PUBLIC DOCUMENT

Service Contract ENER/C3/2017-437/SI2-785.185

SUPPORT THE DISSEMINATION AND ROLL-OUT OF THE SET OF ENERGY PERFORMANCE OF BUILDING STANDARDS DEVELOPED UNDER EC MANDATE M/480

Report on Case Study to EN ISO 52016-1, Annex F, Solar shading reduction factors

October 31th, 2021

Prepared by Dick van Dijk with contributions by the Project Team

Project Leader and contact point:

Mr Jaap (J.J.N.M.) Hogeling

Stichting ISSO

Weena 505, NL 3013 AL Rotterdam, The Netherlands

PO Box 577, NL 3000 AN Rotterdam, The Netherlands

T: Mobile: +31 65 31 61 973 |

E: j.hogeling@isso.nl

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Abbreviations and acronyms in this document:

CEN	**European standards organization**
EN	**European standard**
EPBD	**Energy Performance of Buildings Directive**
EPB standard	**Standard for the calculation of energy performance of buildings, that complies with the requirements given in ISO 52000-1, CEN/TS 16628 and CEN/TS 16629 or later updates**
ISO	**International organization for standardization**
MS	**EU Member State(s)**
NA (/ND)	**National Annex or National Datasheet for EPB standards**
NSB	**National Standards Body of CEN and/or ISO**
TMY	**Typical Meteorological Year**
TR	**Technical report (of CEN and/or ISO)**

1 Introduction

This document is intended to present the case study and to discuss the contents of Annex F, *Calculation of solar shading reduction factors* of EN ISO 52016-1:2017, *Energy performance of buildings - Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads — Part 1: Calculation procedures,*

This concerns the calculation method to assess the solar shading reduction factor in case of external obstacles, as viewed from an object at arbitrary orientation and tilt angle, such as a building element (window, façade, roof), thermal solar collector or PV panel.

A dedicated spreadsheet has been developed to demonstrate the calculation procedures. A first version of this spreadsheet was published early October 2021.

The case study shows which input and parameters are needed and the output of the calculation procedures.

The case study also shows how the output of the spreadsheet on EN ISO 52010-1:2017, *Energy performance of buildings — External climatic conditions — Part 1: Conversion of climatic data for energy calculations*, (see Case study on that standard, [5]) can be directly used as input.

The output is -of course- intended to be used as input for the calculation of energy needs for heating and cooling and internal temperatures according to EN ISO 52016-1, but also for other EPB standards, such as the standards on photovoltaic systems and thermal solar systems.

Therefore, the spreadsheet has been prepared as a stand-alone tool.

The spreadsheet on EN ISO 52016-1 has been prepared to take into account the solar shading reduction factors for specific building elements. Full integration of the solar shading reduction factors calculated with this stand-alone spreadsheet is foreseen for the next update.

The spreadsheet and also this case study focus on the detailed method to calculate hourly the shading of direct solar radiation. Simplified approaches for simple rebates, overhangs and side fins, or monthly calculation procedures that are also covered in Annex F of EN ISO 52016-1 are disregarded. These can be evaluated on the basis of results from the detailed procedure covered in this document.

2 Executive summary

The case study on this Annex F of EN ISO 52016-1 concerned the demonstration of the calculation procedures to assess the solar shading reduction factor in case of external obstacles, as viewed from an object at arbitrary orientation and tilt angle, such as a building element (window, façade, roof), thermal solar collector or PV panel.

The main objective was to show that the module correctly handles the hourly input data for a full year and to show that the impact of obstacles and overhangs, individual but also in case of overlapping, is calculated correctly, for different geometries of objects and obstacles.

Another goal was to demonstrate that, with the dedicated spreadsheet tool, the specification of the input and understanding of the output is easy.

For this purpose, a few examples calculations have been prepared and presented. In this calculation, the same hourly climatic data are used as input as for the calculation of the energy needs and internal temperatures (see case study on EN ISO 52010-1). Different geometries for the shaded object and for the obstacles and overhangs have been tested, for different climatic data sets.

3 The context of the case study

Annex F of ISO 52016-1:2017 specifies a calculation procedure for the hourly or monthly calculation of solar shading reduction factors in case of external obstacles and overhangs.

The essence of the calculation method is that the skyline is divided into a number of segments. In each segment the distance and maximum height of one or more obstacles (measured from the ground) and the distance and minimum height of overhangs can be specified. The object that is shaded is specified by its position and geometry.

The calculation procedure assesses for each hour of the year if the direct part of the solar irradiance is blocked by the obstacle(s) or overhang(s) and -if so- for which fraction of the surface of the object.

Diffuse solar irradiance is assumed to remain unchanged; in reality the diffuse irradiance could become more, or could become less, depending on the colorimetric properties of each of the surfaces involved. These kinds of details are beyond the scope of the energy performance calculations.

Note, however, that it is not the intention of this case study to explain the calculation procedure of (this part of) the standard. This is extensively done in the technical report that accompanies the standard: CEN ISO/TR 52016-2.

4 Coverage of the scope

4.1 Introduction

The scope of Annex F of EN ISO 52016-1 is the calculation the solar shading reduction factor in case of external obstacles as viewed from an object at arbitrary orientation and tilt angle, such as a building element (window, façade, roof), thermal solar collector or PV panel.

This case study focuses on the detailed method to calculate hourly the shading of direct solar radiation.

Simplified approaches for simple rebates, overhangs and side fins (F3.5.1 of the standard) , or monthly calculation procedures (e.g. F3.1.2 and F3.5.1.2 of the standard) are disregarded.

These simplified approaches can be evaluated on the basis of results from the detailed procedure covered in this document.

4.2 Coupling and complementing

The coupling with the calculation procedures of EN ISO 52010-1 and to the application, such as EN ISO 52016-1, is illustrated in Figure 1.

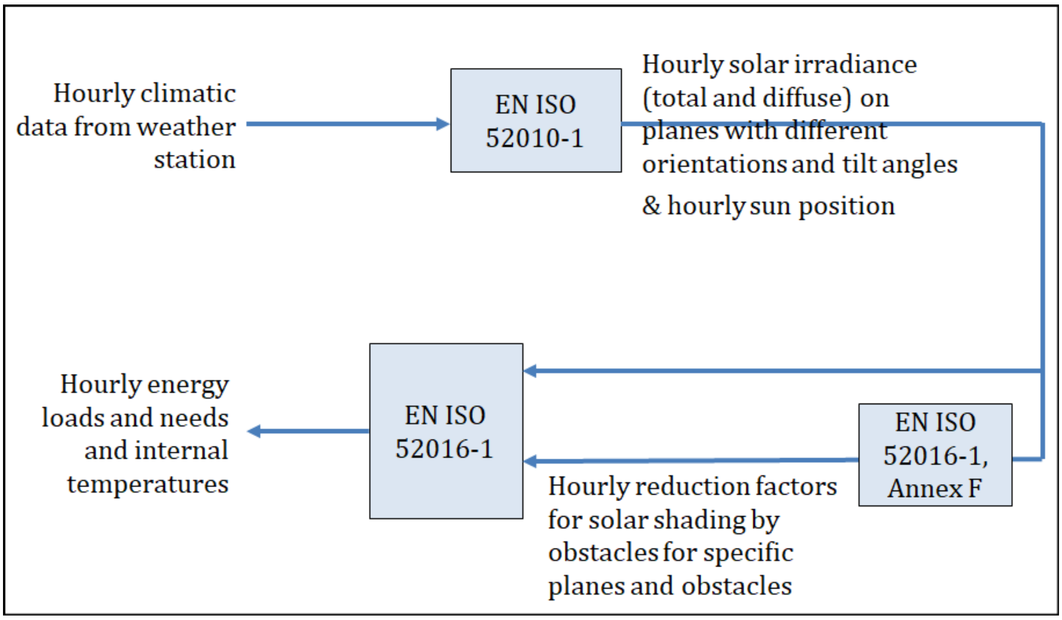


Figure 1 - Principle of the coupling with EN ISO 52010-1 (input) and, for instance, EN ISO 52016-1 (output)

As can be seen from Figure 1 the data stream is one-directional: no interactions involved, other than the orientation and tilt angles of the planes (the building elements in EN ISO 52016-1, the collectors in thermal solar systems or the PV panels in the standard(s) on photovoltaic systems.

