



TUTORIAL

TRANSIENT SIMULATIONS OF VENTILATED DOUBLE SKIN FAÇADE USING THE SOLAR PROCESSOR: GETTING STARTED WITH VOLTRA



VTR TUTORIAL A

1. Introduction

[T_VTR_a_solar_double_skin_facade_a.vtr](#)

[T_VTR_a_solar_double_skin_facade_b.vtr](#)

This tutorial introduces the transient simulation modelling workflow in VOLTRA, demonstrated through a double-skin façade case study using the solar processor. The focus is on VOLTRA-specific functions and parameters. Most of the general geometrical modelling procedures are covered in TRISCO, so it is recommended to complete the TRISCO tutorials beforehand.

Key elements:

- Weather data (EPW-format) as boundary conditions
- Defining glazing properties
- Definition of solar data and sun obstacles
- Defining ventilation flow
- Graphic output, text output and report definitions

2. Model geometry, material properties, boundary conditions

In the 2D room model considered (Figure 1) the frame section is simplified to reduced the simulation time for the purpose of this tutorial. More complex geometrical models are possible.

We start the tutorial with [T_VTR_a_solar_double_skin_facade_a.vtr](#) add step-by-step elements in the following sections. The final result will be [T_VTR_a_solar_double_skin_facade_b.vtr](#).

In the first step, a coarse grid is used. It is generally good practice to begin with transient simulations on a coarse grid to evaluate the model's initial behaviour, identify potential issues, and make necessary adjustments before investing time in a refined mesh. In this tutorial, the initial coarse grid is shown in Figure 2. Later, in section 11, the results obtained using a finer grid are presented ([T_VTR_a_solar_double_skin_facade_b.vtr](#)).

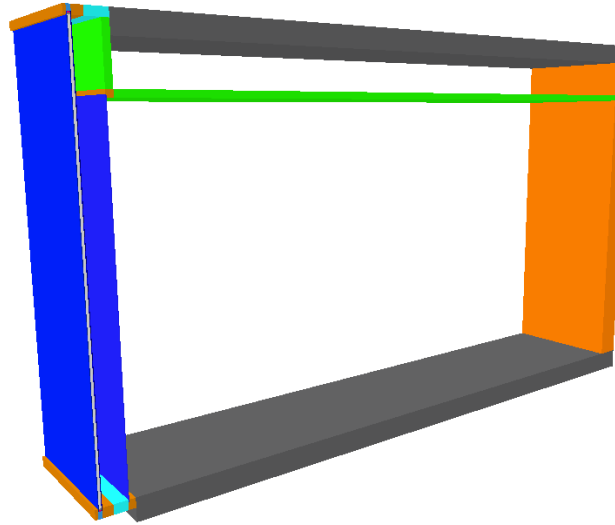


Figure 1 2D room model

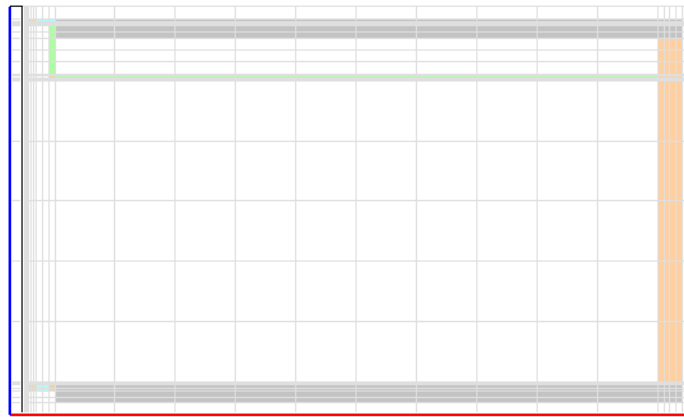


Figure 2 Coarse grid

Col.	Type	Subtype	Physical flow dir.	Geometrical flow dir.	Name	ϵ_1 / ϵ_2 [- / -]	λ [W/mK]	ϵ [-]	ρ [kg/m ³]	c [J/kgK]	θ [°C]	h [W/m ² K]	q [W/m ²]	θ_a [°C]	h_c [W/m ² K]	P_c [W]	θ_r [°C]	Sun	ρ_s [-]	τ_s [-]	Standard
1	BC_SIMPL	NIHIL			adiabatic						0.0	0.00	0					NO			NIHIL
2	BC_SIMPL	NIHIL			outdoors						0.0	13.50	0					YES			NIHIL
4	BC_SIMPL	NIHIL			lower zone						20.0	5.90	0					NO			NIHIL
6	BC_SIMPL	NIHIL			upper zone						20.0	7.70	0					NO			NIHIL
7	BC_SIMPL	NIHIL			back zone						20.0	10.00	0					NO			NIHIL
8	MATERIAL				aluminium		160.000	0.90	2800	880									0.00	0.00	
16	MATERIAL				concrete, reinf. (1% steel)		2.300	0.90	2300	1000									0.50	0.00	
28	MATERIAL				brickwork		0.600	0.90	1200	850									0.50	0.00	
35	MATERIAL				insulation 1		0.040	0.90	40	850									0.50	0.00	
37	MATERIAL				insulation 2		0.040	0.90	40	850									0.50	0.00	
60	MATERIAL				frame conductive part		100.000	0.90	500	1000									0.50	0.00	
61	MATERIAL				frame thermal break part		0.300	0.90	200	1000									0.50	0.00	
62	MATERIAL				silicone, pure		0.350	0.90	1200	1000									0.50	0.00	
66	MATERIAL				glass 1 - colour 1		1.000	0.84	2500	750									0.10	0.84	
82	MATERIAL				glass 1 - colour 2		1.000	0.84	2500	750									0.07	0.84	
98	MATERIAL				glass 2 - colour 3		1.000	0.05	2500	750									0.07	0.84	
114	MATERIAL				glass 2 - colour 4		1.000	0.84	2500	750									0.07	0.84	
130	MATERIAL				glass 3 - colour 5 and 6		1.000	0.84	2500	750									0.07	0.85	
224	BC_FREE	NIHIL			ceiling				1.2	1005			0		2.50	0					
240	BC_FREE	NIHIL			room				1.2	1005			0		2.50	0					
242	BC_FREE	NIHIL			facade cavity				1.2	1005			0		2.50	0					
243	TRANSMAT	NIHIL			argon cavity		0.017		1.2	1005											

Figure 3 Material properties and boundary conditions

Figure 3 shows the colour definitions used in VOLTRA model. There are 4 different types used here.

