TECHNICAL REPORT

**ISO/TR 52010-2**

First edition
2017-06

# Energy performance of buildings - External climatic conditions —

## Part 2: **Explanation and justification of ISO 52010-1**

*Performance énergétique des bâtiments — Conditions climatiques extérieures —*

*Partie 2: Explication et justification de l'ISO 52010-1*



Reference number
ISO/TR 52010-2:2017(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/TR 52010-2 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 parts in the ISO 52010 series can be found on the ISO website.

# Introduction

**The set of EPB standards, technical reports and supporting tools**

In order to facilitate the necessary overall consistency and coherence, in terminology, approach, input/output relations and formats, for the whole set of EPB-standards, the following documents and tools are available:

a) a document with basic principles to be followed in drafting EPB-standards: CEN/TS 16628:2014, *Energy Performance of Buildings - Basic Principles for the set of EPB standards*[1];

b) a document with detailed technical rules to be followed in drafting EPB-standards: CEN/TS 16629:2014, *Energy Performance of Buildings - Detailed Technical Rules for the set of EPB-standards*[2];

The detailed technical rules are the basis for the following tools:

1) a common template for each EPB standard, including specific drafting instructions for the relevant clauses;

2) a common template for each technical report that accompanies an EPB standard or a cluster of EPB standards, including specific drafting instructions for the relevant clauses;

3) a common template for the spreadsheet that accompanies each EPB (calculation) standard, to demonstrate the correctness of the EPB calculation procedures.

Each EPB standard follows the basic principles and the detailed technical rules and relates to the overarching EPB standard, ISO 52000-1 [3].

One of the main purposes of the revision of the EPB standards has been to enable that laws and regulations directly refer to the EPB standards and make compliance with them compulsory. This requires that the set of EPB standards consists of a systematic, clear, comprehensive and unambiguous set of energy performance procedures. The number of options provided is kept as low as possible, taking into account national and regional differences in climate, culture and building tradition, policy and legal frameworks (subsidiarity principle). For each option, an informative default option is provided (Annex B).

**Rationale behind the EPB technical reports**

There is a risk that the purpose and limitations of the EPB standards will be misunderstood, unless the background and context to their contents – and the thinking behind them – is explained in some detail to readers of the standards. Consequently, various types of informative contents are recorded and made available for users to properly understand, apply and nationally or regionally implement the EPB standards.

If this explanation would have been attempted in the standards themselves, the result is likely to be confusing and cumbersome, especially if the standards are implemented or referenced in national or regional building codes.

Therefore each EPB standard is accompanied by an informative technical report, like this one, where all informative content is collected, to ensure a clear separation between normative and informative contents (see CEN/TS 16629[2]):

— to avoid flooding and confusing the actual normative part with informative content,

— to reduce the page count of the actual standard, and

— to facilitate understanding of the set of EPB standards.

This was also one of the main recommendations from the European CENSE project[10] that laid the foundation for the preparation of the set of EPB standards.

## This document

This document accompanies ISO 52010-1, which forms part of the set of EPB standards.

The role and the positioning of the accompanied standard in the set of EPB standards is defined in the Introduction to ISO 52010-1.

Brief articles on the subject can be found in [27] and [28].

ISO 52010-1 provides the common standard climatic data to be used as input by all EPB standards. It builds on ISO 15927-1, ISO 15927-2 and ISO 15927-4 and completes a missing link: the calculation of the distribution of solar irradiation and illuminance on a non-horizontal plane based on measured hourly solar radiation data on a horizontal surface; with or without taking into account solar shading.

Typical inputs for ISO 52010-1 are the hourly values for diffuse horizontal and direct beam solar irradiation. However, these quantities are not necessarily directly measured. In many cases, only the global horizontal irradiation is available as measured parameter, and the two components need to be calculated with a model. There are alternative models provided, open for choice at national or regional level.

For ground reflectivity often a constant value of, e.g., 0,2 is used. However, the value depends greatly on the surface conditions, and the influence on the irradiation is not negligible. Therefore, the option of providing hourly values is included. This may be especially of importance for mountain regions or for high latitudes.

For the solar shading calculation, the height and distance of each shading object are given per sector of the horizon (360 degrees). The subdivision into sectors (small or large) is open for national or regional choice. The same solar shading calculation procedure is adopted in ISO 52016-1 [5] for the calculation of the building energy needs and loads. This is especially important because if there are different shading objects in the same sector, it will not be correct to calculate the effects separately in different standards. It is up to national or regional choice to decide about the details of the solar shading calculations.

## Accompanying spreadsheet

In line with the common template for all EPB standards, a spreadsheet has been prepared for demonstration and validation. This spreadsheet shows an overview of all input variables, the (step by step) hourly calculation procedures and an overview of all output variables.

This accompanying calculation spreadsheet (July 2016) provides:

— full year of hourly calculations of solar irradiance (split in components) on plane with any azimuth and tilt angle;

— validated against BESTEST cases;

— hourly calculations of solar shading by multiple shading objects along the skyline. These calculations also cover the calculation procedures for overhangs from ISO 52016-1[5].

This spreadsheet (including possible updated version) is available at www.epb.center.

# Energy performance of buildings - External climatic conditions —

# Part 2: Explanation and justification of ISO 52010-1

## 1 Scope

This document contains information to support the correct understanding and use of ISO 52010-1.

This document does not contain any normative provision.

## 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/ 52010-1:2010, *Energy performance of buildings — External climatic conditions — Part 1: Conversion of climatic data for energy calculations*

NOTE More information on the use of EPB module numbers, in all EPB standards, for normative references to other EPB standards is given in ISO/TR 52000-2[4].

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 52010-1, apply.

More information on some key EPB terms and definitions is given in ISO/TR 52000-2 [4].

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

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

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

## 4 Symbols and subscripts

For the purposes of this document, the symbols and subscripts given in ISO 52010-1, apply.

More information on key EPB symbols and subscripts is given in ISO/TR 52000-2[4].

## 5 Description of the methods

### 5.1 Output of the method

Beside solar radiation data, ISO 52010-1 also contains data regarding

— air temperature;

— atmospheric humidity;

— wind speed;

— wind direction;

— longwave radiation.

The definitions and data are obtained from the ISO 15927 series regarding hygrothermal performance of buildings ([7],[8]).

The reason for passing these data via this standard is to have one single and consistent source for all EPB standards and to enable any treatment if needed for specific application. The above mentioned climatic data are not processed in this standard.

## 5.2 General description of the method

### 5.2.1 Calculation of the distribution of solar irradiance on a non-horizontal plane

It is (Torres 2006[20],) of paramount importance for HVAC (heating, ventilating and air conditioning) and photovoltaic systems designers to have suitable models requiring usually available data in order to calculate the irradiance on the plane where conversion systems are located.

From all the models developed to fulfil this objective, the one of conversion or translation proposed by Perez et al. (1986) has been widely used, as it considers all sky conditions ranging from completely covered to clear sky (Pohlen et al., 1996[17]).

Essentially, the model is composed of three different components:

1) a geometric representation of the sky dome,

2) a parametric representation of the insolation conditions, and

3) a statistic component linking both components mentioned before (Perez et al., 1987[15]).

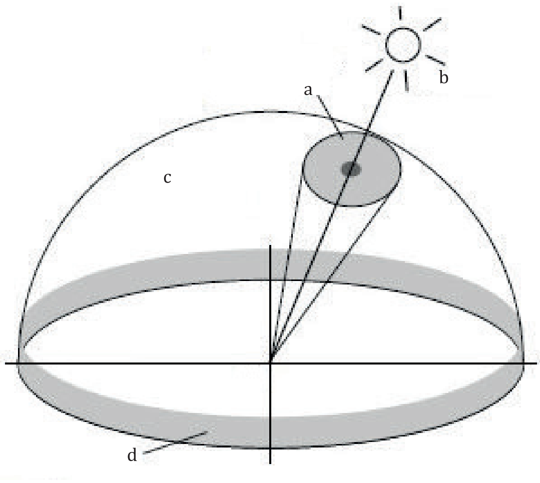
It is a model of anisotropic sky, where the sky dome is geometrically divided into three areas, each of them showing a constant radiance, different from the other two (see Figure 1).

These three areas are:

— isotropic diffuse (for the sky hemisphere);

— circumsolar radiation;

— horizon brightness.




