

Appendix 1.

User manual

3D Viewer Energy Simulation in
Buildings



ENGINENCY

Important announcement:

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1. Introduction

Energy efficiency is the set of practices that aim to reduce energy consumption or, what is the same, optimize production processes and energy consumption to produce more goods and services using the same amount of energy or lower. Efficiency can be understood as an improvement in the use of energy, generating energy savings without reducing the quality of life or production.

In construction, the energy efficiency of a building is embodied in what is known as the energy certificate. The energy certificate provides information about both energy consumption and CO₂ emissions of a real estate property and it is mandatory since June 2013 to be able to rent or sell said real estate, regulated in Spain by Royal Decree 235/2013, from the European Directive. To obtain this certificate it is necessary hiring of a service by a certifying technician that will capture the qualities of the property in what is known as the energy label.

The technician has to measure and collect construction data and heating, hot water and air conditioning facilities, known by its acronym in English (HVAC), and introduces these data in a software tool that allows energy simulation of the property.

There are several tools in the market to perform the energy simulation of a building, like TRNSYS, an extremely flexible software environment used to simulate the behaviour of transient systems which has got 35 years of commercial availability. TRNSYS is very suitable for detailed analyses of any system whose behaviour depends on the passage of time. Although the vast majority of simulations are on evaluation of the performance of thermal and electrical energy systems other applications included are solar systems, low energy buildings and HVAC systems or renewable energy systems.

TRNSYS recognizes a system description language in which the user specifies the components that constitute the system and the manner in which they are connected.

It is made up of two parts. The first, the kernel, is an engine that reads and processes the input file, iteratively solves the system, determines convergence, and plots system variables. The second part is an extensive library of components which includes approximately 150 models constructed in such a way that users can modify existing components or write their own, extending the capabilities of the environment. It also facilitates the incorporation into the program of mathematical models not included in the standard library. As said before TRNSYS does not have a friendly interface for the end user, so due to this, a friendly software has been developed: BCORE that is a software that allows the performance of building energy simulations, working with TRNSYS as calculation engine. It is a ground-breaking solution and an innovative and novel energy simulation program. Through a holistic approach, this software integrates into a single tool multiple utilities and applications, previously not found commercially combined; modelling, simulation, calibration, and the implementation of ECM (Energy Conservation Measures) in buildings. In addition, BCORE has a friendly framework, easily usable for any end-user, not necessarily IT expert.

The main disadvantage of this system with respect to its competitors is the lack of a friendly interface to the end user for the presentation of simulation results and the processing thereof to achieve the verification and eventual adjustment of the energy model obtained. Because of this, a 3D viewer that serves as an intuitive and friendly interface for a non-expert end user has been developed by **PROYESTEGAL S.L.** in collaboration with **GTE** (energetic technology group), a University of Vigo's research group.



2.3D viewer basics

As mentioned, the application is intended to be a simple and intuitive display interface for results. It is implemented with OSG and Qt / C++ and has been virtualized using Guacamole, a clientless remote desktop gateway.

The Viewer has 4 windows where different models, the same models with different simulations or the same simulations in order to visualize the simulation of different parameters at the same time can be loaded in them. These windows can be shown or hidden and the size and location in the interface can be changed.

Furthermore, the application contains another two subwindows. One of them with the elements or models loaded, following a tree structure. The other one contains general information about the models and loaded simulations.

The datasets are hosted on the same server as the application. There is one folder per user configured in Guacamole and each one has exclusive access to theirs. The application reads the directory structure of the user's folder, being able to identify all the available models (BCORE files). The model is loaded in the tree with the name of the BCORE file and an icon indicating in which of the four windows it is represented.

Clicking with the right button on the node of a model the list of simulations available for that model appears. Certain parameters can be combined and represented by icons that the user can choose, which facilitate results understood.

The viewer has one useful tool to explore the results which is activated during the simulation: the navigation bar. It allows the user to select different time steps (by default, time advances from hour to hour) and move forward and go back in time. Furthermore, it is possible to take concrete images of the building at specific times.

This, together with the fact of being able to compare different simulations for the same model, makes possible a better analysis of the results, which will affect the choice of more precise and effective measures for the improvement of energy.

3. Graphical user interface

When the user opens the viewer, the appearance is like in Figure 22. The interface is divided so that in the up part is the toolbar, the loaded models and information about them, called attributes, are on the left side and the different viewers where the models will show are on the right side.