- BC_SIMPL for the boundary conditions in outdoors and in neighbouring rooms. Locations of BC_SIMPL colours are presented in Figure 4
- MATERIAL for all solid materials
- BC_FREE for the room, indoors ceiling cavity and façade cavity
- TRANSMAT for the double glazing argon cavity

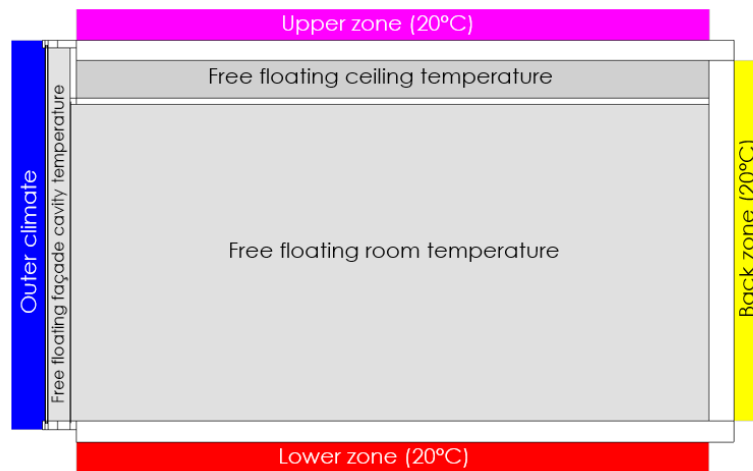


Figure 4 BC_SIMPL positions and colours

Particularities about the input data (Figure 3)

- The outdoor (colour 2) is a 'solar' zone.
- The outdoor global surface heat transfer coefficient $h_e = 13.5 \text{ W/m}^2\text{K}$ (summer conditions, low wind)
- Material properties (including density and specific heat) are adjusted for this case study. User can use existing materials from the material database with corresponding colour number or overwrite new properties manually.
- The infrared emissivity is 0.9 for all materials except glass for which 0.837 is used according to EN 673.

Glass 2 – colour 3 has a low emissivity coating with $\varepsilon = 0.05$

All materials, except the glazing, are opaque ($\tau_s=0$) for solar radiation.

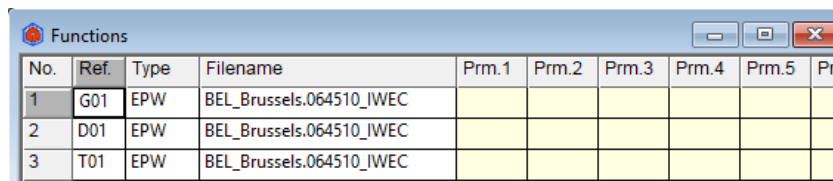
All materials, except the glazing, have a solar absorption $\alpha_s=0.5$ (light colour)

The glazing solar properties are discussed in section 4.

- Room, ceiling, façade cavity are modelled as BC_FREE and argon cavity of the DGU is modelled as TRANSMAT. For these types detailed infrared radiation is considered.

3. Weather data

- Open the Functions window (Edit → Functions).
- Add a new Function: Edit → Insert Row.
- For this tutorials we will create 3 functions for which we use the Type EPW:
 - o G01: horizontal global solar radiation
 - o D01: horizontal diffuse solar radiation
 - o T01 : temperature



No.	Ref.	Type	Filename	Prm.1	Prm.2	Prm.3	Prm.4	Prm.5	Pr
1	G01	EPW	BEL_Brussels.064510_IWEC						
2	D01	EPW	BEL_Brussels.064510_IWEC						
3	T01	EPW	BEL_Brussels.064510_IWEC						

Figure 5 Weather data functions

- The first function with reference G01 refers to the horizontal global solar radiation data for Brussels.
- A function reference consists of a letter which refers to the function type (here “G” = horizontal global solar radiation) and a two-digit sequence number.
- The Function Graph window shows the current function G01.

The time axis shows all days of the year with the origin (abscissa 0) at day number 220 (= August 8th), as defined in the Calculation Parameters dialog box (Edit → Calc Parameters..., day number at start of calculation = 220, see section 5).

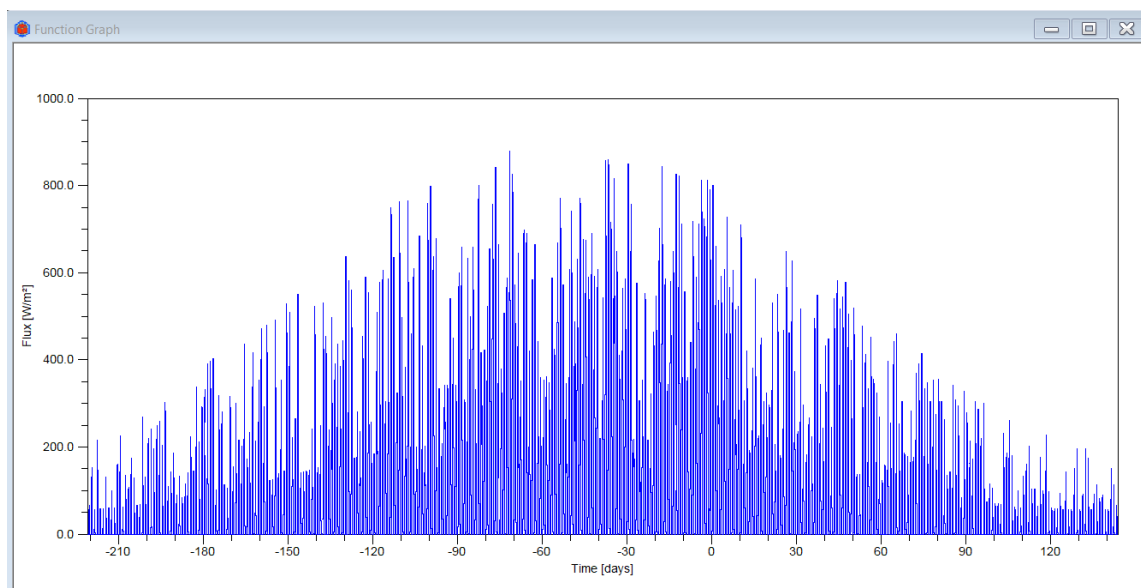


Figure 6 Function G01 graph (function scope)

- *Functions* → *X Scale...* and select “Calculation time” as scope.

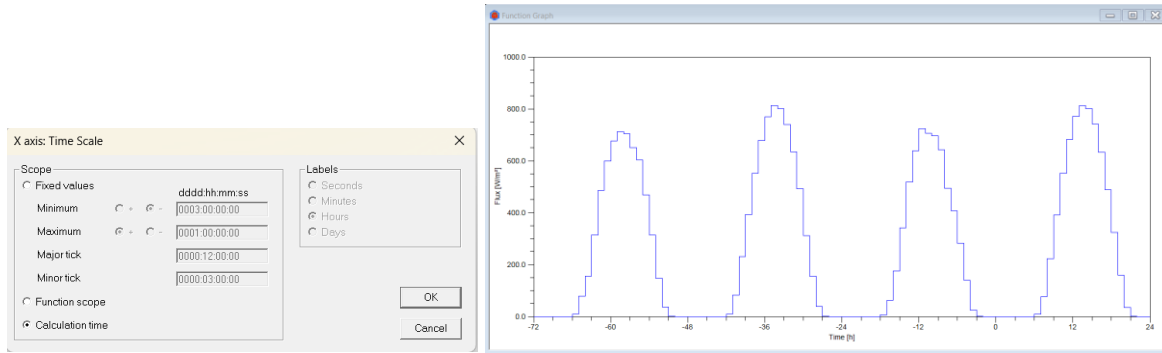


Figure 7 Function G01 graph (calculation time scope)

- The function "D01" is used for the creation of the horizontal diffuse solar radiation data of Brussels (see Figure 8 left). The function "T01" shows the air temperature of Brussels (see Figure 8 right).

