Software Training

User's Manual of the Software BCORE

User's manual version 4, issue date on 22nd October 2018

ENGINENCY – Toolset to improve building's energy efficiency.
A Holistic System for Building Inspection and Energy Efficiency Management

This research project has received funding from the European Union's H2020 Fast Track to Innovation Pilot 2015-1 under Grant Agreement no 720661.

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Produced by	University of Vigo – GTE (Energetic Technology Group)
Main author	Lara Febrero-Garrido, Julia Valdés-Vaello
Co-authors	Pablo Eguía-Oller, Enrique Granada-Álvarez
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Colophon

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Toolset to improve building’s energy efficiency

Publishable executive summary

A User's Manual of the software BCORE has been written and it is going to be released as relevant part of the Training Programme of the project ENGINENCY. BCORE is going to be commercialized as Software as a Service (SaaS), providing a holistic tool able to analyse, manage, report and improve the energy efficiency in buildings. BCORE is an innovative and novel energy simulation software that integrates into a single tool multiple utilities and applications, previously not found commercially combined, resulting in an effective answer to a real market needs. The key objective of the present user's guide is to provide the necessary instructions to use the software, and to get the core skills to easily manage it. Following this manual, any standard end-user may be able to work normally with BCORE, without requiring the presence of Information Technologies (IT) experts. The user's manual consists of three main sections: general information about the software, the core guidelines for getting started and step by step instructions for using the software BCORE.

Note: This is a sixth draft version of the software training. Therefore, it is provisional.

List of acronyms and abbreviations

- SaaS: Software as a Service
- IT: Information Technologies
- ECM: Energy Conservation Measures
- BEM: Building Energy Modelling
- BIM: Building Information Modelling
- osm: Open Studio Model
- gbXML: Green Building XML
- epw: EnergyPlus Weather
- TRT: Thermal Response Test
- ASHRAE: American Society of Heating, Refrigerating and Air-conditioning Engineers
- LBL: Lawrence Berkeley Laboratory
- ACH: Air Changes
- csv: Comma Separated Values
- HVAC: Heating, Ventilation and Air Conditioning
- NCV: Net Calorific Value

Definitions

TRNSYS: Transient System Simulation, developed by the University of Wisconsin, Madison, is a simulation software used to simulate the behaviour of transient systems. It solves complex problems decomposing the model into several interconnected components called types, which model the behaviour of each part of the system. In the present software it is used as calculation engine.

ECM: An Energy Conservation Measure is an action or a practice which aims to conserve or save energy for a building system, seeking to optimize the energy efficiency of the building.

BIM: Building Information Modelling is a 3D model-based process involving the generation and management of digital representations of physical and functional characteristics of buildings, providing tools to professionals to efficiently plan, design, construct, and manage buildings and infrastructures.

BEM: Building Energy Modelling goes a step forward, it is a multi-use tool to assess the energy efficiency of buildings, a physics-based calculation of building energy consumption, including design and retrofit of buildings and development of whole-building energy-efficiency simulations.

SketchUp: SketchUp is a graphic design and three-dimensional (3D) modelling program based on faces that can be used in a wide range of drawing applications such as mechanical engineering, architectural or interior design, and available as a free software.

OpenStudio SketchUp Plug-in: OpenStudio is an open source cross-platform collection of software tools to support whole building energy modelling using EnergyPlus and advanced daylight analysis using Radiance. The OpenStudio SketchUp Plug-in is an extension to SketchUp 3D modelling tool that allows users to quickly create geometry.

Thermal zones: A thermal zone is the basic unit in modelling a building. It is a room or collection of rooms with similar conditioning requirements and the same heating and cooling setpoint. The software reads each space as a thermal zone, so this must be taken into account when drawing the geometric model.

Infiltration: This is the outside air entering inside a room through cracks and other openings which have not been intentionally placed in the envelope of the local. The infiltrations are also known as air leakages introduced into the building.

Thermal Response Test: A TRT is an onsite test used to characterize the thermal properties of the ground as thermal conductivity or thermal resistance. This measurement method is applied by injecting and extracting heat into geothermal closed-loop circuits inserted into the soil.

Heating, Ventilation and Air Conditioning: A HVAC system is the interconnected equipment that provides thermal energy, thermal comfort and air quality in an indoor space of a building.

GenOpt: Generic Optimization Program is an optimization tool used for the minimization of a cost function that is then evaluated by TRNSYS. It has been developed by the Lawrence Berkeley National Laboratory. The optimization is done by systematic variation of specified design parameters in order to minimize the objective function.

Contents

1. General Information

1.1 What is BCORE?

BCORE 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 purpose of this document is to explain, as simplest as possible, the use, features and applications of the program. The software is a BEM (Building Energy Modelling) that enables the introduction of data such as the geometry, materials and enclosures, thermal loads, meteorological data and monitoring data. With all this information, the building is automatically simulated and calibrated. Finally, results and reports are displayed allowing also the application of ECMs to efficiently manage buildings.

The main key differentiating points of this software in comparison with other commercial available programmes are:

- First, and the most ground-breaking is the automated **calibration** of the simulation, resulting in high realistic results.
- Incorporation of predefined **libraries** and expandable materials and enclosures for any type of building.
- Provision of different **infiltration models** that calculate the loads using statistical techniques.
- **Model parameterization** to simulate changes in the building envelope, the loads schedules or the meteorological data.
- Generation of automated **reports** to facilitate decision making.
- Implementation of **ECMs** allowing the user, through both a technical and economic assessment, to manage buildings as efficiently as possible.
- Incorporation of basic **predefined energy generation and distribution systems** to model the most common thermal energy production and distribution systems in buildings.
- **User-friendly** interface, clear and intuitive.

1.2 Organization of the manual

The following user's manual has been created to guide the user step by step through the BCORE software. This user's manual consists of three sections: General Information, Getting Started and Step by Step Instructions for Using BCORE.

- **General Information** section explains in general terms the software and the purpose for which it is intended, providing a general overview of the application.

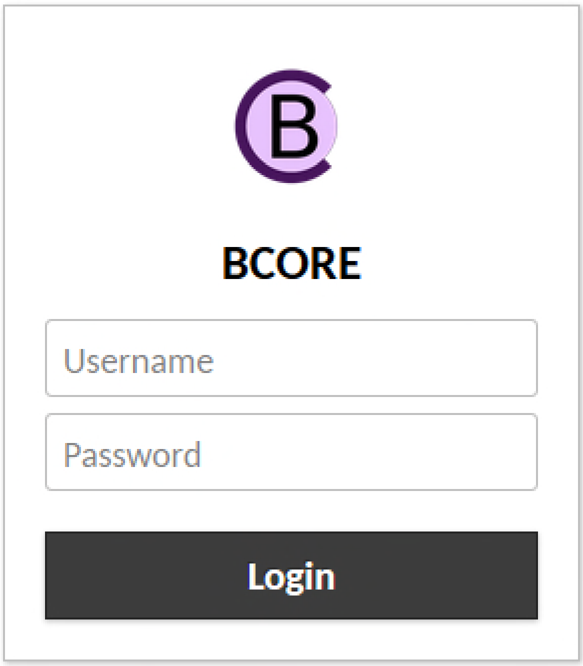
- **Getting Started** section explains the system's hardware and software requirements and how to access and start BCORE, as well as the process to open, save and download files in the web application.

- **Step by Step Instructions for Using BCORE** section explains briefly the menu and provides a description of the software functions.

2. Getting Started

2.1 Register and login

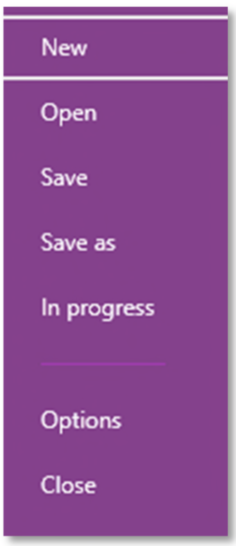
Only registered users can work with BCORE. The user must type the following in the address bar of the web browser bcore.uvigo.es:8082 to use the software. BCORE is a web application located in the Cloud. Therefore, the application just requires Internet connection and no further hardware or software requisites besides a web browser. The software can be used immediately without any further configuration. Just once the software is open, the user has to enter its username and password and login, as shown in the figure below. Currently, the software version is the version 9 that was released in October 2018.



2.2 Starting

Once the user enters BCORE, the general overview of the software is the following.

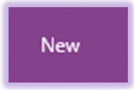
The starting menu of the software has the following tabs: New, Open, Save, Save as, In progress, Options, and Close. When there is not any model or project open the menus of Save and Save as are hidden.



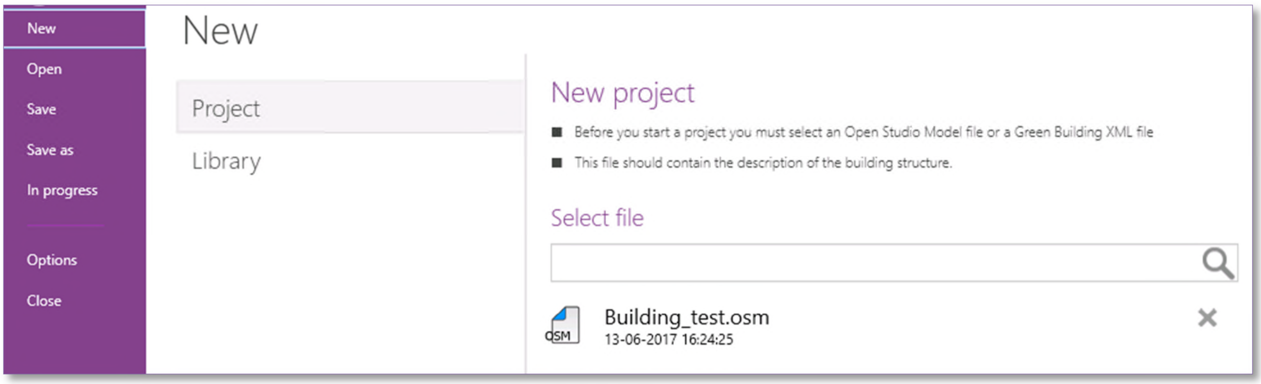
One of the starting points of the application is a BIM (Building Information Modelling) or BEM file containing information of the building, both geometric and constructive. This building model is introduced in specific formats, as an Open Studio Model (osm) or as a Green Building XML (gbXML).

- osm (.osm): This is the output format of the geometry of a building obtained through the SketchUp software, combined with the OpenStudio SketchUp Plug-in. It provides information about geometry, enclosures and materials of the building. As well as some thermal information about the building needed in the simulation.

- gbXML (.XML): It is an open industry supported schema that allows to share building information between different design software tools. It allows to transfer to BCORE the building data stored in BIM. It is integrated in several CAD softwares.

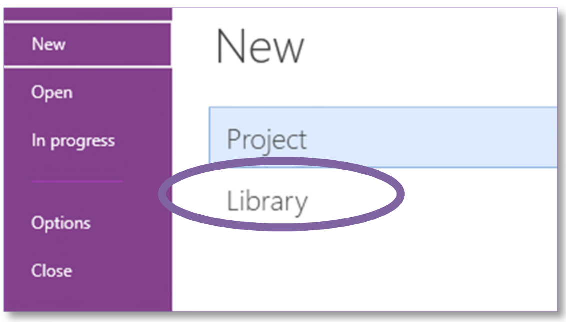


Therefore, to start a **New** project the user must click in new project and open an Open Studio Model (.osm) or a gbXML (.XML) file with the geometry and construction of the building and then complete the model in the BCORE software. After that the file will be available in the files list. It is possible to search a file by name. The cross placed at the right side of the file can be used to delete the file, as shown in the figure below.

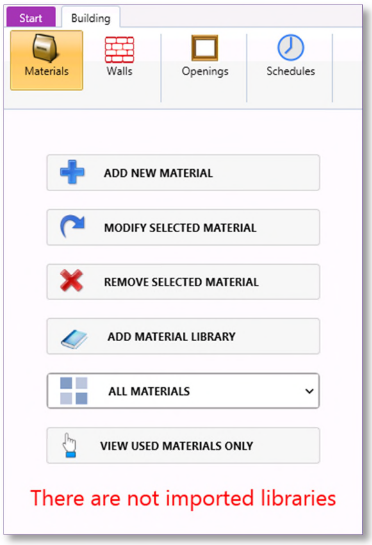


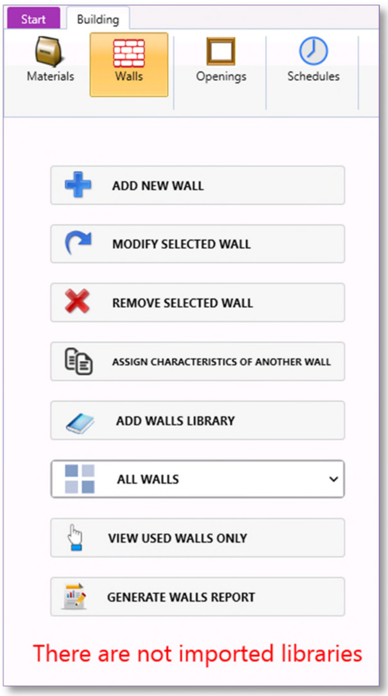
If the user needs to open a new project that is not available in the list of files, it is just necessary to drop the file into the web page to attach it.

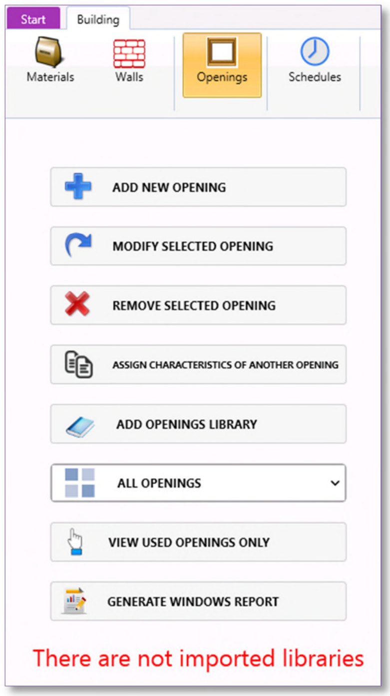
In this menu is also possible to create a new library. These libraries allow to define sets of materials, walls, openings and schedules, and they can be used in the projects.

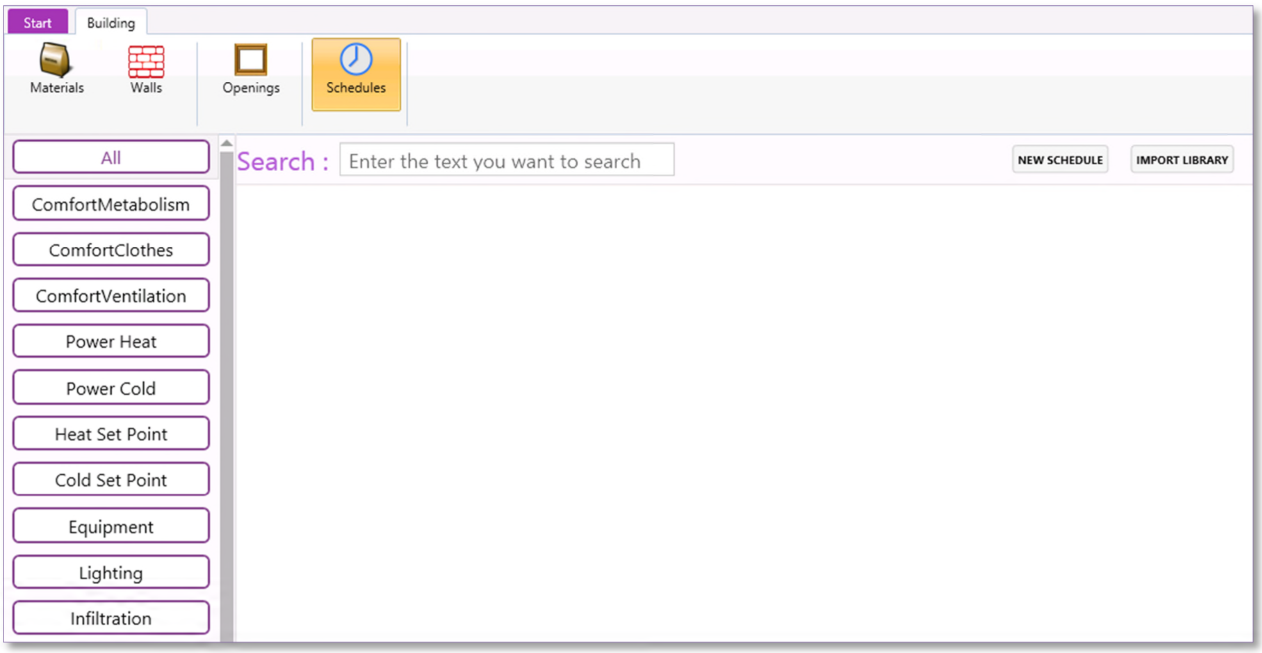


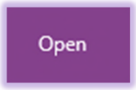
When the user clicks over New Library, the following windows are shown. The user can create libraries of materials, walls, openings and/or schedules.



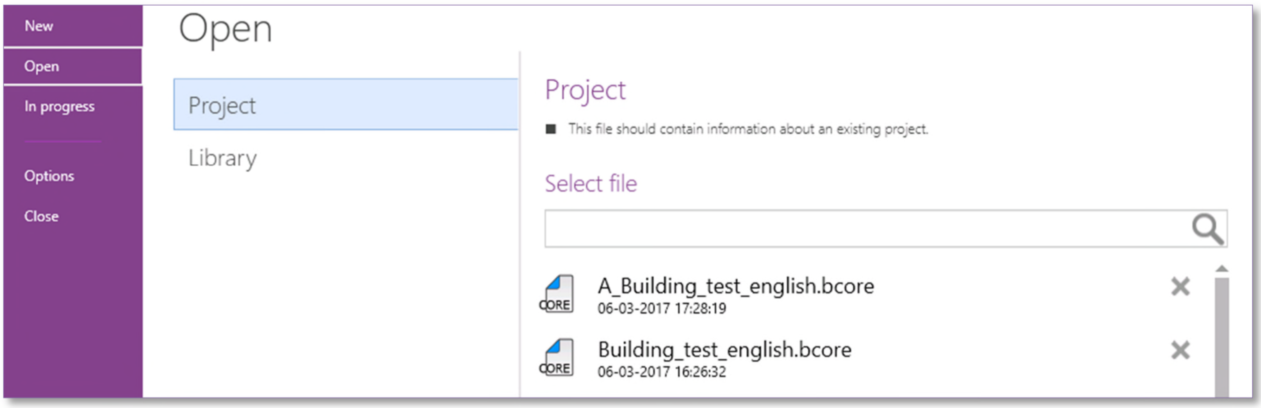




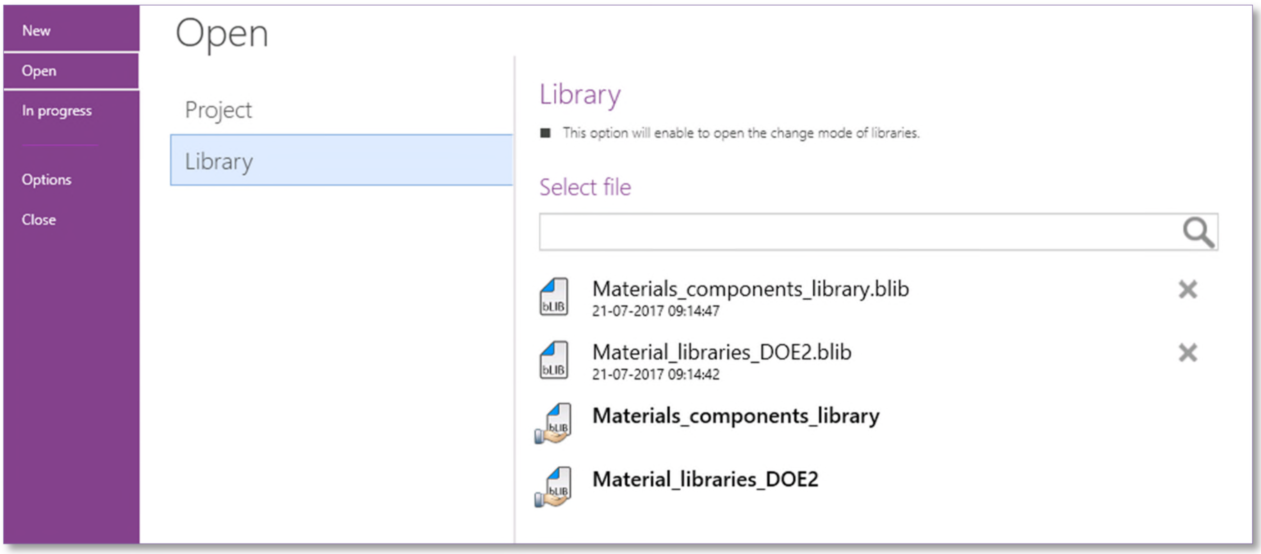




It is possible to **Open** an existing project and modify it. This file must contain information about a project already created. The file extension must be .bcore. The process of attaching files is the same as explain in the button **New**. However, here instead of .osm or .XML files there is the list of .bcore files. It is possible also to delete an existing project by clicking over the cross in the right side of the file name.

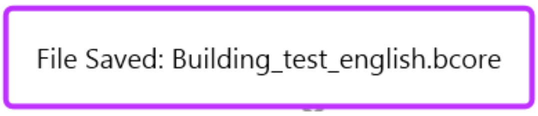


Furthermore, an existing library can be opened to modify it. The libraries extension is .blib. The possibility of delete a file is also maintained for this type of files.

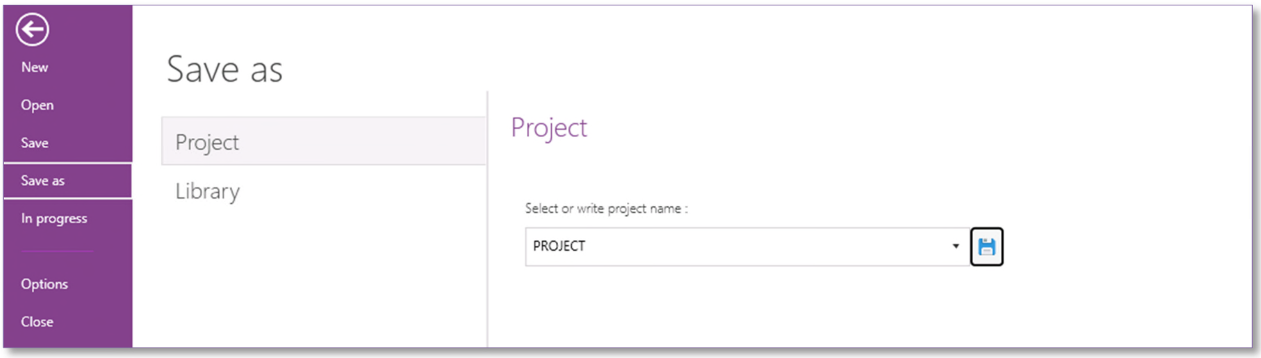


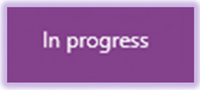
Some libraries are available to all users and they are showed in bold and with a hand below the icon. These libraries can be imported to any project but cannot be deleted. However, the user can open them and modify them to save them with another name.

To **Save** a project or a library that is already open. When the user clicks on the button **Save**, the project or library is saved with the same name and the following message is shown.

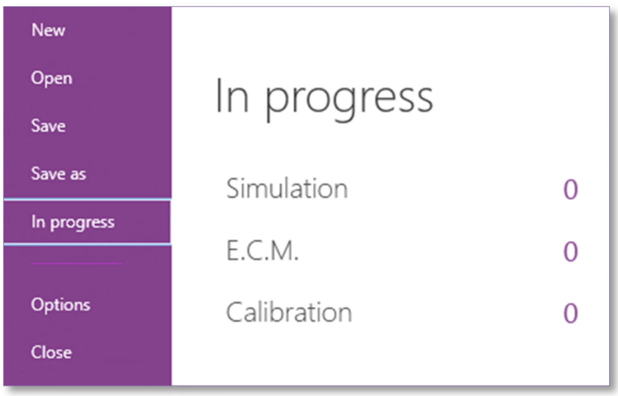


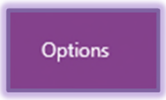
To **Save as** a project or a library. It has to be taken into account that both options **Save** and **Save as** only appear if there is a project or a library open. A project can be saved as a project .bcore or as a library .blib. For example if the user wants to use the libraries of one project into another one, the user has to **Save as** the project as a library and the extension is going to be changed. Then, this library can be used in another project. However, a library can be only saved as .blib. The user has to select o write the name of the project to save it as shown in the following image.



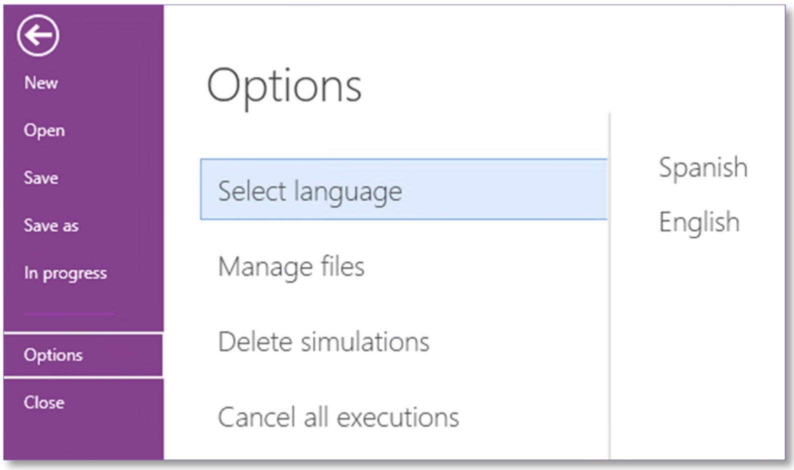


The tab **In progress** shows if there are simulations, ECMs or calibrations working in the background.

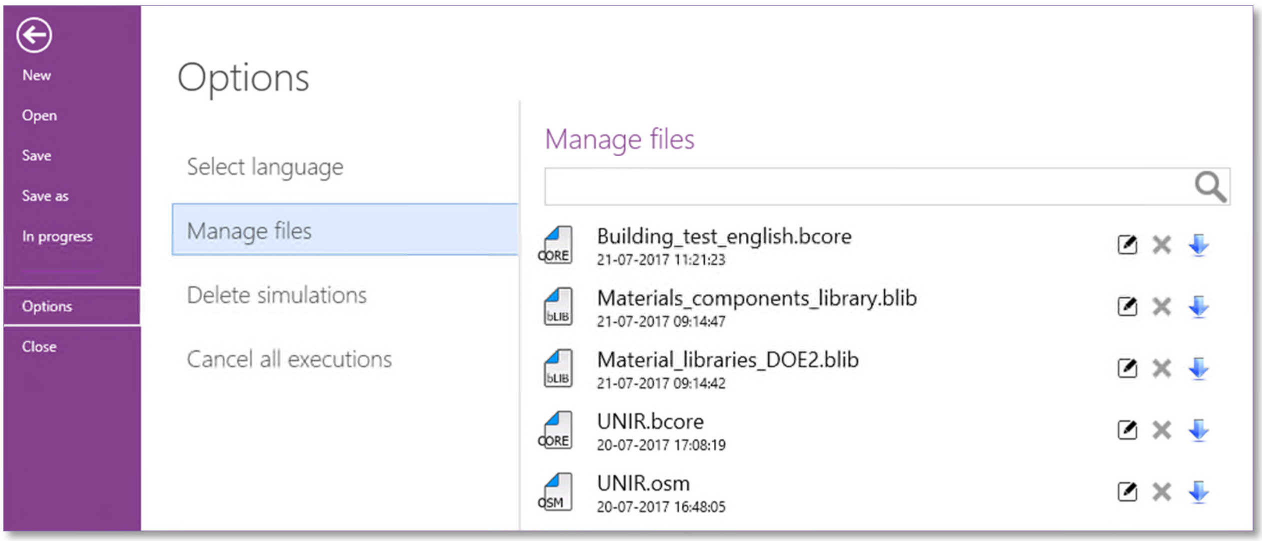




Options button presents different general options for the user. First, the user can select the language of the software, Spanish or English.



Then, the user can manage files. There, the user will find all files she or he has uploaded to the software no matter the extension (osm, bcore, blib, epw (EnergyPlus Weather), dat ...). It is possible to search for a specific name or extension. Therefore, clicking over the cross the user can delete the file and clicking over the arrow the user can download the file and save it in the personal computer. Finally, it is also possible to edit the name of the file.



It is also possible to delete the simulations implemented as they are being saved in the cloud as they are being carried out.

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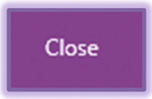
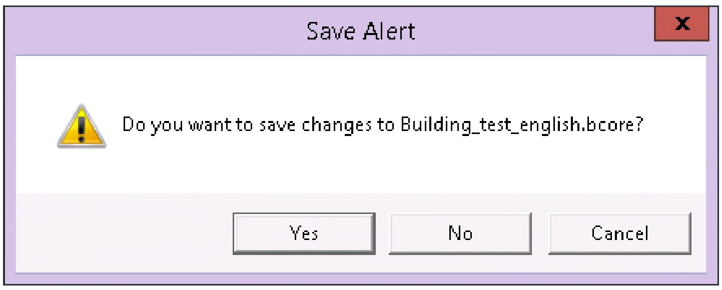
And finally, it is also possible to cancel all executions



The button **Close** closes the current project or library. When the user closes it a save alert window is shown to ask of she or he wants to save changes in the current project.



3. Step by Step Instructions for Using BCORE

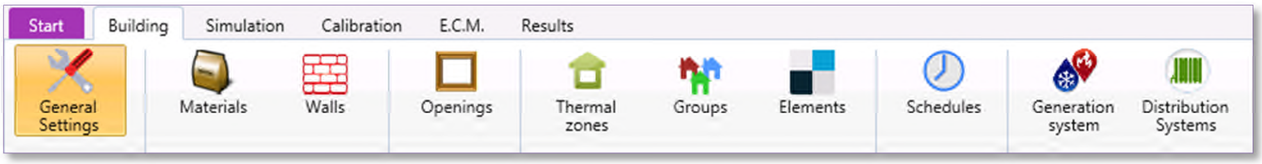
Once a new project is started and the geometry of the building in osm or gbXML is exported, the application enables the introduction of data in different formats and in different ways, automatically or manually, based on user needs. The main screen of the software presents six core tabs.

- **Start:** Explained in the previous section 2.
- **Building:** The building model is defined, thermal loads, schedules, etc.
- **Simulation:** The simulation parameters are described and the building is simulated.
- **Calibration:** The simulation is calibrated based on monitoring and real data in order to achieve a building model as realistic as possible.
- **ECM:** Energy conservation measures can be defined to determine improvements in the energy efficiency.
- **Results:** The results are showed as charts of columnes, lines, pie or bars.

3.1 Building model

Before implementing the simulation it is necessary to complete the building model exported. As stated above, the model has been introduced as an osm or gbXML file. In this way, 3D models are generated and divided into thermal zones or spaces, where construction templates can be used with their thermal characteristics.

In the building section, the following tabs are presented.



- **General settings:** General parameters about the building needed for the simulation.
- **Materials:** Materials of the building can be managed.
- **Walls:** Definition of the building walls.
- **Openings:** The openings can be defined in their surfaces, namely windows and doors.
- **Thermal zones:** Thermal loads and their schedules in each of the spaces or thermal zones are established in this section.
- **Groups:** Thermal zones can be grouped at the discretion of the user.
- **Elements:** The different surfaces and subsurfaces are observed here.
- **Schedules:** All types schedules are summarized in this tab.
- **Energy generation systems:** Different basic energy generation systems can be chosen.
- **Energy distribution systems:** Different basic energy distribution systems can be chosen in this section.

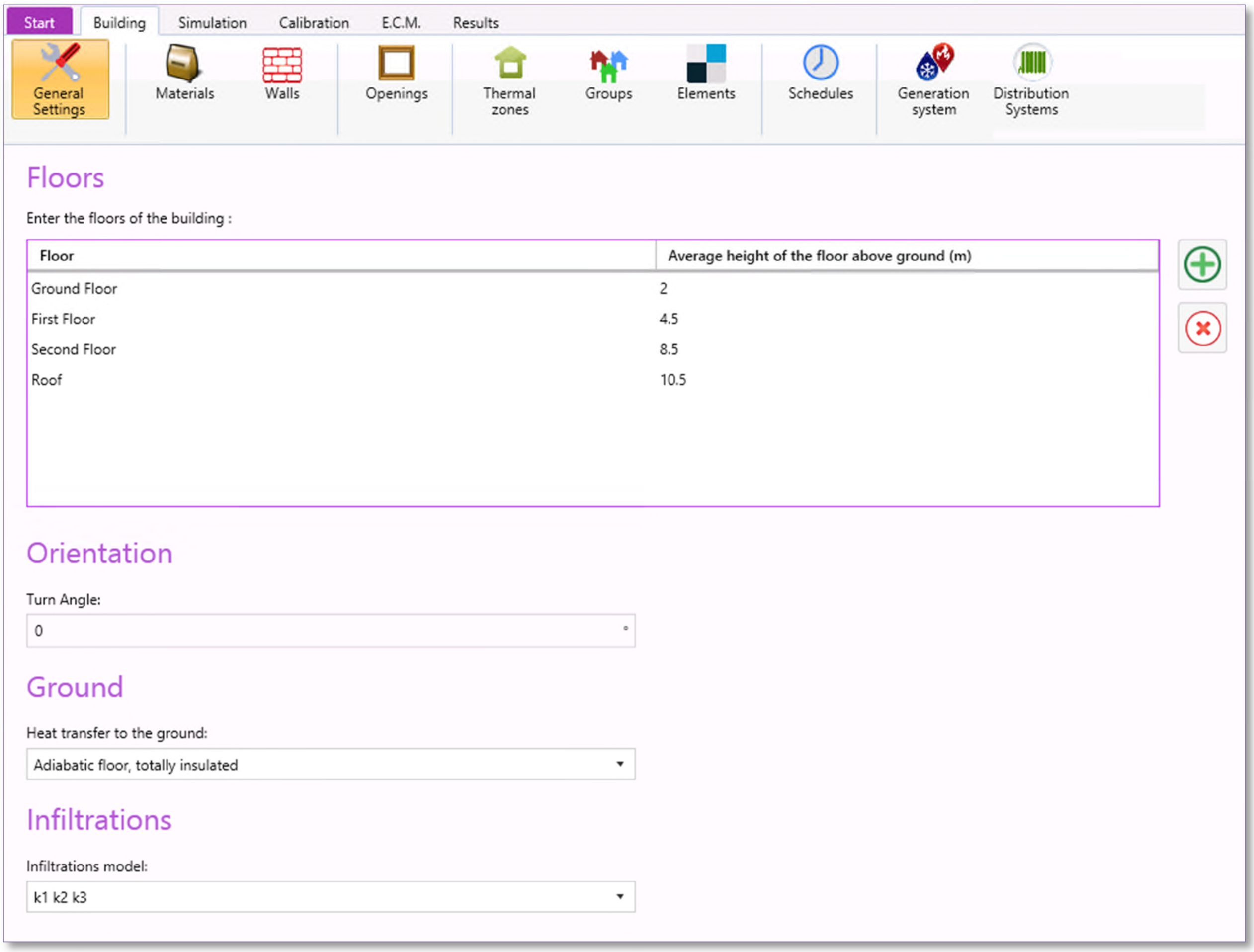
So, in the building tab all the settings of the building are defined, making it ready for simulation. Next, each of the previous items are explained in detail.

3.1.1 General Settings

First, the user must complete the **General settings**.

- Floors. All the floors of the building must be introduced, as well as the average height of the floor over the ground in meters. Keep in mind that this is the height of the floor in reference to ground, not the height of the floor. Clicking over the green cross the user can add new floors, otherwise clicking over the red cross the user can delete the selected floor.

- Orientation. The building orientation can be modified. North is represented with 0 degrees, the rotation must be from North to East. Only positive numbers are allowed.



- Ground.

Heat transfer with the ground. The boundary condition is the heat transfer produced between the building surfaces in contact with the ground in each of the axis. There are three possibilities: the ground data is available, the ground temperature is assumed to be ambient temperature, or to consider an adiabatic ground totally insulated.

If the user has a Thermal Response Test (TRT), **ground data are available** and it is selected as the method for calculating the heat transfer, further information about the terrain is needed:

- ✓ Resistance to heat transfer of the building insulation [m^2·K/W].
- ✓ Soil conductivity [W/m·K].
- ✓ Soil density [kg/m^3].
- ✓ Soil specific heat [J/kg·K].
- ✓ Average annual surface soil temperature [ºC].
- ✓ Extent of surface soil annual temperature profile [ºC]. It can be calculated as the half of the maximum monthly average temperature minus the half of the minimum monthly average temperature.
- ✓ Day of minimum surface soil temperature.
- ✓ Boundary conditions for heat transfer in each of the axis (X, Y and Z). Set if this condition is conductive or adiabatic.
- ✓ A terrain data file (.dat) has to be attached to the program. Files are attached just dropping them into the program. This file is generated using TRNSYS Multizone Slab Plugin for SketchUp.

- Infiltrations. The infiltrations can be modelled with three different models. Or it is possible not to calculate them.

K1, K2, K3 model. The infiltration gain or losses can be calculated by this simple American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) approach to infiltration that consists on an empirical method that estimates the air exchange per hour depending on the tightness level, ambient and room temperature and wind speed.

Lawrence Berkeley Laboratory (LBL) model. This is an empirical method that calculates the infiltrations from the equivalent area of cracks. The ground coefficients are function of the height which the wind velocity is measured and of the building location. Particularly, the information necessary to calculate the infiltrations with this method is the following:

- ✓ Wind speed height [m]. The height at which the wind speed was measured.
- ✓ First and second terrain coefficient where the wind was measured.
- ✓ First and second terrain coefficient for building location.

