



## HI-SMART: HIGHER EDUCATION PACKAGE FOR NEARLY ZERO ENERGY AND SMART BUILDING DESIGN

# MODULE #7

### CHAPTER 3: SIMULATIONS IN DESIGNBUILDER SOFTWARE

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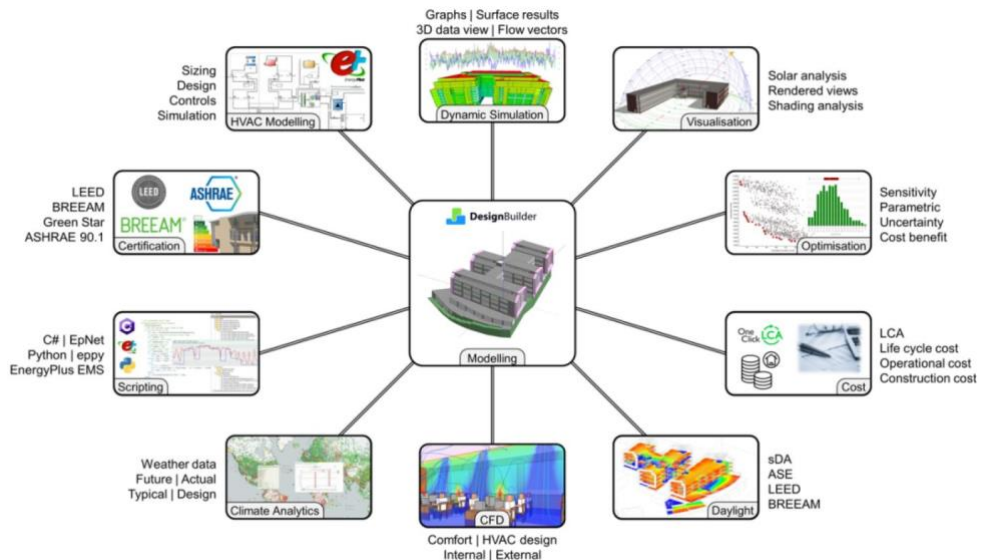


SLOVAK UNIVERSITY OF  
TECHNOLOGY IN BRATISLAVA



### 7.3.1 WHAT IS DESIGNBUILDER?

DesignBuilder represents an advanced computational tool for integrated building design which combines fast 3D building modeling with dynamic energy simulations. It is developed to ease up the building simulation process with user-friendly modelling environment where you can work with virtual building models. It is one of the most popular BES software which works under EnergyPlus dynamic simulation engine to generate performance data. DesignBuilder uses ASHRAE design weather database for certain locations of simulation model. A range of performance data can be simulated such as: energy consumption, CO<sub>2</sub> emissions, comfort conditions, daylight illuminance, maximum summertime temperatures and HVAC systems. DesignBuilder comprises a core 3-D modeller and 11 modules which work together to provide in-depth analysis for any building. Every module fully integrates with its counterparts, so you can pick individual modules or choose one of our packages (Fig. 1).



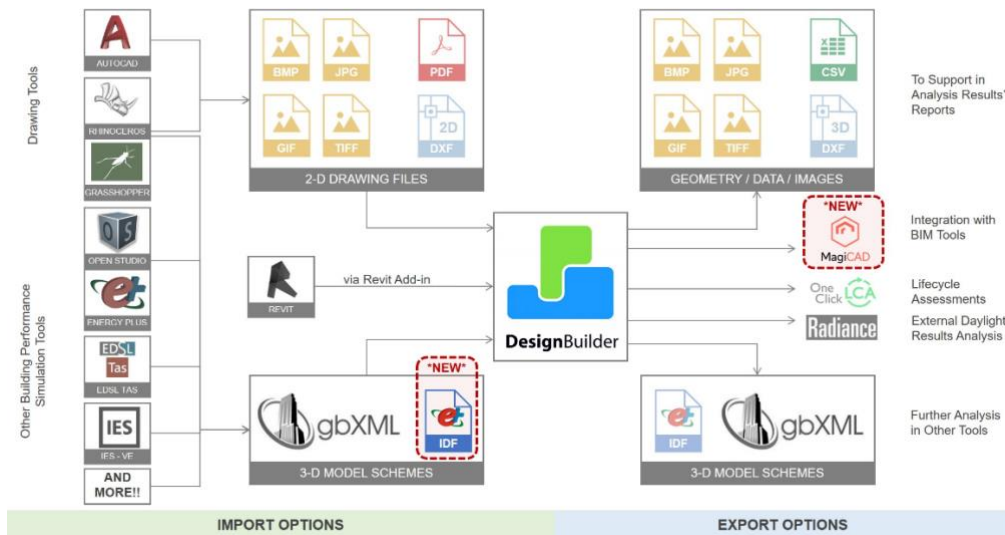
1. figure – Structure and modules of DesignBuilder. Source: [designbuilder.co.uk](http://designbuilder.co.uk)

Modules:

- **3-D Modeller** - The core module, our efficient 3-D building modeller.
- **Visualisation** - Visualisation: Stunning rendered images and site shading analysis.
- **Certification** - EPCs and Part-L2 calculations in UK and Ireland.
- **Simulation** - EnergyPlus simulations for energy and comfort analyses.
- **Daylighting** - Reports daylight factors and illuminance using Radiance.
- **HVAC** - A powerful and flexible interface to EnergyPlus HVAC.
- **Cost** - Early stage building cost estimation.
- **LEED** - LEED EAp2 and ASHRAE 90.1 calculations.

- **Optimisation** - Multi-criteria optimisation to help meet design goals.
- **Scripting** - Customise EnergyPlus simulations using EMS or FMU.
- **CFD** - Computational Fluid Dynamics calculates distribution of air properties in and around buildings.