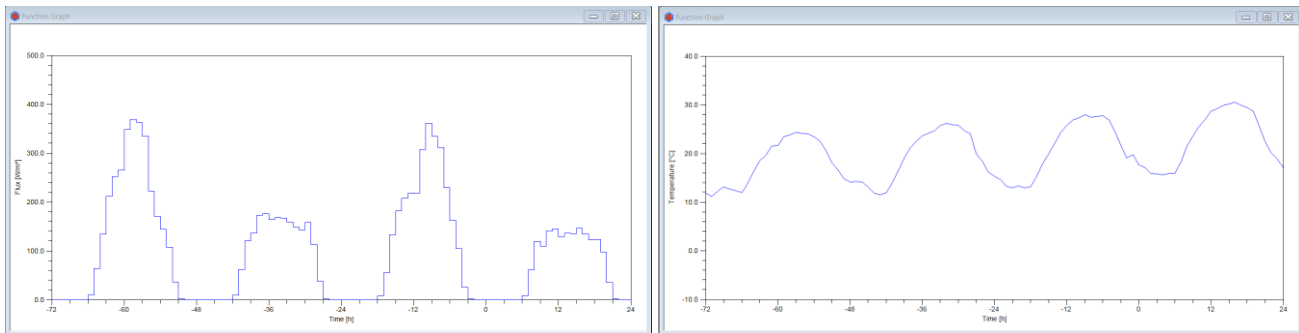


Figure 8 Function D01 (left) and T01 (right)

- After adding the temperature function, it is essential to link it to the external boundary condition. This is done by referencing the function name (e.g., T01) in the temperature value field of the boundary condition settings.

Col.	Type	Subtype	Physical flow dir.	Geometrical flow dir.	Name	ϵ_1 / ϵ_2 [- / -]	λ [W/mK]	ϵ [-]	ρ [kg/m³]	c [J/kgK]	θ [°C]	h [W/m²K]	q [W/m²]	θ_a [°C]	hc [W/m²K]	P_c [W]	θ_r [°C]	Sun	ρ_s [-]	τ_s [-]	Standard
1	BC_SIMPL	NIHIL			adiabatic						0.0	0.00	0					NO			NIHIL
2	BC_SIMPL	NIHIL			outdoors						T01	13.50	0					YES			NIHIL

Figure 9 Temperature function assigned to colour 2 (outside boundary condition)

4. Glazing properties

The glazing properties need some special attention, especially because the solar transmission factor to be entered is defined not in the classic way. In VOLTRA, the solar transmission factor expresses the solar transmission fraction after deduction of reflection (which can be dependent on the angle of incidence).

For more information refer to [H14-How to define glazing in BISTRA & VOLTRA](#).

[Physibel online toolbox](#) can be used to prepare the glazing characteristics.

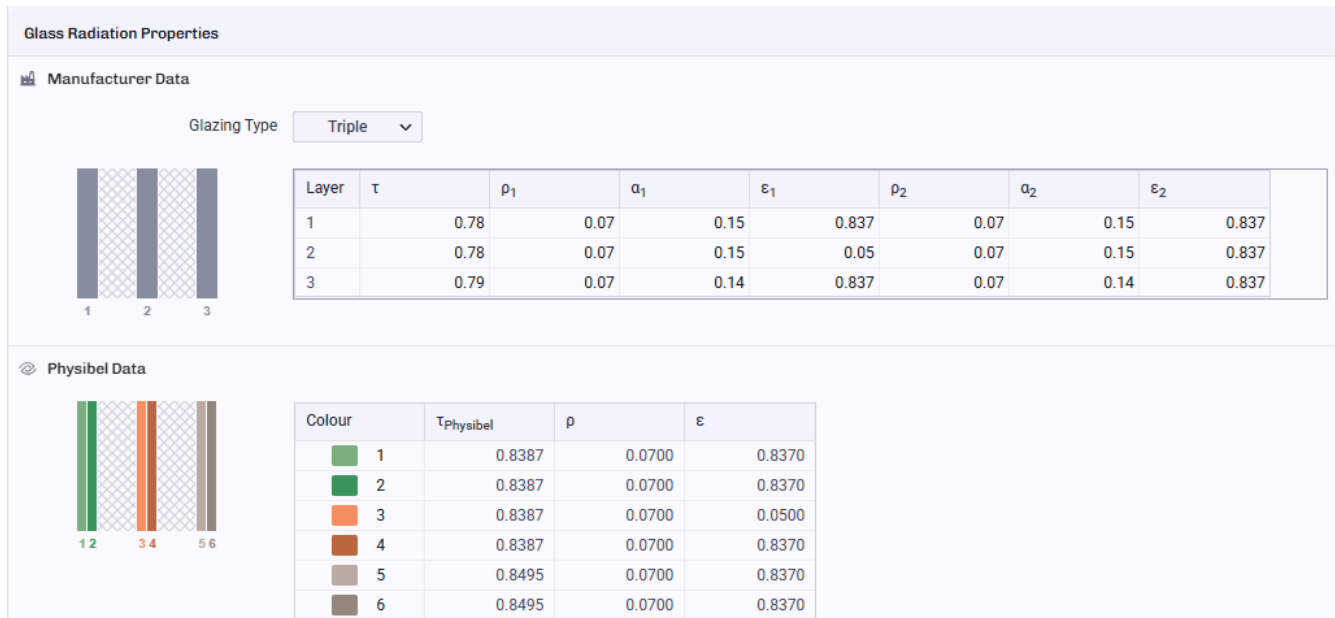


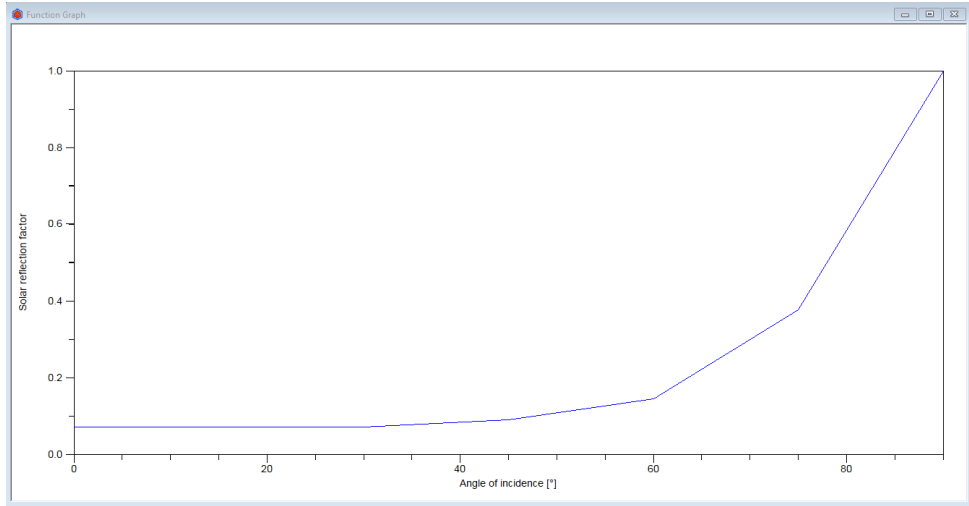
Figure 10 Glazing properties

As shown in Figure 10 each pane is divided into two colours. This allows different parameters to be assigned to the front and back surfaces of each glass layer. In this specific case, however, there is no difference between the properties of colours 1 and 2, nor between 5 and 6. Therefore, these pairs can be treated as a single colour. However, for the first pane, the reflectance of the exterior surface depends on the angle of incidence. Since this angle-dependent reflectivity must be defined as a function in VOLTRA, colours 1 and 2 must remain separate. When using Physibel Toolbox to determine the correct $\tau_{physibel}$ value, the reflectivity at 0° incidence (normal incidence) should be entered using the manufacturer's data.