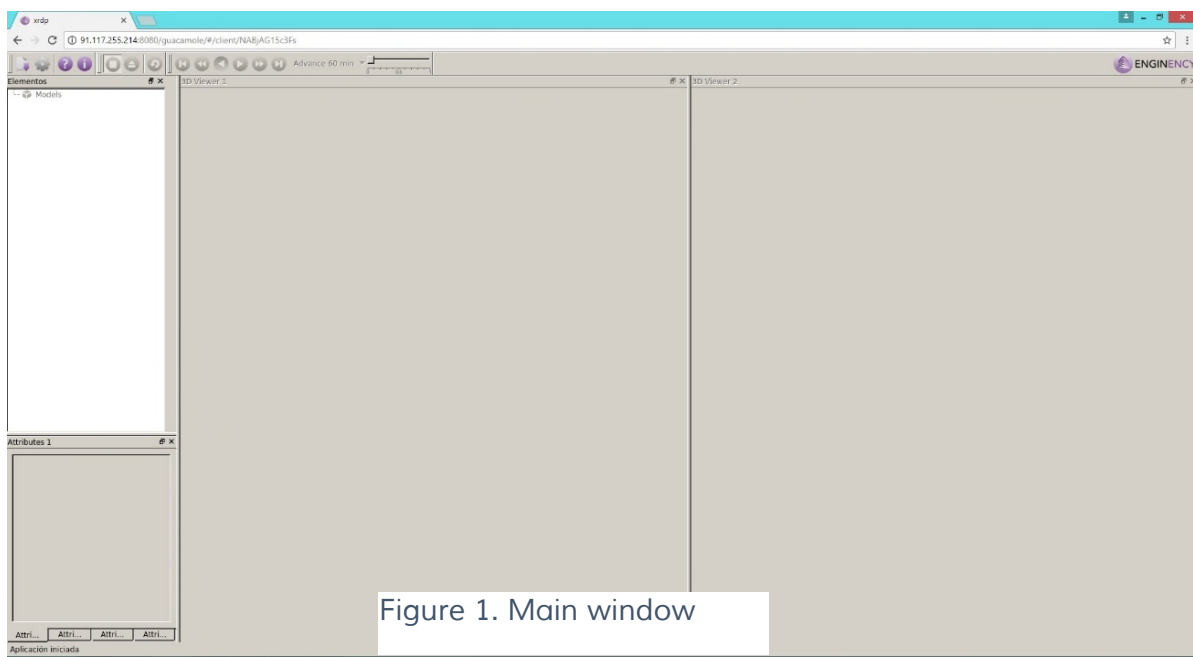


Figure 1. Main window

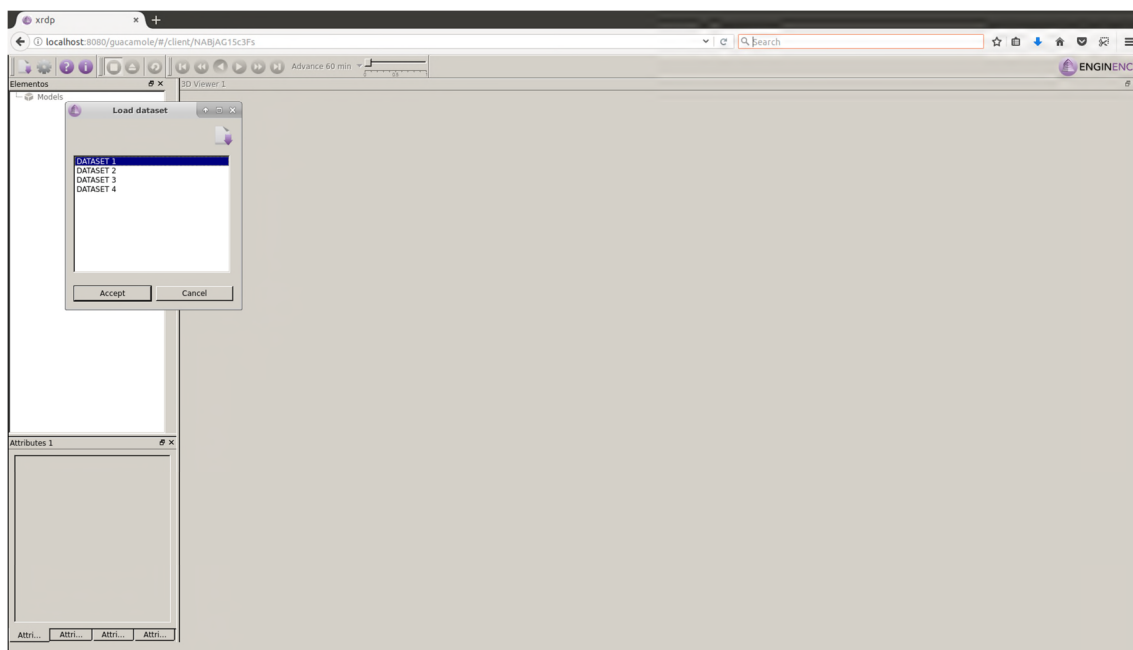
3.1 Data import

To load different models, whose geometries are in a BCORE file, from the main window:

First toolbar's bottom → Select dataset

Up to four models can be loaded:

- Different models
- Same models with different simulations
- Same simulations so as to visualize different parameters at a specific time



By clicking the right button on the background of the main window, you can select the viewers and attribute tables that you want visible.

Figure 2. Form to load a model

All of them have to be available in the user's folder (Figure 23). Each client has his own folder where BCORE and configuration files are saved. BCORE files stored geometry, meteorological data and simulation results.

Configuration files are created to save changes and use them as default settings. They stored information about language, colors, theme and other selectable options. It's possible to delete them and predetermined configuration will be show when restart.

Contextual menu

When the model is loaded its associated options appear in the tree by clicking on the right button (Figure 24). Next possibilities are available:



- Rename: to change the model name
- Delete: to eliminate it from the viewer in main window
- Properties: information about file path
- Move to other viewer: it's possible to move the model to one of the other three available viewers
- Configuration and model consult: surfaces' visualization and information about them
- Configuration and simulation execution: only available when Load Simulation has been pressed

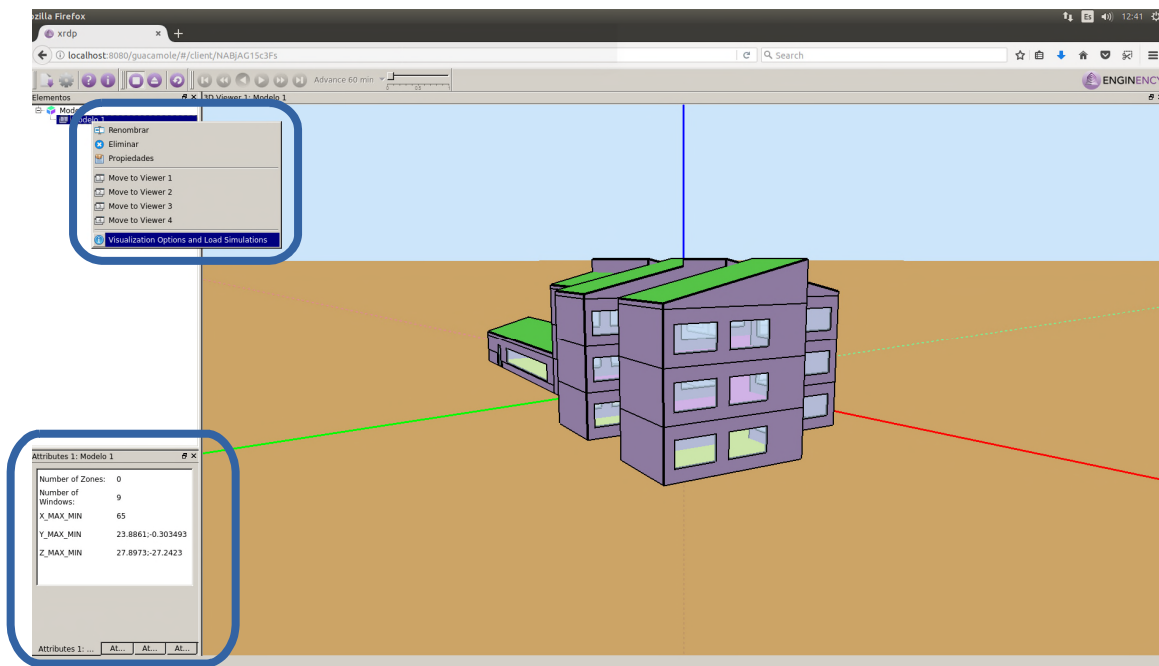
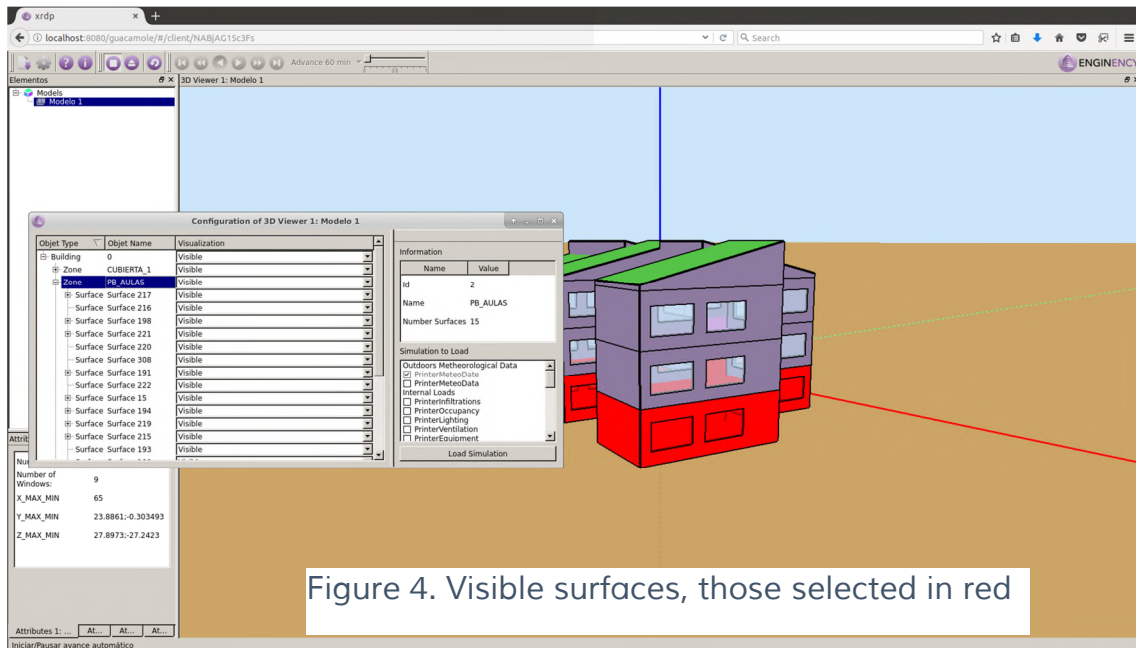