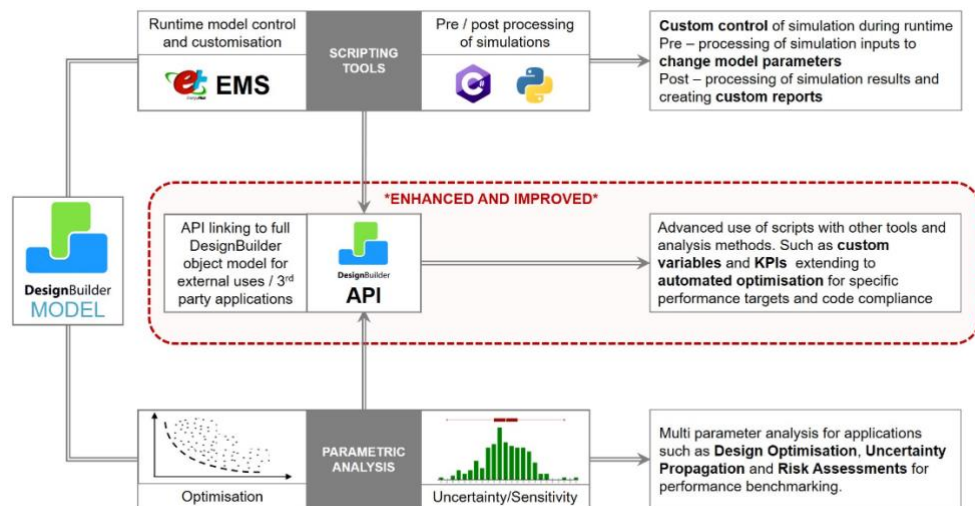
DesignBuilder provides multiple import and export options in a variety of formats to maximise interoperability with other tools (Fig.2).



2. figure – Interoperability of DesignBuilder. Source: designbuilder.co.uk

Moreover, DesignBuilder provides a relatively open platform with full access to simulation inputs, outputs, Energy Management System (EMS) runtime scripting tools and EnergyPlus source code (Fig. 3). The Scripting module provides access to 3 different toolsets:

- **EMS Runtime Scripting tools**
- **C# Scripting tools**
- **Python Scripting**



3. figure – Extensibility of DesignBuilder. Source: designbuilder.co.uk

DesignBuilder stores all of its main model data in a single file with .dsb extension making it easy for you to send project models along with associated results to colleagues and clients. A .dsb file includes:

- Building geometry
- Model data settings
- HVAC data
- Model components and templates
- Any user-defined weather files
- Any user-defined textures
- All results for Heating design, Cooling design, Simulation, Daylighting, Cost/Carbon, Optimisation and CFD (including all project variations)

### 7.3.2 CREATING A MODEL GEOMETRY

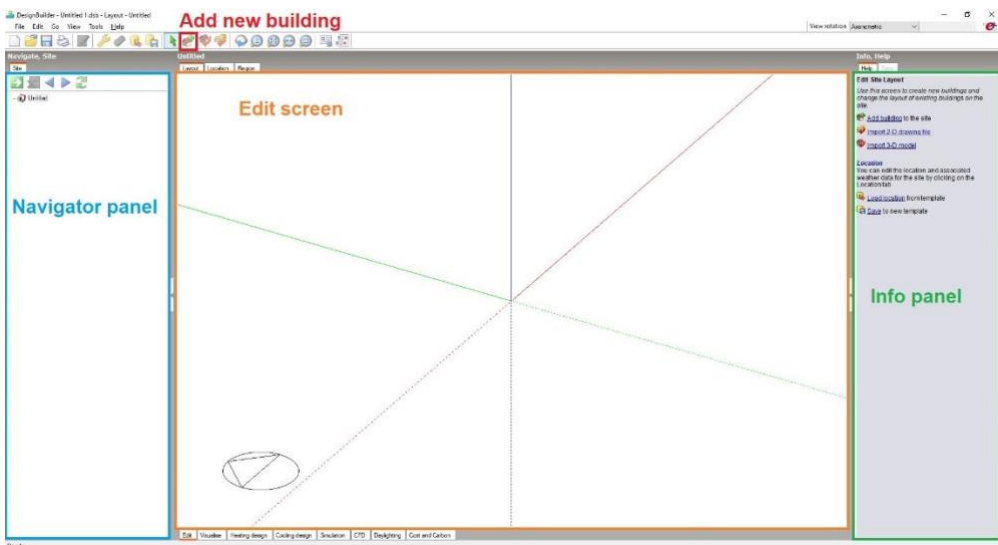
Before we start to create model geometry, it is necessary to define data: title, analysis type and location (Fig. 4). Where the location defines the geographical location and weather data for all buildings on this site. There is possible to load data from various location templates or override the default data. It is also possible to import 2-D DXF floor plan files created in AutoCAD or other CAD programs, or the other bitmap-based drawing formats. This will form the basis plane for the correct creation of individual blocks or zones according to the project documentation of a building. Moreover, it is possible to import 3-D BIM data using the gbXML data format. To start the process, click on the Files and then Import.



4. figure – Creating a new file

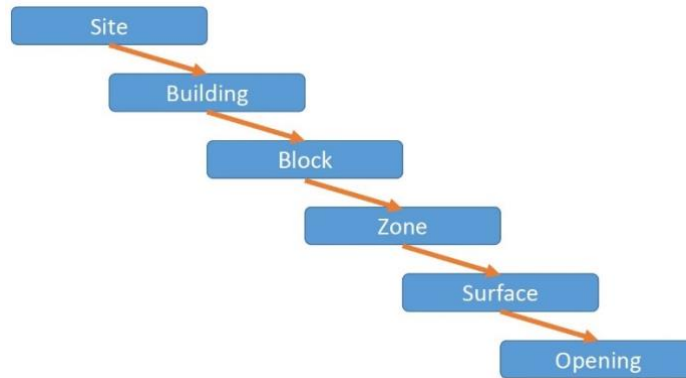
Thereafter, program skips to the modelling environment with various tabs, where are three basic screens: navigator panel, edit screen and info panel (Fig. 5). It is possible to add one or more new buildings from the site level. Each building has its own set of model options and is simulated separately but shares site model data with the other buildings on the site. The **Add new building** tab presents the Add new building dialog which allows to make some basic settings:

- Building - basic setting for the building model
- Default Data - defaults for Construction, Activity, Glazing, Lighting and HVAC



5. Modelling environment in DesignBuilder

DesignBuilder models are organised in a data hierarchy together with data inheritance, where default data is inherited from the level above in the hierarchy, so block data is inherited from building level, zone data is inherited from block data and surface data from zone data (Fig. 6). This hierarchy mechanism provides a fast way of setting data globally in a building model.