Sherman-Grimsrud model. This method is described in the ASHRAE Handbook of Fundamentals (2005), this empirical model estimates the infiltrations from the equivalent area of cracks and level of protection that the environment offers to the building. The equivalent area of cracks is obtained doing a Blower Door Test.

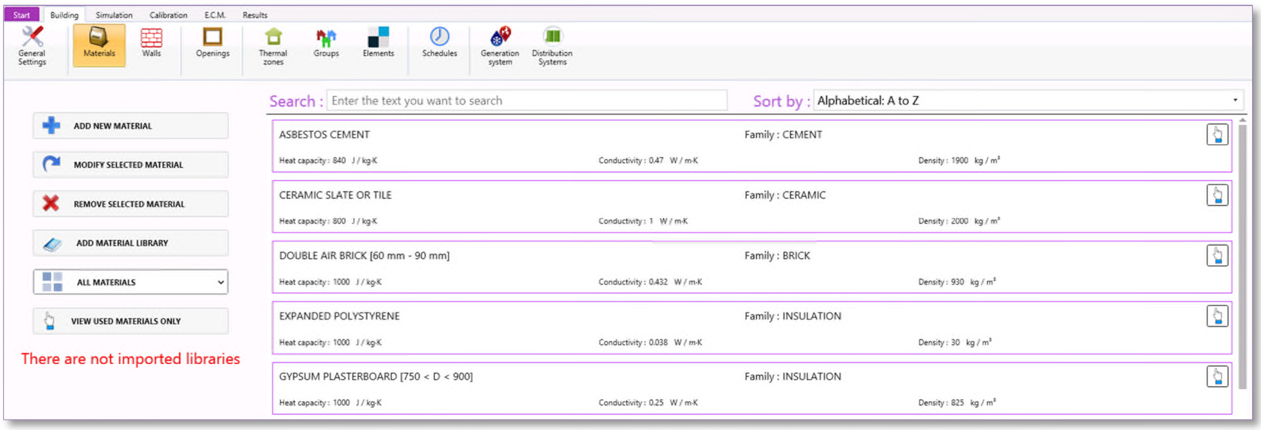
Do not calculate infiltrations. The infiltrations are not calculated in the simulation of the building.

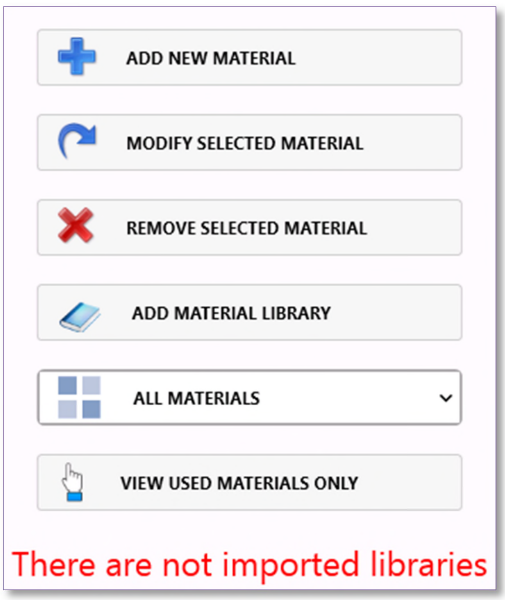
3.1.2 Materials, Walls and Openings

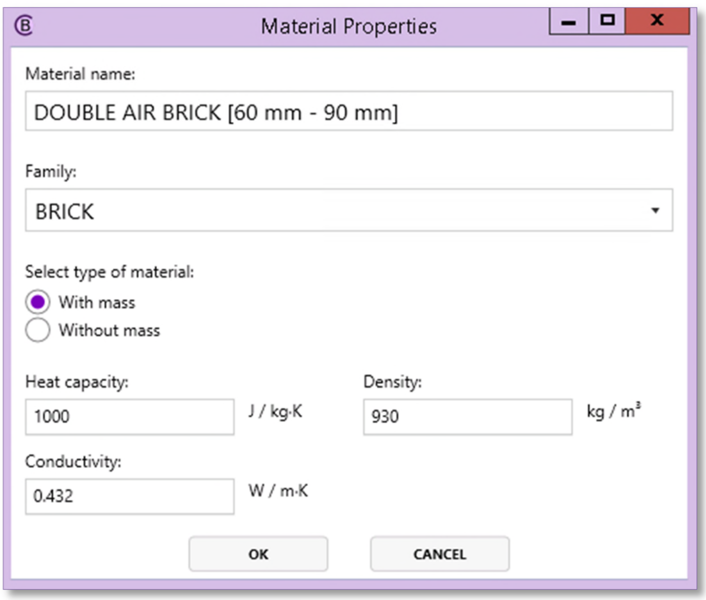
The following tabs are used to define the materials and the building thermal envelope.

MATERIALS

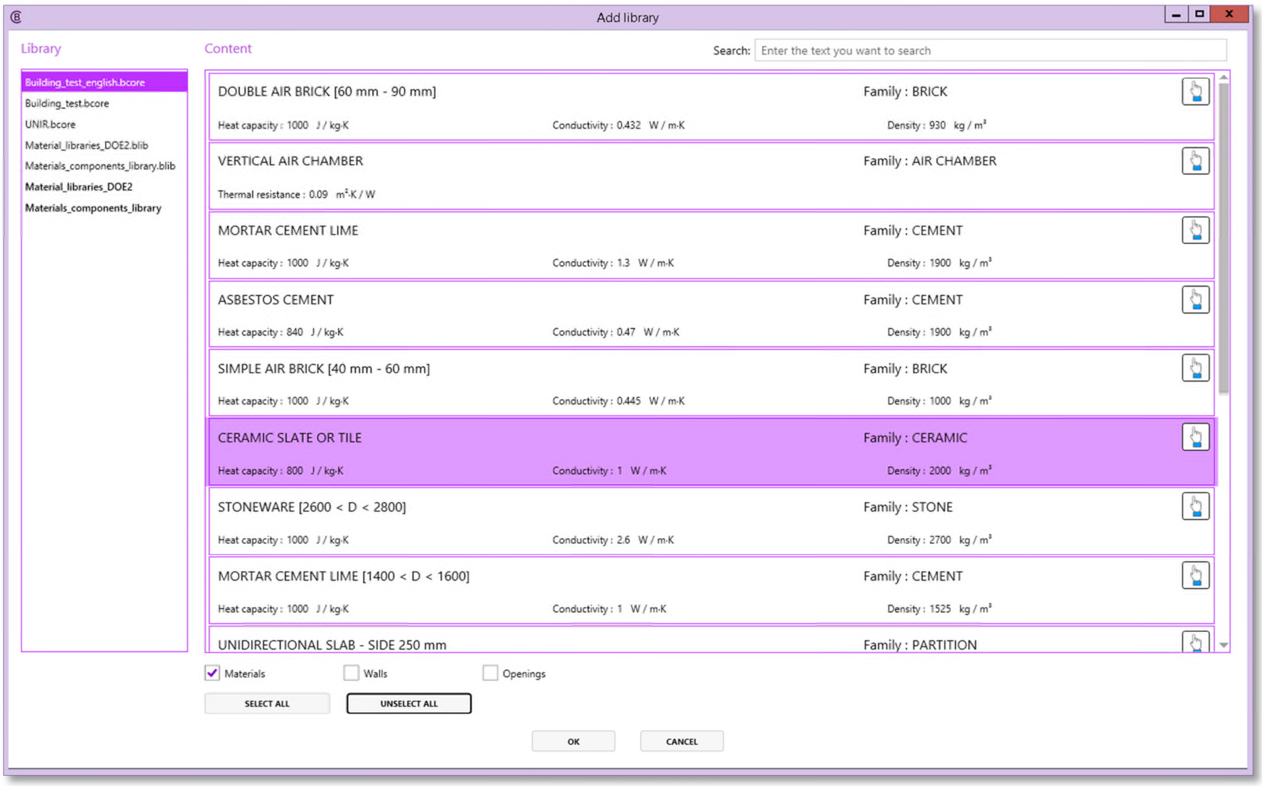
In **Materials**, the user can add, delete or modify the materials of the surfaces, taking into account the requested parameters of heat capacity (J/kg·K), conductivity (W/m·K) and density (kg/m^3) of the material. If the material has not mass, it is needed its thermal resistance (m^2·K/W). Each material can be assigned to a family. Families can be created just writing its name and they can be filtered by family.







Some predefined libraries include the most typical materials in European construction. It is possible to add a material library by clicking the button **ADD MATERIAL LIBRARY**. Libraries can be imported from a library (**.blib**) or from a project (**.bcore**), as can be observed at the left side of the window. It is possible to import all the materials, walls or openings or to select only the ones that the user wants to import.



WALLS

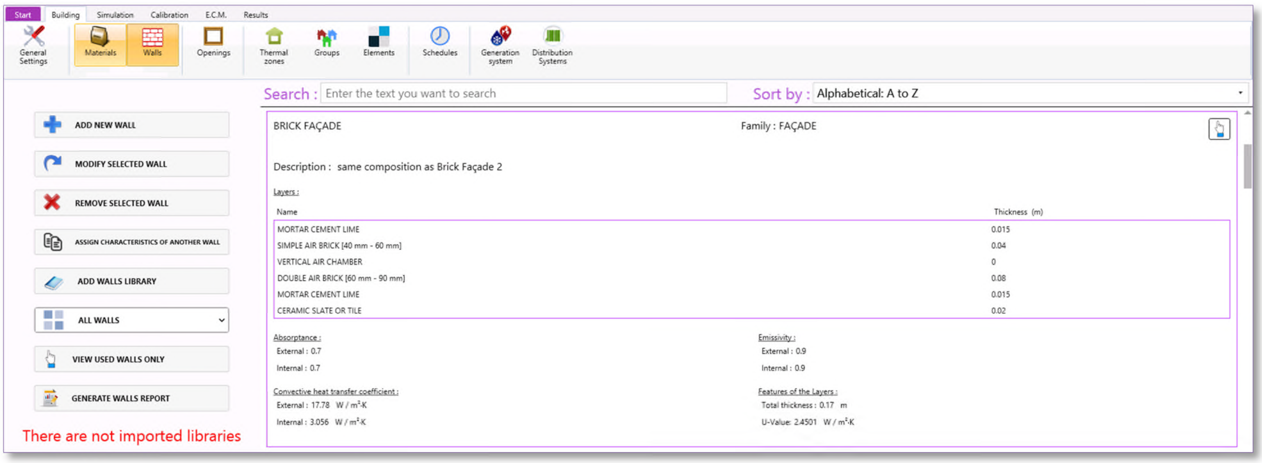
In **Walls**, the user can add, modify and remove the walls, taking into account the requested parameters: name of the wall, family, description, layers (material and thickness (m)), solar absorptance (external and internal), long-wave emissivity (external and internal) and convective heat transfer coefficient (W/m^2·K).

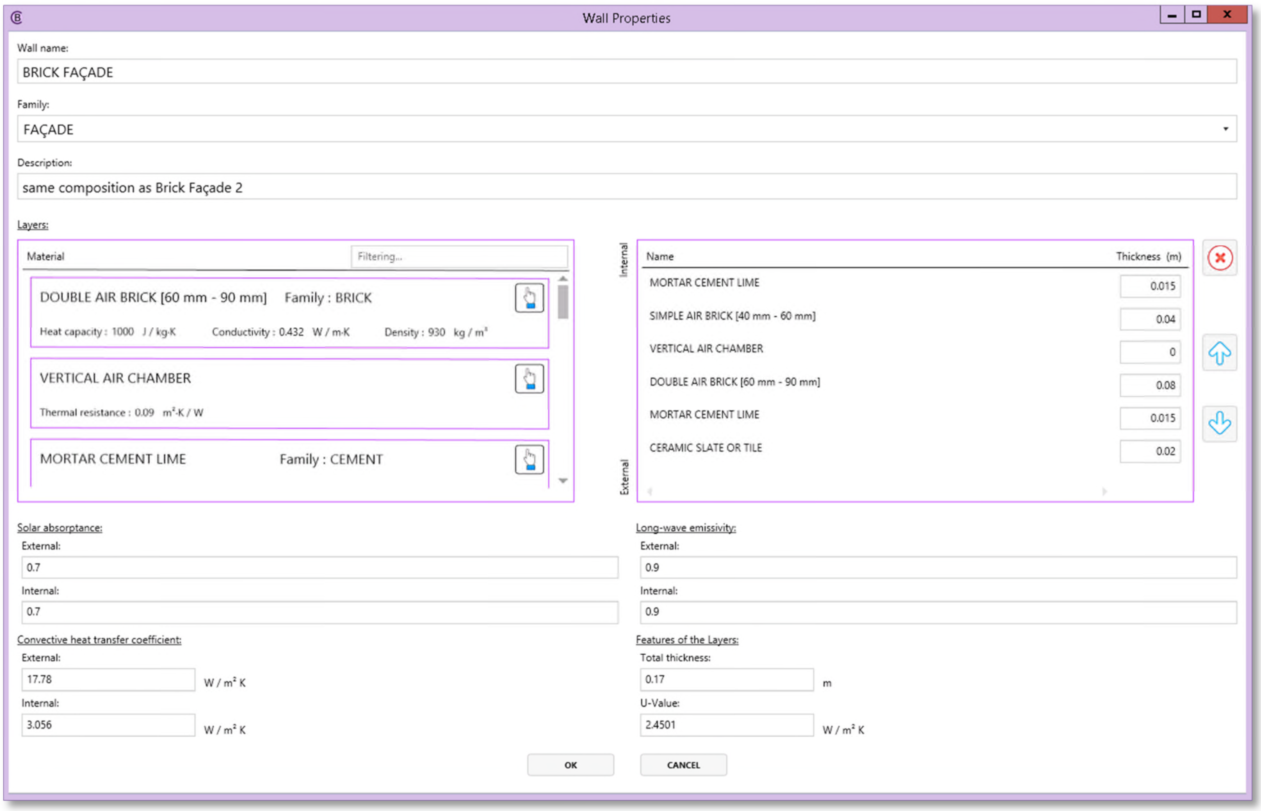
The materials of the layers can be added by dragging them to the right window. In addition, material layers can be repositioned using the blue arrows. Otherwise, in materials without mass, such as air chambers, the thickness of the material layer should be null "0".

The convective heat transfer coefficients of walls are usually; inside: 11 kJ/h·m^2·K = 3.056 W/m^2·K and outside: 64 kJ/h·m^2·K = 17.78 W/m^2·K. These values are the ones that the software takes by default and they represent a wall with inside and outside part. However, if the wall is completely interior, the outside coefficient must be changed to 3.056 W/m^2·K. Otherwise, for a boundary wall a value < 0.001

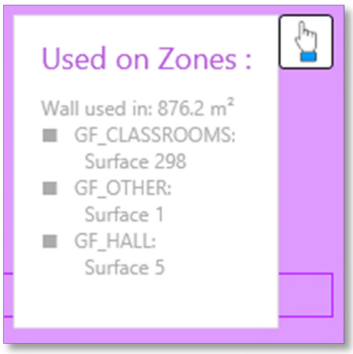
kJ/h·m²·K ≈ 0.0003 W/m²·K must be inserted and it indicates direct contact, for example contact with the ground.

Using the above properties some features of the wall are calculated. The total thickness (m) and the U-value (W/m²·K) are automatically displayed on the screen.

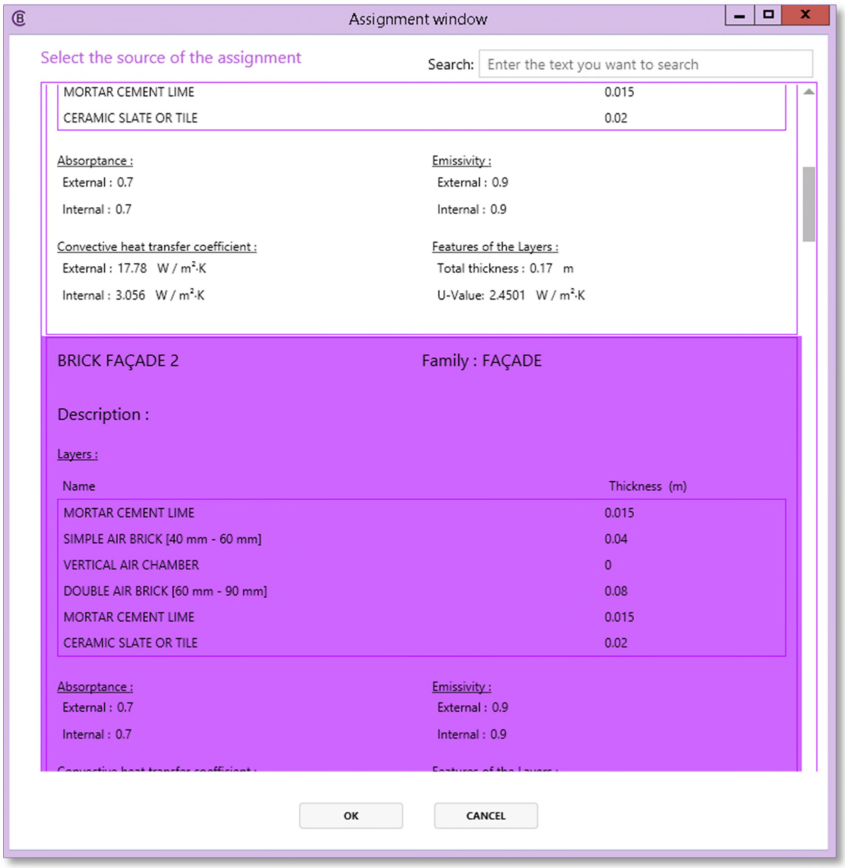




When a wall is being used in the building, the hand of the upper right side turns white, while if the wall is not being used the hand background is dark. Positioning the mouse over the hand, the user can observe some information about the wall, specifically the walls where it is being used.



It is also possible to assign the characteristics of a wall to another one. The user has to click over the wall to be changed, then click the button **ASSIGN CHARACTERISTICS OF ANOTHER WALL** and the following window is shown where the user has to select the source of assignment, namely the wall with the characteristics wanted.

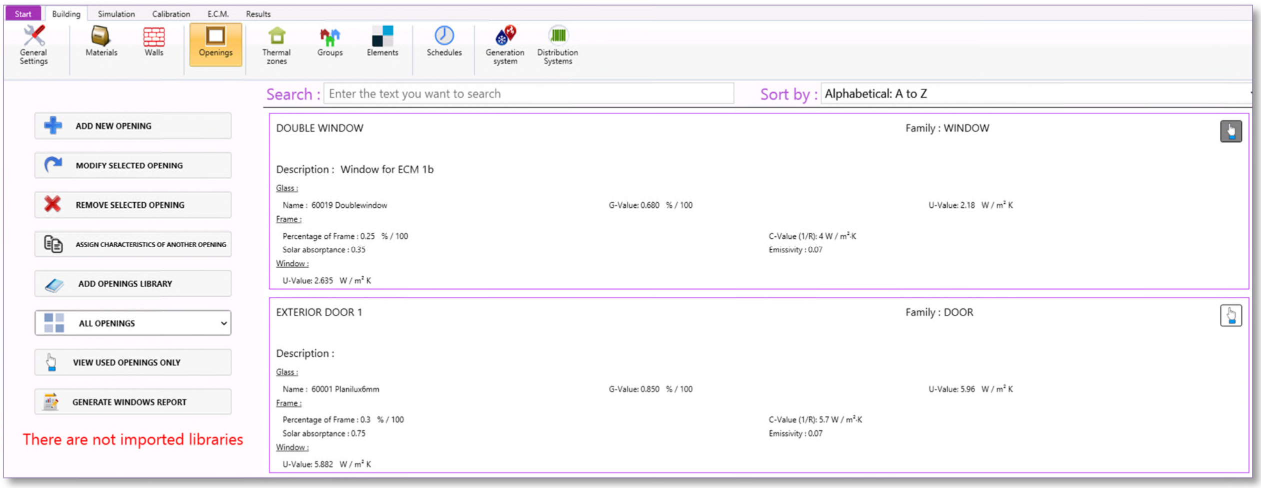


There is the possibility of adding walls libraries the same way as with materials.

And finally, the button **GENERATE WALLS REPORT** creates a word document with the walls information.

OPENINGS

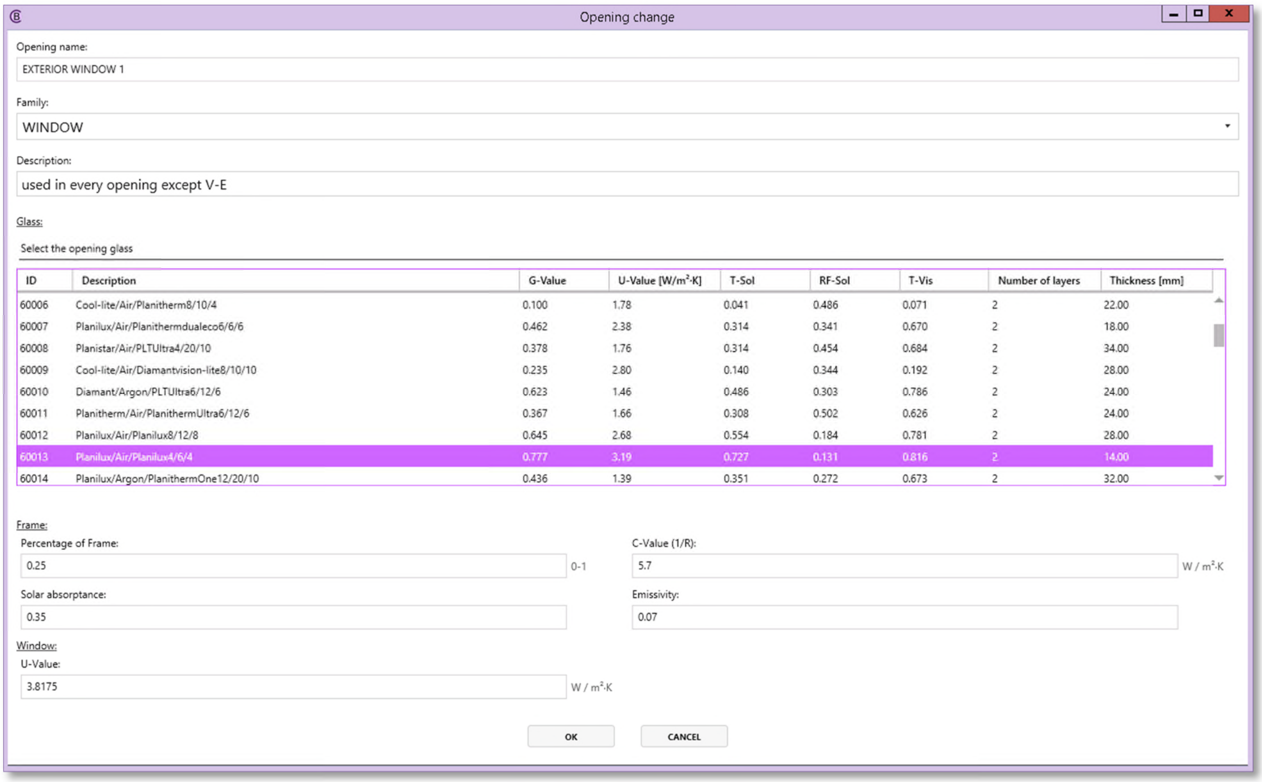
In **Openings**, the user can also add, modify or remove an opening, mainly a window or a door. The fields to fill in are the following: opening name, family, description, glass and frame properties (percentage of frame, solar absorptance, C-value (1/R) (W/m^2·K) and emissivity). An important property is the percentage of frame from 0 to 1. However, 1 cannot be used. When for example a door with no glass has to be modelled, the percentage of frame has to be 0.99.



The glass must be selected from the available opening glass library, the most appropriate glass has to be selected taking into account the properties showed in the list. Then, the U-value of the window (W/m^2·K) is calculated automatically by the program.

Other menus are available as in materials and walls, as **ASSIGN CHARACTERISTICS OF ANOTHER OPENING** or **ADD OPENINGS LIBRARY**.

And finally, it is possible to click over **GENERATE WINDOWS REPORT** and download the openings of the project in a Word document. (.docx).



Opening change

Opening name:

EXTERIOR WINDOW 1

Family:

WINDOW

Description:

used in every opening except V-E

Glass:

Select the opening glass

ID	Description	G-Value	U-Value [W/m²·K]	T-Sol	RF-Sol	T-Vis	Number of layers	Thickness [mm]
60006	Cool-lite/Air/Planitherm8/10/4	0.100	1.78	0.041	0.486	0.071	2	22.00
60007	Planilux/Air/Planithermdualeco6/6/6	0.462	2.38	0.314	0.341	0.670	2	18.00
60008	Planistar/Air/PLTUltra4/20/10	0.378	1.76	0.314	0.454	0.684	2	34.00
60009	Cool-lite/Air/Diamantvision-lite8/10/10	0.235	2.80	0.140	0.344	0.192	2	28.00
60010	Diamant/Argon/PLTUltra6/12/6	0.623	1.46	0.486	0.303	0.786	2	24.00
60011	Planitherm/Air/PlanithermUltra6/12/6	0.367	1.66	0.308	0.502	0.626	2	24.00
60012	Planilux/Air/Planilux8/12/8	0.645	2.68	0.554	0.184	0.781	2	28.00
60013	Planilux/Air/Planilux4/6/4	0.777	3.19	0.727	0.131	0.816	2	14.00
60014	Planilux/Argon/PlanithermOne12/20/10	0.436	1.39	0.351	0.272	0.673	2	32.00

Frame:

Percentage of Frame: 0.25 0-1

C-Value (1/R): 5.7 W / m²·K

Solar absorptance: 0.35

Emissivity: 0.07

Window:

U-Value: 3.8175 W / m²·K

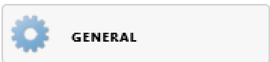
OK CANCEL

Toolset to improve building's energy efficiency

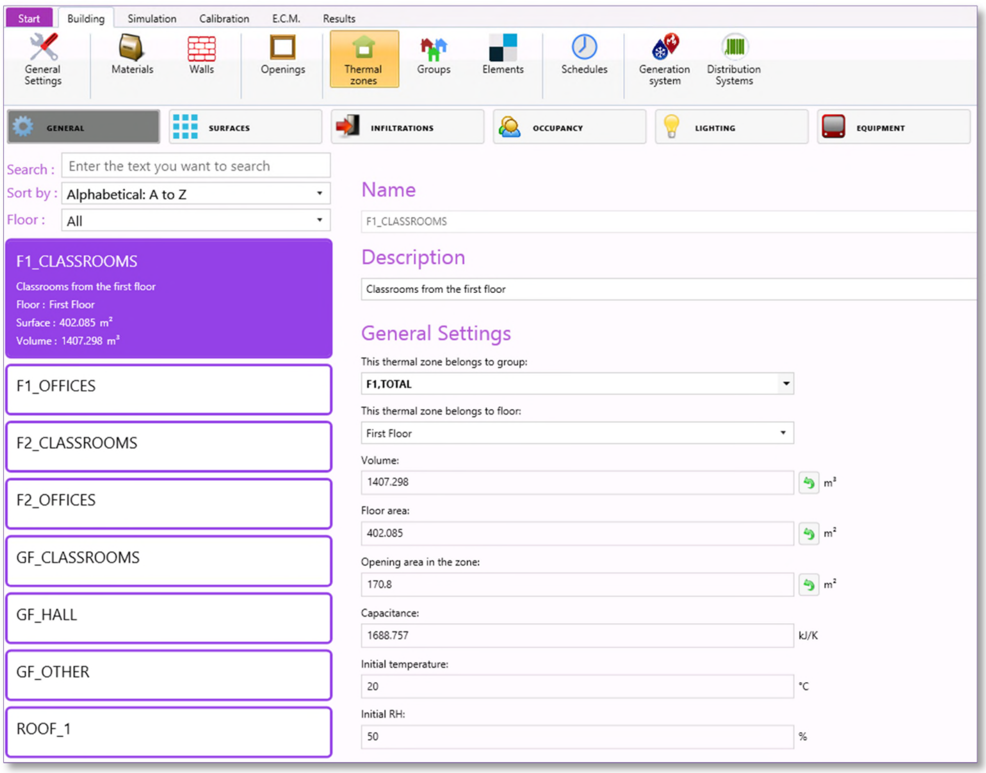
3.1.3 Thermal zones

The thermal zones or spaces of the building come define automatically from the building model file. So here, the user can define all the different loads of each of the thermal zones, such as infiltrations, occupancy or equipment.

- General parameters



In this screen the name, description and general settings of each thermal zone from the building model are presented.

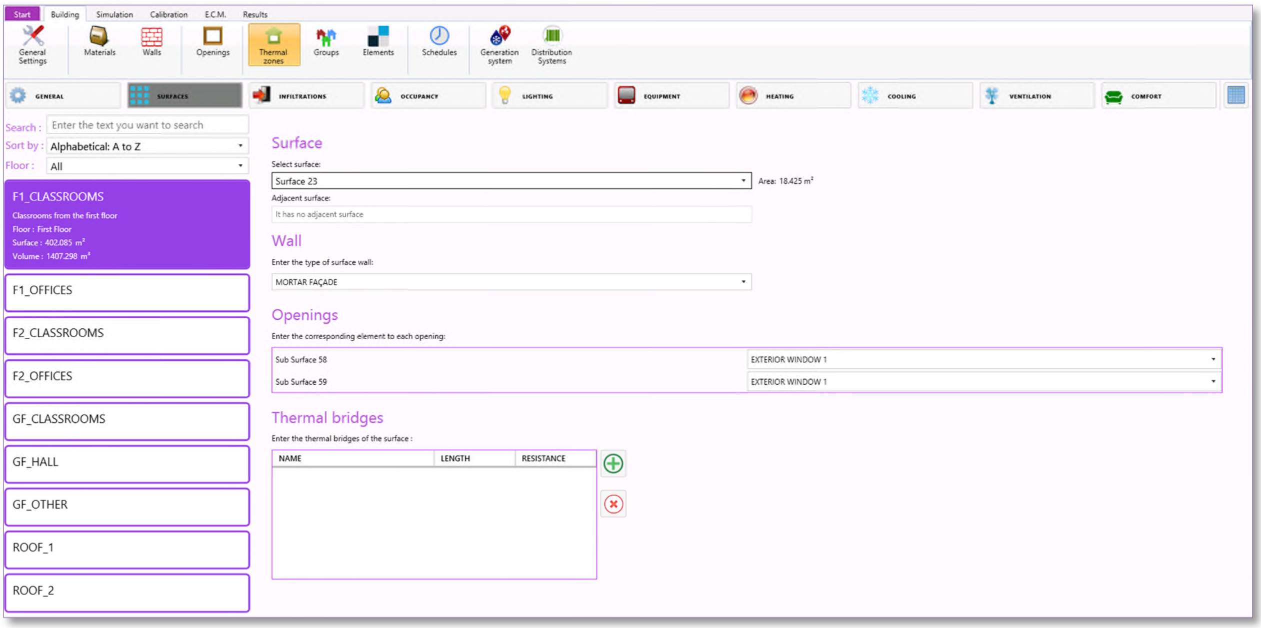


The following information is included: the group to which it belongs, the floor to which it belongs, the volume (m^3), the floor area (m^2), and the openings area (m^2) in the thermal zone, the capacitance (kJ/K), initial temperature (ºC) and the initial relative humidity (%).

The zones can be ordered alphabetically or sorted by floor. There is the possibility to search for different names entering the text you want to search or view only a selected floor.

- Surfaces

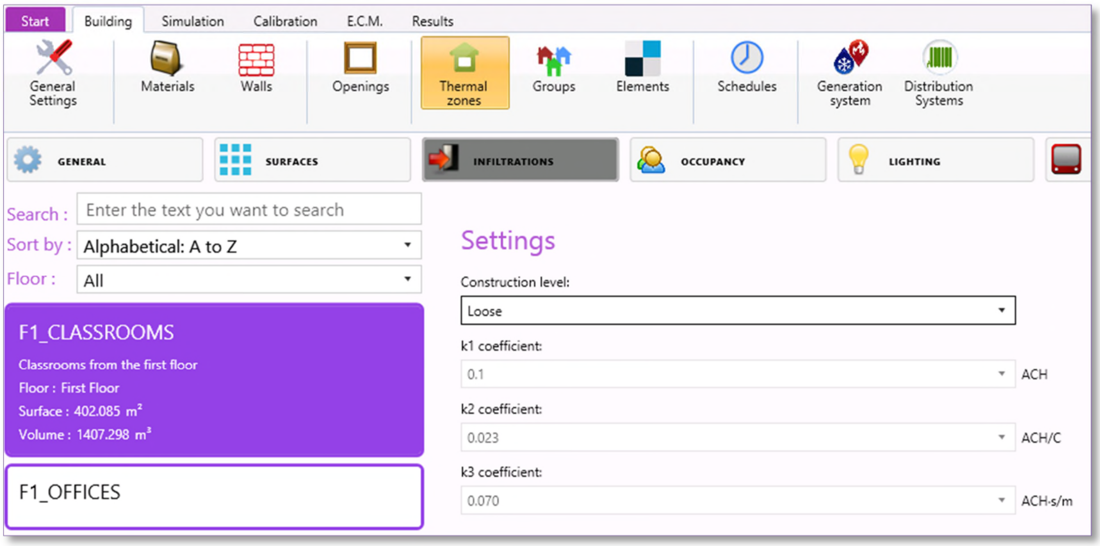
The tab surfaces presents for each of the thermal zones the following information: the surfaces forming the thermal zone showing its area (m^2) and the adjacent surface also with its area (m^2), the type of wall of the surface selected, the openings defined in the selected surface and the thermal bridges. Surfaces come define from the geometry in each of the thermal zones, but it is possible to change the wall associated to the surface, the opening and to define the thermal bridges. The linear thermal bridges in each area can be set by entering the length (m) and thermal resistance (m·K/W) of each thermal bridge. When the selected surface has an adjacent surface, the user can establish an air coupling flow (kg/h) and a schedule for the air coupling. To add a new thermal bridge the user has to click over the green cross. To delete a thermal bridge the user has to click over the red cross.



- Infiltrations

In this tab the user can define the infiltrations in each of the thermal zones in function of the model set previously in general settings.

If the selected model was **K1, K2, K3 method**, now the user defines the level of construction indicating if it is tight, medium or loose. Then, k1, k2 and k3 coefficients are calculated automatically. ACH means air changes. This is the easiest method for the user as it only needs a perception of the level of tightness of the building.



If the selected model was **LBL** you have to complete the following information apart from the parameters established before in the general settings:

- Zone leakage area (cm^2)
- The height from the lowest to the highest leakage site of the zone (m)
- The shielding factor
- The ceiling fraction of leakage
- The floor fraction of leakage

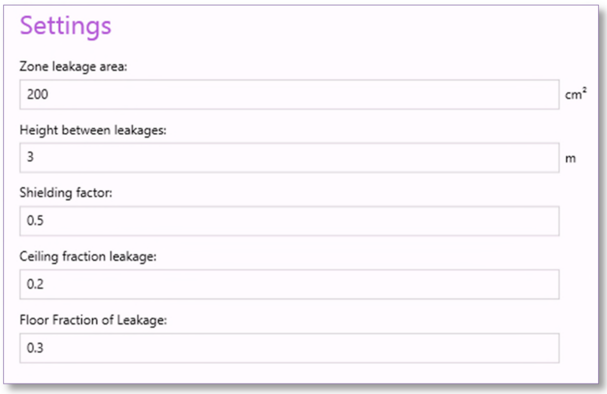
If the selected model **Sherman-Grimsrud** the user must enter the following information:

- Zone leakage area (cm^2).
- The number of floors.
- The shelter class: the user has to choose between no obstructions or local shielding, typical shelter for an isolated rural house, typical shelter caused by other buildings across street from building under study, typical shelter for urban buildings on larger lots where sheltering obstacles are

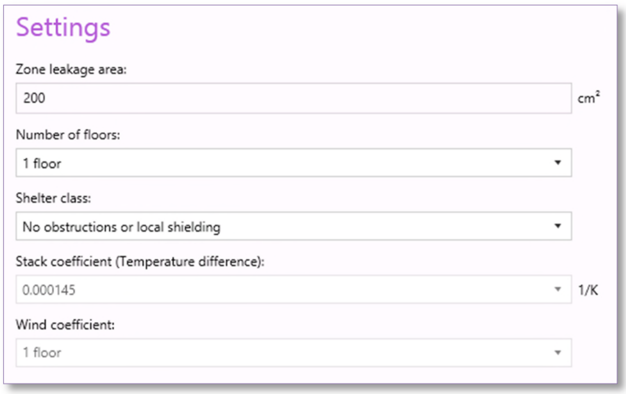
more than one building height away or typical shelter produced by buildings or other structures immediately adjacent.

With the above data, the stack coefficient (1/K) and the wind coefficient are calculated automatically. The stack coefficient depends on zone's number of floors and the wind coefficient depends on zone's number of floors and on how sheltered the building is.