Figure 3. Model's contextual menu

3.2 Visualization options

The zones, surfaces and holes are represented in the tree. By clicking on each of them, it is selected in red in the view. It is possible to change the display type of each one:

- Visible: all the surfaces of each zone are visible, selected zones in red. Figure 25.



-Transparent: the selected zone's surfaces lose the colour, Figure 26.

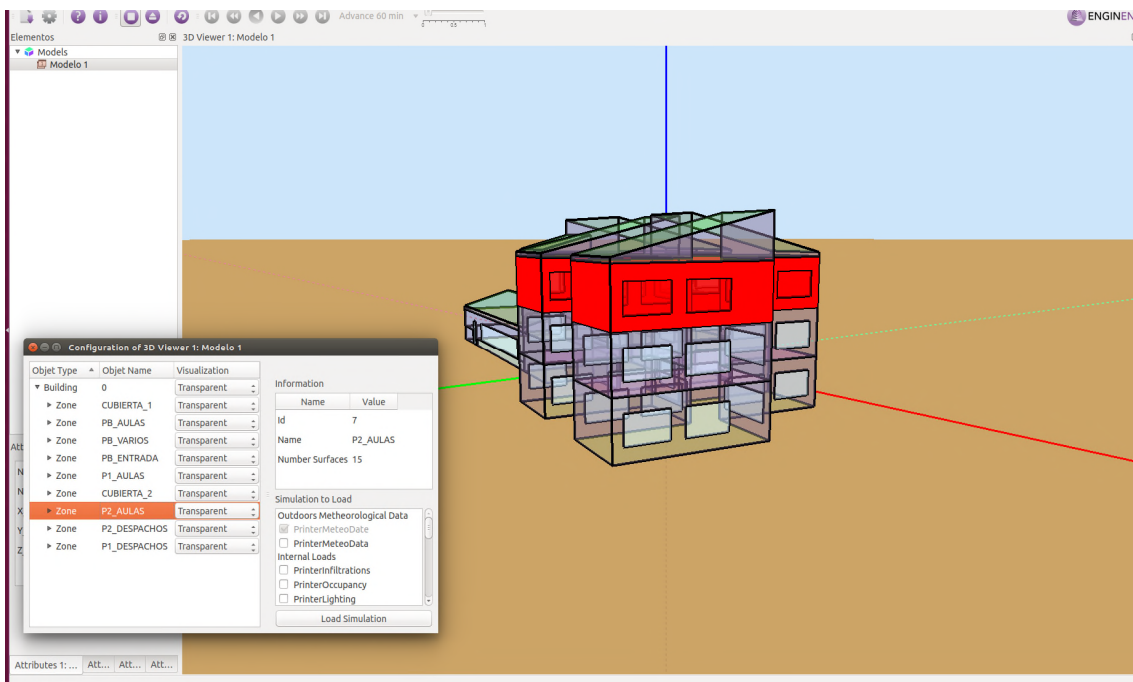


Figure 5. Transparent surfaces

-WireFrame: only edges are shown, Figure 27.