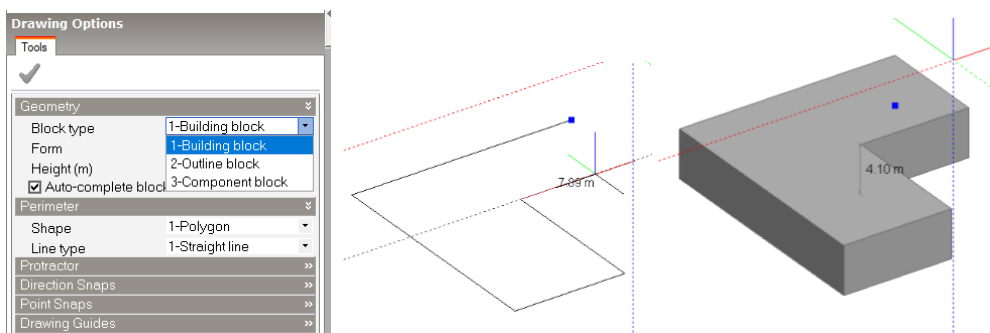


## 6. Model data hierarchy

At building level, it is possible to add or edit blocks. Blocks are the basic elements used to create a 3-D DesignBuilder model and are created by drawing 2-D perimeters on horizontal or vertical planes and then extruding these perimeters to form 3-D shapes. Three types of blocks can be added to the building:

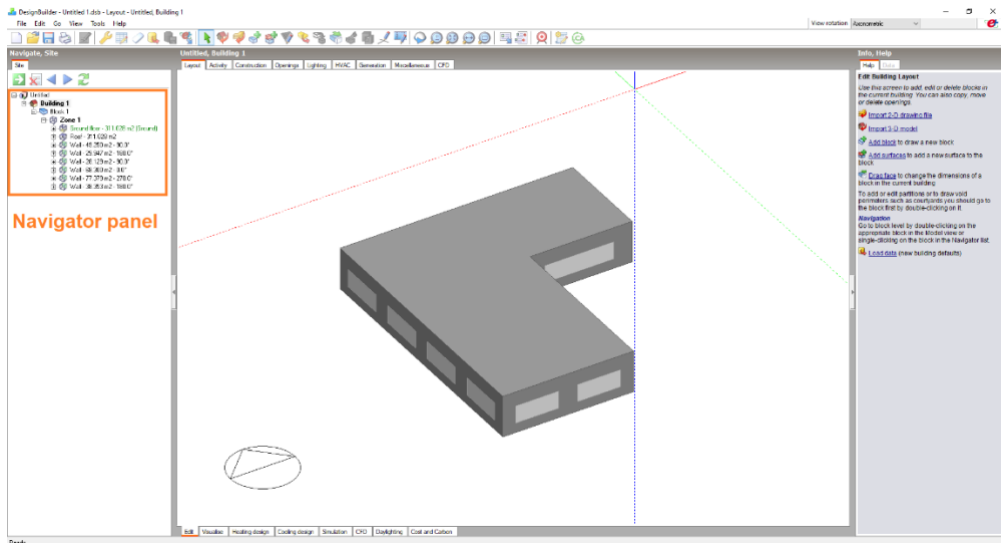
- **Building Blocks** are the mechanism to create 3-D building volumes. They are often referred to in simply as Blocks and are composed of building elements such as walls, floor slabs and roofs . Building blocks may be partitioned internally to form a number of zones.
- **Outline Blocks** are used to help in the creation of more complex building block geometry.
- **Component Blocks** are used to create visual, ground and shading structures which do not contain zones.

Blocks are versatile objects and once created can easily be modified by moving their surfaces, by stretching them and even by cutting them using arbitrary planes. Usually, a block represents an entire building storey. When a block has been placed, additional blocks can be drawn onto any surface of the block to form more complex aggregate blocks.

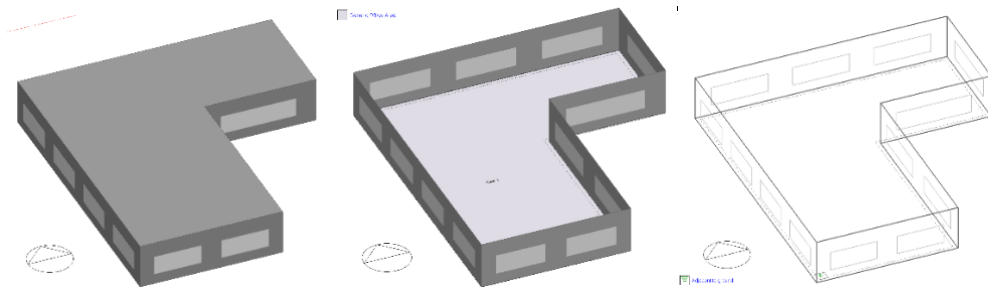


## 7. Creating a building block

After drawing an extruded block perimeter on a plane, the block will be automatically extruded by the height. This new block has predefined building properties with individual construction components. The new entry occurs in the Navigator panel where is possible to click and navigate in site hierarchy continuously between structures, zones, blocks and buildings (Fig. 8). By simple clicking it is possible to switch between these groups (Fig. 9).



