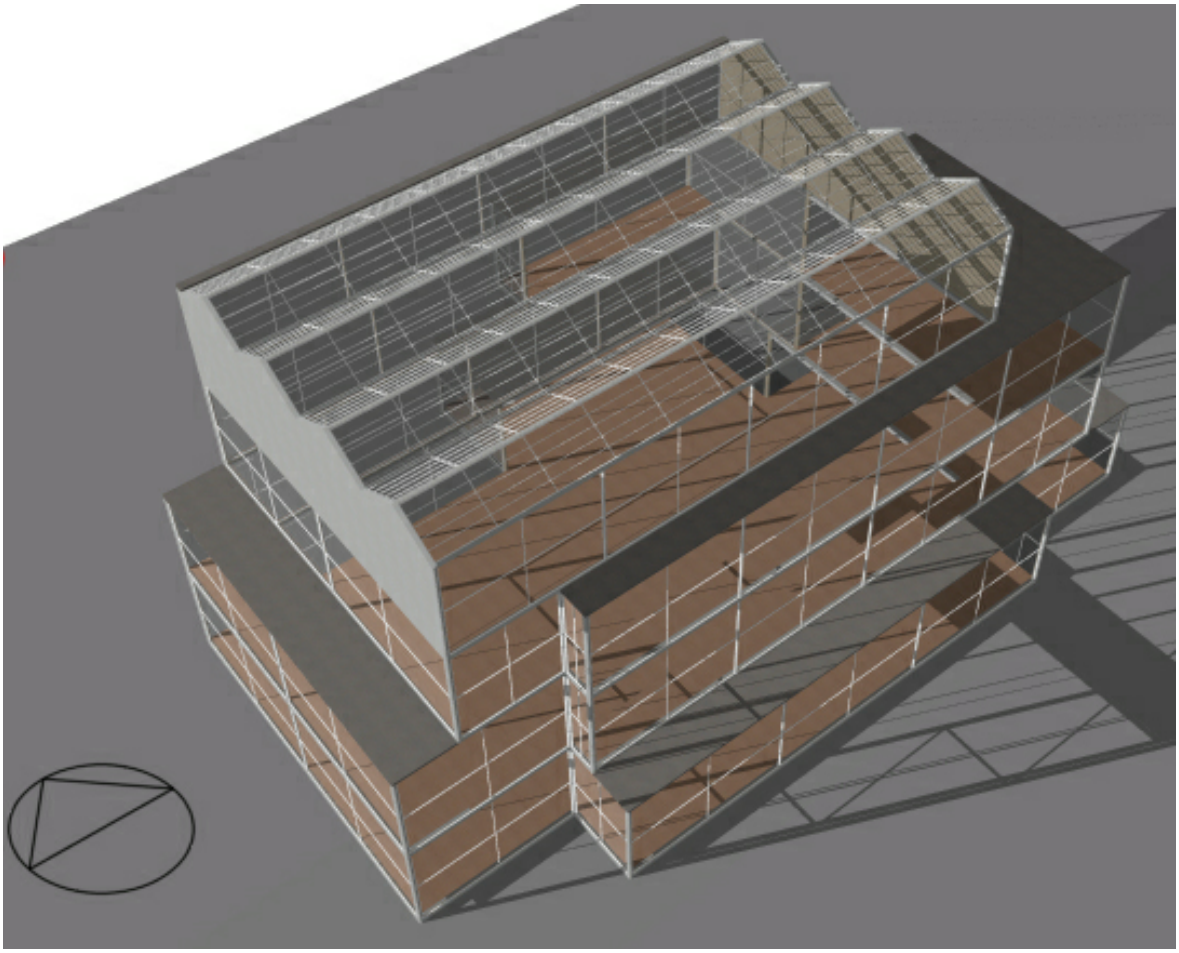
October 2009

DesignBuilder 2.1
User's Manual



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1 Getting Started

Welcome to DesignBuilder 2

DesignBuilder is a user-friendly modelling environment where you can work (and play) with virtual building models. It provides a range of environmental performance data such as: annual energy consumption, maximum summertime temperatures and HVAC component sizes.

Some typical uses are:

- Calculating building energy consumption.
- Evaluating façade options for overheating and visual appearance.
- Thermal simulation of naturally ventilated buildings.
- Daylighting - models lighting control systems and calculates savings in electric lighting.
- Visualisation of site layouts and solar shading.
- Calculating heating and cooling equipment sizes.
- Communication aid at design meetings.
- An educational tool.

DesignBuilder uses the EnergyPlus dynamic simulation engine to generate performance data.

Learning about DesignBuilder

If you're new to DesignBuilder you are probably keen to start using the program right away, but there's a few things you should do before you dive in:

- Watch the Getting Started Tutorials.
- Read Important tips about software use.

A few minutes spent with these resources will be time well spent.

Go to **Building model data**

Keeping up-to-date

Visit www.designbuilder.co.uk for upgrades, new products and news about DesignBuilder.

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1.1 DesignBuilder Tips

Miscellaneous information you should know before starting 'serious work' with DesignBuilder:

1. Buildings are put together by assembling blocks. Block creation and edit operations take place at the building level.
2. Blocks can be subdivided into more than one zone by drawing partitions. Partitioning takes place at the block level.
3. Default data is inherited from the level above, so blocks inherit their data from the building level, zones inherit their data from blocks, surfaces from zones and openings from surfaces. It is therefore possible to make global changes to the model by changing data at building level. It is possible to override default by editing the data. So for example, you could change the external wall construction for a whole block.
4. Data templates are the source of default data in DesignBuilder. They can also be used for loading data to the model en masse. For example you can load the 'Energy code - heavyweight' construction template at the building level to change the construction of the entire building to thermally heavyweight elements which comply with local energy codes/building regulations.
5. You can clear non-default data (i.e. data that has been explicitly entered) to its default state by using the Clear to default command.
6. When drawing a block which touches another block, you should use the shift key to lock the base perimeter to the correct plane before drawing. You can release the shift key once you have placed the first point of the perimeter.
7. Use the snap points - DesignBuilder block geometry is quite easy to work with but you must use the positioning tools provided to ensure that blocks connect exactly. The only way to do this is to use snaps - do not position blocks and partitions relative to each other 'by eye'.
8. Large building models can take a long time to simulate. You should familiarise yourself with the Working with Large Models help topic before creating a large/complex DesignBuilder model.
9. DesignBuilder dsb files are already compressed so there is no need to 'Zip' them when attaching to e-mails or support forums.
10. Understand DesignBuilder constructions, in particular the way floors and ceilings are defined.
11. Name your zones. Do this by clicking twice (not double-clicking) on the name in the Navigator and typing the name. This is especially useful when merging zones and when checking adjacencies of individual surfaces in the Navigator.
12. If you are exporting IDF data for use outside DesignBuilder please read the Exporting EnergyPlus IDF Files topic.

1.2 Capabilities

- Environmental performance data is displayed without needing to run external modules and import data and any simulations required to generate the data are started automatically.
- EnergyPlus ‘Compact HVAC’ descriptions provide an easy way into detailed analysis of commonly used heating and cooling systems.
- Natural ventilation can be modelled with the option for windows to open based on a ventilation set point temperature.
- Daylighting - models lighting control systems and calculates savings in electric lighting.
- Shading by louvres, overhangs and sidefins as well as internal and mid pane blinds.
- A comprehensive range of simulation data can be shown in annual, monthly, daily, hourly or sub-hourly intervals:
  - Energy consumption broken down by fuel and end-use.
  - Internal temperatures
  - Weather data
  - Heat transmission through building fabric including walls, roofs, infiltration, ventilation etc.
  - Heating and cooling loads.
  - CO2 generation.
- Heating and cooling plant sizes can be calculated using design weather data.
- Parametric analysis screens allow you to investigate the effect of variations in design parameters on a

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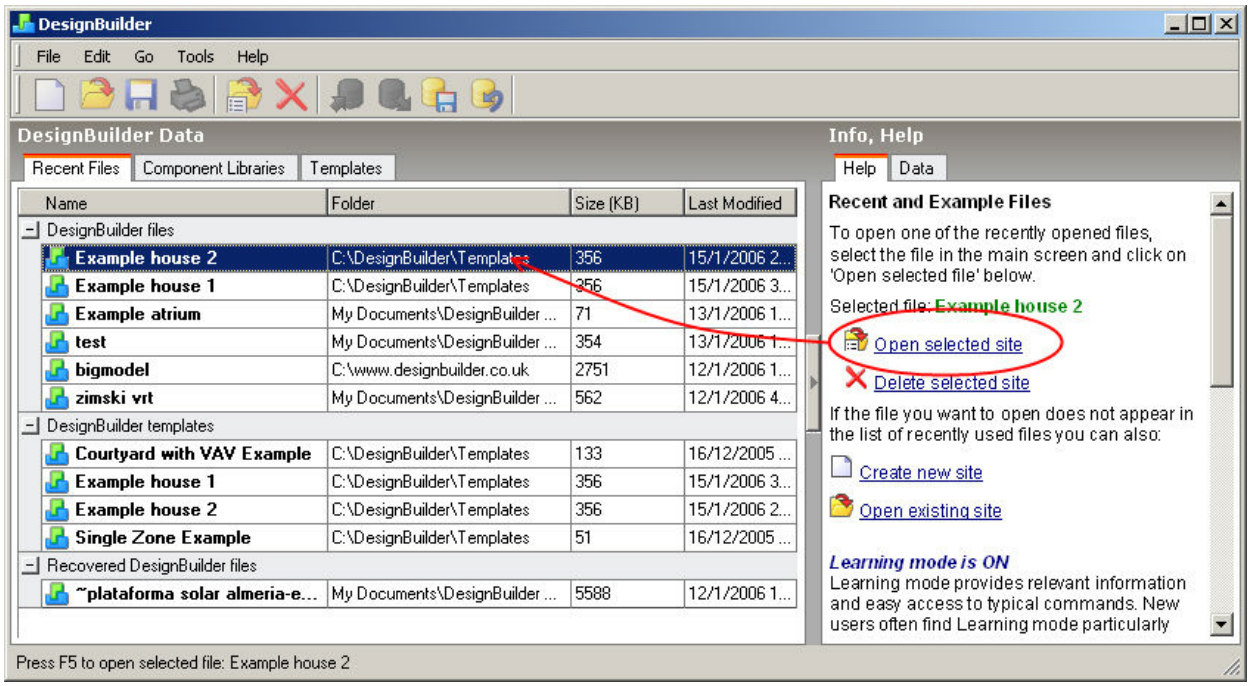
range of performance criteria.
- Generate EnergyPlus IDF files and work with these outside DesignBuilder to access EnergyPlus system functionality not provided by DesignBuilder.

1.3 Recent Files (Opening Screen)

The Recent Files Opening Screen has a list of the files used in your previous DesignBuilder modelling sessions. To access one of these files again you can double-click on it in the grid, or single click in the grid to select it and then 'Open selected site' from the Info Panel on the Toolbar.



You can also:

- Create a new file (site) from this screen.
- Open existing dsb file from the DesignBuilder Data folder. This is located beneath **My Documents** by default (**Documents** in Windows Vista).

1.4 User Interface

The DesignBuilder user interface has been designed from first principles for ease of use. Each screen has a specific purpose which is described in the Info panel on the right of the screen along with context sensitive commands and other relevant information.

The Info panel is only displayed in Learning mode. If you would prefer to have simultaneous access to the Model Data and the Edit View you can switch Learning mode off from the Program Options dialog from the Tools menu.

The user interface is described for each group of screens:

- Opening Screen - Recent Files

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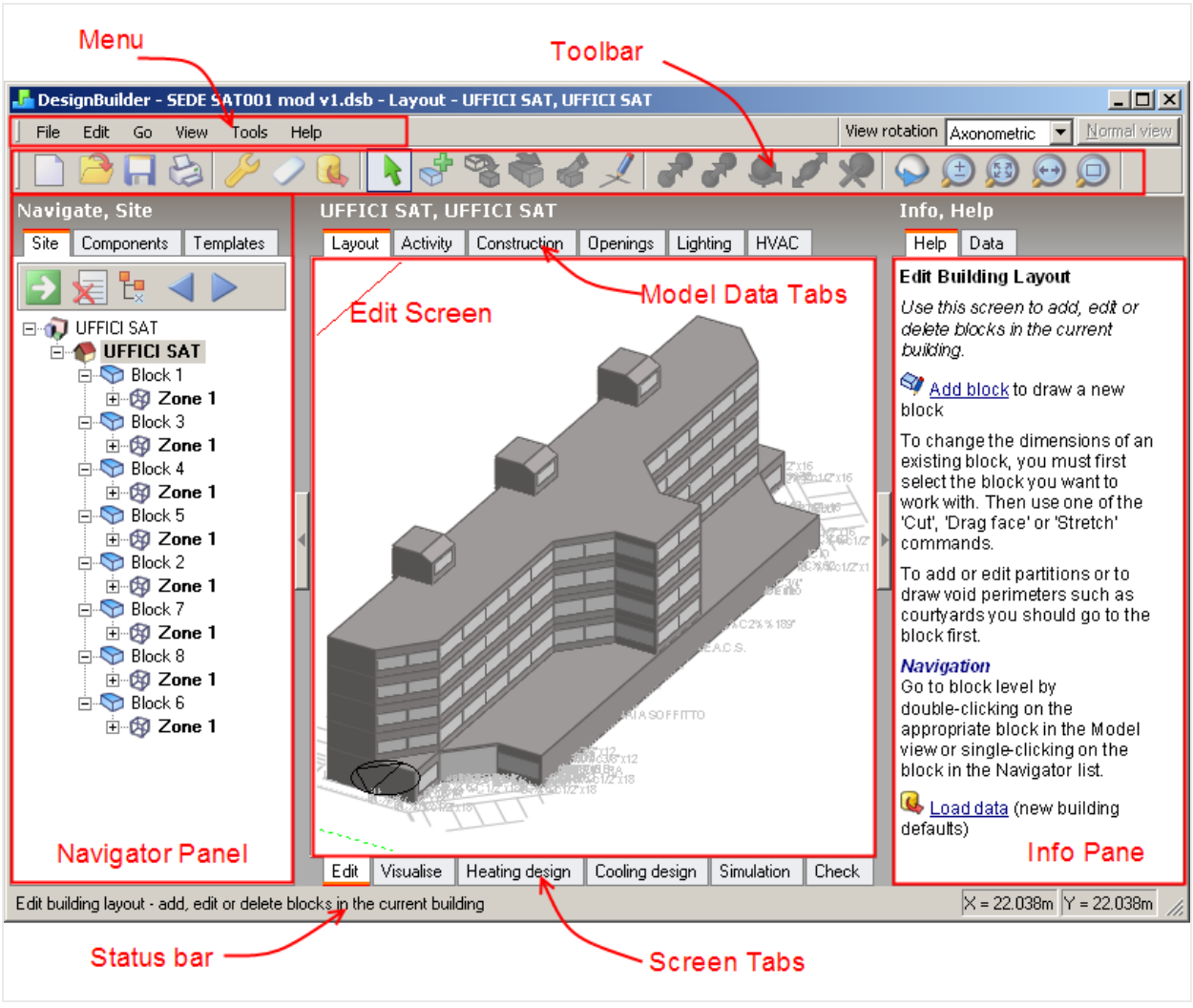
- Opening Screen - Component Libraries
- Opening Screen - Template Libraries
- Edit Screen
- Visualisation Screen

1.5 Edit Screen

The diagrams below illustrate the various components of the DesignBuilder Edit Screen with Learning Mode switched on and off.

Learning Mode On



Use the Model data tabs to access Activity, Construction, Openings, Lighting and HVAC model data.

You can find information on using the Info | Data tab to view component and template data in the Opening Screen - Templates help topic.

Learning Mode Off

Diagram below shows the same model but with Learning Mode Off. Edit Screen and Model Data are visible simultaneously and there is no Info Panel..

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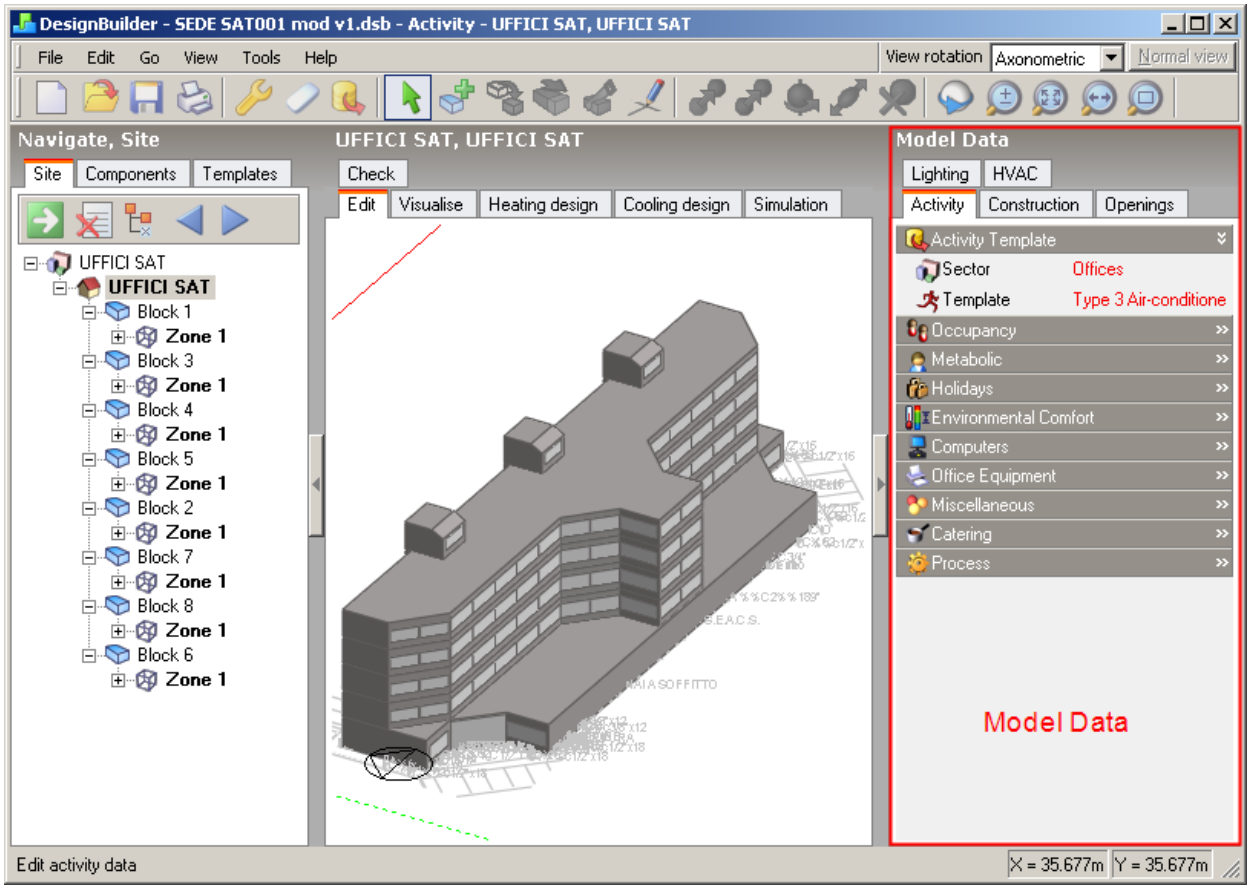

1.6 Licensing & Activation

Help menu > Licence

SINGLE USER LICENSES

DesignBuilder consists of a modelling Graphical User Interface (GUI) connected to a number of modules each providing a particular functionality. You will need a license for each of the modules you intend to use. If you require more than one module then the most convenient way to obtain DesignBuilder licences is to purchase a DesignBuilder package. Each package consists of 2 or more module licences, each module giving access to a particular aspect of DesignBuilder functionality.

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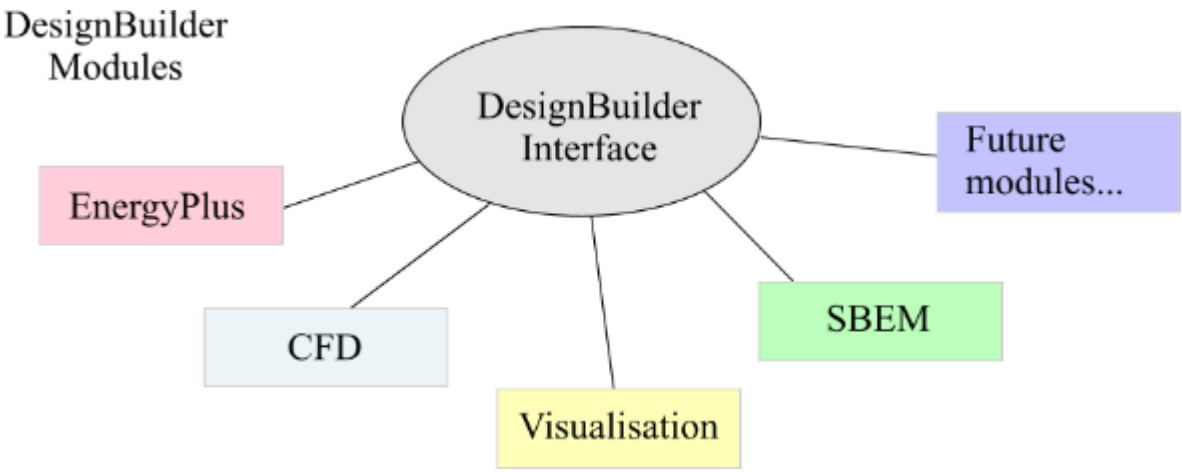
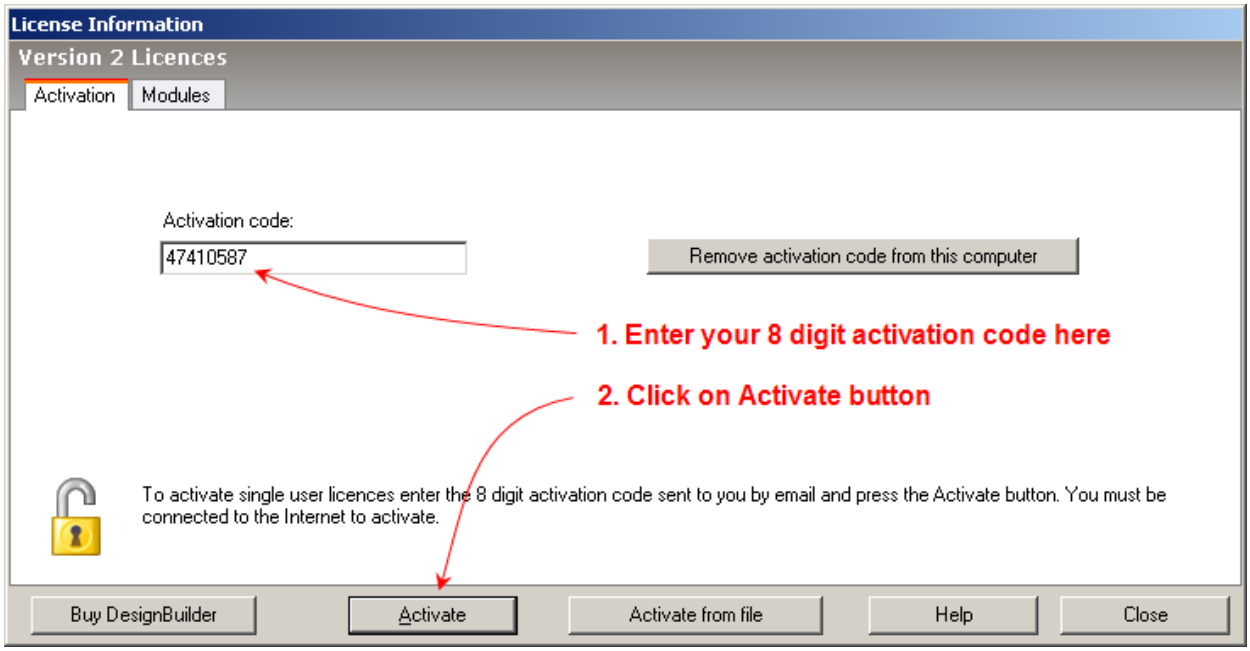


When you first install DesignBuilder an evaluation license key is automatically generated for each module. These evaluation licences are valid for 30 days from the date of installation and allow you to try out a fully functional version of the software to check that it meets your needs and is compatible with your computer. The only restriction with evaluation licences is that a 'nag screen' is displayed prior to each calculation or visualisation session.

When you buy licences to use DesignBuilder, you are sent an e-mail containing an 8 digit activation code and information on when the licences expire (if ever). You should copy (Ctrl-C) the activation code from the e-mail you received when you bought the software and paste (Ctrl-V) directly into the License dialog on the Activation page. The License dialog is accessed from the Help menu. When you paste the activation code and press the Activate button the software attempts to activate the license over the Internet, and if successful, validates the license keys and unlocks the modules.



If the activation was successful you will be shown the Modules tab displaying the licence status of each module (below).

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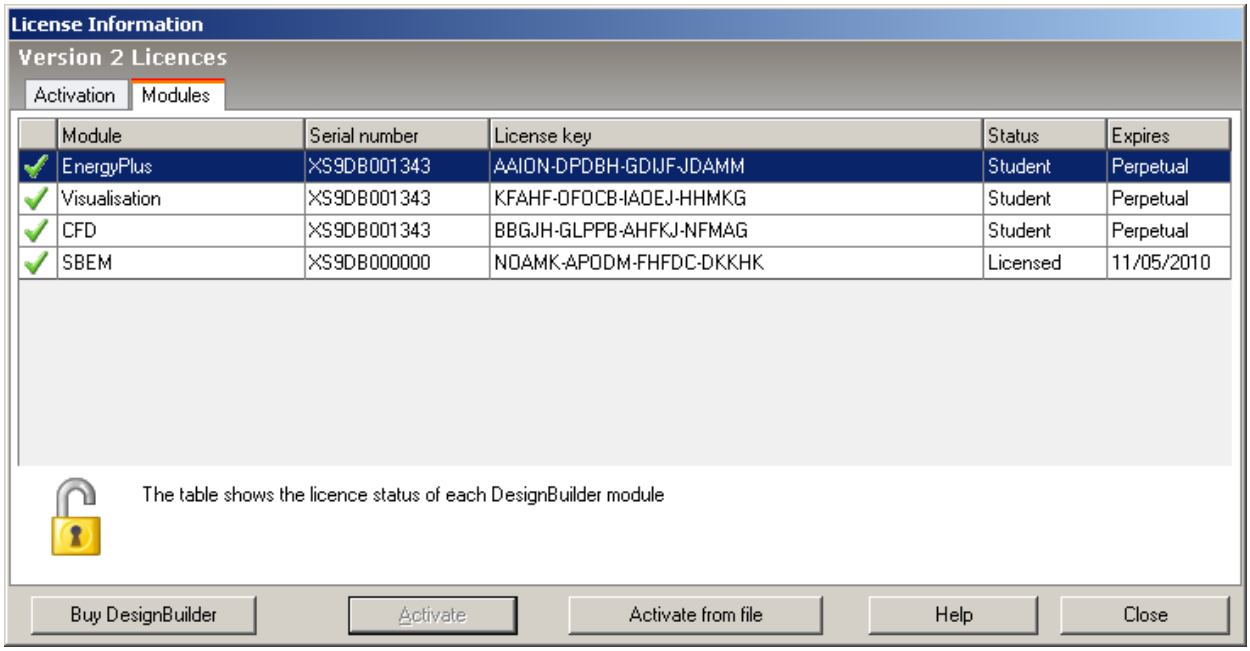

ACTIVATE FROM FILE

You may have been supplied with a licence file with extension .lif containing your licence data or extended evaluations. Typical reasons for using a .lif file for activation are when on a training course where you may not have access to the Internet for activation or for customers who have purchased licences but either do not have Internet access or have strict firewall policies preventing the standard web-based activation from working.

To activate DesignBuilder modules using a .lif file, click on the **Activate from file** button at the bottom of the dialog and select the file. The module list will be updated with the new licence information.

Note that by loading a .lif file containing evaluation keys (for example when at a DesignBuilder training course) you will not overwrite the status of any purchased full licences.

Notes

1. If you purchased a single user licence then you will be able to activate the code up to 2 computers. If you find that DesignBuilder is being used on these 2 computers simultaneously then you should purchase an extra licence.
2. You must be connected to the Internet to activate and deactivate DesignBuilder licenses. if your organisation has a strict firewall policy then you should ensure that DesignBuilder is allowed to access the Internet.
3. If your are a UK or Ireland Energy Assessor do not confuse the DesignBuilder 8-digit activation code with the 8 character authorisation codes provided by the EPCgen system. DesignBuilder 8-digit activation codes are to be entered in the Licence dialog only as described above and provide use of the DesignBuilder SBEM software whereas the 8-character authorisation codes supplied by EPCgen are for entering in the Model options dialog only and allow generation of XML files and removal of the watermark from the EPC.

You need an EnergyPlus license to generate IDF files even if you want to simulate using an external version of EnergyPlus.

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SITE LICENSING

DesignBuilder site licenses use a different technology to single user licenses. With site licenses each client computer on the network can "check out" licenses from the license server which manages the allocation of licenses. The system is designed to provide a maximum number of concurrent users according to the number of seats purchased. For example if you purchased a site licence with 10 seats for the EnergyPlus module then the software can be installed on any number of computers but only a maximum of 10 people will be able to access DesignBuilder EnergyPlus simulations at any one time. If an eleventh person on the network tries to run a simulation then they will receive a message to say that the seats are all in use and to wait until one becomes available.

DesignBuilder site licensing requires a simple server application to run on the network to provide licenses. Each client computer has an environment variable set to tell the software to run in site license mode and where to find the license server on the network. The site licensing system is quite straightforward but does require a network administrator with adequate IT skills to set it up.

More on DesignBuilder Licensing

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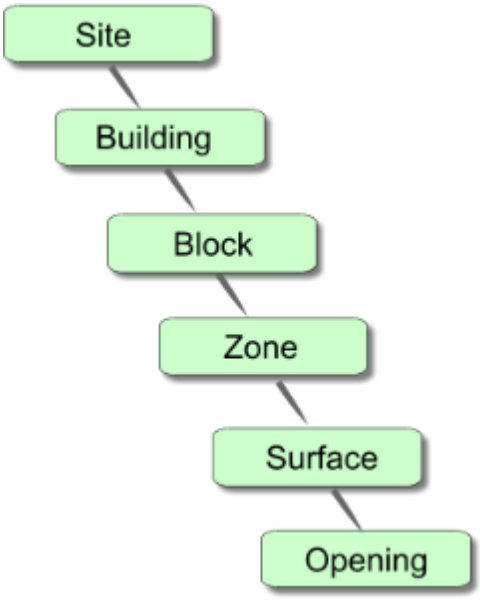
2 Core Concepts

Some core concepts you should be familiar with before attempting to use DesignBuilder on a real project are:

- Model data hierarchy and data inheritance
- Templates and components
- Blocks
- Navigating building models
- Customising model detail

2.1 Model Data Hierarchy & Data Inheritance

DesignBuilder models are organised in a simple hierarchy:



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. This arrangement allows you to make settings at building level which can becomes active throughout the whole building; or make settings at block level to change data for all zones/surfaces in the block. So for example, if the External wall construction is set to 'Wall 1' at building level, then this will be the default External wall for all blocks in the building. It is possible to change the inherited defaults in any of these blocks by making an explicit selection (say 'Wall 2'). All the zones in the block whose external wall construction was set to 'Wall 2' have that default External wall construction.

The construction and opening defaults are inherited down to surface level where the data is actually used in the calculations. For example it is the External wall construction model data at the surface level that defines the actual construction used for that external wall. The External wall model data set at zone, block and building level has no effect on the model (other than by providing the default data for the level below in the hierarchy).

To assist in identifying where data is inherited from DesignBuilder uses a colour code. Data set at building level or user defined data ‘hard set’ at any level below will appear in red. All data inherited at levels below will be in blue (see below).

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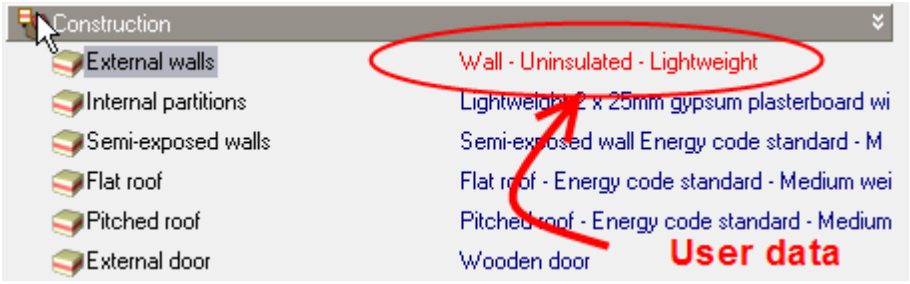

The simplest way of determining where data is inherited from is to start at the lowest level, a surface or opening, and go up through the levels until the data turns red. This then is the level from which the data has been inherited.

The DesignBuilder hierarchy mechanism is a fast way of setting data globally in a building model, but you must take care to *enter the minimum amount of data* to get the most from the inheritance system. For example if all zones in a particular block have the same activity called say 'Office work', you should set the activity at block level and not multiple times at zone level. Equally if all the blocks in the building have the same activity, you should set the data at the building level and allow the blocks to inherit the data from the building. By keeping the amount of user data to a minimum, you will find it quicker to make changes at a later date. Clearly it is much faster to change a few Model data items at building and block level than it is to make multiple changes at zone or surface levels.

When entering construction data, you could set the construction for each surface in the model but in practice this would be an extremely inefficient process. It is faster and less error-prone to set the construction as high up in the hierarchy as possible, possibly at building level (if all external walls in the building have that external wall construction), or at block level if all walls in that block have the construction (and other blocks don't).

Most data at the building level is 'user data' as buildings do not inherit their data from the site level.

To undo user defined ‘hard set’ data run the Edit > Clear to default menu command and select **All data**’ or **Custom openings** and specify level (block, zone or surface) down to which the data is to be cleared.

Defaults

In short the rules are:

- Construction and Openings data is used at the *surface* level, i.e. all construction and opening data at building, block and zone level is default data and only data at surface level is actually used to define the model.
- Activity, Lighting, HVAC, Equipment data is used at the *zone* level, i.e. all Activity, Lighting, HVAC, Equipment data at building and block level is default data. The exception is AHU data for Compact HVAC systems which is set at building level.

A common question is "*Why do I see Pitched roof constructions at building/block/zone level on the Constructions tab when my building/block/zone doesn't have a pitched roof*"?

The answer is that the Pitched roof construction setting at building, block and zone levels should be thought of as the default setting for any pitched roofs that may (or may not) exist in the model further down in the hierarchy. If there are no pitched roofs in the model then the data is simply not used.

Custom openings

When custom openings have been created at surface level these override the facade layout Model data for the surface.

Openings

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Although openings (windows, vents, doors etc) appear in the DesignBuilder hierarchy, there is no way in version 1 to change data at the opening level. All openings inherit their data from the surface level. It is therefore not possible to have different glazing types on a particular surface. If you click on an opening in the Navigator you are actually taken to the surface containing the openings.

Component blocks

Component blocks inherit their data from building level.

2.2 Templates and Components

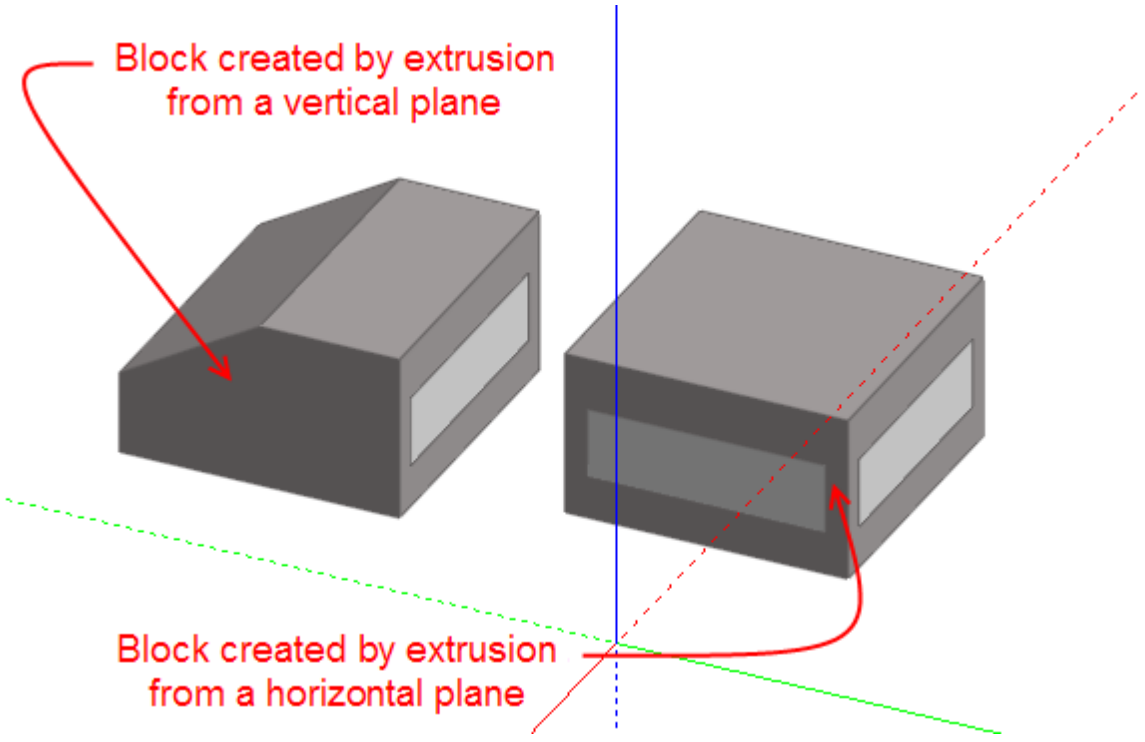
- Templates are databases of typical generic data.
- Components are databases of individual data items (e.g. a construction type, material, window pane) .

DesignBuilder allows you to build up your own libraries of templates and components. Note that each user on a computer maintains their own database of templates and components.

Template and component libraries are loaded into your model at the time it is created and new custom data from other computers can be imported at any time.

2.3 Blocks

Blocks are the basic geometric shapes that you use to assemble a DesignBuilder model. The idea of blocks is to provide fairly simple objects that you can easily move around in 3-D space in a similar fashion to that of building a physical model using bricks from a construction set. Blocks are created by drawing 2-D perimeters on horizontal or vertical planes and then extruding these perimeters to form 3-D shapes:



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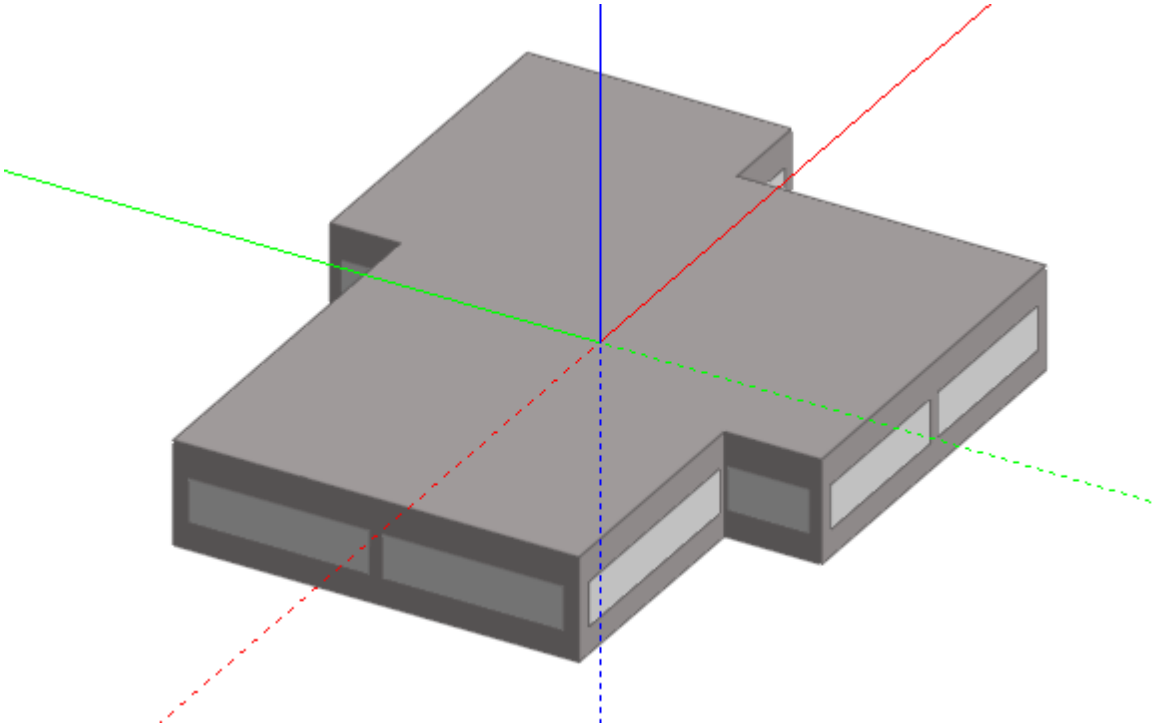
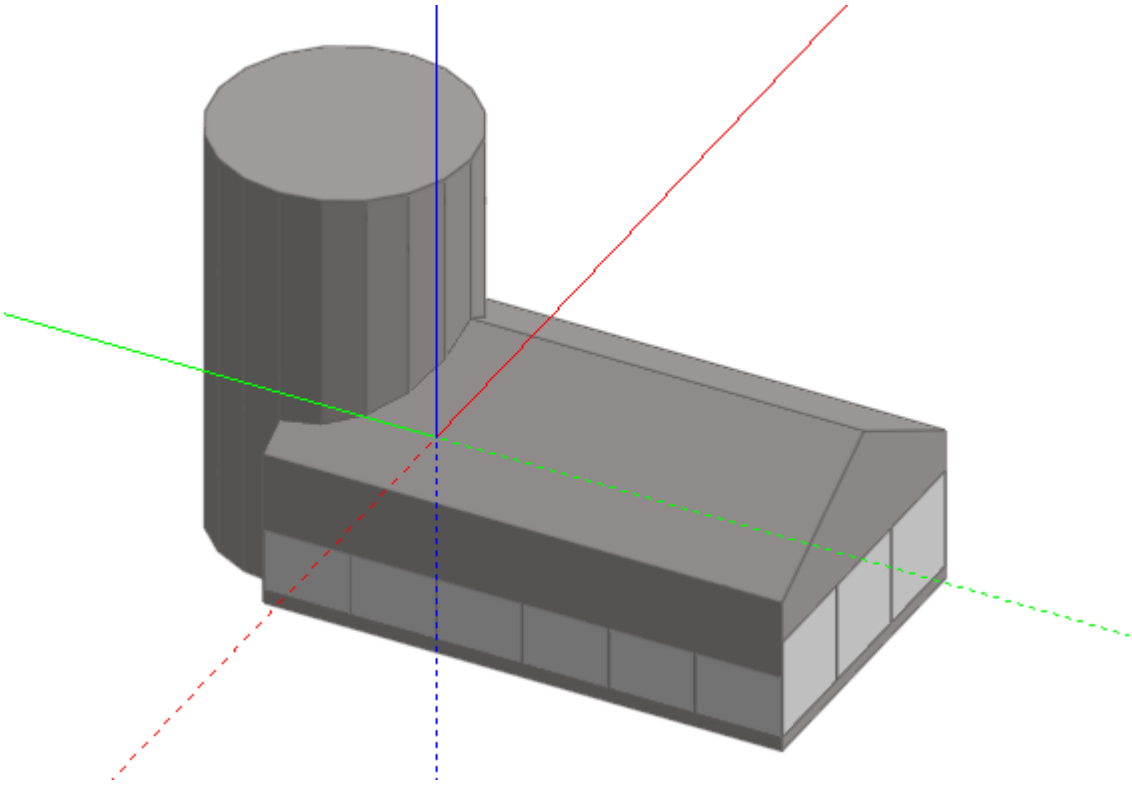
Blocks are versatile objects and once created can easily be modified by moving their surfaces, by stretching them and even by cutting them using arbitrary planes. Typically, you might use a block to represent an entire building storey:



Or a particular building design might lend itself to an obvious division into blocks:



You can model an entire building as a single block:

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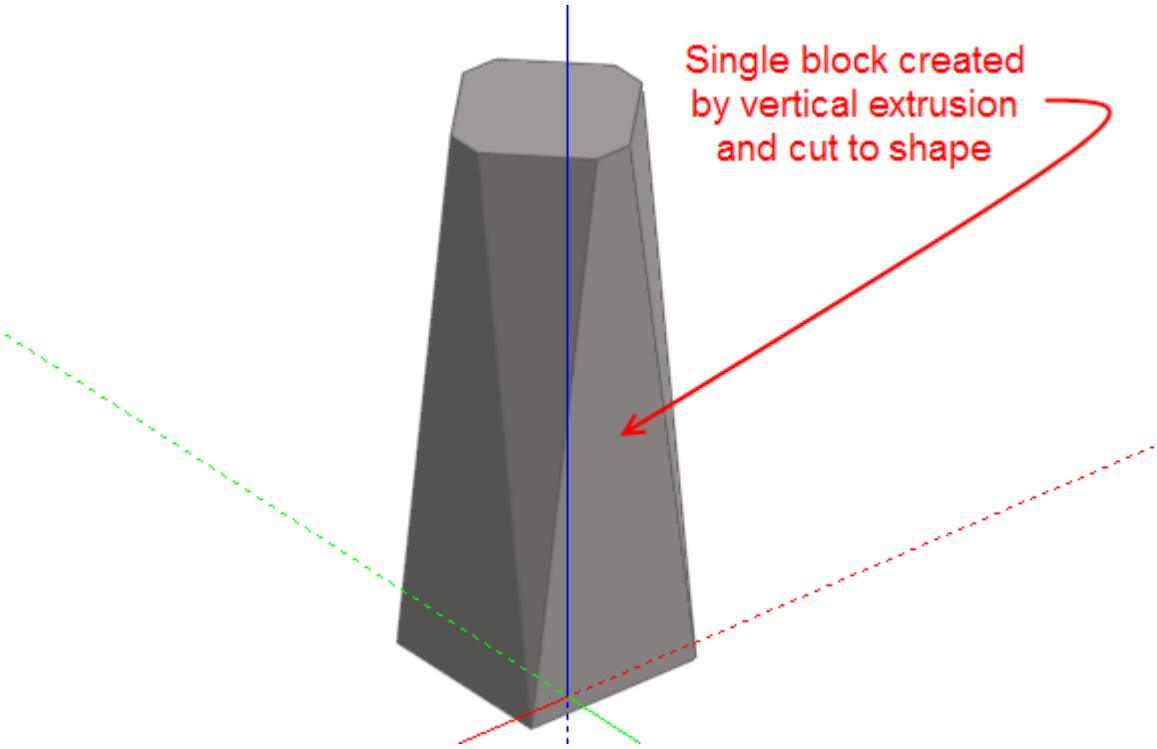
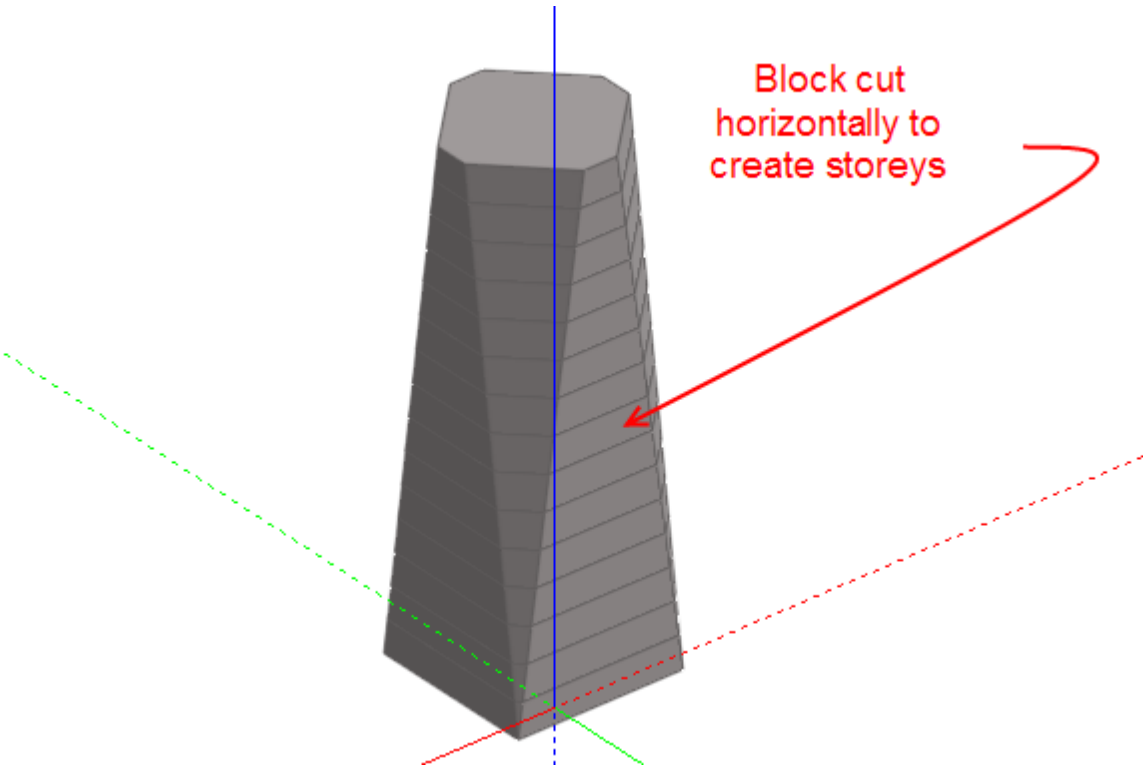


And then cut the block into storeys:



Once the overall geometry of a model has been established with blocks, you can go 'into' a block and sub-divide it into a number of rooms or zones using partitions:

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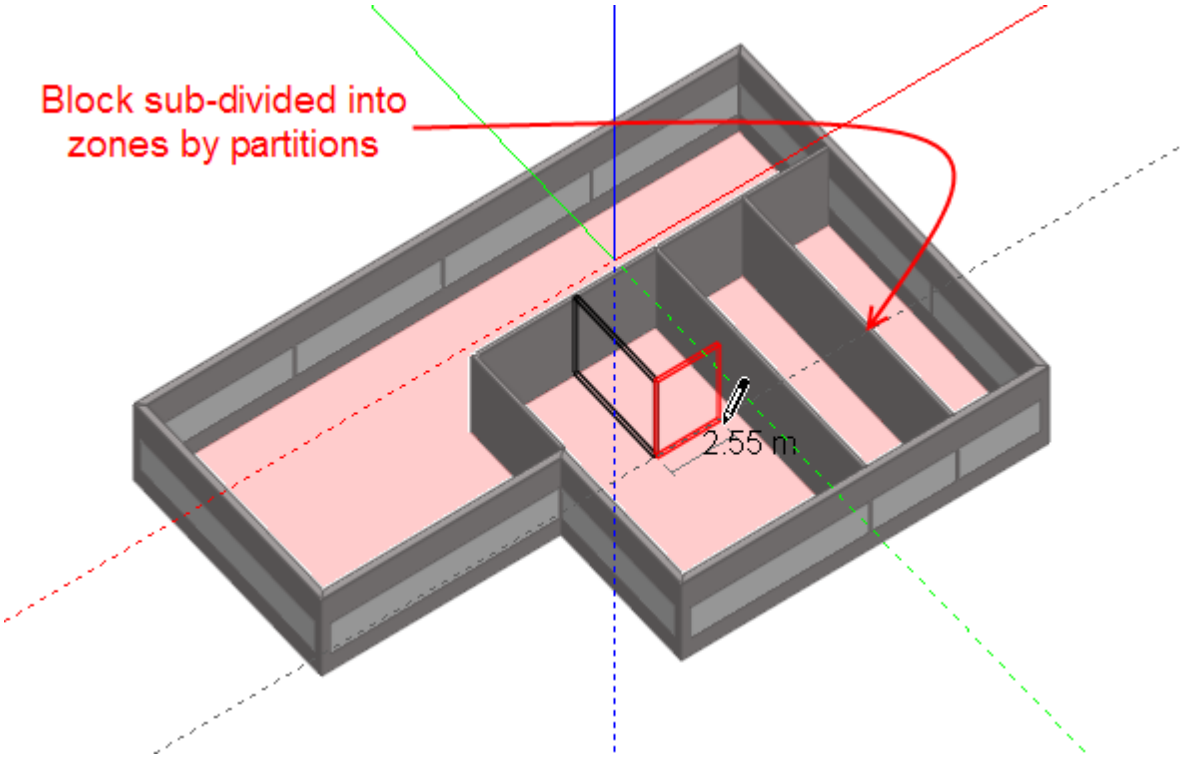

If you sub-divide a block internally using partitions, you can still modify the block by stretching, cutting, rotating, etc. and where possible the internal geometry will be kept.

2.4 Navigating Building Models

- There are various ways of navigating (moving around) DesignBuilder models:
- Single clicking the appropriate entry in the Navigator panel is the most versatile way because every object in the building has an entry in the Navigation panel.
- Double-clicking on the appropriate object in the Edit Screen takes you do it.
- Single-clicking on the appropriate object in the Edit Screen then mouse right mouse clicking on the object and selecting the 'Go to…' menu option at the top.
- Go to the level up in the hierarchy by pressing <F3> or by right mouse clicking in the Edit Screen and selecting the 'Go up...' menu option.
- The Next <F5> and Back <F4> Navigation buttons allows you to move sequentially through the model (avoiding surfaces). This approach can be slow but can be useful when it is necessary to methodically work through the model for any reason.

The Figure below shows how to either click on the Navigator entry or double-click on the Edit Screen to go to 'Zone 1' from 'Block 1'.

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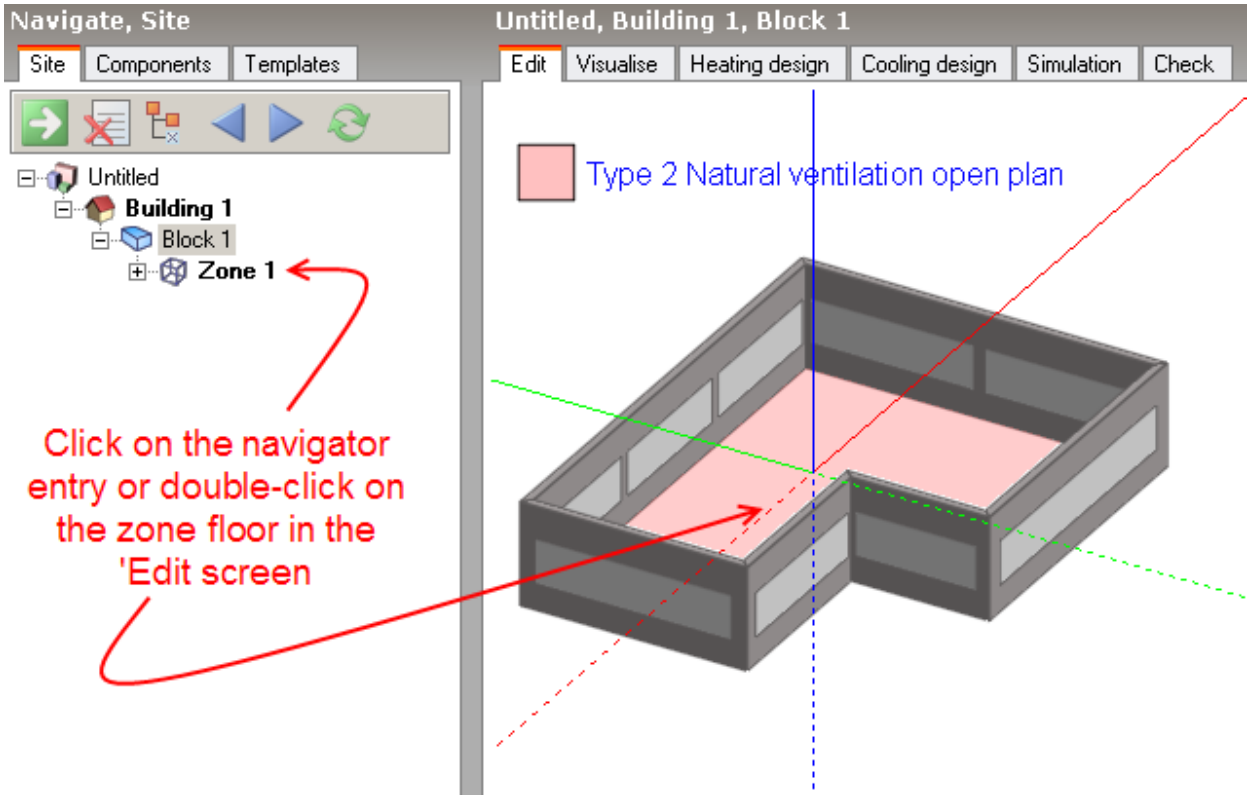

2.5 Customising Model Detail

DesignBuilder models can be customised to allow you to enter the level of detail which is appropriate to your building design or modelling project. In early-stage design work you will generally want to use generic selections for most Model Data and so would choose the corresponding 'low data requirement' model options.

As the building design firms up, more information becomes available and you can change the model options to use more specific data tailored to the project and less generic data.

The 'standard' Model Option set is loaded at the point the building is created and you should generally keep these options unless you have specific reason to change.

Model Options are set in the Model Options dialog from the Edit menu.

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3 Building Models

The process for creating a new building model typically follows a sequence:

1. Create new site.
2. Create new building.
3. Draw and manipulate building blocks to create building geometry.
4. Partition building into thermal zones.
5. Set Model Data.
6. Add any 'custom openings' (windows, doors etc) by drawing up the surface level.
7. Size heating and cooling systems.
8. Check design by carrying out summer and winter simulations displaying hourly data.
9. Once model has been checked over short periods, you can use it with confidence for annual simulations.

3.1 Create New Site

You can create a new site (dsb file) from the Opening Screen. In DesignBuilder, 'Site' is synonymous with the file because each file can only contain one site.

3.1.1 Location

Select the Location Template as a source of location and weather data for the site.

The Location defines the geographical location and weather data for all buildings on this site. You will be able to load data from other location templates or override the default data from the Location Model Data tab at Site level.

3.1.2 Template

You can either select 'Blank' to create a clean site, or select a template to base your site on an existing site.

If you have a DesignBuilder file you would like to use as a template for future sites save or copy it to the 'Templates' folder (accessed from the **File | Folders | Template projects** menu command).

3.2 Building Geometry

This section describes the various facilities within DesignBuilder to create and edit model geometry.

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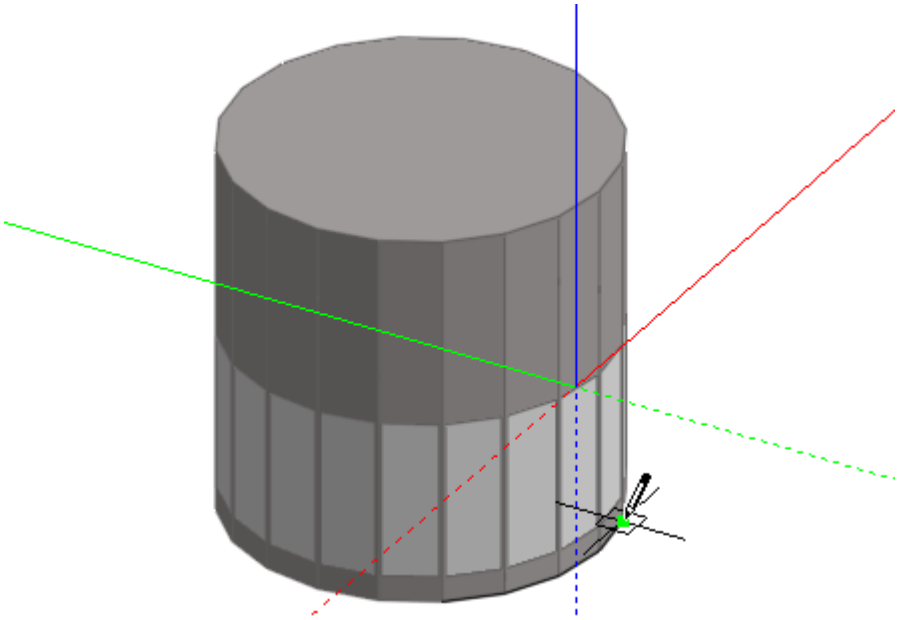
3.2.1 View Controls

A number of view controls are provided to allow you to change the point of view for the model:

- View Rotation
- Orbit
- Zoom
- Fit view
- Pan view
- Zoom window

View tools can be activated at any time during operation of the drawing tools and control returned to the active drawing tool after completing the view process. For example to draw a block perimeter adjacent to an existing cylindrical block:



To continue drawing the perimeter around the other side of the cylindrical block, click on the 'Orbit' tool and orbit the model to reveal the other side and then pan to centre the model:

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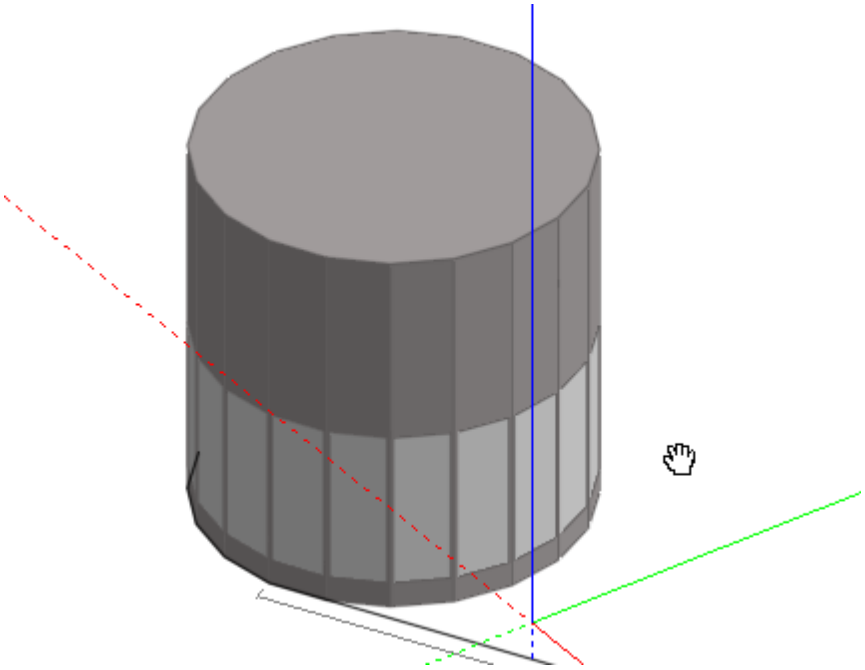
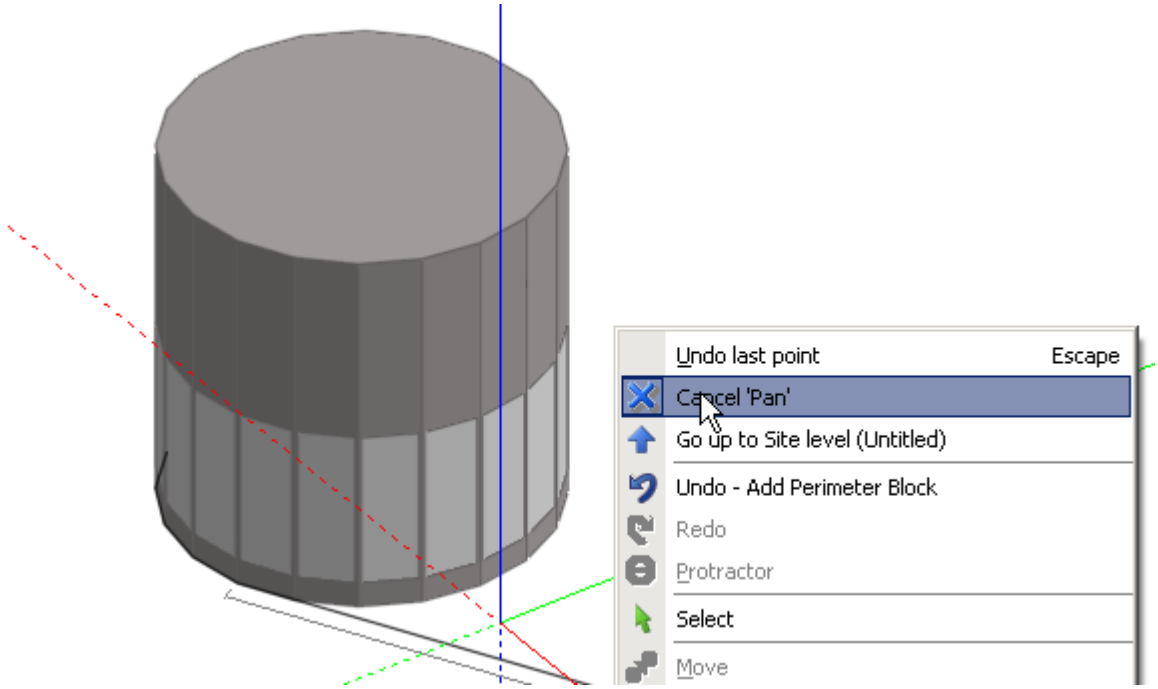


You can then return to the drawing process either by pressing the ESC key or selecting 'Cancel Pan' from the right-click menu:



3.2.1.1 View Rotation

DesignBuilder provides several pre-defined standard view rotations:

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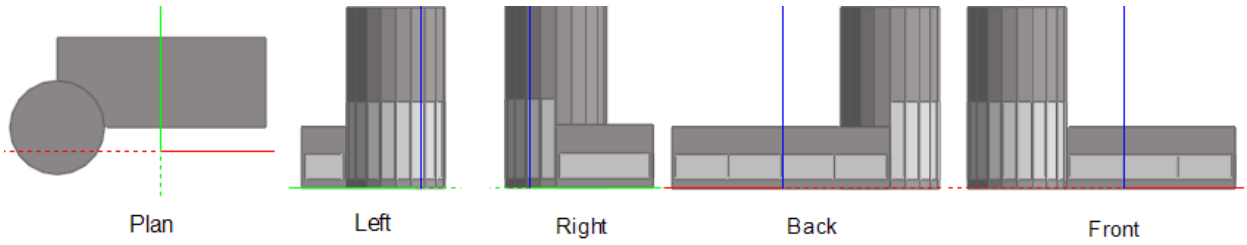
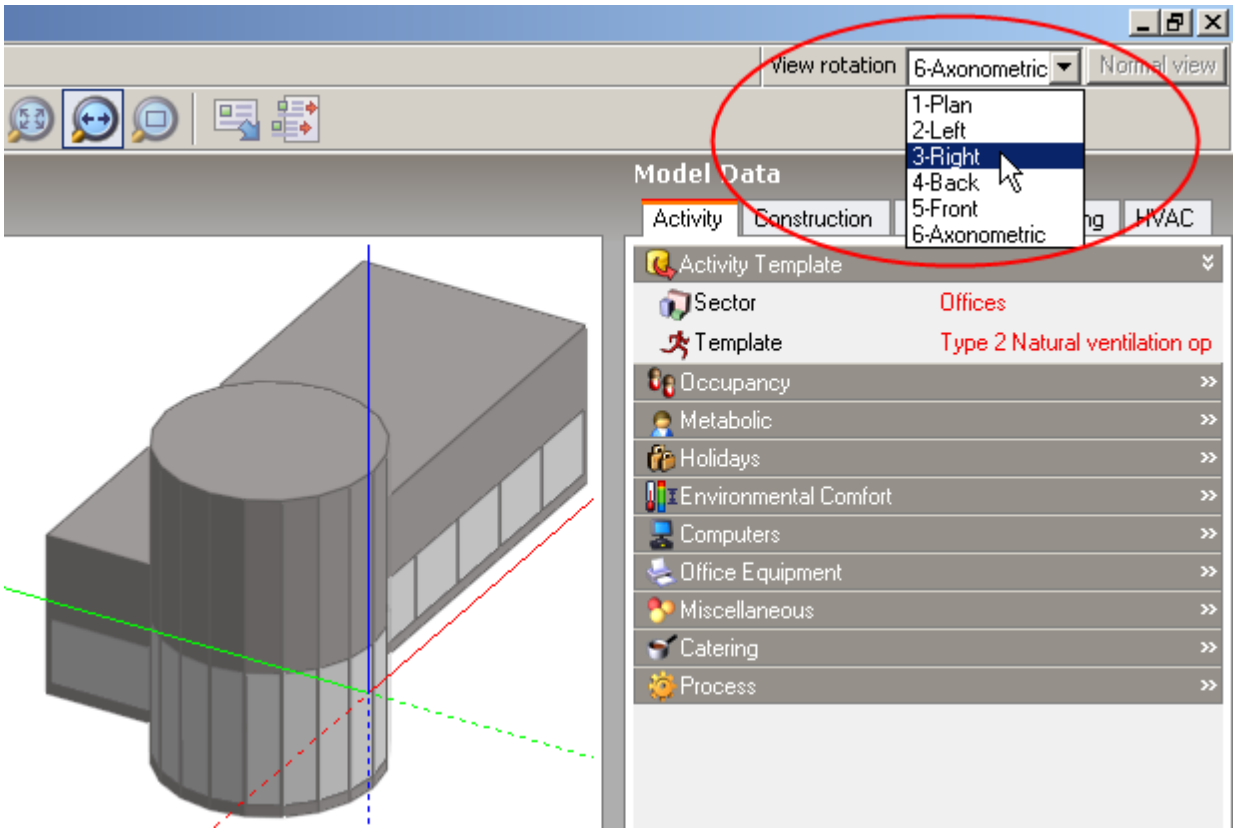


You can select one of these standard views from the view rotation drop list:



The default 'Axonometric' setting is designed to afford a good general axonometric view of the various components at each model level.

3.2.1.2 Orbit

The orbit tool is used to rotate the view around the model. To orbit the model click on the 'Orbit' tool and then press the left mouse button and keep the button pressed as you move the mouse cursor, the view will orbit around the model.

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3.2.1.3 Zoom Dynamic

To zoom in and out from the current model point of view, click on the 'Zoom' tool, then press the left mouse button and keep the button pressed as you move the mouse cursor, the view will zoom in as you move the mouse cursor down and out as you move it up.

3.2.1.4 Zoom Window

The 'Zoom window' tool is used to zoom in on a specific area of your model. To create a window on an area of the model, click on the 'Zoom window' tool and move the mouse cursor to a corner of the window you want to create, then press the left mouse button and keep the mouse button pressed as you drag the window, when you release the mouse button, the view will zoom to the extents of the defined window.

3.2.1.5 Fit view

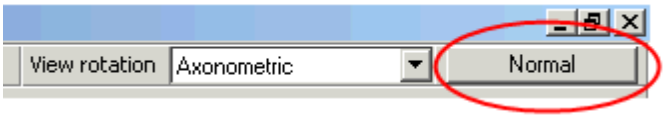
The 'Fit view' tool is used to zoom your view to a distance which will enable the whole model to be made visible and centred in the 'Edit' window.

3.2.1.6 Pan view

The 'Pan' tool is used to move the model point of view vertically and horizontally across the plane of the screen. To pan the view, click on the 'Pan' tool, then press the left mouse button and keep the button pressed as you move the mouse cursor, the point of view will pan horizontally as you move the mouse cursor left and right and vertically as you move it up and down.

3.2.1.7 Normal View

At the surface level, The Normal button in the top right-hand corner of the screen can be used to rotate the point of view to be normal to the surface and to automatically zoom in so that the extents of the surface fill the view.



The Default surface normal viewprogram option allows you to control the behaviour of this command.

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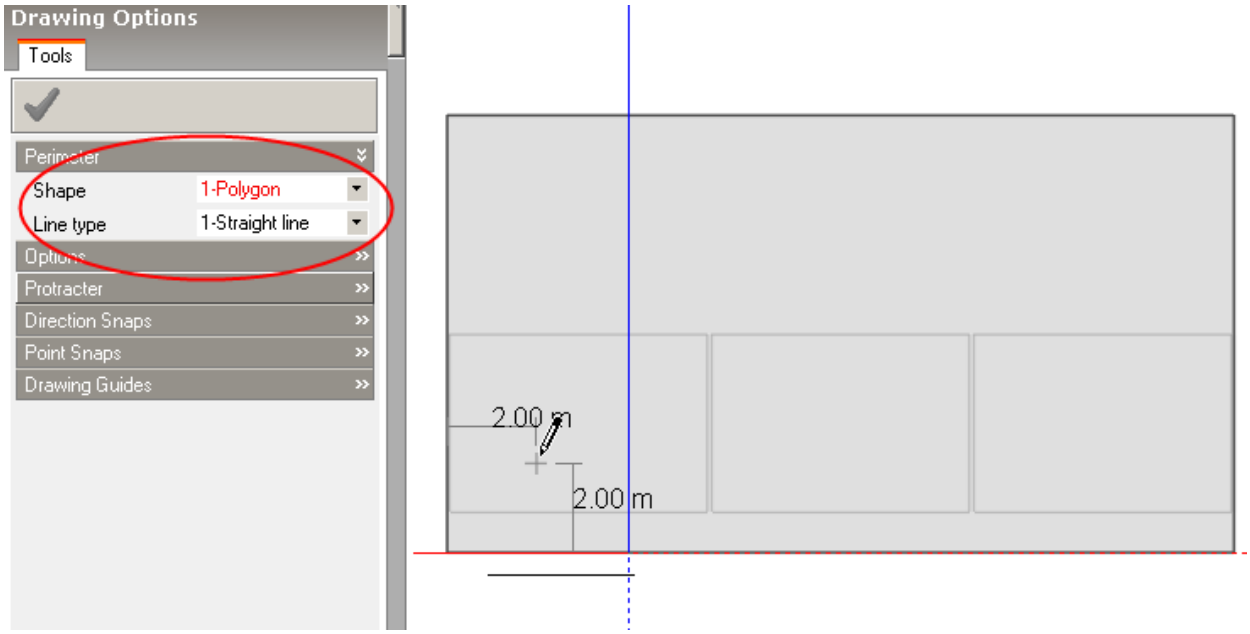
3.2.2 Perimeters

Blocks, courtyards and surface openings are all created using perimeters. When any of these element drawing tools are activated, perimeter options can be accessed from the 'Drawing Options' data panel, for example when the Draw window tool is active at the surface level:



3.2.2.1 Shape

Three perimeter shapes are provided to enable specific perimeter topologies to be drawn efficiently:

- Polygon
- Rectangle
- Circle

The 'Polygon' is probably the most useful shape and can be used to draw perimeters of any topology. The 'Polygon' shape also allows you to change the line type from a straight line to an arc. To draw a perimeter using the 'Polygon' shape, start drawing the first line by clicking anywhere in the active drawing plane to place the starting point, then move the mouse cursor and click to place the line end-point, you can use the snaps and the protractor to help with alignment. Continue placing perimeter lines in the same way. If at any time you want to cancel the last line that you placed, you can press the ESC key or select 'Undo last point' from the right-click menu. If you want to incorporate an arc within the perimeter, you can change the line type to 'Arc' and then place the centre-point of the arc:

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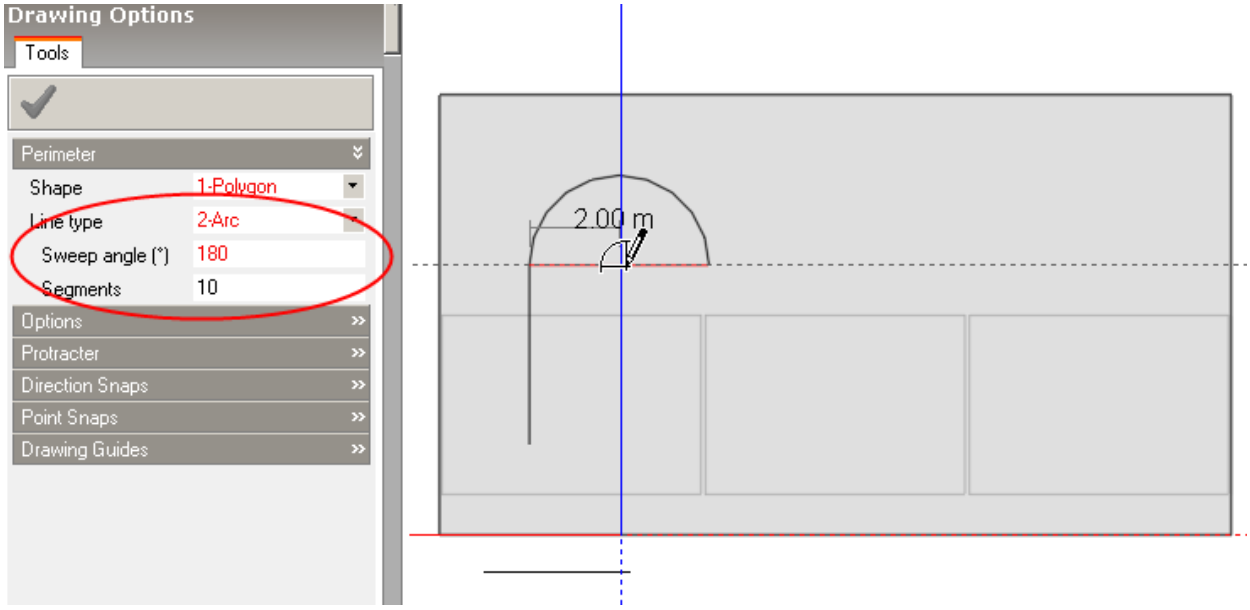
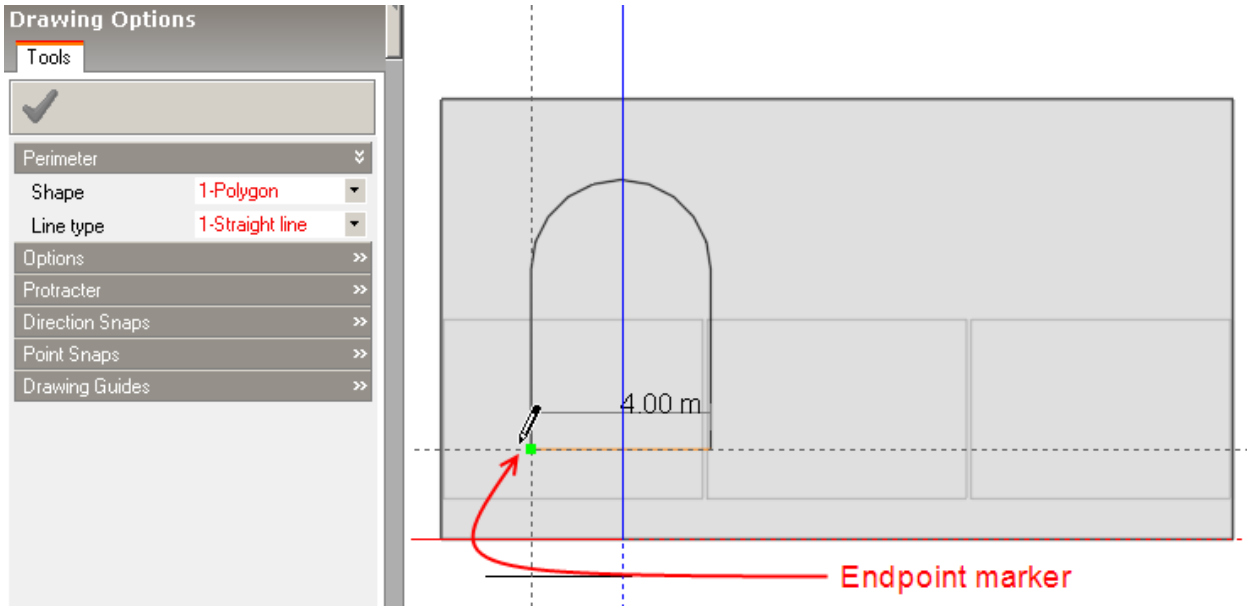


To complete the perimeter, move the mouse cursor to the beginning of the first perimeter line, which activates the end-point snap and click on it to connect the lines:



The 'Rectangle' shape allows you to draw perimeters by placing diagonally opposite corners of a rectangle:

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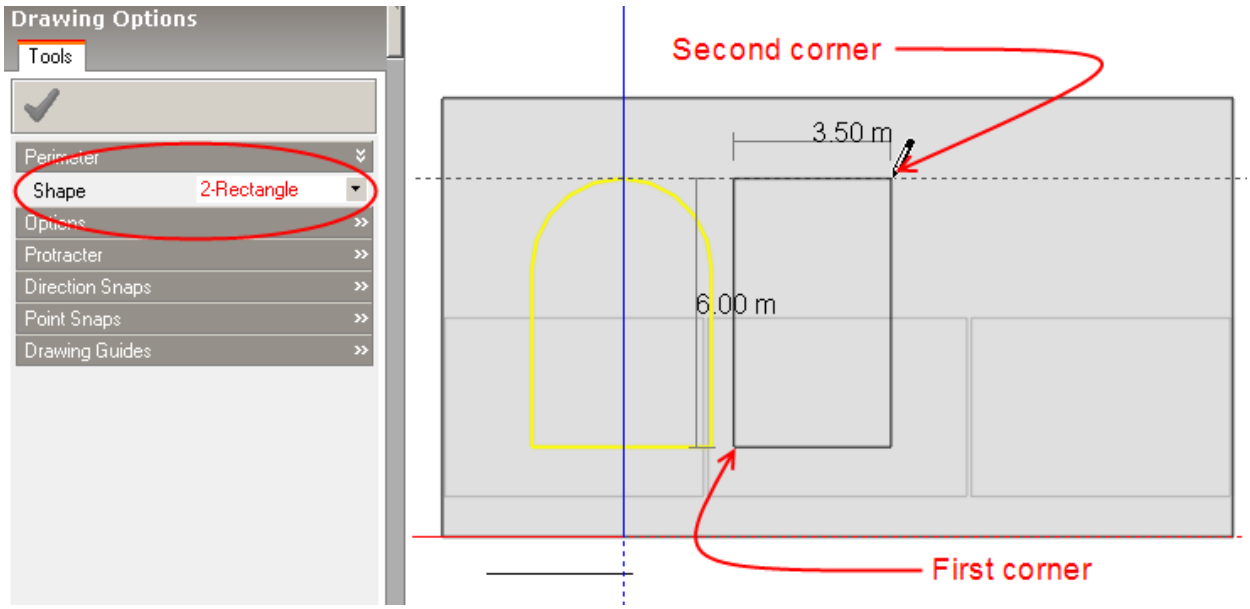
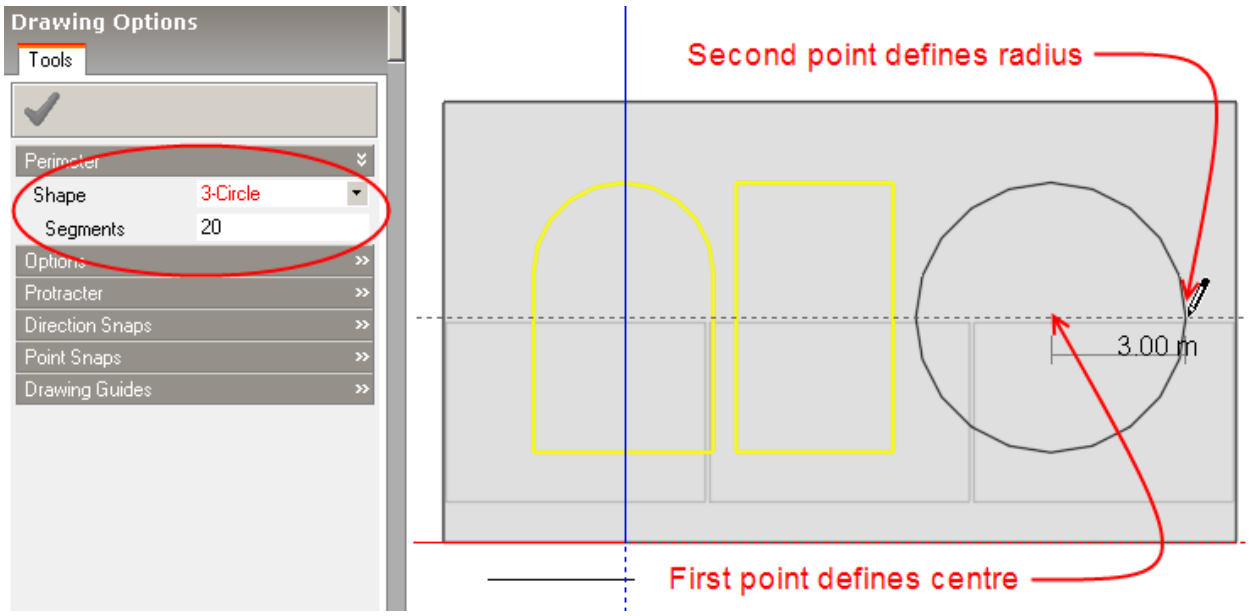


The 'Circle' shape is used to draw circular perimeters by placing the circle centre and then setting the radius by placing a second point:



The associated 'Segments' option allows you to control the accuracy of the circle. In DesignBuilder geometry, circles are actually composed of polygons and the accuracy of the representation can be controlled by defining the number of segments (or lines) used in generating the polygon. Generally speaking, the greater the number of segments used will result in more memory usage and processing time and so, particularly in the case of blocks, it's advisable to use the default number of segments where possible.

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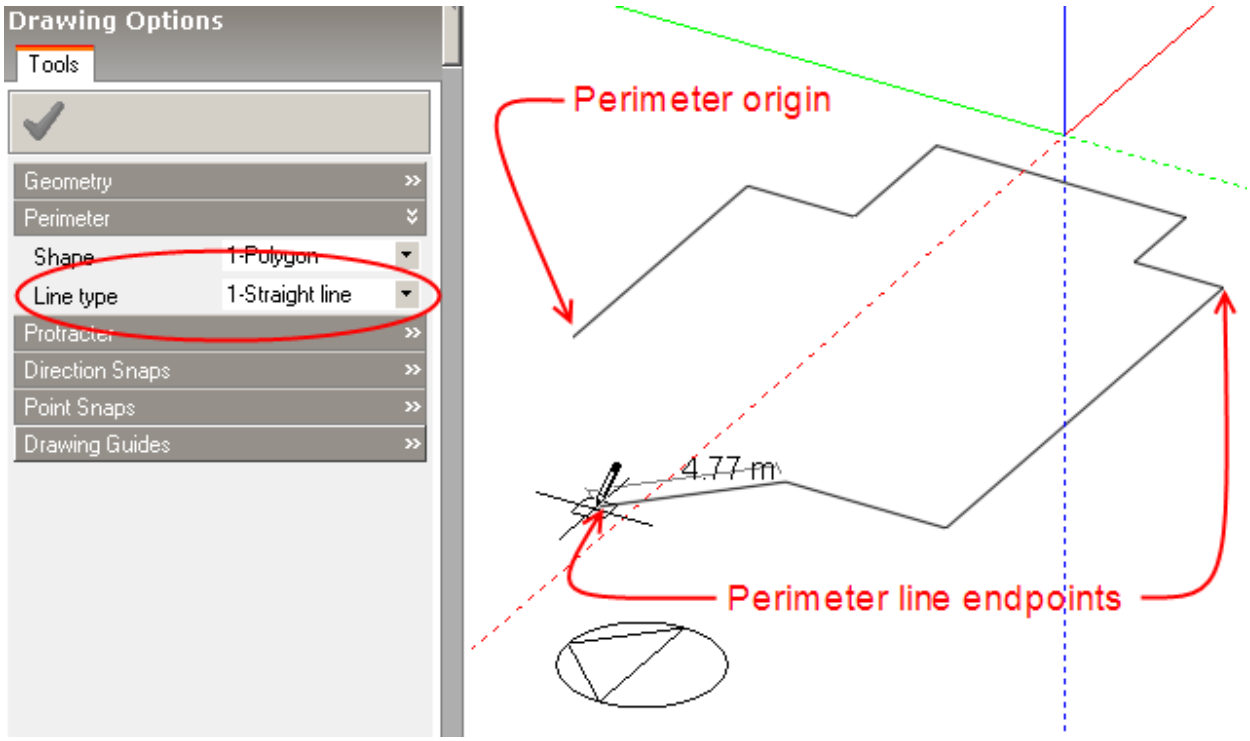
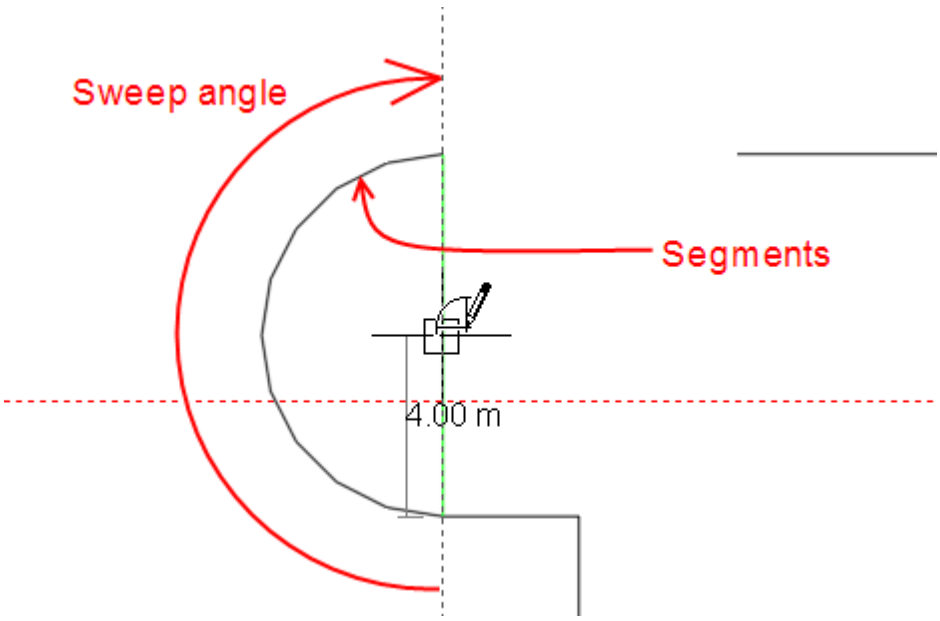
3.2.2.2 Line Type

When the perimeter shape is set to 'Polygon', you can set the perimeter line type to 'Straight line' or 'Arc'. When the line type is set to 'Straight line', a perimeter is drawn by placing the origin and then a series of line end-points:



To incorporate an arc within a perimeter, set the line type to 'Arc'. An arc is defined using the sweep angle and number of segments:



A negative sweep angle can be used to create an arc in an anti-clockwise direction. In DesignBuilder

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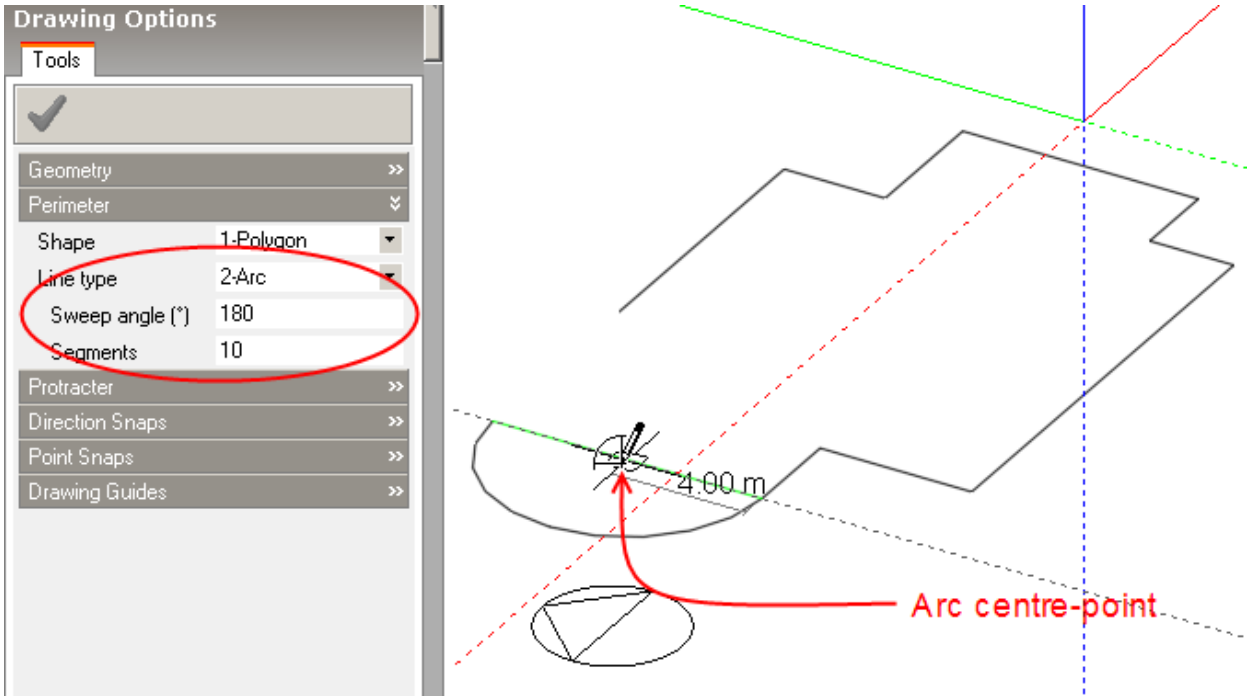
geometry, arcs are created using a number of segments or straight lines and the accuracy of the representation can be controlled by defining the number of segments. Generally speaking, the greater the number of segments used will result in more memory usage and processing time and so, particularly in the case of blocks, it's advisable to use the default number of segments where possible.

To draw the arc, place the arc centre:



3.2.3 Snaps, Drawing Guides & Protractor

A number of drawing aids are provided to enable block perimeter lines, partitions, etc. to be drawn precisely:

- Protractor
- Direction Snaps
- Point Snaps
- Drawing Guides

These items are made available when the various drawing tools are used, such as the 'Draw window' tool at the zone surface:

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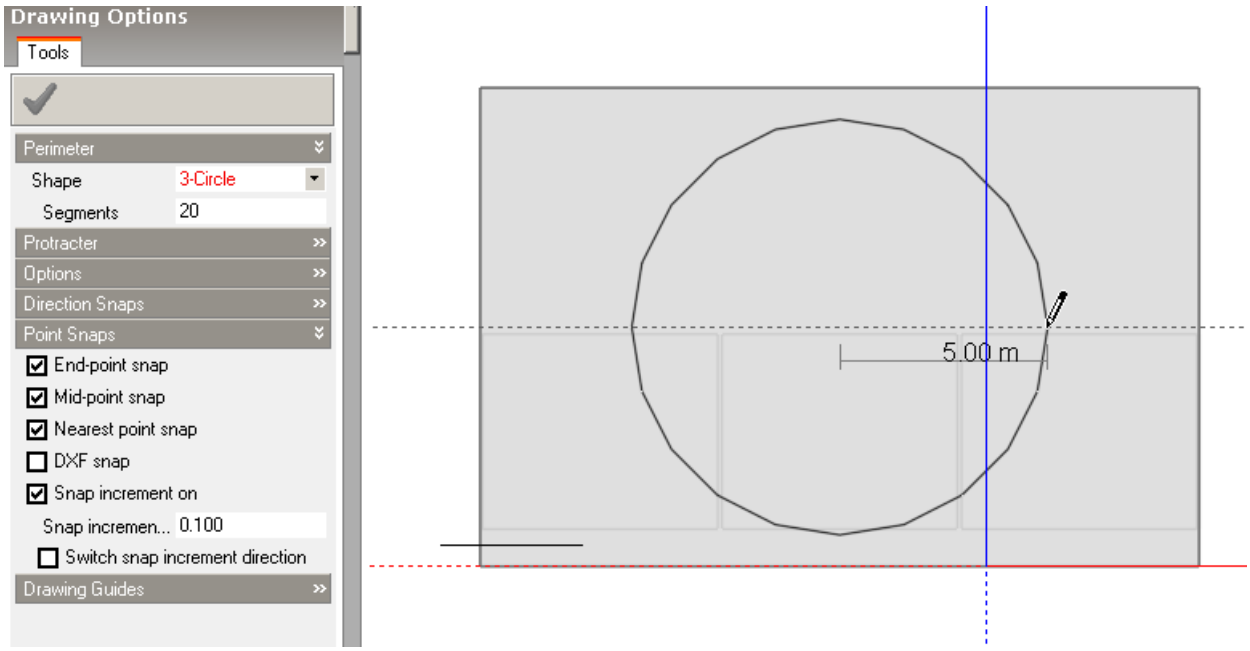

3.2.3.1 Direction snaps

When drawing perimeter lines, block partitions or surface openings direction snaps can be used to draw lines:

- Parallel with the active drawing plane axes (Axis snap),
- Parallel with existing elements (Parallel snap) or
- Perpendicular to existing elements (Normal snap).

3.2.3.1.1 Axis snap

The axis snap check boxes are displayed under 'Direction snaps' in the 'Drawing Options' data panel when the various drawing commands are active. The axis snap is used to draw lines parallel with the major axes of the active drawing plane.

As you move the cursor around to draw a line, the line will change colour and 'stick' slightly as it becomes parallel with one of the major axes:

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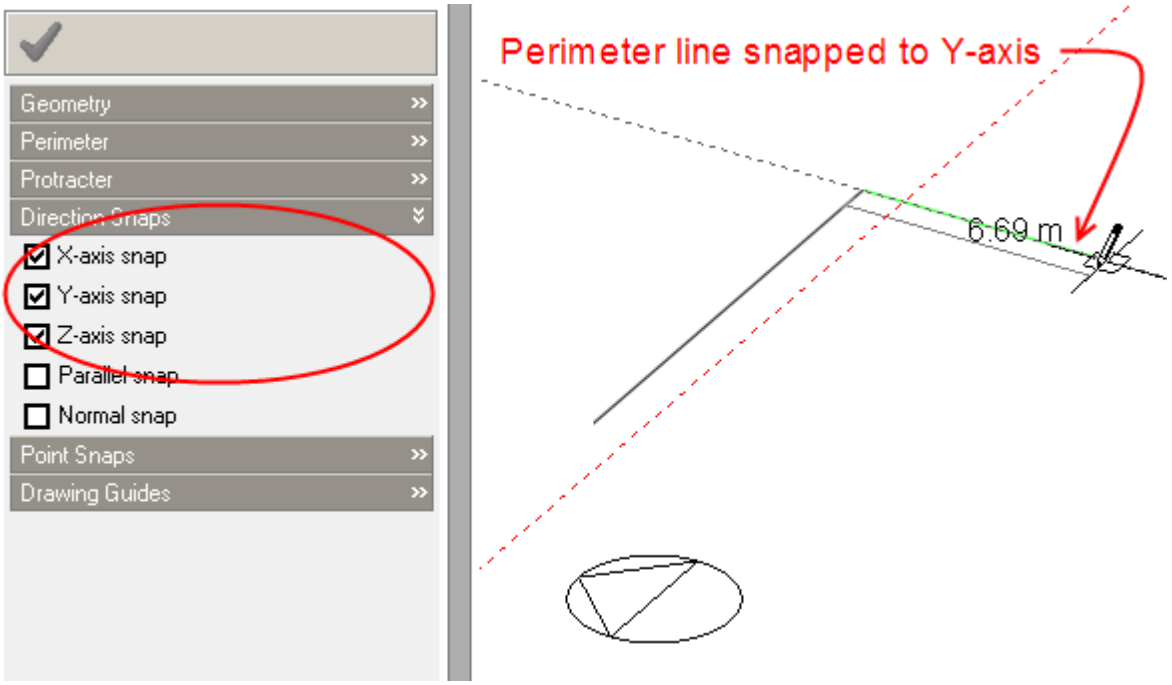
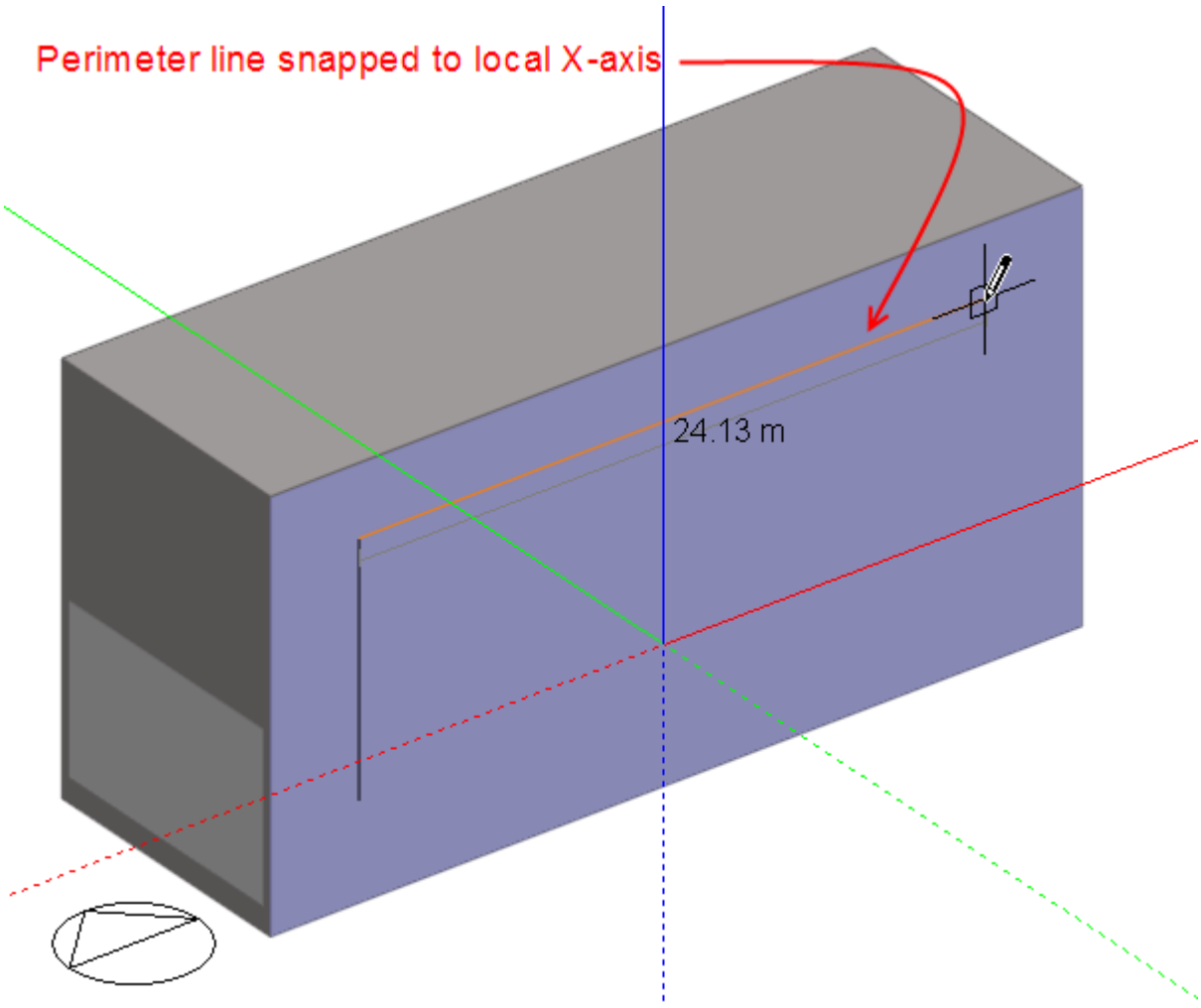


You can use axis snap to draw block perimeters on planes of any orientation. If the plane is non-horizontal, the axis snap applies to the local coordinate system of the plane as if it were rotated to the horizontal:



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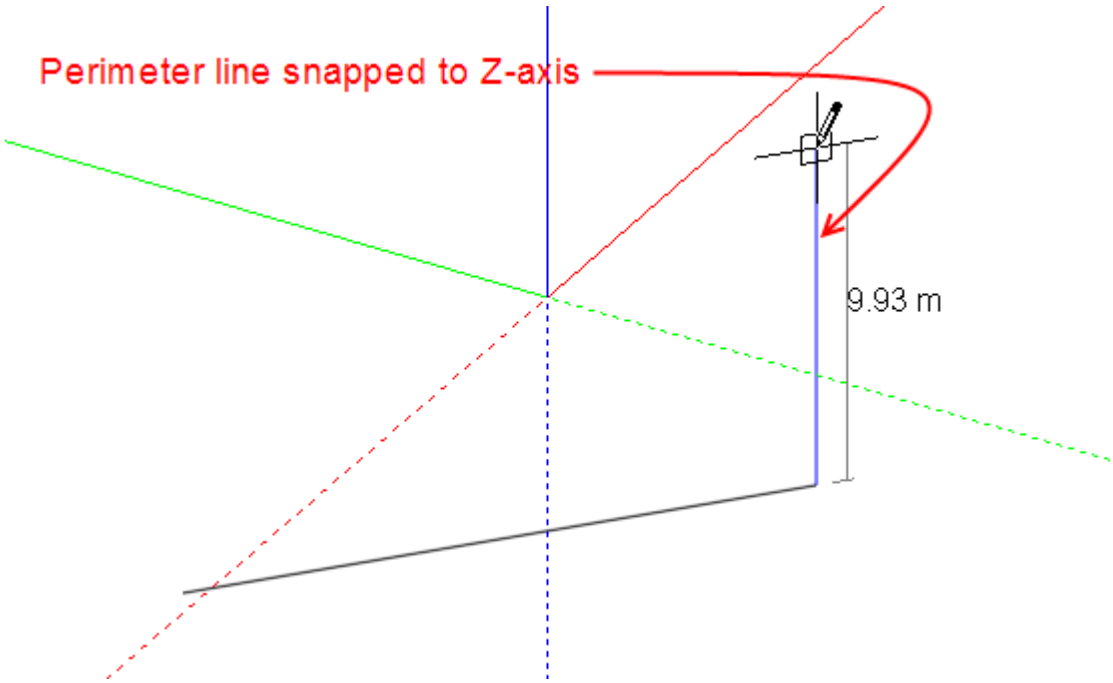
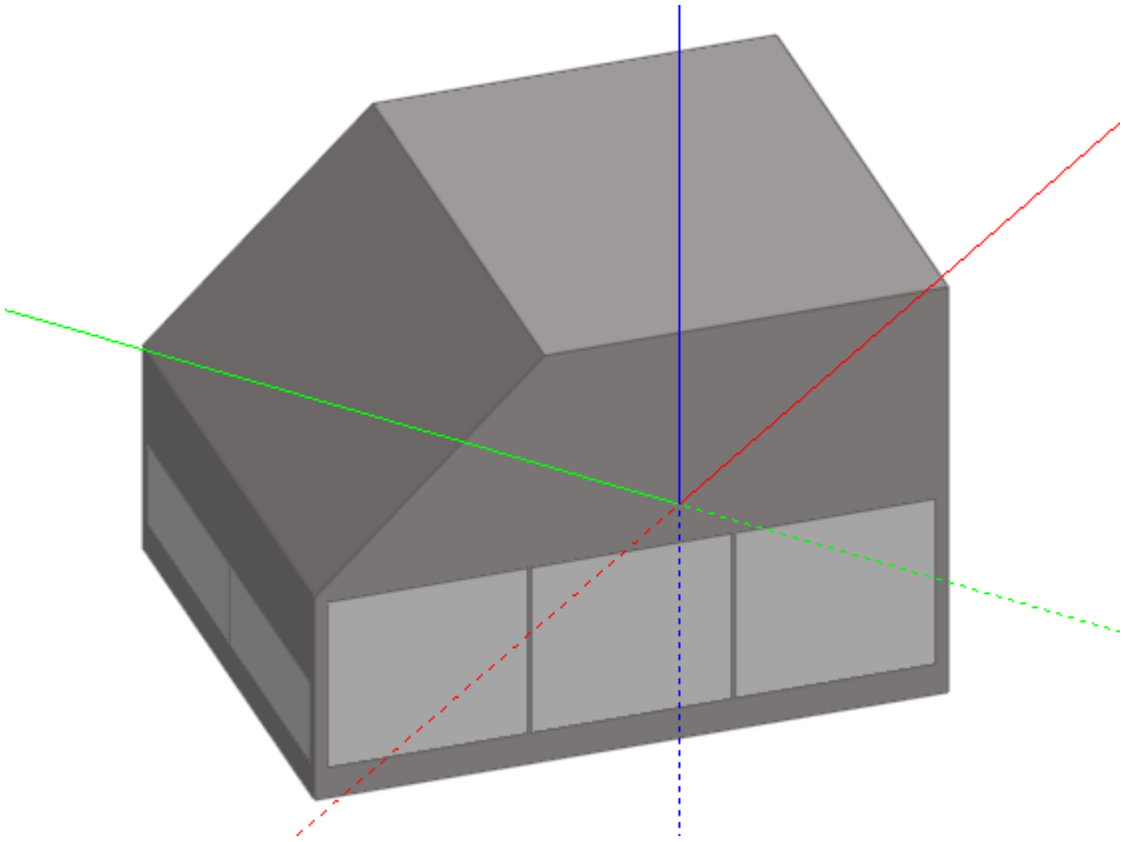
If the axis snap is operating on a horizontal plane, the perimeter line will change colour to red if the line is snapped to the X-axis or green if it's snapped to the Y-axis. However if the active drawing plane is not horizontal, the line will change colour to orange for the X-axis and purple for the Y-axis.

At the building level, when the active drawing plane is horizontal, you can also snap block perimeters and construction lines to the Z-axis:



which allows you to draw horizontally extruded blocks, this process is explained under Adding Blocks



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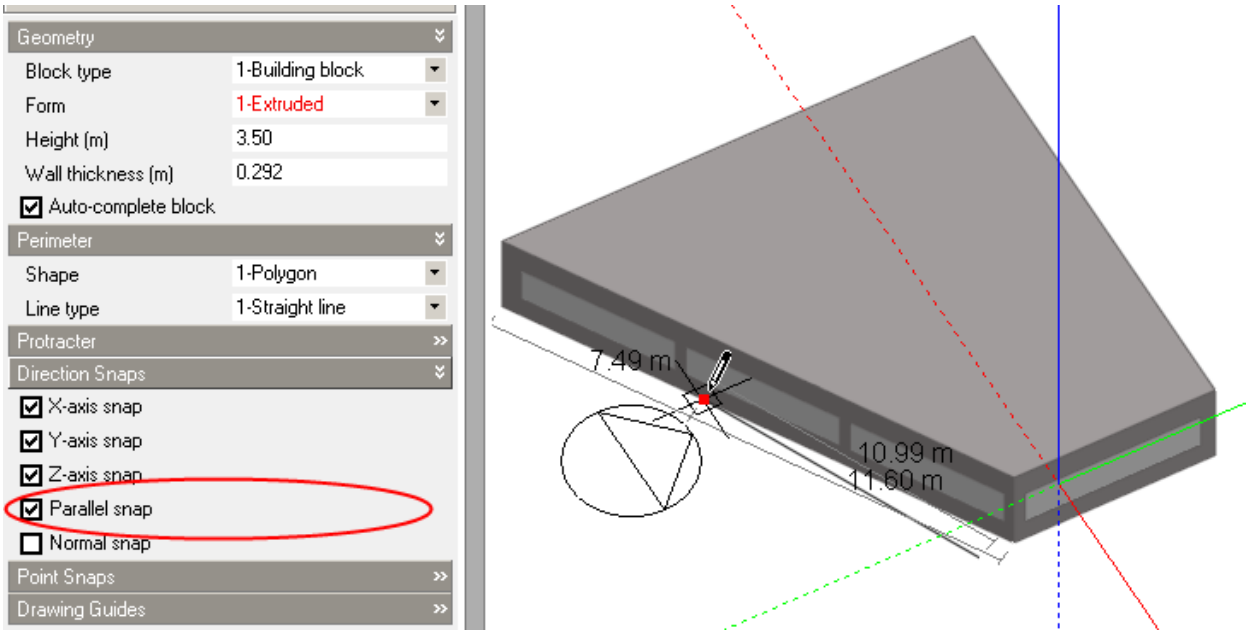
3.2.3.1.2 Parallel snap

The parallel snap is used draw lines parallel with the edges of existing objects. The parallel snap check box is displayed under 'Direction snaps' in the 'Drawing Options' data panel when the various drawing commands are active. To draw a block perimeter line to be parallel with an existing block edge, switch the parallel snap on and move the mouse cursor to touch the edge with which the current perimeter line is to be parallel:



This will enable the active perimeter line to infer a direction from the selected edge and you can lock this inference by pressing the SHIFT key to prevent a parallel inference being picked up from an unwanted edge. So press the SHIFT key and move the mouse cursor to a position approximately parallel with the edge, the cursor will 'stick' when the parallel snap operates and the perimeter line will change colour to cyan:

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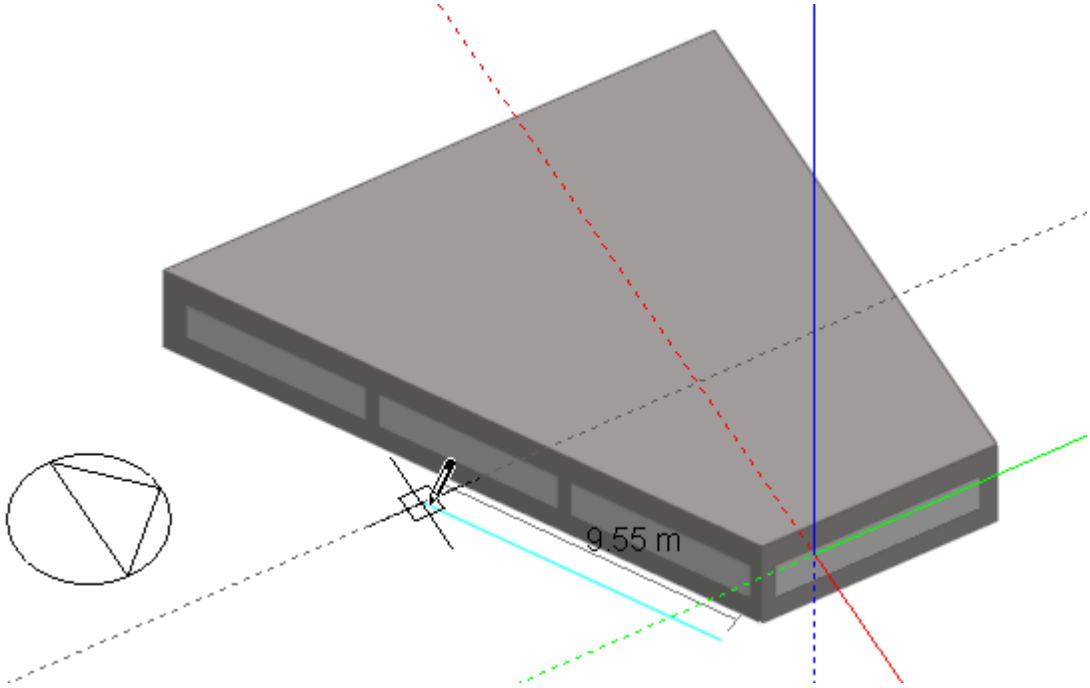

When the parallel snap is in operation, intersections are automatically calculated with drawing guides to allow the two to be combined, so you can snap to the intersection of the two.

3.2.3.1.3 Normal snap

The normal snap is used to draw lines perpendicular to the edges of existing objects. The normal snap check box is displayed under 'Direction snaps' in the 'Drawing Options' data panel when the various drawing commands are active. When the normal snap is switched on and you draw a line string, each line will automatically snap to be perpendicular with it's predecessor if it exists:

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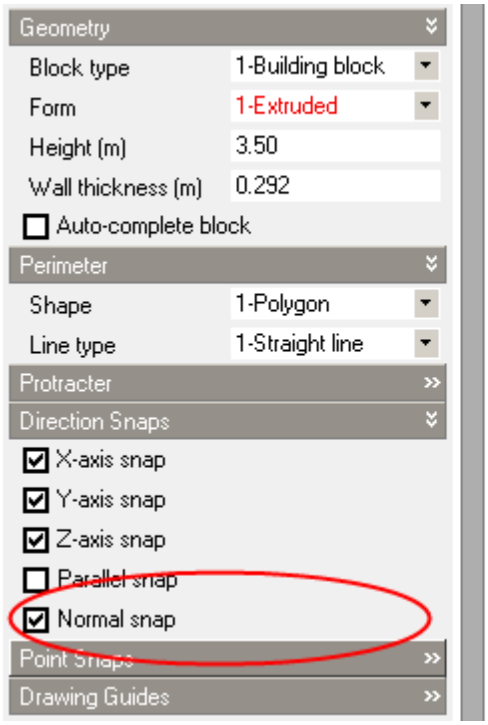
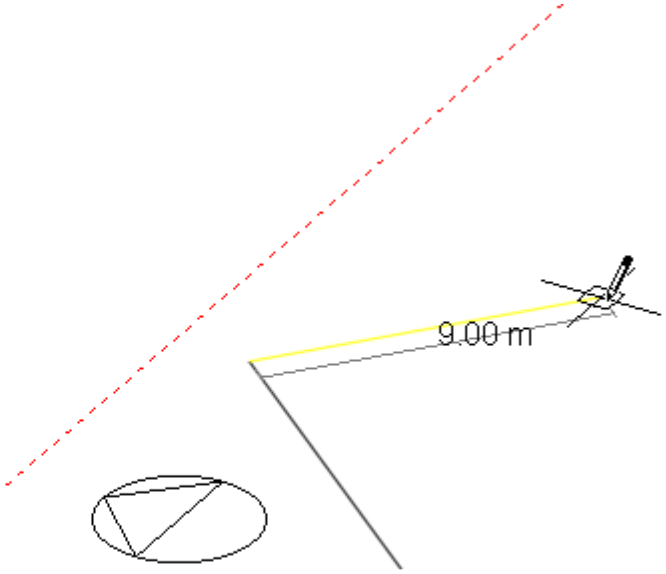
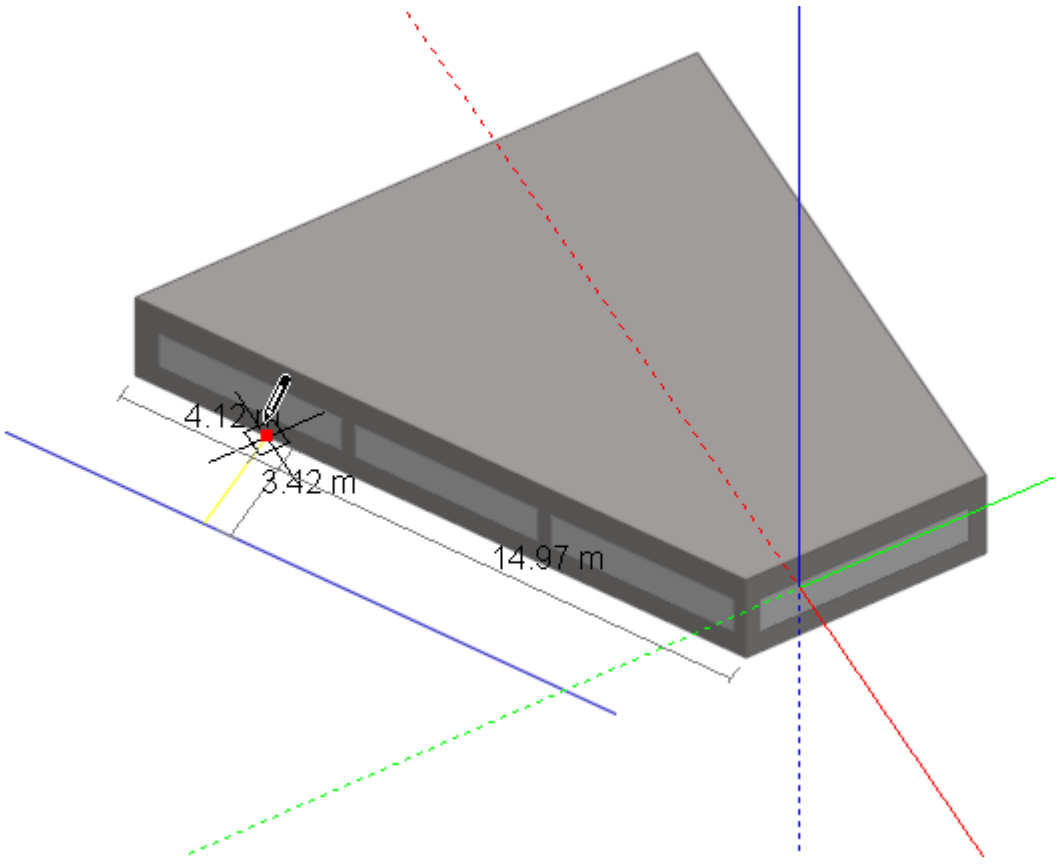




To draw a block perimeter line to be perpendicular with the edge of an existing block, move the mouse cursor to touch the edge and then move it to be approximately perpendicular to it, the cursor will automatically snap to a line which is exactly perpendicular.



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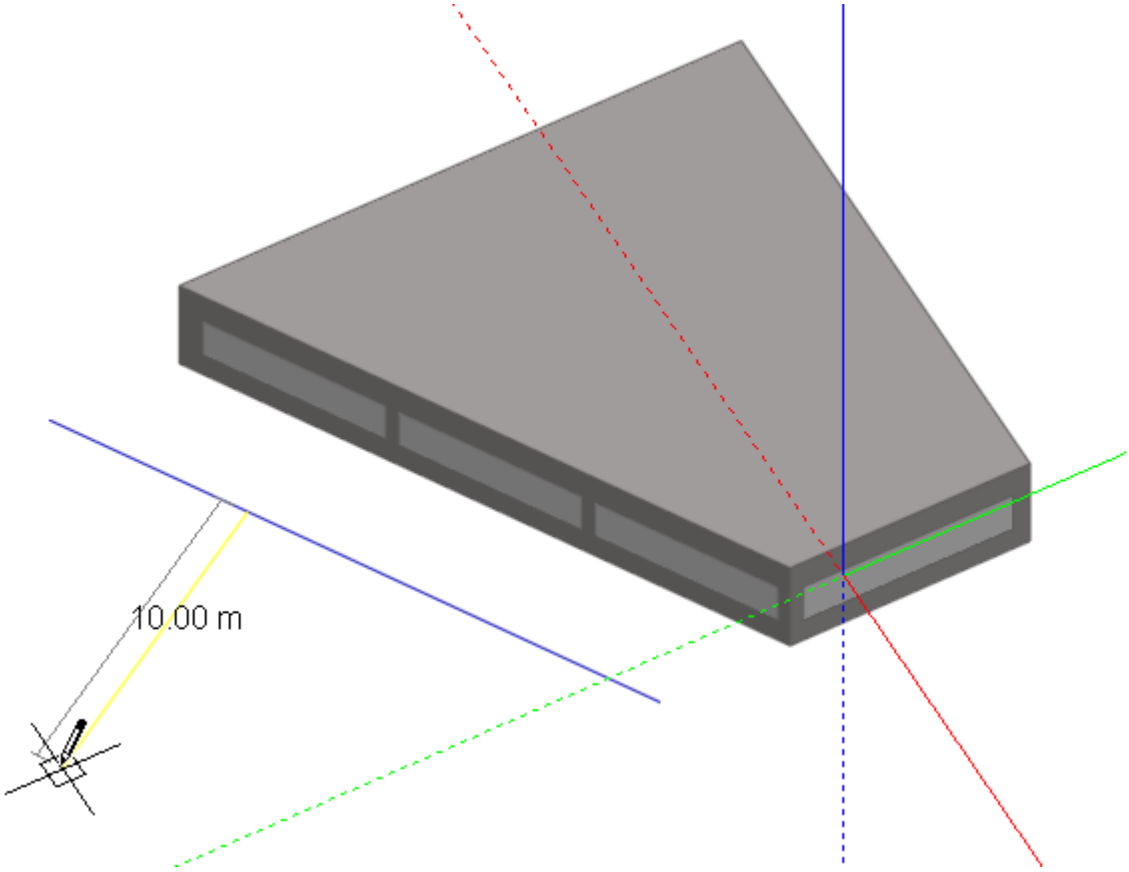
You can lock the perpendicular snap by pressing the SHIFT key which will prevent the cursor from picking up an unwanted direction inference. In this case, a construction line has been placed parallel with the block edge to help in positioning the new block. The perimeter line locks to a perpendicular from the construction line:



When the normal snap is in operation, intersections are automatically calculated with drawing guides, allowing you to snap to the intersection:

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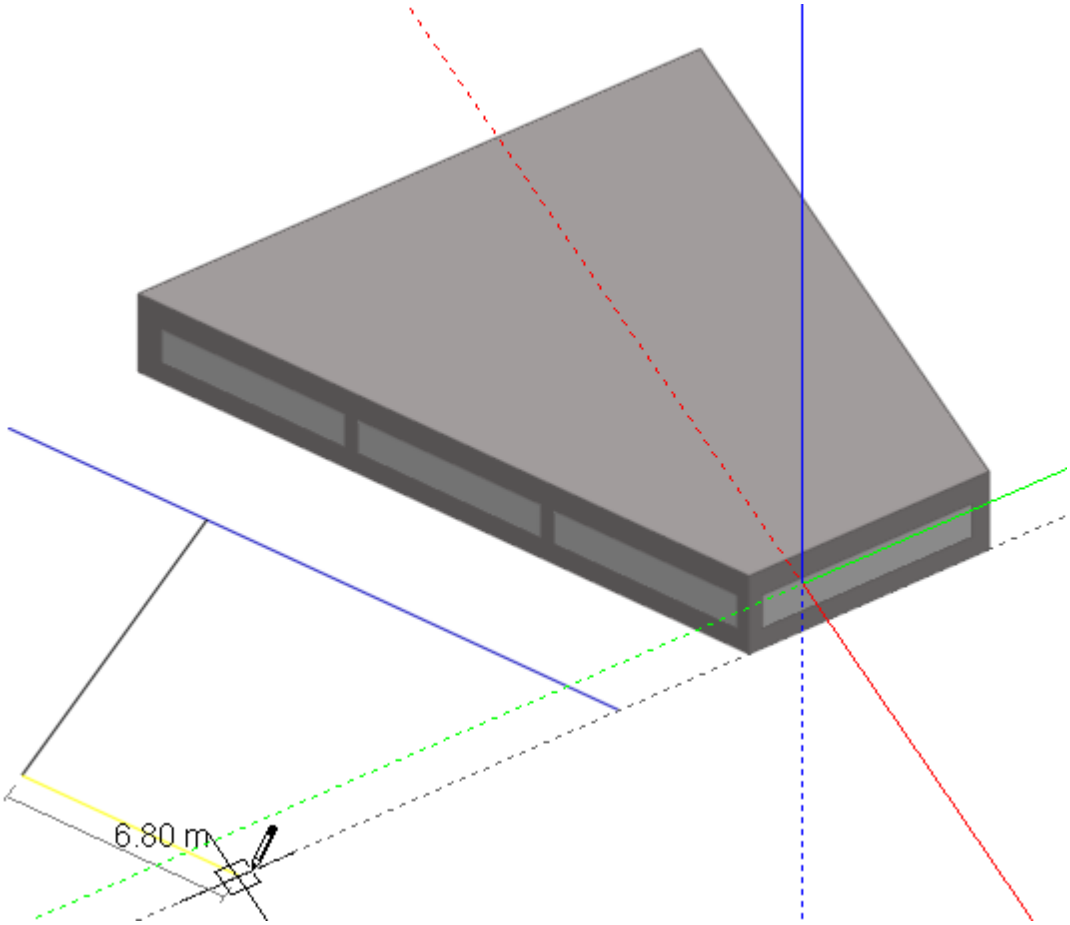

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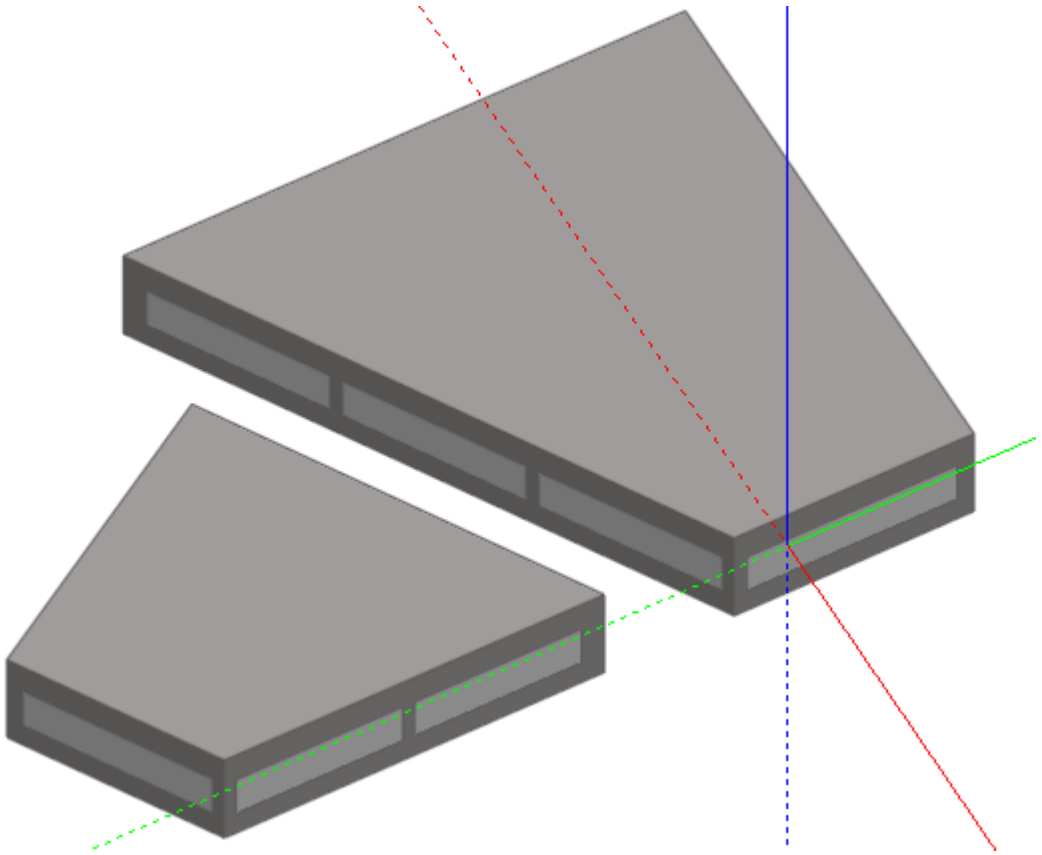

3.2.3.1.4 Offset Snap

The offset snap is used to draw partitions and voids parallel to existing walls and partitions at a fixed offset distance. This help topic describes the use of offset snap for drawing partitions, but the information is equally applicable to drawing voids at a fixed offset from the perimeter.

The offset snap check box is displayed under Direction snaps in the **Drawing Options** data panel when the Draw partitions command is active.

The offset snap can be used whenever a string of partitions is to be located at a fixed offset from a perimeter, but can be specifically applied to dividing large open plan spaces up into 'perimeter' and 'core' zones for thermal simulation.

When the offset snap is switched on, an additional **Distance** item will be displayed under the offset snap check box which allows you to define the offset distance. When you first switch on the offset snap, having clicked on the Draw partition icon, you will see offset snap indicators displayed as you move the cursor within the snap range of an existing wall or partition:

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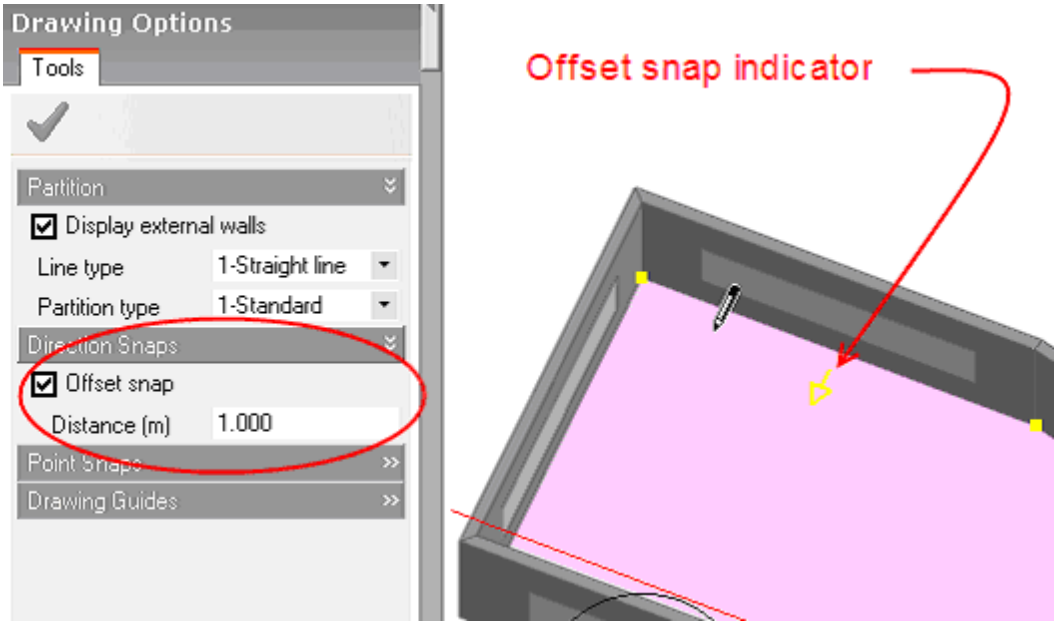
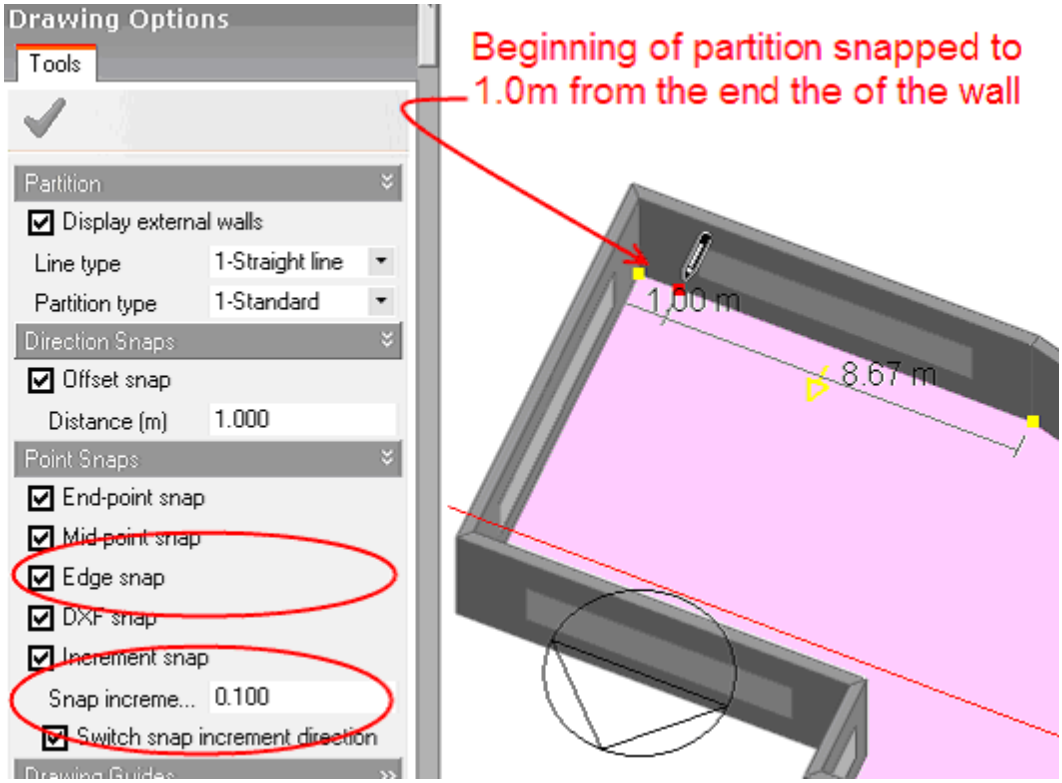


The offset snap works in conjunction with the other snaps and so, for example, you can start an offset partition at a fixed distance from the beginning of an existing wall using the edge snap in combination with the increment snap:



After placing the beginning of the partition, the 'rubber-banded' partition will be automatically snapped to the offset from the selected wall and as you move the cursor to the next connected wall segment, the offset snap indicator will appear again:

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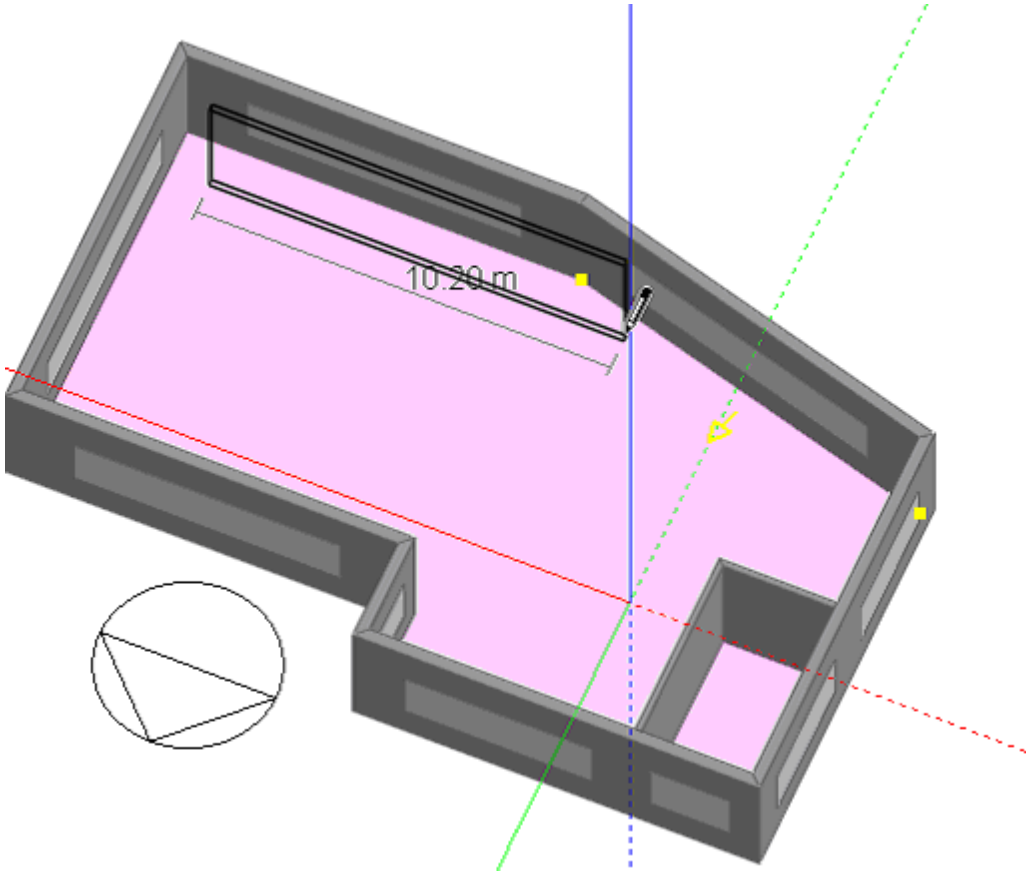

As you move the cursor, you will see that the offset snap interacts with other snaps allowing you to position partitions accurately. If you find that the other snaps are interfering with the offset snap, you can switch them off by pressing the SHIFT key.