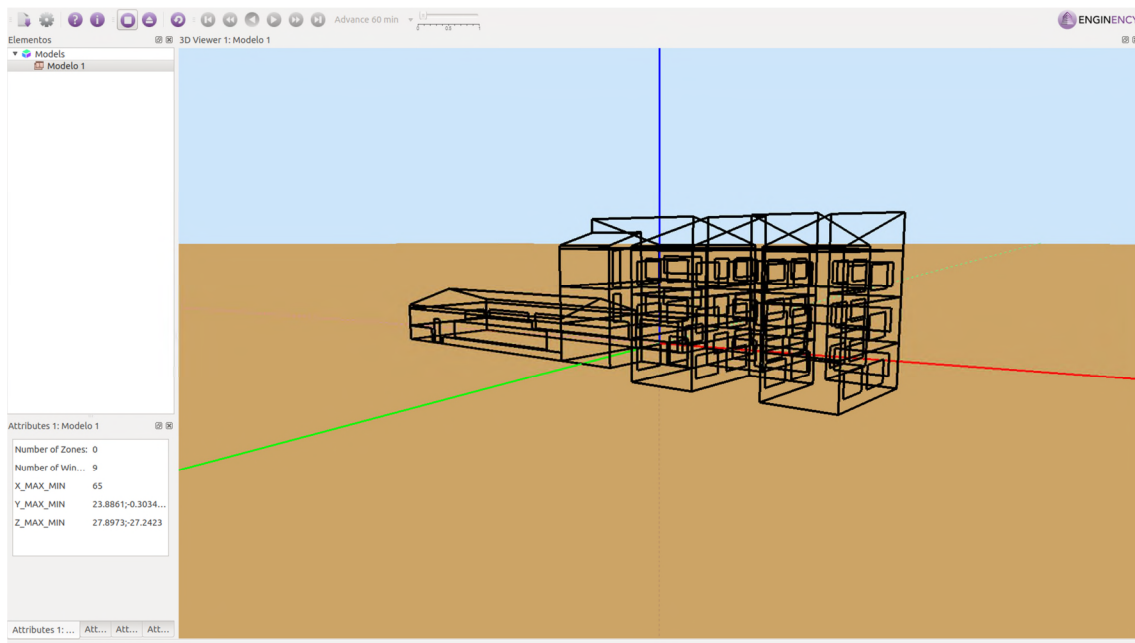
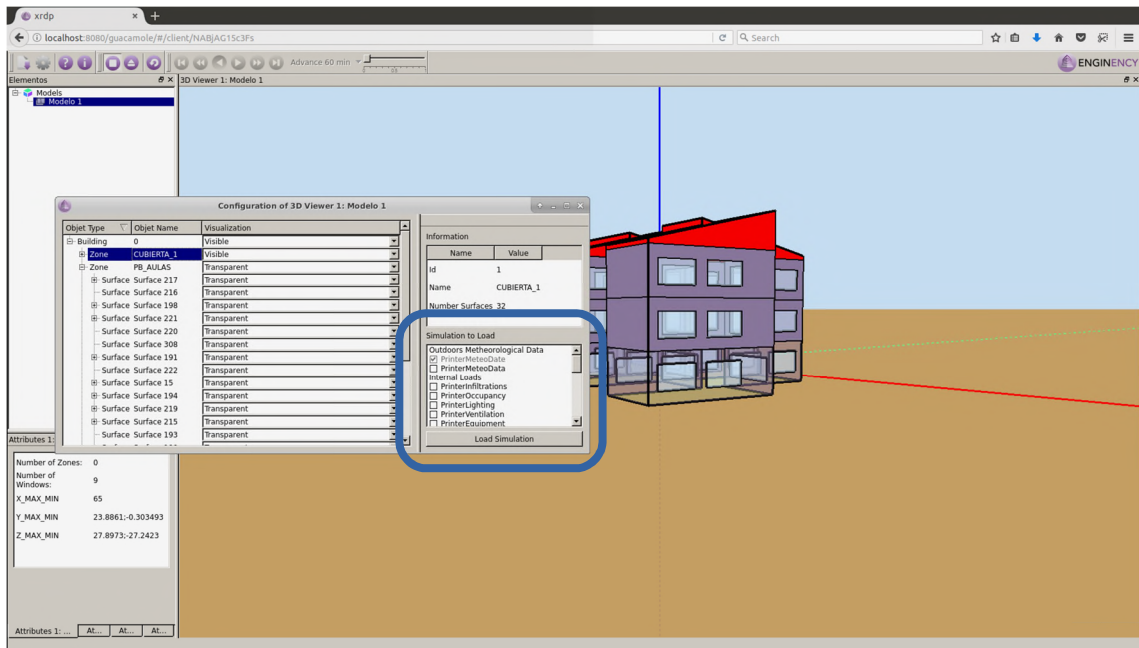


Figure 6. WireFrame surfaces, only edges

-Hide: the zone, the surface or the building doesn't appear.

This visualization is updated in real time and allows access to areas located inside the building, among others.

Within this configuration window, information about the selected area or surface is also provided, as seen in the highlighted area of the form, Figure 28.



3.3 Simulation

Some variables and parameters are available for the simulation: outdoors meteorological data, internal loads, results about temperature or humidity, surface results or generation systems. They can be marked on their own box in the form's lower table, 'Simulation to Load'. When simulations are selected, press the 'Load Simulation' button and they would be ready for navigation.

Once loaded, a new option is enabled in the context menu: 'Simulation options'. This item is highlighted in Figure 29. When opening it, the system checks if the configuration options are compatible for the correct visualization of all of them.

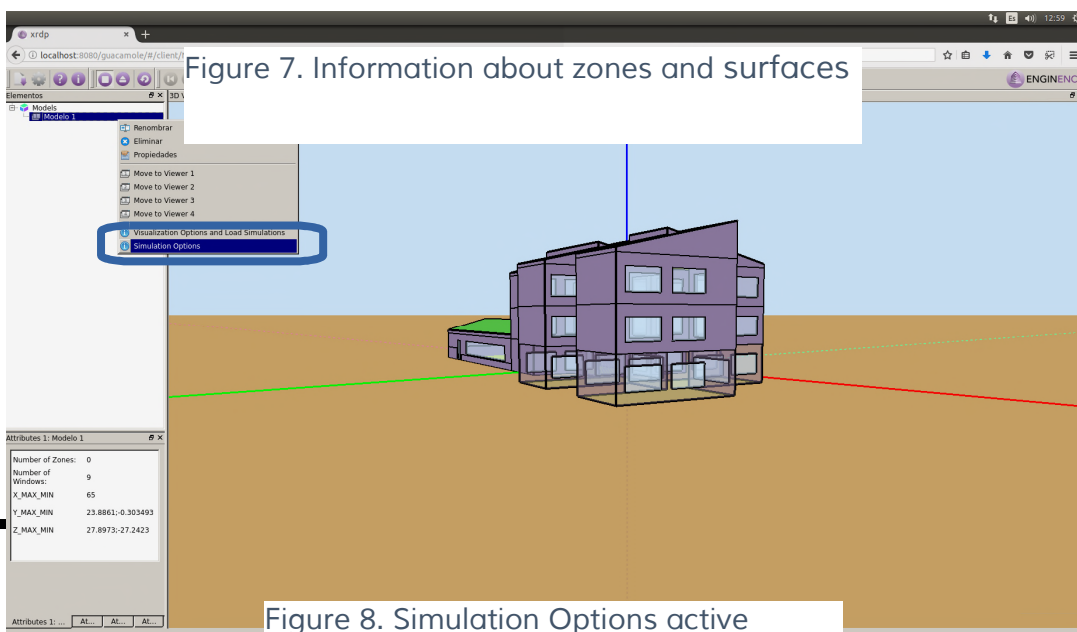


Figure 7. Information about zones and surfaces

Figure 8. Simulation Options active



n options

Pressing this option, a new form is opened, Figure 30. Different viewing options can be configured.