The spreadsheet to calculate the solar shading reduction factors has been prepared as a stand-alone tool.

The spreadsheet on EN ISO 52016-1 (as a whole) has been prepared to take into account the solar shading reduction factors for specific building elements. Full integration of the solar shading reduction factors calculated with this stand-alone spreadsheet is foreseen for the next update.

5 Definition of the cases

5.1 Rationale of the selection of cases

For the demonstration of the intended effects, a selection of climates, a few objects (subject to shading) and a series of obstacles and overhangs with different orientation, height and distance is needed.

The selected climates are the same as presented in the case study on EN ISO 52010-1 [5]: Oslo, Strasbourg and Athens.

5.2 Sources of input data

The climatic data sets have been prepared in another case study, see 0.

The objects that are subject to shading are a few simple geometries, directly specified in the dedicated spreadsheet.

Typical examples of various kinds of obstacles and overhangs are also directly specified in the dedicated spreadsheet.

5.3 Skyline segments

The main parameter for the calculation is the division of the skyline into a number of segments. The height and distance of each obstacle and overhang is given per segment. So the more segments, the more refined the calculation results. The default value chosen in this case study is 24, with equal size, so 15° per segment. See Figure 2 for illustration.

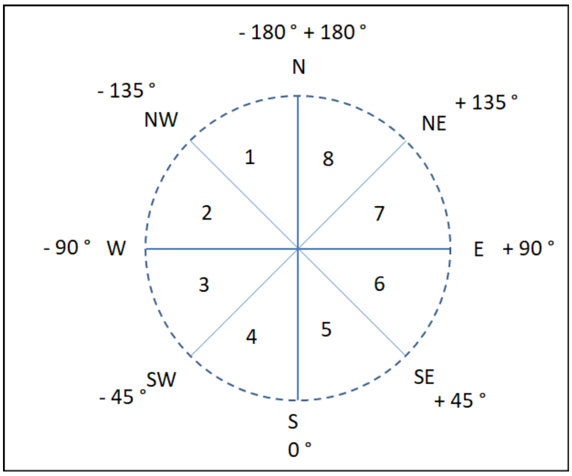
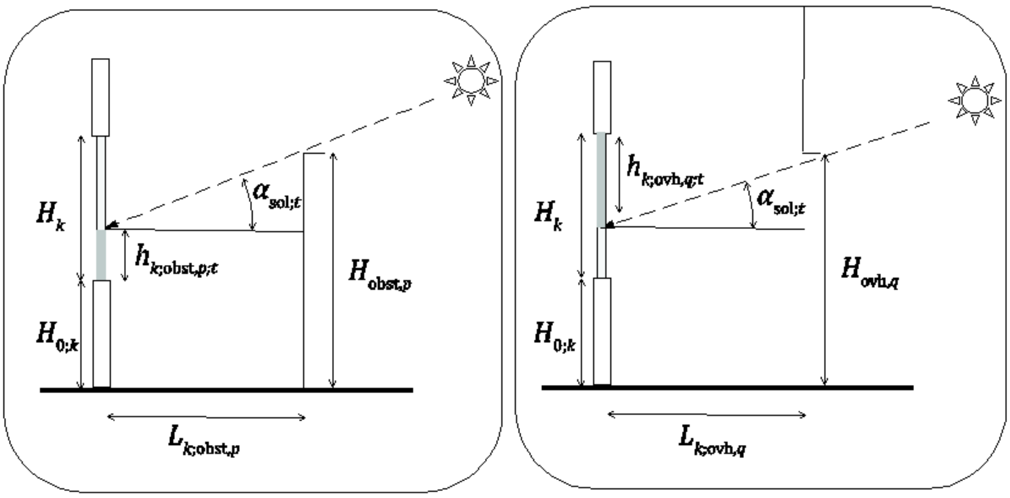


Figure 2 - Illustration of the subdivision of the skyline into segments; in the illustration: 8 segments, in this case study: 24 segments

NOTE In EN ISO 52016-1, Table B.26 (*Number of skyline segments, $n_{sh;segm}$ for input solar shading objects)* the (informative) default number of skyline segments is 15 , equally distributed over the skyline (leading to 24° per segment). This should be 24 segments.

Figure 3 shows the main geometrical parameters involved in the calculation. The height of the obstacle (left) or overhang (right) and the solar angle is considered for each segment of the skyline.



a. Vertical cross-section - obstacles **b. Vertical cross-section - overhangs**

Figure F.2 — Shading of the direct solar beam due to shading objects

Figure 3 - The main geometrical parameters (source: EN ISO 52016-1, Annex F)

5.4 Climates

The selected climates are the same as presented in the case study on EN ISO 52010-1 [5]:

- Oslo
- Strasbourg
- Athens

5.5 Objects

Three objects are specified:

1. (SV) South vertical, with $H_{0;1}$ = 1,0 m and H_1 = 32,0 m..
2. (W45) West, tilted 45 degrees towards the sky, with $H_{0;2}$ = 0,0 m and H_2 = 2,0 m.
3. (EV) East vertical, with $H_{0;3}$ = 1,0 m and H_3 = 5,0 m..

Note that the width of the object does not play a role in the calculation.

5.6 Obstacles and overhangs

A small 'library' of 6 obstacles and 3 overhangs has been prepared. These are specified in the dedicated spreadsheet itself; no separate input data file is needed, because this concerns only a limited number of data.

Note that the distance is the shortest distance to the supposed object: for each segment of the skyline that is not perpendicular to the object, the distance is larger, as illustrated in Figure 4.

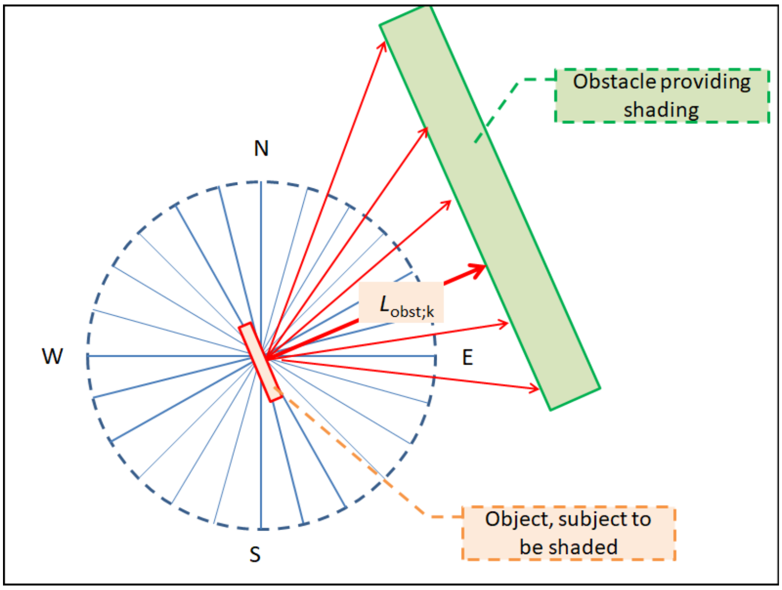


Figure 4 - Illustration of the distance to the obstacle for each skyline segment; in this example the obstacle is a façade opposite and parallel to the object to be shaded

The 'library' of 6 obstacles and 3 overhangs used for this case study:

1. Opposite facade, 15 m high, at 20 m distance, South
2. Hill, 300 m high at the top, at 2 km distance, East
3. Tower, 150 m high and circa 40 m wide, at 100 m distance, West
4. East side wing, South direction, 2 m high, at 3 m distance
5. Example of urban surrounding (obstacle over 360° at constant height)

6. Example of countryside surrounding (obstacle over 360°at constant height)

1. Overhang 1 m wide, at 3 m height, South
2. Overhang 2 m wide, at 3 m height, South
3. Overhang 2 m wide, at 3 m height, East

Note that “Overhang 1 m wide, at 3 m height” can be translated into $H_{ovh;1}$ = 3,0 m and $L_{ovh;1}$ = 1,0 m: the edge of the overhang in the path between the sun and the object that might be shaded.