Figure 11 shows the angle dependency of solar reflection used for the external glazing surface. This angle dependent reflection factor at the solar zone, defined by a function referred to by "R01" (cf. Function window).

The function R01 is defined by the following points $\rho_0 = \rho_{15} = \rho_{30} = 0.070$, $\rho_{45} = 0.089$, $\rho_{60} = 0.144$, $\rho_{75} = 0.377$, $\rho_{90} = 1.0$. All other properties are linearly interpolated (as shown in the function graph (Figure 11)). The function file 'glass.FRF' is a simple text file (see Figure 11). The angle-dependent reflection function is linked to the material property colour 66 glass 1 - colour1 by entering the function reference (e.g., R01) in the ρ_s section. Figure 12 illustrates how this function is linked to colour 66.

The cavity between pane 1 and pane 2 is filled with argon, which has a conductivity of 0.017 W/mK. In the model this cavity is represented using TRANSMAT (colour 243. The façade cavity between pane 2 and pane 3 is filled with air and is modelled using BC_FREE(colour 242).



glass.FRF	
File	Edit
0	0.070
15	0.070
30	0.070
45	0.089
60	0.144
75	0.377
90	1.000

Figure 11 Glazing angle dependent solar reflection

Col.	Type	Subtype	Physical flow dir.	Geometrical flow dir.	Name	c1 / c2 [- / -]	λ [W/mK]	c [-]	ρ [kg/m ³]	c [J/kgK]	θ [°C]	h [W/m ² K]	q [W/m ²]	θ_a [°C]	hc [W/m ² K]	Pc [W]	θ_r [°C]	Sun	ps [-]	τ_s [-]	Standard
66	MATERIAL				glass 1 - colour 1		1.000	0.84	2500	750									R01	0.84	
82	MATERIAL				glass 1 - colour 2		1.000	0.84	2500	750									0.07	0.84	
98	MATERIAL				glass 2 - colour 3		1.000	0.05	2500	750									0.07	0.84	
114	MATERIAL				glass 2 - colour 4		1.000	0.84	2500	750									0.07	0.84	
130	MATERIAL				glass 3 - colour 5 and 6		1.000	0.84	2500	750									0.07	0.85	

Figure 12 Updated glazing properties

Note: it is important to define the gas cavity of the DGU as type TRANSMAT and not as EQUIMAT. EQUIMAT would consider this cavity as an equivalent material, thus not considering detailed radiation properties

5. Solar data and calculation parameters

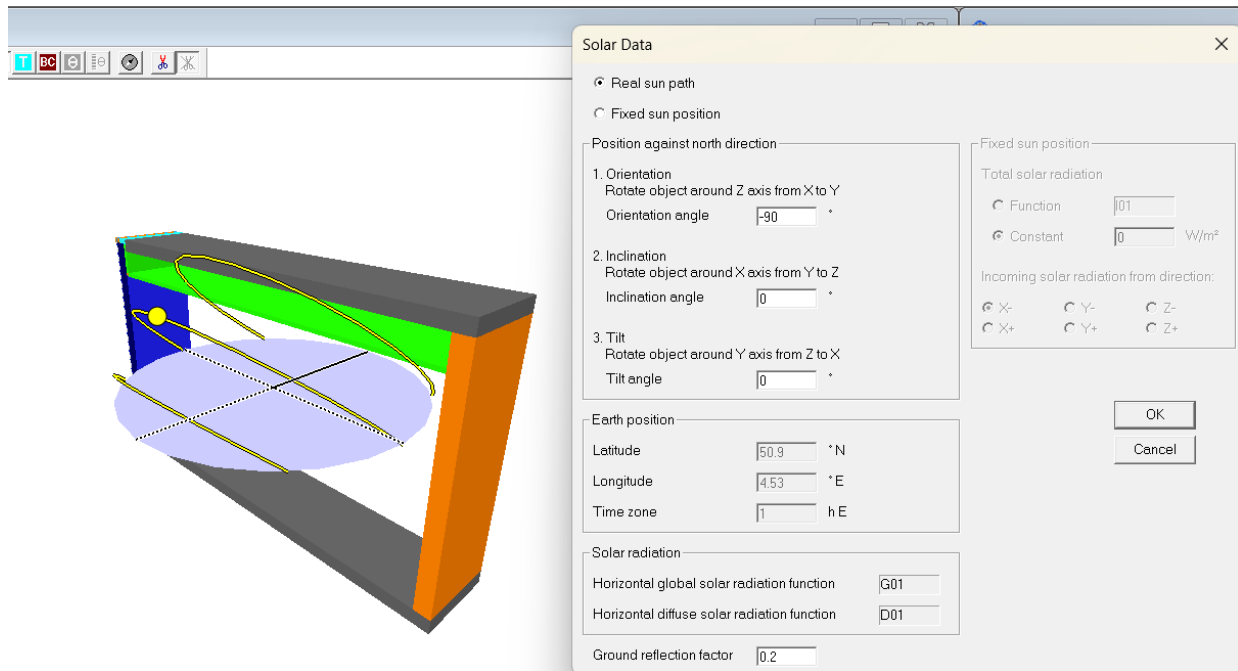


Figure 13 Solar data

Upon opening the Solar Data dialog box (*Edit* → *Solar Data...*), the user can choose to simulate a real sun path or perform a simplified simulation with a fixed sun position. A real sun path is selected for this tutorial. The geographical location (latitude, longitude and time zone) are copied from the EPW file, and the input is not required in the Solar Data dialog box (the corresponding input fields are greyed).

The orientation angle was adjusted by -90° , resulting in a west-facing façade. August 8 (Day 220) was selected because the west façade on this date experiences the highest thermal load, not only compared to all other days of the year, but also relative to façades facing other orientations. For more information how to select the worst day for simulation please refer to Physibel Knowledge base document: [H16 – How to determine the day with the highest outdoor climate load as a function of the façade orientation in BISTRA & VOLTRA](#)

The simulation is performed for one day, preceded by a three-day start-up (initialization) period to ensure thermal stabilization of the model with a time step of 10 minutes. These dynamic calculation parameters are set in the Calculation Parameters dialog box (opened with *Edit* → *Calc Parameters...*). Figure 14 shows the calculation parameters.

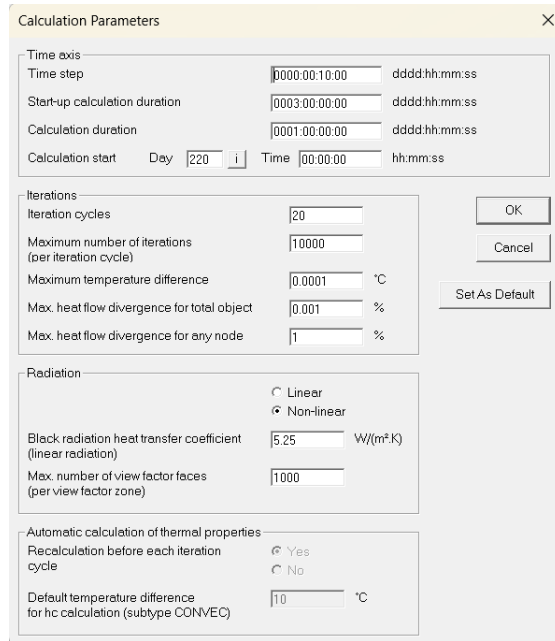


Figure 14 Calculation parameters

6. Sun obstacles

A sun obstacle is a spherical region on the sky hemisphere in the horizontal coordinate system in which the sun is blocked by other objects. Sun obstacles are defined in the Sun Obstacles window (*Edit* → *Sun Obstacles*).