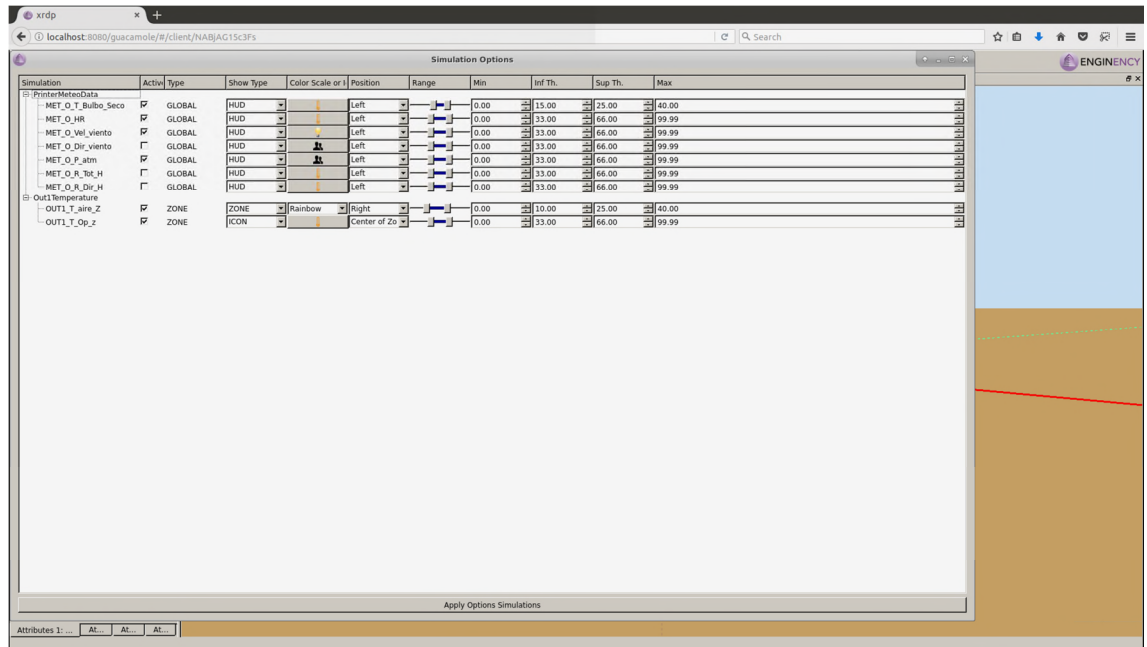


Figure 9. Simulation Options form

Available information:

- Simulated parameters variables.
- Active or desactive variable.
- Type: if the variable is unique for the whole model, if it is by zones, by surface or hole or if it is referred to some element of generation or distribution of energy.
- Display format:
 - HUD (text and icons in screen)
 - Icon (icon in 3D position)
 - Zone (on the 3D model surface)
 - Icon or scale to use
 - Position where it will show
 - Rank (Rank of the display to adapt the scale and the lower and upper limits in which the type of icon or size changes).



When the simulation type are HUD or icon, it is necessary to select the icon to display, as it shown in Figure 31. Next option appeared by pressing the corresponding button. Once choosing, press select.