5.7 List of selected cases and variants

The spreadsheet tool allows per calculation three different objects that are subjected to shading and per object a maximum of 3 obstacles and 1 overhang.

Combined with the three climates this provides a wide range of variants.

Only a selection of these variants is used for presentation in this case study. The spreadsheet tool with library and climatic data files is publicly available to test & demonstrate other variants or to replace or add objects and obstacles/overhangs.

The number of skyline segments is kept fixed in this case study. The spreadsheet has however been tested to work also for other segmentation, including segments with varying width (angle).

6 Calculation details

6.1 Calculation tools

6.1.1 EN ISO 52010-1 spreadsheet

6.1.1.1 Introduction

A dedicated spreadsheet has been developed to demonstrate the calculation. A first version of this spreadsheet was published early October 2021.

Link: *https://epb.center/support/documents/demo-en-iso-52016-1_shad/*

NOTE As a result of this case study a minor bug was detected in the tool and some improvements were made to the graphs. As a consequence, an updated version will be uploaded early 2022.

6.1.1.2 Input data

Climatic data file:

The output of the spreadsheet on EN ISO 52010-1:2017 (see case study [5]) can be simply imported by copying the file name as input and push the “import hourly climatic data” button, as Figure 5 shows:

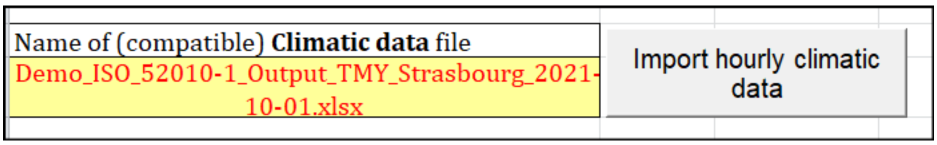


Figure 5 - Illustration of the input data (1): a climatic data file produced as output from the spreadsheet on EN ISO 52010-1 can be simply imported

From the climatic data file only the solar irradiance related data are needed: sun position and total and diffuse solar irradiance.

The objects:

The other input data for the spreadsheet are the data of the objects and of the obstacles/overhangs. These are directly written in the Method_input sheet of the file. To facilitate variations of the objects and obstacles, a small library can be filled of 6 obstacles and 3 overhangs, from which 3 resp. 1 can be selected per object.

The calculation can be run for a single object, or for 3 objects successively. The calculation for a single object has the advantage that all intermediate results for that object can be traced.

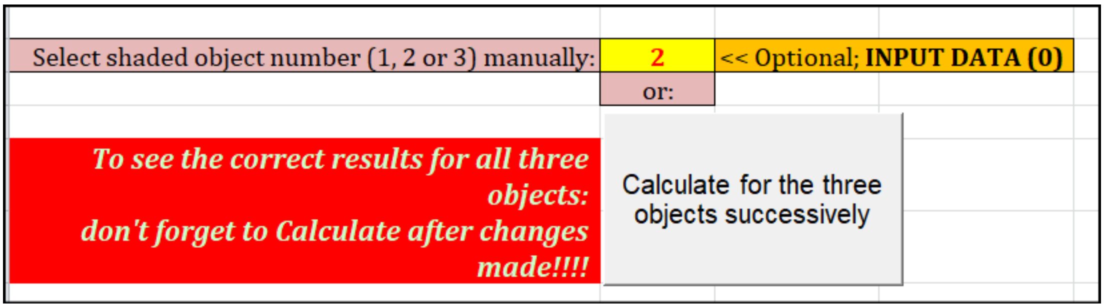


Figure 6 - Illustration of the input data (2): the calculation can be performed for a single object chosen out of 3; or for 3 objects in succession

			ShadObj1	ShadObj2	ShadObj3	
			Value	Value	Value	Value
			1	2	3	For selected object = 2
			SV	W45	EV	W45
Base height of the shaded object k, from ground level	$H_{0;k}$	m	1,0	0,0	1,0	0
Height of the shaded object k, from bottom to top; if tilted: vertical projection	H_k	m	3,0	2,0	5,0	2
The width of the shaded object k; for the detailed types of shading objects the real width is not needed and, if not available, may be set to 1 m;	W_k	m	1,0	1,0	1,0	1,0

Figure 7 - Illustration of the input data (3): the input data for the 3 selected objects; the input data are in red font with a light yellow background

The segments:

NOTE: For strongly tilted (near hor.) 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) [max: 15	
Width of each segment, in degrees, starting from N (-180), via W (-90), etc.	**Shading Sector**	**1st angle** (calculated from 2nd angle)	**2nd angle** ($\gamma_{sh;obst/ovh;max}$)
			Recommendation: don't change unless you're sure...
	1	-180	-165
	2	-165	-150
	3	-150	-135
	4	-135	-120
	5	-120	-105
	6	-105	-90
	7	-90	-75
	8	-75	-60
	9	-60	-45
	10	-45	-30
	11	-30	-15
	12	-15	0
	13	0	15
	14	15	30
	15	30	45
	16	45	60
	17	60	75
	18	75	90
	19	90	105
	20	105	120
	21	120	135
	22	135	150
	23	150	165
	24	165	180
Number of segments, $n_{sh;segm}$	24		

Figure 8 - Illustration of the input data (4): the specification of the skyline segments; the input data are in red font with a light yellow background

The obstacles/overhangs:

This concerns the library of 6 obstacles and 3 overhangs, each specified with its height and distance in each skyline segment. If the data for an obstacle in a specific segment are blank, the obstacle is set to have zero height in that segment; If the data for an overhang in a specific segment are blank, the overhang is set to be at 'infinite' height in that segment.