**Key**

a circumsolar radiation

b sunbeam

c atmosphere

d horizon brightening

**Figure 1 — Sky hemisphere areas according to Perez**

And to be added to these three:

— Isotropic ground reflected radiation.

This anisotropic diffuse (sky) radiation for the plane uses as input hourly values the diffuse horizontal and direct beam solar radiation. Other inputs to the model include the sun's incident angle to the plane, the plane tilt angle from the horizontal, and the sun's zenith angle.

The model is named after Mr Perez. Several improvements were made in the course of time, see the list of references in the bibliography.

The calculation procedure described in ISO 52010-1 is based on the "simplified Perez model" proposed in the early 90s.

### 5.2.2 Calculation of solar shading by distant objects

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

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

NOTE 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 are gathered. It is, as simplification, assumed that:

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

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

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.

Examples of the calculation are presented in Clause 10.

An alternative method is to take diffuse shading into account. In order to do this sky view factors are calculated. This can be simplified by dividing the skyline in different segments and calculate the sky view factors for each segment separately assuming an equal skyline height over the segment. This approach is presented as an option in ISO 52016-1[5], with informative calculation procedures provided in ISO/TR 52016-2[6].

# 6 Calculation method

## 6.1 Output data

No special limitations on the output are applicable.

## 6.2 Calculation time intervals

The conversion from measured solar irradiance on horizontal surface to an arbitrary inclined surface is instantaneous. Most measured data are available integrated over a period of an hour. To convert this data special care is taken for the calculation of the solar position used for the conversion. The position is determined in the middle of the measured period. In the determination of the hour angle (ISO 52010-1:2017, 6.4.1.5) this is taken into account.

## 6.3 Input data

No additional information beyond the accompanied standard.

## 6.4 Calculation procedure

### 6.4.1 Calculation of the sun path

See explanation in 6.2 on the sensitivity of the calculation results for the position of the sun. See also ISO 52010-1:2017, Clause 7.

### 6.4.2 Split between direct and diffuse solar irradiance

A number of models, based on statistical analysis of measured data, have been developed in different climates to enable global solar irradiance to be split into the direct and diffuse parts, if such split is not directly available from measured data.

The European Solar Radiation Atlas (3rd edition) contains a complete description of methods for analysing solar data. The European Solar Radiation Atlas (4th edition of 2000, ESRA 4[20]) contains on a CD-Rom not only a database but also 10 algorithmic chains for deriving modified quantities.

On Method 1 in ISO 52010-1:2017, 6.4.2.1:

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 statistical results in Erbs[19].

### 6.4.3 Solar reflectivity of the ground

No additional information beyond the accompanied standard.

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

See also the general brief explanation given in 5.2.1.

The method in ISO 52010-1 is based on the Perez 1990 method as described in Duffie and Beckman[21].

There are two minor points of discussion.

1) In different literature different values for the values for clearness parameter and brightness coefficient are used (ISO 15010-1:2017, Table 10). The values used in ISO 52010-1 are based on the publication in Duffie and Beckman. The values found in other literature do not differ significantly.

2) In different literature several definitions of the a and b factors (ISO 52010-1:2017, 6.4.2) are given. The values are used to determine the circumsolar component. The definitions used are based on the publication in Duffie and Beckman.

### 6.4.5 Calculation of shading by external objects

See the general brief explanation given in 5.2.2.

### 6.4.6 Calculation of illuminance

See the more detailed method described in Clause 9.

## 7 Quality control

A number of checks can be made to increase confidence in correct implementation of the calculation procedures of the standard. These are presented in ISO 52010-1:2017, Clause 7.

Annex C shows examples of such checks; see in particular Table C.5 and Figure C.2.

## 8 Compliance check

No additional information beyond the accompanied standard.

## 9 Directional (spatial) distribution of hourly solar irradiation or illumination (not covered in ISO 52010-1)

### 9.1 General

The distribution of irradiation on a non-horizontal plane calculated hourly with the method described in the standard can be used to provide a more detailed spatial distribution.

Such detailed spatial distribution can be used for situations where the directional distribution of the solar radiation or luminance is relevant,[24] for instance in case of non-isotropic window elements (e.g., Venetian blinds), (other) daylight elements with Bi-directional Transmission (and Reflection) Distribution Functions (BTDF), for instance for the assessment of task illuminance levels and/or to assess the luminance distribution in a room, discomfort glare or other visual comfort related parameters in a room (with or without additional artificial lighting).

The method used in the standard ISO 52010-1 (based on Perez) yields the following components:

— beam radiation (direct from the sun),

— circumsolar radiation from the immediate vicinity of the sun,

— isotropic diffuse radiation,

— near-horizon radiation,

— ground reflected radiation (assumed to be homogeneously diffuse).

The conversion from radiation to luminance can be done on the basis of the assumption of a constant luminous efficacy (lm/W); see, e.g., ISO 52010-1:2017, 6.4.6.

## 9.2 Tregenza elements

It was Tregenza[23] who suggested the distribution of the sky into 145 elements, to obtain the spatial distribution of the (solar radiation and) luminance over the hemisphere seen by an object (see Figure 2).

Seen from a horizontal position, the 145 Tregenza elements are:

For the sky hemisphere.

Angles from zenith: 0, 12, 24, 36, 48, 60, 72, 84 degrees

Covering azimuth of: 360, 60, 30, 20, 15, 15, 12, 12 degrees

EXAMPLE 360/360 = 1 point at zenith; 360/12 = 30 points in circle at 84 degrees from zenith (6 degrees above horizon).

And similarly: 145 Tregenza elements for the ground hemisphere.

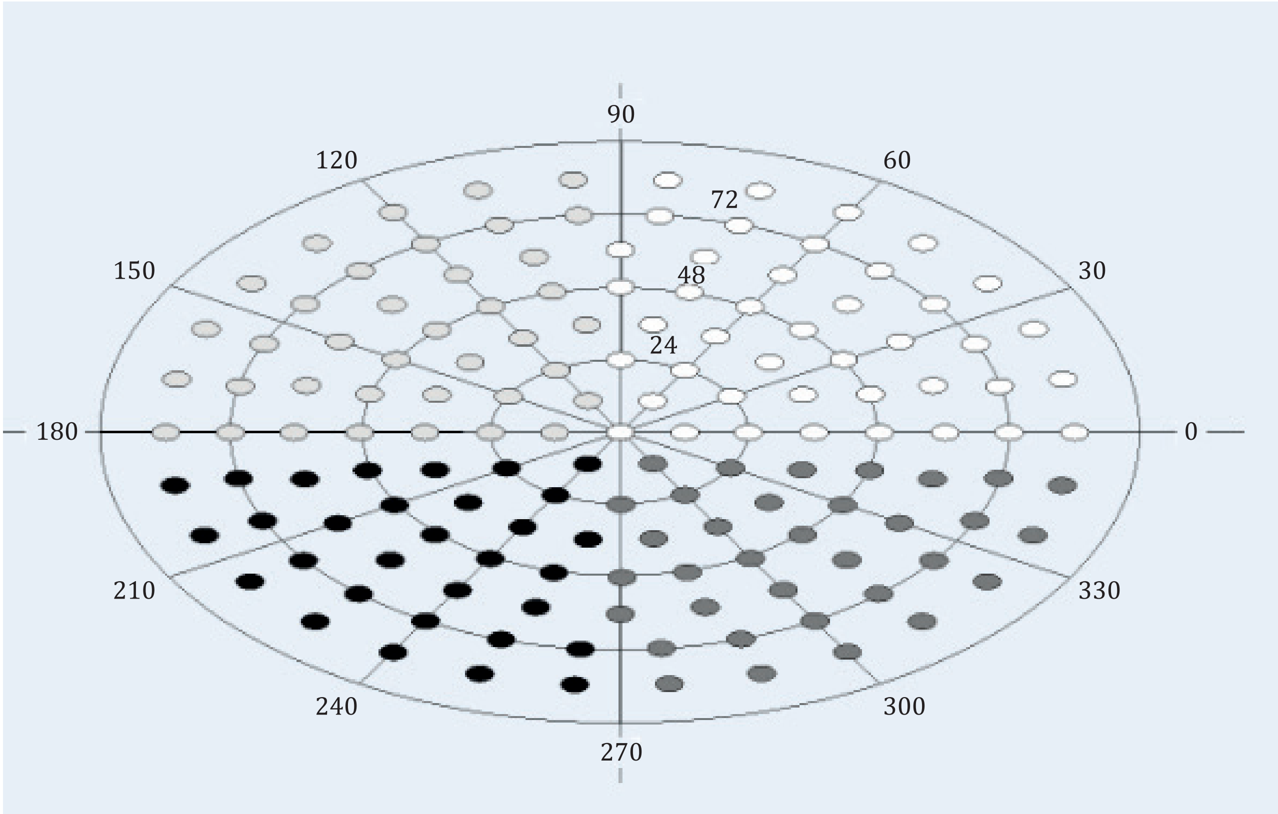



**Figure 2 — Spatial distribution according to Tregenza**

## 9.3 Allocation of the radiation in each element

For each Tregenza elements in the sky and ground hemispheres the radiation intensity is determined in the following way:

The **beam** radiation is attributed to the nearest Tregenza element.