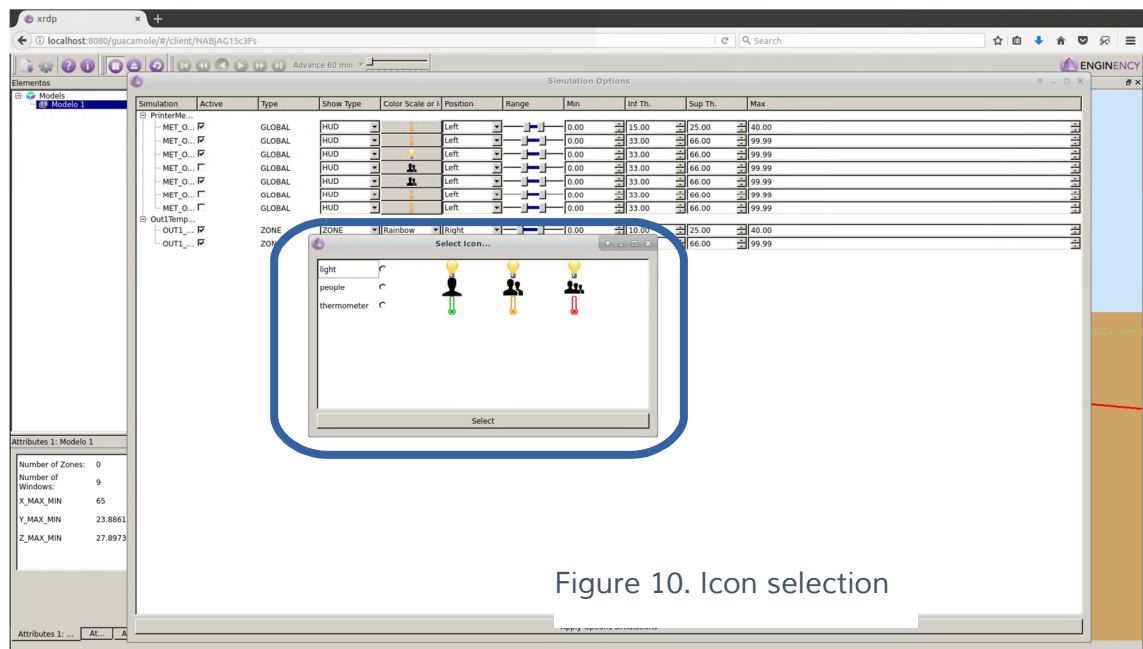


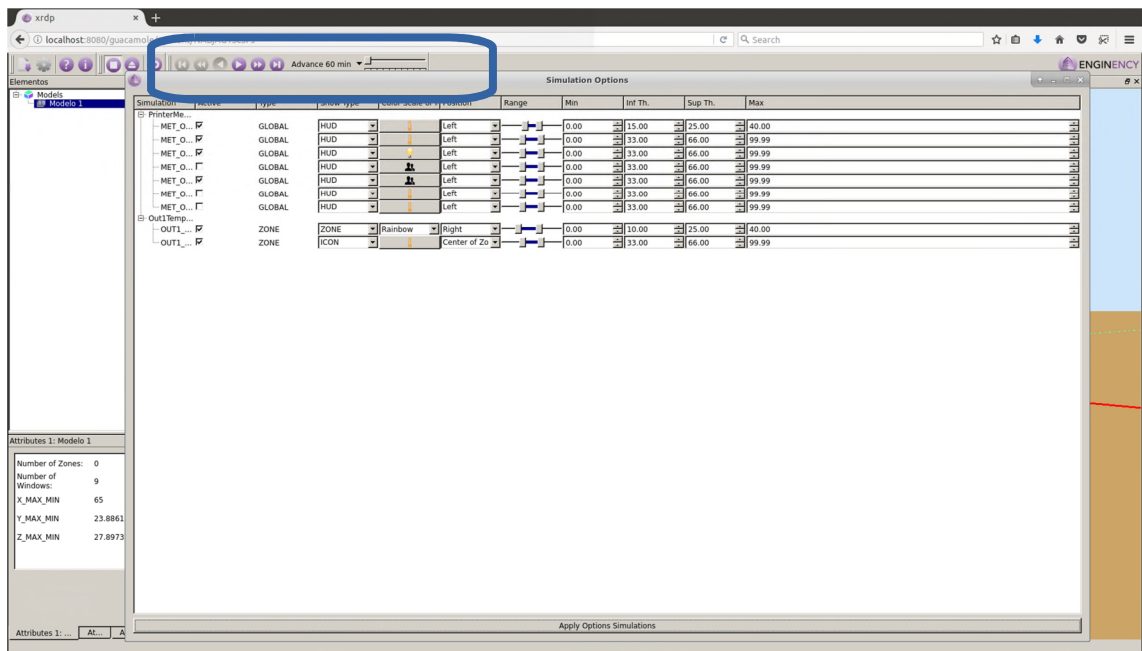
Figure 10. Icon selection

NOTE: The intervals in the aforementioned range are applied to this selected icon. For single icon model, as is the case of light, what the limits will do is mark the size of the icon that will be displayed, being small for low values and big if they are higher. On the other hand, if the 3 icons are different as in the case of the thermometer, the icons will change their appearance, in this case, the colour.

When everything is ready, press "Apply Options Simulations".

3.3.2 Simulation toolbar

If all the simulation options are coherent and do not overlap, the navigation toolbar of the simulations will be activated, as shown in the following figure, Figure 32:



n
Figure

Figure 11. Simulation toolbar active

re 33, task toolbar is shown in more detail.



Figure 12. Task bar description

Navigation bar is one useful tool to explore the results. It allows the user to select different time steps and move forward and go back in time. Furthermore, concrete images of the building at specific times can be taken. In Figure 34 simulation process is shown. In lower left are the variables, the scale for the geometry in the right and icons for some variables inside the building. If it has been activated, we proceed to close the window and start the simulation. A very useful feature is the possibility to modify the time step to view the results. By default, the time advances from hour to hour, but it is possible to make it go faster or slower. It is possible too stop the simulation in a concrete moment to turn the building and obtain a better visualization or take images.



To start the simulation, press play. The information that appears in the viewer, which can be shown in Figure 34, is explained below.

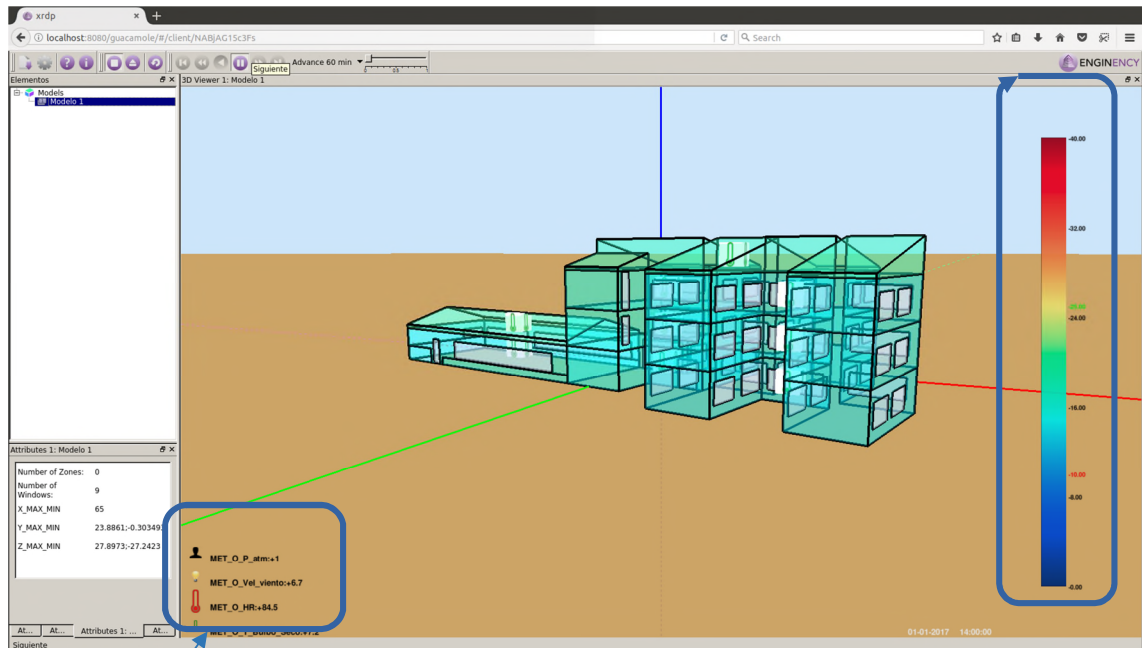


Figure 13. Information about simulation

HUD variables

Scale (only for the geometry)

Simulation date and hour

Inside the building there are cubes with an icon, which can be seen in more detail below, in Figure 35. These are the ones we have selected in the simulation options as icon type. They are in the centre of each associated zone.

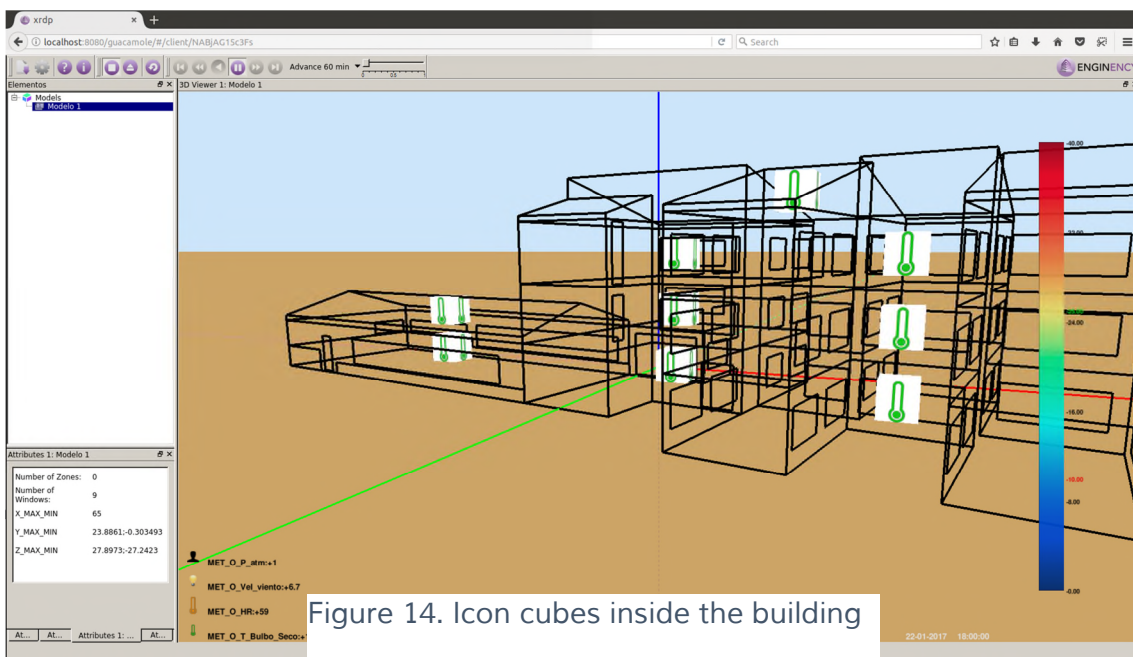


Figure 14. Icon cubes inside the building



During the visualization of the simulation you can modify the display options to focus on the area of interest. To do this, you return to the display options screen and modify it according to your interest. In the Figure 36 we see how the visualization is modified to leave only the area of the annexed building active.