A new row can be inserted in the Sun Obstacles window via *Edit* → *Insert Row* .

No.	Min. Azimuth [°]	Max. Azimuth [°]	Min. Altitude [°]	Max. Altitude [°]
1	-180	180	0	5

Figure 15 Sun obstacles window

The first sun obstacle shown in Figure 15 is a zone around the horizon up to 5° high. This obstacle is by default present for each new VOLTRA data file to avoid numerical rounding errors for low sun positions.

The sun obstacles can be seen via *Output* → *Graphic Output* → *View* → *Sun Position & Sun Obstacles*

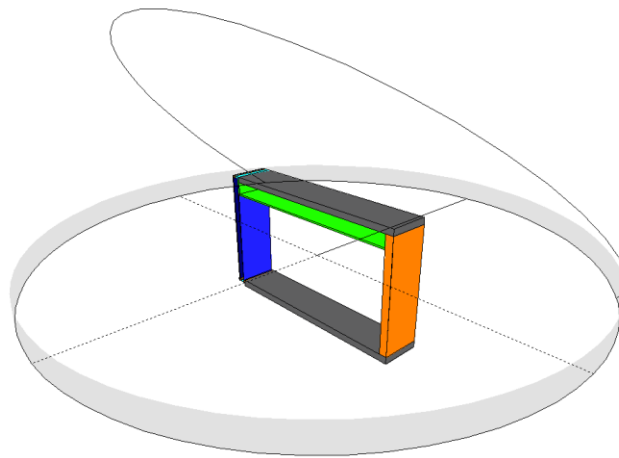


Figure 16 Sun obstacles in Graphic Output

7. Output nodes and report definition

In VOLTRA, output nodes can be defined to report the temperature values in the corresponding node for the calculation period.

First these nodes defined through *Edit* → *Output Nodes*. Figure 17 illustrates the defined output nodes positions and grid numbers.

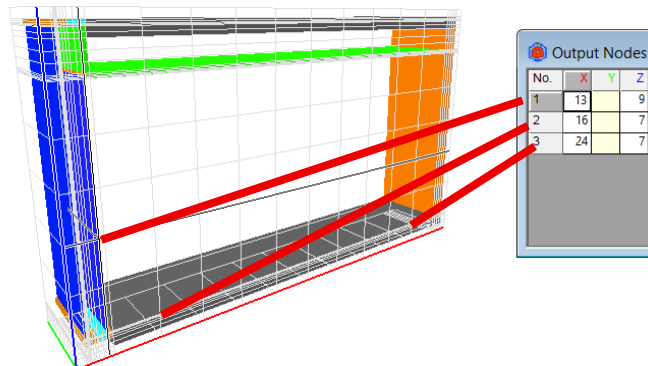


Figure 17 Output nodes

The Report Definition window (*Edit* → *Report Definition*) contains the report items that will be included in the text report output. Adding a new row to define an output: *Edit* → *Insert Row*

The text report tabulates the report values at a regular time step interval (here every time step, cf. setting in *Calc* → *Report Frequency...*).

No.	Object	Object No.	Type	Width	Decimals
1	TIME		[ddd:hh:mm:ss]	8	
2	COLOUR	2	θ	8	2
3	COLOUR	240	θ_a	8	2
4	COLOUR	242	θ_a	8	2
5	OUTPUT NODE	1	θ	8	2
6	OUTPUT NODE	2	θ	8	2
7	OUTPUT NODE	3	θ	8	2

Figure 18 Report definition

Following items are reported in the text report:

- Time, using date format
- Outdoor temperature (colour 2)
- Air temperature inside the room (colour 240)
- Air temperature inside the façade cavity (colour 242)
- Single glazing temperature (output node 1)
- Floor temperature close to the façade (output node 2)
- Floor temperature close to the wall (output node 3)

8. VOLTRA calculation

Before starting the calculation, request that step solutions (.sol files and .sfx files) are saved during the calculation, so that afterwards graphic animations can be made in the graphic output section (*Output → Graphic Output*).

Open the Save Frequency dialog box with *Calc → Save Frequency...* to view the settings.

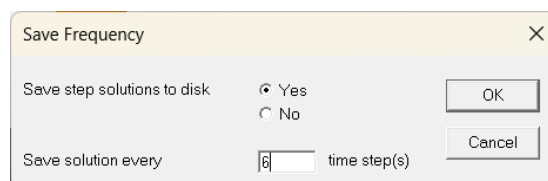


Figure 19 Save frequency settings

Solution is saved for every 6 time steps which means for every hour.

Calculation starts with *Calc → Calc System*.

During the calculation a calculation monitor is displayed showing the progress (with current time step, current iteration step, stopping criteria, number of nodes, view factors).

After the calculation, output is available through the submenus via *Output → Graphic Output* or *Output → Text Output*.

9. Graphic output

- Go to Output → Graphic Output
- Select the view option View → Fill Temperatures.

The temperature range (15°C – 55°C) and the temperature increment (1°C) can be changed in the Temperature Range dialog box, opened with Settings → Temperature Range....

- Get the results at the time step at 5 p.m. (Animate → Go To..., enter 0000:17:00:00). We get highest temperature on the west façade at 5 p.m.

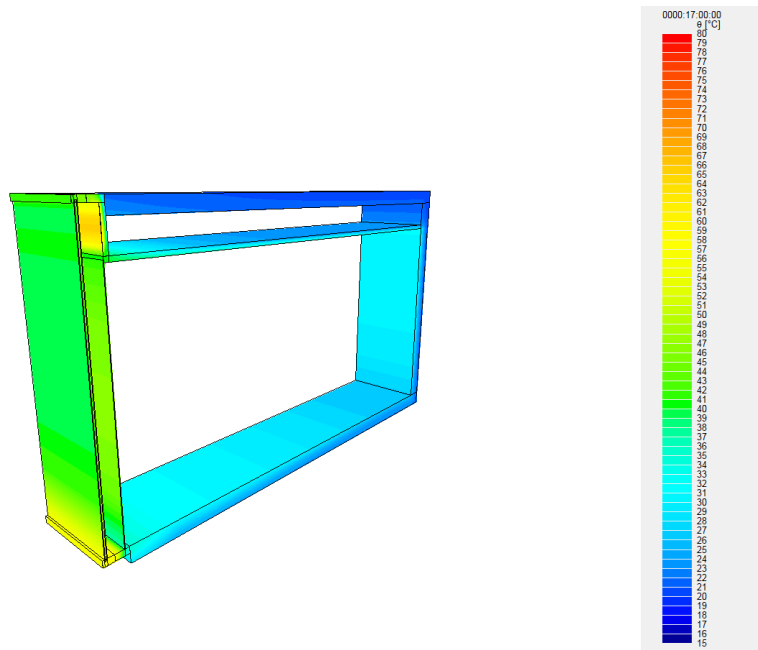


Figure 20 Temperature contour at 5 p.m.