The **circumsolar** radiation is attributed to the same Tregenza element as the beam radiation.

NOTE 1 The equation for circumsolar radiation has been slightly adapted compared to Perez, to allow a calculation without pre-knowledge of the orientation and tilt of the plane; see REVIS FD 19[26].

NOTE 2 For the luminance distribution of the sky, the beam plus circumsolar radiation are stored separately from the other parts to avoid that the high luminance from the (small) sun is diluted in the (large) Tregenza element as explained in REVIS FD 17[25].

The **isotropic diffuse** radiation is equally distributed over all 145 Tregenza sky elements.

The **near horizon** radiation is equally distributed over the row of Tregenza sky elements around the horizon.

NOTE 3 The total value is twice the value used by Perez, because we distribute the near horizon radiation over 360° of the horizon, while Perez 'sees' only 180°.

The **ground reflected** radiation is equally distributed over all 145 Tregenza ground elements.

For the luminance distribution of the sky and ground we convert the radiation into luminance by multiplication with the luminous efficacy. As value for the luminous efficacy we use 115 lm/W which is the average value for different types of sky.

## 9.4 Plane at certain orientation and tilt

For a given plane such as the façade of a building, or any other (e.g., tilted) plane for which the incident radiation or illuminance is to be calculated, we need to know the radiation or luminance for 145 Tregenza elements which are defined for the hemisphere seen from the plane surface.

To that extent, we need to determine which of the sky and ground Tregenza elements are seen from the plane surface.

But in general, the Tregenza elements from the plane surface do not precisely match the Tregenza elements from the sky and/or ground hemispheres.

It is necessary to use a fixed grid of Tregenza points related to the surface of the plane, because the positions of the Tregenza elements should match the positions in the outdoor hemisphere for which the response factors have been pre-calculated.

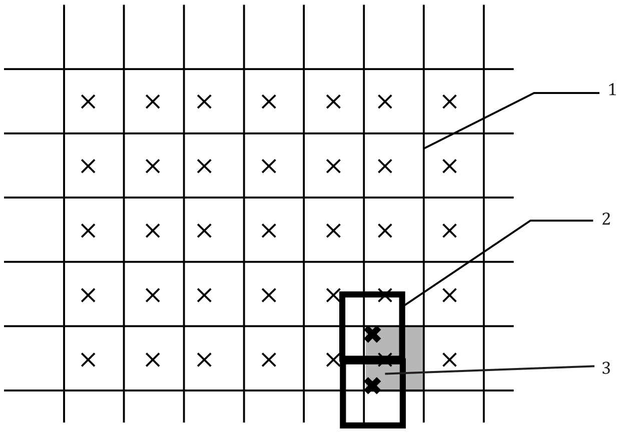
NOTE As a matter of fact: even if the plane is turned around its normal (turned in its own plane) the Tregenza points should turn as well, because the transmission is in general not rotational symmetric. This is related to the convention of marking a daylighting product sample (e.g., in REVIS: in the top left corner facing the light source; see REVIS FD 03, Formats for testing and reporting; see[22]).

The fixed grid is also needed when using the calculation to obtain statistical information concerning the angular distribution of radiation or luminance on the plane.

One possibility to convert the radiation distribution over the Tregenza sky and ground elements to the radiation distribution over the Tregenza elements of the plane, is to take the radiation from the nearest sky or ground element.

However, this may result in a wrong sum of radiation over all elements.

See Figure 3: the two shown grid elements of the plane would both have the same sky/ground element being the closest element (the shaded element). If they both take the radiance/luminance value from this same element, then the total sum may be wrong, because some sky/ground elements will be over-represented and other under-represented.




**Key**

1 Tregenza grid of sky and ground

2 Tregenza grid of plane at certain orientation and tilt

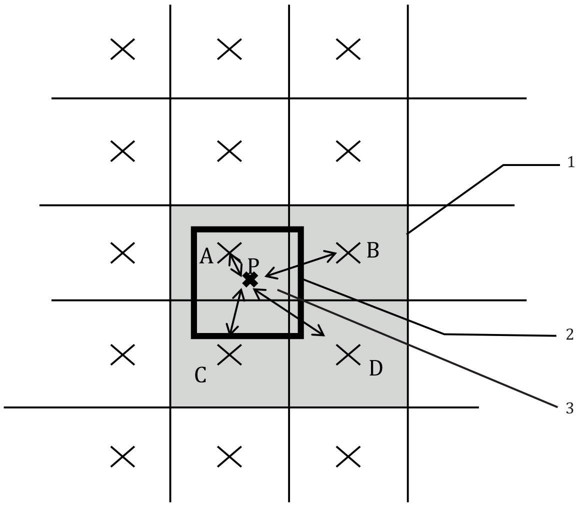
3 problem: the shaded element will be over-represented

NOTE Rectangular presentation of grid is only for illustration.

**Figure 3 — Illustration of problem to match grids of sky/ground versus plane**

Therefore, a different approach is proposed (REVIS FD 19[26]):

We take the weighted mean value of the radiance/luminance from the four nearest sky/ground elements. The weighting is inversely proportional to the square of the distance to that element (see Figure 4).




**Key**

1 Tregenza grid of sky and ground

2 Tregenza grid of plane at certain orientation and tilt

3 better: value for plane element P is weighted average of A, B, C and D

NOTE Rectangular presentation of grid is only for illustration.

**Figure 4 — Illustration of how Tregenza grid of plane gets values from Tregenza grid of sky/ground (from REVIS FD 19[26])**

The drawback is this approach is that differences between adjacent sky/ground elements may to some extent be levelled by the averaging of 4 elements. For most applications this is no problem.

### 9.5 References

See Bibliography [22],[23],[24],[25],[26].

## 10 Worked out examples

### 10.1 Method calculation of the total solar irradiation at given orientation and tilt angle

See Annex C for the examples.

### 10.2 Calculation of shading by external objects

See Annex D for the examples.

## 11 Validation

The calculation procedures have been validated by using relevant cases from the so called BESTEST series.

The BESTEST cases are well established since decades (several IEA ECBCS annexes and IEA SHC tasks), widely used worldwide, well described (e.g., ANSI-ASHRAE 140[9],) and regularly extended with additional cases.

The successive series of test cases are also very powerful as diagnostic tool. Renowned institutes participate in the set-up of the test cases.

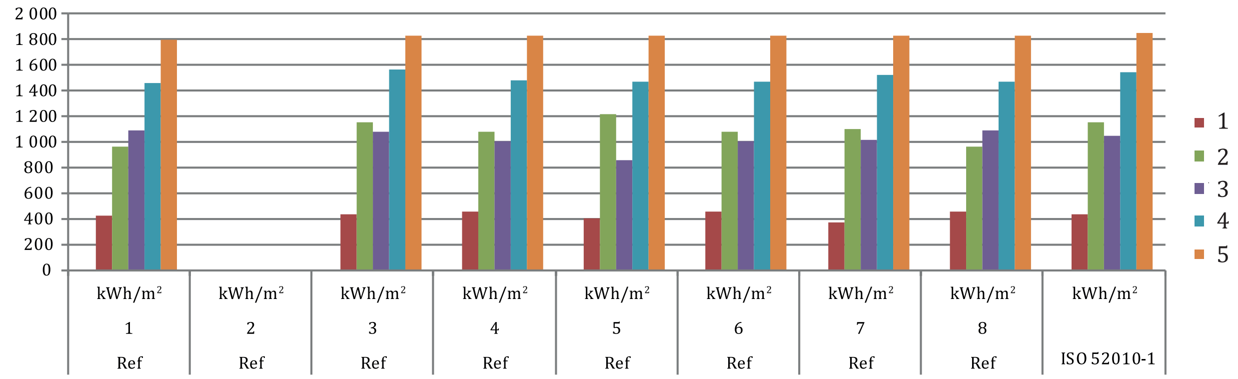
The calculation results of several renowned software tools are available for comparison.