ObstL1	ObstL1	ObstL2	ObstL2	ObstL3	ObstL3	ObstL4	ObstL4	ObstL5	ObstL5	ObstL6	ObstL6	OvhL1	OvhL1	OvhL2	OvhL2	OvhL3	OvhL3
$L_{k;obst;L1}$	$H_{obst;L1}$	$L_{k;obst;L1}$	$H_{obst;L1}$	$L_{k;obst;L1}$	$H_{obst;L1}$	$L_{k;obst;L1}$	$H_{obst;L1}$	$L_{k;obst;L1}$	$H_{obst;L1}$	$L_{k;obst;L1}$	$H_{obst;L1}$	$L_{k;ovh;L1}$	$H_{ovh;L1}$	$L_{k;ovh;L1}$	$H_{ovh;L1}$	$L_{k;ovh;L1}$	$H_{ovh;L1}$
Opposite facade, H=15 m, at 20 m distance, South		Hill, Htop=300 m, at 2 km distance, East		Tower, H=150 m, at 100 m distance, West		East side wing, South direction, H=2 m, at 3 m distance		Example of urban surrounding		Example of countryside surrounding		Overhang 1 m wide, at 3 m height, South		Overhang 2 m wide, at 3 m height, South		Overhang 2 m wide, at 3 m height, East	
								15	8	25	6						
								15	8	25	6						
								15	8	25	6						
								15	8	25	6						
								15	8	25	6						
				101	150			15	8	25	6						
153,2	15			101	150			15	8	25	6	7,66	3	15,3	3		
52,3	15			108	150			15	8	25	6	2,61	3	5,23	3		
32,9	15							15	8	25	6	1,64	3	3,29	3		
25,2	15							15	8	25	6	1,26	3	2,52	3		
21,6	15							15	8	25	6	1,08	3	2,16	3		
20,2	15	2000	50					15	8	25	6	1,01	3	2,02	3	15,3	3
20,2	15	2000	80			3,0	2	15	8	25	6	1,01	3	2,02	3	5,23	3
21,6	15	2000	120			3,2	2	15	8	25	6	1,08	3	2,16	3	3,29	3
25,2	15	2000	200			3,8	2	15	8	25	6	1,26	3	2,51	3	2,52	3
32,9	15	2000	270			4,9	2	15	8	25	6	1,64	3	3,29	3	2,16	3
52,3	15	2000	285			7,8	2	15	8	25	6	2,61	3	5,23	3	2,02	3
153,2	15	2000	300			23	2	15	8	25	6	7,66	3	15,3	3	2,02	3
		2000	280					15	8	25	6					2,16	3
		2000	260					15	8	25	6					2,51	3
		2000	230					15	8	25	6					3,29	3
		2000	200					15	8	25	6					5,23	3
		2000	170					15	8	25	6					15,3	3
		2000	80					15	8	25	6						

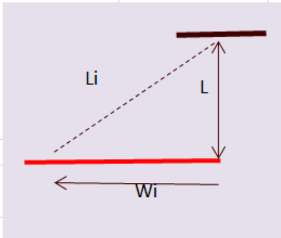
Figure 9 - Illustration of the input data (5): the 'library of 6 obstacles and 3 overhangs; the input data are in red font with a light yellow background

To facilitate the input for the distance for the successive segments, a section of the Method_input sheet provides some help, see Figure 10. For a given distance of the obstacle the width in each segment is calculated. Given the actual width of the obstacle one can see how many segments are covered and what is the distance in those segments.

Examples: Can be used in library, see cell Q55 and further

Height and length per segment for a few typical obstacles and overhangs

Number of (equal sized!) segments over 360 degrees skyline: 24



<- Horizontal cross section

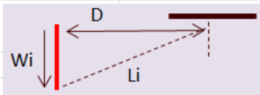
Obstacle or overhang with constant height, at a distance L in front of shaded object

Distance L perpendicular (m): 100

NOTE: For obstacle: H is the upper edge, at distance L (from where the obstacle starts). For overhang: H is the lower edge, at distance L (until where the overhang ends). H can be directly filled in in Library because remains constant	**Segment azim. angle**	**Relat. segment i *)**	**Distance Li in segment i (m)**	**Width Wi in segment i (m)**
1	7,5	1	**766,1**	759,6
2	22,5	2	**261,3**	241,4
3	37,5	3	**164,3**	130,3
4	52,5	4	**126,0**	76,7
5	67,5	5	**108,2**	41,4
6	82,5	6	**100,9**	13,2
*): relative segment number, within the 180 degrees view from the shaded object, counted anti-clockwise. Only one side (quartersphere) is taken, because of symmetry				*If the obstacle or overhang is limited in width: just leave the L and H values blank for Wi that are beyond the actual width*

Side wing with constant height and length, perpendicular to shaded object

Distance (m): 3



<- Horizontal cross section

Relat.

Figure 10 - Illustration of a section to help to determine the distance for each segment and how many segments are covered by the obstacle; the input data are in red font with a light yellow background

A maximum of 3 obstacles and 1 overhang can be assigned to each of the 3 objects. The assignment of the obstacles and overhang is illustrated in Figure 11.

*WARNING: when assigning a shading object, note that the distance of **closeby** shading objects is measured with a specific shaded object in mind...*		**1**	**2**	**3**	**Shading objects assigned to selected shaded object = object 2**	1	**Shading objects assigned to selected shaded object = object 2, description**
Assign a shading object from ObjectLib as Obst1 (if any)		1	3	2	3	2	Tower, H=150 m, at 100 m distance, West
Assign a shading object from ObjectLib as Obst2 (if any)		0	0	0	0	3	None
Assign a shading object from ObjectLib as Obst3 (if any)		5	6	6	6	4	Example of countryside surrounding
Assign a shading object from ObjectLib as Ovh1 (if any)		1	0	3	0	5	None

Figure 11 - Illustration of the input data (6): the max. 3 obstacles and max 1 overhang are selected from the 'library of 6 obstacles and 3 overhangs

6.1.1.3 Calculation

Each step in the calculation is explicitly shown on the Method_calculation sheet, with preparations in the Method_input sheet. An illustration is given in Figure 12.

AF88 =+MAX(0;B22-(AD88+AE88))

W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM
													corrected for solar angle above horizon			
														SV	W45	EV
													For selected object = 3	**Stored after running local macro**		
							max.of the 3 obstacles in this spreadsheet	only 1 overhang in this spreadsheet		No side fins in this spreadsheet	No side fins in this spreadsheet	No side fins in this spreadsheet	Calculated	**ShadObj1**	**ShadObj2**	**ShadObj3**
$H_{obst;3}$	$L_{k;ovh;1}$	$H_{ovh;1}$	$h_{k;obst;1}$	$h_{k;obst;2}$	$h_{k;obst;3}$	$h_{k;ovh;1}$	$h_{k;obst}$	$h_{k;ovh}$	$h_{k;sun}$	$w_{k;finr}$	$w_{k;finl}$	$w_{k;sun}$	$F_{sh;dir;k}$	$F_{sh;dir;1}$	$F_{sh;dir;2}$	$F_{sh;dir;3}$
m	m	m	m	m	m	m	m	m	m	m	m	m	-	-	-	-
6,0	15,3	3,0	169,0	0,0	5,0	3,0	5,0	3,0	0,0			1,0	0,00	0,00	0,00	0,00
6,0	5,2	3,0	199,0	0,0	5,0	3,0	5,0	3,0	0,0			1,0	0,00	0,00	0,00	0,00
6,0	3,3	3,0	229,0	0,0	5,0	3,0	5,0	3,0	0,0			1,0	0,00	0,00	0,00	0,00
6,0	2,5	3,0	0,0	0,0	1,5	3,4	1,5	3,4	0,2			1,0	0,04	0,00	0,00	0,04
6,0	2,5	3,0	0,0	0,0	0,0	3,8	0,0	3,8	1,2			1,0	0,24	0,23	1,00	0,24
6,0	2,2	3,0	0,0	0,0	0,0	4,1	0,0	4,1	0,9			1,0	0,18	1,00	1,00	0,18
6,0	2,0	3,0	0,0	0,0	0,0	4,5	0,0	4,5	0,5			1,0	0,10	0,00	1,00	0,10
6,0	2,0	3,0	0,0	0,0	0,0	5,1	0,0	5,0	0,0			1,0	0,00	0,00	1,00	0,00
6,0	2,2	3,0	0,0	0,0	0,0	6,1	0,0	5,0	0,0			1,0	0,00	0,00	1,00	0,00
6,0	2,5	3,0	0,0	0,0	0,0	7,8	0,0	5,0	0,0			1,0	0,00	0,00	1,00	0,00
6,0	15,3	3,0	0,0	0,0	0,0	35,4	0,0	5,0	0,0			1,0	0,00	0,00	1,00	0,00
6,0	0,0	999,0	0,0	0,0	0,0	0,0	0,0	0,0	5,0			1,0	1,00	0,00	1,00	1,00
6,0	0,0	999,0	0,0	0,0	0,0	0,0	0,0	0,0	5,0			1,0	1,00	0,00	1,00	1,00
6,0	0,0	999,0	0,0	0,0	0,0	0,0	0,0	0,0	5,0			1,0	1,00	0,00	0,00	1,00

Figure 12 - Illustration of some of the intermediate results shown on the calculation sheet (June 15, Object 3)

6.1.1.4 Output

The ***intermediate*** output is the fraction of the object that remains unshaded for the ***direct*** solar irradiance for a given hour. However, the direct solar irradiance is only fraction of the total irradiance.

