy according to Table 9, in lm/W;

I_{tot} is hemispherical solar irradiance according to Formula (39), in W/m^2.

Method 2, Alternative method.

The choice between method 1 and method 2, is indicated in Table A.9 (template), with informative default choice provided in Table B.9.

NOTE Examples of more detailed methods are given in ISO/TR 52010-2[6].

7 Quality control

The following checks can be made to increase confidence in correct implementation of the calculation procedures of this document:

a) Check for each output if the values are within the expected range. Incidental insignificant negative solar irradiation values are allowed, especially at low solar angles.

NOTE At very low sun position (e.g. a few degrees above horizon), the conversion of solar direct normal beam irradiance to irradiance at horizontal plane (multiplication by the sine of solar altitude) is extremely sensitive for the correct calculation (and correct measurement) of the solar time. A few minutes difference can already have a significant effect. Also the apparent size of the sun disc can play a role. This can even result in small negative values of the diffuse irradiance. The effects when the time series is applied on a building or system component is normally negligible,

b) Calculate the hourly diffuse and total irradiance on a horizontal plane. These should match the measured hourly values of the same properties that are used as input (if both available). A perfect match is not to be expected, because of the use of several empirical correlation coefficients (Perez model).

c) Reproduce the example calculation of the full year time series in the accompanying technical report.

8 Compliance check

In 6.3.2 procedures are given for references to documentation to give information on the background and construction of the climatic data time series and the application range.

Annex A
(normative)

Input and method selection data sheet — Template

A.1 General

The template in Annex A of this document shall be used to specify the choices between methods, the required input data and references to other standards.

NOTE 1 Following this template is not enough to guarantee consistency of data.

NOTE 2 Informative default choices are provided in Annex B. Alternative values and choices can be imposed by national/regional regulations. If the default values and choices of Annex B are not adopted because of the national/regional regulations, policies or national traditions, it is expected that:

— national or regional authorities prepare data sheets containing the national or regional values and choices, in line with the template in Annex A; or

— by default, the national standards body will add or include a national annex (Annex NA) to this document, in line with the template in Annex A, giving national or regional values and choices in accordance with their legal documents.

NOTE 3 The template in Annex A is applicable to different applications (e.g., the design of a new building, certification of a new building, renovation of an existing building and certification of an existing building) and for different types of buildings (e.g., small or simple buildings and large or complex buildings). A distinction in values and choices for different applications or building types could be made:

— by adding columns or rows (one for each application), if the template allows;

— by including more than one version of a table (one for each application), numbered consecutively as a, b, c, ... For example: Table NA.3a, Table NA.3b;

— by developing different national/regional data sheets for the same standard. In case of a national annex to the standard these will be consecutively numbered (Annex NA, Annex NB, Annex NC, ...).

NOTE 4 In the section “Introduction” of a national/regional data sheet information can be added, for example about the applicable national/regional regulations.

NOTE 5 For certain input values to be acquired by the user, a data sheet following the template of Annex A, could contain a reference to national procedures for assessing the needed input data. For instance, reference to a national assessment protocol comprising decision trees, tables and pre-calculations.

The shaded fields in the tables are part of the template and consequently not open for input.

A.2 References

The references, identified by the EPB module code number, are given in Table A.1 (template).

Table A.1 — References

Reference	Reference document	
	Number	Title
Mx-y[a]	...	...
	...	...

[a] In this document there are no choices in references to other EPB standards. The Table is kept to maintain uniformity between all EPB standards

A.3 Climatic input data

Table A.2 — Weather station and climatic data set (See 6.3.2)

Name	Value					
Identifier for climatic data set	< text >					
Station and/or name of data set	< text >					
	Symbol	Unit	Value	Validity interval[a]	Origin	Varying[b]
latitude	φ_{w}	°		−90 to +90	station	No
longitude [c]	λ_{w}			−180 to +180	station	No
time zone	TZ	h		−12 to +12	station	No
First day of time series (day of the year)	$n_{\mathrm{day;start}}$	-		1 to 366	station	No
Last day of time series (day of the year)	$n_{\mathrm{day;end}}$	-		1 to 366	station	No
Day of the week for January 1		-		Monday to Sunday (day 1 to 7)	station	No
Daylight saving time? [c]	Example of possible input: — Applicable for this station and taken into account; — Applicable for this station but disregarded; — Not applicable for this station.					
Leap day included	Yes/No					
Specific other information	< free text >					
Name	**Value**					
Reference to documentation on application range and type of data	< free text >					

[a] Practical range, informative.

[b] "Varying": value may vary over time: different values per time interval, for instance: hourly values or monthly values (not constant values over the year).

[c] If Yes: additional information to be added.

A.4 Calculation method

Table A.3 — Method to assess direct (beam) irradiance if not available from weather station (See 6.4.2)

Method		Choice Yes/No[a]
1	Default method	YES or NO
2	Other method	YES or NO
In case of method 2:		
	Reference to procedure:	< Reference >
[a] Only one choice possible.		