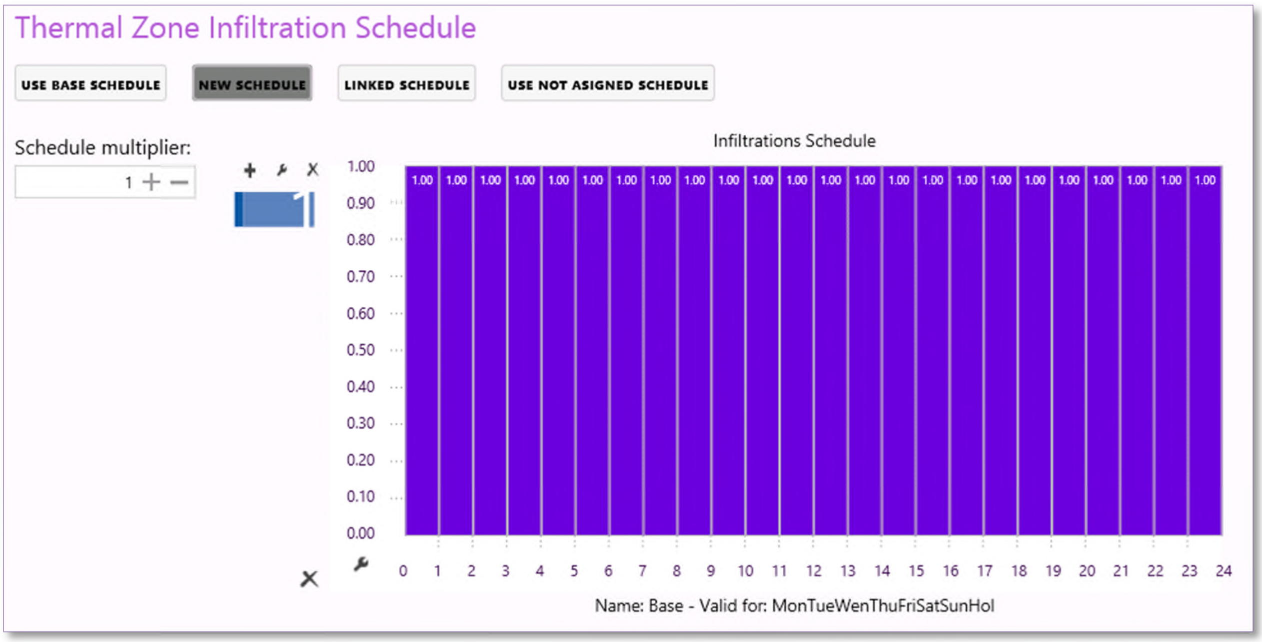
LBL



SHERMAN-GRIMSRUD



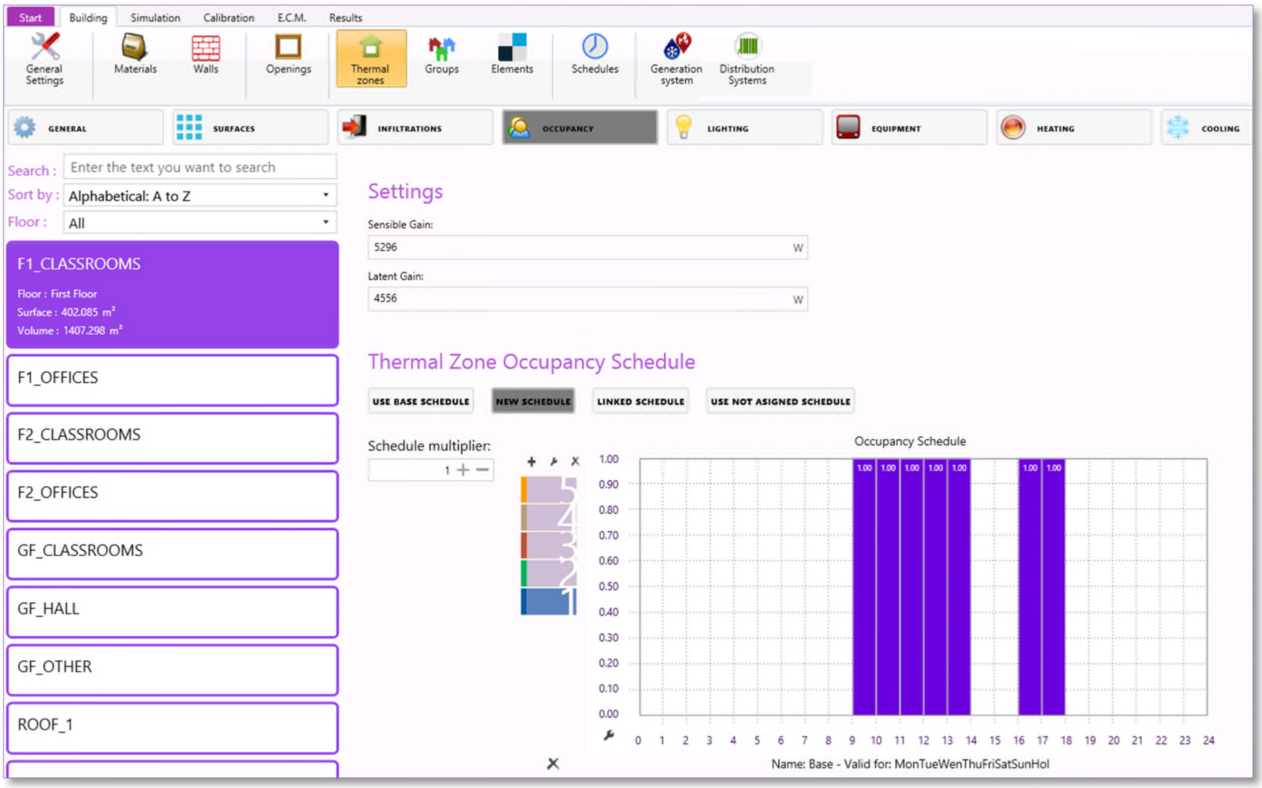
In addition, the schedule infiltrations of each thermal zone must be determined. Later, in 3.1.5 Schedules section is explained how the user must introduce these schedules.



- Occupancy

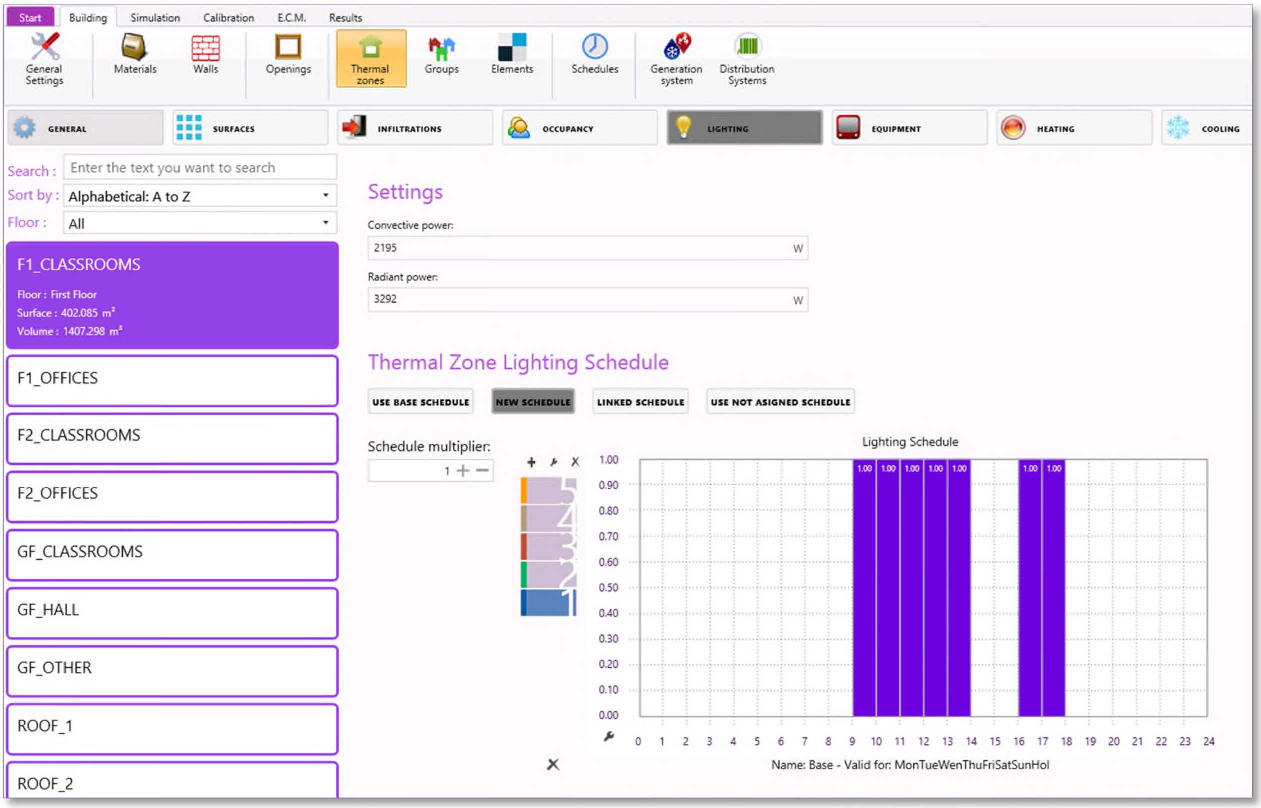
OCCUPANCY

The user can define in each of the thermal zones the occupancy, establishing the sensible and latent heat by occupant in function of its degree of activity multiplied by the number of occupants. These values must be entered in Watts and can be taken from the ISO 7730, tables of Rates of Heat Gain from Occupants of Conditioned Spaces. Also, the occupation schedule in the thermal zone can be introduced, later explained in Section 3.1.5.



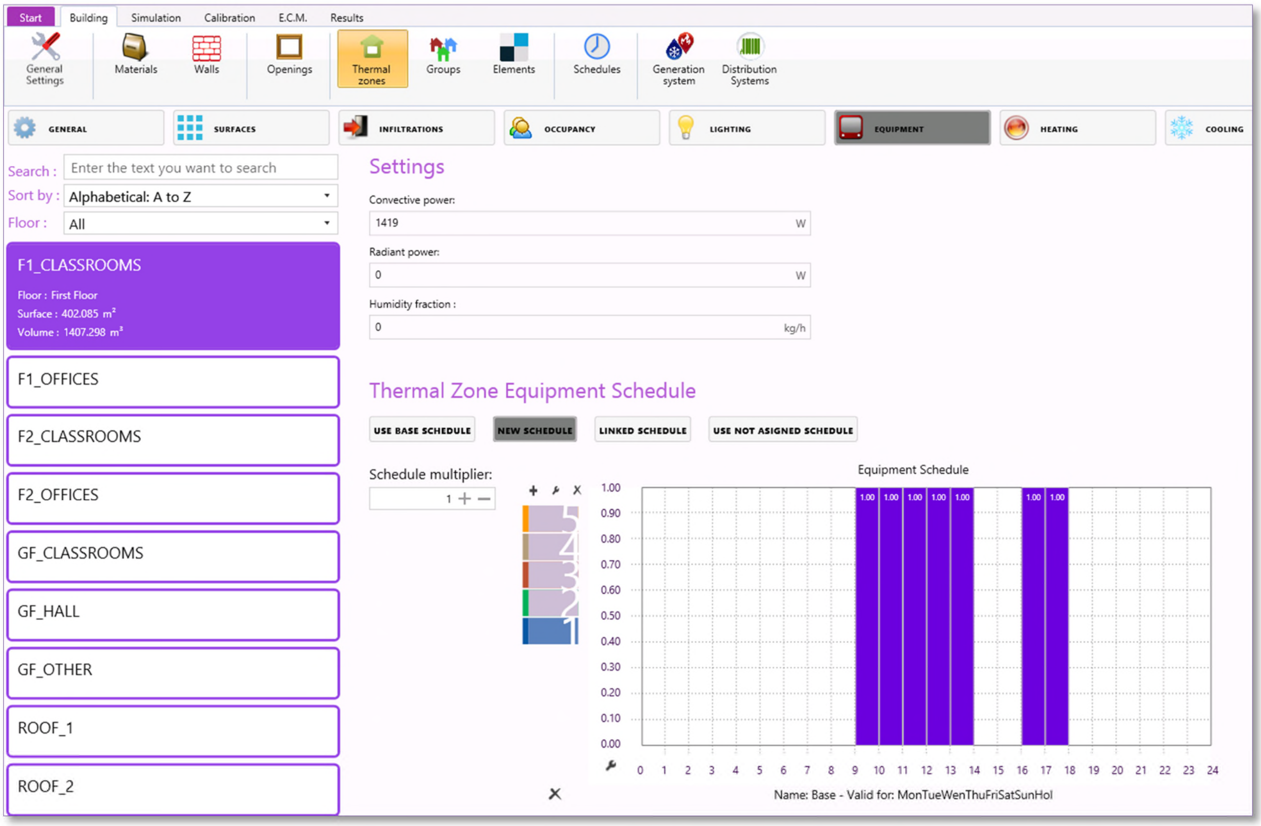
- Lighting

It is necessary to introduce the convective and radiant lighting power in Watts of each of the thermal zones or spaces from the building, as well as to define the schedules. The user needs to know the power and the type of lamp. For example, if the lamps are LED almost the 100% will be radiant, if they are fluorescence lamps above 80% of the power is radiant, however, if they are filament lamps only the 20% of the power is radiant, the rest will be convective.



- Equipment

The user must define in each of the thermal zones the convective and radiant power of the equipment in Watts, as well as the humidity fraction in kg/h. Equipment schedules also have to be introduced.



- ## Heating

In the heating tab, the user must define the following parameters:

Heating power (W): The software does not calculate a heating system, but maintains the temperature of the thermal zone at the desired temperature (indicated in the schedule temperature). The power value given is the maximum power that can be consumed for ideal heating. In case that this power is not enough to reach the target temperature, the temperature will be the maximum that can be reached with the indicated power. So, here it must be indicated the limit power for the ideal heating.

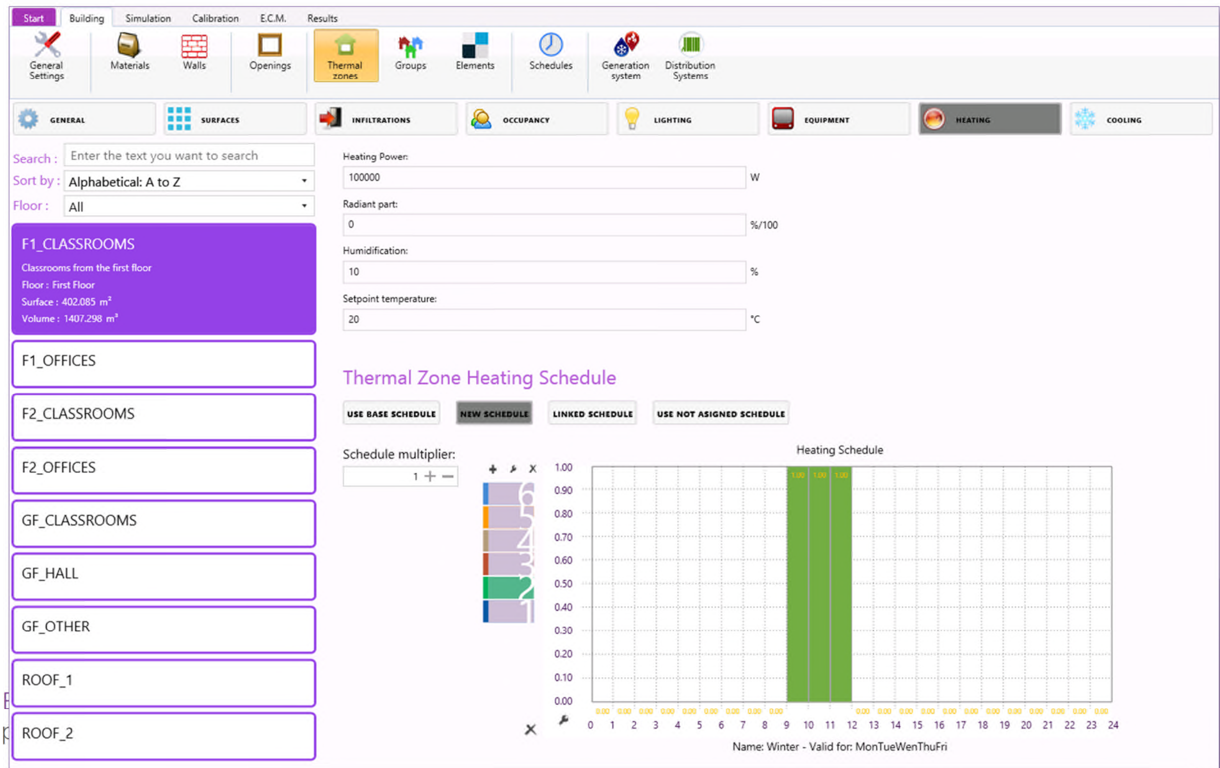
Radiant part (%/100): Radiant fraction from 0 - air to 0.99 radiant.

Humidification (%): The user must introduce the humidity value below which there is humidification, because when the relative humidity of the air decreases from the indicated value, heating the air also humidifies it.

Setpoint temperature (ºC): Target temperature to maintain in the thermal zone with the ideal heating.

It is also necessary to define the heating or the temperature schedules.

- ## Cooling



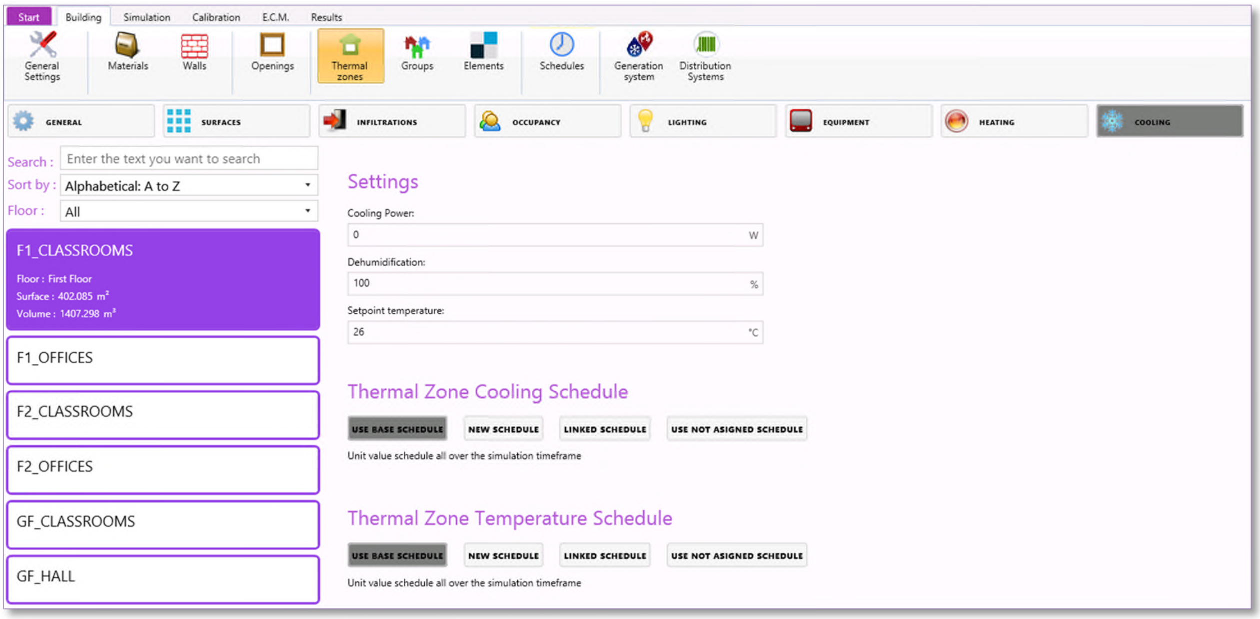
Similarly to heating, if the building has a conditioning system, in cooling the user has to introduce the following parameters.

Cooling power (W): The indicated power value is the limit for an ideal cooling.

Dehumidification (%): The user must introduce the humidity value above which there is dehumidification, because when the relative humidity of the air increases over the indicated value, cooling the air also dehumidifies it.

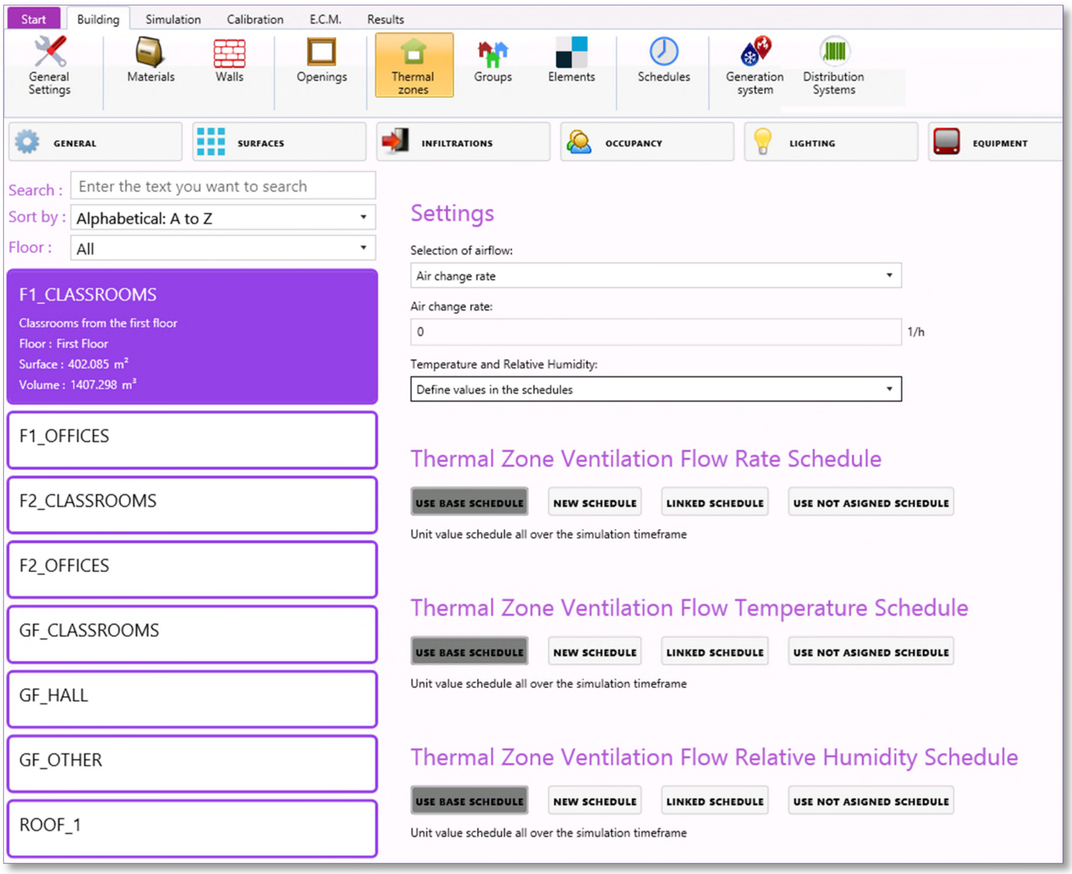
Setpoint temperature (ºC): Target temperature to maintain in the zone with the ideal cooling.

It is also necessary to define the cooling or the temperature schedules in each of the zones.



- Ventilation

First the user has to choose the way to introduce the value of airflow: number of air changes per hour (1/h) or mass airflow (kg/h). Then, the corresponding value is introduced. The value of the temperature and the relative humidity of the air introduced to ventilate can be established through three different schedules (ventilation flow rate schedule, ventilation flow temperature schedule and ventilation flow relative humidity schedule) or can take the values from the outside air. In addition, when in airflow, mass airflow is selected, the user can introduce a heat recovery system in which case the user has to give the value of its efficiency. The option of selecting temperature and relative humidity disappear because the heat recovery unit always takes the values from the outside air.



- Comfort

The last parameter that can be introduced is the comfort. The comfort has to be entered through three different types of schedules: clothing factor, metabolic rate and air velocity. The standard ISO 7730 Ergonomics of the thermal environment establishes parameters for clothing factor or metabolic rate. Otherwise, the wind velocity is usually 0.1 m/s.

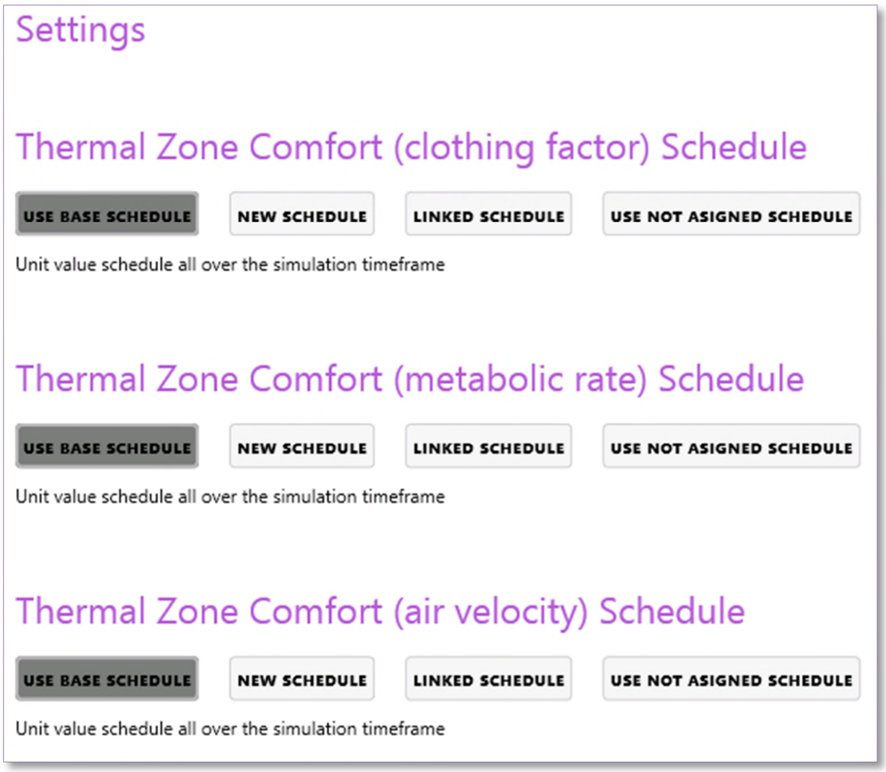
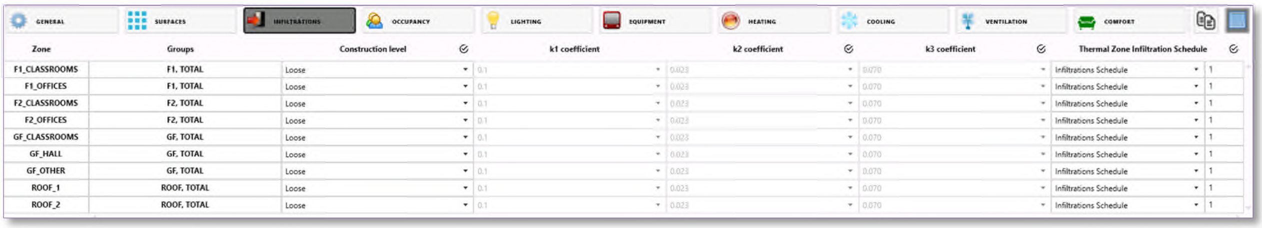
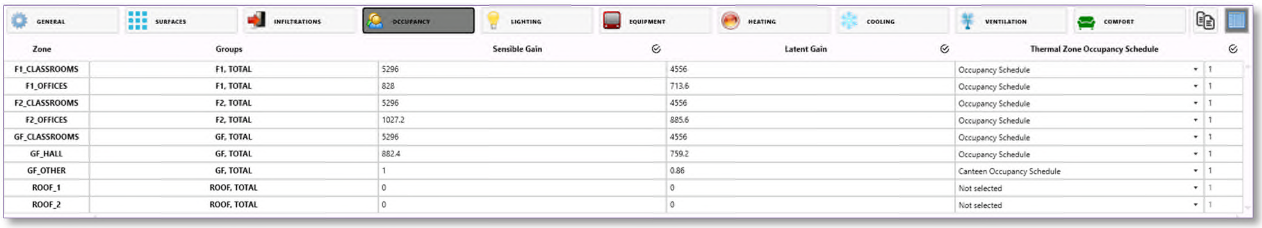


TABLE MODE

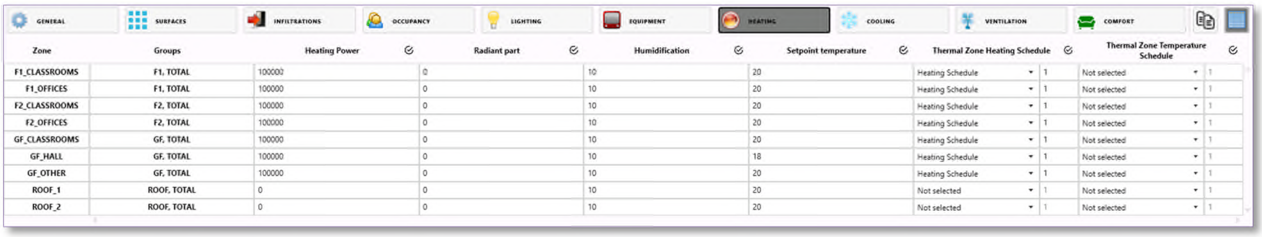
BCORE software adds a novel distribution of the information of the model introduced that will help the user to have a general overview of the data and to review the parameters entered. The different thermal zones tabs can be showed in tables by clicking over the right square button. In this way it is also easier to carry out changes in the different issues. In the following figures this table mode is shown.



Zone	Groups	Construction level	k1 coefficient	k2 coefficient	k3 coefficient	Thermal Zone Infiltration Schedule	
F1_CLASSROOMS	F1, TOTAL	Loose	0.1	0.023	0.070	Infiltrations Schedule	1
F1_OFFICES	F1, TOTAL	Loose	0.1	0.023	0.070	Infiltrations Schedule	1
F2_CLASSROOMS	F2, TOTAL	Loose	0.1	0.023	0.070	Infiltrations Schedule	1
F2_OFFICES	F2, TOTAL	Loose	0.1	0.023	0.070	Infiltrations Schedule	1
GF_CLASSROOMS	GF, TOTAL	Loose	0.1	0.023	0.070	Infiltrations Schedule	1
GF_HALL	GF, TOTAL	Loose	0.1	0.023	0.070	Infiltrations Schedule	1
GF_OTHER	GF, TOTAL	Loose	0.1	0.023	0.070	Infiltrations Schedule	1
ROOF_1	ROOF, TOTAL	Loose	0.1	0.023	0.070	Infiltrations Schedule	1
ROOF_2	ROOF, TOTAL	Loose	0.1	0.023	0.070	Infiltrations Schedule	1



Zone	Groups	Sensible Gain	Latent Gain	Thermal Zone Occupancy Schedule	
F1_CLASSROOMS	F1, TOTAL	5296	4556	Occupancy Schedule	1
F1_OFFICES	F1, TOTAL	828	713.6	Occupancy Schedule	1
F2_CLASSROOMS	F2, TOTAL	5296	4556	Occupancy Schedule	1
F2_OFFICES	F2, TOTAL	1027.2	885.6	Occupancy Schedule	1
GF_CLASSROOMS	GF, TOTAL	5296	4556	Occupancy Schedule	1
GF_HALL	GF, TOTAL	882.4	759.2	Occupancy Schedule	1
GF_OTHER	GF, TOTAL	1	0.86	Canteen Occupancy Schedule	1
ROOF_1	ROOF, TOTAL	0	0	Not selected	1
ROOF_2	ROOF, TOTAL	0	0	Not selected	1

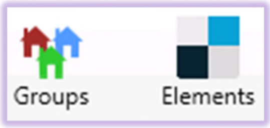


Zone	Groups	Heating Power	Radiant part	Humidification	Setpoint temperature	Thermal Zone Heating Schedule		Thermal Zone Temperature Schedule	
F1_CLASSROOMS	F1, TOTAL	100000	0	10	20	Heating Schedule	1	Not selected	1
F1_OFFICES	F1, TOTAL	100000	0	10	20	Heating Schedule	1	Not selected	1
F2_CLASSROOMS	F2, TOTAL	100000	0	10	20	Heating Schedule	1	Not selected	1
F2_OFFICES	F2, TOTAL	100000	0	10	20	Heating Schedule	1	Not selected	1
GF_CLASSROOMS	GF, TOTAL	100000	0	10	20	Heating Schedule	1	Not selected	1
GF_HALL	GF, TOTAL	100000	0	10	18	Heating Schedule	1	Not selected	1
GF_OTHER	GF, TOTAL	100000	0	10	20	Heating Schedule	1	Not selected	1
ROOF_1	ROOF, TOTAL	0	0	10	20	Not selected	1	Not selected	1
ROOF_2	ROOF, TOTAL	0	0	10	20	Not selected	1	Not selected	1

The following copy button, allows to download the tables and save them into the personal computer. The file is downloaded in a Comma Separated Value (csv) format.

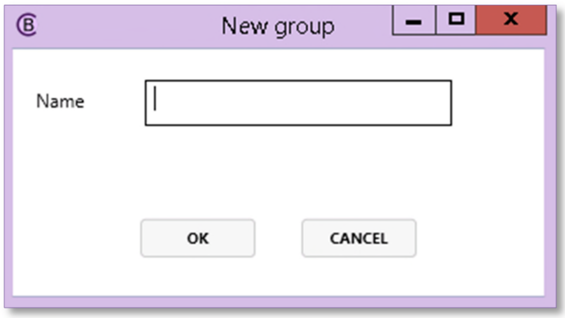
Toolset to improve building's energy efficiency

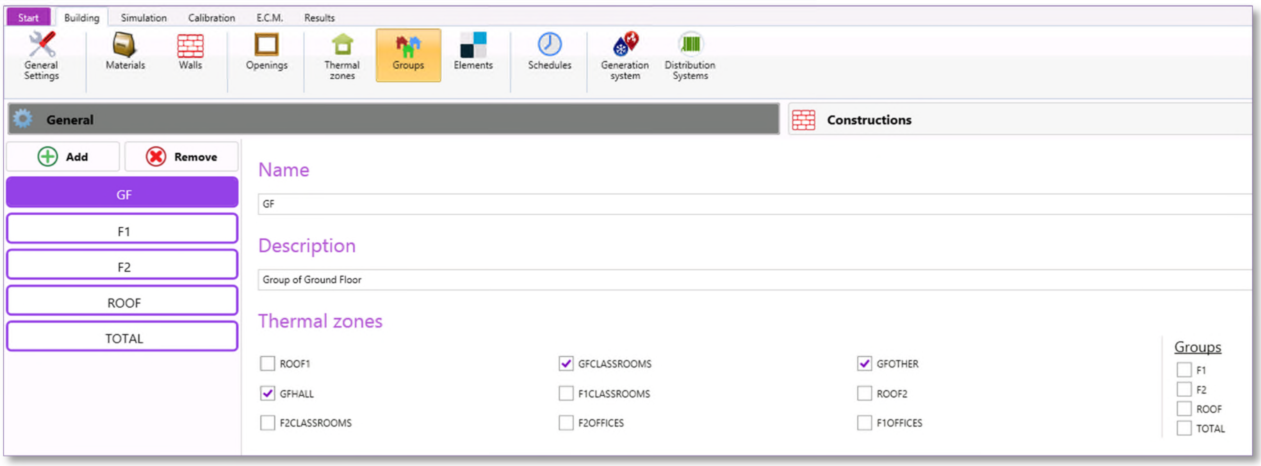
3.1.4 Groups and Elements



GROUPS

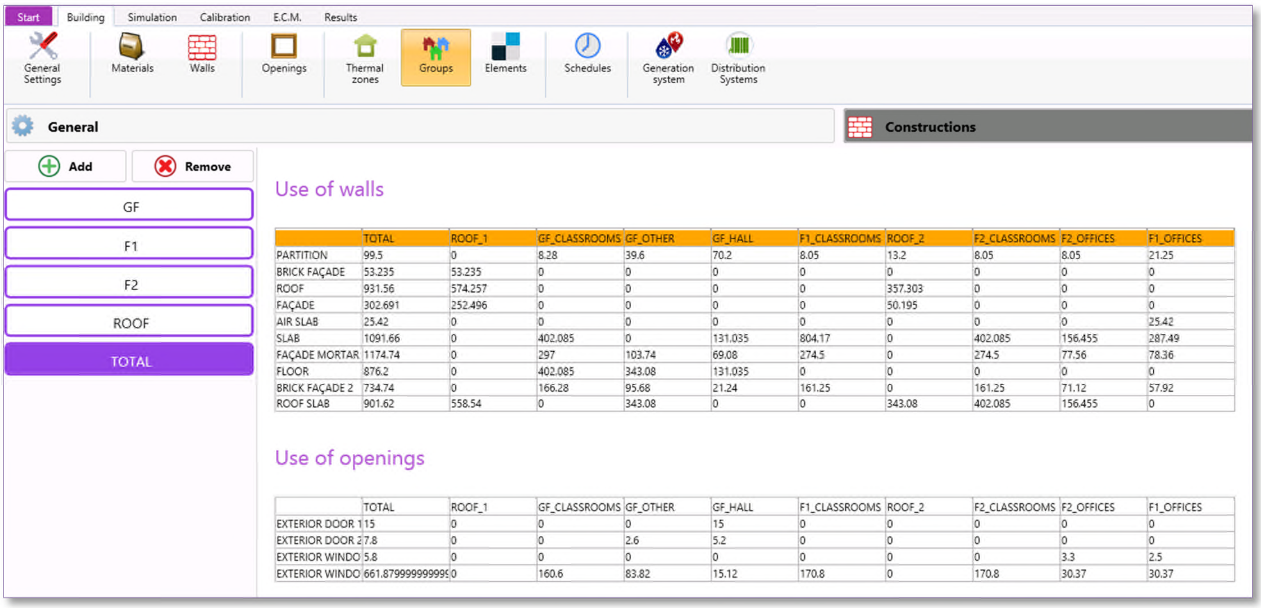
In **Groups**, the user can combine different related thermal zones in a group in order to facilitate the work organisation. For example, all the thermal zones from the same floor can be grouped. First, the user has to click over Add and a window is presented where the user has to name the group. Then, you can write a brief description of the zone and select the thermal zones that belong to that group.





Moreover, the constructions tab represents in table mode the walls and openings associated to a group created. The data displayed is the area (m^2) of each type of wall and opening in each of the thermal zones and in total. It is also possible to download this information in a csv file by clicking over the button that appears on the upper right corner of the table.