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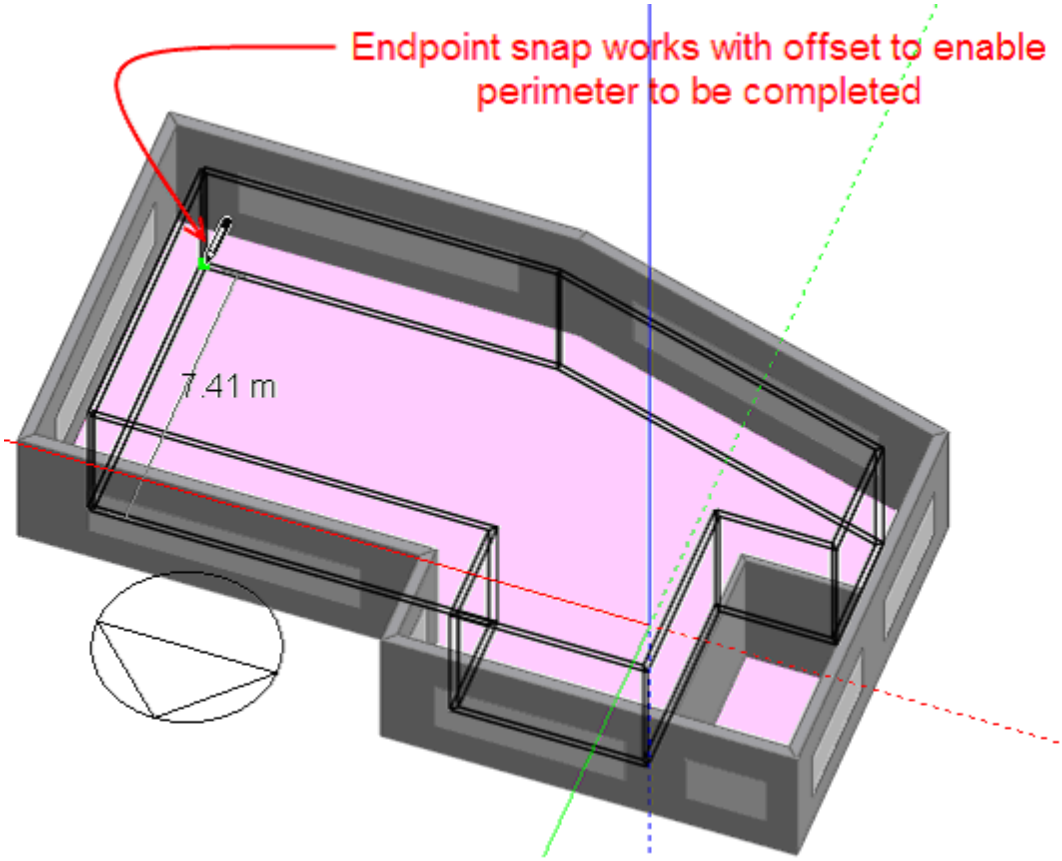
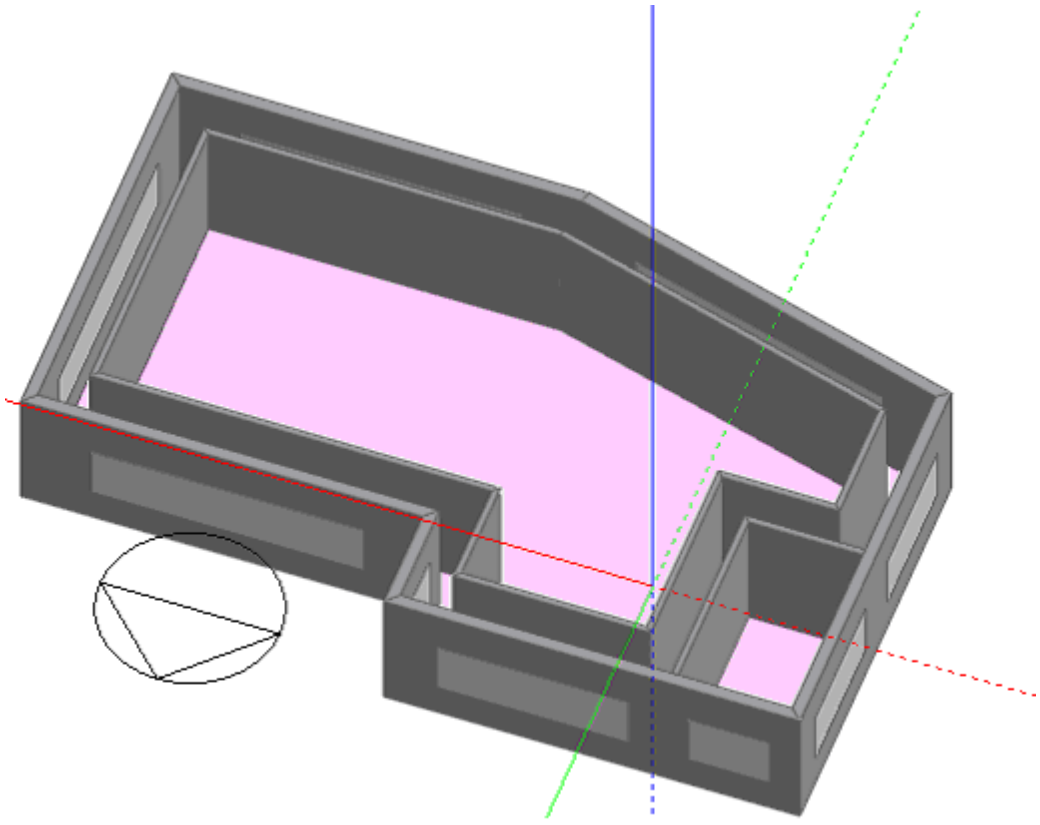


Completed perimeter:



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3.2.3.2 Point Snaps

When the various point snaps are switched on, a coloured indicator is displayed when the mouse cursor is close to a key-point on an existing element allowing a perimeter or partition line end-point to be positioned precisely at the selected key-point. The following point snaps are available:

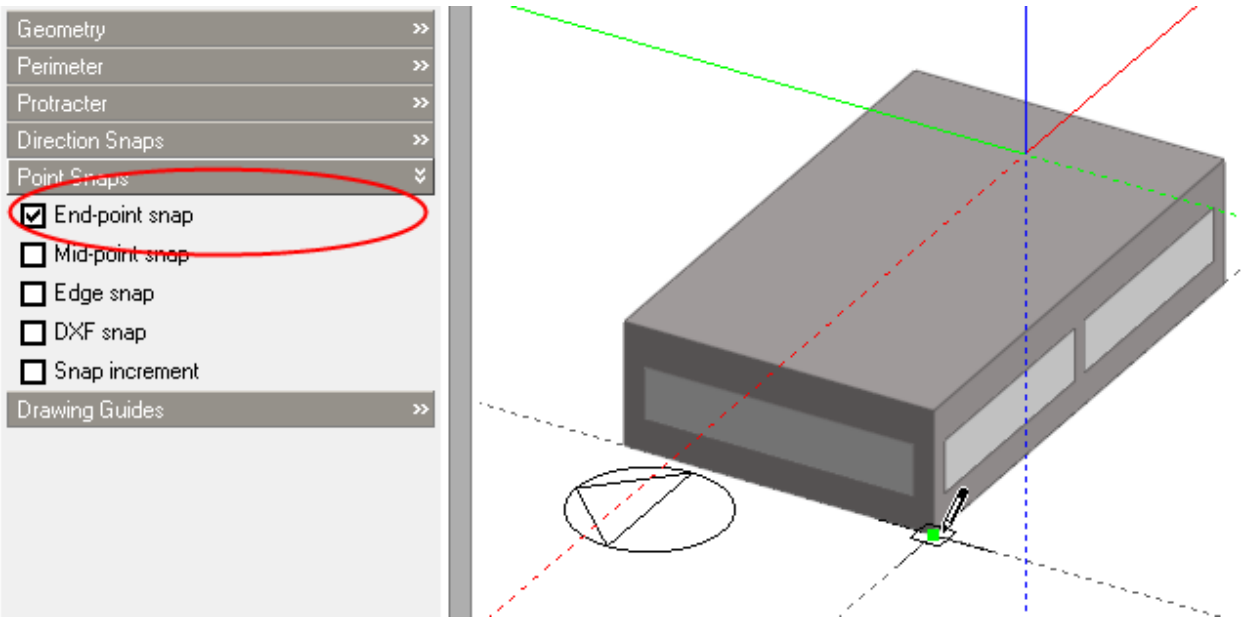
- End-point snap
- mid-point snap
- Edge snap
- DXF snap
- Snap To Lower Perimeters
- Increment snap

Note: In some cases Snaps can interfere with attempts to draw to a particular point and in this case you can temporarily switch off the appropriate snap(s) using the check boxes in the Drawing options panel in the bottom left of the screen.

3.2.3.2.1 End-point Snap

This snap allows you to snap lines to the end-point of an existing edge. A green indicator is displayed when the mouse cursor is within the snap range of an end-point:

For example, to snap the starting point of a new block perimeter to the end-point of an existing block edge, move the mouse cursor onto the background and press SHIFT to lock the drawing plane to the ground plane. Keep the SHIFT key pressed and move the mouse cursor close to the required edge marker to activate the end-point snap:



Similarly to snap the starting point of a new block partition to the end-point of an existing partition, make sure that the 'End-point' snap is switched on and move the mouse cursor close to the partition end-point to activate the snap:

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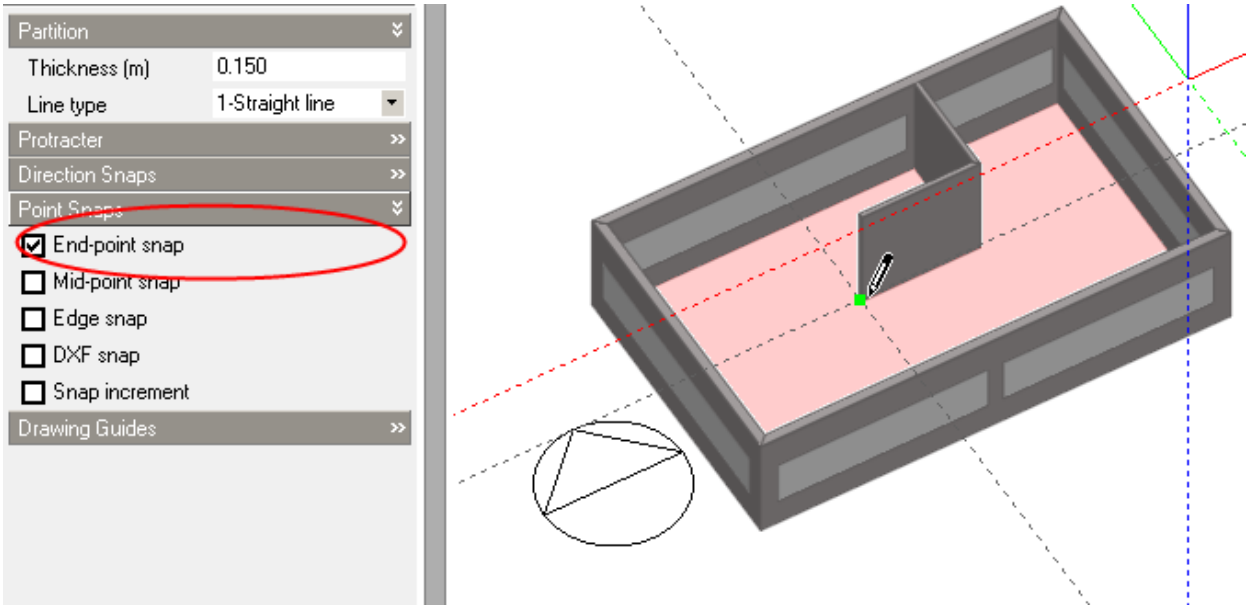
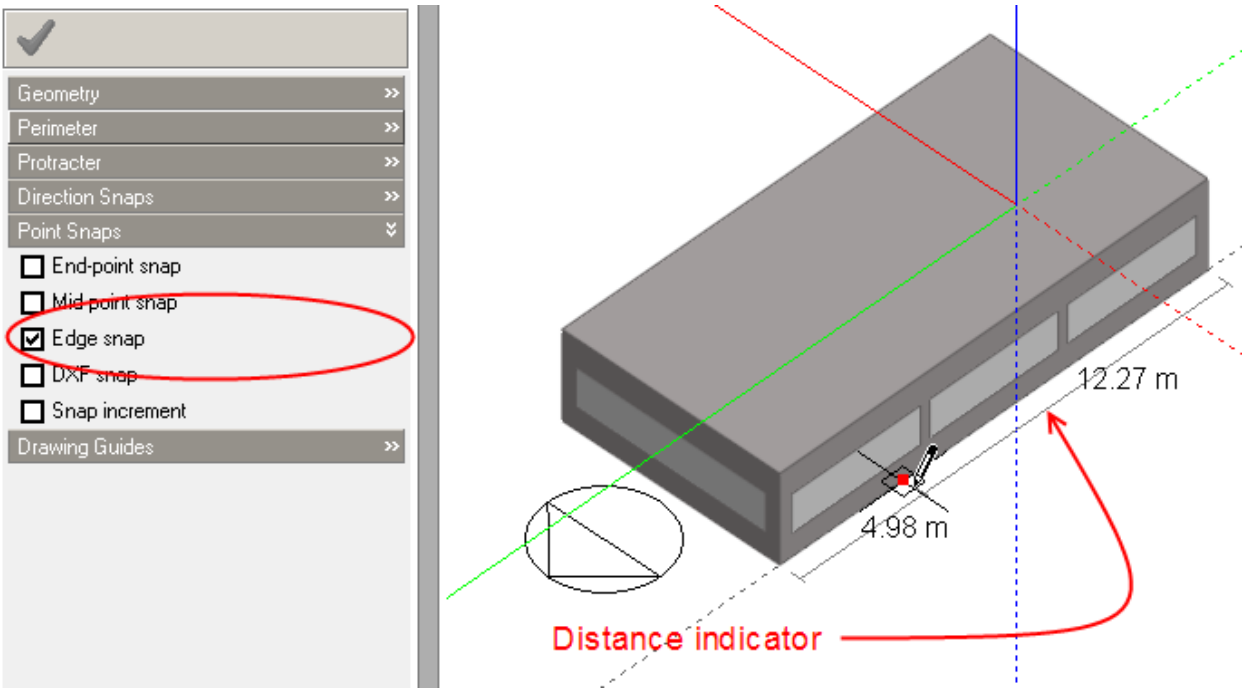


3.2.3.2.2 Mid-point Snap

For details of using the 'Mid-point' snap, please refer to the End-point snap.

3.2.3.2.3 Edge Snap

The edge snap allows you to snap to any point on the edge of an existing object. The edge snap can be used in conjunction with the increment snap to enable a point to be located along an edge by moving it in defined increments. A red indicator is displayed when the mouse cursor is within the snap range of an edge and distance indicators are also displayed to help in locating a point a specific distance from either end of the edge:



By switching the increment snap on, the point can be moved along the edge in defined increments. For

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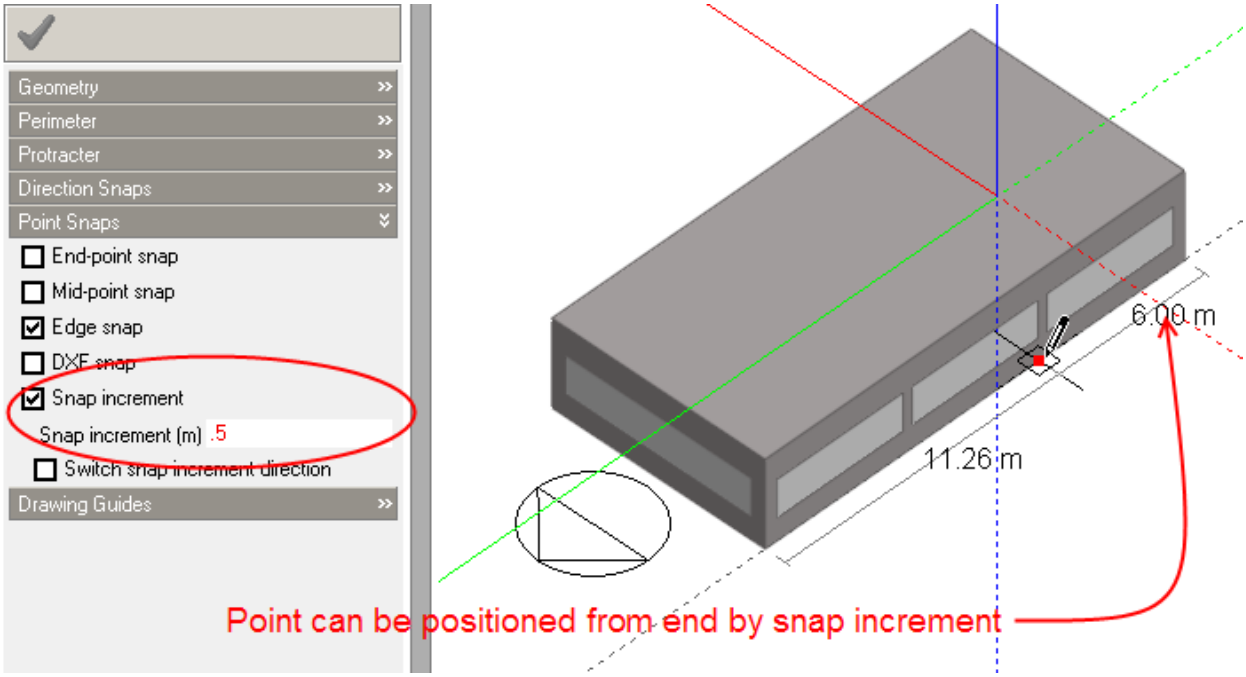
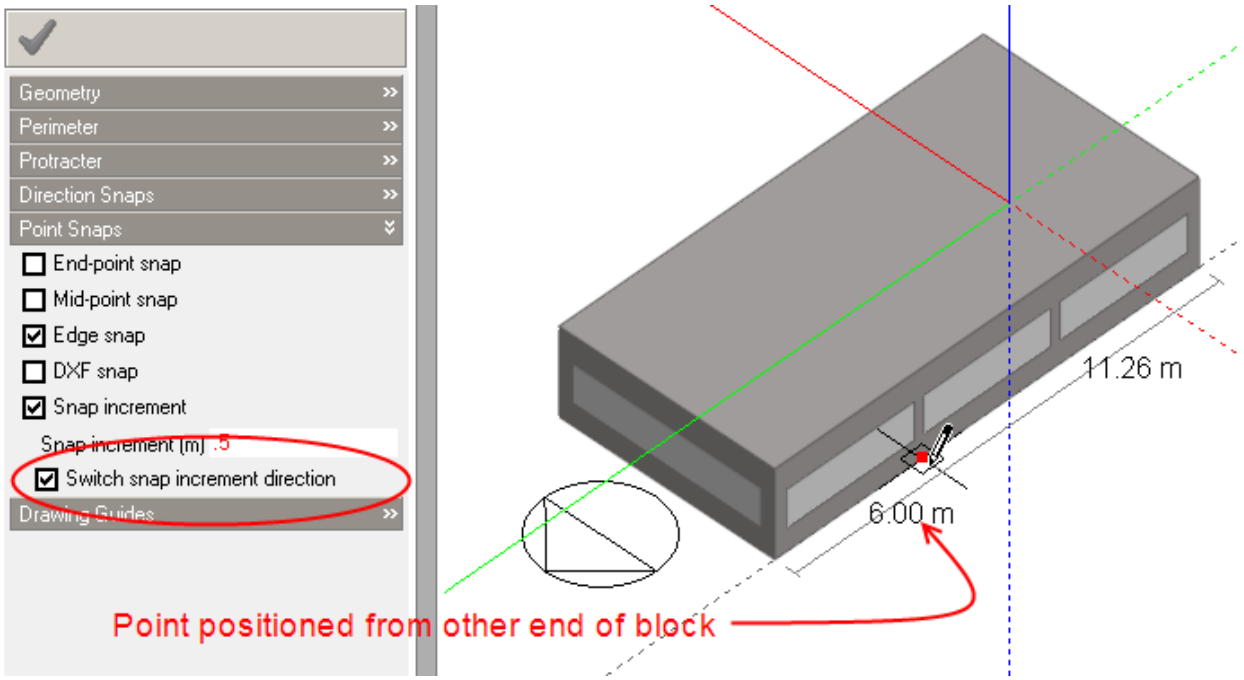
example, if you wanted to start a block perimeter line at 6.0 metres from the end of the block, after switching on the increment snap, you could set the snap increment to say 0.5m and then move the mouse cursor to snap to the edge at a distance of 6.0 metres from the end-point:



If you wanted to locate the beginning of the perimeter line at a specific distance from the other end of the edge, you can switch the end of the edge from which the increment snap operates by toggling the 'Switch snap increment direction' switch:



3.2.3.2.4 DXF Snap

The DXF snap only applies when DXF data has been imported from an external file. The DXF snap enables you to snap to the end-points of DXF lines:

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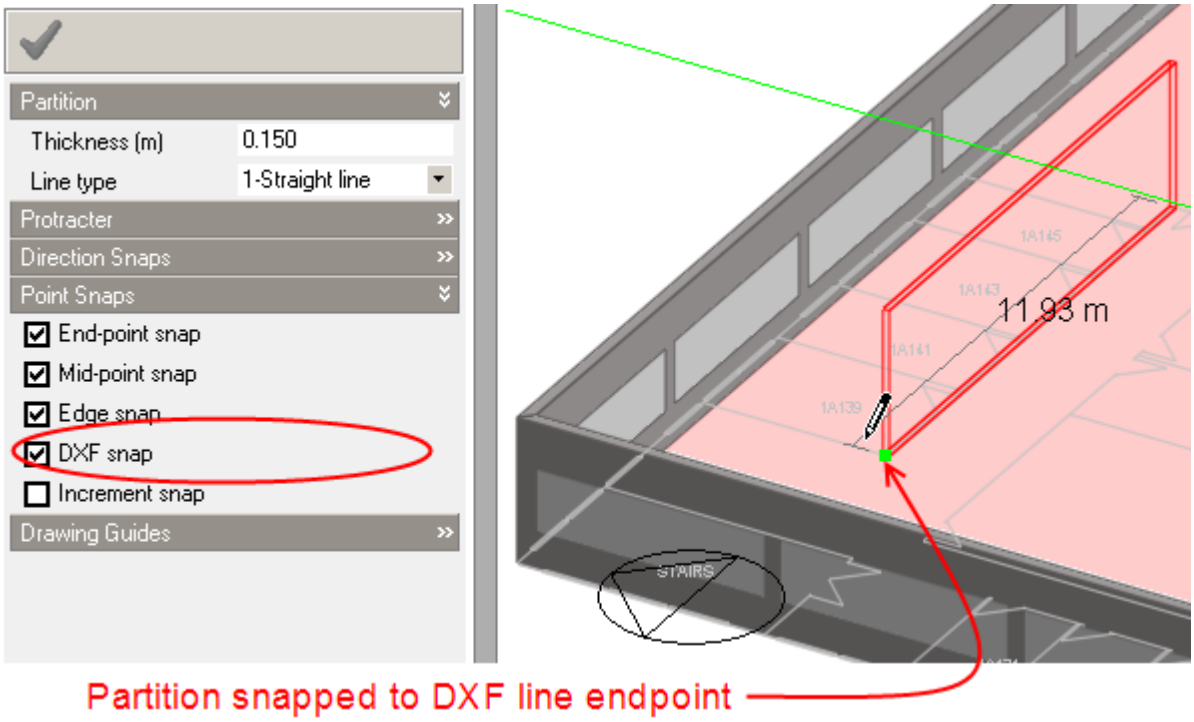

Note: You should generally switch DXF snap off when drawing partitions at block level and simply use the DXF lines as a visual guide. This ensures that partitions correctly snap to perimeters instead of snapping to DXF lines which may be very close to the perimeter but not actually touching.

3.2.3.2.5 Snap To Lower Perimeters

This snap allows you to snap to adjacent lower block perimeters and partitions. This snap is switched on by default but it can be useful sometimes to switch it off to avoid snapping to partitions in the block below.

3.2.3.2.6 Increment Snap

The increment snap applies to any process that involves moving a point or a surface in a particular direction. Such processes include drawing block partitions or perimeter lines which have an active direction snap or dragging the surface of a block normal to the original surface position. The increment snap allows you to move a point in a particular direction by defined increments. You can think of the increment snap acting in the same way as a conventional CAD drawing grid and in fact if you were just to use the axis snaps it would have the same effect, however the increment snap is more powerful in that it provides this type of incremental snap along any defined vector not just the axis vectors.

The increment snap may be particularly useful during early stage design when you want to place geometry with reasonable accuracy but don't want to be constantly keying-in distances.

Note: the increment snap will only come into operation when you are drawing a line or moving a surface along a defined vector. For example if you are drawing a block perimeter parallel with an existing block edge, the increment snap will operate when the parallel snap is active and in this case you would be able to move the mouse cursor along the parallel vector in increments of 0.5m:

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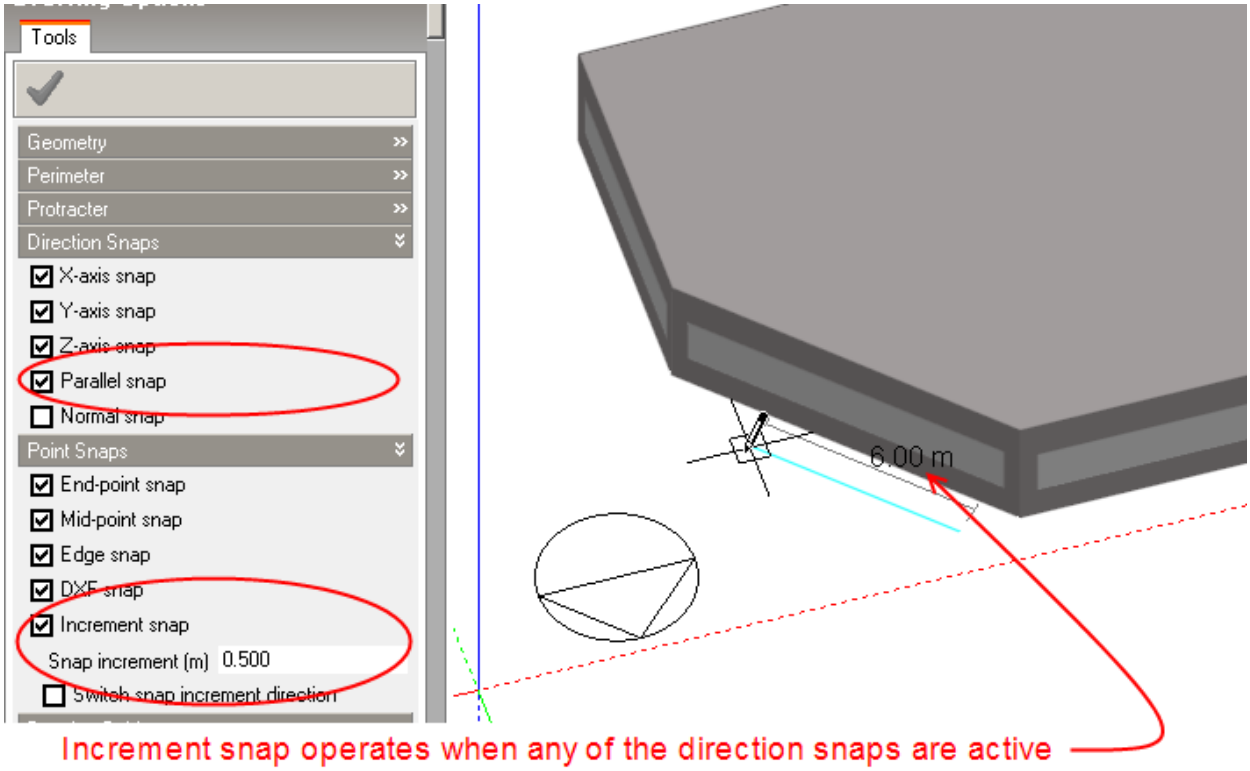
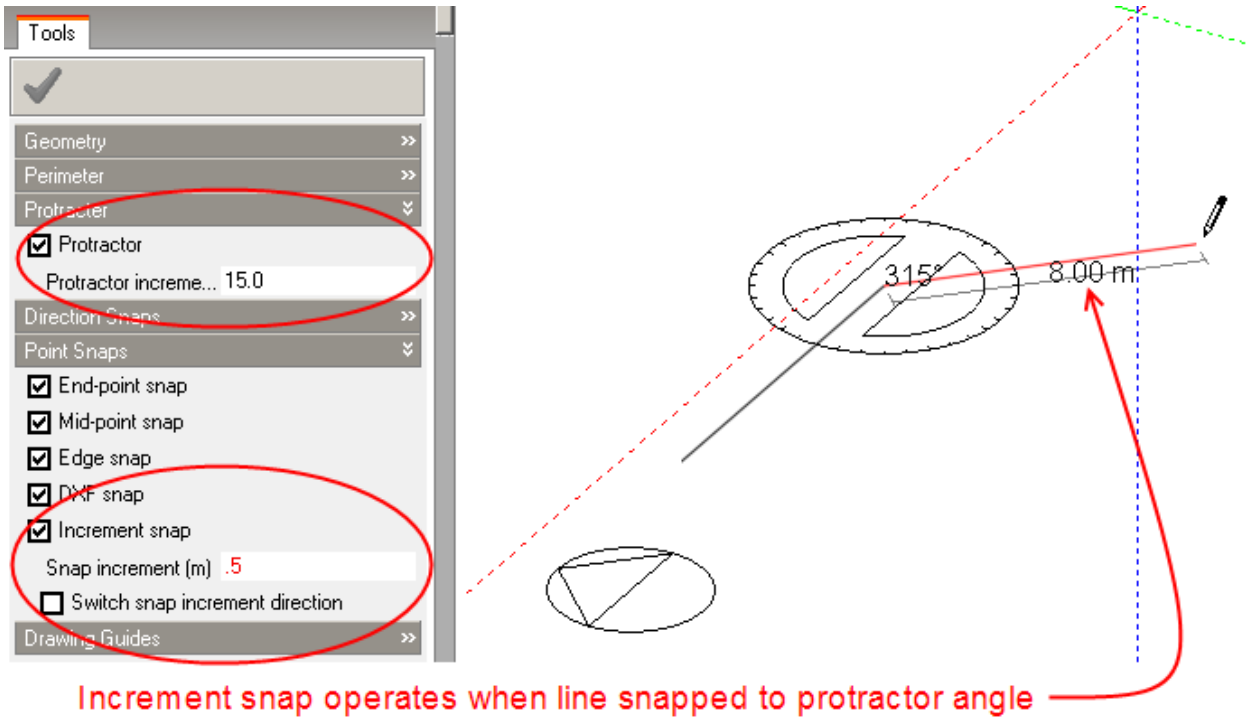


The increment snap also works in conjunction with the Protractor:



You can use the increment snap to control the location of block faces when you extrude a block on creation or drag faces during an edit or stretch operation:

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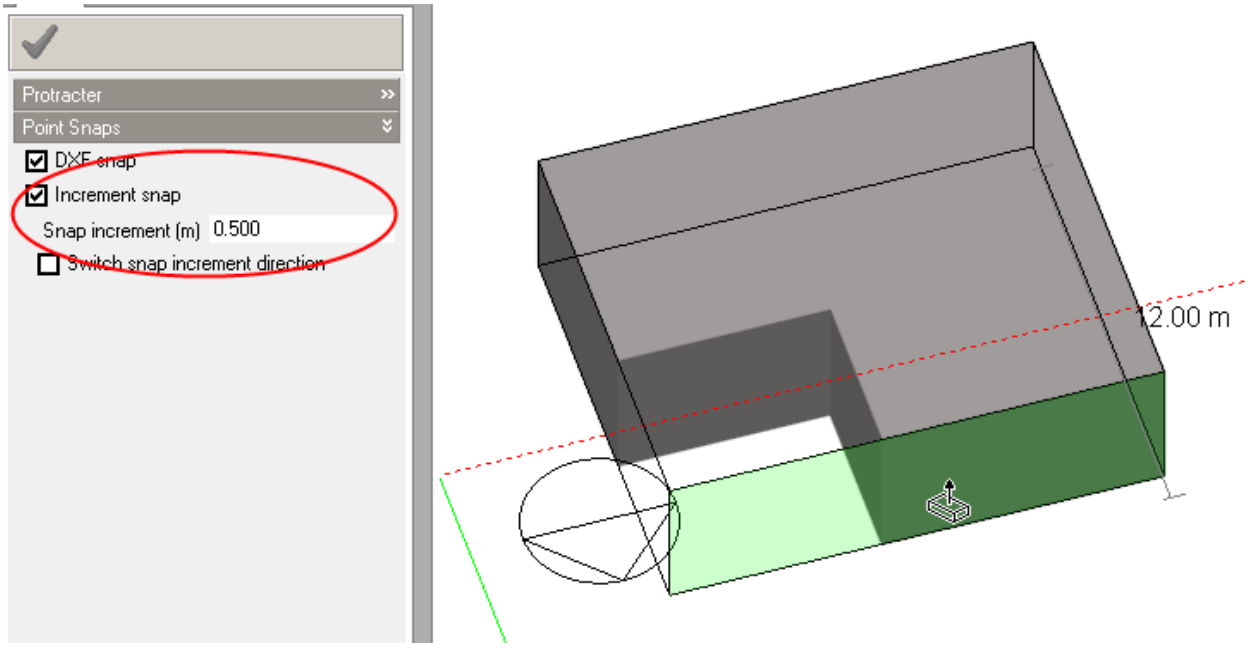

The increment snap also comes into operation when an edge snap is active, allowing you to snap to the edge by increments from either end, please see edge snap for details.

Switch snap increment direction

Increment snap provides increments between the 2 end points of the reference line and increments can only be generated from one end point at a time. You can reverse the direction so that increments are generated from the other end of the reference line by checking the **Switch snap increment direction** drawing option. This option is found immediately below the Increment snap option (screenshot above).

3.2.3.3 Drawing Guides

Drawing guides are invisible lines that are automatically generated as soon as a drawing plane becomes active during a drawing operation. Drawing guides are parallel with the active drawing plane X and Y axes and run through all end-points and mid-points of existing object edges, which lie in the same plane as the drawing plane. As you move the cursor in the vicinity of a drawing guide, it will become visible and you can then snap the cursor to any point on the guide. When drawing guides are used in conjunction with Direction Snaps or the Protractor they offer a powerful mechanism for locating perimeter lines in relation to existing object edges.

For example to create a triangular window in a surface with the same height as an existing opening, first click on the Draw window tool and check that the perimeter shape is set to 'Polygon', switch the protractor on and then move the cursor to align approximately with the lower edge of the existing window which will automatically snap the cursor to the required drawing guide:

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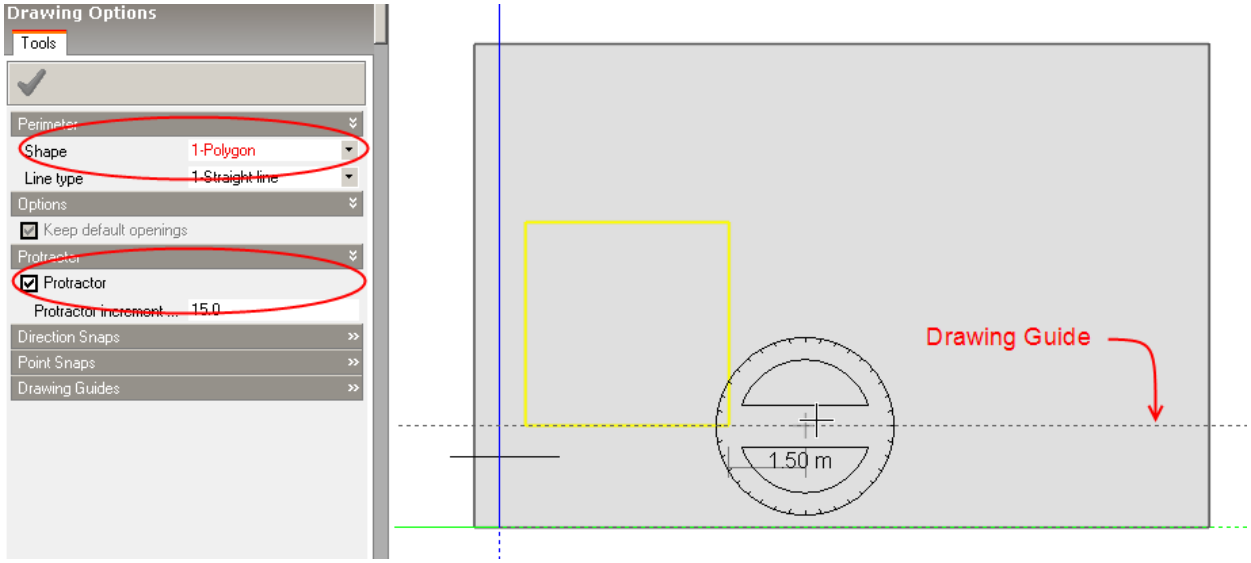
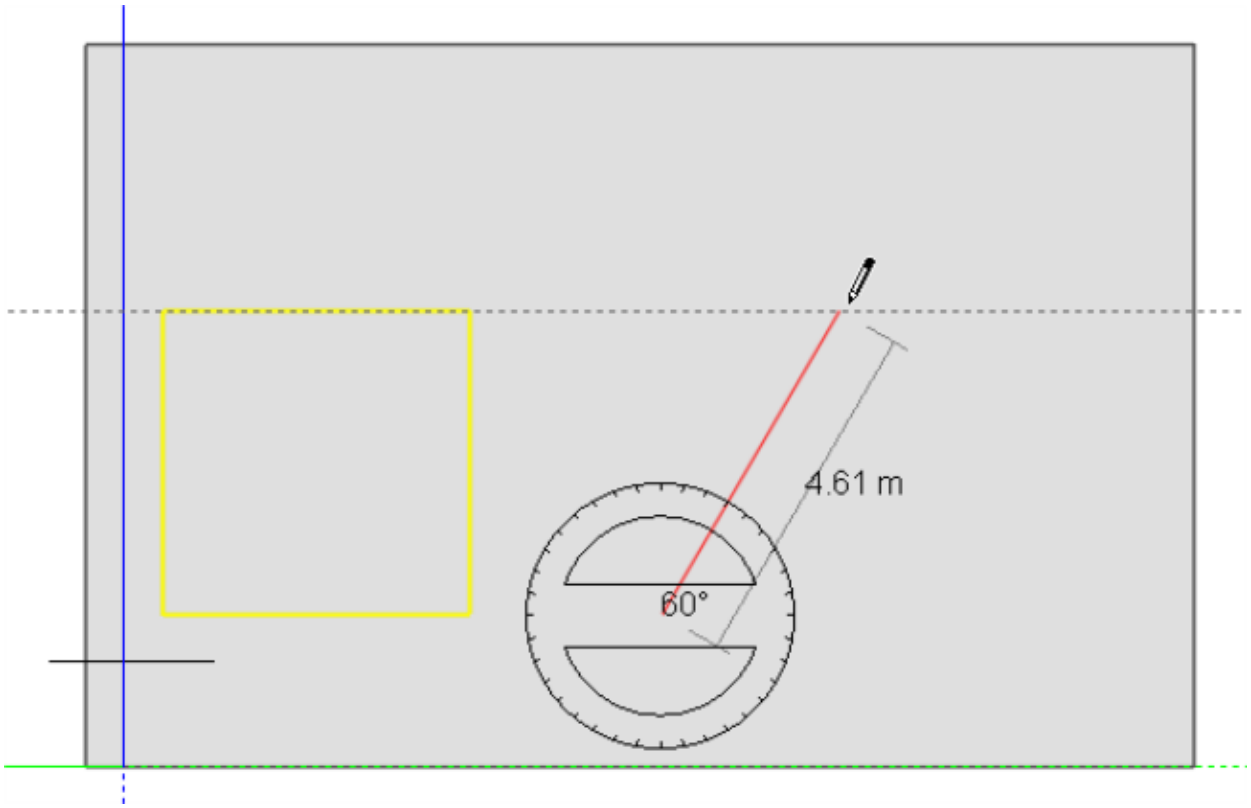


Click to place the window origin and move the cursor to snap to the drawing guide associated with the existing window upper edge, the protractor angle lock will automatically combine with the drawing guide:



Click to place the apex of the window and then place the next point in a similar fashion:

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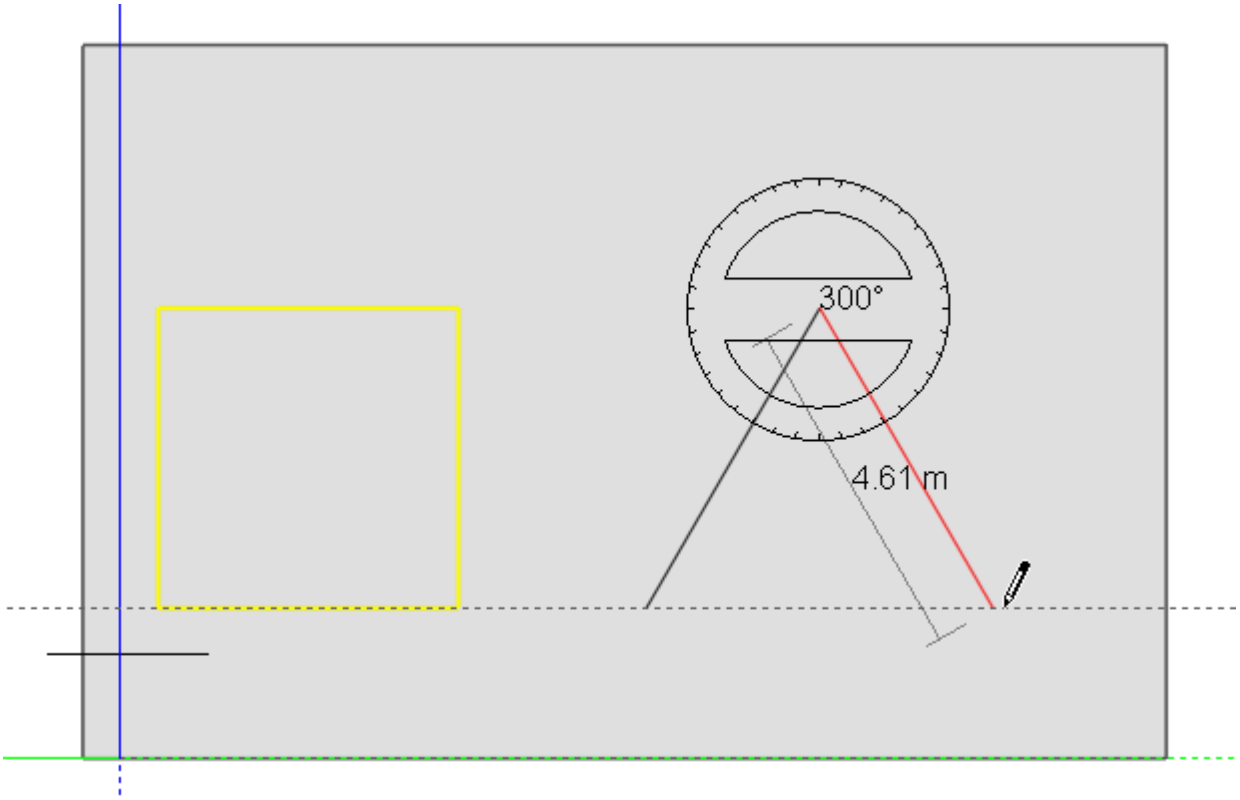
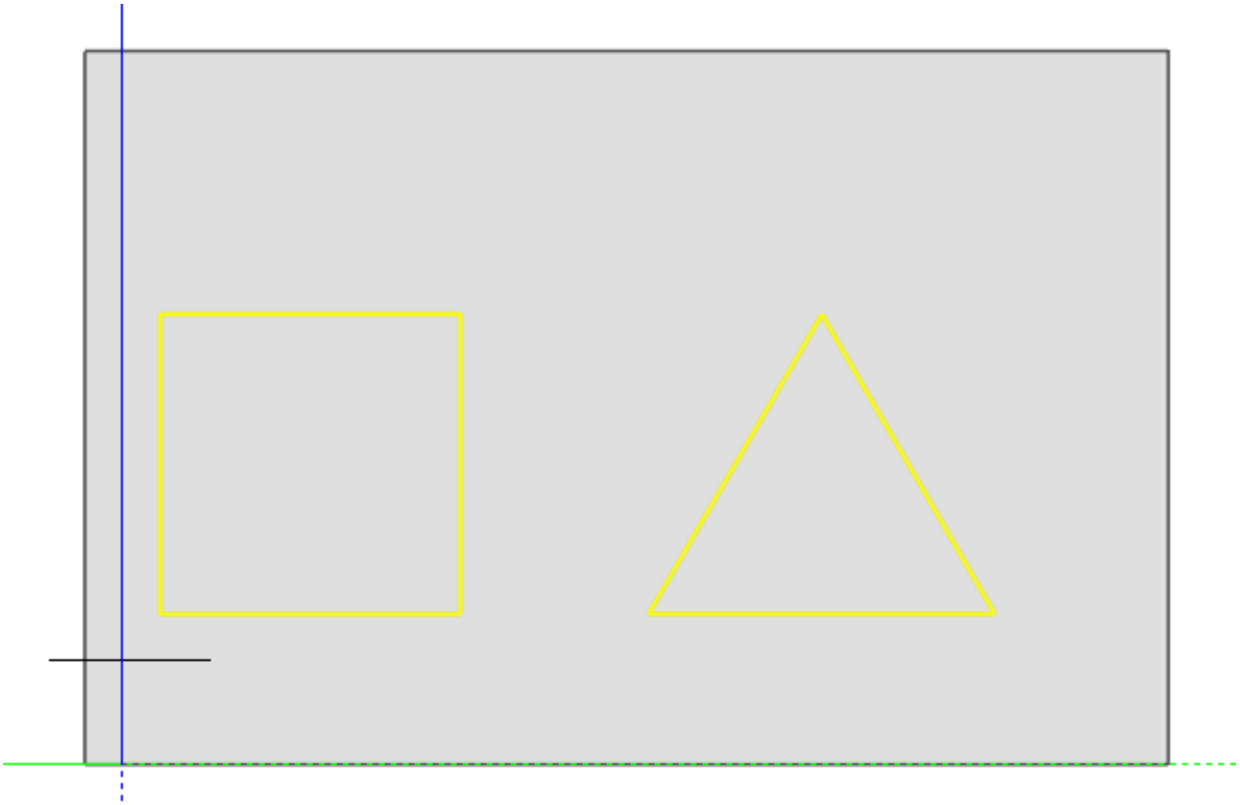


Completing the window perimeter:



Note: In some cases Drawing guides can interfere with attempts to draw to a particular point and in this case you can temporarily switch off Drawing guides using the check boxes in the Drawing Options panel in the bottom left of the screen.

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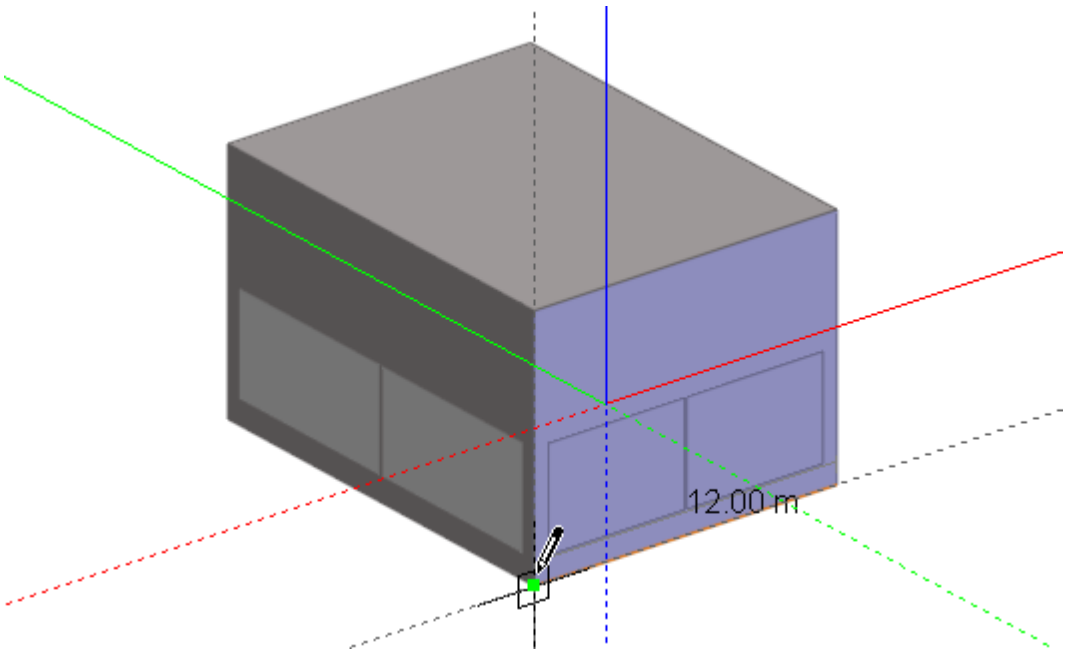
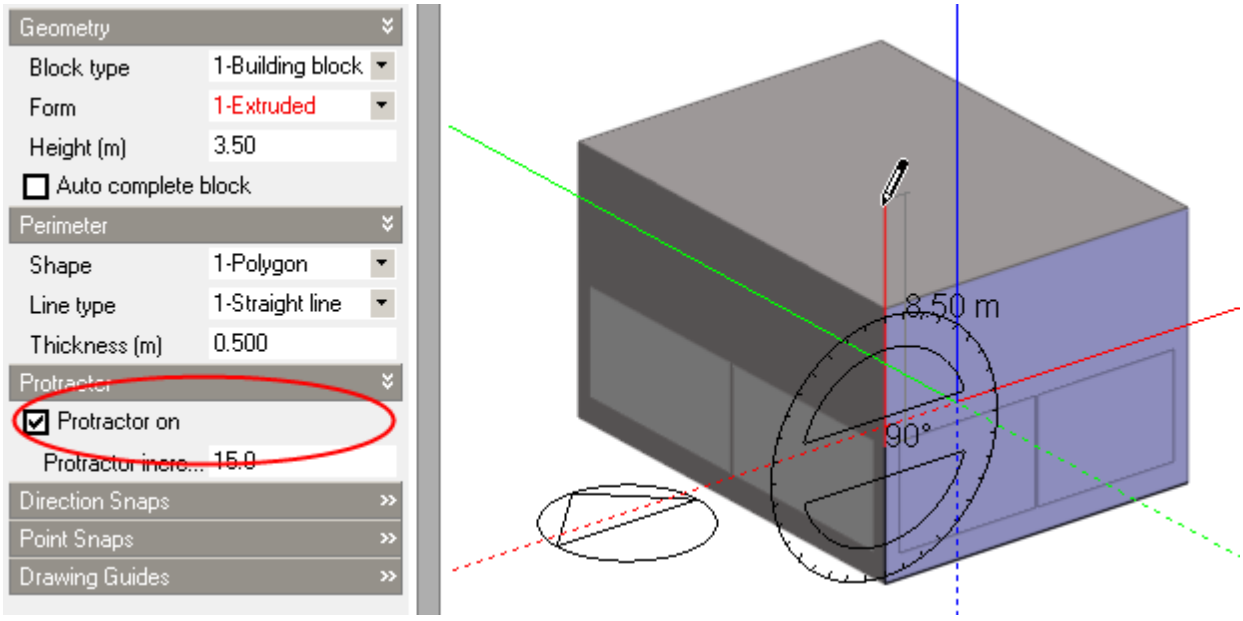
3.2.3.4 Protractor Tool

The protractor tool is used to draw perimeter lines and partitions at specified angles in relation to the current drawing plane. The protractor can be activated from the 'Drawing options' data panel, which is displayed when any of the drawing tools are used. For example, to create an offshoot projecting from an existing block with a roof slope of 30°, move the cursor over the existing block surface, press the SHIFT key to lock the drawing plane and draw the first perimeter line, snapping to the base edge using end-point snap:



Draw the second perimeter line to connect to the mid-point of the block edge and then activate the protractor:



The protractor will automatically snap to the current drawing plane and as you move the mouse cursor, the perimeter line will snap to the protractor in angular increments, which can be set in the 'Drawing options' data panel. The rotation angle is displayed at the centre of the protractor. Move the cursor until the displayed angle is 30° and then move the snapped line towards the upper block edge. When the line end-point nears the edge, it will 'stick' to the edge and the edge snap marker will be displayed:

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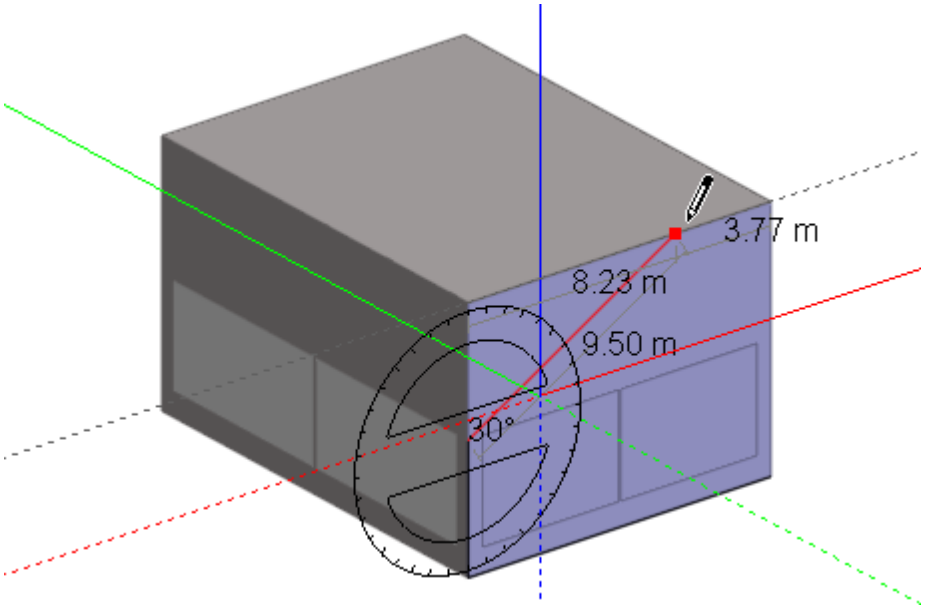
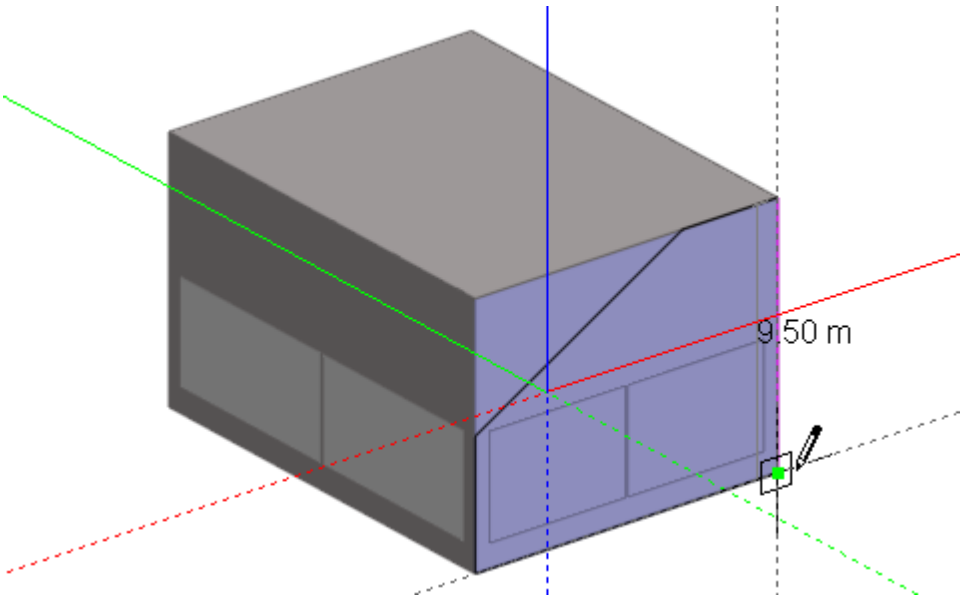


Click to accept the point and complete the perimeter by snapping to the block face vertices using the end-point snap:



Drag the perimeter to complete the offshoot:

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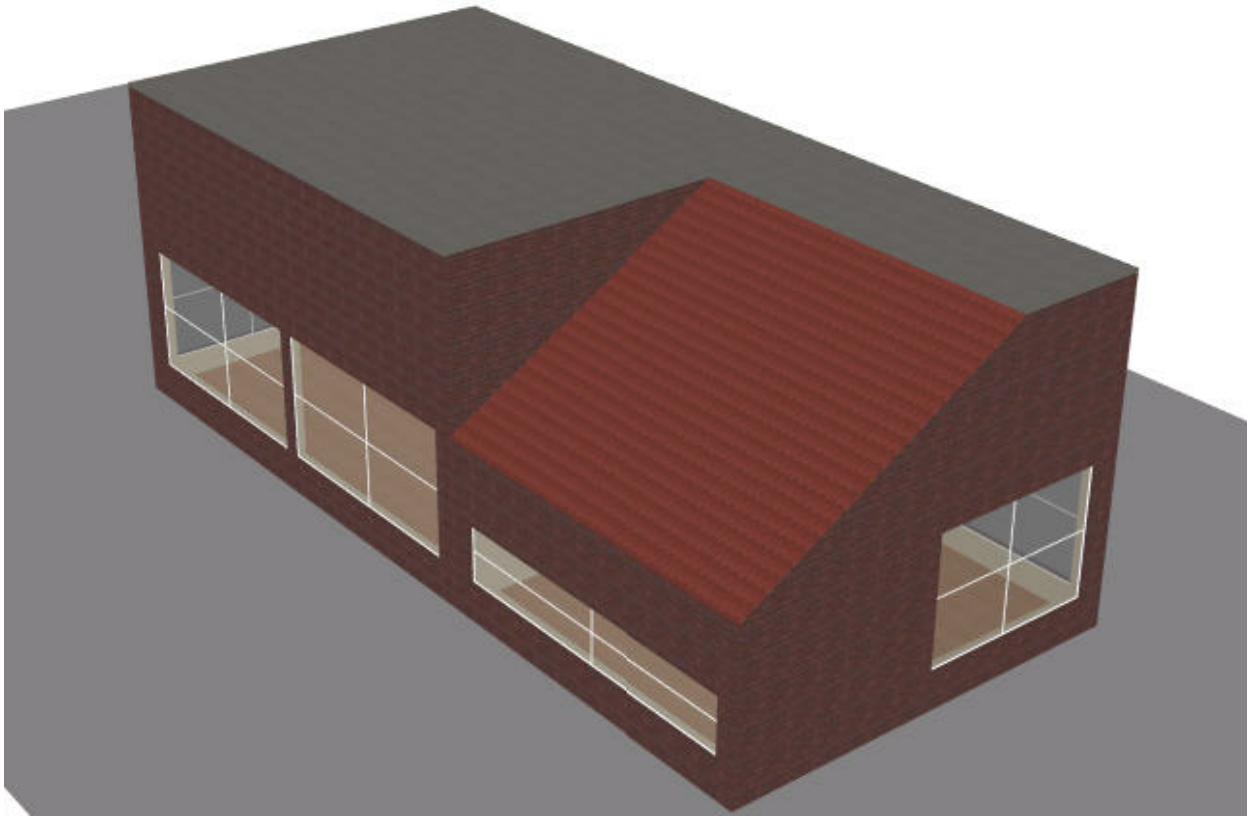

3.2.4 Construction Lines

Construction lines can be used to help in the creation of precise geometry. You can draw construction lines using the snaps and the protractor to lie at defined locations and then use these lines as a framework from which or to which various object geometries can be projected or attached. At the building level, construction lines can also be snapped to the Z-axis to form vertical planes from which block geometry can be extruded.

3.2.4.1 Drawing Construction Lines

Construction lines are drawn in the form of line strings. To draw a construction line, click on the 'Place construction line' tool and start drawing the first line by clicking anywhere in the active drawing plane then move the mouse cursor and click to place the line end-point, you can use point snaps, direction snaps, drawing guides and the protractor to help with alignment. Continue placing construction lines in this way. If at any time you want to cancel the last line that you placed, you can press the ESC key or select 'Undo last point' from the right-click menu.

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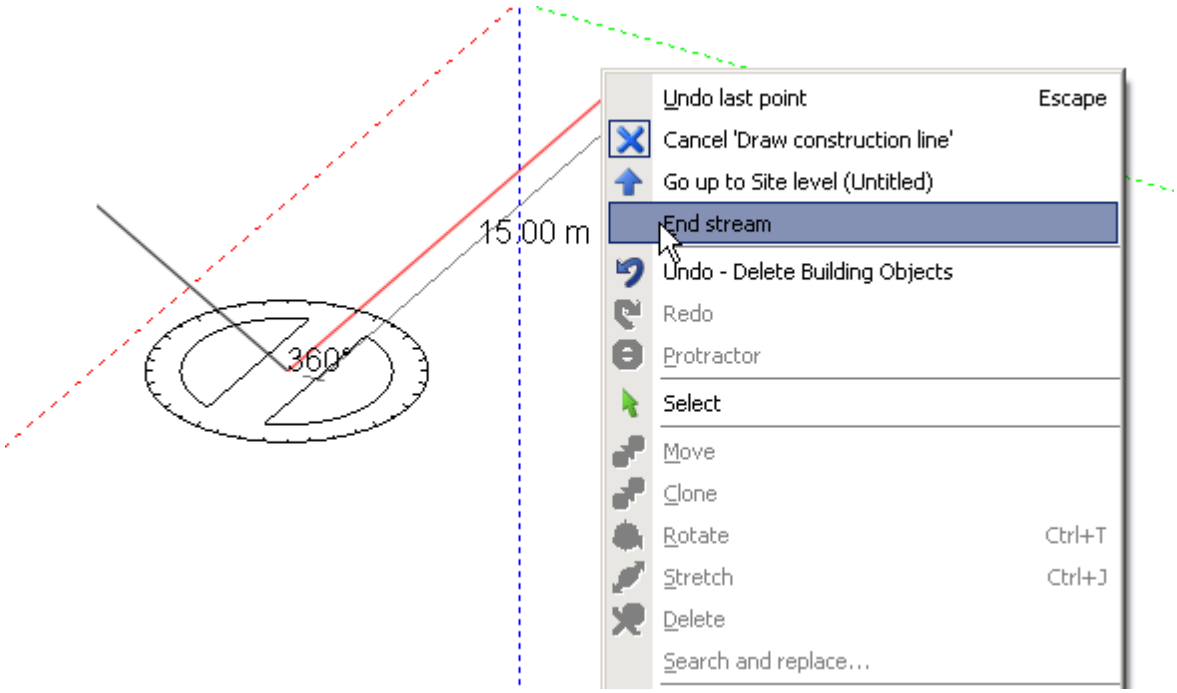
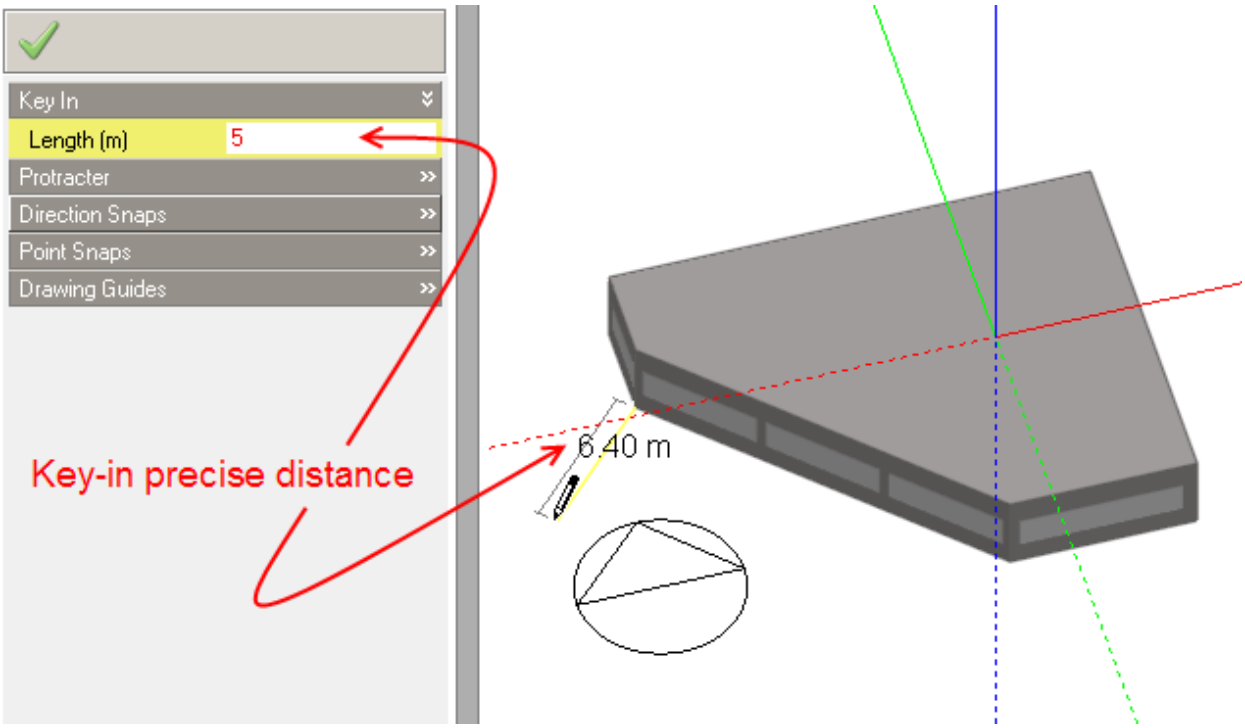


Construction lines have numerous applications in forming temporary attachment points during the creation of precise geometry. As a simple example, if you want to place a block at a precise distance from the angled wall of an existing block, you could switch the Normal snap on, click on the 'Place construction line' tool and draw a perpendicular line a precise distance from the wall. To draw the perpendicular line, place the first point at an end-point of the wall baseline, move the mouse cursor to touch the baseline and press SHIFT to lock the direction inference, then move the mouse cursor to activate the perpendicular lock and key-in the required distance:



You could then place a second construction line normal to the first line and key-in the required length:

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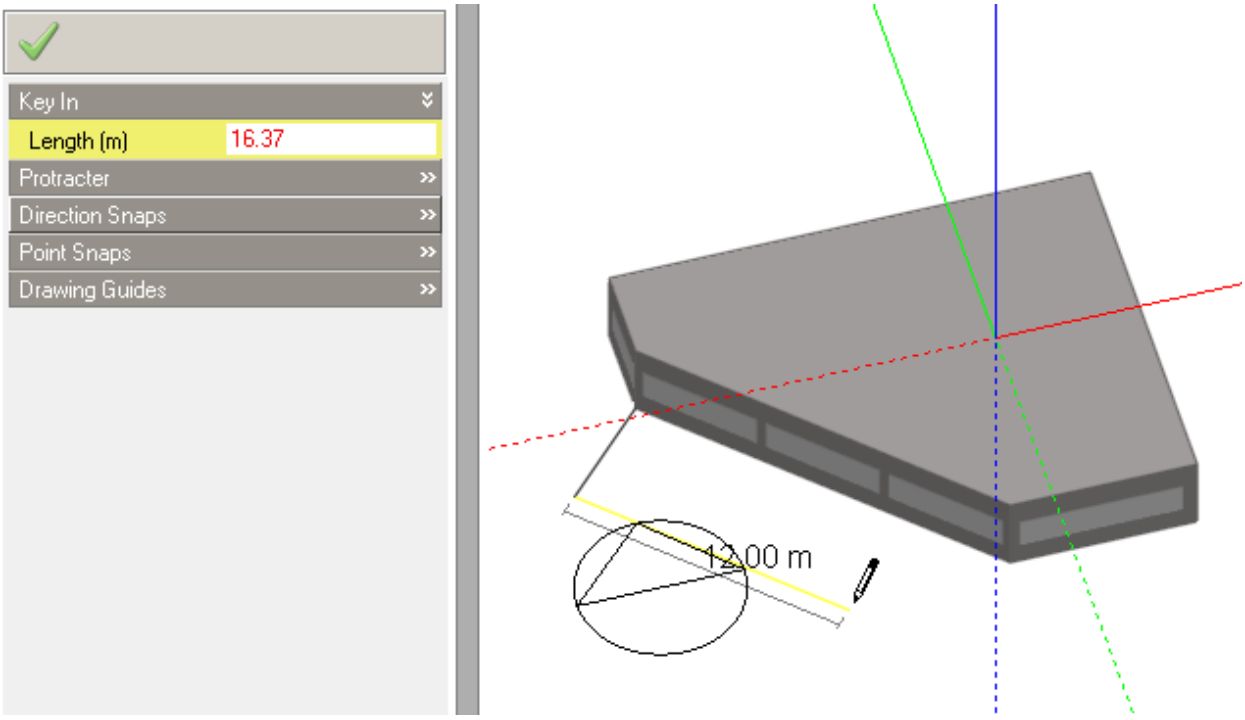
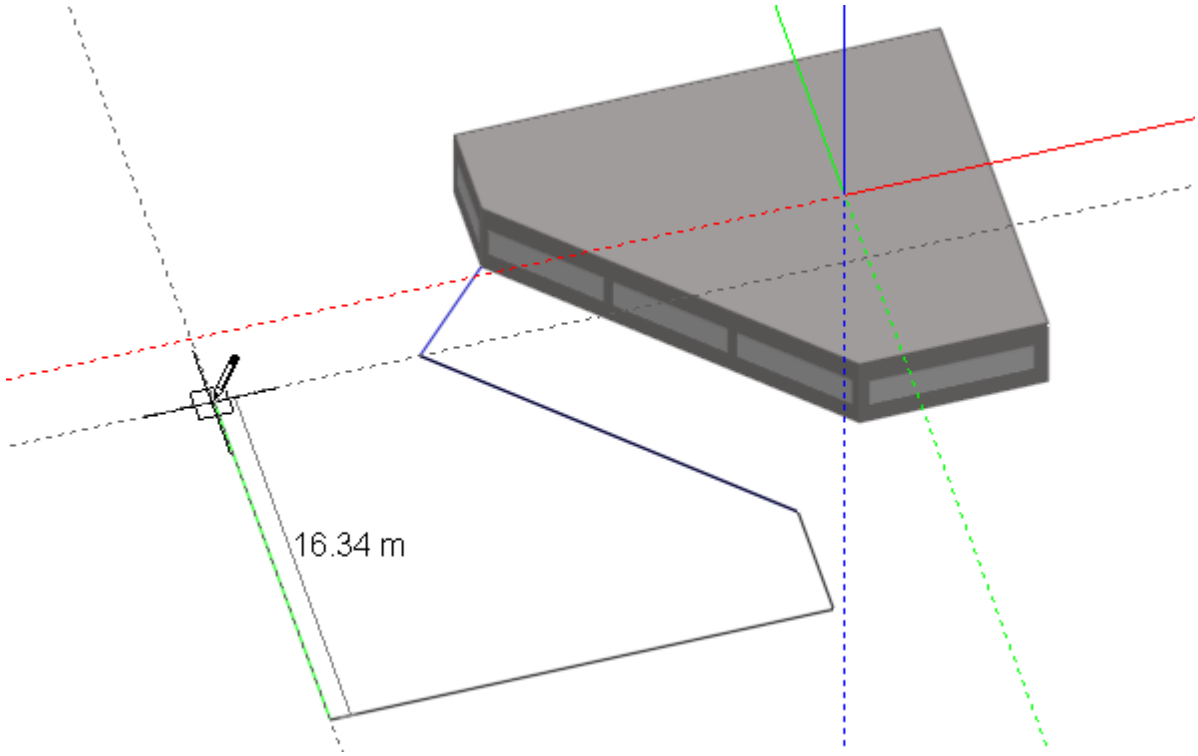


You can then snap to the construction line to draw the new block perimeter:



The finished block:

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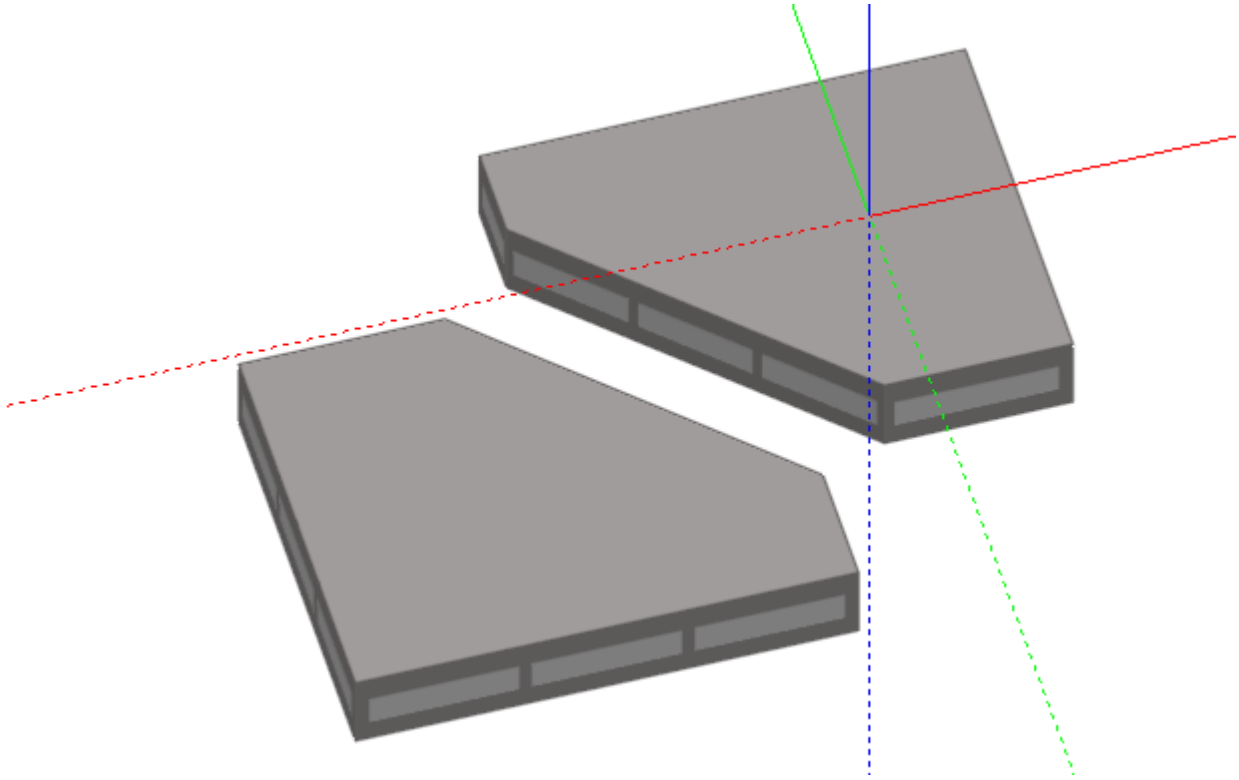
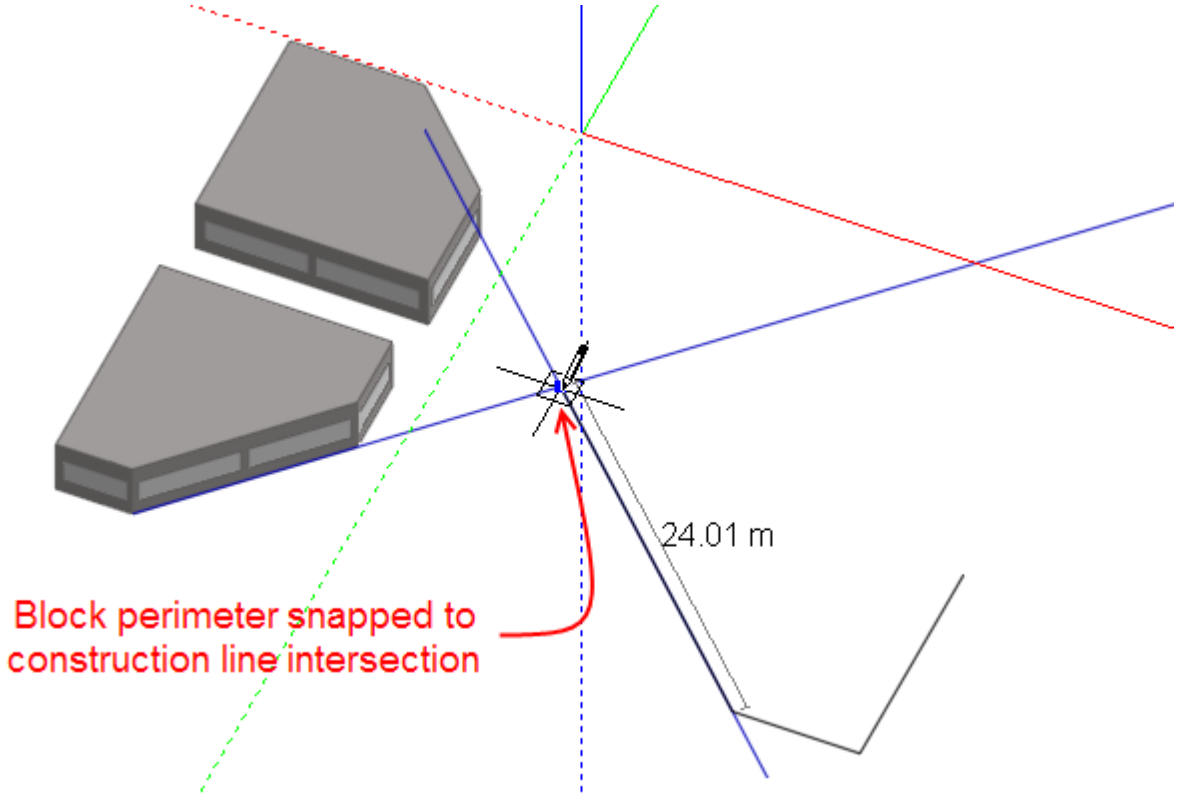


You can also snap to the intersection of construction lines:



At the building level, construction lines can be snapped to the Z-axis in order to create vertical planes to which block geometry can be attached. To draw construction lines in a vertical plane, switch the Z-axis snap on, click on the 'Place construction line' tool and place the first point on the ground plane or any other horizontal plane. Move the mouse cursor to snap the current line to the Z-axis:

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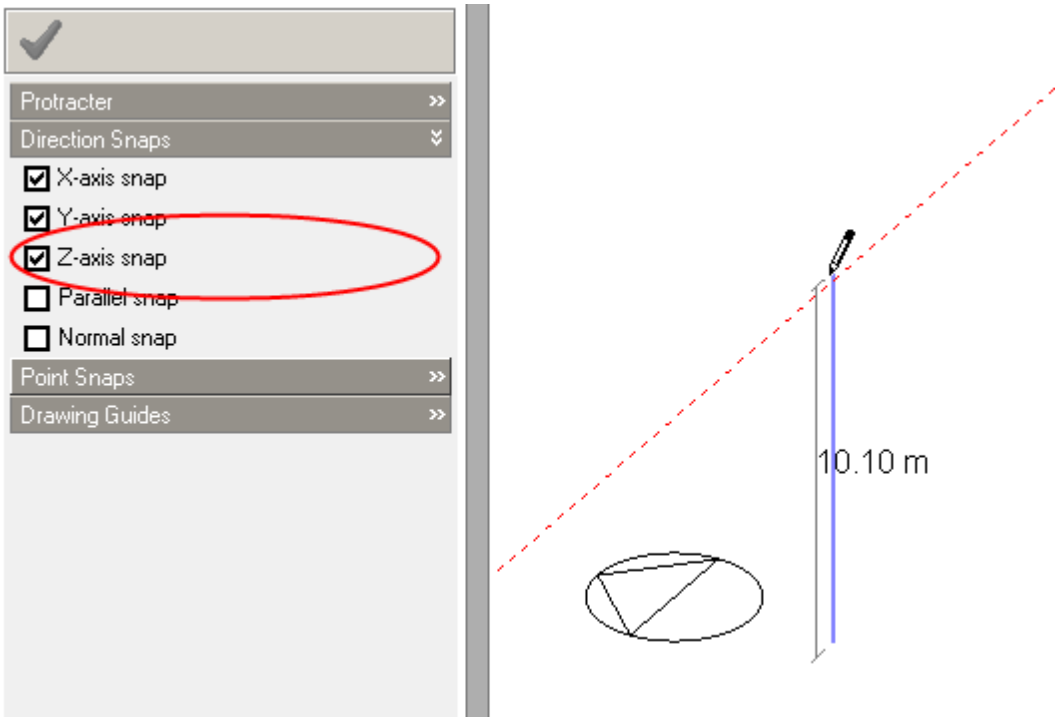
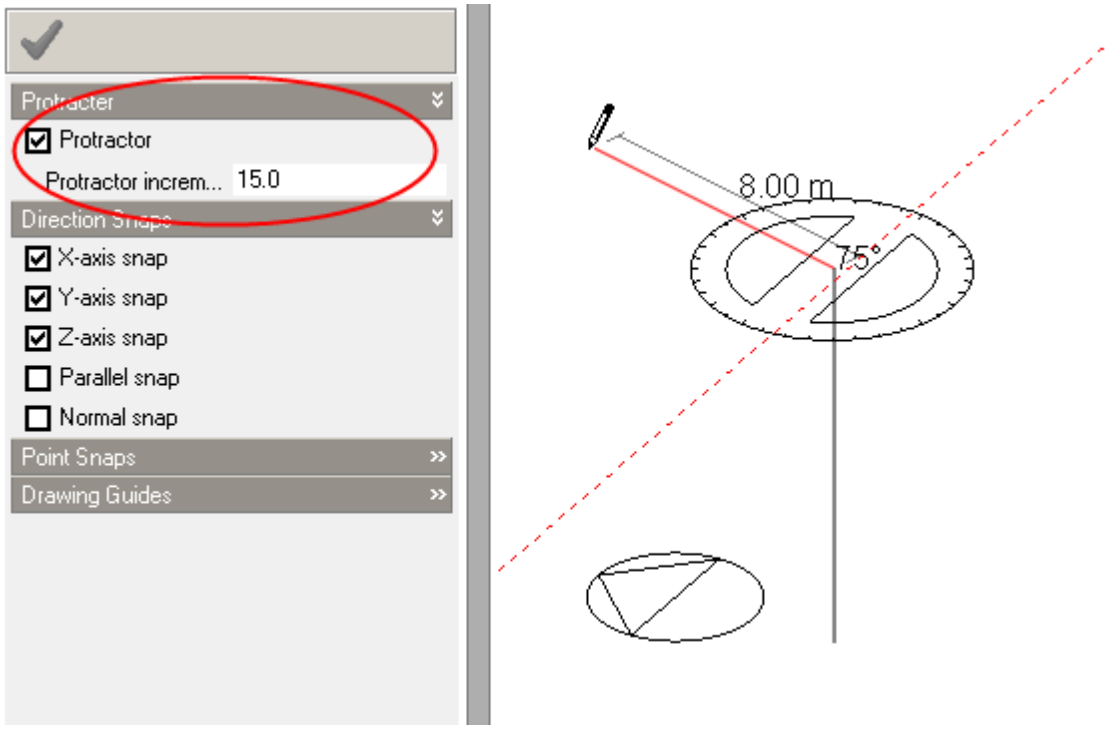


You can then use the protractor to place the next line in order to accurately define a plane:



After placing the second line, the two construction lines form a vertical plane that can be used for extruding blocks or as a plane to be used as a cutting plane.

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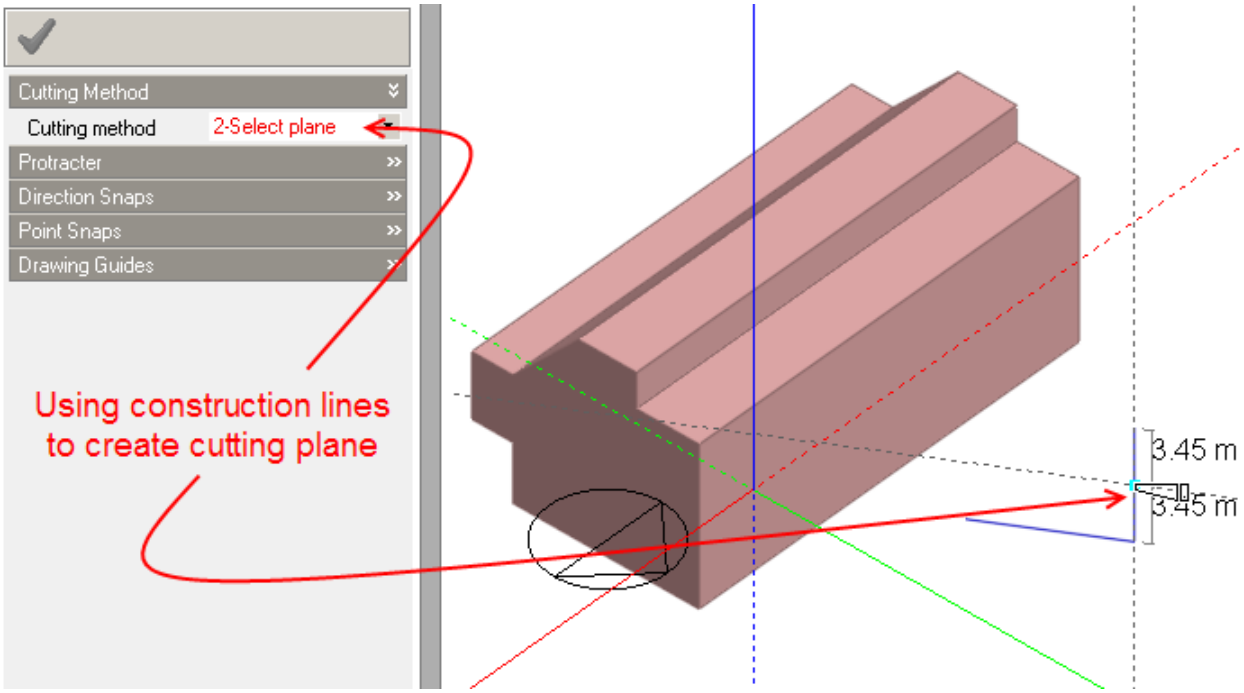

3.2.4.2 Removing Construction Lines

You can remove construction lines individually by selecting and deleting or you can remove all construction lines from the model by selecting 'Remove all construction lines' from the 'Edit' menu.

3.2.5 General Operations

This section describes general geometric operations:

- Select
- Move
- Clone (copy)
- Rotate
- Stretch
- Delete

3.2.5.1 Select

To select an object, click on the 'Select' tool or select 'Select' from the right-click menu, then move the mouse cursor to the object to be selected and click the mouse to select. To select multiple objects you can either press the CTRL key while clicking on objects or drag a selection rectangle by pressing the left mouse button and keeping it pressed as you drag a window across the required selection, when you release the mouse button, the objects inside the window will be selected.

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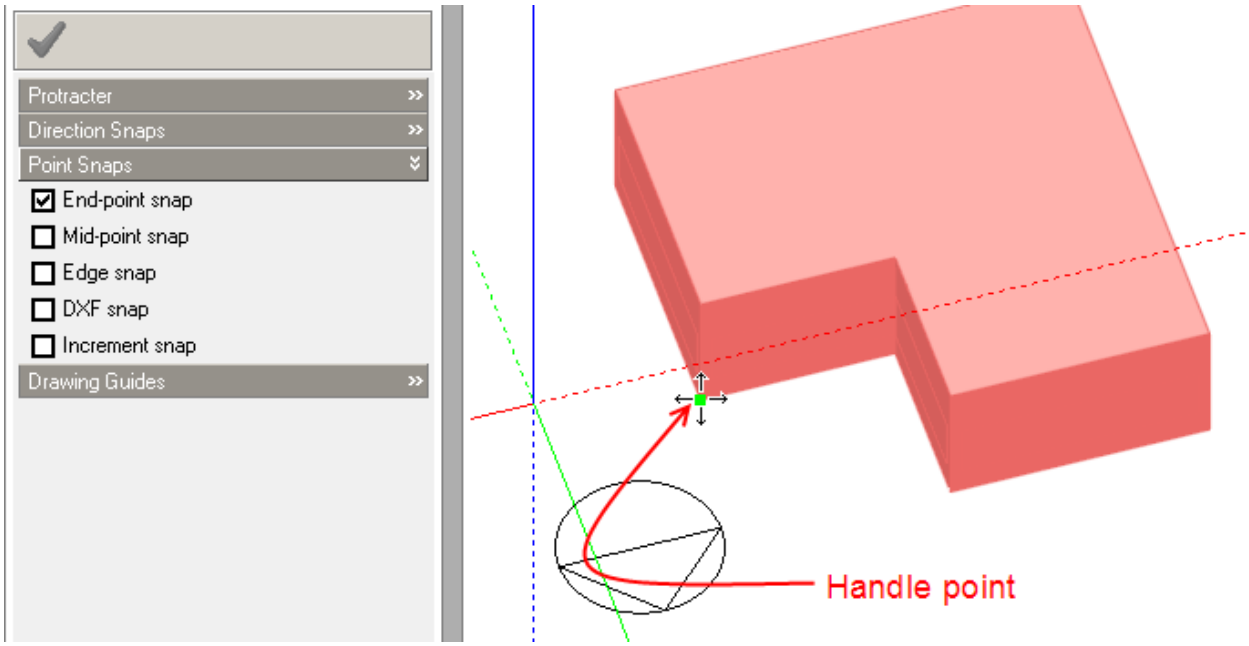
3.2.5.2 Move

You can move blocks, partitions, courtyards and openings. To move an object, first select it and then click on the 'Move' tool or select 'Move' from the right-click menu. If you want, you can move several objects at the same time by doing a multiple selection. You then need to define a 'handle point' for the move operation, the handle point can be any point on a model surface or ground plane but more usually will be a vertex on the object that you want to move, so make sure that the end-point snap is switched on, move the mouse cursor to the required object vertex and snap to it:



When you release the mouse button, you will be able to move the object to any required location. As you move the object, a displacement line is displayed to show how far the object has been moved, the displacement line can be snapped to the axes or the Protractor. When a direction snap is active the increment snap can also be used:

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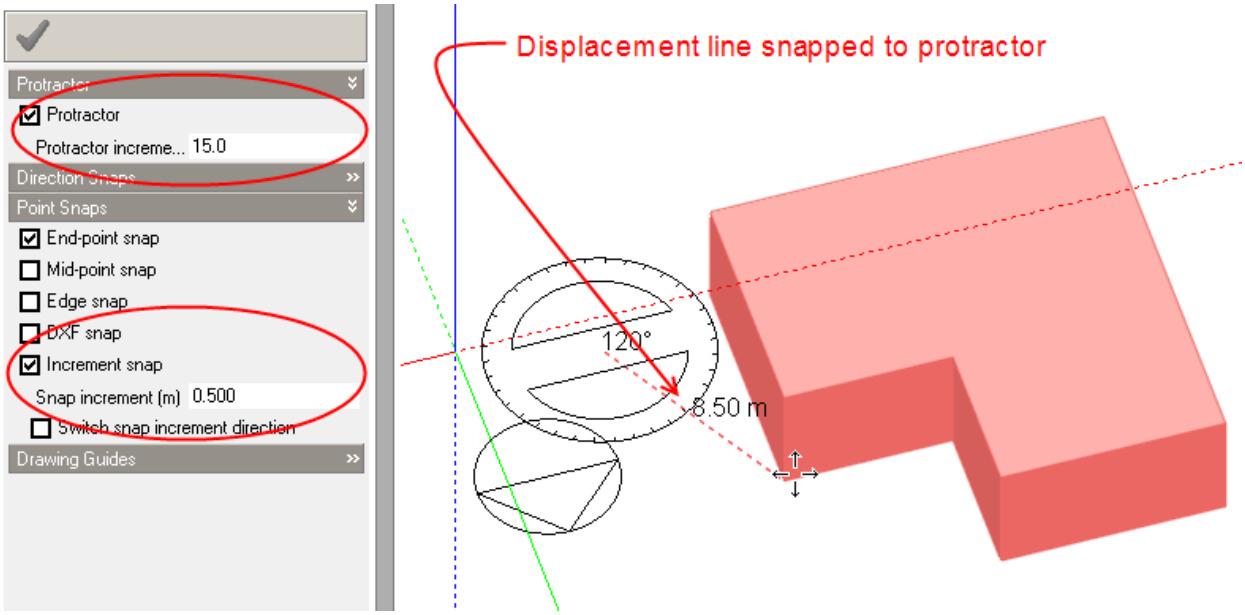
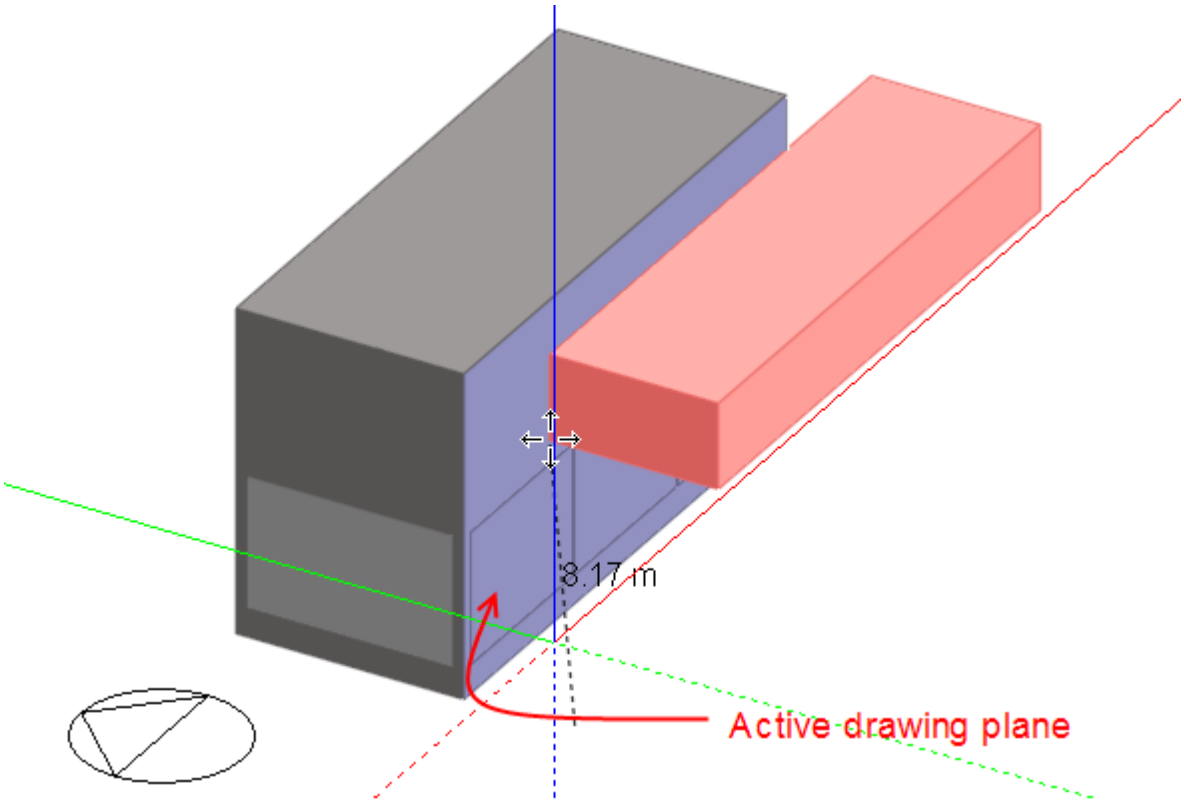


You can then click the mouse button to place the object.

At the building level, blocks can be moved in three dimensions onto any existing block face in the model. As you move the block around the model, each block face will highlight in blue as the block handle point is moved across it, indicating that the face has become the active drawing plane.



You can lock the active drawing plane by pressing the SHIFT key to position the block:

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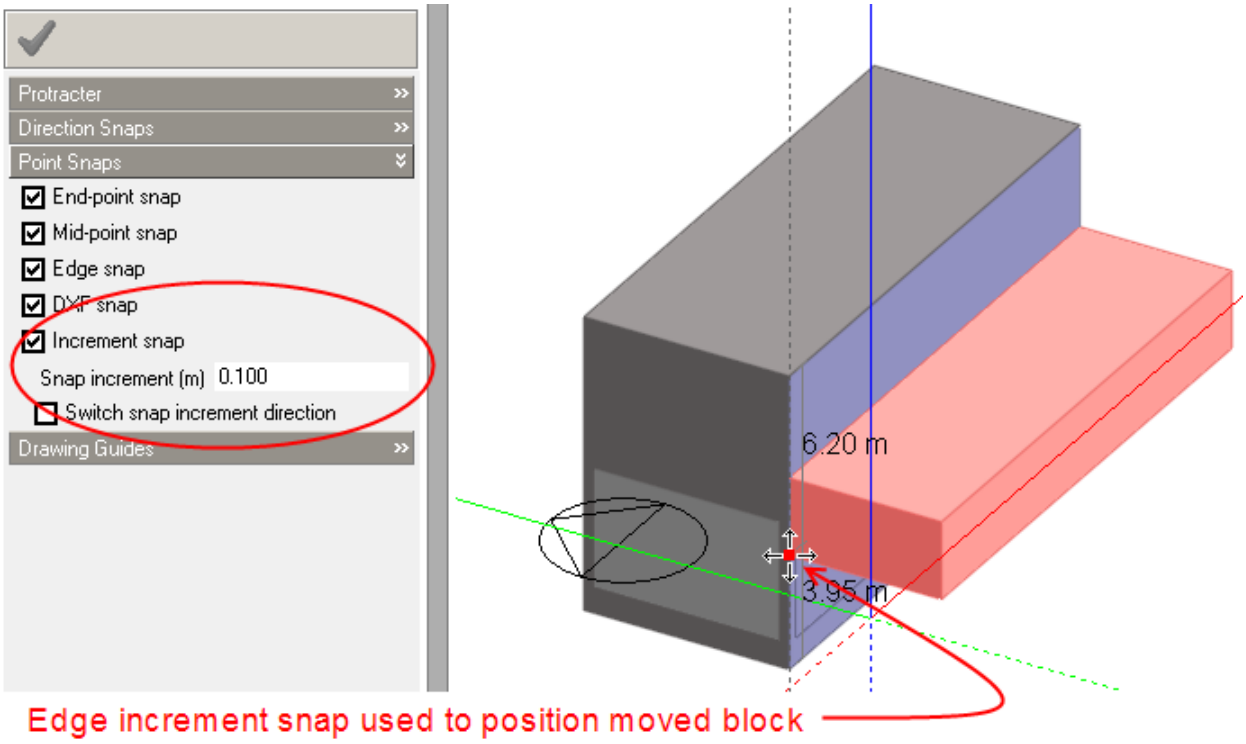

3.2.5.3 Copy (Clone)

For details of using the 'Clone' tool, please refer to the Move tool.

3.2.5.4 Rotate

You can rotate blocks, partitions, courtyards and openings. To rotate an object, first select it and then click on the 'Rotate' tool or select 'Rotate' from the right-click menu. If you want, you can rotate several objects at the same time by doing a multiple selection. As you move the cursor back into the Edit screen, the Protractor will be displayed at the cursor position. At the building level, you can rotate a block around an axis point defined on any plane and as you move the cursor from surface to surface in the model, each surface will highlight in blue to show that it's the active drawing plane and the protractor will automatically rotate into the same plane:

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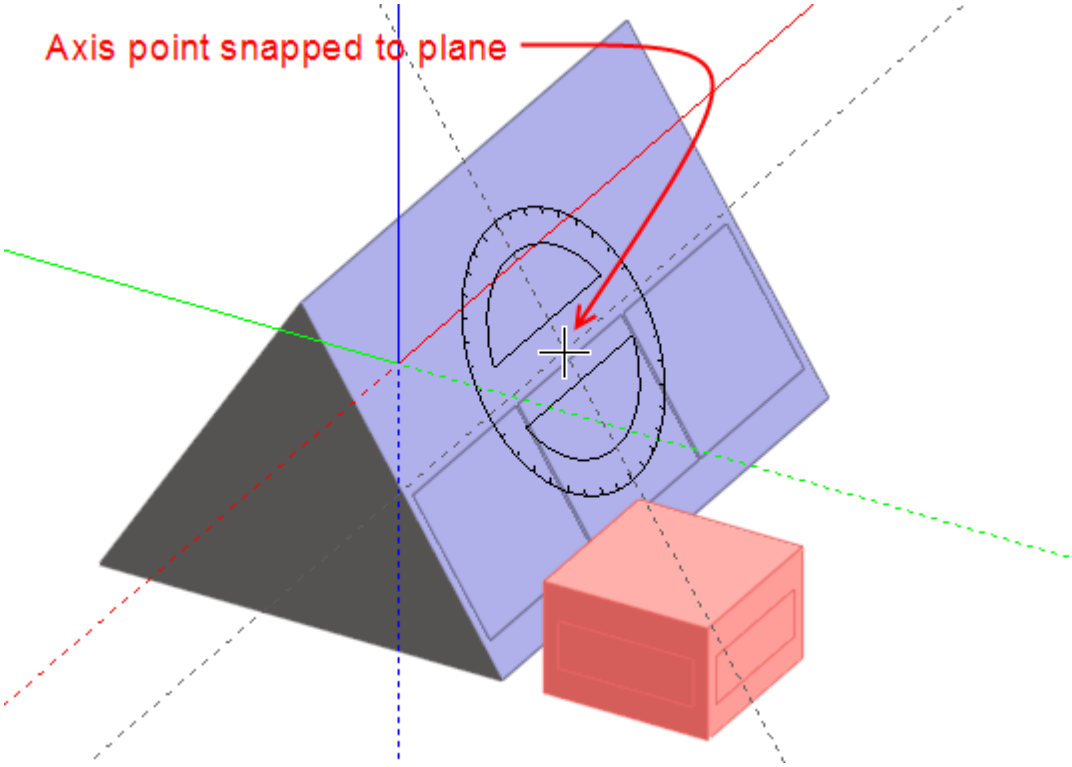
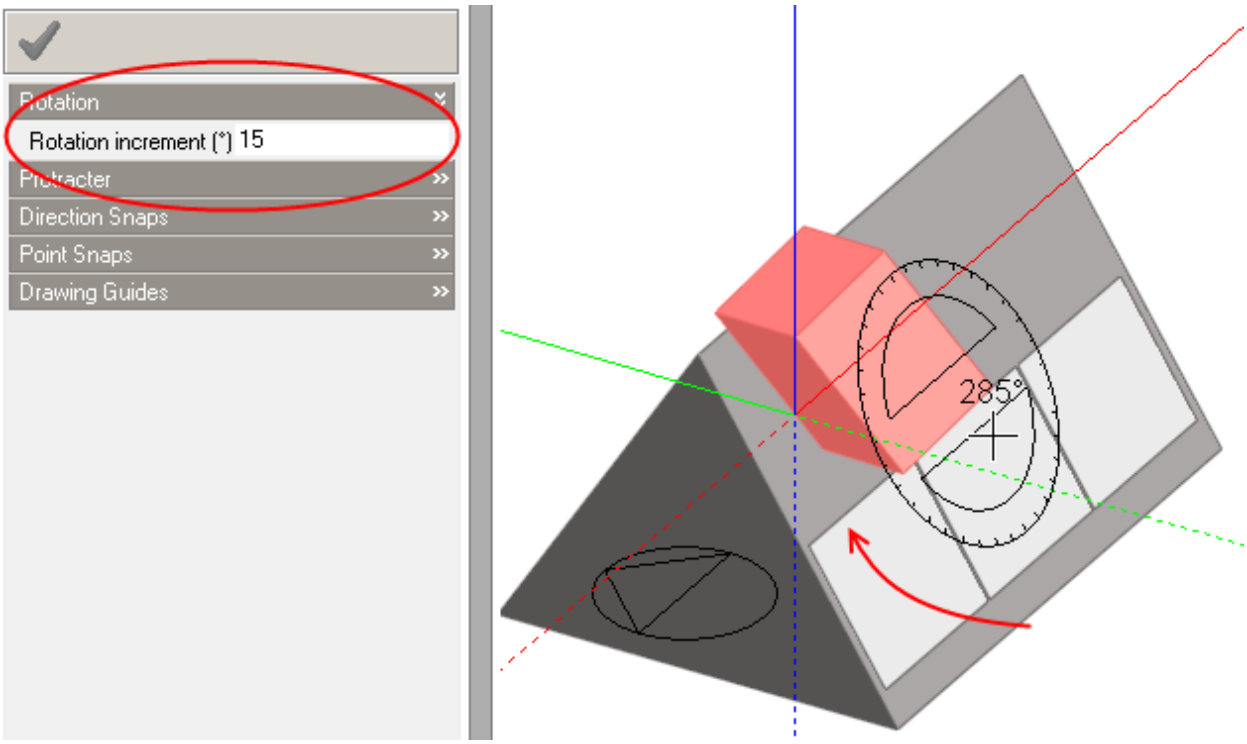


You define the rotation axis about which the object will be rotated by clicking the mouse when the mouse cursor is in the required location, you can use the various snaps and drawing guides to locate the axis point. After placing the axis point, you can then rotate the object around the axis:



In the case of partitions and courtyards at the block level, the active drawing plane for rotation is always the plane of the block floor and in the case of surface openings, the active drawing plane is always the surface plane:

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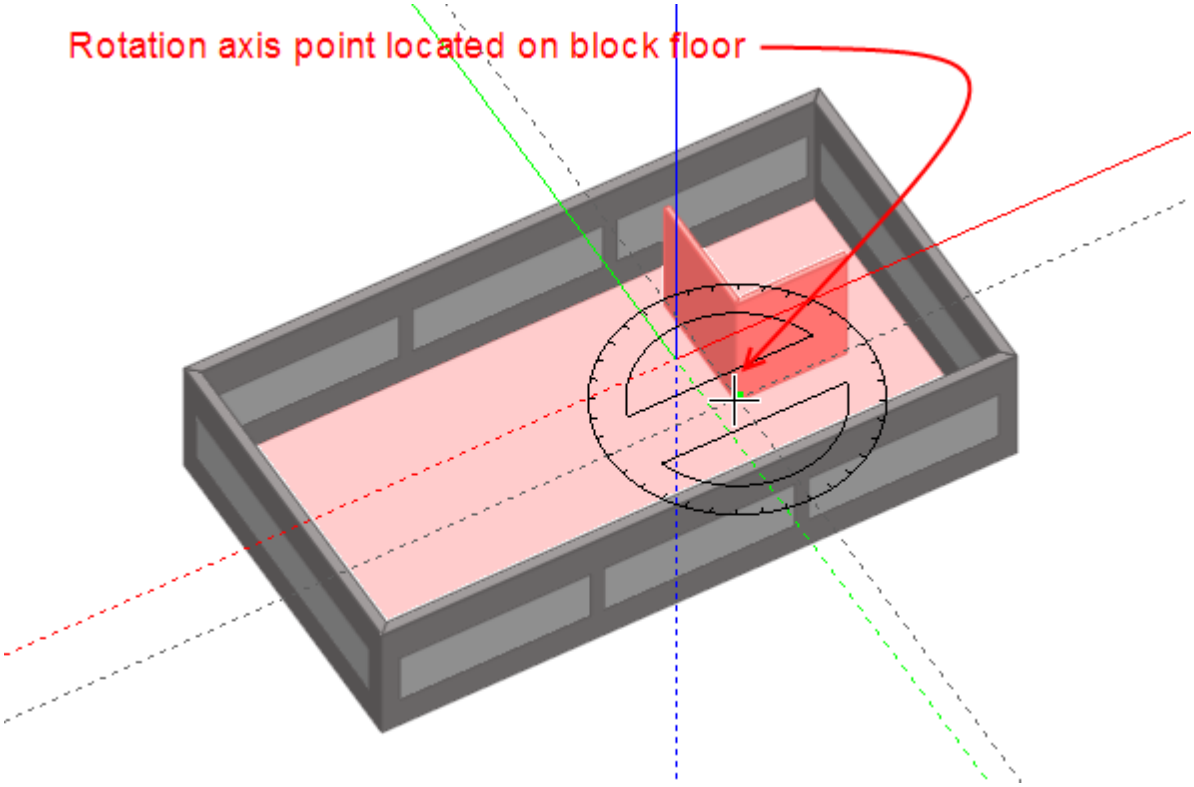

3.2.5.5 Stretch

Building and outline blocks can be stretched (or scaled) at the building level. To stretch a block, first select it and then click on the 'Stretch' tool or select 'Stretch' from the right-click menu. You can only stretch one block at a time. When you activate the 'Stretch' tool, a wire frame is displayed around the extent of the block and as you move the cursor across the faces of this frame, each face will highlight in the colour of the axis to which the face is normal:

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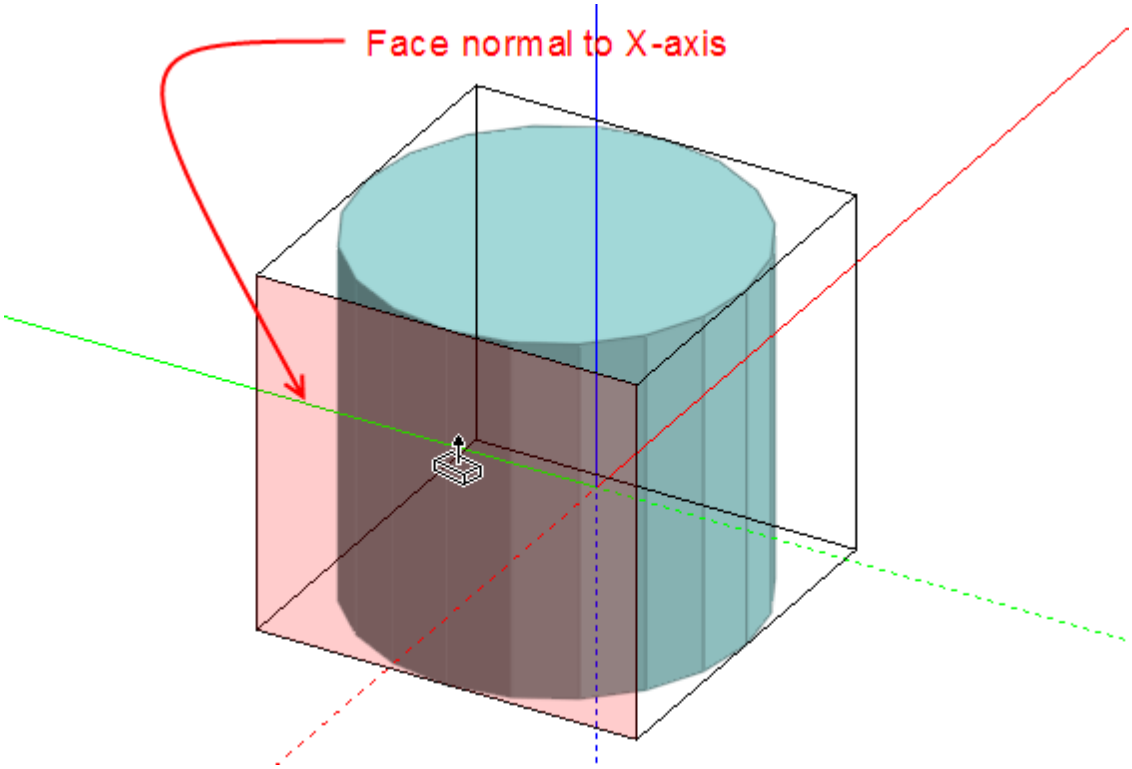
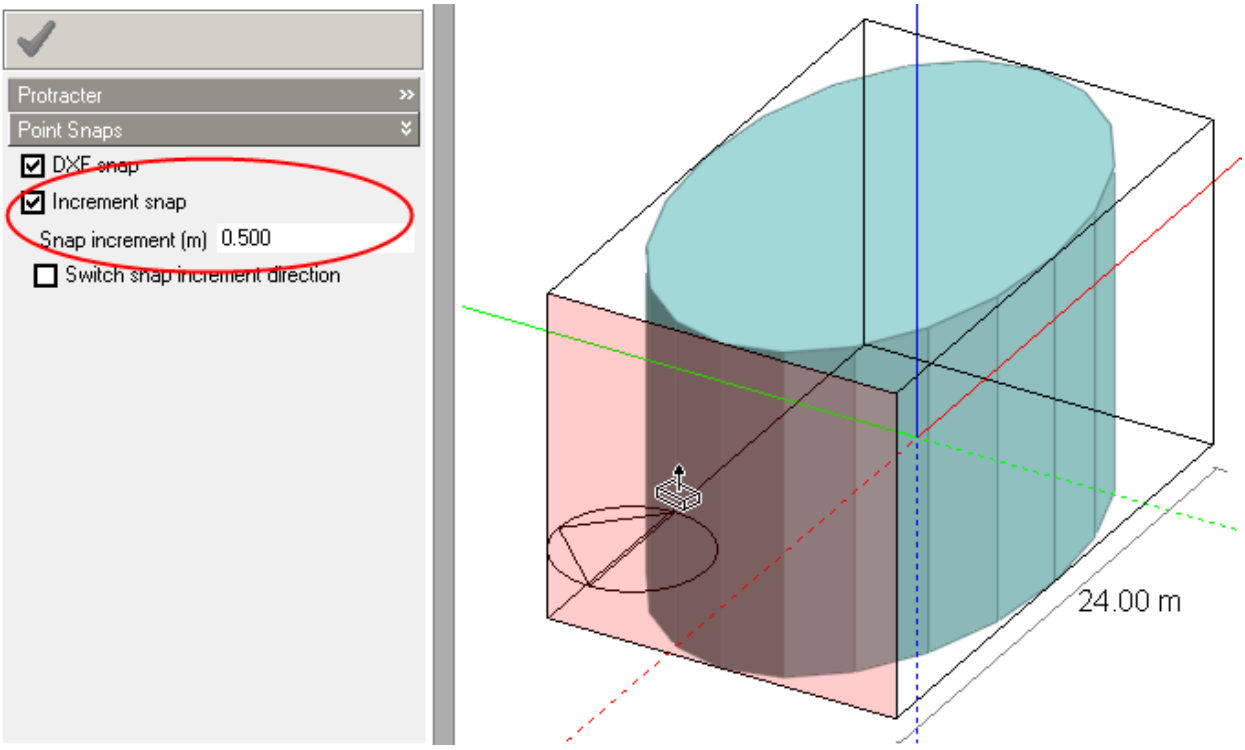


If you then click on one of these highlighted faces, you can then stretch the block along the axis normal to the face. If the increment snap is switched on, the block can be stretched in increments:



In the case of the Z-axis, the stretch operation will only operate along the positive Z-axis:

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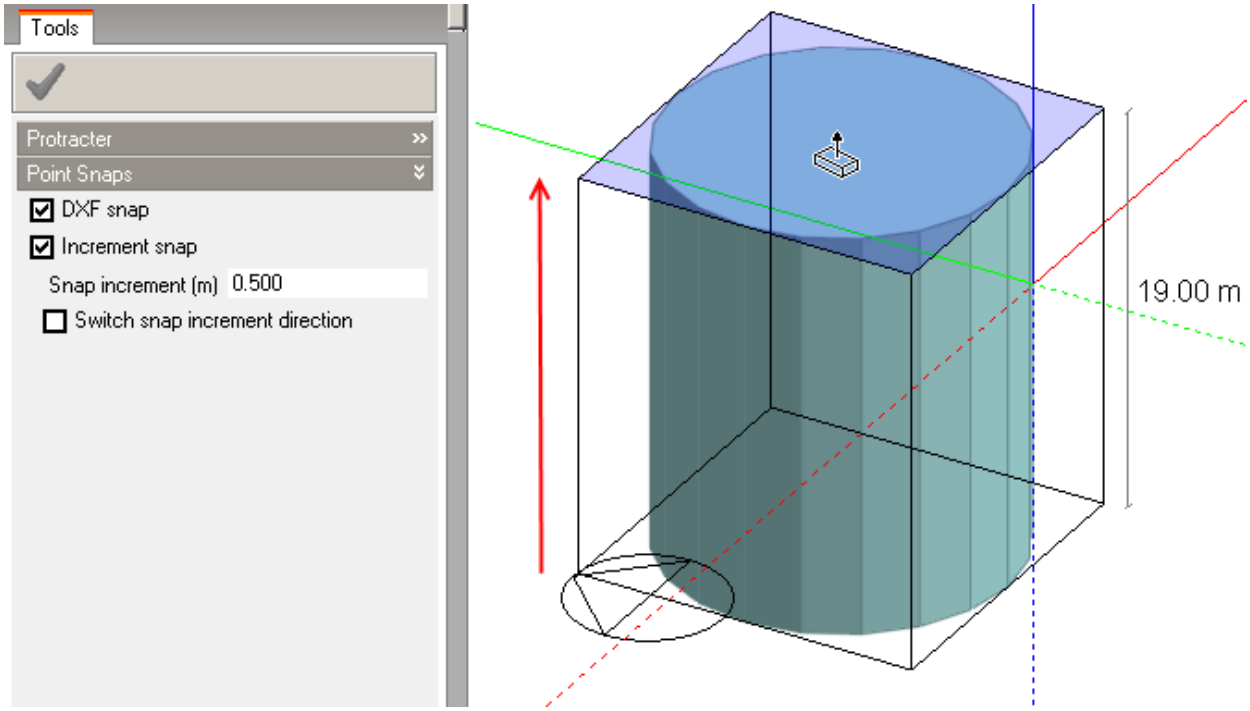


Tip: You can also key in the new dimension using the keyboard. Note the difference to the Drag face tool where the increment in the extrusion is keyed in.

3.2.5.6 Delete

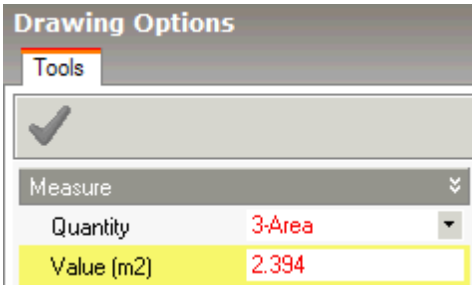
To delete an object, first select the object you want to delete and then click on the 'Delete' tool or select 'Delete' from the right-click menu. If you want, you can delete several objects at the same time by doing a multiple selection.

3.2.5.7 Measure

The measure tool allows you measure distance, angles and areas *on single planes* in the model:

- **Distance** - Click twice on a plane to define the length between the 2 points.
- **Angle** - Click three times on a plane to define the area between the 2 lines.
- **Distance** - Draw an enclosed polygon by clicking with the mouse on a single plane.

The requested data is displayed highlighted in the Drawing Options panel on the left of the screen.



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3.2.6 Importing DXF

DXF and other bitmap-type drawing data formats can be imported in the form of 2-D floor plan layouts. These can be used to trace block perimeters and partitions as a fast way to enter the model geometry. A typical process might go like this:

1. Create new dsb site file.
2. Select location.
3. Import floor plan data.
4. Draw blocks by tracing over the external perimeter corners of the floor plan.
5. Go to block level and draw partitions by tracing over the drawing data.
6. Import other DXF floor plans for other stories if necessary.

You can import 2-D DXF floor plan files created in AutoCAD or other CAD programs or the other bitmap-based drawing formats listed below. To start the process click on the **Files > Import > Import 2-D drawing file** menu command. This starts a the Import Drawing File Wizard (below).

IMPORT DRAWING FILE WIZARD

First select the File type to import. You can select from:

- **1-DXF** - 2-D CAD data. This option allows you to snap to the end-points of the DXF line segments, the other bitmap-based formats below do not allow snapping.
- **2-PDF** - PDF drawing file (single page)
- **3-BMP** - Bitmap drawing file.
- **4-JPG** - JPEG drawing file.
- **5-PNG** - Portable Network Graphic drawing file.
- **6-GIF** - GIF drawing file.
- **7-TIFF** - TIFF drawing file.

When you have selected the file type then select the file by clicking into the 'Filename' control. Click on the ellipsis button to open the file browser dialogue box.

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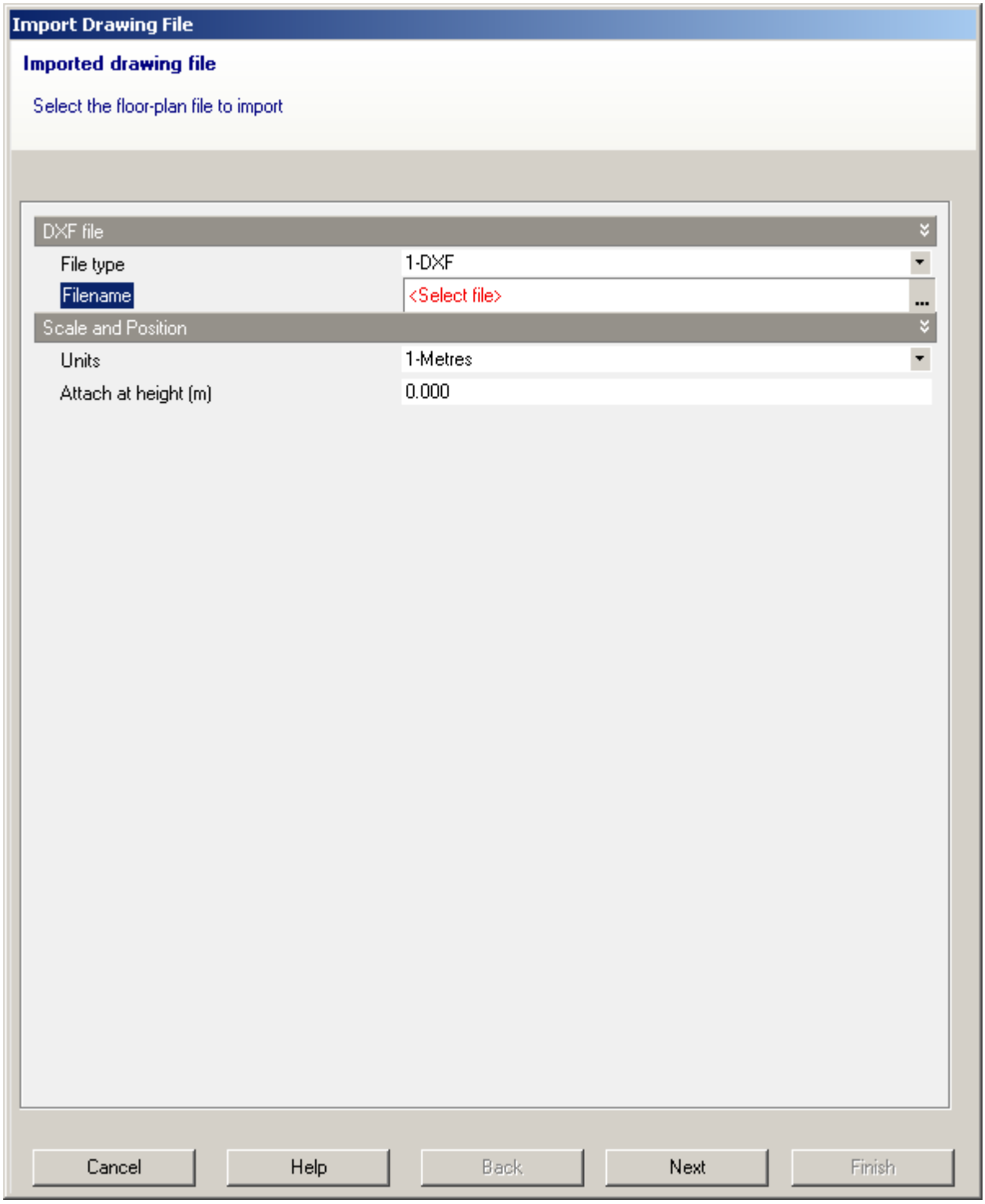

DXF FILE TYPES

If you selected a DXF file you should then set the units used in the DXF file from the 'Units' drop list and set the attachment height at which the 2-D DXF data will be attached. The DXF data can be moved around the model once it is imported, so you do not need to know the exact attachment height - you can import the DXF data at zero height and move it to the correct location using the Move command. Click on the 'Next' button to set up layer visibility:

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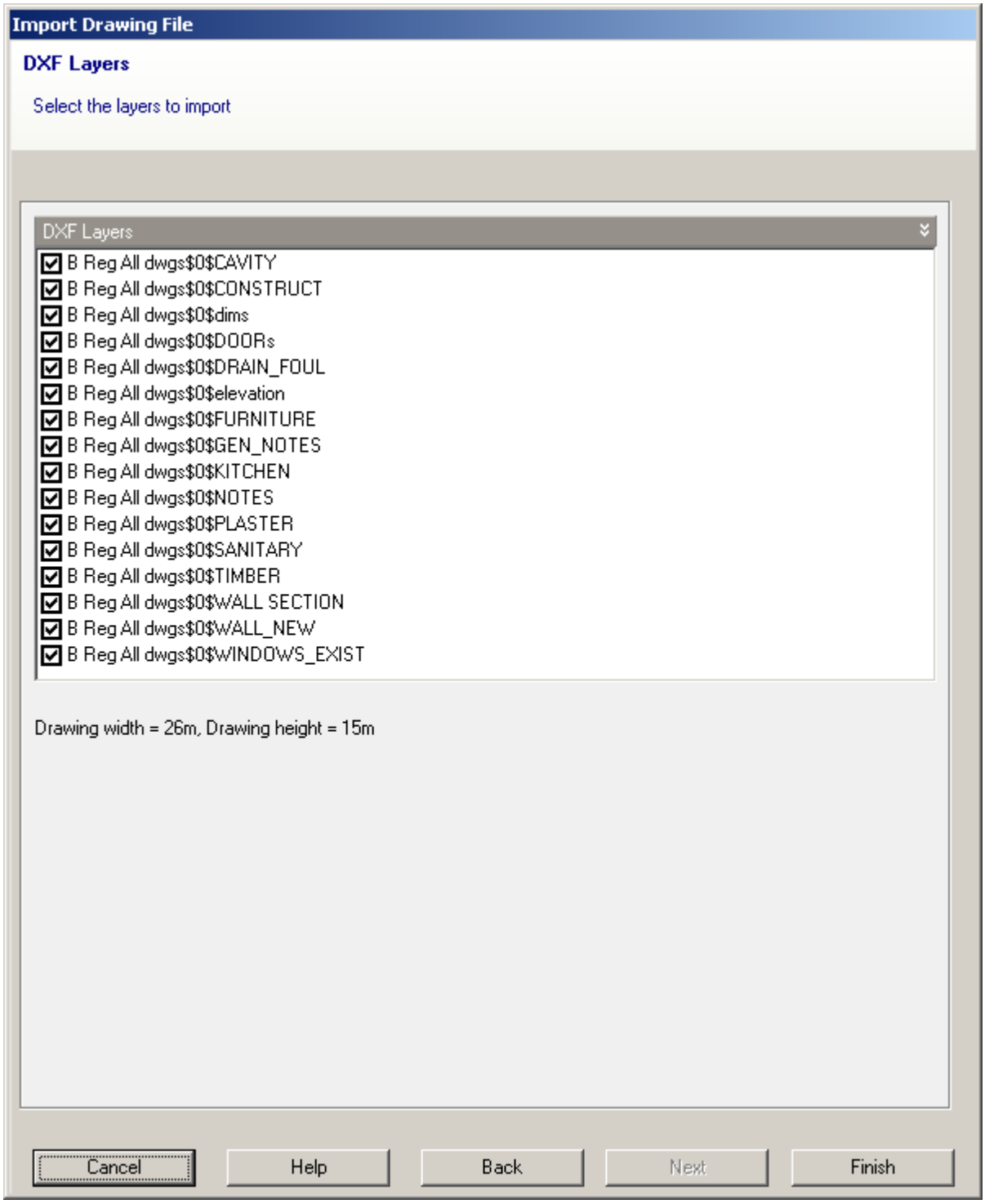

You can use these controls to switch off unnecessary layers in the DXF data. As you check/uncheck the checkboxes you will see the effect of the change in the Edit view under the Wizard. Click on the 'Finish' button to import the data:

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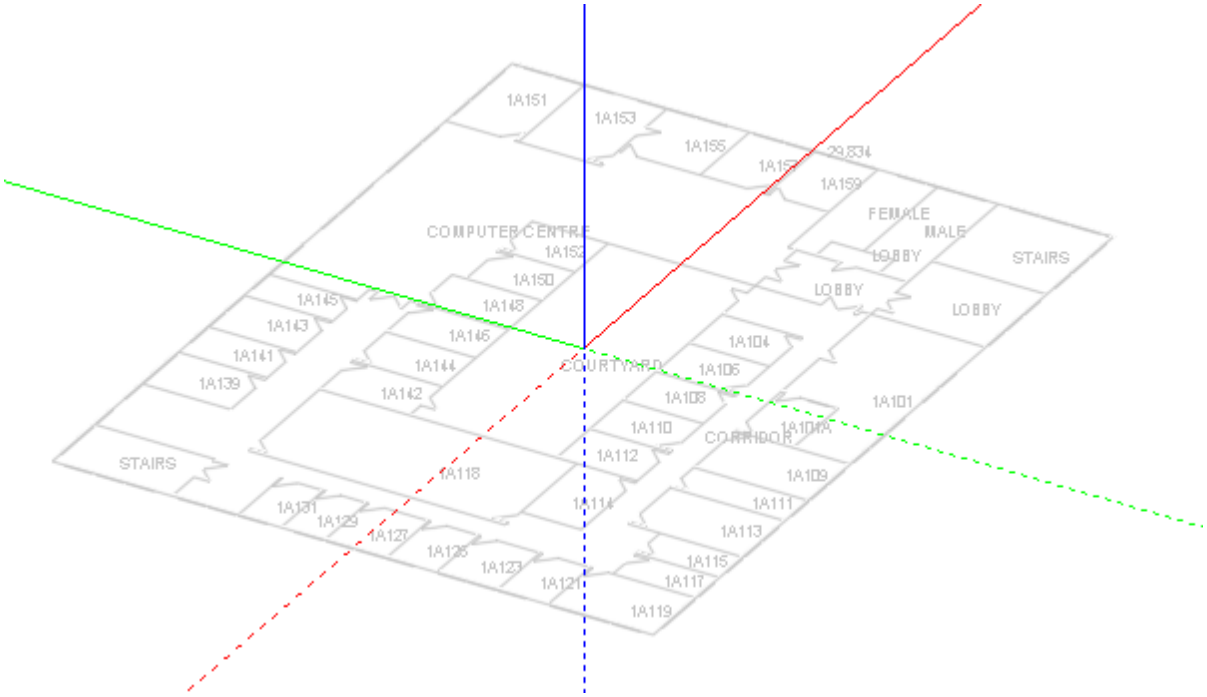
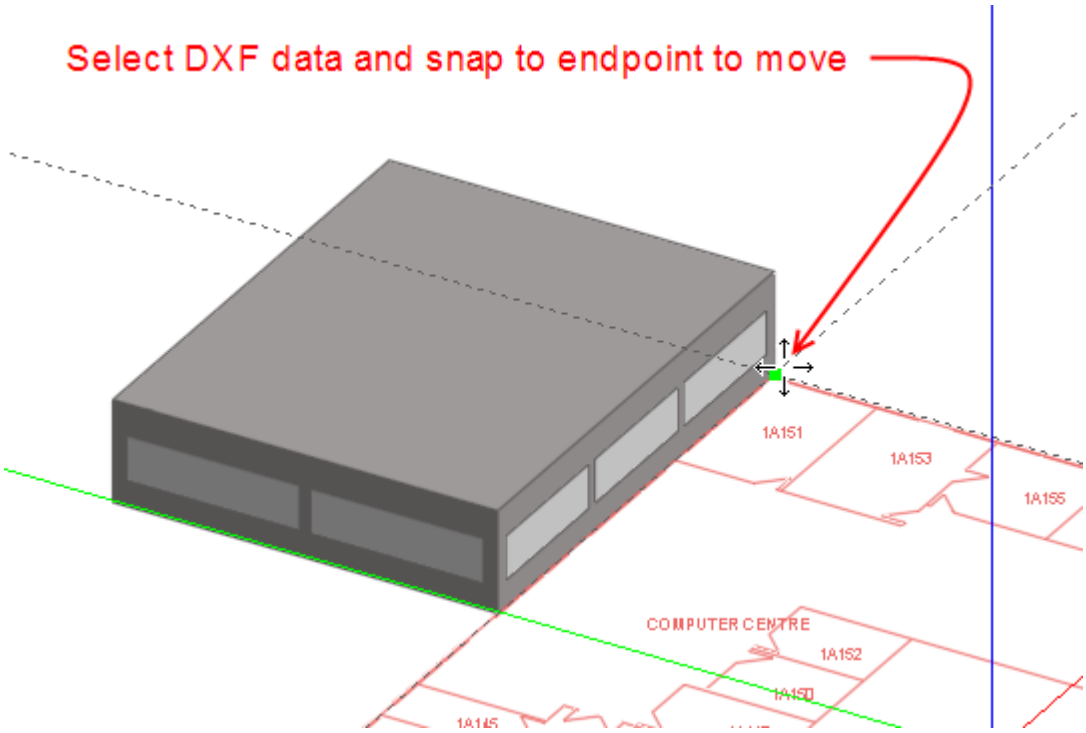


At the **building level**, you can select, move and delete DXF data. When you select DXF data, you may need to zoom in to make the selection. You can move DXF file in 3-D and snap the data to the edges of blocks:



Move the DXF data on top of the existing block and snap to an edge end-point:

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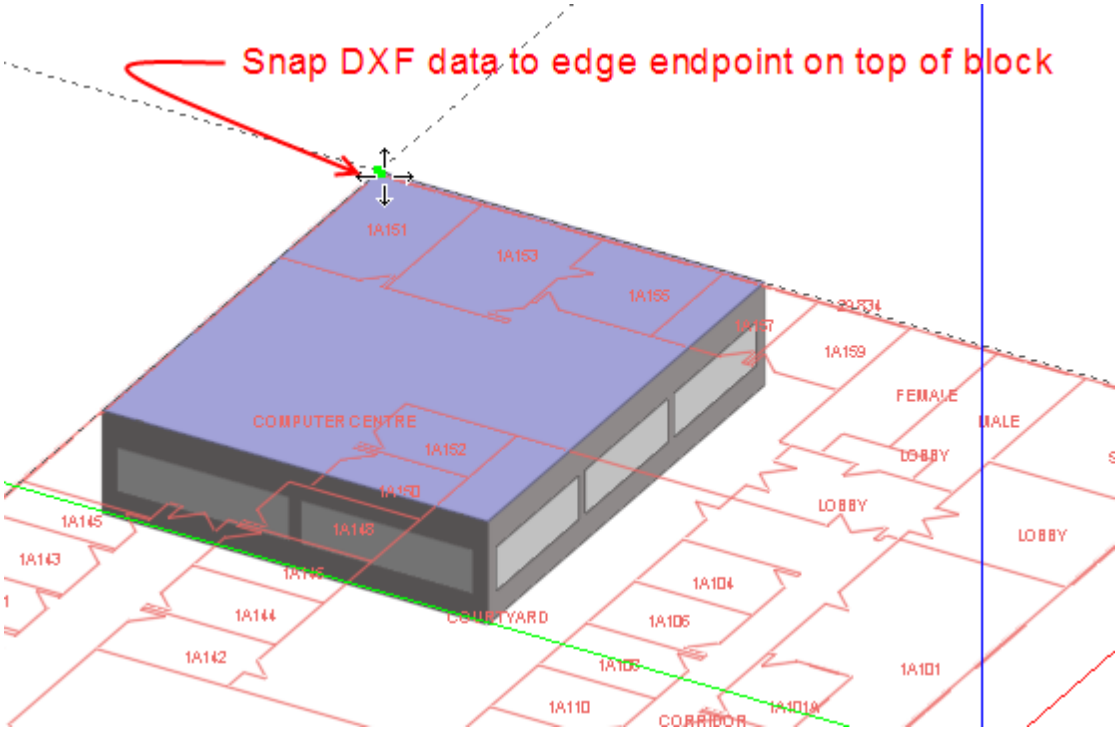

When you have imported the DXF data you can use the Measure tool to check that the dimensions are correct.

Import DXF floor plans for other stories if necessary. Note that only one set of DXF data can be imported at a time. Once the CAD data has been imported into the model, the source DXF file is no longer needed by DesignBuilder and can be moved or deleted.

EDITING DXF DATA

The DXF data must be selected to allow these operations:

Move - move the DXF data
Delete - delete the DXF data (not the source file itself).

Also these 2 menu commands are available from the Edit menu when DXF data is loaded:

Set X-axis for imported DXF

When the command is started click twice to define the end points of a line in the direction of the X-axis on the imported DXF data. After the operation the DXF data is rotated to align with the DesignBuilder X-axis. Normally DXF data will already be orientated to the grid and this command is not required.

Scale DXF drawing

This command allows you to scale the DXF data to be larger or smaller. This may be necessary if the scale of the DXF data was unknown at the import stage. When the command is started click twice to define the end points of a reference line on the DXF data of known length (e.g. a dimension arrow or known length on a building wall). Then either move the cursor to define the new length of the reference line and click again or type in the dimension of the reference line. So a typical sequence might be:

1. Start **Edit > Scale DXF drawing** command.
2. Single click on one end of a large dimension line.
3. Single click on the other end of the dimension line.
4. Type in the dimension in m or ft (depending on the international units setting) followed by <Enter>.

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BITMAP-BASED FILE TYPES

When the file type is one of the bitmap based formats (PDF, BMP, JPG, PNG, GIF, TIFF collectively referred to here as 'bitmap') the next page of the Wizard provides a preview of the drawing and some options.

Invert bitmap

Check this option if you wish the colours in the bitmap to be inverted. For example if the picture is white on a black background then it will generally be best to invert these for use in DesignBuilder.

Auto scale bitmap after loading drawing

If you wish the 'scale bitmap' command to be automatically started when the Import Drawing File Wizard in closed then check this option.

Quality slider

By reducing the number of pixels in the bitmap it is possible to significantly reduce the size of the imported drawing data and hence speed subsequent drawing 'scale' and 'rotate'operations. Quality setting of 0.5 gives a good trade-off between image size and readability but if the drawing file is particularly large you may decide to reduce the quality and vice-versa.

Transparency slider

You can control the transparency of the drawing data from 0 to 1.