Examples of input data for BESTEST cases are available for several building simulation tools and within different ICT environments. The "drawback" of the BESTEST series is that there is no single reference "true" result and no acceptance criteria.

Relevant BESTEST cases are also chosen for the validation of the hourly calculation procedures of ISO 52016-1,[5] with results presented in ISO/TR 52016-2[6].

The relevant BESTEST cases are the calculation of the solar irradiation at vertical planes, using the measured data from the climate file provided for this purpose: DRYCOLD.TMY (Denver, Col., USA).

Figures 5, 6, 7 and 8 show examples of the validation results.




**Key**

1 North
2 East
3 West
4 South
5 horizontal plane

**Figure 5 — BESTEST validation result: Annual solar radiation on five different planes**

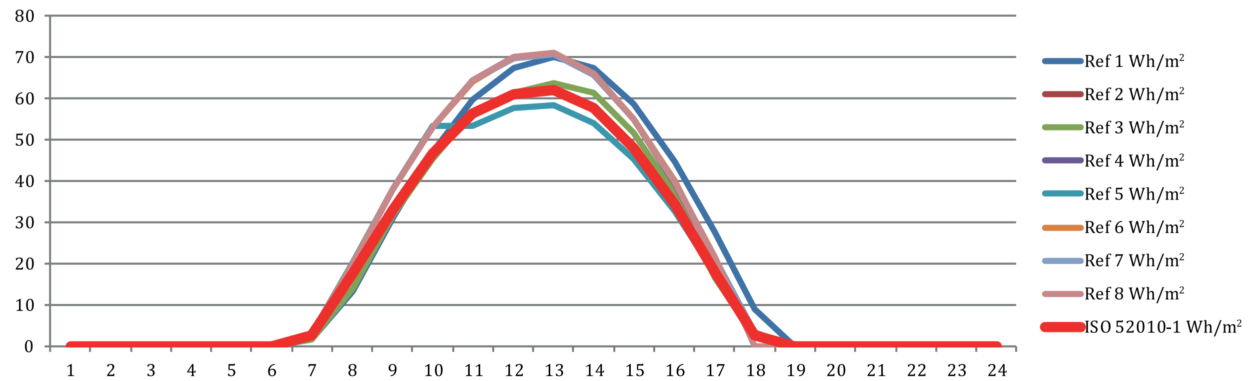



**Figure 6 — BESTEST validation result: Hourly irradiation on vertical West plane, cloudy day**

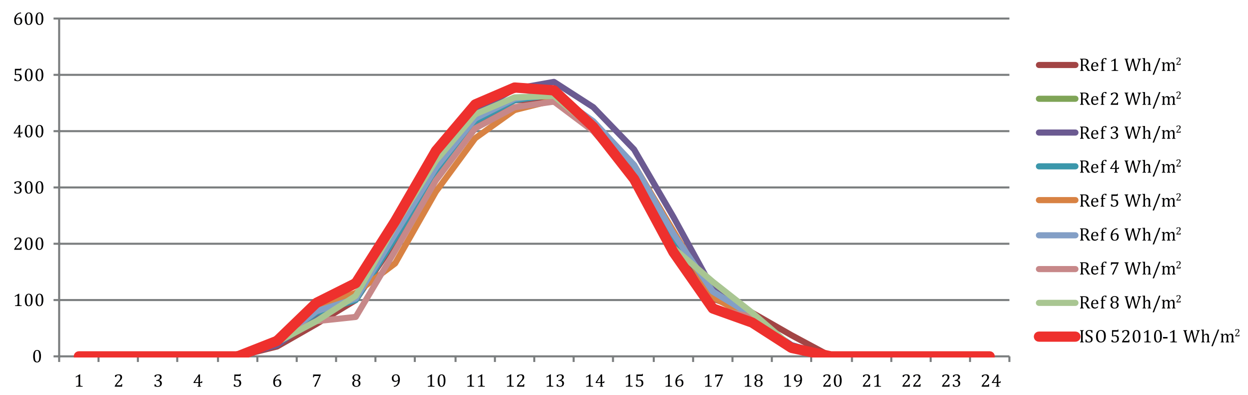



**Figure 7 — BESTEST validation result: Hourly irradiation on vertical South plane, clear day**

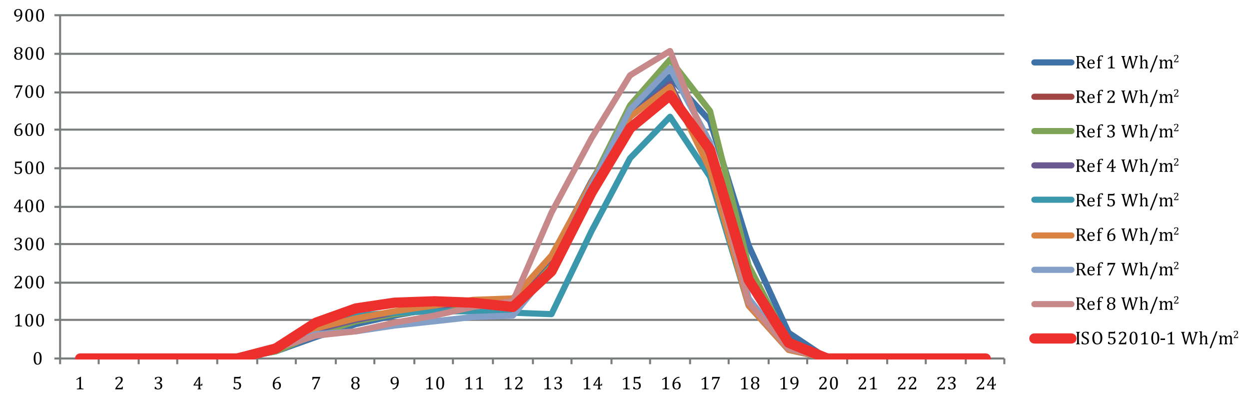



**Figure 8 — BESTEST validation result: Hourly irradiation on vertical West plane, clear day**

The results of the comparison show that the hourly method in ISO 52010-1 is very fit for purpose. It should be taken into consideration that not each software program whose results are available for the comparison use nowadays state-of-the-art algorithms (in that sense these are not reference results). This is because these base cases of the BESTEST series were created and tested many years ago.

Another basic test is the calculation of the hourly diffuse and total irradiation on a horizontal plane. These should match the measured hourly values of the same properties that are used, together with the measured beam radiation normal to the sun, as the source for the calculation of irradiation on tilted and vertical planes.

This test gave also satisfying results, see Figure C.2 in Annex C. Note that a perfect match should not be expected, because of the use of several empirical correlation coefficients (Perez model). Plus: 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 sinus 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 may play a role. This may 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.

## 12 Information on the accompanying spreadsheet

The accompanying spreadsheet (including possible updated version) is available at www.epb.center.

| File name | Reference | Description |
|---|---|---|
| ISO_FDIS_52010–1_SS_2016.07.05.xlsm | 6.4.1 to 6.4.4 | Calculation of solar irradiance on plane with any azimuth and tilt angle |
| | 6.4.5 | Calculation of the solar shading coefficient for multiple shading objects along the skyline |

# Annex A
(informative)

# Input and method selection data sheet — Template

## A.1 General

A.1 is a common subclause for all EPB standards. In ISO 52010-1:2017, Annex A is a normative annex. The explanation in this document is informative.

More information and explanation on the concept of Annex A and Annex B for all EPB standards is given in ISO/TR 52000-2.

## A.2 References

A.2 is a common subclause for all EPB standards.

However, for ISO 52010-1 the table with normative references to other EPB standards remains empty. This is due to the fact that ISO 52010-1 provides input to other EPB standards but requires itself as input no output from other EPB standards.

More information and explanation on the concept of the normative references to other EPB standards via ISO 52010-1:2017, Table A.1 (normative template) and Table B.1 (informative default choices) is given in ISO/TR 52000-2.