- Move the mouse over the image to get the temperature at the mouse point displayed in the status bar at the bottom of the VOLTRA window.

The absorbed solar radiation contour can be obtained through View → Absorbed Solar Fluxes

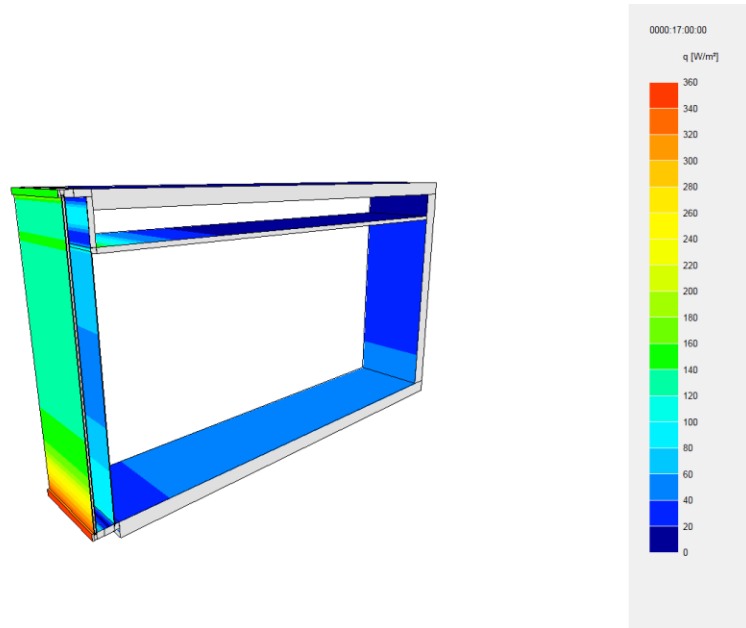


Figure 21 Absorbed solar fluxes at 5 p.m.

These two contours can also be viewed with sun position. View → Sun Position & Fill Temperatures or View → Fill Absorbed Solar Fluxes produce the graphics shown in Figure 22.

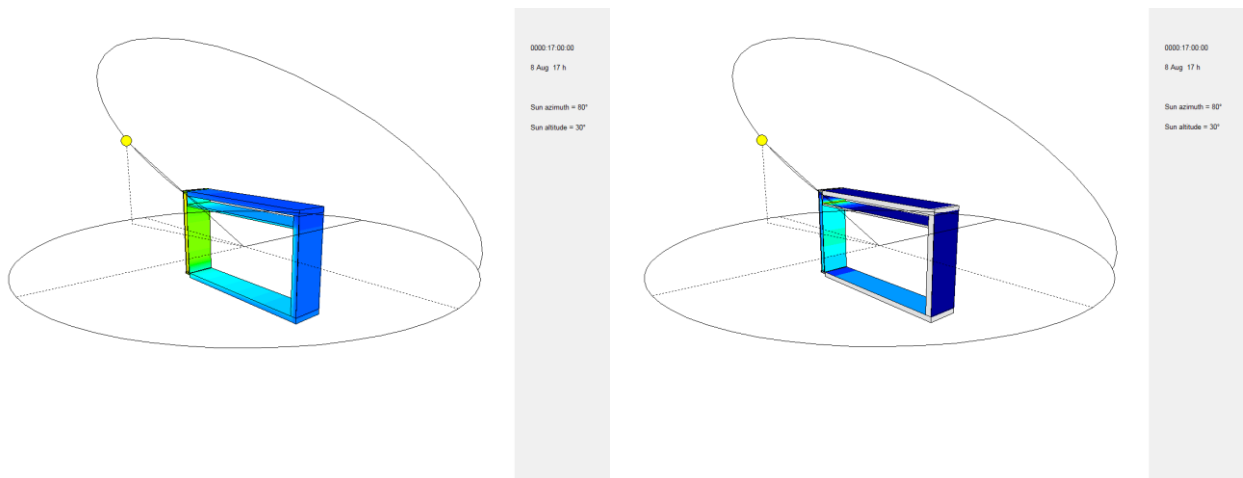


Figure 22 Sun position and temperature (left), sun position and absorbed solar fluxes (right)

To make an animation of the field temperatures with Microsoft Clipchamp

- Prepare the animation images in VOLTRA:
 - o View → Fill Temperatures.
 - o File → Save Animation Images...
- Open Microsoft Clipchamp, start new Blank Video (e.g. Temperature_August 8)
 - o Add the generated Animation Images to the My media via Import media.

- Click Sort → Select Name, and Ascending to have the correct order of the images.
- Select all images, drag and drop them thereafter to the main window.
- Right click → Edit duration → 0.3s (You may choose it different).
- Right click on gap between two image → Delete all visual gaps.
- Finish video to export in .mp4.

10. Text output

- Go to Output → Text Output
- Select View → Time Step Results, and Edit → Go To..., enter 0000:12:00:00. The text window shows the time step results at 12 a.m.

```
VOLTRA - Calculation Results
VOLTRA data file: room_model_01.vtr
Number of nodes = 1148
Number of viewfactors = 26

Time step 0000:12:00:00

Heat flow divergence for total object = 2.2132e-05 %
Heat flow divergence for worst node = 0.0101397 %
```

Col.	Type	Name	tmin [°C]	X	Y	Z	tmax [°C]	X	Y	Z
1	BC_SIMPL	adiabatic	20.59	29	0	19	31.20	11	0	25
2	BC_SIMPL	outdoors	29.71	2	0	9	31.17	1	0	21
4	BC_SIMPL	lower_zone	22.15	24	0	1	23.21	15	0	1
6	BC_SIMPL	upper_zone	20.58	23	0	25	21.06	15	1	25
7	BC_SIMPL	back_zone	20.32	29	0	18	21.39	29	0	7
8	MATERIAL	alluminium	29.88	6	0	7	31.19	6	1	21
16	MATERIAL	concrete,_reinf._(1%_steel)	20.58	23	0	25	24.80	15	0	7
28	MATERIAL	brickwork	20.32	29	0	18	24.04	25	0	12
35	MATERIAL	insulation_1	21.29	15	0	21	32.26	13	0	19
37	MATERIAL	insulation_2	21.06	15	0	25	31.99	12	0	21
60	MATERIAL	frame_conductive_part	24.61	15	0	3	31.21	11	0	21
61	MATERIAL	frame_thermal_break_part	29.79	8	0	3	31.20	8	0	23
62	MATERIAL	silicone,_pure	29.81	6	0	5	31.19	6	1	22
66	MATERIAL	glass_1_-_colour_1	29.71	2	0	9	31.18	3	0	21
82	MATERIAL	glass_1_-_colour_2	29.74	3	0	9	31.19	4	1	22
98	MATERIAL	glass_2_-_colour_3	29.47	7	0	8	31.44	6	0	19
114	MATERIAL	glass_2_-_colour_4	29.44	8	0	8	31.44	7	0	19
130	MATERIAL	glass_3_-_colour_5_and_6	24.84	13	0	5	27.45	13	0	10
224	BC_FREE	ceiling	20.89	23	0	19	26.01	15	0	16
240	BC_FREE	room	23.20	24	0	7	27.35	14	0	10
242	BC_FREE	facade_cavity	25.24	13	0	7	32.26	13	0	19
243	TRANSMAT	argon_cavity	29.48	6	0	8	31.44	6	0	19

Col.	Type	Name	ta [°C]	Flow in [W]	Flow out [W]
1	BC_SIMPL	adiabatic		0.00	0.00
2	BC_SIMPL	outdoors		3.56	27.99
4	BC_SIMPL	lower_zone		0.00	69.91
6	BC_SIMPL	upper_zone		0.00	25.95
7	BC_SIMPL	back_zone		0.00	21.40
224	BC_FREE	ceiling	21.60	38.67	38.71
240	BC_FREE	room	24.67	159.85	37.84
242	BC_FREE	facade_cavity	28.75	72.32	28.38
243	TRANSMAT	argon_cavity		27.04	0.24

Figure 23 Calculation results at 12 a.m.