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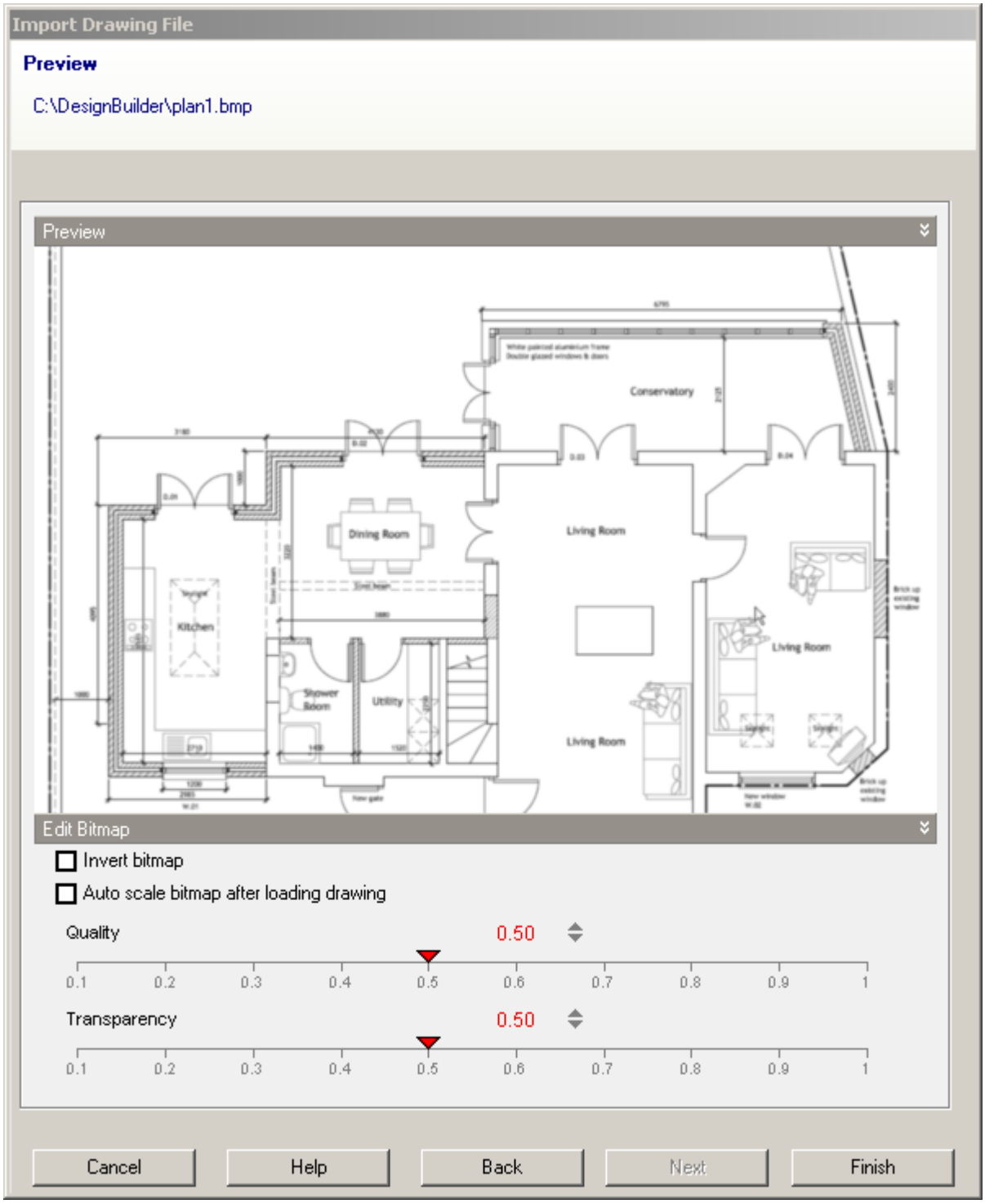

Bitmap-based files may be used for:

1. Existing buildings having paper floor plans that have been scanned into electronic format or,
2. Early stage design sketch ideas are available only in bitmap form.

Note: bitmap drawings do not allow end-point snap like DXF but can be an equally effective option for rapid geometry entry in DesignBuilder.

EDITING BITMAP DATA

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The bitmap data must be selected to allow these operations:

Move - move the bitmap data.
Delete - delete the bitmap data.

Also these 2 commands are available from the Edit menu when bitmap data is loaded:

Set X-axis for imported bitmap

Sometimes scanned bitmap files are not exactly aligned to the X-axis and you can use this command to re-orientate the drawing. When the command is started click twice to define the end points of a line in the direction of the X-axis on the imported bitmap data. After the operation the bitmap data is rotated to align with the DesignBuilder X-axis.

Scale bitmap drawing

This command allows you to scale the bitmap data to be larger or smaller. This will usually be necessary for bitmap drawing formats as the scale is not defined at the import stage. When the command is started click twice to define the end points of a reference line on the bitmap data of known length (e.g. a dimension arrow or known length on a building wall). Then either move the cursor to define the new length of the reference line and click again or type in the dimension of the reference line. So a typical sequence might be:

1. Start **Edit > Scale bitmap drawing** command.
2. Single click on one end of a large dimension line.
3. Single click on the other end of the dimension line.
4. Type in the dimension in m or ft (depending on the international units setting) followed by <Enter>.

PARTITIONS

You can also use the imported floor plan data to draw internal partitions. To do this go to block level and draw partitions by tracing over using the floor plan partition data. You should take care to connect partitions to the external perimeters. A common mistake is to snap partitions to DXF data lying very close to the external perimeter but not close enough to create a connection with the external perimeter. **It is recommended that you switch of DXF snap in the Drawing options panel when drawing partitions at block level to avoid this problem**. Be sure to switch it back on again when you have finished drawing partitions.

3.2.7 Exporting Geometric Data

The model geometric data can be exported in formats:

- **3-D DXF**

3.2.7.1 Exporting 3-D DXF

You can export the geometry of the current building model in 3-D DXF format using the Export 3-D DXF model command from the File > Export menu. This opens the 3-D DXF Export dialog:

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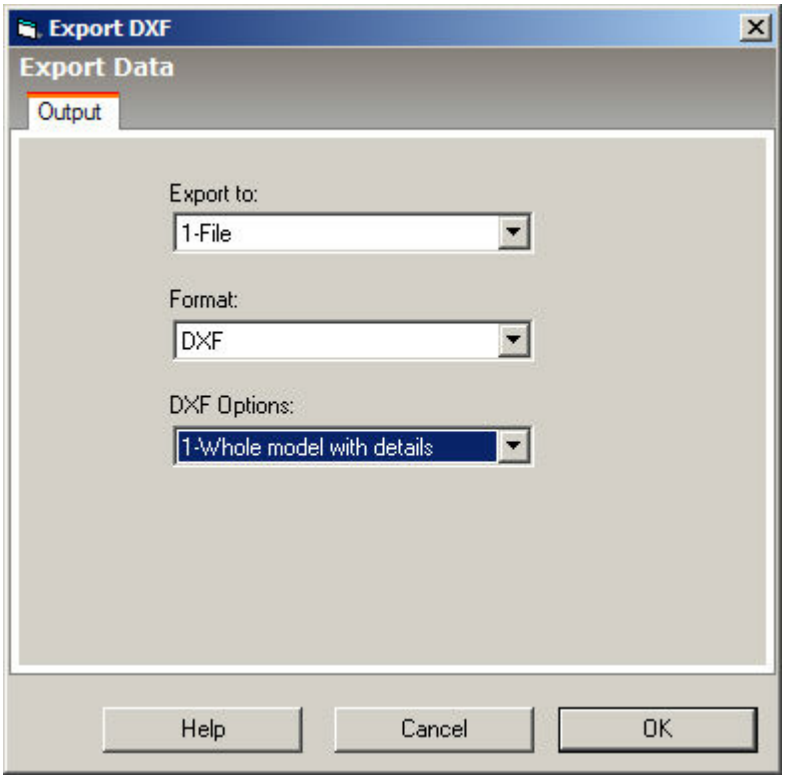

Choose one of two options:

- **1-Whole model with details** - The entire building model is exported including 3-D details such as window frames, 3-D building elements etc. This option can be useful for exporting for visualisation and further processing in other software such as SketchUp (image below)
- **2-Zones** - The building model is exported showing only zones. This option can be useful for visualising the geometry of the model used in simulations.

Example 3-D DXF Output - Whole model with details

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The above model was created in DesignBuilder, exported in DXF format using the **Whole model with details** option and Imported into SketchUp where details such as textures, trees and people were added.

Note: when importing DXF files into SketchUp be sure to set the scale options on the Open dialog.

3.2.8 Working with Buildings (Site Level)

At the site level you can:

- Add new buildings,
- Copy, delete and change the position of existing buildings.
- Change the site orientation.
- Enter site Model Data including information on the site location, weather data etc.

3.2.8.1 Create New Building

You can add one or more new buildings from the site level.

Note that 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.

3.2.8.1.1 Create New Building - Model

Select the type of building model you wish to create from the list of options. Your selection will depend on what you want to do with the building model and the amount of data available. Some typical options are:

- Draw building + standard data - Recommended for general-purpose modelling.
- Single zone + simplified data - Early design stage analysis of building components, facade and cooling options.
- Parametric building + standard data - Buildings of standard form (rectangular, L-shaped or courtyard).

You can adjust the Model Options later if necessary using the Model Options dialog.

3.2.8.1.2 Create New Building - Default Data

This tab allows you to define the templates used to populate the new building:with default Model Data.

Construction

Select the construction template to use as a source of default fabric data for the building.

Activity

Select the activity template to use as a source of default activity-related data for the building.
This will set the following default data:

- Occupancy levels and timing, holidays etc

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- Metabolic rates
- Levels of equipment use
- Heating and cooling temperature setpoints
- Illuminance requirements
- Fresh air requirements

Glazing

The glazing template is used as a source of default window, shading and percentage glazing data for the building.

Lighting

The lighting template is used as a source of default lighting and lighting control data for the building.

HVAC

The HVAC template is used as a source of default data for the HVAC equipment to heat and cool the building.

3.2.9 Working with Blocks (Building Level)

Blocks are the basic elements used to create a DesignBuilder model. Three types of block can be added to the building:

- Building Blocks are composed of building elements such as walls, floor slabs and roofs and 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.

All block types are created at the Building Level in the same way and are drawn using perimeters which can be extruded either horizontally or vertically.

This section describes the various operations involved in creating and editing blocks at the building level. To create or edit a block you must first go to the building level and you can do this by clicking on the building entry in the navigator or if you're at the site level and you want to edit an existing building, you can double-click on the building in the 'Edit' screen.

Go to building level

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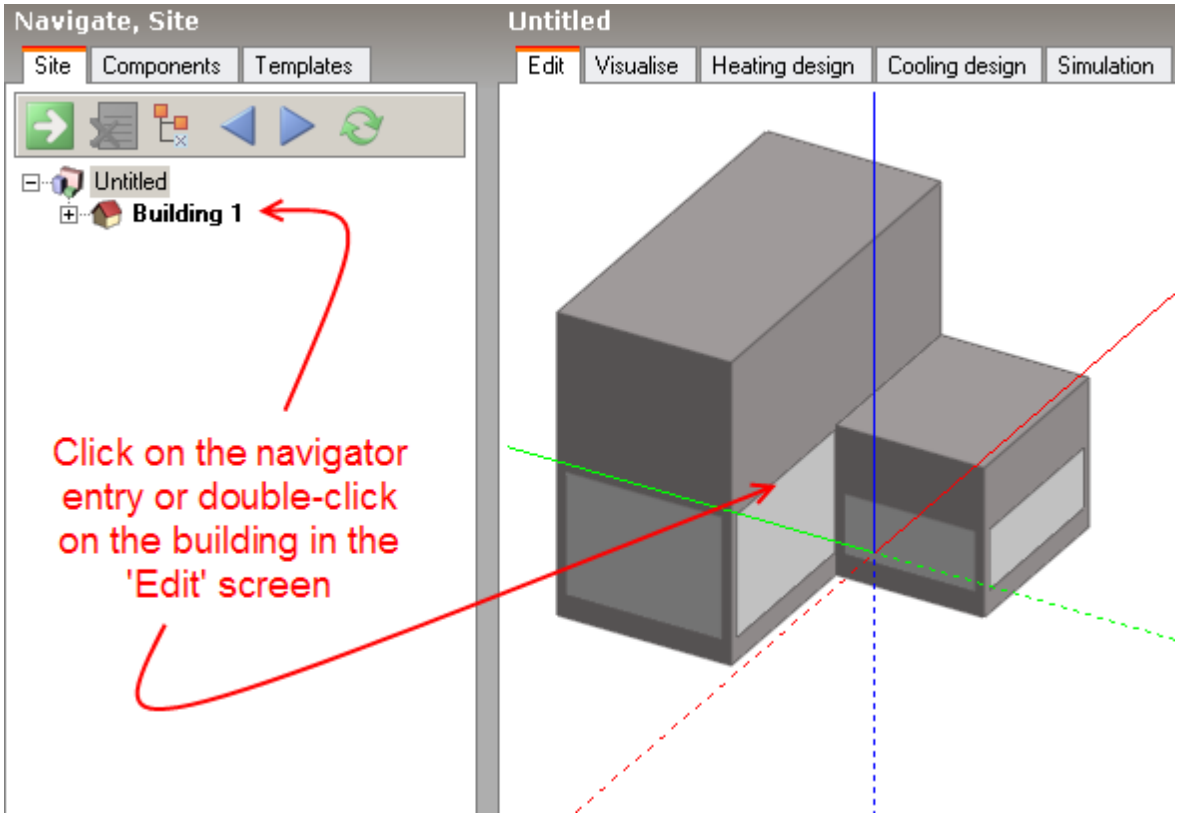
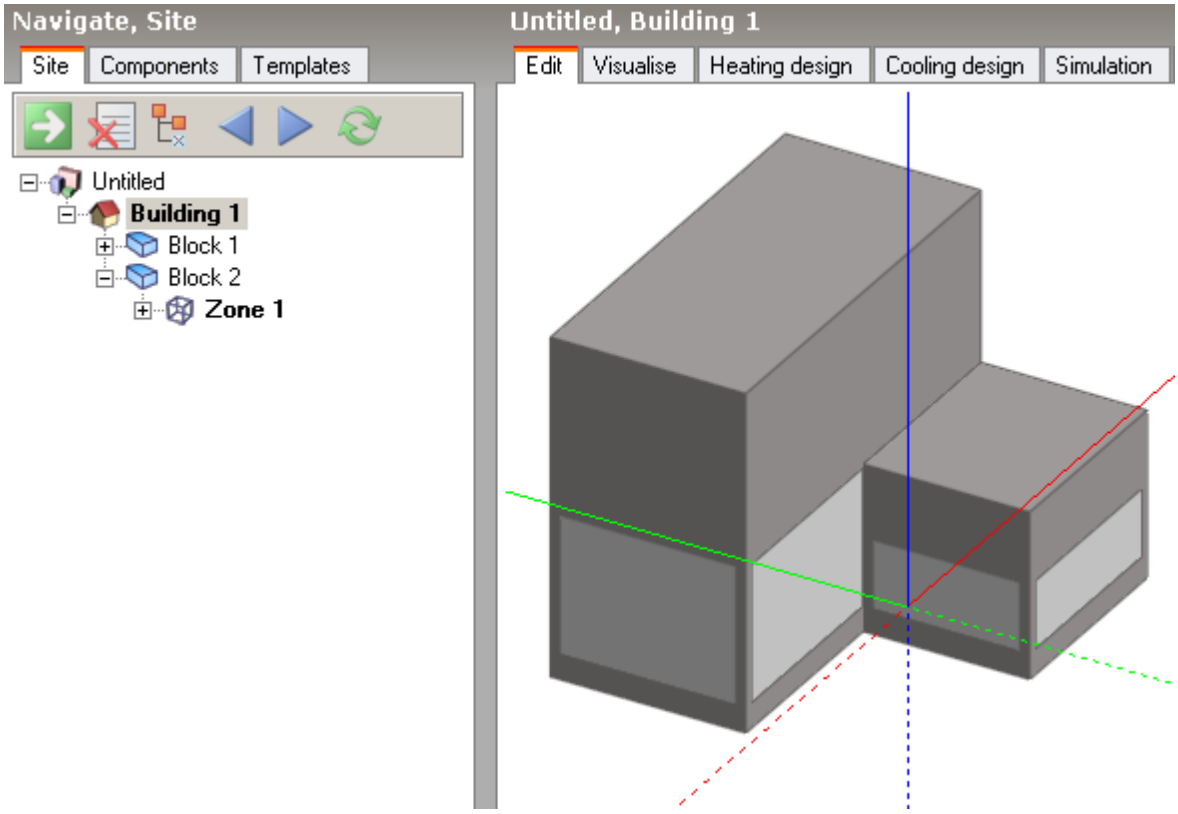


Either operation will take you to the building level:



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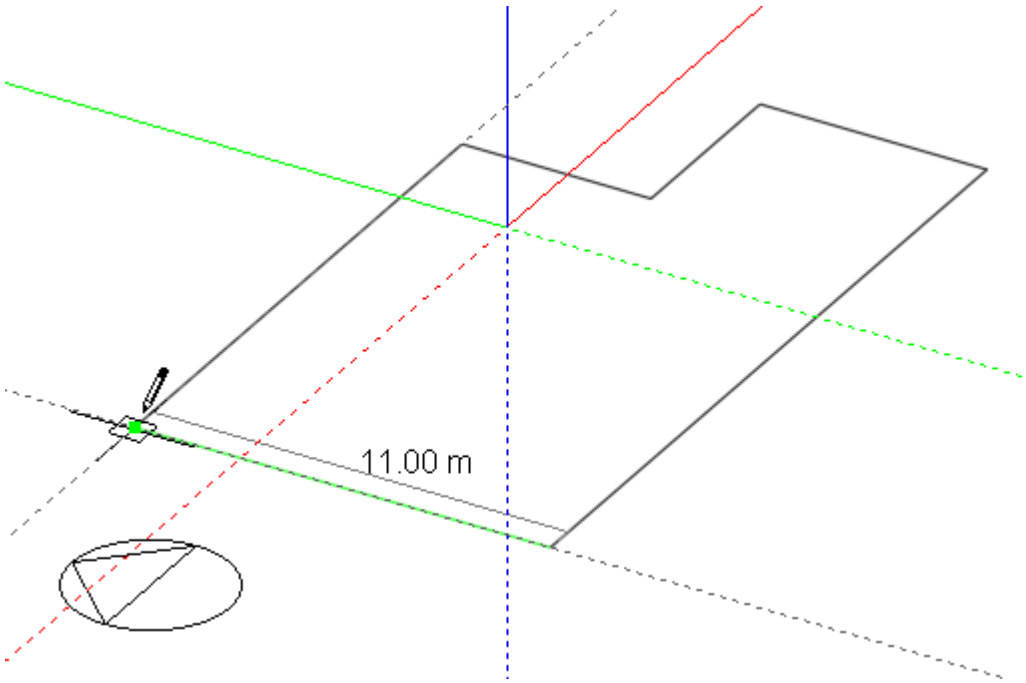
3.2.9.1 Adding Blocks

To add or create a new block, first go to the building level (if you are not already there) and click on the **Add new block** tool. If you've just created a new building, the Add new block tool is automatically activated. A block is created by drawing the base perimeter of the block using one of the perimeter shapes such as a polygon. The dimensions of the block are those measured from the outside, the height of the block is the floor-floor height.



Please refer to perimeter shapes for details of drawing perimeters. After drawing a perimeter, a block will be automatically extruded by the Height entry in the 'Drawing options' settings or if the Auto-complete block setting is switched off, the perimeter can be dragged to form the extrusion. To help in setting the correct extrusion height, the increment snap setting can be used which enables the drag movement to jump by any defined increment. Alternatively, you can simply type in an extrusion height and press the enter key:

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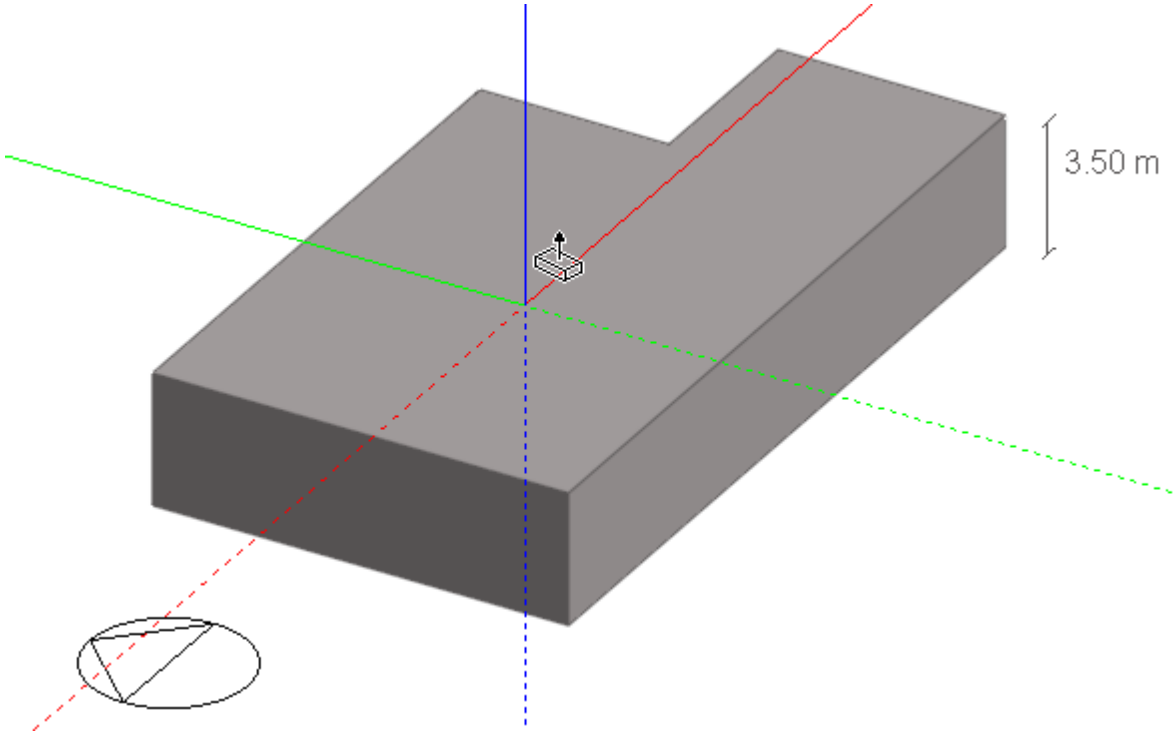

When a block has been placed, additional blocks can be drawn onto any surface of the block to form more complex aggregate blocks. As you move the mouse cursor across the faces of an existing block, each face will change colour from grey to blue to indicate the active drawing plane. You can lock the active drawing plane by pressing the SHIFT key, which allows you to move the cursor off the current face while keeping the plane active. You can also lock the active drawing plane to the ground plane by moving the cursor over the background area and pressing the SHIFT key, this is particularly helpful in avoiding the selection of the wrong plane when drawing a vertically extruded block adjacent to an existing block. Once you've clicked the first data point into the active drawing plane, it becomes locked regardless of whether or not the SHIFT key is pressed until the perimeter has been completed or the tool is cancelled. In the example below the vertical plane shown in blue has been selected, the shape of the block will be drawn in this plane and the volume created by extruding normal to it.

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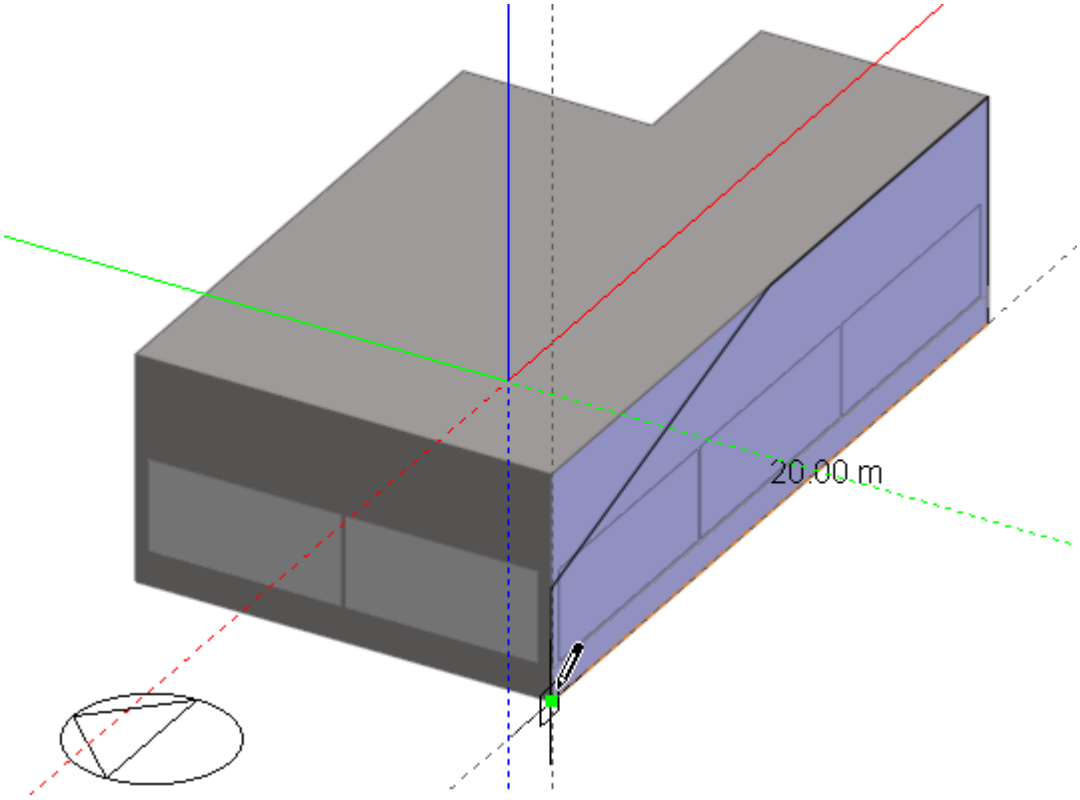
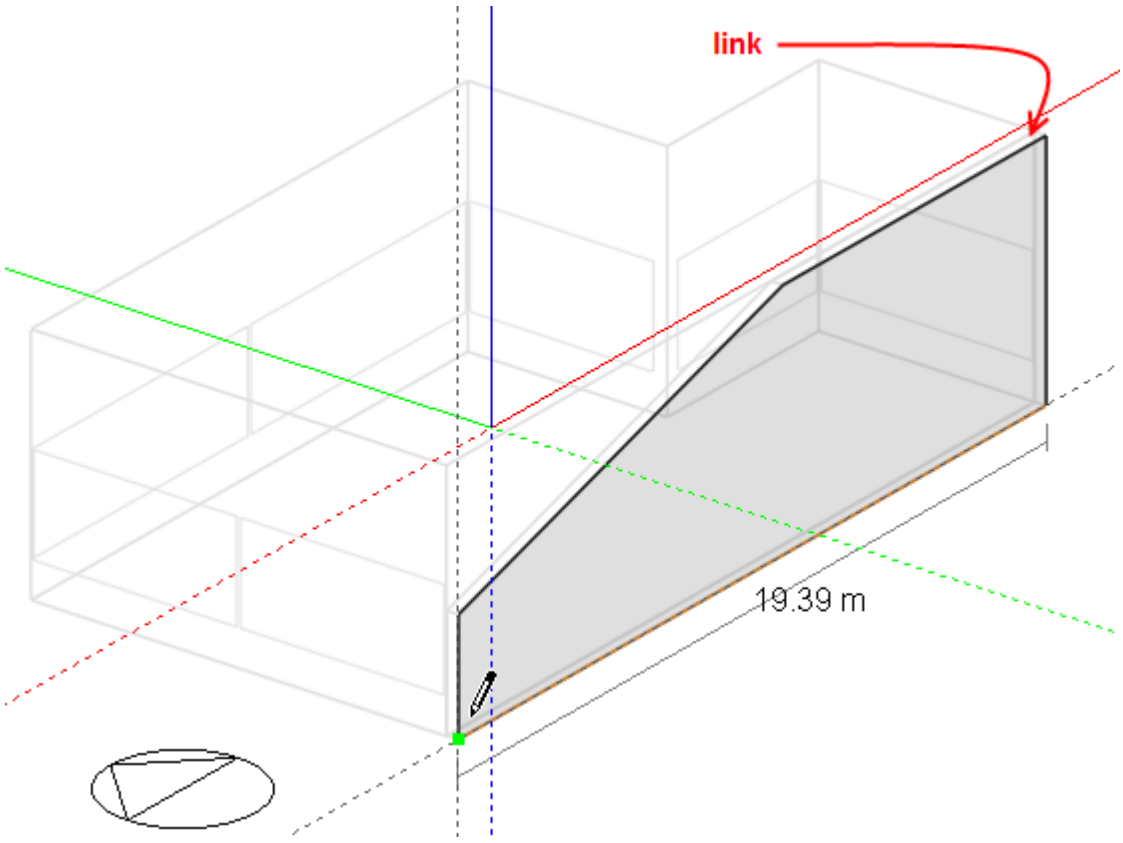


When a block is added to the surface of another block, a geometric link is automatically created between the two blocks:



A hole can be added to the mating surface of this link (the inter-block partition) in order to form one

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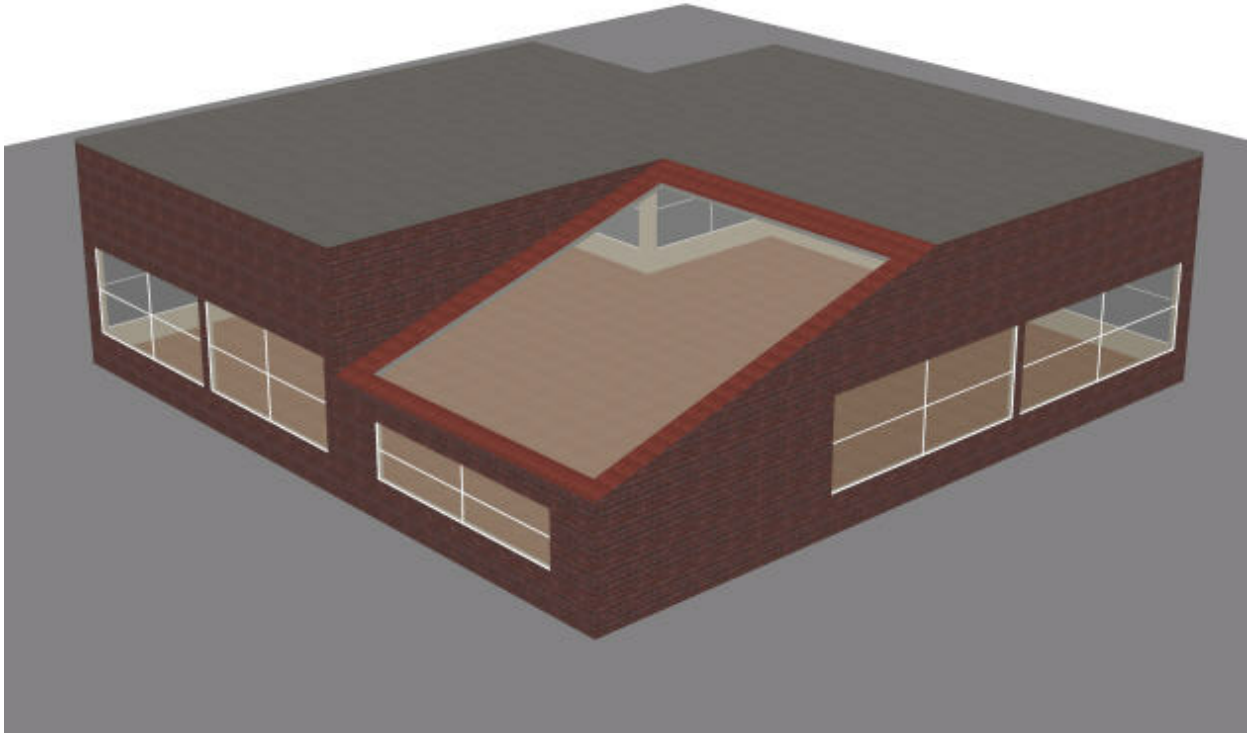
contiguous space:



Note: the Merge zones connected by holes Model option must be set if you wish the two zones in the 2 blocks to be treated as one zone in the thermal calculations.

As already illustrated, a block perimeter can be drawn on the ground plane or onto the surface of an existing block in which case the perimeter is extruded normal to the surface on which it is drawn.

Avoiding Indents

If the perimeter includes indents in such a way that the requested wall thickness is physically impossible and the wall thickness cannot be accommodated then DesignBuilder will still allow the block to be created but the wall thickness is reset to a small value (typically 0.025m). See the Wall thickness topic for more on this.

Drawing in a vertical plane without reference to an existing block

To create horizontal extrusions from a vertical plane, the first perimeter line can be aligned with the Z-axis using the axis snap:

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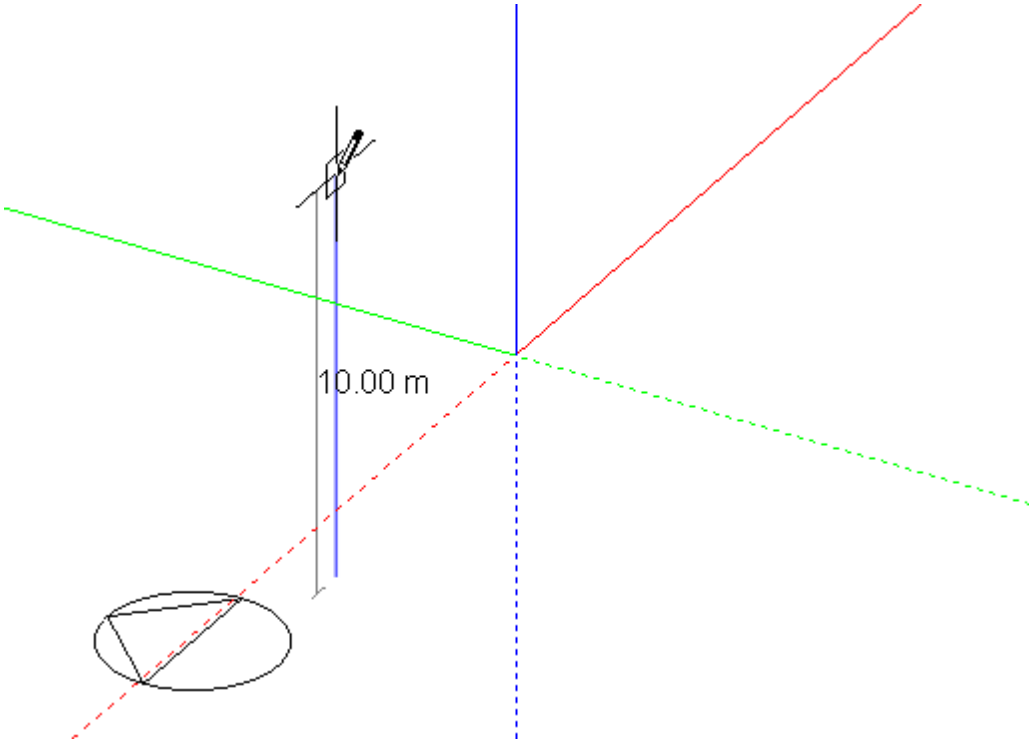
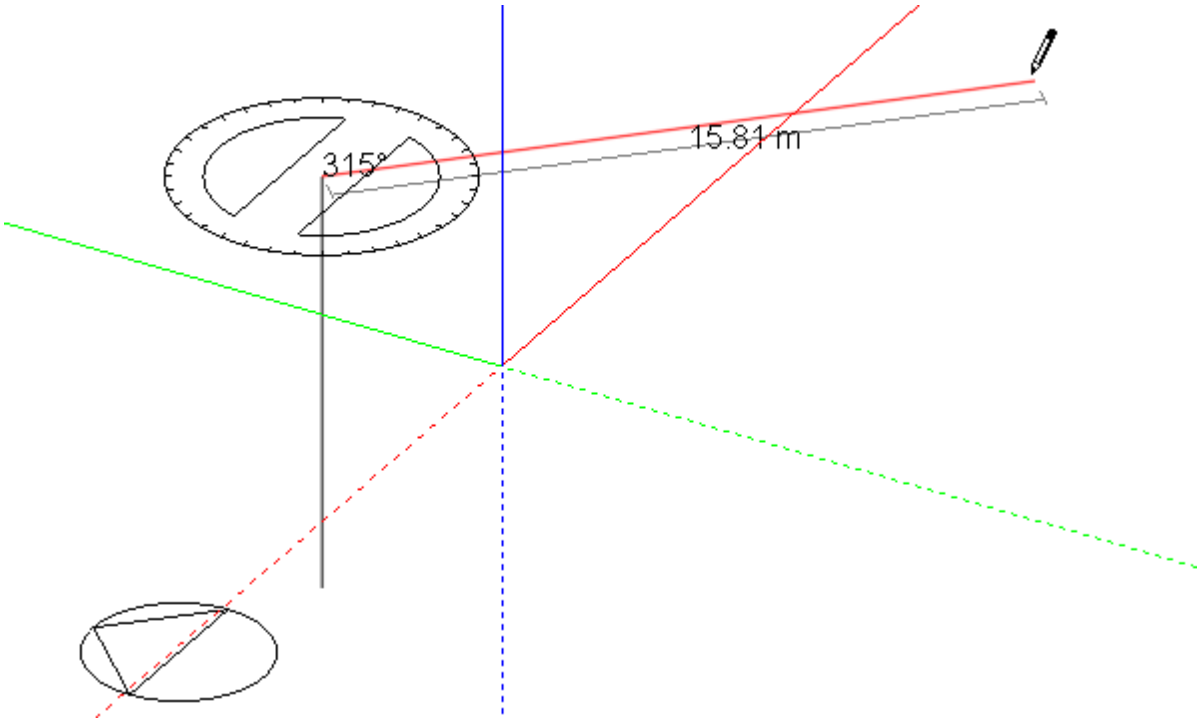


The protractor can be used to place the second line in order to accurately define the orientation of the plane relative to the base or ground plane:



Alternatively, the orientation of the plane can be defined using the first line:

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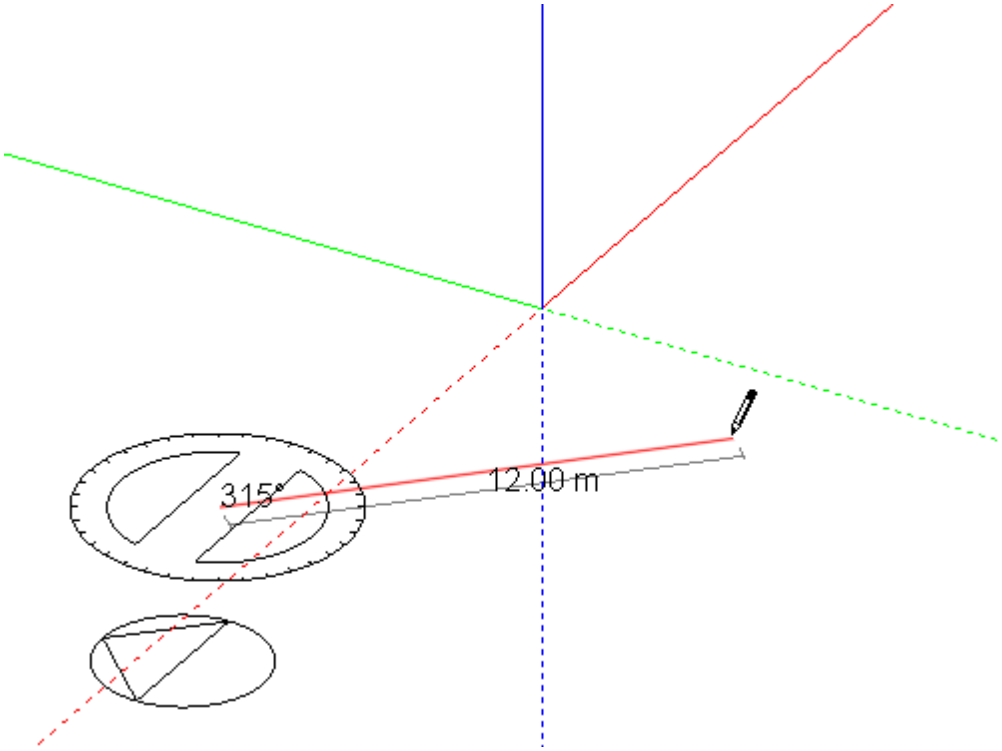
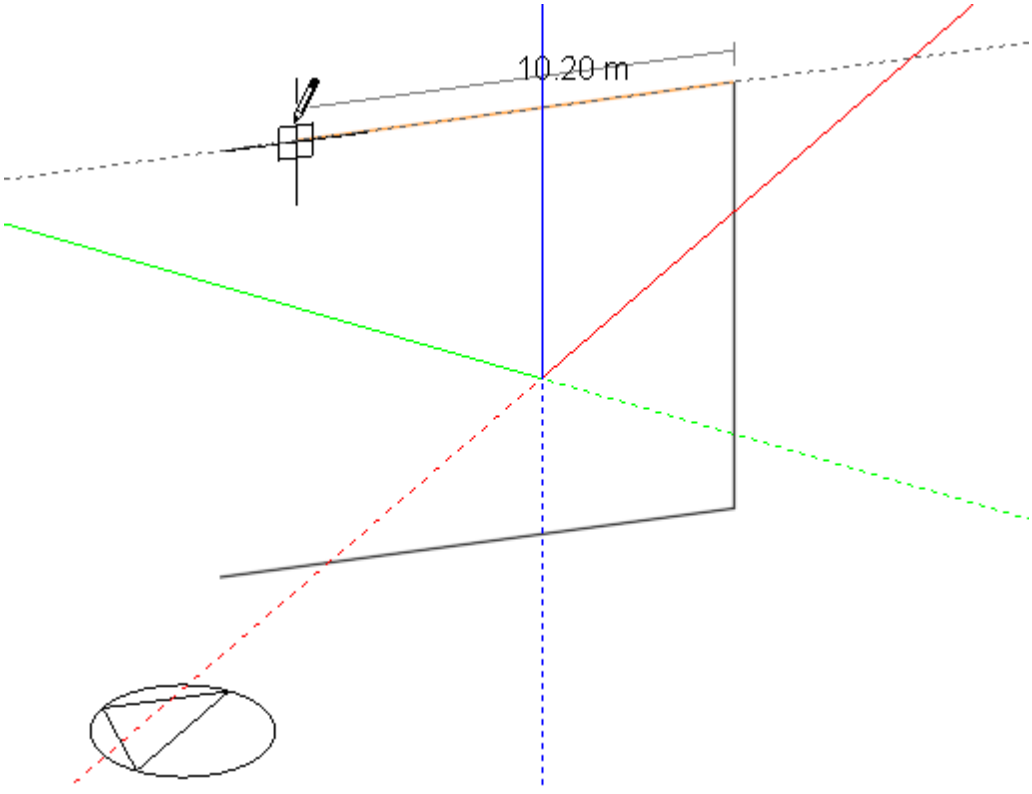


Snapping the second line to the Z-axis then forms the horizontal extrusion:



Once a vertical plane has been defined it will be 'remembered' until the 'Add new block' command is cancelled, so the perimeter can be 'unwound' using the ESC key or the right-click menu 'Undo last point' entry and any perimeter shape drawn into the stored plane:

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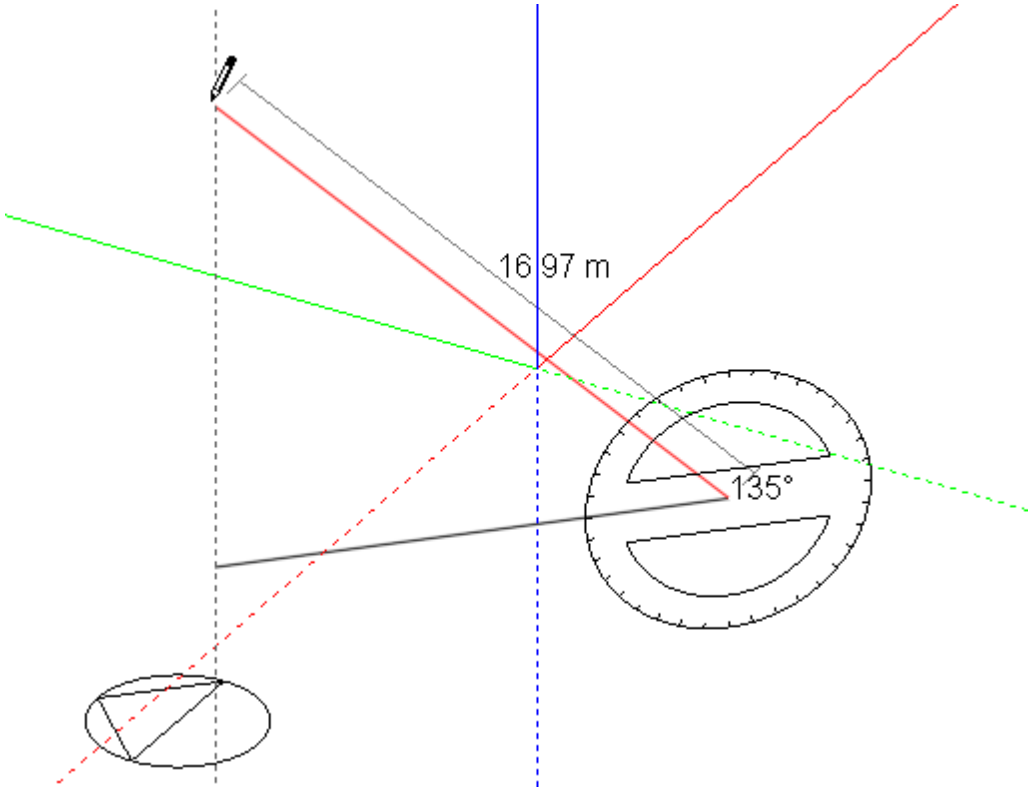
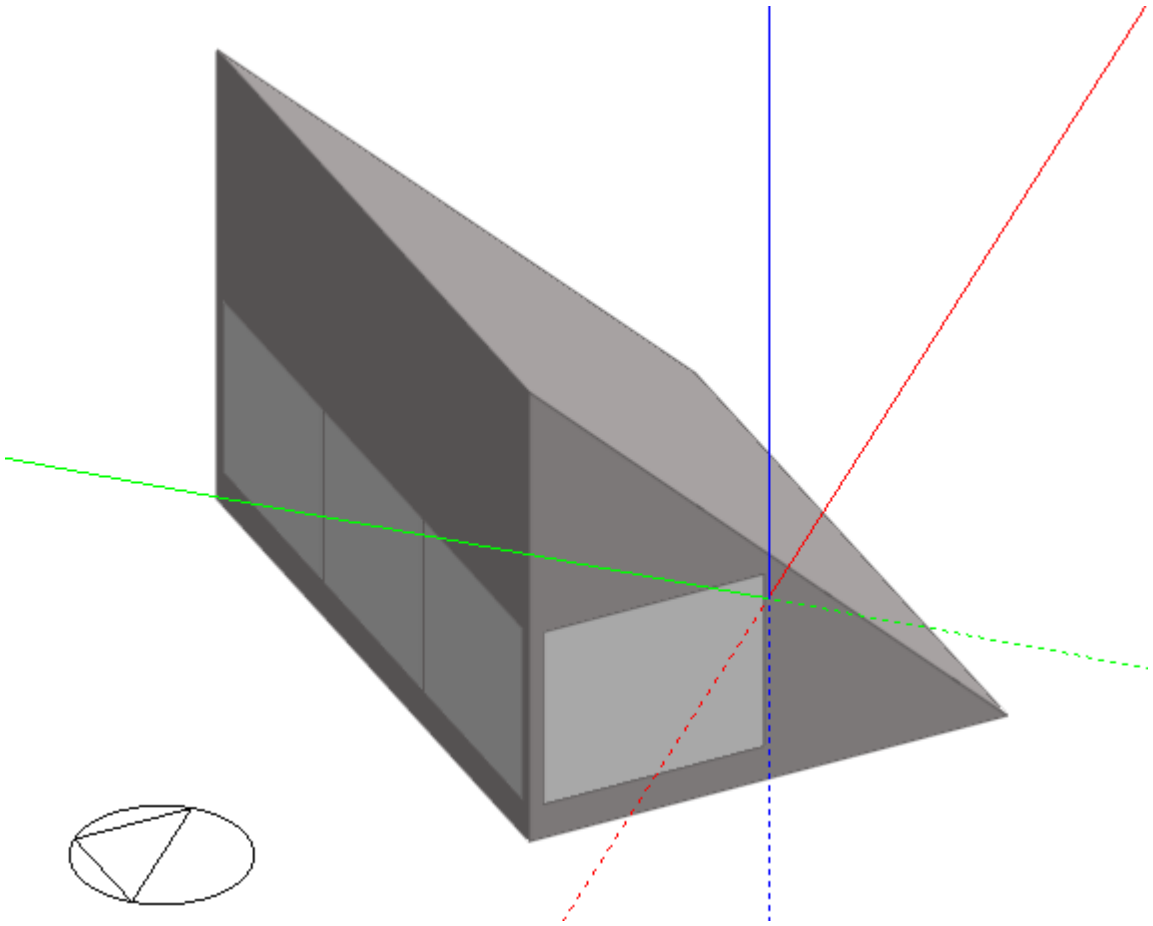


After drawing the last perimeter line to connect to the perimeter start point, the perimeter can then be dragged to create a horizontally extruded block:



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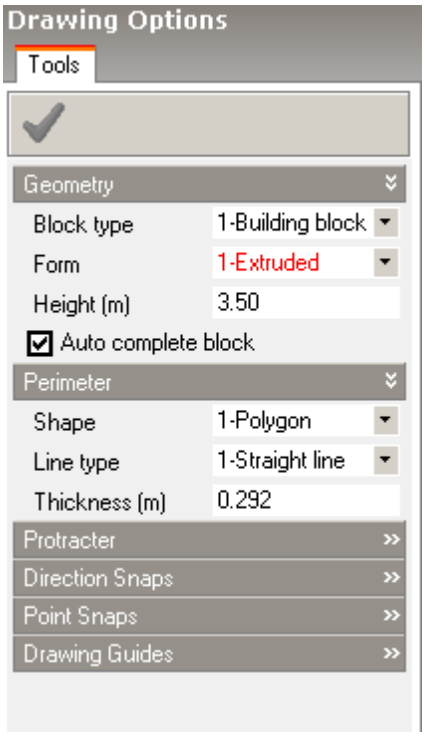
3.2.9.1.1 Block Creation Options

The block creation options enable you to control the way a block is drawn:

- Block type
- Form
- Height
- Wall Thickness
- Auto-complete block

These options are accessed through the 'Drawing options' data panel, which is displayed when you click on the Add new block tool:



COMBINED CONSTRUCTIONS

The diagram below illustrates how blocks should be defined and how zone volumes and surface dimensions are derived from the parent block when using Combined constructions.

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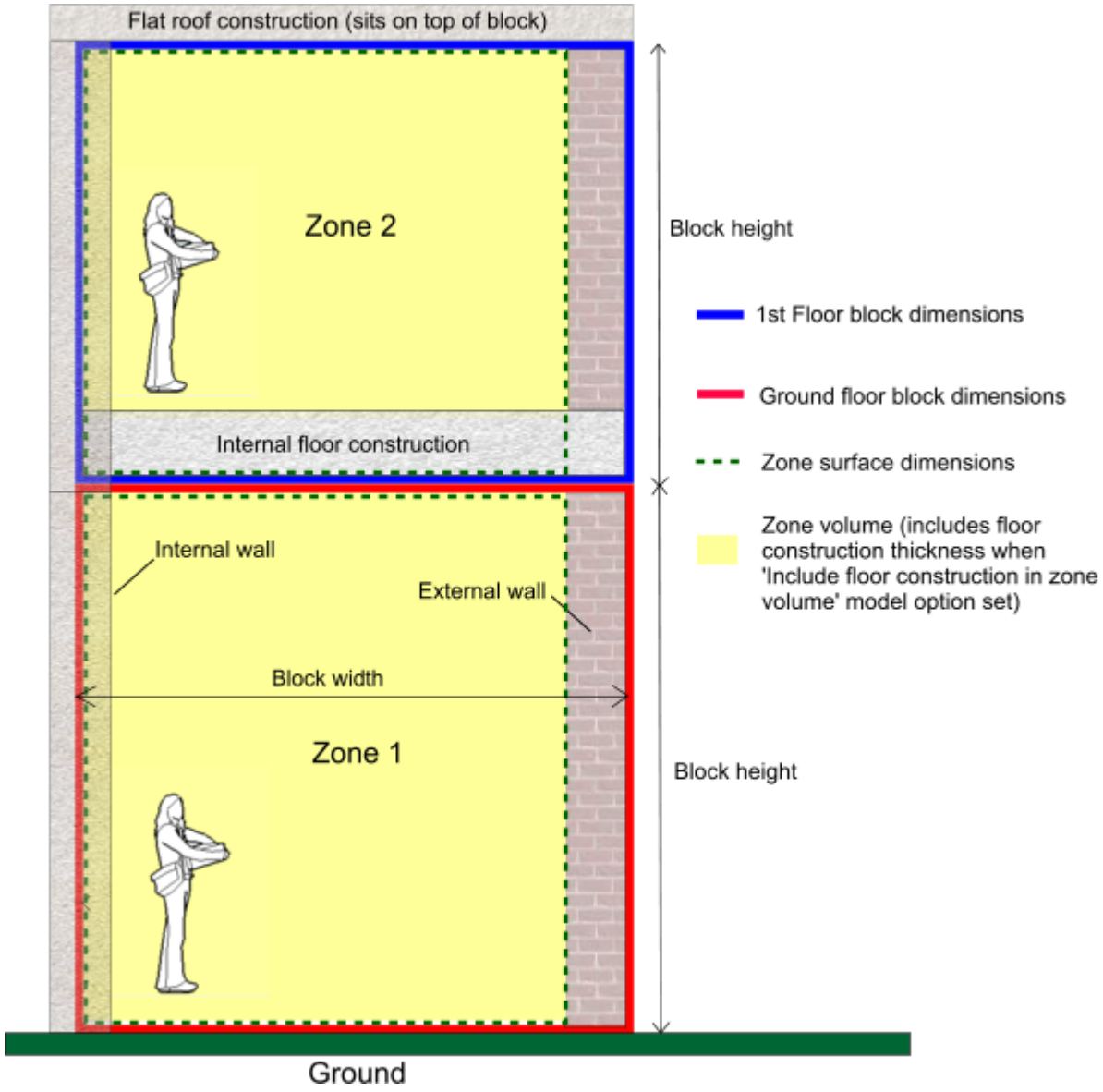

The important things to note are:

1. The length/width dimensions of the block are measured from the outside of external walls.
2. The height of the block is the floor-floor height:
   - For **ground floor** blocks, the block height is the distance from the ground level to the underside of the floor slab of the next block up.
   - For **non-ground floor** blocks, the block height is measured from the bottom of the block floor slab to the bottom of the floor slab of the block above.
3. Flat roofs are placed on top of the block, so when drawing a block with a flat roof you should exclude the roof construction in the height.
4. External floors are placed under the block, so when drawing a block with an external floor you should exclude the external floor construction thickness in the height.
5. Wall surfaces extend the full height of the block.
6. Zone surface dimensions (shown in green dotted lines above) are measured from inner edges of outer walls and the centre line of partitions.
7. Floor surfaces extend horizontally to the inner surface of external walls and to the centre line of partitions. See below for more on zone/surface dimensions.

The zone **volume** used in ventilation calculations is the actual inside volume (shown in yellow in the diagram above). These inside zone surface dimensions are used to define surface heat transfer areas in simulations and other calculations.

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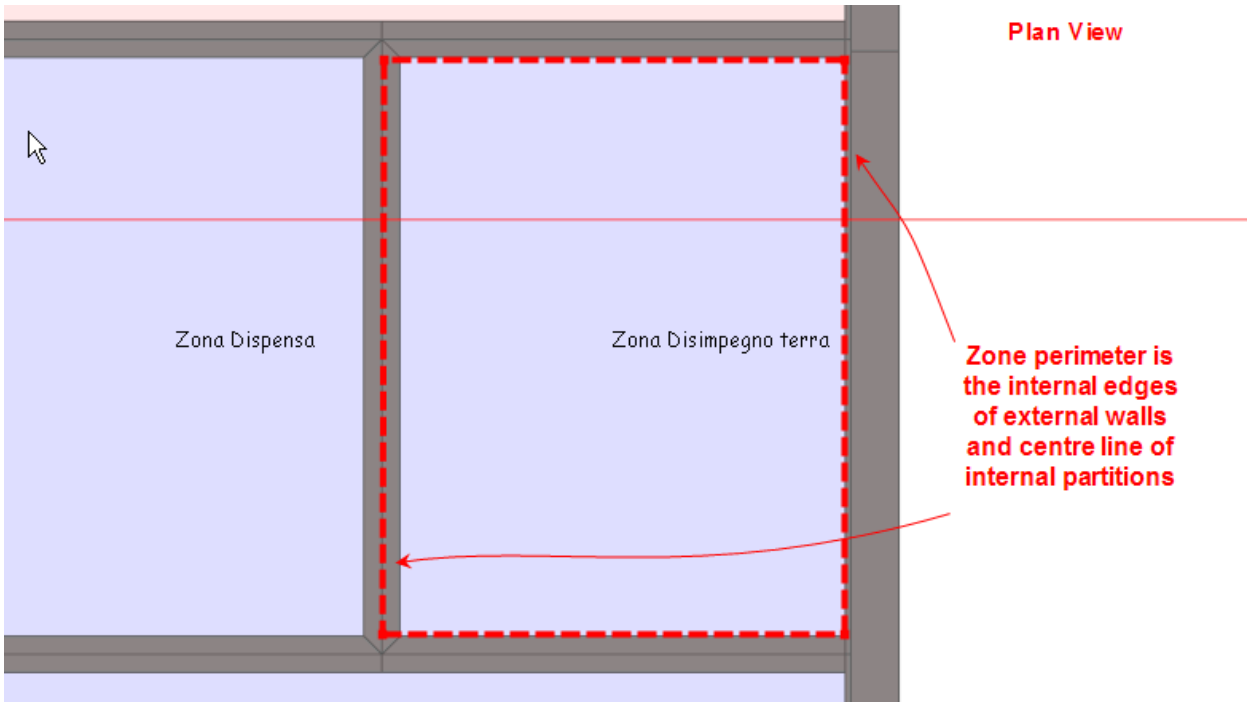
Zone perimeter (plan view)



Other related information

1. See Combined Constructions for information on the meaning of the Construction Model data.
2. Also see Constructions for how to edit the construction configuration.
3. And the Model Geometry Example section for a detailed worked example illustrating how surface areas and volumes are calculated.

Three types of block are available:

- Building Blocks are used to draw the model or a section of the model.
- Outline Blocks are used to help in the creation of building block geometry and do not affect the model.
- Component Blocks are used to create visual and shading structures which do not contain zones.

A building block represents the outer shell of the model or part of the model. A finished block comprises a set of building elements, which may include external walls, roofs and floor slabs, the constructions of which are determined from the current building construction model data. Similarly, using opening model data, block facades are automatically created with the required configuration of windows, doors, vents and solar shading devices:

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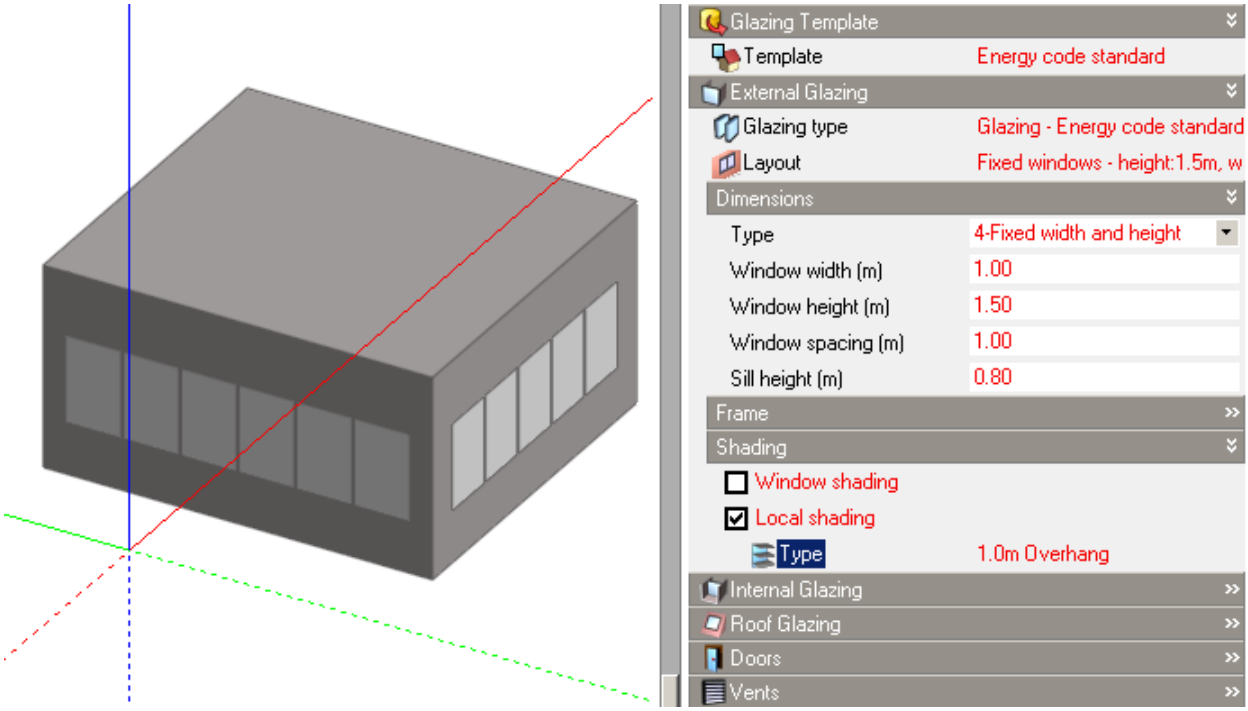
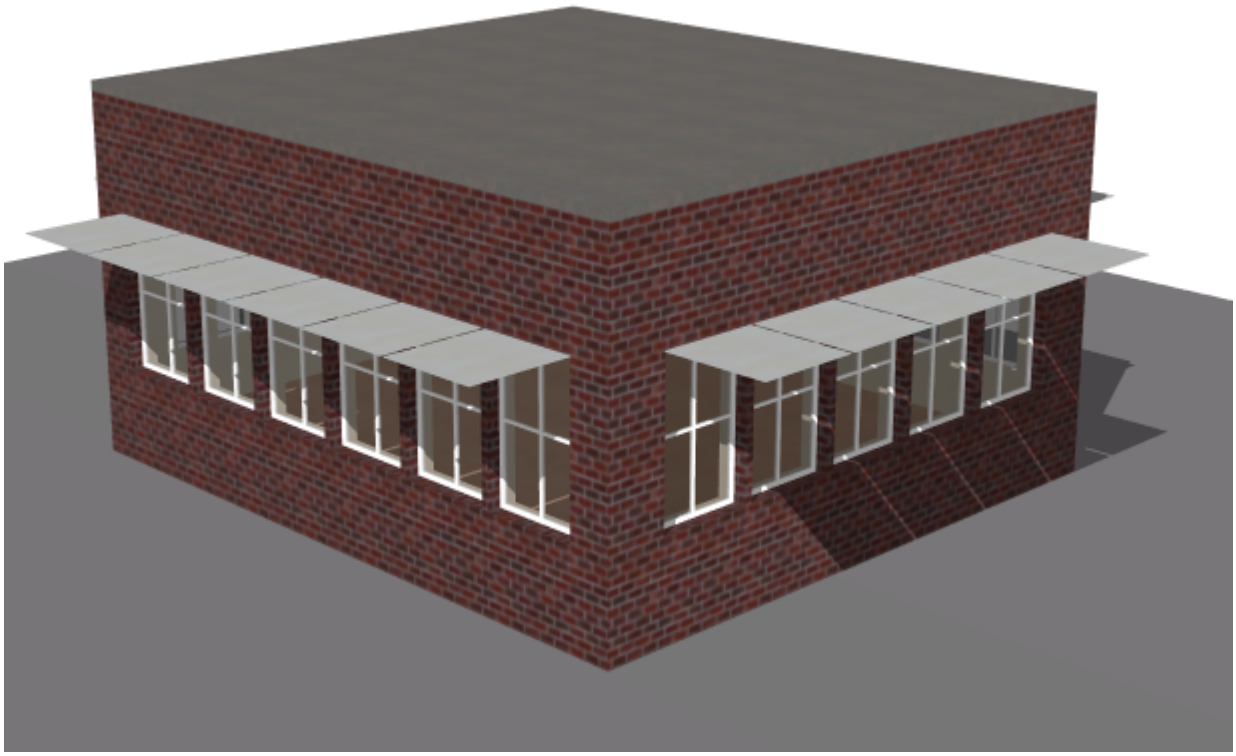


Solar shading devices are displayed in the visualisation screen:



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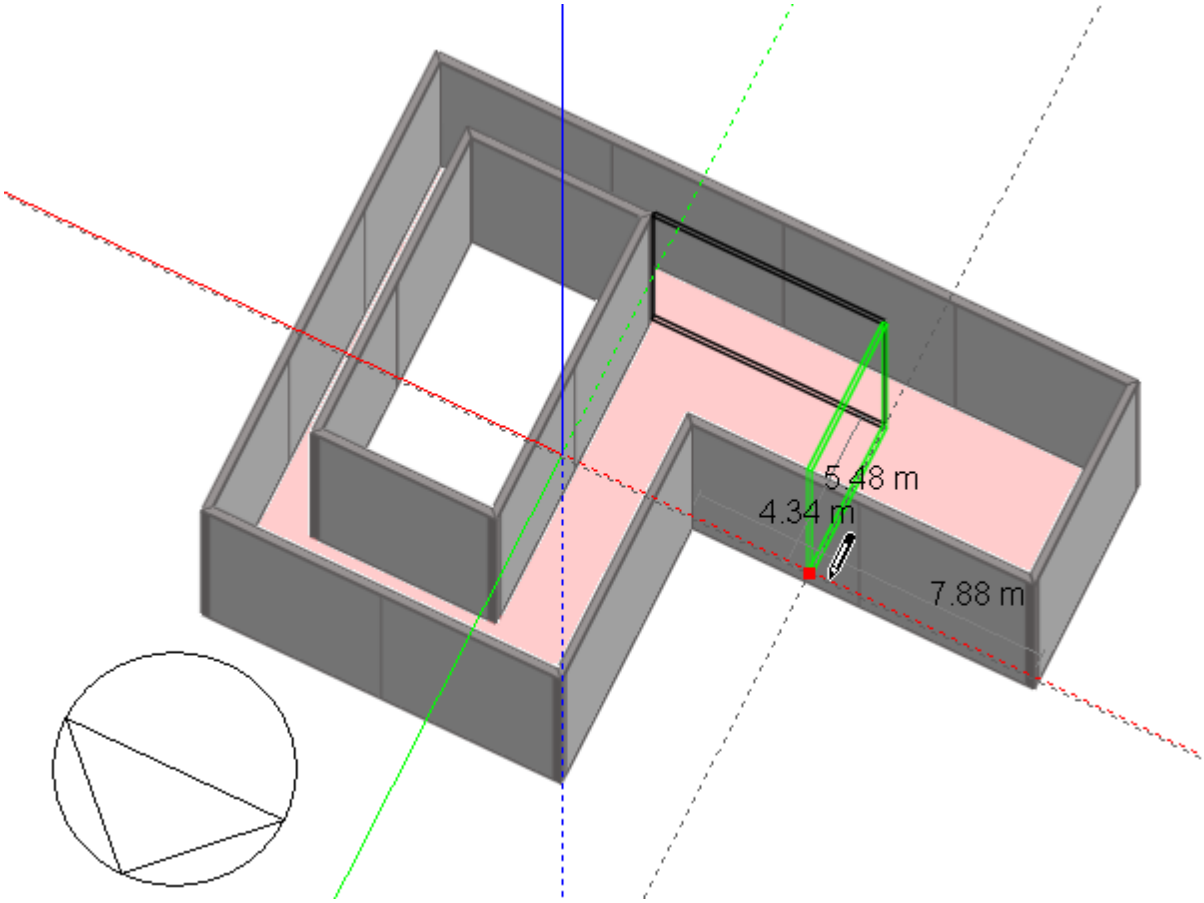
A block may be divided internally into any number of zones by drawing partitions and where needed, voids or courtyards can also be incorporated:



Custom openings (windows, doors, etc.) can be added to block facades by going to the surface level and using the 'Draw window' family of commands.:

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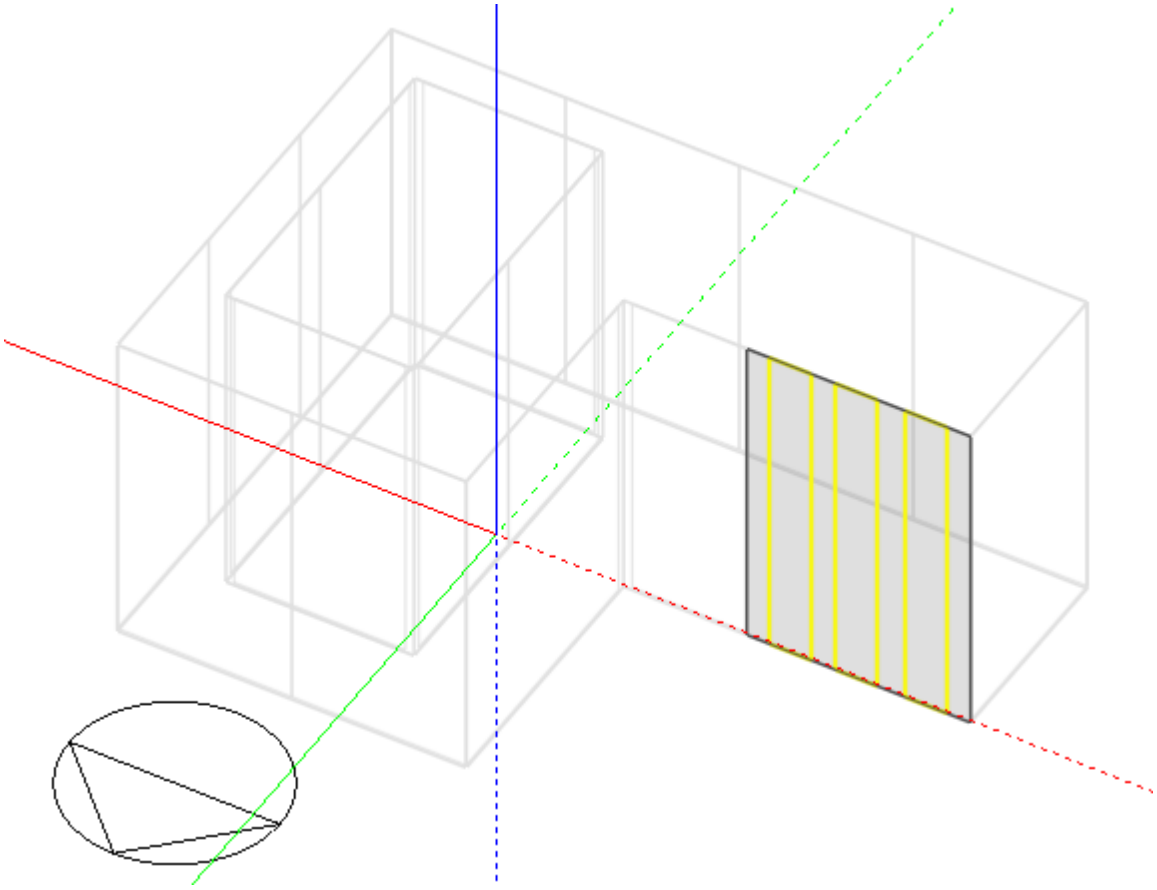

Blocks can be moved, copied and rotated. Blocks can also be cut or stretched and block faces can be dragged to different positions.

An outline block is created and edited in exactly the same way as a building block but is just a 3-D shape without associated building elements such as walls, floors, roofs, etc.

Because Outline blocks are not part of the model they do not appear in the Navigator panel.

Outline blocks are very useful in the creation of more complicated models. Because they are relatively simple objects, they are much faster to create, copy, move, etc. than conventional building blocks and can be manipulated freely without worrying about intersections. Once the required geometry has been established, outline blocks can be converted to conventional blocks. Outline blocks can also be used as a temporary device to create drawing planes from which building blocks or other outline blocks can be extruded. You can remove all outline blocks from a model by selecting **Remove all outlines** from the Edit menu.

For example, to create a dormer window:

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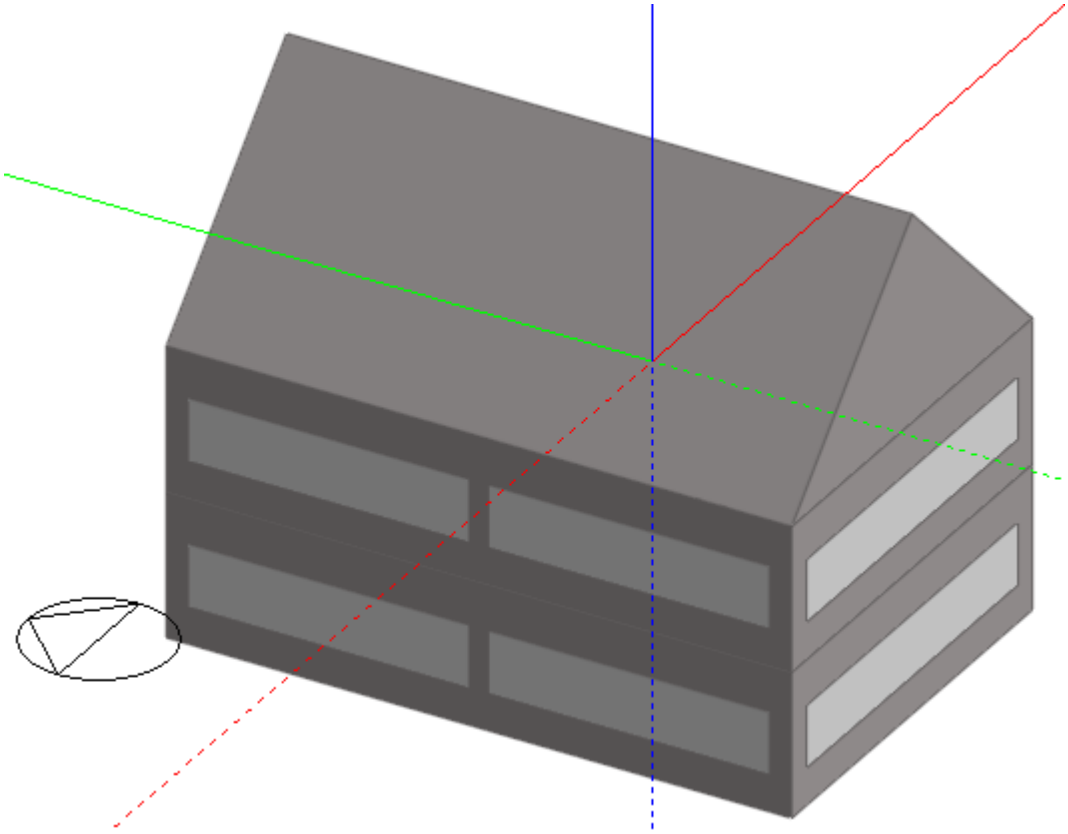
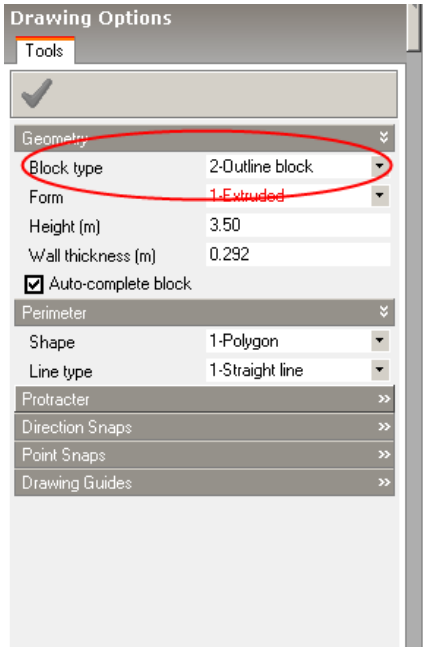
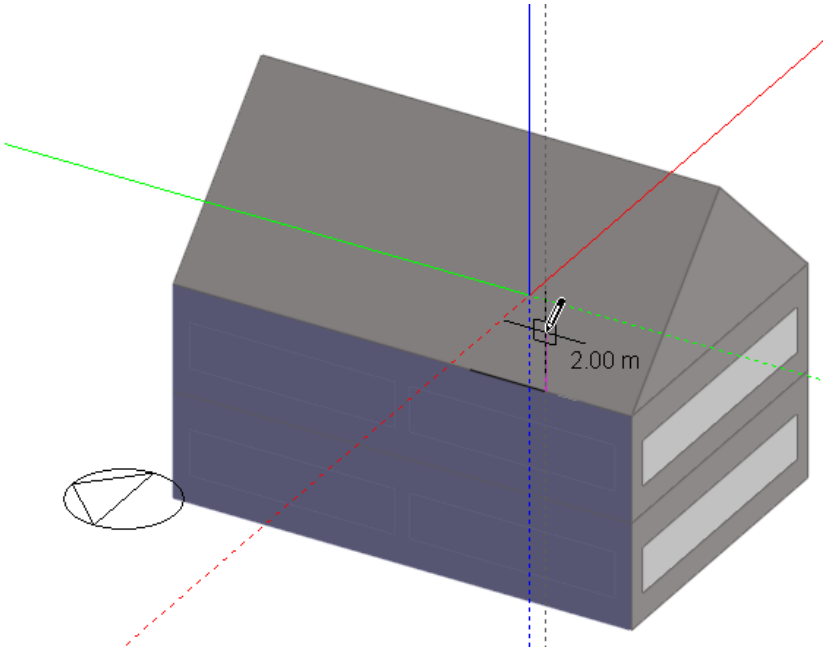


First set the Block type to 'Outline block' and lock the active drawing plane to the front surface of the first floor block by selecting it and pressing the SHIFT key, then draw the base line of the dormer face perimeter:





Create the angle of the dormer pitch using the Protractor:

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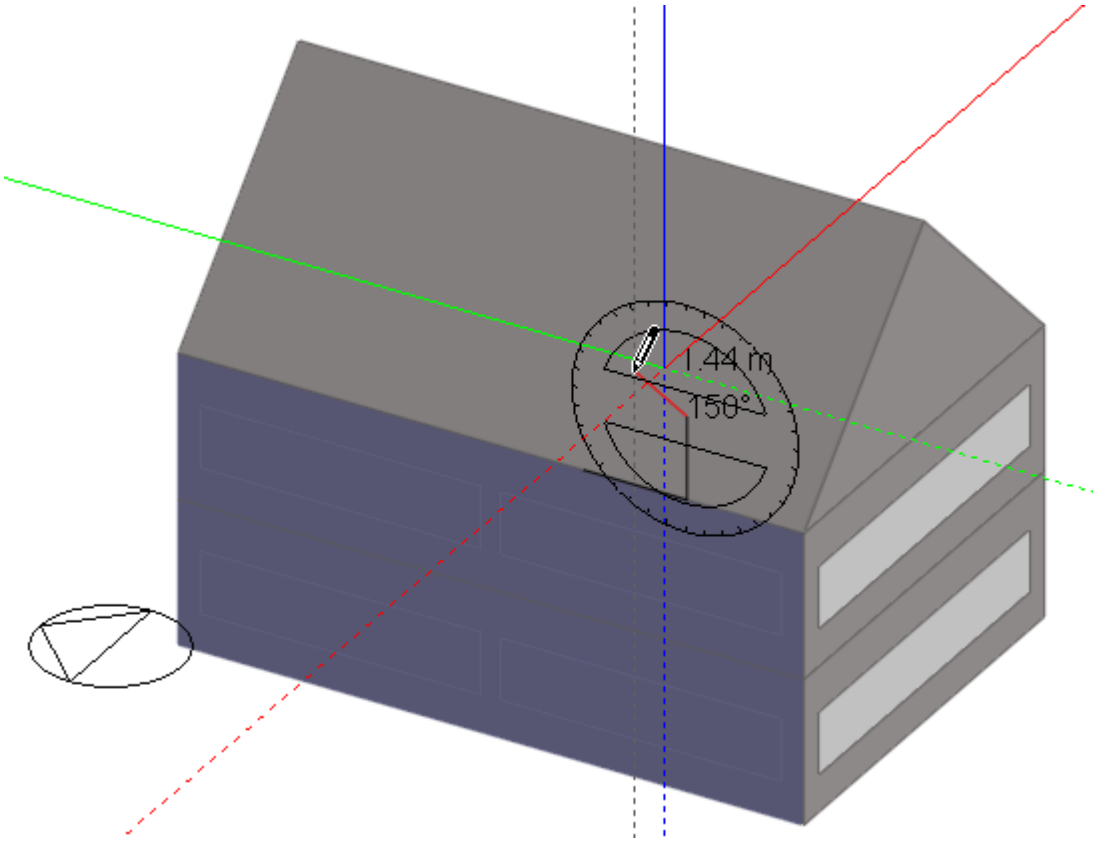

and then complete the perimeter:

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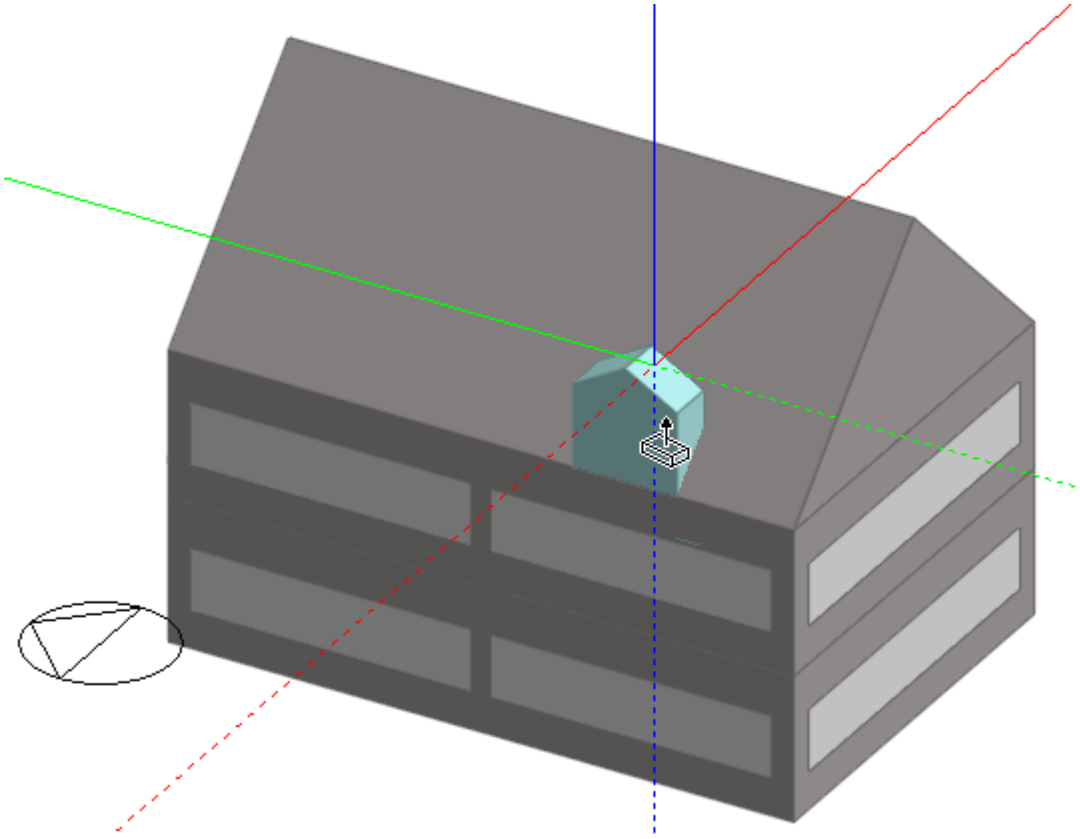
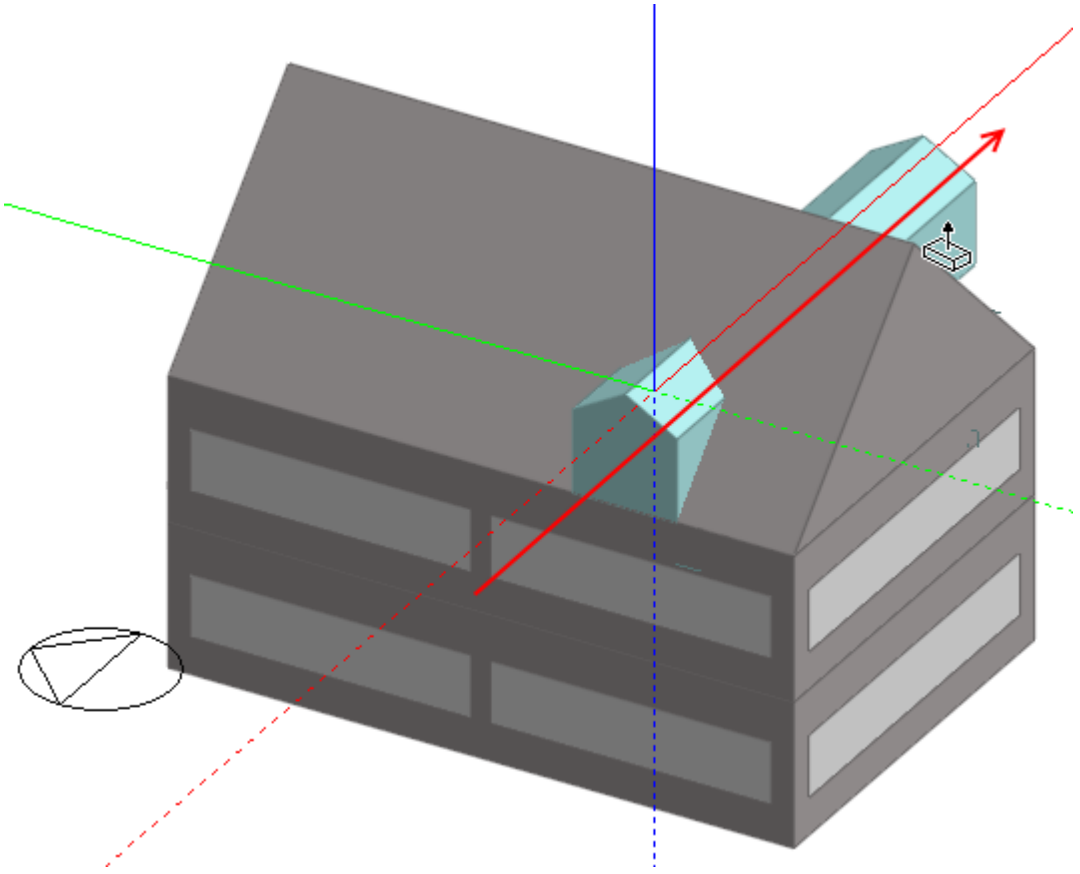


Now drag the dormer perimeter all the way through the main roof block:



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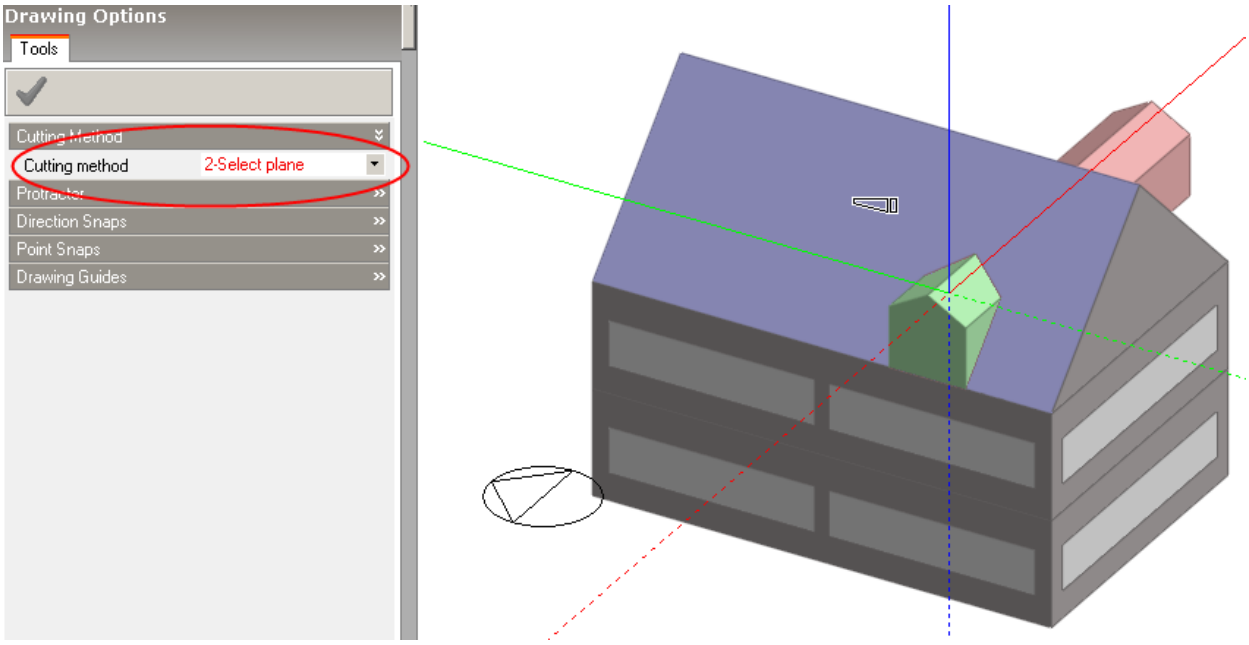
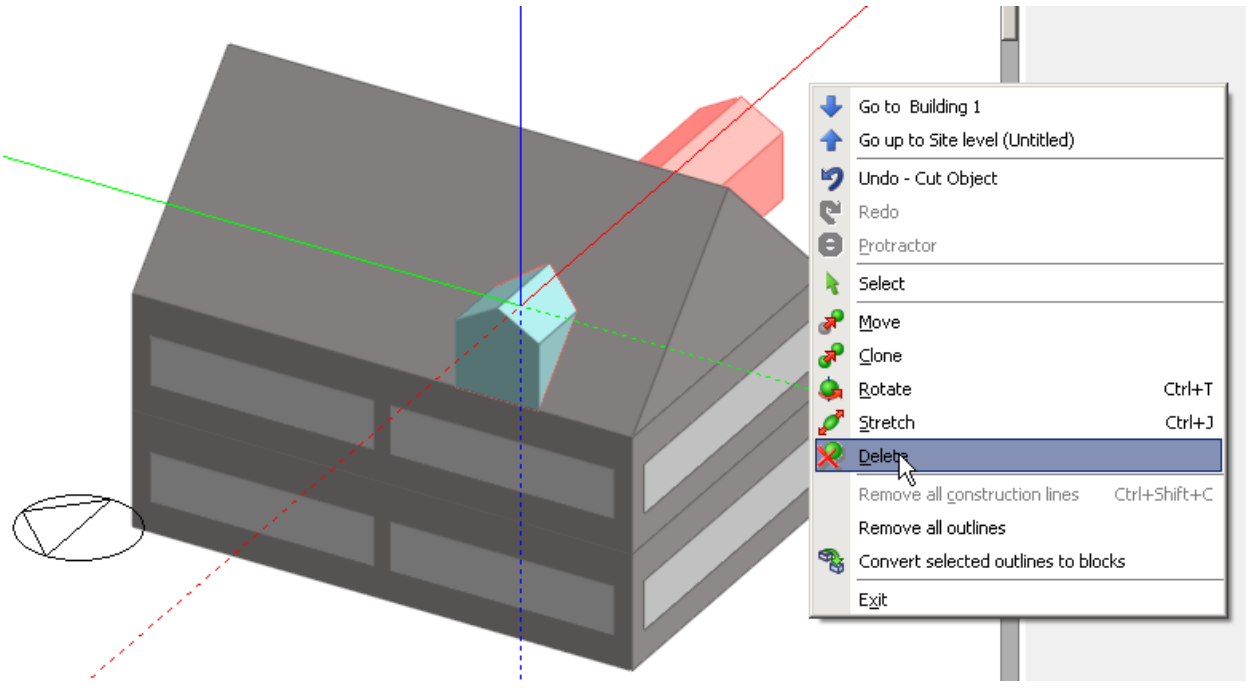
Select the dormer block and click on the Divide block tool, making sure that the 'Cutting method' on the 'Drawing options' data panel is set to 'Select plane' and click on the forward facing plane of the main roof block to create a cut in the dormer block in the plane of the roof:



Click again to finish the cut and then select the section of the dormer block that is not required and delete it:



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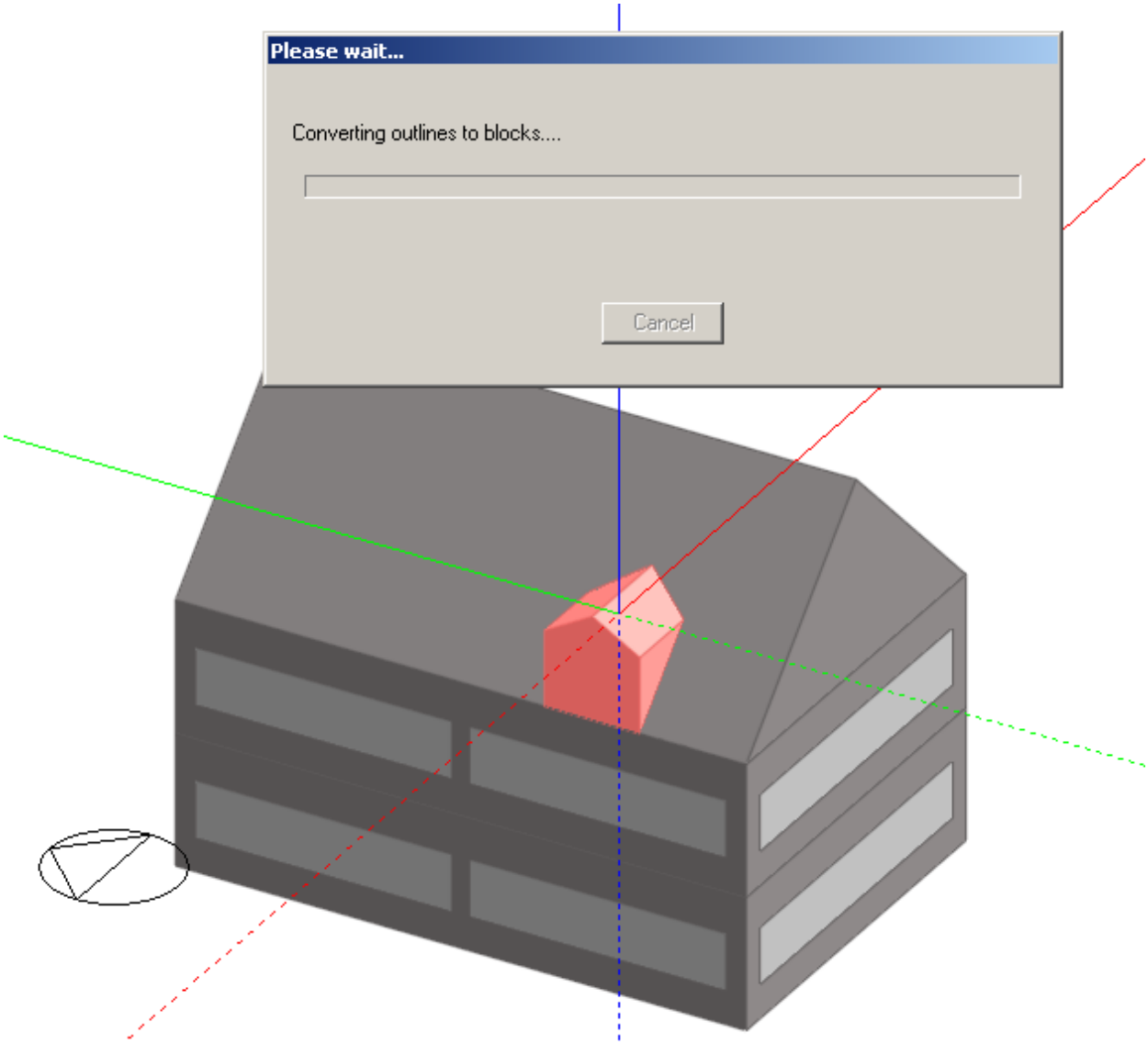
Select the dormer outline block and click on the **Convert outline block** tool to complete the process:



The finished block after adding openings:

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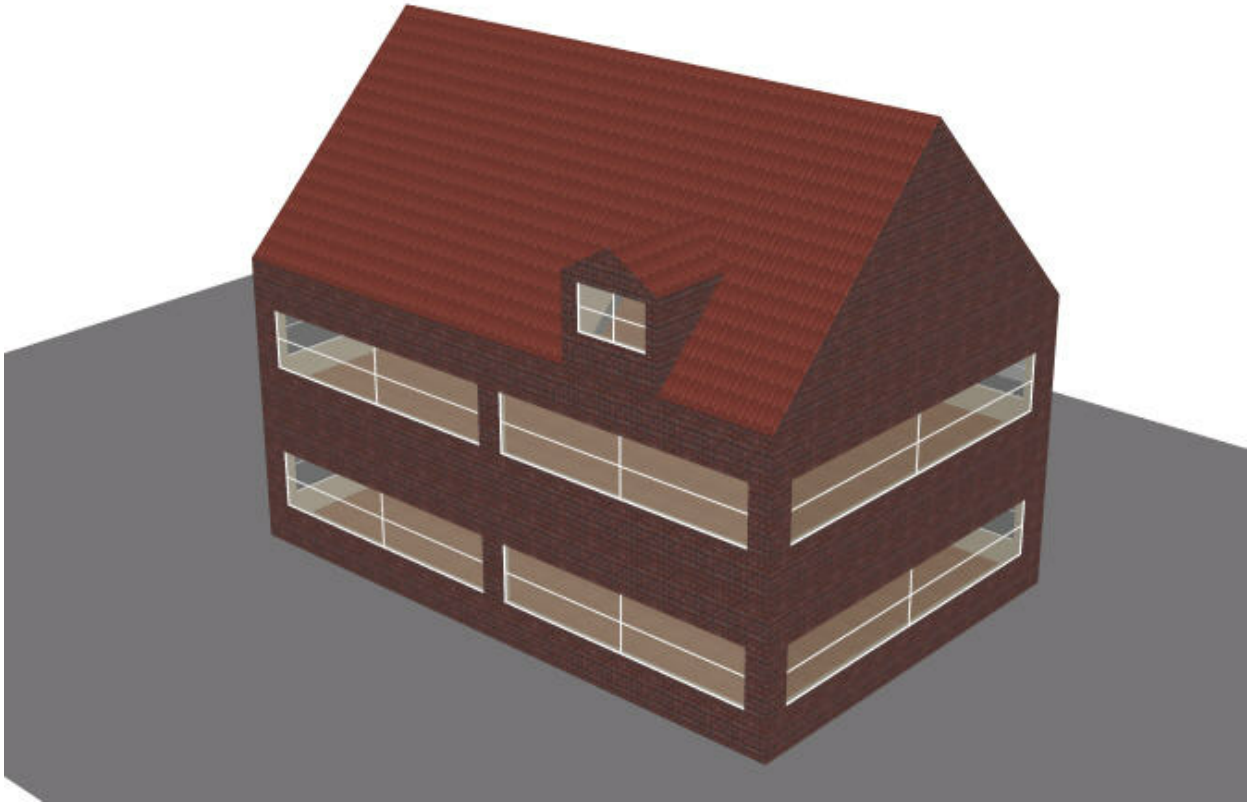

Note: Sometimes when converting outline blocks to component or building blocks you will notice that the new block has a very slightly different size to the original outline block. This can happen when DesignBuilder needs to slightly adjust the size in order to generate a viable zone with 3-D slab surfaces. It is therefore advisable when using outline blocks to create complex geometries to draw and convert the outline blocks individually. This avoids adjacencies between touching outline blocks from getting 'broken' when they are converted 'en-masse'.

There are 3 types of component block:

- **1-Standard** - used for shading, reflection and visualisation.
- **2-Ground** - used for setting ground adjacency, shading, reflection and visualisation.
- **3-Adiabatic** - used for setting adiabatic adjacency, shading, reflection and visualisation.

Component blocks are drawn in the same way as Building blocks but selecting the Block type in the Drawing Options panel as **3-Component block**.

Each Component block has its own Component block material, transmittance schedule and shade/not shade model data. To edit this you must first go to the component block itself by double-clicking on it in the model edit screen or clicking on the entry in the Navigator. Alternatively, component blocks inherit default model data from the building level so if you leave the component block model data in its default state (blue) you can change all model data in one go by making the edit at the building level.

All component blocks cast shadows in Visualisations.

STANDARD COMPONENT BLOCK

Sometimes it can be useful to create structures such as pillars, shading obstructions and balconies which

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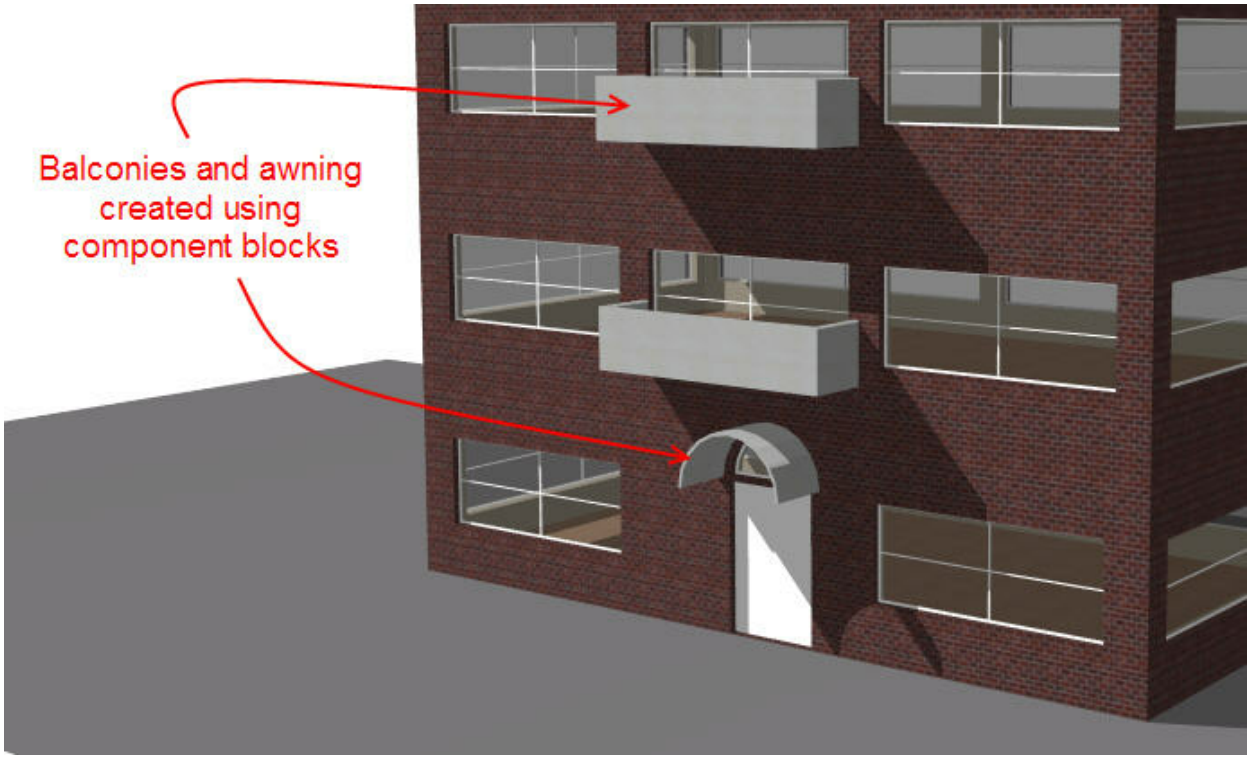
do not contain zones. **Standard component blocks** can be used for modelling such structures as they are treated simply as shading/reflection surfaces in simulations without any zones.

Standard component blocks are visible in Visualisations, using the texture associated with the Component block material as set on the Constructions tab under the Component Block header. They can be used to cast shadows and reflect solar radiation and light in simulations by checking the **Component block shades and reflects** model data under Component Blocks on the Constructions tab.

Note: component blocks do not shade ground reflected solar radiation unless the reflection solar option is used.

The image below shows some typical uses of Standard component blocks.



GROUND COMPONENT BLOCK

Ground component blocks can be used as a convenient way to set the adjacency of any touching building block surfaces as being 'adjacent to ground'. In the model below the Ground block (shown in green) has been positioned in contact with the building block to create a ground adjacency in the part of the Building block surface in contact with the Ground block.

Standard component blocks are visible in Visualisations, using the texture associated with the Component block material as set on the Constructions tab under the Component Block header. They can be used to cast shadows and reflect solar radiation and light in simulations by checking the **Component block shades and reflects** model data under Component Blocks on the Constructions tab.

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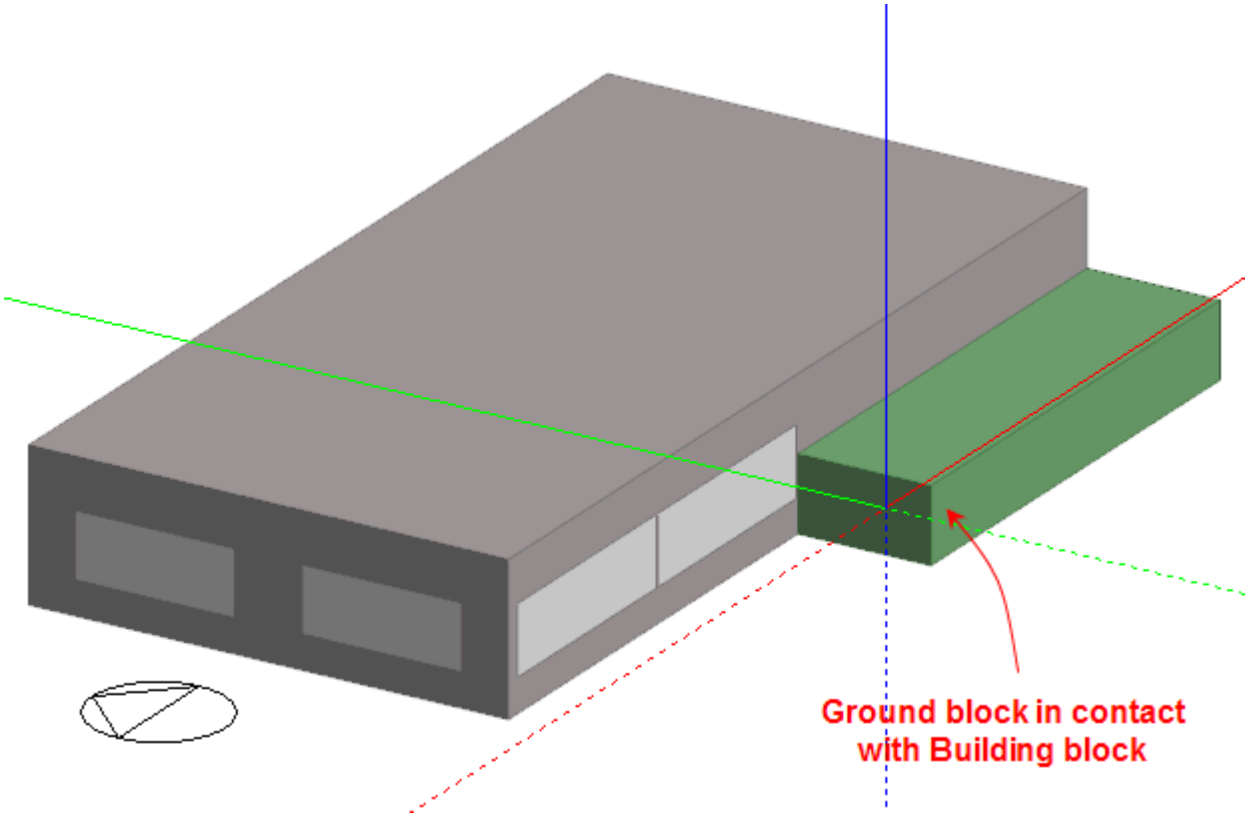
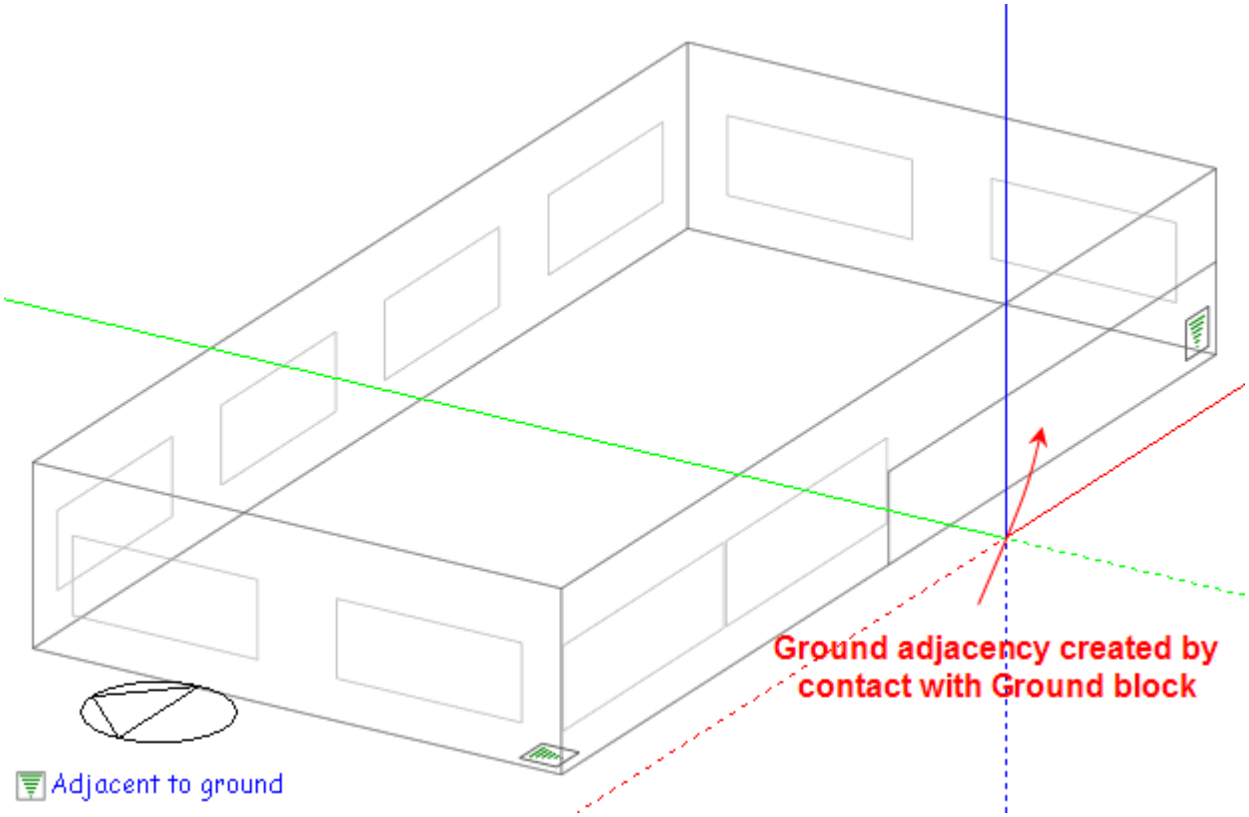


View from building level



View from zone level

Ground component blocks are displayed in the visualisation screen using the Ground texture as set at the site level.

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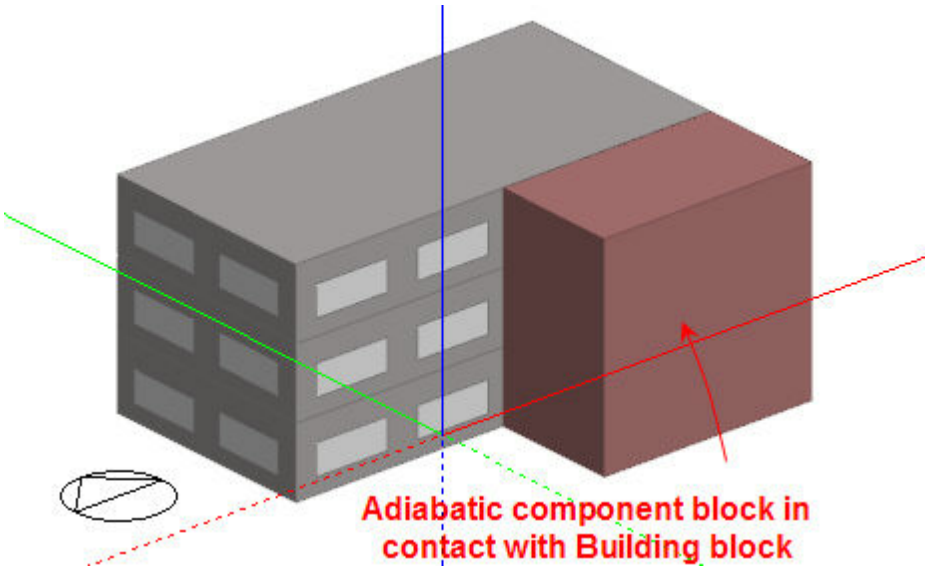
More information on ground modelling can be found in the Ground Modelling topic.

Note: The adjacencies established by contact with ground blocks can be overridden by making settings under Adjacency in Constructions model data at the surface level.

ADIABATIC COMPONENT BLOCKS

Adiabatic component blocks can be used as a convenient way to set the adjacency of any touching building block surfaces to 'adiabatic'. Adiabatic surfaces do not transfer heat beyond their outer surface and are often used for modelling boundaries with other spaces that can be considered to be at roughly the same temperature as the zone. In the model below the Adiabatic block (shown in red) has been positioned in contact with half of the South facade of the building to model the effect of an adjacent building which does not form part of the DesignBuilder model. The touching adiabatic component block creates an adiabatic adjacency in the part of the Building block surface in contact with the Adiabatic block.

Standard component blocks are visible in Visualisations, using the texture associated with the Component block material as set on the Constructions tab under the Component Block header. They can be used to cast shadows and reflect solar radiation and light in simulations by checking the **Component block shades and reflects** model data under Component Blocks on the Constructions tab.



View from building level

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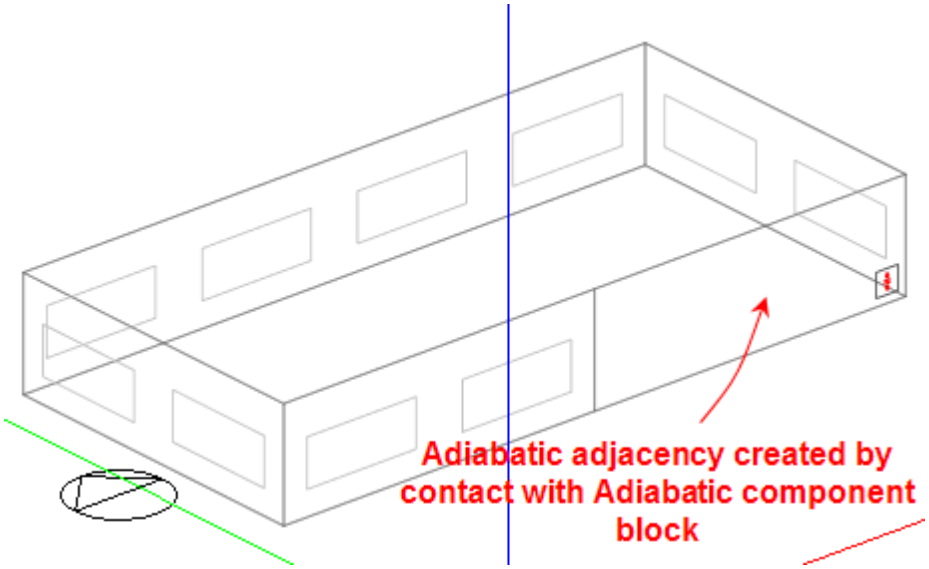

View from zone level

Some standard block forms are provided to facilitate the creation of blocks representing specific building geometries:

- General extrusion
- Sloped wall
- Pitched roof
- Dome

You can select the block form from the Drawing Options data panel in the bottom left of the screen when the Draw Block command is active.

Once a block has been created, it is possible in some cases to change to a new form by navigating to the block and opening the Model options dialog.

The general extrusion block form is probably the most useful form. You create a general extrusion block by drawing a perimeter using a number of pre-defined shapes and then extruding the perimeter by whatever distance is required. If you use the polygon perimeter shape you can create extrusions in both horizontal and vertical planes (or even in sloped planes).

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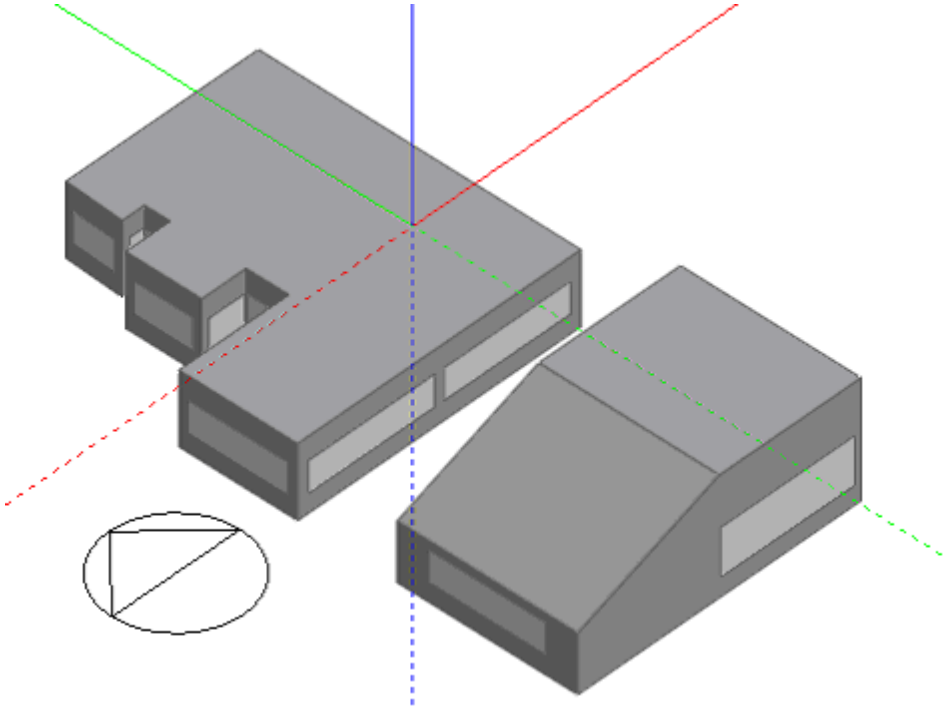
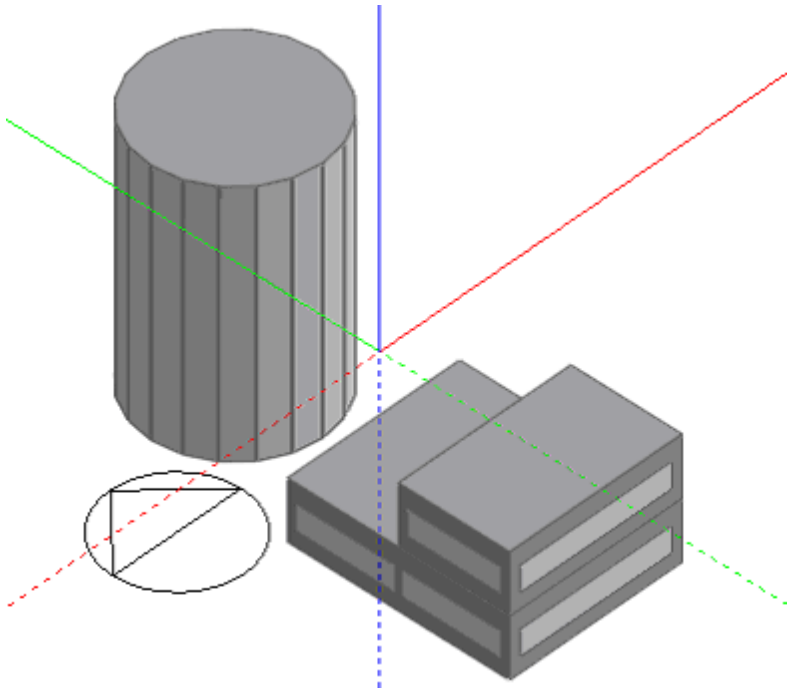


The various methods of drawing general extrusions are explained under Adding Blocks. Circular and rectangular perimeter shapes are used to create cylindrical and rectilinear prismatic extrusions from horizontal planes:



This block form is used to create blocks on horizontal planes with uniformly sloping walls. Sloping wall blocks can be created using any perimeter shape (polygon, rectangle or circle):

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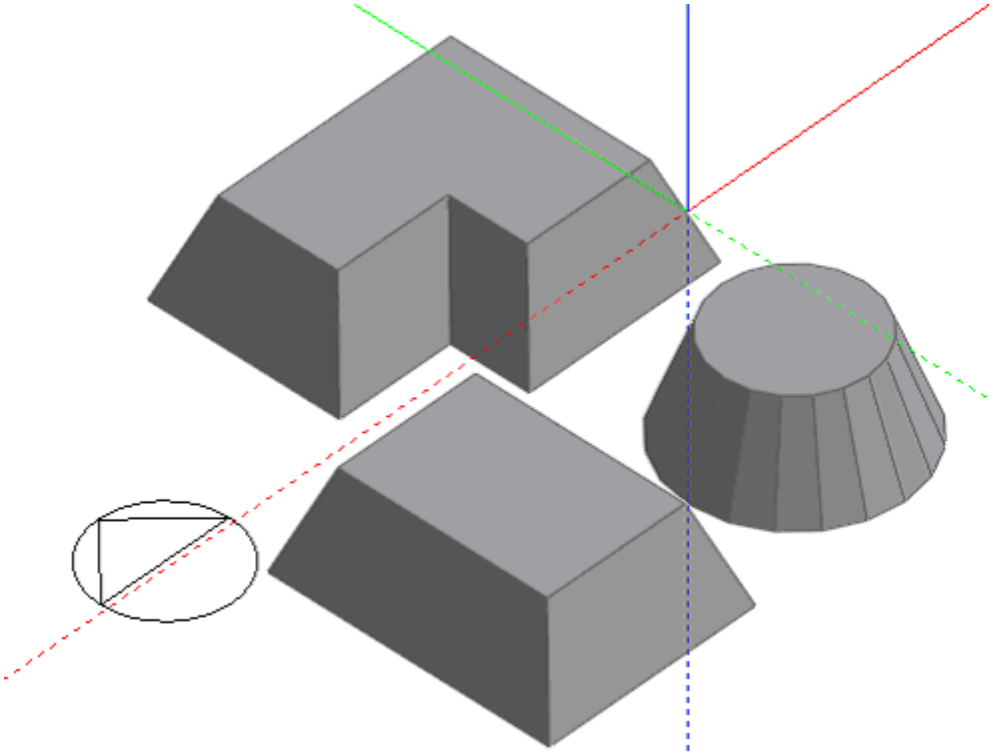
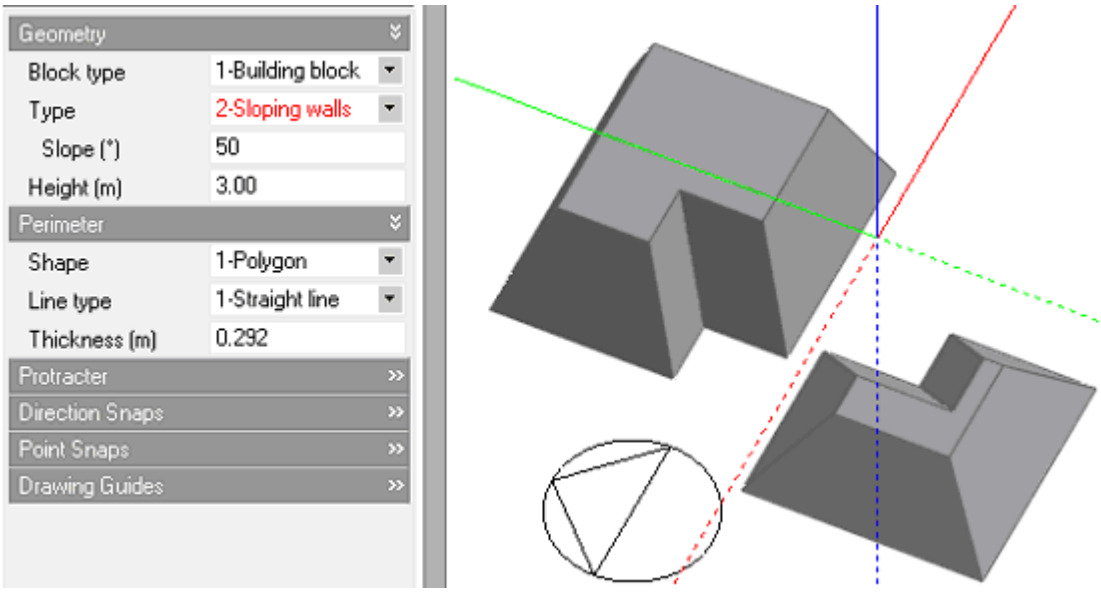


The wall angle is defined using the ‘Slope’ setting in the ‘Drawing options’ data panel and the blocks are automatically truncated by the ‘Height’ setting:



The pitched roof block form automatically generates a pitched roof from a perimeter drawn on a horizontal plane. Pitched roof blocks can be created using any perimeter shape (polygon, rectangle or circle):

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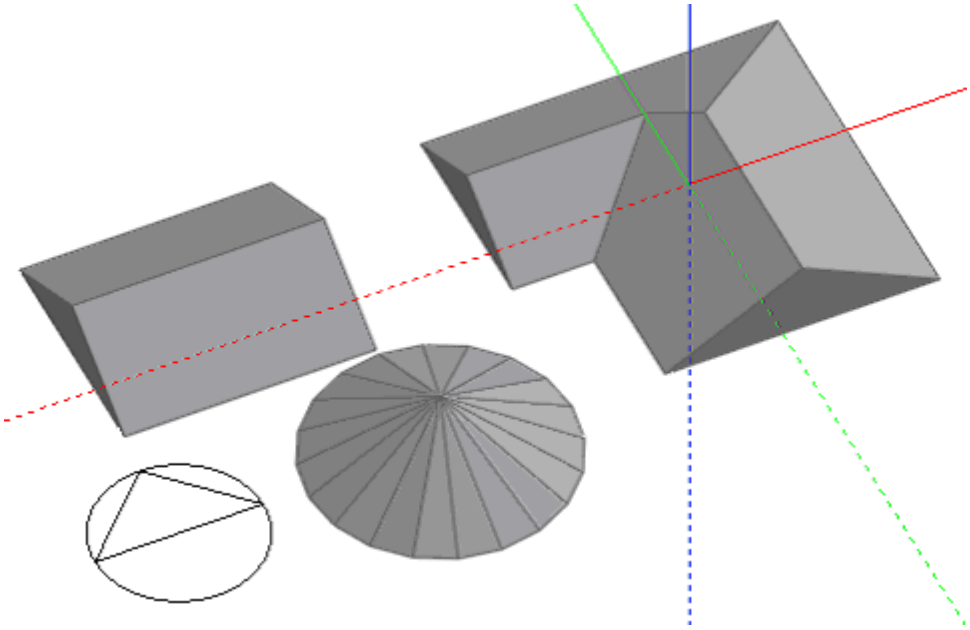
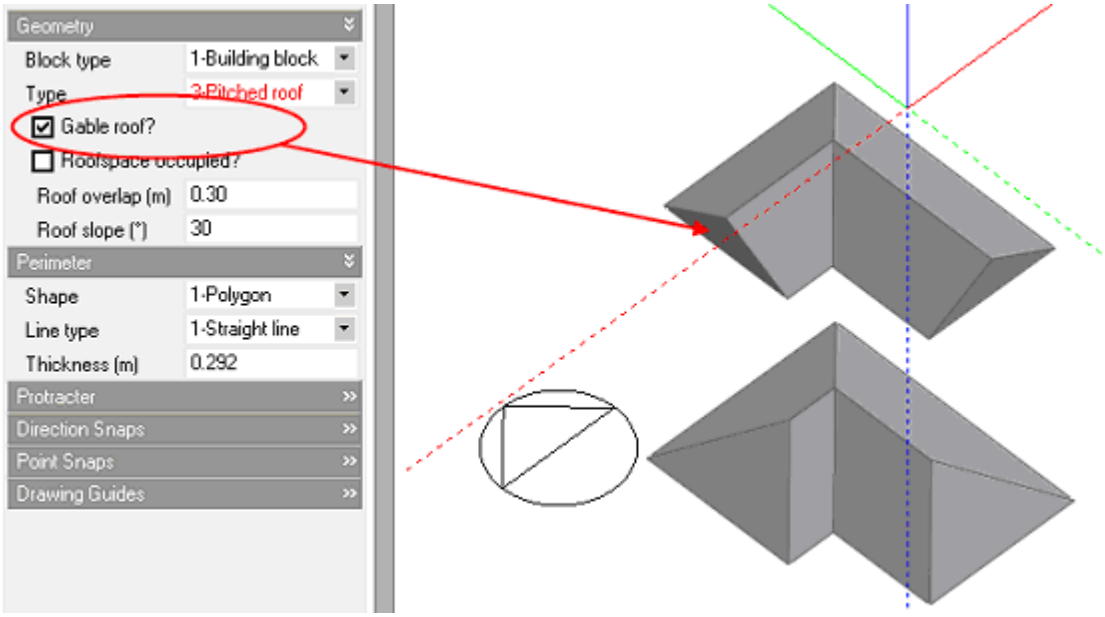


The slope of the roof is defined using the 'Roof slope' setting in the 'Drawing options' data panel. A pitched roof can be created with hips or gable ends using the 'Gable Roof' setting:



If you draw a pitched roof on top of an existing block, you can control the overhang or the depth of the roof eaves using the 'Roof overlap' setting:

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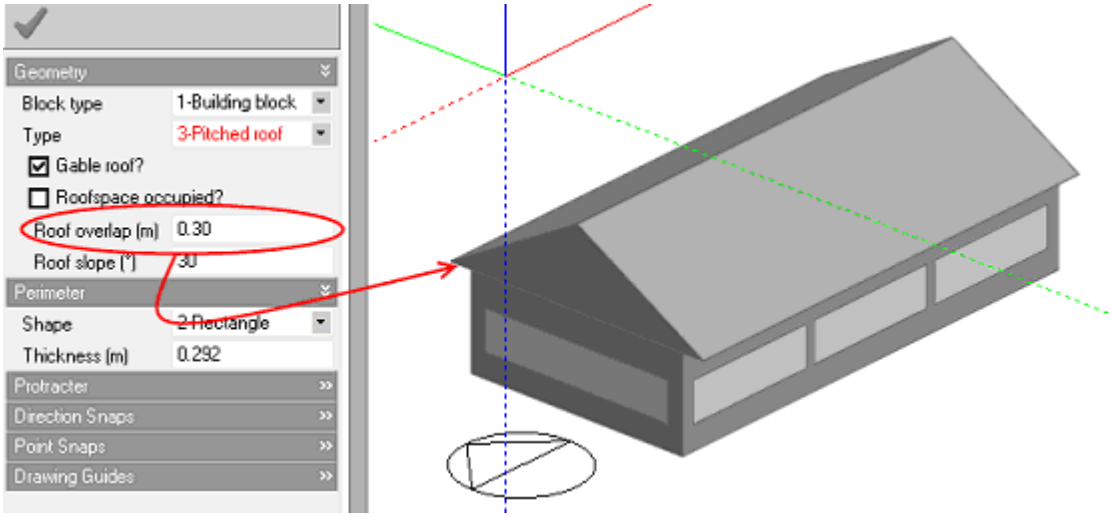
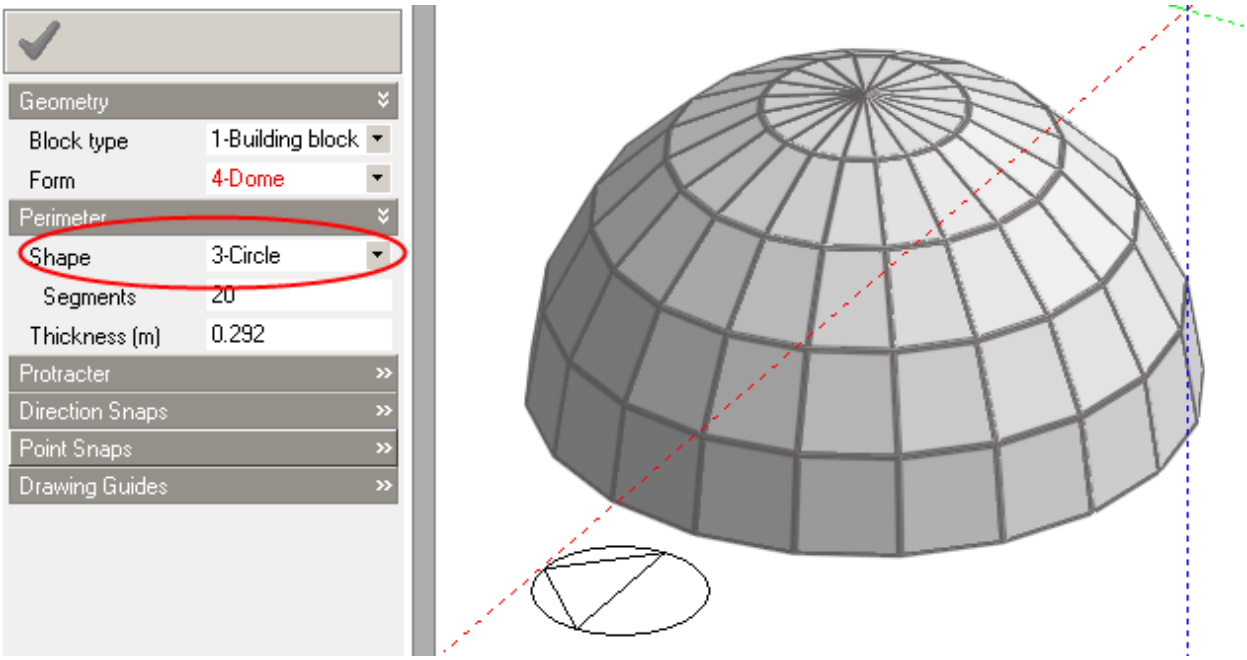


Voids

Where roofs are to be created on top of conventional blocks that contain voids and the voids are to be automatically incorporated within the pitched roof, the Automatically include voids from lower blocks Model options switch must be switched on before drawing the roof perimeter.

The dome block form is used to create hemispherical blocks and can only be created using the circular perimeter shape:



After drawing a vertically extruded block perimeter on a horizontal plane, the block will be automatically extruded using the Height setting, if the Auto-Complete Block option is switched on or the View Rotation has been set to 'Plan'.

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After drawing a vertically extruded block perimeter on a horizontal plane, the block will be automatically extruded by the Height setting if the Auto-Complete Block option is switched on or the View Rotation has been set to 'Plan'. With this option switched off (or in the case of a non-horizontal drawing plane), the perimeter can be dragged along an axis normal to the perimeter to obtain the required extrusion.

3.2.9.2 Editing blocks

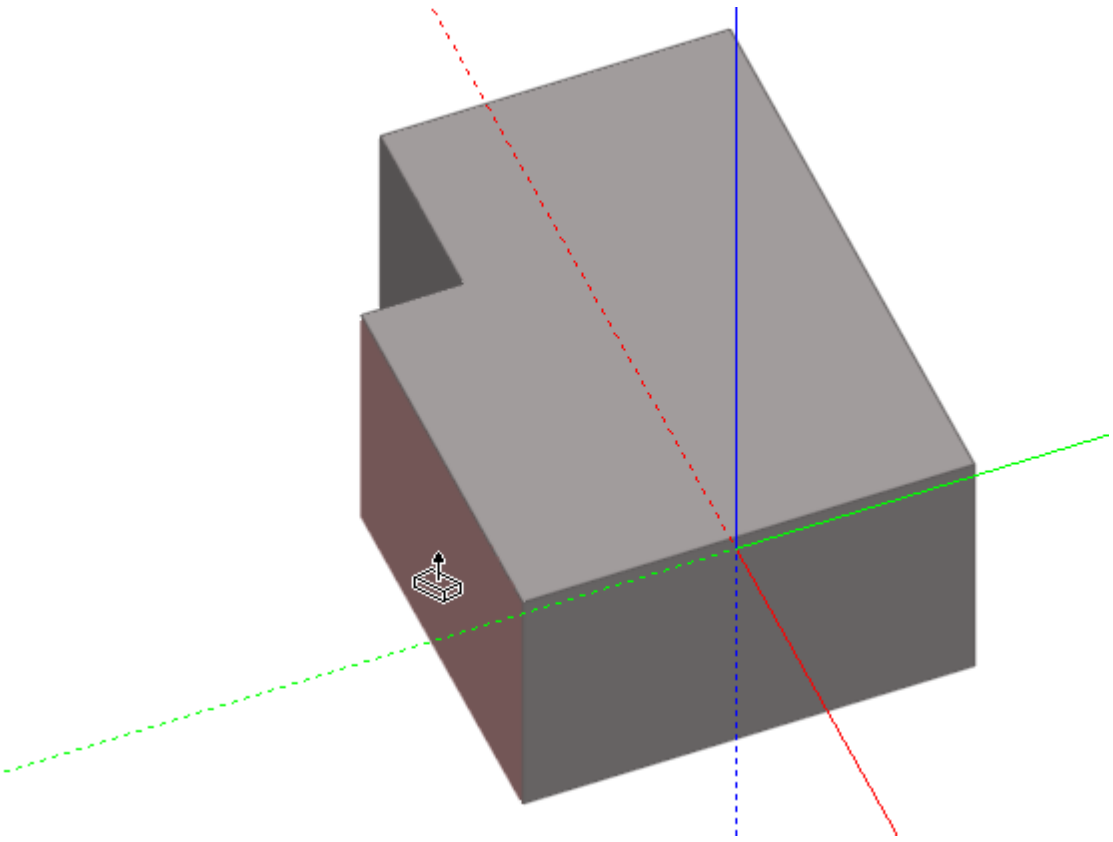
The geometry of blocks can be modified using the following tools:

- Drag block face
- Divide block

Outline blocks can be converted to building blocks using the Convert outline block tool.

3.2.9.2.1 Drag Block Face

The topology of a block can be edited using the 'Drag face' tool which allows you to select a block surface and drag it along an axis, normal to the surface. To edit a block topology first go to the building level, select the block that you want to modify and click on the 'Drag face' tool. Then move the mouse cursor to the surface that you want to move. As you move the cursor across the block surfaces, each surface will highlight to help in selecting the required surface. When the mouse cursor is over the required surface, click to start dragging it:



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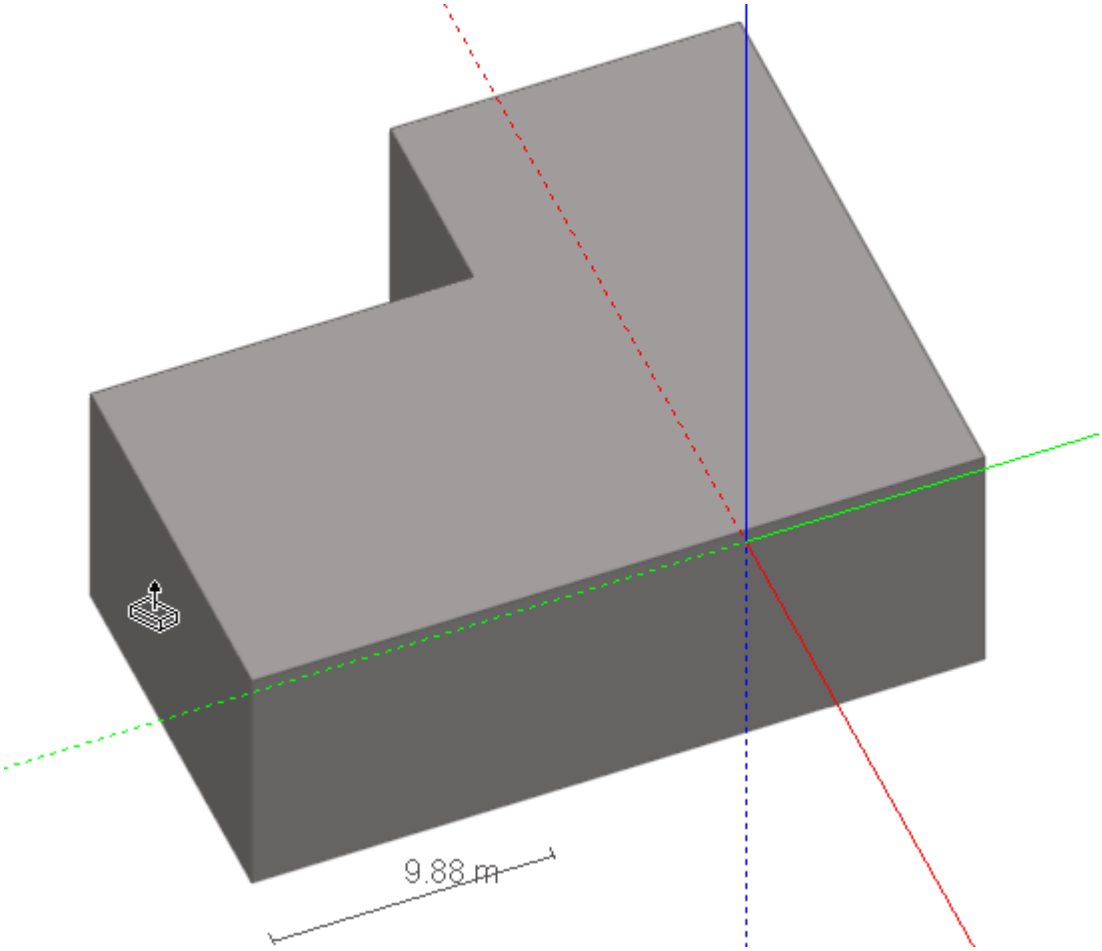
Drag the surface using the mouse or key-in the distance to shift the surface by the required amount:



3.2.9.2.2 Divide Block using Cutting Tool

Blocks can be cut (i.e. divided into 2) using the **Divide Block** Tool. To cut or divide a block first go to the building level, select the block that you want to modify and click on the Divide block toolbar icon. Blocks are divided using a plane which can be defined using one of 2 methods:

- **1-Draw plane** - you define the plane by clicking on 3 points.
- **2-Select plane** - you define the plane by selecting an existing plane in the model.