## A.3 Climatic input data

No additional information beyond the accompanied standard.

## A.4 Calculation method

No additional information beyond the accompanied standard.

# Annex B
(informative)

# Input and method selection data sheet — Default choices

Each EPB standard provides an informative Annex B (the only allowed informative Annex in an EPB standard) which has the same layout as Annex A (the normative template), but is completed with informative default values, informative default choices and informative default references to other EPB standards.

Please read the common text of ISO 52010-1:2017, Introduction and A.1 to get acquainted with the function and use of Annex A and Annex B.

## B.1 General

B.1 is a common subclause for all EPB standards.

More information and explanation on the concept of Annex A and Annex B for all EPB standards is given in ISO/TR 52000-2.

## B.2 References

B.2 is a common subclause for all EPB standards.

The references, identified by the module code number, are given in ISO 52010-1:2017, Table B.1.

However, for ISO 52010-1 the table with normative references to other EPB standards remains empty. This is due to the fact that ISO 52010-1 provides input to other EPB standards but requires itself as input no output from other EPB standards.

More information and explanation on the concept of the normative references to other EPB standards via ISO 52010-1:2017, Table A.1 (normative template) and Table B.1 (informative default choices) is given in ISO/TR 52000-2.

## B.3 Climatic input data

The climatic data file is the file that is documented in ANSI/ASHRAE standard 140[9].

This file is used in the so called BESTEST validation test cases. See Clause 11 for results of the BESTEST case to validate the conversion of solar irradiance from measured horizontal to vertical planes.

## B.4 Calculation method

No additional information beyond the accompanied standard.

# Annex C
(informative)

# Calculation examples on the solar irradiation at given orientation and tilt angle

Tables C.1 to C.5 are copied from the accompanying spreadsheet.

This calculation example covers the BESTEST case, for a South vertical plane.

Tables C.1 to C.5 and Figures C.1 and C.2 illustrate some of the input and output.

**Table C.1 — Sample input of weather station and position of plane**

| | |
|---|---|
| Convention: | red font = input |
| | green font = fixed |
| | blue font = calculated |

| Name | Symbol | | Unit | Value | Range | Origin | Varying | Notes |
|---|---|---|---|---|---|---|---|---|
| Weather station data | | | | | | | | |
| Station and/or file name | | | | DRYCOLD.TMY (Denver (Col, USA)) | | | | |
| Optional special notes | | | | Disregarding daylight saving time | | | | |
| Optional special notes | | | | Winter: MST = UTC - 7 | | | | |
| Optional special notes | | | | Summer: MDT = UTC - 6 | | | | |
| latitude | $\varphi_w$ | | deg | 39,76 | -90 to +90 | Annex A/B | NO | North +90, South, -90 |
| longitude | $\lambda_w$ | | deg | -104,86 | -180 to +180 | Annex A/B | NO | East is positive West is negative |
| time zone | $TZ$ | | h | -7 | -12 to +12 | Annex A/B | NO | |
| | | | | | | | | |
| Geometrical characteristics of plane | | | | | | | | |
| Tilt angle of the inclined surface from horizontal, measured upwards facing | $\beta_{ic}$ | | deg | 90 | 0 to 180 | local | NO | 0 = horizontal up , 90 vertical, 180 facing down |
| Orientation angle of the inclined surface, expressed as the geographical azimuth angle of the horizontal projection of the inclined surface normal | $\gamma_{ic}$ | | deg | 0 | -180 to +180 | local | NO | Convention in this standard: angle from South, eastwards positive, westwards negative |

**Table C.2 — Sample input of climatic data: few of the 8760 hourly values**

| $\rho_{sol;grnd}$ | $G_{sol;g}$ | $G_{sol;b}$ | $G_{sol;d}$ |
|---|---|---|---|
| | | | |
| - | W/m$^2$ | W/m$^2$ | W/m$^2$ |
| 0,2 | 0 | 0 | 0 |
| 0,2 | 0 | 0 | 0 |
| 0,2 | 0 | 0 | 0 |
| 0,2 | 0 | 0 | 0 |
| 0,2 | 0 | 0 | 0 |
| 0,2 | 0 | 0 | 0 |
| 0,2 | 0 | 0 | 0 |
| 0,2 | 7 | 2 | 7 |
| 0,2 | 93 | 68 | 87 |
| 0,2 | 117 | 16 | 113 |
| 0,2 | 357 | 746 | 90 |
| 0,2 | 466 | 933 | 65 |
| 0,2 | 469 | 940 | 40 |
| 0,2 | 424 | 935 | 18 |
| 0,2 | 306 | 826 | 4 |
| 0,2 | 171 | 671 | 0 |
| 0,2 | 21 | 79 | 13 |
| 0,2 | 0 | 0 | 0 |
| 0,2 | 0 | 0 | 0 |

## Table C.3 — Sample output of hourly data: few of the 8760 hourly values (the numbers below the symbols refer to the formula numbers in the standard)

| (0,90) | (0,90) | (0,90) | (0,90) | (0,90) | (0,90) | (0,90) | (0,90) | (0,90) | (0,90) | (0,90) |
|---|---|---|---|---|---|---|---|---|---|---|
| *PerezF22* | *PerezF23* | *PerezF1* | *PerezF2* | $I_{dir}$ | $I_{dif}$ | $I_{dif;grnd}$ | $I_{circum}$ | $I_{dif;tot}$ | $I_{dir;tot}$ | $I_{tot}$ |
| | | 32 | 33 | 26 | 34 | 35 | 36 | 38 | 37 | 39 |
| - | - | - | - | W/m2 | W/m2 | W/m2 | W/m2 | W/m2 | W/m2 | W/m2 |
| 0 | 0 | 0 | 0 | 0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| 0 | 0 | 0 | 0 | 0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| 0 | 0 | 0 | 0 | 0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| 0 | 0 | 0 | 0 | 0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| 0 | 0 | 0 | 0 | 0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| 0 | 0 | 0 | 0 | 0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| 0 | 0 | 0 | 0 | 0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| -0,064 | -0,026 | 0,054598383 | 0,005446 | 1,04096893 | 5,6 | 0,7 | 2,3 | 4,0 | 3,3 | 7,4 |
| -0,152 | -0,014 | 0,222286384 | 0,035713 | 44,4951532 | 109,7 | 9,9 | 72,8 | 46,8 | 117,3 | 164,1 |
| 0,066 | -0,029 | 0,118061705 | -0,03831 | 12,2260839 | 78,8 | 11,8 | 33,3 | 57,3 | 45,6 | 102,8 |
| -1,377 | 0,251 | 0,336139909 | 0,228018 | 628,409317 | 114,1 | 38,8 | 63,7 | 89,2 | 692,1 | 781,4 |
| -1,377 | 0,251 | 0,368470202 | 0,292554 | 824,522838 | 86,6 | 48,4 | 47,1 | 88,0 | 871,6 | 959,6 |
| -1,377 | 0,251 | 0,381969233 | 0,34648 | 832,271455 | 56,2 | 46,4 | 30,0 | 72,7 | 862,2 | 934,9 |
| -1,377 | 0,251 | 0,379494414 | 0,402241 | 792,174187 | 27,1 | 39,7 | 14,3 | 52,6 | 806,4 | 859,0 |
| -1,377 | 0,251 | 0,3625216 | 0,457446 | 637,575088 | 6,7 | 26,4 | 3,6 | 29,5 | 641,1 | 670,7 |
| 0 | 0 | 0 | 0 | 445,84169 | 0,0 | 12,5 | 0,0 | 12,5 | 445,8 | 458,3 |
| -1,377 | 0,251 | 0,225465242 | 0,262934 | 42,0477378 | 26,4 | 1,5 | 17,9 | 10,0 | 59,9 | 69,9 |
| 0 | 0 | 0 | 0 | 0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |

## Table C.4 — Sample output of calculated monthly data (South, vertical)

South is 0, East pos; in CAD conventions North = 0
0 = horizontal up , 90 vertical, 180 facing down