The ***final*** output is the fraction of the ***total*** irradiance that remains unshaded: **the hourly solar shading reduction factor**. See illustration in Figure 13.

	Explanation:									
	F=1: unshaded									
	F=0: fully shaded or no sun									
	Fdir: fraction of direct irradiance									
	Fobst: fraction of total irradiance									
	ShadObj1						**ShadObj2**			
		SV	SVd					W45	W45d	
		0,0	0,0					-90,0	-90,0	
hours/calc		90,0	90,0					45,0	45,0	
	$F_{sh;dir;1}$	Isol_tot	Isol_dif	Isol_tot_sh	$F_{sh;obst;1}$		$F_{sh;dir;2}$	Isol_tot	Isol_dif	Iso
	-	W/m2	W/m2	W/m2	-		-	W/m2	W/m2	W
1	0,00	0,0	0,0	0,0	0,00		0,00	0,0	0,0	
2	0,00	0,0	0,0	0,0	0,00		0,00	0,0	0,0	
3	0,00	0,0	0,0	0,0	0,00		0,00	0,0	0,0	
4	0,00	0,0	0,0	0,0	0,00		0,00	0,0	0,0	
5	0,00	0,0	0,0	0,0	0,00		0,00	0,0	0,0	
6	0,00	0,0	0,0	0,0	0,00		0,00	0,0	0,0	
7	0,00	0,0	0,0	0,0	0,00		0,00	0,0	0,0	
8	0,00	0,0	0,0	0,0	0,00		0,00	0,0	0,0	
9	0,00	0,0	0,0	0,0	0,00		0,00	0,0	0,0	
10	0,00	37,6	24,0	24,0	0,64		0,27	36,6	36,6	
11	0,00	428,5	70,9	70,9	0,17		1,00	80,4	80,4	
12	0,00	409,9	84,4	84,4	0,21		1,00	134,4	102,0	
13	0,00	422,5	90,8	90,8	0,21		1,00	206,8	111,0	
14	0,00	417,8	85,9	85,9	0,21		1,00	259,0	105,6	

_calculation | Method_output | Monthly_output | Graphs | ClimDat_m | ClimDat_t

Figure 13 - Illustration of the hourly output

From the hourly output the **monthly aggregated** values can be derived. Obviously, the hourly solar shading reduction factor needs to be weighted with the solar irradiance to get the (weighted) average monthly solar shading reduction factor. These monthly values can be used for monthly calculation methods, but -evidently- the values cannot simply be extrapolated to other situations. Illustration, see Figure 14.

Fobst: fraction of total irradiance

Object1				Object2				Object3			
SV	SVd		Based on monthly H_{shad}/H_{tot}	W45	W45d		Based on monthly H_{shad}/H_{tot}	EV	EVd		Based on monthly H_{shad}/H_{tot}
$H_{sol;tot}$	$H_{sol;dif}$	$H_{sol;tot;shad}$	$F_{sh;obst;1}$	$H_{sol;tot}$	$H_{sol;dif}$	$H_{sol;tot;shad}$	$F_{sh;obst;2}$	$H_{sol;tot}$	$H_{sol;dif}$	$H_{sol;tot;shad}$	$F_{sh;obst;3}$
kWh/m2	kWh/m2	kWh/m2	-	kWh/m2	kWh/m2	kWh/m2	-	kWh/m2	kWh/m2	kWh/m2	-
40,0	9,3	9,3	0,23	23,1	12,6	18,9	**0,82**	14,5	9,3	10,2	**0,70**
53,9	12,0	12,0	**0,22**	28,3	15,6	24,3	**0,86**	22,7	12,0	13,9	**0,61**
53,4	14,8	15,5	**0,29**	39,1	19,2	35,0	**0,90**	26,0	14,8	16,7	**0,64**
126,2	29,9	58,3	**0,46**	104,9	32,3	66,7	**0,64**	67,2	29,9	34,1	**0,51**
87,5	37,7	48,6	**0,56**	109,2	45,9	55,0	**0,50**	66,8	37,7	39,3	**0,59**
99,1	46,4	48,7	**0,49**	152,8	50,5	50,5	**0,33**	94,4	46,4	49,4	**0,52**
91,3	48,1	48,2	**0,53**	162,0	51,3	51,3	**0,32**	103,5	48,1	52,4	**0,51**
79,3	43,3	43,8	**0,55**	137,4	50,2	50,2	**0,37**	80,4	43,3	46,0	**0,57**
98,4	39,7	48,4	**0,49**	134,7	43,8	49,3	**0,37**	77,6	39,7	41,9	**0,54**
96,5	31,0	51,1	**0,53**	93,0	36,0	58,6	**0,63**	63,0	31,0	34,0	**0,54**
70,3	20,9	26,8	**0,38**	59,2	26,6	48,7	**0,82**	34,3	20,9	22,7	**0,66**
44,2	10,5	10,5	**0,24**	28,1	13,9	23,0	**0,82**	17,6	10,5	11,9	**0,68**
40,0	9,3	9,3	**0,23**	23,1	12,6	18,9	**0,82**	14,5	9,3	10,2	**0,70**
940	**344**	**421**	**0,45**	**1072**	**398**	**531**	**0,50**	**668**	**344**	**372**	**0,56**

Figure 14 - Illustration of the aggregated monthly output

In contrast to the use of monthly values, the input-output relation using the hourly calculation method is straightforward.

The output is -of course- intended to be used as input for the calculation of energy needs for heating and cooling and internal temperatures according to EN ISO 52016-1, but also for other EPB standards, such as the standards on photovoltaic systems and thermal solar systems.

Therefore, the spreadsheet has been prepared as a stand-alone tool.

The spreadsheet on EN ISO 52016-1 (see case study [6]) has been prepared to take into account the solar shading reduction factors for specific building elements. Full integration of the solar shading reduction factors calculated with this stand-alone spreadsheet is foreseen for the next update.

6.1.2 Coupling

No special coupling needed, other than explained above.

6.1.3 Supporting calculations

No special supporting calculations needed, other than explained above

6.2 Results

6.2.1 Climate: Strasbourg

6.2.1.1 Relative height of the obstacles and overhang, as seen from each object

Object 1:

For object 1 (South vertical plane) 3 obstacles were selected plus 1 overhang.

Figure 15 shows the relative height, in angle above horizon (degrees) for each of these obstacles and overhang, as seen from object 1.