- Select View → Report Output to get the report item values per time step for the report items defined in the Report Definition window (cf. section 7)

```

VOLTRA - Report Output

VOLTRA data file: room_model_01.vtr

Column 1: Time [dddd:hh:mm:ss]
Column 2: Colour 2 (outdoors) - Boundary condition temperature [°C]
Column 3: Colour 240 (room) - Boundary condition air temperature [°C]
Column 4: Colour 242 (facade cavity) - Boundary condition air temperature [°C]
Column 5: Output node 1 - temperature [°C]
Column 6: Output node 2 - temperature [°C]
Column 7: Output node 3 - temperature [°C]

0000:00:00:00      17.7      24.4      23.3      24.0      25.6      24.3
0000:00:10:00      17.6      24.4      23.1      23.9      25.5      24.3
0000:00:20:00      17.5      24.3      23.0      23.8      25.4      24.3
0000:00:30:00      17.4      24.3      22.9      23.7      25.4      24.2
0000:00:40:00      17.3      24.2      22.8      23.6      25.3      24.2
0000:00:50:00      17.2      24.1      22.7      23.5      25.2      24.1
0000:01:00:00      17.1      24.1      22.6      23.4      25.2      24.1
0000:01:10:00      16.9      24.0      22.5      23.4      25.1      24.1
0000:01:20:00      16.7      24.0      22.4      23.3      25.0      24.0
0000:01:30:00      16.5      23.9      22.3      23.2      25.0      24.0
0000:01:40:00      16.3      23.9      22.2      23.1      24.9      24.0
0000:01:50:00      16.1      23.8      22.1      23.1      24.8      23.9
0000:02:00:00      15.9      23.8      22.0      23.0      24.8      23.9
0000:02:10:00      15.9      23.7      21.9      22.9      24.7      23.8
0000:02:20:00      15.9      23.7      21.9      22.8      24.6      23.8
0000:02:30:00      15.9      23.6      21.8      22.8      24.6      23.8
0000:02:40:00      15.8      23.5      21.7      22.7      24.5      23.7
0000:02:50:00      15.8      23.5      21.6      22.6      24.5      23.7
0000:03:00:00      15.8      23.5      21.6      22.6      24.4      23.7

```

Figure 24 Report output

The data can be exported to any spreadsheet application to visualize the results.

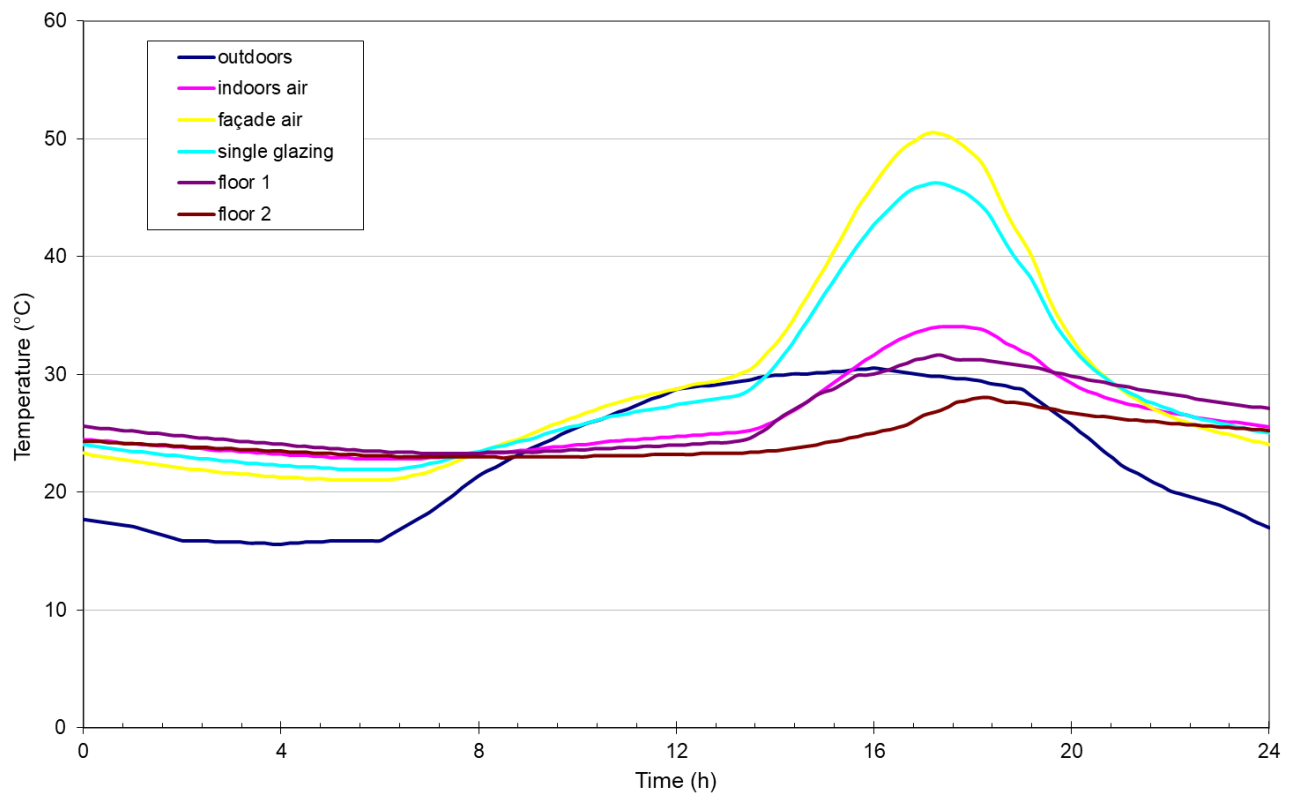


Figure 25 Temperature for specified points

11. Grid refinement and results

[T_VTR_a_solar_double_skin_facade_fine_grid_corrected.vtr](#)

In the previous steps a coarse grid was assumed. The grid was refined in both the X and Z directions.

X-direction refinement

All cells (except those with a width of 500 mm) were subdivided into two equal parts using:

Grid → Split → Method: Geometric → Number of subdivisions: 2

Cells with a width of 500 mm were instead subdivided into five equal parts.

Z-direction refinement

In the vertical direction, all cells with a height greater than 25 mm were subdivided into cells of maximum 25 mm using:

Grid → Split → Method: Maximum → Mesh width: 25 mm

Figure 26 shows the temperature contour at 5 p.m. for finer grid. Because of the too rough grid used in previous steps (Figure 20) the temperature values are inaccurate. It can be seen that in the facade highest temperature is changed. Also the absorbed solar fluxes of finer grid are shown in Figure 27, this can be compared with Figure 21.