DRAW PLANE METHOD

The **Draw plane** cutting method involves drawing two lines which define the plane. For example to cut a pitched roof to fit flush with a rotunda:

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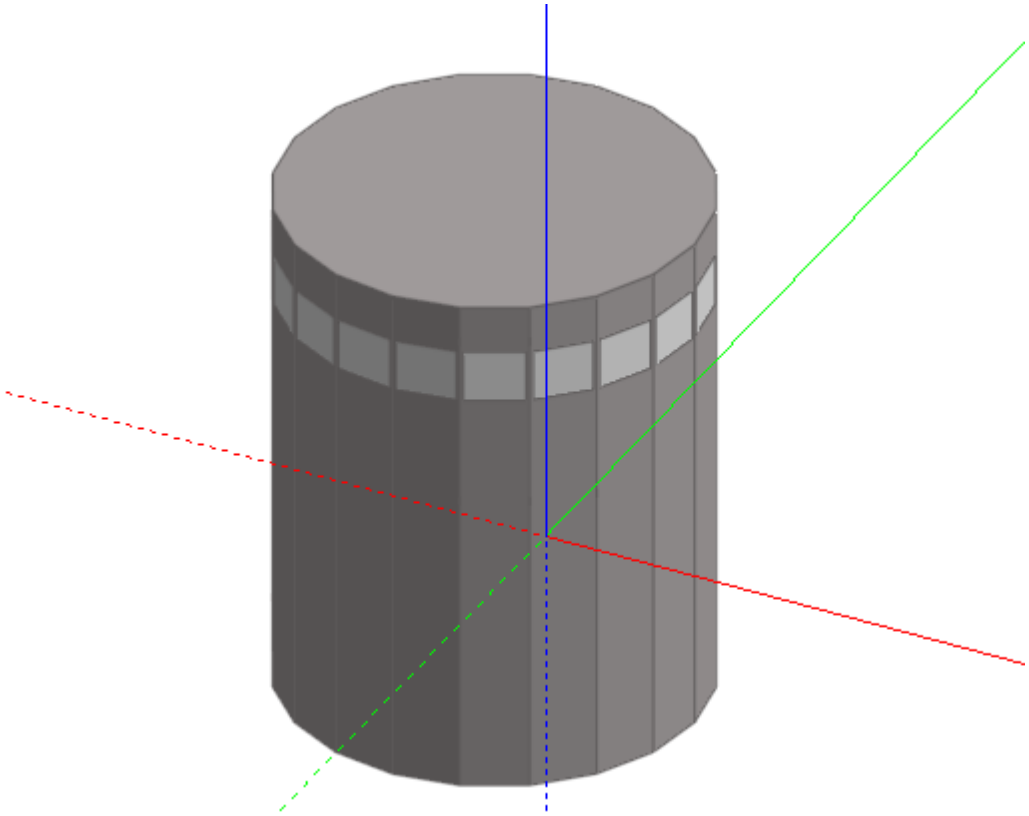

Because the geometry is fairly complicated, it's advisable to use an outline block to generate the intermediate geometry and then convert the block to a building block after the editing process is complete. So, from the building level, click on the Add new block tool, select **2-Outline block** as the block type, set the perimeter shape to **1-Polygon** and the Height to the same height as the rotunda, then draw a conventional vertical extrusion to fit flush to the rotunda. In order to trace round the base of the rotunda, it's probably easier to set the view rotation to 'Plan', click on to the ground plane and press SHIFT to lock the plane before placing the first perimeter point:

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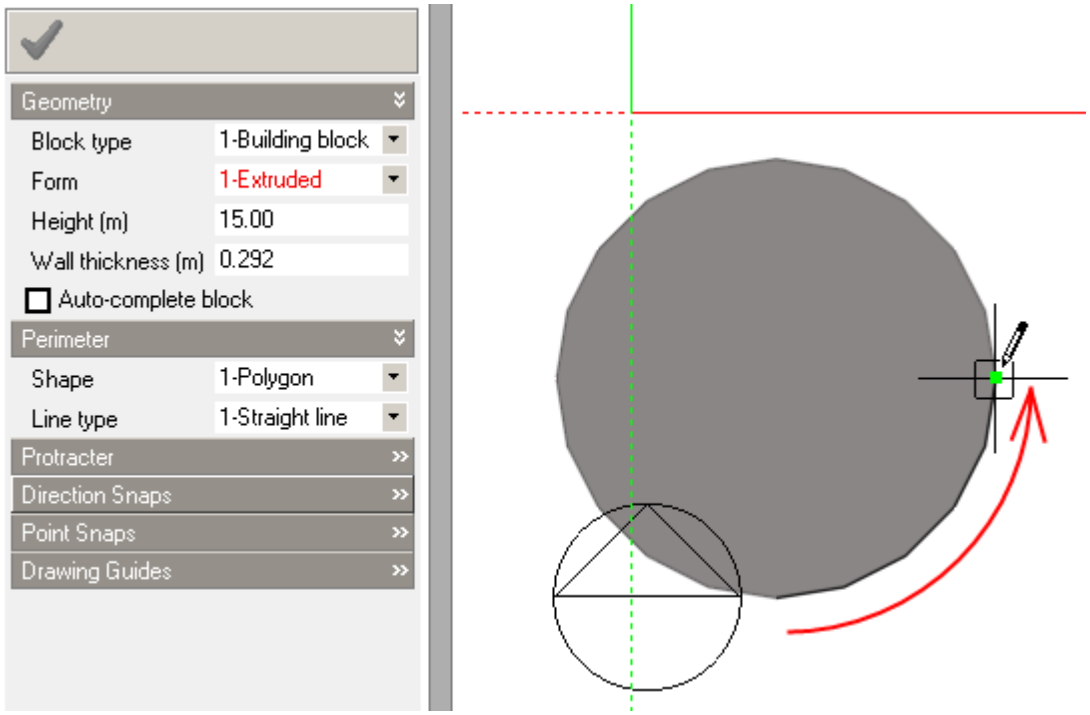
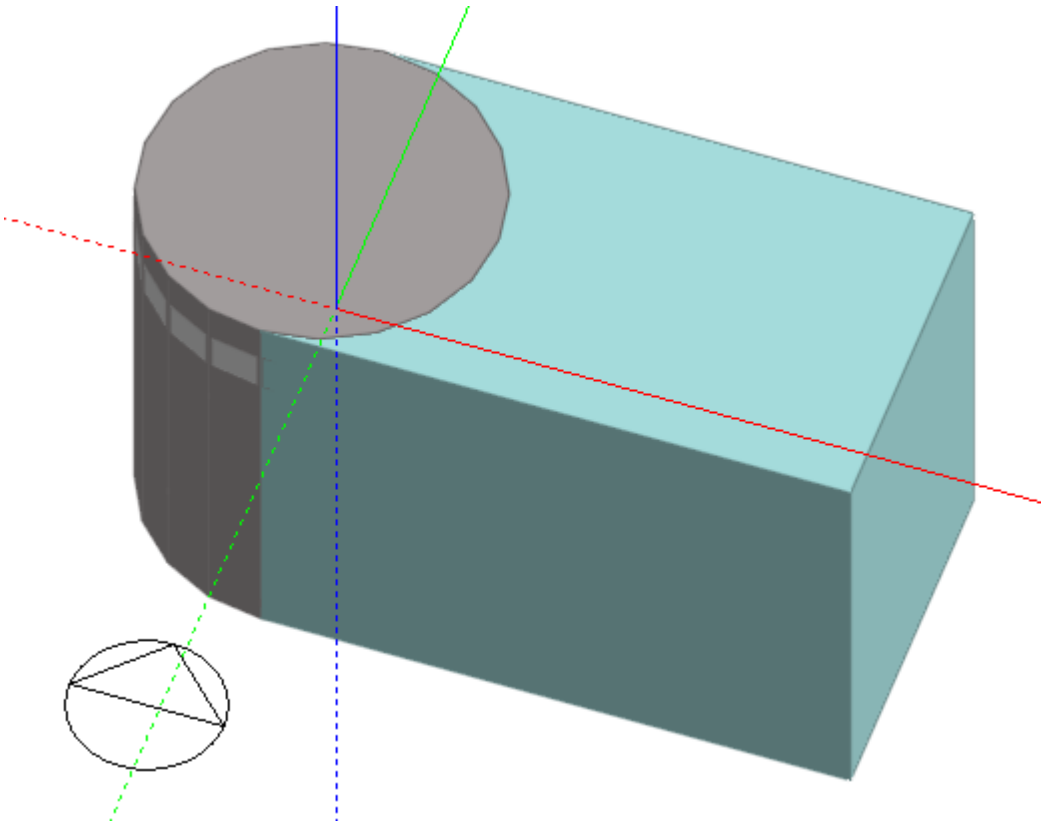


When tracing around a perimeter by snapping from end-point to end-point, it can be helpful to switch off the direction snaps and the drawing guides to prevent them from interfering with the point snaps. Completing the perimeter:



Click on the outline block to select it and then click on the 'Divide block' tool and make sure that the 'Cutting method' is set to **1-Draw plane** in the Drawing Options data panel. Switch the protractor on and move the cursor over the end face of the selected block, the surface will highlight to indicate that it's

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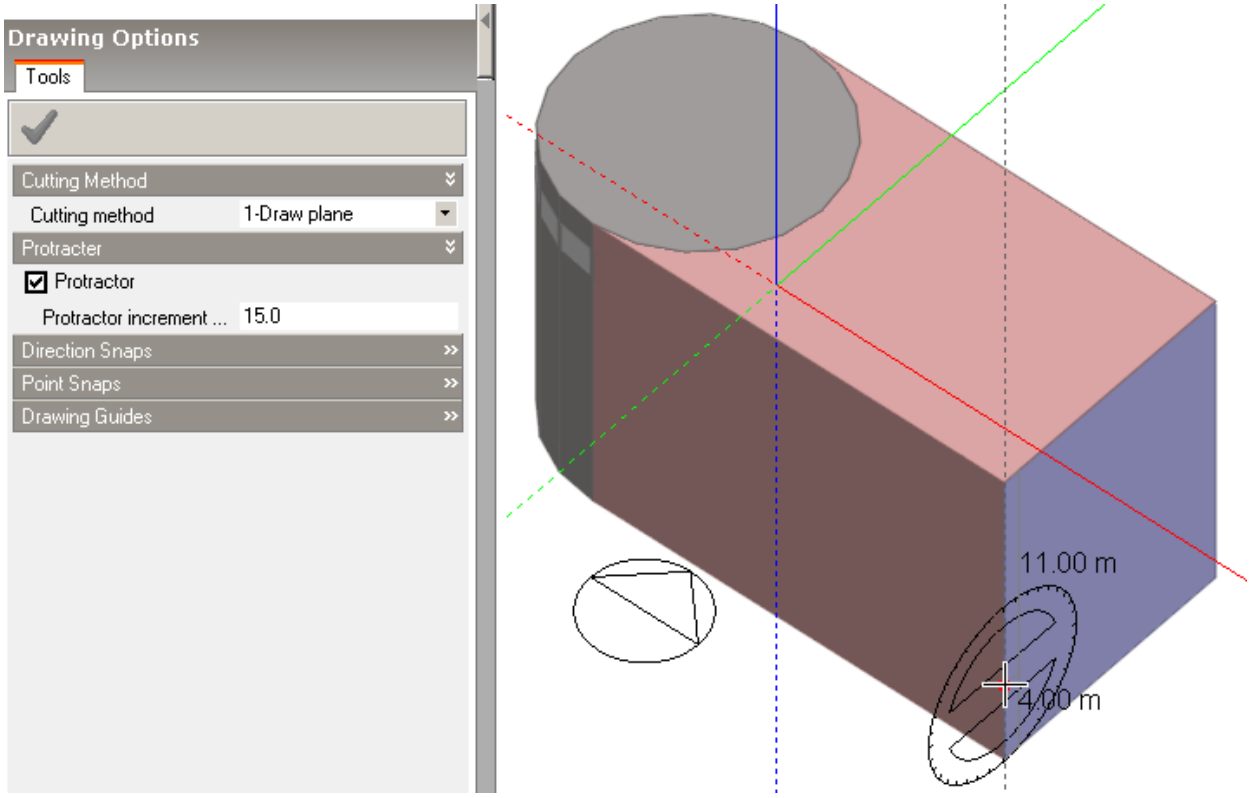
become the active drawing plane. Press the SHIFT key to lock the drawing plane and then locate the cursor 4m from the base of the block using edge snap:



Click to place the beginning of the first cutting plane line, then place the end of the line to intersect the face edge with a pitch angle of 30°:

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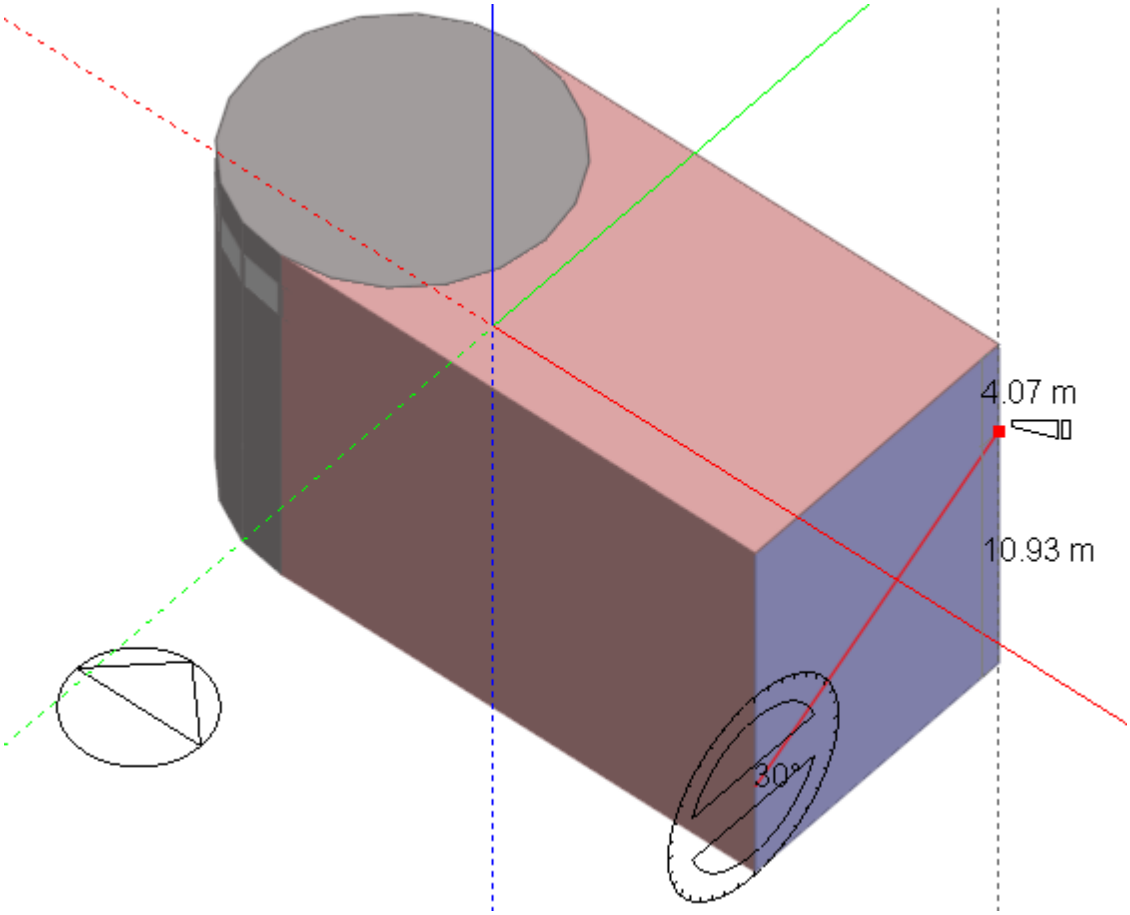
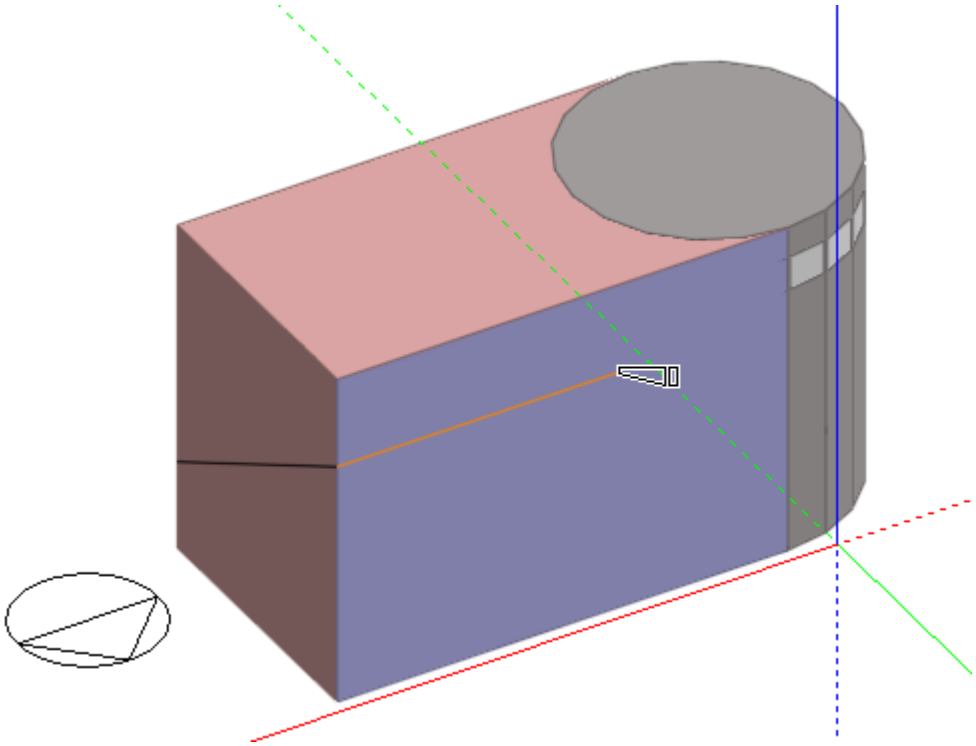


Orbit to make the back face of the block visible. Move the mouse cursor over the back face and when it highlights, press the SHIFT key to lock the plane. Place the second cutting plane line to snap to the local X-axis of the back face:



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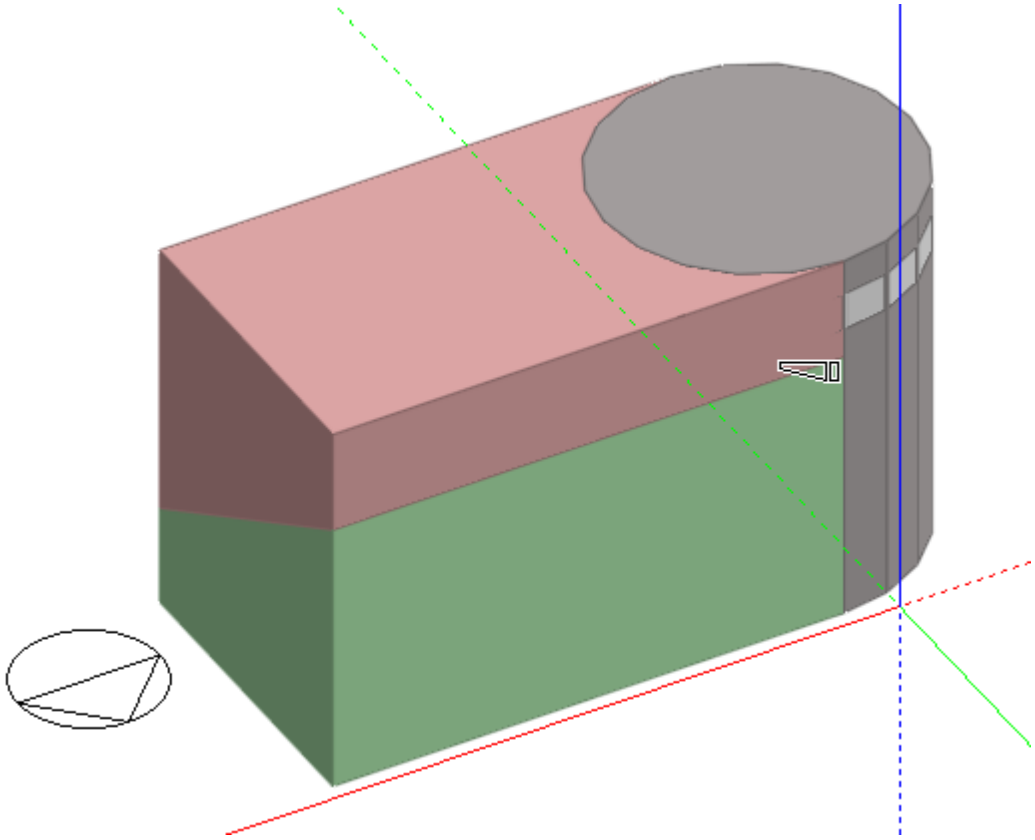
Click to complete the cutting plane. The blocks that will be produced by the cut are displayed in red and green, depending on which side of the cutting plane they lie. At this point, you can choose to cancel the cut by pressing the ESC key or selecting 'Cancel Cut' from the right-click menu.



Click again to complete the cut and then select and delete the block that isn't needed:

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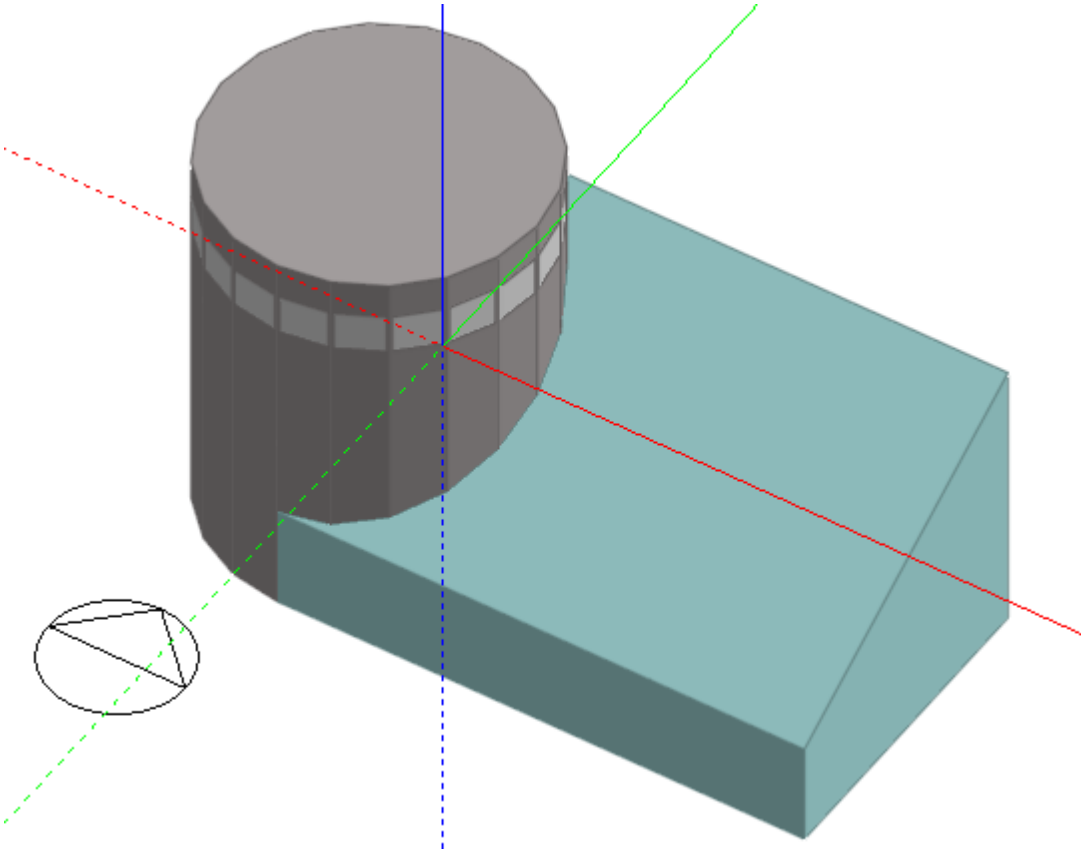

Go through a similar process to create the other pitch. You may need to switch off the drawing guides and mid-point snap to prevent them from interfering with the protractor and edge snap:

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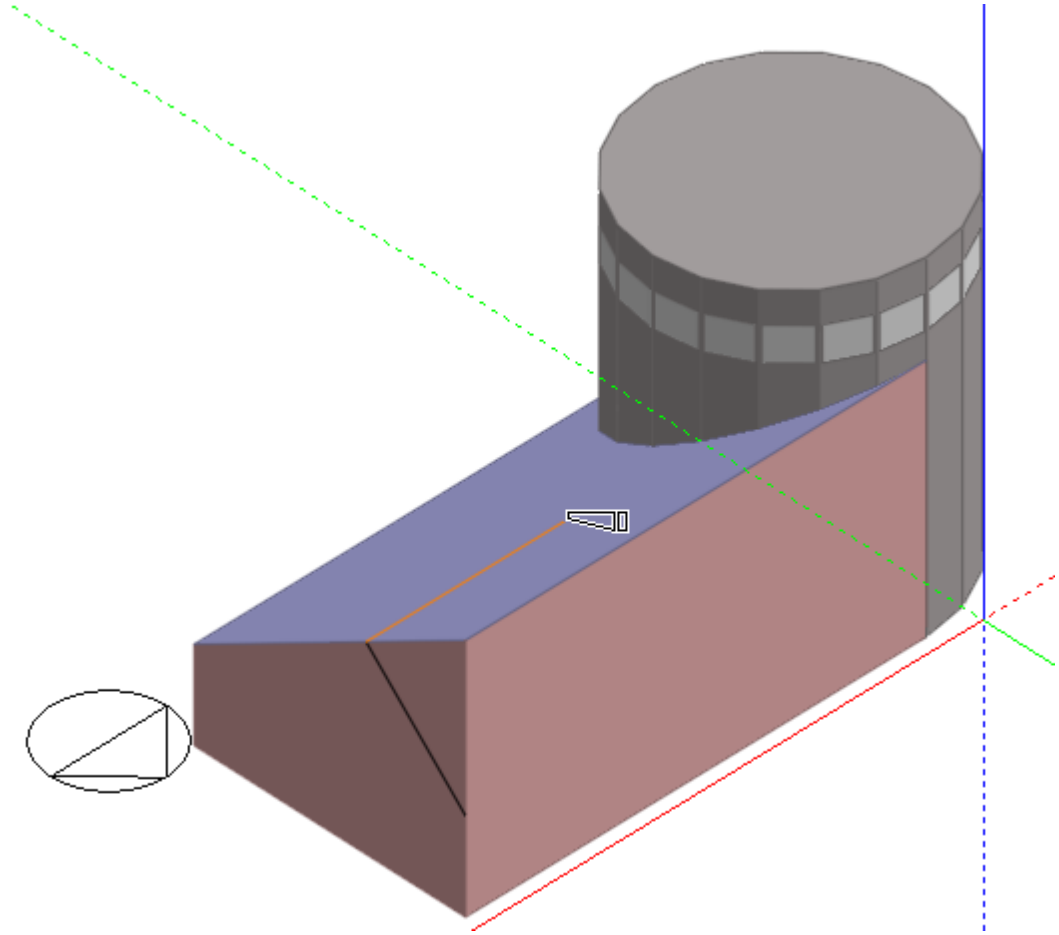

Click to create the cutting plane:

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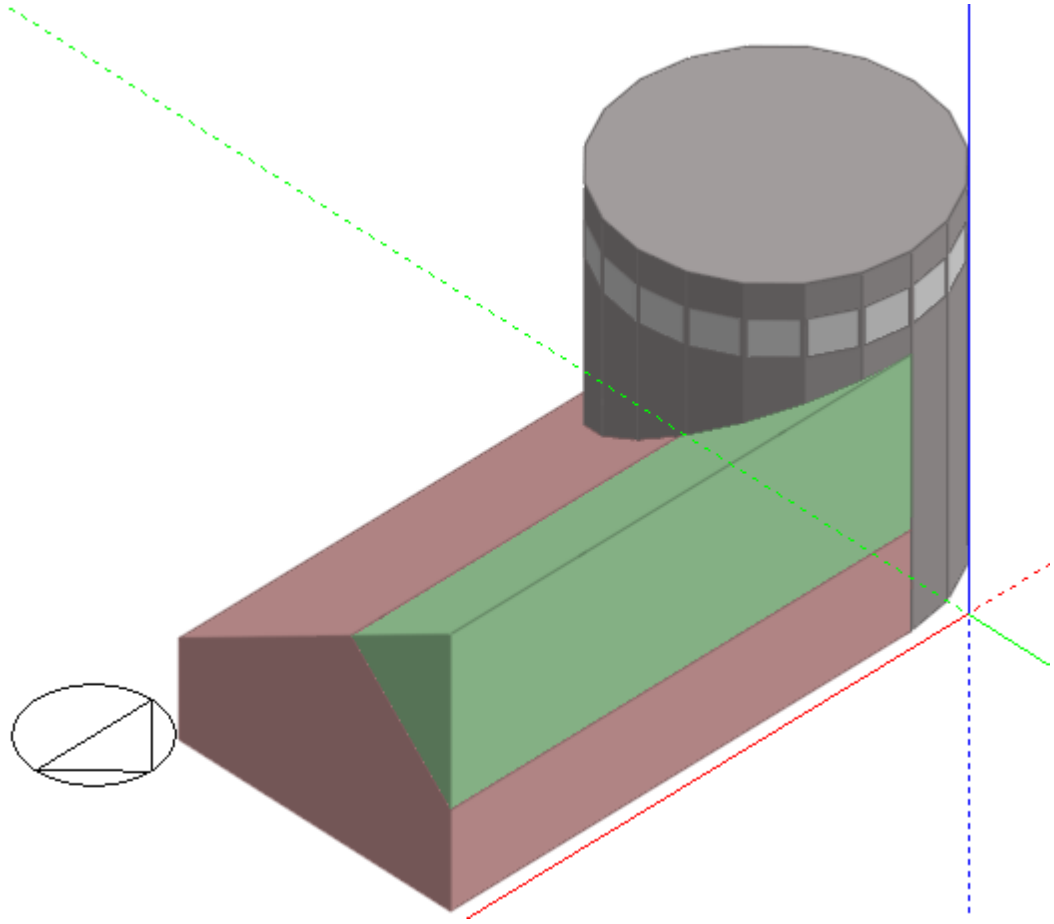

Click again to make the final cut and then select and delete the block that isn't part of the finished structure:

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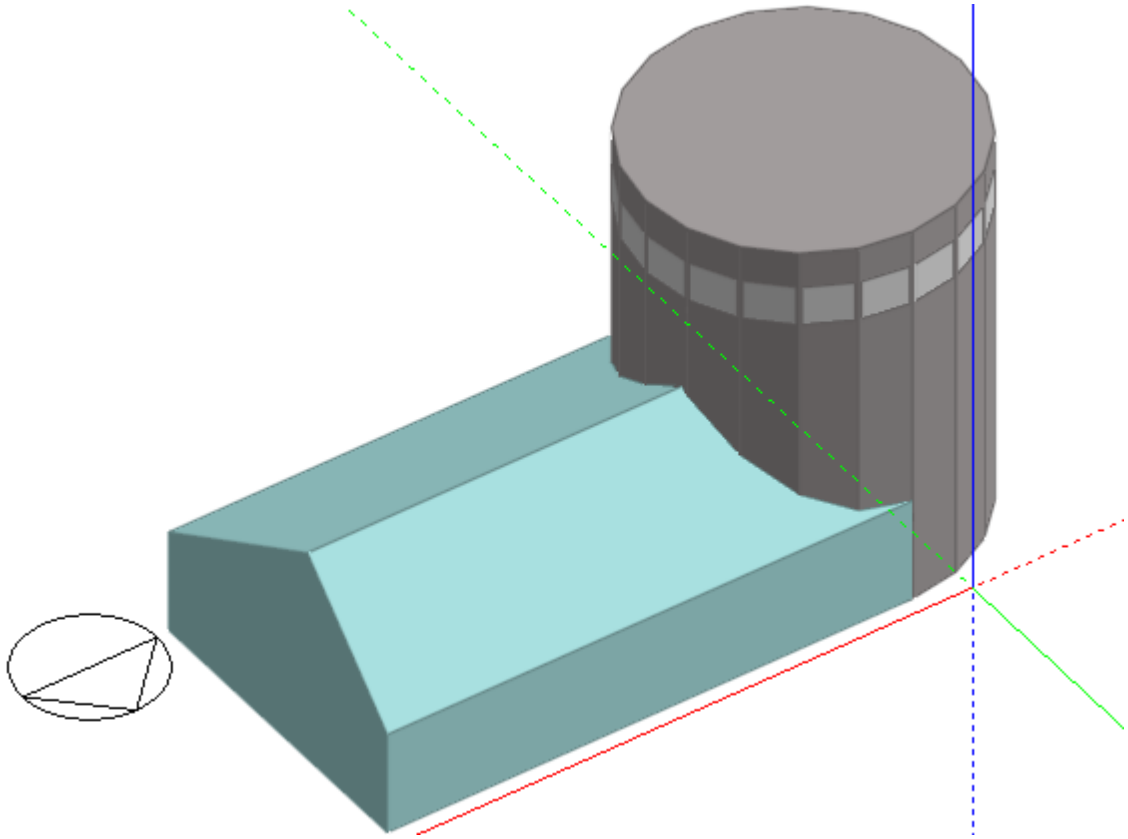

The outline block can then be selected and converted to a building block:

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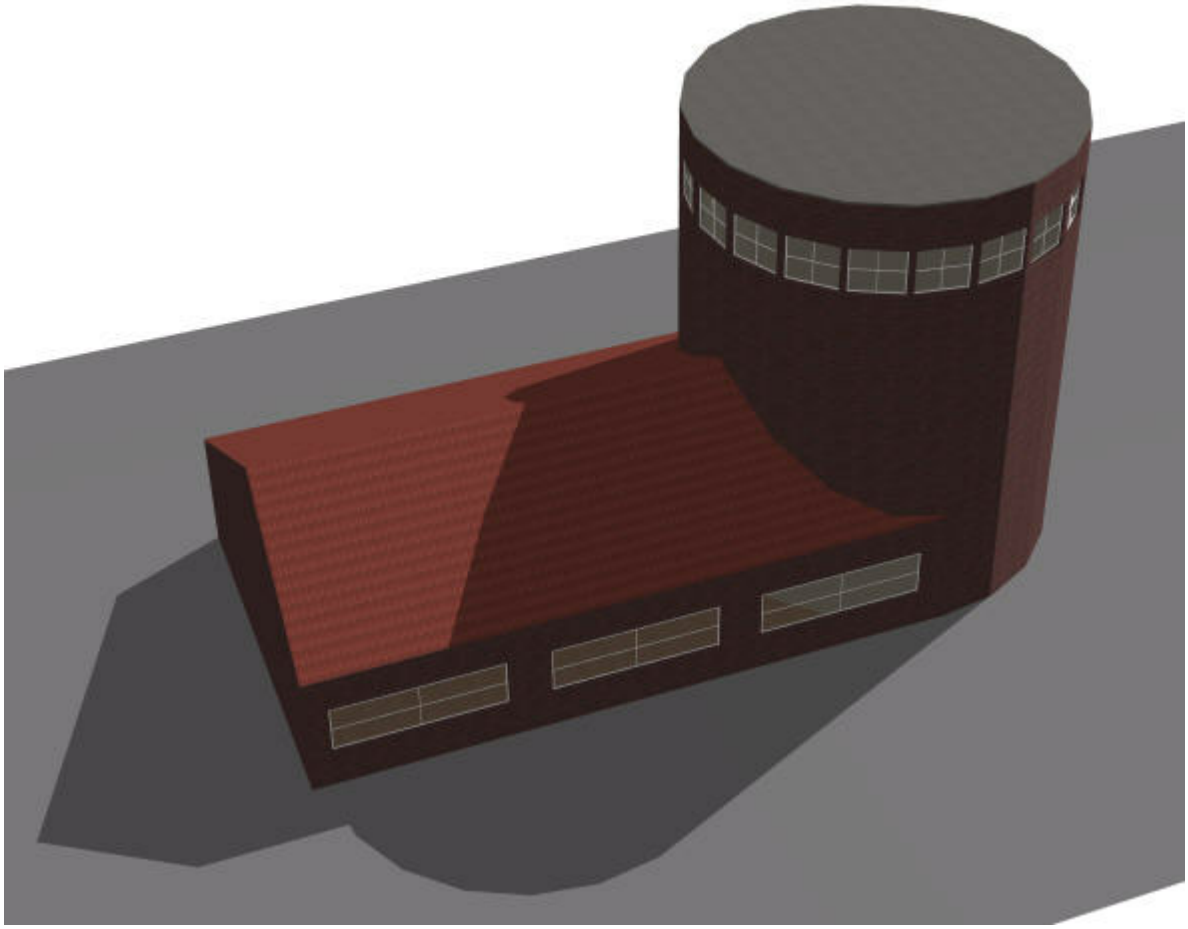

SELECT PLANE METHOD

The Select plane method of cutting a block uses an existing plane to define the cutting plane. It can be demonstrated by modelling a roof offshoot:

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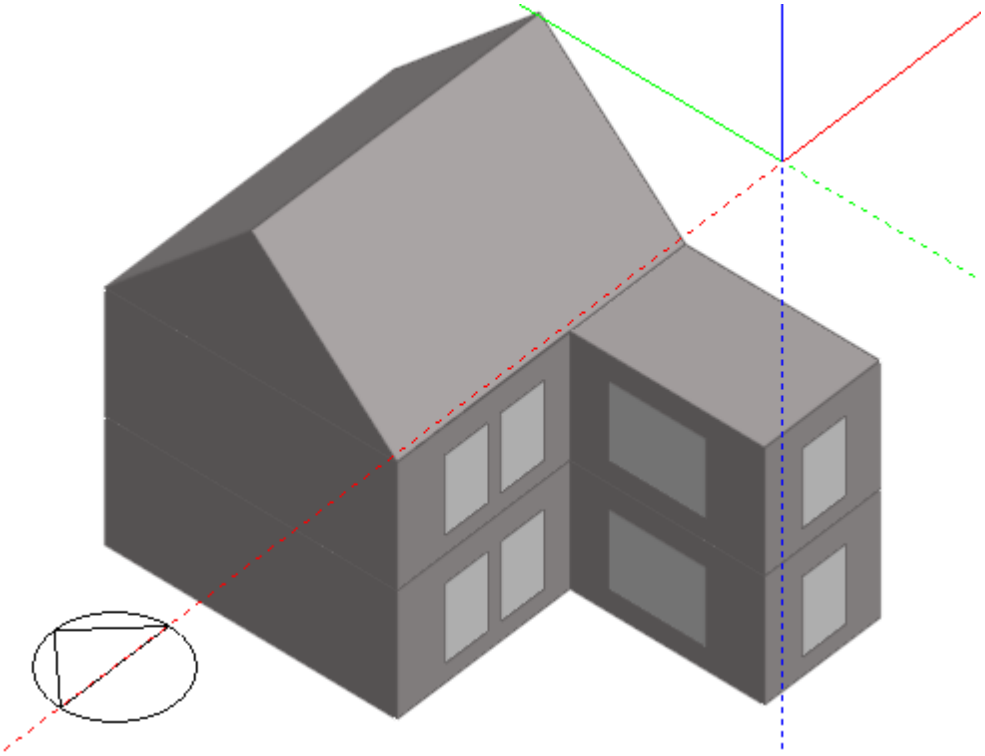
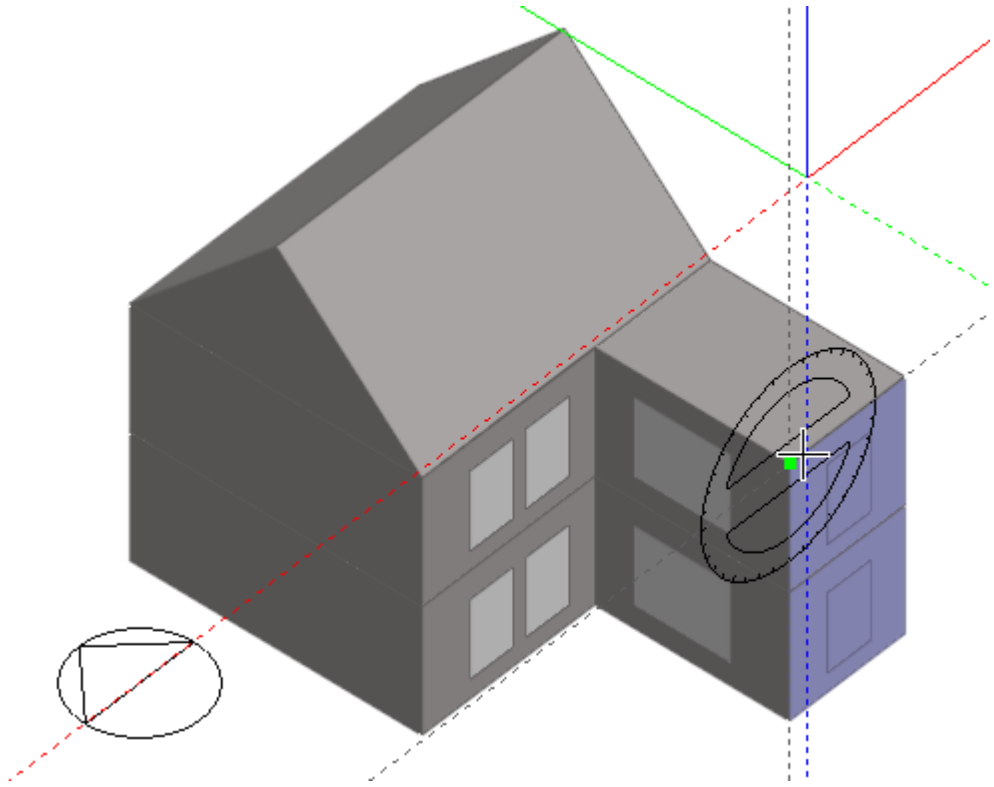


Click on the 'Add new block' tool, select **2-Outline block** as the block type and set the perimeter shape to **1-Polygon**. Switch the protractor on and move the mouse cursor to the back face of the offshoot. When the cursor is over the back face, press the SHIFT key to lock the drawing plane and snap the protractor to the upper edge end-point:



Draw the first perimeter line at a 45° pitch and move the cursor to intersect with the back face upper edge

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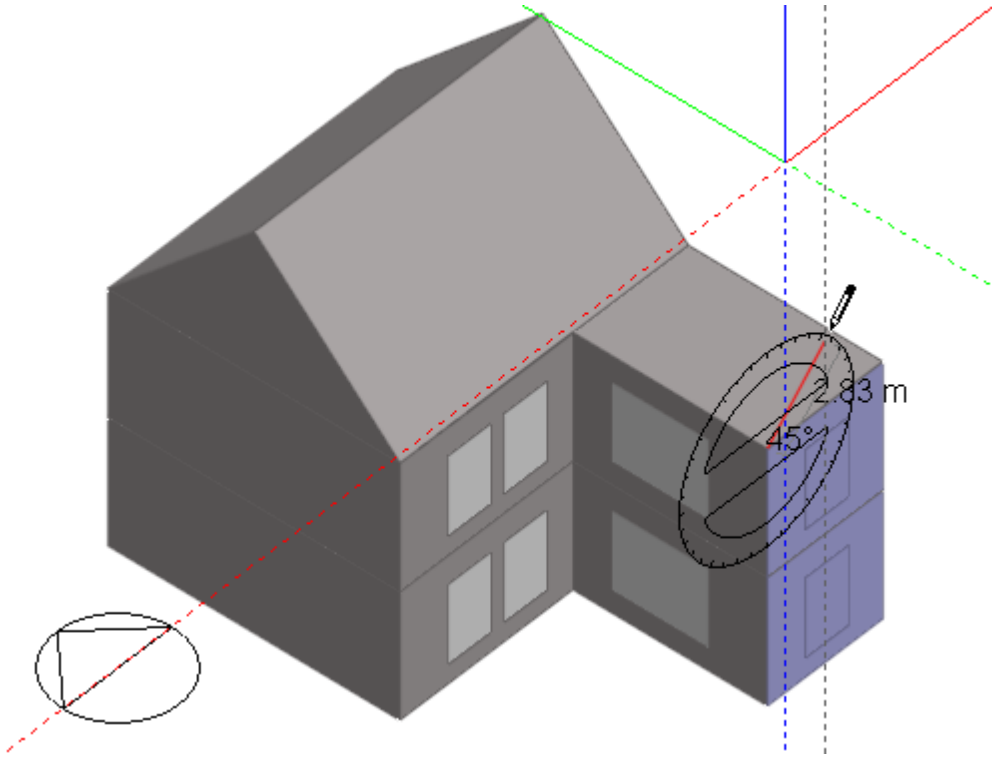
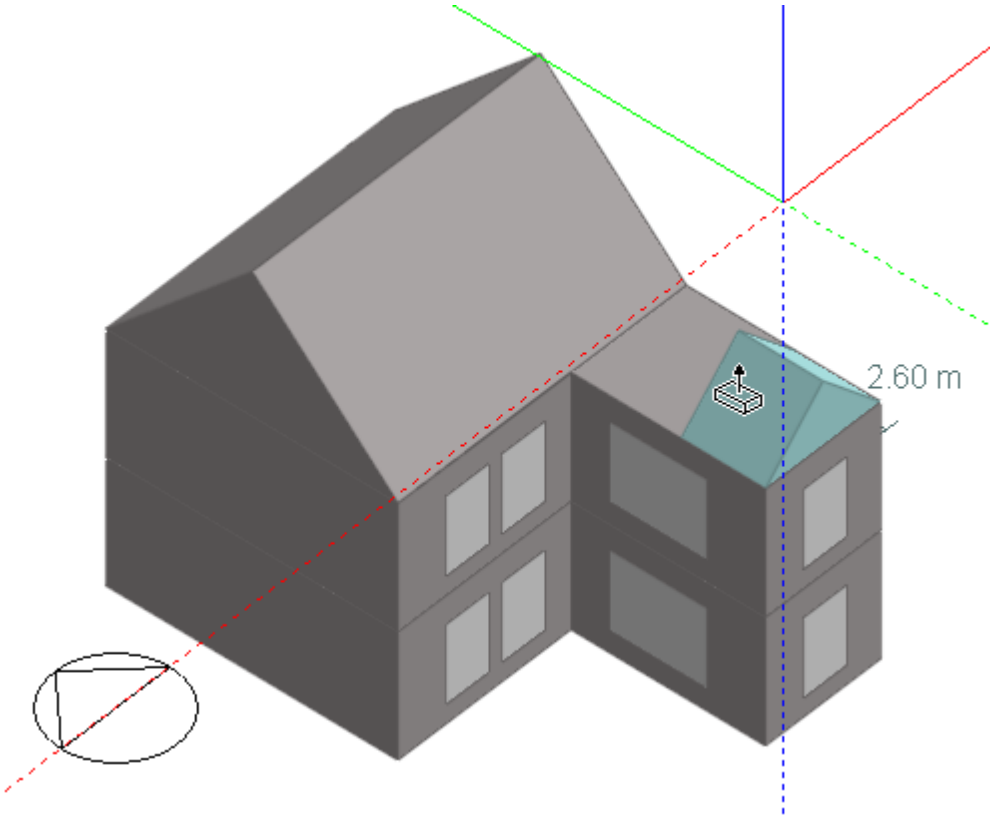
mid-point drawing guide and click to set the end-point:



Move the cursor to snap to the other end-point of the back face upper edge and then complete the perimeter:



Now drag the outline block face through the main roof block:

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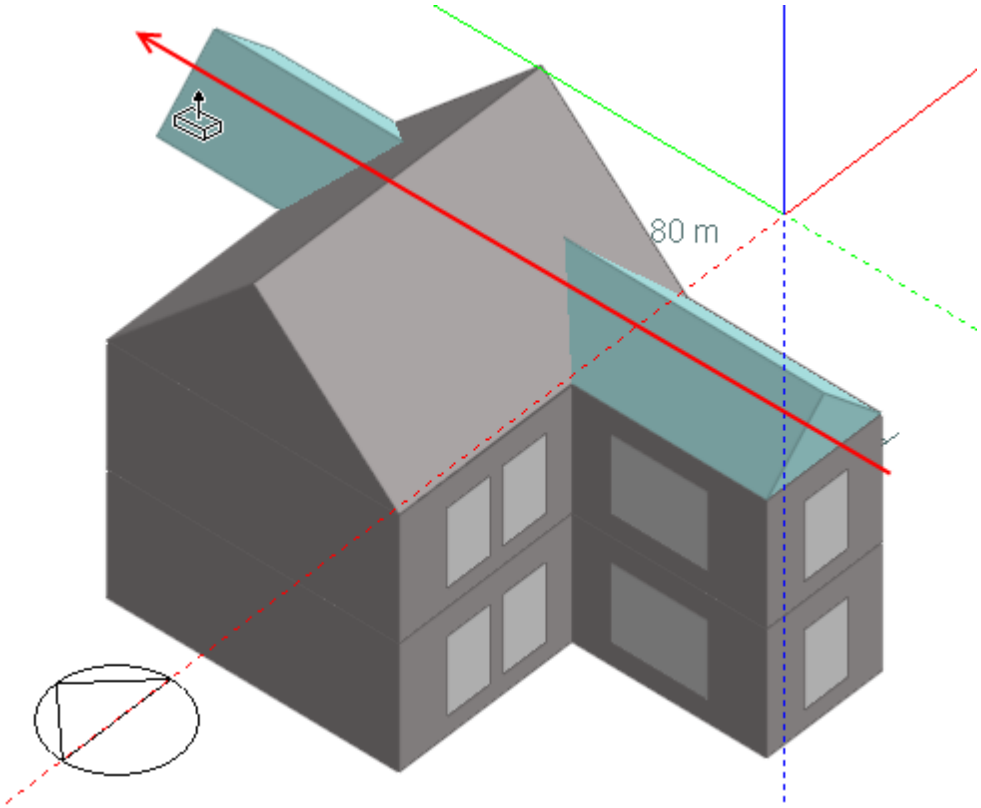
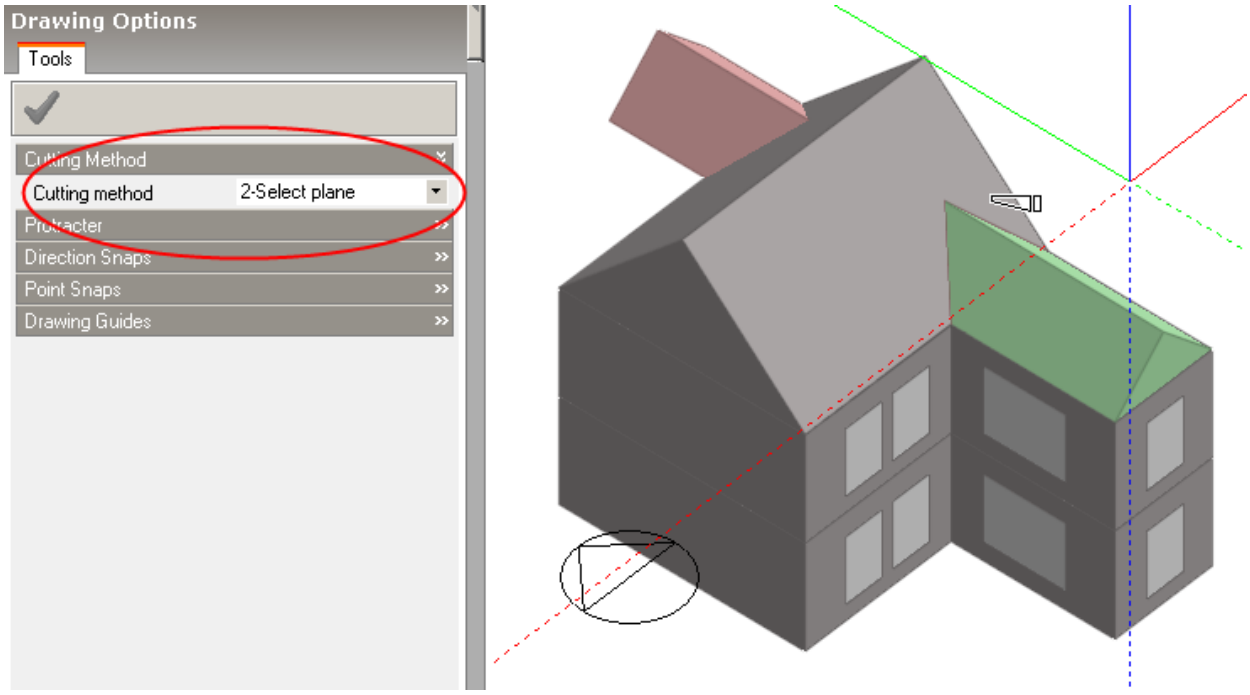


Select the offshoot outline block and click on the ‘Cut block along plane’ tool, making sure that the ‘Cutting method’ on the ‘Drawing options’ data panel is set to 'Select plane’ and click on the forward facing plane of the main roof block to create a cut in the offshoot block in the plane of the roof:



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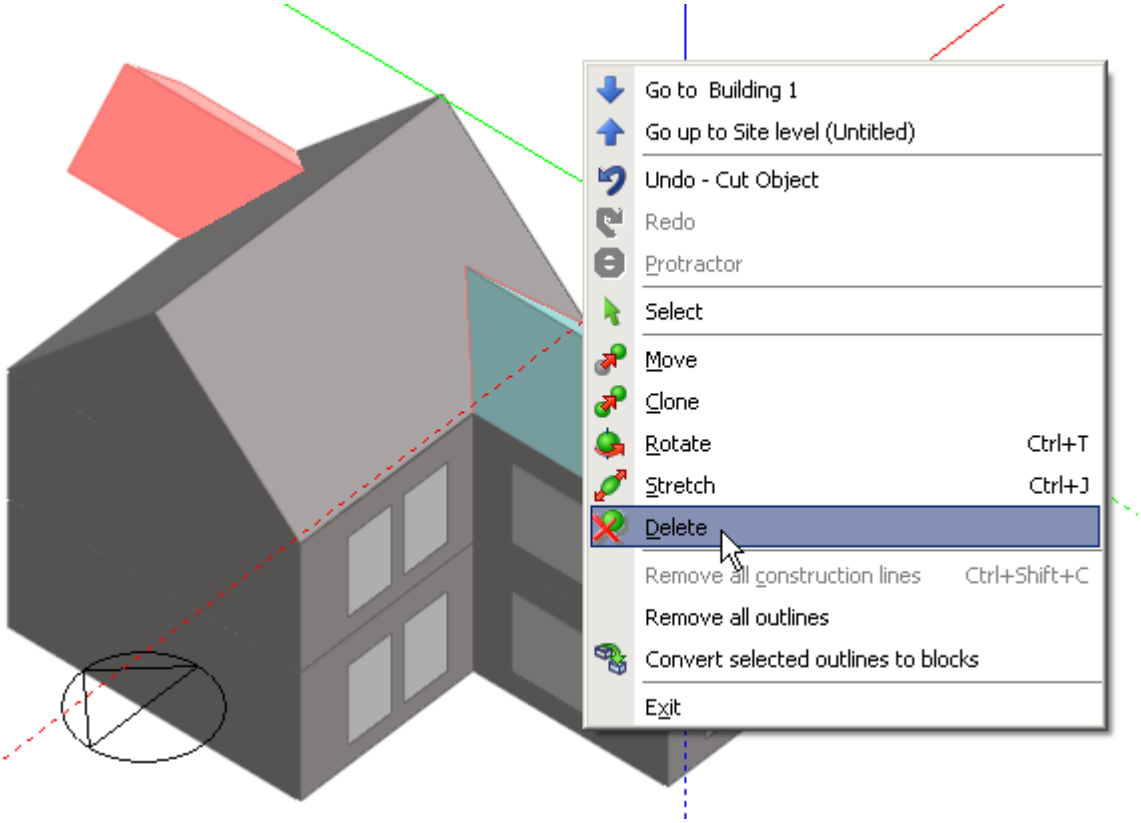
Click again to finish the cut and then select the section of the offshoot roof block that is not required and delete it:



Select the roof offshoot block and click on the 'Convert selected outline blocks to building blocks' tool to complete the process:

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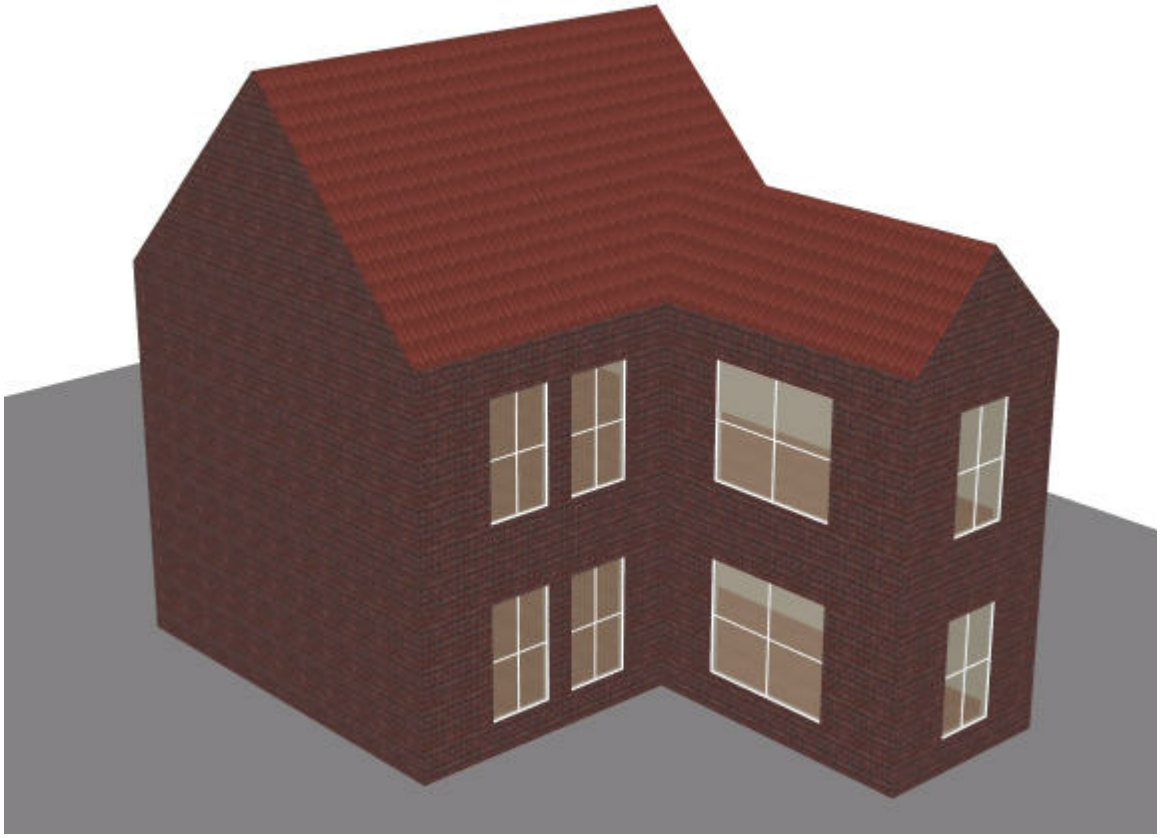

In some circumstances, resulting blocks may not be able to be converted to building blocks due to geometrical limitations. In this case, the block will be displayed in a sepia colour to indicate that it cannot be converted.

3.2.9.2.3 Edit Block Geometry Dialog

You can edit certain aspects of a building block geometry by clicking on the 'Building model options' icon while at the block level. This opens the Model Options dialog box:

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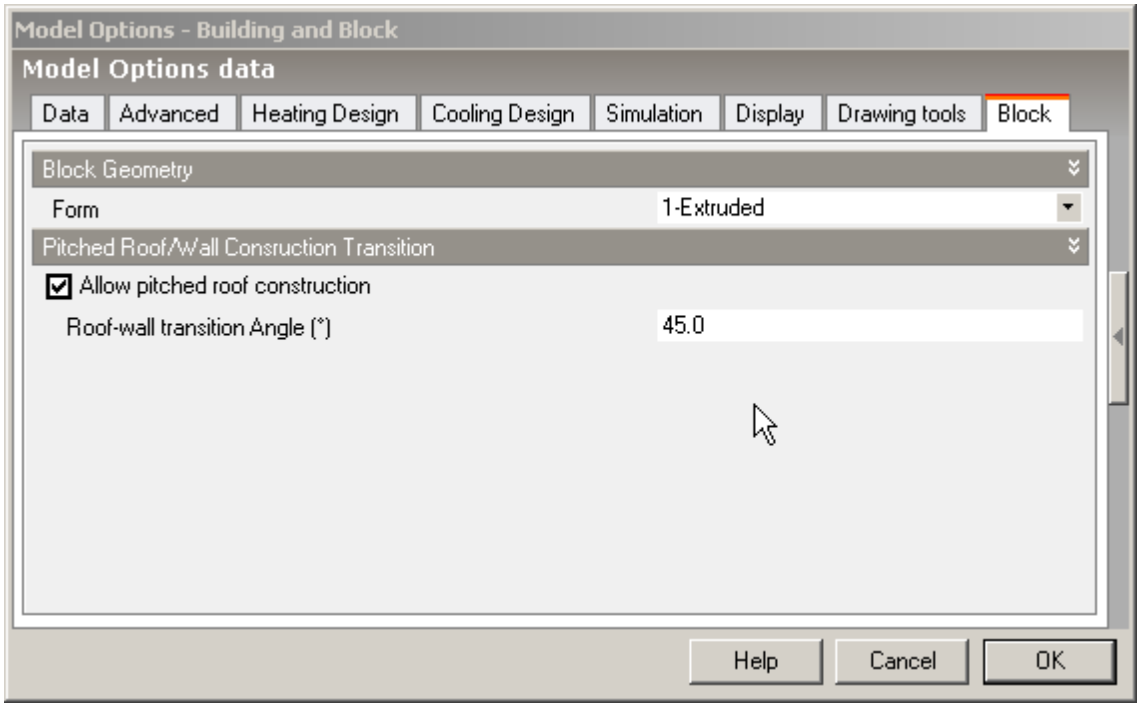

At the block level, the Block tab on the Model Options data dialogue box is enabled and allows you to change the Form of the block and to modify pitched roof assignment.

To change the form of the current block, make a selection from the 'Form' drop list. When you change the form of a block from an 'Extruded' form to 'Pitched Roof' or 'Sloping Walls' the original form will be remembered so that even if you have edited the block by cutting it or dragging a face, when you convert the form back to 'Extruded', the original form will be restored.

The **Pitched Roof/Wall Construction Transition** settings allow you to control which elements within a block will be assigned pitched roof construction, either by disallowing pitched roof construction altogether or by adjusting the element slope to determine which elements should be identified as pitched roofs. The 'Roof-wall transition angle' is the angle from the horizontal below which the element will be considered a roof.

3.2.9.2.4 Wall Thickness

The **Wall thickness** is used to generate the geometric thickness of the external wall elements of a building block. It is a significant parameter because zones are generated from the internal dimensions of the block which are derived from the external block geometry and the block wall thickness. So the Wall thickness influences:

1. Calculation of room air volume (thicker block walls mean less zone air volume).
2. Size and shape of zones, especially roof zones (below).
3. Visual representation of external walls in rendered view (below).

The default setting is automatically generated from the overall thickness of the external wall construction set in Construction Model data panel but can be overridden by typing in the required value.

The block Wall thickness can also be changed once the block has been drawn from the Block tab of Model options dialog when at block level.

The Construction that determines the *thermal* characteristics of the external walls, roofs, floors etc can be edited in Constructions Model data.

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Important Notes on Wall thickness

- The wall thickness does not affect the thermal properties of the wall. Wall thermal properties are based purely on the construction data specified for the walls, floor, roof etc.
- The external wall thickness is *uniform* for all block surfaces.
- A small value of Wall thickness will mean that the zones dimensions will be very similar to the block external dimensions.

The Wall thickness is also entered when Converting an Outline block to a Building block.

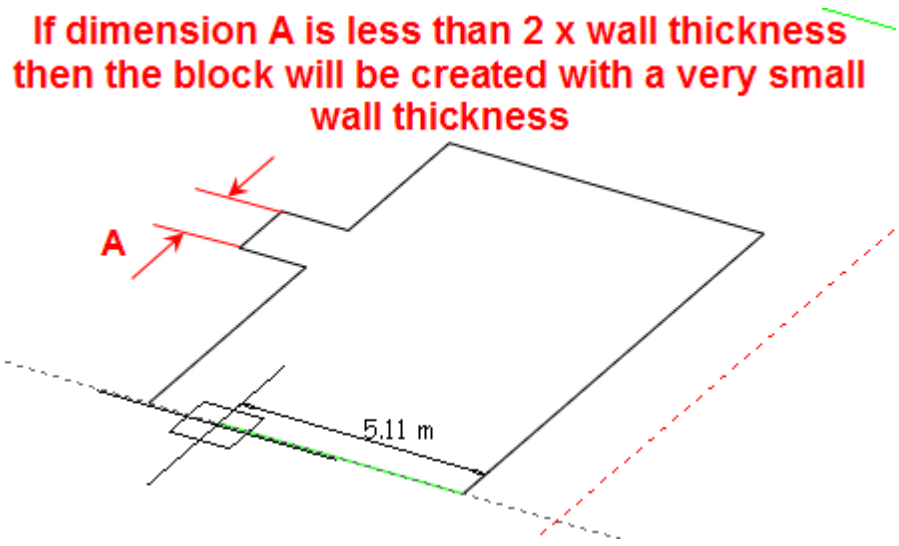
Tip: You should enter a low value of Wall thickness if:

- The block is a roof with low roof slope angle sloping roof elements - see Example 1 below.
- The block is mainly glazed - see Example 2 below.

The lowest value of wall thickness allowed is 0.01m and the highest allowed value is 2.0m.

EFFECT OF INDENTS IN THE BLOCK PERIMETER

When creating the block, if the shape of the perimeter drawn includes indents in such a way that the requested wall thickness is physically impossible and the wall thickness cannot be accommodated then DesignBuilder will still allow the block to be created but the wall thickness is reset to a small value that is compatible (typically 0.025m). See screenshot below. In this case you will not be able to edit the wall thickness to a higher value without redrawing the block to avoid the indent.



ROOF BLOCKS - EXAMPLE 1

Select a small **Wall thickness** when creating a roof block having very shallow slope. This example shows a 2 block, 2 zone model, the top block (selected) representing a roof having shallow slope angles.

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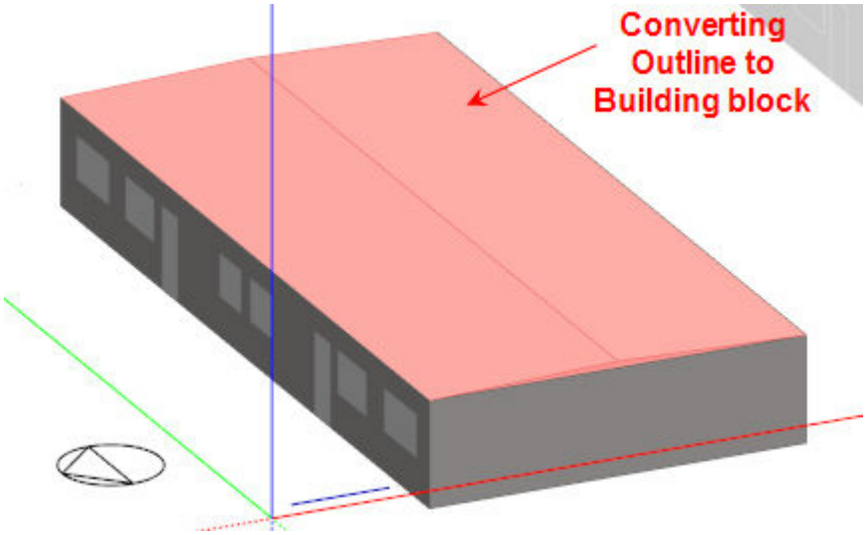
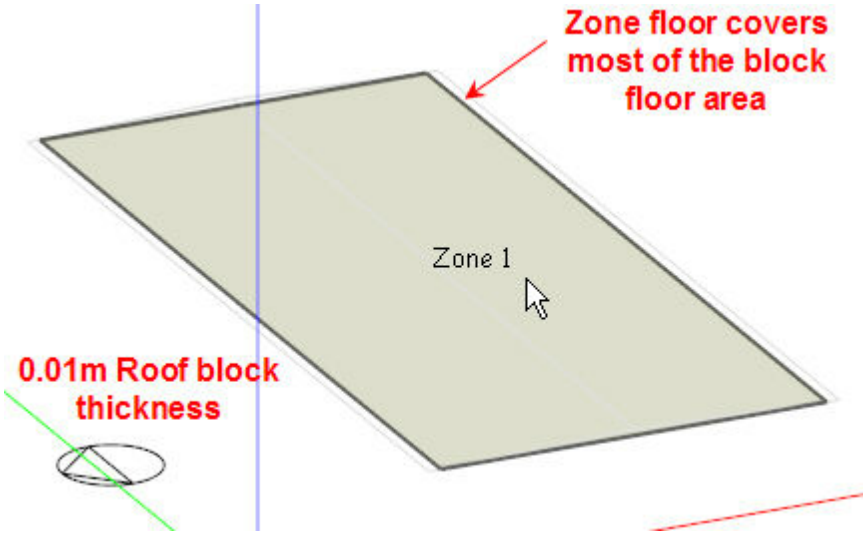
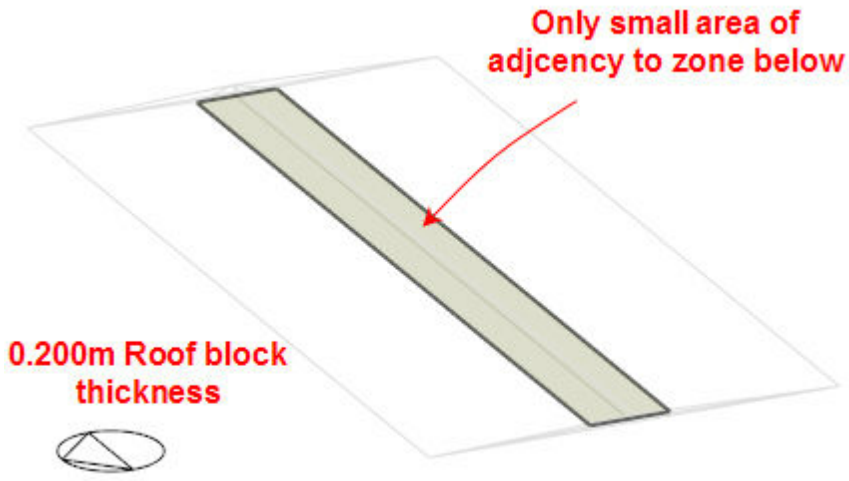


Using a **Wall thickness** 0f 0.01m gives **good results** as the roof zone covers most of the block floor area (below).



Using a large **Wall thickness** makes it impossible for DesignBuilder to generate a floor covering the whole block floor area giving **Poor results** (below).



In the image above the white areas of the block floor will not form part of the model which is probably not

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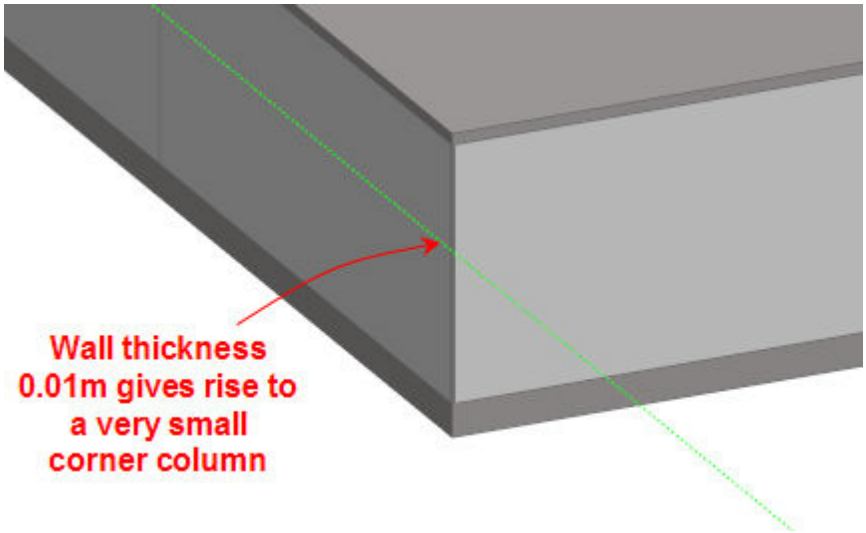
what the user had in mind.

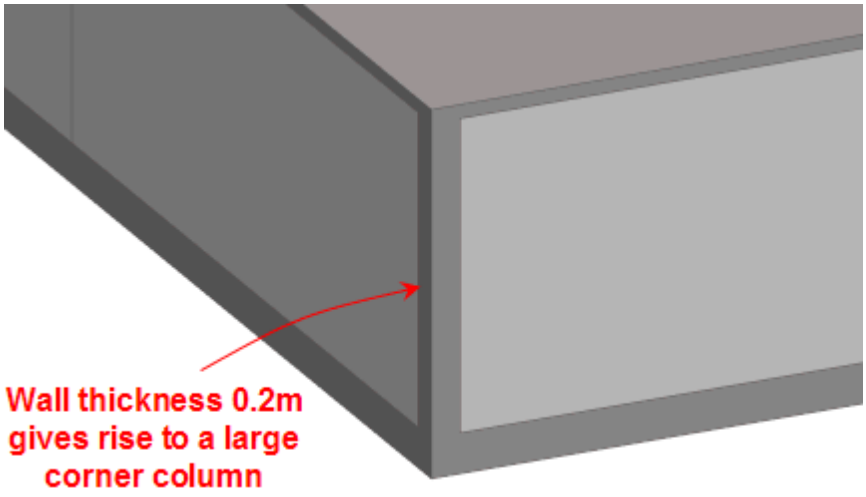
CURTAIN GLAZING - EXAMPLE 2

When modelling continuous glazing for curtain walls, atria, greenhouses etc. it is often necessary to model glazing joining at the corners. It is not possible for windows to literally meet in this way because EnergyPlus requires all openings (windows, doors etc) to be placed on a parent surface with at least a small gap between the opening and the parent surface edge. But by using a low value of block thickness you can give the appearance of adjacent windows as shown below.

A small **Wall thickness**, below, allows the glazing to cover most of the wall giving **Good results** (below).



A larger **Wall thickness**, below, requires more area to cater for the walls joining at the corners and the glazing does not meet 'round the corner' giving **Poor results** (below).



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3.2.9.2.5 Convert Outline Block

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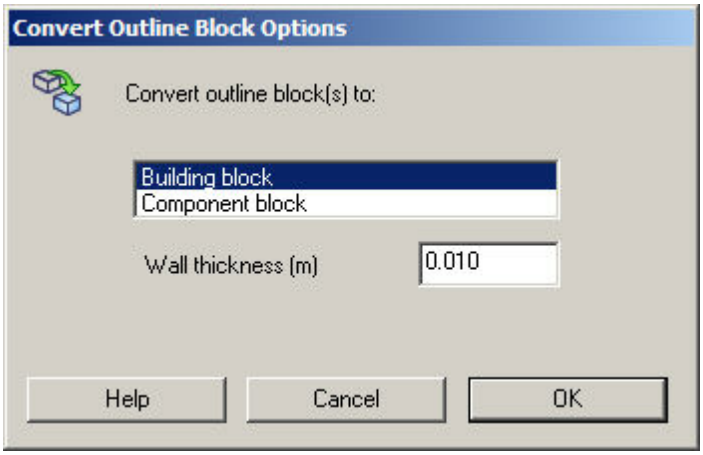
To convert an Outline block to a Building block, or Component block select the blocks that you want to convert and then click on the **Convert selected outline block** tool. This opens the **Convert Outline Block Options** dialog below.



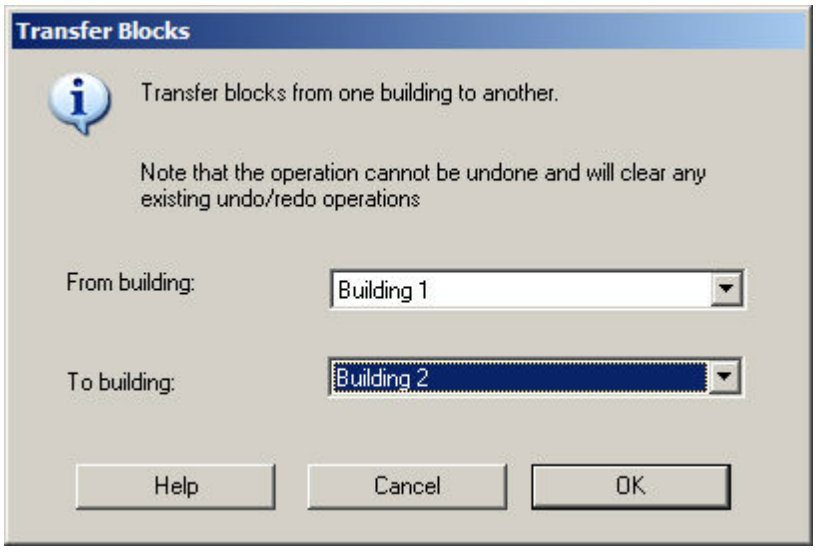
Select the type of block to convert to:

- Building block
- Component block

When converting to a Building block you can also enter the Wall thickness of the block.

3.2.9.2.6 Transfer Blocks

You can move blocks from one building to another using the Transfer blocks command accessed from the Edit menu when the site contains more than 1 building. This starts the Transfer blocks dialog below. Select the building containing the blocks to be copied and the building to receive the blocks and Press OK.



You should check before starting the transfer that none of the source blocks overlap with blocks in the destination building. Even a small overlap will cause the process to fail.

Note: the operation cannot be undone and it clears any existing undo/redo information.

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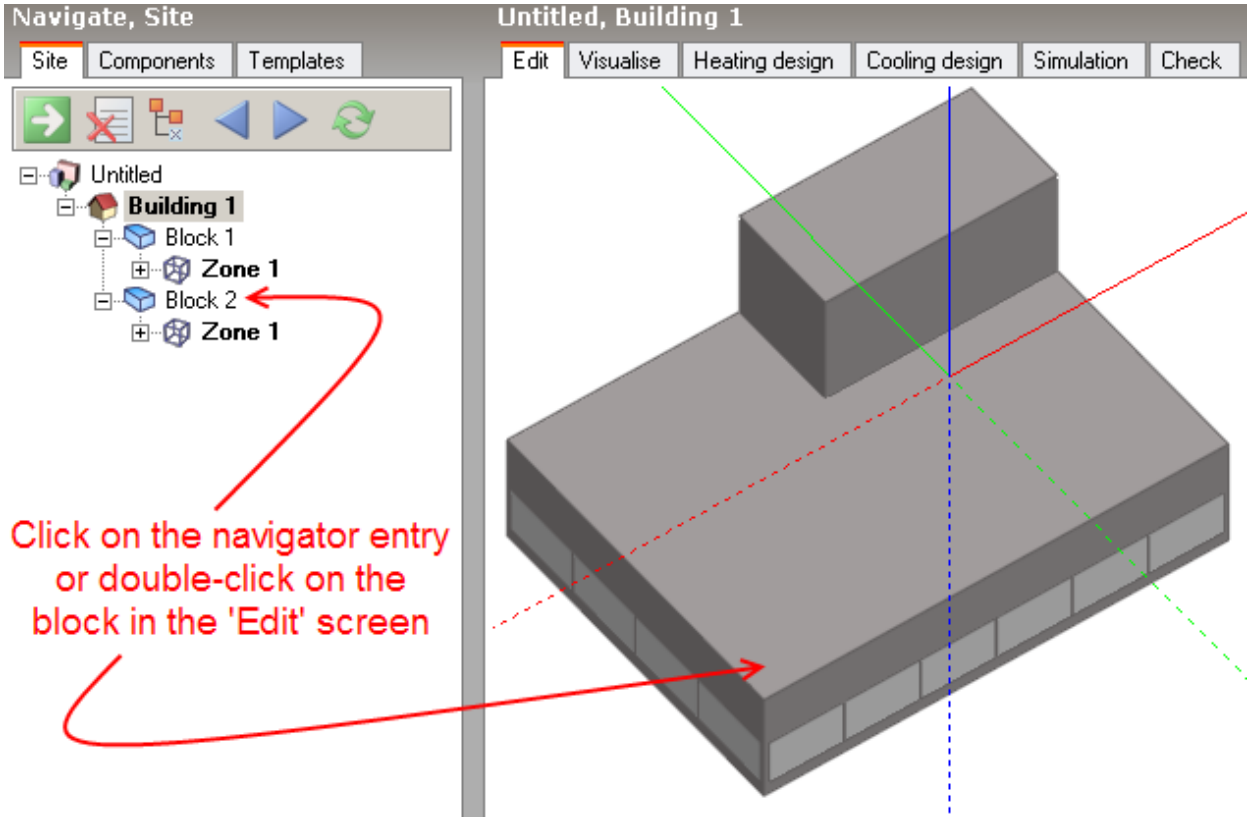
3.2.10 Working WITHIN Blocks

This section describes the various operations involved in partitioning a block to create zones and adding courtyards to blocks. Before you start to draw partitions or courtyards, you first need to go to the block that you want to edit and you can do this by clicking on the block entry in the navigator or by double-clicking on the block in the 'Edit' screen, if you're at the building level.

Go to block level



Either of these operations will take you to the block:

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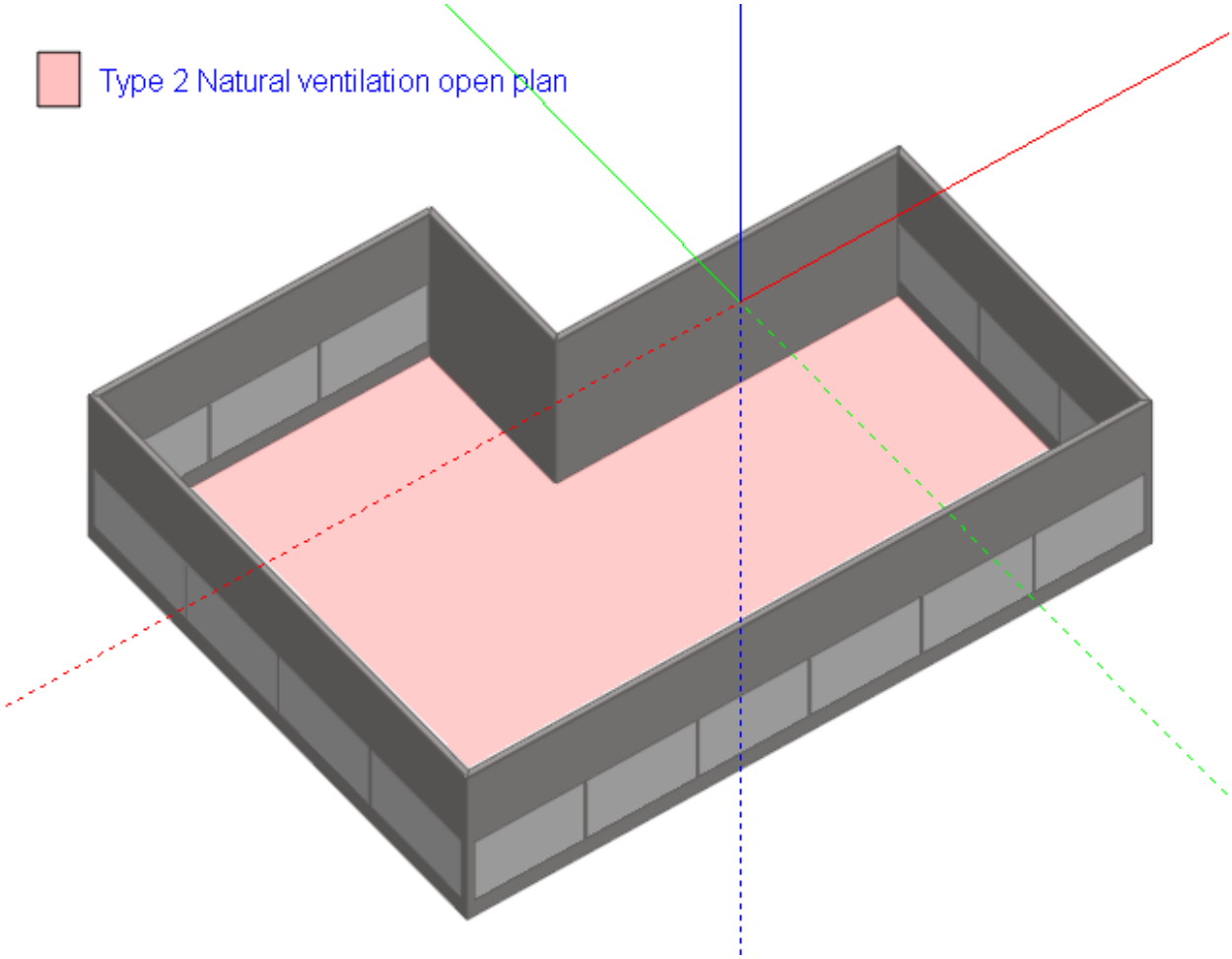

3.2.10.1 Zone Block by Drawing Partitions

Building blocks can be divided into any number of zones by drawing partitions inside the block. To start drawing partitions, click on the 'Draw partitions' tool. You can place partitions freely within a block either free-standing or snapped to an external block wall or existing partition. Partitions can be positioned using the snaps, drawing guides and protractor. A partition doesn't need to be snapped to a wall element, you can drag a partition across a wall and when you click the end-point, it will be automatically trimmed to the wall.

You can enter the thickness of the first partition drawn in the block and subsequent partitions take on the same thickness as the first.

Note for partitioning large models

By default, blocks are automatically re-zoned as soon as complete zone perimeters are formed by drawing partitions. In order to speed up the process of adding partitions, particularly in the case of large and complex blocks, the block zoning process can be postponed until partitioning has been completed. To do this, open the Model options dialog and switch off the Automatic block zoning option under the Miscellaneous Edit header on the Advanced tab. When partitioning has been completed, the block can be manually re-zoned by selecting the Rezone block command from the Tools menu. Partitions drawn with the Automatic block zoning option switched off are called Outline partitions and are shown in blue.

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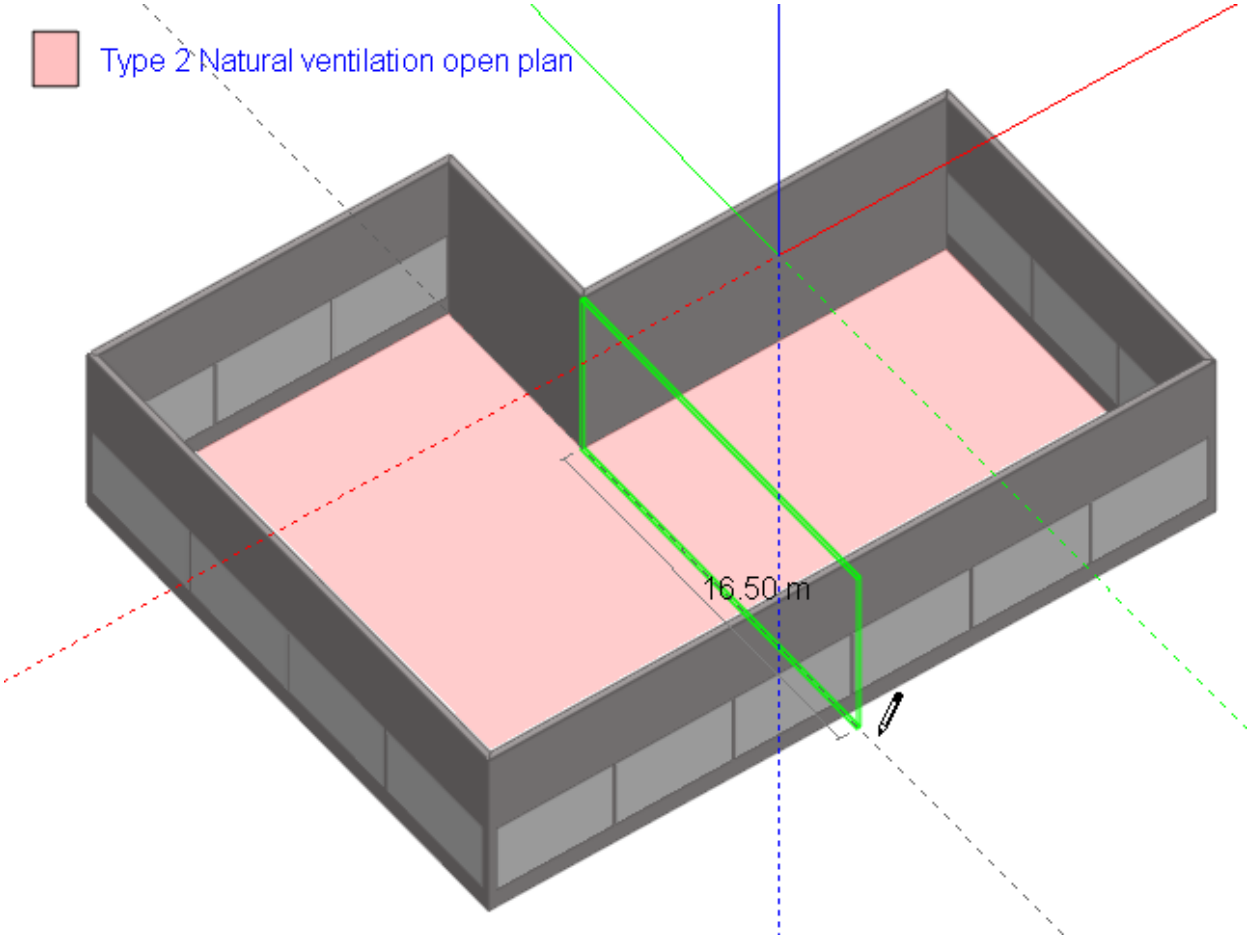

Click the partition end-point on the outside of the wall and it's automatically trimmed:

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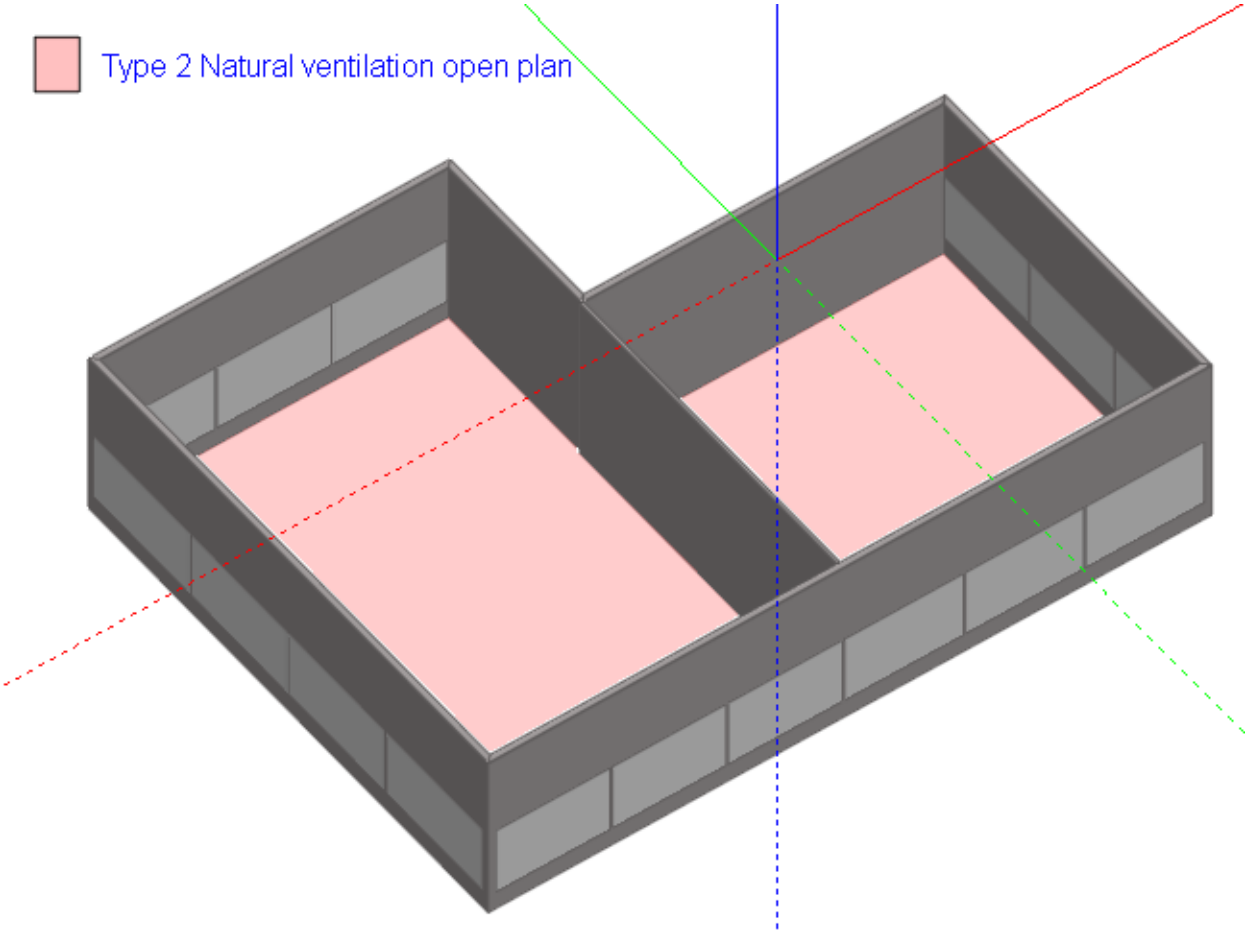

When you draw a partition or a series of partitions (stream), you can undo the last point placed by pressing the ESC key or selecting 'Undo last point' from the right-click menu.

You can also terminate a partition stream anywhere by selecting 'End stream' from the right-click menu (or by pressing the ENTER key):

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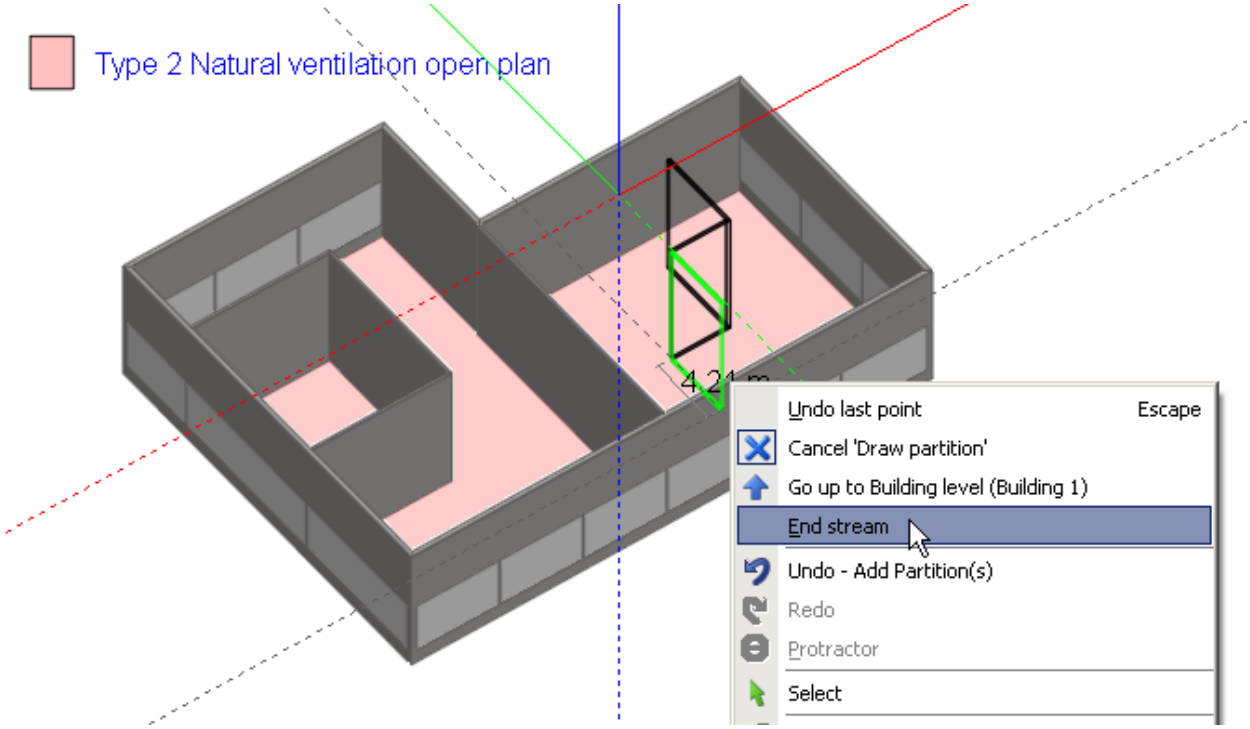
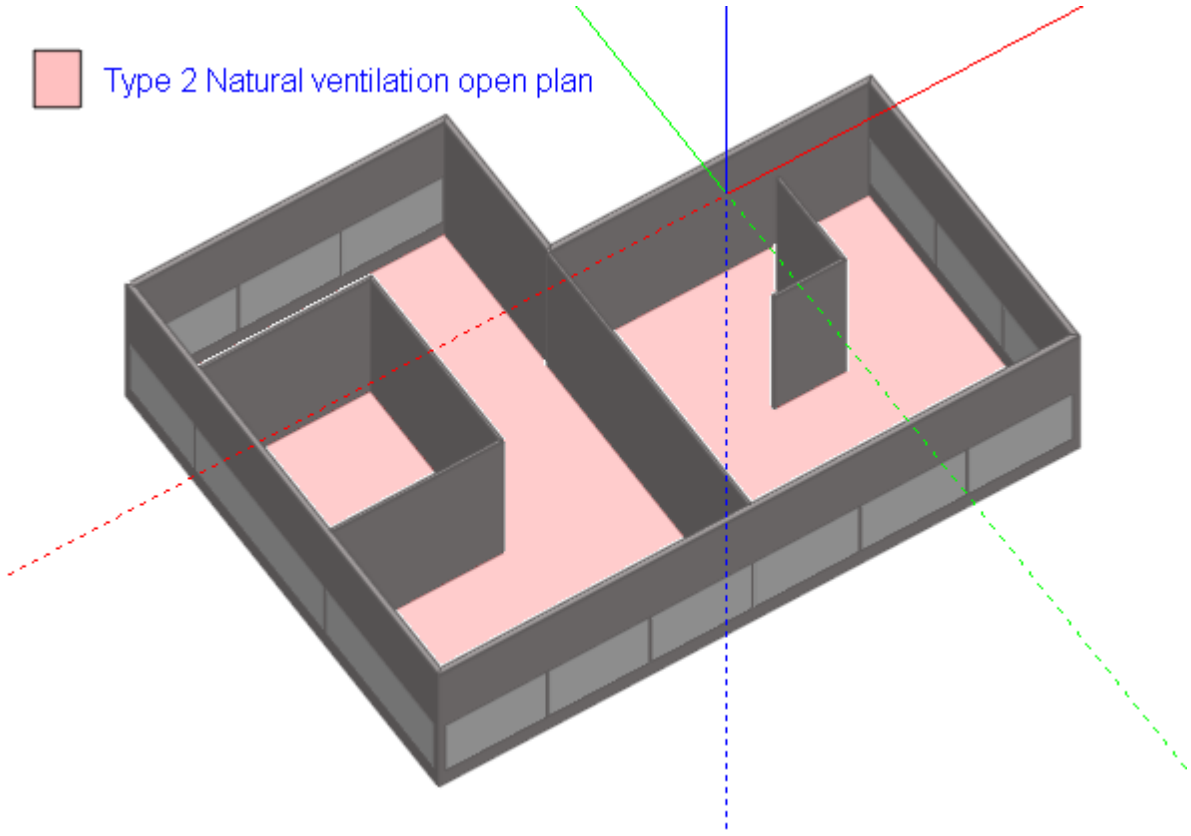


When partitions or partition streams are placed that don't connect with anything at either or both ends, they are called hanging partitions and can be used to add thermal mass to zones:



Once you've placed partitions that divide existing zones within a block, the block is re-zoned automatically:

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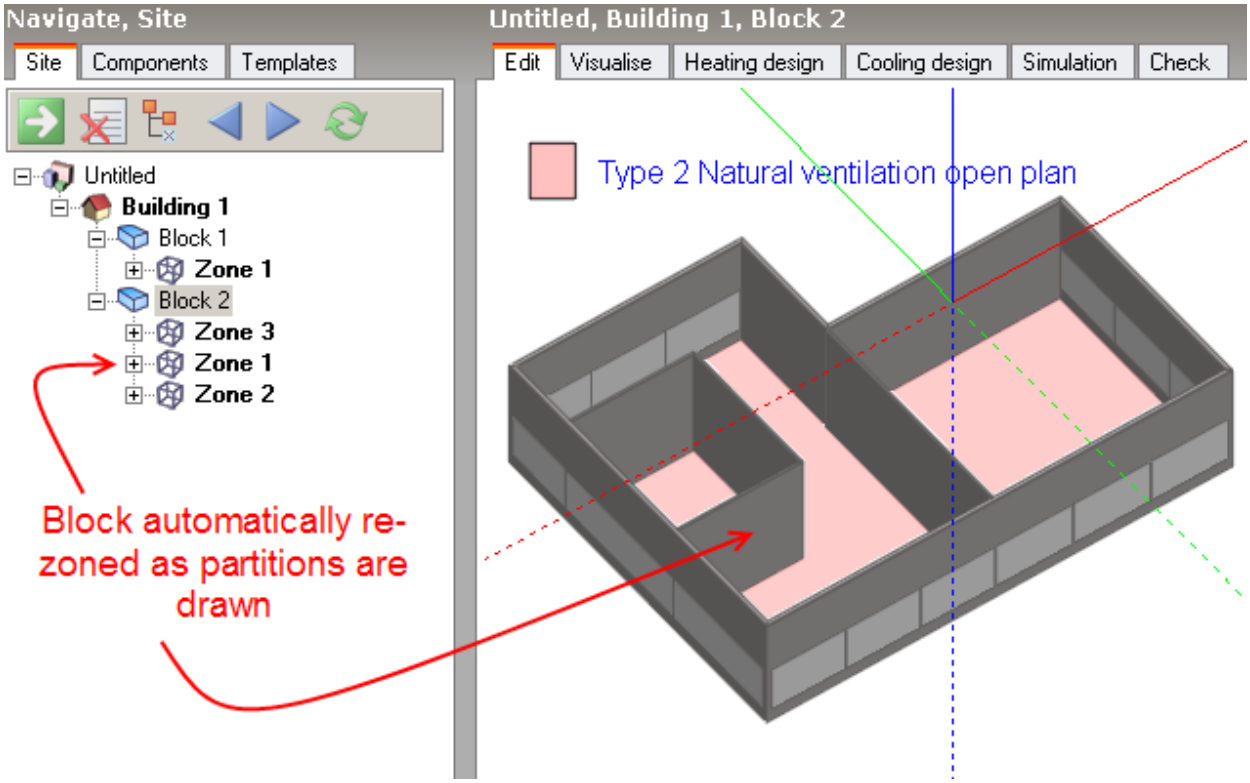
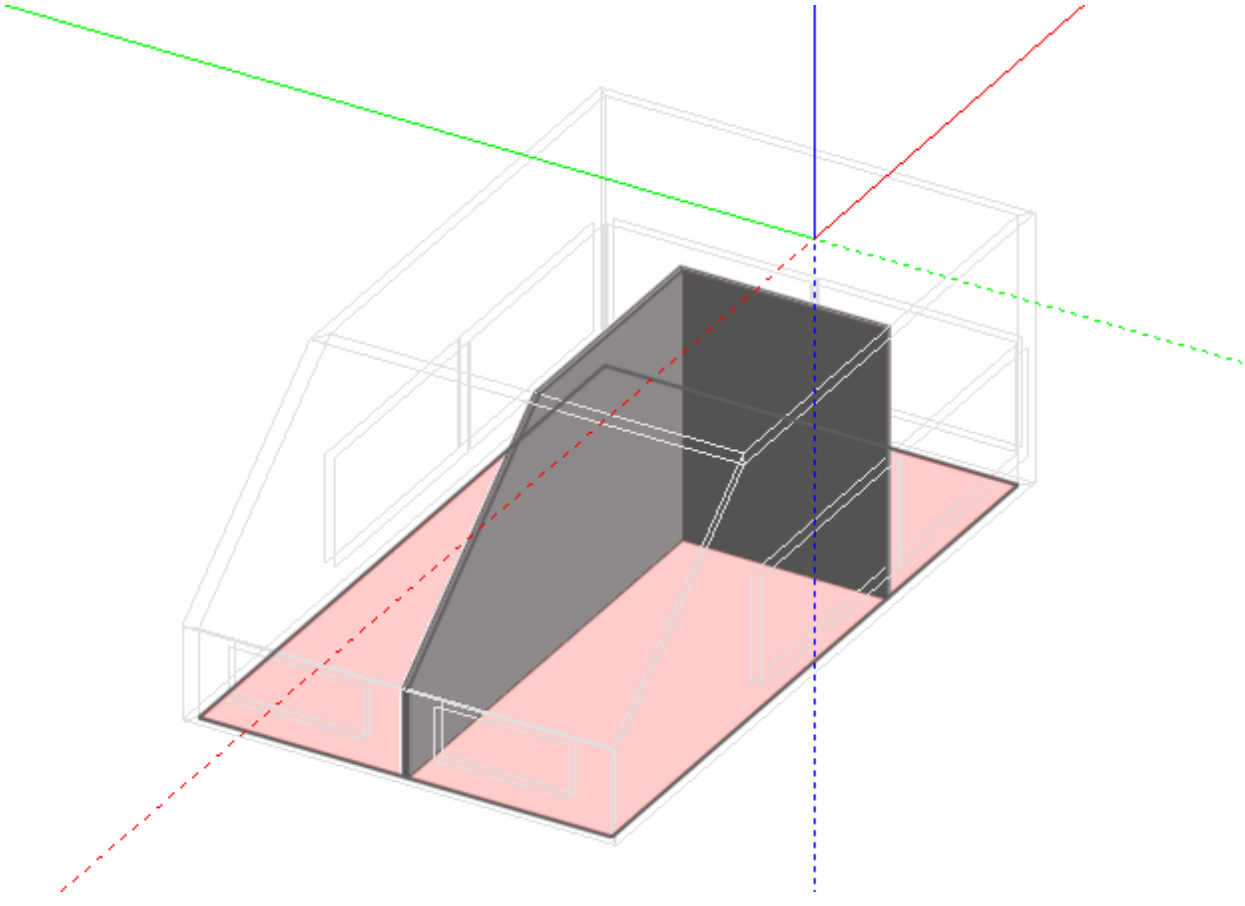


When you partition complex blocks rather than simple vertical extrusions, partitions are automatically cut to fit within the block:



Seeing into blocks with sloping walls

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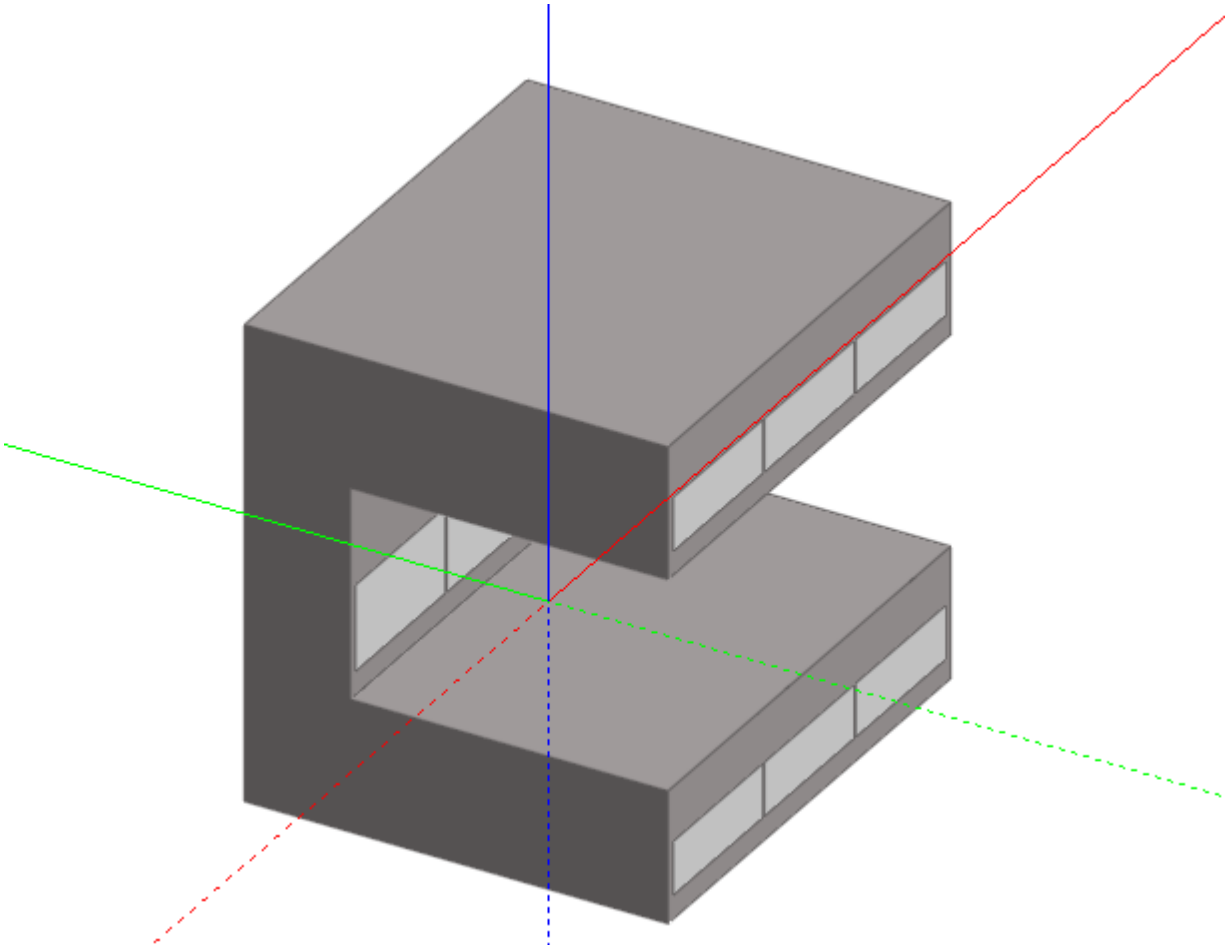
If the display of the block outer walls prevents you from drawing partitions (for example in a pitched roof block) then you can switch off the display of external walls.

ADVANCED TOPIC

In some cases, if the geometry is complex, it can be possible to create a zone that comprises several geometric bodies which are physically separated from each other. For example, in the case of a horizontally extruded 'C' shape:



If a partition is drawn as shown:

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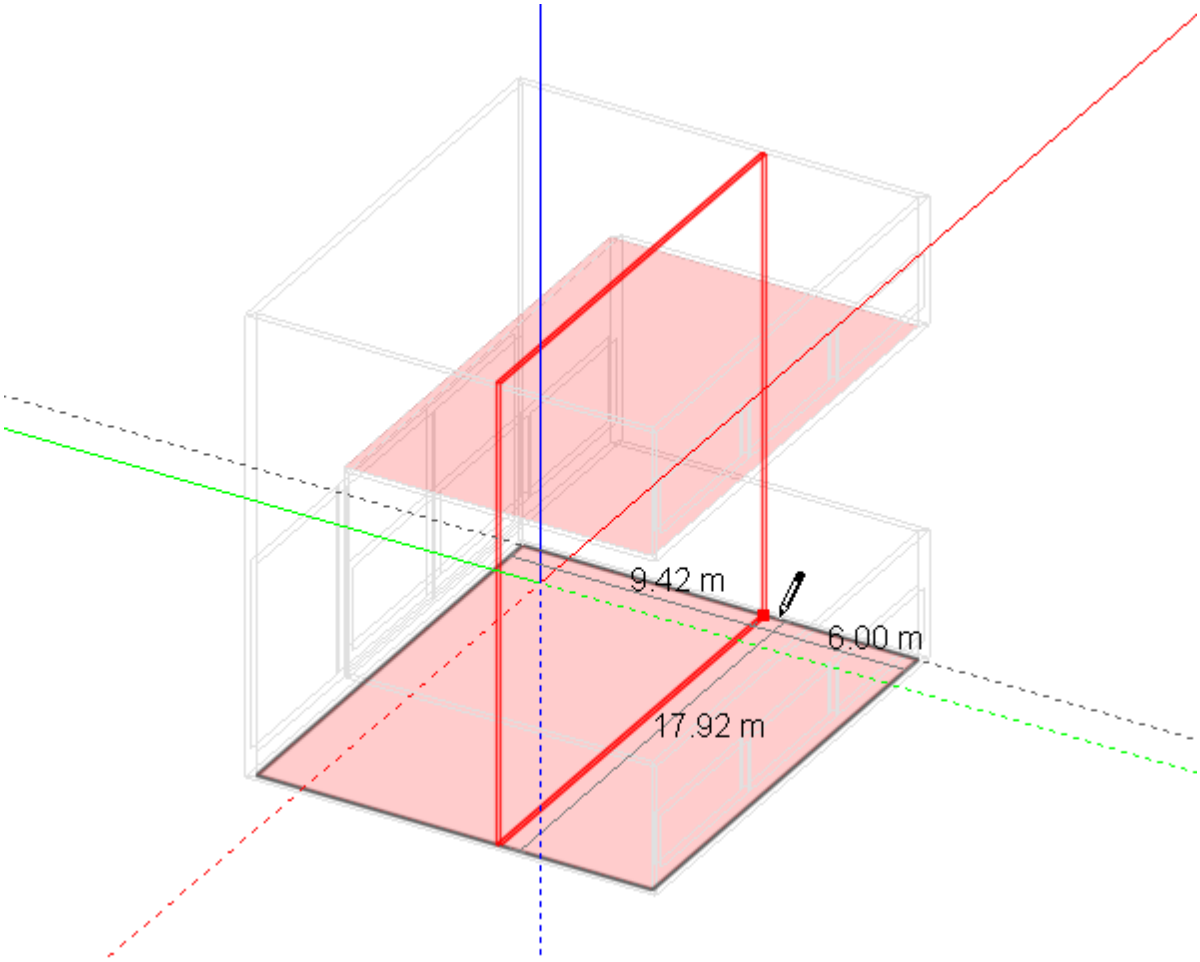

The partition and resulting zone will be cut to form what appears to be two partitions and two zones:

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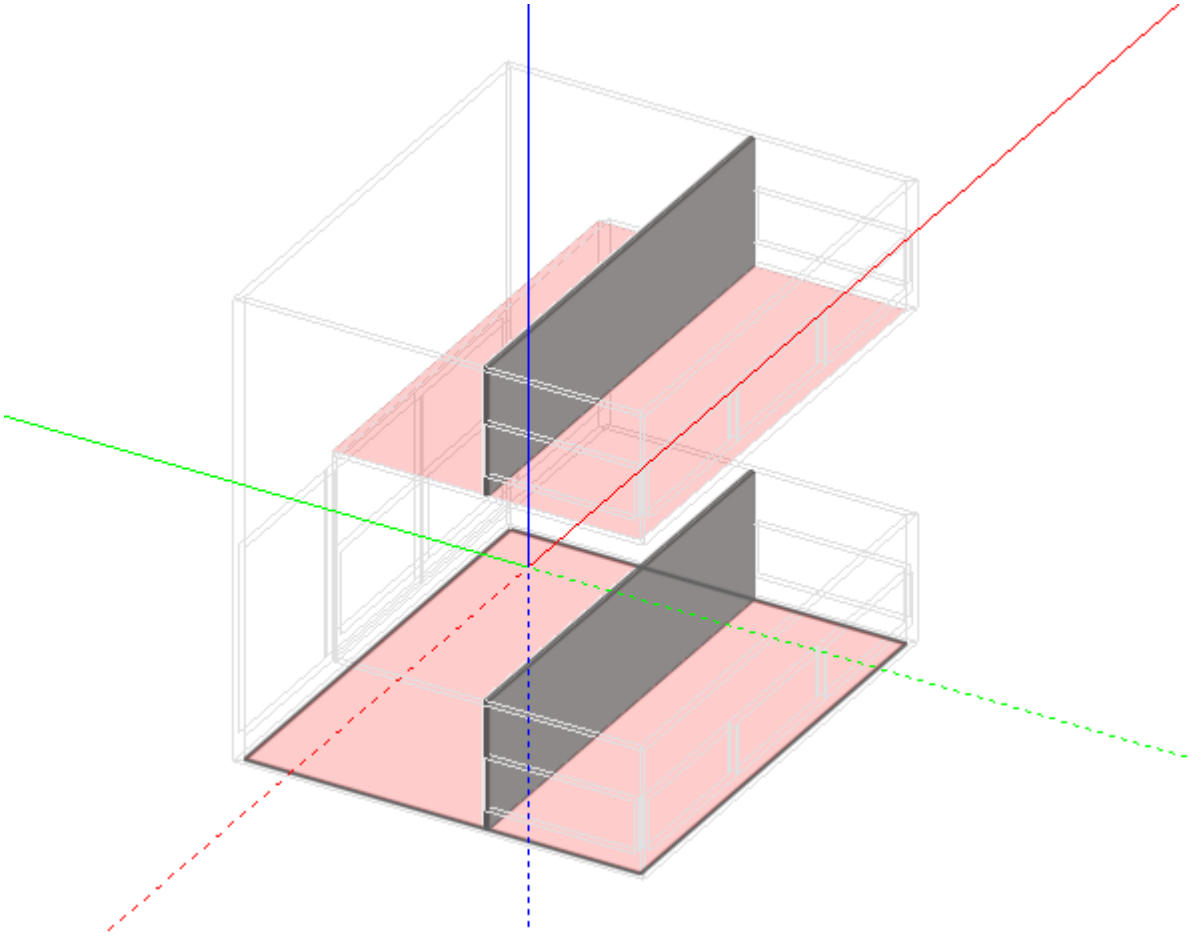
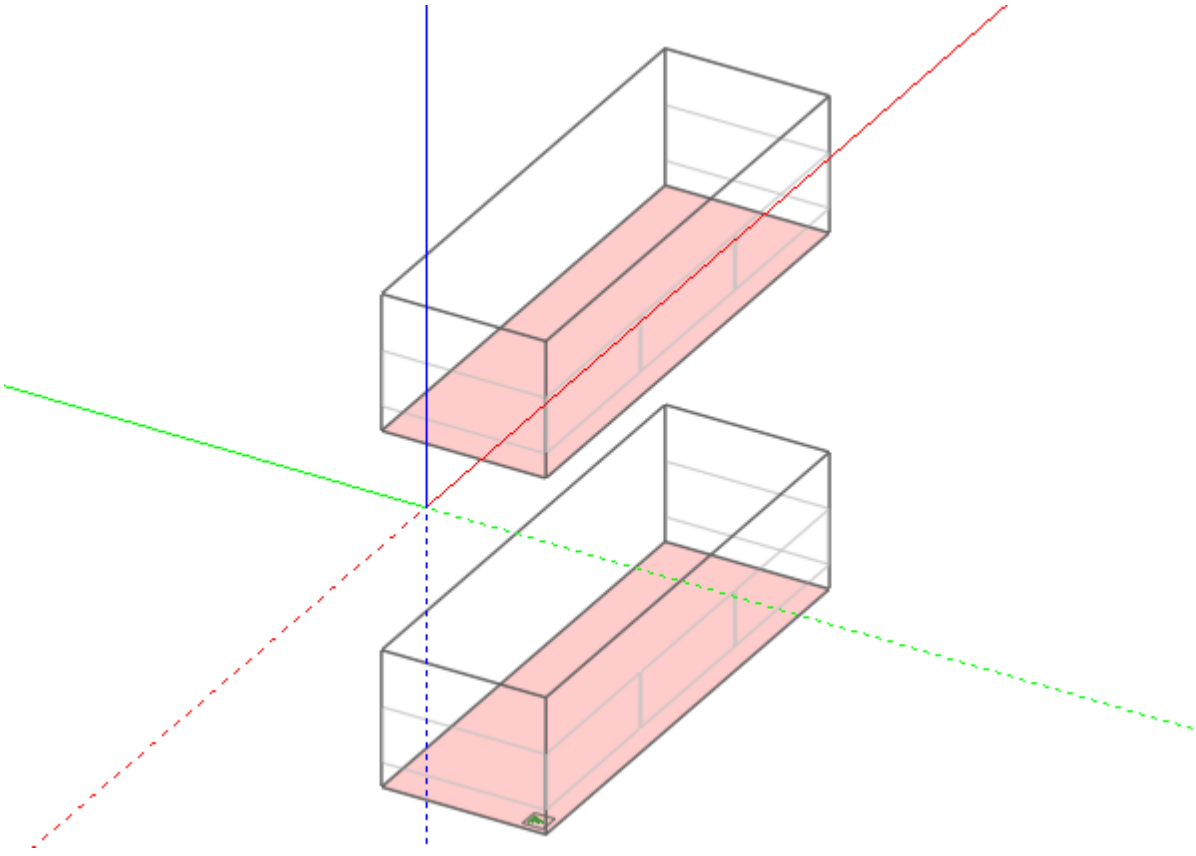


However the two resulting zones are in fact two geometric bodies within one zone:



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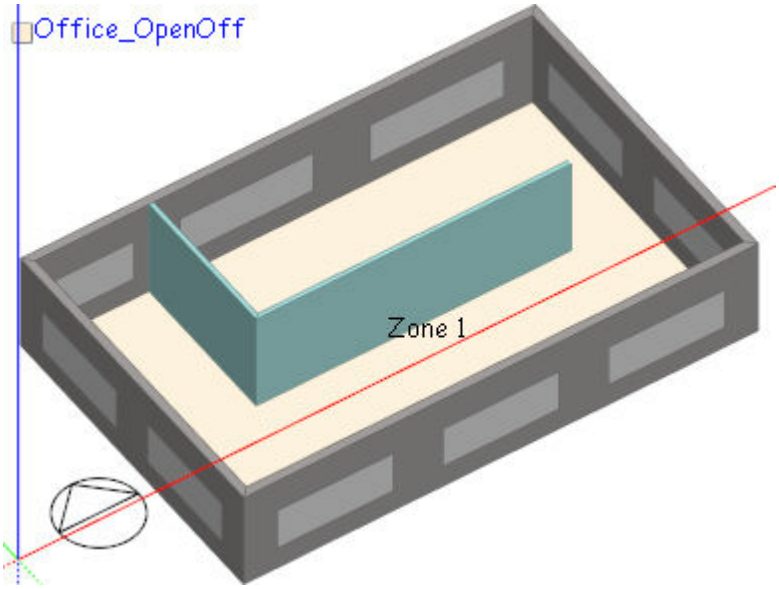
While this geometry is perfectly acceptable for the default EnergyPlus solar calculations (see Model Options), it cannot be processed by the more rigourous Full exterior and interior solar distribution option. If this latter option is required, you can either model the geometry as two separate blocks or cut the block.

3.2.10.2 Hanging and Outline Partitions

Hanging partitions are partitions that do not create zones because they do not connect at both ends with other walls/partitions. Hanging partitions are created in the same way as ordinary partitions using the Draw partition tool, but are finished by pressing <Enter> (or the End partition stream command from the right click menu) to define the end of a partition stream. They are shown in blue (below).



Hanging partitions are modelled non-geometrically in EnergyPlus as Internal thermal mass.

Outline partitions

Also if Automatic block zoning is switched off, all new partitions are treated as outline partitions (shown in blue and do not create zones) until converted to standard partitions by using the Rezone block command from the Tools menu.

3.2.10.3 Virtual Partitions

A virtual partition is a partition between 2 zones which exists purely to sub-divide the space up and has no corresponding wall in the actual building.

Virtual partitions are commonly used for separating perimeter zones from core zones when there is to be different HVAC provision or when carrying out daylighting or solar overheating studies in situations where a large open plan space is subject to a high level of solar gain around the perimeter. Virtual partitions can be placed to create separate perimeter and core zones so that the local effect of the solar gain in the perimeter zone may be calculated. In the absence of virtual partitions, the risk of overheating could be underestimated due to the distribution of solar gain throughout the open plan space.

When drawing partitions you can set the Partition type to **2-Virtual** in the Drawing option panel. Also for

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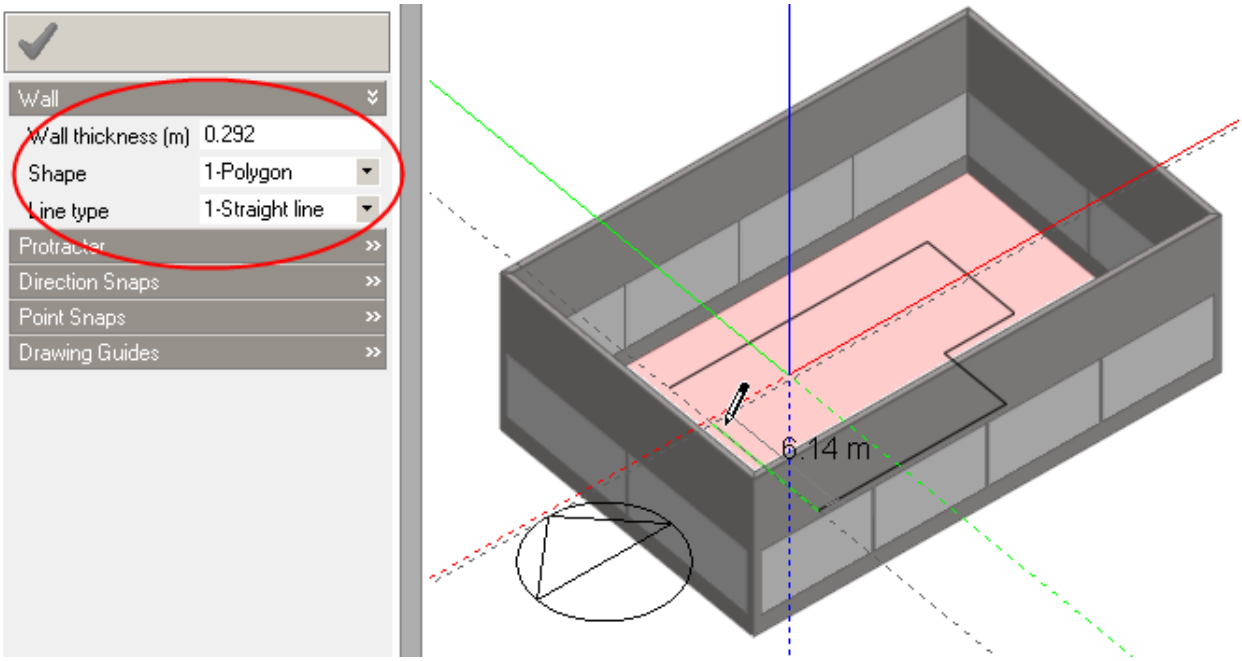
partitions that have already been created you can freely switch the partition type between **1-Standard** and **2-Virtual** using the same control.

Virtual partitions are modelled using a hole that fills the whole surface area. You cannot draw custom openings on a virtual partition. The model options for controlling the effect of holes equally apply to virtual partition holes:

- Merge zones connected by holes
- Model holes (including holes in virtual partitions)
- Model airflow through internal openings using flow per unit area

3.2.10.4 Creating Voids (Courtyard Spaces) Within Blocks

To create an external courtyard within a block, go to the required block by clicking on the navigator entry or double-clicking the block in the 'Edit' screen and then click on the 'Draw void perimeter' tool. You can the select a perimeter shape and set the required wall thickness in the 'Drawing Options' data panel:



After completing the perimeter, a courtyard is automatically generated within the block:

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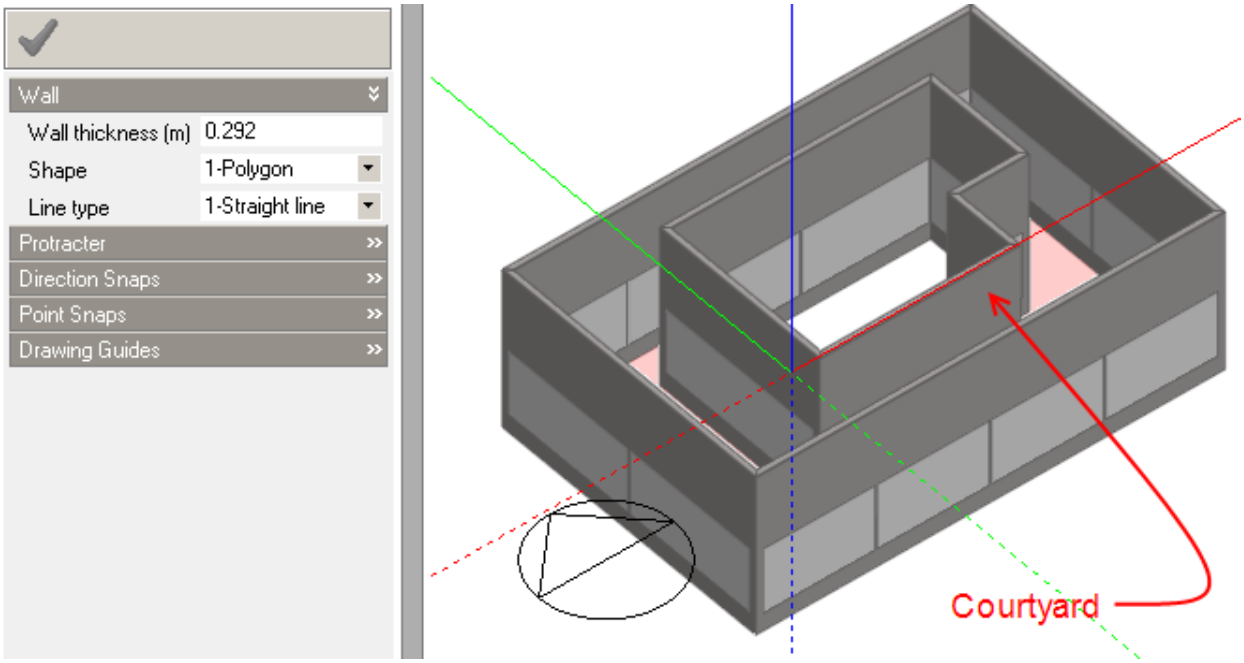

Important note: the void space is modelled as *exterior* and not as any sort of zone. If you need to create an atrium space to be included in the calculations then model it like any other zone within the block using partitions.

Void Restrictions

1. The void perimeter lines you draw to create a void cannot touch any other external or internal wall, so you can't for example use the void command to take chunks out of the external wall - the void must be wholly contained within the block.

2. You can't create any other objects within a void - the void space is reserved and you will get intersection errors if you try to draw a block in the void space.

3.2.10.5 Edit Block Options

You can edit certain aspects of a building block geometry by clicking on the 'Building model options' icon while at the block level. This opens the Model Options dialog box:

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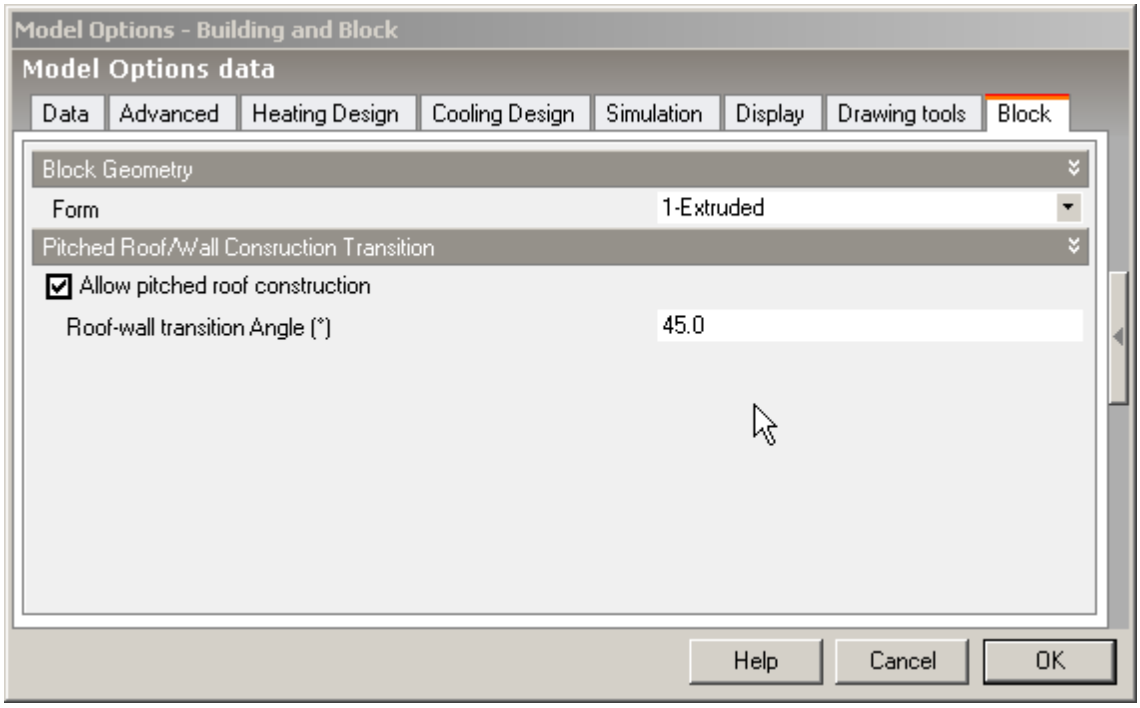

At the block level, the Block tab on the Model Options data dialogue box is enabled and allows you to change the Form of the block and to modify pitched roof assignment.

To change the form of the current block, make a selection from the 'Form' drop list. When you change the form of a block from an 'Extruded' form to 'Pitched Roof' or 'Sloping Walls' the original form will be remembered so that even if you have edited the block by cutting it or dragging a face, when you convert the form back to 'Extruded', the original form will be restored.

The **Pitched Roof/Wall Construction Transition** settings allow you to control which elements within a block will be assigned pitched roof construction, either by disallowing pitched roof construction altogether or by adjusting the element slope to determine which elements should be identified as pitched roofs. The 'Roof-wall transition angle' is the angle from the horizontal below which the element will be considered a roof.

3.2.11 Working within Zones

This section describes the operations involved in placing light sensors within zones. To place light sensors within a zone, you first need to go to the zone that you want to modify. You can do this from the block level either by clicking on the navigator entry or double-clicking on the zone floor in the 'Edit' screen if you're at the block level.

Go to zone level

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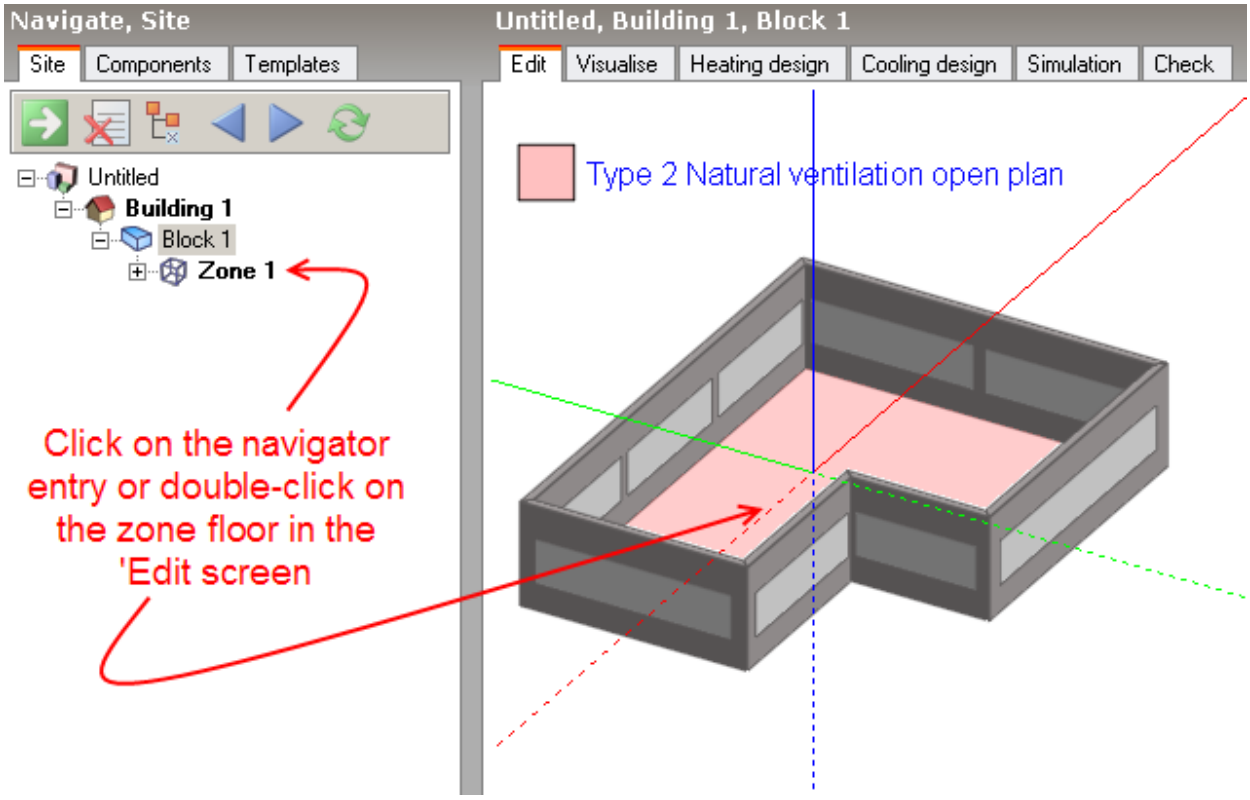
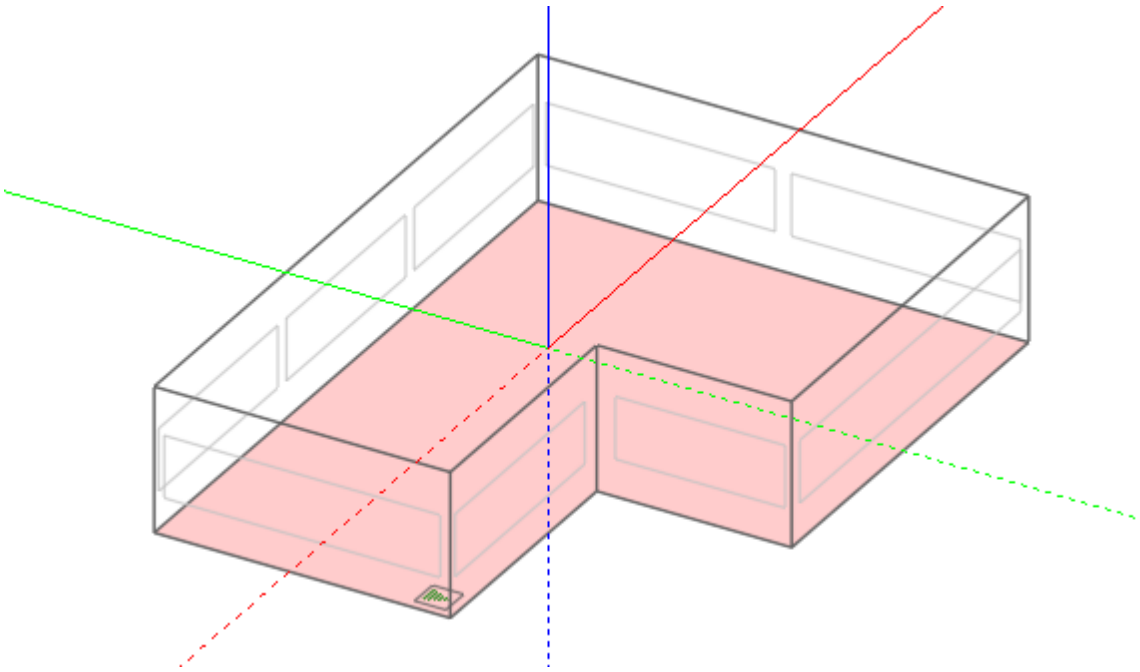


Either of these operations will take you to the zone:



3.2.11.1 Placing Light Sensors

If you switch zone Lighting Control on, a light sensor will be displayed as a blue rectangle with the number '1' inside it indicating 'Light sensor 1'. By default Light sensor 1 is positioned in the geometric centre of the zone.