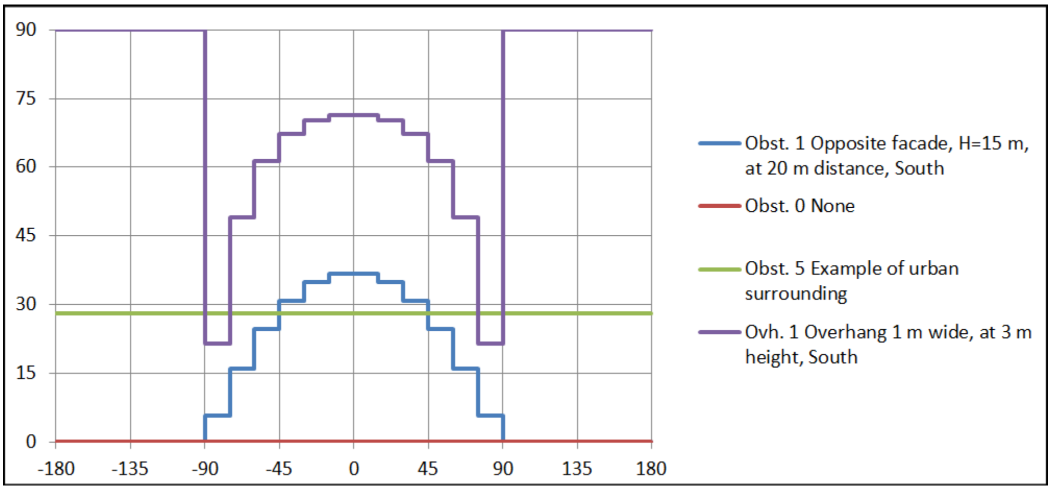


Figure 15 - Relative height of obstacles and overhang for object 1

The horizontal axis gives the skyline segments, from -180 to + 180 degrees (North, West, South, East, North).

The first selected obstacle is "Obst. 1" from the library: an opposite (also South) façade. The distance, and thus the relative height of the obstacle, decreases when turning the 'view' to the West or to the East. The relative height determines if the direct irradiance from the sun is blocked or not, by this obstacle. The sun is blocked if it is in a skyline segment where it has a **lower** angle than the relative height of the obstacle.
So, the impact of the opposite façade **decreases** when the sun position is more to the West or more to the East.
Of course, for the Northern hemisphere, the sun will decline at the same time, but that is the next step in the calculation.

The second selected obstacle is "Obst. 0": none selected. This has been chosen to check if the spreadsheet tool can cope with zero. Apparently this is no problem.

The third selected obstacle is "Obst. 5": the example of (assumed) urban surrounding: all around the skyline the same "default" relative height of about 28 degrees.

The selected overhang is "Ovh 1": a 1 m wide overhang at 3 m height, South oriented. Like for "Obst. 1" the distance and thus the relative height decreases when turning the 'view' to the West or to the East.
The relative height determines if the direct irradiance from the sun is blocked or not, by this overhang.
However, in contrast with the obstacle: the sun is now blocked if it is in a skyline segment where it has a **higher** angle than the relative height of the overhang.
So, the impact of the overhang **increases** when the sun position is more to the West or more to the East.

Note that outside the range from -90 to +90 on the horizontal axis, the South oriented vertical object will not be able to see the sun anyway.

For the 3 obstacles plus 1 overhang combined, one can directly see in the graph for which angles of the sun the sun is not blocked. See the green shaded area in Figure 16.

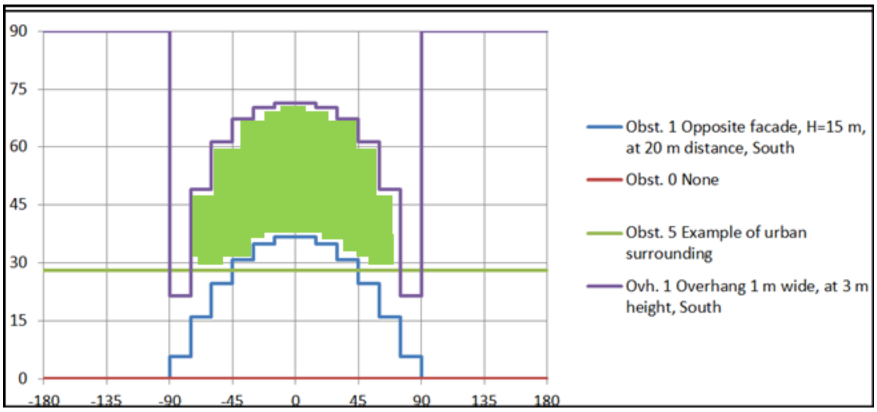


Figure 16 - The green are is the area of sun height and azimuth where the sun is not blocked by any of the 3 obstacles or overhang, as seen from object 1.

Object 2:

For object 2 (West plane, tilted 45 degrees) 2 obstacles were selected and no overhang.

Figure 17 shows the relative height, in angle above horizon (degrees) for each of these obstacles, as seen by object 2.

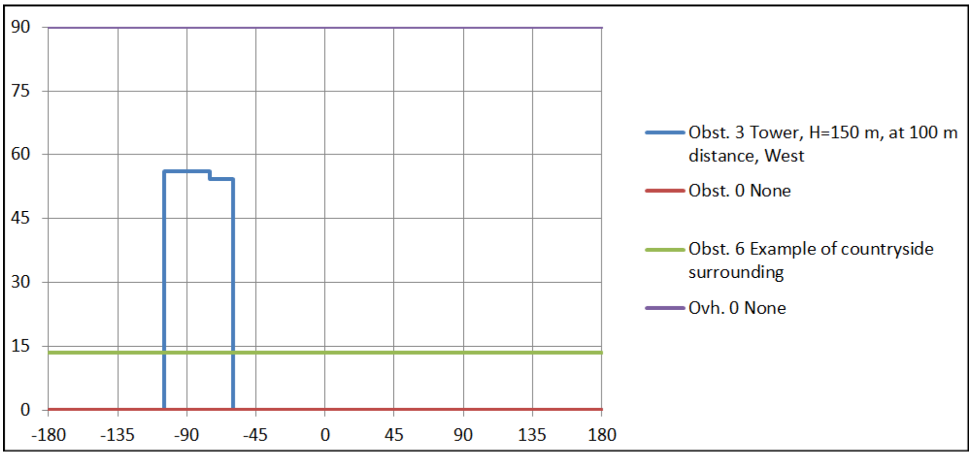


Figure 17 - Relative height of obstacles and overhang for object 2 (West, 45 degrees tilted)

The tower is located in the West direction (-90 on the horizontal axis), so in front of the plane.

“Obst, 6” is the assumed default constant relative height for a country-side: a lower height than the urban surrounding (Fig. 15).

Object 3:

For object 3 (East plane, vertical) 2 obstacles were selected and 1 overhang.

Figure 18 shows again the relative height, in angle above horizon (degrees) for each of these obstacles, as seen by object 3.

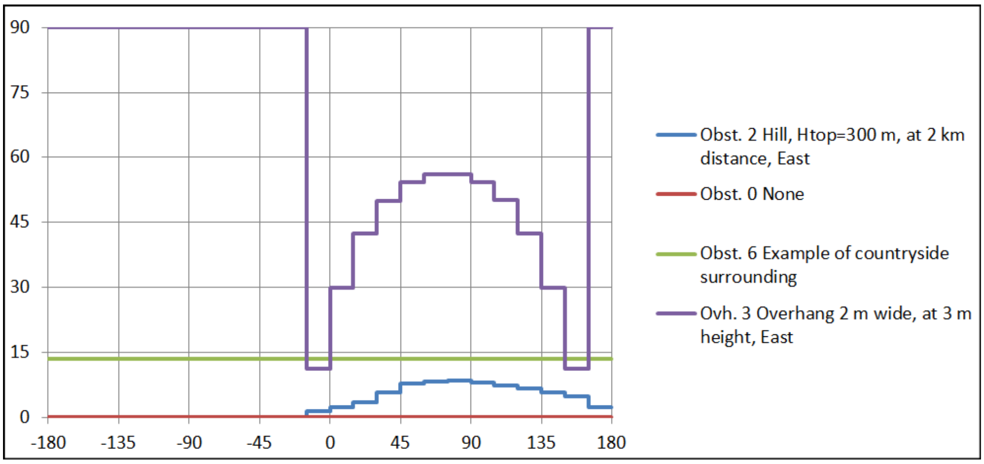


Figure 18 - Relative height of obstacles and overhang for object 3 (East vertical plane)

Given the explanation on the previous figures, Figure 18 speaks for itself. Note that the hill stays below the assumed default countryside surroundings, which implies that it is too far away in this case to provide extra shading.