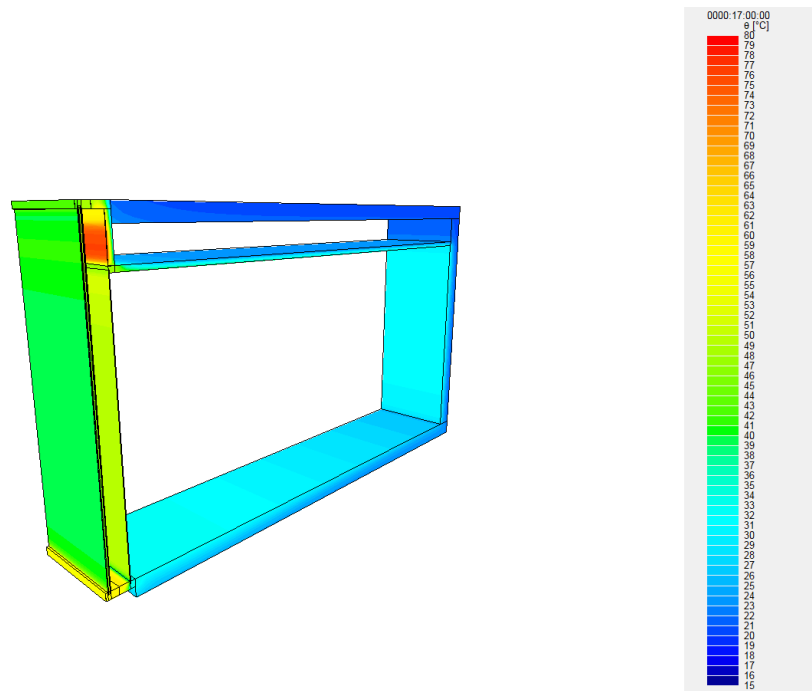


Figure 26 Temperature contour at 5 p.m. (finer grid)

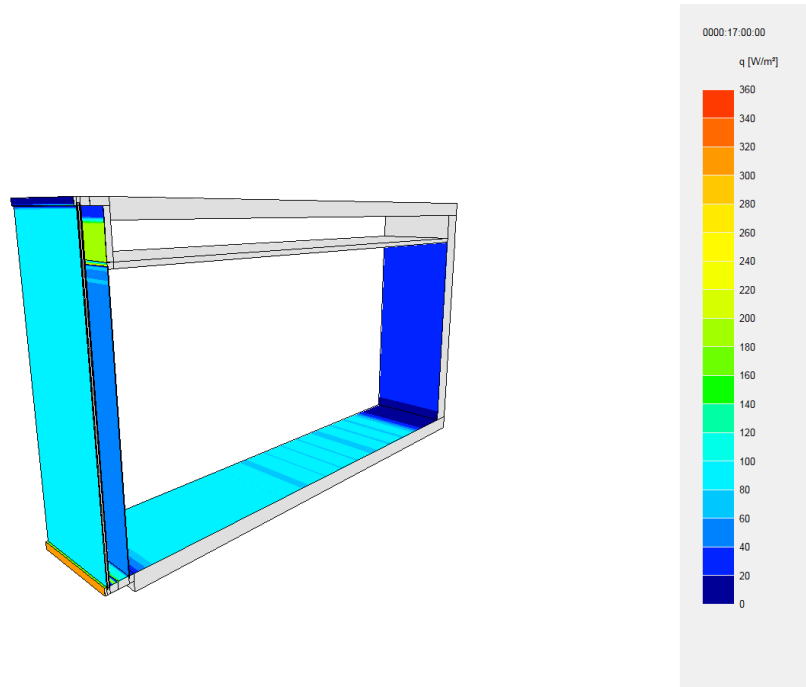


Figure 27 Absorbed solar fluxes at 5 p.m. (finer grid)

A rough grid is interesting during the data preparation (allowing quick test simulations) but for a final simulation a fine grid is required. Figure 28 shows the temperature for specified points throughout the simulation.

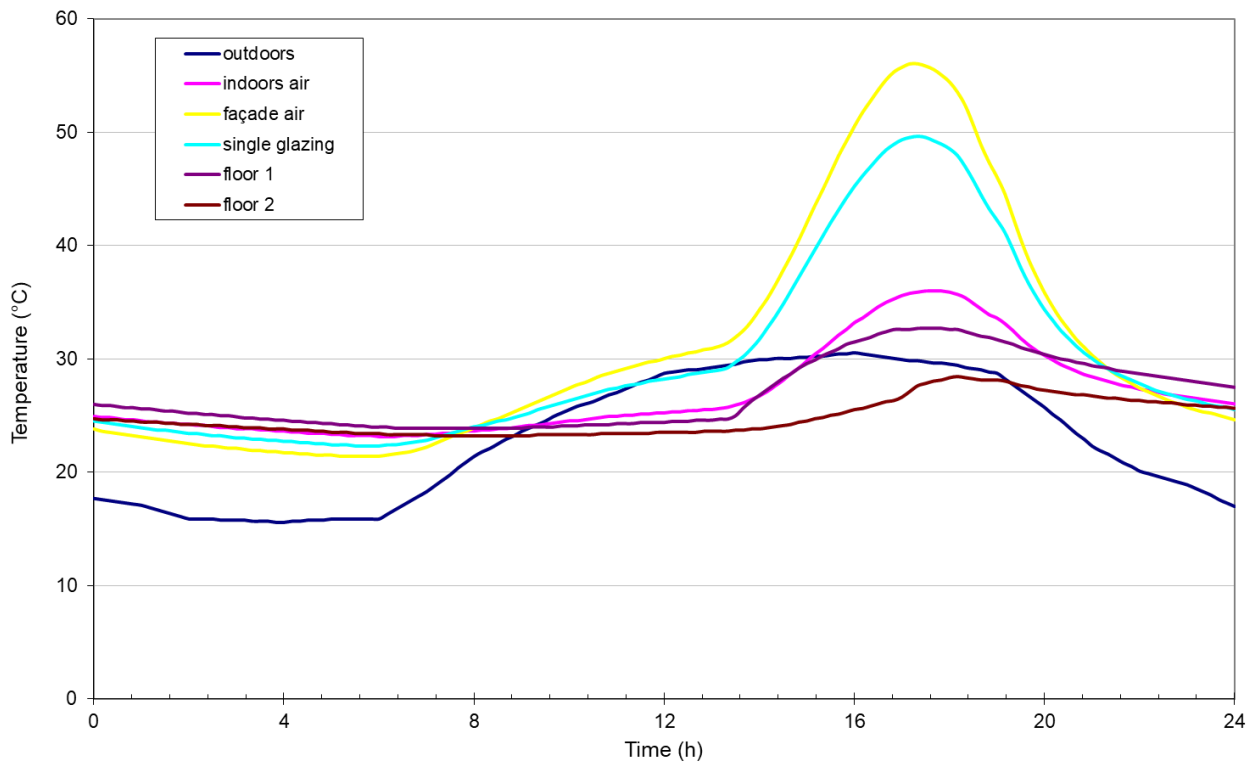


Figure 28 Temperature for specified points (finer grid)