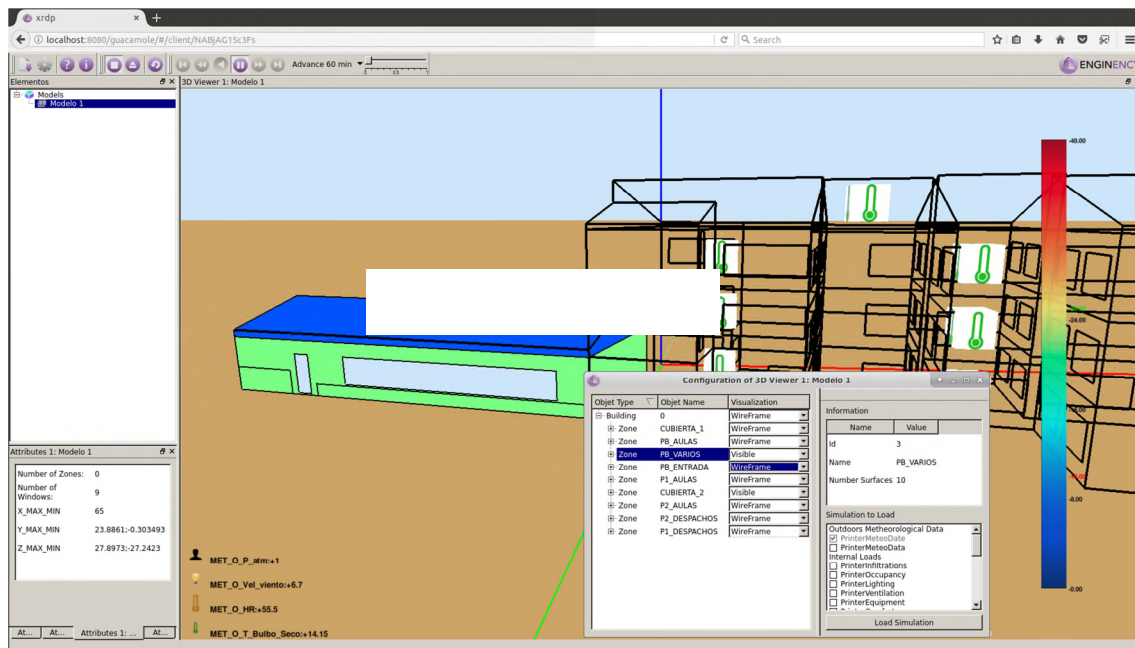


Figure 15. Annexed building active

4. Archive types and description

Both the results files and the geometry definition files, of BCORE format, are described below, specifying all the information related to them.

4.1 File types and description

Next tables contain information about the text files where outputs are saved. The file name, the column's number or the variable's units are some described things.



File	N° columns	Values	Units		Class	Example
			data	visor		
GEOMETRY						
Project.bcore		See 4.2 BCORE fields				Modelo\Project.bcore
OUTDOORS METHEOROLOGICAL DATA						
PrinterMeteoData.txt	1+7	MET_O_T_Bulbo_Seco --> Outdoors Temp MET_O_HR --> Outdoors RH MET_O_Vel_viento --> Outdoors Wind Velocity MET_O_Dir_viento --> Outdoors Wind Direction MET_O_P_atm --> Outdoors Pressure MET_O_R_Tot_H --> Outdoors Total Radiation MET_O_R_Dir_H --> Outdoors Horizontal Radiation	°C % m/s grad atm kJ/h·m ² kJ/h·m ²	- - - - - W/m ² W/m ²	Outdoors	Modelo\Run_01\Simulation\Results\PrinterMeteoData.txt
PrinterMeteoDate.txt	1+6	MET_O_Mes --> Month MET_O_Hora_Mes MET_O_Hora_Dia --> Hour MET_O_Dia_Ano MET_O_Dia_Mes --> Day			--	Modelo\Run_01\Simulation\Results\PrinterMeteoDate.txt
INTERNAL LOADS						
PrinterInfiltrations.txt	1+1*zone	INF_O_ACH_Z --> ACH (Air Changes per Hour)	ACH	-	Zone	Modelo\Run_01\Simulation\Results\PrinterInfiltrations.txt



PrinterOccupancy.txt	1+3*zone	OCU_O_Con_Z --> Convective Power OCU_O_Rad_Z --> Radiative Power OCU_O_Hum_Z --> Humidity	kJ/h	W	Zone	Modelo\Run - 01\Simulation\Results\PrinterOccupancy.txt
PrinterLighting.txt	1+2*zone	ILU_O_Con_Z --> Convective Power ILU_O_Rad_Z --> Radiative Power	kJ/h	W	Zone	Modelo\Run - 01\Simulation\Results\PrinterLighting.txt
PrinterVentilation.txt	1+3*zone	VEN_O_T_Z --> Temperature of air flow VEN_O_Flujo_Z --> Air flow VEN_O_HR_Z --> Humidity of air flow	°C 1/h %	-	Zone	Modelo\Run - 01\Simulation\Results\PrinterVentilation.txt
PrinterEquipment.txt	1+3*zone	EQP_O_Con_Z --> Convective Power EQP_O_Rad_Z --> Radiative Power EQP_O_Hum_Z --> Humidity	kJ/h	W	Zone	Modelo\Run - 01\Simulation\Results\PrinterEquipment.txt
PrinterComfort.txt	1+3*zone	CNF_O_Ropa_Z --> Clothing Factor CNF_O_Metab_Z --> Metabolic Rate CNF_O_VelAire_Z --> Relative Air Velocity	clo met m/s-	-	Zone	Modelo\Run - 01\Simulation\Results\PrinterComfort.txt
RESULTS						
Out1_Temperature.txt	1+2*zone	OUT1_T_aire_Z --> Air temperature OUT1_T_Op_Z --> Operative temperature	°C	-	Zone	Modelo\Run - 01\Simulation\Results\Out1_Temperature.txt
Out1_Humidity.txt	1+1*zone	OUT1_HR_Z --> Relative Humidity	%	-	Zone	Modelo\Run - 01\Simulation\Results\Out1_Humidity.txt
Out2_TTemperature.txt	1+2*zone	OUT2_TMR_Z --> Mean radiant temperature OUT2_TOP_Z --> Operative temperature	°C	-	Zone	Modelo\Run - 01\Simulation\Results\Out2_Temperature.txt