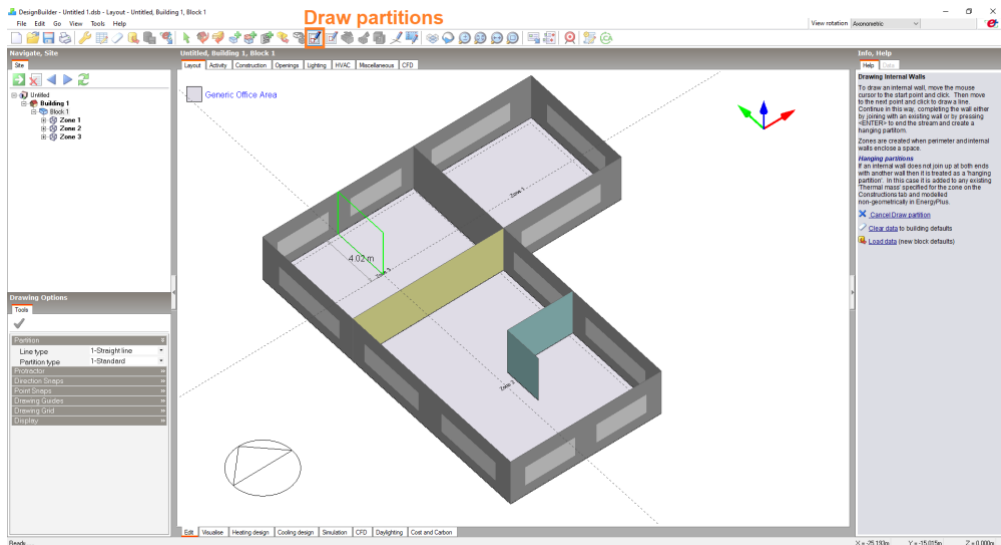
8. New building block



9. Switching between elements in model hierarchy.

Building blocks can be divided into any number of zones by drawing partitions inside the block (Fig. 10). It is possible place partitions freely within a block either free-standing or snapped to an external block wall or existing partition. By entering the thickness of the first partition drawn in the block subsequent partitions will take on the same thickness as the first. Three types of partitions can be entered:

- Standard (grey) - material partitions
- Virtual (yellow) – for creating a separate zone in cases where there is no real construction
- Hanging (blue) – partitions to take into account the heat capacity inside the zone



## 10. Drawing partitions in block

The zone type can be set at block or zone level on the Activity tab, where 4 types of zones can be selected:

- **Standard** - the zone is within the main envelope and is usually (but not necessarily) occupied and heated and/or cooled. This zone type also covers zones within the main building envelope that are unoccupied and not directly heated or cooled such as offices that are temporarily unoccupied may come into this category.
- **Semi-external unconditioned** - the zone is unoccupied and is neither heated nor cooled and lies outside the main building envelope. Examples of unconditioned spaces are roofspaces, sunspaces, crawlspaces, car parks etc.
- **Cavity** - the zone is a narrow sealed vertical cavity such as the glazed cavity within a double façade or a Trombe wall. This algorithm calculates the convection coefficients for such a cavity based on the ISO 15099 standard.
- **Plenum** - the zone is a plenum which is unoccupied and has no heating, cooling, or mechanical ventilation (though of course air can flow through it to meet the needs of the zones it serves).

Constructions components are used to model the conduction of heat through walls, roofs, ground and other opaque parts of the building envelope (wall, floors, roofs, etc.) (Fig. 11). They are made from individual material layers with defined physical properties at Construction tab (Fig. 12). The thermal properties of the construction are calculated based on layers, each layer having a material reference and thickness (Fig. 13). Cross-section of building element is display with each material layer (Fig. 14).



Construction Template	
Template	Project construction template
Construction	
External walls	Project wall
Below grade walls	Project below grade wall
Flat roof	Project flat roof
Pitched roof (occupied)	Project pitched roof
Semi-Exposed	
Semi-exposed ceiling	Project semi-exposed ceiling
Semi-exposed floor	Project semi-exposed floor
Floors	
Ground floor	Project ground floor
External floor	Project external floor
Internal floor	Project internal floor
Sub-Surfaces	
Internal Thermal Mass	
Geometry, Areas and Volumes	
Surface Convection	
Linear Thermal Bridging at Junctions	
Airtightness	
<input checked="" type="checkbox"/> Model infiltration	
Constant rate (ac/h)	0.700
Schedule	On 24/7
Delta T and Wind Speed Coefficients	
Cost	

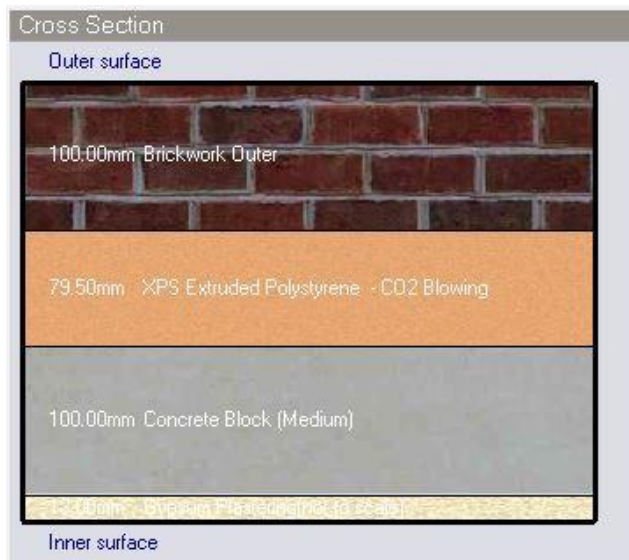
## 11. Construction tab

Constructions	
Layers	Surface properties
Image	Calculated
Cost	Condensation analysis
General	
Name	Project wall
Source	
Category	Walls
Region	SLOVAKIA (Slovak Republic)
Colour	
Definition	
Definition method	1-Layers
Calculation Settings	
Layers	
Number of layers	4
Outermost layer	
Material	Brickwork Outer
Thickness (m)	0.1000
<input type="checkbox"/> Bridged?	
Layer 2	
Material	XPS Extruded Polystyrene - CO2 Blowin
Thickness (m)	0.0795
<input type="checkbox"/> Bridged?	
Layer 3	
Material	Concrete Block (Medium)
Thickness (m)	0.1000
<input type="checkbox"/> Bridged?	
Innermost layer	
Material	Gypsum Plastering
Thickness (m)	0.0130
<input type="checkbox"/> Bridged?	