Monthly total (kWh/m$^2$)

| Measured | | | Calculated Plane (azim, tilt): | (0,90) | (0,90) | (0,90) | (0,90) | (0,90) | (0,90) | (0,90) |
|---|---|---|---|---|---|---|---|---|---|---|
| $G_{sol;g}$ | $G_{sol;b}$ | $G_{sol;d}$ | (*) | $H_{dir;m}$ | $H_{dif;m}$ | $H_{dif;grnd;m}$ | $H_{circum;m}$ | $H_{dif;tot;m}$ | $H_{dir;tot;m}$ | $H_{tot;m}$ |
| kWh/m$^2$ | kWh/m$^2$ | kWh/m$^2$ | | kWh/m$^2$ | kWh/m$^2$ | kWh/m$^2$ | kWh/m$^2$ | kWh/m$^2$ | kWh/m$^2$ | kWh/m$^2$ |
| 82 | 176 | 18 | | 134 | 18 | 8 | 9 | 17 | 143 | 160 |
| 95 | 154 | 27 | | 102 | 21 | 10 | 9 | 21 | 112 | 133 |
| 157 | 207 | 46 | | 103 | 33 | 16 | 13 | 35 | 116 | 151 |
| 181 | 194 | 57 | | 62 | 34 | 18 | 11 | 41 | 73 | 114 |
| 216 | 210 | 70 | | 41 | 35 | 22 | 8 | 49 | 48 | 97 |
| 222 | 222 | 63 | | 30 | 30 | 22 | 5 | 47 | 36 | 83 |
| 227 | 237 | 60 | | 39 | 30 | 23 | 6 | 47 | 45 | 92 |
| 197 | 213 | 55 | | 57 | 32 | 20 | 9 | 42 | 67 | 109 |
| 168 | 212 | 40 | | 93 | 29 | 17 | 11 | 35 | 104 | 139 |
| 131 | 209 | 26 | | 128 | 24 | 13 | 11 | 26 | 139 | 166 |
| 83 | 156 | 21 | | 116 | 23 | 8 | 12 | 19 | 128 | 147 |
| 73 | 163 | 16 | | 130 | 20 | 7 | 11 | 16 | 141 | 157 |
| 1832 | 2354 | 501 | | 1036 | 326 | 185 | 117 | 395 | 1152 | 1547 |

**Table C.5 — Sample output of quick test of some extremes (see Clause 7)**

Quick test of some extremes (whole year of 8 760 hours)

| | Calculated diffuse irradiation | Calculated Ground reflection irradiance | Calculated Circum-solar irradiance | Calculated total direct irradiance | Calculated total diffuse irradiance | Calculated total irradiance | Fdir | Calculated total irradiance, shaded |
|---|---|---|---|---|---|---|---|---|
| | $I_{dif}$ | $I_{dif;grnd}$ | | $I_{dir;tot}$ | $I_{dif;tot}$ | $I_{tot}$ | | $I_{tot;sh}$ |
| | | | | | | | - | W/m² |
| Min value | -24 | 0 | 0 | 0 | -12 | 0 | 0 | -12 |
| at hour | 776 | 1 | 1 | 1 | 752 | 1 | 1 | 752 |
| Max value | 222 | 104 | 129 | 897 | 198 | 989 | 1 | 785 |
| at hour | 1 668 | 3 900 | 1 093 | 84 | 3 132 | 180 | 10 | 1 162 |

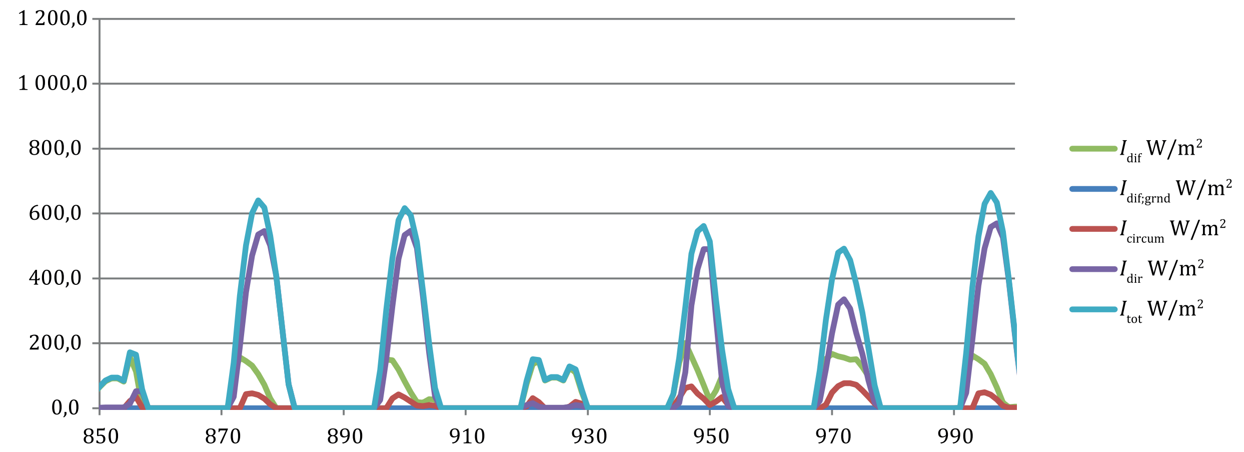



**Figure C.1 — Sample output of calculated irradiance: few of the 8760 hourly values**

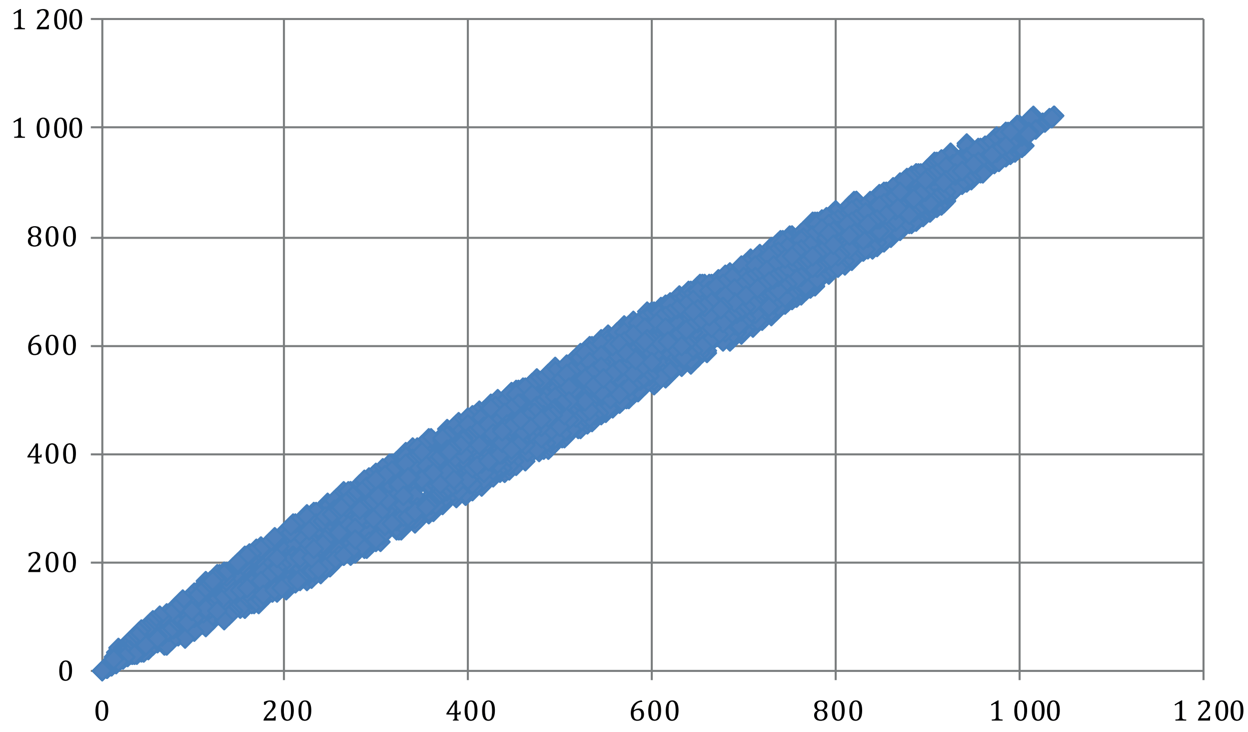



**Figure C.2 — Sample output of calculated irradiance: comparison of measured and recalculated global irradiance (total irradiance on horizontal plane); 8760 hourly values, in W/m2 (see discussion in Clause 11)**

# Annex D
(informative)

# Calculation examples on the effect of solar shading

Tables D.1 to D.5 are copied from the accompanying spreadsheet.