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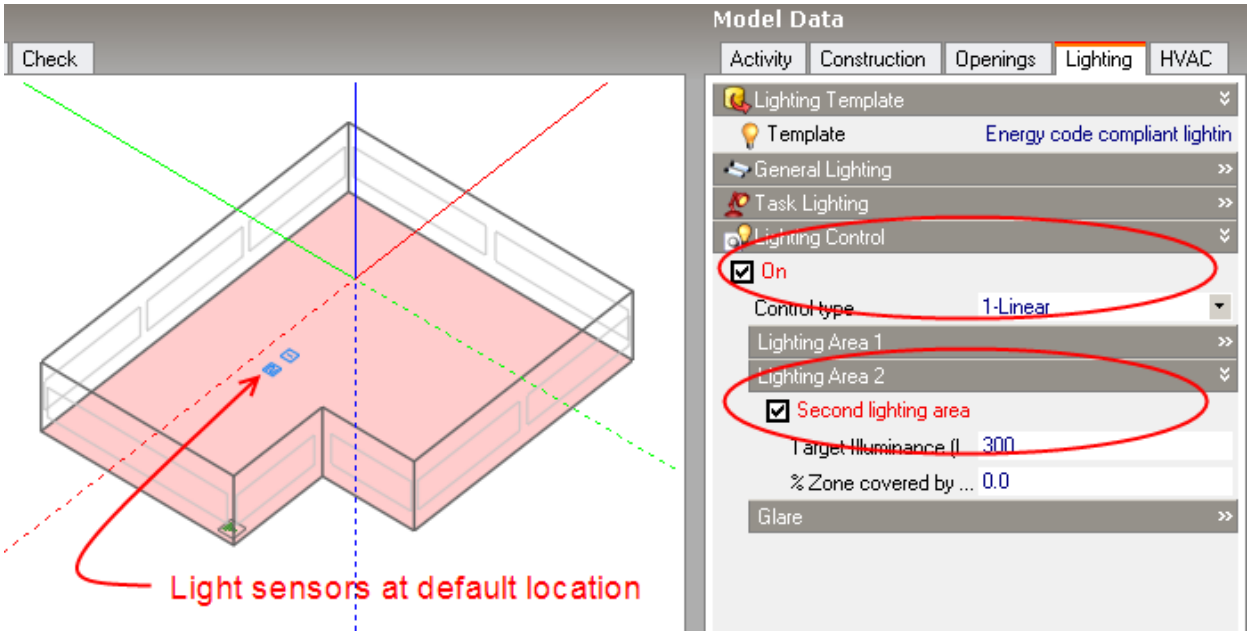
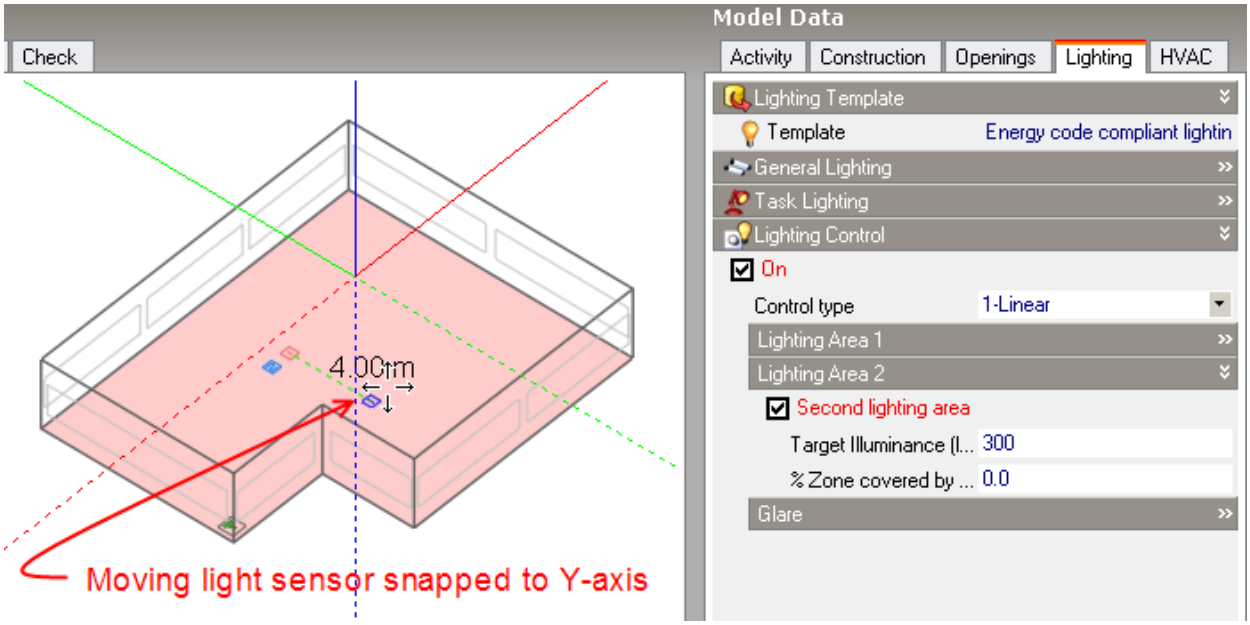
If you now switch on the Second Lighting Area, a second light sensor will be displayed with a number '2' inside it:



To move a light sensor to a different location, move the mouse cursor over the required sensor and click on it to select it and then Move it to wherever you want within a floor perimeter:



Note: You can set the height of the working plane (and hence the z-position of the lighting sensor) on the Advanced tab of the Model options dialog.

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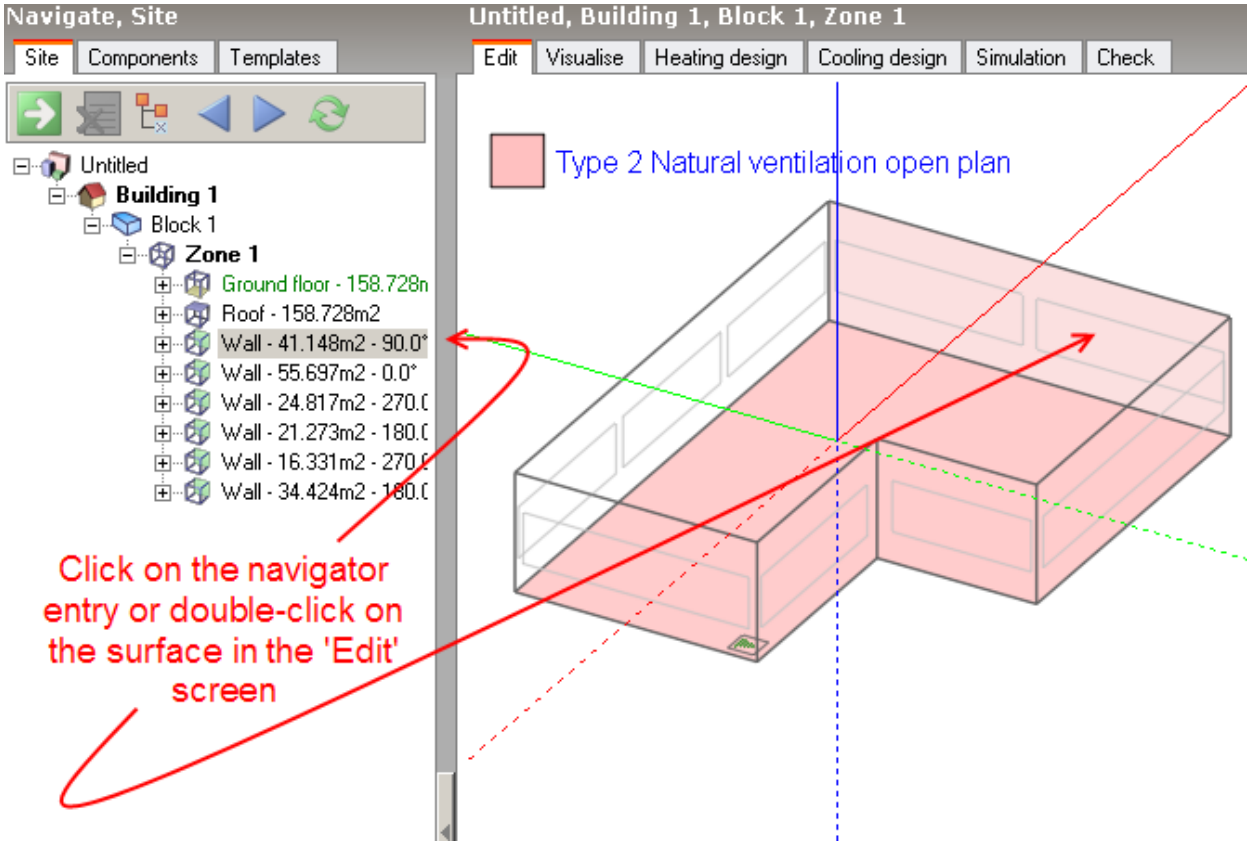
3.2.12 Working with Surfaces (Surface Level)

This section describes the operations involved in creating surface openings and sub-surfaces. To create openings and sub-surfaces in a zone surface, you first need to go to the surface that you want to modify. You can do this from the zone level either by clicking on the navigator entry or double-clicking on the zone surface in the 'Edit' screen, if you're at the zone level.

Go to surface level



Either of these operations will take you to the surface:

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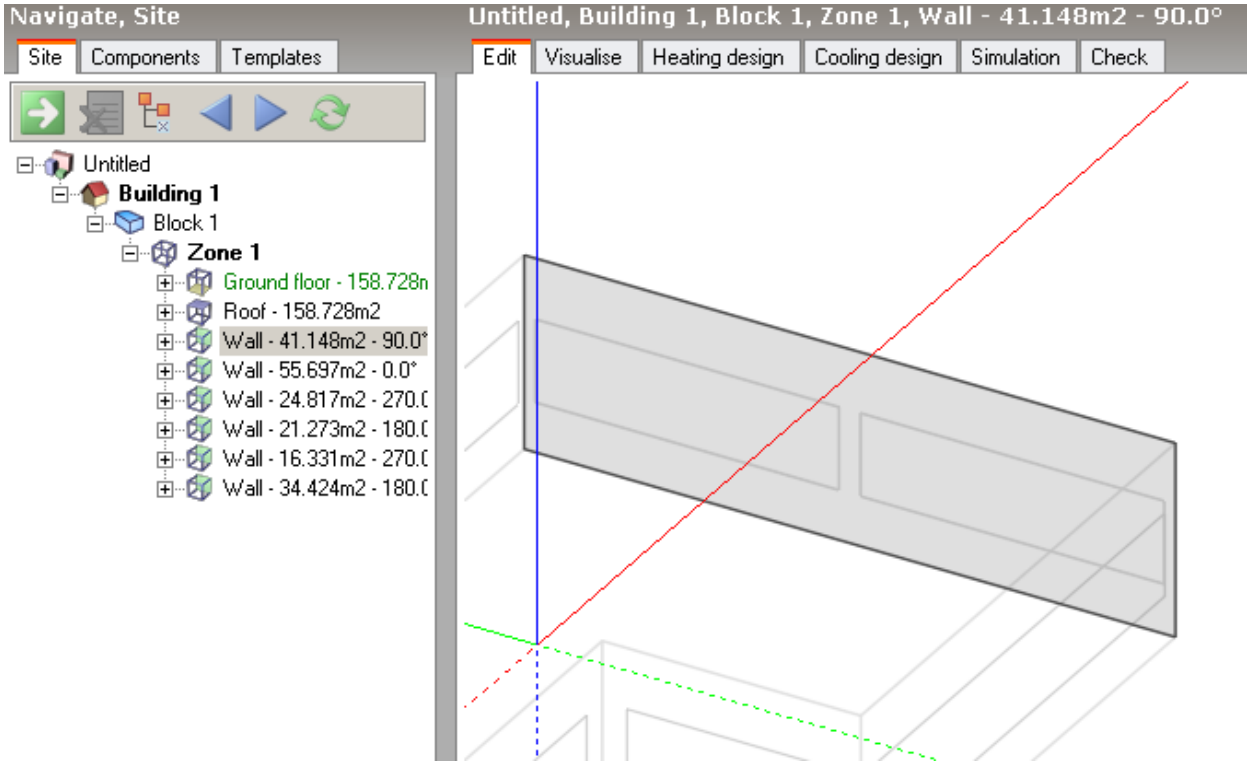
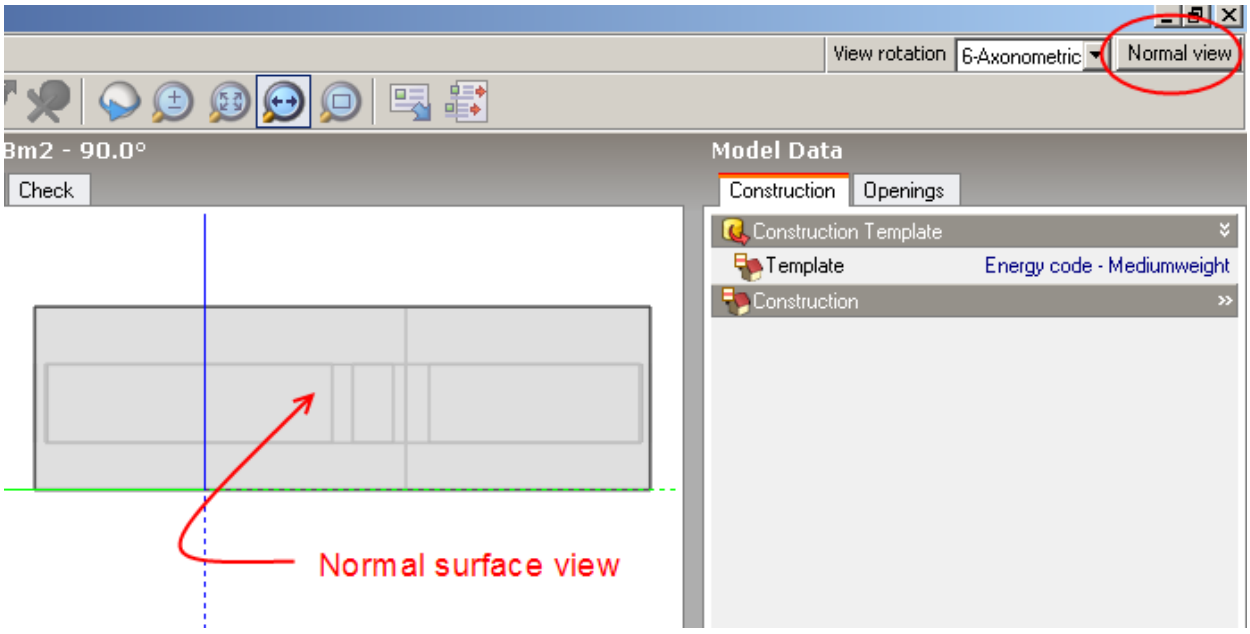


When working with surfaces, switching to Normal view rotation can be helpful in orientating openings and sub-surfaces:



Openings

You can draw, move, clone (copy), rotate and delete the following types of opening:

- Window
- Sub-surface
- Hole
- Door
- Vent

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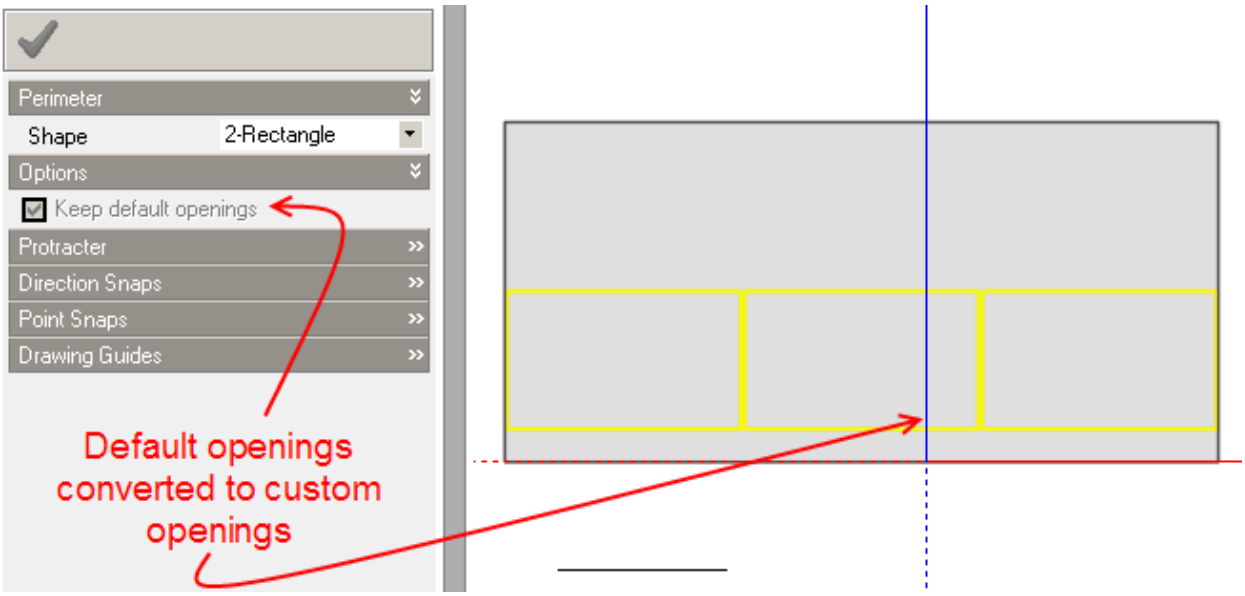
3.2.12.1 Draw Window

Before activating the 'Draw window' tool, you are given the option of keeping any default surface openings. If you choose to keep these openings, they will not be subsequently affected by any changes to the surface attribute data and must be deleted or edited manually.

To add a window to a surface, click on the 'Draw window' tool. If you have opted to keep the default openings, they will be converted to custom openings:



On the other hand, if you un-check the 'Keep default openings' option, all default openings will be removed. Select the perimeter shape that you require and then move the mouse cursor to place the window origin. As you move the mouse cursor over the surface, distance guides will be displayed from each of the surface vertices to help in placing the window origin. If the increment snap is switched on, the origin will snap in increments from the vertex that's nearest to the mouse cursor:

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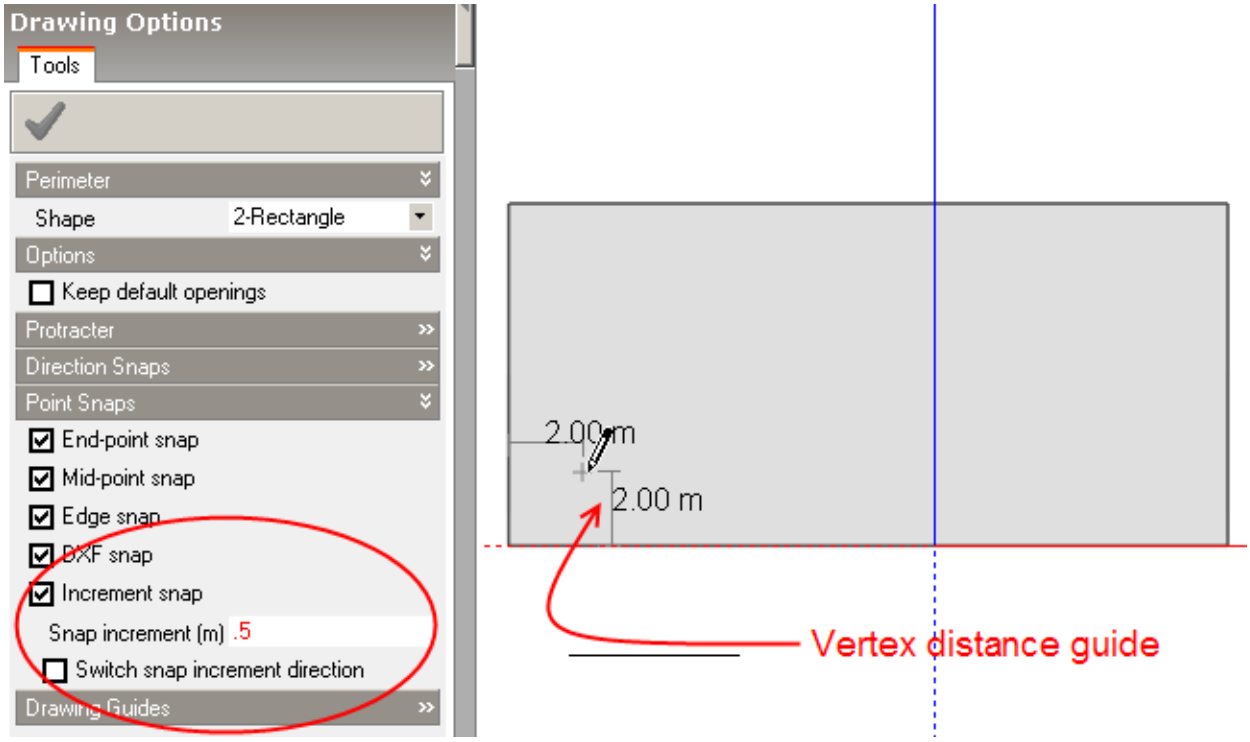
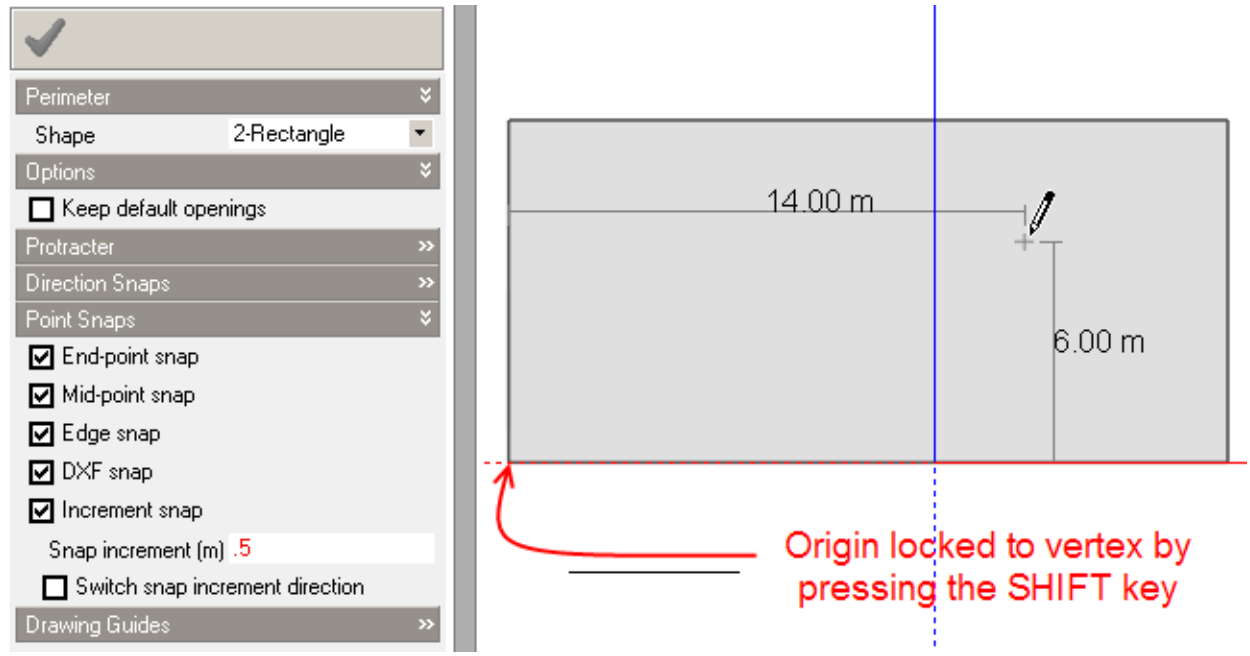


You can lock the origin to a particular vertex by moving the mouse cursor close to the vertex and pressing the SHIFT key and keeping it pressed until you actually place the origin. This can be helpful if you want to place a window relative to a vertex at the other end of the surface:



Having placed the window origin, you can then draw the window using the selected perimeter drawing mode, for details of drawing perimeters please refer to the Perimeters section.

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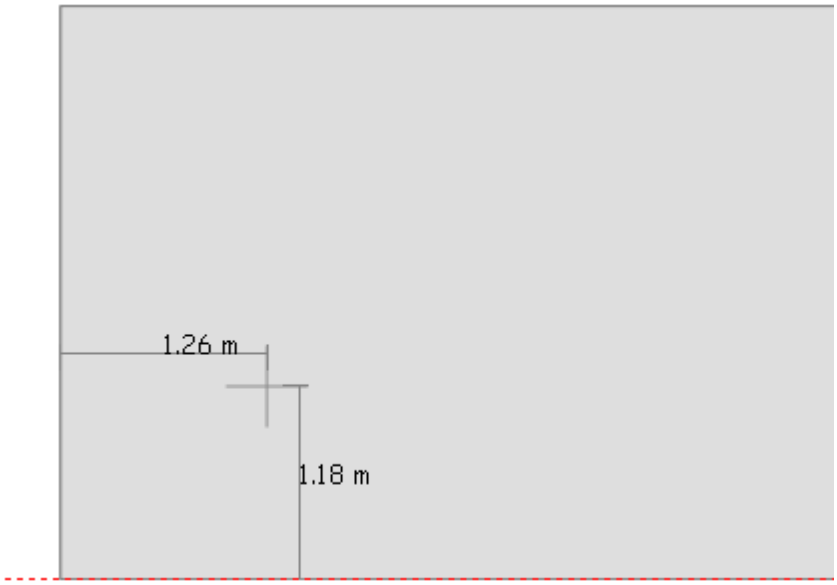
USING KEY INS TO CREATE OPENINGS

You can type in the precise dimensions and offset from the origin of your window using 'Key Ins'. The procedure is:

1. Start the 'Draw window' command as described above.

2. Define the window position relative to an origin by first moving the mouse cursor to define the origin (typically the bottom left corner of the surface)



3. Then type in the offset of the window origin (bottom left corner of the window in this example) in the format x y. Note that there is no comma between the x and the y coordinates.
The coordinates that you type in will appear under the 'Key In' header in Drawing Options panel. The convention used when positioning and drawing openings at surface level is that x increases from left to right and y increases from bottom to top. This is true whether viewing the surface from inside or from outside.

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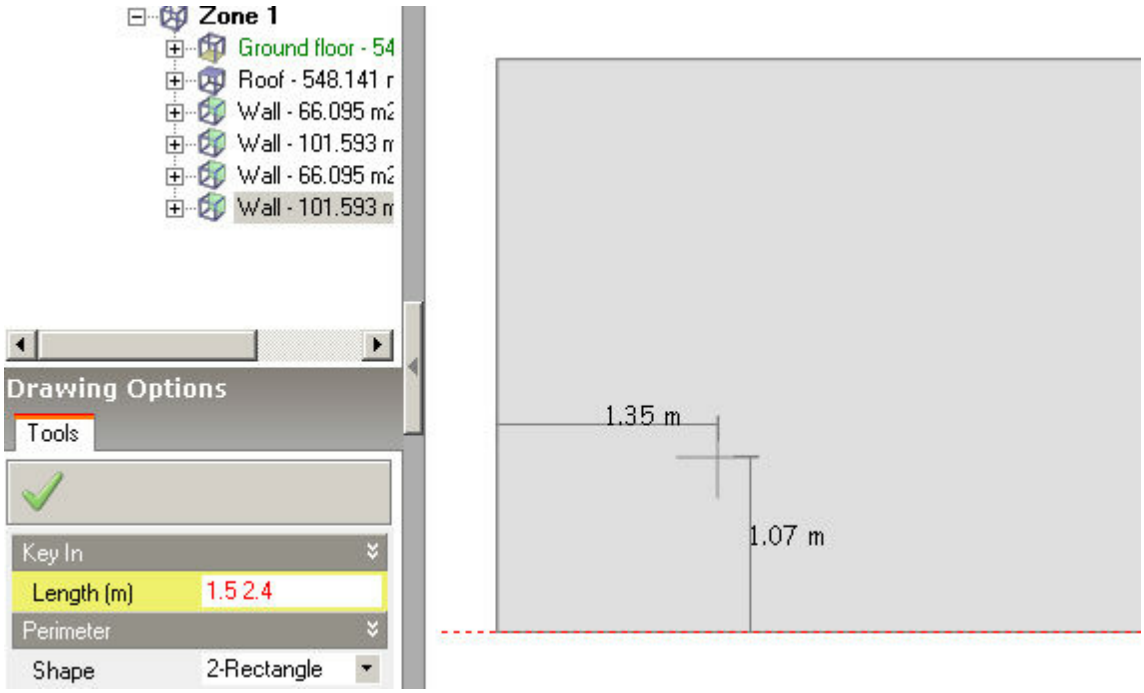
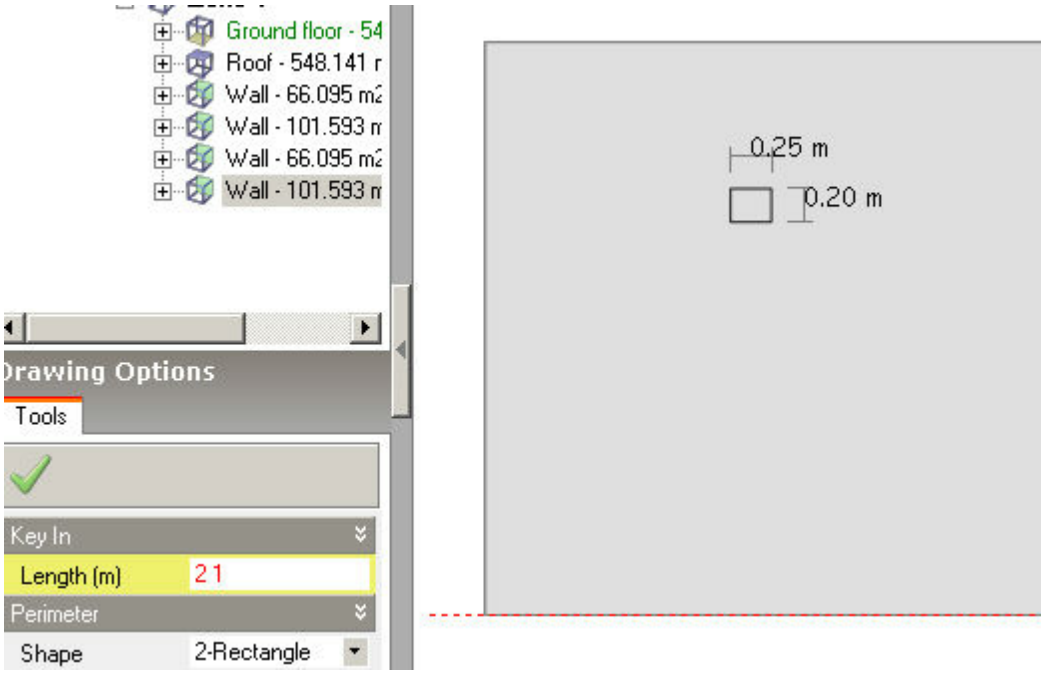


4. Then press <Enter> to define the window origin.

5. Next type in the window width followed by a space followed by the window height. Again the coordinates you type in are shown in the Drawing Options panel. In the example below a window is being defined having width 2m and height 1m.



6. Press enter to create the window:

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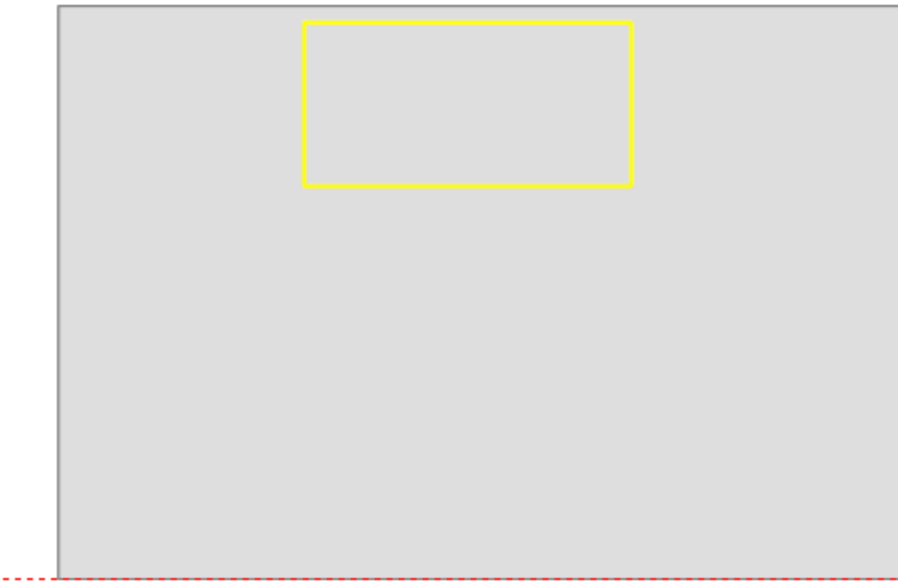

You can use the mouse in conjunction with Key Ins if you prefer. So you could use the mouse to define the window offset from the origin and then use Key Ins to define the window dimensions or vice versa.

Tip: You can also enter negative x and y values when keying in offset and coordinates.

3.2.12.2 Draw Sub-Surface

For details of using the 'Draw sub-surface' tool, please refer to the Draw window tool.

3.2.12.3 Draw Door

For details of using the 'Draw door' tool, please refer to the Draw window tool.

3.2.12.4 Draw Hole

For details of using the 'Draw hole' tool, please refer to the Draw window tool.

Holes are used for two purposes:

1. **As an air flow path between a zone and an other zone or outside** (in much the same way that Vents are used). Holes cannot be controlled - they simply represent a constant air flow path in the fabric.

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Holes are modelled using perfectly clear glass plus in some cases an airflow path. When positioned on ***external*** walls holes only generate airflow in Simulation calculations when the Natural ventilation building model option is set to Calculated. External holes have no effect on airflow in Heating and Cooling Design calculations but will create an additional heat flow path categorised in the heat balance as 'Glazing'. Holes positioned on ***internal*** partition walls are used to mix the air between the two adjacent zones when the Scheduled Natural ventilation building model option is set and for Heating and Cooling design calculations. They also provide an air flow path when the Calculated option is set. You can find information on the way Mixing works by looking at the Vent Operation help topic.

2. **For merging zones together**. Note that the Merge zones connected by holes option must be selected for this to work.

Tip: It is possible to draw large holes in surfaces to give the effect of the surface having being removed. This can be a useful technique for creating atrium-type spaces, connecting gable roof blocks to the main roof block and generally merging zones in different blocks.

Note: Holes transmit solar radiation.

Warning: Large horizontal holes
You can draw holes in internal and external horizontal surfaces to model the flow of air between different floors or to outside, but you should be aware when using the Calculated natural ventilation option that Large horizontal openings are only modelled approximately.

3.2.12.5 Draw Vent

For details of using the 'Draw vent' tool, please refer to the Draw window tool.

3.2.12.6 Edit Surfaces

You can select custom openings and move, clone (copy), delete and rotate them. Default openings cannot be selected and manipulated in this way.

You can also clear custom openings their default state using the Clear Data to Default command.

3.2.13 Editing Openings at the Building Level

Building block façade openings can be selected at the building level and subsequently moved, copied or deleted. In order to edit openings at the building level you first need to select the openings either clicking on them using the Select tool or by dragging a selection window around them:

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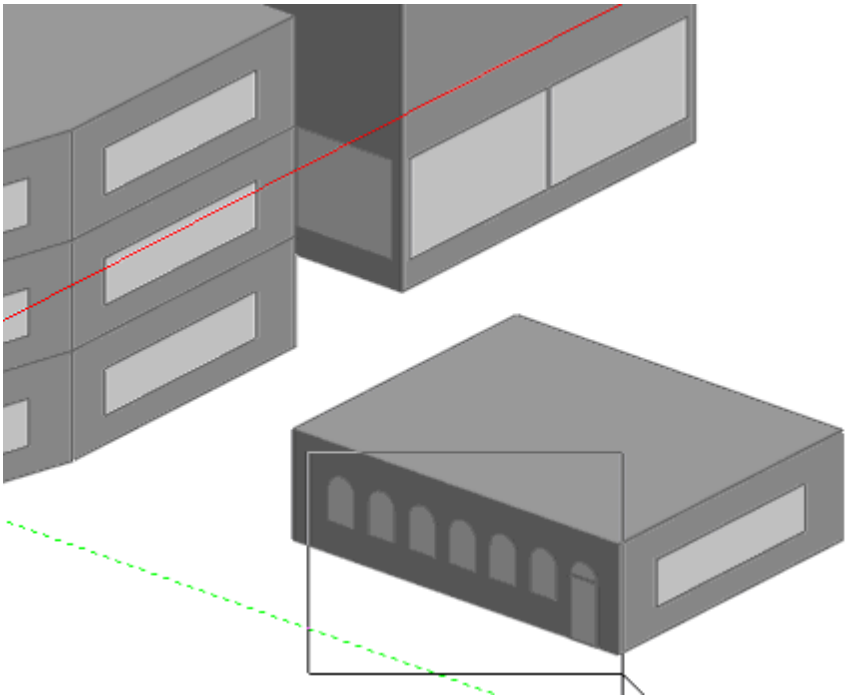
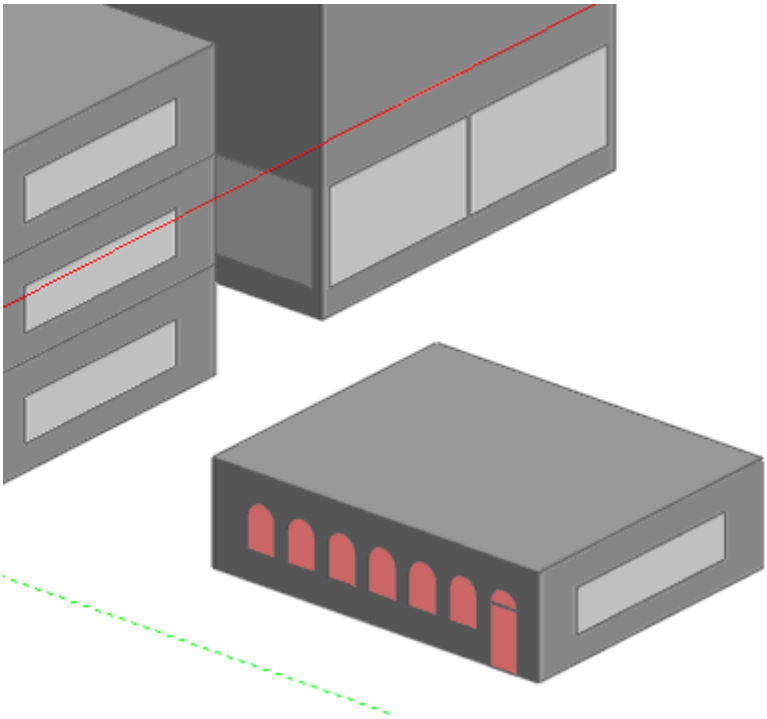


The selected openings are highlighted:



When you have selected an opening, you will see that the Move selected object(s), Clone selected object(s) and Delete selected object(s) icons are active and you can select one of these commands. As an example, the arched openings and doorway are to be copied onto the angled façade of the leftmost block. To begin with, you need to delete the existing opening on the angled façade by selecting it and clicking on the Delete selected object(s) icon:

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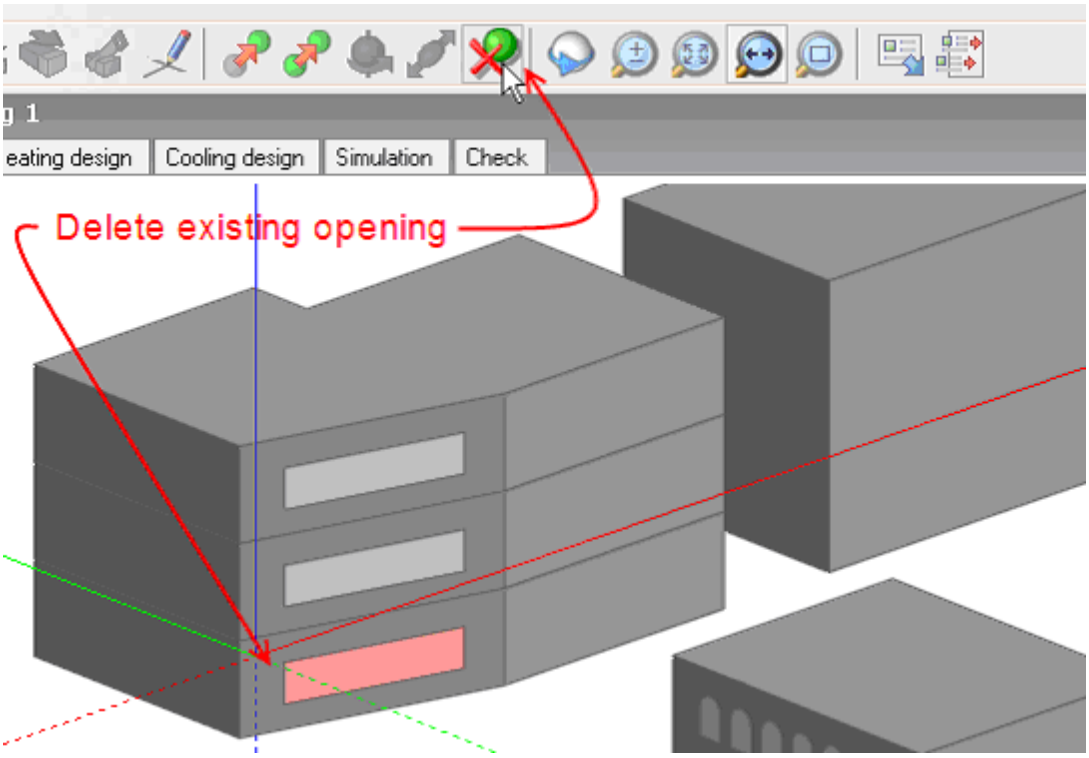
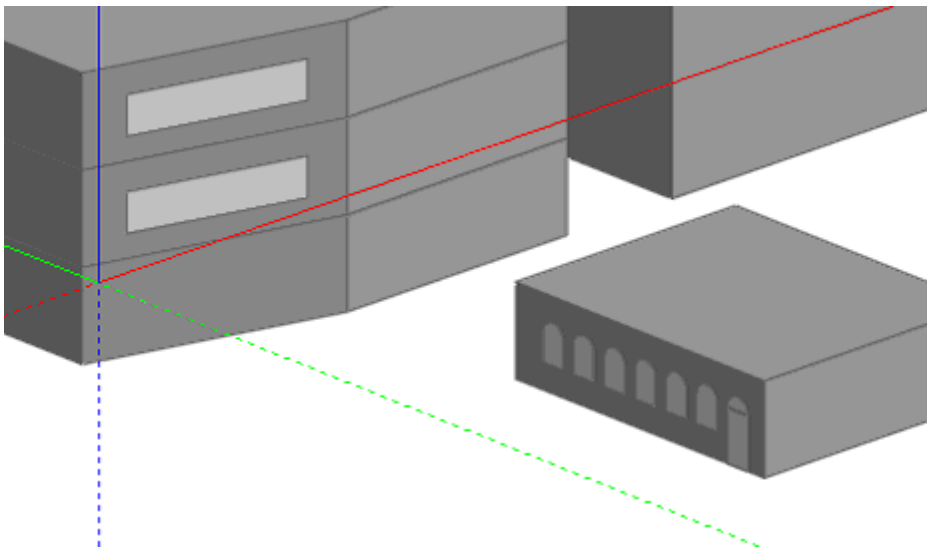


Opening removed:



All opening edit operations at the building level automatically convert default openings to custom openings, which is why you need to remove the existing opening.

Then in order to copy the openings, you need to select a **handle point** and you can do this by first clicking on the Clone selected object(s) command icon and then clicking on the required handle point - the endpoint snap will help in selecting the handle point.

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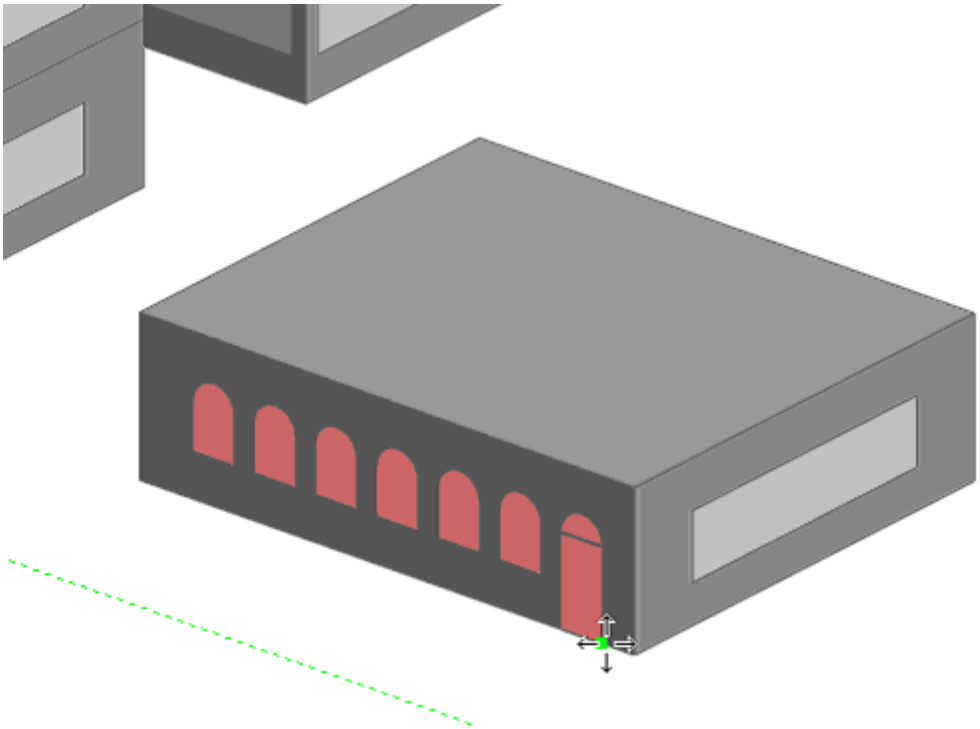
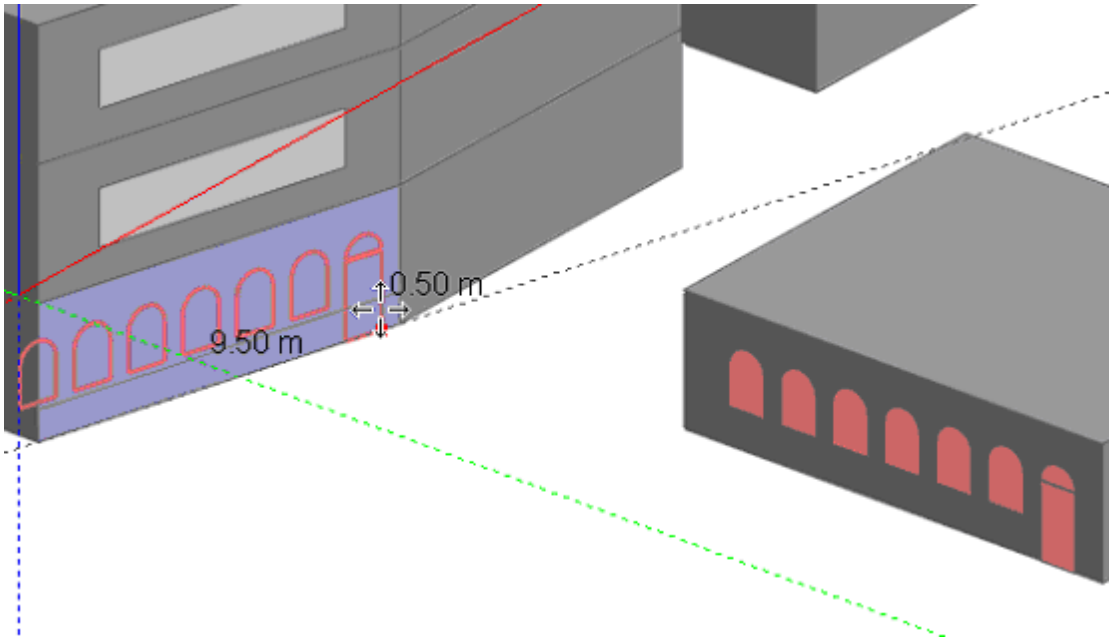


First select the handle point, and then position the copy using the various snaps:



As you move the copied openings across each block façade you will see them automatically snap into the façade plane and after positioning the openings, you can then click on the mouse key to add the openings in the required position:

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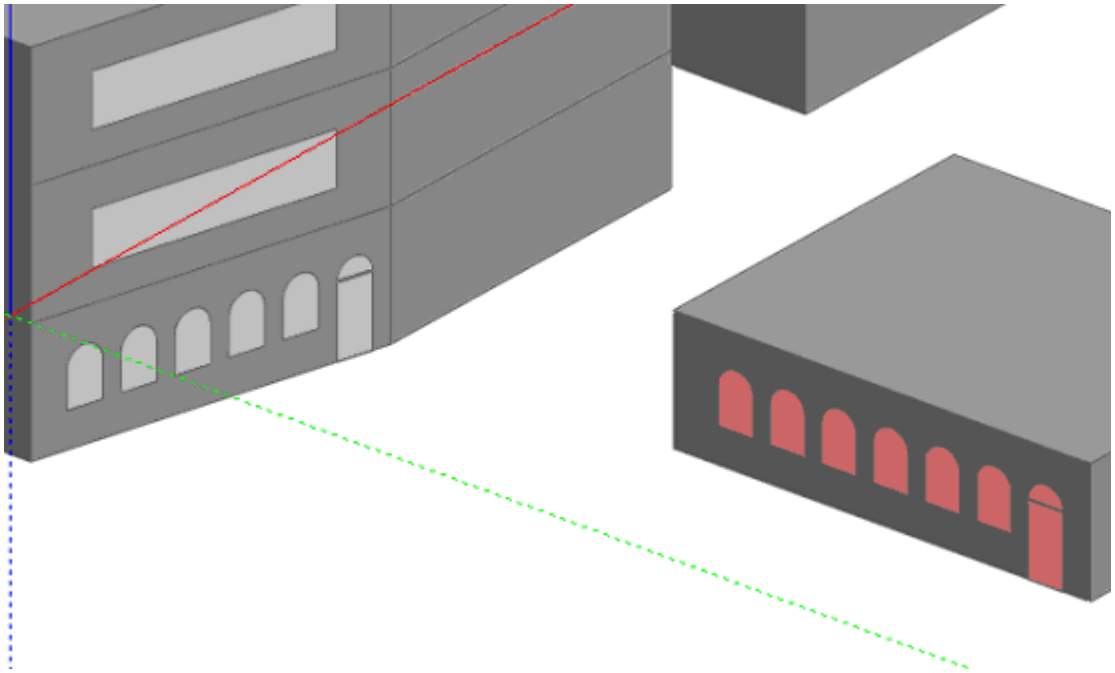

You will see that any copies that won't fit into the selected location are automatically discarded.

Note: You can select openings on multiple planes but in this case the openings can only be deleted, not moved or copied.

3.2.14 Undo/Redo

Undo/Redo commands accessed from Edit menu

To undo a geometric operation, select Undo from the 'Edit' menu (or press <Control-Z>) and similarly to redo a geometric operation, select Redo (or press <Control-R>). Because many of the geometric operations are dependent on specific model levels, you may need to undo or redo navigation operations before you get to the required geometric operation, e.g. 'Undo - Go to surface', etc.

Note that Undo/Redo applies only to geometric operations and *changes to Model Data cannot be undone*.

3.2.15 Rebuild

Rebuild command accessed from Tools menu

Sometimes the adjacencies within DesignBuilder models can become corrupt. The **Rebuild** command recalculates the zone, surface and adjacency geometry from the base building elements.

3.2.16 Rezone Block

Rezone block command accessed from Tools menu

Use the Rezone block command to refresh the zoning in the current block. The command converts any outline partitions in a block to standard partitions and updates zones due to any partitions that may have deleted. The command should be used when the Automatic block zoning model option is switched off. When the option is switched on (and it has always been switched on during the life of a model) then you will

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not need to use this command.

3.3 Model Data

Model Data is the data for the **site** on the tabs:

- Location
- Legislative region and insulation standards

and data for **building model** on the tabs:

- Activity (usage)
- Constructions
- Openings (windows, doors, vents, holes, sub-surfaces)
- Lighting
- HVAC

The Model Data tabs are shown in the Edit Screen - User Interface help topic.

At the point of the building is created, building model default data is initially loaded at the building level from templates. This is inherited from the building to blocks to zones to surfaces and to openings. This default model data can be overwritten by making edits on the Model Data tabs on the Edit screen.

3.3.1 Site Data

The **site data** represents information about the site including its location, the conditions of the ground, weather, the legislative region and the maximum allowed U-values for new buildings. All buildings on the site use the same site model data.

To edit site model data, go to site level and click on the Location or Region tabs (below).

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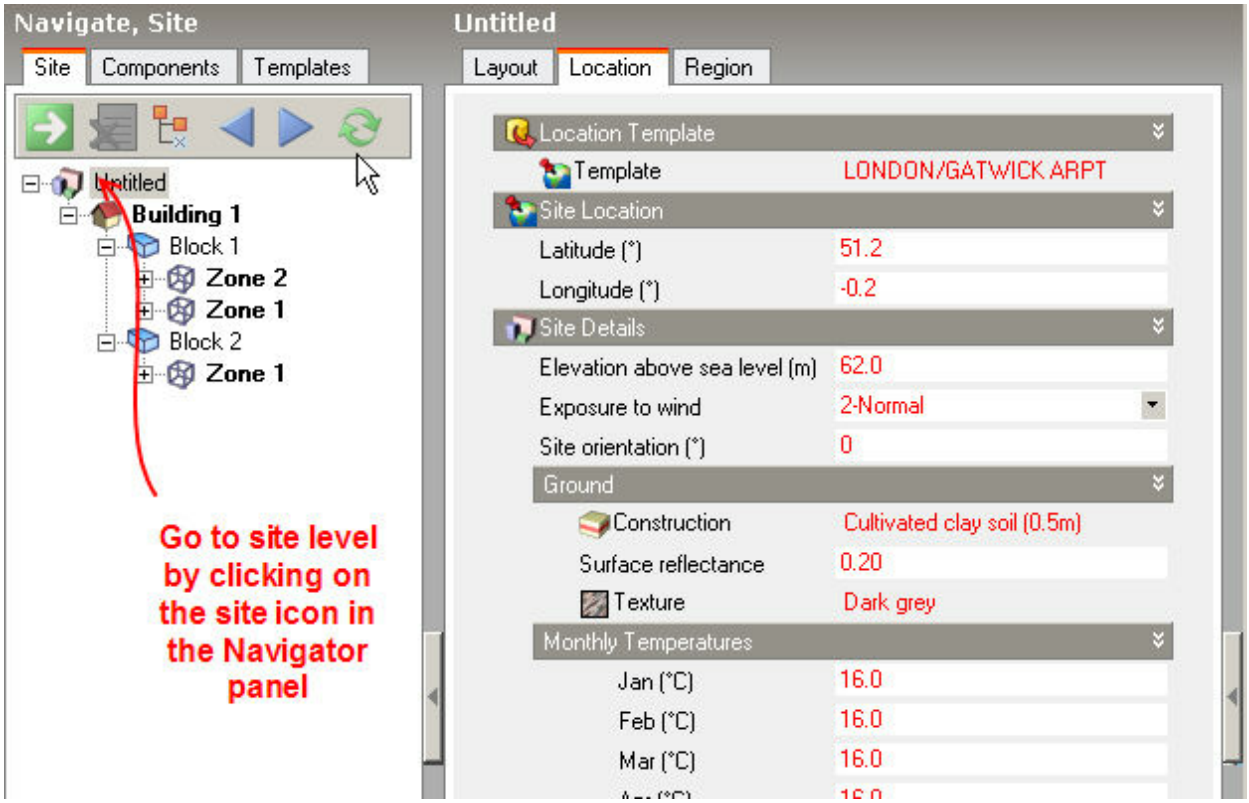


You can easily change the location of the site by making a selection for the Location template on the Location tab or by using the Load data from template command.

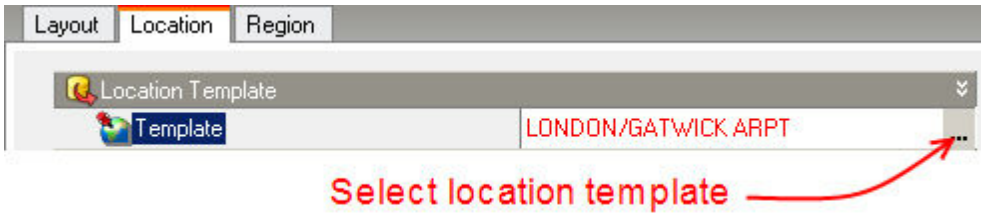
Alternatively you can open up the headers on the Location and Region tabs to edit the data.

3.3.1.1 Location

Location tab on model data at Site level

Use this screen to edit the location of the site, its weather data, the daylight savings and energy codes which apply.

You can load a location from the database by clicking on Template line under the Location Template header then on the '...' at the right of the line.



When you make a selection from the list of location templates data from selected template will be loaded to the model.

Alternatively you can use the Load data from template tool.

You can enter data on:

- Site location,
- Site details,

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- Time and daylight saving,
- Simulation weather,
- Winter design weather and
- Summer design weather.

3.3.1.1.1 Site Location

Location tab on model data at Site level

You can set the latitude/longitude of the site as well as a number of site characteristics.

Latitude

The latitude (in degrees) of the site. By convention, North Latitude is represented as positive; South Latitude as negative. Minutes should be represented in decimal fractions of 60. (15' is 15/60 or .25)

Longitude

The longitude (in degrees) of the site. By convention, East Longitude is represented as positive; West Longitude as negative. Minutes should be represented in decimal fractions of 60. (15' is 15/60 or .25).

3.3.1.1.2 Site Details

Location tab on model data at Site level

Elevation above sea level

This data are defines the elevation of the site relative to sea level and is passed directly to EnergyPlus for use in pressure-related calculations. It is also used to calculate air density within DesignBuilder when calculating volumetric flow rates from cooling loads.

Site orientation

The site orientation is the angle of the site plan view relative to North. For example enter 45 to rotate the building(s) clockwise by 45°.relative to North (screenshot example below). This is the quickest and most reliable way to rotate all the buildings on the site
relative to North and allows you to keep your x and y axes aligned with the building.

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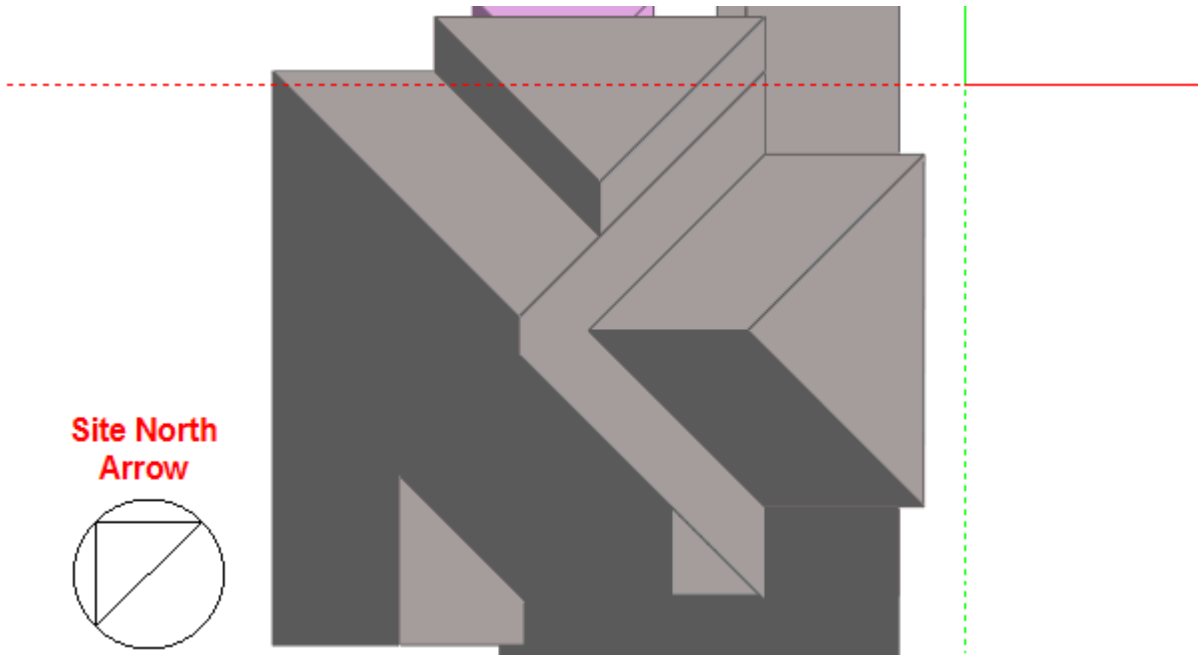

North is indicated by the direction of the North arrow in the sketch plan view (above).

Note: Rotating the building(s) is also possible but once this is done it is more difficult to make further geometric edits because, for rotations other than 90, 180 or 270°, the x and y axes will be out of alignment with the building.

Exposure to wind

The exposure to wind model data affects the pressure coefficients used when the 'Calculated' Natural ventilation option is set. It also affects the calculation of U-values but these are not used in EnergyPlus simulations.

GROUND

Add ground construction layers to surfaces in contact with ground

You can choose to add ground construction layers to any surface that is in contact with the ground. If you select this option you can define the construction layers of the ground.

Note: this option only affects the model for buildings having the Separate constructions model option set.

Ground construction

When the **Add ground construction layers to surfaces in contact with ground** option is selected you can define the construction layers to be added below any ground floor constructions and on the outside of any other surfaces which have been specified as being adjacent to ground.

More info on ground modelling.

Ground texture

The texture used to represent the ground in the rendered view on the Visualisation screen.

Ground surface reflectance

This field is a decimal number between 0.0 and 1.0 and is used to characterize the average reflectivity of the

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ground throughout the year. Ground reflectance data is used to calculate the ground reflected solar amount. This fractional amount is used in the following equation:

GroundReflectedSolar = (BeamSolar x COS(SunZenithAngle) + DiffuseSolar) x GroundReflectance

Important note on ground reflection

Reflection from the ground is calculated even if the Reflections option is not used, but if Reflections are not calculated the ground plane is considered unobstructed, i.e., the shadowing of the ground by the building itself or by component blocks is ignored.

Shadowing of the ground by component blocks is only taken into account if the Reflections option is used.

Conclusion: Switch Reflections on for accurate shading calculations.

Snow reflected solar modifier

A number between 0.0 and 10.0 which is used to modify the basic ground surface reflectance when snow is on the ground. Note that the value of $GroundReflectance_{Used}$ (below) must be <=1.

$GroundReflectance_{Used}$ = GroundReflectance x $Modifier_{Snow}$

During simulations, the ground is considered to be snow-covered when the SnowDepth data in the hourly weather file is > 0.

Snow reflected daylight modifier

A number between 0.0 and 10.0 which is used to modify the basic ground surface reflectance when snow is on the ground. Note that the value of $DaylightingGroundReflectance_{Used}$ (below) must be <=1.

$DaylightingGroundReflectance_{Used}$ = GroundReflectance x $Modifier_{Snow}$

During simulations, the ground is considered to be snow-covered when the SnowDepth data in the hourly weather file is > 0.

Ground monthly temperatures

There are 12 fields allowing you to represent the mean ground temperature for each month of the year. These temperatures are used as the outside surface temperature for all surfaces adjacent to ground.

Note that the depth at which these temperatures apply depends on the thickness of the ground construction (see above) added to the main floor/wall construction.

Caution: It may not be appropriate to use the 'undisturbed' ground temperatures calculated by the weather converter and listed in EnergyPlus hourly weather files as these values are too extreme for the soil under typical large conditioned buildings. A reasonable default value is 2°C less than the average monthly indoor space temperature is appropriate for such buildings. For *smaller buildings*, the ground temperatures will be closer to be undisturbed ground temperatures.

More information about determining appropriate ground temperatures is given in Ground Modelling and in the EnergyPlus Auxiliary Programs document.

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SITE PRECIPITATION

The Site precipitation data is used to describe the amount of precipitation on all **Green roof** surfaces over the course of the simulation. Precipitation includes both rain and the equivalent water content of snow. Precipitation is not yet described well enough in the usual building weather data file. So this object is used to provide the data using Schedule objects that define rates of precipitation in meters per hour. A set of schedules for site precipitation have been developed for USA weather locations and are provided with EnergyPlus in the data set called "PrecipitationSchedulesUSA.idf." The user can develop schedules however they want. The schedules in the data set were developed using EnergyPlus' weather file (EPW) observations and the average monthly precipitation for the closest weather site provided by NOAA. EPW files for the USA that were based on TMY or TMY2 include weather observations for Light/Moderate/Heavy rainfall, however most international locations do not include these observations. The values were modeled by taking the middle of the ranges quoted in the EPW data dictionary. The assumed piecewise function is shown below.

Amount	Light	Medium	Heavy
m/hr	0.0125	0.052	0.1

The values were inserted on hour by hour basis for the month based on the observations. Then each month was rescaled to meet the average precipitation for the month based on the 30-year average (1971-2000) provided by the NOAA/NCDC. Therefore, the flags in the EPW file match the precipitation schedules for the USA. Note that summing the average monthly precipitation values will not give you the average yearly precipitation. The resulting value may be lower or higher than the average yearly value. Once the typical rainfall pattern and rates are scheduled, the Site Precipitation data provides a method of shifting the total rainfall up or down for design purposes. Wetter or drier conditions can be modelled by changing the Design Annual Precipitation although the timing of precipitation throughout the year will not be changed.

Design annual precipitation

Magnitude of total precipitation for an annual period to be used in the model. Value selected by the user to correspond with the amount of precipitation expected or being assumed for design purposes. The units are in meters. This field works with the following two fields to allow easily shifting the amounts without having to generate new schedules. Units are m/yr or ft/yr

Irrigation schedule

The schedule that describes the rate of precipitation. The precipitation rate schedule is analogous to weather file data. However, weather files for building simulation do not currently contain adequate data for such calculations. Therefore, EnergyPlus schedules are used to enter the pattern of precipitation events. The values in this schedule are the average rate of precipitation in meters per hour. The integration of these values over an annual schedule should equal the nominal annual precipitation.

Nominal annual precipitation

Magnitude of annual precipitation associated with the rate schedule. This value is used to normalize the precipitation.

ROOF IRRIGATION

The Site Roof irrigation data is used to describe the amount of irrigation on all **Green roof** surfaces over the course of the simulation. You can define time-varying irrigation data using a maximum irrigation value and a schedule. There is also an option to apply some intelligence to the irrigation system to avoid over-watering the green roof.

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Irrigation type

Defines the way irrigation water is supplied. Select from:

- **1-Scheduled** - water is proved using the maximum irrigation rate and schedule modifier (below).
- **2-Smart** - as Scheduled but overrides the irrigation to be off when the earth is 30% or more saturated with water.

Max irrigation rate

Maximum rate of irrigation per hour. Units are m/hr or ft/hr.

Irrigation schedule

The schedule defining the operation of the irrigation system. A schedule value of zero means the irrigation is switched off and a value of 1 means that the **Max irrigation rate** is used.

3.3.1.1.3 Time and Daylight Saving

Location tab on model data at Site level

Select the Time zone for the site location. The time zone defines both the standard time meridian and information on daylight saving. Generally you should leave this as the default for the location.

You can override daylight savings to be off by unchecking the **Use daylight saving** model data.

DesignBuilder models the effect of daylight saving time where the clocks are moved forward one hour in the summer months in most non-equatorial countries. The timing of this is handled automatically using the Time zones database when you load data from one of the Location templates supplied with the program.

There are some factors you should be aware of:

- In EnergyPlus, summer Daylight saving works by adding the number of hours specified in the Time zone data (usually 1 hour) to the local mean time to get the time to determine schedule operation. Because Simulation results are displayed in **local mean time,** during the summer when daylight saving time is in use, occupancy and equipment etc will appear to start 1 hour earlier in the day than it does in the winter. To help you pinpoint this, DesignBuilder prints the times when daylight saving starts and ends on the graph.
- When comparing results with and without Daylight saving you will notice:
  - Solar radiation data has exactly the same timing with and without daylight saving.
  - Occupancy, equipment (and other aspects of building operation controlled by schedules) will start 1 hour earlier with daylight saving.
- Visualisations use local mean time when setting the position of the sun for site shading analysis. Again you can account for daylight saving time by adding 1 hour to the time during summer months to see shading for local clock time.

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3.3.1.1.4 Simulation Weather Data

Location tab on model data at Site level

DesignBuilder uses EnergyPlus epw format hourly weather data for simulations (heating and cooling design calculations use much simpler design weather data).

You can review, edit and convert weather using the Edit hourly weather data dialog.

You can also add your own hourly weather data.

3.3.1.1.5 Winter Design Weather Data

Location tab on model data at Site level

You can select the 'confidence' of the design data, i.e. the probability that the design data will be at the very extreme of conditions encountered over recent years. Select either 99.6 or 99% confidence (i.e. 0.4 or 1% chance of more extreme winter weather occuring).

The weather data used in heating design calculations:

- Minimum outside dry-bulb temperature - the design outside air temperature
- Co-incident wind speed and direction. - the speed of the wind and its direction for design conditions. Note that the direction is not used at the moment.

3.3.1.1.6 Summer Design Weather Data

Location tab on model data at Site level

You can select the 'confidence' of the design data, i.e. the probability that the design data will be at the very extreme of conditions encountered over recent years. This risk can be specified based on dry or wet-bulb temperatures, for 99.6, 99 and 98% confidence (i.e. 0.4, 1 or 2% chance of more extreme weather occuring).

The weather data used in cooling design calculations:

- Maximum outside dry-bulb temperature - the maximum dry bulb air temperature over the day
- Minimum outside dry-bulb temperature - the minimum dry bulb air temperature (nighttime)
- Wet-bulb temperature at the time of the maximum dry-bulb temperature.

The daily temperature profile used in the cooling design calculations is calculated from the maximum and minimum values using a sinusoidal curve and assuming that the maximum temperature lags maximum solar elevation by 3 hours.

3.3.1.2 Legislative Region and Insulation Standards

Region tab on model data at Site level

The data on the tab is related to the Legislative Region and associated insulation standards of the site.

Legislative region

A Legislative region in DesignBuilder is typically a whole country or a region, province or state within a

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country which has its own building control powers. The legislative region contains information on:

- Local energy codes and building regulations
- Carbon dioxide emission factors for a range of fuels

3.3.1.2.1 Energy codes/insulation standards

Region tab on model data at Site level

You can select the mandatory energy code in force as well as three additional levels of reference insulation standards to represent buildings with 'Uninsulated', 'Stock average' and 'Best practice' construction standards.

This data is used:

- To identify the mandatory energy code in force in the region.
- To set the insulation levels used when the 'Pre-design' Construction and glazing Model option is selected.
- When calculating asset ratings.

Note that if you change any of this data, the insulation standards of the constructions in the <System> category will be automatically updated.

3.3.2 Building Model Data

Building Model Data can be entered at building, block, zone and surface levels (but not at site level). The set of data shown will depend on the level in the hierarchy (building, block etc) and on the Model options selected.

Default data is inherited from the level above in the hierarchy and is shown in blue, while 'user data', i.e. data you have explicitly set (or loaded from template) is shown in red. You can clear user data back to its default state so it inherits from the level above using the Clear data to default command.

Building Model Data is laid out on the tabs:

- Activity
- Construction
- Openings
- Lighting
- HVAC
- Options
- CFD

Each of these categories of data has a template selection at the top of the tab allowing rapid loading of the data from template.

Tip: **Use DesignBuilder defaults wisely!**
Take care to enter the minimum amount of data to get the most from the inheritance system. For example if all zones in a particular block have the same activity called say 'Office work', you should set the activity at block level and not multiple times at zone level. Equally if all the blocks in the building have the same activity, you should set the data at the building level and allow the blocks to inherit the data from the building. By keeping the amount of user data to a minimum, you will find it quicker to make changes at a later date. Clearly it is much faster to change a few Model Data items at building and block level than it is to make multiple changes at zone or surface levels.

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See also section on Model Data Hierarchy & Data Inheritance.

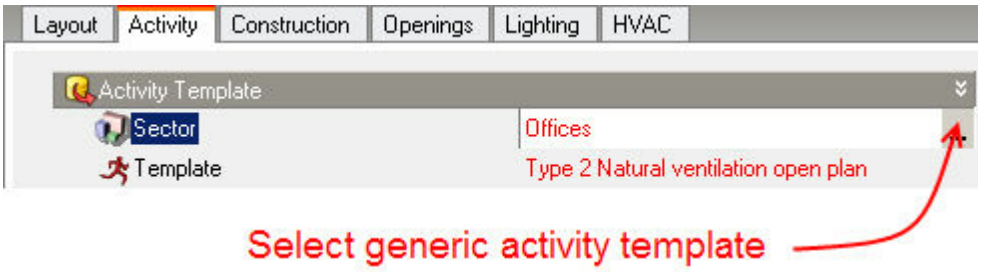
3.3.2.1 Activity Data

Activity tab in model data

Data on the Activity tab allows you to define the activity (usage) of the zones including information on:

- Zone Type (block and zone level only)
- Include zone
- Occupancy
- Metabolic rates
- Holidays (building level only)
- Domestic Hot Water (DHW)
- Environmental control
- Computer gains
- Office equipment gains
- Miscellaneous gains
- Catering gains
- Process gains

You can load generic activity data by clicking on the Template option under Activity Template and then by clicking on the '...' at the right of the line (below).



When you make a selection from the list of Activity templates, data from selected template will be loaded to the model.

Alternatively you can use the Load data from template tool.

Note that the appropriate Sector is loaded with the activity (screenshot above).

All Activity data (apart from Holidays) is used to generate simulation data at the **Zone level**. Holiday data is used at **Building level**.

3.3.2.1.1 Zone Type

Activity tab in model data under Activity Template header

The zone type can be set at block or zone level on the Activity tab and can be one of:

- **1-Standard** - considered to be occupied and heated or cooled.
- **2-Semi-exterior unconditioned** - is an unoccupied zone in the building which is neither heated or cooled. Examples of 'semi-exterior unconditioned' spaces are roofspaces, sunspaces, car parks etc).

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- **3-Cavity** - the zone is a cavity such as the glazed cavity within a double facade or a Trombe wall. This algorithm correctly calculates the convection coefficients for a narrow sealed vertical cavity based on the ISO 15099 standard.
- **4-Plenum** - the zone is a plenum which is unoccupied and has no heating, cooling, or mechanical ventilation (though of course air will flow through it to meet the needs of the zones it serves).

Semi-exterior unconditioned

When the Zone type is set to **2-Semi-exterior unconditioned**, the program asks you 'Do you want to load default unoccupied data including Activity, HVAC and Construction templates'. If you reply 'Yes' then the zone is set as unoccupied by loading **<None>** Activity, HVAC and Lighting template data.

Also Semi-exposed constructions will be used instead of standard partitions for adjacencies with 'Semi-exterior unconditioned' zones. For example the wall between an occupied office and a car park would use the Semi-exposed construction, whereas the wall between two occupied offices would use Internal partition construction.

Also roofspace insulation is applied in the floor of a Semi-exterior unconditioned space when it is above a Standard space, if 'Floor fitted above floor slab' option is checked.

Glazed cavity

When the Zone type is set to **3-Cavity**, the program asks you 'Do you want to load default 'Glazed cavity' data including appropriate convection coefficients, calculation options and Activity, HVAC and Construction templates'. If you reply 'Yes' then the following changes are made:

- The zone is set as unoccupied by loading **<None>** Activity, HVAC and Lighting template data.
- Suspended floors and ceilings are switched off.
- The **5-Cavity** Inside convection algorithm is set for Cooling design, Heating design and simulation calculations.
- The **3-Full interior and exterior** Solar distribution algorithm is set for Cooling design and simulation calculations.

You can find out more about Trombe wall simulations in the Modelling Issues section.

Plenum

When the Zone type is set to **4-Plenum**, the program asks you 'Do you want to load default plenum data including appropriate convection coefficients, calculation options and Activity and HVAC templates?'. If you reply 'Yes' then the following changes are made:

- The zone is set as unoccupied by loading **<None>** Activity, HVAC and Lighting template data.
- Suspended floors and ceilings are switched off.
- The **4-Ceiling diffuser** Inside convection algorithm is set for Cooling design, Heating design and simulation calculations.

You can find out more about modelling plenums under HVAC.

3.3.2.1.2 Zone Multiplier

Activity tab in model data under Activity Template header

The Zone multiplier data allows you to reduce the size of your model in cases where there are similar zones by specifying that certain zones are repeated and so only need to be simulated once. A typical use is for multi-storey buildings with identical (or very similar) floors. The image below is taken from the *Zone Multiplier Example.dsb* file and illustrates how the zone multiplier mechanism works.

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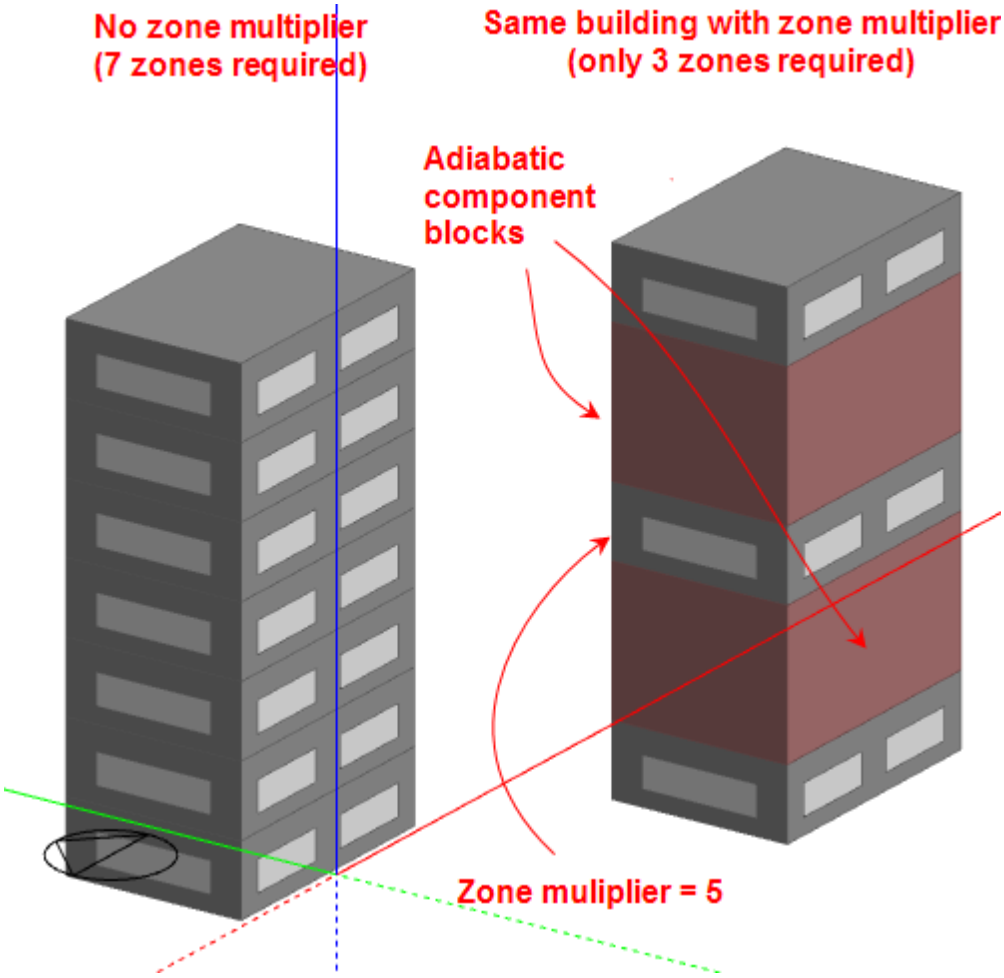

The basic 7 storey building on the left doesn't use the zone multiplier and, as each storey has one zone, the whole building contains 7 zones. The equivalent building on the right has been simplified by using the zone multiplier. The single mid-storey zone has a zone multiplier of 5 which means that during the simulation the zone is treated as if there were 5 of them. In particular the energy consumption and HVAC airflow rates are multiplied by 5 so the results for the reduced building match approximately with that of the non-reduced model.

The top floor and ground floor zones cannot be combined using the zone multiplier of course because they have roof and ground adjacencies respectively and so must be retained in the reduced model. However the 5 mid-floor zones all have the same operation and adjacencies and so can be combined.

Note the use of the adiabatic component blocks. These have 3 functions:

- They set the adjacency to be adiabatic for the underside of the top floor zone, the top and underside of the mid-floor zone and the top of the ground floor zone.
- Ensures correct shading in a more complex model.
- Improves the look of the reduced model to match that of the non-reduced model.

For other ways to simplify models see Simplification on the Advanced tab of the Model options.

3.3.2.1.3 Include Zone

Activity tab in model data under Activity Template header

By default zones are included in the model but they can be excluded. You may wish to exclude a zone or series of zones from the analysis to focus on a smaller part of the building for example a single shop within a mall and in this case you should uncheck the **Include zone** option on the Activity tab for zones as

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appropriate.

Surfaces between included and excluded zones are modelled as being adiabatic, i.e .heat is transferred into the wall mass as if the temperature of the excluded zone is the same as the included zone.

3.3.2.1.4 Occupancy

Activity tab in model data

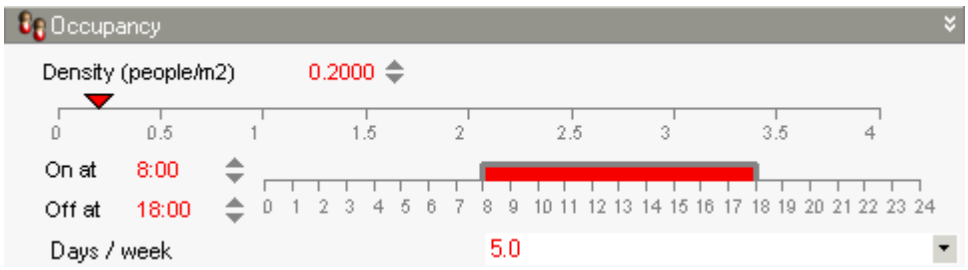
The Occupancy model data defines the number people in the space and the times of occupancy. This data is used in Simulations and Cooling design calculations together with the Metabolic heat output of the occupants and Holidays to calculate the heat input to the building. Occupancy gains are not included in the Heating design calculations.

The Occupancy schedule setting (Typical workday or Schedule) may also be used to control internal gains and/or HVAC systems if the appropriate Model options are set.

Set the number of people (per unit floor area) and the occupancy times. Occupancy time definition depends on the Timing model data option:

TYPICAL WORKDAY TIMING MODEL OPTION

When the Typical workday Timing model option is set, the occupancy times are controlled by setting **On** and **Off** values and the number of days in the working week.

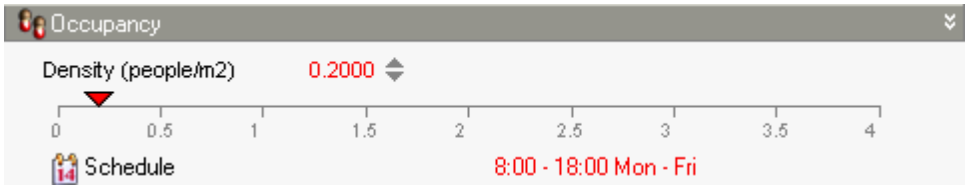


In above example there are 0.2 people per m2 between 8am and 6pm and there are no people outside these times and at weekends.

Note: The Occupancy **Days / week** is set at the building level only and is used for all other Typical workday schedules in the model apart from Mechanical ventilation, and Heating and Cooling operation which have their own Days / week data.

SCHEDULE TIMING MODEL OPTION

When the Schedule Timing model option is set, the occupancy times are controlled by a Schedule . The metabolic gains for the zone are multiplied by the value of the Schedule at each time step in the simulation so you can define periods of part-occupancy using Schedule values less than 1. Use values of 0 to indicate that the space in unoccupied.



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In above example number of people per m2 is calculated as *0.2 x Schedule value*.

3.3.2.1.5 Metabolic

Activity tab in model data under Occupancy header

Set the metabolic rate according to the level of activity within the space.

The metabolic rate determines the amount of heat gain per person in the zone *under design conditions*. This value is modified during simulations based on a correlation to account for variations in space temperature. *This should be borne in mind when analysing occupant sensible heat output in the Cooling design and Simulation results screens*. Metabolic rate has units Watts per person and represents the total heat gain per person including convective, radiant, and latent heat. An internal algorithm is used to determine what fraction of the total is sensible and what fraction is latent. Then, the sensible portion is divided into radiant and convective portions based on the assumption of 50% radiant fraction.

Metabolic rate data can be found in the ASHRAE Handbook of Fundamentals, Chapter 8, Table 5.

DesignBuilder data is derived from this data and is for adult males having typical surface area of 1.8m2. For women multiply the adult male value by 0.85 and for children multiply by 0.75.

The **metabolic factor** accounts for people of various sizes. Enter 1.00 for men, 0.85 for women, 0.75 for children or you can use an average value if there is a mix of sizes.

Background

Heat is generated in the human body by oxidation at a rate called the metabolic rate. This heat is dissipated from the body surface and respiratory tract by a combination of radiation, convection and evaporation. The relative proportions of sensible and latent heat from people is a complex function of the metabolic rate and the environmental conditions.

EnergyPlus uses a polynomial function to divide the heat gain into sensible and latent portions. More details can be found in the EnergyPlus EngineeringDoc.pdf documentation.

Note: sensible/latent split for occupancy gains is affected by the internal temperature and relative humidity. With high internal temperatures, people cool themselves largely by evaporation and sensible occupancy gains can be very low or even zero.

Clothing

You can define the clothing levels of the occupants for summer and winter periods. This data is used when generating comfort output.

Clothing reduces the body's heat loss and is classified according to its insulation value. The unit normally used for measuring clothing's insulation is the Clo unit. The more technical unit is m²°C/W is also used frequently (1 Clo = 0.155 m2°C/W). The Clo value can be calculated by adding the Clo value of each individual garment. The insulation value for individual garments can be found in ISO 7730.

Clo-Values for Different Items of Clothing and Ensembles

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Clothing	Clo-Value
Naked	0.0
Briefs	0.06
T-shirt	0.09
Bra and panties	0.05
Long underwear	
upper	0.35
lower	0.35
Shirt	
White, short sleeve	0.14
heavy, long sleeve	0.29
Add 5% for tie or turtleneck	
Skirt	0.22-0.70
Trousers	0.26-0.32
Sweater	0.20-0.37
Socks	0.04-0.10
Light summer outfit	0.3
Working clothes	0.8
Typical indoor winter clothing combination	1.0
Heavy business suit	1.5

Note 1: Clo-values are additive, so one can calculate the clo-value for a person wearing a T-shirt and light socks (0.09 + 0.04) = 0.13. (Adapted from ASHRAE Fundamentals and "Technical Review of Thermal Comfort," Bruel and Kjaer, No. 2, 1982.)

Note 2: for equatorial regions where there is no clear 'summer/winter' weather pattern you should generally use a 'summer' value for both summer and winter clo factors.

3.3.2.1.6 Holidays

Activity tab in model data (building level only)

You can define the dates of holidays to include the effect of building shutdown during certain periods of the year. Do this by selecting the Holidays option under the Holidays header on the Activity tab at building level. Holidays defined at building level in this way are used for the whole simulation. The holiday data is used for Simulations only (not Heating/Cooling Design Calculations) and allows you to set the **Holiday Schedule** and the number of days of holiday per year. The possible holiday dates are defined in the Holiday schedule and the actual holidays to be used in the simulation are selected from the top of the list based on the **Holidays per year** data entered.

Note that you must have at least as many days defined in the holiday schedules as you request here. If there are insufficient holidays in the holiday schedule you will receive an error message to this effect prior to a simulation.

With the data in the above screenshot there will be 5 holidays and the dates are given by the first 5 holiday dates set in the 'Typical UK' Holiday schedule.

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The way holiday definition works depends on the Timing model option:

COMPACT SCHEDULES

When the Timing model option is Schedules you can use Compact schedules. The value of Compact schedule output during holidays can be defined explicitly using the Holidays day type following **For:**.

For example:

```
SCHEDULE:COMPACT,
Bedroom_Cool,
Temperature,
Through: 31 Dec,
For: Weekdays SummerDesignDay WinterDesignDay,
Until: 05:00, 0.5,
Until: 09:00, 1,
Until: 24:00, 0.5,
For: Weekends,
Until: 05:00, 0.5,
Until: 24:00, 1,
For: Holidays AllOtherdays,
Until: 24:00, 0;
```

The Holiday data in this Compact schedule indicates that the cooling is switched off on holidays.

7/12 SCHEDULES

Holiday operation is not defined explicitly and holidays use the same data as Sundays

TYPICAL WORKDAY

Holidays use the same data as Sundays

3.3.2.1.7 Environmental Control

Activity tab in model data

The heating and cooling setpoint temperatures, minimum fresh air per person and illuminance requirements are related to the Activity or Usage of the zone and are accessed by opening the Environmental Comfort group header.

HEATING SETPOINT TEMPERATURES

Heating setpoint temperature

Defines the ideal temperature (i.e. the setting of the heating thermostat) in the space when heating is required. Its meaning depends on the Temperature control calculation option. When using **1-Air temperature** control the **Heating setpoint temperature** corresponds to the air temperature in the space and when it is set to set to **2-Operative temperature** it is the operative temperature (MAT+MRT)/2.

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Heating setback setpoint temperature

Some buildings require a low level of heating during unoccupied periods to avoid condensation/frost damage or to prevent the building becoming too cold and to reduce peak heating requirements at startup. Enter the setpoint temperature to be used at night-time, weekends and other holidays during the heating season. Its meaning depends on the Temperature control calculation option (above).

Note: when using the **Typical workday** timing option, this setback temperature set point is only applied during unoccupied periods such as night-time and holidays during the heating season. It is not applied during the summer (if heating is switched off during the summer.)

Note: if the setback temperature set does not appear to affect results when using a Compact schedule, this may be because the **Zone setpoint heating schedule** selected uses only 0 and 1, not the 0.5 required to access setback temperature. See Defining setpoint temperature schedules for more on this.

COOLING SETPOINT TEMPERATURES

Cooling setpoint temperature

Defines the ideal temperature (i.e. the setting of the cooling thermostat) in the space when cooling is required. Its meaning depends on the Temperature control calculation option. When using **1-Air temperature** control the **Cooling setpoint temperature** corresponds to the air temperature in the space and when it is set to set to **2-Operative temperature** it is the operative temperature (MAT+MRT)/2.

Note: the cooling setpoint temperature must be higher than the heating setpoint temperature.

Cooling setback setpoint temperature

Some buildings require a low level of cooling during unoccupied periods to prevent the building becoming too hot and to reduce the startup cooling load the next morning. Enter the setpoint temperature to be used at night-time, weekends and other holidays during the cooling season. Its meaning depends on the Temperature control calculation option (above).

Note: when using the **Typical workday** timing option, this setback temperature set point is only applied during unoccupied periods such as night-time and holidays during the cooling season. It is not applied during the winter (if cooling is switched off during the winter.)

Note: if the setback temperature set does not appear to affect results when using a Compact schedule, this may be because the **Zone setpoint cooling schedule** selected uses only 0 and 1, not the 0.5 required to access setback temperature. See Defining setpoint temperature schedules for more on this.

HUMIDITY SETPOINT TEMPERATURES

When using VAV, CAV and unitary Compact HVAC systems you can control humidity. More specifically, in the case of AHU-type systems the humidity in a control zone is actually controlled. The humidification and dehumidification setpoints can be defined here

Humidification setpoint

The zone humidistat Relative humidity setpoint for humidification (0 to 100%).

Dehumidification setpoint

The zone humidistat Relative humidity setpoint for dehumidification (0 to 100%).

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VENTILATION SETPOINT TEMPERATURES

Natural ventilation cooling setpoint temperature

The natural ventilation cooling setpoint temperature controls the activation of **natural ventilation**. If the inside air temperature is greater than this setpoint temperature (and the natural ventilation operation schedule is on) then natural ventilation can take place. The way this works depends on the Natural ventilation model option.

Note that when using the Calculated natural ventilation model option windows and vents are only opened when:

- The inside air temperature is above this cooling setpoint temperature, and
- The inside air temperature is greater than the outside air temperature, and
- The operation schedule allows ventilation.

Also, the data under the Calculated Natural Ventilation header on the Advanced tab of the Model Options dialog can modify ventilation control behaviour.

When using the Scheduled natural ventilationmodel option the **Max natural ventilation in-out delta T** (below) can prevent natural ventilation from occurring if the outside air temperature is too high.

Natural ventilation max natural ventilation in-out delta T

The Natural ventilation Max. int-out temp difference is used for Scheduled natural ventilationonly and is the temperature difference between the indoor and outdoor air dry bulb temperatures below which ventilation is shut off. This is to allow ventilation to be stopped if the temperature outside is too warm and could potentially heat the space. It is not related to preventing drafts.

For example, if you specify a maximum delta temperature of 2°C, ventilation is assumed to be available if the outside air temperature is at least 2°C cooler than the zone air temperature. If the outside air dry bulb temperature is less than 2°C cooler or warmer than the indoor dry bulb temperature, then ventilation is automatically turned off. The values for this field can include negative numbers. This allows ventilation to occur even if the outdoor temperature is above the indoor temperature. The Delta Temperature control works in the code in the following way:

if (*IndoorTemp - OutdoorTemp)* < *Max ventilation in-out delta T* then ventilation is ***not allowed***.

For example:

Value of Natural ventilation Max in-out delta T	Effect
0	Natural ventilation only operates when *OutdoorTemp* < *IndoorTemp*
-50	Natural ventilation unrestricted by Inside-Outside delta T
2	Natural ventilation only operates when *OutdoorTemp* + *2* < *IndoorTemp*

Tip: input a large negative number to allow ventilation even if the outdoor temperature is greater than the indoor temperature. This useful for uncontrolled natural ventilation (open windows) or as a way to estimate the effect of required ventilation air for load calculations.

See also Defining setpoint temperature schedules.

Mechanical ventilation cooling setpoint temperature

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The mechanical ventilation cooling setpoint temperature controls the activation of mechanical ventilation when using Simple HVAC data. If the inside air temperature is greater than this setpoint temperature (and the mechanical ventilation operation schedule is on) then mechanical ventilation can take place. This data is not used when working with Compact HVAC data.

Mechanical ventilation max natural ventilation in-out delta T

The mechanical ventilation Max int-out temp difference is used for Scheduled mechanical ventilationonly and is the temperature difference between the indoor and outdoor air dry bulb temperatures below which ventilation is shut off. This is to allow ventilation to be stopped if the temperature outside is too warm and could potentially heat the space. It is not related to preventing drafts.

For example, if you specify a maximum delta temperature of 2°C, ventilation is assumed to be available if the outside air temperature is at least 2°C cooler than the zone air temperature. If the outside air dry bulb temperature is less than 2°C cooler or warmer than the indoor dry bulb temperature, then ventilation is automatically turned off. The values for this field can include negative numbers. This allows ventilation to occur even if the outdoor temperature is above the indoor temperature. The Delta Temperature control works in the code in the following way:

if (*IndoorTemp - OutdoorTemp)* < *Max ventilation in-out delta T* then ventilation is ***not allowed***.

For example:

Value of Mechanical ventilation Max in-out delta T	Effect
0	Mechanical ventilation only operates when *OutdoorTemp* < *IndoorTemp*
-50	Mechanical ventilation unrestricted by Inside-Outside delta T
2	Mechanical ventilation only operates when *OutdoorTemp* + *2* < *IndoorTemp*

Tip: input a large negative number to allow ventilation even if the outdoor temperature is greater than the indoor temperature. This useful for uncontrolled mechanical ventilation or as a way to estimate the effect of required ventilation air for load calculations.

See also Defining setpoint temperature schedules.

MINIMUM FRESH AIR

Minimum fresh air data is defined on the Activity tab because the fresh air requirement of the people in the zone depends on the activity (use) of the space.

Fresh air (fresh air *flow per person)*

The **Minimum fresh air per person** defines the fresh air requirements of each person in the zone and is used to generate appropriate mechanical outside air distribution rates when the *mechanical* air distribution Flow type on the HVAC tab is set to any of:

- **2-Min fresh air per person** where the fresh air flow rate is calculated as the **Fresh air (l/s//person)** x People / m2 x Zone floor area (m2)
- **4-Min fresh air (Sum per person + per area)** where the fresh air flow rate is the sum of 'per person' and 'per area' fresh air requirements
- **5-Min fresh air (Max per person and per area)** where the fresh air flow rate based on 'per person' is compared with 'per area' and the minimum is used.

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This data is also used to calculate *natural* ventilation outside air flow rates into the zone when the natural ventilation Flow type on the HVAC tab is set to **2-Min fresh air per person.**

Mech vent (fresh air *flow per area)*

The **Mech vent fresh air per area** defines the fresh air requirements of the zone per floor area and is used to calculate mechanical outside air distribution rates when the mechanical air distribution Flow type on the HVAC tab is set to any of:

- **3-Min fresh air (Per area),** where the fresh air flow rate is calculated as the **Mech vent per floor area** (l/s/m2) x Zone floor area (m2)
- **4-Min fresh air (Sum per person + per area),**
- **5-Min fresh air (Max per person and per area).**

The data is not currently used for natural ventilation.

LIGHTING

Target illuminance

The desired lighting level (in lux) at the first daylighting sensor. This is also the lighting level that would be produced at this sensor position at night if the overhead electric General lighting were operating at full input power. Recommended values depend on type of activity; they may be found, for example, in the Lighting Handbook of the Illuminating Engineering Society of North America and in CIBSE A Guide. A typical value for general office work (excluding computer terminals) is 500 lux.

Display lighting

The typical density of display lighting for the activity. This value is used as a default on the Lighting tab for the Task and Display lighting density.

3.3.2.1.8 Domestic Hot Water (DHW)

Activity tab in model data

In DesignBuilder the amount of DHW consumed is considered to be a function of the activity in the zone. For example, there is a demand assumed to arise from the occupants of an office for activities such as washing hands and washing up cups. This demand is associated with the office rather than the toilet or tea room. Thus the demand from each space needs to be assigned to a DHW system even if the system itself is not present in the space.

The effect of hot water consumption (hot water taps, showers etc) on building energy use can be included in your thermal model by switching on DHW on the HVAC tab.

The data on this tab defines the hot water consumption rate in each zone as l/day/m2 data (gal/day/ft in IP units). **The DHW consumption data is only used if DHW is selected on the HVAC tab**.

Note: Convert **l/person/day** DHW consumption data to the DesignBuilder format by multiplying it by occupant density (people/m2).

The hot water generation system is defined under DHW on the HVAC tab.

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3.3.2.1.9 Computer Gains

Activity tab in model data

Set the thermal gains due to computers and other related IT equipment per unit floor area. The fuel is assumed to be *electricity*, all gains are assumed to be emitted to the space and

Radiant Fraction

This field is a decimal number between 0.0 and 1.0 and is used to characterise the amount of long-wave radiant heat being given off by computer equipment in a zone. The radiant fraction will be multiplied by the total energy consumed by electric equipment and (1-Fraction lost) to give the amount of long wavelength radiation gain from computer equipment in a zone. A value of zero means that the heat gain is entirely convective in which case all the heat is transferred to the air node in simulations. A value of 1 means that the gain is entirely radiative in which case all the heat is distributed to the inside surfaces. a typical value is somewhere between 0.1 and 0.2.

If the Internal gains operate with occupancy model option is not selected you can also set the operation schedule.

Entering large computer gains

Some spaces like IT suites and dealing rooms have very high computer gain densities and you may need to Switch off the slider controls from the Program options dialog to enter these high values.

3.3.2.1.10 Office Equipment Gains

Activity tab in model data

Set the thermal gains due to office equipment per unit floor area. The fuel is assumed to be *electricity*, all gains are assumed to be emitted to the space.

Radiant Fraction

This field is a decimal number between 0.0 and 1.0 and is used to characterise the amount of long-wave radiant heat being given off by office equipment in a zone. The radiant fraction will be multiplied by the total energy consumed by electric equipment and (1-Fraction lost) to give the amount of long wavelength radiation gain from office equipment in a zone.

A value of zero means that the heat gain is entirely convective in which case all the heat is transferred to the air node in simulations. A value of 1 means that the gain is entirely radiative in which case all the heat is distributed to the inside surfaces. a typical value is somewhere between 0.1 and 0.4.

If the Internal gains operate with occupancy model option is not selected you can also set the operation schedule.

3.3.2.1.11 Miscellaneous Gains

Activity tab in model data

Gain

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Set the design level of energy consumption due to miscellaneous equipment per unit floor area. The actual heat gain to the space may be reduced through the **Fraction lost** data (below).

The Gain, entered in Watts/m2 (or Watts/ft2), is typically used to represent the maximum fuel consumption of miscellaneous equipment in a zone that is then multiplied by a schedule fraction (below). This is slightly more flexible in that the design level could be a 'diversity factor' applied to a schedule of real numbers. Note that while the schedule value can vary from hour to hour, the design level field is constant.

Fuel

The fuel can be selected from a drop down list. Note that these fuels are currently mapped to a shorter list in the results as follows:

Fuel in Model Data	Mapped to Fuel in Output
1-Electricity from grid	Electricity
2-Natural gas	Gas
3-Oil	Oil
4-Coal	Solid
5-LPG	Gas
6-Biogas	Gas
7-Anthracite	Solid
8-Smokeless fuel (including coke)	Solid
9-Dual fuel appliances (mineral + wood)	Other
10-Biomass	Other
11-Waste heat	Other

Fraction lost

This field is a decimal number between 0.0 and 1.0 and is used to characterise the amount of 'lost' heat being given off by the equipment in a zone. The number specified in this field will be multiplied by the total energy consumed by equipment to give the amount of heat which is 'lost' and does not impact the zone energy balances. This might correspond to electrical energy converted to mechanical work or heat that is vented to the atmosphere.

Latent fraction

This field is a decimal number between 0.0 and 1.0 and is used to characterize the amount of latent heat given off by miscellaneous equipment in a zone. The number specified in this field will be multiplied by the total energy consumed to give the amount of latent energy produced by the miscellaneous equipment. This latent energy affects the moisture balance within the zone.

Radiant Fraction

This field is a decimal number between 0.0 and 1.0 and is used to characterise the amount of long-wave radiant heat being given off by miscellaneous equipment in a zone. The radiant fraction will be multiplied by the total energy consumed by electric equipment and (1-Fraction lost) to give the amount of long wavelength radiation gain from miscellaneous equipment in a zone. A value of zero means that the heat gain is entirely convective in which case all the heat is transferred to the air node in simulations. A value of 1 means that the gain is entirely radiative in which case all the heat is distributed to the inside surfaces. a typical value is somewhere between 0.1 and 0.5.

If the Internal gains operate with occupancy model option is not selected you can also set the operation schedule.

Calculation

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The fuel input to the equipment ultimately appears as heat that contributes to zone loads. In the simulation this heat is divided into four different fractions. Three of these are given by the input fields Latent fraction, Radiant fraction and Fraction lost. The convected fraction, defined as the fraction of the heat from electric equipment convected to the zone air, is calculated by the program as:

$$F_{convected} = 1.0 - (\text{Latent fraction} + \text{Radiant fraction} + \text{Fraction lost})$$

You will get an error message if Fraction Latent + Fraction Radiant + Fraction Lost exceeds 1.0.

3.3.2.1.12 Catering Gains

Activity tab in model data

Set the thermal gains due to cooking and other catering activities per unit floor area.

Gain

Set the design level of energy consumption due to catering equipment per unit floor area. The actual heat gain to the space may be reduced through the **Fraction lost** data (below).

The Gain, entered in Watts/m2 (or Watts/ft2), is typically used to represent the maximum fuel consumption of catering equipment in a zone that is then multiplied by a schedule fraction (below). This is slightly more flexible in that the design level could be a 'diversity factor' applied to a schedule of real numbers. Note that while the schedule value can vary from hour to hour, the design level field is constant.

Entering large Catering gains

Kitchens can have very high process gain densities and you may need to Switch off the slider controls from the Program options dialog to enter these high values.

Fuel

The fuel can be selected from a drop down list. Note that these fuels are currently mapped to a shorter list in the results as follows:

Fuel in Model Data	Mapped to Fuel in Output
1-Electricity from grid	Electricity
2-Natural gas	Gas
3-Oil	Oil
4-Coal	Solid
5-LPG	Gas
6-Biogas	Gas
7-Anthracite	Solid
8-Smokeless fuel (including coke)	Solid
9-Dual fuel appliances (mineral + wood)	Other
10-Biomass	Other
11-Waste heat	Other

Fraction lost

This field is a decimal number between 0.0 and 1.0 and is used to characterise the amount of 'lost' heat being given off by the catering equipment in a zone. The number specified in this field will be multiplied by

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the total energy consumed by equipment to give the amount of heat which is 'lost' and does not impact the zone energy balances. This might correspond to cooker heat that is vented to the atmosphere through an extract hood.

Latent fraction

This field is a decimal number between 0.0 and 1.0 and is used to characterize the amount of latent heat given off by catering equipment in a zone. The number specified in this field will be multiplied by the total energy consumed to give the amount of latent energy produced by the catering equipment. This latent energy affects the moisture balance within the zone.

Radiant fraction

This field is a decimal number between 0.0 and 1.0 and is used to characterise the amount of long-wave radiant heat being given off by catering equipment in a zone. The radiant fraction will be multiplied by the total energy consumed by electric equipment and (1-Fraction lost) to give the amount of long wavelength radiation gain from catering equipment in a zone. A value of zero means that the heat gain is entirely convective in which case all the heat is transferred to the air node in simulations. A value of 1 means that the gain is entirely radiative in which case all the heat is distributed to the inside surfaces. a typical value is somewhere between 0.1 and 0.5.

If the Internal gains operate with occupancy model option is not selected you can also set the operation schedule.

Calculation

The fuel input to the equipment ultimately appears as heat that contributes to zone loads. In the simulation this heat is divided into four different fractions. Three of these are given by the input fields Latent fraction, Radiant fraction and Fraction lost. The convected fraction, defined as the fraction of the heat from electric equipment convected to the zone air, is calculated by the program as:

$$F_{convected} = 1.0 - (\text{Latent fraction} + \text{Radiant fraction} + \text{Fraction lost})$$

You will get an error message if Fraction Latent + Fraction Radiant + Fraction Lost exceeds 1.0.

3.3.2.1.13 Process Gains

Activity tab in model data

Set the thermal gains due to process heat per unit floor area.

Gain

Set the design level of energy consumption due to process activity per unit floor area. Process heat is the heat from any manufacturing or industrial process which is part of the business activity. The actual heat gain to the space may be reduced through the **Fraction lost** data (below).

The Gain, entered in Watts/m2 (or Watts/ft2), is typically used to represent the maximum fuel consumption of process equipment in a zone that is then multiplied by a schedule fraction (below). This is slightly more flexible in that the design level could be a 'diversity factor' applied to a schedule of real numbers. Note that while the schedule value can vary from hour to hour, the design level field is constant.

LARGE Process gains

Spaces such as industrial units can have very high process gain densities and you may need to Switch off the
slider controls from the Program options dialog to enter these high values.

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NEGATIVE Process gains

You can enter negative process gains for modelling the cooling effect from refrigeration units such as those found in supermarkets where the refrigerator doors may open and cool air may enter the zone.

Note that Negative process gains are modelled in EnergyPlus using 'Other equipment' data instead of the usual
'Electrical equipment' data. The energy from negative process gains is calculated in the same way as for positive gains.

Fuel

The fuel can be selected from a drop down list. Note that these fuels are currently mapped to a shorter list in the results as follows:

Fuel in Model Data	Mapped to Fuel in Output
1-Electricity from grid	Electricity
2-Natural gas	Gas
3-Oil	Oil
4-Coal	Solid
5-LPG	Gas
6-Biogas	Gas
7-Anthracite	Solid
8-Smokeless fuel (including coke)	Solid
9-Dual fuel appliances (mineral + wood)	Other
10-Biomass	Other
11-Waste heat	Other

Fraction lost

This field is a decimal number between 0.0 and 1.0 and is used to characterise the amount of 'lost' heat being given off by the process equipment in a zone. The number specified in this field will be multiplied by the total energy consumed by equipment to give the amount of heat which is 'lost' and does not impact the zone energy balances. This might correspond to electrical energy converted to mechanical work or heat that is vented to the atmosphere.

Latent fraction

This field is a decimal number between 0.0 and 1.0 and is used to characterize the amount of latent heat given off by process equipment in a zone. The number specified in this field will be multiplied by the total energy consumed to give the amount of latent energy produced by the process equipment. This latent energy affects the moisture balance within the zone.

Radiant fraction

This is a decimal number between 0.0 and 1.0 and is used to characterise the amount of long-wave radiant heat being given off by process equipment in a zone. The radiant fraction will be multiplied by the total energy consumed by electric equipment and (1-Fraction lost) to give the amount of long wavelength radiation gain from process equipment in a zone. A value of zero means that the heat gain is entirely convective in which case all the heat is transferred to the air node in simulations. A value of 1 means that the gain is entirely radiative in which case all the heat is distributed to the inside surfaces. a typical value is somewhere between 0.1 and 0.5.

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If the Internal gains operate with occupancy model option is not selected you can also set the operation schedule.

Calculation

The fuel input to the equipment ultimately appears as heat that contributes to zone loads. In the simulation this heat is divided into four different fractions. Three of these are given by the input fields Latent fraction, Radiant fraction and Fraction lost. The convected fraction, defined as the fraction of the heat from electric equipment convected to the zone air, is calculated by the program as:

$$F_{convected} = 1.0 - (\text{Latent fraction} + \text{Radiant fraction} + \text{Fraction lost})$$

You will get an error message if Fraction Latent + Fraction Radiant + Fraction Lost exceeds 1.0.

3.3.2.2 Construction Data

Construction tab in model data

DesignBuilder uses construction components to model the conduction of heat through walls, roofs, ground and other opaque parts of the building envelope . Constructions can be selected on the Constructions model data tab to define the thermophysical and visual properties of the various internal and external surface elements in the building. From the Construction model data tab, you can access data on:

- Construction and
- Airtightness

Open the headers to enter construction details where they are different from those loaded from the template. Any changes you make that are different from the template data originally loaded shown in bold red.

TEMPLATES

General Construction and glazing

When you have the **General** Construction and glazing model option set, you can load generic Construction data by clicking on the Template option under Construction Template and then by clicking on the '...' at the right of the line (below).

When you make a selection from the list of Construction templates data from selected template is loaded to the model.

Pre-design Construction and glazing

Alternatively if you have the **Pre-design** Construction and glazing model option set, generic constructions can be loaded using the sliders shown below. In this case you are restricted to the 4x3 construction templates from the <System> Construction templates category identified by the combination of Insulation and Thermal mass selected on the sliders. For example in the screenshot shown below data will be loaded

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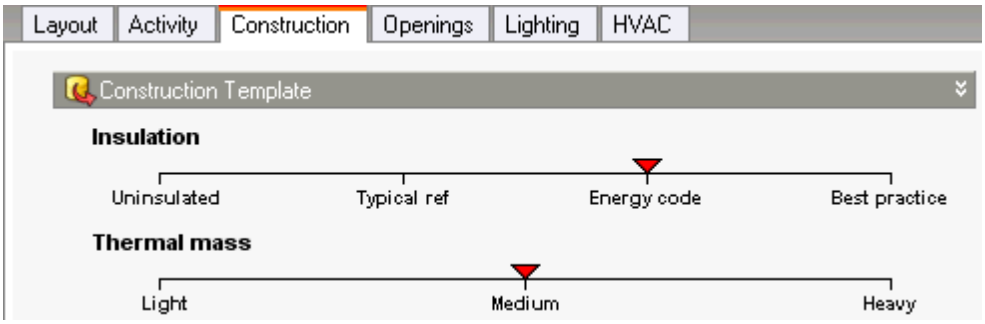
from the 'Energy code - Mediumweight' template.



Or in either case you can use the Load data from template tool.

3.3.2.2.1 Constructions

Construction tab in model data

From the Construction tab, you can open the group header boxes to edit detailed makeup of the construction of walls, roofs, floors, ceilings, partitions etc. used in the building.

The default/inheritance system used in DesignBuilder allows you to define building constructions quickly and easily by loading data from templates and by making global settings at building, block and zone levels.

There are 2 alternative methods for representing floors/slabs/ceilings in DesignBuilder depending on the setting of the Floor/slab/ceiling representation model option :

- **Combined** - option generally recommended for flexibility and ease of use.
- **Separate** - only option in v 1.2 and earlier allows you to set up floor/slab/ceiling configuration by making selections in model data.

Other construction data:

- Sub-Surface Construction - construction details of sub-surfaces (opaque surfaces within surfaces)
- Internal Thermal Mass - how to define additional thermal mass
- Component Block - construction and surface properties of component blocks
- Adjacency - defining special adjacency conditions
- Surface Convection - defining special surface convection options

Note: data on the Openings tab can be used to define the layout of the facade.

View/Edit construction details

To inspect the details of a selected construction, click on the icon to the left of the appropriate data entry box (Learning mode only). Alternatively double-click the icon to view/edit the data in a dialog.

Note: Please be aware that **all settings made on the Constructions Model data tab are defaults, (unless you are working at the surface level).** Model data at the surface level (inherited from the zone above or directly set) defines the thermal and visual characteristics of the surface in the model.

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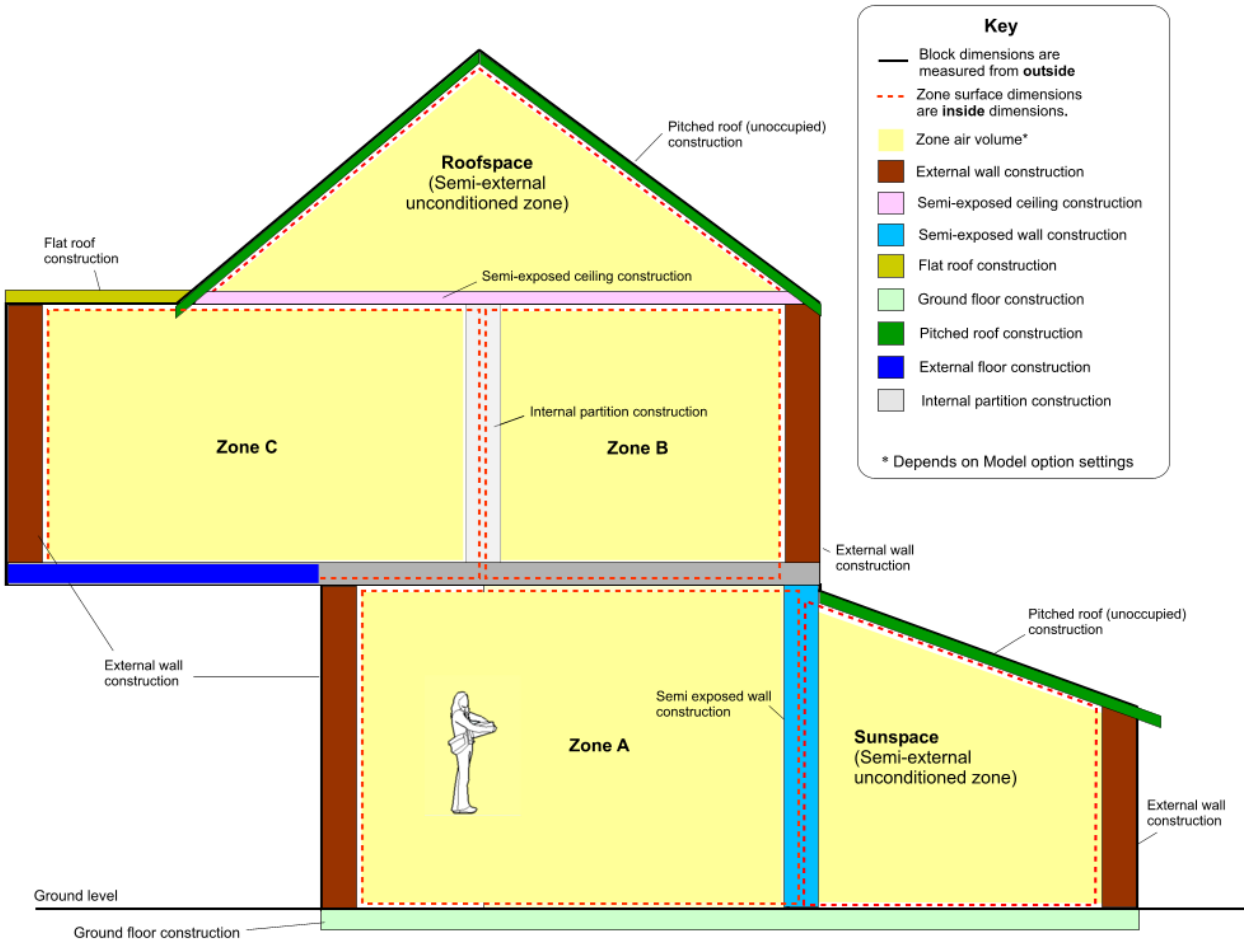
Construction tab in model data under Construction header

When the Floor/slab/ceiling representation model option is set to Combined wall, floor and roof constructions are all defined using simple constructions as shown in the diagram below.

The diagram shows:

- The location/definition of the various categories of construction
- Block and zone dimension definitions

Schematic Diagram Showing 'Combined' Floor/Slab/Ceiling Constructions



External walls

The external wall construction defines the construction of walls adjacent to outside. The definition of walls is given by the roof-wall transition angle model option. In cold climates this construction will generally include an insulating layer.

Flat roof

Flat roof constructions apply to external horizontal surfaces. The construction used to represent the flat roof should include any slabs, insulation and suspended ceiling layers. If there are no flat roof surfaces, just ignore this data.

Pitched roof (occupied)

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The Pitched roof (occupied) construction applies to external sloped surfaces when they appear in occupied zones. In cold climates this construction will generally include an insulating layer. If there are no pitched roof surfaces, just ignore this data.

The definition of 'pitched roof' is given by the roof-wall transition angle model option.

Pitched roof (unoccupied)

The Pitched roof (unoccupied) construction applies to external sloped surfaces when they appear in semi-exterior unconditioned zones. This construction will generally not include any insulation layers. If there are no pitched roof surfaces, just ignore this data.

The definition of 'pitched roof' is given by the roof-wall transition angle model option.

Internal partitions

The internal partition construction defines the construction of internal partitions (walls used to divide blocks into zones) and inter-block partitions (internal walls shared with other blocks). Internal partitions are used where both zones are occupied. When one of the zones is occupied and the other is not the **Semi-exposed walls** construction data is used (below). If there are no partitions just ignore this data.

The construction for the partition should represent all the layers in the actual internal wall. There is only one element representing the partition between the zones and all it's layers should be defined in the same construction.

Note that changes in model data settings at the surface level are reflected as equivalent changes in data for the partition on the other side.

SEMI-EXPOSED

Semi-exposed walls

The semi-exposed wall construction applies to walls between fully occupied zones and Semi-exterior unconditioned zones. They will normally include some insulation. DesignBuilder determines which of the zones is relatively 'outside' and uses this information to correctly order the material layers in the wall. The material layer defined in the construction as being 'outermost' (first-in list) will be the one adjacent to the semi-external unconditioned zone. If there are no semi-exposed wall surfaces, just ignore this data.

Semi-exposed roof

The semi-exposed roof construction is used between occupied zones and Semi-exterior unconditioned zones (such as roofspace/attic/loft spaces) above. The construction should include any slabs, insulation and suspended ceiling layers. DesignBuilder determines which of the zones is relatively 'outside' and uses this information to correctly order the material layers in the roof. If there are no semi-exposed roof surfaces, just ignore this data.

Semi-exposed floor

The semi-exposed floor construction is used between occupied zones and Semi-exterior unconditioned spaces below. The construction should include any slabs, insulation and raised floor layers. If there are no semi-exposed floor surfaces, just ignore this data.

FLOORS

Ground floor

The ground floor construction is used between all internal zones and the ground and can be optionally

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combined with additional ground constructions layer(s) as shown in diagram above. The site ground temperatures are applied to the outside of all surfaces adjacent to ground. If there are no ground wall surfaces, just ignore this data.

External floor

External floors are floors that are adjacent to outside air, e.g. the floor of a cantilevered part of the building or where for any other reason there is no ground or other zone below. The External floor construction should include any slabs, insulation and raised floor layers. If there are no external floor surfaces, just ignore this data.

Internal floor

The internal floor construction defines the makeup of floors between occupied zones including any slabs, air gaps, raised floors and suspended ceilings. It will not usually contain insulation. Where the zone above is unoccupied the **Semi-exposed roof** construction is used instead. Likewise where the zone below is unoccupied the **Semi-exposed floor** construction is used instead. If there are no internal floor surfaces, just ignore this data.

ZONE STATISTICS

Zone Volume

The zone volume is calculated for all zone geometries and by default, the volume is the actual air volume of the space excluding the volume of floor and ceiling constructions but including half the volume of partition walls. The volume of the floor constructions can be optionally subtracted from the zone volume by using the Zone volume calculation Model options.

Other related information

1. Block and Zone Dimensions is an introductory section explaining how to enter blocks and the relationship with zones.
2. Also see Constructions for how to edit the construction configuration.
3. And the Model Geometry Example section for a detailed worked example illustrating how surface areas and volumes are calculated.

Construction tab in model data under Construction header

When the Floor/slab/ceiling representation model option is set to Separate floor/ceiling and roof constructions are defined by combining constructions as shown in the diagram below.

The diagram shows:

- The location/definition of the various categories of construction
- How constructions are combined (behind-the-scenes) to form the floor/ceiling 'combo constructions' passed to calculations.
- Block and zone dimension definitions

Schematic Diagram Showing 'Separate' Floor/Slab/Ceiling Constructions

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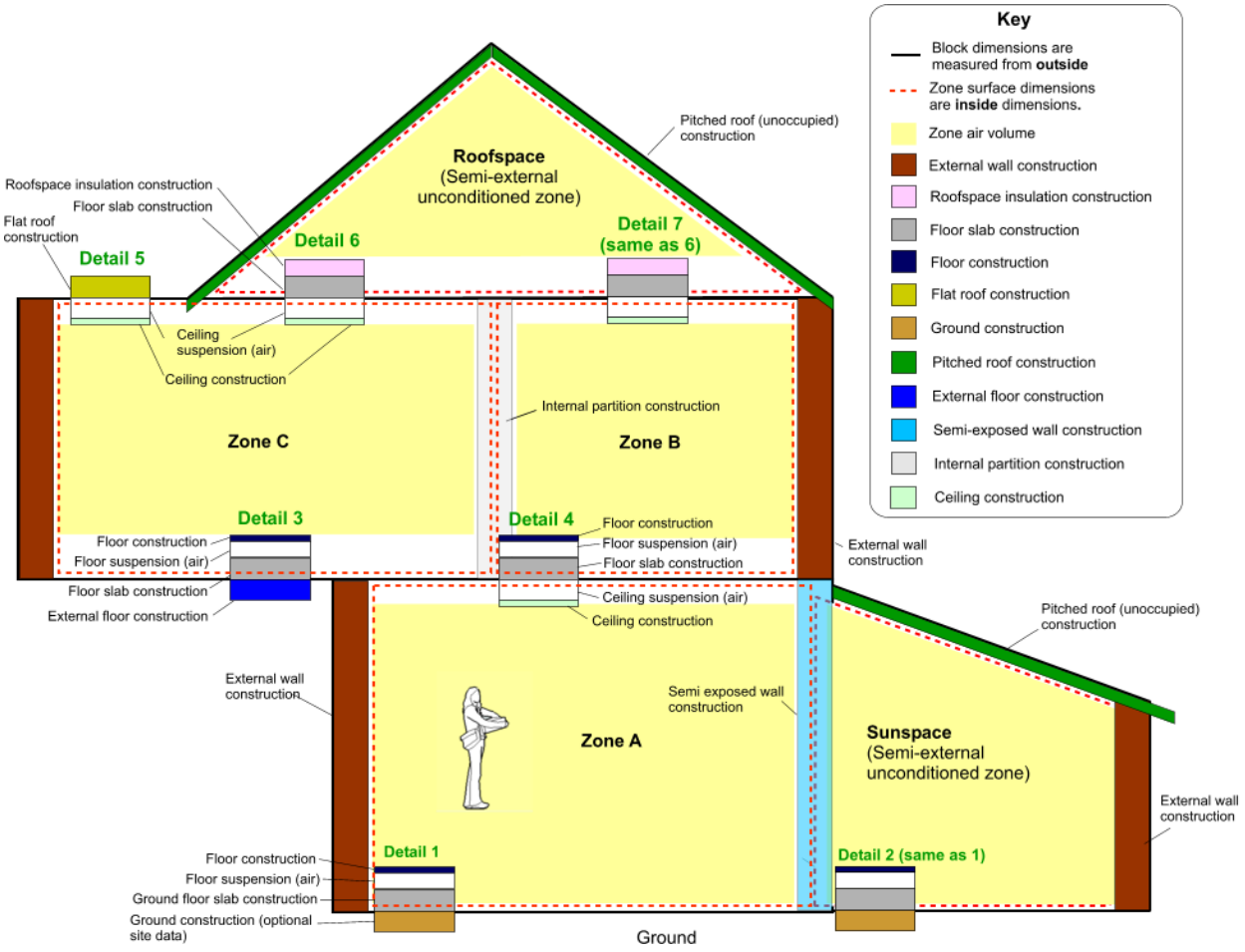

External walls

The external wall construction defines the construction of walls adjacent to outside. The formal definition of walls is given by the roof-wall transition angle model option. In cold climates this construction will generally include an insulating layer.

Flat roof

Flat roof constructions apply to external horizontal surfaces. The construction used to represent the flat roof should include all construction layers between inside and outside excluding any suspended ceiling and ceiling construction which is most easily included using the **Suspended ceiling?, Suspension height** and **Ceiling construction** data described below. In cold climates this construction will generally include an insulating layer.

See Detail 5 above.

Pitched roof (occupied)

The Pitched roof (occupied) construction applies to external sloped surfaces when they appear in occupied zones. In cold climates this construction will generally include an insulating layer.

The definition of 'pitched roof' is given by the roof-wall transition angle model option.

Pitched roof (unoccupied)

The Pitched roof (unoccupied) construction applies to external sloped surfaces when they appear in semi-exterior unconditioned zones. This construction will generally not include any insulation layers.

The definition of 'pitched roof' is given by the roof-wall transition angle model option.

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Internal partitions

The internal partition construction defines the construction of internal partitions (walls used to divide blocks into zones) and inter-block partitions (walls shared with other blocks). Internal partitions are used where both zones are occupied. When one of the zones is occupied and the other is not the **Semi-exposed walls** construction data is used (below).

Semi-exposed walls

The semi-exposed wall construction applies to walls which separate fully occupied zones with semi-exterior unconditioned zones. They will normally include some insulation. DesignBuilder determines which of the zones is relatively 'outside' and uses this information to correctly order the material layers in the wall. The material layer defined in the construction as being 'outermost' (first-in list) will be the one adjacent to the semi-external unconditioned zone.

Ceilings

In separate mode, you can define ceiling and floor constructions by combining standard structural slab constructions with optional ceiling and floor layers and air gaps. In DesignBuilder a ceiling is the construction immediately adjacent to the room at the top and is positioned below the floor slab of the zone above (diagram above). Often its' purpose is to as a finish (e.g. to hide ugly concrete slabs) or to provide an air gap between the slab above and the ceiling to allow light fittings, ducting, circuits and other services to be hidden from sight. Ceilings can also provide improved thermal and acoustic properties. If the ceiling is 'suspended' from the slab above it will have an air gap between the slab and the ceiling. You can use the following model data to define ceilings:

- **Suspended ceiling?** - check this option if there is a ceiling in the zone and it is to be defined separately from the floor slab. Checking this option shows:
- **Suspension height** - sets the height of the air gap between the floor slab of the zone above and the ceiling.
- **Ceiling construction** - the construction of the ceiling tiles or other ceiling construction layers, not including the suspension, slab or floor above.

See Details 4, 5, 6 and 7 in the diagram above.

If there is no suspended ceiling, you should clear the 'Suspended ceiling' checkbox. In this case, the zone will be in direct contact with the floor slab of the zone above (if it is an internal ceiling) or the underside of the flat roof construction (if it is an external flat roof).

Floors

Floors are made up by combining floor, slab and ceiling constructions with floor and ceiling suspension voids as shown in the diagram above. If there is no raised floor, you should clear the 'Floor fitted above slab' check box. In this case, the room will be in direct contact with the floor slab.

Note: it is not possible in v.1 to use the gap defined by the suspension height in floors and ceilings as a plenum zone - supply and return plenums for use in Compact HVAC must be completely separate zones.

Roofspace insulation

In Semi-exterior unconditioned spaces such as roofspaces, the **Roofspace insulation** data is used instead of the floor construction as the topmost floor layer. To include Insulation in the roofspace floor follow the steps:

1. Go to the roofspace block or zone
2. Check the **Floor fitted above slab** checkbox
3. Select the appropriate **Roofspace insulation** data. Note that this construction contains just the construction layers above the slab. The construction might typically contain two layers: i) insulation and possibly ii) boarding or other lining material.

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4. If the roofspace floor construction is directly in contact with the slab, i.e. there is no suspension, set the suspension height to zero.

See Detail 6 in the diagram above.

Ground floors

Ground floors are made up by combining floor, ground floor slab and ground constructions (optional site level data) with an optional floor suspension void as shown in Construction Location and Block and Zone Dimensions. The site ground temperatures are applied to the outside of all surfaces adjacent to ground. In cold climates the Ground floor slab construction will generally include an insulating layer.

See Detail 1 in the diagram above.

External floors

External floors are floors that are adjacent to outside air, e.g. the floor of a cantilevered part of the building or where for any other reason there is no ground or other zone below. With Separate constructions, External floors are generated from Floor slab and External floor constructions plus optional Floor suspension and Floor construction. In cold climates the External floor construction will generally include an insulating layer.

See Detail 3 above.

Zone Volume

The zone volume is calculated correctly for all zone geometries and by default, the volume is the actual air volume of the space excluding the volume of floor and ceiling constructions and any raised floor and suspended ceiling voids (if selected) but including half the volume of partition walls.

Construction tab in model data under Construction header

Sub-surfaces are exceptions to the main surface construction. Examples include cold-bridging elements such as window lintels and opaque panels in a lightweight facade. You can define different sub-surface construction types for external walls, internal partitions and pitched roofs.

Note: because DesignBuilder Version 1 does not have model data associated with 'openings', it is not possible to have more than one type of sub-surface on any particular surface.

To **add** a sub-surface, go to the surface you wish to work on, click on the Layout tab and select the Draw sub-surface command.

You can also define constructions for doors.

Walls

Any opaque sub-surfaces created in a wall will have this construction.

Internal

Any opaque sub-surfaces created in any inside surface (partitons, internal floor etc) will have this construction.

Roof

Any opaque sub-surfaces created in any pitched roof will have this construction.

External door

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Defines the construction of external doors.

Internal door

Defines the construction of internal doors.

Construction tab in model data under Construction header

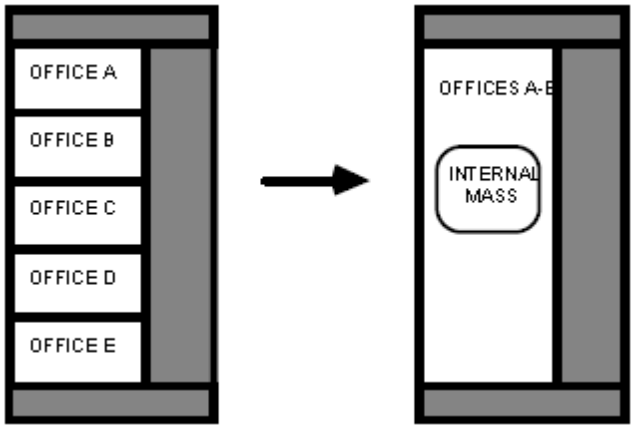
DesignBuilder uses the thermal characteristics of the constructions for each of the walls, floors, roofs, partitions etc in each zone and accounts for the thermal mass in the simulations. You can also include additional thermal mass to account for partitions within a zone, furniture and any other mass which will affect the dynamic thermal response of the zone. There are two ways you can define additional internal thermal mass in DesignBuilder:

1. Drawing **hanging partitions** (i.e. partitions which do not meet other walls at both ends),
2. Entering a non-zero internal thermal mass exposed area on the Constructions tab under the Internal Thermal Mass header at zone level.

Thermal mass defined using these methods is lumped together for each zone and modelled in EnergyPlus in a 'non-geometric' way. In both cases, the construction is defined under the **Internal Thermal Mass** header on the Constructions tab.

Internal thermal mass defined in this way is used to specify the construction and area of items within the space that are important to heat transfer calculations but not necessarily important geometrically. For example, furniture within the space – particularly for large spaces. It can also be used for internal walls that are not needed for solar distribution, when Solar distribution is set to **3-Full interior and exterior** or to represent all interior walls when solar is distributed to the floors only with Solar distribution set to **2-Full exterior**.

Example
When zoning an office building, five west-facing offices have been combined into one zone. All of the offices have interior walls made of the same materials. As shown in the figure below, this zone may be described with 5 exterior walls and 11 internal walls or 1 exterior wall and 1 internal mass. Note that fewer surfaces will speed up the EnergyPlus calculations.



Example
A five-story building has the same ceiling/floor construction separating each of the levels. Zones that are on floors 2 through 4 may be described using a single piece of internal mass to represent both the floor and ceiling. The construction for this internal mass would be identical to the ceiling/floor construction that would be used to describe separate surfaces.

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Exposed Area
The exposed area is the surface area of the internal mass. The area that is specified must be the entire surface area that is exposed to the zone. If both sides of a wall are completely within the same zone, then the area of both sides must be included when describing that internal wall.

Construction tab in model data under Construction header

The adjacency of individual surfaces can be set to be either adjacent to ground or adiabatic. The adjacency data is used at the surface level, though defaults can be set at a block and zone level as well if all surfaces in a block or zone have the same adjacency.

The full range of options are:

- **1-Auto** - the adjacency of the surface is determined automatically by DesignBuilder based on its position. External surfaces below the ground plane are, by default, considered to be adjacent to ground and external surfaces above the ground plane are considered to be adjacent to outside conditions.
- **2-Not adjacent to ground** - the surface is not adjacent to ground even if it is situated below the ground plane.
- **3-Adjacent to ground** - the surface is adjacent to ground even if it is above the ground plane or it is an internal surface.
- **4-Adiabatic** - the surface is adiabatic. This means that heat is not transferred across in its external surface. Adiabatic surfaces are frequently used in thermal modelling to represent surfaces which are between two zones at substantially similar conditions. Note that thermal mass is still modelled in Adiabatic surfaces because heat can still be transferred into the mass through the internal surface. Adiabatic surfaces are often used for modelling the boundary between the actual building model and any adjacent buildings which are not to be modelled.

You can determine which surfaces are adiabatic or adjacent to ground by looking for the corresponding surface adjacency markers in the Edit Screen at zone and surface levels:

Note that the recommended way to set ground and adiabatic adjacencies is to use component blocks.

Adiabatic surfaces use internal constructions:

- Adiabatic external floors use **Internal floor** construction.
- Adiabatic flat roofs use *reversed* **Internal floor** construction.
- Adiabatic external wall surfaces use **Internal partition** construction.

You can find out the construction that will be used for each adiabatic surface by looking at data on the Construction tab at surface level.

Note that in the current version of DesignBuilder the Visualisations shows adiabatic surfaces using external surfaces properties but internal surfaces (Internal floor and partition constructions) are used in calculations as described above.

Exclude this surface area from total zone floor area?

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When modelling situations such as offices space within large warehouse zones where the ceiling at the top of the offices is not usable floor area in the warehouse it may be useful to exclude the area of any unused floor surfaces from the floor area of the zone.
So for internal floors such as the unused 'floor' on top of the office space you can check the **Exclude this surface area from total zone floor area?** checkbox to ensure the floor is not used in the calculation of zone and building floor area and in the calculation of internal gains where defined per m2 or per ft2.

Construction tab in model data under Construction header

You can select the inside and outside surface convection algorithms in the Model data on the Construction tab under the Surface Convection header. This provides you with the option of making different selections in different parts of the building.