## 12. Definition of individual material layers of the wall in Construction tab

Inner surface		«
Convective heat transfer coefficient (W/m <sup>2</sup> -K)	2.152	
Radiative heat transfer coefficient (W/m <sup>2</sup> -K)	5.540	
Surface resistance (m <sup>2</sup> -K/W)	0.130	
Outer surface		«
Convective heat transfer coefficient (W/m <sup>2</sup> -K)	19.870	
Radiative heat transfer coefficient (W/m <sup>2</sup> -K)	5.130	
Surface resistance (m <sup>2</sup> -K/W)	0.040	
No Bridging		«
U-Value surface to surface (W/m <sup>2</sup> -K)	0.372	
R-Value (m <sup>2</sup> -K/W)	2.856	
<b>U-Value (W/m<sup>2</sup>-K)</b>	<b>0.350</b>	
With Bridging (BS EN ISO 6946)		«
Thickness (m)	0.2925	
Km - Internal heat capacity (KJ/m <sup>2</sup> -K)	134.8000	
Upper resistance limit (m <sup>2</sup> -K/W)	2.856	
Lower resistance limit (m <sup>2</sup> -K/W)	2.856	
U-Value surface to surface (W/m <sup>2</sup> -K)	0.372	
R-Value (m <sup>2</sup> -K/W)	2.856	
<b>U-Value (W/m<sup>2</sup>-K)</b>	<b>0.350</b>	

### 13. Calculated thermal properties of the wall structure



### 14. Cross-section of the wall structure

Openings Model Data (Windows, Doors, Vents, Holes, Sub-Surfaces) can be entered in Openings tab in model data (Fig. 15), where the layout, operation and construction data for these (apart from sub-surfaces) can be set. The settings such as Window to wall % (WWR) and Window height, Window spacing and Sill height can easily change the amount of glazing and its layout on the walls. The configuration of the building façades can be controlled in

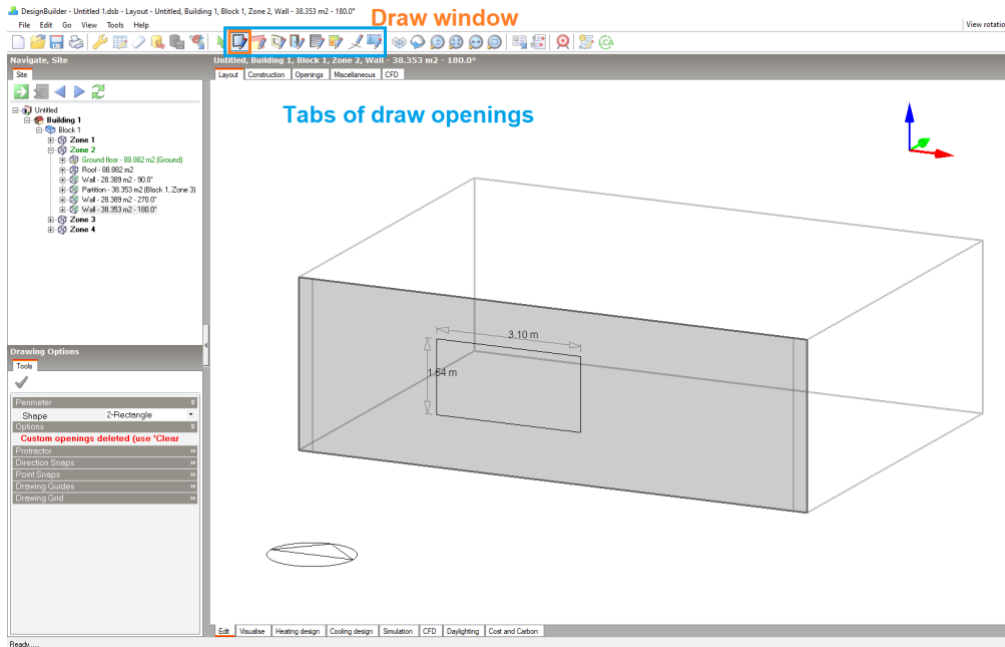
greater detail by drawing individual "custom" windows at the surface level or by copying previously drawn windows at building level. Moreover, window shading can be included to reduce solar gains and increase resistance to heat conduction through windows. Two types of shading for external windows can be entered:

- Window shading (blinds, curtains etc walls and roofs).
- Local shading (overhangs, louvres, side fins on external walls only)

Glazing Template	
Template	Project glazing template
External Windows	
Glazing type	Project external glazing
Layout	Preferred height 1.5m, 30% glazed
Dimensions	
Type	3-Preferred height
Window to wall %	30.00
Window height (m)	1.50
Window spacing (m)	5.00
Sill height (m)	0.80
Outside reveal depth (m)	0.000
Frame and Dividers	
<input checked="" type="checkbox"/> Has a frame/dividers?	
Construction	Painted Wooden window frame
Reveal	>>
Frame	>>
Dividers	>>
Shading	
<input checked="" type="checkbox"/> Window shading	
Type	Blind with high reflectivity slats
Position	1-Inside
Control type	3-Schedule
Slat Angle Control	>>
Operation	>>
Schedule definition	1-Follow occupancy
<input type="checkbox"/> Local shading	
Airflow Control Windows	
<input type="checkbox"/> Airflow control	
Free Aperture	
Opening position	1-Top
% Glazing area opens	5.0
Internal Windows	
Sloped Roof Windows/Skylights	
Glazing type	Project roof glazing
Layout	No roof glazing
Dimensions	>>
Frame and Dividers	>>
Shading	>>
Free Aperture	>>
Doors	