This calculation example covers the BESTEST case.

Example of input of shaded plane:

South vertical shaded surface, with height from 1,0 to 3,0 m above ground.

Tables D.1 to D.5 illustrate some of the input and output.

**Table D.1 — Sample input: weather station and position of shaded surface**

| Name | Symbol | | Unit | Value | Range | Origin | Varying | Notes |
|---|---|---|---|---|---|---|---|---|
| Weather station data | | | | | | | | |
| Station and/or file name | | | | DRYCOLD.TMY (Denver (Col, USA)) | | | | |
| Optional special notes | | | | Disregarding daylight saving time | | | | |
| Optional special notes | | | | Winter: MST = UTC - 7 | | | | |
| Optional special notes | | | | Summer: MDT = UTC - 6 | | | | |
| latitude | $\varphi_{w}$ | | deg | 39,76 | -90 to +90 | Annex A/B | NO | North +90, South, -90 |
| longitude | $\lambda_{w}$ | | deg | -104,86 | -180 to +180 | Annex A/B | NO | East is positive West is negative |
| time zone | *TZ* | | h | -7 | -12 to +12 | Annex A/B | NO | |
| | | | | | | | | |
| Geometrical characteristics of plane | | | | | | | | |
| Tilt angle of the inclined surface from horizontal, measured upwards facing | $\beta_{ic}$ | | deg | 90 | 0 to 180 | local | NO | 0 = horizontal up , 90 vertical, 180 facing down |
| Orientation angle of the inclined surface, expressed as the geographical azimuth angle of the horizontal projection of the inclined surface normal | $\gamma_{ic}$ | | deg | 0 | -180 to +180 | local | NO | Convention in this standard: angle from South, eastwards positive, westwards negative |
| Base height of the shaded surface, from ground level | $H_{0;ic}$ | | m | 1 | ≥ 0 | local | NO | |
| Height of the shaded surface, from bottom to top; if tilted: vertical projection | $H_{1;ic}$ | | m | 3 | >0 | local | NO | If horizontal: choose small value, e.g. $H_1$ =0,01 m |

Example of input of shading objects:

Skyline divided into (flexible) segments. In the spreadsheet, for demonstration and validation, in each segment up to 3 obstacles (with distance and highest height from the ground) can be entered, plus one overhang (with distance and lowest height from the ground).

## Table D.2 — Sample input: examples of 3 shading obstacles and 1 overhang

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | For information: | |
| Shading | | Create azim angle segments | | Obstacles | | | | | | Overhangs | | Plane azim angle | 0 |
| NOTE: For strongly tilted planes the results for close-by obstacles or overhangs are not correct | | Absolute angles from -180 to + 180 (S=0;E=90;N=180;W=-90;N=-180) | | | | | | | | | | Relative angles as seen from plane (-90 <-> + 90) | |
| | Shading Sector | 1st angle | 2nd angle ($\gamma_{sh;obst/ovh;max}$) | $L_{sh;obst;1}$ | $H_{sh;obst;1}$ | $L_{sh;obst;2}$ | $H_{sh;obst;2}$ | $L_{sh;obst;3}$ | $H_{sh;obst;3}$ | $L_{sh;ovh}$ | $H_{sh;ovh}$ | 1st angle | 2nd angle |
| Don't change the dark grey cells | 1 | -180 | -135 | | | | | | | | | -180 | -135 |
| | 2 | -135 | -90 | 100 | 20 | 20 | 8 | | | 2 | 5 | -135 | -90 |
| | 3 | -90 | -45 | | | 30 | 6 | | | 2 | 4,5 | -90 | -45 |
| | 4 | -45 | 0 | 100 | 15 | 40 | 4 | | | 2 | 4 | -45 | 0 |
| | 5 | 0 | 45 | 100 | 10 | 50 | 6 | | | 2 | 3,5 | 0 | 45 |
| | 6 | 45 | 90 | 100 | 30 | 60 | 8 | 3 | 2 | | | 45 | 90 |
| | 7 | 90 | 140 | | | | | 3 | 2 | | | 90 | 140 |
| | 8 | 140 | 180 | | | | | 3 | 2 | | | 140 | 180 |
| | 9 | 180 | | | | | | | | | | | |
| | | 180 | | | | | | | | | | | |
| | | 180 | | | | | | | | | | | |
| | | 180 | | | | | | | | | | | |
| | | 180 | | | | | | | | | | | |
| | | 180 | | | | | | | | | | | |
| | | 180 | 180 | | | | | | | | | | |

## Table D.3 — Sample output of hourly data: few of the 8760 hourly values for 3 shading obstacles and 1 overhang

| (0,90) | (0,90) | (0,90) | (0,90) | (0,90) | (0,90) | (0,90) | (0,90) | (0,90) | (0,90) | (0,90) | (0,90) | (0,90) | (0,90) | (0,90) | (0,90) | (0,90) | (0,90) | (0,90) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | max.of 3 obstacles | | | | | | | Compare: |
| Check view sun (azimuth) | Check view sun (altitude) | Shading Sector, $n_{sh;segm}$ | $L_{sh;obst;1}$ | $H_{sh;obst;1}$ | $L_{sh;obst;2}$ | $H_{sh;obst;2}$ | $L_{sh;obst;3}$ | $H_{sh;obst;3}$ | $L_{sh;ovh}$ | $H_{sh;ovh}$ | $h_{sh;obst}$ | $h_{sh;ovh}$ | $F_{dir;unsh}$ | $F_{dir;sh;obst}$ | $F_{dir;sh;ovh}$ | $F_{dir;sh;tot}$ | $I_{tot;sh}$ | $I_{tot}$ |
| F.3 in ISO/FDIS 52016-1 | F.3 in ISO/FDIS 52016-1 | | | | | | | | | | 42 | F.11 (52016-1) | | | | 41 | 40 | 39 (copy) |
| degrees | degrees | - | m | m | m | m | m | m | m | m | m | m | - | - | - | - | W/m$^2$ | W/m$^2$ |
| 158,7 | 0,0 | 8,0 | 0,0 | 0,0 | 0,0 | 0,0 | 3,0 | 2,0 | 0,0 | 0,0 | 1,0 | | 0,0 | 0,00 | 1,00 | 0,00 | 0,0 | 0,0 |
| 125,5 | 0,0 | 7,0 | 0,0 | 0,0 | 0,0 | 0,0 | 3,0 | 2,0 | 0,0 | 0,0 | 1,0 | | 0,0 | 0,00 | 1,00 | 0,00 | 0,0 | 0,0 |
| 107,1 | 0,0 | 7,0 | 0,0 | 0,0 | 0,0 | 0,0 | 3,0 | 2,0 | 0,0 | 0,0 | 1,0 | | 0,0 | 0,00 | 1,00 | 0,00 | 0,0 | 0,0 |
| 94,9 | 0,0 | 7,0 | 0,0 | 0,0 | 0,0 | 0,0 | 3,0 | 2,0 | 0,0 | 0,0 | 1,0 | | 0,0 | 0,00 | 1,00 | 0,00 | 0,0 | 0,0 |
| 85,3 | 0,0 | 6,0 | 100,0 | 30,0 | 60,0 | 8,0 | 3,0 | 2,0 | 0,0 | 0,0 | 29,0 | | 1,0 | 0,00 | 1,00 | 0,00 | 0,0 | 0,0 |
| 76,5 | 0,0 | 6,0 | 100,0 | 30,0 | 60,0 | 8,0 | 3,0 | 2,0 | 0,0 | 0,0 | 29,0 | | 1,0 | 0,00 | 1,00 | 0,00 | 0,0 | 0,0 |
| 67,9 | 0,0 | 6,0 | 100,0 | 30,0 | 60,0 | 8,0 | 3,0 | 2,0 | 0,0 | 0,0 | 29,0 | | 1,0 | 0,00 | 1,00 | 0,00 | 0,0 | 0,0 |
| 58,6 | 0,7 | 6,0 | 100,0 | 30,0 | 60,0 | 8,0 | 3,0 | 2,0 | 0,0 | 0,0 | 27,7 | | 1,0 | 0,00 | 1,00 | 0,00 | 4,0 | 7,4 |
| 48,4 | 10,0 | 6,0 | 100,0 | 30,0 | 60,0 | 8,0 | 3,0 | 2,0 | 0,0 | 0,0 | 11,3 | | 1,0 | 0,00 | 1,00 | 0,00 | 46,8 | 164,1 |
| 36,6 | 17,8 | 5,0 | 100,0 | 10,0 | 50,0 | 6,0 | 0,0 | 0,0 | 2,0 | 3,5 | 0,0 | 1,9 | 1,0 | 1,00 | 0,62 | 0,62 | 85,5 | 102,8 |
| 23,2 | 23,6 | 5,0 | 100,0 | 10,0 | 50,0 | 6,0 | 0,0 | 0,0 | 2,0 | 3,5 | 0,0 | 1,6 | 1,0 | 1,00 | 0,54 | 0,54 | 464,7 | 781,4 |
| 8,4 | 26,7 | 5,0 | 100,0 | 10,0 | 50,0 | 6,0 | 0,0 | 0,0 | 2,0 | 3,5 | 0,0 | 1,5 | 1,0 | 1,00 | 0,50 | 0,50 | 521,9 | 959,6 |
| -7,1 | 26,8 | 4,0 | 100,0 | 15,0 | 40,0 | 4,0 | 0,0 | 0,0 | 2,0 | 4,0 | 0,0 | 2,0 | 1,0 | 1,00 | 0,66 | 0,66 | 644,0 | 934,9 |
| -22,0 | 23,9 | 4,0 | 100,0 | 15,0 | 40,0 | 4,0 | 0,0 | 0,0 | 2,0 | 4,0 | 0,0 | 2,1 | 1,0 | 1,00 | 0,70 | 0,70 | 620,3 | 859,0 |
| -35,6 | 18,4 | 4,0 | 100,0 | 15,0 | 40,0 | 4,0 | 0,0 | 0,0 | 2,0 | 4,0 | 0,0 | 2,3 | 1,0 | 1,00 | 0,78 | 0,78 | 528,7 | 670,7 |
| -47,4 | 10,7 | 3,0 | 0,0 | 0,0 | 30,0 | 6,0 | 0,0 | 0,0 | 2,0 | 4,5 | 0,0 | 3,1 | 1,0 | 1,00 | 1,00 | 1,00 | 458,3 | 458,3 |
| -57,8 | 1,6 | 3,0 | 0,0 | 0,0 | 30,0 | 6,0 | 0,0 | 0,0 | 2,0 | 4,5 | 4,2 | 3,4 | 1,0 | 0,00 | 1,00 | 0,00 | 10,0 | 69,9 |
| -67,1 | 0,0 | 3,0 | 0,0 | 0,0 | 30,0 | 6,0 | 0,0 | 0,0 | 2,0 | 4,5 | 5,0 | 3,5 | 1,0 | 0,00 | 1,00 | 0,00 | 0,0 | 0,0 |