6.2.1.2 Part of the direct solar irradiance that remains unshaded

An illustration of the part of the direct solar irradiance that remains unshaded, is given in Figure 19. Figure 19 shows the hourly values for one winter and one summer day of each of the 3 objects.

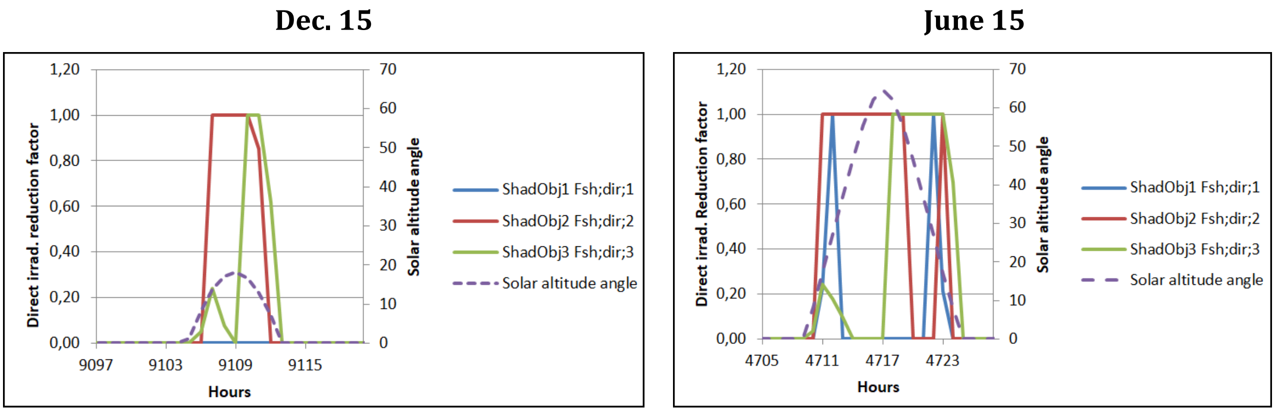


Figure 19 - Illustration of the direct part of the solar shading that remains unshaded; example for one winter and one summer day

If the factor is 1, then the object is fully unshaded. If the factor is 0, then the direct solar irradiance is either fully blocked by one or more of the obstacles/overhang, or the sun is below the horizon.

The solar altitude is also plotted in the graph to allow a rough qualitative comparison with the previous graphs. For a precise analysis the minimum and maximum height of the object and the azimuth angle of the sun should also be taken into account, which is of course all covered in the calculation procedures.

But just for a quick impression:

Object 1 (South) is shaded all the time in December, due to the low sun position: lower than the assumed urban surroundings. In June the high sun position makes that the solar beam reaches the object only at the early and late hours of the day.

For **Object 2** (West 45°) the West tower leads to shading in the afternoon in June; in December the sun is at that hour of the day already below the horizon.

For **Object 3** (East): in the early morning both the surrounding and the overhang lead to partial shading and eventually to full shading (0). But about midday the sun turns out of the range of the overhang, leading to a sharp rise of the shading reduction factor to 1 (unshaded).

6.2.1.3 Finally: the shading reduction factor

In Figure 20 the graphs show, for each of the three shaded objects, the hourly values for the total irradiance, unshaded and shaded and the ratio: the hourly shading reduction factor.

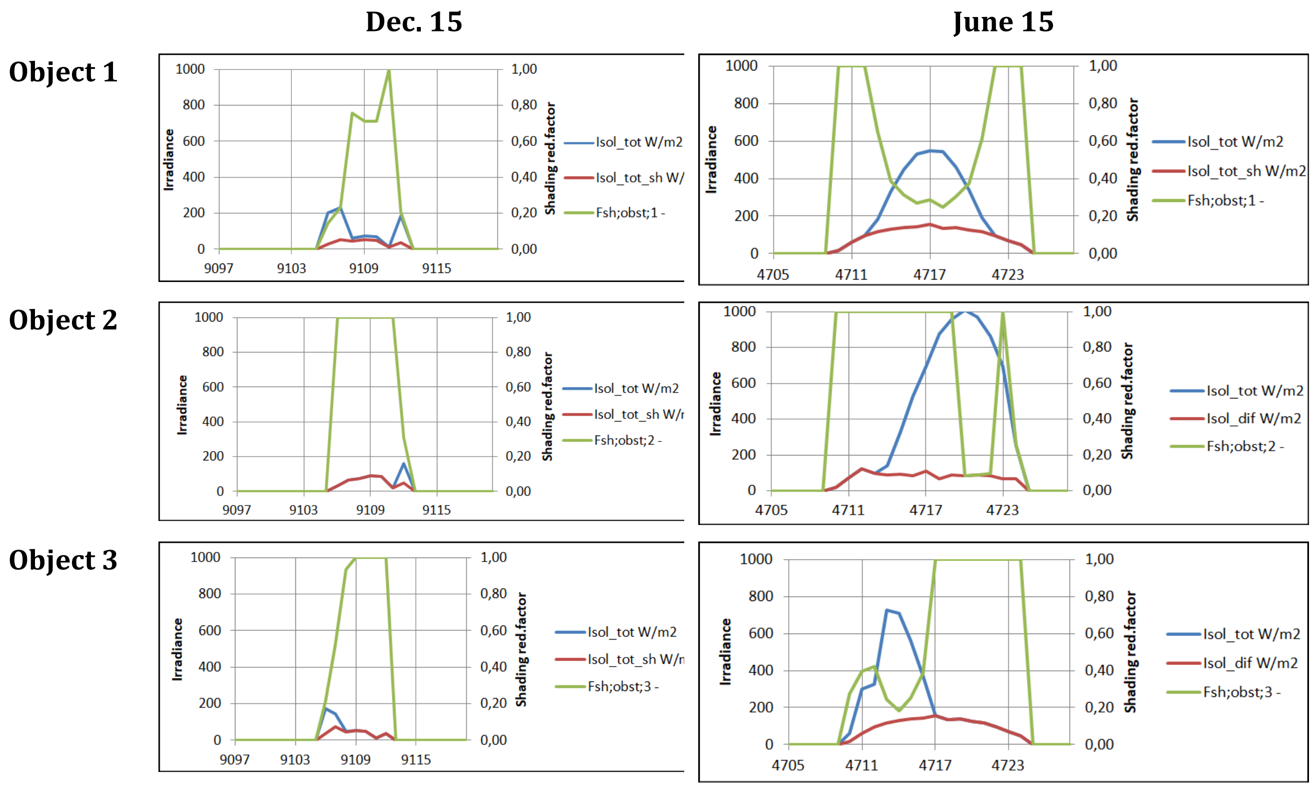


Figure 20 - Illustration, for each of the 3 objects, of the hourly total unshaded and shaded solar irradiance and the ratio: the solar shading reduction factor (the output of the calculation)

Only direct radiation is assumed to be shaded; diffuse radiation is not (see EN ISO 52016-1 and CEN ISO/TR 52016-2 for details).

Consequently, the actual shading reduction factor for the total solar irradiance can be (much) higher, meaning: closer to 1, than the shading reduction factor for only direct radiation shown in Figure 19. In the "extreme" case that there is only diffuse irradiance, the shading reduction factor becomes 1, even if fully shaded for direct solar irradiance.