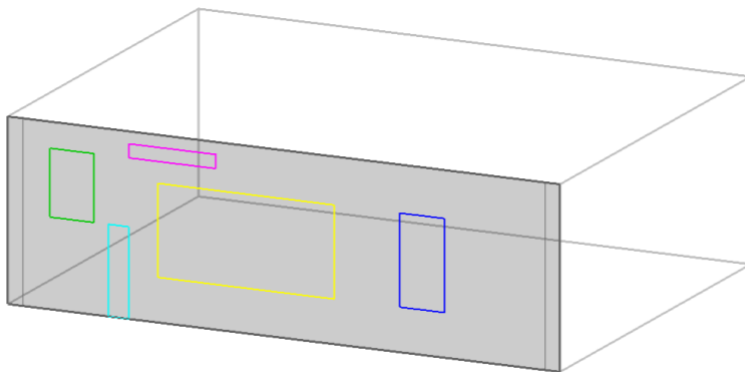
#### 15. Options in Openings tab

Creating of openings and sub-surfaces in a zone surface can be done by the clicking on the surface that you want to modify. When drawing windows, it should be drawn the whole opening area in the fabric including the space required for the frame. To add a window to a surface, click on the 'Draw window' tool (Fig. 16).



**16. Drawing windows**

Custom openings that have been drawn by hand or copied are displayed in bright colours to differentiate them from (grey) default openings: Yellow – windows, Blue - sub-surfaces, Green – holes, Cyan – doors, Magenta – vents (Fig. 17).



**17. Various options of drawing openings**

### 7.3.3 HVAC SYSTEMS

HVAC systems can be modelled in two ways: simple HVAC (Fig. 18) and detailed HVAC. There are also independent of HVAC model options: Natural Ventilation, Earth Tubes, Domestic Hot Water, Air Temperature Distribution.

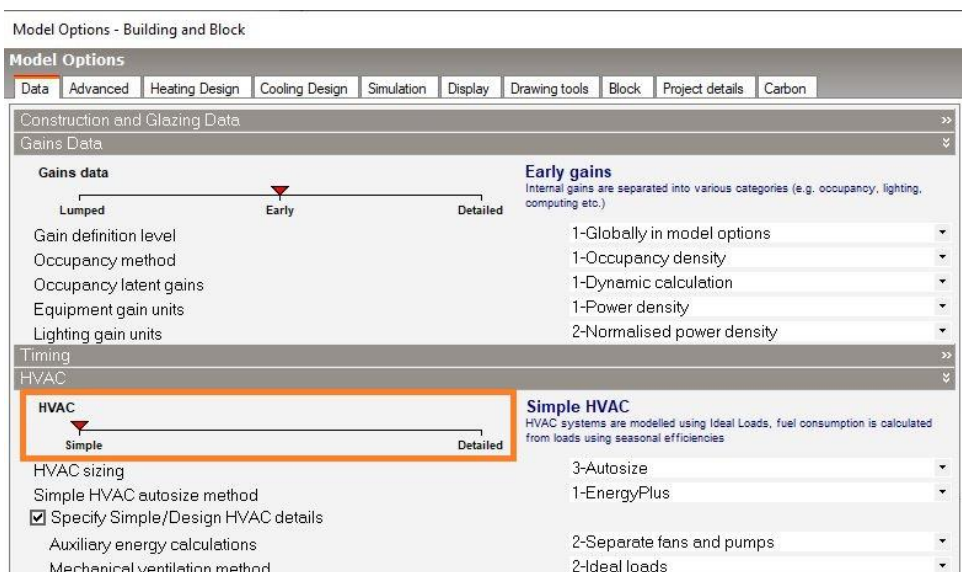
HVAC Template	
Template	Fan Coil Unit (4-Pipe), Air cooled Chiller
Mechanical Ventilation	
<input checked="" type="checkbox"/> On	
Outside air definition method	4-Min fresh air (Sum per person + per area)
Operation	
Schedule	Office_OpenOff_Occ
Economiser (Free Cooling)	>>
Heat Recovery	>>
Auxiliary Energy	
Pump etc energy (W/m2)	0.0000
Schedule	Office_OpenOff_Occ
Heating	
<input checked="" type="checkbox"/> Heated	
Fuel	2-Natural Gas
Heating system seasonal CoP	0.850
Sizing Zone Equipment	>>
Type	>>
Operation	
Schedule	Office_OpenOff_Heat
Cooling	
<input checked="" type="checkbox"/> Cooled	
Cooling system	Default
Fuel	1-Electricity from grid
Cooling system seasonal CoP	1.800
Supply Air Condition	>>
Operation	
Schedule	Office_OpenOff_Cool
Humidity Control	
>>	
DHW	
<input checked="" type="checkbox"/> On	
DHW Template	Project DHW
Type	4-Instantaneous hot water only
DHW CoP	0.8500
Fuel	1-Electricity from grid
Water Temperatures	
Delivery temperature (°C)	65.00
Mains supply temperature (°C)	10.00
Operation	
Schedule	Office_OpenOff_Occ
Natural Ventilation	
<input type="checkbox"/> On	
Earth Tube	
>>	

18. Simple HVAC tab

Simple HVAC is suitable for use at early design stages or for other analyses where detailed treatment of heating, cooling and mechanical ventilation systems is required. In summary, with Simple HVAC:

- Energy use is calculated based on space loads and system CoP value.
- Operational control provided by setpoints and schedules.
- Simple checkbox adds or removes the systems.
- Templates can be used to set performance characteristics of different systems.
- Auxiliaries and DHW are modelled based on schedules.
- Mech-vent, HR, nat-vent, mixed mode ventilation etc can also be modelled.

Switching between the simple HVAC and detailed HVAC option is in Model Options dialog and then in Data tab (Fig. 19).