## Table D.4 — Sample output of calculated monthly data (South, vertical)

South is 0, East pos; in CAD conventions North = 0
0 = horizontal up , 90 vertical, 180 facing down

| Calculated Plane (azim, tilt): | (0,90) | (0,90) | (0,90) | (0,90) | (0,90) | (0,90) | (0,90) | (0,90) | (0,90) | (0,90) | | Monthly average (W/m²) Calculated (0,90) | (0,90) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (*) | $H_{dir;m}$ | $H_{dif;m}$ | $H_{dif;grnd;m}$ | $H_{circum;m}$ | $H_{dif;tot;m}$ | $H_{dir;tot;m}$ | $H_{tot;m}$ | | $H_{tot;sh;m}$ | $F_{sh;m}$ | | $I_{tot;m}$ | $I_{tot;sh;m}$ |
| | kWh/m² | kWh/m² | kWh/m² | kWh/m² | kWh/m² | kWh/m² | kWh/m² | | kWh/m² | - | | W/m² | W/m² |
| | 134 | 18 | 8 | 9 | 17 | 143 | 160 | | 98 | 0,61 | | 214,9 | 131,9 |
| | 102 | 21 | 10 | 9 | 21 | 112 | 133 | | 83 | 0,62 | | 197,5 | 123,0 |
| | 103 | 33 | 16 | 13 | 35 | 116 | 151 | | 91 | 0,60 | | 203,5 | 122,9 |
| | 62 | 34 | 18 | 11 | 41 | 73 | 114 | | 67 | 0,58 | | 158,8 | 92,6 |
| | 41 | 35 | 22 | 8 | 49 | 48 | 97 | | 67 | 0,70 | | 130,5 | 90,7 |
| | 30 | 30 | 22 | 5 | 47 | 36 | 83 | | 60 | 0,73 | | 114,9 | 83,6 |
| | 39 | 30 | 23 | 6 | 47 | 45 | 92 | | 64 | 0,69 | | 123,5 | 85,8 |
| | 57 | 32 | 20 | 9 | 42 | 67 | 109 | | 67 | 0,61 | | 146,5 | 89,7 |
| | 93 | 29 | 17 | 11 | 35 | 104 | 139 | | 81 | 0,58 | | 192,5 | 112,3 |
| | 128 | 24 | 13 | 11 | 26 | 139 | 166 | | 99 | 0,60 | | 222,5 | 133,5 |
| | 116 | 23 | 8 | 12 | 19 | 128 | 147 | | 92 | 0,62 | | 203,6 | 127,2 |
| | 130 | 20 | 7 | 11 | 16 | 141 | 157 | | 101 | 0,64 | | 211,3 | 136,0 |
| | 1036 | 326 | 185 | 117 | 395 | 1152 | 1547 | | 970 | 0,63 | | 176,6 | 110,8 |

## Table D.5 — Sample output

| max.of 3 obstacles | | | | | | | Compare: |
|---|---|---|---|---|---|---|---|
| $h_{sh;obst}$ | $h_{sh;ovh}$ | $F_{dir;unsh}$ | $F_{dir;sh;obst}$ | $F_{dir;sh;ovh}$ | $F_{dir;sh;tot}$ | $I_{tot;sh}$ | $I_{tot}$ |
| 42 | F.11 (52016-1) | | | | 41 | 40 | 39 (copy) |
| m | m | - | - | - | - | W/m² | W/m² |
| 1,0 | | 0,0 | 0,00 | 1,00 | 0,00 | 0,0 | 0,0 |
| 1,0 | | 0,0 | 0,00 | 1,00 | 0,00 | 0,0 | 0,0 |
| 1,0 | | 0,0 | 0,00 | 1,00 | 0,00 | 0,0 | 0,0 |
| 1,0 | | 0,0 | 0,00 | 1,00 | 0,00 | 0,0 | 0,0 |
| 29,0 | | 1,0 | 0,00 | 1,00 | 0,00 | 0,0 | 0,0 |
| 29,0 | | 1,0 | 0,00 | 1,00 | 0,00 | 0,0 | 0,0 |
| 29,0 | | 1,0 | 0,00 | 1,00 | 0,00 | 0,0 | 0,0 |
| 27,7 | | 1,0 | 0,00 | 1,00 | 0,00 | 4,0 | 7,4 |
| 11,3 | | 1,0 | 0,00 | 1,00 | 0,00 | 46,8 | 164,1 |
| 0,0 | 1,9 | 1,0 | 1,00 | 0,62 | 0,62 | 85,5 | 102,8 |
| 0,0 | 1,6 | 1,0 | 1,00 | 0,54 | 0,54 | 464,7 | 781,4 |
| 0,0 | 1,5 | 1,0 | 1,00 | 0,50 | 0,50 | 521,9 | 959,6 |
| 0,0 | 2,0 | 1,0 | 1,00 | 0,66 | 0,66 | 644,0 | 934,9 |
| 0,0 | 2,1 | 1,0 | 1,00 | 0,70 | 0,70 | 620,3 | 859,0 |
| 0,0 | 2,3 | 1,0 | 1,00 | 0,78 | 0,78 | 528,7 | 670,7 |
| 0,0 | 3,1 | 1,0 | 1,00 | 1,00 | 1,00 | 458,3 | 458,3 |
| 4,2 | 3,4 | 1,0 | 0,00 | 1,00 | 0,00 | 10,0 | 69,9 |
| 5,0 | 3,5 | 1,0 | 0,00 | 1,00 | 0,00 | 0,0 | 0,0 |
| 5,0 | 3,5 | 1,0 | 0,00 | 1,00 | 0,00 | 0,0 | 0,0 |

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