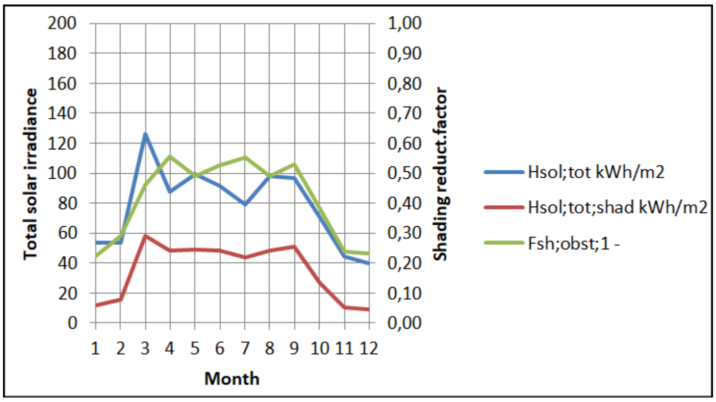
6.2.1.4 Monthly aggregated values

Of course the hourly values presented in the previous sections can be aggregated to monthly values.

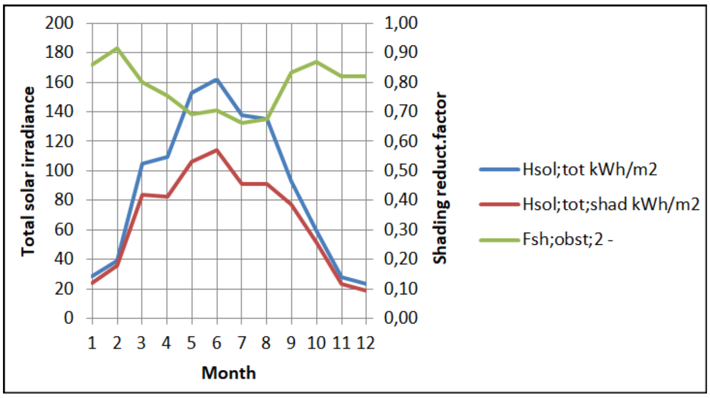
For evident reasons, one should not directly take the average of the hourly shading reduction factors, but take the resulting shading reduction factors on the basis of the monthly accumulated solar irradiance with versus without shading.

The monthly values, again for the 3 example objects and the assigned obstacles/overhang, are given in Figure 21. In Figure 21 the graphs show, for each of the three shaded objects, the monthly values of the total irradiance, unshaded and shaded and the ratio: the shading reduction factor.

Object 1



Object 2



Object 3

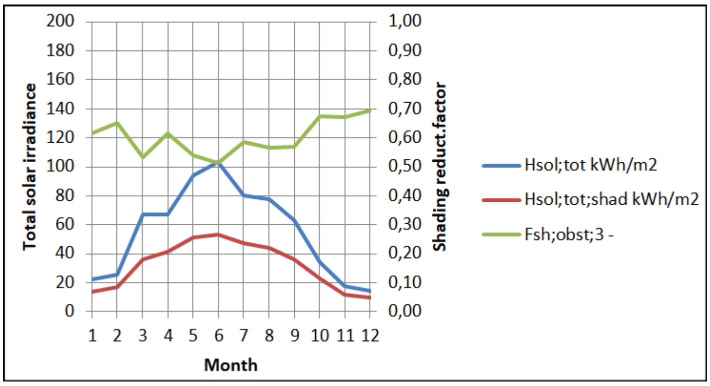


Figure 21 - Illustration, for each of the 3 objects, of the monthly total unshaded and shaded solar irradiance and the ratio: the solar shading reduction factor

Comparing the three objects reveals that Object 1 has a higher value of the shading reduction factor in winter compared to summer, while the other two objects have a lower value in winter compared to summer. Of course, this is the result of a number of influencing factors. But one of the contributing factors was mentioned in 6.2.1.3: the reduction factor is by definition high (close to 1) if there is little difference between total and diffuse solar irradiance. And this occurs more often on West (Object 2) and East (Object 3) orientation in winter. The low South sun in winter easily leads to shading on a South oriented surface (Object 1).

6.2.2 Other climates

The spreadsheet tool is publicly available, with climatic data files for Oslo and Athens to perform similar exercises for these climates, using the same objects and obstacles or customized.

No tests were done for locations in the Southern hemisphere. However, during the preparation of the calculation procedures tests have been performed which give confidence that the procedures are universally valid.

7 Analysis

7.1 Functionality

The spreadsheet on Annex F of EN ISO 52016-1 enabled to check the functionality of the procedures of this normative Annex of EN ISO 52016-1, to calculate the hourly shading reduction factors in case of external obstacles or overhangs.

This case study demonstrates that this Annex provides the necessary (hourly and monthly) information for the other EPB standards, on the basis of available input data.

7.2 Completeness

This case study demonstrates that Annex F of EN ISO 52016-1 provides all the data that are needed, for any climate, any location and any plane.

The spreadsheet does not cover the simplified approaches for simple rebates, overhangs and side fins, or monthly calculation procedures that are covered in Annex F. These are also ignored in this case study.

These simplified approaches can be evaluated on the basis of results from the detailed procedure covered in this document.

7.3 Sensitivity

The Annex F of EN ISO 52016-1 and the dedicated spreadsheet can handle any variety of input data, regarding climatic data, geometry and position of objects that are subject to shading and geometry and position of obstacles that may cause the shading.

7.4 Usability

The spreadsheet tool has not been developed for application in daily practice, but for demonstration and validation. This document shows that it is easy to use for this purpose.

For daily use in practice, as part of the assessment of the energy performance of a building, a user friendly software tool is needed. This is only a matter of user friendly interface and connection to the other parts of the calculation. The connections are clearly identified.

8 Conclusions and recommendations

The presented calculation procedures on Annex F of EN ISO 52016-1 cover adequately the need and produces results that can be readily used in EN ISO 52016-1 itself and in other EPB standards.

The spreadsheet works well to demonstrate, validate and illustrate the calculation procedure. In particular because each step of the calculation is visible and can be tracked and traced.

The spreadsheet tool is not suited for application in daily practice. It has not been developed for that purpose. For daily use in practice, software tools can be used that have a user-friendly interface and that make the connections to other parts of the calculation. Which connections are needed is clearly shown in the Annex F of the standard as illustrated in this document.

An update of the spreadsheet, with minor improvements resulting from this case study, will be published early 2022.

Bibliography

[1] (EN) ISO 52010-1:2017, *Energy performance of buildings — External climatic conditions — Part 1: Conversion of climatic data for energy calculations*

[2] (CEN) ISO/TR 52010-2:2017, *Energy performance of buildings — External climatic conditions — Part 2: Explanation and justification of ISO 52010-1*

[3] (EN) ISO 52016-1:2017, *Energy performance of buildings — Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads — Part 1: Calculation procedures*

[4] (CEN) ISO 52016-2:2017, *Energy performance of buildings — Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads — Part 2: Explanation and justification of ISO 52016-1 and ISO 52017-1*

[5] ENERC32017-437-SI2-785.185, Case study on EN ISO 52010-1, Climatic data
October 31, 2021

[6] ENERC32017-437-SI2-785.185, Case study on EN ISO 52016-1, Heating and cooling needs and internal temperatures
October 31, 2021

Please check the EPB Center website for the overview and most recent versions of the other case study reports.

Link: EPB Center support documents

NOTE References to the applied tools and supporting data are provided in the relevant paragraphs of this document.

This document has been produced under contract with the European Commission (service contract ENER/C3/2017-437/S12-785.185).