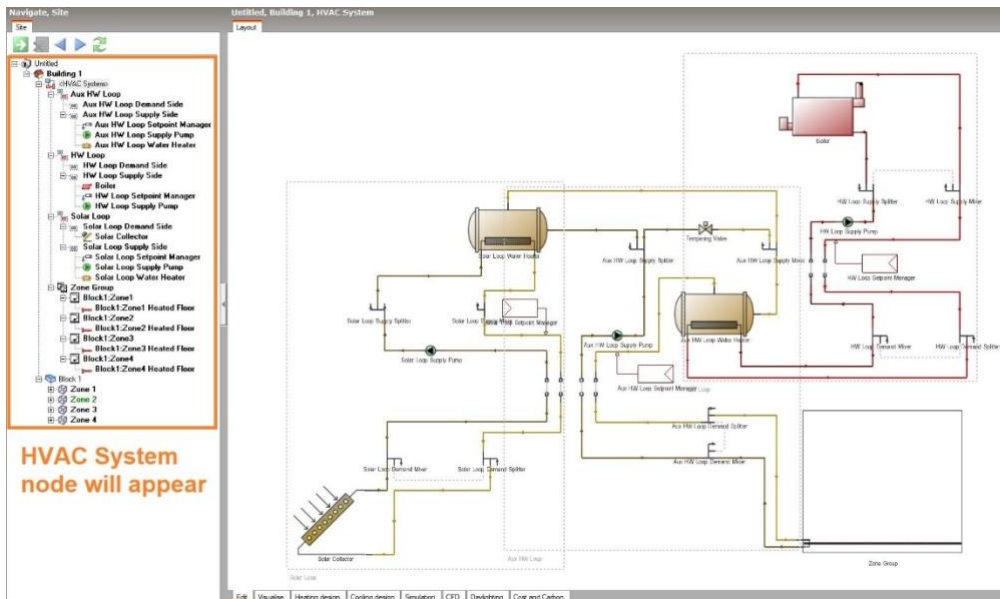


19. Simple HVAC tab

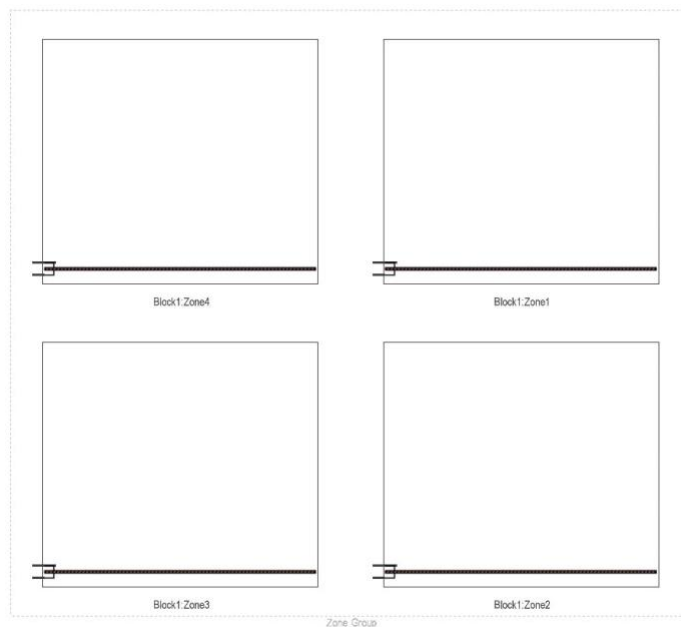
In Detailed HVAC, HVAC system is modelled in full detail using EnergyPlus air and water-side components linked together on a schematic layout drawing (Fig. 20). This method requires more effort in setting up the HVAC model description and a greater knowledge of HVAC systems than the Simple HVAC option. Moreover, this option provides increased flexibility but at the expense of extra work in setting up the setpoints etc, especially for large models. For example it is possible to have a range of different heating and cooling setpoint values set up using schedules for different times of the day or year. In summary, with Detailed HVAC:

- Energy use is calculated based on detailed performance and control parameters such as performance curves, setpoint managers, sequential controls etc.
- Diagrammatic system is built by connecting components of most common type of E+ systems to form loops.

- Air and water distribution systems are modelled using loops for hot water, chilled water loop, condenser and air supply.
- Zone groups are used to specify secondary, zone level system components and zones can have multiple types of terminal units simultaneously (Fig. 21).



20. Detailed HVAC system



21. Detailed HVAC elements in the zone

### 7.3.4 ACTIVITY

Data on the Activity tab allows you to define the activity (usage) of the zones including several information (Fig. 22).

The screenshot shows a software window titled "Activity Template" with a dropdown menu showing "Generic Office Area". The window is organized into several sections, each with a header bar and a dropdown arrow on the right:

- Template**:
  - Sector: B1 Offices and Workshop businesses
  - Zone type: 1-Standard
  - Zone multiplier: 1
  - ☒ Include zone in thermal calculations
  - ☒ Include zone in Radiance daylighting calculations
- Floor Areas and Volumes**: >>
- Occupancy**:
  - ☒ Occupied?
    - Occupancy density (people/m2): 0.1110
    - Schedule: Office\_OpenOff\_Occ
  - Metabolic: >>
  - Clothing: >>
  - Comfort Radiant Temperature Weighting: >>
  - Air Velocity: >>
- Contaminant Generation and Removal**: >>
- DHW**: >>
- Environmental Control**:
  - Heating Setpoint Temperatures:
    - Heating (°C): 22.0
    - Heating set back (°C): 12.0
  - Cooling Setpoint Temperatures:
    - Cooling (°C): 24.0
    - Cooling set back (°C): 28.0
  - Humidity Control: >>
  - Ventilation Setpoint Temperatures: >>
  - Minimum Fresh Air: >>
  - Lighting: >>
- Computers**:
  - ☐ On
- Office Equipment**:
  - ☒ On
    - Power density (W/m2): 11.77
    - Schedule: Office\_OpenOff\_Equip
    - Radiant fraction: 0.200
- Miscellaneous**:
  - ☐ On
- Catering**: >>
- Process**: >>