Inside convection algorithm

You can select from 5 different EnergyPlus inside convection algorithms for calculating the convection between internal zone surfaces and the rest of the zone air in the simulation calculations:

- **1-Detailed** - The detailed inside convection algorithm adjusts the convective heat transfer coefficient based on the surface orientation and the difference between the surface and zone air temperatures. The algorithm is taken directly from Walton (1983). Walton derived his algorithm from the ASHRAE Handbook (2001), Table 5 on p. 3.12, which gives equations for natural convection heat transfer coefficients in the turbulent range for large, vertical plates and for large, horizontal plates facing upward when heated (or downward when cooled). A note in the text also gives an approximation for large, horizontal plates facing downward when heated (or upward when cooled) recommending that it should be half of the facing upward value. Walton adds a curve fit as a function of the cosine of the tilt angle to provide intermediate values between vertical and horizontal. The curve fit values at the extremes match the ASHRAE values very well.
- **2-Simple** - The simple convection model uses constant coefficients for different heat transfer configurations, using the same criteria as the detailed model to determine reduced and enhanced convection. The coefficients are also taken directly from Walton (1983). Walton derived his coefficients from the surface conductances for ε=0.90 found in the ASHRAE Handbook (1985) in Table 1 on p. 23.2. The radiative heat transfer component was estimated at 1.02 * 0.9 = 0.918 BTU/h-ft2-F and then subtracted off. Finally the coefficients were converted to SI units to yield the values below. For a vertical surface: h = 3.076 For a horizontal surface with reduced convection: h = 0.948 For a horizontal surface with enhanced convection: h = 4.040 For a tilted surface with reduced convection: h = 2.281 For a tilted surface with enhanced convection: h = 3.870.
- **3-CIBSE** - applies constant heat transfer coefficient derived from traditional CIBSE values.
- **4-Ceiling diffuser** - a mixed and forced convection model for ceiling diffuser configurations. The model correlates the heat transfer coefficient to the air change rate for ceilings, walls and floors. The ceiling diffuser algorithm is based on empirical correlations developed by Fisher and Pedersen (1997). The correlation was reformulated to use the room outlet temperature as the reference temperature. The correlations are shown below. For Floors: h = 3.873 + 0.082 x ACH ^ 0.98, For ceilings: h = 2.234 + 4.099 x ACH ^ 0.503 and for Walls: h = 1.208 + 1.012 ACH ^ 0.604
- **5-Cavity** - The Trombe wall algorithm is used to model convection in a "Trombe wall zone", i.e. the air space between the storage wall surface and the exterior glazing. (See the later sections on Passive and Active Trombe Walls below for more information about Trombe walls.) The algorithm is identical to the convection model (based on ISO 15099) used in Window5 for convection between glazing layers in multi-pane window systems. The use of the algorithm for modelling an unvented Trombe wall has been validated against experimental data by Ellis (2003).This algorithm gives the convection coefficients for air in a narrow vertical cavity that is sealed and not ventilated. This applies both to the air gap in between panes of a window or to the air gap between the Trombe wall glazing and the inner surface (often a selective surface). These convection coefficients are really the only difference between a normal zone and a Trombe zone. The 5-Cavity Inside convection algorithm is not available at the surface level.

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Paraphrased note from EnergyPlus developers: "The Trombe wall convection coefficients only make sense for a zone. They are specific coefficients calculated for a narrow enclosed space. The two major walls of a Trombe wall zone are so close together that the convection patterns for the two walls actually interact. If they are close enough they can fight each other and totally stagnate the convection cell in the space. This is not free-boundary convection such as that found in a typical room. Therefore, it does not make sense to apply these coefficients to a single surface. The algorithm analyses the zone to figure out which are the two major surfaces and then sets the coefficients on those surfaces. The other minor surfaces receive negligible convection."

To avoid discontinuities in surface heat transfer rate calculations, all correlations are extrapolated beyond the lower limit of the data set (3 ACH) to a natural convection limit which is applied during the hours when the system is off. These models are explained in greater detail in the EnergyPlus Engineering Reference Document.

Outside convection algorithm

Substantial research has gone into the formulation of models for estimating the exterior convection coefficient. Since the 1930's there have been many different methods published for calculating this coefficient, with much disparity between them (Cole and Sturrock 1977; Yazdanian and Klems 1994). You can select from 7 different outside convection algorithms:

- **1-Detailed -** The Detailed, BLAST, and TARP convection models are very similar. In all three models, convection is split into forced and natural components (Walton 1981). The forced convection component is based on a correlation by Sparrow, Ramsey, and Mass (1979. The natural convection component is calculated in the same way as the Detailed Inside convection algorithm (see above).
- **2-Simple** - applies heat transfer coefficients depending on the roughness and wind speed. This is a combined heat transfer coefficient that includes radiation to sky, ground, and air. The correlation is based on Figure 1, Page 25.1 (Thermal and Water Vapor Transmission Data), 2001 ASHRAE Handbook of Fundamentals.
- **3-CIBSE** - applies constant heat transfer coefficients depending on orientation, derived from traditional CIBSE values.
- **4-BLAST** - Identical to the Detailed option
- **5-TARP** - Identical to the Detailed option
- **6-DOE-2** - The DOE-2 convection model is a combination of the MoWiTT and BLAST Detailed convection models (LBL 1994).
- **7-MoWiTT** - The MoWiTT model is based on measurements taken at the Mobile Window Thermal Test (MoWiTT) facility (Yazdanian and Klems 1994). The correlation applies to very smooth, vertical surfaces (e.g. window glass) in low-rise buildings. The MoWiTT algorithm may not be appropriate for rough surfaces, high-rise surfaces, or surfaces that employ movable insulation.

All of the above algorithms are described fully in the EnergyPlus Engineering Reference.

When the surface is wet (i.e. it is raining and the surface is exposed to wind) then the convection coefficient appears in results as a very large number (1000) and the surface is exposed to the Outdoor Wet Bulb Temperature rather than the Outdoor Dry Bulb Temperature.

Inside and Outside convection algorithm settings can be made in various places.

- Model options dialog (Heating design, Cooling design, Simulation tabs)
- Calculation options dialog (Heating design, Cooling design, Simulation)
- Model data on Construction tab

You cannot make changes to individual surface convection settings where the surface is an internal partition.

Note: the equivalent inside and outside surface convection options in the Calculation and Model options dialogs control ***building default values*** (equivalent of making a setting in Model data at building level) and changes at block, zone or surface levels in the Model data will override these settings.

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Construction tab in model data under Construction header

Component blocks can be used to include shading and reflection effects of objects such as local shading devices, awnings, adjacent buildings and trees. They can also be used to define ground and adiabatic adjacencies. The component block model data allows you to define the component block type, whether the component block shades and reflects in simulations, transmittance of the shading material and also a schedule for modelling seasonal variations in transmittance.

Component block type

You can change the type of the component block. Select from:

- **1-Standard** - used for shading, reflection and visualisation.
- **2-Ground** - used for setting ground adjacency, shading, reflection and visualisation.
- **3-Adiabatic** - used for setting adiabatic adjacency, shading, reflection and visualisation.

For more information on the Component block types see Component Block under Working with Blocks (Building Level)

Component block shades and reflects

Switch this option on to include the component block as a shading/reflection surfaces in the simulations. Shading surfaces have the following effects:

- Shade direct beam solar radiation.
- Reflect solar radiation onto the building (if you select Model reflections in the calculation options).
- Shade diffuse solar and long-wave radiation from the sky.
- Shade diffuse solar radiation from the ground (if you select Model reflections in the calculation options).

Important note on ground reflection

Solar and light reflection from the ground is included even if the solar Reflections option is not used, but if Reflections are not calculated the ground plane is considered unobstructed, i.e., the shadowing of the ground by the building itself or by component blocks is ignored.

Shadowing of the ground by component blocks is only taken into account if the Reflections option is used.

Conclusion: Switch Reflections on for accurate shading calculations.

Note: all component block types cast shadows in the visualisations.

Material

The component block material is used to define the solar and visible reflectance of the block surfaces in Cooling design calculations and Simulations using real weather data when the model reflections calculation option is selected.

Note: Although component blocks are displayed in DesignBuilder as solid objects, non-flat component blocks are modelled in EnergyPlus as a group of surfaces and it is the reflectance and transmission of each of these surfaces that is being described here. The solar flux incident upon a building facade will be attenuated by each successive shading object located on a path between the facade and the sun position.

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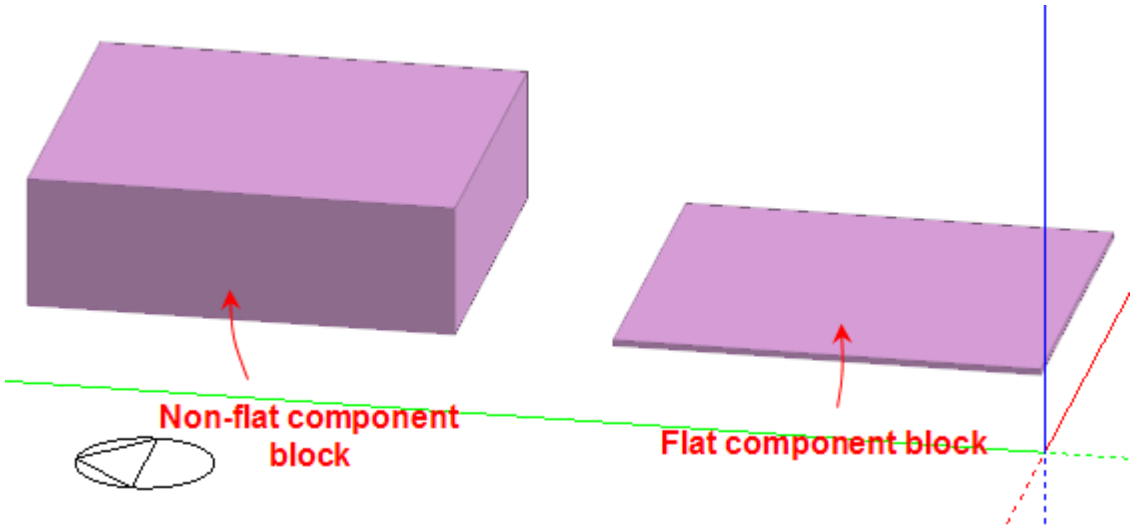
Maximum Transmittance

This is the maximum solar transmittance of the entire component block. The transmittance of the component block during the simulation is calculated by multiplying the maximum transmittance by the time varying schedule value:

Transmittance = Max Transmittance x Schedule value

In most cases you will want component blocks to provide 100% shading for 100% of the time. In this case you can leave the **Maximum transmittance** and **Transmittance schedule** in their default states of 0 and **On** respectively. If you wish the component block to transmit solar and visible radiation you can define the extent and timing of the transmission. The component block transmittance is calculated during the simulations as the **Maximum transmittance** multiplied by the value of the transmittance schedule below. The maximum transmittance can have any value between 0 and 1. Note that if the component block is flat (i.e. it consists of 2 large surfaces and several smaller 'edge' surfaces) the block is represented in the simulations by a single shading surface. In this case the surface used will depend on the value of the Flat component block surface selection model option.

Tip: If your component block has a constant transmittance you can set the transmittance schedule below to On and set the constant transmittance for the block here.



For non-flat component blocks every surface is included in the simulation as a shading surface and the solar flux incident upon a building facade will be attenuated by each successive shading object located on a path between the facade and the sun position. The shading transmittance schedule you define is therefore modified to ensure that the overall transmittance of the block is the Maximum Transmittance value multiplied by the schedule you selected. This is done assuming that the component block is convex and that therefore solar rays can only pass through a maximum of 2 surfaces. The transmittance of each non-flat component block surface is set to square root of the value you defined to achieve this.

Note: non-convex non-flat component blocks will provide more shading than you specified during times when solar rays pass through more than 2 surfaces.

Note: there was a bug in the calculation of transmittance through multiple shading devices having fractional transmittance in EnergyPlus version 2.0 and earlier. We haven't yet verified that the bug has been fixed and so we recommend that you check results carefully when using fractional transmittance for component blocks.

Transmittance schedule

The component block transmittance schedule defines any time varying transmittance of the component block surfaces. By default, the component block is fully opaque for the whole year. The transmittance

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schedule can contain any value between 0 and 1. The transmittance schedule can be used to allow for seasonal transmittance change, such as deciduous trees that have a higher transmittance in winter than in summer. Transmittance based on time of day can also be used - a movable awning, for example, where the transmittance is some value less than 1.0 when the awning is in place and is 1.0 when the awning is retracted.

The following assumptions are made in the shading surface transmittance calculation:

- Both sides of the shading surface have the same transmittance properties.
- The transmittance is the same for both beam and diffuse solar radiation.
- Beam solar transmittance is independent of angle of incidence on the shading surface.
- Beam radiation incident on a shading surface is transmitted as beam radiation with no change in direction, i.e., there is no beam-to-diffuse component.
- If two shading surfaces with non-zero transmittance overlap, the net transmittance is the product of the individual transmittances. Inter-reflection between the shading
- surfaces (and between the shading surfaces and the building) is ignored.
- For the daylighting calculation the shading surface's visible transmittance is assumed to be the same as its solar transmittance.
- Shading devices are assumed to be opaque to long-wave radiation no matter what the solar transmittance value is.

Note that shading devices only shade solar radiation when the sun is up, which is automatically determined by EnergyPlus from latitude, time of year, etc. The user need only account for the time-varying transmittance of the shading device in the transmittance schedule, not whether the sun is up or not.

3.3.2.2.2 Airtightness

Construction tab in model data

There are two ways of defining air tightness depending on the Natural ventilation model option:

- Scheduled
- Calculated

In both cases infiltration can be switched off at building, block or zone level.

Construction tab in model data under Airtightness header

The infiltration rate (rate of entry of unintentional air from outside through cracks, holes and through the porosity of the fabric) can be set in Air changes per hour (ac/h) and is constant throughout the simulation. The air flow rate in m3/s is calculated from the ac/h data using:

```
m3/s = ac/h * ZoneVolume / 3600
```

where `ZoneVolume` is the *total* air volume of the space including the volume of floor and ceiling constructions and any raised floor and suspended ceiling voids (if selected in Separate constructions) and including half the volume of partition walls.

Note: this *total* zone volume value may be different from the value used for calculating air flow rates for natural ventilation and mechanical ventilation which have model options for excluding floor/ceiling constructions.

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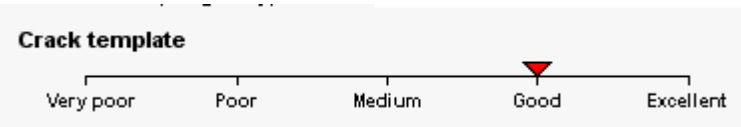
Construction tab in model data under Airtightness header

When Calculated natural ventilation is active, the Airtightness is defined by a position on a five point scale:



The five settings correspond to the five Crack templates.

You can switch off calculated infiltration off by unchecking the **Model infiltration** checkbox. This may be useful if you are carrying out a summertime simulation of a large building to reduce the number of cracks in the model and so speed simulations.

Note: if you do switch off infiltration when calculated natural ventilation is active, you should make sure that Natural ventilation (HVAC tab) is switched on to ensure that sufficient flow paths exist. Otherwise EnergyPlus may crash.

3.3.2.3 Openings Data (Windows, Doors, Vents, Holes, Sub-surfaces)

Openings tab in model data

The term **opening** is used in DesignBuilder to describe any opening in the main building fabric. These are modelled as exceptions to the main surface construction. There are five types of opening:

- Windows
- Sub-surfaces (i.e. opaque elements within the surface that have different properties from the main construction. For example lintels and lightweight panels can be defined as sub-surfaces. Data for these is held on the Construction tab)
- Holes
- Doors
- Vents

The layout, operation and construction data for these (apart from sub-surfaces) can be set on the Openings tab.

Templates

You can load generic Opening data by clicking on the Template option under Glazing Template and then by clicking on the '...' at the right of the line (below).

When you make a selection from the list of Glazing templates, data from selected template will be loaded to the model.

You can also open the:

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- External Glazing
- Internal Glazing
- Roof Glazing
- Doors
- Vents

headers to enter opening details where they are different from those loaded from the template.

Note: Once you have created custom openings on any particular surface, changes made to facade layout on this tab will not affect the layout for the surface.

All Openings data is used to generate simulation data at the **Surface level**.

You can also override default Pressure Coefficient data when the Calculated Natural ventilation option is set and you are at surface level.

3.3.2.3.1 External Glazing

Openings tab in model data

The data under the External Glazing header applies to all glazing lying on external walls. You can enter information on:

- Dimensions
- Frame
- Shading
- Operation

Openings tab in model data under External Glazing and Internal Glazing headers

Facade types

There are a number of standard facade types:

- **None** - there is no glazing.
- **Continuous horizontal** - glazing is generated in a continuous horizontal strip using Sill height, Window spacing and Percentage glazing.
- **Fixed height** - glazing is generated with a fixed height at the specified Sill height and Window spacing, and width is calculated based on the Percentage glazing. This option uses **Window to wall %** but prioritises window height.
- **Preferred height** - glazing is generated using the window height data and the Percentage glazing, but the Window height may be adjusted to achieve the required **Window to wall %**. This option uses Window height, Window spacing and Sill height but prioritises **Window to wall %**.
- **Fixed width and height** - windows have fixed width and height. This option uses **Window to wall %** but prioritises Window Width, Height, Spacing and Sill height.
- **Fill surface (100%)** - the entire surface is filled with glazing and there is **no frame**.

You can use the **Window to wall %** (WWR) data and Window height, Window spacing and Sill height to easily change the amount of glazing and its layout on the walls. This data is used as described above under Facade types.

Note 1: you can control the makeup of the building facades in greater detail by drawing individual windows at the surface level. In this case glazing, vent and door layout model data is ignored.

Note 2: flat roofs do not have default glazing set up using Roof glazing layout model data. To create

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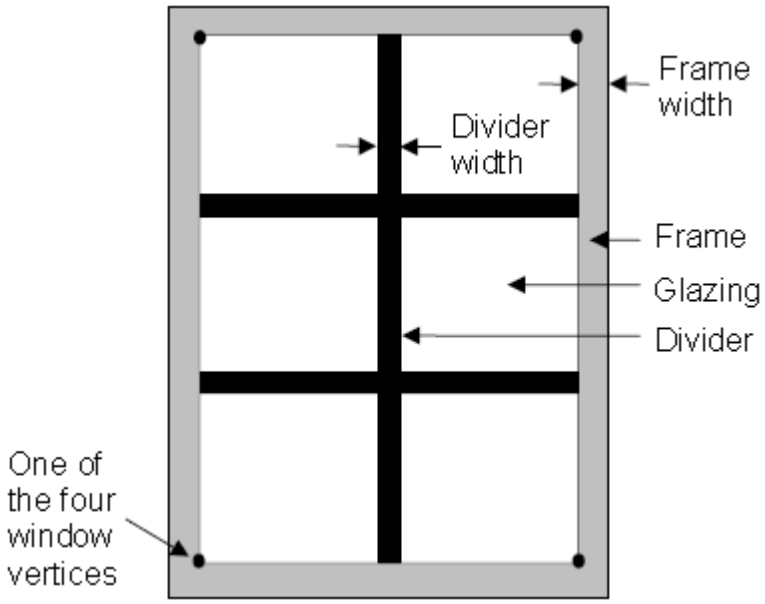
openings on a flat roof you should go to the surface level and add them there.

Openings tab in model data under External Glazing, Internal Glazing and Roof Glazing headers

Frames are applied to all rectangular windows (default and custom) but not to other shaped windows and not when using the **Fill surface (100%)** facade type.

If the glazing does not have a frame or dividers, uncheck the **Has a frame?** box. If **Has a frame?** is checked and then you can enter:

- The construction of the frame and dividers,
- The number of horizontal dividers and vertical dividers,
- Frame width and divider with (see diagrams below for definition).



EXTERNAL WINDOWS ON WALLS

For **external windows on walls** the following dimensions in the direction of the glazing normal can also be entered:

- Inside reveal depth
- Inside sill depth
- Outside divider projection
- Inside divider projection
- Outside frame projection
- Inside frame projection
- Divider glass edge-centre conduction ratio
- Frame glass edge-centre conduction ratio
- Divider type

The definition of the above dimensions is shown in the diagrams.

REVEAL

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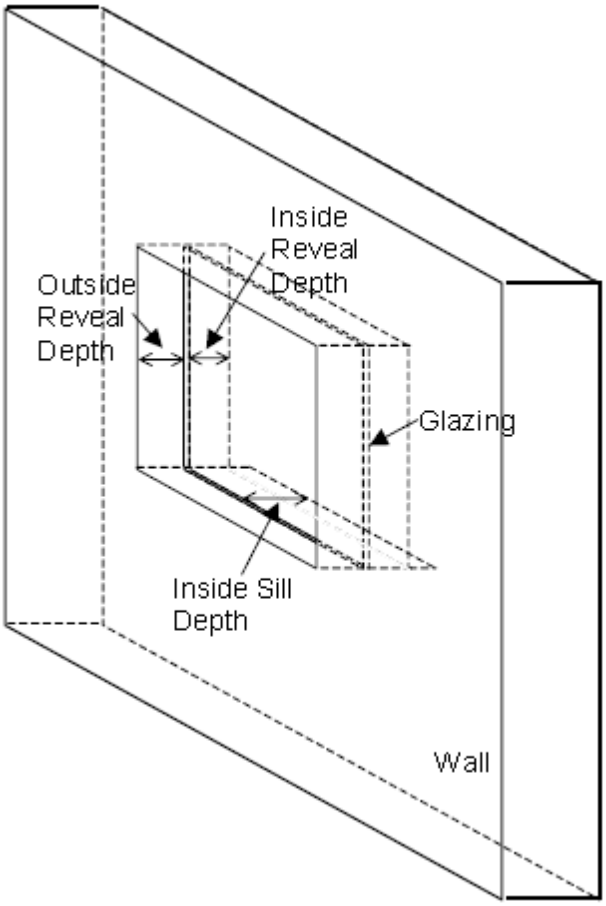

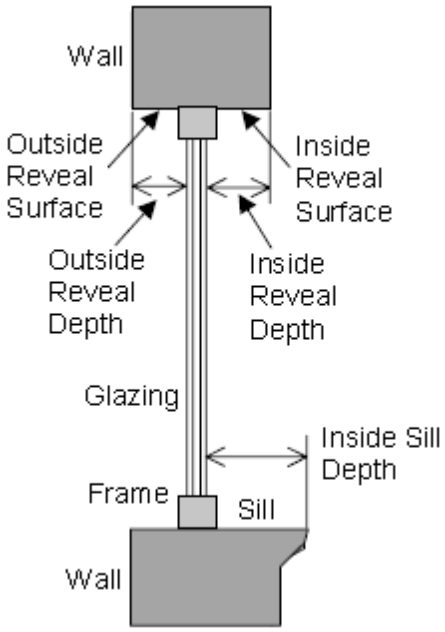

DIVIDERS

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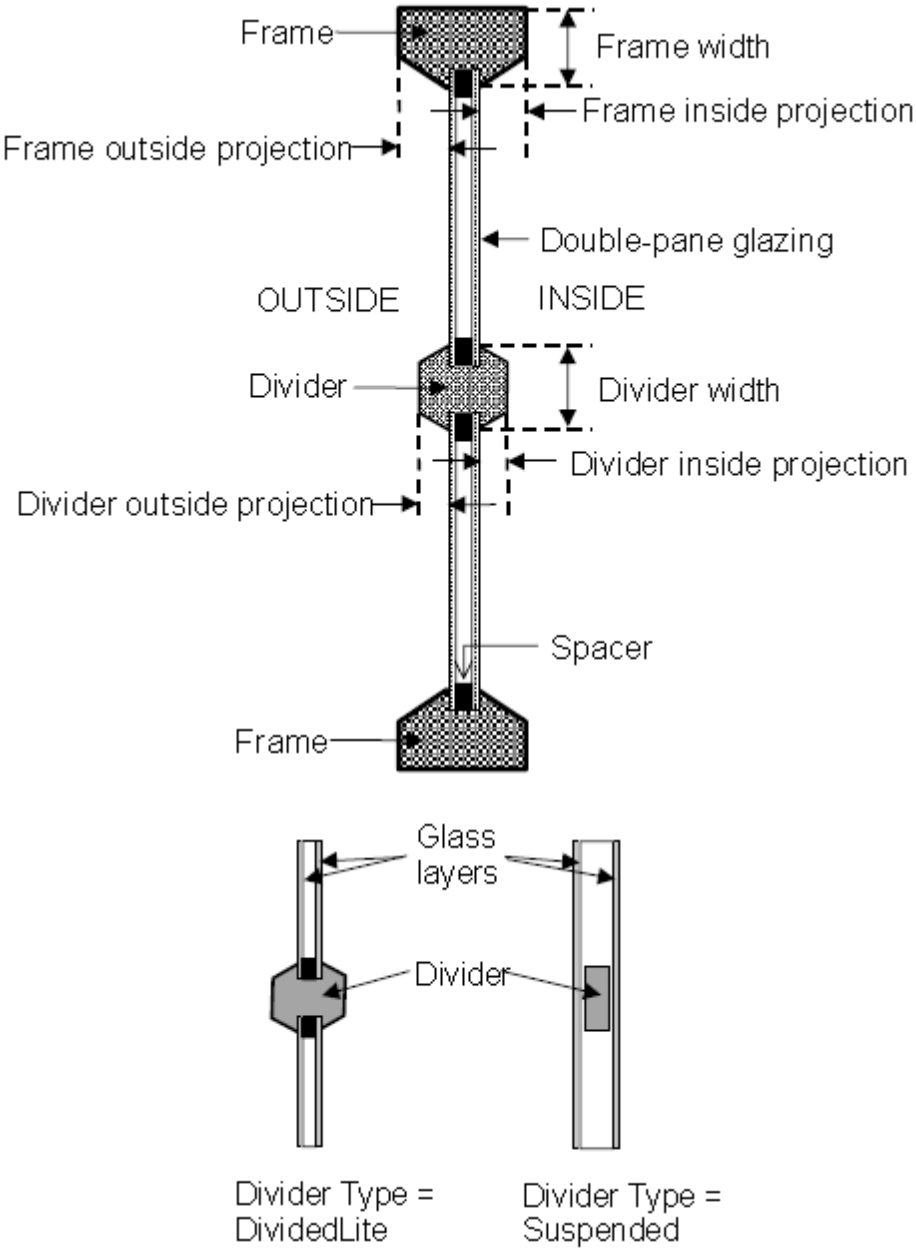

Note: If you do not wish to model the shading/reflection effect of the reveal/frame/divider then simply set the projection/depth to zero.

Openings tab in model data under External Glazing, Internal Glazing and Roof Glazing headers

You can select two types of shading for external windows:

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

These types of shading can be used individually or combined.

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Openings tab in model data under External Glazing, Internal Glazing and Roof Glazing headers

To include blinds, transparent insulation or electrochromic glazing check the 'Window shading' checkbox.

This displays the data above.

Type

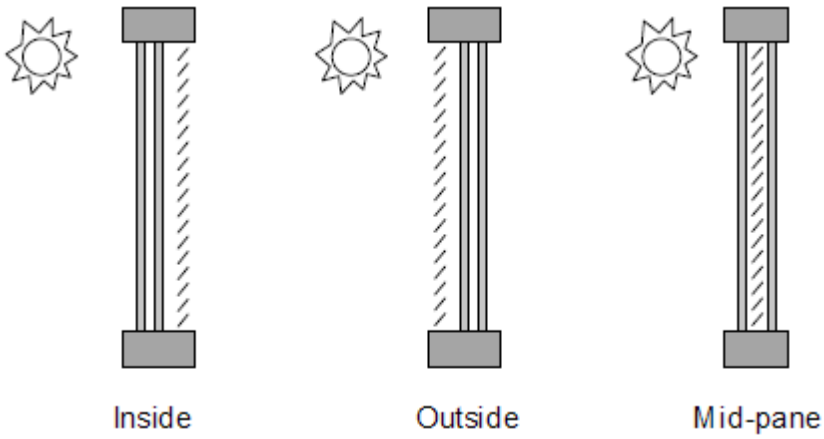
Select the Window blind component type. There are 4 categories of window blinds:

- Slat
- Shade
- Transparent insulation
- Electrochromic switching (if you select a blind of this category the position must be 'Switchable'.

Position

The window shading devices can be positioned in one of four ways:

- **1-Inside** - the window shading devices is positioned inside the zone.
- **2-Mid-pane** - the window shading device is positioned between the inner pane and the second pane.
- **3-Outside** - the shading devices positioned outside.
- **4-Switchable** - select this option for electrochromic glazing in which case the outer pane is switched based on the shading control (below).



Control type

Control data specifies how the shading device is controlled. It determines whether the shading device is “on” or “off.” For blinds and shades, when the device is “on” it is assumed to cover all of the window except its frame; when the device is “off” it is assumed to cover none of the window (whether “on” or “off” the shading device is assumed to cover none of the wall that the window is on). For switchable glazing, “on” means that the glazing is in the fully-switched state and “off” means that it is in the unswitched state; for example, for electrochromic glazing, “on” means the glazing is in its darkest state and "off” means it is in its lightest state.

The choices for **Shading control type** are the following. *Equivalent EnergyPlus control types* are shown in italics. If SetPoint is applicable its units are shown in parentheses.

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1- Always on (*AlwaysOn*) - Shading is always on.

The following six control types are used primarily to reduce zone cooling load due to window solar gain.

2-Daylight (*MeetDaylightIlluminanceSetpoint*) - Used only with Position = **4-Switchable** in zones with daylighting controls. In this case the transmittance of the glazing is adjusted to just meet the daylight illuminance set point at the first daylighting reference point. Note that the daylight illuminance set point is specified under Environmental Control on the Activity tab.
3-Schedule - Shading operation is defined by a schedule.
4-Solar (*OnIfHighSolarOnWindow*) - Shading is on if beam plus diffuse solar radiation incident on the window exceeds SetPoint (W/m2 or BTU/hr-ft2).
5-Glare (*OnIfHighGlare*) - Shading is on if the total daylight glare index at the zone's first daylighting sensor from all of the exterior windows in the zone exceeds the maximum glare index specified in the daylighting input for zone.

Note: Glare control requires Lighting control to be switched on in the zone.

6-Outside air temp (*OnIfHighOutsideAirTemp*) - Shading is on if outside air temperature exceeds SetPoint (C or F).
7-Inside air temp (*OnIfHighZoneAirTemp*) - Shading is on if zone air temperature in the previous time step exceeds SetPoint (C or F)
8-Cooling (*OnIfHighZoneCooling*) - Shading is on if zone cooling rate in the previous time step is non-zero.

The following two control types can be used to reduce zone cooling load. They are applicable to any Shading type but are most appropriate for interior or exterior blinds, interior or exterior shades with low insulating value, or switchable glazing.

9-Day cooling and solar + night (*OnNight/OnDayIfCoolingAndHighSolarOnWindow*) - Shading is on at night. Shading is on during the day the solar radiation incident on the window exceeds SetPoint (W/m2 or BTU/hr-ft2) and if the zone cooling rate in the previous time step is non-zeo.
10-Day cooling and solar (*OffNight/OnDayIfCoolingAndHighSolarOnWindow*) - Shading is off at night. Shading is on during the day when the solar radiation incident on the window exceeds SetPoint (W/m2 or BTU/hr-ft2) and if the zone cooling rate in the previous time step is non-zero.

The following three control types can be used to reduce zone heating load during the winter by reducing window conductive heat loss at night and leaving the window unshaded during the day to maximize solar gain. They are applicable to any Shading Type but are most appropriate for interior or exterior shades with high insulating value ("movable insulation"). "Night" means the sun is down and "day" means the sun is up.

11-Night outside low air temp (*OnNightIfLowOutsideTemp/OffDay*) - Shading is on at night if the outside air temperature is less than SetPoint (C or F) and schedule, if specified, allows shading. Shading is off during the day.
12-Night inside low air temp (*OnNightIfLowInsideTemp/OffDay*) - Shading is on at night if the zone air temperature in the previous time step is less than SetPoint (C or F) and schedule, if specified, allows shading. Shading is off during the day.
13-Night heating (*OnNightIfHeating/OffDay*) - Shading is on at night if the zone heating rate in the previous time step exceeds SetPoint (W) and schedule, if specified, allows shading. Shading is off during the day.

The following two control types can be used to reduce zone heating and cooling load. They are applicable to any Shading type but are most appropriate for translucent interior or exterior shades with high insulating value ("translucent movable insulation").

14-Night outside low air temp + day cooling (*OnNightIfLowOutsideTemp/OnDayIfCooling*) - Shading is on at night if the outside air temperature is less than Set point (C or F). Shading is on during the day if the zone cooling rate in the previous time step is non-zero.
15-Night heating + day cooling (*OnNightIfHeating/OnDayIfCooling*) - Shading is on at night if the zone heating rate in the previous time step is non-zero. Shading is on during the day if the zone cooling rate in the previous time step is non-zero.

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SetPoint

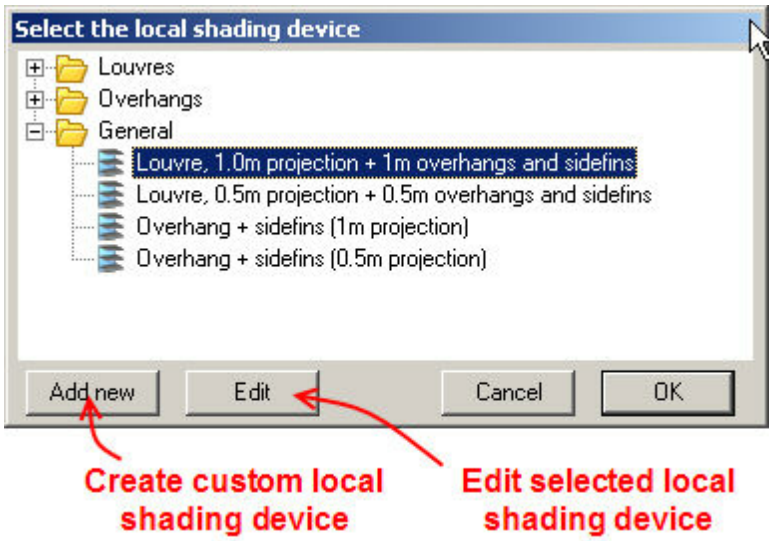
The setpoint for activating window shading. The units depend on the type of trigger:

- W/m2 or BTU/hr-ft2 for solar-based controls.
- C or F for temperature-based controls.

Openings tab in model data under External Glazing headers

To include overhangs, sidefins and/or louvres check the 'Local shading' checkbox.

This shows the Local shading component data. DesignBuilder comes with a small database of Local shading devices, but if you cannot find a suitable component for your model, you can create a custom local shading component by clicking on the New button from the Selection dialog (below).



Note: the DesignBuilder Local shading devices allow a range of different overhangs, side fins and louvres to be defined, but if you need to model a shading device not covered by the standard mechanism, you can draw custom shading devices using Component blocks.

Openings tab in model data under External Glazing, Internal Glazing and Roof Glazing headers

The operation of windows can be defined by entering data under Operation headers. The data will depend on the Natural ventilation model option set:

Calculated Natural Ventilation

The **% Glazing area opens** slider allows you to define the openable window area as a percentage of the total window area. For example enter '20' if 20% of the window area can open.

The air flow opening is assumed to be a gap in the *side* of the window which takes on the full height of the window.

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Note: if modulation is switched on (it is by default) the glazing opening areas are multiplied by a factor to account for external conditions.

You can also enter a schedule to define the timing of the window operation. The schedule should have values of 0 and 1 only and intermediate fractional values do not indicate partial opening.

The windows are 'open' when:

$T_{zone_air} > T_{setpoint}$ AND $T_{zone_air} > T_{outside_air}$ AND the schedule value = 1

The ventilation rate is calculated based on the pressure difference across the opening calculated from wind and stack pressure effects using equations described in Natural Ventilation Modelling.

Scheduled Natural Ventilation

Airflow through *external* windows, vents, doors and holes are not modelled with **Scheduled** natural ventilation because the natural ventilation airflow from outside is explicitly defined using the total natural ventilation flow rate and operation on the HVAC tab. *No operation data is entered on the Openings tab for external windows in this case*.

Note: Natural Ventilation can be overridden to be off on the HVAC tab for both Calculated and Scheduled model options.

3.3.2.3.2 Internal Glazing

Openings tab in model data

The data under the Internal Glazing header applies to all glazing lying on internal partition walls. You can enter information on:

- Dimensions
- Frame
- Operation

Openings tab in model data under External Glazing and Internal Glazing headers

Facade types

There are a number of standard facade types:

- **None** - there is no glazing.
- **Continuous horizontal** - glazing is generated in a continuous horizontal strip using Sill height, Window spacing and Percentage glazing.
- **Fixed height** - glazing is generated with a fixed height at the specified Sill height and Window spacing, and width is calculated based on the Percentage glazing. This option uses **Window to wall %** but prioritises window height.
- **Preferred height** - glazing is generated using the window height data and the Percentage glazing, but the Window height may be adjusted to achieve the required **Window to wall %**. This option uses Window height, Window spacing and Sill height but prioritises **Window to wall %**.
- **Fixed width and height** - windows have fixed width and height. This option uses **Window to wall %** but prioritises Window Width, Height, Spacing and Sill height.
- **Fill surface (100%)** - the entire surface is filled with glazing and there is **no frame**.

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You can use the **Window to wall %** (WWR) data and Window height, Window spacing and Sill height to easily change the amount of glazing and its layout on the walls. This data is used as described above under Facade types.

Note 1: you can control the makeup of the building facades in greater detail by drawing individual windows at the surface level. In this case glazing, vent and door layout model data is ignored.

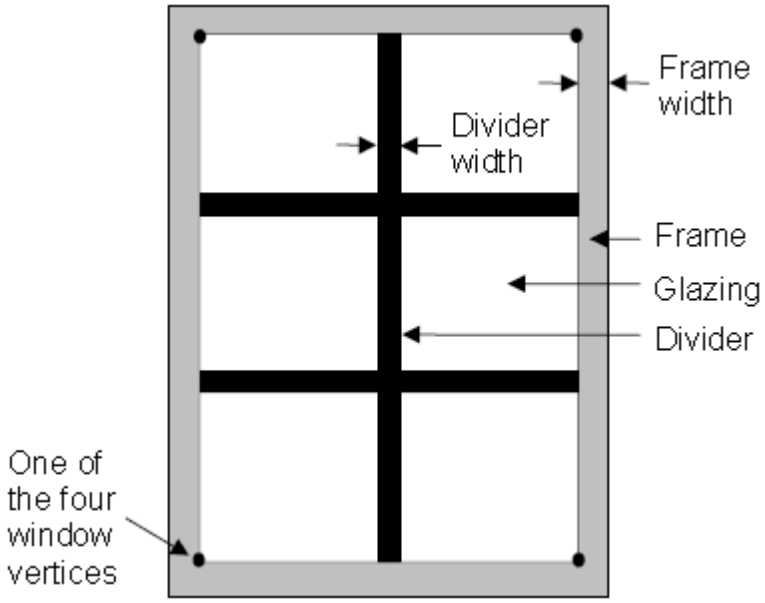
Note 2: flat roofs do not have default glazing set up using Roof glazing layout model data. To create openings on a flat roof you should go to the surface level and add them there.

Openings tab in model data under External Glazing, Internal Glazing and Roof Glazing headers

Frames are applied to all rectangular windows (default and custom) but not to other shaped windows and not when using the **Fill surface (100%)** facade type.

If the glazing does not have a frame or dividers, uncheck the **Has a frame?** box. If **Has a frame?** is checked and then you can enter:

- The construction of the frame and dividers,
- The number of horizontal dividers and vertical dividers,
- Frame width and divider with (see diagrams below for definition).



EXTERNAL WINDOWS ON WALLS

For **external windows on walls** the following dimensions in the direction of the glazing normal can also be entered:

- Inside reveal depth
- Inside sill depth
- Outside divider projection
- Inside divider projection
- Outside frame projection
- Inside frame projection

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- Divider glass edge-centre conduction ratio
- Frame glass edge-centre conduction ratio
- Divider type

The definition of the above dimensions is shown in the diagrams.

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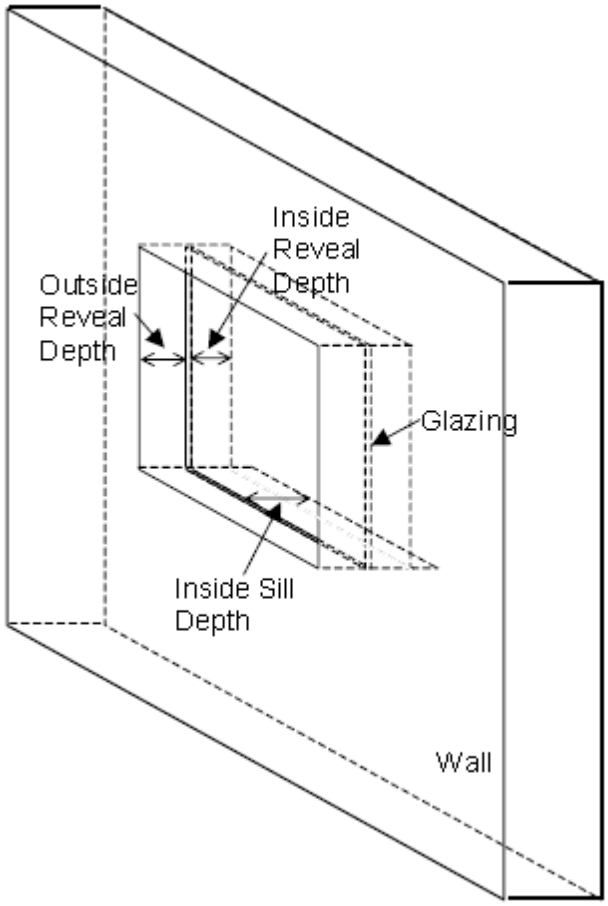

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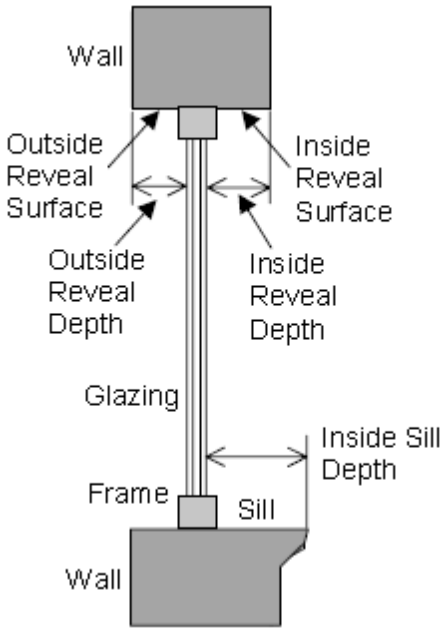
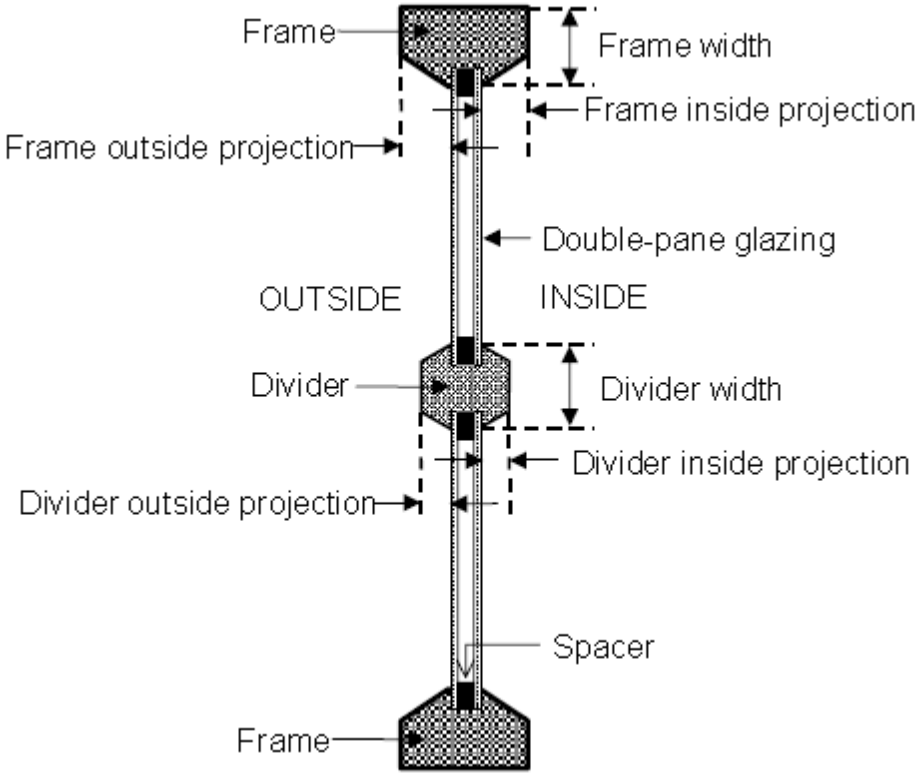


DIVIDERS



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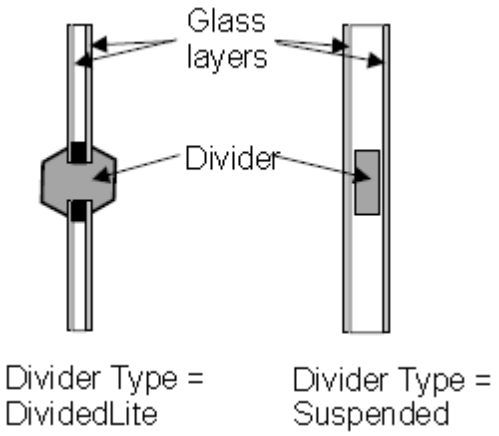

Note: If you do not wish to model the shading/reflection effect of the reveal/frame/divider then simply set the projection/depth to zero.

Openings tab in model data under External Glazing, Internal Glazing and Roof Glazing headers

The operation of windows can be defined by entering data under Operation headers. The data will depend on the Natural ventilation model option set:

Calculated Natural Ventilation

The **% Glazing area opens** slider allows you to define the openable window area as a percentage of the total window area. For example enter '20' if 20% of the window area can open.

The air flow opening is assumed to be a gap in the *side* of the window which takes on the full height of the window.

Note: if modulation is switched on (it is by default) the glazing opening areas are multiplied by a factor to account for external conditions.

You can also enter a schedule to define the timing of the window operation. The schedule should have values of 0 and 1 only and intermediate fractional values do not indicate partial opening.

The windows are 'open' when:

$T_{zone_air} > T_{setpoint}$ AND $T_{zone_air} > T_{outside_air}$ AND the schedule value = 1

The ventilation rate is calculated based on the pressure difference across the opening calculated from wind and stack pressure effects using equations described in Natural Ventilation Modelling.

Scheduled Natural Ventilation

Airflow through *external* windows, vents, doors and holes are not modelled with **Scheduled** natural ventilation because the natural ventilation airflow from outside is explicitly defined using the total natural ventilation flow rate and operation on the HVAC tab. *No operation data is entered on the Openings tab for external windows in this case*.

Note: Natural Ventilation can be overridden to be off on the HVAC tab for both Calculated and Scheduled model options.

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3.3.2.3.3 Roof Glazing

Openings tab in model data

The data under the Roof Glazing header applies to all glazing lying on external roof surfaces. You can enter information on:

- Dimensions
- Frame
- Shading
- Operation

Note: flat roofs do not have default glazing set up using Roof glazing layout model data. To create openings on a flat roof you should go to the surface level and add them there.

Openings tab in model data under External Glazing and Internal Glazing headers

Facade types

There are a number of standard facade types:

- **None** - there is no glazing.
- **Continuous horizontal** - glazing is generated in a continuous horizontal strip using Sill height, Window spacing and Percentage glazing.
- **Fixed height** - glazing is generated with a fixed height at the specified Sill height and Window spacing, and width is calculated based on the Percentage glazing. This option uses **Window to wall %** but prioritises window height.
- **Preferred height** - glazing is generated using the window height data and the Percentage glazing, but the Window height may be adjusted to achieve the required **Window to wall %**. This option uses Window height, Window spacing and Sill height but prioritises **Window to wall %**.
- **Fixed width and height** - windows have fixed width and height. This option uses **Window to wall %** but prioritises Window Width, Height, Spacing and Sill height.
- **Fill surface (100%)** - the entire surface is filled with glazing and there is **no frame**.

You can use the **Window to wall %** (WWR) data and Window height, Window spacing and Sill height to easily change the amount of glazing and its layout on the walls. This data is used as described above under Facade types.

Note 1: you can control the makeup of the building facades in greater detail by drawing individual windows at the surface level. In this case glazing, vent and door layout model data is ignored.

Note 2: flat roofs do not have default glazing set up using Roof glazing layout model data. To create openings on a flat roof you should go to the surface level and add them there.

Openings tab in model data under Roof Glazing headers

You can select one type of shading for external roof windows:

- Window shading (blinds, curtains etc walls and roofs).

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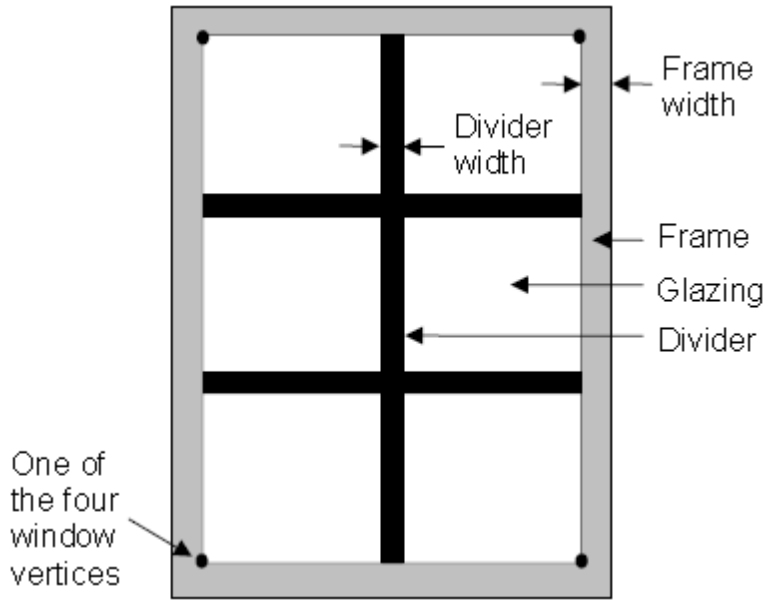
Openings tab in model data under External Glazing, Internal Glazing and Roof Glazing headers

Frames are applied to all rectangular windows (default and custom) but not to other shaped windows and not when using the **Fill surface (100%)** facade type.

If the glazing does not have a frame or dividers, uncheck the **Has a frame?** box. If **Has a frame?** is checked and then you can enter:

- The construction of the frame and dividers,
- The number of horizontal dividers and vertical dividers,
- Frame width and divider with (see diagrams below for definition).



EXTERNAL WINDOWS ON WALLS

For **external windows on walls** the following dimensions in the direction of the glazing normal can also be entered:

- Inside reveal depth
- Inside sill depth
- Outside divider projection
- Inside divider projection
- Outside frame projection
- Inside frame projection
- Divider glass edge-centre conduction ratio
- Frame glass edge-centre conduction ratio
- Divider type

The definition of the above dimensions is shown in the diagrams.

REVEAL

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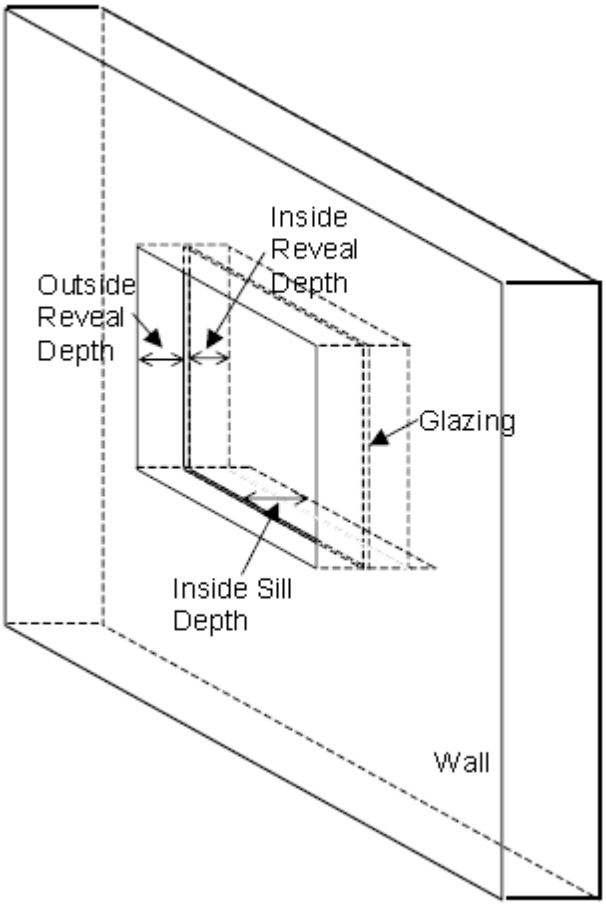

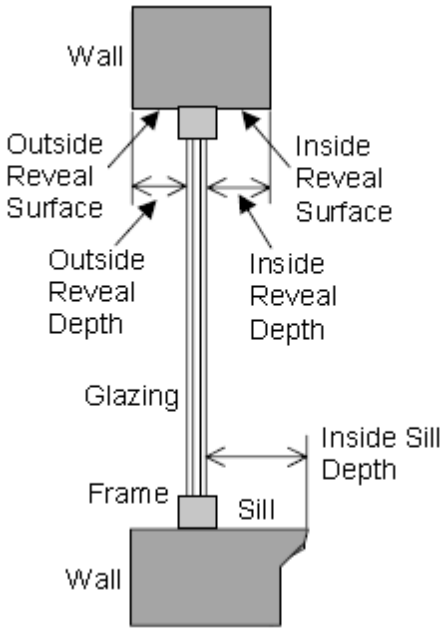

DIVIDERS

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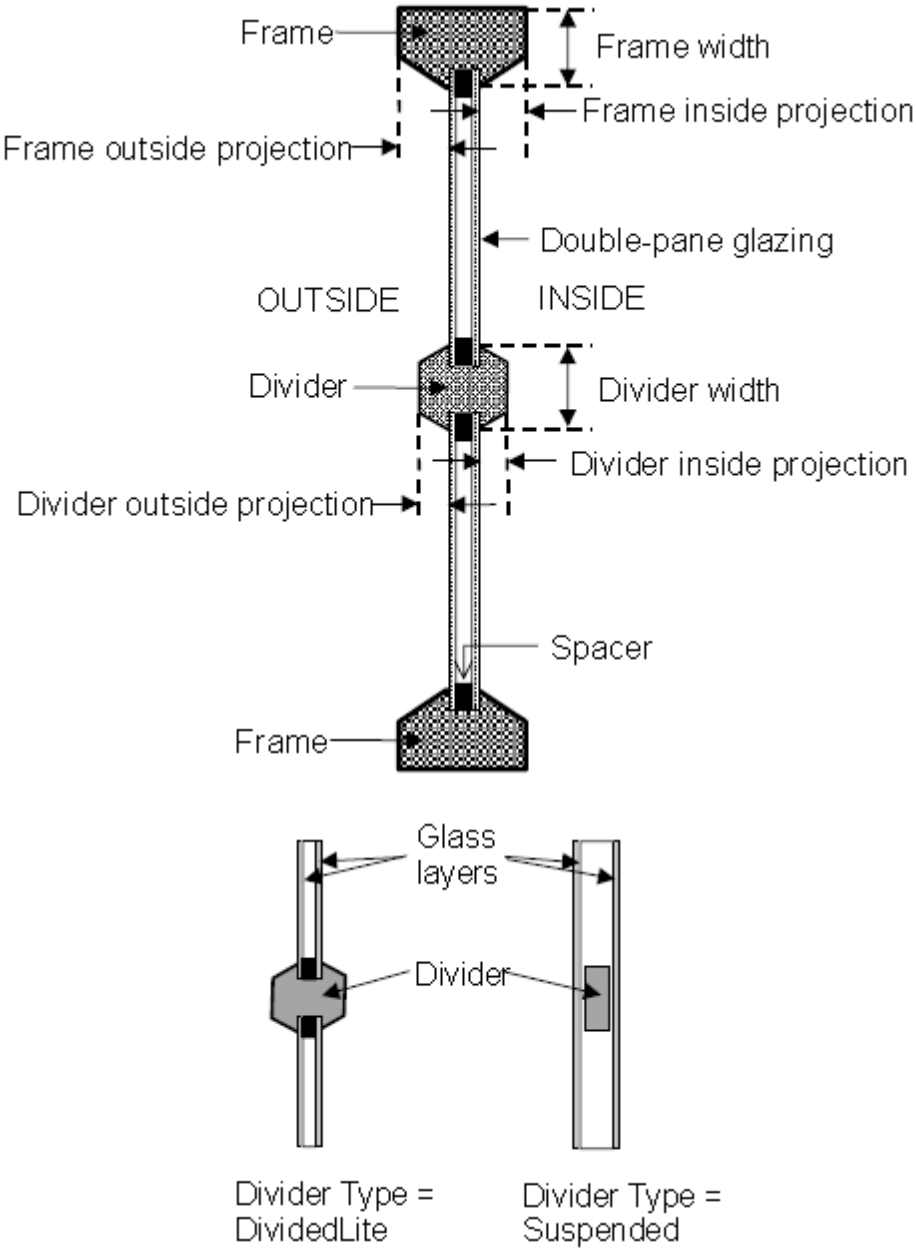

Note: If you do not wish to model the shading/reflection effect of the reveal/frame/divider then simply set the projection/depth to zero.

Openings tab in model data under External Glazing, Internal Glazing and Roof Glazing headers

To include blinds, transparent insulation or electrochromic glazing check the 'Window shading' checkbox.

This displays the data above.

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Type

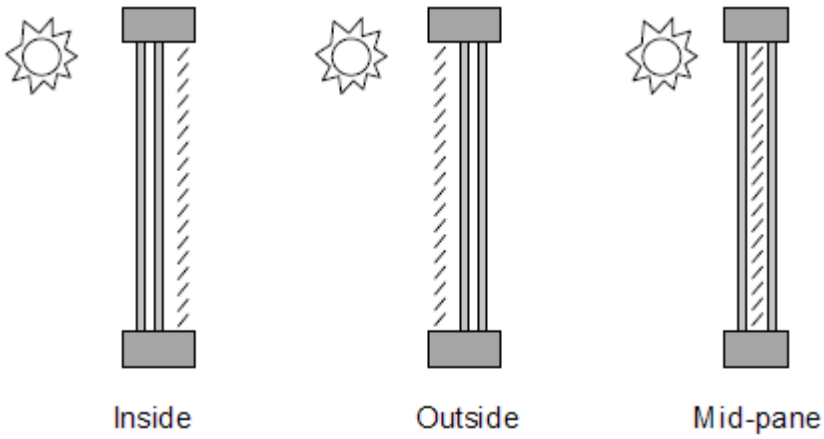
Select the Window blind component type. There are 4 categories of window blinds:

- Slat
- Shade
- Transparent insulation
- Electrochromic switching (if you select a blind of this category the position must be 'Switchable'.

Position

The window shading devices can be positioned in one of four ways:

- **1-Inside** - the window shading devices is positioned inside the zone.
- **2-Mid-pane** - the window shading device is positioned between the inner pane and the second pane.
- **3-Outside** - the shading devices positioned outside.
- **4-Switchable** - select this option for electrochromic glazing in which case the outer pane is switched based on the shading control (below).



Control type

Control data specifies how the shading device is controlled. It determines whether the shading device is “on” or “off.” For blinds and shades, when the device is “on” it is assumed to cover all of the window except its frame; when the device is “off” it is assumed to cover none of the window (whether “on” or “off” the shading device is assumed to cover none of the wall that the window is on). For switchable glazing, “on” means that the glazing is in the fully-switched state and “off” means that it is in the unswitched state; for example, for electrochromic glazing, “on” means the glazing is in its darkest state and "off” means it is in its lightest state.

The choices for **Shading control type** are the following. *Equivalent EnergyPlus control types* are shown in italics. If SetPoint is applicable its units are shown in parentheses.

1- Always on (*AlwaysOn*) - Shading is always on.

The following six control types are used primarily to reduce zone cooling load due to window solar gain.

2-Daylight (*MeetDaylightIlluminanceSetpoint*) - Used only with Position = **4-Switchable** in zones with daylighting controls. In this case the transmittance of the glazing is adjusted to just meet the daylight illuminance set point at the first daylighting reference point. Note that the daylight illuminance set point is specified under Environmental Control on the Activity tab.
3-Schedule - Shading operation is defined by a schedule.
4-Solar (*OnIfHighSolarOnWindow*) - Shading is on if beam plus diffuse solar radiation incident on the window exceeds SetPoint (W/m2 or BTU/hr-ft2).

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5-Glare (*OnIfHighGlare*) - Shading is on if the total daylight glare index at the zone's first daylighting sensor from all of the exterior windows in the zone exceeds the maximum glare index specified in the daylighting input for zone.

Note: Glare control requires Lighting control to be switched on in the zone.

6-Outside air temp (*OnIfHighOutsideAirTemp*) - Shading is on if outside air temperature exceeds SetPoint (C or F).
7-Inside air temp (*OnIfHighZoneAirTemp*) - Shading is on if zone air temperature in the previous time step exceeds SetPoint (C or F)
8-Cooling (*OnIfHighZoneCooling*) - Shading is on if zone cooling rate in the previous time step is non-zero.

The following two control types can be used to reduce zone cooling load. They are applicable to any Shading type but are most appropriate for interior or exterior blinds, interior or exterior shades with low insulating value, or switchable glazing.

9-Day cooling and solar + night (*OnNight/OnDayIfCoolingAndHighSolarOnWindow*) - Shading is on at night. Shading is on during the day the solar radiation incident on the window exceeds SetPoint (W/m2 or BTU/hr-ft2) and if the zone cooling rate in the previous time step is non-zeo.
10-Day cooling and solar (*OffNight/OnDayIfCoolingAndHighSolarOnWindow*) - Shading is off at night. Shading is on during the day when the solar radiation incident on the window exceeds SetPoint (W/m2 or BTU/hr-ft2) and if the zone cooling rate in the previous time step is non-zero.

The following three control types can be used to reduce zone heating load during the winter by reducing window conductive heat loss at night and leaving the window unshaded during the day to maximize solar gain. They are applicable to any Shading Type but are most appropriate for interior or exterior shades with high insulating value ("movable insulation"). "Night" means the sun is down and "day" means the sun is up.

11-Night outside low air temp (*OnNightIfLowOutsideTemp/OffDay*) - Shading is on at night if the outside air temperature is less than SetPoint (C or F) and schedule, if specified, allows shading. Shading is off during the day.
12-Night inside low air temp (*OnNightIfLowInsideTemp/OffDay*) - Shading is on at night if the zone air temperature in the previous time step is less than SetPoint (C or F) and schedule, if specified, allows shading. Shading is off during the day.
13-Night heating (*OnNightIfHeating/OffDay*) - Shading is on at night if the zone heating rate in the previous time step exceeds SetPoint (W) and schedule, if specified, allows shading. Shading is off during the day.

The following two control types can be used to reduce zone heating and cooling load. They are applicable to any Shading type but are most appropriate for translucent interior or exterior shades with high insulating value ("translucent movable insulation").

14-Night outside low air temp + day cooling (*OnNightIfLowOutsideTemp/OnDayIfCooling*) - Shading is on at night if the outside air temperature is less than Set point (C or F). Shading is on during the day if the zone cooling rate in the previous time step is non-zero.
15-Night heating + day cooling (*OnNightIfHeating/OnDayIfCooling*) - Shading is on at night if the zone heating rate in the previous time step is non-zero. Shading is on during the day if the zone cooling rate in the previous time step is non-zero.

SetPoint

The setpoint for activating window shading. The units depend on the type of trigger:

- W/m2 or BTU/hr-ft2 for solar-based controls.
- C or F for temperature-based controls.

Openings tab in model data under External Glazing, Internal Glazing and Roof Glazing headers

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The operation of windows can be defined by entering data under Operation headers. The data will depend on the Natural ventilation model option set:

Calculated Natural Ventilation

The **% Glazing area opens** slider allows you to define the openable window area as a percentage of the total window area. For example enter '20' if 20% of the window area can open.

The air flow opening is assumed to be a gap in the *side* of the window which takes on the full height of the window.

Note: if modulation is switched on (it is by default) the glazing opening areas are multiplied by a factor to account for external conditions.

You can also enter a schedule to define the timing of the window operation. The schedule should have values of 0 and 1 only and intermediate fractional values do not indicate partial opening.

The windows are 'open' when:

$T_{zone_air} > T_{setpoint}$ AND $T_{zone_air} > T_{outside_air}$ AND the schedule value = 1

The ventilation rate is calculated based on the pressure difference across the opening calculated from wind and stack pressure effects using equations described in Natural Ventilation Modelling.

Scheduled Natural Ventilation

Airflow through *external* windows, vents, doors and holes are not modelled with **Scheduled** natural ventilation because the natural ventilation airflow from outside is explicitly defined using the total natural ventilation flow rate and operation on the HVAC tab. *No operation data is entered on the Openings tab for external windows in this case*.

Note: Natural Ventilation can be overridden to be off on the HVAC tab for both Calculated and Scheduled model options.

3.3.2.3.4 Doors

Openings tab in model data

DesignBuilder doors are opaque and are added to the model by navigating to the appropriate surface and checking the 'Door fitted' option. This adds a single door replacing one of the windows. Alternatively, for more control over the placement position of the doors, you can go to surface level and draw the doors using the Draw Door command. On surfaces where custom openings have been defined, any changes to door layout model data on the Opening tab is ignored.

- Door Placement
- Door Operation

Note: if you have drawn custom doors at the surface level then these will be used even if the **Doors fitted** checkbox is not checked. The **Doors fitted** checkbox only controls the automatic generation of doors, not their use in the calculations.

Airflow through Doors: Doors positioned on ***external*** walls only have an effect on airflow in Simulation calculations when the Natural ventilation building model option is set to Calculated. They have no effect on airflow in Heating and Cooling Design calculations. Doors positioned on ***internal*** partition walls are used to mix the air between the two adjacent zones when the Scheduled Natural ventilation building model option is set. They also provide an air flow path when the Calculated option is set.

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Openings tab in model data under Doors

On surfaces where no custom openings have been defined, you can create doors simply by checking the 'Doors fitted?' options under the External and Internal Doors headers. In this case a single door is positioned on each surface in place of one of the windows in the automatically generated facade layout.

Openings tab in model data under Doors

The operation of doors can be defined by entering data under Operation headers:

- **% Area door opens** - defines the area of the door which opens relative to the total area to give an approximation of the actual opening size and,
- **% Time door is open** - defines the average time the door is in the open position. Accounts for the fact that during occupied periods the door may open and close repeatedly. The average effect

The way this data is used depends on the Natural ventilation model option set:

Calculated

The average door opening size used in the simulation is calculated by multiplying the **% Area door opens** by the **% Time the door is open** by the gross door area. A schedule can be applied to control timing of the opening.

The ventilation rate through the door opening is calculated based on the wind and stack pressure effects.

Scheduled

External door opening is not modelled explicitly with the Scheduled natural ventilation model data setting. Instead, the total natural ventilation flow rate and operation is defined for each zone on the HVAC tab. *No operation data is entered on the Openings tab for external doors*.

Internal doors are modelled using the EnergyPlus 'Mixing' object which mixes air between the two adjacent zones. DesignBuilder uses a very approximate empirical relationship to calculate the mixing flow:

*Flow (m3/s) = Door area (m2) * % area door opens * % time door is open * Farea-flow*

where *Farea-flow* is a factor used to obtain the mixing flow from the opening area = 0.1.

A schedule can be applied to control timing of the mixing flow..

3.3.2.3.5 Vents and Holes

Openings tab in model data

Vents

DesignBuilder vents are used for modelling airflow through openings and are added to the model by navigating to the appropriate surface and checking the Vents fitted option. This adds a single vent under each of the windows (if the vent spacing is the same as the window spacing). Alternatively, for more control over the placement position of the vents, you can go to surface level and draw the vents using the Draw vent command. On surfaces where custom openings have been defined, any changes to vent layout model data

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on the Opening tab is ignored.

- Vent Placement
- Vent Operation

Note: if you have drawn custom vents at the surface level then these will be used even if the **Vents fitted** checkbox is not checked. The **Vents fitted** checkbox only controls the automatic generation of vents, not their use in the calculations.

See also vent components for more information.

Holes

Holes are modelled in a similar way to vents with some exceptions:

- Holes must be drawn at surface level
- Airflow through holes is uncontrolled, i.e. the airflow path is active all the time.
- Drawing holes can be used as a way to merge two zones when the Merge zones connected by holes Model option is set.
- Holes are used internally with DesignBuilder to model the heat transfer and airflow through Virtual partitions.
- Discharge coefficient of 0.65 is used whereas with vents the vent component defines the discharge coefficient.

VENT MODELLING

Calculated Natural Ventilation (Simulations only)

Each vent is modelled using:

- An EnergyPlus 'Door'. The heat conduction through the vent 'door' component is displayed in results as **Internal Natural vent** and **External Natural vent**.
- An EnergyPlus 'AIRFLOWNETWORK:MULTIZONE:COMPONENT DETAILED OPENING' and other associated AIRFLOW components, providing a controllable flow path. You can define Vent operation.

Scheduled Natural Ventilation (and Design Calcs)

Each vent is modelled using:

- An EnergyPlus 'Door'. The heat conduction through the vent 'door' component is displayed in results as **Internal Natural vent** and **External Natural vent**.
- Internal vents have an EnergyPlus 'Mixing' object using parameters set in the Model options dialog. External vents .

HOLE MODELLING

Calculated Natural Ventilation (Simulations only)

Each hole is modelled using a sub-surface and an airflow connection:

- Sub-surface:
  - If using 1-Minimum shadowing or 2-Full exterior solar distribution the hole is represented using an EnergyPlus 'Door'. In this case the heat conduction through the vent 'Door' component is displayed in results as **Internal Natural vent** and **External Natural vent**.

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- If the 3-Full interior and exterior solar distribution Model option is set then the hole is modelled using a 'perfectly clear' window which transmits solar radiation and visible light.
- EnergyPlus 'AIRFLOWNETWORK:MULTIZONE:COMPONENT DETAILED OPENING' and other associated AIRFLOW components, providing a controllable flow path. You can define Vent operation.

Scheduled Natural Ventilation (and Design Calcs)

Each hole is modelled using a sub-surface and a 'mixing' flow:

- Sub-surface:
  - If using 1-Minimum shadowing or 2-Full exterior solar distribution the hole is represented using an EnergyPlus 'Door'. In this case the heat conduction through the vent 'Door' component is displayed in results as **Internal Natural vent** and **External Natural vent**.
  - If the 3-Full interior and exterior solar distribution Model option is set then the hole is modelled using a 'perfectly clear' window which transmits solar radiation and visible light.
- Internal vents have an EnergyPlus 'Mixing' object using parameters set in the Model options dialog. External vents.

Openings tab in model data under Vents

On surfaces where no custom openings have been defined, you can create vents simply by checking the 'Vents fitted?' options under the External and Internal Vents headers. In this case vents are positioned on each surface using 'Vent spacing' and 'Vent height above floor' in the automatically generated facade layout. Typically, a single vent is positioned under each of the windows (if the vent spacing is the same as the window spacing).

Openings tab in model data under Vents

The operation of vents can be defined by entering timing data under Operation headers:

The way this data is used depends on the Natural ventilation model option set:

Calculated

A schedule can be applied to control timing of the vents. Note that the schedule should have values of 0 and 1 only and intermediate fractional values do not indicate partial opening.

The ventilation rate through the vent is calculated based on the wind and stack pressure effects.

Scheduled

External vent opening is not modelled explicitly with the Scheduled natural ventilation model data setting. Instead, the total natural ventilation flow rate and operation is defined for each zone on the HVAC tab. *No operation data is entered on the Openings tab for external vents*.

Internal vents are modelled using the EnergyPlus 'Mixing' object which mixes air between the two adjacent zones. DesignBuilder uses a very approximate empirical relationship to calculate the mixing flow:

*Flow (m3/s) = Door area (m2) * % area door opens * % time door is open * Farea-flow*

where *Farea-flow* is a factor used to obtain the mixing flow from the opening area = 0.1.

A schedule can be applied to control timing of the mixing flow..

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3.3.2.3.6 Wind Pressure Coefficients

Openings tab in model data

You can enter wind pressure coefficients (WPC) for wind incidence angles in 45° increments for each surface in the model. DesignBuilder sets up default WPC data for each surface using Wind Pressure Coefficient template data derived from the **AIVC Applications Guide: A guide to energy-efficient ventilation**.

3.3.2.4 Lighting Data

Lighting tab in model data

Templates

You can load generic Lighting data by clicking on the Template option under Lighting Template and then by clicking on the '...' at the right of the line (below).

When you make a selection from the list of Lighting templates, data from selected template will be loaded to the model.

With 'Early' gains detail the lighting gains in the space are separated into Task and General lighting. You can also open the:

- General Lighting
- Task Lighting
- Lighting Control

headers to enter lighting details where they are different from those loaded from the template.

When you load lighting data from template, the actual lighting casual gain is calculated by dividing the W/m2/100 lux data in the template by the required illuminance level as set on the Activity tab. Consequently you should make sure the correct activity data has been loaded in each zone before loading lighting templates. Also, you may need to explicitly load data in each zone by checking each zone in the Target tab of the 'Load data from template' dialog.

Lighting data generates simulation data at the **Zone level**.

3.3.2.4.1 General Lighting

Lighting tab in model data

General lighting accounts for the main lighting in the room. It is assumed to be able to be replaced by daylight through lighting control, if this option is selected.

Lighting energy

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This is typically the maximum electrical power input (in Watts) to lighting in a zone, including ballasts, if present. This value is multiplied by a schedule fraction (see previous field) to get the lighting power in a particular time step.

Note that when you load lighting data from template, the actual lighting casual gain is calculated by dividing the W/m2/100 lux data in the template by the required illuminance level as set on the Activity tab.

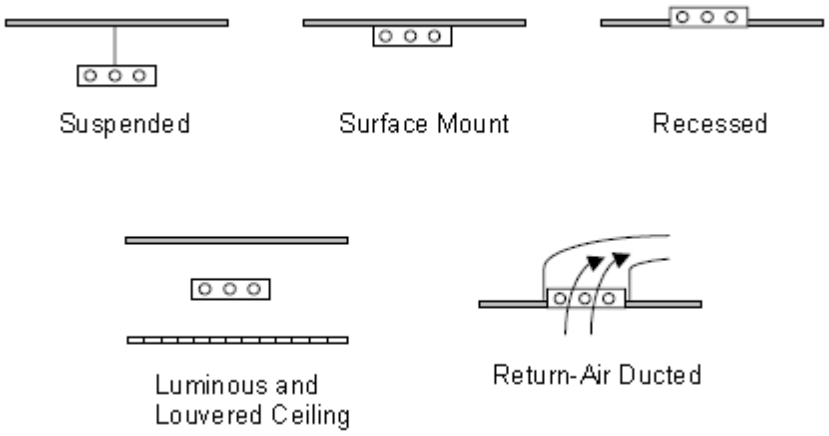
The electrical input to lighting ultimately appears as heat that contributes to zone loads or to return air heat gains. In EnergyPlus this heat is divided into four different fractions. Three of these are given by the input fields Return Air Fraction, Fraction Radiant and Fraction Visible. A fourth, defined as the fraction of the heat from lights convected to the zone air, is calculated by EnergyPlus as:

Convected Fraction = 1.0 – (Return Air Fraction + Radiant Fraction + Visible Fraction)

You will get an error message if Return Air Fraction + Radiant Fraction + Visible Fraction exceeds 1.0. These fractions depend on the type of lamp and luminaire, whether the luminaire is vented to the return air, etc.

Luminaire type

Select from:



When you select using the drop-down list an appropriate set of defaults for the luminaire type is loaded according to the table below, assuming fluorescent lighting.

Data	1-Suspended	2-Surface Mount	3-Recessed	4-Luminous and Recessed Ceiling	5-Return-air Ducted
Return Air Fraction	0.0	0.0	0.0	0.0	0.54
Radiant Fraction	0.42	0.72	0.37	0.37	0.18
Visible Fraction	0.18	0.18	0.18	0.18	0.18
Convected Fraction	0.40	0.10	0.45	0.45	0.10

Approximate values of Return Air Fraction, Radiant Fraction and Visible Fraction for overhead fluorescent lighting for different luminaire configurations. These values assume that no light heat goes into an adjacent zone. Source: *Lighting Handbook: Reference & Application, 8th Edition, Illuminating Engineering Society of North America, New York, 1993, p. 355.*

Return air fraction

For Return Air Ducted luminaires this is the fraction of the heat from lights that is convected out of the room and into the zone return air (normally into a return plenum). If the return air flow is zero or the zone has no

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return air system, the program will put this fraction into the zone air. Return Air Fraction is only visible on the screen for **5-Return-air ducted** luminaires.

Radiant fraction

The fraction of heat from lights that goes into the zone as long-wave (thermal) radiation. The program calculates how much of this radiation is absorbed by the inside surfaces of the zone according the area times thermal absorptance product of these surfaces.

Fraction visible

The fraction of heat from lights that goes into the zone as visible (short-wave) radiation. The program calculates how much of this radiation is absorbed by the inside surfaces of the zone according the area times solar absorptance product of these surfaces.

Note: selecting an option from the Luminaire type drop-down list loads default Return Air Fraction, Radiant Fraction and Visible Fraction data from the table above.

Fraction convected

The fraction of the heat from lights convected to the zone air is calculated from:

Fraction convected = 1.0 – (Return Air Fraction + Fraction Radiant + Fraction Visible)

You will get an error message if Return Air Fraction + Fraction Radiant + Fraction Visible exceeds 1.0.

This data is provided on screen for information purposes.

Operation

If 'Internal gains operate with occupancy' under model options is not set General lighting has a specific operation schedule set under General Lighting, otherwise these gains are synchronised with occupancy.

3.3.2.4.2 Task and Display Lighting

Lighting tab in model data

Task and Display Lighting accounts for lighting used for specific tasks (e.g. desk lamps) or for displaying items (e.g. display lighting for goods in shops). Task and Display Lighting is not offset by lighting control.

The following other data is assumed:

Data	Value
Radiant fraction	0.42
Visible fraction	0.18
Return air fraction	0

Internal gain

Note that when you load lighting data from template, the actual lighting casual gain is calculated by dividing the W/m2/100 lux data in the template by the required illuminance level as set on the Activity tab.

Operation

If 'Internal gains operate with occupancy' under model options is not set Task lighting has a specific operation schedule set under Task Lighting, otherwise these gains are synchronised with occupancy.

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3.3.2.4.3 Lighting Control

Lighting tab in model data

You can control the electric lights according to the availability of natural daylight. When Lighting control is switched on, illuminance levels are calculated at every time step during the simulation and then used to determine how much the electric lighting can be reduced. The daylight illuminance level in a zone depends on many factors, including sky condition, sun position, photocell sensor positions, location, size, and glass transmittance of windows, window shades and reflectance of interior surfaces. Reduction of electric lighting depends on daylight illuminance level, illuminance set point, fraction of zone controlled and type of lighting control.

You must not use daylight control in zones without any windows - this will generate errors preventing calculations from running.

LIGHTING AREAS

When lighting control is switched on, by default all of the lights in the zone are controlled by the first (main) lighting sensor and **% Zone Controlled by Lighting Area 1** has value 100%. Some larger spaces may have 2 **Lighting Areas,** each area having its own lighting sensor and covering its own area of the zone. The area is not defined geometrically in DesignBuilder - it simply reflects the fraction of the total General overhead electric lighting that can be dimmed by its lighting sensor.

You may wish to use 2 Lighting Areas for these situations:

1. A large zone may need more than one sensor if the output from main sensor does not represent the daylight available in other parts of the zone. For example a zone having facades in both South and East directions would need 2 sensors (and 2 Lighting Areas), one on each facade.
2. The zone has 2 different activity areas which have been lumped into a single zone for convenience. The 2 activities have different visual illuminance requirements and the Lighting Areas for both can benefit from daylighting through daylighting control. An example would be a zone having both office and recreational space. The office space may have a lighting requirement of 500 lux and the recreational space may need 300 lux.

Note 1: if the zone has a different sensor for the back half (for example) you should check the **Second light sensor** option.

Note 2: if the zone has ***perimeter and core areas***, perimeter lights having daylight control and core lights not, then you only need to use a single lighting sensor. The fact that the core lights are not controlled can be modelled using **% Zone Controlled by Lighting Area 1**. If 60% of the lights in the zone are located in the core zone and do not have daylight control then set **% Zone Controlled by Lighting Area 1** to 40.

Perimeter Area

A typical perimeter area would be the areas of the zone that are close to a window. By convention perimeter areas are defined as the area within a fixed distance from a normal to the perimeter. In the UK NCM the fixed distance is 6m.

If you wish to create a separate thermal zone to model the different lighting and solar conditions in the perimeter area, you can use the Offset snap option to draw Virtual partitions.

Daylight illuminance on the 'working plane' is calculated for up to two locations in each zone during the simulation and illuminance setpoints are maintained where necessary by electric lighting. The sensor is always located in the working plane which, by default, is 0.8m above the floor. By default, when lighting control is switched on, a single photo sensor monitors the daylight illuminance at the first sensor location

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and controls the lights for the whole of the zone. You can however set up 2 **Lighting Areas** in each zone, by checking the **Second lighting area** check box. In this case you can set a target illuminance for the second lighting area separately and also define the percentage of the zone covered by Lighting Area 2.

Note 1: the floor area covered by the 2 sensors does not need to add to 100%. The lights in the remaining floor area operate without daylight control.

Note 2: the target illuminance for Lighting Area 1 is set on the Activity tab under Environmental Control.

If there is only one lighting area then a percentage equal to

100 - (%Zone covered by Lighting Area 1)

is assumed to have no lighting control..

% Zone Controlled by Lighting Area 2

The fraction of the zone floor-area whose electric lighting is controlled by the daylight illuminance on the second sensor. This data is required if Lighting Area 2 is being used. A percentage equal to

100 – [%Zone Controlled by Lighting Area 1] - [%Zone Controlled by Lighting Area 2]

is assumed to have no lighting control (i.e. in this uncontrolled area of the space, the lights operate purely according to the schedule without any dimming/switching).

PROCEDURE

The procedure for introducing the lighting control is:

1. Check the **Lighting Control On** checkbox (at building level if all zones are to have lighting control).
2. Select the type of control as described below.
3. Position the first sensor in each zone having lighting control. The z-position is set by the Working plane height on the Advanced tab of the Model options dialog.
4. Set the **% Zone covered by Lighting Area 1**. If all the lights in the zone are in Lighting Area 1 (i.e. they are controlled by the 1st (main) lighting sensor then enter 100%.
5. If there are two lighting areas then position the second sensor.
6. Set the **% Zone covered by Lighting Area 2**. If all the lights in the zone are in Lighting Area 2 (i.e. they are controlled by the 2nd lighting sensor) then enter *100 - %Zone covered by Lighting Area 1*.

Note: by default the main lighting sensor is positioned in the geometric centre of the zone. It is important that you check the position of all lighting sensors to obtain accurate results. For example, if the lighting sensor is positioned right next to a window receiving large amounts of daylight, the lighting sensor will signal 'enough daylight' even if the rest of the zone is only dimly lit and electric lighting energy will be under-estimated (daylight savings over-estimated).

Continuous Control

With **Continuous** control, the overhead lights dim continuously and linearly from maximum electric power, maximum light output to minimum electric power, minimum light output as the daylight illuminance increases. The lights stay at the minimum point with further increase in the daylight illuminance.

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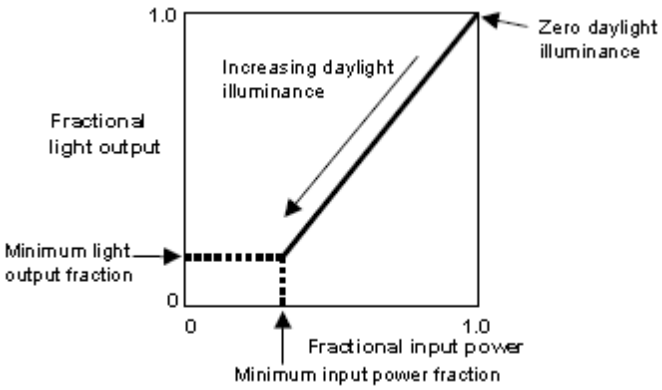


The **Minimum input power fraction** for **Continuous** control type is the lowest power the lighting system can dim down to, expressed as a fraction of maximum input power. For **Continuous/off** lighting control, this is the power fraction reached just before the lights switch off completely.

The **Minimum output fraction** for **Continuous** control type, is the lowest lighting output the lighting system can dim down to, expressed as a fraction of maximum light output. This is the fractional light output that the system produces at minimum input power. For **Continuous/off** lighting control, this is the power fraction reached just before the lights switch off completely.

Note: Continuous control provides an idealised lighting control mechanism which can be useful for calculating upper limits on the potential for savings using natural daylight.

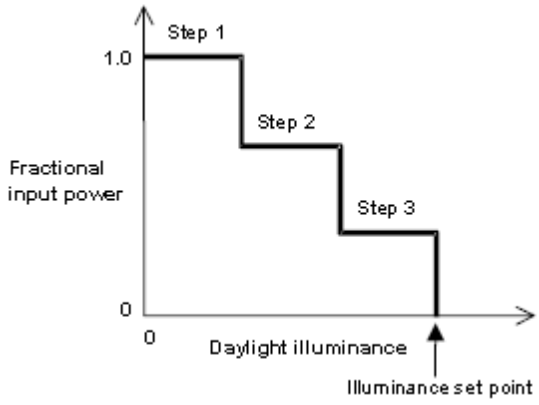
Continuous/Off Control

Continuous/off control is the same as continuous control except that the lights switch off completely when the minimum dimming point is reached.

Stepped Control

Stepped control allows you to switch lighting on/off according to the availability of natural daylight in discrete steps. Whereas the Continuous control described above provides precisely controlled illuminance by dimming the lights, the stepped control models blocks of lights switching on/off according to the electric lighting requirement.

The electric power input and light output vary in discreet, equally spaced steps. The number of steps can be set.



See also **EnergyPlus Daylight Calculations**.

GLARE

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Maximum allowable glare index

If a daylit zone has windows with Window shading devices, the shades will be deployed if the daylight glare at sensor 1 exceeds the value of Maximum allowable glare index. To get this type of glare control you have to specify Shading control type as **5-Glare** for one or more windows in the zone (see Window Shading Control).

View angle relative to y-axis

Daylight glare from a window depends on occupant view direction. It is highest when you look directly at a window and decreases as you look away from a window. This field specifies the view direction for calculating glare. It is the angle, measured clockwise in the horizontal plane, between the positive y-axis and the occupant view direction, i.e. it is the bearing of the persons line of sight. For example, with Site orientation = 0, in the Northern Hemisphere, 90 = Facing East, 180 = Facing South etc).

ALGORITHMS

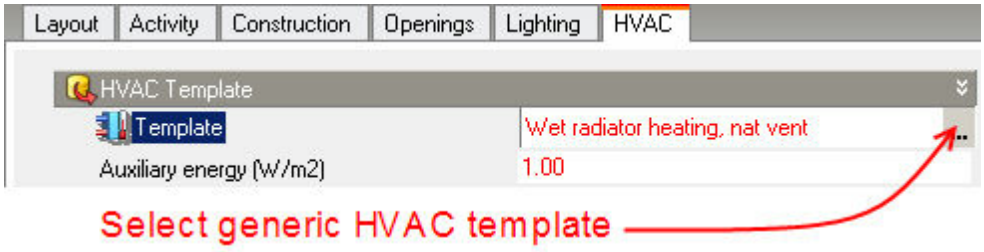
DesignBuilder uses the EnergyPlus DAYLIGHTING:DETAILED object to model the control of electric lighting according to daylight illumination levels. You can find more information on the algorithms used in the EnergyPlus documentation.

3.3.2.5 HVAC Data

HVAC tab in model data

Templates

You can load generic HVAC data by clicking on the Template option under HVAC Template and then by clicking on the '...' at the right of the line (below).



When you make a selection from the list of HVAC templates, data from selected template will be loaded to the model.

You can also open headers to enter HVAC details where they are different from those loaded from the template:

- Mechanical Ventilation
- Heating
- Cooling
- Humidity Control
- DHW - Domestic Hot Water
- Natural Ventilation
- Mixed Mode
- Air Temperature Distribution
- Plenums

See Compact HVAC System Types for details on Compact HVAC systems.

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System type

When using Compact HVAC data, the HVAC Type is displayed beneath the Template. This cannot be edited directly - if you want to choose a different HVAC system type you should do this by selecting an appropriate template.

Auxiliary energy

When using Simple HVAC data, the Auxiliary energy can be entered as kWh/m2/year (SI units) or Btu/ft2 (IP units). Auxiliary energy accounts for any additional energy consumption due to fans, pumps, control gear etc. It is specified per floor area and is modelled as being consumed 24/7 during the simulation.

SYSTEM AVAILABILITY

When using Compact HVAC data, the system availability schedule can be defined to control the overall operation of the HVAC system, including heating, cooling and ventilation. This schedule is used at the building level for **2-Unitary multizone, 3-VAV** and **5-CAV** systems and at the zone level for **1-Unitary single zone** and **5-Fan coil.**

System availability schedule

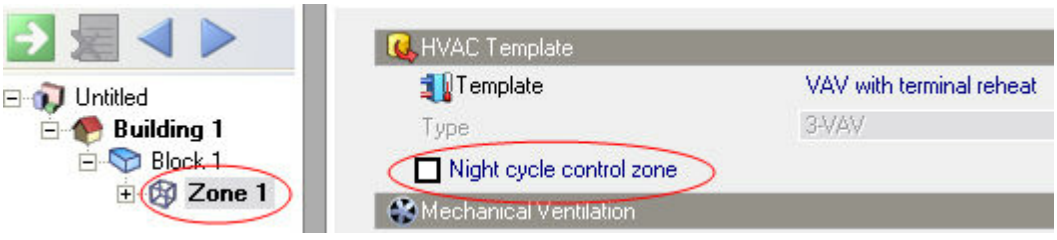
The **System availability schedule** defines the operation of the air system fans. For Compact Unitary systems the Fan operation mode can be set to **2-Cycling** in which case air distribution only occurs when there is heating or cooling demand.

Night cycle control (VAV/CAV)

The Night cycle control manager is used for cycling on CAV and VAV air systems when one or more zones become too hot or too cold. The usual situation is that the central air handler is turned off at night. However if the building gets too cold there might be condensation on the walls and other damage. Thus the control system is usually programmed to turn the system on if one control thermostat or any thermostat shows a zone temperature of less than a night time set point. Similarly there might be a concern about a building getting too hot. Again the control system is programmed to turn the air handler back on if one or any zone temperature exceeds a night time cooling set point. This data gives the user flexibility in determining how the night time on/off decision will be made. The manager can look at the temperature in one **Night cycle control zone** or it can sample all the zones connected to the air handler (**Cycle on any**).

Enter the system behavior during times when the **System availability schedule** (above) is zero (off). The possible inputs are:

- **Stay Off** - the system will remain off, no matter how hot or cold the zones may be.
- **Cycle on any** - if any zone served by this system has an air temperature outside the cooling or heating set points the central fan will turn on even though the System availability schedule indicates the fan is off.
- **Cycle on control zone** - same as **Cycle on any** except the availability manager looks at the temperature in only the zone specified by the **Night cycle control zone**. Note that when using this option you must select one zone as being the **Night cycle control zone**. Do this by checking the option at zone level in the zone used as the control zone (below).



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The default is **1-Stay off**.

The On cycle period is the time for which the system will run after it has cycled on. This is hard-set to 1 hour.

3.3.2.5.1 Compact HVAC System Types

HVAC tab in model data

Compact HVAC systems are used when the HVAC model option is set to Compact and is a powerful entry way into EnergyPlus HVAC modelling allowing you to model HVAC systems in quite some detail without the need to draw an air flow network and deal with the complexities of control systems and node connections. You can model many common HVAC systems including VAV with terminal reheat, VAV with PIU, Constant volume, Fan coil units, Packaged DX units and Mechanical ventilation.

EnergyPlus simulations are carried out on the detailed HVAC component models generated by DesignBuilder from the compact descriptions.

When the HVAC model option is set to Compact, there are 5 HVAC system types:

- Unitary single zone
- Fan Coil Units
- Unitary multizone
- VAV
- CAV

Rules

1. Only one CAV, VAV or Unitary multizone system can be defined per building.
2. If you select Unitary multizone, CAV or VAV at zone level, then the same selection must be made at building level.
3. You can enter Fan coil and Unitary single zone systems in any zone without concern for the selection at building level.
4. Up to 400 zones can be modelled simultaneously using Compact HVAC systems. It is possible to model more zones than this by making changes to the IDD file (contact DesignBuilder or EnergyPlus Support desks for more information about this).
5. Pumps are modelled using typical default data.
6. Unitary multizone and Fan coil units cannot be used in same building.
7. Fan coil units are incompatible with Calculated natural ventilation.

The Unitary single zone option allows you to model simple single constant volume direct-expansion (DX) based HVAC configurations with several different heating options. Direct expansion includes single packaged rooftop systems commonly seen in commercial buildings and split systems commonly seen in residential buildings. In this system, local cooling coils are used to condition air which is supplied to the zone through a local air delivery system. Air delivery can be set up to ensure minimum fresh air supply and there are options for economisers to provide free cooling and heat recovery.

Note: With Unitary single zone systems each zone has its own 'AHU' and so, unlike the **Unitary multizone, CAV** and **VAV** Compact HVAC types, Unitary single zone systems take all their data from the zone level.

System availability

You can model unitary single zone systems with or without outside air. If you include Air distribution with

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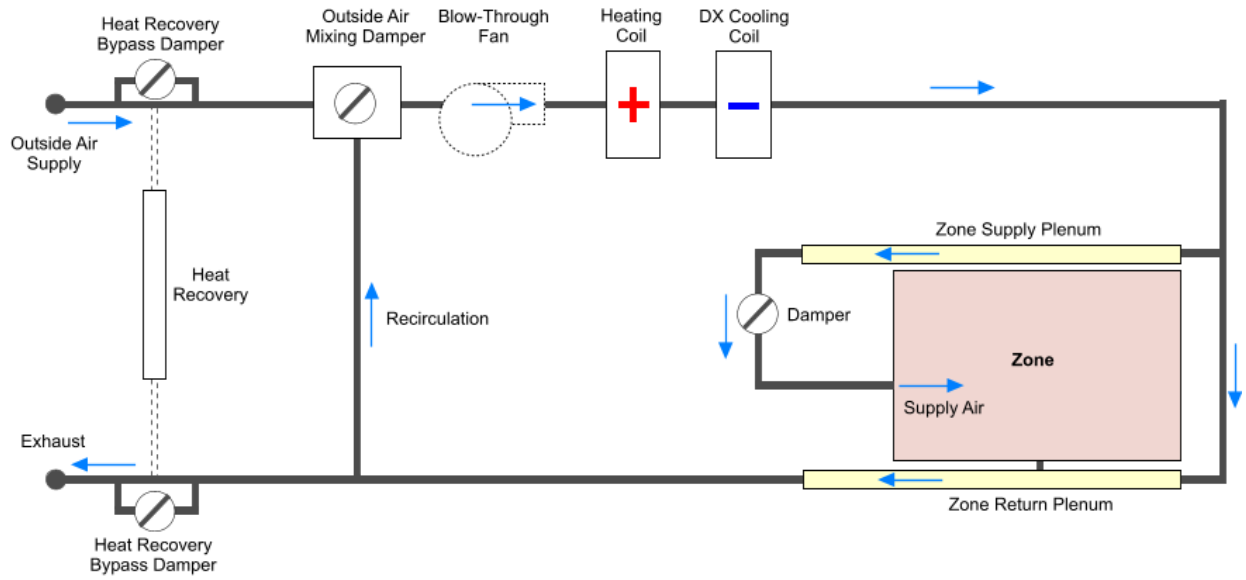
your Unitary single zone system then heating and cooling will only operate when the Air distribution operation schedule is on.

If you do not want to include outside air in your system, you should uncheck the Mechanical ventilation 'On' check box. In this case heating/cooling availability is determined entirely from the heating/cooling operation schedules under the Heating and Cooling headers.

Unitary Single Zone Compact HVAC Airflow Schematic



Notes:

1. The Unitary Single Zone system supplies one zone only.
2. The diagram shows the zone with its *Zone* supply and return plenums. These are optional as are Heat recovery, Cooling coil, Heating coil.

Technical EnergyPlus

EnergyPlus needs both the heating coil and cooling DX coil to be defined so even if heating or cooling is not selected in the input, DesignBuilder will include both coils in the IDF data supplied to EnergyPlus and schedule the appropriate coil to be off.

The Fan coil unit Compact option simulates a 4 pipe fan coil unit with hot water heating coil, chilled water cooling coil, and an outside air mixer. The fan coil units are zone equipment units which are assembled from other components. Fan coils contain an outdoor air mixer, a fan, a simple heating coil and a cooling coil. The fan coil unit is connected to a hot water loop (demand side) through its hot water coil and to a chilled water loop (demand side) through its cooling coil. The unit is controlled to meet the zone (remaining) heating or cooling demand. If there is a heating demand, the cooling coil is off and the hot water flow through the heating coil is throttled to meet the demand. The hot water control node must be specified (same as the hot water coil inlet node) as well as maximum and minimum possible hot water volumetric flow rates. If there is a cooling demand from the zone, the hot water coil is off and the chilled water flow through the cooling coil is throttled to meet the load.

You can model Fan coil unit systems with or without outside air. If you include Mechanical ventilation with your Fan coil unit system then heating and cooling will only operate when the Mechanical ventilation operation schedule is on.

If you do not want to include outside air in your system, you should uncheck the Mechanical ventilation 'On' check box. In this case heating/cooling availability is determined entirely from the heating/cooling operation

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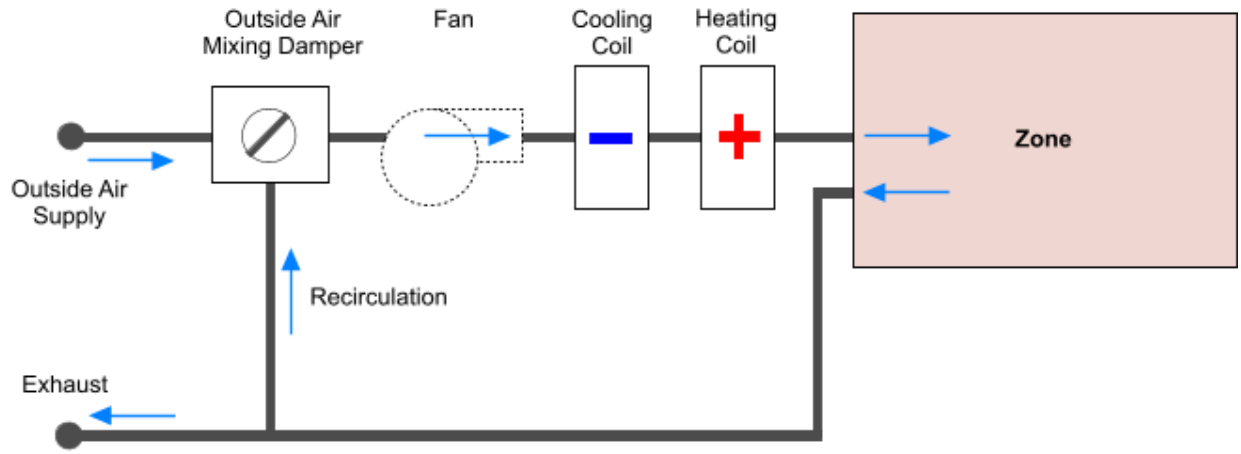
schedules under the Heating and Cooling headers.

Unlike the **Unitary multizone** and **CAV** and **VAV** Compact HVAC types, Fan coil unit zone systems take all their data from the zone level.

Fan Coil Compact HVAC Airflow Schematic



Notes:

1. The Fan Coil Unit system supplies one zone only.
2. Cooling coil and Heating coil are optional.

Note 1: EnergyPlus fan coil supply fans run continuously at full speed whenever the availability schedules are > 0 so fan coil outside air flow can be 'fully on' or 'fully off' but cannot reduce to fractional values in between. You may therefore get higher outside air delivery rates than with other systems if you are using Schedules and your Mechanical ventilation operation schedule has fractional values.

Limitations

1. Outside air flow rate is either off, or on at a fixed flow rate depending on the value of the Fan operation schedule..
2. Fan coil units cannot incorporate economisers and variable speed fans.

Technical EnergyPlus

EnergyPlus needs both the heating coil and cooling coil to be defined so even if heating or cooling is not selected in the input, DesignBuilder will schedule the appropriate coil to be off to mimic a 2-pipe system.

The Unitary multizone option allows you to model constant volume direct-expansion (DX) based HVAC configurations with several different heating options. Direct expansion (DX) includes single packaged rooftop systems commonly seen in commercial buildings and split systems commonly seen in residential buildings. In this system, central heating and cooling coils are used to condition air which is delivered to the each of the zones in the system through an air delivery system. Air delivery can be set up to ensure minimum fresh air supply and there are options for economisers to provide free cooling and heat recovery.

For a multizone system, only one zone is specified as the control zone. The thermostat is located in this control zone as set by the Thermostatic control zone for unitary system at the top of the HVAC tab at zone level. So when using this system you should be careful to locate the thermostat in a zone which will have a representative temperature for the whole building, otherwise some zones may become over/under heated/

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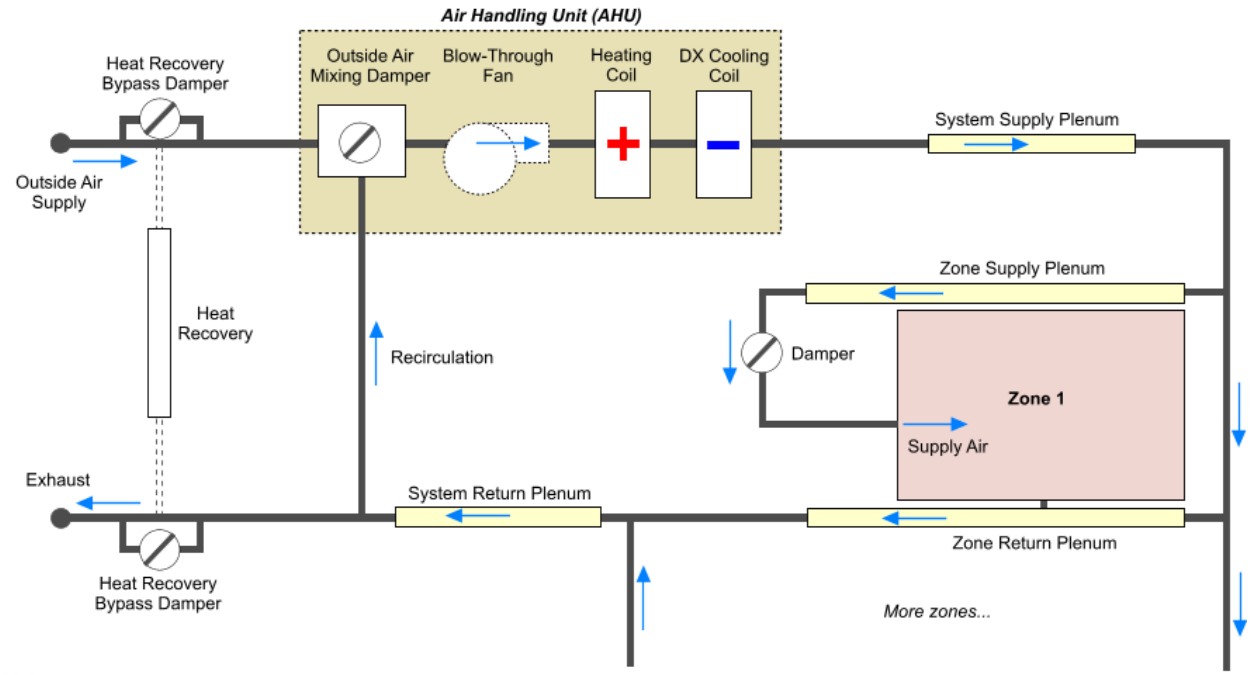
cooled.

Only one Unitary multizone system can be defined per building and it can serve up to 400 zones.

Unitary Multizone Compact HVAC Airflow Schematic



Notes:

1. The AHU is illustrated connected to a single zone.Up to 400 zones can be served by the Unitary Multizone AHU.

2. The diagram shows each zone with its *Zone* supply and return plenums and also *System* supply and return plenums. These are optional.

3. Also optional are Heat recovery, Cooling coil, Heating coil.

Note

The Compact HVAC type must be set to Unitary multizone at building level and in all zones which are part of the system. Other zones can have HVAC type **Unitary single zone** or **Fan coil units** but not **VAV** or **CAV.**

Technical EnergyPlus

EnergyPlus needs both the heating coil and cooling DX coil to be defined so even if heating or cooling is not selected in the input, DesignBuilder will include both coils in the IDF data supplied to EnergyPlus and schedule the appropriate coil to be off.

The VAV option allows you to model Variable Air Volume (VAV) HVAC configuration with optional preheat, main heating coils and reheat and several different heating coil options. You can select series or parallel fan powered terminal units (also known as powered induction units or PIU). There are options to control the air distribution system in various ways including the ability to ensure minimum fresh air delivery to each zone, set VAV box minimum flow fraction and various outside air options including an economiser to provide free cooling when appropriate. You can also model heating and cooling coil temperature reset.

Only one VAV system can be defined per building and it can serve up to 400 zones.

Note: the Compact HVAC type must be set to **VAV** at building level and in all zones which are part of the VAV system. Other zones can have HVAC type **Unitary single zone** or **Fan coil units** but not **Unitary**

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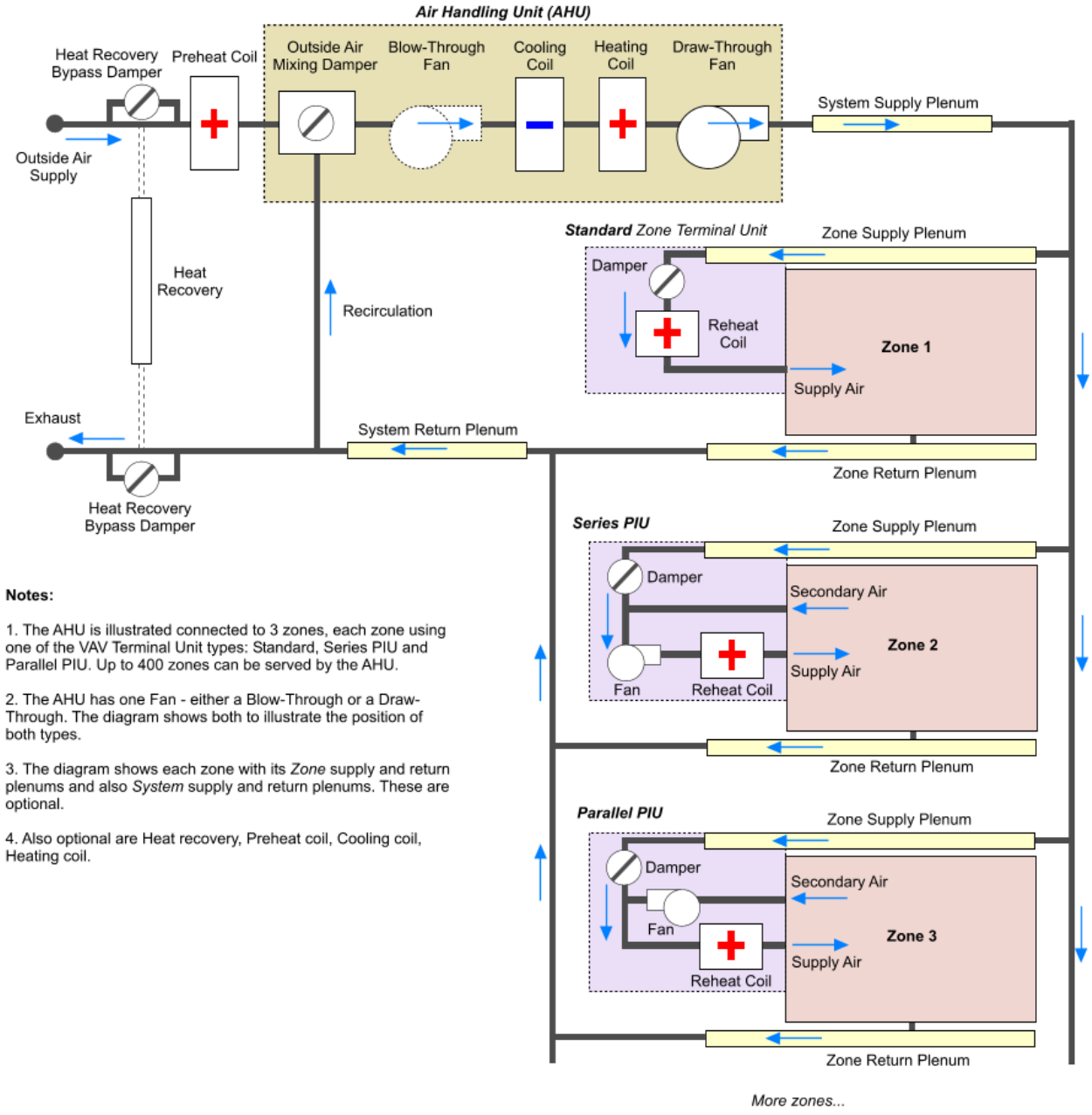
multizone or **CAV.**

VAV Compact HVAC Airflow Schematic



Notes:

1. The AHU is illustrated connected to 3 zones, each zone using one of the VAV Terminal Unit types: Standard, Series PIU and Parallel PIU. Up to 400 zones can be served by the AHU.

2. The AHU has one Fan - either a Blow-Through or a Draw-Through. The diagram shows both to illustrate the position of both types.

3. The diagram shows each zone with its *Zone* supply and return plenums and also *System* supply and return plenums. These are optional.

4. Also optional are Heat recovery, Preheat coil, Cooling coil, Heating coil.

See also Zone Terminal Units for more on VAV systems.

The CAV option allows you to model Constant Air Volume HVAC configuration with optional preheat, main AHU heating coils and zone terminal reheat and several different heating coil options. There are options to control the air distribution system in various ways including the ability to ensure minimum fresh air delivery to each zone, set various outside air options including an economiser to provide free cooling when appropriate and heating and cooling coil temperature reset .

Only one CAV system can be defined per building.

Note: the Compact HVAC type must be set to **CAV** at building level and in all zones which are part of the CAV system. Other zones can have HVAC type **Unitary single zone** or **Fan coil units** but not **Unitary**

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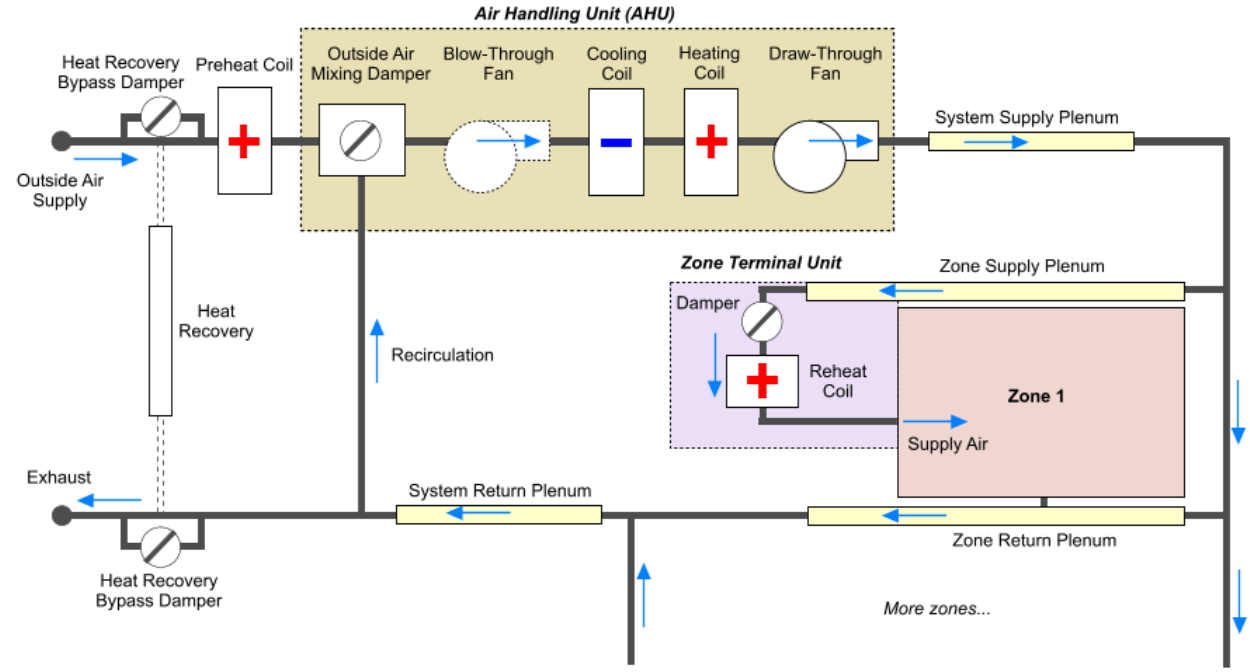
multizone or **VAV.**

CAV Compact HVAC Airflow Schematic



Notes:

1. The AHU is illustrated connected to a single zone.Up to 400 zones can be served by the CAV AHU.

2. The AHU has one Fan - either a Blow-Through or a Draw-Through. The diagram shows both to illustrate the position of both types.

3. The diagram shows each zone with its *Zone* supply and return plenums and also *System* supply and return plenums. These are optional.

4. Also optional are Heat recovery, Preheat coil, Cooling coil, Heating coil.

See also Zone Terminal Units for more on VAV systems.

3.3.2.5.2 Mechanical Ventilation and Air Distribution

HVAC tab in model data

Check the mechanical ventilation checkbox to indicate that outside air and/or recirculated air is delivered to the zone. You can use this setting to define mechanical ventilation and air delivered through centrally ducted air conditioning systems. Simple and Compact HVAC options share many of the same data fields. Data which applies only to Compact systems is indicated in the text below.

Note that **Mechanical Ventilation** data refers to the fan-powered air delivery through the main HVAC system and not a separate mechanical ventilation system.

See also:

- Outside Air
- Fans
- Economisers
- Heat Recovery
- Plenums
- VAV Terminal Units

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HVAC tab in model data under Mechanical Ventilation header

You can set the amount, timing and control of outside air delivery through the HVAC air distribution system on the HVAC tab.

- **Outside air requirement** data is set at the ***zone*** level on the HVAC tab for all HVAC configurations and options.
- **Outside air flow control through the AHU** (when using **2-Unitary multizone**, **3-VAV** and **5-CAV** Compact HVAC) is set at ***building*** level on the HVAC tab.
- **Outside air flow control through zone units** (**1-Unitary single zone** and **4-Fan coil** Compact HVAC) is set at *zone* level on the HVAC tab with the rest of the zone unit data.

The **Mech Vent + Nat Vent + Infiltration**data can displayed on the Heating design, Cooling design and Simulation screens when you select **1-All** or **3-Comfort** data. This is the sum of fresh air delivered through the HVAC system, infiltration and natural ventilation outside airflow in air changes per hour (ac/h) and when used together with the other environmental output it can be very useful in checking for occupant discomfort.

Outside air definition method

Defines the method used to set the maximum **outside air** delivery rate. The options are:

- **1-By zone** - enter the zone **outside air** delivery rate in air changes per hour in the control directly below. The air flow rate in m3/s is calculated from the ac/h data using:

  ```
  m3/s = ac/h x ZoneVolume / 3600
  ```

  where `ZoneVolume` is the actual air volume of the space calculated according to Model options for excluding floor/ceiling constructions.

  Note: this zone volume may be slightly different from the value used for the purposes of calculating air flow rates for infiltration which uses the *total* zone volume.

- **2-Min fresh air (Per person)** - maximum natural ventilation rate is defined using Minimum fresh air requirements per person as set on the Activity tab. The air flow rate in m3/s is calculated as:

  ```
  m3/s = MinFreshAir x NumberPeople / 1000
  ```

  `NumberPeople = Occupancy density (people / m2) * Zone floor area (m2).`
  `MinFreshAir` is the minimum fresh air rate per person (l/s/person or CFM).

- **3-Min fresh air (Per area)** - maximum natural ventilation rate is defined using Minimum fresh air requirements as set on the Activity tab. The air flow rate in m3/s is calculated as:

  ```
  m3/s = l/s-m2 x ZoneFloorArea / 1000
  ```

  where `ZoneFloorArea` is the actual floor area of the space.
  `MinFreshAir` is the minimum fresh air rate per floor area (l/s-m2 or CFM/ft2).

- **4-Min fresh air (Sum per person + per area)** - maximum natural ventilation rate is defined using Minimum fresh air requirements for both as set on the Activity tab. The air flow rate in m3/s is calculated as:

  ```
  m3/s = (l/s-m2 x ZoneFloorArea + MinFreshAir x NumberPeople)/ 1000
  ```

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where ZoneFloorArea is the actual floor area of the space.
MinFreshAir is the minimum fresh air rate per floor area (l/s-m2 or CFM/ft2).
NumberPeople = Occupancy density (people / m2) * Zone floor area (m2).
MinFreshAir is the minimum fresh air rate per person (l/s/person or CFM).

- **5-Min fresh air (Max per person and per area)** - maximum natural ventilation rate is defined using Minimum fresh air requirements for both as set on the Activity tab. The air flow rate in m3/s is calculated as:

  m3/s = Maximum of (l/s-m2 x ZoneFloorArea / 1000) and (MinFreshAir x NumberPeople/ 1000)

  where ZoneFloorArea is the actual floor area of the space.
  MinFreshAir is the minimum fresh air rate per floor area (l/s-m2 or CFM/ft2).
  NumberPeople = Occupancy density (people / m2) * Zone floor area (m2).
  MinFreshAir is the minimum fresh air rate per person (l/s/person or CFM).

Outside air flow rate

Enter the minimum zone **outside air** delivery rate in air changes per hour when **Outside air definition method** (above) is **1-By zone**.

The actual minimum amount of outside air entering the AHU can be modified by the **Minimum AHU outside air requirement schedule** (below).

Note: in Compact HVAC systems, the *total* mixed air flow rate into the zone is calculated by EnergyPlus and will often be higher than the outside air flow rate due to the mixing of recirculated air to provide enough airflow to delivery any additional heating/cooling.

Minimum AHU outside air requirement schedule

You can modify the total outside airflow using the **Minimum AHU outside air requirement schedule.** Whatever the outside air flow would have been without the schedule is multiplied by the current schedule value. So, for example, if you select a schedule which is always 0.5, then the system will supply half the outside air flow at all times vs. the same run without the schedule. You can also use this schedule to switch off outside air during unoccupied periods.

Maximum supply air flow rate

The **maximum supply air flow rate** is the total flow rate of air entering the zone (not necessarily all fresh air). It can be defined at the zone level when using Compact HVAC or it can be left in the default state (**Auto**), in which case the maximum supply air flow rate is calculated based only on the maximum heating and cooling capacities.

This data is available at the zone level when using Unitary single zone, Unitary multizone or VAV Compact HVAC and the plant sizing options **Autosize when not set** or **Manual**.

System availability schedule

The **System availability schedule** defines the operation of the air system fans. For Compact Unitary systems the Fan operation mode (below) can be set to **2-Cycling** in which case air distribution only occurs when there is heating or cooling demand.

OUTSIDE AIR MIXING

This data is defined for CAV/VAV air handling units (AHU) at building level.

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Outside air mixing

Select the way outside air is used:

- **1-Recirculation** - the outside airflow supply to the AHU is mixed with recirculated return air from the zones. This is done to save energy often in conjunction with an economiser to ensure that optimal use is made of outside air. When heat recovery is used with the **1-Recirculation** outside air mixing option, the economiser must be selected in the interface for the heat recovery to be by-passed.
- **2-Full fresh air** - the airflow into the AHU is 100% outside air, without any recirculation. This is modelled in EnergyPlus by setting the supply airflow rate to the outside air flow rate. Note that when using this option, fixing the supply air flow rate to the outside air rate will in many cases mean that the system will not be capable of meeting the design cooling load. To increase the maximum cooling capacity of a Full fresh air VAV/CAV system you can increase the outside air flow rate (such systems could be very inefficient in energy use without heat recovery). When heat recovery is used with the **2-Full fresh air** outside air mixing option, the heat recovery is by-passed when this is advantageous in reducing AHU cooling coil loads. The heat recovery also operates when the outside air temperature is less than 12°C.

Important note for Full fresh air systems

In order to ensure that there is no recirculation you must set the HVAC sizing factor to 1 (the default is 1.2)

Outside air control minimum flow type

This option allows you to specify the way minimum outside air flow rate is controlled for **3-VAV** and **5-CAV** Compact HVAC types when the **Outside air mixing type** (above) is **1-Recirculation**:

- **1-Fixed** - the minimum outside air flow rate is fixed as set above no matter what the actual system flow rate is. In practice even with 'Fixed' outside air control minimum it is possible for the outside air flow rate into individual zones to be slightly different from the requested value. This is because the minimum outside air is controlled at the AHU level to ensure that the total fresh air entering the AHU is the total required for the building (the sum of the individual zone outside air requirements). But depending on the heating/cooling loads in each zone, some zones will require more supply air to meet the load than others. So the total fresh air entering the building will be correctly set as the sum of all the zone minimum fresh air requirements as specified but the distribution around the building may not be perfectly maintained.
- **2-Proportional** - the minimum outside air flow rate varies in proportion to the total system air flow rate.

The minimum outside air flow rate through the AHU outside air inlet is automatically calculated as the sum of the individual zone ventilation requirements. This is the 'design minimum'. During the simulation, 'minimum' and 'maximum' represent the limits for economizer operation. If there is no economizer, then the minimum flow of outside air is delivered. If **1-Fixed** is selected, then this value will remain fixed (unless the total VAV system flow rate falls below this value, in which case, the system will deliver 100% outside air at whatever the system flow rate is). If, **2-Proportional** is specified, then the operating minimum falls as system flow rate falls. This simulates a typical system with a fixed lower stop on the outside air supply damper. Delivering **1-Fixed** requires enhanced control systems.

Note: To ensure minimum outside air is delivered to all zones you should use **1-Fixed.**

If you select **2-Manual** HVAC sizing you can enter the **Outside air control minimum flow rate** manually at building level.

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Outside air sizing

When the Outside air definition method is **2-Min fresh air per person,** sizing for minimum Outside air (OA) flow rate is done using the 'Number of People' value (see above) with no regard for the schedules. The total OA requirement for each zone on the air handler is summed and used to set the minimum OA flow rate for the air handler. The OA controller sets an OA flow rate for the air handler each time step. After that, each zone receives a pro-rated share of the total OA flow proportioned by the current supply flow rate to each zone. There is no further zone-by-zone allocation of OA quantities, which is what happens in a real system.

HVAC tab in model data under Mechanical Ventilation header

Fan operation mode (Compact, Unitary systems only)

In Compact Unitary HVAC systems the supply fan has two different possible operating modes. The choices for this field are:

- **1-Continuous** - fan operates using air distribution availability schedule (above)
- **2-Cycling** - fan operates when heating or cooling is delivered.

For most commercial buildings, continuous fan operation will continue to supply outside air to the zones as typically required by code. For continuous fan operation, the 'System Availability Schedule' (see above) is the supply fan operating schedule. For systems where the supply fan only runs when either cooling or heating needs to be supplied to the zone such as for many residential systems, cycling should be specified.

Fan Type

When using Simple HVAC, enter the type of fan. Select from:

- **1-Intake** - fan blows outside air into the zone and the zone receives heat from the fan if **Fan in air** (below) > 0
- **2-Exhaust** - fan exhausts air from the zone. In this case there is no fan heat pickup. It is assumed that makeup air comes from outside.

Note that in Simple HVAC the Auxiliary energy data accounts for all fan, pump and other electrical energy use.

Fan pressure rise

Enter the pressure rise at full flow and standard conditions. Standard conditions are considered 20C at sea level, 101325 Pa.

You can calculate the approximate fan pressure rise from Specific Fan Power (SFP) data using:

Delta P = 1000 * SFP * Fan total efficiency

Where SFP is fan power per flow rate in W/l/s.

Typical values for various system types are shown in the table below.

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System Type	Specific Fan Power (Watts/litre/second)
Central mechanical ventilation including heating, cooling and heat recovery	2.5
Central mechanical ventilation including heating and cooling	2.0
All other systems	1.8
Local ventilation units within the local area, such as window/wall/roof units, serving one room/area	0.5
Local ventilation units remote from the local area, such as ceiling void or roof mounted units, serving one room/area	1.2
Fan coil units (rating weighted average)	0.8

Source ESTA: http://www.esta.org.uk/

Fan total efficiency (%)

Enter the product of the fan motor and impeller efficiency of the supply fan. This is the ratio of the power delivered to the air to the electrical input power at maximum flow expressed as a percentage. The motor efficiency is the power delivered to the shaft divided by the electrical power input to the motor. The fan efficiency is power delivered to the air divided by the shaft power. The power delivered to the fluid is the mass flow rate of the air multiplied by the pressure rise divided by the air density. Must be greater than 0 and less than or equal to 100.

Fan in air (%)

Enter the percentage of the motor heat that is added to the air stream. A value of 0 means that the motor is completely outside the air stream. A value of 100 means that all of the motor heat will go into the air stream and act to cause a temperature rise. Must be between 0 and 100.

Fan placement

Enter the supply fan placement type. There are two choices:

- **1-Draw through** models a system where the supply air fan is after the cooling and heating coils.
- **2-Blow through** where the supply air fan is before the cooling and heating coils.

The default is **1-Draw through**.

Fan part-load power coefficients

Select the set of generic pre-defined coefficients to use for the supply fan part-load power consumption. Choices are:

- Inlet Vane Dampers
- Outlet Dampers
- Variable Speed Motor
- ASHRAE 90.1-2004 Appendix G

The resulting power curves are shown in the graph below. The ASHRAE 90.1-2004 Appendix G coefficients are from TABLE G3.1.3.15, Method 2. The other sets of coefficients are from the EnergyPlus Input Output

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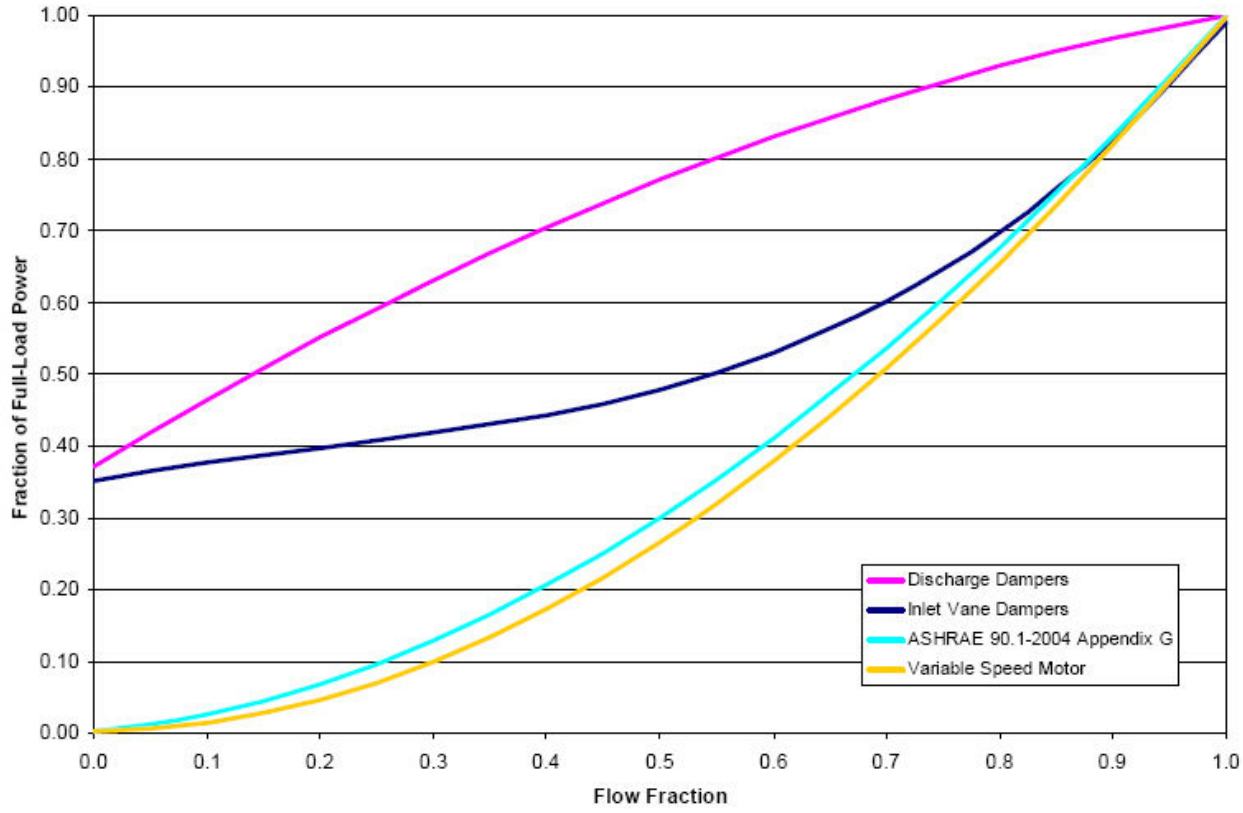
Reference, Fan Coefficient Values table.



HVAC tab in model data under Mechanical Ventilation header

HVAC Economisers are useful for facilities which require some cooling even when the outdoor temperature is lower than the indoor temperature. An economizer is a damper opening that draws up to 100% outside air when the outside air is cooler than the temperature inside the building, thereby providing **free cooling**. Economisers can reduce energy use by 15 percent or more, and are often required by energy codes for larger air conditioning units.

Economisers can be modelled when using Compact HVAC but not Simple HVAC.

See under Heat recovery for information about how economisers interact with heat recovery.

> Economiser operation applies to the overall HVAC system and so for **Unitary multizone** , **CAV** and **VAV** systems its data is set at building level. For **Fan coil unit** and **Unitary single zone** systems the data at zone level is used.

There are four options:

- **1-None** where no economizer operation will be simulated and outside fresh air is based on the Mechanical ventilation Outside air rate and associated operation schedule.
- **2-Return air temperature** establishes a limit control on the return air temperature so that when the temperature of the air entering the mixer on the outside air side is greater than the return air temperature the outside airflow rate is set to the minimum.

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- **3-Return air enthalpy** establishes a limit control on the return air enthalpy so that when the enthalpy of air entering the mixer on the outside air side is greater than the return air enthalpy the outside airflow rate is set to the minimum.

- **4-Return air temperature and enthalpy** - where both the above limit controls are in operation, i.e. both temperature or enthalpy limits are used so that when either the temperature or the enthalpy of the air entering the mixer on the outside air side is greater than the return air temperature/enthalpy, the outside airflow rate is set to the minimum.

In addition to the above checks, the economiser can also have absolute limits on temperature and enthalpy of the outside air. When the outside air conditions go beyond these limits the EnergyPlus economiser switches to minimum outside air mode, i.e. the outside air damper is closed to its minimum position and heat recovery will be enabled if available.

Economiser upper temperature limit

Enter the outside air temperature high limit for economizer operation. If the outside air temperature is above this limit, the outside air flow rate will be set to the minimum.

Economiser lower temperature limit

Enter the outside air temperature low limit for economizer operation. If the outside air temperature is below this limit, the outside air flow rate will be set to the minimum.

Economiser upper enthalpy limit

Enter the outside air upper enthalpy limit for economizer operation. If the outside air enthalpy is above this value, the outside air flow rate will be set to the minimum.

Lockout

Unitary systems can also have lockout control:

- **1-No lockout** - default option.
- **2-Lockout with heating** - when the packaged unit is in heating mode, the economiser is locked out – i.e., the economiser dampers are closed and there is minimum outside air flow.
- **3-Lockout with compressor** - in addition to locking out the economizer when the unit is in heating mode the economizer is locked out when the DX unit compressor is on. In other words, when the DX coil is off, the economizer must meet the entire cooling load – it isn't allowed to operate in conjunction with the DX cooling coil. Similarly, when the DX coil is operating, the economizer is not allowed to operate. The Lockout with compressor option is sometimes called a 'non-integrated economizer'.

HVAC tab in model data under Mechanical Ventilation header

With Compact HVAC, you can specify air-to-air heat recovery which is available between the relief air stream and the outside air inlet stream. Heat recovery is selected for Unitary multizone, CAV and VAV systems by checking Heat Recovery On under the Mechanical Ventilation header at building level. For Unitary single zone make the selection at the zone level.

Heat recovery type

Enter the type of air-to-air heat recovery. The choices are:

- **1-Sensible** - recovers sensible heat
- **2-Enthalpy** - recovers sensible and latent heat.

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Sensible heat recovery effectiveness

Enter the sensible heat recovery effectiveness. This is applied as a constant effectiveness at all conditions. The valid range is from 0.0 to 1.0, and the default is 0.70.

Latent heat recovery effectiveness

Enter the latent heat recovery effectiveness if Heat Recovery Type is Enthalpy. This is applied as a constant effectiveness at all conditions. The valid range is from 0.0 to 1.0, and the default is 0.65.

Heat recovery heating setpoint temperature (Unitary systems only)

When no economiser is selected this data defines the heating setpoint temperature of the heat recovery device for Unitary and Unitary multizone systems. Note that the single value is applied throughout the year. For example enter 15C to model a system which heats outside air up to 15C and no higher. A high setpoint value will provide optimal heating but this may add to cooling loads in the summer.

Heat recovery + economizer

If an economiser option is selected, the heat recovery is bypassed whenever the economiser operates and the heat recovery is always bypassed if economiser operation would be beneficial.

The heat recovery will operate when:

- Heat recovery is switched on at the building level for VAV and unitary multizone systems and at zone level for Unitary single zone and Fan coil systems AND
- When economiser operation is off.

You can have heat recovery and no Economiser action by switching on Heat recovery and setting economiser to **1-None**. In this case the heat recovery units heats outside air using the **Heat recovery heating setpoint temperature** above. It also cools outside air when return air temperature is lower than outside air temperature.

If the economiser is selected together with heat recovery then the **Heat recovery heating setpoint temperature** data is not shown and the effective heat recovery setpoint temperature is given by the lower economiser limit temperature.

When heat recovery is used with the **2-Full fresh air** outside air mixing option in CAV/VAV systems, the heat recovery is by-passed when this is advantageous in reducing AHU heating/cooling coil loads. Otherwise, when using the **1-Recirculation** option, the economiser must be selected in the interface for the heat recovery to be by-passed in this way.

HVAC tab in model data under Mechanical Ventilation header

Variable air volume (VAV) systems control the dry bulb temperature inside a zone by varying the supply air volume instead of the air temperature. At full cooling the VAV terminal unit damper is fully open supplying the specified maximum air flow rate. As the cooling load decreases, the damper closes until it reaches the minimum stop specified by the turndown ratio (zone minimum air flow fraction). VAV systems can be used for interior or perimeter zones with a common fan system, air temperature control, and reheating devices. Heating is provided by use of reheat coils.

Note: Zone Terminal unit data is used at the **zone** level.

Turndown ratio (supply air minimum flow fraction)

The fraction that the zone VAV box can reduce to based on the supply air maximum flow rate. The minimum flow rate to the zone while the system is operating is specified as a fraction of the maximum air

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flow rate. The turndown ratio is normally specified to meet the minimum ventilation requirement for the occupants.

The reheat coil operates only when the damper is at this minimum flow rate when **Zone damper heating action** is set to **1-Normal** (the default).

A value of 0 means the VAV box can completely shut off flow into the zone and a value of 1.0 means that the VAV box cannot reduce supply air at all (i.e. it is a constant volume system). For CAV systems this data is fixed at 1 and is not available for edit.

Turndown ratio is typically in range **0.3 - 0.5**. Minimum is 0 and maximum is 1.

Note: in EnergyPlus v.2.0 and earlier a turndown ratio of zero (unusual value) has a special meaning as the reheat coils can never operate in this case even if the **Zone damper heating action** is set to **2-Reverse.**

VAV terminal unit type

DesignBuilder provides 3 different VAV zone terminal unit types:

1-Standard - The VAV terminal unit contains a damper and optionally a reheat coil. During heating the VAV unit can either work in Normal mode where the supply air flow into the zone is the minimum air flow rate of the VAV system, essentially acting like a constant volume system or in Reverse action mode the air flow rate through the VAV box may increase above the minimum air flow when the heating demand cannot otherwise be satisfied. This is also the terminal type used for CAV systems.
2-Series PIU - The Series Powered Induction Unit is an air system terminal unit that mixes varying amounts of secondary (recirculated) air and primary (conditioned supply) air to produce a fixed flow of air to a zone. The unit contains a small fan that acts to induce the secondary air and a heating coil for heating the mixed secondary and primary air. The fan runs at a constant volume flow rate whenever the unit is on. The fan is downstream of the primary and secondary air inlets. The variable mixing is accomplished by a damper in the unit's primary air supply inlet duct. This damper can move from fully open (100% primary air. 0% secondary air) to a minimum stop that can be specified in the input description. At full cooling the damper will be fully open. At minimum cooling and for heating the damper will be at the minimum stop and the secondary air flow will be at its maximum. It uses the EnergyPlus SINGLE DUCT:SERIES PIU:REHEAT data.
3-Parallel PIU - The Parallel Powered Induction Unit is an air system terminal unit that mixes varying amounts of secondary (recirculated) air and primary (conditioned supply) air to produce a variable total flow of air to a zone. The unit contains a small fan that acts to induce the secondary air and a heating coil for heating the mixed secondary and primary air. The secondary and primary air streams enter the unit in parallel. The fan sits in the secondary air stream and runs only when secondary air is needed. The primary air inlet contains a damper that can move from fully open (maximum primary air) to a minimum stop (minimum primary air). At full cooling load the primary air damper is fully open and the fan is off. The primary air flow is at maximum and there is little or no secondary air flow. As the cooling load decreases, the primary air damper gradually closes and the secondary air flow remains close to zero. At some point, usually when the primary air flow has reached the minimum, the fan switches on and secondary air is induced. The heating coil will switch on as needed to meet any heating demand. It uses the EnergyPlus SINGLE DUCT:PARALLEL PIU:REHEAT data.

See VAV for a schematic diagram showing the 3 Zone terminal unit types connected to an air distribution system.

Parallel fan on flow fraction

For parallel PIUs, this data specifies the fraction of the primary air flow at which fan turns on. In the parallel PIU the fan operation is intermittent. If the primary air flow is above this fraction of the maximum, the fan is off. Otherwise it is on.

This data is available when using VAV Compact HVAC with the **Parallel PIU** VAV terminal unit type and the plant sizing options **Autosize when not set** or **Manual**.

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Terminal Unit Fans

When using fan powered terminal units (PIU) you can specify the characteristics of the terminal unit fans.

Terminal Unit Fan Total Efficiency

Enter the total efficiency of the zone induction fan. This is the ratio of the power delivered to the air to the electrical input power at maximum flow. This is also the product of the fan motor efficiency and fan (impeller) efficiency. The motor efficiency is the power delivered to the shaft divided by the electrical power input to the motor. The fan efficiency is the power delivered to the air divided by the shaft power. The power delivered to the fluid is the mass
flow rate of the air multiplied by the pressure rise divided by the air density. Must be greater than 0 and less than or equal to 1.