Table A.4 — Solar reflectivity of the ground ($\rho_{sol;grnd}$) (See 6.4.3)

Name	Value[a]
Fixed value	YES/NO
Dependent on ground condition, listed in climatic data file	YES/NO
Dependent on local ground condition (near the inclined surface)	YES/NO
Values available in climatic data file	YES/NO
[a] Only one choice possible.	

If fixed value:

Table A.5 — Solar reflectivity of the ground; if fixed value

Name	Value
Solar reflectivity of the ground, $\rho_{sol;grnd}$ [-]	0 to 1

If dependent on ground condition:

Table A.6 — Solar reflectivity of the ground; if dependent on ground conditions

Description of ground condition[a]	Value for solar reflectivity of the ground, $\rho_{sol;grnd}$ [-]
Dry or wet ground snow free	0 to 1
…	0 to 1
[a] Example; rows can be added or deleted.	

Table A.7 — Choice between options and methods for calculation of shading by external objects (See 6.4.5.1)

Application[b]	.....	....
Description	**Choice**	**Choice**
Effect of shading calculated in this document?	Yes/No	Yes/No
If Yes:	**Choice**[a]	**Choice**[a]
Only method 1, Simplified method (shading of direct radiation)	Yes/No	Yes/No
Only method 2, Detailed method (shading of direct and diffuse radiation)	Yes/No	Yes/No
Both methods are allowed	Yes/No	Yes/No

[a] Only one Yes per column possible.

[b] Add more columns if needed to differentiate between applications (e.g. building categories, new or existing buildings, etc.).

Table A.8 — Number of skyline segments, $n_{sh;segm}$ for input solar shading objects (See 6.4.5.2)

Application[b]	.....	....
Description	**Value of $n_{sh;segm}$**[a]	**Value of $n_{sh;segm}$**[a]
Maximum number of segments over 360 degrees	8 to 36	8 to 36
Fixed width (= 360 / $n_{sh;segm}$) [c]	Yes/No	Yes/No

[a] Practical range, informative.

[b] Add more columns if needed to differentiate between applications (e.g. building categories, new or existing buildings, etc.).

[c] If not fixed, the width of each segment can be adapted to the width of the shading object, with limitation of maximum number of segments $n_{sh;segm}$.

Table A.9 — Choice between methods for calculation of illuminance (See 6.4.6)

Application[a]	.....	....
Description	**Choice**	**Choice**
Method 1, Default method, or Method 2, Alternative method	Method 1 or method 2	Method 1 or method 2
If choice is method 2:	**Description**	**Description**
Describe method 2	Reference or formula	Reference or formula

[a] Add more columns if needed to differentiate between applications (e.g. building categories, new or existing buildings, etc.).

Annex B
(informative)

Input and method selection data sheet — Default choices

B.1 General

The template in Annex A of this document shall be used to specify the choices between methods, the required input data and references to other standards.

NOTE 1 Following this template is not enough to guarantee consistency of data.

NOTE 2 Informative default choices are provided in Annex B. Alternative values and choices can be imposed by national/regional regulations. If the default values and choices of Annex B are not adopted because of the national/regional regulations, policies or national traditions, it is expected that:

— national or regional authorities prepare data sheets containing the national or regional values and choices, in line with the template in Annex A; or

— by default, the national standards body will add or include a national annex (Annex NA) to this document, in line with the template in Annex A, giving national or regional values and choices in accordance with their legal documents.

NOTE 3 The template in Annex A is applicable to different applications (e.g., the design of a new building, certification of a new building, renovation of an existing building and certification of an existing building) and for different types of buildings (e.g., small or simple buildings and large or complex buildings). A distinction in values and choices for different applications or building types could be made:

— by adding columns or rows (one for each application), if the template allows;

— by including more than one version of a table (one for each application), numbered consecutively as a, b, c, ... For example: Table NA.3a, Table NA.3b;

— by developing different national/regional data sheets for the same standard. In case of a national annex to the standard these will be consecutively numbered (Annex NA, Annex NB, Annex NC, ...).

NOTE 4 In the section “Introduction” of a national/regional data sheet information can be added, for example about the applicable national/regional regulations.

NOTE 5 For certain input values to be acquired by the user, a data sheet following the template of Annex A, could contain a reference to national procedures for assessing the needed input data. For instance, reference to a national assessment protocol comprising decision trees, tables and pre-calculations.

The shaded fields in the tables are part of the template and consequently not open for input.

B.2 References

The references, identified by the EPB module code number, are given in Table B.1.

Table B.1 — References

Reference	Reference document	
	Number	Title
Mx-y[a]	...	...
	...	...

[a] In this document there are no choices in references to other EPB standards. The Table is kept to maintain uniformity between all EPB standards.