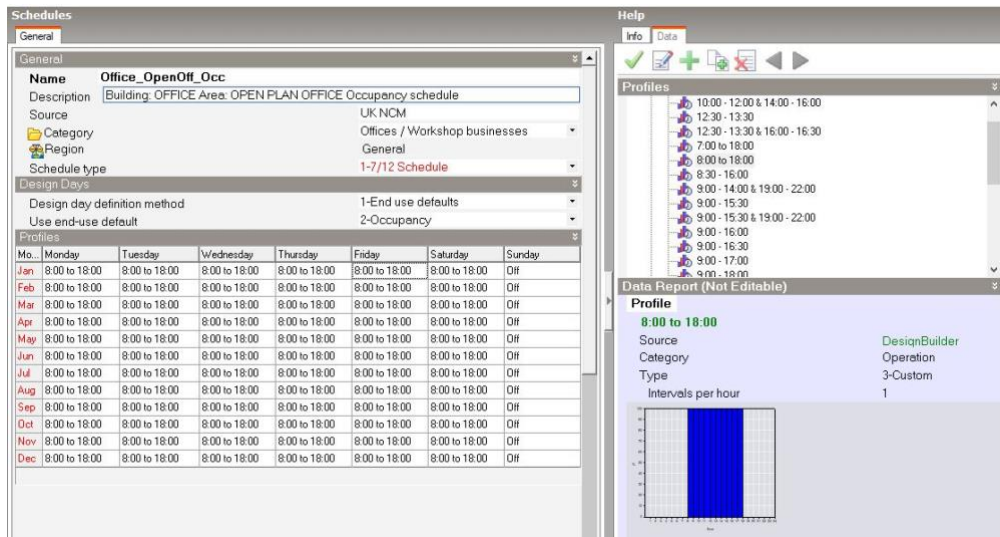
22. Activity tab

Very important modes are to define: Occupancy times, Equipment, lighting, HVAC operation, Heating and Cooling temperature setpoints, Transparency of component blocks (usually seasonal). Schedules are only used in simulations when the Timing model option is set to



'Schedules' (Fig. 23). Time schedules are used to set time-varying properties and can be entered in several ways:

- Typical working day (simple, less flexible)
- Schedules (flexible, most used)
  - 7/12 (enter values within 24 hours for 7 days a week and 12 months a year)
  - Compact (write profile using text notation)
- Holidays (supplement to the timetable)



23. Editing schedules

### 7.3.5 SIMULATION

After completing the simulation model, the simulation process can be initiated by clicking on Simulation tab, where are several options that control simulation and generated outputs. Select the start and end days for the simulation by selecting the start day and month and the end day and month (Fig. 24), or alternatively select a typical period using the links on the Info panel:

- **Annual simulation** - all 365 days of the year.
- **Summer design week** - a week identified as being the hottest of the year.
- **Summer typical week** - a week identified as being typical of the summer.
- **All summer** - simulate the whole summer (as identified by the weather data translator).
- **Winter design week** - a week identified as being the coldest of the year.
- **Winter typical week** - a week identified as being typical of the winter.
- **All winter** - simulate the whole winter (as identified by the weather data translator).

Moreover, Output Intervals for Reporting can be selected by one or more intervals for reporting from the available list:

- Monthly and Run period
- Daily
- Hourly
- Sub-hourly

Edit Calculation Options

The screenshot shows the 'Calculation Options' dialog box with the 'Output' tab selected. The 'Calculation Description' field is empty. The 'Simulation Period' section includes checkboxes for 'Run simulation for sizing periods' (unchecked) and 'Run simulation for hourly weather' (checked). The 'From' section shows 'Start day' as 1 and 'Start month' as Jan. The 'To' section shows 'End day' as 31 and 'End month' as Dec. The 'Output Intervals for Reporting' section has checkboxes for 'Monthly and Run period' (checked), 'Daily' (checked), 'Hourly' (unchecked), and 'Sub-hourly' (unchecked).

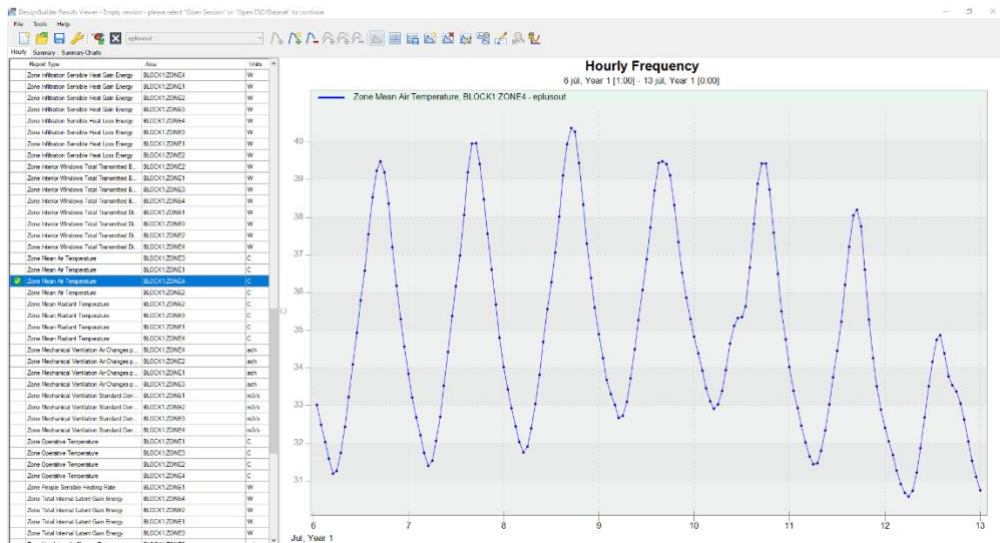
24. Adjusting calculation options

### 7.3.6 RESULTS

After finishing the simulation process, Analysis tab will display average and total simulation data for the selected building or other groups according to model hierarchy (blocks, zones, etc) (Fig. 25). Moreover, it is possible to work with the Results Viewer, which is a separate application and can be used to view EnergyPlus results stored in one or more .eso files (Fig. 26). It can be downloaded from the DesignBuilder website.



25. Simulation data in DesignBuilder



26. Simulation data in Result Viewer

### 7.3.7 REFERENCES

DesignBuilder Simulation Documentation for DesignBuilder v7.

[www.designbuilder.co.uk](http://www.designbuilder.co.uk)

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