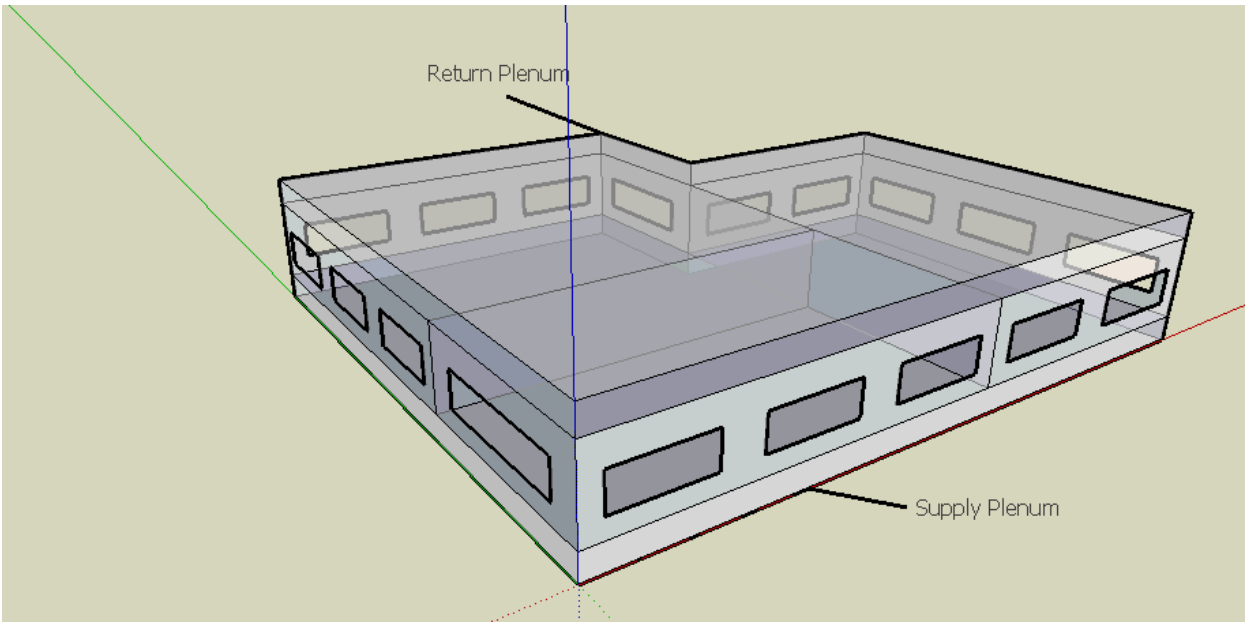
Terminal Unit Fan Delta Pressure

Enter the pressure rise of the zone induction fan in Pa at full flow and standard conditions. Standard conditions are considered 20C at sea level, 101325 Pa.

HVAC tab in model data under Mechanical Ventilation header

A plenum is an air compartment or chamber including uninhabited crawl spaces, areas above ceilings or below a floor, including air spaces below raised floors of computer/data processing centers, or attic spaces, to which one or more ducts are connected and which forms part of either the supply air, return air or exhaust air system, other than the occupied space being conditioned.

DesignBuilder Compact HVAC Unitary multizone, Unitary single zone and VAV systems can have air supplied and returned via plenums. The system supply and return plenums in the diagram below serve each of the 3 zones.



There are 4 types of plenum:

1. **System supply plenum** - a supply air plenum serving *all zones* in 3-VAV and 2-Unitary multizone system. If any zone supply plenums have been specified, the outlet from the system supply plenum will flow through the zone supply plenum to the zone terminal unit. The system supply plenum is

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defined at building level and only one is allowed per simulation.

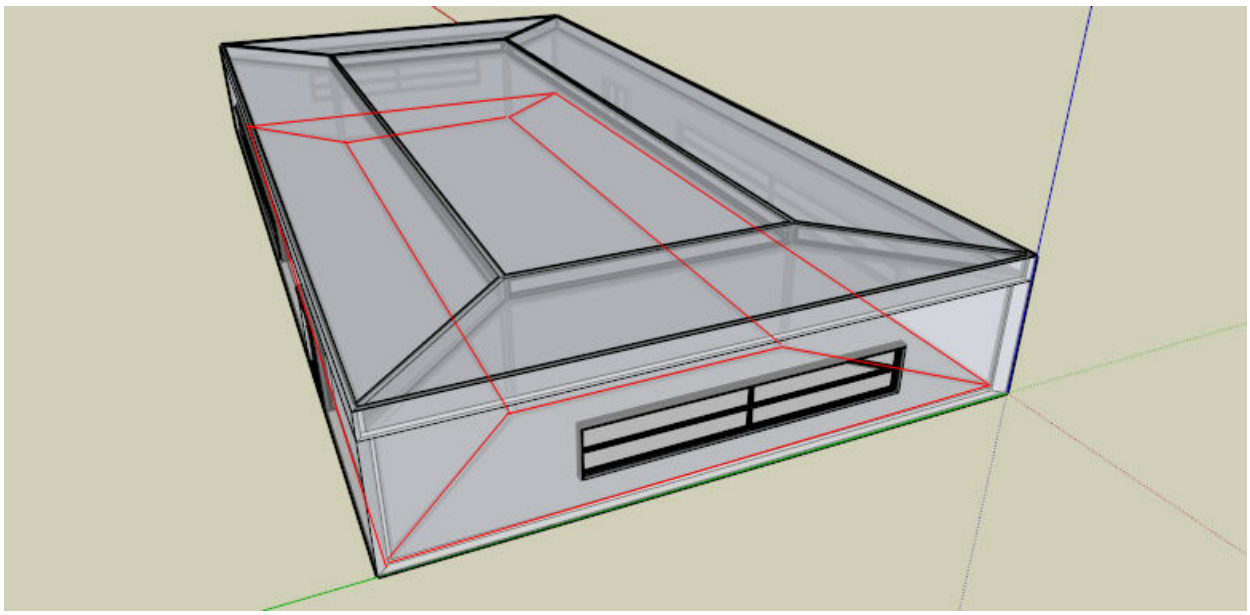
2. **System return plenum** - return air plenums serving *all zones* in 3-VAV and 2-Unitary multizone systems. If any zone return plenums have been specified, the return air from the zone will flow through the zone return plenum and then into the system return plenum. The system return plenum is defined at building level and only one is allowed per simulation.
3. **Zone supply plenum** - a supply air plenum serving *only this zone* in 3-VAV, 2-Unitary multizone and 1-Unitary single zone systems. The plenum zone is added to the supply air path after the system splitter or system-level supply plenum and before the zone terminal unit. The zone supply plenum is defined at zone level. A zone supply plenum can serve only one zone.
4. **Zone return plenum** - return air plenums serving *only this zone* in 3-VAV, 2-Unitary multizone and 1-Unitary single zone systems. The plenum zone is added to the return air path immediately after the zone and before the system mixer or system-level return plenum. The zone supply plenum is defined at zone level. A zone return plenum can serve only one zone.

When specifying a system or zone supply or return plenum you should enter a *unique zone name*. The zone does not need to be in the same block.

Plenum modelling

- Maximum of 1 *system* supply plenum allowed per simulation
- Maximum of 1 *system* return plenum allowed per simulation
- Each *zone* plenum can only serve one zone
- Set the Zone type of any plenum zones to 4-Plenum. This makes the necessary changes (remaining requirements and recommendations in bullet list)
- Plenum zones cannot be controlled. Use the HVAC template **<None>** to switch off heating, cooling and mechanical ventilation in all plenum zones.
- Remember to ensure plenum zones have no internal gains, occupancy, lighting etc.
- We recommend using the **4-Ceiling diffuser** interior convection heat transfer coefficient for plenum zones to model the effect of fast moving air on surface heat transfer.
- You will probably find it easiest to use the Combined method for Floor/slab/ceiling definition for models using plenums as each surface element in the model has just a single construction and you don't have the confusion of Model data referring to 'raised floors' and 'suspended ceilings'.
- The floor of a ceiling plenum is the ceiling of the zone below so you will often define the plenum floor as 'Ceiling tiles' construction or similar.

If the building you are modelling has more than one plenum zone, each serving multiple zones you should use *zone* plenums. Use virtual partitions to partition the large plenum zones (which in reality serve multiple zones) into multiple plenum zones, each serving a single zone. See image below.



Red lines show the 5 zones of the occupied space. Each zone has its own return-air ceiling plenum.

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This technique is also illustrated in the example file supplied with DesignBuilder **Zone vs System Plenums Example.dsb.**

Note: it is not possible in DesignBuilder v.1 to use the suspended ceiling/floor (as set on the Constructions tab when using Separate constructions) as a plenum - the plenum must be a completely separate zone.

3.3.2.5.3 Control Zones

When using some Compact HVAC options you may need to specify a zone to be the control zone, i.e. the conditions in this single zone will be used to decide the operation of the HVAC system as a whole. The control zone checkboxes are only visible at zone level and for certain system types.

Thermostatic control zone for unitary system

Check this if the current zone provides the conditions used to control the operation of the Unitary multizone system.

Humidification control zone

The zone to be used to control humidification in Compact VAV, CAV and Unitary multizone systems.

Dehumidification control zone

The zone to be used to control dehumidification in Compact VAV, CAV and Unitary multizone systems.

> **Note:** Thehumidification and dehumidification zones cannot be the same. For unitary single zone systems this means that you cannot have humidification and dehumidification in the same zone.

Mixed mode control zone

The zone to be used to control the operation of the change over mixed mode system.

3.3.2.5.4 Heating

HVAC tab in model data

The data required to define the heating system will depend on whether the HVAC model option is set to Simple or Compact and if set to Compact the type of Compact HVAC system selected.

HEATING CAPACITY

The heating capacity can either be entered by hand or can be Autosized using the Heating Design Calculations. By default, if immediately prior to a Simulation the heating capacity has not been entered (neither by hand nor from a previous Heating design calculation) then a Heating design autosizing simulation is started to calculate the capacity. The Plant sizing building model option controls the way this works.

You can change heating capacities by hand if you wish but you should bear in mind that, by default, if Model Options change, all heating and cooling capacities are reset to zero. Set the Plant sizing model option to '2-Manual' to avoid this happening.

If the HVAC system is Unitary multizone then the central heating coil capacity is calculated as the sum of the individual zone heating energy requirements.

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HEATING PLANT

Fuel

Select the type of fuel used to generate the heating energy - choose from:

- 1-Electricity
- 2-Gas
- 3-Oil
- 4-Solid fuel
- 5-Bottled gas
- 6-Other

Heating system CoP (Simple HVAC only).

The heating system Coefficient of Performance is used to calculate the fuel consumption required to meet heating demand. The value represents the total seasonal efficiency of the entire heating system and should include the effect of all energy consumption associated with building heating such as any boiler fan energy, boiler inefficiency, control equipment etc. It does not include energy involved in air or water distribution (fans or pumps) or control gear, which is accounted for in the Auxiliary energy.

Heating system CoP data is specified by zone so you can model different heating efficiencies in each zone. But generally you should access this data from the building level and allow zones to take on building default.

Heat generator CoP (Compact HVAC only).

Heat generators are devices such as boilers and heat pumps used to heat water for distribution to heating coils, radiators and DHW systems. The heat generator Coefficient of Performance is used to calculate the fuel consumption required to meet heating demand. It represents the total seasonal efficiency of the boiler excluding losses/consumption due to external pumps and fans but including all energy consumed by such ancillary devices within the boiler.

CoP is entered as a fractional value (not % value). So a boiler might have a CoP of 0.89.

Heat generator CoP data is specified for the whole building, i.e. a single hot water circuit (served by one boiler) is simulated.

Part-load boiler/heat pump performance cannot be calculated in DesignBuilder v.1.

Heating distribution loss (%)

The heating distribution loss is the loss of heat due to the distribution of hot water/air around the building. It is used to increase the heating load prior to calculating boiler heating energy consumption.

RADIATOR/BASEBOARD HEATING

Radiator/baseboard heating is controlled to meet any remaining zone load not met by other equipment in the zone that have higher heating priority.Radiators/baseboards operate according to the same set of time varying zone heating temperature setpoints as the main heating system. You can use radiator/baseboard heating with these Compact HVAC systems:

- Unitary single zone
- Unitary multizone
- VAV
- CAV

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When used with a unitary single system you have the option for the radiator/baseboard heating to either supplement the main heating coil or to replace it. With the other system types the radiators/baseboard heater always supplements the main heating though you can operate the system without terminal reheat and/or AHU heating coils and heat purely by baseboard heating.

To use radiant/baseboard heating switch on the option under the Heating header on the HVAC tab and enter information on:

Type

Choose between:

- **1-Hot water** - where the radiator/baseboard coils are served by hot water from the main heating system. In this case you can also enter a radiant fraction to model radiant heat (more below).
- **2-Electric** - where the radiator/baseboard coils are heated by electricity and heating is considered to be entirely convective.

Mode

This option is only available for single zone unitary systems:

- **1-Supplements main heating** - where the radiator/baseboard coils provide additional backup heating in cases where the heating setpoint temperature has not been satisfied by the main heating system.
- **2-Replaces main heating** - where the radiator/baseboard coils are used instead of the main unitary single zone heating coils.This option allows you to model radiant heating systems.

Radiant fraction

Radiant fraction specifies what fraction of the power input to the radiator/baseboard heater is actually transferred to the space as radiant heat. The fraction should be between 0 and 1. This is the portion of the total power that is modelled as radiant, the remaining energy is added to the zone as convective heat transfer. The portion that is radiant heat transfer from the baseboard heater is distributed to people and specific surfaces using the remaining fields.

This option is only available for hot-water radiator/baseboard systems.

Technical Notes

Entering a value greater than zero will cause a the EnergyPlus ZoneHVAC:Baseboard: RadiantConvective:Water system to be used instead of the default ZoneHVAC:Baseboard: Convective:Electric system as a post-process to the idf data.

The radiant heat is transferred to the floor, or if the floor is smaller than 1m2 then to the largest other surface in the zone.

A default of 10% of the radiant heat is assumed to fall directly on the zone occupants and this is subsequently convected into the zone.

VAV OUTSIDE AIR PREHEAT COILS

AHU preheat data is specified for the whole building and is not accessible at zone level.

Coil type

The preheat coil is located in the outside air stream, upstream of the outside air mixing box and tempers the outside air. If no preheat coil is used in the VAV system, then the option 1-None should be specified here. Otherwise this indicates the type of preheat coil. It is unlikely that both a heating coil and a preheat coil would be used at the same time. The options are:

- **1-None** - no preheat.

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- **2-Electric** - preheat coils powered by electricity (assumed 100% efficient, 0 distribution loss).
- **3-Gas** - gas-fired preheat coils (assumed 80% efficient, 0 distribution loss).

Off-coil air temperature set point

When preheat is specified, this data defines the temperature of the air coming off the preheat coils assuming idealised control. Preheat coils are automatically sized by EnergyPlus before the simulation to provide this off coil temperature given the flow rates in the air handling unit.

VAV AND CAV CENTRAL HEATING COILS

The central AHU heating coil data is specified for the whole building and is not accessible at zone level.

Coil type

The main central heating coil is located in the supply air stream, upstream of the cooling coil and after the outside air mixing box. If no central heating coil is used in the VAV system, then the option 1-None should be specified here. Otherwise this indicates the type of heating coil. It is unlikely that both a heating coil and a preheat coil would be used at the same time. The options are:

- **1-None** - no heating.
- **2-Electric** - heating coils powered by electricity (assumed 80% efficient, 0 distribution loss).
- **3-Hot water** - heating coils supplied with hot water generated by a boiler.
- **4-Gas** - gas-fired heating coils (assumed 80% efficient, 0 distribution loss).

If you select 3-Hot water main heating coils, the program generates data to simulate the boiler and the pumps required to serve the heating coil.

Off-coil air temperature set point

When main heating coils are specified, this data defines the temperature of the air coming off the coils assuming idealised control. Heating coils are automatically sized by EnergyPlus before the simulation to provide this off coil temperature given the flow rates in the air handling unit.

Heating coil setpoint reset type

Select the type of automatic reset control for the central heating supply air temperature for CAV and VAV system. The choices are:

- **1-None** – no reset, use the **Off-coil air temperature set point** in conjunction with the Zone setpoint schedule.
- **2-Outdoor air temperature reset** – reset the heating supply air temperature based on the following default rules. When the outdoor dry bulb temperature (ODB) is at or below –6.7C the setpoint is the **Off-coil air temperature set point**. When the ODB is at or above 10.0C the setpoint is 20.0C. In between, the setpoint is varied linearly. These control parameters are from ASHRAE 90.1 Appendix G.

The default is **1-None**.

Note: you should be aware when using **2-Outdoor air temperature reset** that the effective off-coil setpoint for the AHU heating coil used in the simulation will be between 20C and the value you enter for the **Off-coil air temperature set point.** If you also have an AHU cooling coil you must make sure that it does not operate simultaneously with the AHU heating coil by making the appropriate AHU coil operation schedules.

VAV TERMINAL REHEAT COILS

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Reheat data is specified for individual zones.

Coil type

Use this data to either switch reheat off or select either electric or hot water reheat coils. The options are:

- **1-None** - no heating.
- **2-Electric** - heating coils powered by electricity (assumed 100% efficient, 0 distribution loss).
- **3-Hot water** - heating coils supplied with hot water generated by a boiler.

If you select **3-Hot water** main heating coils, DesignBuilder generates data to simulate the boiler and the pumps required to serve the reheat coil.

Zone damper heating action

During heating operation, there are two control options for the damper controlling the air flow in the VAV terminal unit as the zone moves above or below the zone setpoint. With both control options, the damper is at the minimum air flow rate whenever the zone temperature is between the cooling and heating setpoints.

- **1-Normal** - the damper will remain at the minimum air flow rate during heating operation. As the heating load increases, the water flow rate in the reheat coil will be increased to maintain temperature in the zone until the maximum water flow rate is reached. The system essentially acts like a constant volume system during heating.
- **2-Reverse** - the air flow rate through the VAV box may increase above the minimum air flow when the heating demand cannot be satisfied unless greater air flow is provided. As the heating load increases, the unit starts at minimum air flow and minimum hot water flow. The hot water flow is increased until it reaches maximum flow, then the air damper starts to open to meet the load. This option is used if the minimum air flow rate is not adequate to serve the peak heating load.

Note: you should switch heating 'on' if you want the zone to be heated to the heating setpoint temperature specified on the Activity tab.

LOCAL HEATING UNITS

Heating type (Simple HVAC only)

There are currently two heating types:

- **1-Convective** - the space is heated by an air system and controlled to the air temperature set point. The system is modelled using EnergyPlus 'purchased air'.
- **2-Radiative/convective units** - used for modelling general systems where a radiant heat is a factor. Allows modelling of convective systems, hot water radiator systems, underfloor heating systems, baseboard heating etc. using EnergyPlus 'High Temp Radiant System'.

1-CONVECTIVE

When using Simple HVAC you can specify the heating supply air conditions of the air.

Supply air delivery temperature

The constant dry-bulb air temperature of the air supplied for heating the zone.

Supply air humidity ratio

The constant humidity ratio (mass of water per mass of dry air) of the warm supply air to be delivered

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when heating is required. The default humidity ratio is 0.01. You should be careful to enter a value that is a valid condition, i.e. it is under the 100% saturation line on the Psychrometric Chart.

2-RADIANT/CONVECTIVE UNITS

When the Simple HVAC model option is set you can model radiant heating systems. Set the heating system type as '2-Radiant/convective units' (above) and enter the heating radiant fraction, control method and the way radiant heat is distributed through the space.

EnergyPlus 3.1 no longer supports this radiant/convective option combined with Simple HVAC cooling systems so if you need radiant heating and cooling then you should switch to Compact HVAC and use a Unitary single system with hot-water radiator/baseboard heating.

Heating radiant fraction

The fraction of the power input to the radiant heater that is actually radiant heat transfer. The fraction should be between 0 and 1. In conjunction with the Radiant distribution option, it defines the breakdown of how the power input to the heater is distributed to the rest of the zone.

Control method

Radiant units can be controlled in one of three ways:

- **1-MAT** - control the room mean air temperature to the heating setpoint temperature specified on the Activity tab.
- **2-Operative** - control the room operative temperature (MAT+MRT) / 2 to the heating setpoint temperature specified on the Activity tab.
- **3-MRT** - control the room mean radiant temperature to the heating setpoint temperature specified on the Activity tab.

This option overrides the overall simulation control radiant fraction option.

Note: You should ideally use ***Operative*** control if you want to calculate realistic heating energy because heating systems controlled using the operative temperature continue to heat the building until comfort conditions are met (just that they are in the real building). Also, the default heating temperature set points from the Activity templates are derived from sources quoting Operative temperatures. With MAT control the room ***air*** temperature is controlled to the heating set point temperature, which (depending on internal radiant temperatures) may not necessarily be comfortable.

Radiant distribution

The Radiant distribution allows you to control how the radiant heat from the Radiant unit is distributed around the room. Options are:

- **1-Uniform** - radiant heat is distributed uniformly around the zone.
- **2-Floor** - heat is distributed uniformly across all floors in the zone. Use this for modelling floor heating systems.
- **3-Wall** - heat is distributed uniformly across all walls in the zone. Use this for modelling hot water radiators and other radiant heaters close to wall surfaces.

Technical Note

DesignBuilder uses the EnergyPlus 'HIGH TEMP RADIANT SYSTEM' to model radiant heating systems. This system type is intended for modelling 'high-temperature' radiant sources but it can equally well be used for low temperature radiant sources.

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VAV

When using the **1-VAV** system type, you can set the operation schedule for the central air handling unit heating coils separately from the schedules for the local reheat coils. The operating schedule for the central heating coils is set under the **AHU Heating Coil Operation** header at building level. Local reheat coils are controlled using **Operation** data at zone level.

Unitary Multizone

When using the **2-Unitary multizone** system type, the operating schedule for the central heating coils is set under the **AHU Heating Coil Operation** header at building level.

Note: only one set of zone thermostatic control data is used per Unitary multizone system - this is the zone for which **Thermostatic control zone for unitary system** is selected.

Unitary Single zone

Heating operation schedules are set at zone level and there is no central plant apart from the boiler.

Note: for all systems, heating setpoint temperatures are defined on the Activity tab.

Zone setpoint schedule

This schedule data is used in conjunction with the heating setpoint temperatures on the Activity tab to define the heating demand in the zone by creating a heating setpoint schedule. The schedule defines the times when full and setback setpoints should be met and the setpoint data on the Activity tab define the actual setpoint values. See Defining setpoint temperature schedules for more on this.

3.3.2.5.5 Cooling

HVAC tab in model data

You can enter details on the cooling system including the maximum capacity (at zone level).

Cooling capacity

The Cooling capacity can either be entered by hand or can be Autosized using the Cooling Design Calculations. If, immediately prior to a Simulation the Cooling capacity has not been entered (neither by hand nor from a previous Cooling Design Calculation) then a Cooling design autosizing simulation is started to calculate the capacity. The Plant sizing building model option controls the way this works.

You can change cooling capacities by hand if you wish but you should bear in mind that, by default, if Model Options change, all heating and cooling capacities are reset to zero. Set the Plant sizing model option to '2-Manual' to avoid this happening.

SUPPLY AIR CONDITIONS

When using Simple HVAC you can specify the cooling supply air conditions of the air. This data is used for simulations only - cooling design calculations have a specific equivalent setting.

Supply air delivery temperature

The constant dry-bulb air temperature of the air supplied for cooling the zone.

Supply air humidity ratio

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The constant humidity ratio (mass of water per mass of dry air) of the cold supply air to be delivered when cooling is required. The default humidity ratio is 0.009. You should be careful to enter a value that is a valid condition, i.e. it is under the 100% saturation line on the Psychrometric Chart.

COOLING PLANT

Fuel

Select the type of fuel used to generate the cooling energy - choose from:

- 1-Electricity
- 2-Gas
- 3-Oil
- 4-Solid fuel
- 5-Bottled gas
- 6-Other

Cooling system CoP (Simple HVAC only).

The cooling system coefficient of performance is used to calculate the fuel consumption required to meet cooling demand. The value represents the total seasonal efficiency of the entire cooling system and should include the effect of all energy consumption associated with building cooling such as fan and pump energy, chiller inefficiency, control equipment etc.

Cooling system CoP data is specified by zone so you can model different cooling efficiencies in each zone. But generally you should access this data from the building level and allow zones to take on building default.

Chiller CoP (Compact HVAC only).

The chiller coefficient of performance is used to calculate the fuel consumption required to meet cooling demand. It represents the total seasonal efficiency of the chiller excluding losses/consumption due to external pumps and fans but including all energy consumed by such ancillary devices within the chiller.

Chiller CoP data is specified for the whole building.

Cooling distribution loss (%)

The cooling distribution loss is the loss of heat (cooling energy) due to the distribution of cold water/air around the building. It is used to increase the cooling load prior to calculating chiller energy consumption.

VAV CENTRAL COOLING COILS

The central AHU cooling coil data is specified for the whole building and is not accessible at zone level.

Cooling coil type

The cooling coil must be one of:

- **1-None** i.e. there is no cooling coil
- **2-Chilled water** to model a chilled water coil.

The default is **2-Chilled water**.

Note: you can achieve 'free cooling' without a cooling coil by selecting **1-None** but you will only get the cooling effect of the HVAC air on the zone if the outside air + any fan pickup is cooler than the zone air

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temperature.

The difference between switching cooling off altogether (by unchecking the **Cooled** checkbox) and setting cooling coil type to **1-None** is that in the latter case controlled free cooling is possible due to relatively cool outside air being introduced to the building but when cooling is switched off altogether there is no possibility of controlled cooling through the HVAC system.

Off-coil air temperature set point

This data defines the temperature of the air coming off the coils assuming idealised control. Cooling coils are automatically sized by EnergyPlus before the simulation to provide this off coil temperature given the flow rates in the air handling unit.

Cooling coil setpoint reset type

Select the type of automatic reset control for the central cooling supply air temperature. The choices are:

- **1-None** – no reset, use the **Off-coil air temperature set point** in conjunction with the Zone setpoint schedule.
- **2-Outdoor air temperature reset** – reset the cooling supply air temperature based on the following default rules. When the outdoor dry bulb temperature (ODB) is at or below 15.6C the setpoint is 18C. When the ODB is at or above 26.7C the setpoint is the **Off-coil air temperature set point**. In between, the setpoint is varied linearly. These control parameters are from ASHRAE 90.1 Appendix G par. G3.1.3.9.
- **3-Warmest** - reset the cooling supply air temperature to the highest supply air temperature that will meet the cooling requirements of all the zones (i.e. according to the cooling demand of the warmest zone). The minimum setpoint allowed is the **Off-coil air temperature set point** (above). The maximum setpoint allowed is defaulted to 18C. For each zone in the system at each system time step the EnergyPlus set-point manager calculates a supply air temperature that will meet the zone cooling load at the maximum zone supply air flow rate. The lowest of the possible supply air temperatures becomes the new supply air temperature set point, subject to minimum and maximum supply air temperature constraints. The resulting temperature set point is the highest supply air temperature that will meet the cooling requirements of all the zones. When compared to a fixed cooling supply air temperature set point, this strategy minimizes zone reheat coil energy (or overcooling) and central chiller energy consumption (if the chilled water temperature is also reset) at the cost of possible increased fan energy.

  The 2003 ASHRAE Applications Handbook discusses warmest reset control for constant volume systems (p.41.27) and calls it "Supply Air Temperature Reset for Constant Air Volume (CAV)". A requirement is set out in ASHRAE Std 90.1-2004, Appendix G, paragraph G3.1.3.12: *Supply air temperature shall be reset based on zone demand from the design temperature difference to a 10°F temperature difference under minimum load conditions. Design air flow rates shall be sized for the reset supply air temperature, i.e., a 10°F temperature difference.*

Tip: using **Warmest** or **Outside air temperature** cooling coil setpoint reset can drastically improve energy efficiency by reducing the cooling energy delivered to the airstream to the minimum required for occupant comfort.

The DesignBuilder HVAC template default is **3-Warmest** for constant volume systems and **1-None** for other system types.

OPERATION

Unitary Multizone and VAV

When using the **2-Unitary multizone 5-CAV** and **3-VAV** Compact HVAC system types, the **AHU cooling**

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coil operation is defined by AHU cooling coil operation data.

Note: only one set of zone thermostatic control data is used per Unitary multizone system - this is the zone for which **Thermostatic control zone for unitary system** is selected.

Unitary Single zone and Fan Coil Units

Cooling operation schedules are set at zone level and there is no central plant apart from the chiller.

Note: for all systems, cooling setpoint temperatures are defined on the Activity tab.

Zone setpoint schedule

This schedule data is used in conjunction with the cooling setpoint temperatures on the Activity tab to define the cooling demand in the zone by creating a cooling setpoint schedule. The schedule defines the times when full and setback setpoints should be met and the setpoint data on the Activity tab define the actual setpoint values. See Defining setpoint temperature schedules for more on this.

3.3.2.5.6 Humidity Control

HVAC tab in model data

When using Compact HVAC you can control humidity in zones by including separate humidification and/or dehumidification equipment and controls. Both humidification and dehumidification require settings at building level for AHU-based or at zone level for Single zone unitary systems (of course in the latter case defaults can be set at building level).

HUMIDIFICATION

To include humidification check the Humidification checkbox and make further settings. The humidifier is electric powered and the data required is: availability schedule, rated capacity and water supply rate. The humidification setpoint is defined on the Activity tab.

For AHU-based systems you must also define the humidification control zone.

Humidification availability schedule

Select the schedule that defines the availability of humidification. The schedule values denote whether the humidifier can run during a given time period. A schedule value of 1.0 indicates that the humidifier can be on during a given time period. A value of zero denotes that the humidifier cannot be used during that time period.

Humidifier Rated Capacity

Enter the rated moisture output rate in m3/s or CFM. The humidifier does not currently autosize, so the default is very large to allow for adequate capacity. The default is 0.000001 m3/s.

DE-HUMIDIFICATION

To include dehumidification check the Dehumidification checkbox and make further settings. The dehumidification setpoint is defined on the Activity tab.

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For AHU-based systems you must also define the humidification control zone.

Control type

For **unitary** systems, there are two dehumidification control type options available:

- **1-Cool-Reheat Heating Coil** cools beyond the dry-bulb setpoint as required to meet the humidity setpoint if the system is capable of doing so. Reheat is provided as required by the heating coil. In the simulation, two instances of the heating coil are modelled, one for heating, and one for reheat. The two coil objects represent the same physical coil and never operate simultaneously.

- **2-Cool-Reheat Desuperheater** cools beyond the dry-bulb setpoint as required to meet the humidity setpoint if the system is capable of doing so. Reheat is provided by a desuperheater coil.

For **VAV** and **CAV** only one option is available:

- **1-Cool Reheat** cools beyond the dry-bulb setpoint as required to meet the humidity setpoint if the system is capable of doing so. Reheat is provided as required by the terminal unit reheat coils if available.

Important Notes:

1. EnergyPlus autosizing does not yet account for dehumidification so in many cases you will have to increase the Compact HVAC sizing factor above the default of 1.2 to a value up to 10 to obtain adequate cooling coil sizes, depending on latent loads and the dehumidification setpoint.
2. If you use one of the reheat dehumidifiers you must have reheat available to heat during times when dehumidification is required. In practice this normally means having reheat available all year.
3. You may need to use shorter timesteps for accurate humidity control. We recommend 10 per hour.

3.3.2.5.7 Domestic Hot Water (DHW)

HVAC tab in model data

The effect of hot water consumption (hot water taps, showers etc) on building energy use can be included in your thermal model by switching on DHW on the HVAC tab.

Domestic Hot Water (DHW) is modelled in DesignBuilder by using hot water consumption rates based on the activity in each zone. DHW hot water consumption is defined on the Activity tab and the definition of the hot water generating equipment is described below) is defined on the HVAC tab.

Type

Three types of DHW are available:

1-Boiler - heat is supplied by the same boiler used for heating the building
2-Gas - gas-fired hot water system
3-Electric - electric immersion heater

Delivery hot water temperature

The temperature of the water supplied to the taps.

Mains supply temperature

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The temperature of the water delivered to the building. This can be approximated to the annual average outside air temperature.

Operation

The operation schedules define the timing of the hot water draw off when the Timing HVAC + natural ventilation operates with occupancy option model option is not selected. The profile of hot water consumption in the EnergyPlus simulation is calculated from l/person/day data (gal/person/day in IP units) entered on the Activity tab by first estimating a typical number of hours per day. When typical workday schedules are used, this is simply the number of hours occupied during the working day. When 7/12 schedules are used the typical occupancy hours per day is determined from ***January Monday*** data.

Note: When using a Compact schedule to define DHW operation DesignBuilder assumes a ***fixed 8 hours per day*** operation when calculating the maximum m3/s hot water draw off for passing to EnergyPlus.

DHW volumetric consumption supplied to EnergyPlus is calculated as:

DHW (m3/s) = DHW (l/day/m2) x 0.001 x m2 / (Typical hours per day x 3600)

DHW Type

A range of DHW types can be selected but note that different types of DHW system do not affect results in EnergyPlus simulations, apart from **1- Same as HVAC** which causes heating CoP and fuel to be taken from the heating system. Other options all give the same results.

1- Same as HVAC
2- Dedicated DHW boiler
3- Stand alone water heater
4- Instantaneous DHW only
5- Instantaneous Combi
6- Direct (or off-peak) electricity
7- Heat pump

3.3.2.5.8 Natural Ventilation

HVAC tab in model data

You can control the operation of natural ventilation using the data under the Natural Ventilation header on the HVAC tab. When using Calculated natural ventilation model option there is additional data on the Openings tab to control the timing and extent of operation of openings.

SCHEDULED

When the Natural ventilation model option is set to **Scheduled**, natural ventilation is defined simply as follows:

- Check the 'On' checkbox under the Natural Ventilation header.
- Select the flow type
- Set the maximum zone natural ventilation rate in air changes per hour (if flow type is **1-By zone**).
- Enter the operation information.

Find out more about Natural Ventilation Modelling under Modelling Issues.

Flow type

Defines the method used to set the maximum outside air natural ventilation rate. The options are:

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- **1-By zone** - enter the zone natural ventilation rate in air changes per hour in the control directly below. The air flow rate is calculated from the ac/h data using:

  `m3/s = ac/h x ZoneVolume / 3600`

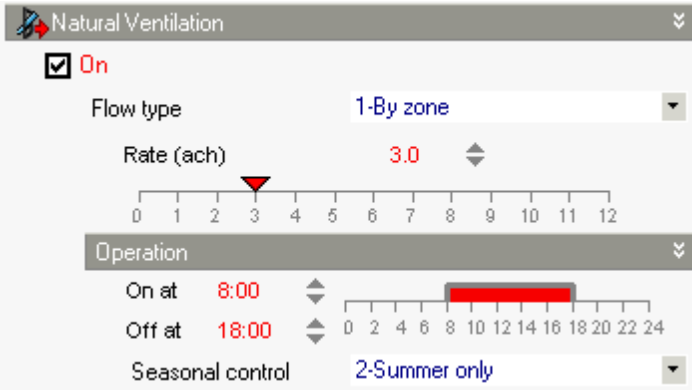
  where `ZoneVolume` is the actual air volume of the space calculated according to options for optionally excluding floor/ceiling constructions.

  Note: this zone volume may be different from the value used for the purposes of calculating air flow rates for infiltration which uses the *total* zone volume.

- **2-Min fresh air per person** - maximum natural ventilation rate is defined using Minimum fresh air requirements as set on the Activity tab. The air flow rate in m3/s is calculated as:

  `m3s = MinFreshAir x NumberPeople / 1000`

  `NumberPeople = Occupancy density (people / m2) * Zone floor area (m2)`
  `MinFreshAir` is the minimum fresh air rate per person (l/s/person)



Scheduled natural ventilation is active at any time in the simulation when:

- The air temperature in the zone is higher than the Ventilation cooling set-point temperature (as set on the Activity tab under the 'Environmental Comfort' header) AND ...
- The difference between inside and outside air temperatures (Tin - Tout) is less than 'Max ventilation in-out delta T' (below the Ventilation cooling setpoint data on the Activity tab) AND ...
- The operation schedule is on at that time in the simulation.

Note: to avoid *temperature control* of natural ventilation set a very low Natural ventilation cooling setpoint temperature and to avoid *temperature difference control*of natural ventilation set a high negative value of Max ventilation in-out delta T.

The actual natural ventilation rate at any one time in the simulation is calculated by multiplying the maximum natural ventilation rate (ac/h) by the value of the operation schedule.

When using the '**Typical workday**' Timing option, natural ventilation can be either on or off. When it is on, the ventilation rate is the 'maximum natural ventilation rate'.

When using the **7/12** Timing option, it is possible to vary the natural ventilation rate between 0 and the maximum value by using daily profiles which have values between 0 and 100%.

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Internal Windows, Doors and Vents

Airflow through *external* windows, vents, doors and holes are not modelled with **Scheduled** natural ventilation because the natural ventilation airflow from outside is explicitly defined (above). Internal windows, vents, doors and holes cause air to be exchanged between the two adjacent zones using the EnergyPlus 'Mixing' object. You can override operation of *internal* windows, vents, doors be **off** as follows:

Window, Vent, Door position	Override Off Action
Internal adjacent to unconditioned semi-exterior	Switch off the Natural ventilation 'On' checkbox in the occupied zone
Other internal	Unaffected by the Natural ventilation 'On' checkbox. Use the operation schedules on the Openings tab to switch off

CALCULATED

When the Natural ventilation model option is set to **Calculated**, natural ventilation is defined as follows:

- Check the 'On' checkbox under the Natural Ventilation header.
- On the Openings tab by setting window, door and vent opening sizes and operation times.

You can override operation of windows, vents, doors to be **off** as follows:

Window, Vent, Door position	Override Off Action
External	Switch off the Natural ventilation 'On' checkbox
Internal adjacent to unconditioned semi-exterior	Switch off the Natural ventilation 'On' checkbox in the occupied zone
Other internal	Unaffected by the Natural ventilation 'On' checkbox. Use the operation schedules on the Openings tab to switch off

Note that even when operation is switched off as described above (or because operation schedules on the Openings tab are off) windows, vents and doors still provide a small flow path through the crack between the opening and the surrounding surface if the Model infiltration data is switched on.

Important Notes

1. For ***cooling design*** calculations, natural ventilation is always handled as Scheduled even when the Natural ventilation model option is set to Calculated. In this case you can still enter natural ventilation air change rates and operation schedule data on the HVAC tab but *it is used only for design simulations*.

2. With both the Scheduled and Calculated options, natural ventilation can be overridden to be off in Heating and Cooling design calculations. In Heating design calculations natural ventilation is switched off by default because it is considered to be a cooling mechanism - windows and vents will normally be closed during the coldest winter periods.

Mixed Mode

You can also enter Mixed mode and data on opening Modulation under the Natural Ventilation header on

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the HVAC tab when using Calculated natural ventilation.

3.3.2.5.9 Mixed Mode

HVAC tab in model data

You can include mixed mode natural ventilation and HVAC change-over control by checking the Mixed mode checkbox on the HVAC tab under the Natural ventilation header. Mixed mode is only available when Calculated natural ventilation is selected.

The mixed mode control serves two purposes:

1. Prevents simultaneous natural ventilation and HVAC system operation, and,
2. Allows you to examine various ventilation strategies to maximize natural ventilation in order to reduce heating/cooling loads.

The mixed mode change-over controller links the associated HVAC system with the operable windows and vents in the zones served by the HVAC system. The controller overrides the natural ventilation controls for windows and vent openings, closing these openings under certain conditions and allowing the HVAC system to operate. If the controller determines that conditions are favourable for natural ventilation, then the HVAC system is disabled and the openings are able to operate based on the standard natural ventilation control mechanism (natural ventilation setpoint, maximum opening area, modulation etc).

See also the Summary of Mixed mode modelling for background information.

Mixed mode control zone

For VAV, CAV and Unitary multizone Compact HVAC system types you must select a control zone to define which zone conditions are used by the mixed mode controller for the HVAC system. Do this by going to the zone level and checking the **Mixed mode control zone** checkbox located near the top of the data on HVAC tab. You must select just one control zone per AHU. The selected mixed-mode control zone should generally have conditions representative of all of the zones served by the HVAC system.

Zone-based HVAC systems (Unitary single zone and Fan coil units) don't require a control zone to be set because the zone itself will always be the control zone.

Control mode schedule

This schedule determines whether or not for a given time the mixed mode ventilation control is to be applied. Schedule values equal to zero indicate no ventilation control, resulting in natural ventilation and HVAC system operation being performed based on their own controls. Schedule values equal to one denote temperature control for either cooling or heating, which is determined internally based on thermostat set point. The temperature control is restricted between the minimum and maximum outdoor temperatures provided in two additional input fields (below). Schedule values equal to two denote enthalpy control, which is restricted between minimum and maximum outdoor enthalpy values given in two additional input fields (below). Schedule values equal to three denote dew point control for either dehumidification or humidification. Schedule values equal to four represent outdoor ventilation air control.

Schedule value	Operation mode
0	No mixed mode control - HVAC and natural ventilation operate separately according to their own controls.
1	Temperature control for either cooling or heating - temperature control is restricted between minimum and maximum outdoor temperatures. When the outside air temperature falls below the minimum value or goes above the maximum value the openings are closed and the HVAC system operates.
2	Enthalpy control, outside enthalpy is restricted between minimum and maximum outdoor

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	enthalpy values.
3	Dew point control, outside dew point temperature is restricted between minimum and maximum outdoor dew point values.
4	The minimum outdoor ventilation air for a given time in ac/h. The program calculates the natural (outdoor) ventilation in the controlled zone first and compares the amount of outdoor air brought by opening windows or doors and other small openings to this minimum value. If the amount of outdoor air from natural ventilation is less than the minimum value, the natural ventilation is shut off (i.e., the window or door openings are closed) and the HVAC system may operate if needed. Otherwise, the natural ventilation is on and the HVAC system is shut off. The amount of outdoor ventilation air entering the controlled zone is determined as air from outdoors and not from other adjacent zones. Therefore, this option is only applied to a zone having a window or door exposed to outdoors.

Close windows and vents when raining

Indicates whether the rain indicator in the hourly weather data is used to shut off natural ventilation. This can help simulate conditions where one would normally close windows to avoid rain penetration in a space. Any possible rain getting into a space will not be counted as a zone load.

Maximum wind speed

The wind speed above which natural ventilation is shut off. This can help simulate conditions where one would normally close windows to avoid wind problems in a space (papers blowing around, etc).

Minimum outdoor temperature

The outdoor temperature below which natural ventilation is shut off when the control mode schedule value = 1 (Temperature). This lower temperature limit is intended to avoid overcooling a space, which could result in a heating load.

Maximum outdoor temperature

The outdoor temperature above which natural ventilation is shut off when the control mode schedule value = 1 (Temperature). This upper temperature limit is intended to avoid overheating a space, which could result in a cooling load.

Minimum outdoor enthalpy

The outdoor enthalpy below which natural ventilation is shut off when the control mode schedule value = 2 (Enthalpy).

Maximum outdoor enthalpy

The outdoor enthalpy (in J/kg) above which natural ventilation is shut off when the control mode schedule value = 2 (Enthalpy).

Minimum outdoor dewpoint

The outdoor dew point temperature below which natural ventilation is shut off when the control mode schedule value = 3 (Dew point). This lower dew point temperature limit is intended to avoid dehumidifying a space.

Maximum outdoor dewpoint

The outdoor dew point temperature above which natural ventilation is shut off when the control mode schedule value = 3 (Dew point). This upper dew point temperature limit is intended to avoid humidifying a space.

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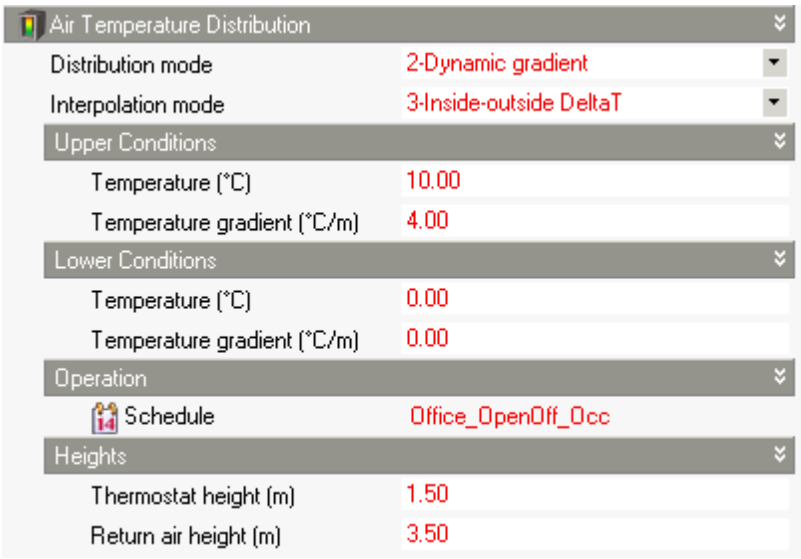
3.3.2.5.10 Air Temperature Distribution



HVAC tab in model data

By default EnergyPlus assumes that air temperature within a zone is completely uniform (i.e. the air is fully mixed). The Air Distribution model data allows you to model stratification within a zone by setting up a temperature gradient which varies dynamically depending on:

- Outside temperature.
- Inside temperature.
- Inside-outside temperature difference.
- Heating load.
- Cooling load.

How it works

Changing the Distribution mode to **2-Dynamic gradient** reveals the air temperature distribution data. By default the Interpolation mode is **2-Inside-outside DeltaT**. This means that the temperature gradient within the space is modelled as varying according to the inside-outside temperature difference. The Upper conditions define the most extreme temperature gradient, typically under design conditions. In the screenshot above right, the upper temperature difference is 10°C and the corresponding temperature gradient is 4°C/m. This means that when the temperature difference between inside and outside if 10°C or more the internal temperature gradient is 4°C/m. The Lower conditions data shows that when the temperature difference between inside and outside is zero there is no temperature gradient, i.e. the air is fully mixed. EnergyPlus calculates the temperature gradient for other inside-outside temperature differences by linear interpolation.

Operation schedule

The operation schedule defines the times when air temperature distribution is to be calculated. When the value of the schedule is 1, the distribution calculations take place, when the value is 0, the zone air temperature is fully mixed.

Thermostat height

Thermostat height specifies the distance above the floor where the thermostat for HVAC control is situated. This height is used by the model to determine the thermostat temperature relative to the mean air temperature by applying the gradient.

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Return air height

Return air height specifies the distance above the floor where the air leaves the zone and returns to the air system. This height is used by the model to determine the return air temperature relative to the mean air temperature by applying the gradient.

Range of applicability

The air temperature distribution within the zone is used as follows:

1. To calculate boundary conditions for conduction through surfaces (walls, roofs, glazing etc).
2. To include the effects of extracting relatively warmer air at the ceiling level when using Compact HVAC.
3. To include the vertical position of the thermostat sensor for HVAC control.

Limitations

The air temperature distribution mechanism does not include:

1. The effects of extracting relatively warmer air at the ceiling level when using Scheduled and Calculated natural ventilation.
2. The vertical position of the sensor for ventilation control.

3.3.2.6 Detailed Equipment

Equipment tab in model data (*zone level only*)

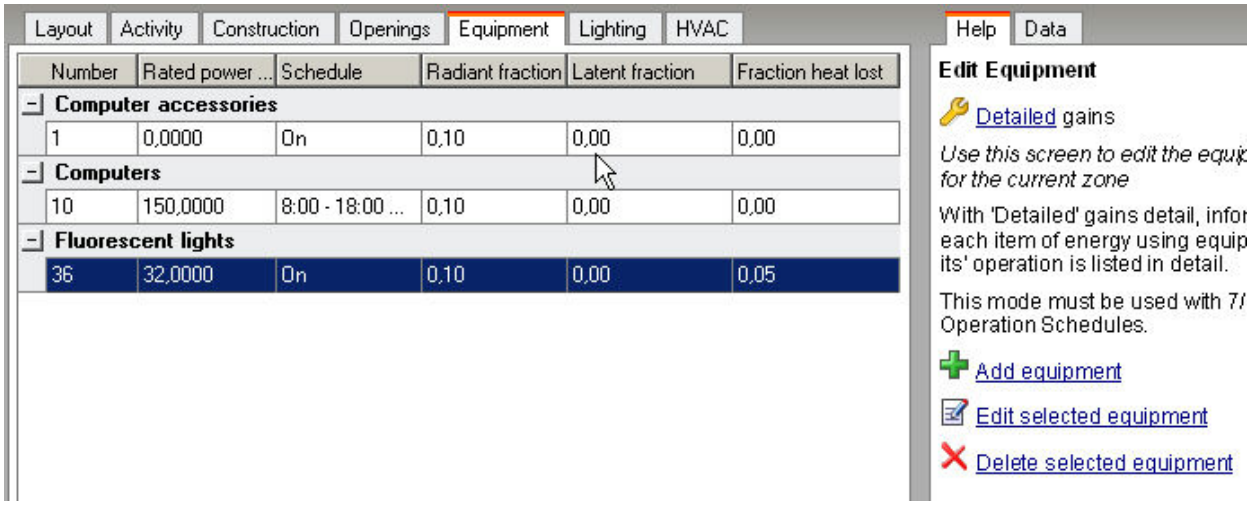
*This option is intended for modelling existing buildings where individual items of equipment have been recorded as part of a detailed survey and is **not intended for general design simulation work**.*

When the Gains model option is set to **Detailed** you can enter data on individual items of equipment in each zone.

Details on editing Equipment data

DesignBuilder has a software utility for recording and calibrating this data available on the Prerelease and beta test versions Downloads page of the DesignBuilder website.

Note: For other modelling applications you should use the Early gains model option because data can be set at the building level and/or loaded from template with much less effort.



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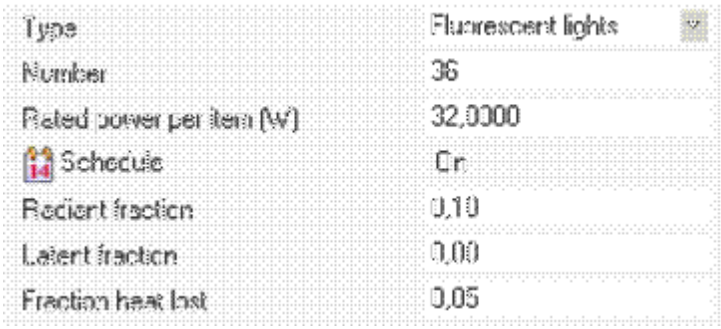
3.3.2.6.1 Edit Detailed Equipment

You can model time-varying internal gains and energy consumption of individual items of equipment in each zone by adding equipment data at the zone level on the Equipment tab. To add an item of equipment click on the Add toolbar icon, or if you are running DesignBuilder in Learning mode you can use the link in the Info panel to the right of the screen. This opens the **Edit Equipment** dialog:



You can define the category of internal gain (below), the number of items of equipment, the rated power per item of equipment as well as the operational schedule.

The **Radiant fraction** is the fraction of heat emitted by the device as long-wave radiation. The rest of the heat is considered to be convective i.e. it is modelled as heating up the zone air directly.

The **Latent fraction** is the fraction of the rated power which is converted to latent energy and affects the moisture balance in the zone instead of the sensible heat balance.

Fraction heat lost is the fraction of the sensible heat emitted which is lost or vented directly to outside without affecting the zone heat balance. This can be used for modelling equipment such as fluorescent lighting with control gear which can have different higher energy consumption than heat gain into the space.

A number of categories of gains are available. These are listed below together with the output data with which they are associated:

- **Fluorescent lights** - General lighting
- **Tungsten lights** - Task lighting
- **Office equipment** - Computer + equipment
- **Computers** - Computer + equipment
- **Computer accessories** - Computer + equipment
- **Telecoms** - Computer + equipment
- **Lifts** - Miscellaneous
- **Catering** - Catering
- **Small power** - Miscellaneous
- **Heating** - Miscellaneous
- **Cooling** - Miscellaneous
- **Pumps** - Miscellaneous
- **Fans** - Miscellaneous
- **DHW** - Miscellaneous.
- **Process** - Miscellaneous
- **External lighting** - Task lighting
- **Other external** - Miscellaneous
- **Miscellaneous** - Miscellaneous

Note that all of the above gains are modelled as scheduled gains in the zone and the data is reported as such in the program output. So for example categorising an item of equipment as DHW does not affect in any way DHW modelling as defined on the HVAC tab. Likewise data for Heating, Cooling, Pumps and Fans

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is simply modelled as a scheduled gain in the zone, completely unconnected with HVAC modelling.

3.3.2.7 Options

Options tab in model data

You can control the output data that is generated in the design calculations and simulations by making selections on the Options model data tab.

- Heating Design Output Options
- Cooling Design Output Options
- Simulation Output Options

3.3.2.7.1 Heating Design Output Options

Options model data tab

Heating design output options apply to the whole building and are only visible at building level.

Include unoccupied zones in block and building averages and totals

By default, data for unoccupied zones is *excluded* from block and building totals and averages. Check this option to include data for unoccupied zones.

This option can also be accessed from the Heating Design tab of the Model options dialog and on the Output tab of the Heating Design Calculation Options dialog.

Store surface output

Causes the following output to be stored for all walls, floors, roofs, ceilings, partitions etc:

- Inside Surface Temperature
- Outside Surface Temperature
- Glazing Heat Loss
- Internal Convective Heat Transfer Coefficient
- External Convective Heat Transfer Coefficient

Store opening output

Only visible when the **Store surface output** option is selected, this option causes the following data to be stored for windows vents, doors, holes, sub-surfaces:

- Inside Surface Temperature
- Outside Surface Temperature
- Glazing Heat Loss
- Internal Convective Heat Transfer Coefficient
- External Convective Heat Transfer Coefficient

Note: Use these options with caution on large models as, when selected, they will cause large amounts of data to be stored.

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3.3.2.7.2 Cooling Design Output Options

Options model data tab

Cooling design output options apply to the whole building and are only visible at building level.

Include unoccupied zones in block and building averages and totals

By default, data for unoccupied zones is *excluded* from block and building totals and averages. Check this option to include data for unoccupied zones.

This option can also be accessed from the Cooling Design tab of the Model options dialog and on the Output tab of the Cooling Design Calculation Options dialog.

Store surface output

Causes the following output to be stored for all walls, floors, roofs, ceilings, partitions etc:

- Inside Surface Temperature
- Outside Surface Temperature
- Surface Heat Gain
- Solar Incident
- External Sunlit Fraction
- Internal Convective Heat Transfer Coefficient
- External Convective Heat Transfer Coefficient

Store opening output

Only visible when the **Store surface output** option is selected, this option causes the following data to be stored for windows vents, doors, holes, sub-surfaces:

- Inside Surface Temperature
- Outside Surface Temperature
- Glazing Heat Gain
- Solar Incident
- Solar Transmitted
- External Sunlit Fraction
- Internal Convective Heat Transfer Coefficient
- External Convective Heat Transfer Coefficient

Note: Use these options with caution on large models as, when selected, they will cause large amounts of data to be stored.

3.3.2.7.3 Simulation Output Options

Options model data tab

Simulation output options can be accessed at building, block, zone, surface and opening levels giving you control of the elements in the model for which output data will be generated.

The following options are available at building level only and the same options can also be accessed from the Simulation tab of the Model options dialog and on the Output tab of the Simulation Calculation Options dialog:

- Include unoccupied zones in block and building averages and total
- Building and block output of zone data

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- Report
- Surface heat transfer incl solar
- Environmental
- Comfort
- Internal gains
- Energy, HVAC
- Temperature distribution
- Daylight map output
- DXF model output
- Construction and surface details
- RDD file

Store surface output

To obtain data for a particular surface or opening you should first navigate to that surface or opening and switch on the **Store surface output** option. This causes a table of results to be stored for that surface or opening but does not yet select any results. To do this select one or more of these options:

- **Store opening output** - *at surface level and above in the model hierarchy, this is a default value for openings*. It much be selected for a particular opening for any data for that opening to be generated.
- **Inside Surface Temperature** - for surfaces and openings.
- **Outside Surface Temperature** - for surfaces and openings.
- **Surface Heat Gain** - for surfaces.
- **Glazing Heat Gain** - for openings.
- **Solar Incident** - for surfaces and openings.
- **Solar Transmitted** - for window openings.
- **External Sunlit Fraction** - for surfaces and openings.
- **Internal Convective Heat Transfer Coefficient** - for surfaces and openings.
- **External Convective Heat Transfer Coefficient** - for surfaces and openings.
- **Airflow in** - for surfaces and openings - for surfaces it is infiltration and does not include the sum of the opening airflow in values.
- **Airflow out** - for surfaces and openings - for surfaces it is infiltration and does not include the sum of the opening airflow out values.

Note: **Use these options with caution on large models** as, when selected, they will cause large amounts of data to be generated and stored. Select only the data you need for the building elements of interest.

3.3.2.8 CFD Model Data

CFD tab of model options

This tab allows you set various types of boundary condition for CFD calculations.

If you have previously loaded simulation results as boundary conditions using the CFD Boundary Conditions Edit dialog then this data will be displayed at surface and opening levels.

The attributes that can be set on this tab are shown with the boundary condition type to which they apply. Note that all attributes are displayed at zone level and above in the hierarchy because these act as defaults, but at surface and opening level only the data applicable to the current object is displayed.

Inside surface temperature (internal surfaces)

Applies to: *Internal surfaces, doors and sub-surfaces*

Default inside surface temperature for internal surfaces (partitions, internal floors and ceilings). It can be set for all levels in the model hierarchy from building level down.

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Inside surface temperature (external surfaces)

Applies to: *External surfaces, doors and sub-surfaces*

Default inside surface temperature for external surfaces (walls, roofs, external floors etc). It can be set for all levels in the model hierarchy from building level down.

Inside Surface window temperature

Applies to: *Internal and external windows*

Default inside surface temperature for window surfaces. It can be set for all levels in the model hierarchy from building level down.

Average zone air temperature

Applies to: *Zone*
Average zone temperatures are stored at zone level. These aren't used yet in CFD calculations yet but will be used in checks in a future version to ensure equal convective heat gains are considered in the CFD and EnergyPlus simulations.

Incoming air temperature

Applies to: *Supply diffusers (types 1-3) and windows, vents, doors and holes*

Temperature of air entering the space through windows, vents, doors and holes.

Aperture position

Applies to: *Windows*

The position of the window aperture. Select from:

- **1-Top** - the aperture is in the top of the window. Air flow in and out will flow through the top of the window.
- **2-Bottom** - the aperture is in the bottom of the window. Air flow in and out will flow through the bottom of the window.
- **3-Left** - the aperture is in the left of the window (looking from outside). Air flow in and out will flow through the left of the window.
- **4-Right** - the aperture is in the right of the window (looking from outside). Air flow in and out will flow through the right of the window.

Aperture size

Applies to: *Windows*

Enter the fractional size of the aperture relative to the overall window size. Zero means there is no aperture and 1 means the entire window is open.

Component Blocks, Assemblies and Boundary Condition patchs

Data on this tab is also used for entering boundary conditions for component blocks, assemblies and for boundary condition patches drawn onto zone or component block surfaces. For details see:

- Component Blocks and Assemblies as CFD Boundaries
- Boundary Conditions for Internal CFD Analyses

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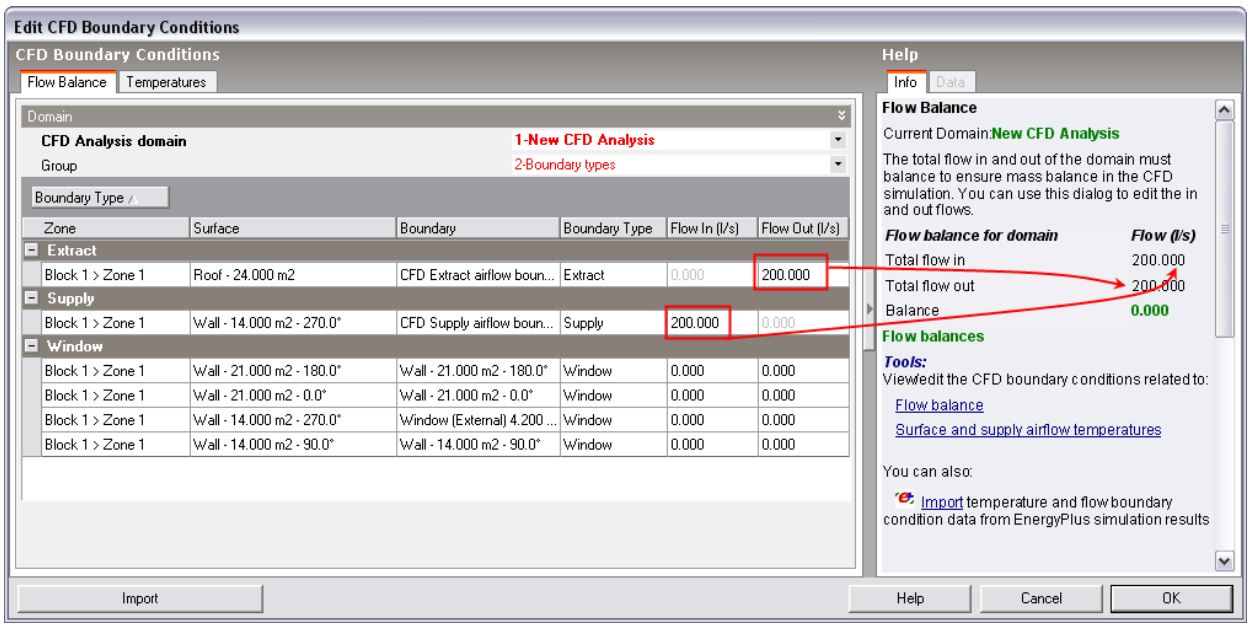
3.3.2.8.1 CFD Boundary Conditions Editor

The CFD Boundary Conditions Editor allows you to view and edit all of the boundary conditions in the selected domain in one place. In particular you can:

- Check and set the airflow rate through each supply and extract boundary condition and also through each window, vent, door and hole in the selected domain.
- Check that total flow in balances with total flow out (a key requirement for the CFD calculations). If flows do not balance there are options to automatically apply a correction flow to one of the existing openings to ensure balance.
- Check and set the temperatures of each boundary condition where temperature is defined (surfaces, supply flow, windows, temperature boundary conditions).
- Import surface and opening boundary conditions for a specific time/date from a previous EnergyPlus simulation.



CFD Analysis Domain

You can select the CFD Analysis domain from previously defined CFD Analyses - this defines the extent of the model that is displayed and checked for flow balance. If you have more than one analysis then you must make sure to select the correct one here before starting.

Group

The Group options allows you to group boundary condition data by one of:

- **1-None** - each boundary condition is displayed in a simple list without any grouping.
- **2-Boundary types** - boundary conditions are displayed groups according to type (extract, supply, temperature, window etc). See screenshot above.
- **3-Zones and surfaces** - the boundary conditions are grouped by zone and then by surface.

Under some circumstances the display can be erratic when using the **2-Boundary type** grouping and in this case you may find it better to use one of the other grouping options.

You can edit the **flow in** and **flow out** airflow rates and temperatures as appropriate on the dialog and the changes are only saved to the model when you press the OK button. No changes are made if you press Cancel.

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EDIT BOUNDARY CONDITIONS

Airflow

The Zone, Surface, Boundary and Boundary Type columns indicate the local of the boundary condition and it's type. You can edit the flow rates in the Flow In and Flow Out columns for windows, vents, doors and holes and the Flow In for supply diffusers and Flow Out for extracts.

If flows do not already balance this will be indicated in red on the Info panel to the right and you can select one of the openings in the dialog and click on the **Correct balance using selected opening** link. A flow is added or subtracted as appropriate to get flows to balance.

Temperature

You can edit the temperature for all temperature-related boundary conditions.

IMPORT ENERGYPLUS BOUNDARY CONDITIONS

You can import data that have been calculated in a previous EnergyPlus simulation as boundary conditions for the CFD simulation. The data that can be imported is:

- Surface inside temperatures of walls, floors, roofs, partitions, ceilings, windows, doors and sub-surfaces.
- Flow in and flow out of windows, vents, doors and holes when using the Calculated natural ventilation model option.

To import simulation data click on the **Import** button in the Boundary Conditions Editor (above).

Import Dialog

The Import data dialog allows you to select boundary conditions for a particular snapshot in time from the simulation results.

Interval

Select **Hourly** or **Sub-hourly** interval depending on how the data was generated in the simulation.

Time, Day, Month

Select the time and date to use for the import. The date must lie between the simulation start and end periods for the last simulation carried our.

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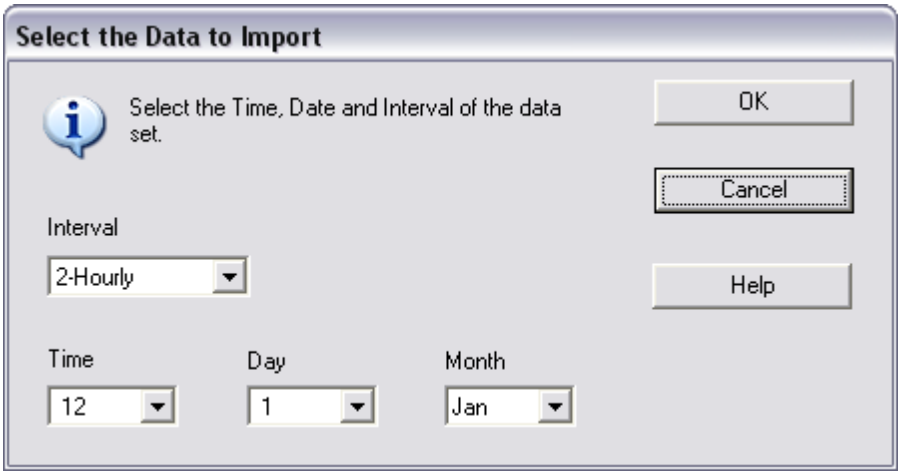

Press OK to import the results to the CFD Boundary Conditions Editor.

3.3.2.8.2 Preparing Simulations to Generate CFD Boundary Conditions

You can use DesignBuilder simulations to generate boundary conditions for the CFD calculations. EnergyPlus simulations calculate the overall thermal behaviour of the building in terms of inside surface temperatures and natural ventilation flow rates then CFD allows you to 'zoom in' on the details of the temperature and flow distribution within the space for a particular snapshot in the simulation.

The simulation data that can be used as boundary conditions in CFD calculations are:

- Surface inside temperatures
- Natural ventilation airflow rates through external windows, doors, vents and holes.

To generate the above data clearly the simulation must generate inside surface temperatures and any natural ventilation airflow rates to be included in the CFD calculations. Before starting you should decide on the extent of the CFD domain and the time period you wish to analyse. Then only generate simulation data for these areas and time periods.Otherwise, for large models you might generate an impractical amount of data and overload the software.

The steps required to generate boundary condition data from simulation are:

1. If the CFD simulation is to use natural ventilation airflows through windows calculated by EnergyPlus then you must use the Calculated natural ventilation model option. Scheduled natural ventilation does not calculate airflows through individual windows.
2. Because CFD calculations do not use infiltration flows you may want to switch off Infiltration treatment on the Constructions model data tab. This will help ensure that the flow balance with little or no need for extra correction flows to be introduced on the CFD Boundary Conditions dialog. It also speeds up simulations by reducing the complexity of the Airflow network in EnergyPlus.
3. Switch off the Lump similar windows on surface model option to ensure that all windows are modelled individually.
4. Prepare the simulation model data and carry out test simulations to check that the model is behaving as expected during the period of interest (e.g. summer design conditions). Look at hourly results.
5. Navigate to the level in the model covering the CFD domain. If you are modelling a single zone in the CFD simulation, then navigate to that zone, if you are modelling a block then go that block or if you are modelling the whole building then go to building level. Then on the Options model data tab select the following output options:

    - **Store opening output** - ensure that data for windows, vents, doors, holes and sub-surfaces is included in the output.

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- **Inside Surface Temperature** - to store inside surface temperatures for all surfaces and openings in the domain.
- **Airflow in** - to record the flow in through windows, vents, doors and hole (natural ventilation calculations only).
- **Airflow out** - to record the flow out through windows, vents, doors and hole (natural ventilation calculations only).

6. Once the model is prepared, click on the Simulation tab and request **hourly** or **sub-hourly** results and run the simulation.
7. Check the simulation results by examining hourly results before feeding them into the CFD calculations. Check that airflow through windows is in the expected direction based on wind direction and expected wind pressures etc.
8. Start the CFD Boundary Conditions Editor and follow instructions for importing the simulation hourly or sub-hourly results
9. Add any assemblies or component blocks with any further boundary conditions needed to represent heat, temperature and flow boundaries imposed by HVAC, lighting and other equipment and occupants.
10. Make sure you have the same total convective heat from your internal gains in the CFD model as you had in the EnergyPlus simulation.
11. Check that CFD results correspond with the boundary conditions provided by the simulation.

Note 1: it is not currently possible to set flow boundary conditions on internal openings. This means that the flows through internal openings calculated by the CFD won't necessarily match exactly with the flows calculated by the EnergyPlus Airflow network.

Note 2: Infiltration airflow is not modelled in CFD and if you are looking at summer time natural ventilation you may wish to switch Infiltration off in simulations. Winter time simulation may need infiltration included if it is significant.

3.3.3 Model Data Management

The DesignBuilder building Model Data inheritance mechanism is a powerful way to edit building models. Tools are provided to help manage and manipulate this data.

- Load data from template
- Clear data to default

3.3.3.1 Load Data from Template

Model Data Management

Access the Load Data from Template from:

1. The Toolbar
2. The Edit menu
3. Mouse right-click in the Model Data.

Use it to load template data into the model. You can select one or more data sources from the following template libraries:

- Construction
- Glazing

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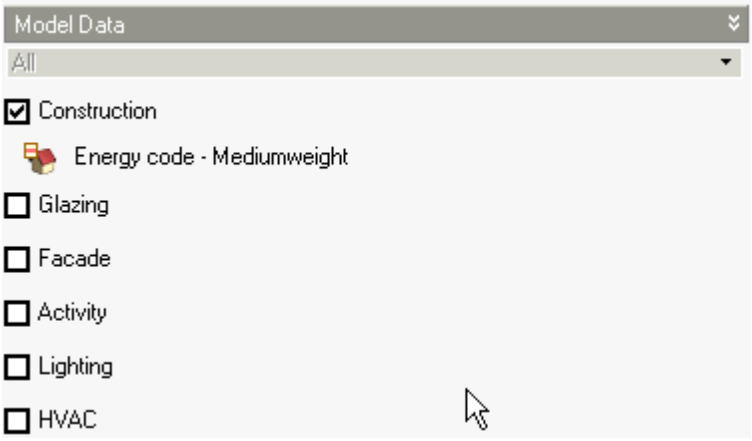
- Facade
- Activity
- Lighting
- HVAC

When you select one of the above templates as a source of data you must also set the template from which to load:



Target Object(s)

On the Target tab you can select the way you want to set data and, where appropriate, which model objects to load to.

- Selected object(s) - choose this option if you want to load the same data to one or more building, block, zone or surface. Check the boxes next to the target objects to select them as targets.
- Reload templates - reloads template data for the current building and all blocks, zones and surfaces in the building. Data is only loaded if the template selection is non-default. If the template inherits from the hierarchical level above, data is not loaded.
- Search & replace - allows you to search the model for particular data and replace with data from a template.

Selection tools are available to allow you to control the selection of building objects:

- Select all.
- Select all down to zone level.
- Select none.

Making global lighting settings

When you load lighting data from template you should consider that DesignBuilder sets the lighting output from the lights based on:

a) Lighting system efficiency (W/m2/100 lux) using data from the lighting template and,
b) Illuminance levels required in the zone as set on the Activity tab.

If you have many types of activity in the building you can load lighting data for each zone taking into account the required illuminance level in the zone by selecting the appropriate zones in the Target tab.

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3.3.3.2 Clear Data to Default

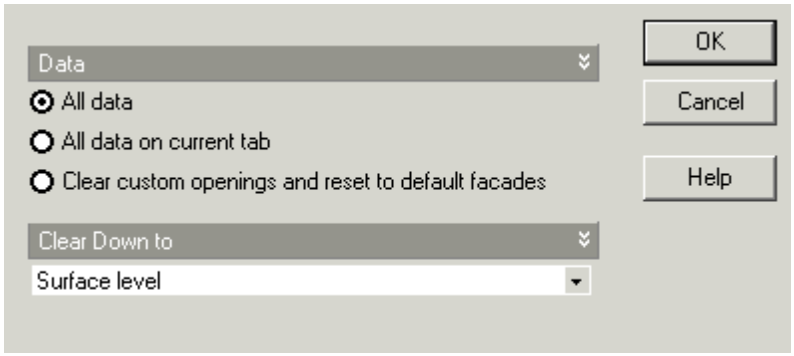
Model Data Management

The Clear Data to Default dialog allows you to:

- Clear Model Data
- Clear custom openings and revert back to default facades.

'Clearing to default' removes any 'user data' (shown in red) from the current object and instead default data is passed from the 'parent' object in the hierarchy (Model Data shown in blue).

You can control the extent of the 'clearance' by setting the 'Clear Down to' data at the bottom. Leave this data as 'Surface level' if you want all data in the currently selected model object (including child objects) to be returned to a default state.



3.4 Model Options

All Model Options are stored in the DesignBuilder dsb file and so any changes you make to the model configuration will not affect other models.

You can open the Model Options dialog by:

- Pressing F11.
- Clicking on the spanner icon on the toolbar.
- From the Edit menu.

All Model Options are stored in a single dialog but the options you can access depend on where you are in the model hierarchy.

Some model options are stored at the **site level**:

- All options on the Display tab

Most are stored at the **building level**:

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- Options on the Data, Advanced, Heating design, Cooling design, Simulation tabs

and some are stored at **block level**:

- All options on the Block tab.

So if you open the Model Options dialog when you are at building level you will not be able to access the Block Model Options. Likewise if you are at site level you will only be able to access the Display tab.

3.4.1 Model Data Options

Data tab on Model Options dialog.

Use this dialog to customise the Model Data Options for the current building.

You can edit the amount of detail in various aspects of the model:

- Model scope
- Construction and Glazing
- Gains
- Timing
- HVAC
- Natural ventilation

The descriptions to the right of the sliders, taken together, provide a summary of the current model options.

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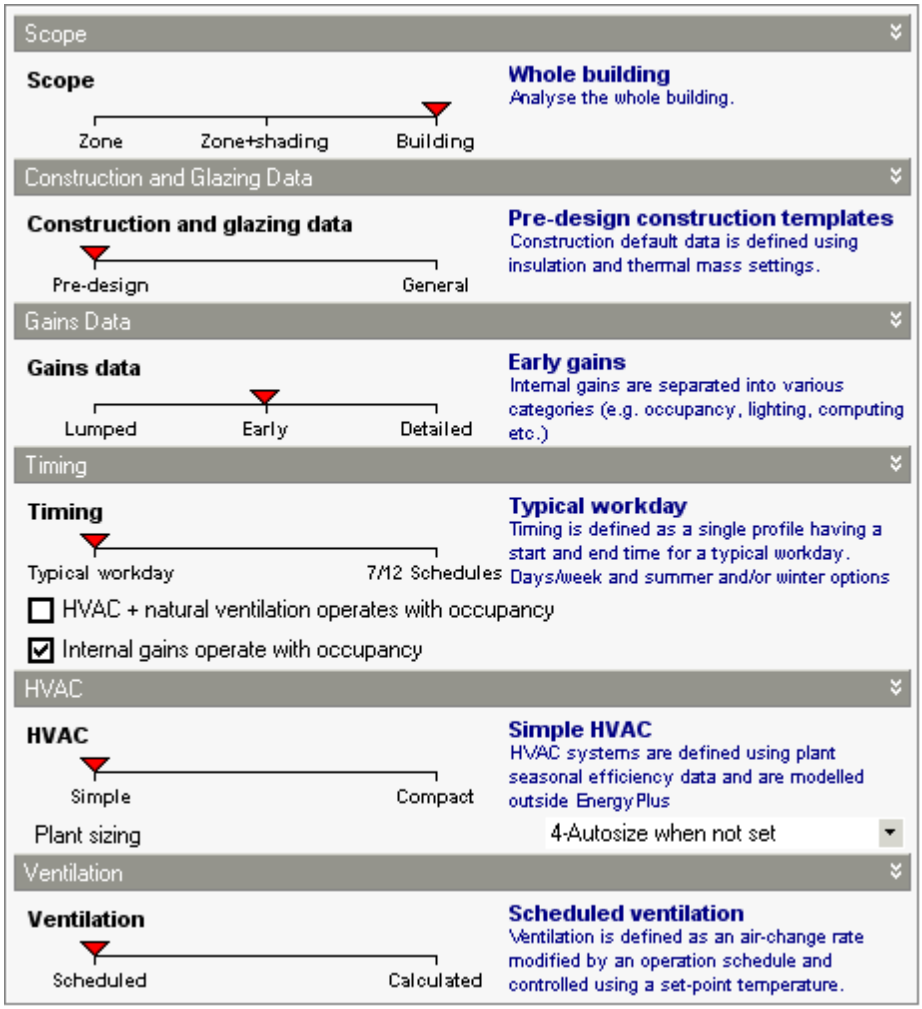

3.4.1.1 Model scope

Data tab on Model Options dialog.

You can use the scope control to switch between whole building and single zone modes.

1. **Zone** - only the current zone is modelled and all internal surfaces between this zone and other zones are modelled as being adiabatic, i.e .heat is transferred into the wall mass as if the temperature of the other zone is the same as the current zone.. This option is only allowed if you are at zone level because the current zone is used to select the single zone to be analysed.
2. **Zone + Shading** - as above but the surfaces of other zones are modelled as shading surfaces. This option models a single zone but includes shading due to other parts of the building and its shading devices. Note that if the single zone is part of a large complex building, simulations using this option are often little or no quicker to complete than the full building simulation. This is because the shading calculations required for the large number of shading elements used to model the rest of the building are slow.
3. **Building** - All zones and shading in the model are included in the simulations

To use one of the single-zone options make sure you are currently editing the zone you want to model.

See also the Include zone option.

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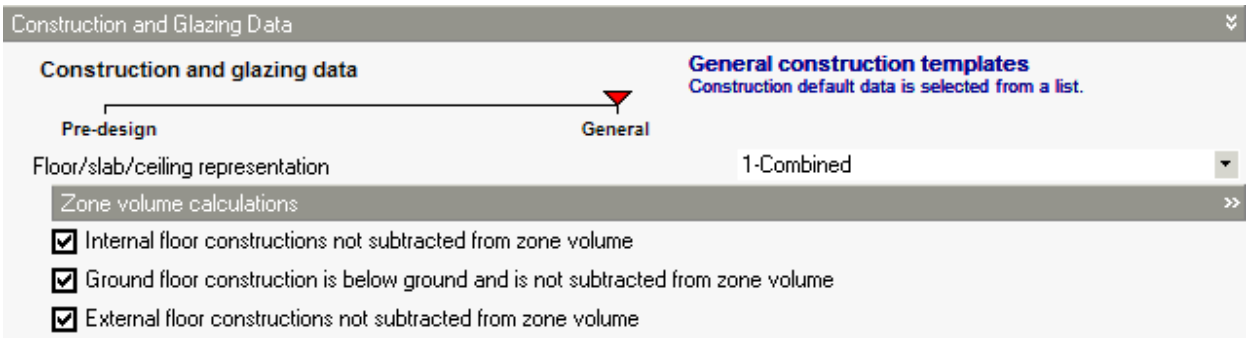
3.4.1.2 Construction and glazing

Data tab on Model Options dialog.

Construction and glazing

The Construction and glazing model option controls the way construction templates are loaded on the construction model data tab. When the option is set to **Pre-design** you can load construction templates using the Insulation and Thermal mass slider controls. When set to **General**, templates are loaded by selection from a list in the usual way.



Floor/slab/ceiling representation

You can choose to model floors, ceilings and flat roofs each having a single construction or by combining separate constructions for floor, slab and ceiling. The options are:

- **1-Combined** - all wall, floor and roof constructions are defined using a series of single constructions (Exception: ground floors can optionally have a ground construction added) without the complication of understanding how layers are combined. This can be easier to understand for new users and requires less input model data. You may also find it easier to use this option when assessing your building for compliance with energy codes because by default the combined constructions used have exactly the maximum U-values allowed by the local code. See the Combined Constructions section for more details.)

  With **Combined** constructions, the **volume** of the floor constructions can be included or excluded from the zone air volume used in calculations by making the appropriate setting under **Zone volume calculations.** By default the volume of floor constructions is ignored in the calculation of zone volume, i.e. for a single zone rectangular box block the zone volume is:

  Zone volume = Block height x (Block width - wall thickness) x (Block depth - wall thickness).

  When the floor constructions are to be subtracted from the zone volume then the volume of the floors are calculated by multiplying the construction Thickness by the surface area.

  The 3 options (shown in the screenshot above) are:

  Internal floor constructions not subtracted from zone volume - selected by default, this option allows you to include/exclude the volume of the internal floors from the zone volume. Clear this option if you wish internal floor constructions to be subtracted from zone volume.

  External floor constructions not subtracted from zone volume - selected by default, this option allows you to include/exclude the volume of the external floors from the zone volume. Clear this option if you wish external floor constructions to be subtracted from zone volume.

  Ground floor construction is below ground and is not subtracted from zone volume - selected by default, this option allows you to include/exclude the volume of the ground floors from the

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zone volume. Clear this option if you wish ground floor constructions to be considered as being within the zone and subtracted from zone volume. Keep option selected if the ground construction is to be modelled as being below ground level and not subtracted from the zone volume.

For more information on the effect of these options and also some limitations see the Model Geometry Example section.

- **2-Separate** - internal floors are defined in model data by selecting constructions for floor, slab and ceiling with air gaps. Likewise flat roofs are defined by separately defining the ceiling and roof details etc. This approach can be more economical in the number of different construction components required, but requires more input model data and more careful planning. When using this option you must first familiarise yourself with the meaning on the data as described in the Separate Constructions section. Choosing this option configures constructions in the same way as DesignBuilder version 1.2 and earlier.

  With **Separate** constructions, the volume of the floor constructions + floor void and ceiling constructions + ceiling void can be included or excluded from the zone air volume by making the appropriate setting under **Zone volume calculations**.

Note: the zone air volume referred to above is for calculating air flow rates for natural ventilation, mechanical ventilation ***and also (starting with v.1.4.0.049) for infiltration***. *Previous versions always included the construction volume in the zone volume used for infiltration regardless of these settings.*

3.4.1.3 Gains

Data tab on Model Options dialog.

There are three levels of gains model detail:

- **Lumped** - all internal gains including occupancy, computer, office equipment, miscellaneous, catering process and lighting gains are lumped together into a single value. Solar gains are still calculated in the usual way.Note that with **Lumped** gains you cannot generate Temperature distribution and Comfort simulation output data.
- **Early** - gains can be defined separately under various categories (see above).
- **Detailed** - gains are specified by defining each individual item of equipment in each zone on the Equipment tab. If you select this option then DesignBuilder will automatically set the Timing model option to **Schedules**. Note that this option was developed for creating very detailed models of existing buildings based on survey data. Entering this data for a large building is very time-consuming and in most cases you will be better served by the **Early** gains option above.

Note: When using the **Lumped** Gains model option, Comfort data is not generated because in EnergyPlus the request for comfort calculations is made in the 'PEOPLE' statement and this is not used with Lumped gains.

Internal gains operate with occupancy

Check this option if you wish the timing of internal gains to be the same as occupancy. Unchecking the option allows you to set the timing of each type of gain individually. For example there may be low levels of emergency lighting and some IT equipment usage while the building is unoccupied.

3.4.1.4 Timing

Data tab on Model Options dialog.

You can specify schedules in DesignBuilder using two approaches:

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- **Typical workday** - where the timing is defined by a start time, end time, working days per week and seasonal variation. This approach is intended for easy early stage modelling of non-domestic buildings.
- **Schedules** - where Schedules can either be defined for each day of the week and each month of the year using daily Profiles or by using Compact Schedule format. Schedules are more flexible and can be used in other projects but they take longer to set up.

Generally if you start to find the Typical workday timing mode too restrictive you should switch to Schedules mode.

You can also request:

Timing HVAC + natural ventilation operates with occupancy

Select this option if all heating, cooling, natural ventilation and DHW operation follows occupancy.

*This option is only available if Timing is set to **Typical workday**.*

Note that HVAC operation data can modify the HVAC operation even when **Timing HVAC + natural ventilation operates with occupancy** is set. For example:

- **Simple HVAC -** Mechanical ventilation, Heating and Cooling operation have additional Days / week and seasonal operation data. Heating operation also has Preheat hours and Cooling operation also has Precool hours.
- **Compact HVAC:**
  - **Fan-coil units, Unitary single zone** - Mechanical ventilation, Heating and Cooling operation have additional Days / week and seasonal operation data. Heating operation also has Preheat hours and Cooling operation also has Precool hours.
  - **VAV/CAV/Unitary multizone** - Min AHU outside air, AHU heating/cooling, Zone setpoint schedules have additional Days / week and seasonal operation data. Heating operation also has Preheat hours and Cooling operation also has Precool hours.

These differences are applied as 'modifiers' to the basic occupancy schedule because HVAC systems generally switch on and off based on the occupancy time but with differences. e.g. Heating systems are often switched off in summer, they may operate during weekends when the building is unoccupied and they will often have a preheat period to get the building up to temperature before occupancy.

Internal gains operate with occupancy

Select this option if lighting and other internal gains operation follows occupancy. If you wish to enter specific schedules for lighting and/or other internal gains you should uncheck this option.

3.4.1.5 Natural Ventilation

Data tab on Model Options dialog.

Natural ventilation can either be 'Scheduled' or 'Calculated'

- Scheduled - the ventilation rates are predefined using a maximum air change rate modified by operation schedules.
- Calculated - the ventilation rates are calculated using wind and buoyancy-driven pressure, opening sizes and operation, crack sizes etc.

You should generally use the 'Scheduled' natural ventilation model option because it is quicker and easier to enter the related model data and also because the simulations run more quickly. However if you need to calculate natural ventilation rates which can be achieved with a particular configuration then you should use

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the 'Calculated' option.

More on Natural Ventilation modelling.

3.4.1.6 HVAC

Data tab on Model Options dialog.

HVAC can be defined in DesignBuilder using:

- **Simple** - the heating/cooling system is modelled using basic loads calculation algorithms. For convective heating systems and all cooling systems the EnergyPlus 'Purchased air' system is used to calculate heating and cooling loads. 'Purchased air' supplies hot/cold air at predefined temperature and humidity for heating and cooling. See topics on Heating and Cooling for more on defining the condition of the supply air. Mechanical ventilation loads are calculated locally for each zone. When using Radiant/convective the heating system type the EnergyPlus 'High Temp Radiant System' system type is used to calculate heating loads.
- **Compact** - the heating/cooling systems are defined in DesignBuilder using Compact HVAC descriptions but modelled in detail in EnergyPlus.

In both cases heat generator (boiler) and chiller fuel energy consumption is calculated from loads as a post-process using efficiency factors.

HVAC + natural ventilation operate with occupancy

You can force all HVAC systems to have the same operation schedule as occupancy by checking the 'HVAC + natural ventilation operate with occupancy' option under 'Timing'.

Plant Sizing- Autosizing

DesignBuilder can be used to automatically calculate heating and cooling capacity in each zone based on the output from the Heating and Cooling design calculations. The Plant sizing model option provides control over how heating and cooling capacities are set for Simulations. Select from:

- **1-Adequate**
- **2-Manual**
- **3-Autosize**
- **4-Autosize when not set**

Note: Heating and Cooling design calculations assume that heating and cooling loads are always met and so do not use this option.

Adequate

The effect of this option depends on the HVAC model option. When using Simple HVAC, equipment is modelled as having adequately large capacity to meet any heating or cooling demand and setpoint temperatures are always maintained. This option can cause extremely large peaks in heating and cooling delivery to zones and will tend to over-predict heating and cooling energy and under predict discomfort hours. When using Compact HVAC this option is equivalent to **Autosize** and the Compact HVAC autosizing mechanism is used to size the components and flow rates to ensure that the required comfort conditions are met.

Manual

Heating and cooling capacity Model Data must be entered manually. Choose this option if you have specific heating and cooling capacity data you wish to use and do not want it to be overwritten when

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model data or model options change.

If you would like DesignBuilder to calculate the heating and cooling sizes and also maximum supply flow if you are using Compact HVAC you should follow this procedure:

1. Switch to the **Autosize** option.
2. Run heating and cooling design calculations.
3. If you are using Compact HVAC also run a simulation.
4. Switch to the **Manual** option.
5. You should now see the heating and cooling sizes shown for each zone in the HVAC model data.
6. If you are using Compact HVAC then you can also copy the Maximum supply flow in m3/s from the epluszsz.csv file. This can be found in the EnergyPlus folder straight after a Compact HVAC system simulation. The Maximum supply flow data is the bottom row labelled 'Peak Vol Flow (m3/s)'.

If you are using the Manual sizing option together with Compact HVAC and wish to use different cooling sizes to those autosized you will need to ensure that the maximum supply flow is changed accordingly. If you increase the maximum cooling capacity but don't increase the Maximum supply flow rate (or even leave it as Auto) you will get "Rated air volume flow rate per watt of rated total cooling capacity is out of range" errors in the EnergyPlus simulation because the cooling capacity requested cannot be achieved with the specified air flow rate. Also due to a quirk in EnergyPlus the Auto Maximum supply flow rate option does not work well with Manual sizing option and automatically calculated Maximum supply flow rates do not account for the 'higher than autosized' cooling capacity requested.

Autosize

Autosize is the default option where heating and cooling capacities are always calculated prior to each simulation and the heating and cooling capacity model data is not displayed. When using Simple HVAC the heating and cooling design calculations will be run as required before the simulation to calculate the required sizes. When using Compact HVAC the components and flow rates are sized using the EnergyPlus autosizing mechanism to ensure that the required comfort conditions are met. In this case heating and cooling autosizing calculations are done internally within EnergyPlus and no extra autosizing calculations are carried out by DesignBuilder.

Autosize when not set

In this case heating and cooling capacities are autosized and loaded into model data following heating and cooling design simulations. If Capacity model data is not present before a simulation, it is generated by automatically by carrying out heating and cooling design calculations and is written into the HVAC model data.

You should be aware that when using the **Autosize when not set** option, the heating/cooling zone capacity model data is not treated the same way as other calculated results. In general, calculated results are deleted when any edit is made to the building model, but this is not the case for zone capacity model data. This is only updated when:

1. There is no heating/cooling capacity data (the value is either blank or zero when heating/cooling is switched on) and a simulation is requested. In this case the appropriate design calculations are carried out to fill in the capacity data, before the simulation.
2. The appropriate design calculation is carried out by clicking on the Heating/Cooling design tab.
3. Model Options change. In this case zone HVAC capacity is deleted.

If you always want the heating capacity to be kept up-to-date with your model and do not have any specific capacity sizes you wish to use, you should consider using the **Autosize** option. This will cause autosizing to be carried out prior to every simulation.

You can change heating capacities by hand if you wish but you should bear in mind that, if Model

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options change, all heating and cooling capacities are reset to zero. Set the option to **Manual** to avoid this happening.

3.4.2 Advanced Concepts

Advanced tab on Model Options dialog.

- Simplification - options to allow zones to be merged and for controlling lumping of similar windows, openings and cracks and eliminating unnecessary zones and elements from the model.
- Natural ventilation - options to control the operation of natural ventilation.
- Miscellaneous Edit - options for controlling data displayed.
- Lighting - options for lighting.
- Filters - excluding elements from the model.

This data applies to the current building.

3.4.2.1 Simplification

Advanced tab on Model Options dialog.

You can simplify and speed up simulations (sometimes quite significantly) by lumping zones, walls and windows and/or eliminating unnecessary zones and elements from the model. The following options are available:

Merge zones of same activity

Option reduces the number of zones by merging all zones of same activity. See below for more on merging zones.

Merge zones connected by holes

Merges zones which are connected by holes drawn at surface level (*not* the holes used to represent the airflow path in virtual partitions). You can merge one or more zones within the same block or across multiple blocks. See below for more on merging zones.

Lump similar windows on surface

Causes all windows on a zone surface having the same area, construction, frame/dividers, shading etc to be lumped into a single opening. Lumping only occurs in zones which have no lighting control. The EnergyPlus Window Multiplier mechanism is used. For models having surfaces with many similar windows this option can provide a worthwhile reduction in simulation times.

> **Calculated natural ventilation**
>
> You should not use this option if you have repeated windows having same size, glazing type and shading on a surface but different **% Glazing opens** and/or **Operation schedule** because any differences in the natural ventilation settings are not accounted for when checking for similar windows on a surface.

DesignBuilder does not allow a multiplier for windows to be used for zones with daylight lighting control or if the **3-Full interior and exterior** Solar distribution option is set. This is because for daylight control or **Full interior and exterior** Solar distribution, EnergyPlus must know where each of the individual windows is located to properly calculate the solar and visible light transmitted.

This is currently the only 'Simplification' option switched on by default for new models.

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Lump similar cracks

Causes all cracks in a zone which are facing the same direction and have similar height to be lumped into a single crack. This option applies only when the natural ventilation model option is **Calculated**.

Lump walls and windows (developer option)

Reduces the number of walls and windows. *This is currently a **research only** tool because it has **undocumented restrictions**. It is not available for general users*

Generate fully enclosed zones

Check the **Generate fully enclosed zones** checkbox to model Link surfaces. This has 2 main effects on the model:

1. Extra Link surfaces are generated to connect adjacent blocks together for both visual continuity and to allow fully closed zones to be generated.
2. The volume enclosed by the link surfaces and the inter-block partition is included in the zone volume. This volume is essentially the thickness of the block wall x inter-block partition area).

Model 'semi-exterior unconditioned' zones as simple R-value to outside

Including complex roof structures in the model can sometimes cause simulations to run slowly for little benefit in accuracy. This option allows you to exclude such spaces from the calculations adding in their place a single R-value resistance to outside. The resistance can be used as a way to include the 'buffering' of the occupied space by the semi-exterior zones without sacrificing simulation speeds.

This option can be very useful for speeding data entry for simple calculation methods like SBEM.

Openings in semi-exposed surfaces

Any openings (window, doors, vents, sub-surfaces and holes) in semi-exposed surfaces do not include the additional R-Value when this option is selected.

By default this option is off and roofspace zones (and all other semi-exposed unconditioned zones) are modelled as separate zones in calculations.

R-Value to outside

The R-value added to the outside of semi-exposed elements when **Model 'semi-exterior unconditioned' zones as simple R-value to outside** option (above) is set.

You can enter an R-Value of 0 if you don't want to include a resistance between semi-exposed elements and outside. In this case it your responsibility to include the effect of the adjacent semi-exterior unconditioned zone in the semi-exposed constructions themselves.

Tip: You can calculate approximations for **R-Value to outside** by adjusting the R-Value until the results match those of the equivalent simulation with **Model 'semi-exterior unconditioned' zones as simple R-value to outside** switched off.

MERGING ZONES

When zones are merged using **Merge zones of same activity** or **Merge zones connected by holes**, combined merged zones are treated as a single zone in thermal calculations. When zones are merged, DesignBuilder marks one of the zones as being the 'parent' zone, and the other zones 'child' zones. The

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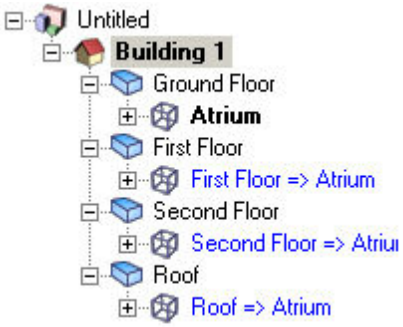
child zones are marked in blue in the Navigator together with the parent zone they have been merged into as shown below.



This screenshot of the Navigation list shows the First floor zone, Second floor zone and Roof zones all merged into the Atrium zone.

The parent zone is the zone that is used for defining Activity, HVAC, Lighting (and all other zone related data) for itself and all it's child zones. You therefore cannot access this zone-related Model data for merged child zones. You must go to
the parent zone to edit the Model data for the combined zone. The internal gains are calculated based on the data set on the Activity tab for the parent zone but using the combined total floor area of all of the merged zones.

Constructions, glazing and other surface level data can be defined separately in each of the parent and child zones in the normal way.

> **Important:** when merging 2 or more stacked zones using holes in the floor and the **Merge zones connected by holes option**, you should be aware that the *combined floor area used to calculate internal gains in the simulations will exclude the area of any holes in the floor*. In this case, if you have any gains calculated using the combined floor area you should either ensure that the area of the hole is very small or else use the **Merge zones of same activity** option instead and avoid using holes.

Why merge zones?

You may want to merge zones for various reasons:

- Speed up simulations.
- A geometrically complex space in the actual building is to be modelled using more than one block in DesignBuilder (e.g. Dormer windows, Atria).
- To reduce the number of zones and simplify HVAC system descriptions when exporting EnergyPlus IDF data for use outside DesignBuilder.
- If you have created a tall merged zone, you may want to use the Air distribution model data on the HVAC tab to create a dynamic vertical temperature gradient. This approach to modelling tall spaces is preferred over connecting a number of horizontal slices with air flow openings, because it does not rely on getting correct airflow conductances between the horizontal slices.

Technical note When generating data for the calculations, surfaces between zones are defined twice, once from each side. Surfaces between 2 zones that have been merged are called **Surfaces within zone.** By default these are modelled in the same way as standard surfaces but with both sides adjacent to the same zone. If the **Surfaces within zone treated as adiabatic** option is set, the 'other side' in each of the 2 surfaces is modelled as adiabatic.

Disadvantages of merging

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Merging zones can reduce cooling load peaks resulting in an underestimate of cooling equipment required to condition the building. To understand this consider a building in the Northern hemisphere with two zones, a North zone and a South zone connected to each other along the E-W axis. When solar gains are highest, the South zone may experience a cooling load and the North Zone not. Now imagine the same 2 spaces merged into a single zone. The combined zones will probably now have a lower cooling load than the load in the original South zone because the air from the South side of the merged space is cooled by the shaded North side.

As simple guide, where the temperatures, internal/solar gains, ventilation, HVAC system and other operational parameters in the actual separate zones are about the same as each other then the merging process should not cause much inaccuracy, but merging zones which have different conditions and/or load profiles the merging will reduce accuracy.

In most cases merging zones will speed up simulations but sometimes simulations can slow down, especially the initialisation stage. This may be because any very large zones generated through merging can have many windows which can slow down solar and daylighting initialisation.

Merging rules

1. When merging zones using the **Merge zones of same activity** or **Merge zones connected by holes** zones connected by the merge option are lumped together into a single 'parent' zone, which in a vertical stack of zones, will be the lowest zone in the stack.
2. The zone surfaces are generated in exactly the same way as they would have been without the merging but are associated with the parent zone rather than the original zone.
3. In child merged zones, you can access Constructions and Openings surface-based Model data but not space related data such as Activity, Lighting, HVAC. This is accessed from the parent zone only.

Merging buildings

You can merge 2 existing buildings (including component blocks) using the Transfer blocks command from the Edit menu.

See also Zone multiplier for a manual way to reduce models having similar zones.

3.4.2.2 Natural Ventilation

Advanced tab on Model Options dialog.

Model holes (including holes in virtual partitions)

You can optionally switch off all holes in the model including those holes generated by defining partitions as virtual partitions. In this case the building is modelled as if no holes were defined.

Tip: Unchecking this data can be a quick way to model virtual partitions as standard partitions.

CALCULATED NATURAL VENTILATION OPTION

Wind Factor

When carrying out conservative design simulations you may prefer to exclude (or reduce) the effects of wind from Calculated natural ventilation. To exclude wind-driven airflow from the analysis altogether set the Wind factor to 0. For full treatment of wind effects set it to 1 and for intermediate treatment of wind set to a number between 0 and 1.

Modulation of Openings

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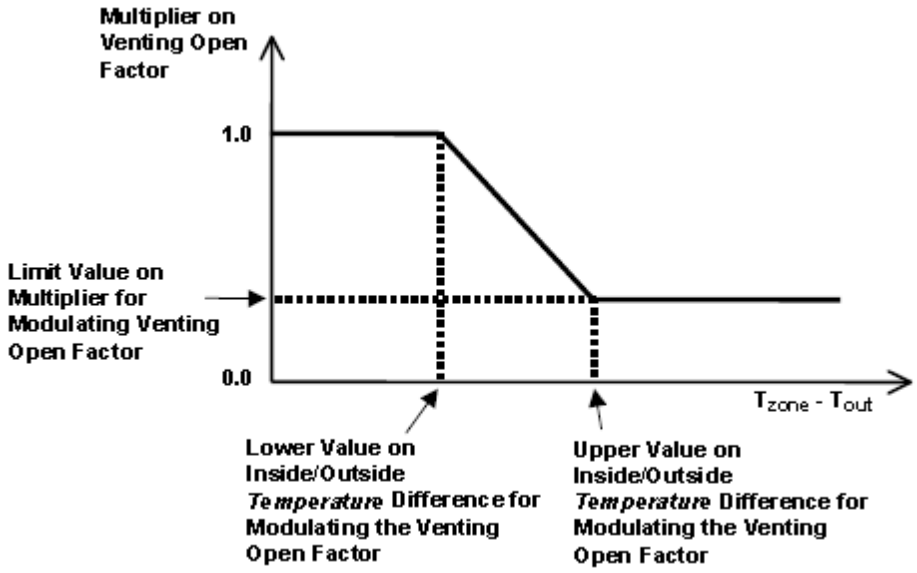
You can modulate the window/door openings when using Calculated natural ventilation by making appropriate settings to:

- **Modulate opening areas** - switch on modulation by checking this option.
- **Limit value of opening modulation factor** - gives the reduction on opening area for low outside air temperatures.
- **Lower value of Tin-Tout** - lower value on inside/outside temperature difference for modulating the venting open factor.
- **Upper value of Tin-Tout** - upper value on inside/outside temperature difference for modulating the venting open factor (defines 'low outside air temperatures')

This data is used within EnergyPlus to calculate a factor between 0 and 1 that multiplies the opening factor of each window and door in the building. Modulation of the openings can reduce the large temperature swings that can occur if the windows/doors are too far open when they are venting, especially when there is a large inside-outside temperature difference. This can avoid discomfort due to introduction of cold air and/or prevent heating system operation in summer when not really required.



Temperature difference (Tin - Tout)	Opening Multiplier
Tin - Tout <= [Lower value of Tin - Tout]	1.0
[Lower value of Tin - Tout] < **Tin - Tout** < [Upper value of Tin - Tout]	Factor varies linearly from 1.0 to Limit value of Opening modulation factor.
Tin - Tout >= [Upper Value of Tin - Tout]	Factor = Limit value of opening modulation factor.

For example if the Lower value of Tin - Tout is 0, the Upper value is 15 and the Limit value of opening modulation factor is 0.05, the windows and doors are only opened 5% of their full opening area when the outside air is 15K colder than inside.When the inside and outside temperatures are the same the windows are open to their maximum opening area and when the temperature difference is 7.5K the windows are opened halfway between these extremes.

Important Notes

1. The purpose of the Modulate option is to prevent discomfort due to very cold air being introduced into the zone. You should keep in mind though that this control will also prevent ventilation when the temperature in the space is very hot and the outside air is not particularly cold because of the large temperature difference between inside and outside.

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For example if the upper modulation temperature difference is 15K and the limiting modulation factor is 0.05 then the maximum window and vent opening area will be reduced to 5% of their normal size if the temperature in the zone is 35°C and the temperature outside is 20°C. In this case the natural ventilation through the 'almost closed' openings would probably not be adequate to cool the zone back down again. So you should not use this option if you wish natural ventilation to occur when the temperature inside is very high.

2. With Modulation active, openings will be completely closed if the difference between inside and outside air temperatures is greater than **Upper value of Tin-Tout.**

This modulation data can also be accessed from the HVAC tab under the Natural Ventilation > Options headers in v.1.8.1 and later.

Airflow through internal openings

When using Scheduled natural ventilation, windows, vents, doors and holes in internal partitions can be modelled by mixing a predefined amount of air from one zone with the adjacent zone by selecting the **Airflow through internal openings** option and entering the **Airflow rate per opening area.**

Technical note: this airflow is modelled using the EnergyPlus *Mixing* option.

3.4.2.3 Miscellaneous Edit

Advanced tab on Model Options dialog.

Automatic block zoning

By default DesignBuilder automatically generates zones as partitions are drawn. You can change this behaviour by unchecking the **Automatic block zoning** option. In this case partitions are shown in blue as they are drawn and are referred to as **outline partitions**. Outline partitions do not create new zones and are modelled in the same way in simulations as hanging partitions. To convert any outline partitions to standard partitions and to rezone the block use the Rezone block command accessed from the Tools menu. Note that outline partitions that do not connect at both ends (known in DesignBuilder as hanging partitions) will remain in blue even after the Rezone block command.

Alternatively to convert *all* outline partitions in the *building* to standard partitions and hence rezone the whole building you can use the Rebuild command. This will take longer to process than the Rezone block command as it recalculates the surface and adjacency geometry as well rezoning.

Note: switching **Automatic block zoning** off also prevents rezoning following other partition edit commands such as delete, copy and undo/redo.

Automatically include voids from lower blocks

Select this option if you would like DesignBuilder to automatically punch voids through new blocks drawn on top of existing blocks having voids. If you leave this option switched off (default state) you can still draw voids at the block level using the ghosted outline of adjacent voids in a block below as a guide.

Edit block model data

Use this option to allow editing of block level model data.

Note: If you disable block editing you will no longer be able to edit Model Data at the block level in the

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current building and so will not be able to set different defaults for different blocks.

3.4.2.4 Lighting

Advanced tab on Model Options dialog.

Working plane height

You can set the height of the working plane (and hence the z-position of the lighting sensor). The x-y coordinate is set by placing the Lighting sensor marker(s) at zone level.

3.4.2.5 Filters

Advanced tab on Model Options dialog.

Exclude surface elements smaller than

You can also filter out very small surfaces from the simulations (and from the Navigator panel) by defining a minimum area.

Experience suggests that a value of 0.05 is a good default. If you set the limit much lower than this you will run the risk of including very small surface slivers in the calculations. These can cause problems with EnergyPlus.

3.4.2.6 Component Blocks

Advanced tab on Model Options dialog.

Fraction two largest areas

A component block is considered 'flat' when its' 2 largest surfaces make up most of the total surface area of the component block. The **Fraction two largest areas** data defines the meaning of 'most'. The default value of 0.8 means that when the two largest equal areas make up 80% or more of the total surface area of the component block then the block is considered to be 'flat' and only one of the 2 surfaces will be modelled. Which of these surfaces is used in the calculations defined by **Flat component block surface selection**.

Flat component block surface selection

For flat component blocks DesignBuilder uses the selection made here to decide which of the 2 largest surfaces of the component block is used in the simulation as a shading surface. Choose from:

- **1-Highest** - the upper of the 2 largest surfaces is used.
- **2-Lowest** - the lower of the 2 largest surfaces is used.

3.4.3 Heating Design Calculation Options

Heating Design tab on Model Options dialog.

Data on this tab allows you to control the Heating Design calculations.

- Winter Design Day

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- Calculation Options
- Heating system sizing
- Advanced Calculation Options
- Output Options

This data is also shown before Heating Design Calculations.

3.4.3.1 Winter Design Day

Schedule types for Compact HVAC Autosizing (Compact and Typical workday Schedules)

7/12 Schedules can be categorised using the following categories when using the **End-use defaults** option:

- **General** - include general purpose schedules in Compact HVAC heating autosizing calculations - on by default.
- **Occupancy** - include occupancy schedules - off by default
- **Lighting** - include lighting schedules - off by default.
- **Equipment** - include equipment schedules - off by default.
- **Heating demand** - include heating demand schedules - on by default.
- **Cooling demand** - include cooling demand schedules - on by default.
- **HVAC** - HVAC schedules - on by default.
- **Natural ventilation demand** - natural ventilation schedules - off by default.
- **DHW** - DHW schedules - on by default.

For example, occupancy gains should normally be excluded when sizing heating plant to ensure that the design heating plant meets all heating loads itself. So leave the Occupancy check box unchecked. Heating and cooling demand schedules must be included to ensure the system operates so the Heating demand and Cooling demand options should normally left selected.

These options are also used for Typical workday schedules.

3.4.3.2 Calculation Options

Heating Design, Cooling Design and Simulation tabs on Model Options dialog and Options tab on Simulation Options dialog.

Calculation description

Enter some text to identify the calculation. This will be used in reports and in the filename for automatically generated ESO files.

Number of time steps per hour (*Simulation only*)

The 'time steps per hour' is the number of times the building thermal network is solved per hour in the simulations. When the HVAC portion of the simulation begins it's solution for the current time step, it uses the basic time step as its maximum but then can reduce the time step, as necessary, to reach the solution.

The technical details of the approach are explained in the EnergyPlus Engineering Documentation under 'Integrated Solution Manager'.

Advanced EnergyPlus users can obtain and view data at intervals of the HVAC time step used if they select the 'detailed' option on an HVAC report variable (e.g. Zone/Sys Air Temp).

The time step entered here is also known in the EnergyPlus documentation as the Zone Time Step.

Though many buildings can be successfully simulated with 1 or 2 time steps per hour, EnergyPlus

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suggest 4 for non-HVAC simulations and 6 for simulations with HVAC.

Hourly data (such as outdoor conditions expressed by Design Days or Weather data) are interpolated to the Zone Time Step. This is discussed the EnergyPlus documentation under: Weather Data Hourly Interpolation.

Note 1: In general, increasing the number of time steps improves accuracy but slows the simulation (and generates more data if output is requested at the 'sub-hourly' interval).

Note 2: When using **1 time steps per hour** you will not be able to access Temperature distribution results

Temperature Control

Heating and cooling systems control internal temperatures to meet the setpoint temperatures specified on the Activity tab. These setpoint temperatures can be interpreted as air, operative or some other radiant fraction and DesignBuilder provides corresponding options to allow HVAC systems to be controlled by:

- **1-Air temperature** - control the room mean air temperature to the heating and cooling setpoint temperatures specified on the Activity tab.
- **2-Operative temperature** - control the room temperature using 0.5 radiant fraction. See notes of operative temperature control below if you plan to use this option.
- **3-Other**- you can enter the radiant temperature control fraction.

The radiant fraction should be less than 0.9 and the minimum is 0.0. A value of 0.0 is the same as controlling on only zone air temperature. If air velocities are higher than 0.2 m/s, then lower values for radiative fraction might apply. Niu and Burnett (1998) cite International Standard ISO 77300 in recommending the values for this fraction listed in the following table.

Radiative Fraction vs Air Velocity

Air Velocity (m/s)	<0.2	0.2 - 0.6	0.6 - 1.0
Radiant fraction	0.5	0.4	0.3

Reference: J. Niu and J. Burnett. 1998. Integrating Radiant/Operative Temperature Controls into Building Energy Simulations. ASHRAE Transactions Vol. 104. Part 2. page 210. ASHRAE. Atlanta, GA.

You can think of the Temperature control option as:

- The radiant fraction sensed by the room thermostat, or,
- Given a room thermostat that mainly senses air temperature, the extent of automatic modification of the setpoint temperature to ensure occupant comfort.

Notes

1. This option is overridden when using radiant heating systems by the radiant heating system control setting.
2. This option does not affect natural and mechanical ventilation setpoints - these always use **air temperature** set points.

Operative vs Air temperature control - Advanced discussion

There has been much debate amongst simulation experts over the years on the extent to which radiant effects should be included on the simulated thermostat. Most real-world thermostats probably don't actually sense more than about 20% radiant heat transfer - mostly the temperature sensor will be sensitive to the temperature of room air nearby. So one would think that air temperature (or 20% radiant) control is the best choice. But Operative control (radiant fraction = 0.5) can be useful for calculating realistic heating and cooling energy based on published summer and winter temperature requirements for the activities in each zone. This is because HVAC systems controlled using the operative temperature continue to condition the building until comfort conditions are met (just like they are in the real building where occupants may adjust thermostats until they are comfortable). Also, the default temperature set points from the Activity templates

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are generally derived from sources quoting operative temperatures. With Air temperature control the room *air* temperature is controlled to the set point temperature, which (depending on internal radiant temperatures) may not necessarily be comfortable.

The disadvantage of **Operative** temperature control is that start up loads can be unrealistically high due to the lag in thermal response of the walls, floor, ceilings. The slow temperature response of the building fabric part governs the output of the operative thermostat and hence the operation of the heating/cooling equipment. If this effect dominates it can lead to an overestimate of the required design cooling load. You should be familiar with this issue before using operative temperature control to size heating and cooling equipment. In our experience using Operative temperature control usually leads to higher peak loads in Heating and Cooling design calculations and higher heating and cooling energy consumption in Simulations.

Caution

Operative temperature control can cause EnergyPlus Error 3 when using Simple HVAC, or Cooling design calculations with Operative control in zones with strong radiant heat gains causing high radiant temperatures (e.g. uninsulated roof or zone is highly glazed). The error is caused by the fixed supply air temperature being higher than the zone air temperature required to give the operative setpoint (.e.g. 24°C). The solution may be to use Air temperature control and to manage the high radiant temperatures using solar shading/insulation as appropriate.

Air temperature control is easier to use as none of the aforementioned problems apply, but it can lead to inadequate equipment sizes peak loads in Heating and Cooling design calculations when not used with a design safety factor. This is especially true when radiant temperatures are very different from air temperatures for example in poorly insulated buildings, buildings with large unshaded glazing areas or high ventilation rates. Generally using air temperature control in Simulations of such buildings will underestimate energy consumption.

Autosizing simple HVAC convective systems with operative temperature control
Another issue to bear in mind with operative temperature control is that in simple HVAC convective systems, autosized cooling systems use a different algorithm to calculate the maximum supply airflow rate used in the EnergyPlus **Purchased Air** system. In convective systems the equation used is:

`DeltaT = ZoneCoolingSetPointTemperature - HVACCoolingCoilSetpointTemp` *(difference in temperature between zone air and supply air)*

```
DesignSupplyAirFlowM3PerS = DesignMaxCoolingLoad / (Cp * DeltaT * AirDensity)
```

This equation works because the temperature of the air in the zone can safely be assumed to be the zone cooling set point and so there is fixed difference in temperature between zone air and supply air. Calculating the design supply cooling airflow rate in this way does not work for operative temperature control because the air temperatures in the space are often much lower than the zone cooling setpoint temperature and sometimes in zones having very high radiant temperatures, the air temperature in the zone approaches the supply air temperature. In other words the difference in temperature between zone air and supply air in the simulated system becomes very low and therefore very large airflow rates are required to meet cooling loads. So in order to account for this DesignBuilder assumes a Delta T of 1K in the above calculation when operative temperature control is in use.

Checking results

As a general rule you should prioritise checking building ***comfort*** levels when using Air temperature control and ***realistic plant operation*** (oversized equipment, supply temperatures very low) when using Operative temperature control.

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Exclude all zone mechanical ventilation

Select this option if you wish to exclude the zone mechanical ventilation load from the heating/cooling loads in all zones. The option is useful in cases where the AHU is to meet mechanical ventilation loads and these loads are to be calculated separately when sizing the AHU coil capacity.

Exclude all zone natural ventilation

This option should be selected when natural ventilation is to be excluded from the Heating/Cooling calculations in all zones. Note that infiltration is always included regardless of this setting.

3.4.3.3 Heating System Sizing

Heating Design tab on Model Options dialog.

Design margin

The Heating Design margin is used to multiply calculated steady state heating loads in each zone to give a recommended heating plant size. It accounts for the additional heat required to bring the building up to temperature in a reasonably short preheat period and allows you to be confident that comfort conditions will be maintained in all but the most extreme winter conditions.

3.4.3.4 Advanced Calculation Options

Heating Design, Cooling Design and Simulation tabs on Model Options dialog, Options tab on Simulation Options dialog and General tab on the Heating and Cooling Design Calculation options dialogs.

Maximum warmup days (*not heating/cooling design*)

The maximum number of 'warmup' or pre-conditioning days that can be used in the simulation before the simulation proper starts. Warmup is the process of repeatedly simulating the first day before the simulation proper starts to ensure that the temperatures in the building fabric are realistic. **Warmup** continues until temperatures and heat flows in each zone have converged. If convergence does not occur then simulation continues for the maximum number of days as specified in the calculation options.

A warning message will occur when the warmup simulation does not converge in the allowed maximum number of warmup days.

```
Loads Initialization did not Converge (CheckWarmupConvergence)
```

You may be able to increase the Maximum Number of Warmup Days and get convergence, but some anomalous buildings may still not converge. Simulation proceeds for x warmup days until convergence is reached (see Temperature and Loads Convergence below).

Temperature and Loads convergence

The temperature and loads convergence values represent the maximum difference in zone temperature and loads between successive daily iterations before convergence is reached during warmup.

Convergence of the simultaneous heat balance/HVAC solution is reached when either the loads or

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temperature criterion is satisfied. Both tolerances work the same way, one looks at temperatures and one looks at heating and cooling loads. After the second warm-up day, the program compares the maximum temperature experienced in a space with the maximum temperature from the previous day. If those two temperatures are within the tolerance, then it has passed the first warm-up check. It does a similar comparison with lowest temperatures experience within all the zones. If the current simulation day and the previous day values are within the tolerance, then it has passed the second warm-up check. A similar comparison is carried with the loads tolerance and the maximum heating and cooling loads that are experienced within the spaces. Those are compared individually to the values for the previous day. If they are both in tolerance, then the simulation has passed the third and fourth warm-up check. The simulation stays in the warm-up period until ALL FOUR checks have been passed.

Note that the maximum number of warmup days will override the above convergence criteria, i.e. the simulation proper will start even if convergence has not occurred after the maximum number of warmup days.

Inside and Outside convection algorithms

You can select from a range of EnergyPlus inside convection algorithms for calculating the convection between internal zone surfaces and the rest of the zone air in the simulation calculations. More details on this and external convection can be found under Constructions Model Data > Surface Convection header.

Solution Algorithm

Select from:

- **CTF** - sensible heat only solution not taking into account moisture storage or diffusion in the construction elements. The method used in EnergyPlus for CTF calculations is known as the state space method (Ceylan and Myers 1980; Seem 1987; Ouyang and Haghighat 1991).
- **Finite Difference** - **currently research only because instabilities can occur with complex constructions.**

Maximum shadow overlap (*not heating design*)

Enter the maximum number of figures per shadow overlap. The shadow overlaps is a measure of the amount of complexity in the shading calculation and this maximum value allows you to limit the amount of time spent in the solar initialisation calculations.

Note: entering a small value here can speed up simulations in complex buildings. If you plan to use **Maximum shadow overlaps** below the default value of 15000 you should check accuracy of solar gains relative to results using default value

Surfaces within zone treated as adiabatic

EnergyPlus support recommend modelling surfaces wholly contained within a zone as adiabatic and this option allows you to follow this advice. We have found that in practice this option not make much difference in results or in simulation speed so for most cases you can leave it in its default state.

Note: 'surfaces contained within a zone' are frequently generated when one of the zone merging options is used where a partition or floor which would have separated two zones actually sits within the merged zone. These surfaces *do not* refer to hanging partitions which are modelled using Internal thermal mass.

COMPACT HVAC SIMULATION AUTOSIZING OPTIONS

The following 2 data items are used when autosizing Compact HVAC systems before simulations.

Sizing factor (*not heating/cooling design*)

This ratio is applied at the zone level to all of the zone heating and cooling loads and air flow rates. These

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new loads and air flow rates are then used to calculate the system level flow rates and capacities and are used in all of the component sizing calculations.

Default value is 1.2.

You must set this to 1.0 to achieve a full fresh air system when using Compact HVAC CAV/VAV.

Design averaging window period (*not heating/cooling design*)

The time in the zone design flow sequence averaging window during EnergyPlus Compact HVAC autosizing calculations. The default is 1 hour, in which case the calculated zone design flow rates are averaged over an hour. The autosizing zone design air flow rate calculation is performed assuming a potentially infinite supply of heating or cooling air at a fixed temperature. Thus the calculated design air flow rate will always be able to meet any load or change in load no matter how large or abrupt. In reality air flow rates are limited by duct sizes and fan capacities. The idealized zone design flow calculation may result in unrealistically large flow rates, especially if the user is performing the sizing calculations using thermostat schedules with night setup or setback. The calculated zone design flow rates are always averaged over the load timestep. You may want to perform a broader average to mitigate the effect of thermostat setup and setback and prevent the warm up or cool down flow rates from dominating the design flow rate calculation. Specifying the width of the averaging window allows the user to do this.

INCLUDE IDF DATA *(NOT HEATING/COOLING DESIGN)*

You can include up to 2 custom IDF data in your EnergyPlus simulations by checking the **IDF File 1** or **IDF File 2** check boxes and entering the name of the IDF data source file. The contents of any files specified are copied to the end of the IDF dataset generated by DesignBuilder before simulation.

Note: Included IDF files must be located in the EnergyPlus folder.

3.4.3.5 Output Options

Include unoccupied zones in block and building totals and averages

By default data for unoccupied zones is *excluded* from block and building totals and averages. Check this option to include data for unoccupied zones.

A zone is defined as unoccupied if it has:

- No occupancy and,
- No cooling and,
- No heating and,
- No mechanical ventilation

Note: if you uncheck this option and all zones in the model are unoccupied then you will get a 'Zero floor area error' message

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3.4.4 Cooling Design Calculation Options

Cooling Design tab on Model Options dialog.

Data on this tab allows you to control the Cooling Design calculations:

- Summer Design Day
- Calculation Options
- Cooling system sizing
- Solar Options
- Advanced Calculation Options
- Output Options

This data is also shown before Cooling Design Calculations.

3.4.4.1 Summer Design Day

Day

Select the day of the month for the design day

Month

Select the month for the design day

Day of week

Select the day of week. This is used to identify the appropriate daily profile.

3.4.4.2 Calculation Options

Heating Design, Cooling Design and Simulation tabs on Model Options dialog and Options tab on Simulation Options dialog.

Calculation description

Enter some text to identify the calculation. This will be used in reports and in the filename for automatically generated ESO files.

Number of time steps per hour (*Simulation only*)

The 'time steps per hour' is the number of times the building thermal network is solved per hour in the simulations. When the HVAC portion of the simulation begins it's solution for the current time step, it uses the basic time step as its maximum but then can reduce the time step, as necessary, to reach the solution.

The technical details of the approach are explained in the EnergyPlus Engineering Documentation under 'Integrated Solution Manager'.

Advanced EnergyPlus users can obtain and view data at intervals of the HVAC time step used if they select the 'detailed' option on an HVAC report variable (e.g. Zone/Sys Air Temp).

The time step entered here is also known in the EnergyPlus documentation as the Zone Time Step.

Though many buildings can be successfully simulated with 1 or 2 time steps per hour, EnergyPlus

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suggest 4 for non-HVAC simulations and 6 for simulations with HVAC.

Hourly data (such as outdoor conditions expressed by Design Days or Weather data) are interpolated to the Zone Time Step. This is discussed the EnergyPlus documentation under: Weather Data Hourly Interpolation.

Note 1: In general, increasing the number of time steps improves accuracy but slows the simulation (and generates more data if output is requested at the 'sub-hourly' interval).

Note 2: When using **1 time steps per hour** you will not be able to access Temperature distribution results

Temperature Control

Heating and cooling systems control internal temperatures to meet the setpoint temperatures specified on the Activity tab. These setpoint temperatures can be interpreted as air, operative or some other radiant fraction and DesignBuilder provides corresponding options to allow HVAC systems to be controlled by:

- **1-Air temperature** - control the room mean air temperature to the heating and cooling setpoint temperatures specified on the Activity tab.
- **2-Operative temperature** - control the room temperature using 0.5 radiant fraction. See notes of operative temperature control below if you plan to use this option.
- **3-Other**- you can enter the radiant temperature control fraction.

The radiant fraction should be less than 0.9 and the minimum is 0.0. A value of 0.0 is the same as controlling on only zone air temperature. If air velocities are higher than 0.2 m/s, then lower values for radiative fraction might apply. Niu and Burnett (1998) cite International Standard ISO 77300 in recommending the values for this fraction listed in the following table.

Radiative Fraction vs Air Velocity

Air Velocity (m/s)	<0.2	0.2 - 0.6	0.6 - 1.0
Radiant fraction	0.5	0.4	0.3

Reference: J. Niu and J. Burnett. 1998. Integrating Radiant/Operative Temperature Controls into Building Energy Simulations. ASHRAE Transactions Vol. 104. Part 2. page 210. ASHRAE. Atlanta, GA.

You can think of the Temperature control option as:

- The radiant fraction sensed by the room thermostat, or,
- Given a room thermostat that mainly senses air temperature, the extent of automatic modification of the setpoint temperature to ensure occupant comfort.

Notes

1. This option is overridden when using radiant heating systems by the radiant heating system control setting.
2. This option does not affect natural and mechanical ventilation setpoints - these always use **air temperature** set points.

Operative vs Air temperature control - Advanced discussion

There has been much debate amongst simulation experts over the years on the extent to which radiant effects should be included on the simulated thermostat. Most real-world thermostats probably don't actually sense more than about 20% radiant heat transfer - mostly the temperature sensor will be sensitive to the temperature of room air nearby. So one would think that air temperature (or 20% radiant) control is the best choice. But Operative control (radiant fraction = 0.5) can be useful for calculating realistic heating and cooling energy based on published summer and winter temperature requirements for the activities in each zone. This is because HVAC systems controlled using the operative temperature continue to condition the building until comfort conditions are met (just like they are in the real building where occupants may adjust thermostats until they are comfortable). Also, the default temperature set points from the Activity templates

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are generally derived from sources quoting operative temperatures. With Air temperature control the room *air* temperature is controlled to the set point temperature, which (depending on internal radiant temperatures) may not necessarily be comfortable.

The disadvantage of **Operative** temperature control is that start up loads can be unrealistically high due to the lag in thermal response of the walls, floor, ceilings. The slow temperature response of the building fabric part governs the output of the operative thermostat and hence the operation of the heating/cooling equipment. If this effect dominates it can lead to an overestimate of the required design cooling load. You should be familiar with this issue before using operative temperature control to size heating and cooling equipment. In our experience using Operative temperature control usually leads to higher peak loads in Heating and Cooling design calculations and higher heating and cooling energy consumption in Simulations.

Caution

Operative temperature control can cause EnergyPlus Error 3 when using Simple HVAC, or Cooling design calculations with Operative control in zones with strong radiant heat gains causing high radiant temperatures (e.g. uninsulated roof or zone is highly glazed). The error is caused by the fixed supply air temperature being higher than the zone air temperature required to give the operative setpoint (.e.g. 24°C). The solution may be to use Air temperature control and to manage the high radiant temperatures using solar shading/insulation as appropriate.

Air temperature control is easier to use as none of the aforementioned problems apply, but it can lead to inadequate equipment sizes peak loads in Heating and Cooling design calculations when not used with a design safety factor. This is especially true when radiant temperatures are very different from air temperatures for example in poorly insulated buildings, buildings with large unshaded glazing areas or high ventilation rates. Generally using air temperature control in Simulations of such buildings will underestimate energy consumption.

Autosizing simple HVAC convective systems with operative temperature control
Another issue to bear in mind with operative temperature control is that in simple HVAC convective systems, autosized cooling systems use a different algorithm to calculate the maximum supply airflow rate used in the EnergyPlus **Purchased Air** system. In convective systems the equation used is:

`DeltaT = ZoneCoolingSetPointTemperature - HVACCoolingCoilSetpointTemp` *(difference in temperature between zone air and supply air)*

```
DesignSupplyAirFlowM3PerS = DesignMaxCoolingLoad / (Cp * DeltaT * AirDensity)
```

This equation works because the temperature of the air in the zone can safely be assumed to be the zone cooling set point and so there is fixed difference in temperature between zone air and supply air. Calculating the design supply cooling airflow rate in this way does not work for operative temperature control because the air temperatures in the space are often much lower than the zone cooling setpoint temperature and sometimes in zones having very high radiant temperatures, the air temperature in the zone approaches the supply air temperature. In other words the difference in temperature between zone air and supply air in the simulated system becomes very low and therefore very large airflow rates are required to meet cooling loads. So in order to account for this DesignBuilder assumes a Delta T of 1K in the above calculation when operative temperature control is in use.

Checking results

As a general rule you should prioritise checking building ***comfort*** levels when using Air temperature control and ***realistic plant operation*** (oversized equipment, supply temperatures very low) when using Operative temperature control.

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Exclude all zone mechanical ventilation

Select this option if you wish to exclude the zone mechanical ventilation load from the heating/cooling loads in all zones. The option is useful in cases where the AHU is to meet mechanical ventilation loads and these loads are to be calculated separately when sizing the AHU coil capacity.

Exclude all zone natural ventilation

This option should be selected when natural ventilation is to be excluded from the Heating/Cooling calculations in all zones. Note that infiltration is always included regardless of this setting.

3.4.4.3 Cooling System Sizing

Cooling Design tab on Model Options dialog.

Design margin

The Cooling Design margin is a 'safety factor' used to multiply calculated cooling loads in each zone to give a recommended maximum cooling equipment capacity. It accounts for the additional cooling required to cool the building down in a reasonably short precool period and allows you to be confident that comfort conditions will be maintained in all but the most extreme summer conditions (risk depends on the Summer Design Weather Data options selected at site level).

Sizing method

Sizing methods available are:

- **1-ASHRAE** - standard Heat Balance method implemented in EnergyPlus.
- **2-Unitary DX** - calculations are made through a detailed EnergyPlus simulation using Unitary DX equipment.
- **3-VAV** - detailed EnergyPlus simulation using VAV equipment.
- **4-Fan coil** - detailed EnergyPlus simulation using Fan coil equipment.

Note: you do not need to have the Compact HVAC model option set to use the detailed cooling load sizing options 2, 3 and 4 above.

3.4.4.3.1 ASHRAE Cooling Sizing

In the ASHRAE cooling sizing method the cooling design load calculations are carried out using the standard ASHRAE Heat Balance method implemented in EnergyPlus using the 'Purchased air' system type. You can define the conditions of the supply air delivered to cooled zones using Design supply temperature and Supply air humidity ratio. The total (sensible + latent) load is calculated as the enthalpy change between the zone return air and the specified supply air condition for the current load.

The ASHRAE system is modelled assuming:

- No economiser,
- No heat recovery,
- No heating,
- Zero pressure rise fan,
- No humidification/dehumidification,
- Zone plenums will not be used if specified,
- Outside airflow rate and operation schedule defined by the data under the Mechanical Ventilation header on the HVAC tab at the zone level,

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- Cooling coil availability defined by the schedule under the Cooling header on the HVAC tab at the zone level,
- Zone design cooling temperature setpoints are defined by the data under Environmental Control on the Activity tab.

Unlike the other 3 cooling sizing options, **1-ASHRAE** *cannot* be used in conjunction with Natural ventilation.

SUPPLY AIR CONDITIONS

Cautionary Note: The Ideal Loads Air System component does not control zone humidity levels. The Ideal Loads Air System component total cooling load is simply the enthalpy change between the mixed air condition (return air plus outdoor air, if specified) and the userspecified supply air condition for the current load. The latent load is the total load less the sensible load and may be positive or negative.

Supply air delivery temperature

The constant dry-bulb air temperature of the air supplied for cooling the zone.

Supply air humidity ratio

The constant humidity ratio (mass of water per mass of dry air) of the cold supply air to be delivered when cooling is required. The default humidity ratio is 0.008. You should be careful to enter a value that is a valid condition, i.e. it is under the 100% saturation line on the Psychrometric Chart.

C**autionary Note:** The EnergyPlus Ideal Loads Air System component used for these calculations does not control zone humidity levels. Total cooling load is simply calculated as the enthalpy change between the return air condition and the user-specified supply air condition for the current load. The latent load is the total load less the sensible load and may be positive or negative.

3.4.4.3.2 Unitary DX Cooling Sizing

When using the Unitary DX cooling sizing method the Cooling design calculation is made through a detailed EnergyPlus simulation using Compact HVAC Single zone Unitary DX equipment. A diagram of the system layout used is shown in the Unitary Single Zone topic.

Each zone has it's own Unitary system with a fan (generating no pickup), a DX cooling coil, an outside air controller and a damper to reduce supply air flow. More specifically:

- No economiser,
- No heat recovery,
- No heating coil,
- Zero pressure rise fan,
- No humidification/dehumidification,
- Zone plenums will be used if specified,
- Outside airflow rate and operation schedule defined by the data under the Mechanical Ventilation header on the HVAC tab at the zone level,
- Cooling coil availability defined by the schedule under the Cooling header on the HVAC tab at the zone level,
- Zone design cooling temperature setpoints are defined by the data under Environmental Control on the Activity tab.

Unlike the ASHRAE cooling sizing option, **Unitary DX** can be used in conjunction with Natural ventilation.

Note: Unitary DX will tend to calculate higher latent loads than the other 3 cooling sizing methods and the

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zone air humidity will generally be lower. This is because DX coils run colder than water-cooled coils and will condense out more water from the supply air. Unitary DX can often be used to provide a conservative calculation for the latent cooling loads.

3.4.4.3.3 VAV Cooling Sizing

When using the VAV cooling sizing method, the Cooling design calculation is made through a detailed EnergyPlus simulation using Compact HVAC VAV equipment. A diagram of the system layout used is shown in the VAV topic.

Each zone has it's own VAV AHU with a fan (generating no pickup), a water-cooled AHU cooling coil, an outside air controller and a zone terminal box with a damper to reduce supply air flow. More specifically:

- No economiser,
- No heat recovery,
- No AHU heating coil,
- No reheat coil,
- No preheat coil,
- Zero pressure rise fan,
- No humidification/dehumidification,
- Standard zone terminal unit,
- Zone plenums will be used if specified,
- Outside airflow rate and operation schedule defined by the data under the Mechanical Ventilation header on the HVAC tab at the zone level,
- Cooling coil availability defined by the schedule under the Cooling header on the HVAC tab at the zone level,
- Zone design cooling temperature setpoints are defined by the data under Environmental Control on the Activity tab.

Unlike the ASHRAE cooling sizing option, **VAV** *can* be used in conjunction with Natural ventilation.

Design supply temperature

The constant dry-bulb air temperature of the air supplied for cooling the zone

Design turndown ratio (supply air minimum flow fraction)

The Design turndown ratio is the fraction that the zone VAV box can reduce to based on the supply air maximum flow rate. It is normally specified to meet the minimum ventilation requirement for the occupants. A value of 1.0 means that the VAV box cannot reduce supply air at all (i.e. it is a constant volume system).

Turndown ratio is typically in range **0.3 - 0.5**. Minimum is 0 and maximum is 1.

3.4.4.3.4 Fan Coil Cooling Sizing

When using the Fan coil cooling sizing method, the Cooling design calculation is made through a detailed EnergyPlus simulation using Compact HVAC Fan coil equipment. A diagram of the system layout used is shown in the Fan Coil Units topic.

Each zone has it's own Fan coil unit with a fan (generating no pickup), a water-cooled cooling coil, an outside air controller and a zone terminal box with a damper to reduce supply air flow. More specifically:

- No economiser,
- No heat recovery,
- No heating coil,
- Zero pressure rise fan,

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- No humidification/dehumidification,
- Outside airflow rate and operation schedule defined by the data under the Mechanical Ventilation header on the HVAC tab at the zone level (*see note below about outside air flow rates*),
- Cooling coil availability defined by the schedule under the Cooling header on the HVAC tab at the zone level,
- Zone design cooling temperature setpoints are defined by the data under Environmental Control on the Activity tab.

Unlike the ASHRAE cooling sizing option, **Fan coil** *can* be used in conjunction with Natural ventilation.

Design supply temperature

The constant dry-bulb air temperature of the air supplied for cooling the zone

Note: the Fan coil outside air flow can be fully on or fully off but cannot reduce to fractional values in between. You may therefore get higher outside air delivery rates than with the other methods if you are using Schedules and your Mechanical ventilation operation schedule has fractional values.

3.4.4.4 Solar Options

Cooling Design and Simulation tabs on Model Options dialog and Options tab on Simulation Options dialog.

Solar Options allow you to control aspects of the model related to solar gains.

Include all buildings in shading calcs

The standard wall,floor, roof surfaces defining the current building provide shading but by default the other buildings on the site are excluded from the analysis. Use this option to include other buildings on the site as shading obstructions.

Note: there is no way to simulate > 1 building at a time. All external surfaces in buildings other than the current one are modelled as shading surfaces. If you need to model the adjacency of another building in contact with the current one, you can use the adiabatic adjacency option to model the touching surfaces.

Cooling Design Calculations and Simulations both use this option but have separate Model option data.

Note: if one or more 'other buildings' are large/complex then you could generate a large number of shading elements and the simulation could be slow (even if the current building being simulated is simple).

Model reflections

If using reflections, the program calculates beam and sky solar radiation that is reflected from exterior surfaces and then strikes the building. These reflecting surfaces fall into 3 categories:

1. Shadowing surfaces. These are surfaces like overhangs or neighboring buildings (see below). These surfaces can have diffuse and specular (beam-to-beam) reflectance values derived from the material properties of the wall/windows.

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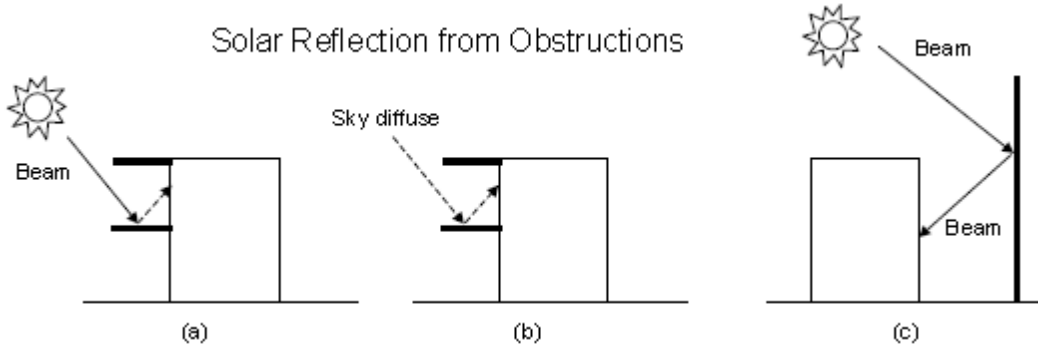
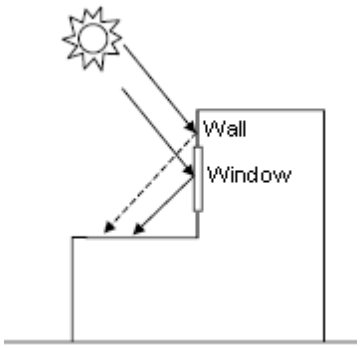


Solar reflection from shadowing surfaces. Solid arrows are beam solar radiation; dashed arrows are diffuse solar radiation. (a) Diffuse reflection of beam solar radiation from the top of an overhang. (b) Diffuse reflection of sky solar radiation from the top of an overhang. (c) Beam-to-beam (specular) reflection from the façade of an adjacent highly-glazed building represented by a vertical shadowing surface.

2. Exterior building surfaces. In this case one section of the building reflects solar radiation onto another section (and vice-versa). See below. The building surfaces are assumed to be diffusely reflecting if they are opaque (walls, for example) and specularly reflecting if they are windows or glass doors. The reflectance values for opaque surfaces are calculated by the program from the Solar Absorptance and Visible Absorptance of the outer material layer of the surface's construction. The reflectance values for windows and glass doors are calculated by the program from the reflectance properties of the individual glass layers that make up surface's construction assuming no shading device is present and taking into account inter-reflections among the layers.