ENGINENCY



	TOTAL	ROOF_1	GF_CLASSROOMS	GF_OTHER	GF_HALL	F1_CLASSROOMS	ROOF_2	F2_CLASSROOMS	F2_OFFICES	F1_OFFICES
PARTITION	99.5	0	8.28	39.6	70.2	8.05	13.2	8.05	8.05	21.25
BRICK FAÇADE	53.235	53.235	0	0	0	0	0	0	0	0
ROOF	931.56	574.257	0	0	0	0	357.303	0	0	0
FAÇADE	302.691	252.496	0	0	0	0	50.195	0	0	0
AIR SLAB	25.42	0	0	0	0	0	0	0	0	25.42
SLAB	1091.66	0	402.085	0	131.035	804.17	0	402.085	156.455	287.49
FAÇADE MORTAR	1174.74	0	297	103.74	69.08	274.5	0	274.5	77.56	78.36
FLOOR	876.2	0	402.085	343.08	131.035	0	0	0	0	0
BRICK FAÇADE 2	734.74	0	166.28	95.68	21.24	161.25	0	161.25	71.12	57.92
ROOF SLAB	901.62	558.54	0	343.08	0	0	343.08	402.085	156.455	0

Use of openings

	TOTAL	ROOF_1	GF_CLASSROOMS	GF_OTHER	GF_HALL	F1_CLASSROOMS	ROOF_2	F2_CLASSROOMS	F2_OFFICES	F1_OFFICES
EXTERIOR DOOR 1	15	0	0	0	15	0	0	0	0	0
EXTERIOR DOOR 2	7.8	0	0	2.6	5.2	0	0	0	0	0
EXTERIOR WINDO	5.8	0	0	0	0	0	0	0	3.3	2.5
EXTERIOR WINDO	661.87999999999	0	160.6	83.82	15.12	170.8	0	170.8	30.37	30.37

ELEMENTS

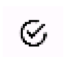
In the tab **Elements**, the user can find a list of the surfaces, openings and thermal bridges used in the building model. In addition, these items can be observed as tables.

▪ Surfaces

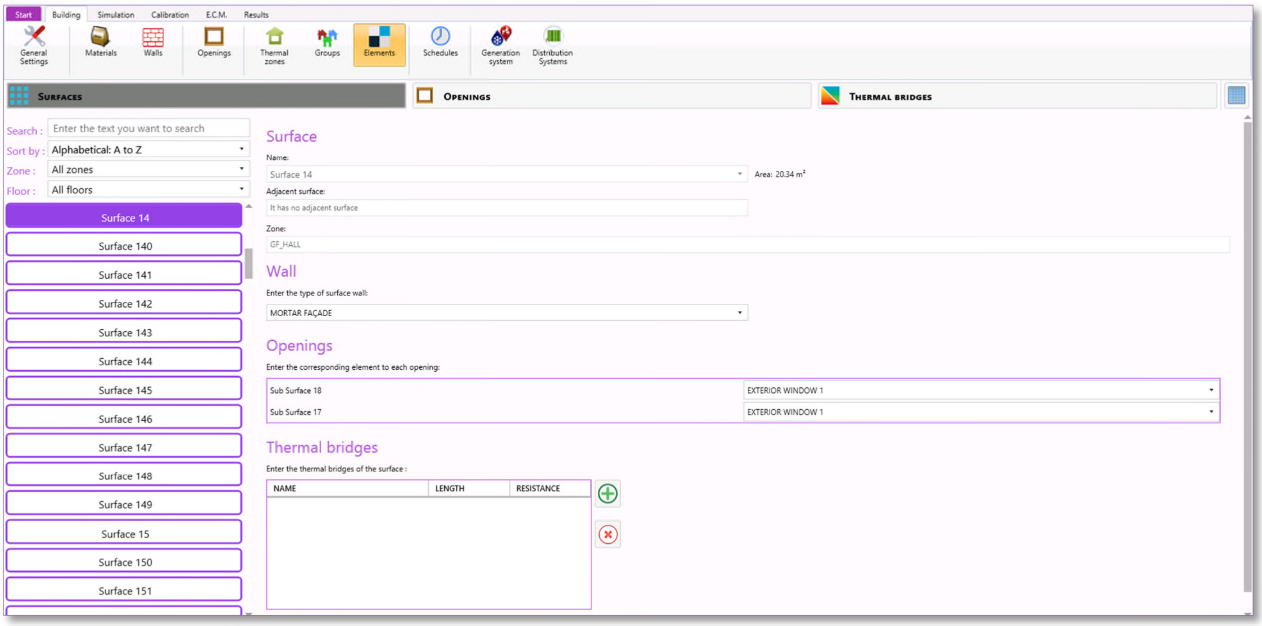
In the button surfaces, the user can observed the following information about all the surfaces comprising the building:

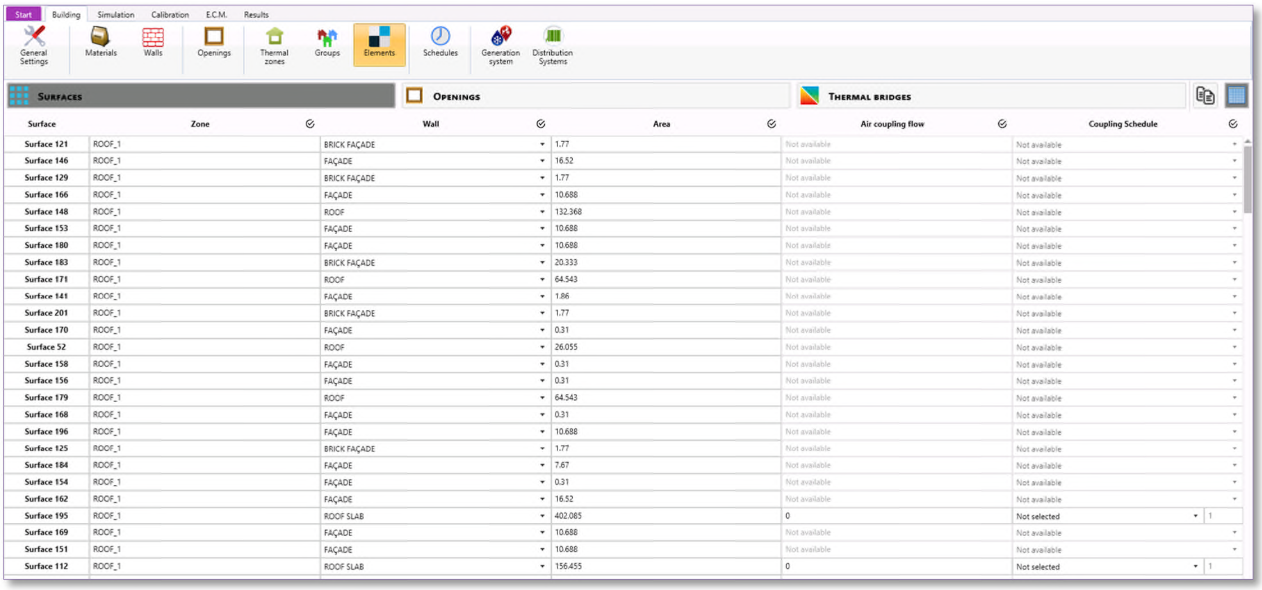
- The name and area (m^2) of the surface, name and area (m^2) of the adjacent surface if it exists.
- The thermal zone where the surface belongs.
- The type of surface wall that can be changed.
- It can be observed also if the surface has any openings and its type that can be also changed.
- The thermal bridges can be observed, added or removed in the same way explained before. Thermal bridges cannot be established in floors or ceilings.
- And in case of having adjacent surfaces it can be defined the air coupling flow (kg/h) and its schedule.

It is also possible to display the surfaces in table mode and to download these tables as explained before. In addition, an interesting feature can be used clicking over the following button:



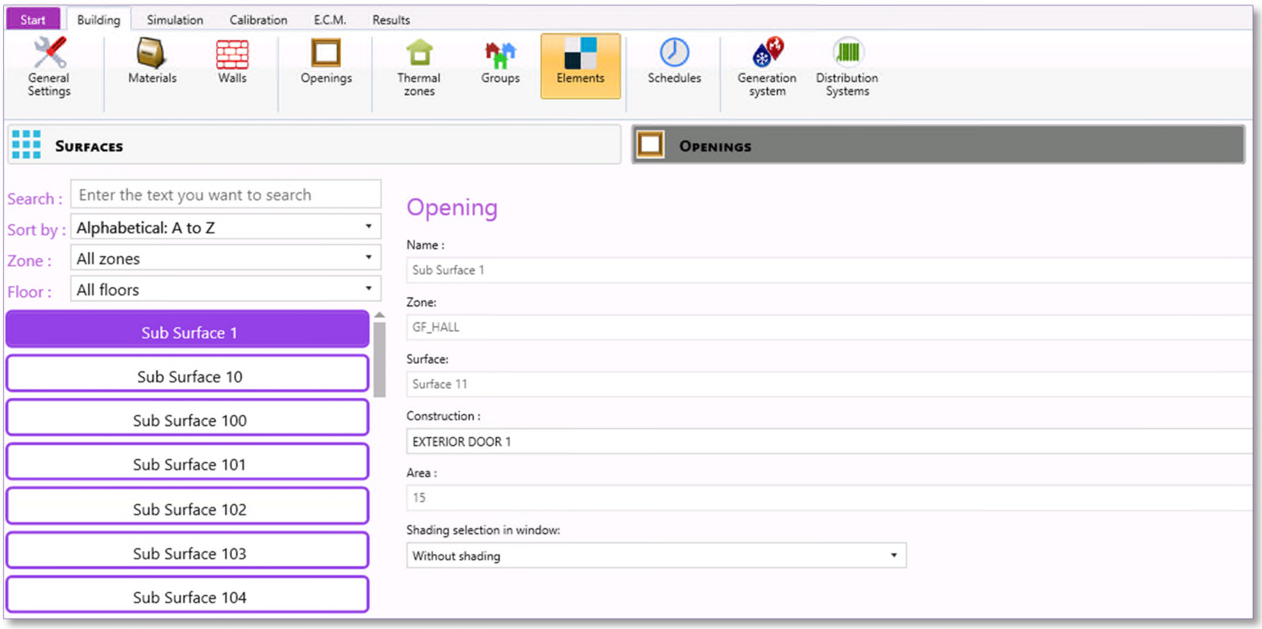
The user can click over that button and then select one or several boxes using Ctrl and then write a new value, so all the selected boxes will change to that value. It is also possible, for example, to double the value by entering *2. In this way, the user can change quickly all values.

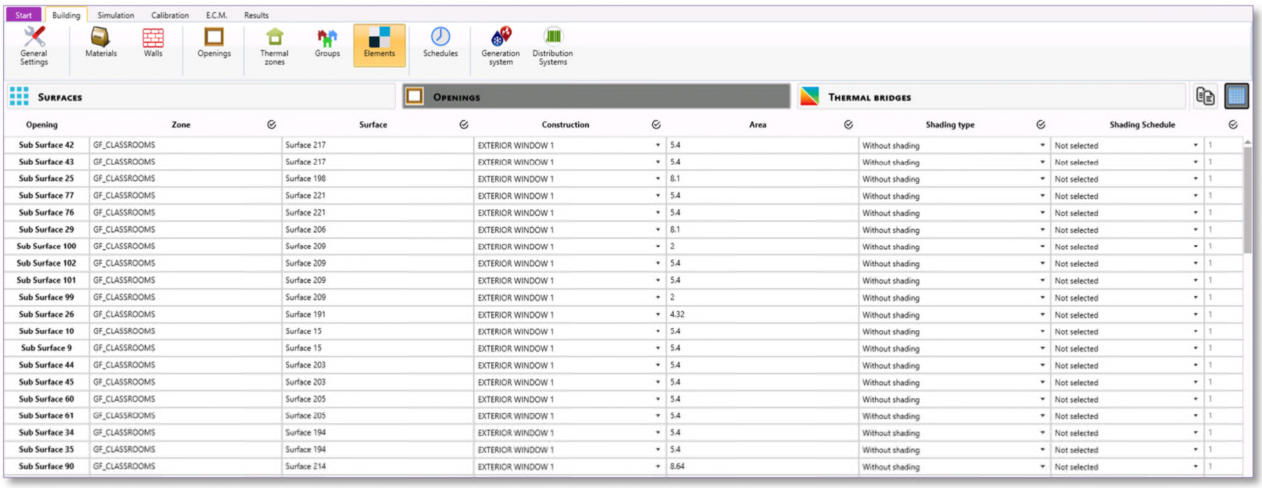




- Openings

In the opening button the information showed is the following: the sub surface name of the opening, the thermal zone where it belongs, the surface over where the opening appears, the construction, namely the type of opening that is a parameter that can be changed, the opening area (m^2) and finally the user has to select the shading in the window; it can be without shading, indoor shading or outdoor shading. When indoor or outdoor shading is selected, it is possible to define a window shading factor schedule.



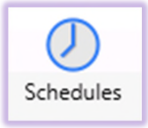


- Thermal bridges

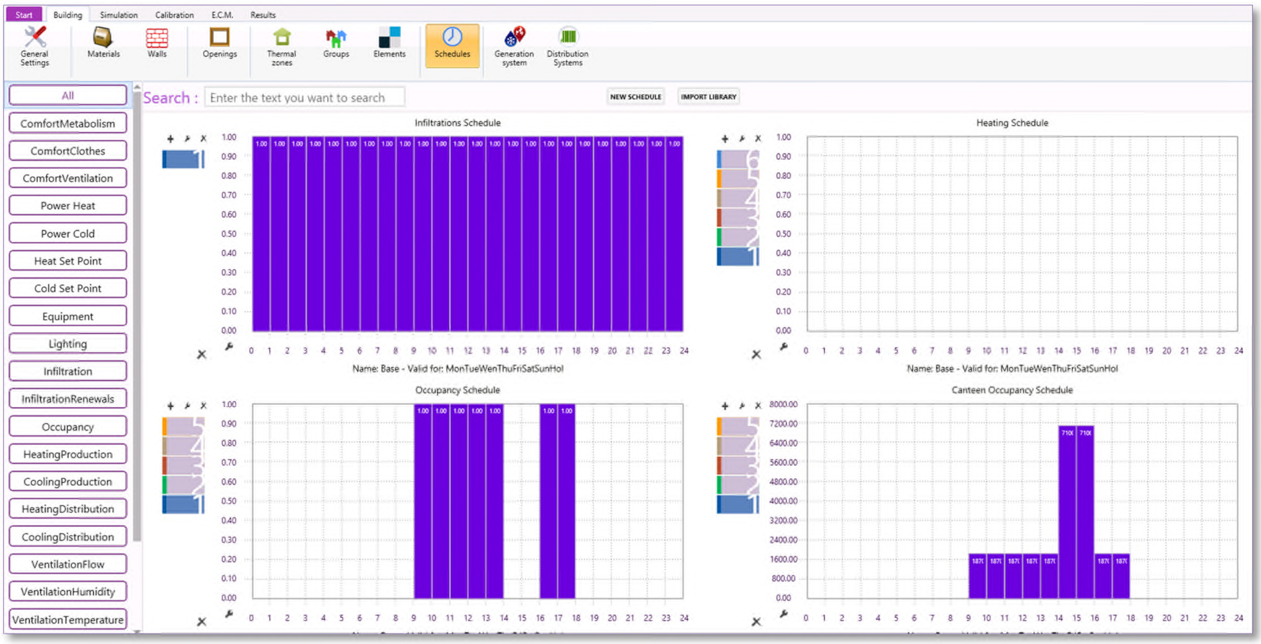
Toolset to improve building's energy efficiency

If the user clicks over thermal bridges, she or he can observe the zone and the surface where the thermal bridge is occurring, and observe and change the name of the thermal bridge, the length (m) and the resistance (m·K/W) of the thermal bridge. The table mode can be also showed in this tab.

3.1.5 Schedules

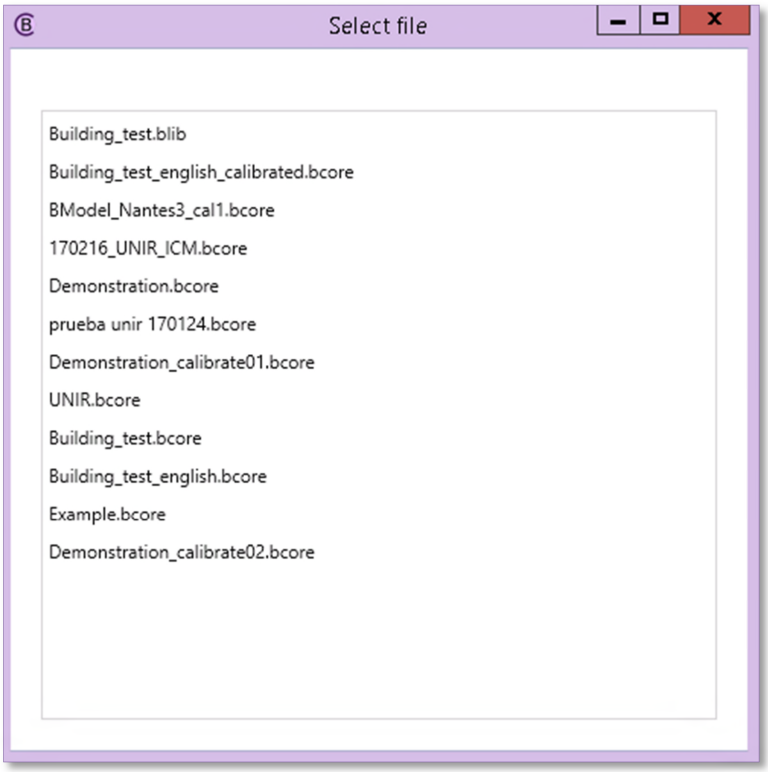


Besides the necessary parameters defining the thermal load of these aspects, for each one of them schedules or timetables are used to establish a pattern of activity in a certain date with an accuracy of hours, simply moving the bars to the appropriate value. In the tab of schedules, the user can observe all the timetables defined for the building.



All the schedules are visualized in this tab. There are 23 different types of schedules, such as, power heat, occupancy, cooling production, cooling distribution, etc. The schedules can be defined in this tab or can be defined in each of the thermal loads tabs specifically, as explained before.

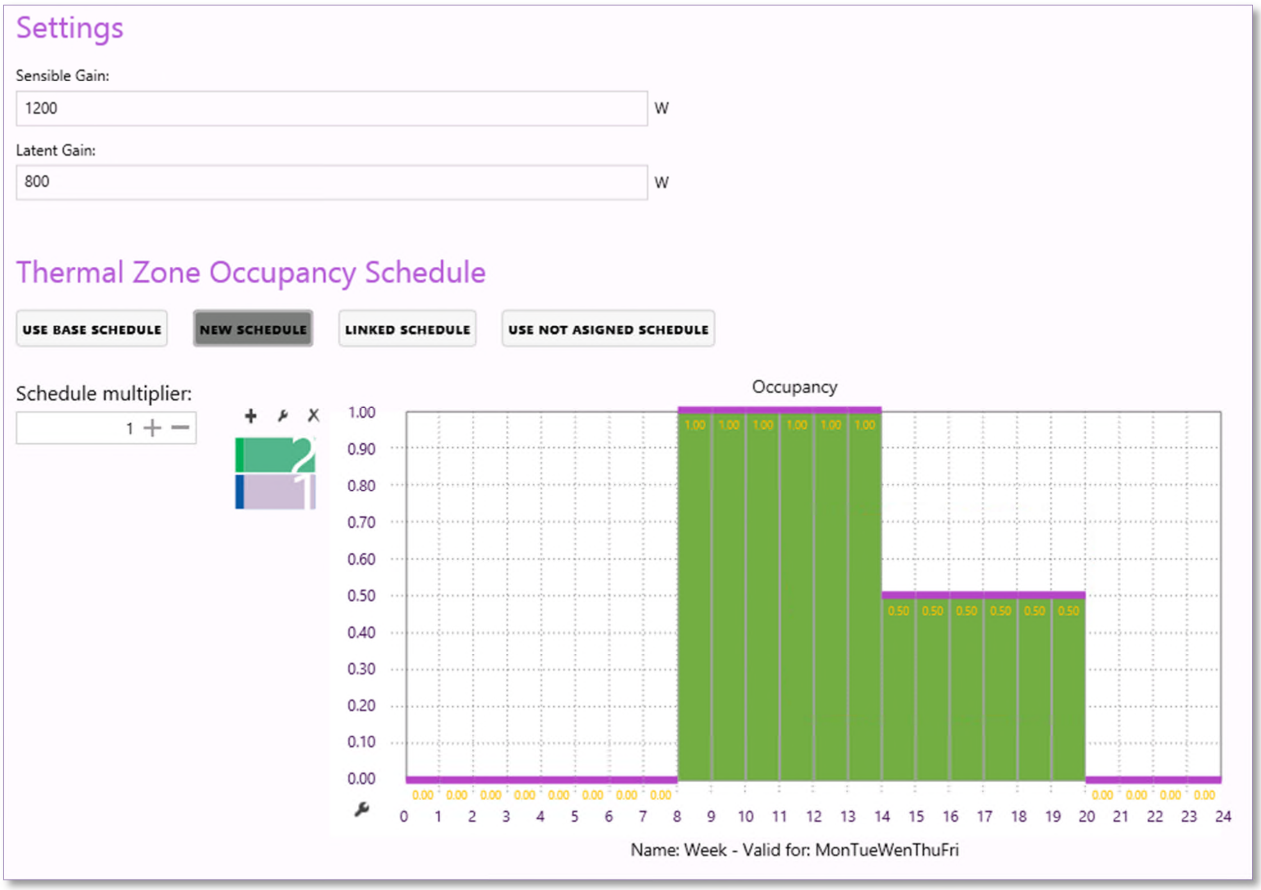
The user can create a **NEW SCHEDULE**, as it is explained in the following section 3.1.5.1., or import a library of schedules. When the user clicks over **IMPORT LIBRARY,** the following window is shown where the user can select the library or the project where schedules can be imported from. This option allows the user to open a library or project and use its schedules in another project.


Select file
Building_test.blib
Building_test_english_calibrated.bcore
BModel_Nantes3_cal1.bcore
170216_UNIR_ICM.bcore
Demonstration.bcore
prueba unir 170124.bcore
Demonstration_calibrate01.bcore
UNIR.bcore
Building_test.bcore
Building_test_english.bcore
Example.bcore
Demonstration_calibrate02.bcore

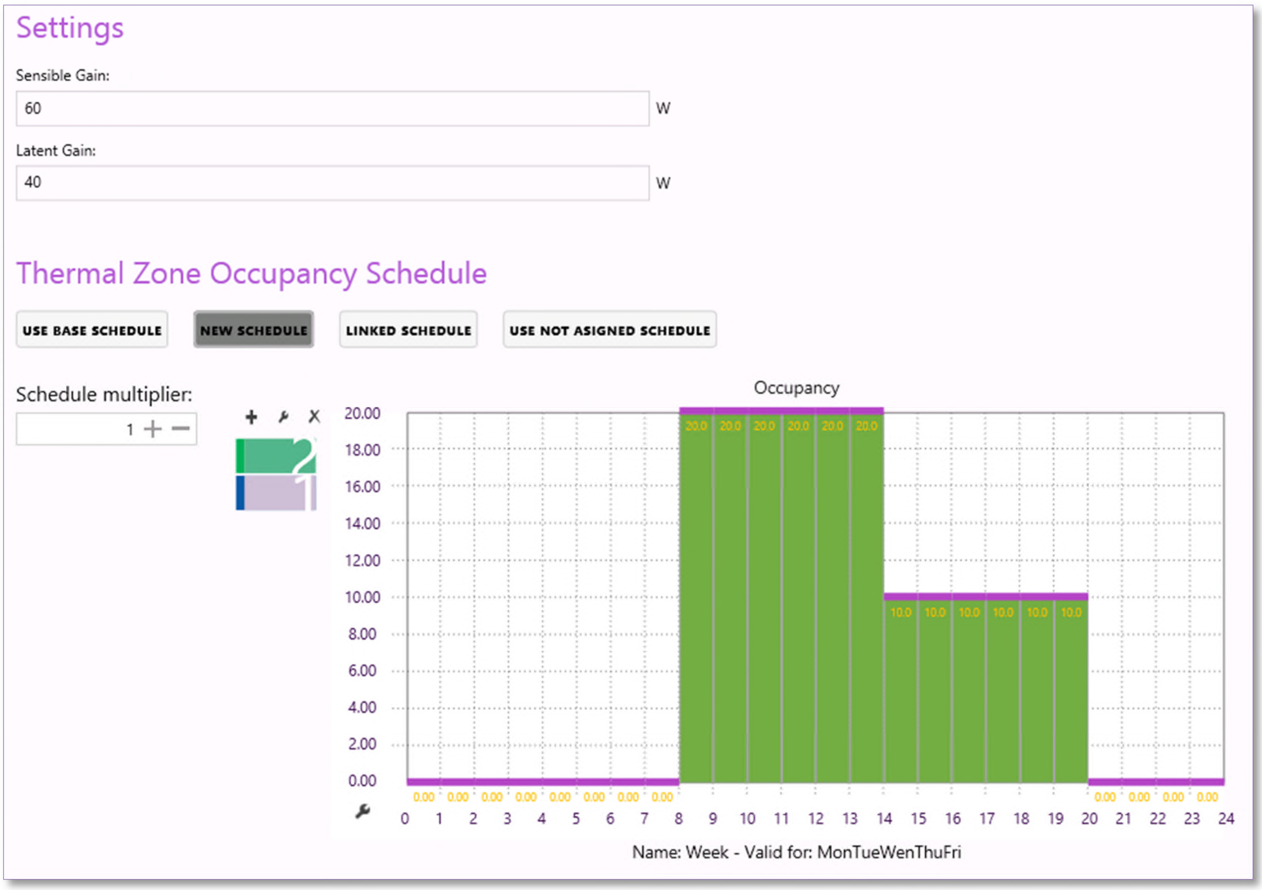
3.1.5.1 CREATING SCHEDULES

First, along the previous parameters, the schedules can be filled using two different CRITERIA:

- Setting values from 0 to 1 in the schedule and the total power in the settings. For example: The schedule goes from 0 to 1 depending on the day hour and the total power can be calculated as follows. Occupancy = W/person * Number of people. Lighting = W/light * Number of lights. The schedule multiplier can also be modified, it multiplies every parameter of the schedules. When it becomes really useful is in calibration where the user will be able to calibrate each schedule changing this schedule multiplier.



- Setting unit values in power and the number of unities in the schedule. For example, in occupancy: the schedule goes from 0 to the maximum number of people of the thermal zone and the power is unitary, the value of one person. The schedule multiplier fulfills the same function.



The first option allows the user to reuse the schedule for different thermal zones easier.

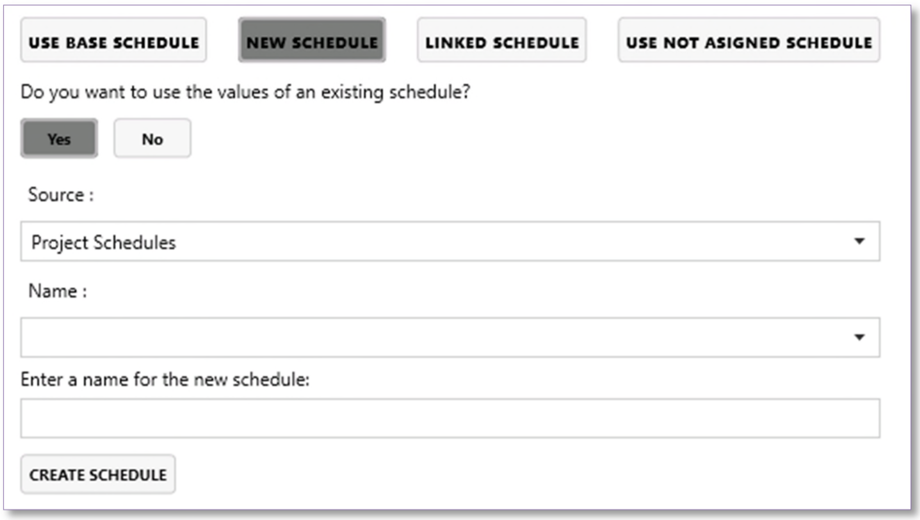
PROCEDURE TO CREATE A SCHEDULE

As commented before, schedules must be defined in every thermal zone for every thermal load. There are four possibilities: to use base schedule, new schedule, linked schedule or to use not assigned schedule. So, the thermal zone schedule can be set in different ways.

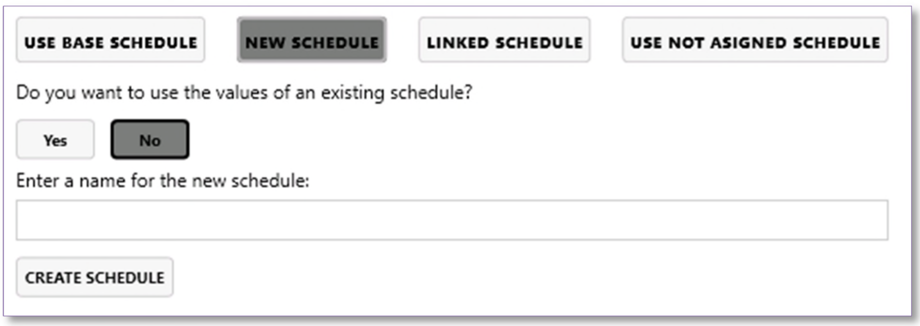
- Use base schedule: a unit value schedule is established all over the simulation timeframe.
- New schedule: it is possible to use the values of an existing schedule, or to create a new one.
- Linked schedule: it is possible to link an existing schedule from other thermal zone of the same thermal load.
- Use not assigned schedule: it is also possible to use a schedule that is defined but it is not yet assigned to any of the thermal loads.

CREATE A NEW SCHEDULE

When creating a new schedule, it is possible to use the values of an existing schedule of another type. In this case, it is necessary to choose the source and the name of the schedule with the wanted values, as well as to enter a name for the new schedule.

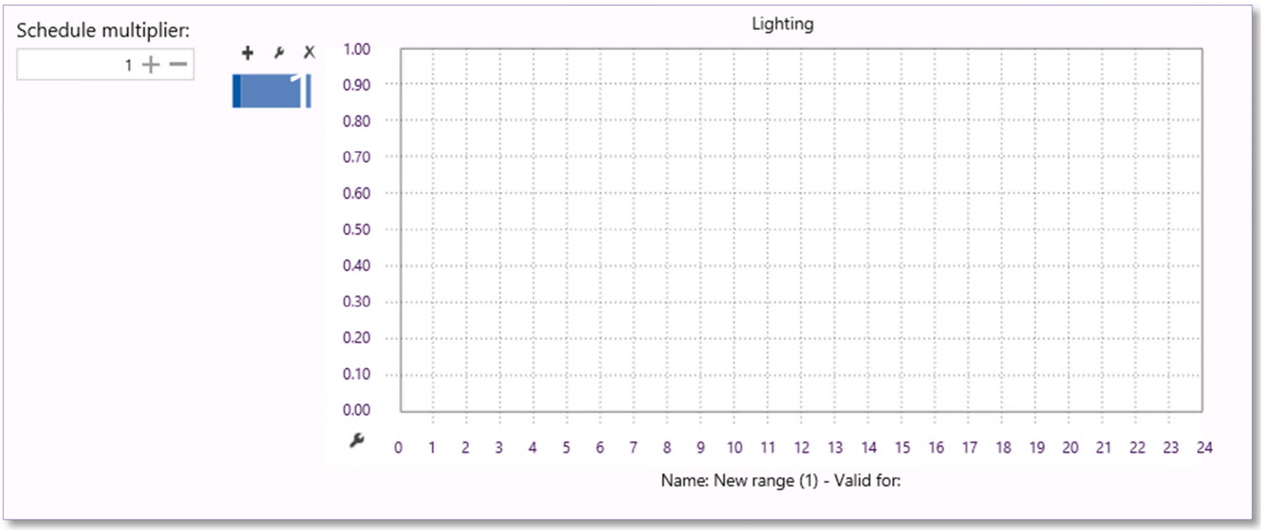


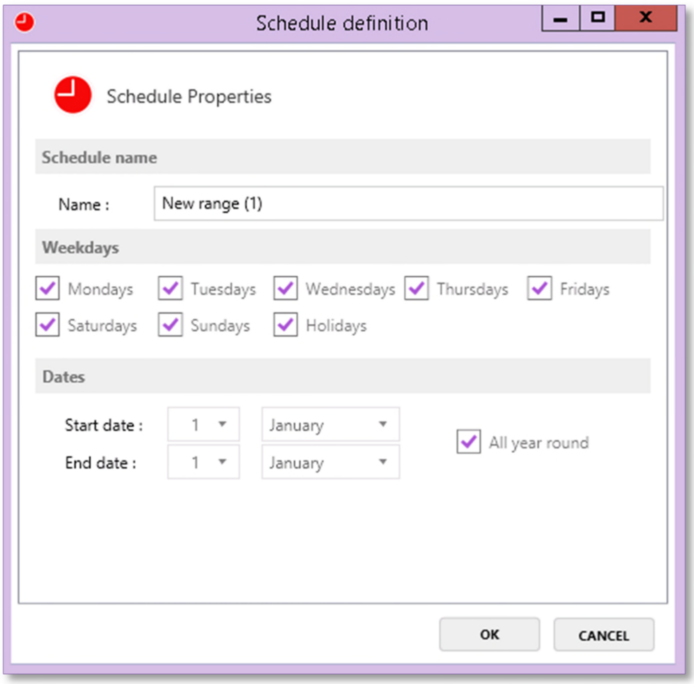
It is also possible to create a new schedule from the beginning, answering "No" to the first question and entering the name of the new schedule.

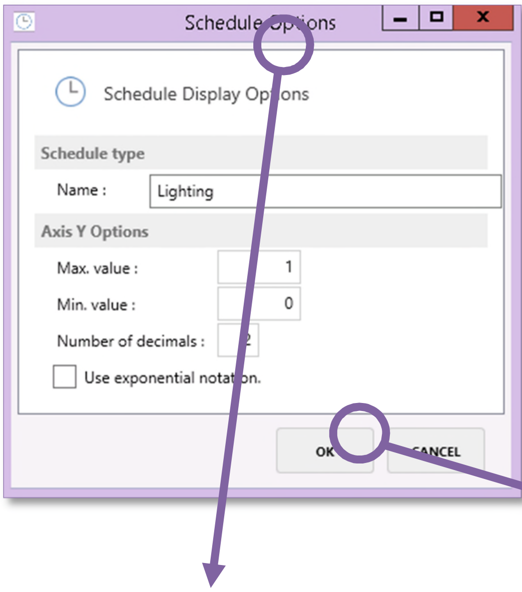


Then, the user clicks over the button of **CREATE SCHEDULE** and the following windows appear.

ENGINENCY







Creates a new schedule range. +

Opens the window "Schedule definition" (Upper). Opens the window "Schedule options" (Lower).

Removes the schedule range.

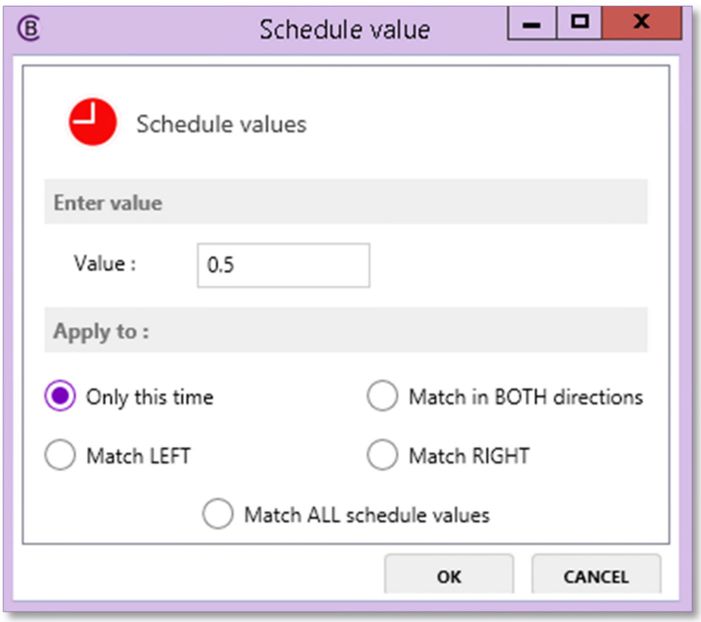
The first range "1" appears always by default for all year and all days of the week. Then, it is possible to create different ranges of schedules: for example one for the working days of the week, other for the weekends, or other for the holidays. The priority goes from the upper to the lower range showed. This means that if there are 3 different schedules, the program first follows the "3", when the period does not have correspondence it searches for the following schedules, that means the "2".

Clicking on the schedules settings, the user can define the schedule, defining the name, selecting the weekdays and the start and the end dates of this schedule range. In addition, it is possible to modify the axis options by clicking on the axis settings and modifying the maximum and minimum value of the axis and the number of decimals. Exponential notation can be used.

The chart shows the 24 hours of a day. The user has to make double click over the 0 horizontal and a double arrow is shown, then just moving the mouse up and down the schedule can be established. Moreover, clicking with the right bottom of the mouse over the chart, the user can modify the values of the schedule. It is also possible to do this using the keyboard:

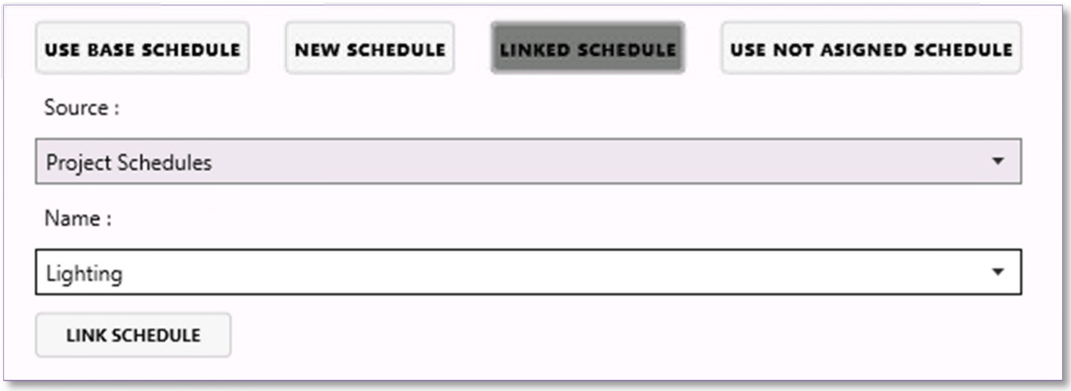
- Ctrl to rise only one hour.
- Right Caps to rise every hour from the right.
- Left Caps to rise every hour from the left.