B.3 Climatic input data

Table B.2 — Weather station and climatic data set (See 6.3.2)

Name	Value					
Identifier for climatic data set	DRYCOLD.TMY					
Station and/or name of data set	Denver, Colorado, USA File: DRYCOLD.TMY					
	Symbol	Unit	Value	Validity interval[a]	Origin	Varying[b]
latitude	φ_{w}	°	39,76	−90 to +90	station	No
longitude [c]	λ_{w}		−104,86	−180 to +180	station	No
time zone	*TZ*	h	−7	−12 to +12	station	No
First day of time series (day of the year)	$n_{\mathrm{day;start}}$	-	1	1 to 366	station	No
Last day of time series (day of the year)	$n_{\mathrm{day;end}}$	-	365	1 to 366	station	No
Day of the week for January 1		-	Monday (day 1)	Monday to Sunday (day 1 to 7)	station	No
Daylight saving time? [c]						
Leap day included	No					
Specific other information	Time at this station: Winter: MST = UTC − 7 Summer: MDT = UTC − 6					
Name	**Value**					
Reference to documentation on application range and type of data	ANSI/ASHRAE standard 140[10]					

[a] Practical range, informative.

[b] “Varying”: value may vary over time: different values per time interval, for instance: hourly values or monthly values (not constant values over the year).

[c] If Yes: additional information to be added.

B.4 Calculation method

Table B.3 — Method to assess direct (beam) irradiance if not available from weather station (See 6.4.2)

Method		Choice Yes/No[a]
1	Default method	YES
2	Other method	NO
In case of method 2:		
	Reference to procedure:	Not applicable

[a] Only one choice possible.

Table B.4 — Solar reflectivity of the ground ($\rho_{sol;grnd}$) (See 6.4.3)

Name	Value[a]
Fixed value	YES
Dependent on ground condition, listed in climatic data file	NO
Dependent on local ground condition (near the inclined surface)	NO
Values available in climatic data file	NO

[a] Only one choice possible.

If fixed value:

Table B.5 — Solar reflectivity of the ground; if fixed value

Name	Value
Solar reflectivity of the ground, $\rho_{sol;grnd}$ [-]	0,2

If dependent on ground condition:

Not applicable and therefore no Table B.6 given.

Table B.7 — Choice between options and methods for calculation of shading by external objects (See 6.4.5.1)

Application[b]	All applications	
Description	**Choice**	
Effect of shading calculated in this document?	No	
If Yes:	**Choice**[a]	
Only method 1, Simplified method (shading of direct radiation)	Yes	
Only method 2, Detailed method (shading of direct and diffuse radiation)	No	
Both methods are allowed	No	

[a] Only one Yes per column possible.

[b] Add more columns if needed to differentiate between applications (e.g. building categories, new or existing buildings, etc.).

Table B.8 — Number of skyline segments, $n_{sh;segm}$ for input solar shading objects (See 6.4.5.2)

Application[b]	All applications	....
Description	**Value of $n_{sh;segm}$**[a]	**Value of $n_{sh;segm}$**[a]
Maximum number of segments over 360 degrees	15	
Fixed width (= 360 / $n_{sh;segm}$) [c]	No	

[a] Practical range, informative.

[b] Add more columns if needed to differentiate between applications (e.g. building categories, new or existing buildings, etc.).

[c] If not fixed, the width of each segment can be adapted to the width of the shading object, with limitation of maximum number of segments $n_{sh;segm}$.

Table B.9 — Choice between methods for calculation of illuminance (See 6.4.6)

Application[a]	All applications	....
Description	**Choice**	**Choice**
Method 1, Default method, or Method 2, Alternative method	Method 1	
If choice is method 2:	**Description**	**Description**
Describe method 2	Not applicable	

[a] Add more columns if needed to differentiate between applications (e.g. building categories, new or existing buildings, etc.).

Bibliography

[1] ISO 15927-1, *Hygrothermal performance of buildings — Calculation and presentation of climatic data — Part 1: Monthly means of single meteorological elements*

[2] ISO 15927-2, *Hygrothermal performance of buildings — Calculation and presentation of climatic data — Part 2: Hourly data for design cooling load*

[3] ISO 15927-4, *Hygrothermal performance of buildings — Calculation and presentation of climatic data — Part 4: Hourly data for assessing the annual energy use for heating and cooling*

[4] ISO 15927-5, *Hygrothermal performance of buildings — Calculation and presentation of climatic data — Part 5: Data for design heat load for space heating*

[5] ISO 15927-6, *Hygrothermal performance of buildings — Calculation and presentation of climatic data — Part 6: Accumulated temperature differences (degree-days)*

[6] ISO/TR 52010-2, *Energy performance of buildings — External climatic conditions — Part 2: Explanation and justification of ISO 52010-1*

[7] ISO/TR 52000-2, *Energy performance of buildings — Overarching EPB assessment – Part 2: Explanation and justification of ISO 52000-1*

[8] CEN/TS 16628, *Energy performance of buildings — Basic principles for the set of EPB standards*

[9] CEN/TS 16629, *Energy performance of buildings — Detailed technical rules for the set of EPB standards*

[10] ANSI/ASHRAE standard 140, Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs, 2014

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