Out2_PMV.txt	1+1*zone	OUT2_PMV_Z --> Predicted mean vote	-	-	Zone	Modelo\Run - 01\Simulation\Results\Out2_PMV.txt
Out2_PPD.txt	1+1*zone	OUT2_PPD_Z --> Percentage of person dissatisfied	%	-	Zone	Modelo\Run - 01\Simulation\Results\Out2_PPD.txt
Energy_zone.BAL	2+12*zone	1_B4_QBAL= --> no representar -1_B4_DQAIRdT --> no representar 1_B4_QHEAT --> Ideal Heating Power -1_B4_QCOOL --> Ideal Cooling Power +1_B4_QINF --> Infiltration Gains +1_B4_QVENT --> Ventilation Gains +B4_QCOUP --> Coupling Gains +1_B4_QTRANS --> Transmission from surfaces +1_B4_QGINT --> Internal Gains +1_B4_QWGAIN --> Wall Gains +1_B4_QSOL --> Solar Gains +1_B4_QSOLAIR --> convective energy gain of zone due transmitted solar radiation	kJ/h	W	Zone	Modelo\Run - 01\Simulation\Energy_zone.BAL
SURFACES RESULTS						
OutSurf_Temp_Zx.txt	1+2*surface (1file*zone)	EDF_O_Tsi_S --> Inside surface Temperature EDF_O_Tso_S --> Outside surface Temperature	°C °C	-	Surface	Modelo\Run - 01\Simulation\Results\OutSurf_Temp_Z1.txt
OutSurf_RadW_Zx.txt	1+1*Sub-surface (1file*zone)	EDF_O_QSGL_Sxx --> Solar radiation absorbed in window xx	kJ/h	W	Surface	Modelo\Run - 01\Simulation\Results\OutSurf_RadW_Z2.txt
GENERATION SYSTEMS						



PrinterSisDist_Gains.txt	1+3*zone	DIS_Gain_Conv_Z --> Convective Power DIS_Gain_Rad_Z --> Radiative Power DIS_Gain_Hum_Z --> Abs. Humidity	kJ/h kJ/h kg/h	W W -	Zone	Modelo\Run -01\Simulation\Results\PrinterSisDist_Gains.txt
PrinterSisGen_Consumption.txt	1+4* generation system	GEN_Produccion --> Energy Production GEN_Consumo --> Fuel consumption GEN_Combustible--> Fuel consumption GEN_Coste--> Fuel consumption	kJ/h kJ/h l/h €/h	W W -	Generation system	Modelo\Run -01\Simulation\Results\PrinterSisGen_Consumption.txt
OutSis_ElectricalConsumption.txt	1+1* pumps	GEN_O_BbaPot --> Power Pump Generation HID_O_BbaPot--> Power Pump Tank	kJ/h kJ/h	W W	Generation system	Modelo\Run -01\Simulation\Results\OutSis_ElectricalConsumption.txt
OutSis_SysDemands.txt	1+1*equipm. distribution	DIS_Gain_Cx_Zxx --> Power Equipment xx in Circuit x	kJ/h	W	Generation system	Modelo\Run -01\Simulation\Results\OutSis_SysDemands.txt
OutSis_SysLosses.txt	1+1	DIS_Perdidas --> Losses in Distribution system	kJ/h	W	Generation system	Modelo\Run -01\Simulation\Results\OutSurf_RadW_Z2.txt
OutSis_States.txt	1+2*gen. sys + 1* circuit	OnOffBbaGen --> Generation Pump state OnOffBbaRet --> Return Pump state OnOff_valvula_Cx --> Circuit x valve state	-	-	Generation system	Modelo\Run -01\Simulation\Results\OutSis_States.txt

All files are text files, in .txt format separated by spaces, except Energy_Zone.BAL, which uses, in addition to space, the character "|" to distinguish between thermal zones. The route where the results / data files are located is the same as in the example, varying the name of the project, in this case "Model" and the number of the simulation, that in case of simple simulation, as in this example, is "Run -01", but when there are simulations with EMC (Energy Conservation Measures) they will be numbered in the following way: Run 00-0000, Run 00-0001, ..., Run 00-000n, Run 01-0000, Run 01-0001, ..., Run 01-000n.



4.2 BCORE files

BCORE files are compressed files in gzip that has a first version field of the file followed by structured data in JSON.

Fields containing the geometry are the following:

1. Zones – Dictionary of the different areas of the building
Key: Zone's id [string]
Value: zone's data [[Zone](#)]
2. Shades – Building shadows list
 - Name – Shadow name [string]
 - Vertex – Shadow vertexes list [[Vertex](#)]
3. Walls – Wall's dictionary
Key: Wall's id [int]
Value: wall's data [[Wall](#)]
4. Windows – Window's dictionary
Key: window's id [int]
Value: window's data [[Window](#)]

Classes

Zone: information about each zone.

- BuildingSurfaces – Surface's list [[BuildingSurface](#)]
- Name – zone's name [string]

BuildingSurface: information about each Surface.

- Id – Surface's identifier [int]
- Name – Surface's name [string]
- SurfaceType – Surface's type [string]
- Vertex – List of surface vertexes [[Vertex](#)]
- OutsideBoundaryCondition – Surface's boundary condition [string]
- FenestrationSurfaces – List of surface holes [[FenestrationSurface](#)]
- WallId – Wall's identifier associated with the surface [int]

FenestrationSurface: Hole information

- Id – Surface's identifier [int]
- Name – Surface's name [string]
- SurfaceType – Surface's type [string]
- Vertexes – List of surface vertexe [[Vertex](#)]
- WindowId – Window's identifier associated with the hole [int]

Vertex: contains the vertex's coordinates.

- X – Coordinate X [int]
- Y – Coordinate Y [int]
- Z – Coordinate Z [int]

Wall contains wall's information.

- Name – Wall's name [string]

Window contains window's information.

- Name – Window's name [string]

BuildingSurface : SurfaceType:

- Floor



- Wall
- Roof
- Ceiling

BuildingSurface: OutsideBoundaryCondition:

- Zone
- Outdoors
- Ground
- OtherSideCoefficients

FenestrationSurface: SurfaceType

- Window

Wall: name and Window: name

String defined by the user. It can have any value.