In addition, if the user clicks on the right button of the mouse when the double arrow is shown, the following window appears where the user can write down the value and establish if this value has to be set only this hour, if it has to match left, match right or match in both directions or match all schedule values.

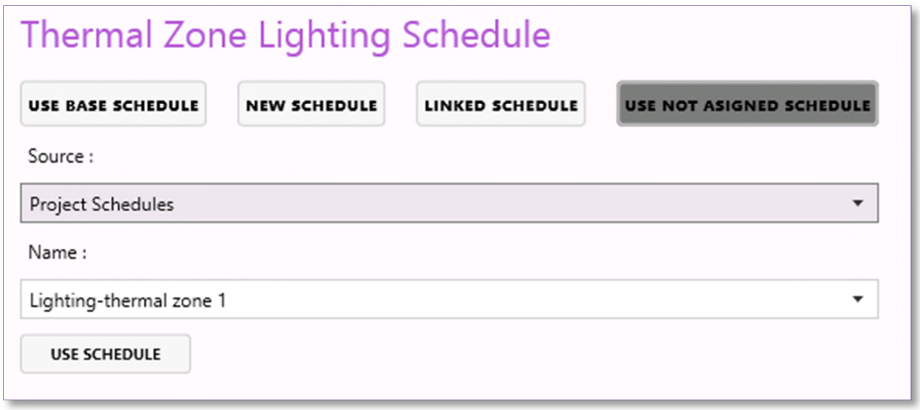


Toolset to improve building's energy efficiency

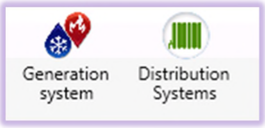
To link a schedule, the user has to select the source and the name of the schedule that she or he want to link. It has to be a schedule of the same type.



Finally, it is possible to use a defined schedule not yet assigned to any other thermal load, and click over **USE SCHEDULE.**



3.1.6 Energy Generation and Distribution Systems

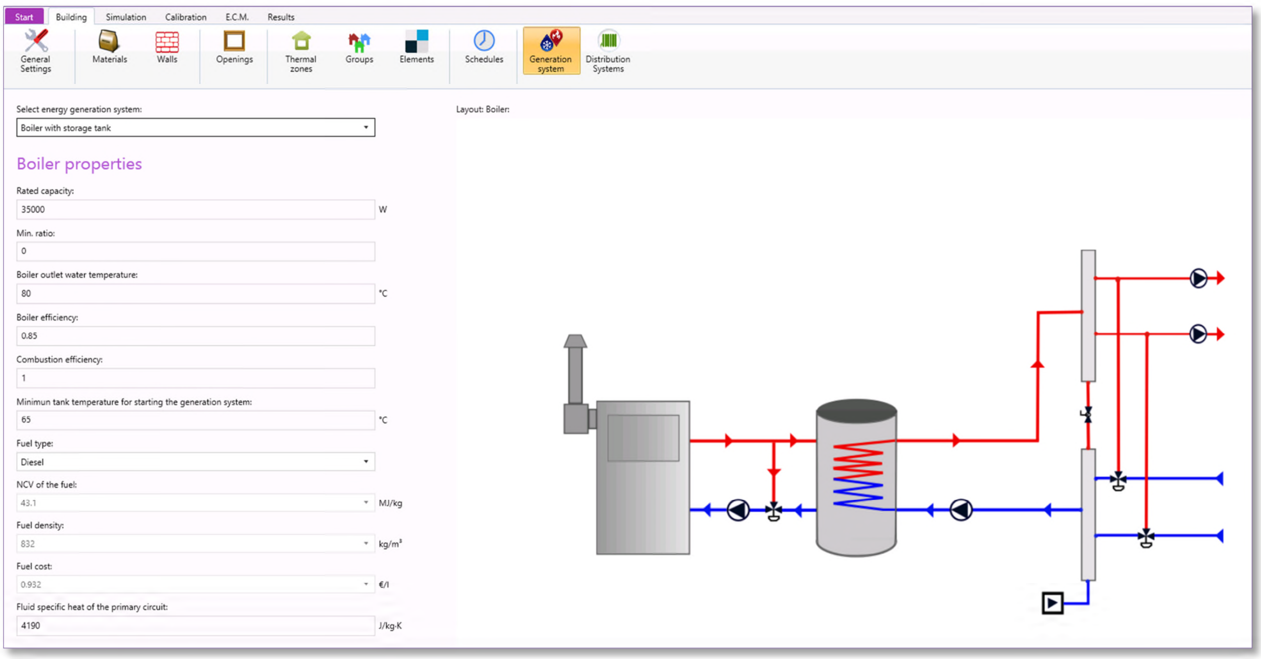


The energy generation and distribution systems included in the software are the most basic and common ones in most buildings. For each of them it is necessary to know the parameters that characterize them and then model them. It is also possible to establish an ideal heating and cooling.

ENERGY GENERATION SYSTEMS

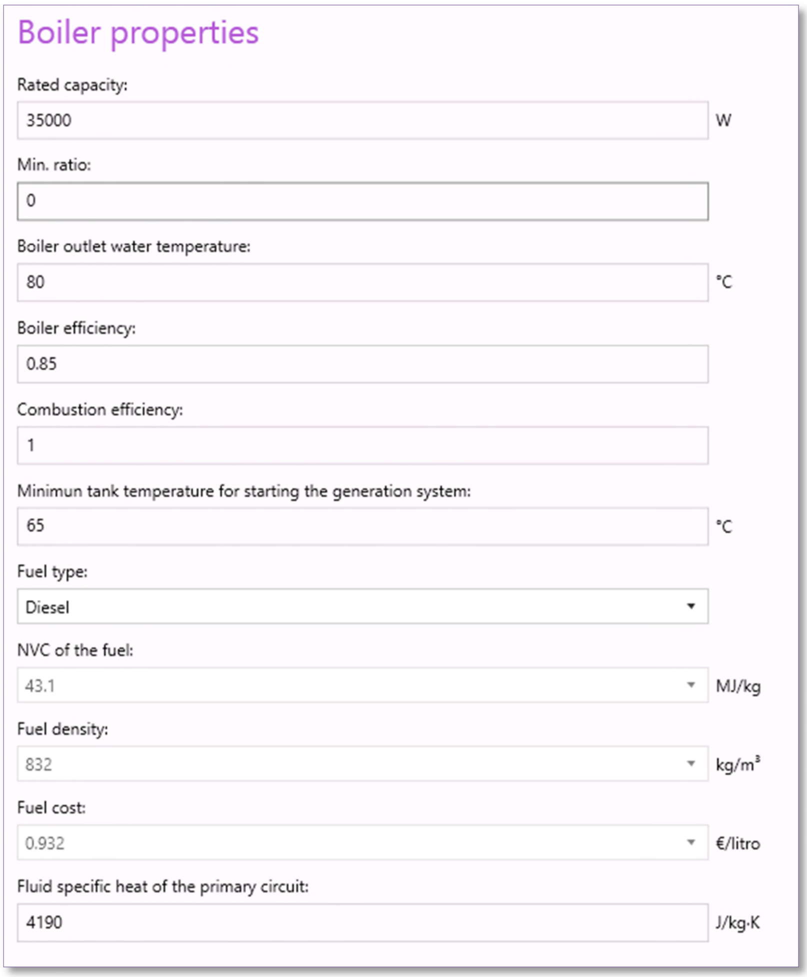
First, the user has to select the generation system.

Ideal Heating/Cooling. The software can simulate the building model with an ideal heating and cooling system that means that the power and demand are calculated to achieve the setpoint temperature established in the definition of the building. It does not take into account the real Heating, Ventilation and Air Conditioning (HVAC) system of the building.



Boiler with storage tank. The user can select the following energy generation system. To fill in the system it is necessary to complete some of the following information:

- **Boiler properties.** The information that has to be completed here is the following; rated capacity (W), minimum partial load ratio, boiler outlet water temperature (ºC), boiler efficiency (0 - 1), minimum tank temperature for starting the generation system (ºC), the fuel type (diesel, natural gas or user-defined values), Net Calorific Value (NCV) of the fuel (MJ/kg), fuel density (kg/m^3), fuel cost (€/liter) and fluid specific heat of the primary circuit (J/kg·K).



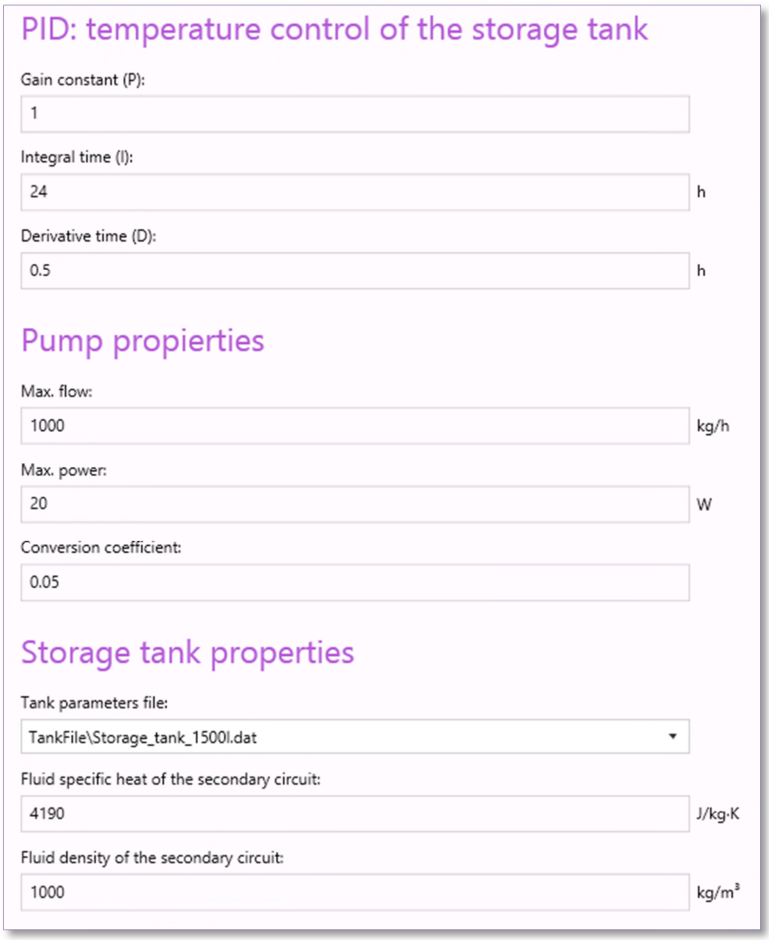
- **PID: temperature control of the storage tank.** The following information of the PID regulation has to be completed; the gain constant (P), the integral time (I) in hours and derivative time (D) also in hours.

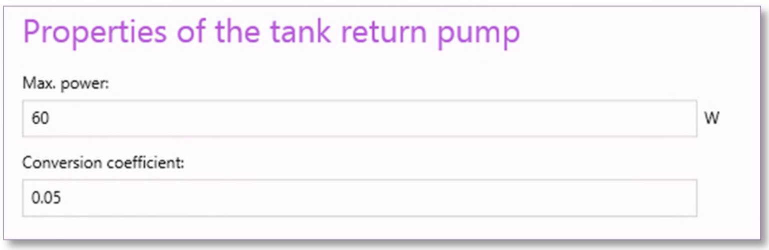
- **Pump properties.** The following information of the pump has to be set; the maximum flow (kg/h), the maximum power (W) and the conversion coefficient that is the power fraction converted into fluid thermal energy.

- **Storage tank properties.** The storage tank has to be defined with the following information; the tank parameters file in a **.dat** file, fluid specific heat at the secondary circuit (J/kg·K) and the fluid density of the secondary circuit (kg/m^3).

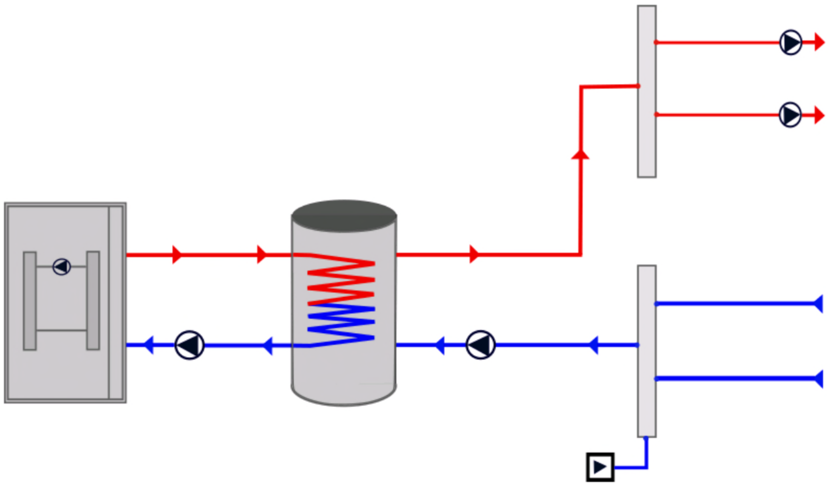
- **Tank return pump properties.** The necessary data of the return tank are; the maximum power (W) and the conversion coefficient that is the power fraction converted to fluid thermal energy.

The heating production schedule can be also defined as explained in the previous section.

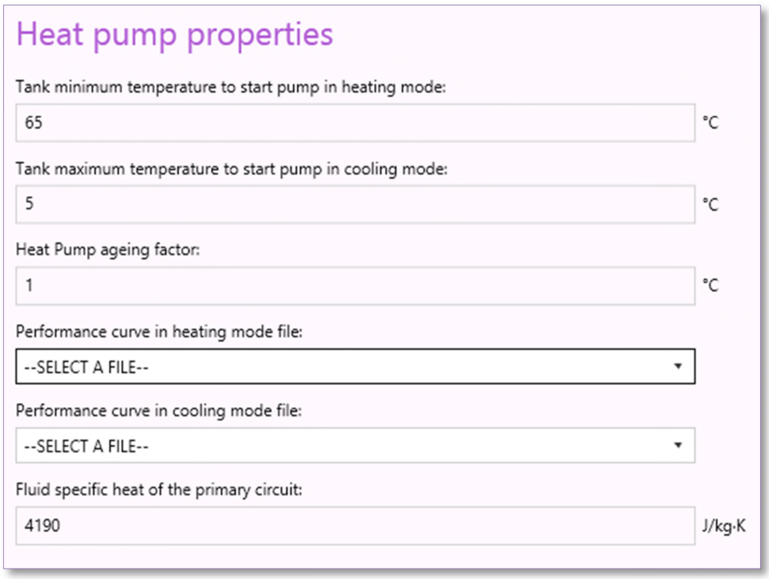




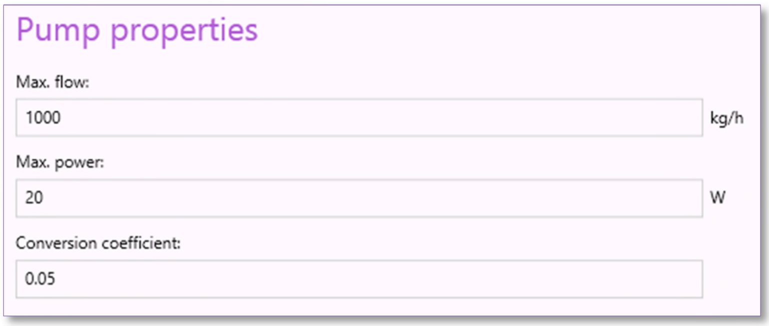
Air-water heat pump with 1 storage tank. The user can select the following energy generation system. To fill in the system it is necessary to complete some of the following information:



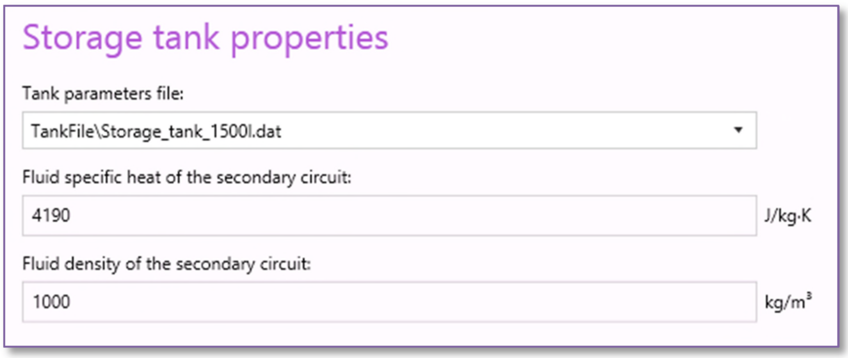
- **Heat pump properties:** The information that has to be completed here is the following; the tank minimum temperature to start pump in heating mode (ºC), the tank maximum temperature to start pump in cooling mode (ºC), the heat pump ageing factor (ºC), the performance curves in heating and cooling mode have to be chosen within a list of available files and the fluid specific heat of the primary circuit has to be introduced (J/kg·K).



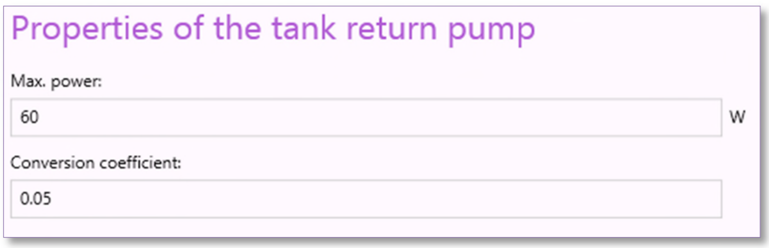
- **Pump properties:** The following information about the pump properties has to be set; the maximum flow (kg/h), the maximum power (W) and the conversion coefficient of the pump.



- **Storage tank properties:** A tank file has to be selected with the appropriate parameters, the fluid specific heat of the secondary circuit (J/kg·K) and the fluid density of the secondary circuit (kg/m^3) have to be introduced.

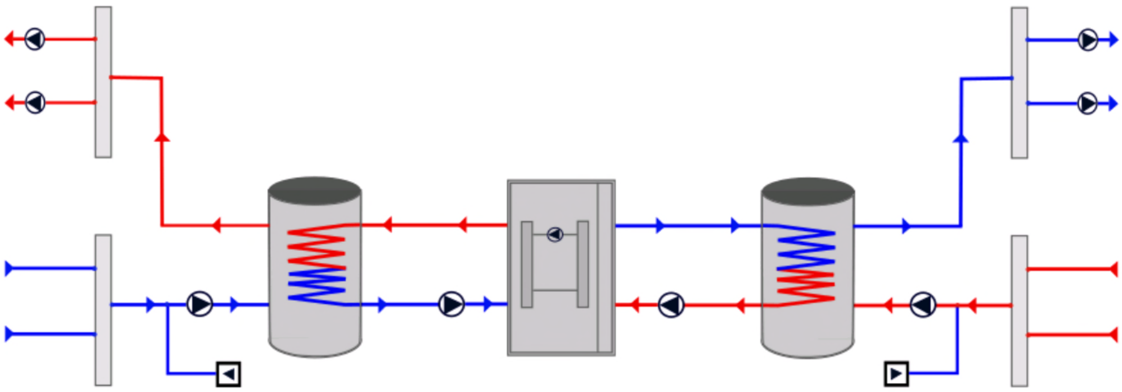


- **Properties of the tank return pump:** The information that has to be completed is the maximum power (W) and the conversion coefficient.

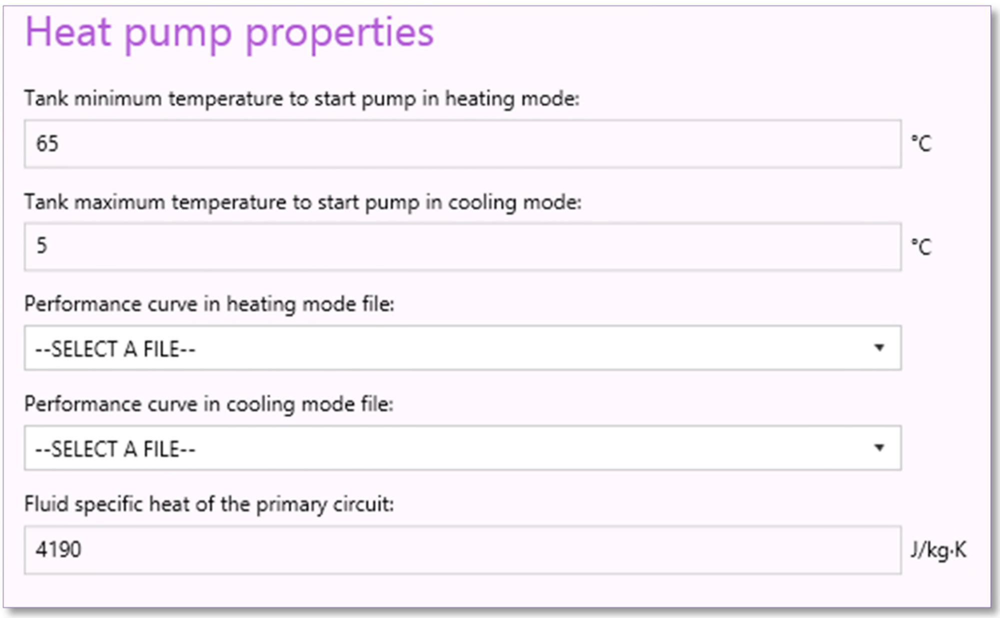


In addition, the user if necessary can determine the heating and cooling schedules.

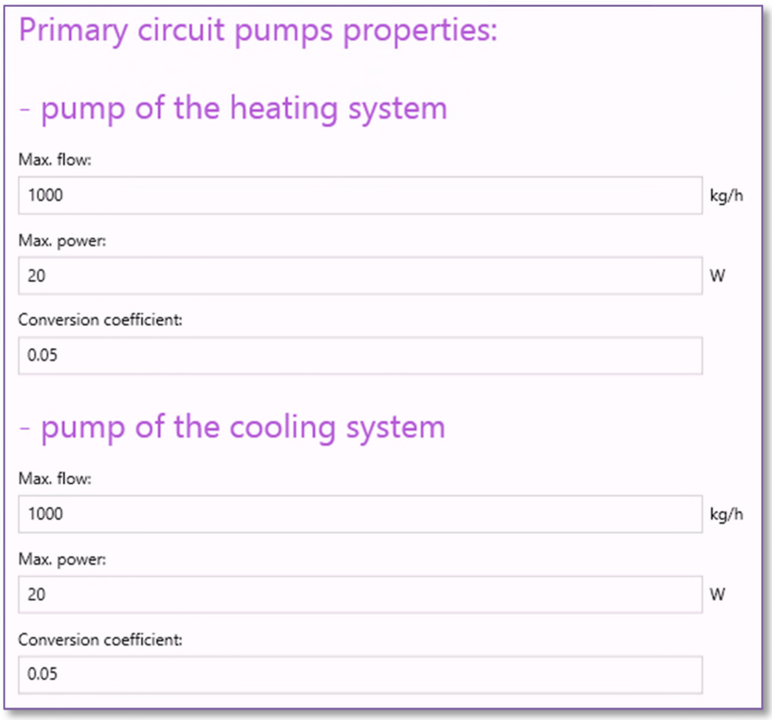
Air-water heat pump 4-pipes: The user can select the following energy generation system. To fill in the system it is necessary to complete some of the following information:



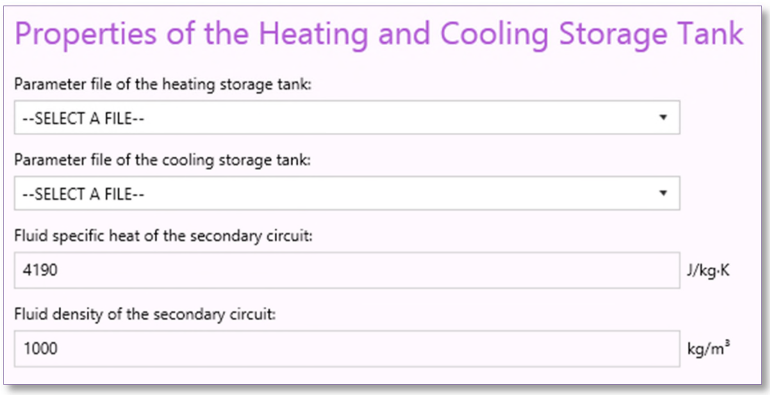
- **Heat pump properties:** The following information has to be set: Tank minimum temperature to start pump in heating mode (ºC), tank maximum temperature to start pump in cooling mode (ºC), the performance curves in heating and cooling mode and fluid specific heat of the primary circuit (J/kg·K).



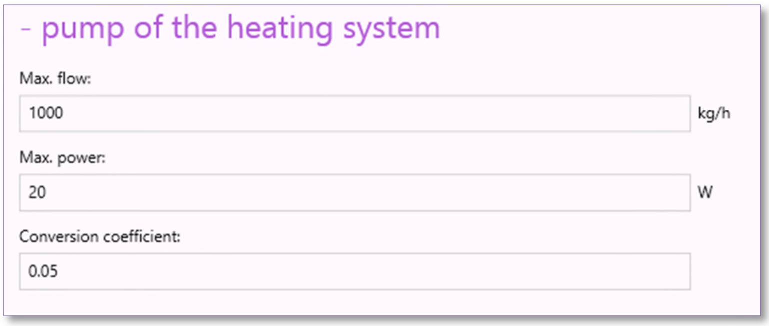
- **Primary circuit pumps properties:** The user has to complete parameters of the heating and cooling pump system. In particular, the maximum flow (kg/h), the maximum power (W) and the conversion coefficient.

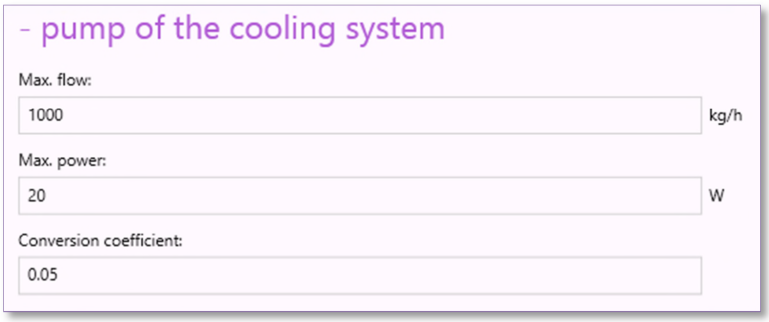


- **Properties of the heating and cooling storage tank:** The information that has to be completed here is the following. The parameter file of the heating storage tank, the parameter fiel of the cooling storage tank, the fluid specific heat of the secondary circuit (J/kg·K) and fluid density of the secondary circuit (kg/m^3).



- **Properties of the tank return pump (heating and cooling system):** the user can introduce the maximum flow (kg/h), the maximum power (W) and the conversion coefficient.

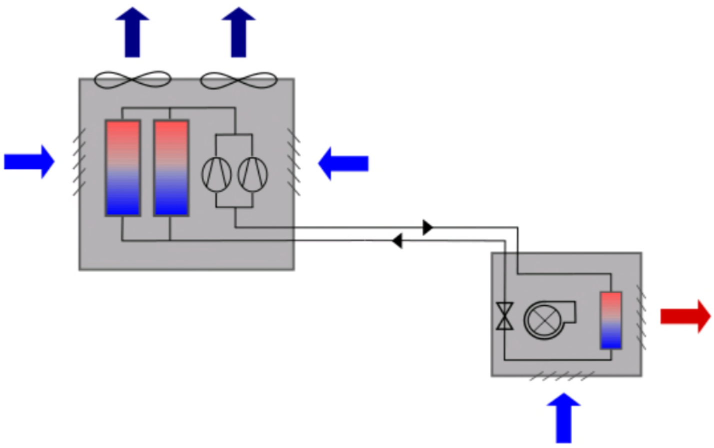




In addition, the user if necessary can determine the heating and cooling schedules.

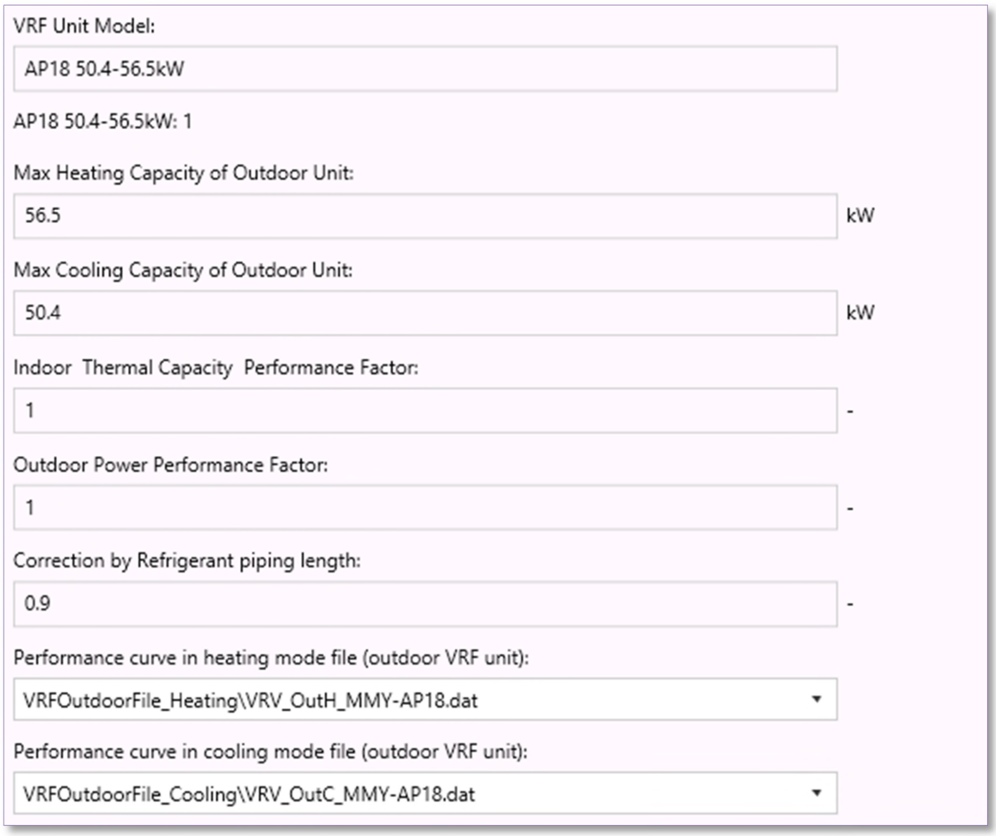
Simple direct expansion system (split system heat pump)

Variable Refrigerant Flow (VRF) system: The user can select the following energy generation system and complete the information required. First, the minimum load for outdoor unit ON has to be set.

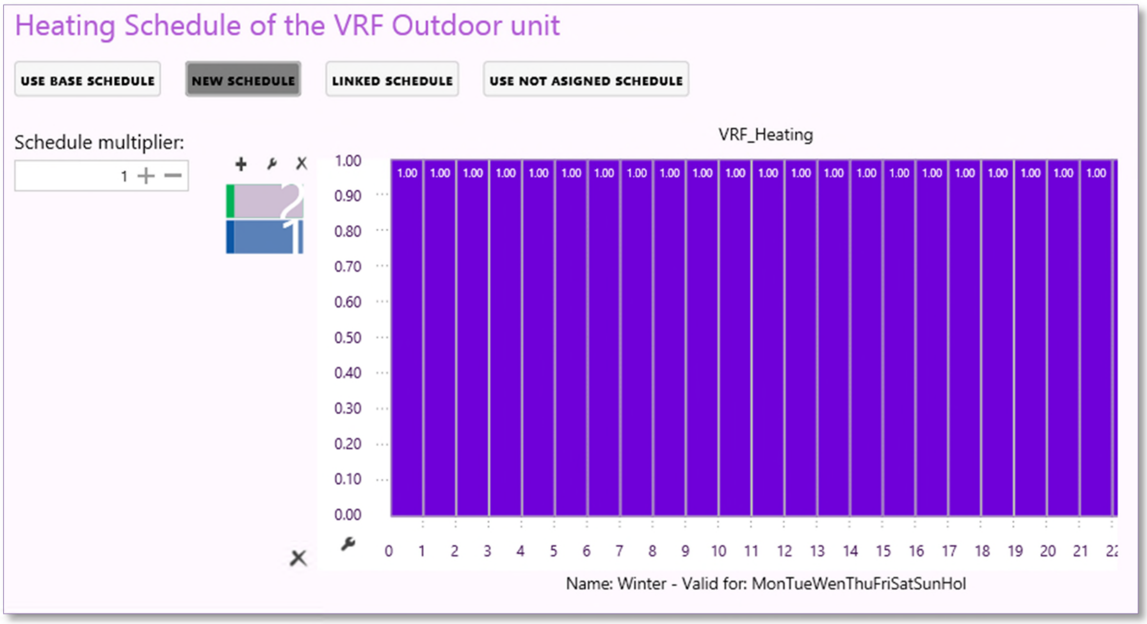


- **Outdoor VRF units:** The user can include different units adding them in the green cross and deleting them in the red cross.

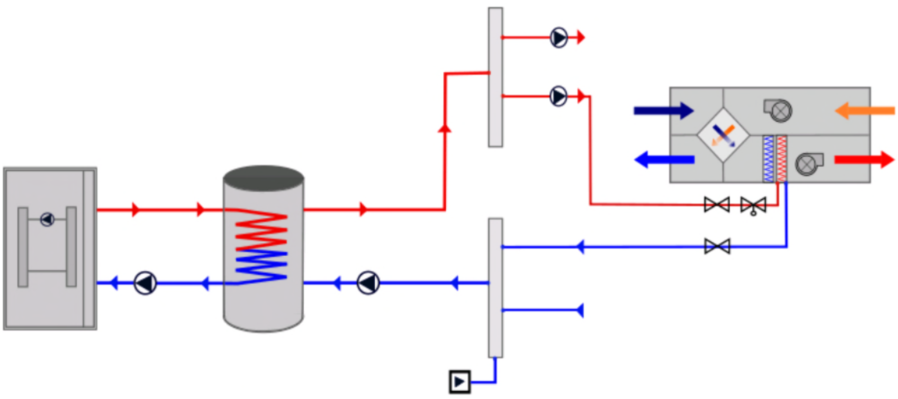
The user can also to set up the following information; the VRF unit model, the maximum heating capacity of the outdoor unit (kW), the maximum cooling capacity of the outdoor unit (kW), the indoor thermal capacity performance factor, the outdoor power performance factor, the correction by refrigerant piping length, and the performance curves in heating and cooling mode.

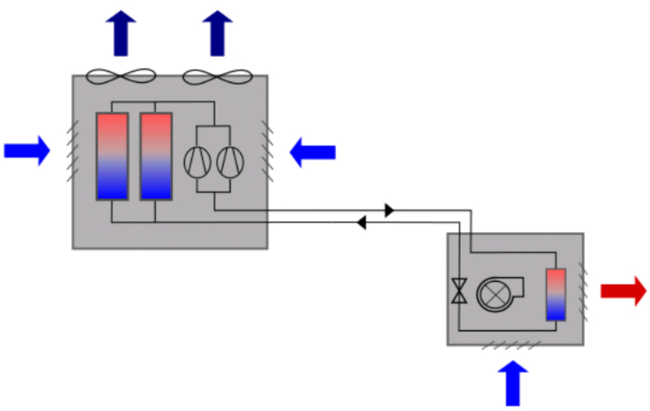


In addition, heating and cooling schedules of the VRF outdoor units can be introduced.

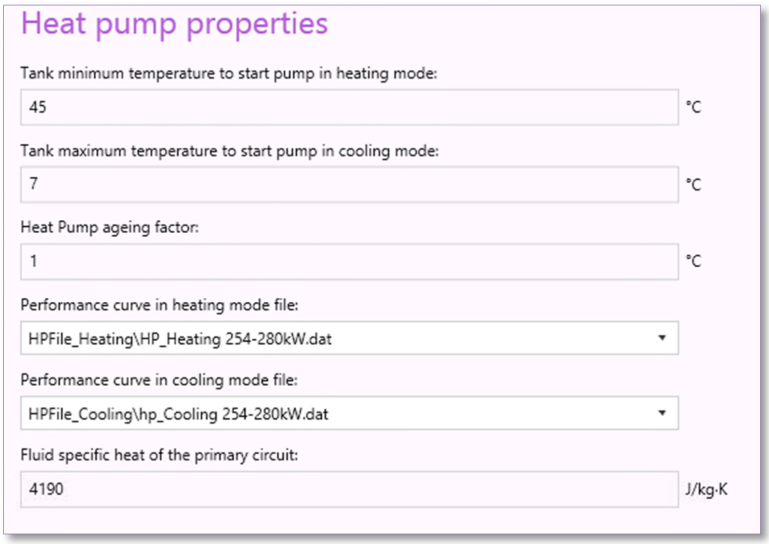


Variable Refrigerant Flow (VRF) system and air water heat pump with AHU: The user can select the following energy generation system. To fill in the system it is necessary to complete some of the following information.

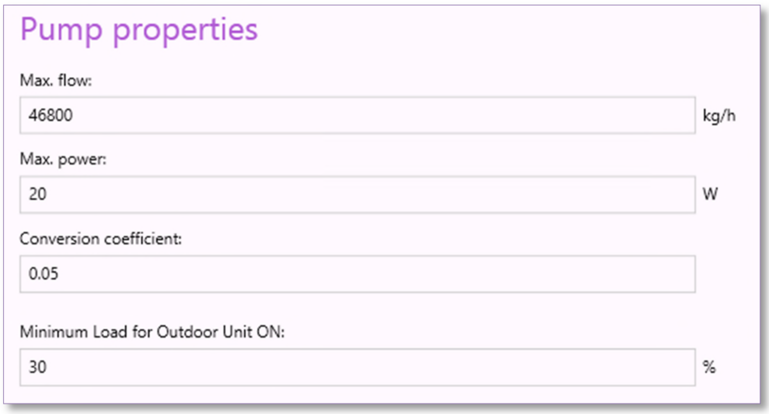




- **Heat pump properties:** The following data can be introduced; the tank minimum temperature to start pump in heating mode (ºC), the tank maximum temperature to start pump in cooling mode (ºC), the heat pump ageing factor (ºC), the performance curve in heating and cooling mode and the fluid specific heat of the primary circuit (J/kg·K).

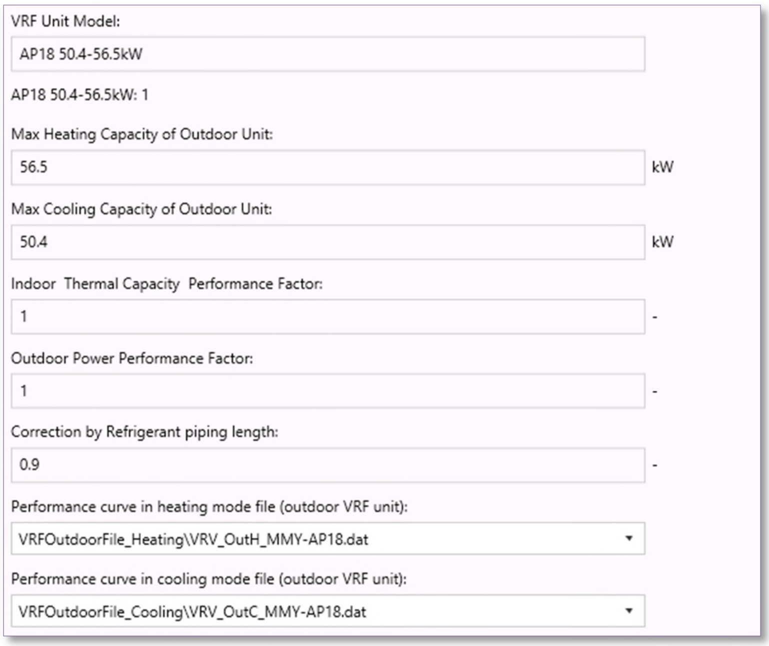


- **Pump properties:** The following information has to be set: the maximum flow (kg/h), the maximum power (W), the conversion coefficient and minimum load for outdoor unit ON (%).

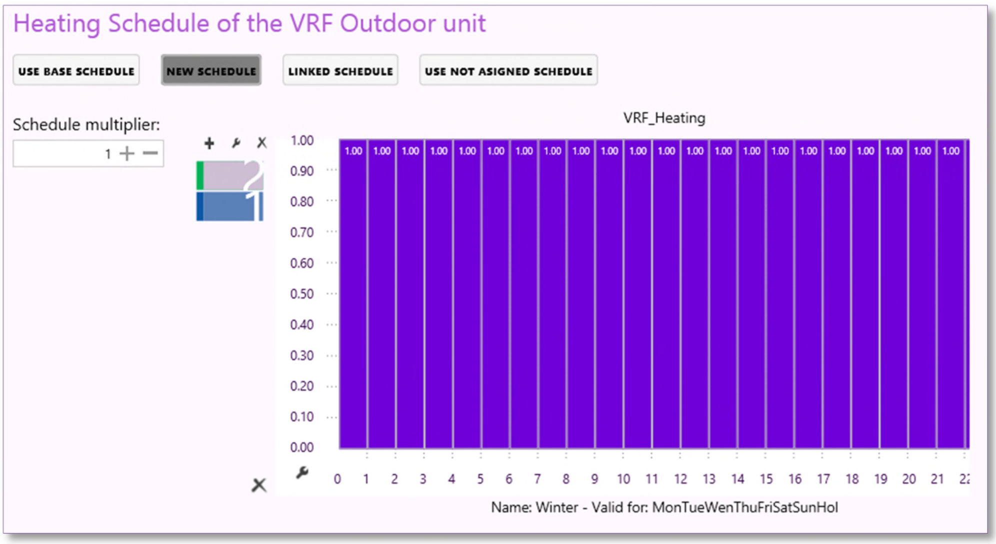


- **Outdoor VRF units:** the user can include different units adding them in the green cross and deleting them in the red cross.

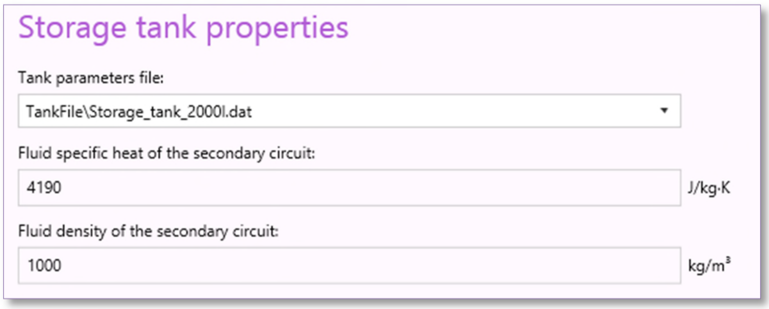
The user can also introduce the following information; the VRF unit model, the maximum heating capacity of the outdoor unit (kW), the maximum cooling capacity of the outdoor unit (kW), the indoor thermal capacity performance factor, the outdoor power performance factor, the correction by refrigerant piping length, and the performance curves in heating and cooling mode.



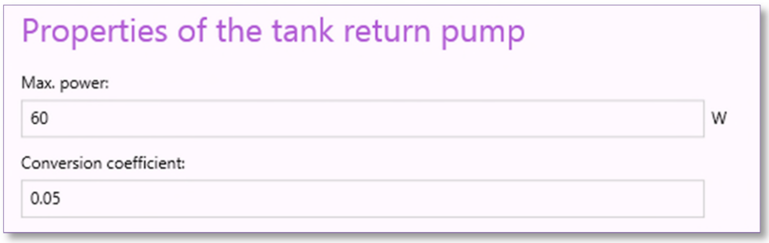
In addition, heating and cooling schedule of the VRF outdoor unit can be introduced by the user, as well as the heating and cooling schedule of the heat pump.



- **Storage tank properties:** The information that has to be completed here is the following; the tank parameters file, the fluid specific heat of the secondary circuit (J/kg·K), and the fluid density of the secondary circuit (kg/m^3).



- **Properties of the tank return pump:** The user can enter the maximum power (W) and the conversion coefficient.



Ground source heat pump

ENGINENCY

ENERGY DISTRIBUTION SYSTEMS

Once the energy generation system is defined, the user can set the energy distribution system.

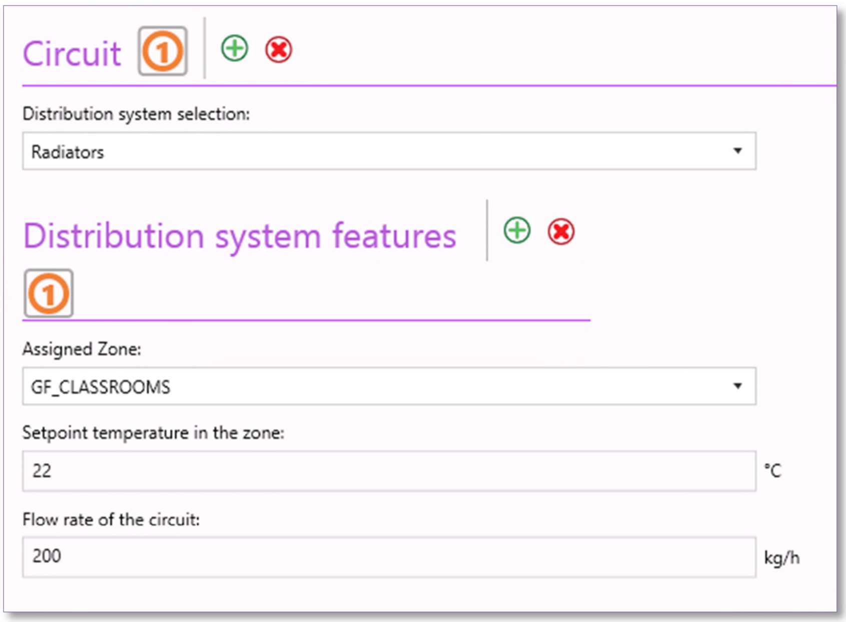
Without distribution system. This option is only possible when ideal energy generation system is selected.

Otherwise, it is possible to include different circuits adding them in the green cross and deleting them in the red cross. This means that, for example, the user can simulate a building where some of the thermal zones have an energy distribution system as radiators and other thermal zones have another energy distribution system as a radiant floor.

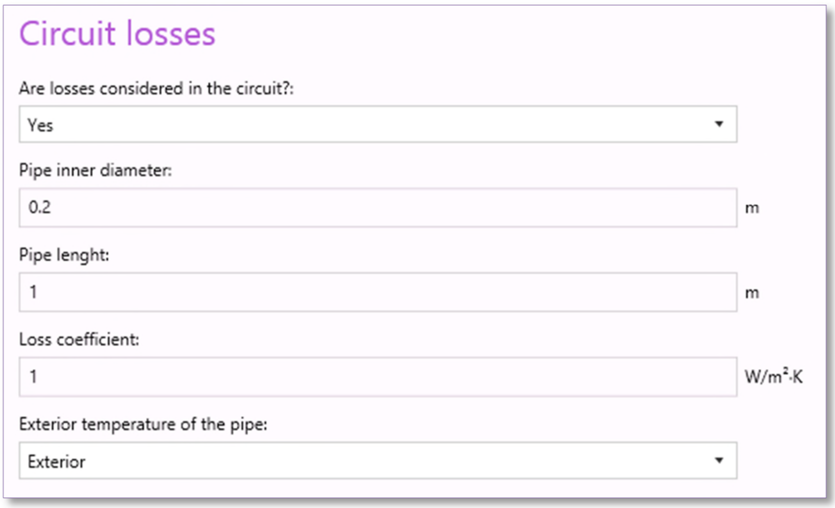
The user has to select the energy distribution system.

Radiators. Once the energy distribution system is selected, the different properties of the circuit have to be set for each of the thermal zones. The user has to create a new feature for each thermal zone with radiators.

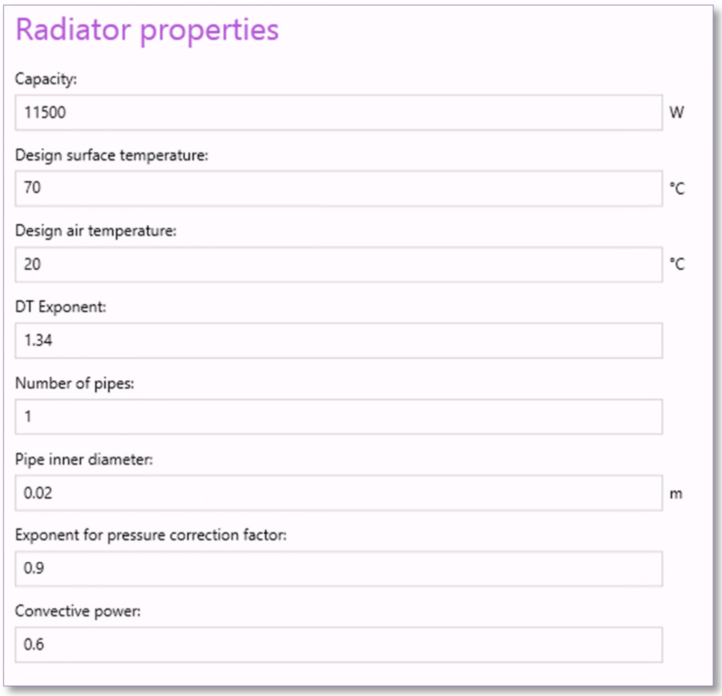
- **Distribution system features.** First, the assigned zone has to be established, then the setpoint temperature in the zone (ºC) and the flow rate of the circuit (kg/h).



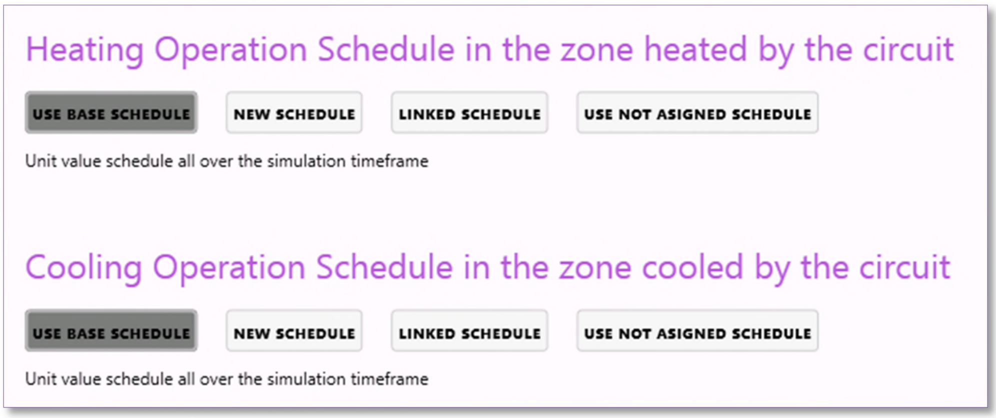
- **Circuit losses.** The losses can be or cannot be consired in the circuit. It also has to be set the pipe inner diameter (m), the pipe lenght (m) and the loss coefficient (W/m²·K). The exterior temperature of the pipe can be set as the exterior temperature, the temperature of the zone, the temperature of other zone of the building or a fixed temperature (ºC).



- **Radiator properties.** The following information has to be established; the capacity (W), the design surface temperature (ºC), design air temperature (ºC), the DT exponent, number of pipes, the pipe inner diameter (m), exponent for pressure correction factor and the convective power.

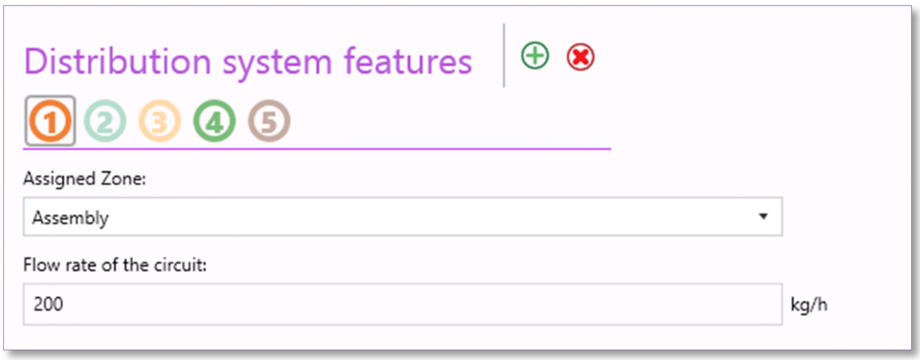


Finally, it is also possible to define a heating or cooling operation schedule of the distribution system.

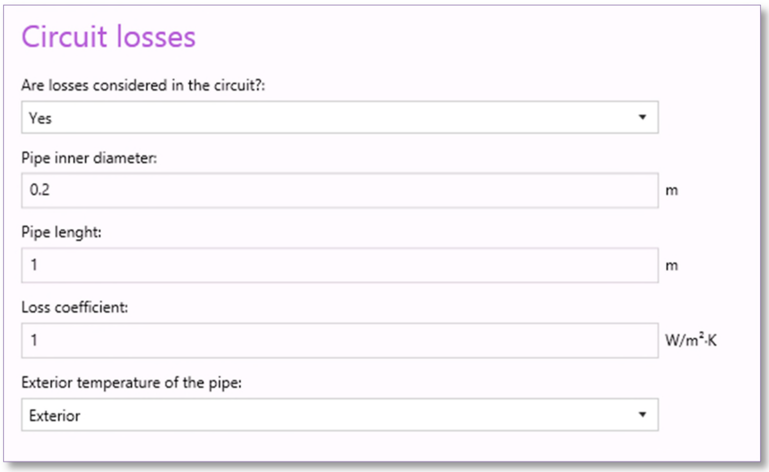


2 tubes Fan-Coils: This distribution system can be also selected and the user has to create a new feature for each thermal zone.

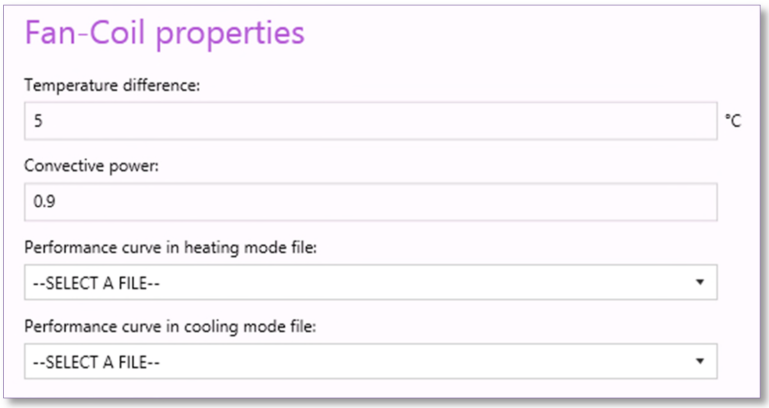
- **Distribution system features.** First, the assigned zone has to be established, and the flow rate of the circuit (kg/h).



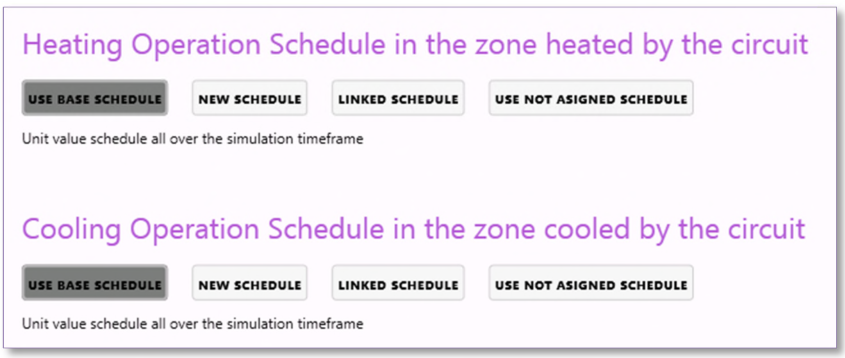
- **Circuit losses.** The losses can be or cannot be considered in the circuit. It also has to be set the pipe inner diameter (m), the pipe length (m) and the loss coefficient (W/m^2·K). The exterior temperature of the pipe can be set as the exterior temperature, the temperature of the zone, the temperature of other zone of the building or a fixed temperature (ºC).



- **Fan-Coils properties.** The following information has to be established; the temperature difference (ºC), the convective power and the performance curve in heating and cooling mode file.

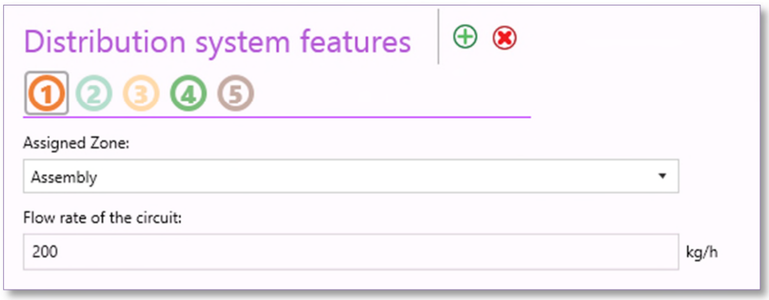


Finally, it is also possible to define a heating or cooling setpoint temperature and operation schedule of the distribution system.

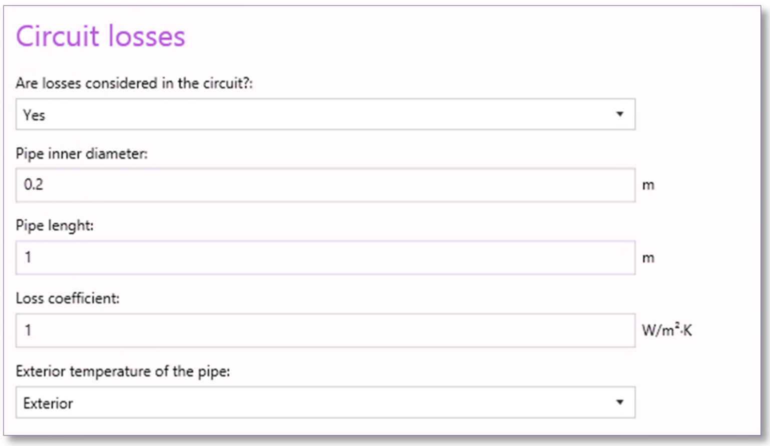


4 tubes Fan-Coils: Once the energy distribution system is selected, the different properties of the circuit have to be set for each of the thermal zones.

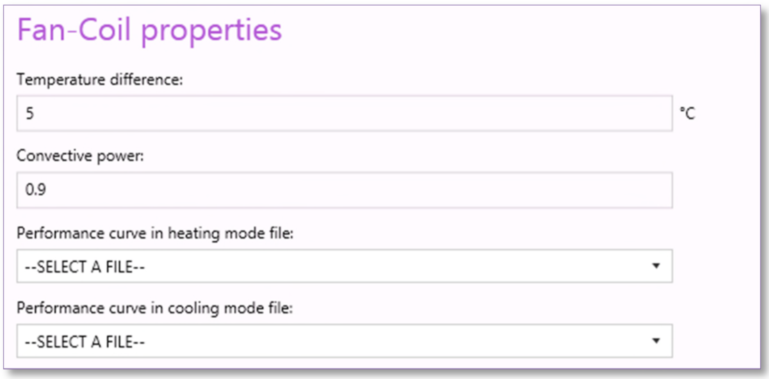
- **Distribution system features.** First, the assigned zone has to be established, and the flow rate of the circuit (kg/h).



- **Circuit losses.** The losses can be or cannot be considered in the circuit. It also has to be set the pipe inner diameter (m), the pipe length (m) and the loss coefficient (W/m²·K). The exterior temperature of the pipe can be set as the exterior temperature, the temperature of the zone, the temperature of other zone of the building or a fixed temperature (°C).



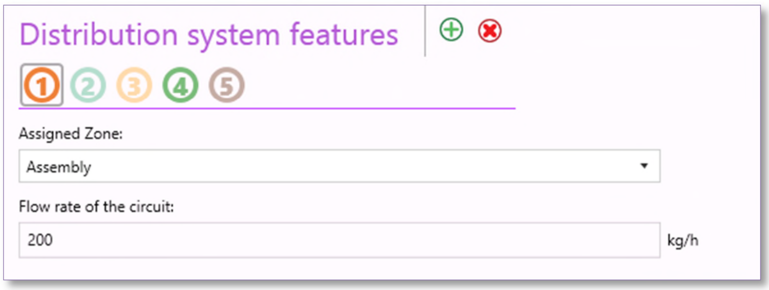
- **Fan-Coils properties.** The following information has to be established; the temperature difference (ºC), the convective power, and the performance curve in heating and cooling mode file.



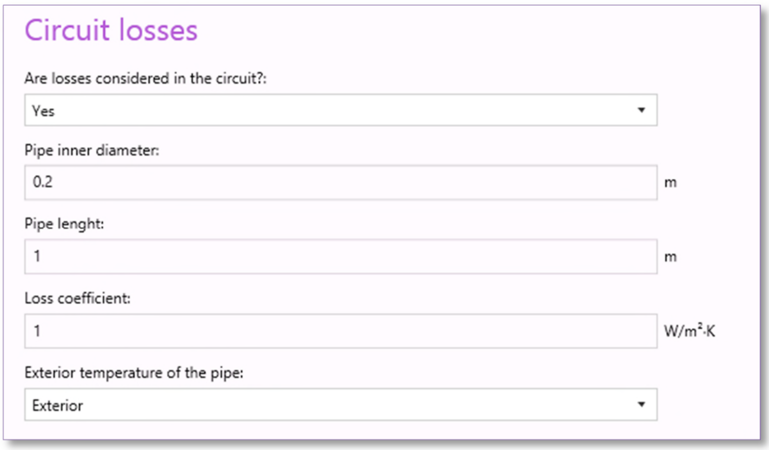
Finally, it is also possible to define a heating or cooling setpoint temperature and operation schedule of the distribution system.

AHU: Once the energy distribution system is selected, the different properties of the circuit have to be set for each of the thermal zones. The user has to create a new feature for each thermal zone with AHU.

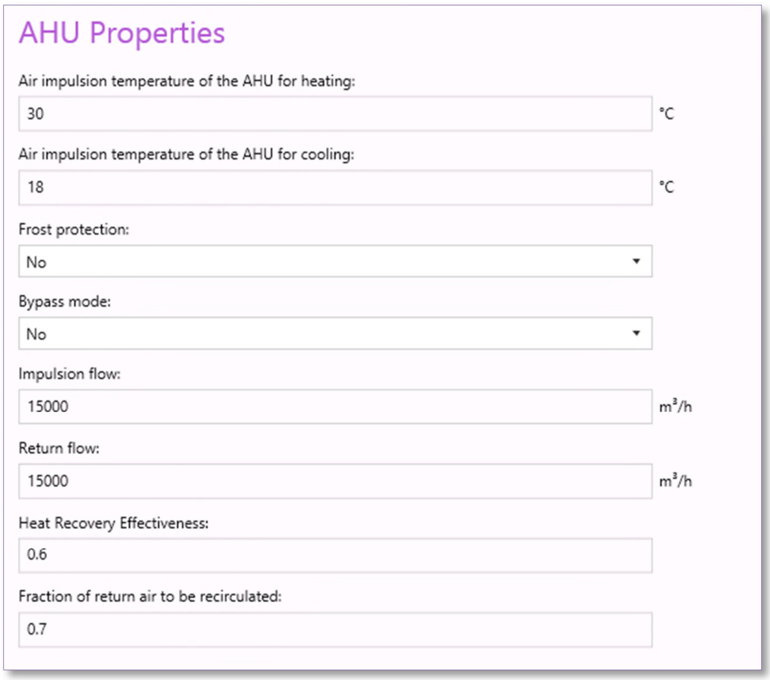
- **Distribution system features.** First, the assigned zone has to be established, and the flow rate of the circuit (kg/h).



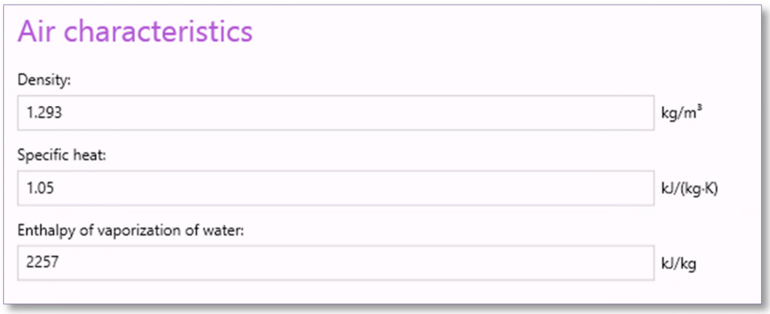
- **Circuit losses.** The losses can be or cannot be considered in the circuit. It also has to be set the pipe inner diameter (m), the pipe length (m) and the loss coefficient (W/m^2·K). The exterior temperature of the pipe can be set as the exterior temperature, the temperature of the zone, the temperature of other zone of the building or a fixed temperature (°C).



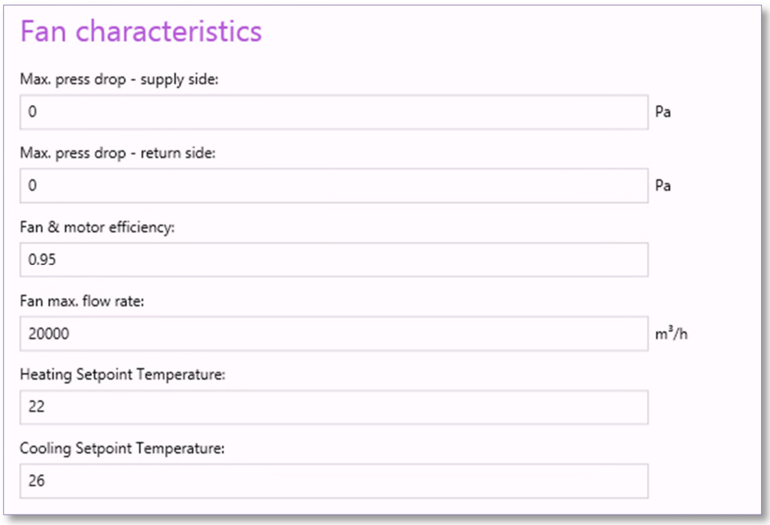
- **AHU properties.** The following information has to be established, the air impulsion temperature of the AHU for heating and cooling (ºC), frost protection, bypass mode, impulsion flow (m^3/h), return flow (m^3/h), heat recovery effectiveness and fraction of return air to be recirculated.



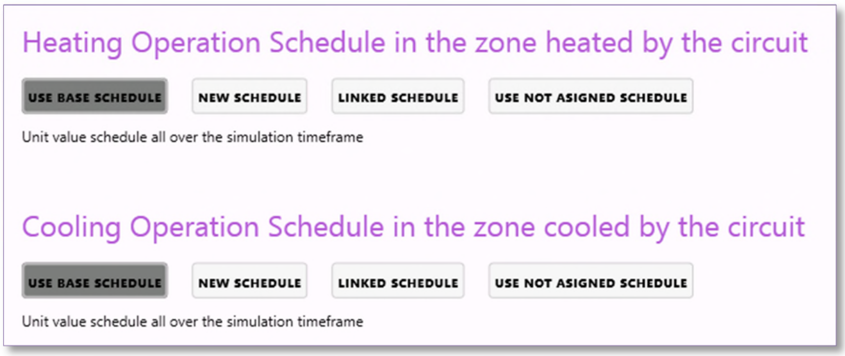
- **Air characteristics.** The user can introduce the density (kg/m^3), the specific heat (kJ/(kg·K)) and the enthalpy of vaporization of water (kJ/kg).



- **Fan characteristics**: The information that has to be established here is the following: Maximum press drop – supply side (Pa), maximum press drop – return side (Pa), fan & motor efficiency, fan maximum flow rate (m^3/h), and heating and cooling setpoint temperature.



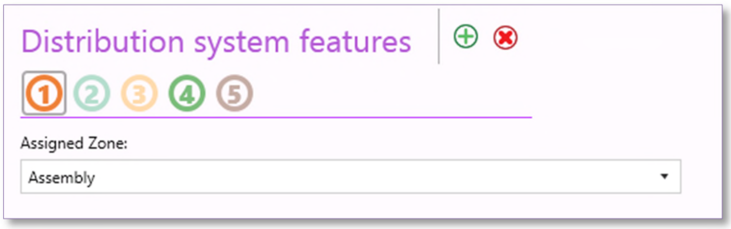
Finally, it is also possible to define a heating or cooling operation schedule of the distribution system.



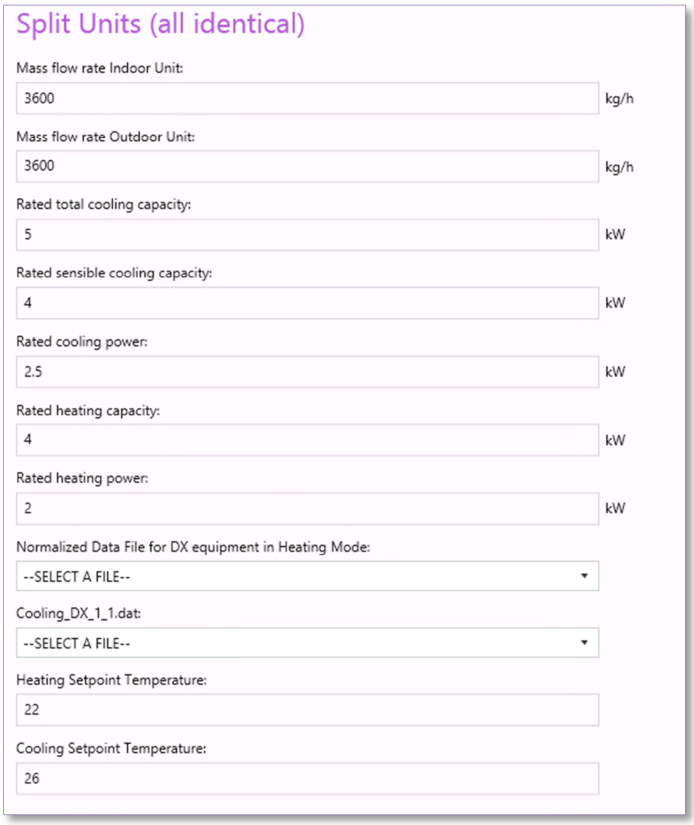
Radiant floor

Direct expansion indoor unit (split unit). Once the energy distribution system is selected, the different properties of the circuit have to be set for each of the thermal zones. The user can create a new feature for each thermal zone with direct expansion indoor unit (split unit).

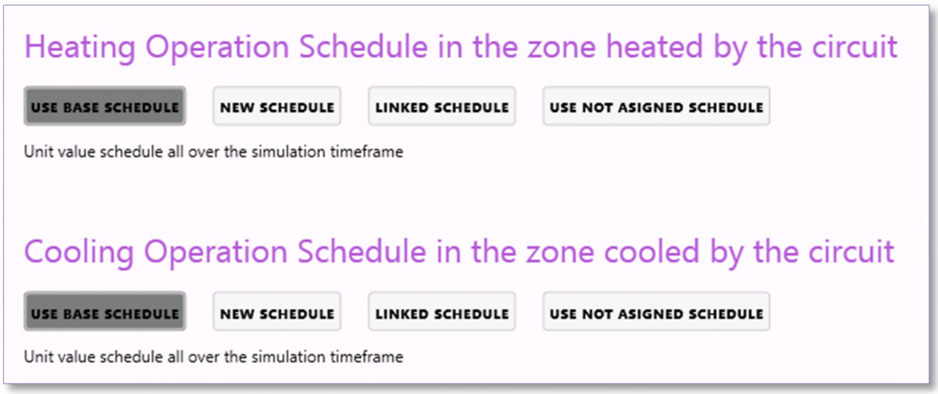
- **Distribution system features.** First, the assigned zone has to be established.



- **Splits unit (all identical).** The user can introduce the following data; the mass flow rate indoor unit (kg/h), the mass flow rate outdoor unit (kg/h), the rated total cooling capacity (kW), the rated sensible cooling capacity (kW), the rated cooling power (kW), the rated heating capacity (kW), the rated heating power (kW), the normalized data file for DX equipment in heating and cooling mode.

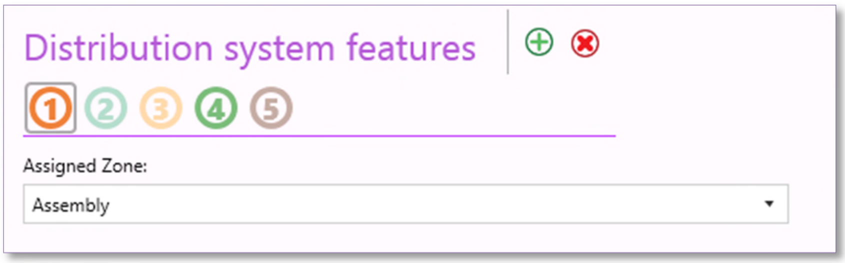


Finally, it is also possible to define a heating or cooling temperature schedule and operation schedule of the distribution system.

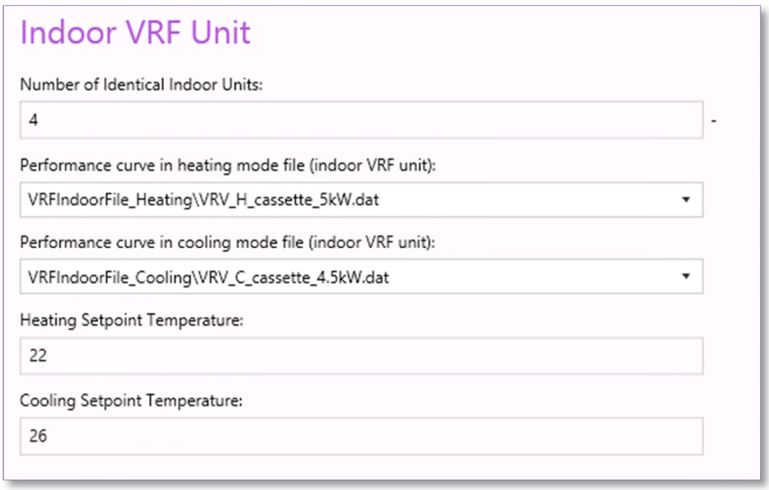


VRF indoor units. Once the energy distribution system is selected, the different properties of the circuit have to be set for each of the thermal zones. The user can select VRF indoor units as distribution system and select the outdoor unit.

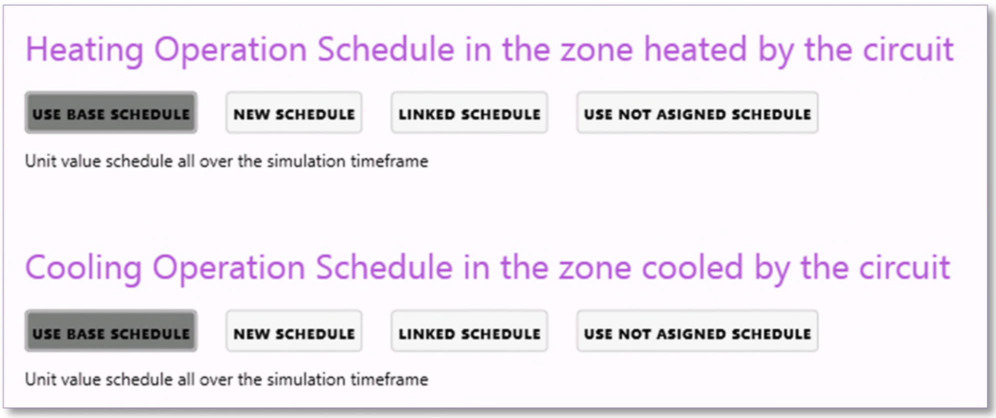
- **Distribution system features.** First, the assigned zone has to be established.



- **Indoor VRF unit**. The following information has to be established; the number of identical indoor units, the performance curve in heating and cooling mode file and the heating and cooling setpoint temperature.



Finally, it is also possible to define a heating or cooling operation schedule of the distribution system.



DHW

Completing all the previous sections included in the tab “Building”, it is completely defined and the simulation can be carried out.

3.2 Simulation

Once the building is completely defined, the simulation can be implemented. First, some general parameters have to be set as the name of the output files location that indicates the folder where the output files are going to be located, and one of the most important input data for simulation, that is the weather data. The meteorological data must be introduced in epw format. The epw file contains the hourly weather data needed by the simulation program TRNSYS. Therefore, the weather data file has to be provided to BCORE in epw format. It is an open format supported by almost every thermal simulation software. It contains 8 lines of header and the rest of the lines contain the meteorological data separated by commas. At least we need the following data to simulate: year (-), month (-), day (-), hour (-), minute (-), dry bulb temperature (ºC), relative humidity (%), atmospheric pressure (Pa), global horizontal radiation (W·h/m^2), wind direction (º), wind speed (m/s).

Then, the user has to introduce the duration of the simulation, indicating the start day and hour and the end day and hour of the simulation, the time step in hours and the time base in hours. Finally, the outputs of the simulation have to be selected.

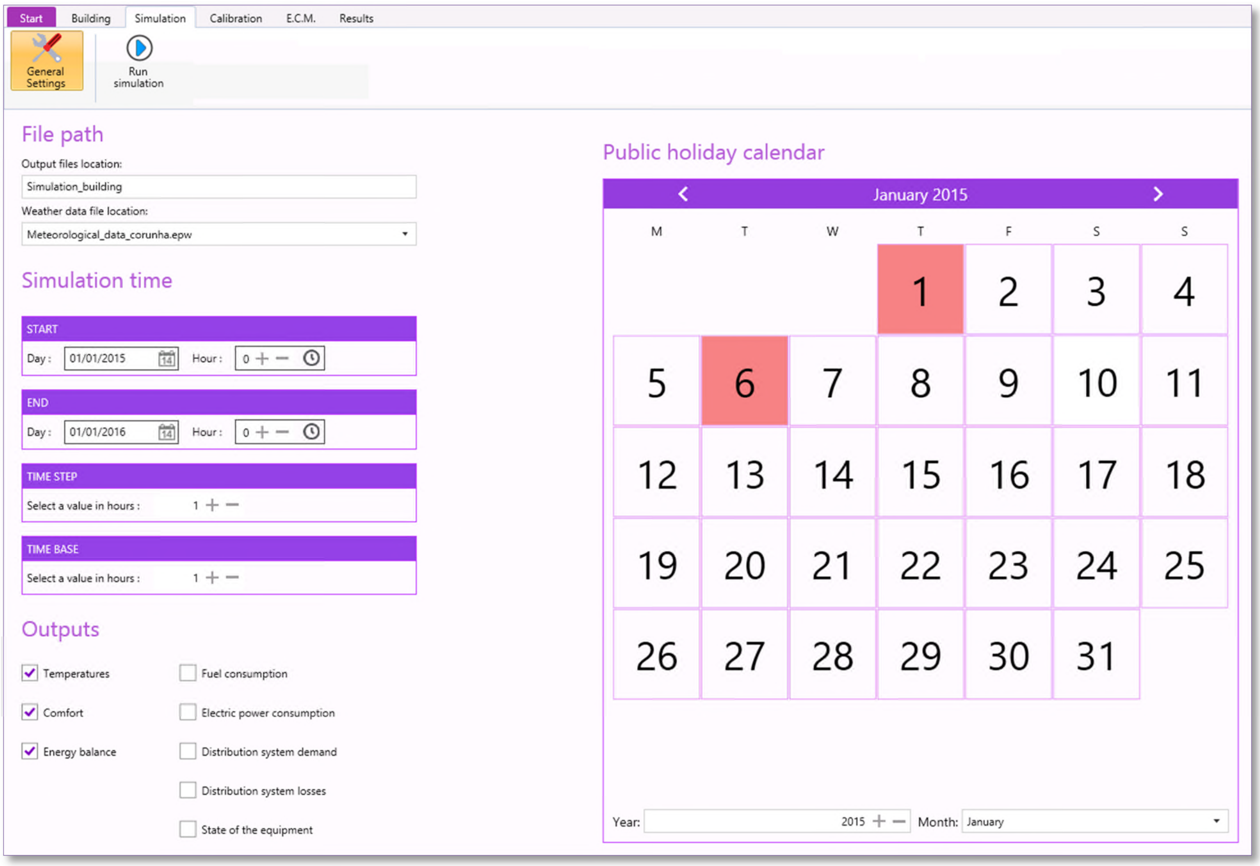
- Temperatures
- Comfort
- Energy balance

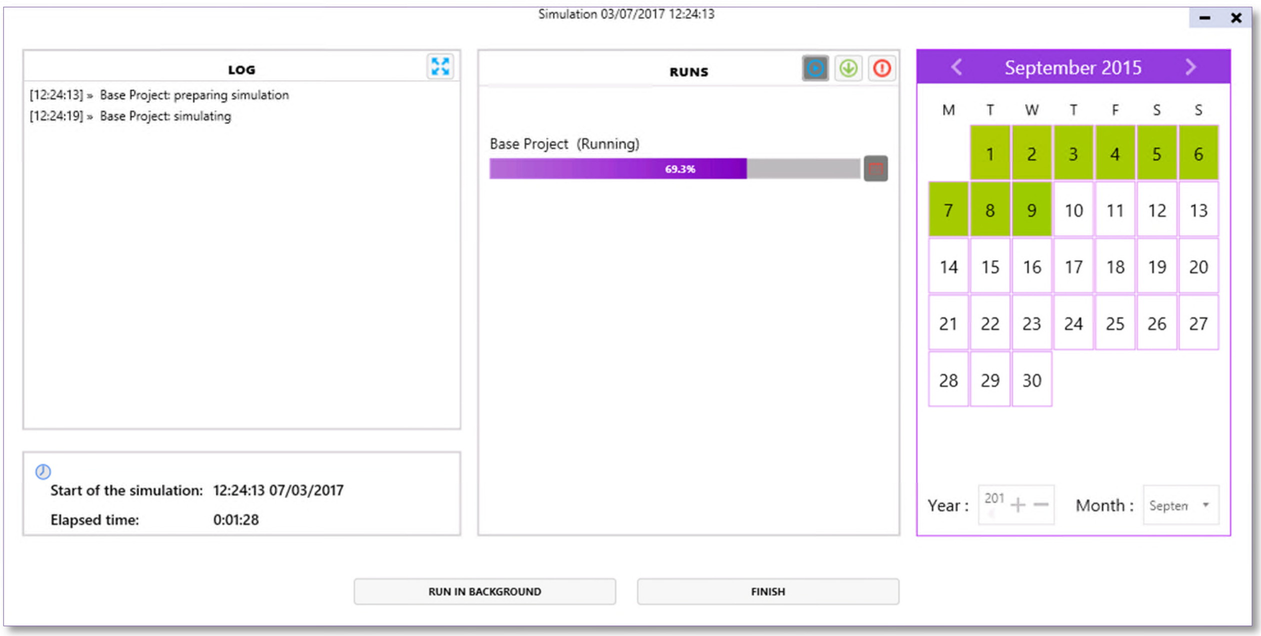
In the case that an energy generation and distribution system is selected, more outputs are available:

- Fuel consumption
- Electric power consumption
- Distribution system demand
- Distribution system losses
- State of the equipment

Besides the outputs, it is also necessary to define the public holiday calendar, especially if there are different schedules for holidays. This holidays can be defined just clicking on the day with the left mouse button, the days can be deselected by clicking on the day with the right mouse button.

Once all the factors affecting the thermal system comprising building model are defined, the simulation phase is started. Then, the user can run the simulation, clicking “Run simulation”. The thermal simulation is performed with the simulation software TRNSYS, and the user can observe the progress in the screen.





Once the simulation is finished, the results can be observed in the tab of results explained later.

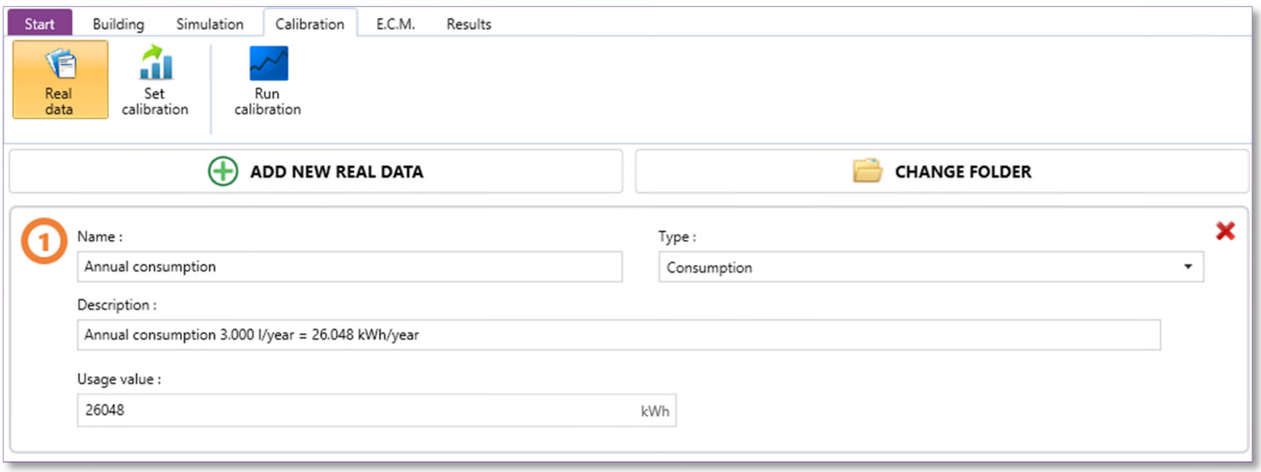
3.3 Calibration

When a building model is simulated but that does not fit the actual building, it is completely useless for a thermal analysis focused on energy efficiency. And usually, a first ideal simulation does not fit to the reality, therefore it is necessary a calibration. Calibration of a building model is necessary to reduce the discrepancies between the simulation results and real data. Calibration processes aim to approximate the thermal model results to the real ones as closely as possible. For this reason it is necessary to perform a calibration using actual data extracted from the building through its monitoring and the model generated in the software. The calibration is automated and is done using the optimization tool GenOpt, which by a search algorithm, generates the optimal calibration option.

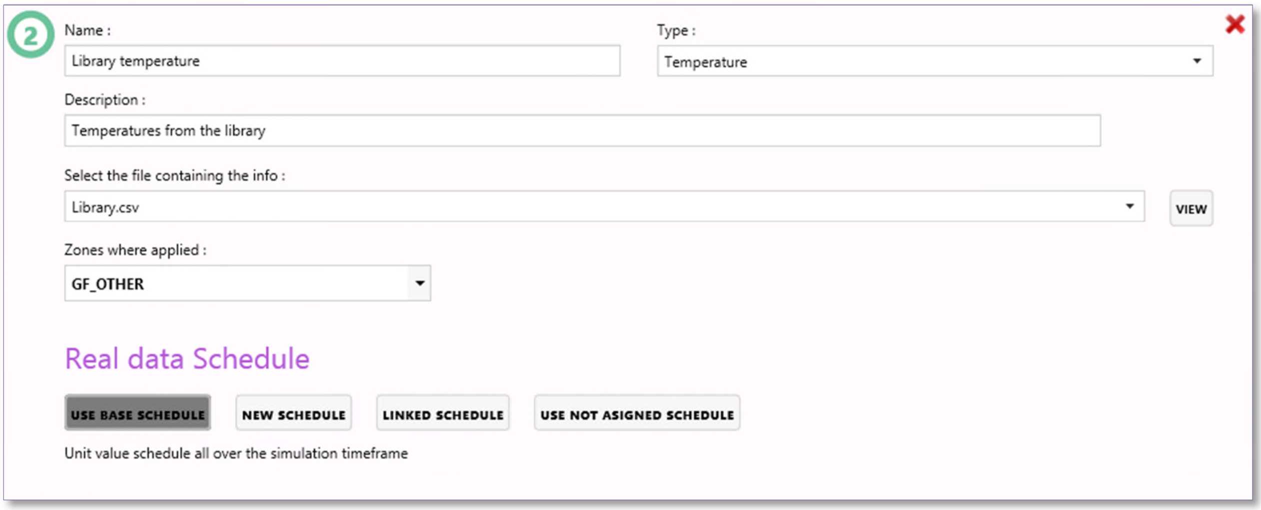
The first step in the calibration process is the introduction of the real data. Then parameters of the calibration are defined and, finally the calibration is run.

REAL DATA

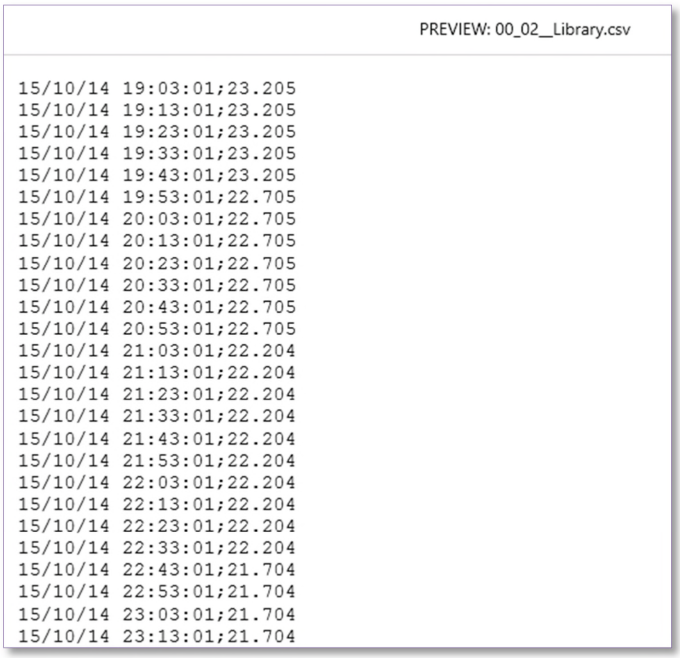
The user can introduce real data from monitoring by clicking over **ADD NEW REAL DATA**. There are three possible types of input real data: consumption, temperature and relative humidity. To enter the consumption, a value of the energy consumption in kWh is needed.



However, when the temperature or the relative humidity is selected, the information to be introduced is different. The user writes a name and a description about the real data and selects the type of data. Then, the file with the appropriate information has to be selected in a text file in csv or txt format. This file can be uploaded as every file, just dragging it into the software screen. The thermal zones where applied have to be selected also. In addition, a real data schedule can also be defined. The user can delete a real data by clicking over the red cross.



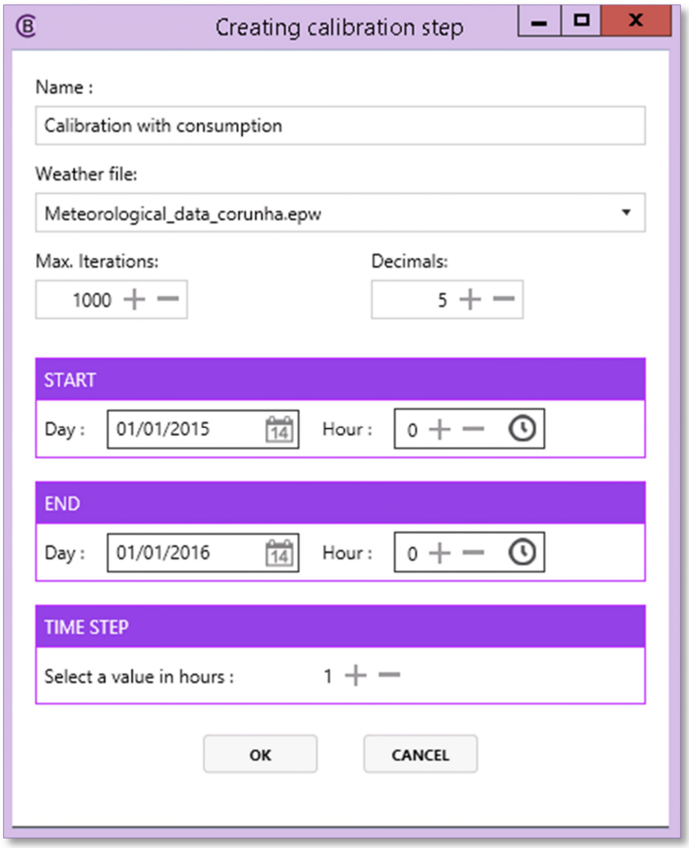
The file structure containing the information of the temperature or relative humidity is the date with the time and the value. Therefore, it is needed a different file for each of the variables and zones. Clicking in view, the file is visualised.


PREVIEW: 00_02__Library.csv

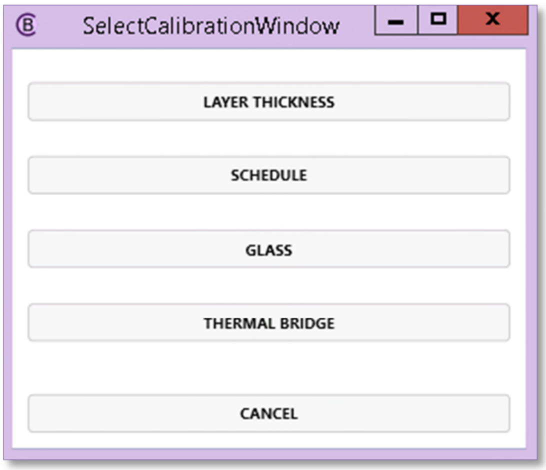
```
15/10/14 19:03:01;23.205
15/10/14 19:13:01;23.205
15/10/14 19:23:01;23.205
15/10/14 19:33:01;23.205
15/10/14 19:43:01;23.205
15/10/14 19:53:01;22.705
15/10/14 20:03:01;22.705
15/10/14 20:13:01;22.705
15/10/14 20:23:01;22.705
15/10/14 20:33:01;22.705
15/10/14 20:43:01;22.705
15/10/14 20:53:01;22.705
15/10/14 21:03:01;22.204
15/10/14 21:13:01;22.204
15/10/14 21:23:01;22.204
15/10/14 21:33:01;22.204
15/10/14 21:43:01;22.204
15/10/14 21:53:01;22.204
15/10/14 22:03:01;22.204
15/10/14 22:13:01;22.204
15/10/14 22:23:01;22.204
15/10/14 22:33:01;22.204
15/10/14 22:43:01;21.704
15/10/14 22:53:01;21.704
15/10/14 23:03:01;21.704
15/10/14 23:13:01;21.704
```

SET CALIBRATION

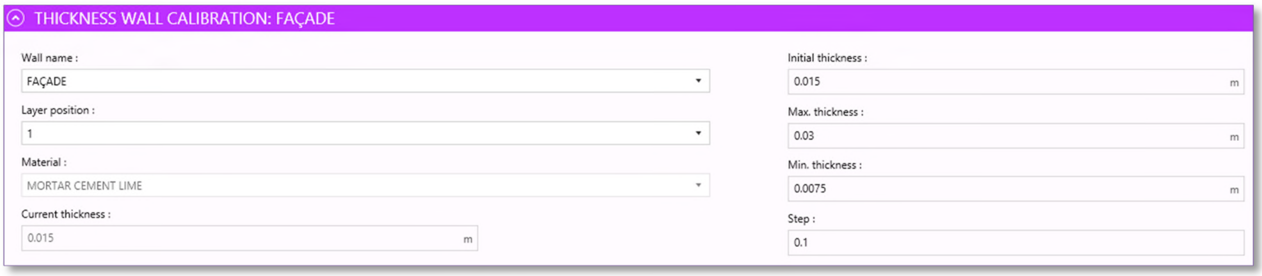
Once all the available real data are introduced, the calibration can be configured. By clicking "Add" the window "Creating a calibration step" is opened. In this window the calibration is set, the name of the calibration, the weather data file in epw format, the maximum iterations for the calibration, the number of decimal places of the solution, the start data and hour of the calibration, the end date and hour of the calibration and the time step.



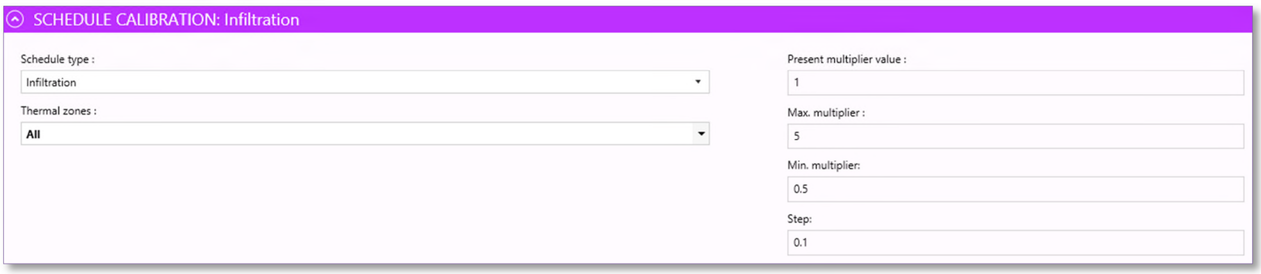
Then, the following steps are to select the real data that are going to be used and click over **ADD NEW CALIBRATION** and select in the calibration window the parameters that are going to be calibrated: layer thickness, schedule, glass or thermal bridge. Depending on the parameter selected the information to introduce is different. For example, if the schedule is going to be calibrated. First, it is necessary to decide the type of schedule to calibrate, then the thermal zones where applicable and to establish a maximum and a minimum multiplier as well as a step.



- Layer thickness. The user has to select the wall name and the layer position, therefore, the material and the current thickness (m) is taken, and the initial, maximum and minimum thickness and step are set by the user.

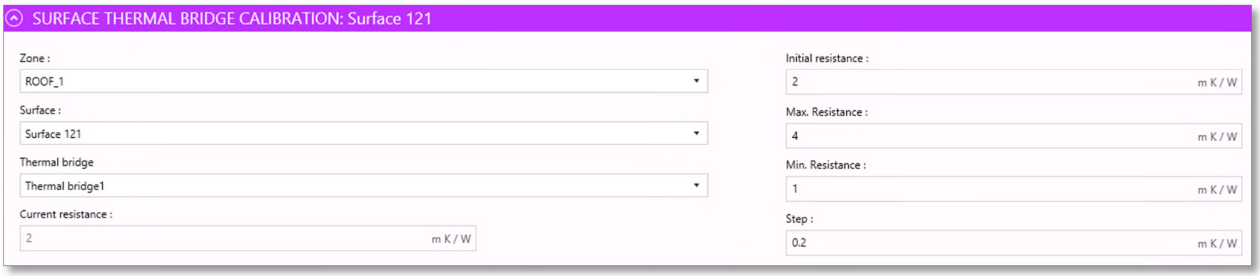


- Schedule. The user selects the schedule type to be calibrated and the themal zones applied. It appears the current multiplier value and the user set the maximum and minimum multiplier as well as the step.



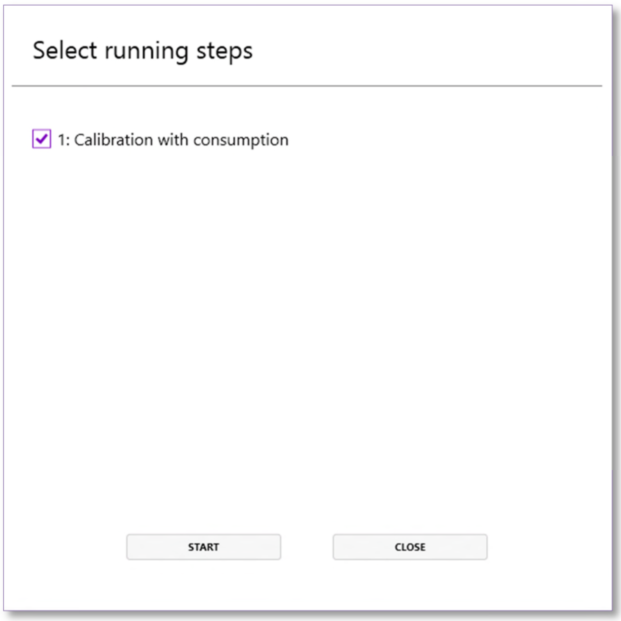
- Glass. The user selects the opening that wants to calibrate, the current glass appears and the user also selects possible glasses to change the current one

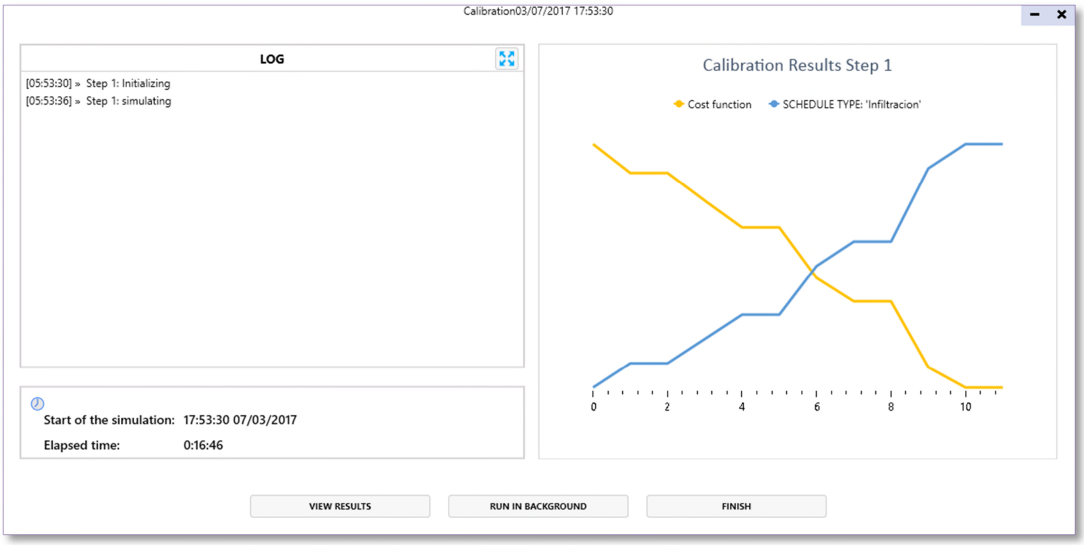
- Thermal bridge. Thermal bridges can also be calibrated. The user has to select the zone, the surface and the thermal bridge. It is shown the current resistance (m·K/W). The initial, maximum and minimum resistance (m·K/W) and step are established.

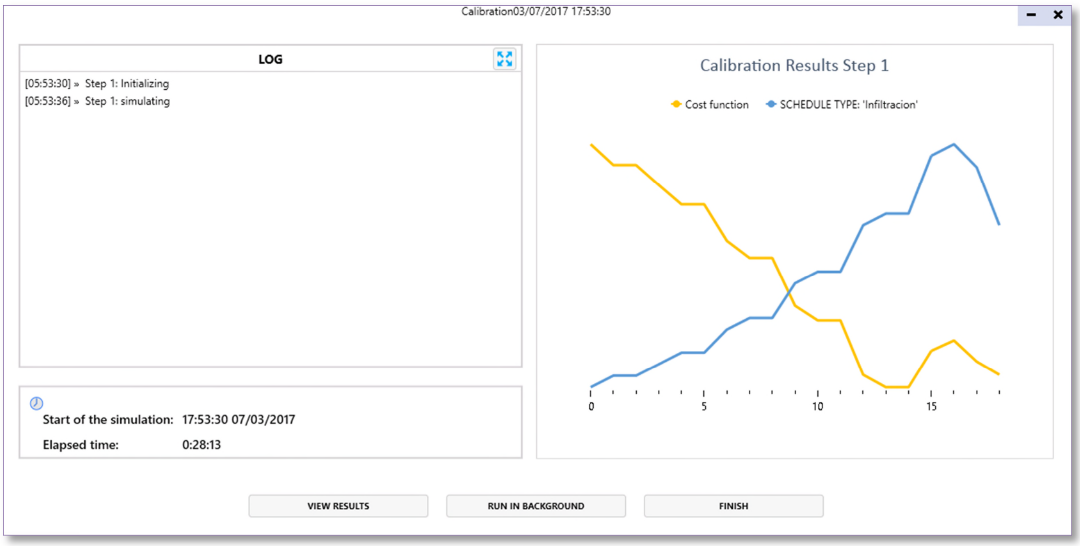


RUN CALIBRATION

When running the calibration, several simulations are implemented reaching the calibrated value for the parameters selected. First, the user selects the running steps and clicks start. The procedure is to minimize the cost function by varying the parameters to be calibrated between the specified values.

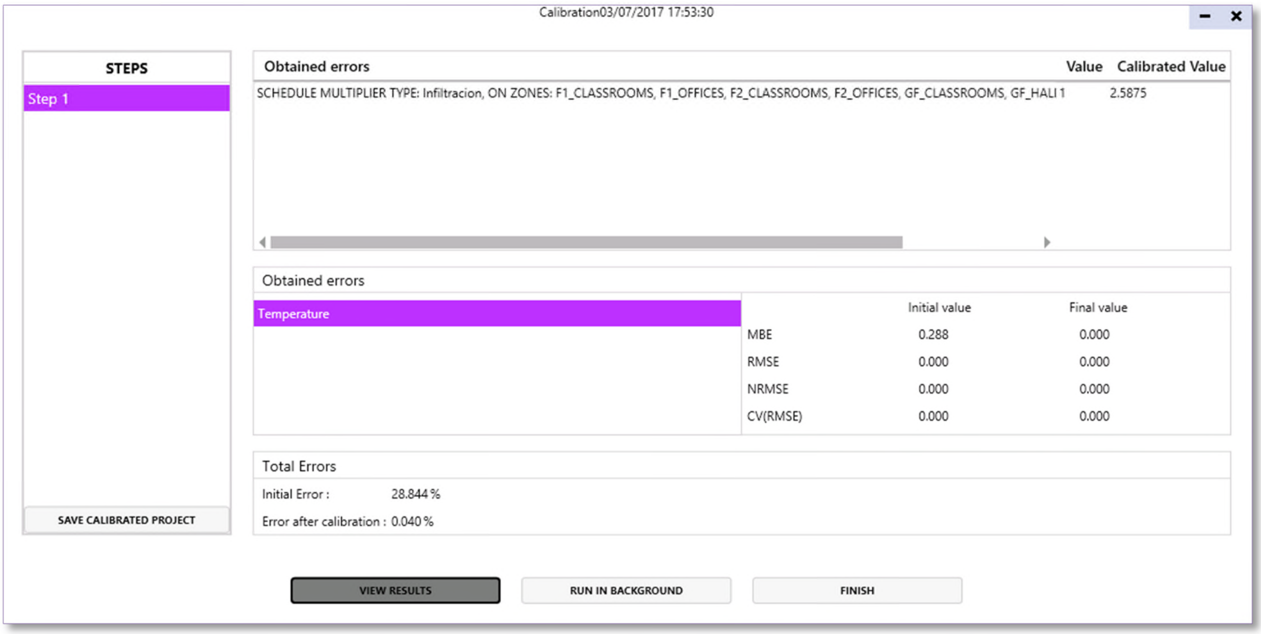



Calibration03/07/2017 17:53:30
LOG
[05:53:30] » Step 1: Initializing
[05:53:36] » Step 1: simulating
Start of the simulation: 17:53:30 07/03/2017
Elapsed time: 0:16:46
Calibration Results Step 1
Cost function
SCHEDULE TYPE: 'Infiltracion'
0
2
4
6
8
10
VIEW RESULTS
RUN IN BACKGROUND
FINISH


Calibration03/07/2017 17:53:30
LOG
[05:53:30] » Step 1: Initializing
[05:53:36] » Step 1: simulating
Start of the simulation: 17:53:30 07/03/2017
Elapsed time: 0:28:13
Calibration Results Step 1
Cost function
SCHEDULE TYPE: 'Infiltracion'
0
5
10
15
VIEW RESULTS
RUN IN BACKGROUND
FINISH


Calibration03/07/2017 17:53:30
LOG
[05:53:30] » Step 1: Initializing
[05:53:36] » Step 1: simulating
Start of the simulation: 17:53:30 07/03/2017
Elapsed time: 0:40:36
Calibration Results Step 1
Cost function
SCHEDULE TYPE: 'Infiltracion'
0
5
10
15
20
25
30
35
VIEW RESULTS
RUN IN BACKGROUND
FINISH

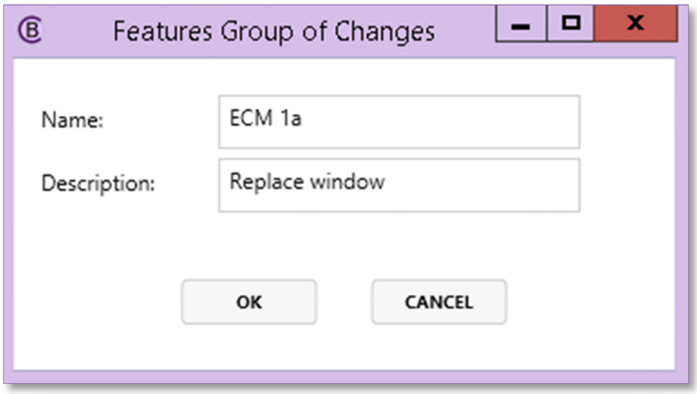
Once the calibration is finished, clicking on **VIEW RESULTS** it is possible to observe the initial and the calibrated values, the obtained errors before and after calibration, as well as the total initial error and the total error after calibration. In addition, the button **SAVE CALIBRATED PROJECT**, saves the project with the calibrated values modified.



3.4 Energy Conservation Measures

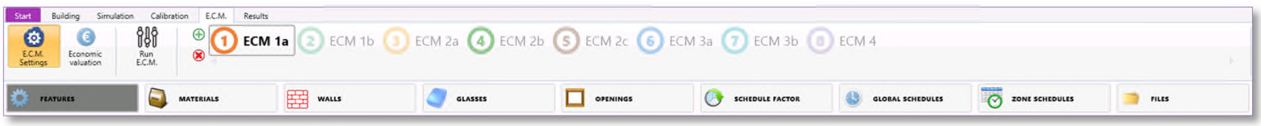
Once the calibrated building model under study is obtained, ECM can be taken. To this end, the software has a section in which the user can enter various building improvements that favour the increase of energy efficiency. In the software, the user can modify and change parameters that affect both the thermal envelope of the building and the reality of usage.

To add a new ECM, the user must click over the green cross and the following window will appear where the user has to describe briefly the measure with a name and a description.

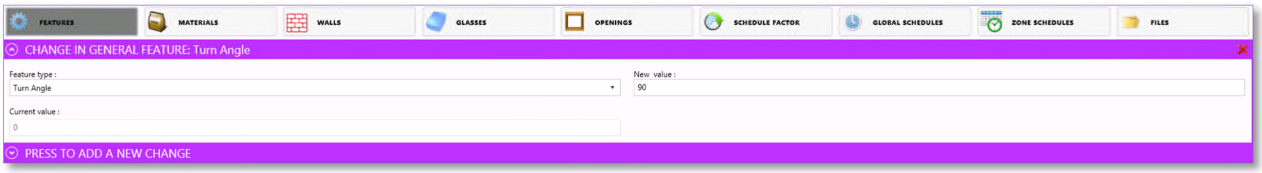


ECM SETTINGS

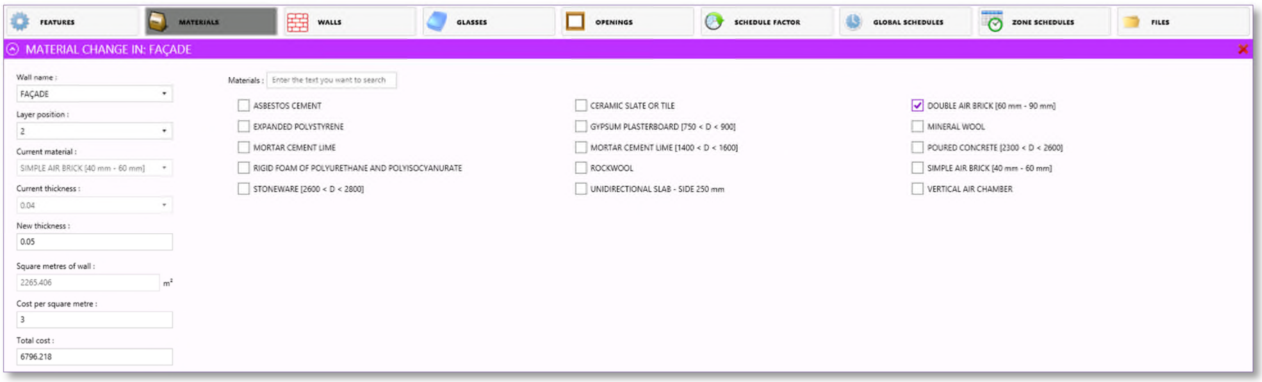
Numerous ECM can be defined and several characteristics can be modified. Next, all the possibilities are explained in detail.



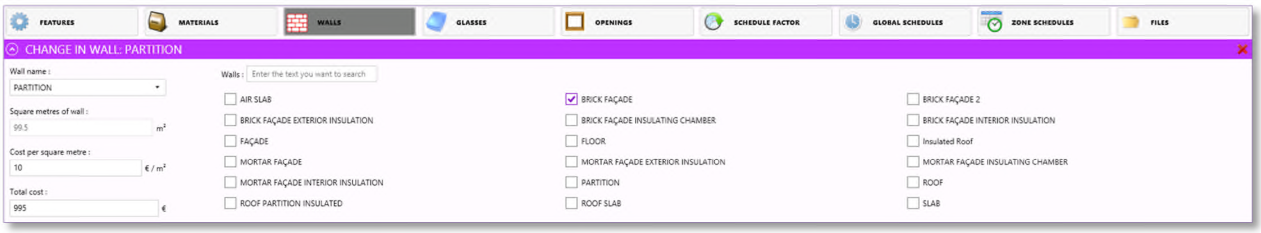
- **Features.** The user has to press to add a new change. In this tab the changes can be established in the turn angle where the user observes the current value and sets a new one, or in the construction level modifying all the building into tight, medium or loose construction.



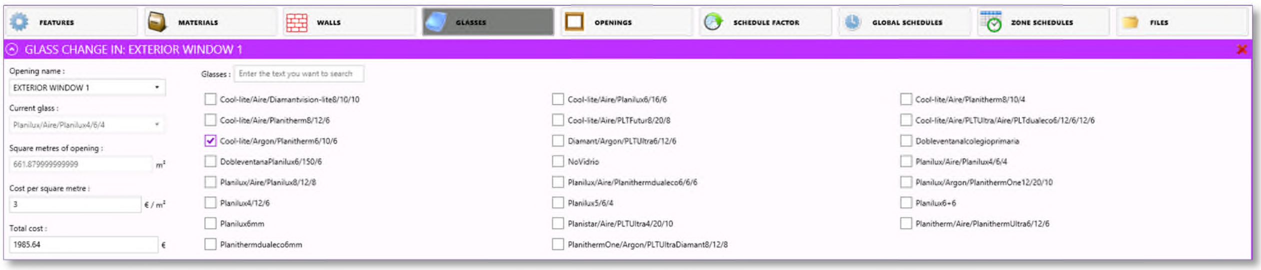
- **Materials.** If the user wants to change a material, first she or he has to select the wall name where it is going to be changed and the layer position of this material. The user can observe the current material and thickness (m) and select the new material establishing the new thickness (m) and cost per square meter (€) in order to calculate a total cost of the modification.



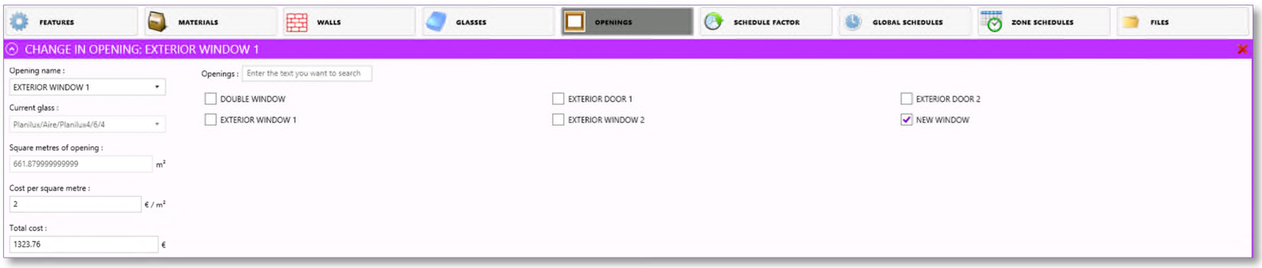
- **Walls.** If the user wants to change a wall, first she or he has to select the wall to be changed. The user can observe the square meters of the wall (m^2), and if she or he sets a cost per square meter (€/m^2) and the program calculates the total cost (€). Then, the new wall or walls that are going to be simulated have to be selected. The program can implement parametric solutions of different measures at the same time.



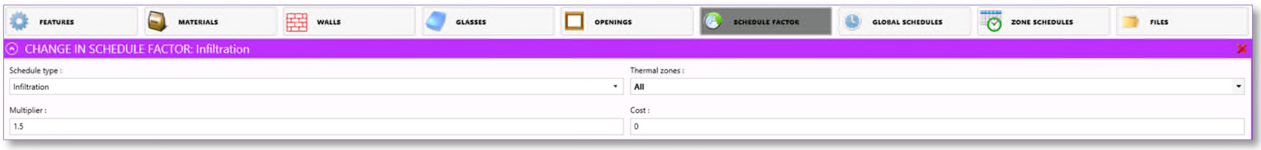
- **Glasses.** If the user wants to change the glass, first the user has to select the opening name and the current glass and the square meters of opening are shown. If the user sets a cost per square meter (€/m^2), the program calculates the total cost (€). Then, the user has to select the new glass or glasses.



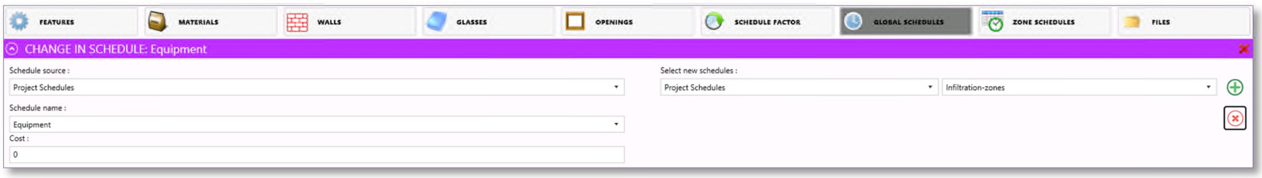
- **Openings.** If the user wants to change the opening, she or he just has to select the current opening and the new one. The current glass is observed as well as the square meters of opening (m^2). Establishing a cost per square meter (€/m^2) the program calculates a total cost (€).



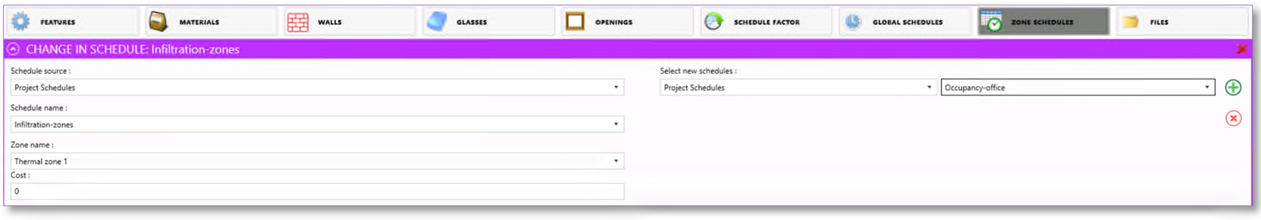
- **Schedule factor.** It is also possible to simulate an ECM with a new schedule multiplier. The user has to select the schedule type and the thermal zones to be applied and modify the multiplier.



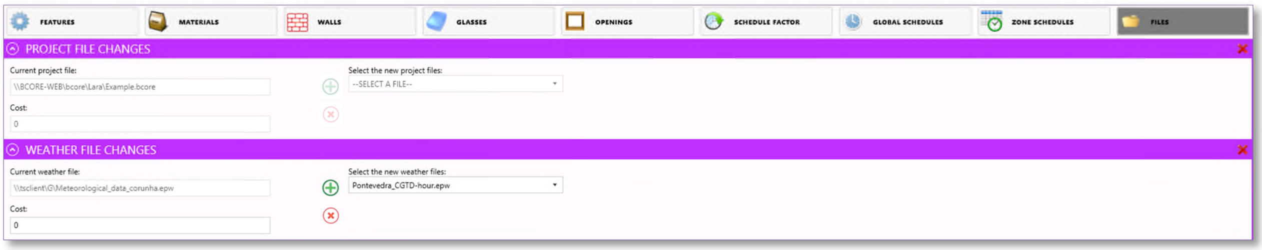
- **Global schedules.** It is possible to change one schedule for another in all the thermal zones.



- **Zone schedules.** And it is also possible to change one schedule for another but only in a selected thermal zone.

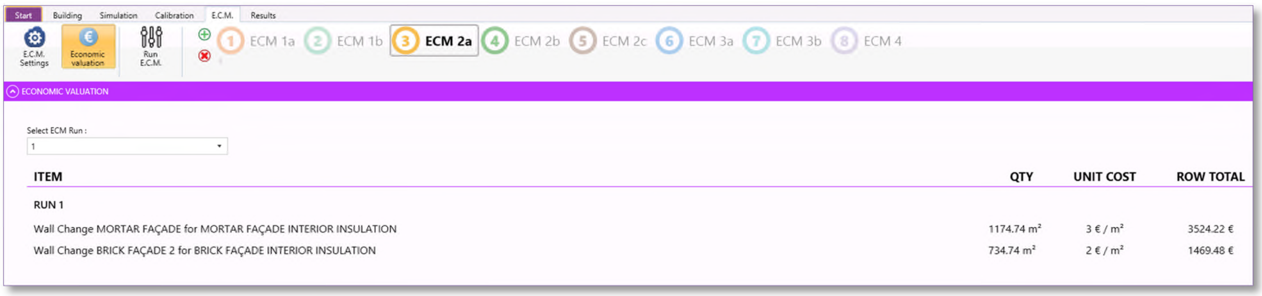


- **Files.** Finally, it is possible to change files as for example the weather data file or the project file.



ECONOMIC VALUATION

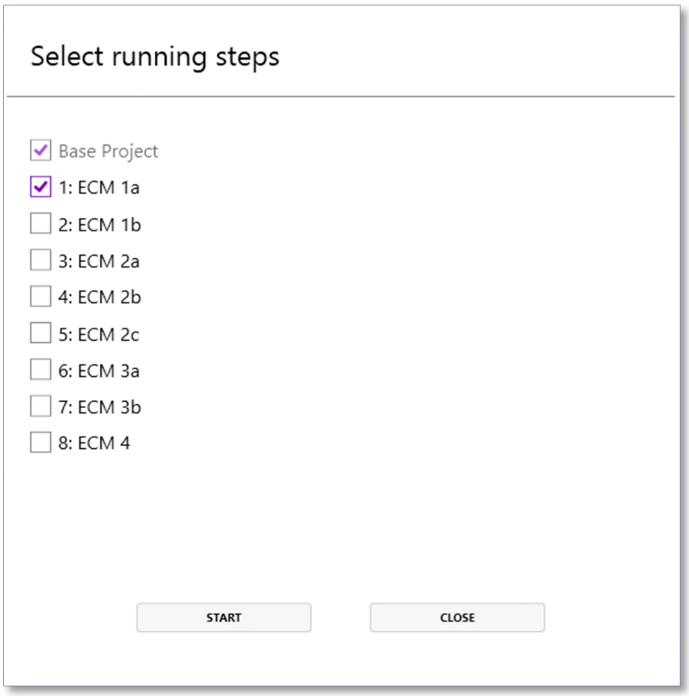
In addition, it is possible to set an economic assessment for each of the measures or modifications. This economic assessment is shown in this tab.

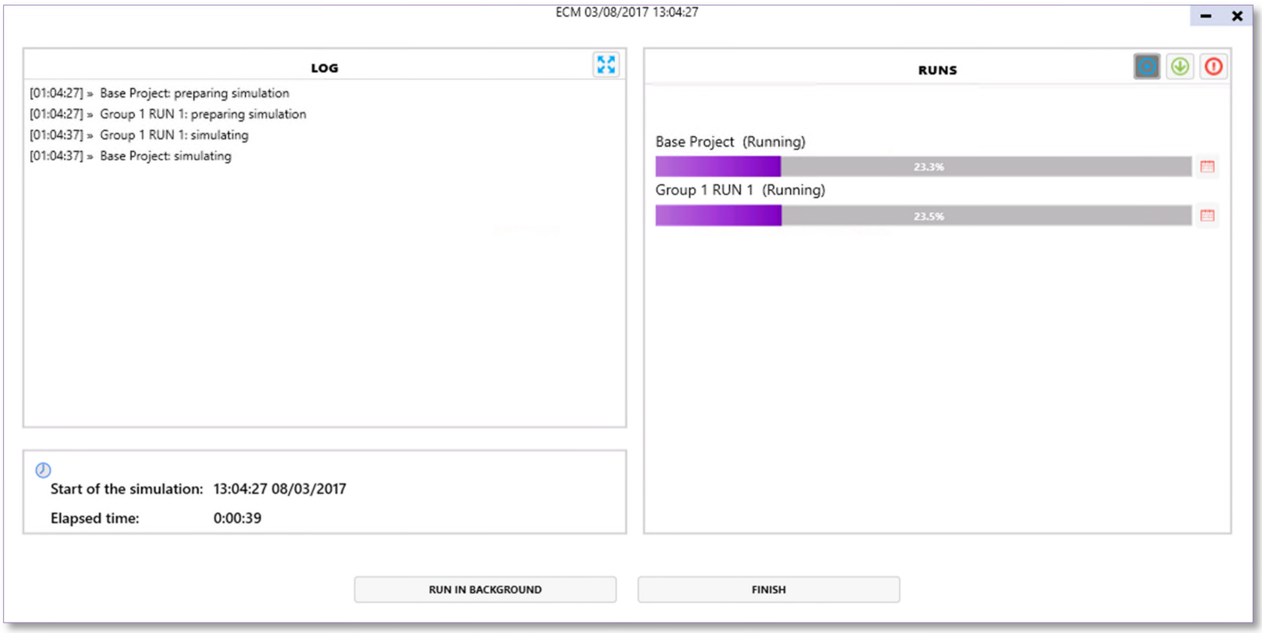


RUN ECM

Then, the user can run the ECM and the selected ECM is simulated as well as the base project.

Once these modifications are simulated, a simple comparison of results between the current state and altered states can be done, observed in the tab "Results". With this analysis, the user can adopt optimal measures for energy conservation in a building. Now, loading the outputs of the simulations, the base project can be compared with the measure selected.

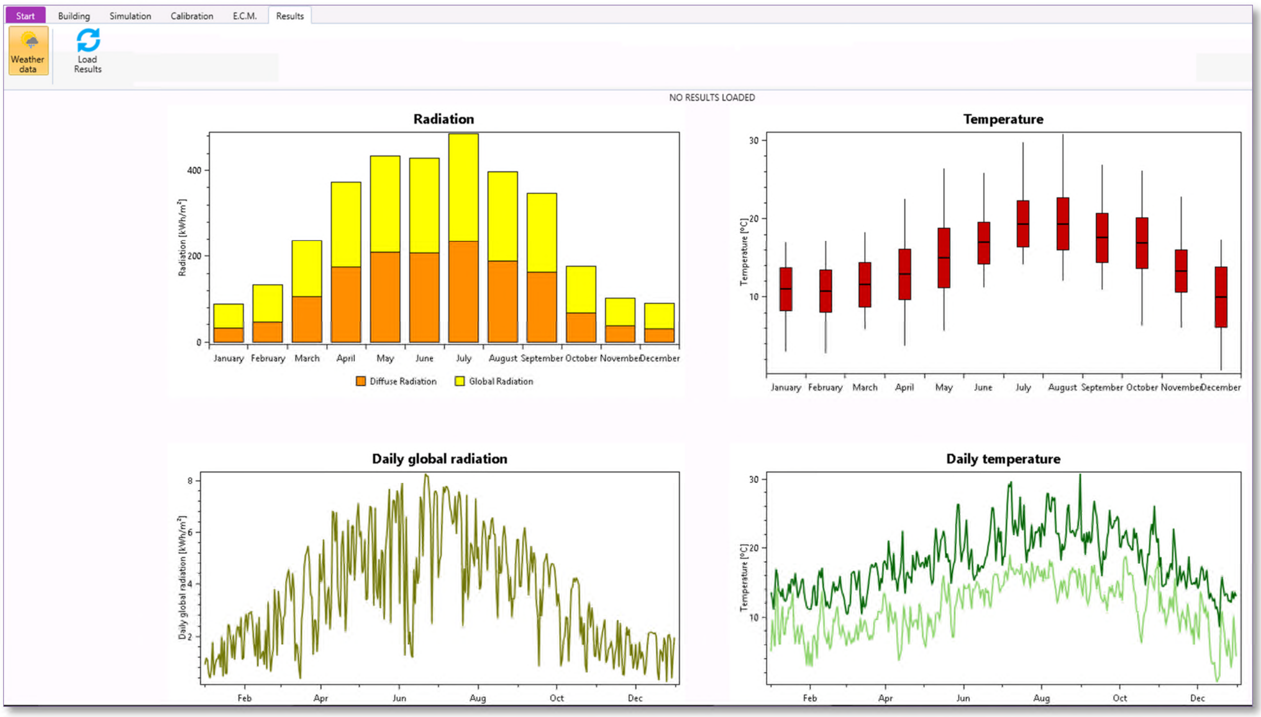

Select running steps
Base Project
1: ECM 1a
2: ECM 1b
3: ECM 2a
4: ECM 2b
5: ECM 2c
6: ECM 3a
7: ECM 3b
8: ECM 4
START
CLOSE


ECM 03/08/2017 13:04:27
LOG
[01:04:27] » Base Project: preparing simulation
[01:04:27] » Group 1 RUN 1: preparing simulation
[01:04:37] » Group 1 RUN 1: simulating
[01:04:37] » Base Project: simulating
Start of the simulation: 13:04:27 08/03/2017
Elapsed time: 0:00:39
RUNS
Base Project (Running)
23.3%
Group 1 RUN 1 (Running)
23.5%
RUN IN BACKGROUND
FINISH

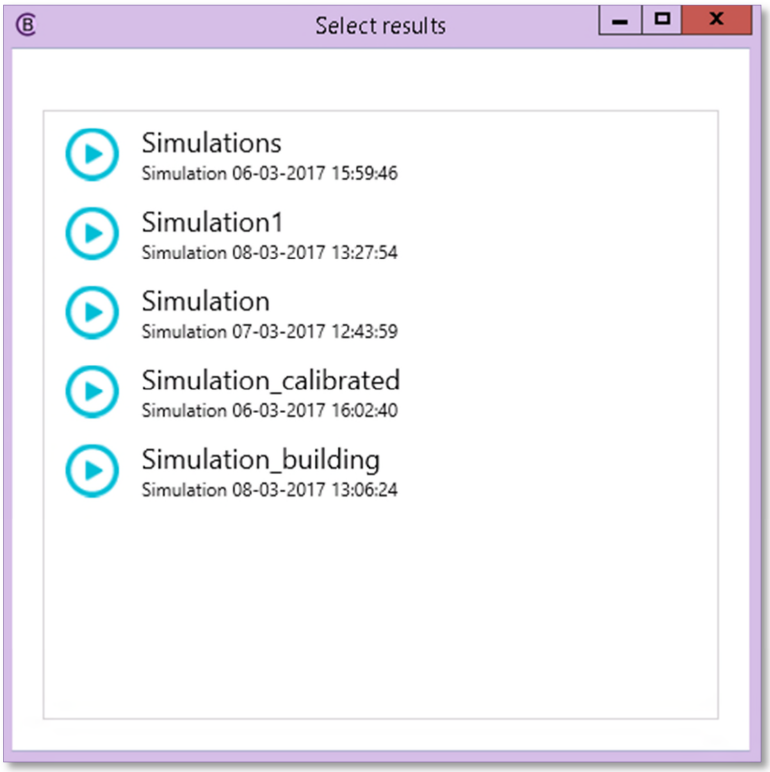
3.5 Results

Once the simulation model building is complete, the results are automatically saved and can be displayed represented as graphs. These results depend on the outputs selected previously. The information can be showed as an overview, by floor or by thermal zone. In addition, the data can be represented as bars, lines or circular graphs providing global information of the building, or distinguishing the results by floors or thermal zones. Reports can be generated with the results in an Excel file.

In addition, weather data file is represented and observed in figures of radiation, daily global radiation, temperature and daily temperature.



The user clicks over Load Results and select the simulation to show the results. Then, results of temperature, power and demand can be observed by overview, floor or zone.

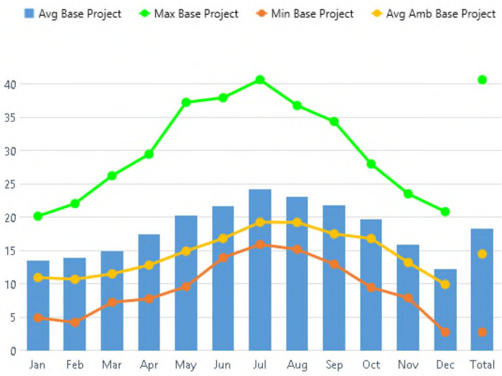


In the following figures, it is showed an example of results of a building simulation.

TEMPERATURE (ºC)

OVERVIEW

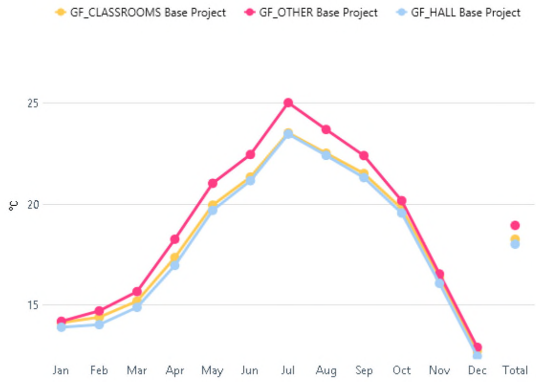
Building Summary: monthly temperatures



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Avg Base Project	13.6	13.9	15	17.5	20.3	21.8	24.3	23.1	21.8	19.8	15.9	12.3	18.3
Max Base Project	20.2	22.1	26.3	29.5	37.3	38	40.7	36.8	34.4	28.1	23.6	20.9	40.7
Min Base Project	5	4.3	7.3	7.8	9.7	14	16	15.2	13	9.5	8	2.8	2.8
Avg Amb Base Project	11	10.8	11.6	12.9	15	16.9	19.3	19.3	17.6	16.9	13.3	10	14.5

FLOOR

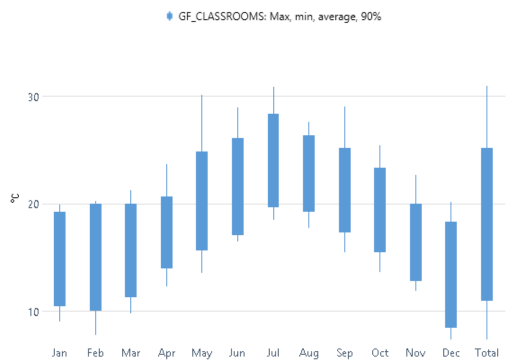
Ground Floor: Average temperatures (°C)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
GF_CLASSROOMS	14.1	14.4	15.2	17.4	20	21.4	23.5	22.5	21.5	19.8	16.4	12.7	18.3
GF_OTHER	14.2	14.7	15.7	18.3	21	22.5	25	23.7	22.4	20.2	16.5	12.9	19
GF_HALL	13.9	14	14.9	17	19.7	21.2	23.5	22.4	21.3	19.6	16.1	12.5	18

ZONE

GF_CLASSROOMS: Max, min, average, 90%

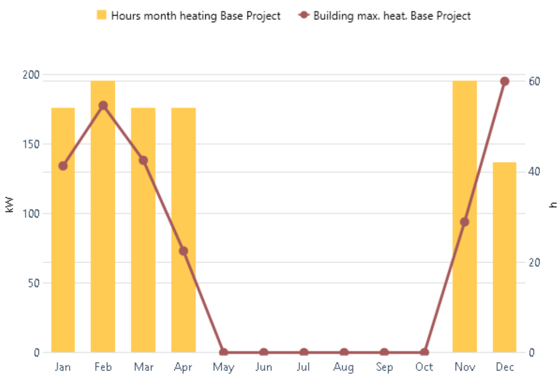


	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
	20	20.3	21.4	23.7	30.2	29.1	30.9	27.7	29.2	25.5	22.8	20.3	30.9
	14.1	14.4	15.2	17.4	20	21.4	23.5	22.5	21.5	19.8	16.4	12.7	18.3
	9.2	7.8	9.9	12.4	13.6	16.6	18.5	17.9	15.6	13.7	12	7.4	7.4
	10.5	10.1	11.4	14	15.7	17.2	19.7	19.3	17.4	15.6	12.9	8.5	11.1
	19.3	20	20	20.6	24.8	26.1	28.4	26.4	25.2	23.3	20	18.4	25.2

POWER (kW)

OVERVIEW

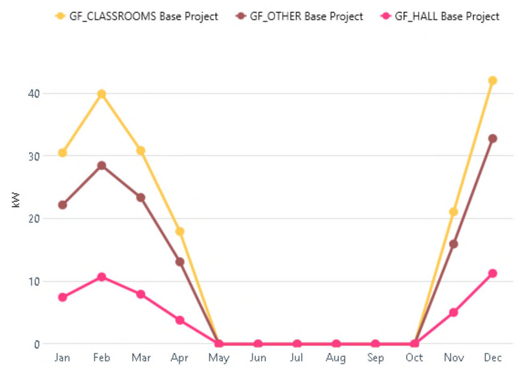
Building Heating. Monthly analysis: max. power required and hours of use



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	54	60	54	54	0	0	0	0	0	0	60	42
	134.12	177.6	138.14	72.98	0	0	0	0	0	0	93.88	194.9

FLOOR

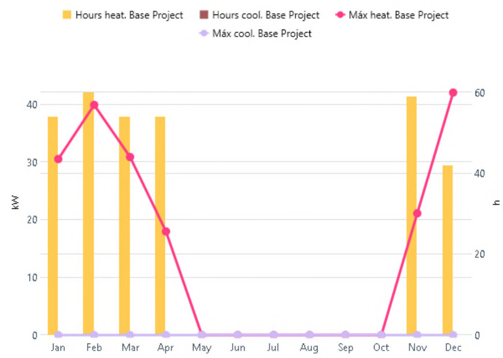
Ground Floor: max. power required for heating



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	30.53	39.92	30.89	17.98	0	0	0	0	0	0	21.12	42.06
	22.22	28.5	23.39	13.13	0	0	0	0	0	0	15.98	32.81
	7.48	10.72	7.96	3.82	0	0	0	0	0	0	5.06	11.29

ZONE

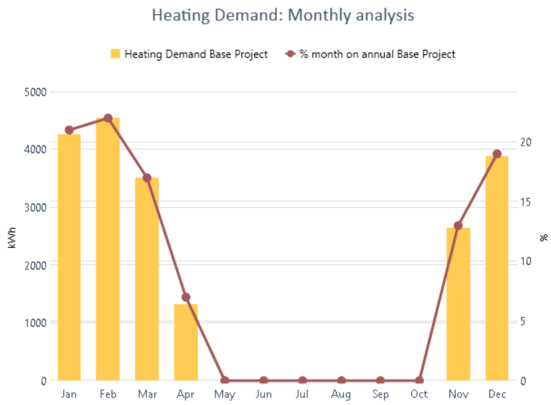
GF_CLASSROOMS: max. power required and hours of use



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	54	60	54	54	0	0	0	0	0	0	59	42
	0	0	0	0	0	0	0	0	0	0	0	0
	30.53	39.92	30.89	17.98	0	0	0	0	0	0	21.12	42.06
	0	0	0	0	0	0	0	0	0	0	0	0

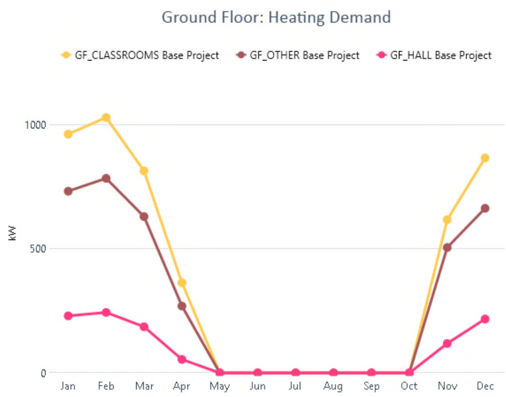
DEMAND (kWh)

OVERVIEW



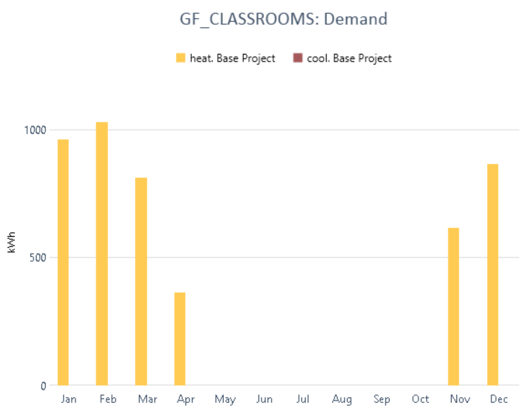
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	4274	4548	3522	1331	0	0	0	0	0	0	2642	3899
	21	22	17	7	0	0	0	0	0	0	13	19

FLOOR



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	963.58	1030.7	815.44	364.13	0	0	0	0	0	0	618.4	867.46
	733.38	785.26	631.01	270.03	0	0	0	0	0	0	506.18	664.49
	230.34	244.21	186.4	54.66	0	0	0	0	0	0	118.91	217.57

ZONE

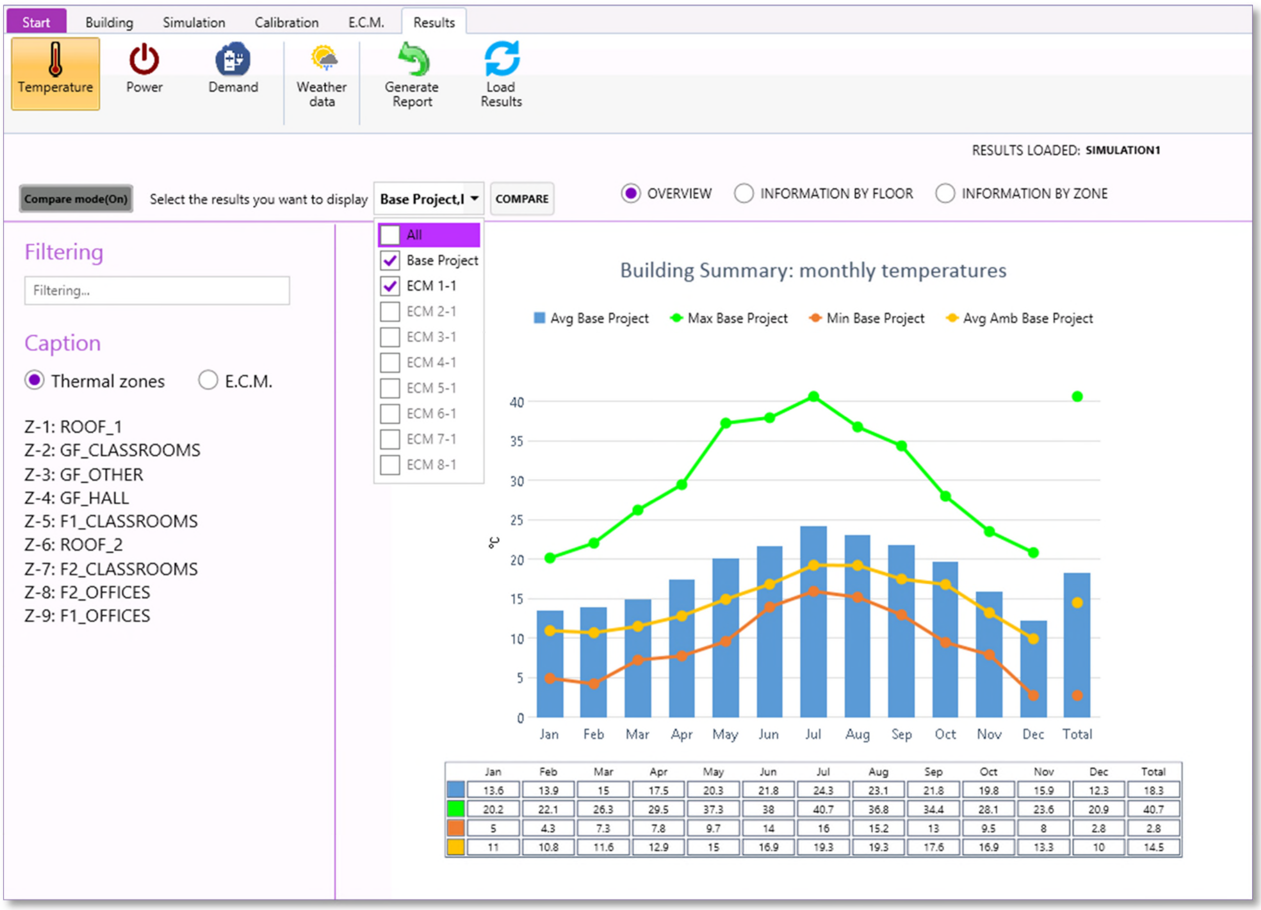


	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	964	1031	815	364	0	0	0	0	0	0	618	867
	0	0	0	0	0	0	0	0	0	0	0	0

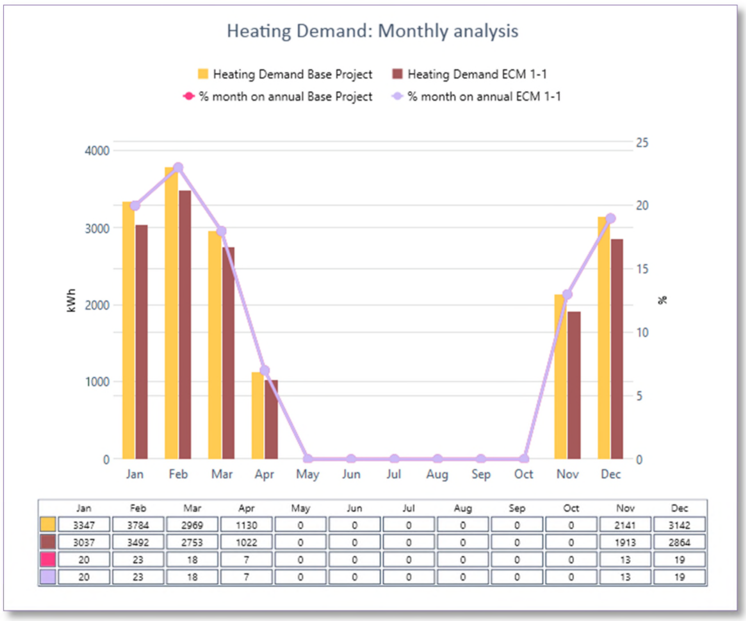
When an ECM is simulated, it can be observed among with the project base in the outputs, activating the "comparison mode" that allows the comparison between the projects.

Toolset to improve building's energy efficiency

ENGINENCY

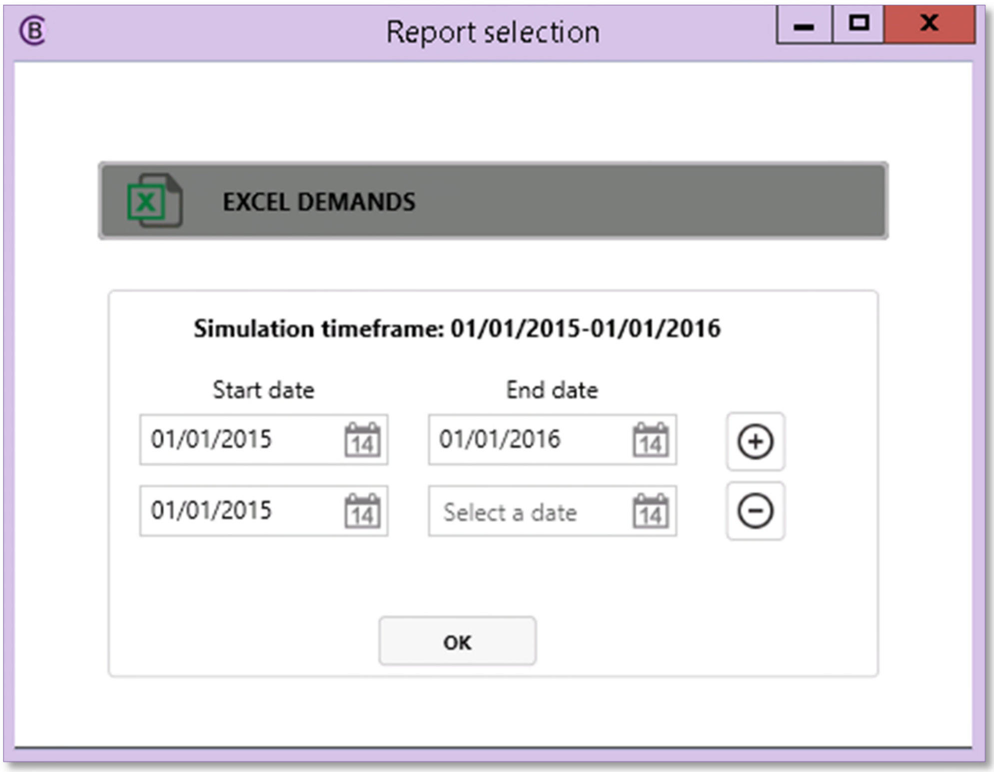


	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Avg Base Project	13.6	13.9	15	17.5	20.3	21.8	24.3	23.1	21.8	19.8	15.9	12.3	18.3
Max Base Project	20.2	22.1	26.3	29.5	37.3	38	40.7	36.8	34.4	28.1	23.6	20.9	40.7
Min Base Project	5	4.3	7.3	7.8	9.7	14	16	15.2	13	9.5	8	2.8	2.8
Avg Amb Base Project	11	10.8	11.6	12.9	15	16.9	19.3	19.3	17.6	16.9	13.3	10	14.5



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Heating Demand Base Project	3347	3784	2969	1130	0	0	0	0	0	0	2141	3142
Heating Demand ECM 1-1	3037	3492	2753	1022	0	0	0	0	0	0	1913	2864
% month on annual Base Project	20	23	18	7	0	0	0	0	0	0	13	19
% month on annual ECM 1-1	20	23	18	7	0	0	0	0	0	0	13	19

Finally, the button Generate Report allows to generate a report of the thermal demands that can be downloaded as an Excel file. The program allows the user to select the start date and the end date of the simulation timeframe even in different periods.



Toolset to improve building's energy efficiency