Solar reflection from building surfaces onto other building surfaces. In this example beam solar reflects from a vertical section of the building onto a roof section. The reflection from the window is specular. The reflection from the wall is diffuse.

3. The ground surface.

Reflection from the ground is calculated even if the reflections option is not used. But in this case the ground plane is considered unobstructed, i.e., the shadowing of the ground by the building itself or by obstructions such as neighboring buildings is ignored. This shadowing is taken into account if the reflections option is used. This is shown in diagrammatically below.

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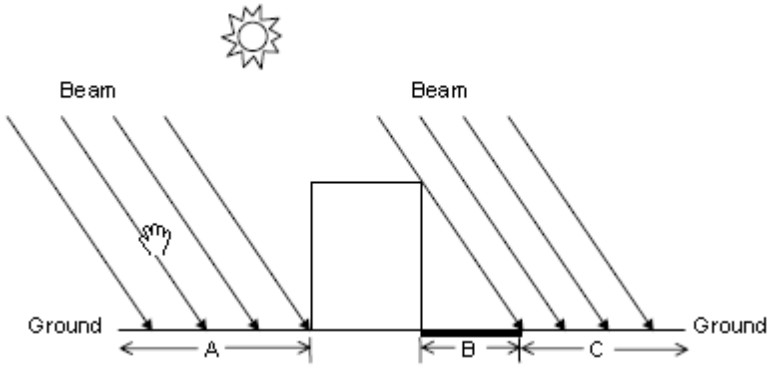

Shadowing from building affects beam solar reflection from the ground. Beam-to-diffuse reflection from the ground onto the building occurs only for sunlit areas, A and C, not from shaded area, B.

If reflections option is used for the ground surface then the ground view factor is NOT used.

Solar distribution

This option determines how EnergyPlus treats beam solar radiation and reflectance from exterior surfaces that strike the building and, ultimately, enter the zone. There are five choices:

1-Minimal shadowing - In this case, there is no exterior shadowing except from window and door reveals. All beam solar radiation entering the zone is assumed to fall on the floor, where it is absorbed according to the floor's solar absorptance. Any reflected by the floor is added to the transmitted diffuse radiation, which is assumed to be uniformly distributed on all interior surfaces. If no floor is present in the zone, the incident beam solar radiation is absorbed on all interior surfaces according to their absorptances. The zone heat balance is then applied at each surface and on the zone's air with the absorbed radiation being treated as a flux on the surface.

2-Full Exterior - in this case, shadow patterns on exterior surfaces caused by detached shading, wings, overhangs, and exterior surfaces of all zones are computed. As for Minimal shadowing, shadowing by window and door reveals is also calculated. Beam solar radiation entering the zone is treated as for 'Minimal shadowing' - all beam solar radiation entering the zone is assumed to fall on the floor, where it is absorbed according to the floor's solar absorptance. Any reflected by the floor is added to the transmitted diffuse radiation, which is distributed among interior surfaces according to view factors. If no floor is present in the zone, the incident beam solar radiation is absorbed on all interior surfaces according to their absorptance.

> If you use **2-Full Exterior** you should make sure that all of your zones have a floor. If your building model has any zones of unusual shape without floors then the EnergyPlus simulation may not work because it will not have a surface to apportion solar gains to.

3-Full interior and exterior - this is the same as 'Full exterior' except that instead of assuming all transmitted beam solar falls on the floor the program calculates the amount of beam radiation falling on each surface in the zone, including floor, walls and windows, by projecting the sun's rays through the exterior windows, taking into account the effect of exterior shadowing surfaces and window shading devices. If this option is used, you should be sure that the surfaces of the zone totally enclose a space. This can be determined by viewing the eplusout.dxf file with an external DXF viewer program.

You should also be sure that the zone is convex. Examples of convex and non-convex zones are shown below. The most common non-convex zone is an L-shaped zone. (A formal definition of convex is that any straight line passing through the zone intercepts at most two surfaces.) If the zone's surfaces do not enclose a space or if the zone is not convex you should use 'Full exterior' instead.

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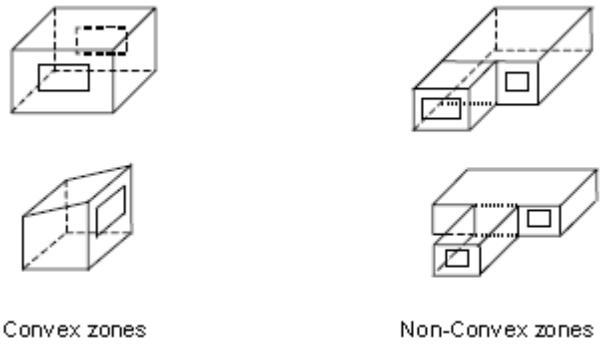

If you use **3-Full Interior and exterior** the program will also calculate how much beam radiation falling on the inside of an exterior window (from other windows in the zone) is absorbed by the window, how much is reflected back into the zone, and how much is transmitted to the outside. In this calculation the effect of a shading device, if present, is accounted for.

Important!

You must use **3-Full Interior and exterior** to account for solar and light transmission through internal windows.

Check for non-convex zones

When the solar distribution selection is **3-Full interior and exterior** (above) you can choose whether DesignBuilder is to check for non-convex zones. By default the option is to carry out the check to prevent invalid results, but if the zones are only slightly non-convex you can switch off this check and allow EnergyPlus to continue calculations. You will probably receive error message 2 if you switch this option off and have non-convex zones.

Shadowing interval (Simulation only)

Enter the number of days (1-365) covered by each shadowing calculation.

Enter 1 if you want shadowing to be calculated every day (for greater detail but slower calculations).

3.4.4.5 Advanced Calculation Options

Heating Design, Cooling Design and Simulation tabs on Model Options dialog, Options tab on Simulation Options dialog and General tab on the Heating and Cooling Design Calculation options dialogs.

Maximum warmup days (*not heating/cooling design*)

The maximum number of 'warmup' or pre-conditioning days that can be used in the simulation before the simulation proper starts. Warmup is the process of repeatedly simulating the first day before the simulation proper starts to ensure that the temperatures in the building fabric are realistic. **Warmup** continues until temperatures and heat flows in each zone have converged. If convergence does not occur then simulation continues for the maximum number of days as specified in the calculation options.

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A warning message will occur when the warmup simulation does not converge in the allowed maximum number of warmup days.

```
Loads Initialization did not Converge (CheckWarmupConvergence)
```

You may be able to increase the Maximum Number of Warmup Days and get convergence, but some anomalous buildings may still not converge. Simulation proceeds for x warmup days until convergence is reached (see Temperature and Loads Convergence below).

Temperature and Loads convergence

The temperature and loads convergence values represent the maximum difference in zone temperature and loads between successive daily iterations before convergence is reached during warmup.

Convergence of the simultaneous heat balance/HVAC solution is reached when either the loads or temperature criterion is satisfied. Both tolerances work the same way, one looks at temperatures and one looks at heating and cooling loads. After the second warm-up day, the program compares the maximum temperature experienced in a space with the maximum temperature from the previous day. If those two temperatures are within the tolerance, then it has passed the first warm-up check. It does a similar comparison with lowest temperatures experience within all the zones. If the current simulation day and the previous day values are within the tolerance, then it has passed the second warm-up check. A similar comparison is carried with the loads tolerance and the maximum heating and cooling loads that are experienced within the spaces. Those are compared individually to the values for the previous day. If they are both in tolerance, then the simulation has passed the third and fourth warm-up check. The simulation stays in the warm-up period until ALL FOUR checks have been passed.

Note that the maximum number of warmup days will override the above convergence criteria, i.e. the simulation proper will start even if convergence has not occurred after the maximum number of warmup days.

Inside and Outside convection algorithms

You can select from a range of EnergyPlus inside convection algorithms for calculating the convection between internal zone surfaces and the rest of the zone air in the simulation calculations. More details on this and external convection can be found under Constructions Model Data > Surface Convection header.

Solution Algorithm

Select from:

- **CTF** - sensible heat only solution not taking into account moisture storage or diffusion in the construction elements. The method used in EnergyPlus for CTF calculations is known as the state space method (Ceylan and Myers 1980; Seem 1987; Ouyang and Haghighat 1991).
- **Finite Difference** - **currently research only because instabilities can occur with complex constructions.**

Maximum shadow overlap (*not heating design*)

Enter the maximum number of figures per shadow overlap. The shadow overlaps is a measure of the amount of complexity in the shading calculation and this maximum value allows you to limit the amount of time spent in the solar initialisation calculations.

Note: entering a small value here can speed up simulations in complex buildings. If you plan to use **Maximum shadow overlaps** below the default value of 15000 you should check accuracy of solar gains relative to results using default value

Surfaces within zone treated as adiabatic

EnergyPlus support recommend modelling surfaces wholly contained within a zone as adiabatic and this option allows you to follow this advice. We have found that in practice this option not make much difference

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in results or in simulation speed so for most cases you can leave it in its default state.

Note: 'surfaces contained within a zone' are frequently generated when one of the zone merging options is used where a partition or floor which would have separated two zones actually sits within the merged zone. These surfaces *do not* refer to hanging partitions which are modelled using Internal thermal mass.

COMPACT HVAC SIMULATION AUTOSIZING OPTIONS

The following 2 data items are used when autosizing Compact HVAC systems before simulations.

Sizing factor (*not heating/cooling design*)

This ratio is applied at the zone level to all of the zone heating and cooling loads and air flow rates. These new loads and air flow rates are then used to calculate the system level flow rates and capacities and are used in all of the component sizing calculations.

Default value is 1.2.

You must set this to 1.0 to achieve a full fresh air system when using Compact HVAC CAV/VAV.

Design averaging window period (*not heating/cooling design*)

The time in the zone design flow sequence averaging window during EnergyPlus Compact HVAC autosizing calculations. The default is 1 hour, in which case the calculated zone design flow rates are averaged over an hour. The autosizing zone design air flow rate calculation is performed assuming a potentially infinite supply of heating or cooling air at a fixed temperature. Thus the calculated design air flow rate will always be able to meet any load or change in load no matter how large or abrupt. In reality air flow rates are limited by duct sizes and fan capacities. The idealized zone design flow calculation may result in unrealistically large flow rates, especially if the user is performing the sizing calculations using thermostat schedules with night setup or setback. The calculated zone design flow rates are always averaged over the load timestep. You may want to perform a broader average to mitigate the effect of thermostat setup and setback and prevent the warm up or cool down flow rates from dominating the design flow rate calculation. Specifying the width of the averaging window allows the user to do this.

INCLUDE IDF DATA *(NOT HEATING/COOLING DESIGN)*

You can include up to 2 custom IDF data in your EnergyPlus simulations by checking the **IDF File 1** or **IDF File 2** check boxes and entering the name of the IDF data source file. The contents of any files specified are copied to the end of the IDF dataset generated by DesignBuilder before simulation.

Note: Included IDF files must be located in the EnergyPlus folder.

3.4.4.6 Output Options

Include unoccupied zones in block and building totals and averages

By default data for unoccupied zones is *excluded* from block and building totals and averages. Check this option to include data for unoccupied zones.

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A zone is defined as unoccupied if it has:

- No occupancy and,
- No cooling and,
- No heating and,
- No mechanical ventilation

Note: if you uncheck this option and all zones in the model are unoccupied then you will get a 'Zero floor area error' message.

3.4.5 Simulation Calculation Options

Simulation tab on Model Options dialog.

Data on this tab allows you to control the simulations:

- Simulation Period
- Calculation options
- Solar options
- Advanced Calculation Options
- Output options

This data is also shown before simulations in the Simulation Calculation Options dialog.

3.4.5.1 Simulation Period

Simulation tab on Model Options dialog and General tab on Simulation Options dialog.

Simulation Period

Select the start and end days for the simulation, or 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 by the weather data translator as being the hottest of the year.
- **Summer typical week** - a week identified by the weather data translator 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 by the weather data translator as being the coldest of the year.
- **Winter typical week** - a week identified by the weather data translator as being typical of the winter.
- **All winter** - simulate the whole winter (as identified by the weather data translator).

The above typical simulation periods are derived from the Statistics data from the currently selected Hourly weather data.

3.4.5.2 Calculation Options

Heating Design, Cooling Design and Simulation tabs on Model Options dialog and Options tab on Simulation Options dialog.

Calculation description

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Enter some text to identify the calculation. This will be used in reports and in the filename for automatically generated ESO files.

Number of time steps per hour (*Simulation only*)

The 'time steps per hour' is the number of times the building thermal network is solved per hour in the simulations. When the HVAC portion of the simulation begins it's solution for the current time step, it uses the basic time step as its maximum but then can reduce the time step, as necessary, to reach the solution.

The technical details of the approach are explained in the EnergyPlus Engineering Documentation under 'Integrated Solution Manager'.

Advanced EnergyPlus users can obtain and view data at intervals of the HVAC time step used if they select the 'detailed' option on an HVAC report variable (e.g. Zone/Sys Air Temp).

The time step entered here is also known in the EnergyPlus documentation as the Zone Time Step.

Though many buildings can be successfully simulated with 1 or 2 time steps per hour, EnergyPlus suggest 4 for non-HVAC simulations and 6 for simulations with HVAC.

Hourly data (such as outdoor conditions expressed by Design Days or Weather data) are interpolated to the Zone Time Step. This is discussed the EnergyPlus documentation under: Weather Data Hourly Interpolation.

Note 1: In general, increasing the number of time steps improves accuracy but slows the simulation (and generates more data if output is requested at the 'sub-hourly' interval).

Note 2: When using **1 time steps per hour** you will not be able to access Temperature distribution results

Temperature Control

Heating and cooling systems control internal temperatures to meet the setpoint temperatures specified on the Activity tab. These setpoint temperatures can be interpreted as air, operative or some other radiant fraction and DesignBuilder provides corresponding options to allow HVAC systems to be controlled by:

- **1-Air temperature** - control the room mean air temperature to the heating and cooling setpoint temperatures specified on the Activity tab.
- **2-Operative temperature** - control the room temperature using 0.5 radiant fraction. See notes of operative temperature control below if you plan to use this option.
- **3-Other**- you can enter the radiant temperature control fraction.

The radiant fraction should be less than 0.9 and the minimum is 0.0. A value of 0.0 is the same as controlling on only zone air temperature. If air velocities are higher than 0.2 m/s, then lower values for radiative fraction might apply. Niu and Burnett (1998) cite International Standard ISO 77300 in recommending the values for this fraction listed in the following table.

Radiative Fraction vs Air Velocity

Air Velocity (m/s)	<0.2	0.2 - 0.6	0.6 - 1.0
Radiant fraction	0.5	0.4	0.3

Reference: J. Niu and J. Burnett. 1998. Integrating Radiant/Operative Temperature Controls into Building Energy Simulations. ASHRAE Transactions Vol. 104. Part 2. page 210. ASHRAE. Atlanta, GA.

You can think of the Temperature control option as:

- The radiant fraction sensed by the room thermostat, or,
- Given a room thermostat that mainly senses air temperature, the extent of automatic modification of

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the setpoint temperature to ensure occupant comfort.

Notes

1. This option is overridden when using radiant heating systems by the radiant heating system control setting.
2. This option does not affect natural and mechanical ventilation setpoints - these always use **air temperature** set points.

Operative vs Air temperature control - Advanced discussion

There has been much debate amongst simulation experts over the years on the extent to which radiant effects should be included on the simulated thermostat. Most real-world thermostats probably don't actually sense more than about 20% radiant heat transfer - mostly the temperature sensor will be sensitive to the temperature of room air nearby. So one would think that air temperature (or 20% radiant) control is the best choice. But Operative control (radiant fraction = 0.5) can be useful for calculating realistic heating and cooling energy based on published summer and winter temperature requirements for the activities in each zone. This is because HVAC systems controlled using the operative temperature continue to condition the building until comfort conditions are met (just like they are in the real building where occupants may adjust thermostats until they are comfortable). Also, the default temperature set points from the Activity templates are generally derived from sources quoting operative temperatures. With Air temperature control the room *air* temperature is controlled to the set point temperature, which (depending on internal radiant temperatures) may not necessarily be comfortable.

The disadvantage of **Operative** temperature control is that start up loads can be unrealistically high due to the lag in thermal response of the walls, floor, ceilings. The slow temperature response of the building fabric part governs the output of the operative thermostat and hence the operation of the heating/cooling equipment. If this effect dominates it can lead to an overestimate of the required design cooling load. You should be familiar with this issue before using operative temperature control to size heating and cooling equipment. In our experience using Operative temperature control usually leads to higher peak loads in Heating and Cooling design calculations and higher heating and cooling energy consumption in Simulations.

> **Caution**
>
> Operative temperature control can cause EnergyPlus Error 3 when using Simple HVAC, or Cooling design calculations with Operative control in zones with strong radiant heat gains causing high radiant temperatures (e.g. uninsulated roof or zone is highly glazed). The error is caused by the fixed supply air temperature being higher than the zone air temperature required to give the operative setpoint (.e.g. 24°C). The solution may be to use Air temperature control and to manage the high radiant temperatures using solar shading/insulation as appropriate.

Air temperature control is easier to use as none of the aforementioned problems apply, but it can lead to inadequate equipment sizes peak loads in Heating and Cooling design calculations when not used with a design safety factor. This is especially true when radiant temperatures are very different from air temperatures for example in poorly insulated buildings, buildings with large unshaded glazing areas or high ventilation rates. Generally using air temperature control in Simulations of such buildings will underestimate energy consumption.

Autosizing simple HVAC convective systems with operative temperature control
Another issue to bear in mind with operative temperature control is that in simple HVAC convective systems, autosized cooling systems use a different algorithm to calculate the maximum supply airflow rate used in the EnergyPlus **Purchased Air** system. In convective systems the equation used is:

`DeltaT = ZoneCoolingSetPointTemperature - HVACCoolingCoilSetpointTemp` *(difference in temperature between zone air and supply air)*

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```
DesignSupplyAirFlowM3PerS = DesignMaxCoolingLoad / (Cp * DeltaT * AirDensity)
```

This equation works because the temperature of the air in the zone can safely be assumed to be the zone cooling set point and so there is fixed difference in temperature between zone air and supply air.
Calculating the design supply cooling airflow rate in this way does not work for operative temperature control because the air temperatures in the space are often much lower than the zone cooling setpoint temperature and sometimes in zones having very high radiant temperatures, the air temperature in the zone approaches the supply air temperature. In other words the difference in temperature between zone air and supply air in the simulated system becomes very low and therefore very large airflow rates are required to meet cooling loads. So in order to account for this DesignBuilder assumes a Delta T of 1K in the above calculation when operative temperature control is in use.

Checking results

As a general rule you should prioritise checking building ***comfort*** levels when using Air temperature control and ***realistic plant operation*** (oversized equipment, supply temperatures very low) when using Operative temperature control.

Exclude all zone mechanical ventilation

Select this option if you wish to exclude the zone mechanical ventilation load from the heating/cooling loads in all zones. The option is useful in cases where the AHU is to meet mechanical ventilation loads and these loads are to be calculated separately when sizing the AHU coil capacity.

Exclude all zone natural ventilation

This option should be selected when natural ventilation is to be excluded from the Heating/Cooling calculations in all zones. Note that infiltration is always included regardless of this setting.

3.4.5.3 Advanced Calculation Options

Heating Design, Cooling Design and Simulation tabs on Model Options dialog, Options tab on Simulation Options dialog and General tab on the Heating and Cooling Design Calculation options dialogs.

Maximum warmup days (*not heating/cooling design*)

The maximum number of 'warmup' or pre-conditioning days that can be used in the simulation before the simulation proper starts. Warmup is the process of repeatedly simulating the first day before the simulation proper starts to ensure that the temperatures in the building fabric are realistic. **Warmup** continues until temperatures and heat flows in each zone have converged. If convergence does not occur then simulation continues for the maximum number of days as specified in the calculation options.

A warning message will occur when the warmup simulation does not converge in the allowed maximum number of warmup days.

```
Loads Initialization did not Converge (CheckWarmupConvergence)
```

You may be able to increase the Maximum Number of Warmup Days and get convergence, but some anomalous buildings may still not converge. Simulation proceeds for x warmup days until convergence is reached (see Temperature and Loads Convergence below).

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Temperature and Loads convergence

The temperature and loads convergence values represent the maximum difference in zone temperature and loads between successive daily iterations before convergence is reached during warmup.

Convergence of the simultaneous heat balance/HVAC solution is reached when either the loads or temperature criterion is satisfied. Both tolerances work the same way, one looks at temperatures and one looks at heating and cooling loads. After the second warm-up day, the program compares the maximum temperature experienced in a space with the maximum temperature from the previous day. If those two temperatures are within the tolerance, then it has passed the first warm-up check. It does a similar comparison with lowest temperatures experience within all the zones. If the current simulation day and the previous day values are within the tolerance, then it has passed the second warm-up check. A similar comparison is carried with the loads tolerance and the maximum heating and cooling loads that are experienced within the spaces. Those are compared individually to the values for the previous day. If they are both in tolerance, then the simulation has passed the third and fourth warm-up check. The simulation stays in the warm-up period until ALL FOUR checks have been passed.

Note that the maximum number of warmup days will override the above convergence criteria, i.e. the simulation proper will start even if convergence has not occurred after the maximum number of warmup days.

Inside and Outside convection algorithms

You can select from a range of EnergyPlus inside convection algorithms for calculating the convection between internal zone surfaces and the rest of the zone air in the simulation calculations. More details on this and external convection can be found under Constructions Model Data > Surface Convection header.

Solution Algorithm

Select from:

- **CTF** - sensible heat only solution not taking into account moisture storage or diffusion in the construction elements. The method used in EnergyPlus for CTF calculations is known as the state space method (Ceylan and Myers 1980; Seem 1987; Ouyang and Haghighat 1991).
- **Finite Difference** - **currently research only because instabilities can occur with complex constructions.**

Maximum shadow overlap (*not heating design*)

Enter the maximum number of figures per shadow overlap. The shadow overlaps is a measure of the amount of complexity in the shading calculation and this maximum value allows you to limit the amount of time spent in the solar initialisation calculations.

Note: entering a small value here can speed up simulations in complex buildings. If you plan to use **Maximum shadow overlaps** below the default value of 15000 you should check accuracy of solar gains relative to results using default value

Surfaces within zone treated as adiabatic

EnergyPlus support recommend modelling surfaces wholly contained within a zone as adiabatic and this option allows you to follow this advice. We have found that in practice this option not make much difference in results or in simulation speed so for most cases you can leave it in its default state.

Note: 'surfaces contained within a zone' are frequently generated when one of the zone merging options is used where a partition or floor which would have separated two zones actually sits within the merged zone. These surfaces *do not* refer to hanging partitions which are modelled using Internal thermal mass.

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COMPACT HVAC SIMULATION AUTOSIZING OPTIONS

The following 2 data items are used when autosizing Compact HVAC systems before simulations.

Sizing factor (*not heating/cooling design*)

This ratio is applied at the zone level to all of the zone heating and cooling loads and air flow rates. These new loads and air flow rates are then used to calculate the system level flow rates and capacities and are used in all of the component sizing calculations.

Default value is 1.2.

You must set this to 1.0 to achieve a full fresh air system when using Compact HVAC CAV/VAV.

Design averaging window period (*not heating/cooling design*)

The time in the zone design flow sequence averaging window during EnergyPlus Compact HVAC autosizing calculations. The default is 1 hour, in which case the calculated zone design flow rates are averaged over an hour. The autosizing zone design air flow rate calculation is performed assuming a potentially infinite supply of heating or cooling air at a fixed temperature. Thus the calculated design air flow rate will always be able to meet any load or change in load no matter how large or abrupt. In reality air flow rates are limited by duct sizes and fan capacities. The idealized zone design flow calculation may result in unrealistically large flow rates, especially if the user is performing the sizing calculations using thermostat schedules with night setup or setback. The calculated zone design flow rates are always averaged over the load timestep. You may want to perform a broader average to mitigate the effect of thermostat setup and setback and prevent the warm up or cool down flow rates from dominating the design flow rate calculation. Specifying the width of the averaging window allows the user to do this.

INCLUDE IDF DATA *(NOT HEATING/COOLING DESIGN)*

You can include up to 2 custom IDF data in your EnergyPlus simulations by checking the **IDF File 1** or **IDF File 2** check boxes and entering the name of the IDF data source file. The contents of any files specified are copied to the end of the IDF dataset generated by DesignBuilder before simulation.

Note: Included IDF files must be located in the EnergyPlus folder.

3.4.5.4 Output Options

Simulation tab on Model Options dialog and Output tab on Simulation Options dialog.

You can control the data generated from simulations by making selections on the Simulation tab of the Model options dialog and on the Advanced tab of the Simulation calculation options dialog.

Zone environmental and comfort reports

You can restrict the simulation comfort output to just occupied periods by selecting **2-Just occupied periods**. Options are:

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- **1-All periods** - comfort data is generated for all periods including times when the zone is unoccupied.
- **2-Just occupied periods** - comfort data is only output during times when the zone is occupied so daily and monthly comfort statistics become more meaningful.

Default is **1-All periods**.

Building and block output of zone data

This option causes average and total zone data to be generated for building and blocks. For example average temperatures, comfort conditions, total solar radiation, internal gains, fabric transmission losses etc. It does not affect the generation of energy consumption and CO2 data at the building level.

Include unoccupied zones in block and building totals and averages

By default, data for unoccupied zones is *excluded* from block and building totals and averages. Check this option to include data for unoccupied zones.

A zone is defined as unoccupied if it has:

- No occupancy and,
- No cooling and,
- No heating and,
- No mechanical ventilation

The way building and block averages are calculated is described in the Comfort Analysis section.

Note: if you uncheck this option and all zones in the model are unoccupied then you will get a 'Zero floor area error' message

Surface heat transfer incl. solar

Select this option to generate heat flow at surface boundaries. Note that selecting this option results in large amounts of data being generated as EnergyPlus must generate output for every surface and window in the zone and you should only select it if you need to look at the zone heat balance.The following EnergyPlus reports are generated:

- Opaque Surface Inside Face Conduction
- Window Heat Gain
- Window Heat Loss
- Window Transmitted Solar

Environmental

This option generates temperatures and humidity data. The following EnergyPlus reports are generated:

- Zone Mean Air Temperature
- Zone Mean Radiant Temperature
- Zone Air Relative Humidity
- Outdoor Dry Bulb

Comfort

Select this option to generate Comfort output. The following EnergyPlus reports are generated:

- FangerPMV
- PiercePMVET
- PiercePMVSET
- PierceDISC
- PierceTSENS
- KsuTSV

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- Time Not Comfortable Summer Clothes
- Time Not Comfortable Winter Clothes
- Time Not Comfortable Summer or Winter Clothes

Internal gains

Select this option to generate internal gains-related output. The following EnergyPlus reports are generated:

- Zone Lights Total Heat Gain
- Zone Task Lights Total Heat Gain
- Zone People Sensible Heat Gain
- Zone Electric Equipment Cat02 Electric Consumption
- Zone Electric Equipment Cat03 Electric Consumption
- Zone Electric Equipment Cat04 Electric Consumption
- Zone Electric Equipment Cat05 Electric Consumption
- Zone Transmitted Solar
- Zone Infiltration Sensible Heat Loss
- Zone Infiltration Sensible Heat Gain
- Zone Ventilation Sensible Heat Loss
- Zone Ventilation Sensible Heat Gain

Energy, HVAC etc

Select this option to generate energy consumption data.

Temperature distribution

Select this option to generate Temperature distribution data for each zone (distribution data for Blocks and Buildings not available).

DXF model output

This option causes EnergyPlus to generate a DXF file summarising the building model. The file is called eplusout.dxf and it is stored in the EnergyPlus folder. This option can be useful for checking that the correct geometry has been generated.

Construction and surface details

This option causes EnergyPlus to generate a comma separated value file summarising the building model. The file is called eplusout.eio and it is stored in the EnergyPlus folder.

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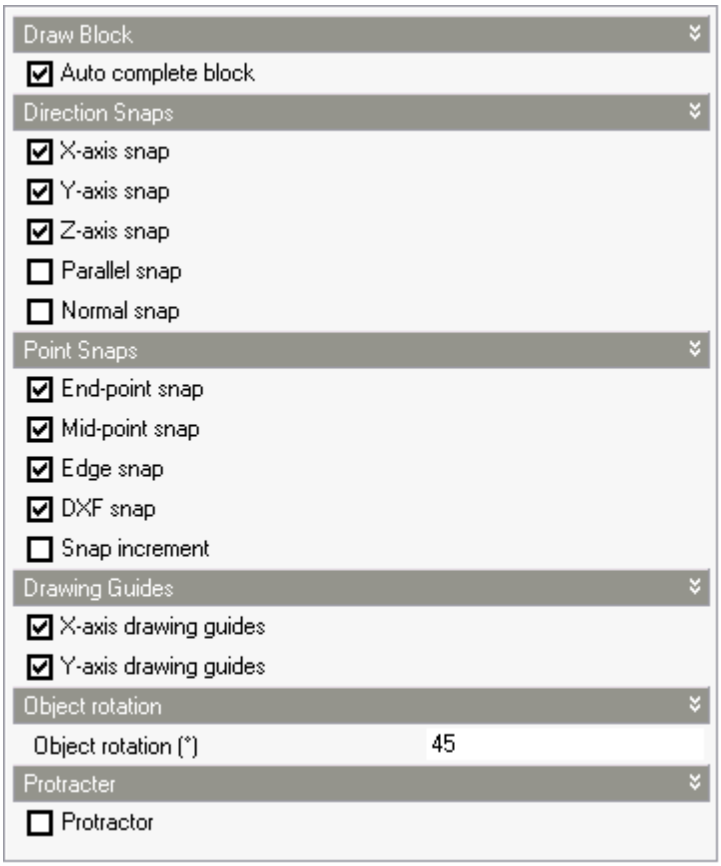
3.4.6 Drawing Tools



Drawing Tools tab on Model Options dialog.

Options for:

- Draw Block
- Direction Snaps
- Point Snaps
- Drawing Guides
- Object Rotation
- Protractor

To learn more about Drawing Tools go to the Block Creation Options and Snaps, Drawing Guides & Protractor sections.

3.4.6.1 Solar Options

Cooling Design and Simulation tabs on Model Options dialog and Options tab on Simulation Options dialog.

Solar Options allow you to control aspects of the model related to solar gains.

Include all buildings in shading calcs

The standard wall,floor, roof surfaces defining the current building provide shading but by default the other buildings on the site are excluded from the analysis. Use this option to include other buildings on the site

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as shading obstructions.

Note: there is no way to simulate > 1 building at a time. All external surfaces in buildings other than the current one are modelled as shading surfaces. If you need to model the adjacency of another building in contact with the current one, you can use the adiabatic adjacency option to model the touching surfaces.

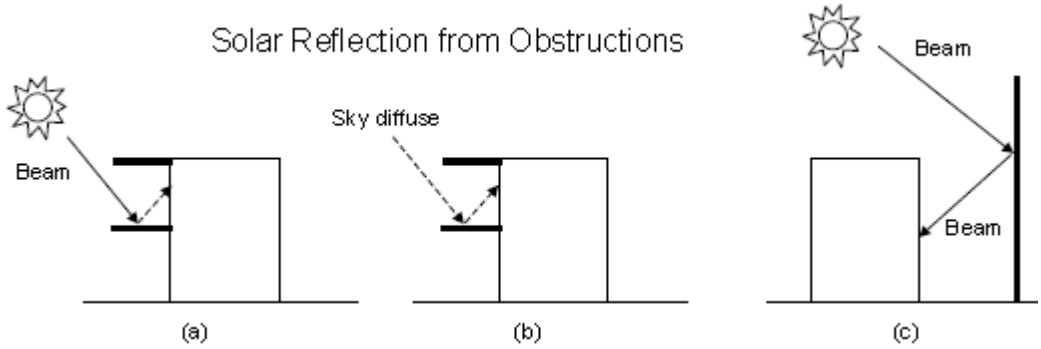
Cooling Design Calculations and Simulations both use this option but have separate Model option data.

Note: if one or more 'other buildings' are large/complex then you could generate a large number of shading elements and the simulation could be slow (even if the current building being simulated is simple).

Model reflections

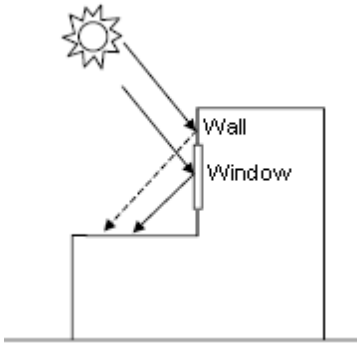
If using reflections, the program calculates beam and sky solar radiation that is reflected from exterior surfaces and then strikes the building. These reflecting surfaces fall into 3 categories:

1. Shadowing surfaces. These are surfaces like overhangs or neighboring buildings (see below). These surfaces can have diffuse and specular (beam-to-beam) reflectance values derived from the material properties of the wall/windows.



Solar reflection from shadowing surfaces. Solid arrows are beam solar radiation; dashed arrows are diffuse solar radiation. (a) Diffuse reflection of beam solar radiation from the top of an overhang. (b) Diffuse reflection of sky solar radiation from the top of an overhang. (c) Beam-to-beam (specular) reflection from the façade of an adjacent highly-glazed building represented by a vertical shadowing surface.

2. Exterior building surfaces. In this case one section of the building reflects solar radiation onto another section (and vice-versa). See below. The building surfaces are assumed to be diffusely reflecting if they are opaque (walls, for example) and specularly reflecting if they are windows or glass doors. The reflectance values for opaque surfaces are calculated by the program from the Solar Absorptance and Visible Absorptance of the outer material layer of the surface's construction. The reflectance values for windows and glass doors are calculated by the program from the reflectance properties of the individual glass layers that make up surface's construction assuming no shading device is present and taking into account inter-reflections among the layers.



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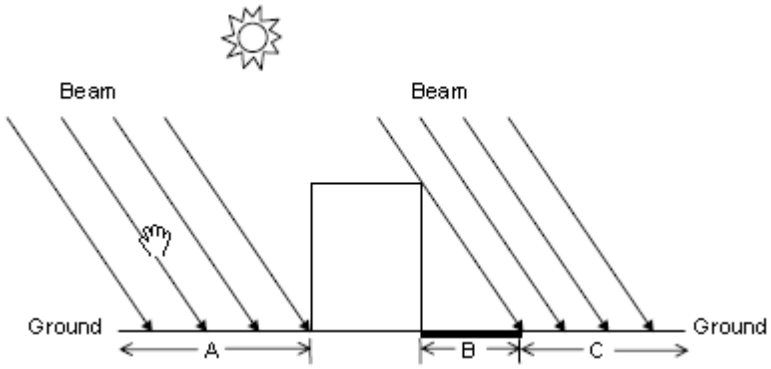
Solar reflection from building surfaces onto other building surfaces. In this example beam solar reflects from a vertical section of the building onto a roof section. The reflection from the window is specular. The reflection from the wall is diffuse.

3. The ground surface.

Reflection from the ground is calculated even if the reflections option is not used. But in this case the ground plane is considered unobstructed, i.e., the shadowing of the ground by the building itself or by obstructions such as neighboring buildings is ignored. This shadowing is taken into account if the reflections option is used. This is shown in diagrammatically below.



Shadowing from building affects beam solar reflection from the ground. Beam-to-diffuse reflection from the ground onto the building occurs only for sunlit areas, A and C, not from shaded area, B.

If reflections option is used for the ground surface then the ground view factor is NOT used.

Solar distribution

This option determines how EnergyPlus treats beam solar radiation and reflectance from exterior surfaces that strike the building and, ultimately, enter the zone. There are five choices:

1-Minimal shadowing - In this case, there is no exterior shadowing except from window and door reveals. All beam solar radiation entering the zone is assumed to fall on the floor, where it is absorbed according to the floor's solar absorptance. Any reflected by the floor is added to the transmitted diffuse radiation, which is assumed to be uniformly distributed on all interior surfaces. If no floor is present in the zone, the incident beam solar radiation is absorbed on all interior surfaces according to their absorptances. The zone heat balance is then applied at each surface and on the zone's air with the absorbed radiation being treated as a flux on the surface.

2-Full Exterior - in this case, shadow patterns on exterior surfaces caused by detached shading, wings, overhangs, and exterior surfaces of all zones are computed. As for Minimal shadowing, shadowing by window and door reveals is also calculated. Beam solar radiation entering the zone is treated as for 'Minimal shadowing' - all beam solar radiation entering the zone is assumed to fall on the floor, where it is absorbed according to the floor's solar absorptance. Any reflected by the floor is added to the transmitted diffuse radiation, which is distributed among interior surfaces according to view factors. If no floor is present in the zone, the incident beam solar radiation is absorbed on all interior surfaces according to their absorptance.

> If you use **2-Full Exterior** you should make sure that all of your zones have a floor. If your building model has any zones of unusual shape without floors then the EnergyPlus simulation may not work because it will not have a surface to apportion solar gains to.

3-Full interior and exterior - this is the same as 'Full exterior' except that instead of assuming all

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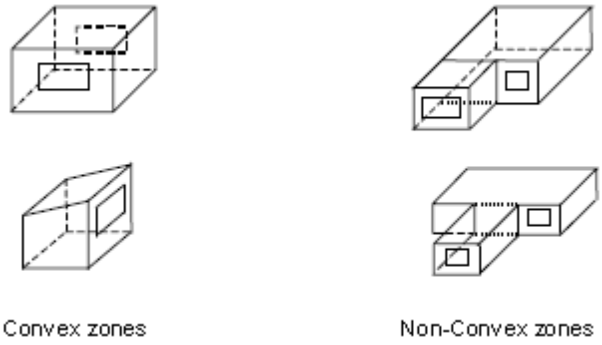
transmitted beam solar falls on the floor the program calculates the amount of beam radiation falling on each surface in the zone, including floor, walls and windows, by projecting the sun's rays through the exterior windows, taking into account the effect of exterior shadowing surfaces and window shading devices. If this option is used, you should be sure that the surfaces of the zone totally enclose a space. This can be determined by viewing the eplusout.dxf file with an external DXF viewer program.

You should also be sure that the zone is convex. Examples of convex and non-convex zones are shown below. The most common non-convex zone is an L-shaped zone. (A formal definition of convex is that any straight line passing through the zone intercepts at most two surfaces.) If the zone's surfaces do not enclose a space or if the zone is not convex you should use 'Full exterior' instead.



If you use **3-Full Interior and exterior** the program will also calculate how much beam radiation falling on the inside of an exterior window (from other windows in the zone) is absorbed by the window, how much is reflected back into the zone, and how much is transmitted to the outside. In this calculation the effect of a shading device, if present, is accounted for.

Important!

You must use **3-Full Interior and exterior** to account for solar and light transmission through internal windows.

Check for non-convex zones

When the solar distribution selection is **3-Full interior and exterior** (above) you can choose whether DesignBuilder is to check for non-convex zones. By default the option is to carry out the check to prevent invalid results, but if the zones are only slightly non-convex you can switch off this check and allow EnergyPlus to continue calculations. You will probably receive error message 2 if you switch this option off and have non-convex zones.

Shadowing interval (Simulation only)

Enter the number of days (1-365) covered by each shadowing calculation.

Enter 1 if you want shadowing to be calculated every day (for greater detail but slower calculations).

3.4.6.2 Draw Block

Drawing Tools tab on Model Options dialog.

Auto complete block

See Auto-complete block entry under Block Creation Options.

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3.4.6.3 Direction Snaps

Drawing Tools tab on Model Options dialog.

See Direction Snaps entry under Snaps, Drawing Guides & Protractor.

3.4.6.4 Point Snaps

Drawing Tools tab on Model Options dialog.

See Point Snaps entry under Snaps, Drawing Guides & Protractor.

3.4.6.5 Drawing Guides

Drawing Tools tab on Model Options dialog.

See Drawing Guides entry under Snaps, Drawing Guides & Protractor.

3.4.6.6 Object Rotation

Drawing Tools tab on Model Options dialog.

You can change the rotation increment to control the angular increments for the object rotation process.

See Rotation entry under General Operations.

3.4.6.7 Protractor Tool

Drawing Tools tab on Model Options dialog.

See Protractor entry under Snaps, Drawing Guides & Protractor.

3.4.7 Display

Display tab on Model Options dialog.

Options related to the display of data:

- Show Data for Calculations
- Edit Screen
- Visualisation Display

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3.4.7.1 Show Data for Calculations

Display tab on Model Options dialog.

Analysis type

DesignBuilder user interface adapts to the currently selected Analysis type as set under Show Data for Calculations. This ensures that the Model data displayed in the UI is relevant to the calculation results. You can change the Analysis type at any time to carry out different calculations.

The list of Analysis type options available will depend on the Location of the site. For example when the site is located in the UK, it possible to set the Analysis type to SBEM Part-L Compliance Checking mode.

New Analysis type options will be available in future versions.

3.4.7.2 Edit Screen

Display tab on Model Options dialog.

Show zone labels

Select this option to display the name of each zone in the Edit screen while at block level. Zone labels are shown by default.

Fit includes imported drawing

Select this option to get the imported drawing included in the calculation of the model extent at site and building levels when the Fit view command is run and when the screen is refreshed internally within DesignBuilder.

Show imported drawing at zone and surface levels

Select this option to show the imported drawing at zone and surface levels. The option is switched off by default for the sake of clarity but you may wish to switch it on when drawing openings at surface level to help position windows, doors etc.

Show shading devices

Select this option to display shading devices while in the Edit screen. Shading devices are shown by default.

Show windows

You can speed up display in the edit screen by switching off window display. Windows are shown by default.

Zone floor shading at block level

Zone floors can be shaded by:

- **1-Activity Template**, where zone floors are shaded according to the Activity Template selection allowing different areas of the block to be easily identified.
- **2-HVAC Template**, where zone floors are shaded according to the HVAC Template selection to show the distribution of HVAC systems in the block.
- **3-None**

The image below illustrates shading by Activity Template.

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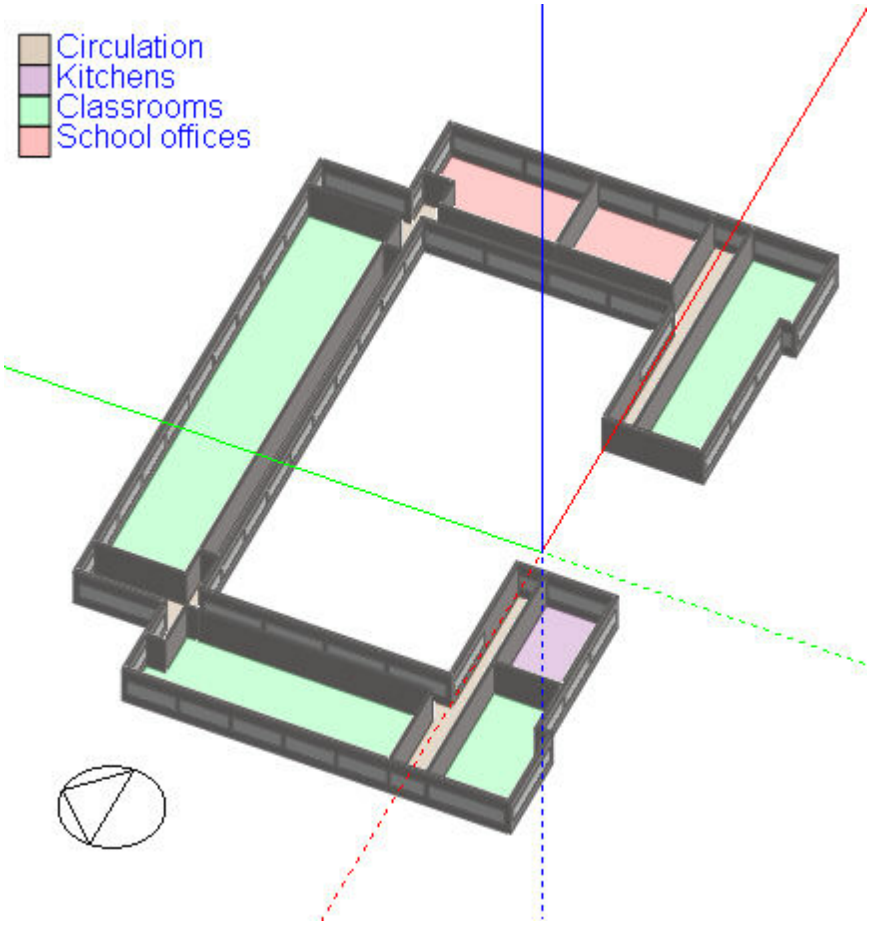

3.4.7.3 Visualisation Display

Display tab on Model Options dialog.

Dynamics

This option affects the display of the model when orbiting and zooming in the Edit and Visualisation Screens:

- **1-Rendered** - the default setting where the whole building image is retained during the operation. For a large models/slow graphic adapters, this can result in a jerky motion in which case you should use...
- **2-Wire-frame** - where the building is represented using a wire frame which moves smoothly even for large models/slow graphic adapters.

Show shadows

Use this option to display shadows in the Visualisation Screen.

Show North arrow

You can display the North Arrow in the Visualisation Screen.

Show ground plane

You can choose to show/hide the plane used to represent the ground in the Visualisation Screen. You may wish to hide the ground plane if you have used component blocks to represent the ground.

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Note: when displayed, the ground plane extents just beyond the x-y size of the model and hides any other building object situated at or below z=0.

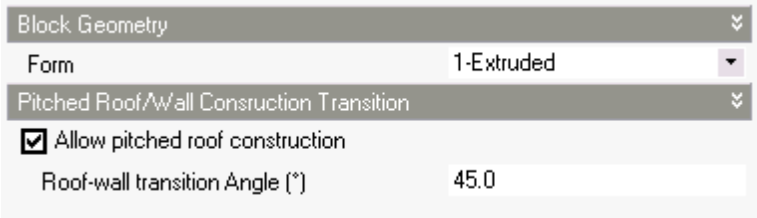
Antialiasing

Antialiasing is the process used to remove 'jaggy' edges of lines which are not horizontal or vertical. Most modern medium-high-end graphics adapters allow effective antialiasing to be automatically applied to OpenGL screens using hardware acceleration. If you have one of these cards you should be getting sharp lines already and you can switch the DesignBuilder software antialiasing off. See hardware requirements for more on this.

If you switch on software antialiasing you can select a quality setting from 1-4 where 4 gives the smoothest edges and takes longest time to generate.

Note: some low-end graphics adapters are not suited to software antialiasing because they lack hardware acceleration for this feature.

3.4.8 Block Options



Block tab on Model Options dialog.

Data on the Block tab of the Model options dialog allows you to edit the form and related properties of the current block:

- Block geometry
- Roof-wall transition

See also Edit Block Geometry Dialog.

3.4.8.1 Block Geometry

Block tab on Model Options dialog.

Wall thickness

You can change the Wall Thickness of the current block by entering the new thickness here. The thickness must be in the range 0.01m - 2.0m (0.39 - 78 inches).

Display external walls

You can choose to switch on/off display of external walls for each block. Generally for standard extruded blocks it is best to show external walls to help reference location within the block with respect to existing openings etc. For roof blocks and other non-plan extrusion blocks the external walls can obscure the internal space and so the default for these block types is to hide the external walls. You can override the defaults using this option. It can be useful to switch off external wall display when drawing partitions in roof blocks.

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Block form

Once a block has been created it's form can usually be changed to one of:

- **1-General**,
- **2-Sloped walls** or
- **3-Pitched roof**

For more on block forms see help on creating blocks.

3.4.8.2 Roof-Wall Transition

Block tab on Model Options dialog.

You can enter the angle which defines the surface tilt below which a wall becomes a roof. For example if the roof-wall transition angle for a particular block is 45°, a surface in this block having tilt 40° is modelled as being a roof (using roof constructions, glazing layout etc). And a surface having tilt 50° is modelled as being a wall (using wall constructions, glazing layout etc).

You can force all non-horizontal surfaces to be walls by unchecking the 'Allow pitched roof construction' option.

3.4.9 Project Details and Notes

Use the Notes tab to record General information about the building model:

- Project Details
- Owner Details
- Analyst Details
- Notes

The Project, Owner and Analyst Details data is used as a header in UK Part-L2 Compliance Check reports.

3.4.9.1 Project Details

Enter the building Sector, Project name and address.

3.4.9.2 Owner Details

Enter the name and contact details for the building owner/client.

3.4.9.3 Analyst Details

Enter your own name and contact details.

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3.4.9.4 Notes

You can enter any information about the building model in free text format.

Note: If you want to add hard carriage returns in the text you should hold the CTRL key down while pressing ENTER. Pressing ENTER on its own will save and close the dialog.

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4 Library management

DesignBuilder is supplied with libraries of Templates and Components and these can be managed from the opening screen (i.e. when no dsb file is loaded).

Click on Component Libraries or Templates tabs (above) to manage library data.

Tip: you can load the latest library components and templates into your model using the **Import library data to model** command from the Tools menu when a model is loaded. Any new data that has been added to the library since the model file was created will be imported to the model. Also if there have been any changes to library component and template data, this new data will overwrite the original data.

Keeping Templates and Component Libraries

You may build up a large database of your own templates and components and to avoid losing this data between version upgrades, DesignBuilder backs up your library data in a series of .dat files which you can access from the **File > Folders > Library data** menu command. These files are retained when the software is uninstalled. When you install a new version of DesignBuilder and run it for the first time, any data you entered in the old libraries is merged with the new libraries. This ensures that you keep any data you created, while receiving the latest DesignBuilder system template and component data.

Note: DesignBuilder keeps separate program options and template and component libraries for each user on the computer system.

4.1 Opening Screen - Component Libraries

From the Component Library screen you can add, clone (copy), delete, view, edit, import, export, backup, restore components as shown below. You can also save the libraries by clicking on the Save toolbar icon (libraries are also saved when the program exits).

Library Components are automatically loaded into the model *at the time the file is created* and from then on, they are associated specifically with this model and so are known as 'Model Components'. Any change made to the Library Components does not affect existing building models because they reference their own set of Model Components.

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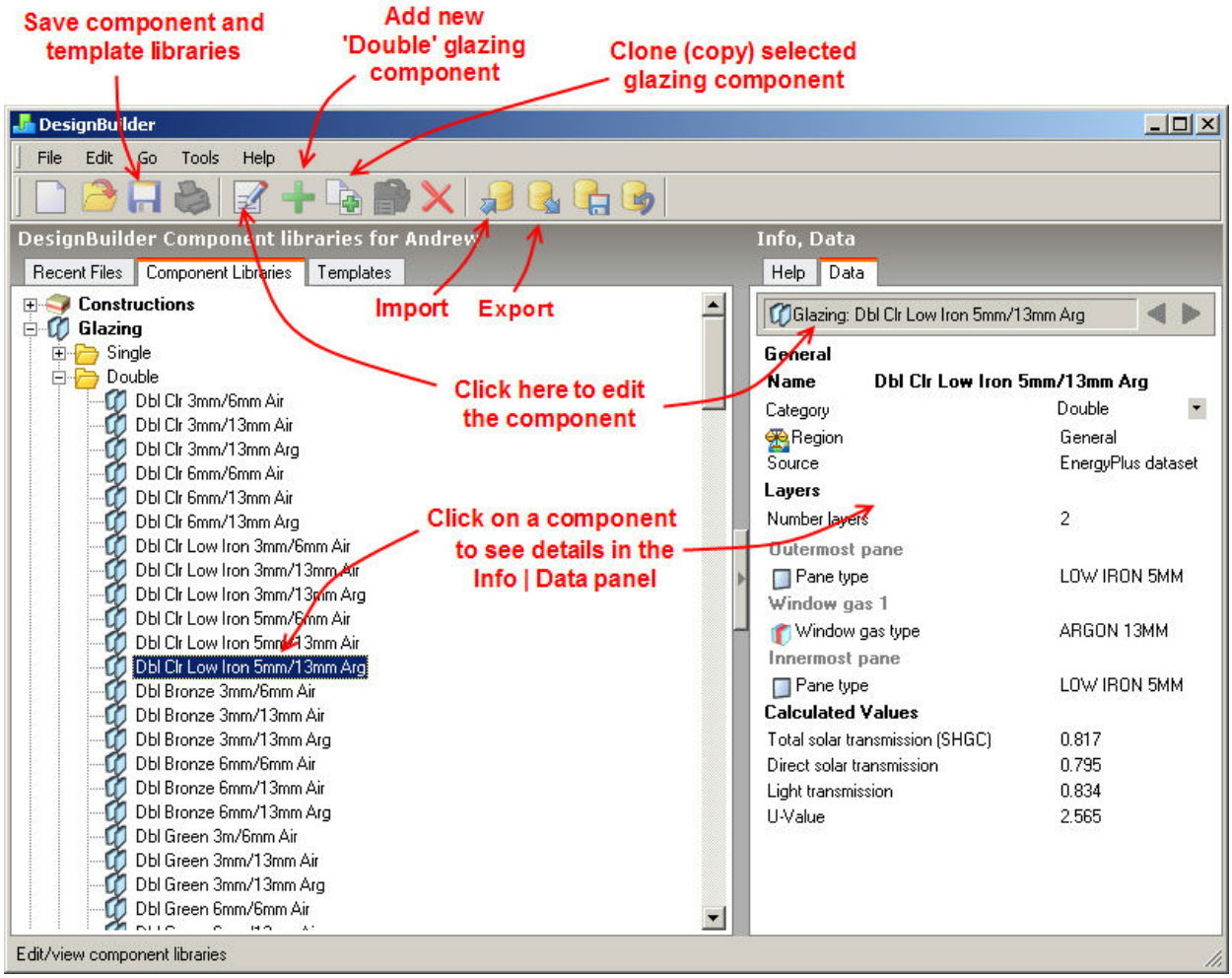

Add New Component

To add a component:

1. Click on the + to the left of the component type (Glazing in the above screen shot).
2. Click on the category (folder icon) or on a component within a category.
3. Click on the green + on the toolbar to create a new component of the selected category.
4. Fill in the details on the dialog and press OK.

The component has been added.

Clone (Copy) Component

Cloning a component creates an exact copy of the selected component gives the copy name 'Copy of ...' followed by the name of the original component.

1. Click on the + to the left of the component type (Glazing in the above screen shot).
2. Click on the component you wish to copy.
3. Click on the clone icon on the toolbar to create a new component identical to the selected one. This creates the copy and selects it,
4. To edit the new component click on the Edit toolbar button
5. Fill in the details on the dialog and press OK.

View Component

You can view the details of a component in the Info | Data panel on the right of the screen as shown in the

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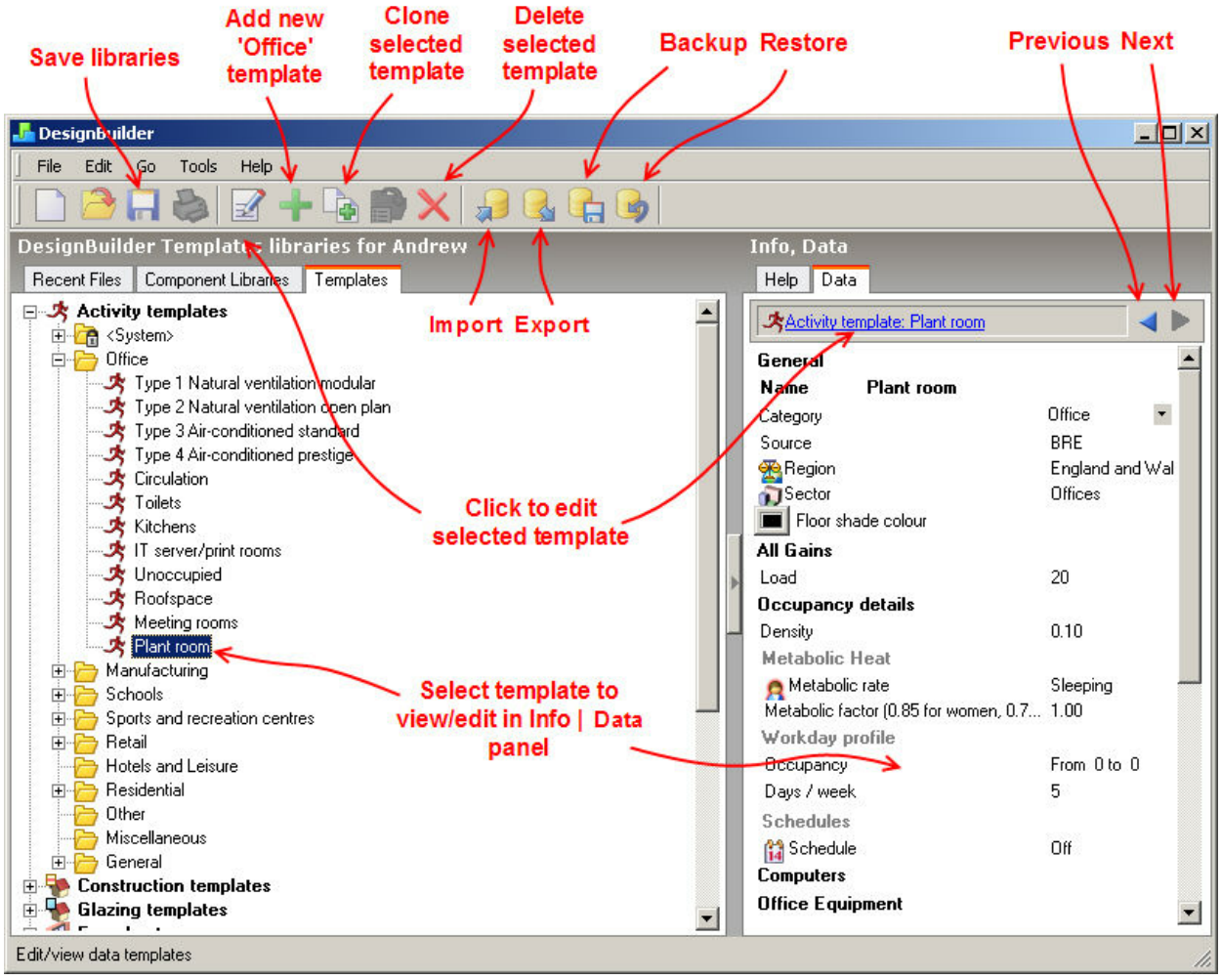
diagram above. Note that icons in the View panel indicate that you can click on the component to see its' details. You can also use the Previous and Next Navigation buttons above the Info panel to navigate through previously viewed components and templates.

4.2 Opening Screen - Template Libraries

Use the opening screen to work with template libraries. The whole screen is dedicated to the job and you get access to the Info Data panel which allows you to review the data for the currently selected template (screen shot below).

You can add, clone (copy), delete, view, edit, import, export, backup, restore library templates as shown below. You can also save the libraries by clicking on the Save toolbar icon (libraries are also saved when the program exits)



Add New Template

To add a template:

1. Click on the + to the left of the template type (Activity templates in the above screen shot).
2. Click on the category (folder icon) or on a template within a category.
3. Click on the green + on the toolbar to create a new template of the selected category.

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4. Fill in the details on the dialog and press OK.

The template has been added.

Clone (Copy) Template

Cloning a template creates an exact copy of the selected template gives the copy name 'Copy of ...' followed by the name of the original template.

1. Click on the + to the left of the template type (Activity templates in the above screen shot).
2. Click on the template you wish to copy.
3. Click on the clone icon on the toolbar to create a new template identical to the selected one. This creates the copy and selects it,
4. To edit the new template click on the Edit toolbar button
5. Fill in the details on the dialog and press OK.

View Template

You can view the details of a template in the Info | Data panel on the right of the screen as shown in the diagram above. Note that icons in the View panel indicate that you can click on the template to see its' details. You can also use the Previous and Next Navigation buttons above the Info panel to navigate through previously viewed components and templates.

Note: You can work with templates with a file open from the Templates tab on the Navigator panel but in this case you're working with Model Templates, i.e. templates specifically associated with a particular model not the library.

4.3 Import Components/Templates

Import component/template .DDF files previously exported using the **File > Import > Library data** menu command:

- Import the data to the *model* by selecting the Import menu command with a file open.
- Import to *libraries* by working from the Opening screen.

This command imports **all** components/templates in the DDF file.

4.4 Export Components/Templates

You can export your user DesignBuilder Component/Template libraries by selecting the **File > Export > Library data** menu command to create a .DDF file. This file can be shared with other users, imported on other computers in your office or simply used as a backup.

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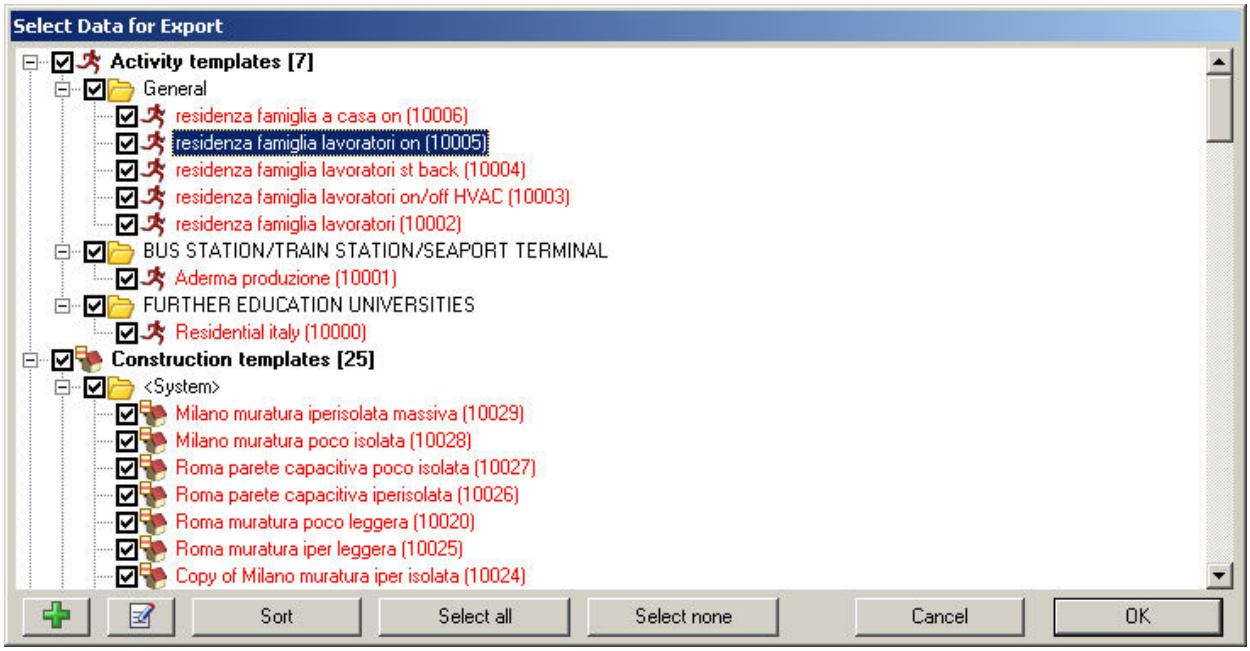
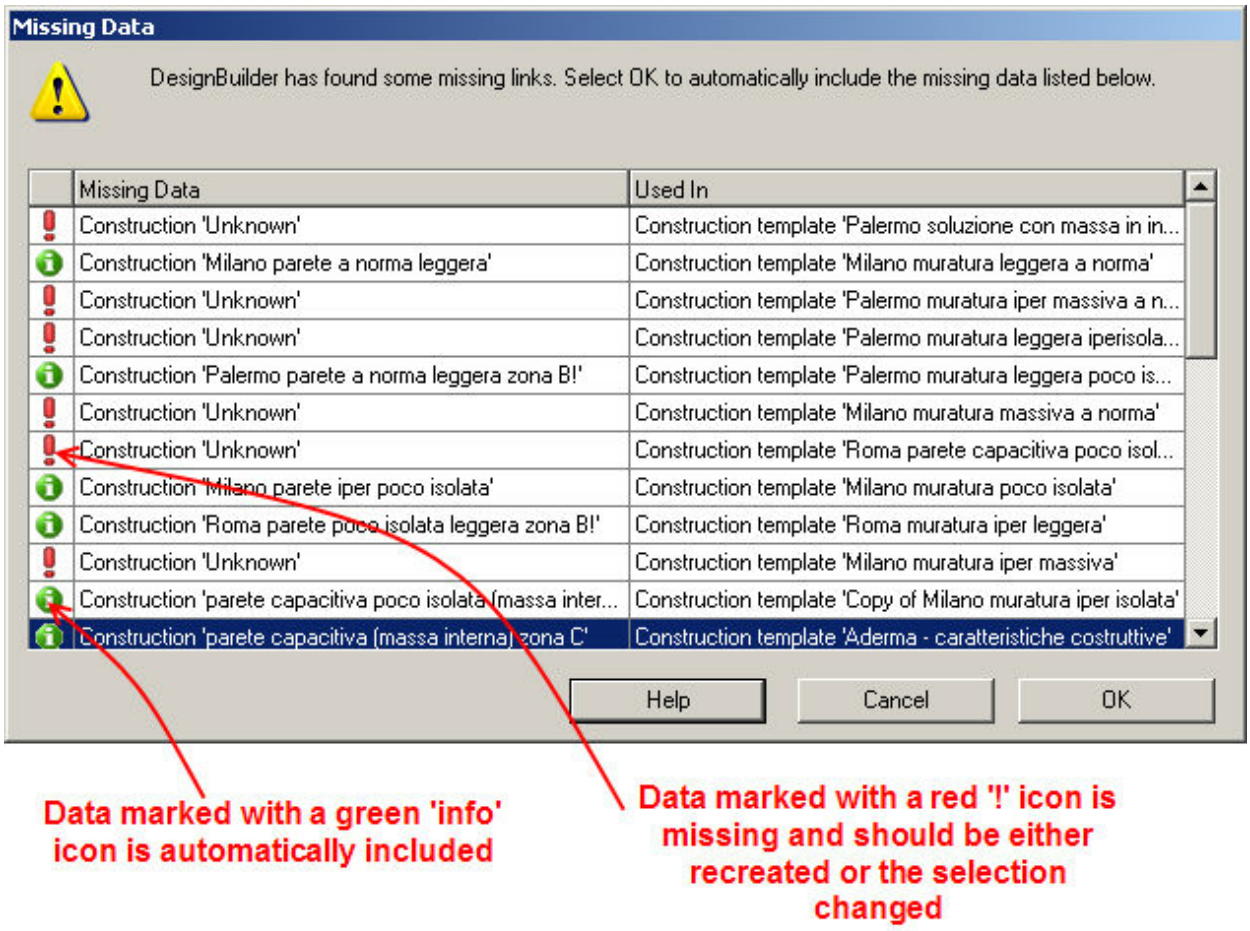


When exporting a complex set of data, DesignBuilder will check that where user data references other user components, these referenced components are also selected. For example, if you select a construction for export which uses your own materials, you must make sure that all materials used in this construction are also selected. If any required user components are not selected DesignBuilder displays a dialog showing the missing components. See below.



Press the OK button to continue with the export automatically including the missing data.

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Note: if there is any data that is referenced but does not exist it is flagged with a red '!' icon (above). In this case you should press the Cancel button and make the necessary edits to ensure that all referenced data exists. DesignBuilder will not prevent you from continuing so it is possible to create DDF files with missing data.

When you use the library data **Export** command *with a model data file open*, the data exported will be user ***Model* components/templates**, not ***Library* components/templates**.

From the Opening screen you can also export entire data tables as **csv-spreadsheet files** suitable for viewing in a spreadsheet. This data cannot be read back into DesignBuilder.

4.5 Backup Component/Template Libraries

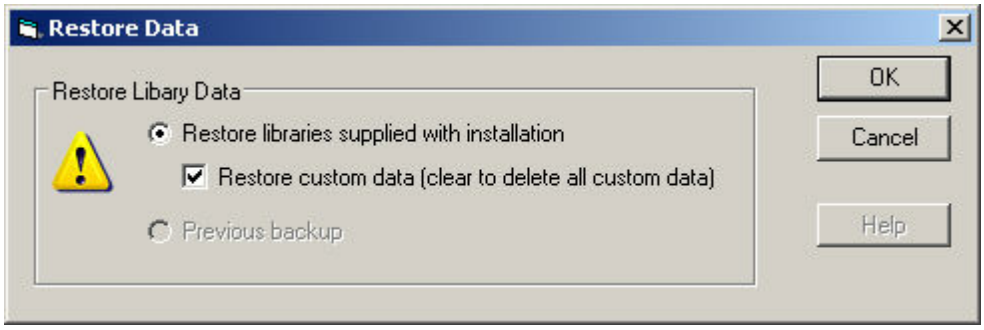
Back up your Component and Template libraries by clicking on the Backup toolbar icon. Backups created in this way are stored in the 'Backup\Manual' folder beneath the rest of the library data.

As well as backing up the compiled .dbt files, DesignBuilder also exports the files in .dat format and packages the whole backup into a zip file. If you have problems with your libraries you may find it helpful to send this zip file to DesignBuilder Support for analysis.

You can use this data as a backup of your library data and can restore it at a later date using the Restore libraries command.

4.6 Restore Component/Template Libraries

Click on the Restore icon to open the Restore Data dialog which allows you to Restore previously backed up Component/Template libraries. Select the source of the restore - you can either restore the libraries to their state when you first installed DesignBuilder or you can restore library data from a previous backup (if one exists). In the screenshot below, no backup had been made so the Previous backup option is not available.



If you choose to restore libraries supplied with installation you can use the **Restore custom data (clear to delete all custom data)** option to either:

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1. Restore the custom data which existed on the computer at the time the software was installed, or,
2. Clear all custom data to keep only the data supplied by DesignBuilder.

Note to restore the libraries supplied with the installation and clear any custom data select **Restore libraries supplied with installation** and uncheck the **Restore custom data (clear to delete all custom data)** option.

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5 Components

Components represent individual building elements and can be referenced from other components, templates or model data. The following components are available:

- Constructions
- Glazing
- Materials
- Panes
- Profiles
- Schedules
- Textures
- Window gas
- Local shading
- Window blinds
- Vents
- Holidays

Library components are loaded into the model at the time the file is created and from then on they are associated specifically with the model and so are known as **Model components.** Any later change made to the Library components does not affect existing building models because they reference their own set of Model components.

Managing component data

You can edit and move component data around in various ways:

1. Add, Edit, Delete, Import and Export Component library data from the Opening Screen - Component Library tab.
2. If a model file is loaded you can edit Model components from the Components tab in the Navigator panel (Learning mode switched off) or by using the Data management panel on the right of the screen (Learning mode switched on).
3. In either case, **to add a component** open up the component type you wish to define by clicking on the + to the left of the component icon, then click on the category of component you wish to define. Now click on the Green '+' to add a component of the selected category.
4. Import/export Model component using the **File > Export > Library data** menu command to create a .ddf file with the .dsb model file open.
5. To import the previously exported Model component data to the Component library close the .dsb file and import the .ddf file to the library.
6. Load the latest library components into your model using the **Import library components and templates to model** command from the Tools menu when a model is loaded. Any new data that has been added to the library since the model file was created will be imported to the model. Also if there have been any changes to library component data, this new data will overwrite the original data.

Important Note: any component you add while a model is open will be added to Model components and not to the Component library. It will only be added to the library and hence to new models if you export the new component model data in .ddf form and import the .ddf file to the library before creating the new model.

Colour code

Components are coded by colour in the Navigator panel and selection lists as follows:

Red shows user data, i.e. data that was not supplied by DesignBuilder.
Green indicates that the data is derived from a reputable national or international source.
Blue indicates that the data is generated internally by DesignBuilder.

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Black is used for other data.

5.1 Constructions

The thermal properties of the construction are calculated based on layers, each layer having a material reference and thickness. The combination of thickness and material gives the thermal characteristics of the layer.

Construction Components also store derived data on the thermal properties of the overall layered construction for example U-value, convective heat transfer coefficients etc.

There are three tabs on Constructions dialogs:

- Layers
- Image
- Calculated

Construction component data can be accessed:

- from the Components tab on the opening screen (to view/edit library components if no file is open),
- from the Components tab in the Navigator panel (to view/edit model components if a file is open),
- by double-clicking on the construction icon in the model data,
- by clicking on the Edit button when selecting constructions from a list.

5.1.1 Layer Data

Layers tab on Constructions Dialog.

Set the number of layers first, then select the material and thickness for each layer. Use the Controls in the Info Panel to insert and delete layers. For example to delete a layer, first click on the material for the layer to identify which layer you want to delete, then click on Delete layer.

You can create constructions with up to 6 layers.

You should define the layers in the same order they appear in the actual construction starting with the outermost layer and finishing with the innermost. The outermost layer will be positioned adjacent to outside (or in the case of Semi--exposed walls) adjacent to the semi-exposed unconditioned zone.

For interior surfaces (partitions, internal floors etc) the order of the layers is determined through a series of checks to see which zone is relatively ‘more external’. So, for example, if one zone is unconditioned and the other not then the partition layers are ordered so that the outermost layer is next to the unconditioned zone. When both zones are occupied, a similar check is made using heating and cooling setpoint temperatures. If after all these checks the zones are still both equally ‘internal’ then the direction of the layers will be set up in an arbitrary way.

Note: You should not include surface resistance (film coefficient) layers to represent the resistance of the air films adjacent to the inner and outer surfaces. These are included automatically by DesignBuilder.

Thickness

This field characterizes the thickness of the material layer. This is the dimension of the layer in the direction perpendicular to the main path of heat conduction. This value must be a positive.

Note: If the material referenced is defined as a simple R-value then the construction thickness does not

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have to be entered.

Bridging

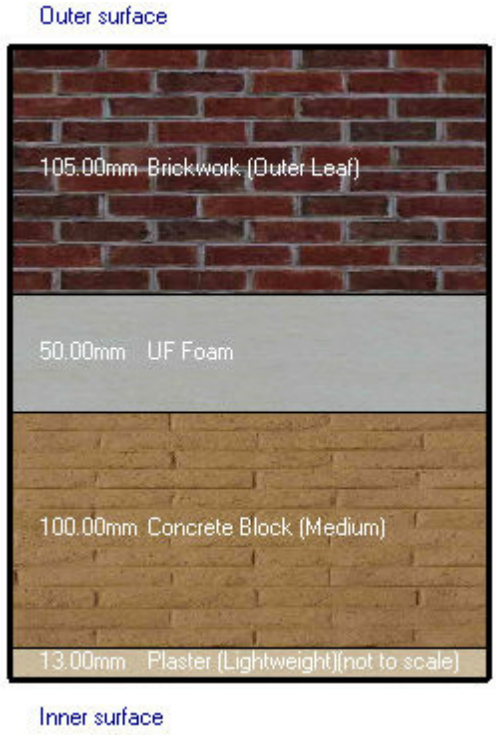
You can also add bridging to any layer to model the effect of a relatively more conductive material bridging a less conductive material. For example wooden joists briging an insulation layer.

Note: bridging effects are NOT yet used in EnergyPlus, but are used in energy code compliance checks requiring U-values to be calculated according to BS EN IOS 6946.

5.1.2 Image

Image tab on Constructions Dialog.

This tab shows the construction to scale (except for very thin layers) using material textures as specified.



Bridging elements are ignored

5.1.3 Calculated Data

Calculated tab on Constructions Dialog.

This tab provides further information on the heat transmission properties of the construction.

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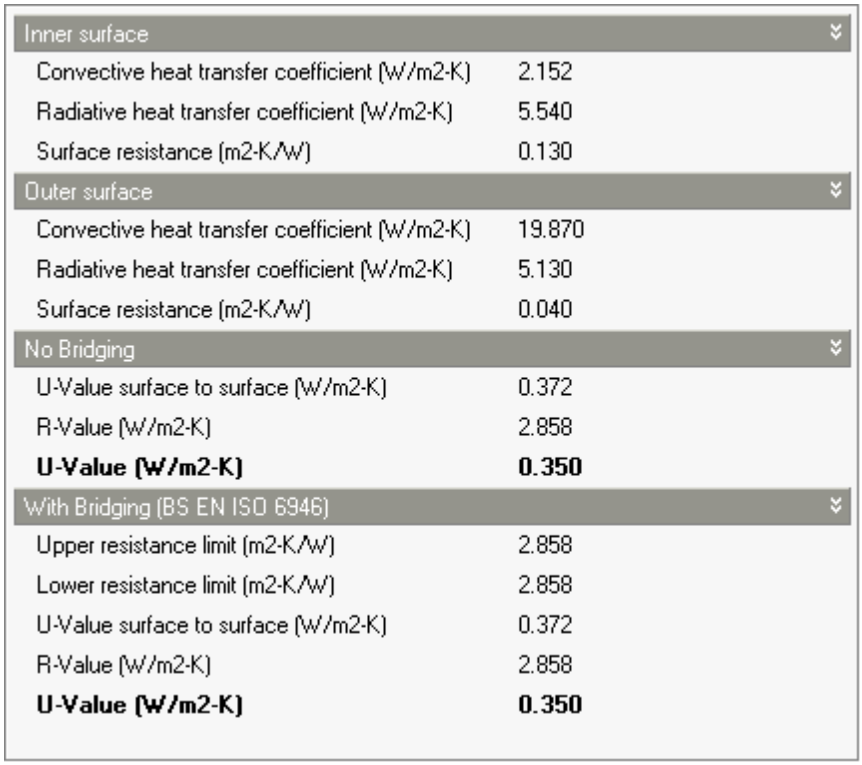

Inner surface	
Convective heat transfer coefficient (W/m2-K)	2.152
Radiative heat transfer coefficient (W/m2-K)	5.540
Surface resistance (m2-K/W)	0.130
Outer surface	
Convective heat transfer coefficient (W/m2-K)	19.870
Radiative heat transfer coefficient (W/m2-K)	5.130
Surface resistance (m2-K/W)	0.040
No Bridging	
U-Value surface to surface (W/m2-K)	0.372
R-Value (W/m2-K)	2.858
U-Value (W/m2-K)	**0.350**
With Bridging (BS EN ISO 6946)	
Upper resistance limit (m2-K/W)	2.858
Lower resistance limit (m2-K/W)	2.858
U-Value surface to surface (W/m2-K)	0.372
R-Value (W/m2-K)	2.858
U-Value (W/m2-K)	**0.350**

U-values and R-Values are shown including and excluding the effect of surface resistance and are calculated with and without bridging effects.

Note that when working with **library constructions**, the outer surface resistance is calculated assuming a 'typical' exposure to wind. When working with **model constructions** the outer surface resistance is calculated using the wind exposure as defined on the Location tab at site level.

Convective heat transfer coefficients

The calculated convective heat transfer coefficients are used in EnergyPlus when the 'CIBSE' Inside/Outside convection algorithm is selected. Otherwise EnergyPlus uses its' own convection algorithm as set in the simulation options and the transmission data displayed here is not used.

5.2 Glazing

Each Glazing Component consists of a series of glazing layers (Panes) separated from each other by Window Gas layers.

There are two tabs on the Glazing data dialog:

- Layers
- Calculated

Glazing component data can be accessed:

- from the Components tab on the opening screen (to view/edit library components if no file is open),
- from the Components tab in the Navigator panel (to view/edit model components if a file is open),
- by double-clicking on the glazing icon on the Openings tab in the model data,
- by clicking on the Edit button when selecting glazing components from a list.

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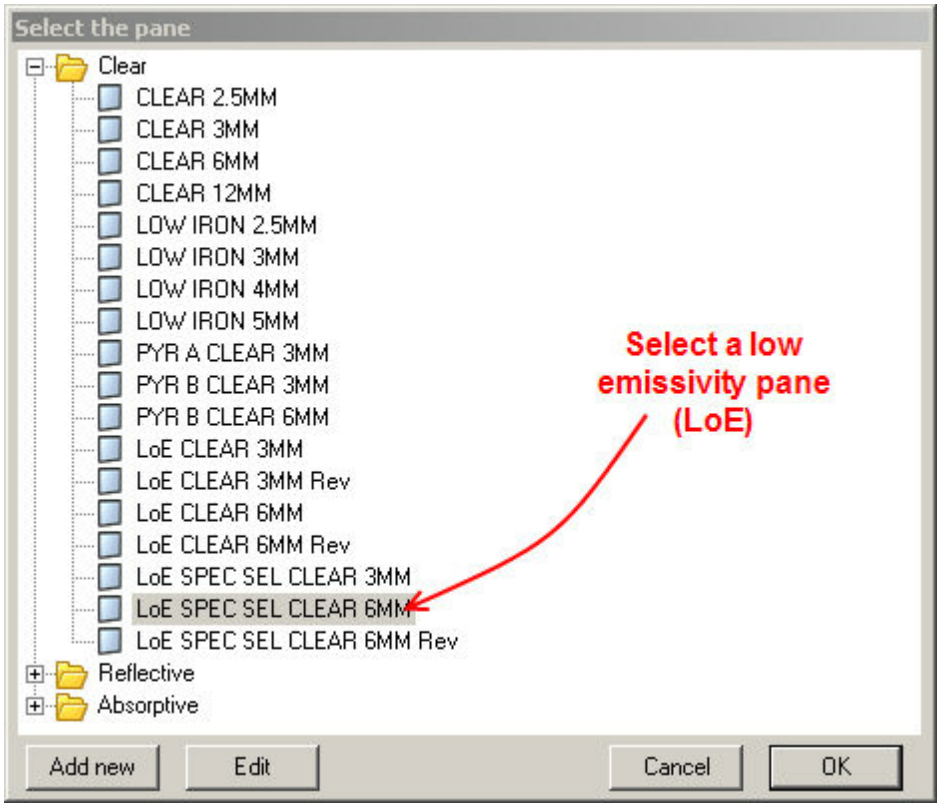
5.2.1 Layers

Layer tab on Glazing Dialog.

Set the number of layers first, then select the pane and window gas material for each layer. The DesignBuilder Glazing data simply consists of layers of panes interspersed with layers of window gases. Other data such as internal and external surface heat transfer coefficients, U-values etc can be calculated and stored on the Calculated tab.

Note that you can define **low emissivity glazing systems** by specifying an appropriate 'LoE' Pane type for the Innermost Pane. You can find some typical low emissivity panes under the 'Clear ' Panes category.



5.2.2 Calculated

Calculated tab on Glazing Dialog.

The Calculated data on the Glazing tab has been calculated by EnergyPlus using the Layer data on the previous tab. You can refresh the Calculated data by clicking on the Update link in the Info panel on the right of the dialog.

The data can be useful for setting up glazing model descriptions in cases where global glazing system data is known rather than data on individual panes and window gases. The Calculated data is used in DBSim and 3TC simulations*.

The U-value is determined by doing a heat balance calculation on the glazing layers for the following standard ASHRAE winter conditions:

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- Inside air temperature = 21.1C (70F)
- Outside air temperature = -17.8C (0F)
- Wind speed = 6.71 m/s (15 mph)
- Outside convective air film conductance = 25.47 W/m2-K (4.486 Btu/h-ft2-F)
- Inside convective air film conductance: calculated by EnergyPlus
- No solar radiation

The 'Total solar transmission (SHGC)' (Solar Heat Gain Coefficient) is the fraction of incident beam solar radiation that enters the zone. This includes the transmitted solar radiation and the inward flowing heat from the solar radiation that is absorbed by the glazing. SHGC applies only to the center of the glazed part of a window construction; it does not include the effect of beam solar radiation absorbed by a window frame or divider. SHGC is calculated for the following standard summer condition:

- Inside air temperature = 23.9C (75F)
- Outside air temperature = 31.7C (89F)
- Wind speed = 3.35 m/s (7.5 mph)
- Incident beam solar radiation normal to glazing = 783 W/m2 (248 Btu/h-ft2)

* DBSim and 3TC are alternative calculation methods which are still under development.

5.3 Materials

Material data contains data accessed from 3 tabs:

Thermophysical data on building material.
Surface Properties - data on the surface characteristics of the material.
Green Roof - if the material is a green roof enter the data on the corresponding here.

Material component data can be accessed:

- from the Components tab on the opening screen (to view/edit library components if no file is open),
- from the Components tab in the Navigator panel (to view/edit model components if a file is open),
- by double-clicking on the material icon in the model data,
- by clicking on the Edit button when selecting a material from a list.

5.3.1 Material Properties

General tab on Materials Dialog.

Materials are used to define the properties of construction layers. There are 2 types of material:

1. **Detailed properties** including the thermophysical properties, surface properties and visual appearance for the material.
2. **Simple resistive material** with no thermal mass. This option will typically be used to model air gaps.

DETAILED PROPERTIES

Thermal bulk properties

Thermal conductivity

This field is used to enter the thermal conductivity of the material layer. Thermal conductivity must be

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greater than zero.

Specific heat

This field represents the specific heat of the material layer. Only positive values of specific heat are allowed.

Density

This field is used to enter the density of the material layer. Density must be a positive quantity.

SIMPLE RESISTANCE

Thermal resistance

This field is used to enter the thermal resistance (R-value) of the material layer.

Note: Materials defined using an R-value do not contribute to construction (and hence building) thermal mass in the calculations and so should be used with care, especially if you plan to use the model for dynamic thermal simulations.

5.3.2 Surface Properties

Surface properties tab on Materials

Surface properties are only used in simulations when the material is located on an inner or outer surface of the construction.

Thermal absorptance (emissivity)

The thermal absorptance represents the fraction of incident long wavelength radiation that is absorbed by the material. This parameter is used when calculating the long wavelength radiant exchange between various surfaces and affects the surface heat balances (both inside and outside as appropriate). Values for this field must be between 0.0 and 1.0 (with 1.0 representing “black body” conditions).

Solar absorptance

The solar absorptance field in the Material input syntax represents the fraction of incident solar radiation that is absorbed by the material. Solar radiation includes the visible spectrum as well as infrared and ultraviolet wavelengths. This parameter is used when calculating the amount of incident solar radiation absorbed by various surfaces and affects the surface heat balances (both inside and outside as appropriate). Values for this field must be between 0.0 and 1.0.

Visible absorptance

The visible absorptance field in the Material input syntax represents the fraction of incident visible wavelength radiation that is absorbed by the material. Visible wavelength radiation is slightly different than solar radiation in that the visible band of wavelengths is much more narrow while solar radiation includes the visible spectrum as well as infrared and ultraviolet wavelengths. This parameter is used when calculating the amount of incident visible radiation absorbed by various surfaces and affects the surface heat balances (both inside and outside as appropriate) as well as the daylighting calculations. Values for this field must be between 0.0 and 1.0.

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Roughness

This field is a character string that defines the relative roughness of a particular material layer. This parameter only influences the the calculated exterior convection coefficient. A special keyword is expected in this field with the options being “VeryRough”, “MediumRough”, “Rough”, “Smooth”, “MediumSmooth”, and “VerySmooth” in order of roughest to smoothest options.

Colour

The colour data is used for display purposes when the texture is not available for any reason. It is not used in any of the calculations.

Texture

The texture is used to represent this material when it is specified as either the inside or outside material of a construction which is selected in the building model. It is also used to represent the material in diagrams of any construction using this material.

5.3.3 Green Roof

Green roof tab on Materials

Green roofs can be modelled in DesignBuilder by creating a roof construction using a Green roof material as the outer layer. The green roof can receive water during the simulation from an irrigation system and/or from site precipitation (defined separately from the hourly weather data). The initial properties of the soil layer are defined on the Green roof tab of the Materials dialog.

Background

Use of green roofs (aka ecoroofs or vegetated roofs) is becoming increasingly common for both new and retrofit buildings. There is widespread recognition and a growing literature of measured data that suggest green roofs can reduce building energy consumption. The EnergyPlus Green Roof capability can assist developers and architects in assessing the likely magnitude of energy savings associated with various implementation options (e.g., soil type/depth, irrigation options, plant type). It provides a quantitative and physically-based building energy simulation tool that represents the effects of green roof constructions and facilitates more rapid spread of green roof technologies and make it possible to account for green roof benefits in state energy codes and related energy efficiency standards such as LEED.

The green roof model accounts for:

- Long wave and short wave radiative exchange within the plant canopy,
- Plant canopy effects on convective heat transfer,
- Evapotranspiration from the soil and plants, and
- Heat conduction (and storage) in the soil layer

The ability to track moisture-dependent thermal properties is not implemented yet due to stability issues in the CTF scheme, but is under development for use with the finite difference solution scheme made available in EnergyPlus starting in version 2. As implemented in EnergyPlus the green roof module allows the user to specify “ecoroof” as the outer layer of a rooftop construction. The user can then specify various aspects of the green roof construction including growing media depth, thermal properties, plant canopy density, plant height, stomatal conductance (ability to transpire moisture), and soil moisture conditions (including irrigation). The model formulation includes the following:

- Simplified moisture balance that allows precipitation, irrigation, and moisture transport between two soil layers (top and root zone).
- Soil and plant canopy energy balance based on the Army Corps of Engineers’ FASST vegetation

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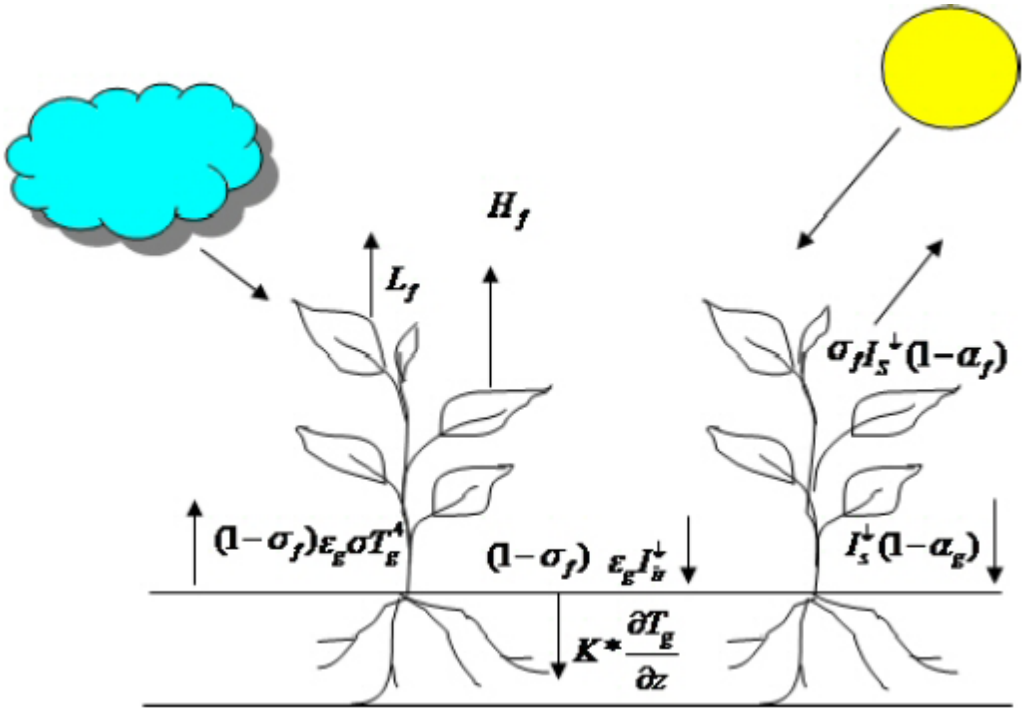
models (Frankenstein and Koenig), drawing heavily from BATS (Dickenson et al.) and SiB (Sellers et al.).

- Soil surface (Tg) and foliage (Tf) temperature equations are solved simultaneously each time step, inverting the CTF to extract heat flux information for the energy balance calculation. The detailed energy balance analysis and resulting equations, being rather complicated, are summarized here. The interested reader is referred to the FASST documentation cited herein for the complete development. The end result is a set of two simultaneous equations for temperature—one for the soil surface and the other for the foliage.

Green Roof Model Description

As with a traditional roof, the energy balance of an green roof is dominated by radiative forcing from the sun. This solar radiation is balanced by sensible (convection) and latent (evaporative) heat flux from soil and plant surfaces combined with conduction of heat into the soil substrate. This energy balance is illustrated in the diagram below. The variables introduced in this figure are defined in the EnergyPlus Engineering Document.



The energy balance for a green roof.

The energy budget analysis follows the Fast All Season Soil Strength (FASST) model developed by Frankenstein and Koenig for the US Army Corps of Engineers. FASST was developed, in part, to determine the ability of soils to support manned and unmanned vehicles and personnel movement. In order to accomplish this, however, FASST tracks the energy and moisture balance (including ice and snow) within a vegetated soil. It is a one-dimensional model that draws heavily from other plant canopy models including BATS (Dickinson et al.) and SiB (Sellers et al.). FASST is implemented in EnergyPlus with only a few modifications to adapt it for use with a relatively thin soil layer.

GREEN ROOF DATA

Height of Plants

The average height of plants in the green roof.

Leaf Area Index

This is the projected leaf area per unit area of soil surface. It is a dimensionless number between 0.001 and

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5.0.

Leaf Reflectivity

The fraction of incident solar radiation that is reflected by the individual leaf surfaces. Solar radiation includes the visible spectrum as well as infrared and ultraviolet wavelengths. Values for this field must be between 0.1 and 0.4.

Leaf Emissivity

This field is the ratio of thermal radiation emitted from leaf surfaces to that emitted by an ideal black body at the same temperature. This parameter is used when calculating the long wavelength radiant exchange at the leaf surfaces. Values for this field must be between 0.8 and 1.0 (with 1.0 representing “black body” conditions).

Minimum Stomatal Resistance

This field represents the resistance of the plants to moisture transport. It has units of s/m. Plants with low values of stomatal resistance will result in higher evapotranspiration rates than plants with high resistance. Values for this field must be in the range of 50.0 to 300.0.

Max volumetric moisture content of the soil layer (saturation)

Maximum volumetric moisture content of the soil depends on the properties of the soil and in particular the porosity.

Min (residual) volumetric moisture content of the soil layer

The minimum possible volumetric moisture content of the soil layer.

Initial volumetric moisture content of the soil layer

The volumetric moisture content of the soil layer at the start of the simulation. The moisture content will be updated during the course of the simulation based on surface evaporation, irrigation and precipitation.

5.4 Panes

Pane components holds data on the thermal, solar, visible and infrared properties of individual window panes.

Note that the Info Panel on the right of the Dialog contains information on the naming convention is used with EnergyPlus glazing data.

There are five tabs on the Pane dialog:

- General
- Thermal
- Solar
- Visible
- Infra-red
- Spectral data

Pane component data can be accessed:

- from the Components tab on the opening screen (to view/edit library components if no file is open),
- from the Components tab in the Navigator panel (to view/edit model components if a file is open),

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- by clicking on the Edit button when selecting panes from a list.

5.4.1 General

General tab on Panes Dialog.

Enter the name, description and category of the pane. Also enter the source of the data.

Data type

The Data type allows you to define whether the glazing pane has solar transmission and reflectance data in spectral or broadband form. The options are:

- **1-Broadband** - where transmission and reflection data is averaged across all wavelengths,
- **2-Spectral** - the more accurate option where solar transmission and reflectance data is defined for a range of wavelengths between 0.1 and 4 microns on the Spectral data tab of the dialog.

> **Spectral data**
>
> ***Where possible you should use glazing panes which have Spectral data defined*** because the calculations in EnergyPlus are more accurate accounting for the way solar transmission varies with wavelength. In particular, the results for glazing systems using spectral data can be significantly more accurate relative to the equivalent broadband data for panes with selective coatings e.g. low-e glass.

International Glazing Database (IGDB)

The IGDB is a comprehensive international glazing layer database compiled by NFRC and provided through the specialist WINDOW and OPTICS fenestration analysis software provided by LBNL. The IGDB contains, amongst other things, detailed spectral data for around 2500 manufacturers glazing pane products from around the world.

5.4.2 Thermal Data

Thermal Data tab on Panes Dialog.

Thickness

Enter the thickness of the pane.

Thermal conductivity

This field is used to enter the thermal conductivity of the material layer. Thermal conductivity must be greater than zero.

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5.4.3 Solar Data

This data is not used in simulations when the Data type is **2-Spectral** *but is still displayed as it gives a spectral-average overview of the solar transmission and reflectance.*

Solar transmittance

The solar transmittance at normal incidence averaged over the solar spectrum.

Solar reflectance

The inside (back-side) and outside (front-side) solar reflectance properties of the pane at normal incidence averaged over the solar spectrum.

Note, For uncoated glass, when alternative optical properties (thickness, solar index of refraction, and solar extinction coefficient) are available, they can be converted to equivalent solar transmittance and reflectance values using the equations given in 'Conversion from Alternative Specification of Glass Optical Properties' in the EnergyPlus documentation).

5.4.4 Visible Data

Visible Data tab on Panes Dialog.

Visible transmittance

The visible transmittance at normal incidence averaged over the solar spectrum, and weighted by the response of the human eye.

Visible reflectance

The inside (back-side) and outside (front-side) visible reflectance properties of the pane at normal incidence averaged over the solar spectrum, and weighted by the response of the human eye.

Note, For uncoated glass, when alternative optical properties (thickness, visible index of refraction, and visible extinction coefficient) are available, they can be converted to equivalent visible transmittance and reflectance values using the equations given in 'Conversion from Alternative Specification of Glass Optical Properties' in the EnergyPlus documentation).

5.4.5 Infra-red Data

Infra-red tab on Panes Dialog.

Long-wave transmittance

The long wave transmittance at normal incidence.

Emissivity (long wave reflectance)

Enter the inside (back-side) and outside (front-side) hemispherical emissivity (long wave reflectance) properties of the pane.

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5.4.6 Spectral Data

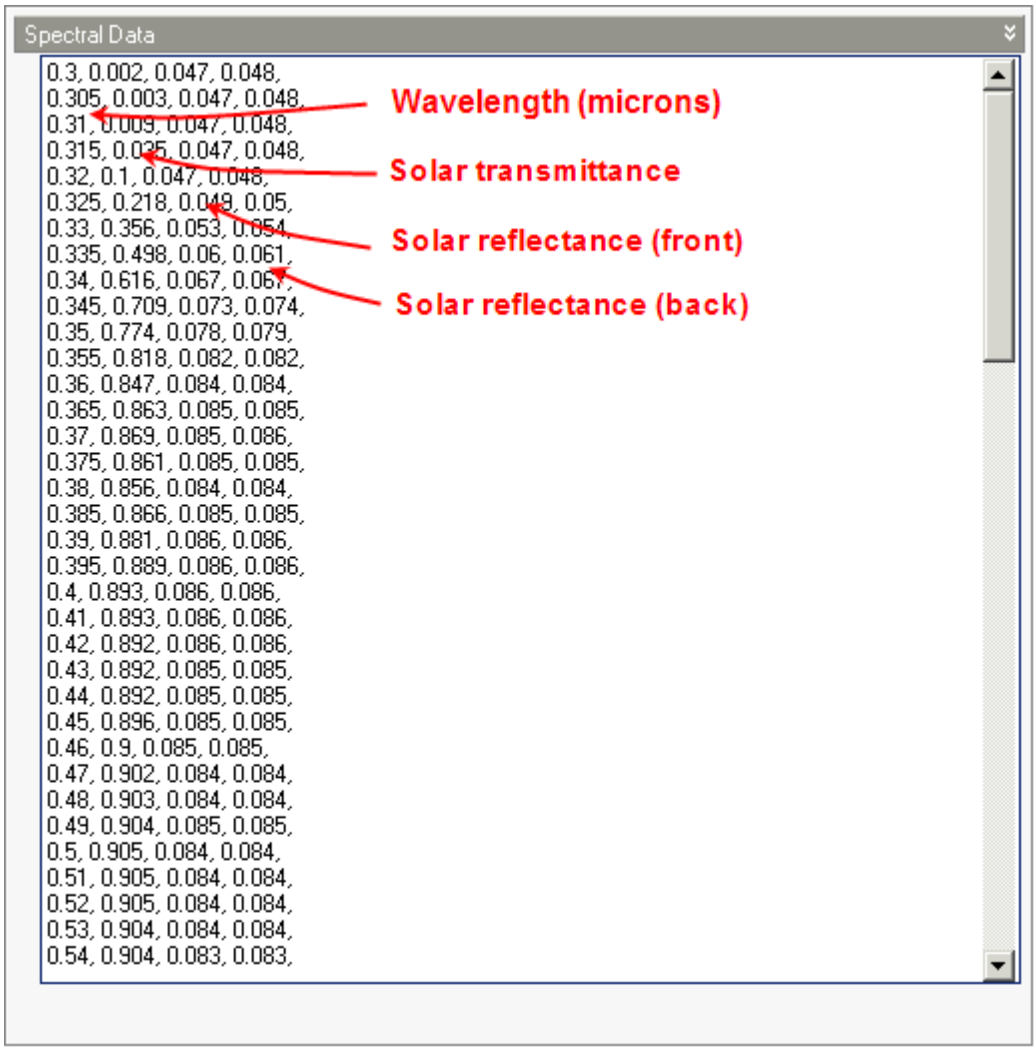
Spectral data tab on Panes Dialog.

Solar transmission and reflectance data is entered for a range of wavelengths between 0.1 and 4 microns. This data will generally have been extracted from the IGDB (International Glazing Database) and supplied by DesignBuilder.

The data is arranged in comma-separated table form with a single line per wavelength, each line having 4 columns:

1. Wavelength (microns)
2. Solar transmittance (Tsol)
3. Solar reflectance, front (Rsol1)
4. Solar reflectance, back (Rsol2)

An example is shown in the screenshot below.



Note: due to the large volume of data involved, spectral data is only stored in the Library and not in the model and DesignBuilder uses this Library data in the simulations and display screens. Therefore any changes to the spectral data when a file is open will have no effect.

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5.5 Schedules

Schedules are used in DesignBuilder to define:

- Occupancy times
- Equipment, lighting HVAC operation
- Heating and Cooling temperature setpoints
- Transparency of component blocks (usually seasonal)

Apart from their use for defining Transparency of component blocks, Schedules are only used in simulations when the Timing model option is set to 'Schedules'

You can define schedules in one of 2 ways:

- 7/12 Schedules - where each day of the week and each month of the year has a unique daily variation defined using profiles.
- Compact Schedules - more flexible definition using EnergyPlus **Schedule:Compact** text-based data format.

Use the **Schedule type** drop list on the Schedules dialog to make the selection.

Click here for information on temperature setpoint schedule definition.

Schedule data can be accessed:

- from the Components tab on the opening screen (to view/edit library components if no file is open),
- from the Components tab in the Navigator panel (to view/edit model components if a file is open),
- by double-clicking on the schedules icon in the model data,
- by clicking on the Edit button when selecting schedules from a list.

5.5.1 7/12 Schedules - Defined Using Profiles

General tab on Schedules Dialog.

7/12 Schedules reference Profiles, one Profile for each day of the week and for each month of the year (hence 7/12).

You can select multiple rows (months) or columns (days) and edit the data by clicking on the **Edit selected cells** link in the Info Panel. Likewise, you can select individual profiles by clicking on the appropriate cell and clicking **Edit selected cells.**

Design days

Winter and summer design day simulations are carried out when required for autosizing heating and cooling equipment prior to a Compact HVAC simulation.

Design day definition method

With 7/12 Schedules there are 2 ways to define the schedule output during these winter design day simulations:

1. End-use defaults - use the default heating autosizing behaviour defined on the Heating design tab of the Model option dialog.

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In this case for summer design, the profile for Wednesday is used. If Wednesday is not a good choice for Summer design autosizing then you can instead define the profile explicitly using the Profiles design day definition method below.

Use End use default - apply the behaviour for the selected category as defined on the Model options on the Heating design tab.

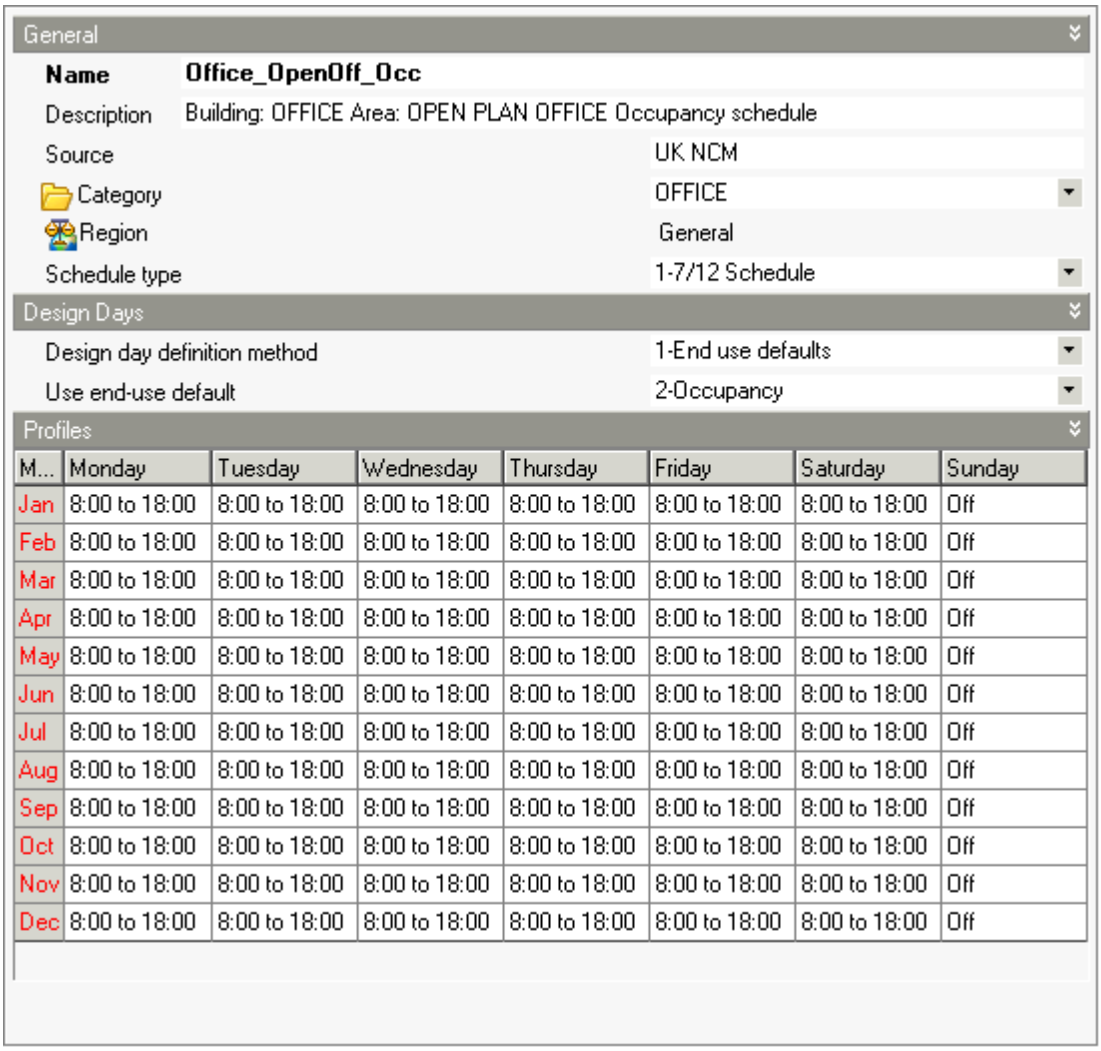
2. Profiles - define both heating and cooling design day operation as a Profile. This option is more flexible and clearer than **End-use defaults** but can take slightly longer to set up.

Heating design day profile - the profile defining the schedule output during the heating autosizing design day.
Cooling design day profile - the profile defining the schedule output during the cooling autosizing design day.

Weekly and monthly variations

Other tools are available for rapid selection/deselection and setting of schedule data:

- Select all weekdays
- Select all weekends
- Set all weekends 'Off'
- Select all
- Deselect all



M...	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Jan	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	Off
Feb	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	Off
Mar	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	Off
Apr	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	Off
May	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	Off
Jun	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	Off
Jul	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	Off
Aug	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	Off
Sep	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	Off
Oct	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	Off
Nov	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	Off
Dec	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	Off

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See also EnergyPlus Compact Schedules

5.5.2 Compact Schedules

General tab on Schedules Dialog.

Compact Schedules are defined using a slightly modified version of the standard EnergyPlus **Schedule: Compact** format documented below.

Using the Compact Schedule definition all the features of the schedule components are accessed in a single command. Each Compact Schedule must cover all the days for a year and it must have values for all 24 hours and all values for all day types.

Tip: When entering the text for the Compact Schedule, to start a new line you should hold the <CTRL> key down while pressing <ENTER>. Just pressing <ENTER> will save and close the dialog.

Name

This field is for your own use and is replaced by DesignBuilder with the name of the Schedule when generating data for EnergyPlus.

ScheduleType

ScheduleType should generally be **Fraction** even for schedules to be used for temperature setpoint definition.

You can enter **Any Number** to enter values greater than 1 but please bear in mind:

- The maximum gains values (e.g. people/m2) are multiplied by the values in the schedule to obtain the actual value to use at each time step in the simulation. So if you enter large schedule values the actual maximum value in the simulation will be higher than the 'maximum' value entered in DB. There is no problem with this, just a methodological concern that if the Interface indicates that the maximum occupancy density is say 0.1 people/m2 but the schedule has values > 1 then the simulation results will, at first sight, appear incorrect. If you come back to the model 6 months later you may not remember the reason.
- Temperature set-point schedules should only have values 0, 0.5 or 1.0.

So generally we recommend using **Fraction** Compact schedules for clarity.

Field-Set (Through, For, Interpolate, Until, Value)

Each Compact Schedule must contain the elements **Through** (date), **For** (days), **Interpolate** (optional), **Until** (time of day) and **Value**.

Field: Through

This field starts with 'Through:' and contains the ending date for the schedule period. You may define multiple schedule periods in this way, for example to define seasonal variations. If there are no seasonal variations then enter: `Through: 31 Dec,` to indicate that the data that follows applies to the whole year.

Note that only Month-Day combinations are allowed for this field.

Field: For

This field starts with 'For: ' and contains the applicable days. Multiple choices may be combined on the line.

Choices are:

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- Weekdays,
- Weekends,
- Holidays,
- Alldays,
- SummerDesignDay,
- WinterDesignDay,
- Sunday,
- Monday,
- Tuesday,
- Wednesday,
- Thursday,
- Friday,
- Saturday,
- CustomDay1,
- CustomDay2.

In fields after the first 'For', 'AllOtherDays' may also be used.

Note: EnergyPlus has limit of line length of about 60 characters so lines like:

```
For: Weekdays SummerDesignDay WinterDesignDay Weekends Holidays
AllOtherDays,
```

should be changed to:

```
For: AllDays,
```

Field: Interpolate (optional)

Schedule values are input to the simulation at the zone time step, so there is also a possibility of 'interpolation' from the entries used in this object to the value used in the simulation. This field, if used, starts with 'Interpolate:' and contains the word 'Yes' or 'No'.

Field: Until

This field contains the ending time for the current days and day schedule being defined. The data should represent clock time (standard) in the format HH:MM. 24 hour clock format (i.e. 1pm is 13:00). Note that 'Until: 7:00' includes all times up through 07:00 (7am). The time is followed by a comma and the value the schedule takes until the given time. See note above on usual values. Generally you should enter values between zero and 1.

Field: Value

Finally, the value field is the schedule value for the specified time interval.

Note: you can use 0 for Temperature type Compact Schedules to indicate that the heating/cooling system is switched off during the specified period. See Example 2 below.

Example 1 - Operation Schedule

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```
SCHEDULE:COMPACT,
Office_CellOff_Light,
Fraction,
Through: 31 Dec,
For: Weekdays SummerDesignDay WinterDesignDay,
Until: 07:00, 0,
Until: 19:00, 1,
Until: 24:00, 0,
For: Weekends,
Until: 24:00, 0,
For: Holidays AllOtherDays,
Until: 24:00, 0;
```

This schedule is intended to be used to describe the lighting operation in an office. It indicates:

- Schedule is a fraction (0-1).
- No seasonal variation.
- Weekdays and cooling and heating design days the schedule is 1 (i.e. 'on') between 7am and 7pm and 0 (i.e. 'off') other times.
- Weekends, holidays and all other days the schedule is 'off'.

Example 2 - Temperature Setpoint Schedule

```
SCHEDULE:COMPACT,
Bedroom_Cool,
Temperature,
Through: 31 Dec,
For: Weekdays SummerDesignDay WinterDesignDay,
Until: 05:00, 0.5,
Until: 09:00, 1,
Until: 17:00, 0.5,
Until: 24:00, 1,
For: Weekends,
Until: 05:00, 0.5,
Until: 24:00, 1,
For: Holidays AllOtherDays,
Until: 24:00, 0;
```

This schedule is intended to be used to describe the cooling temperature setpoint and setback in a bedroom. It indicates:

- Schedule is a temperature (degC).
- No seasonal variation.
- Weekdays and cooling and heating design days the **main** temperature setpoint data (Activity tab) is used between 5am and 9am and also between 5pm and midnight. Cooling operates at **setback** temperature setpoint data at all other times on these days.
- Weekends the cooling setpoint is **main** temperature setpoint between 5am and midnight. Cooling operates at **setback** temperature setpoint data at all other times on these days.
- Holidays and all other days the cooling is off.

More on Temperature setpoint schedules.

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5.6 Hourly Weather Data

DesignBuilder uses EnergyPlus format hourly weather data to define external conditions during simulations. Each location has a separate file describing the external temperature, solar radiation, atmospheric conditions etc. for every hour of the year at that location. These hourly weather data sets are often 'typical' data derived from hourly observations at a specific location by the National weather service or methodological office. Examples of these typical data include TMY2 and WYEC2 in the United States and Canada and TRY (CEC 1985) in Europe. See EnergyPlus Hourly Weather Data for more on the hourly weather data itself.

Because hourly weather data is not always available for every location, it is often necessary to use weather data for a nearby location which represents the weather of the actual site.

The DesignBuilder hourly weather data has been obtained from the Weather section of the EnergyPlus website and processed using the DesignBuilder weather data translator, but you can use any weather data provided it is in the correct format.

EnergyPlus format hourly weather data has extension 'epw' by convention.

See also:

- Add new hourly weather data
- Edit/Translate hourly weather data
- EnergyPlus Hourly Weather Data

Downloading Hourly Weather Data

DesignBuilder comes with a database of hourly weather data but the EnergyPlus epw files are not loaded onto your computer until you actually need them. This keeps the size of the DesignBuilder setup program small. The first time you require an hourly weather data file it is automatically downloaded from the DesignBuilder Website into the Weather data folder on your computer where it can be accessed by EnergyPlus for any subsequent simulations. You must be connected to the Internet to download weather data in this way.

Selecting hourly weather data

When you select an hourly weather data set on the Location tab at Site level, you do not select the file directly, but rather an hourly weather data component, which in turn references the actual file. It works this way so that we can supply you with a database of hourly weather data locations without needing to include hundreds of large hourly weather files.

When editing an hourly weather data component there are two tabs on the Hourly Weather Data dialog:

- General
- Statistics

Template data can be accessed:

- from the Templates tab on the opening screen (if no file is open),
- from the Templates tab in the Navigator panel (if a file is open),
- by double-clicking on the template icon in the model data,
- by clicking on the Edit button when selecting templates from a list.

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5.6.1 Hourly Weather Data - General

General tab on Hourly Weather data Dialog.

Select the Hourly weather data filename and the rest of the data is loaded directly from the .epw and .stat files.

Each file is named using the ISO standard three-letter country abbreviation (i.e. CUB for Cuba), followed by the location name, and the source format (CityUHK, CSWD, CTYW, CTZ2, CWEC, ISHRAE, IWEC, IGDG, INETI, KISR, SWEC, SWERA, TMY2, or TMY).

Thus, **CUB_Havana_IWEC.epw** is the EnergyPlus weather file (epw) from the ASHRAE International Weather for Energy Calculations (IWEC) data for Havana, Cuba (CUB).

There are three files associated with each location:

- **epw** - EnergyPlus weather files
- **stat** - a summary report on the data. Data from this file is loaded into the Statistics tab when an hourly weather data file is selected.
- **ddy** - design conditions.

Note: the above hourly weather data and associated statistics files are located in the Weather data folder.

5.6.2 Hourly Weather Data - Statistics

Statistics tab on Hourly Weather data Dialog.

Simulation Options

These options control the simulation and the output produced.

Simulation Period

Select the start and end days for the simulation, or select a typical period:

- Annual simulation
- Summer design week
- Summer typical week
- All summer
- Winter design week
- Winter typical week
- All winter

Interval

Monthly and annual output is always generated and daily, hourly and sub-hourly data can selected by checking the appropriate boxes.

Note that selecting output at hourly or

The statistics displayed are generated by the EnergyPlus weather data translation utility.

The statistics data is used to identify useful simulation periods:

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Summer start month, Summer end month define the summer simulation period in **mmm** format.
Winter start month, Winter end month define the winter simulation period in **mmm** format.

Extreme hot week, starting defines the first day of the hottest week of the year.
Typical hot week, starting defines the first day of a typical summer week.
Extreme cold week, starting defines the first day of the coldest week of the year.
Typical cold week, starting defines the first day of a typical winter week.

Note: week starting dates must be in the format **mmm dd -** any other format will generate an error when clicking on the links in the Simulation Options dialog.

This data can be accessed from the Simulation Calculation options dialog to set up typical simulation periods (screenshot right) .

5.6.3 Add new hourly weather data

If you have hourly weather you wish to use in simulation you can add it to the library by following the steps below:

1. Copy the **EnergyPlus format** hourly weather data .epw file to the weather data folder (File > Folders > Weather data). If you have it, copy the .stat file there too.
2. From the Opening screen click on the Component libraries tab.
3. Click on the + to the left of Hourly weather data to open up the list of countries.
4. Select the country of the location (or a location within the country).
5. Add a new Hourly weather data set by clicking on the green + icon in the Toolbar.
6. Select the epw file and enter any extra information in the dialog as described below. Note that the location and other statistics are automatically loaded from the .stat and .epw files when you select the file.
7. Click OK to save the new Hourly weather data.

See further below for the alterative steps to follow if you have a file open and wish to create a new hourly weather data set just for that model.

> **Note 1:** Any custom hourly weather epw file you select in your model will be saved with the dsb file so that the model can be used on other computers without the need to copy weather files manually.
>
> **Note 2:** Although DesignBuilder can been used with any valid epw data sets, you are strongly advised to process the data first to ensure that each hourly record has year 2002. This ensures that daily, hourly and sub-hourly data generated by EnergyPlus is correctly synchronised with the DesignBuilder graphics display. If you do not set the year to 2002 it will not affect the results but it will affect the day of the week display in DesignBuilder. If you do not set the year to 2002, daily, hourly and sub-hourly data will not necessarily show the correct day of the week in the results display graphics.

The steps are shown in the screenshots below.

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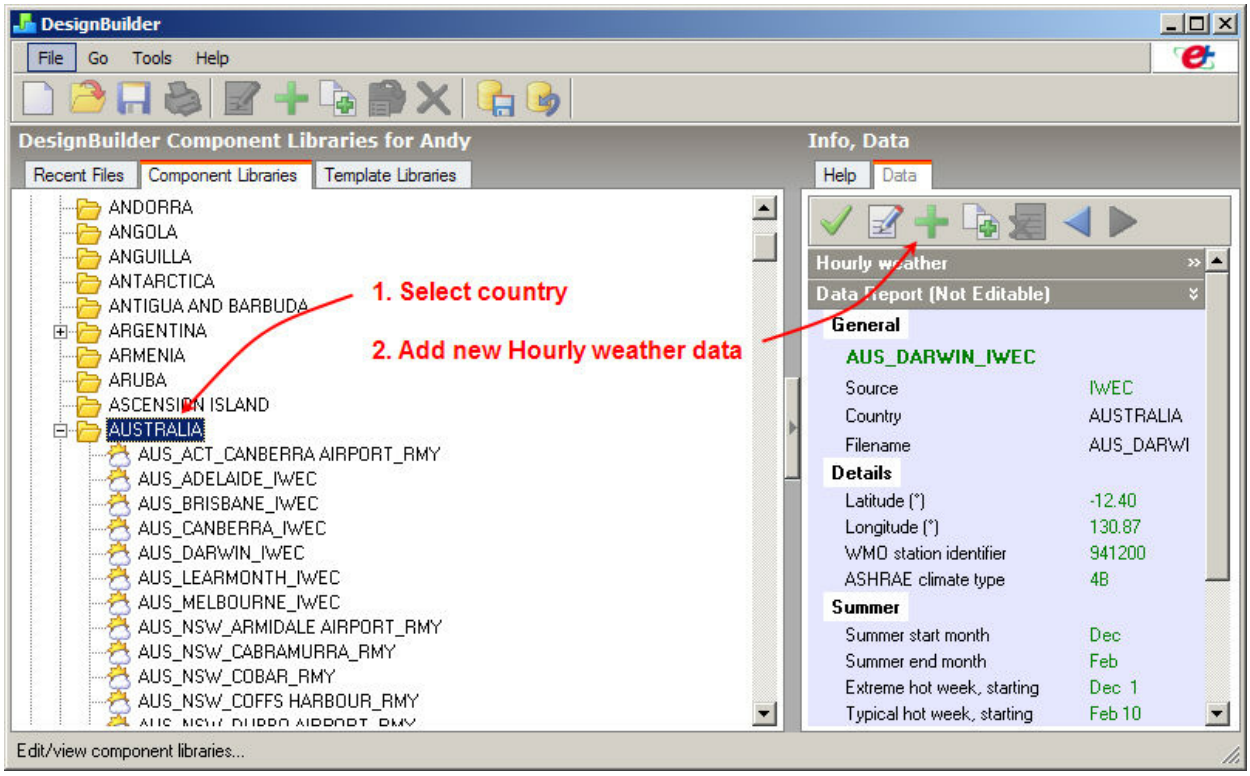
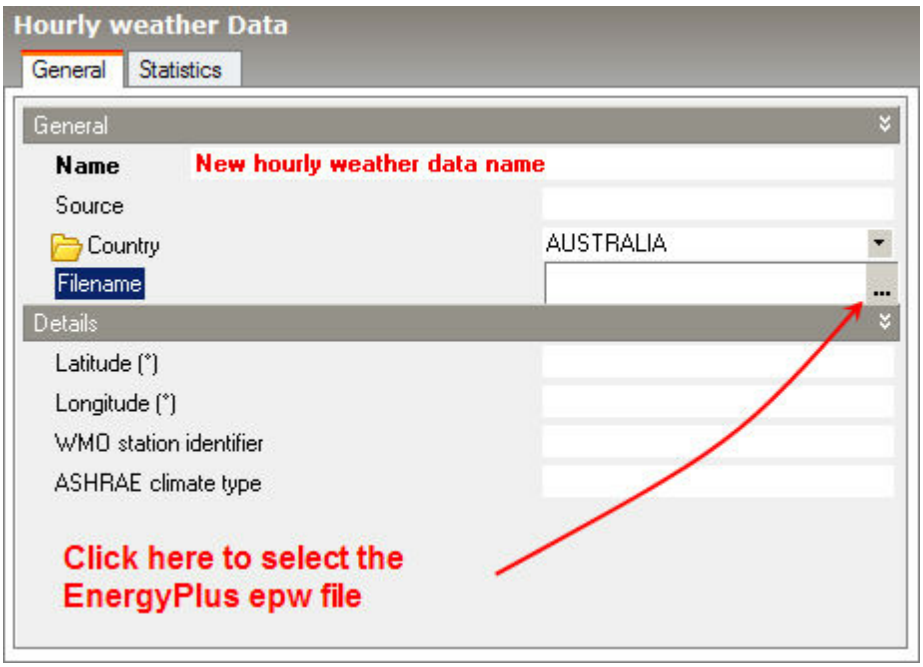


In the Hourly weather data, enter the details of the location and select the EnergyPlus epw filename as shown below.



Once the epw has been selected, DesignBuilder loads the Latitude, Longitude and WMO station identifier.

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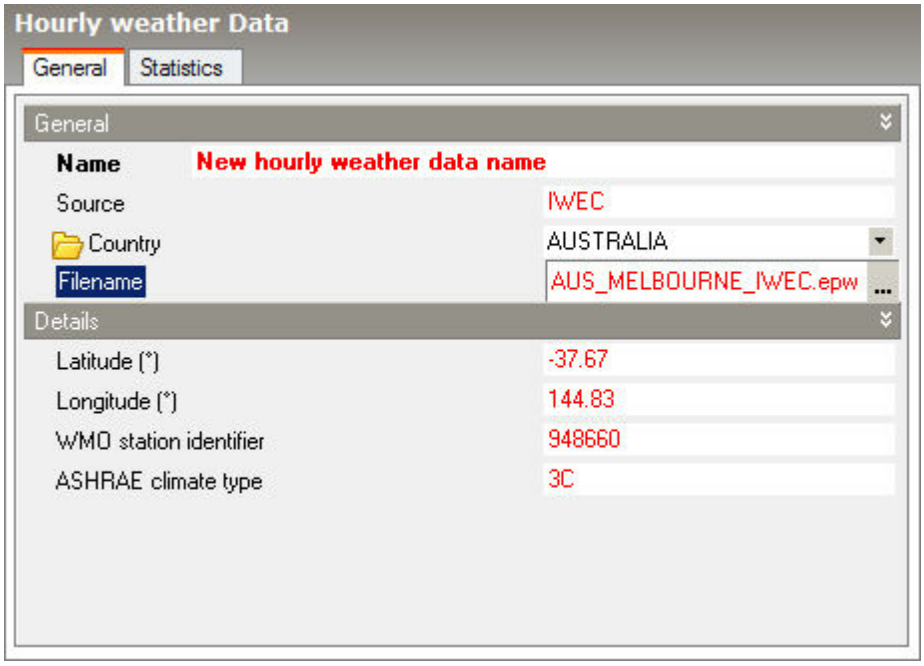
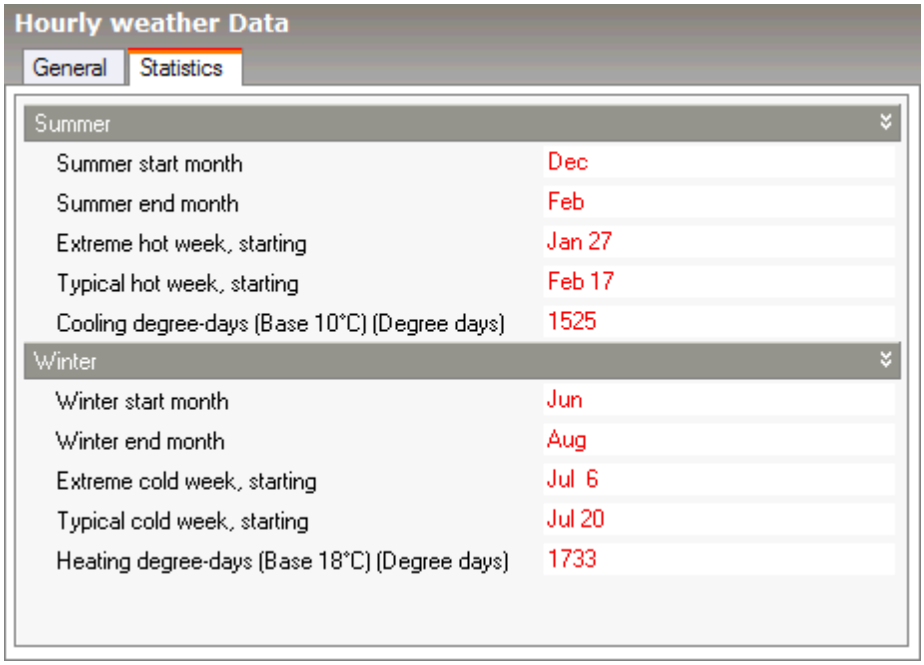


It also searches for the equivalent .stat file and if it is found (in the weather data folder) the data on the Statistics tab is also loaded (below).



Note: If a stat is not available you should enter the information on the Statistics tab by hand in the format shown above. The stat file is automatically generated by the Hourly weather data translation process.

When you click on the OK button you will be able to select this new Hourly weather data from:

1. Location tab at site level.
2. Add New site dialog.

The above process creates a *library* Hourly weather data component. If you have a dsb file open, you can follow an equivalent process to create a *model* Hourly weather data component. In this case the process is:

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1. Copy the **EnergyPlus format** hourly weather data epw file to the weather data folder (File > Folders > Weather data). If you have it, copy the .stat file there too.
2. Go to site level, Location tab, open the Simulation Weather Data header and click on the currently selected **Hourly weather data** selection.
3. In Learning mode, select the country of the location (or a location within the country) in the Info, data panel on the right of the screen.
4. Add a new Hourly weather data set by clicking on the green + icon in the Toolbar.
5. Select the epw file and enter any extra information in the dialog as described above.
6. Click OK to save the new Hour weather data.

In this case you will need to export the hourly weather data you have just created from this model and reload the ddf file to the library if you wish to use the weather data in other models.

If you don't have the data in epw format yet then it can be translated from a range of formats using the inbuilt DesignBuilder weather data translation tool or if the format is not supported then you can use the EnergyPlus translation tool that supports all weather formats. Obtain this from the EnergyPlus website. The documentation can be found in the Auxiliary Programs document. It can be worth contacting EnergyPlus support about obtaining weather data for particular locations as they have a lot of contacts and sometimes can provide data that is not on the main website.

5.6.4 Edit/Translate hourly weather data

You can use the Edit/Translate Hourly Weather Data dialog to process hourly weather data. You may wish to do this for various reasons:

- Convert EnergyPlus epw data to be compatible with DesignBuilder day of week results for daily, hourly and sub-hourly output (set the year to 2002).
- Translate weather data in other formats to the EnergyPlus format so that it can be used in DesignBuilder.
- Generating modified weather data sets for investigating climate change scenarios.

Translating

Use this dialog to convert weather data to and from a range of file formats. Supported formats are:

EnergyPlus data files (.epw)
EnergyPlus 'comma separated values' files (.csv)
TMY2 data files (.tmy2 or tm2)
TMY data files (.tmy)
IWEC data files (.iwec or iwc)
Samson data files (.samson or dat)
WYEC2 data files (.wyec2 or wy2)
DOE-2 formatted data files (.fmt or txt)
ESP-r formatted data files (.esp-r or clm)
BLAST ASCII formatted data files (.blast or asc)

Required extensions are shown in brackets. To edit/convert a file or files:

1. Select the folder containing the file(s) using the browse box at the top of the left-hand side of the screen. All relevant weather data files are then loaded into the table on the left.
2. Check the files to be converted.
3. Ensure that the correct options have been set on the Options tab.
4. Press the Convert button to start the process.

Converted files are stored in the Weather data folder. You can access these files by clicking on the 'Edit/ Review' tab.

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5.6.5 EnergyPlus Hourly Weather Data

All of the hourly weather data that comes with DesignBuilder is supplied by DOE from:

www.eere.energy.gov/buildings/energyplus/cfm/weather_data.cfm

But with the year changed to 2002 as described in Add new hourly weather data.

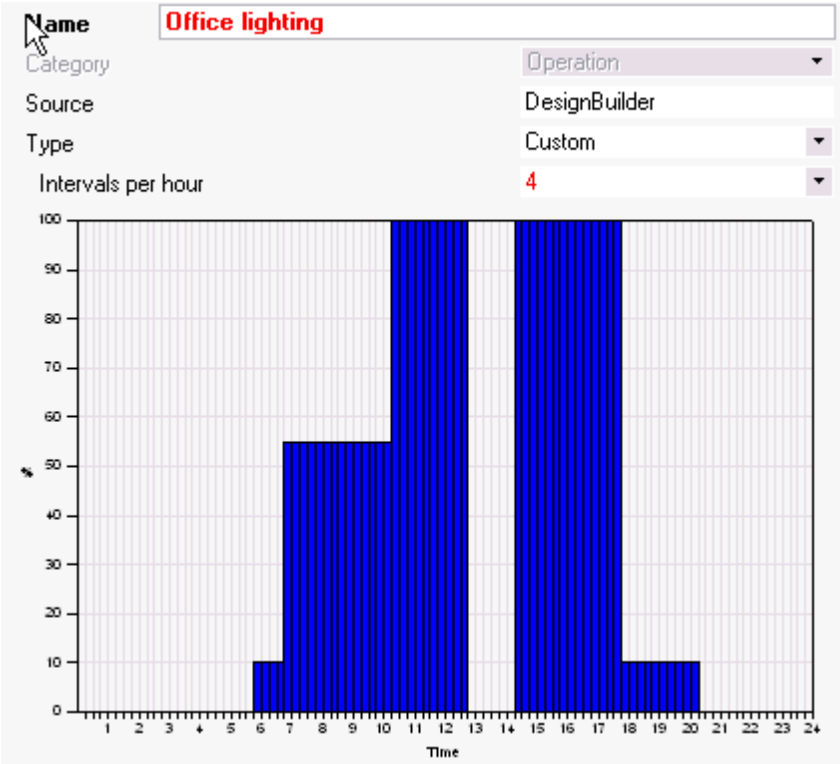
Most of these weather files are composite files from multiple years. Each month has been selected to be representative of that month for the period of record. Representative of the normal patterns for that month not the average. The selection of months is usually based on a weighting of temperature, humidity, wind, and solar. There are some variations among the weighting, most are similar to the TMY2 done in the US in the 1990s:

http://rredc.nrel.gov/solar/pubs/tmy2/

You can find the details of the file format in the AuxiliaryPrograms.pdf EnergyPlus document.

5.7 Profiles

Profiles define the variation in occupancy, equipment usage or temperature over the course of a single day. They are used as building blocks in the definition of Schedules.



There are 3 types of profile:

1. **Constant** - has the same value all day. Enter the constant value for the profile
2. **Single period** - define the 'on' period by setting the start and end times for the profile using the mouse. The operation is assumed to be 'off' for the rest of the day
3. **Custom** - the profile is defined by a number of intervals, each of which can have a different value.

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There are two ways to set interval values:

3.a. To change the value for a single interval (single histogram bar) select the top of the histogram bar and drag up/down using the LEFT mouse button.

3.b. To apply a constant value over a range of intervals select the top of the histogram bar which has the required value and drag left/right over the range of intervals to be set using the RIGHT mouse button.

The figure above shows an example custom profile.

Profile data can be accessed:

- from the Components tab on the opening screen (to view/edit library components if no file is open),
- from the Components tab in the Navigator panel (to view/edit model components if a file is open),
- by clicking on the Edit button when selecting profiles from a list in the Schedules dialog.

5.8 Defining setpoint temperature schedules

SCHEDULES TIMING MODEL OPTION

Operation of heating and cooling equipment is defined by selecting a **Schedule** under the Heating, Cooling and Operation headers on the HVAC tab. These schedules are used to generate both the heating/cooling availability schedule and the temperature setpoint schedules used in the simulations. Schedule values greater than 0.5 indicate the system is in full operation controlling temperature to the main heating/cooling setpoint, values between 0 and 0.5 indicate the equipment in setback mode and values of 0 indicate that the equipment is switched off. See Table below.

Value	Heating/Cooling Equipment Operation
0	Equipment is **off**
> 0.5	Equipment is controlled using the **main** temperature setpoint data (Activity tab)
0 < Value <= 0.5	Equipment is controlled using the **setback** temperature setpoint data (Activity tab)

Notes

1. When using 7/12 Schedules, for 0.5 read 50% etc.
2. When using **2-Single period** profiles with 7/12 Schedules to generate temperature setpoints the 'Off' periods are modelled using setback temperatures, i.e. the system is not switched off. If you wish the system to switch off outside main heating/cooling hours use the **3-Custom** profile type.
3. If the setback temperature set does not appear to affect results, this may be because the heating/cooling operation schedule selected uses only 0 and 1, not the 0.5 required to access setback temperature (see table above).

TYPICAL WORKDAY TIMING MODEL OPTION

You can define the operation of heating and cooling equipment by entering **Typical workday** start and end times and seasonal operation under the Heating and Operation headers on the HVAC tab.

This data is used to generate both the heating/cooling availability schedule and the temperature setpoint schedule used in the simulations.

The equipment is switched on between the On and Off times (8am and 6pm in the example below). During this time the equipment is controlled using the **main** temperature setpoint (Activity tab). At other times and during weekends the equipment is controlled using the **setback** temperature setpoint. Weekends are

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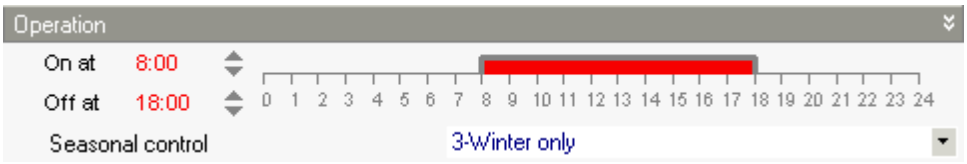
defined on the Activity tab at the building level under Occupancy by setting the number of working days per week.

The Seasonal control data allows you to set times when the equipment is switched off altogether. For example the heating system data shown below indicates that the heating system will be switched on during the winter only and switched off in the summer.



5.9 Textures

Textures are used to represent the external surface of building constructions in the rendered views in the Visualisation Screen.

Select the texture file and the real-world width and height represented by the texture. Textures are associated with materials and used to render the model in the Visualisation Screen.

DesignBuilder comes with a library of textures. Future versions of the software will allow user-defined textures to be added to the library but version 1.0 does not allow this.

Note: If an image does not appear under the Image header this means that the selected file is not installed.

Texture data can be accessed:

- from the Components tab on the opening screen (to view/edit library components if no file is open),
- from the Components tab in the Navigator panel (to view/edit model components if a file is open),
- by double-clicking on the texture icon in the model data,
- by clicking on the Edit button when selecting textures from a list.

5.10 Window Gas

Window Gas component data is used to define the thermal properties of the cavity fill gas between window Panes in Glazing components.

The gas which fills the inter-glazing cavity affects the heat transfer through the assembly but has almost no effect on the solar heat gain or the visible light transmission. Air, of course, is the most common cavity fill gas, but the use of an inert gas (typically argon or krypton) can significantly reduce window heat transfer. Krypton and argon are colourless, odourless and non-toxic. Argon is the most commonly-used fill gas because it offers good thermal performance at low cost. Krypton is more effective at reducing heat loss, but is roughly 200 times more expensive than argon per unit volume. Because krypton works best at smaller pane spacings (8 mm), it is often used in triple and quadruple-glazed windows to minimize the overall thickness of the unit. Other types of gases are used (e.g. sulphur hexafluoride (SF6) and carbon dioxide (CO2)) to reduce sound transmission, but these gases do not offer the improved thermal performance of the inert gases.

Category

This is the gas type. Select from:

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- Air
- Argon
- CO2
- Krypton
- Other
- SF6
- Xenon

The window gas you are defining does not fit with the available options select **Other.** Select **Air** for an air gap.

Thickness

Enter the thickness of the inter-glazing cavity.

Custom material properties

The window gas properties of the gases Air, Argon, Krypton, Xenon are known by EnergyPlus and so no further data is required for these gases.

For CO2, Other and SF6 you must enter custom properties.

CUSTOM GASES ONLY

If you elect to enter custom material properties then you must enter the details. The A and B coefficients are those in the following expression that gives a property value as a function of temperature in degrees K:

Property = Coefficient_A + Coefficient_B * Gas_Temperature (K)

Conductivity Coefficient A

The A coefficient for gas conductivity (W/m-K).

Conductivity Coefficient B

The B coefficient for gas conductivity (W/m-K2).

Viscosity Coefficient A

The A coefficient for gas viscosity (kg/m-s).

Viscosity Coefficient B

The B coefficient for gas viscosity (kg/m-s-K).

Specific Heat Coefficient A

The A coefficient for gas specific heat (J/kg-K).

Specific Heat Coefficient B

The B coefficient for gas specific heat (J/kg-K2).

Molecular Weight

The molecular weight (mass) of the gas (Kg/kmol).

Window gas component data can be accessed:

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- from the Components tab on the opening screen (to view/edit library components if no file is open),
- from the Components tab in the Navigator panel (to view/edit model components if a file is open),
- by clicking on the Edit button when selecting window gases from a list.

5.11 Metabolic Rate Templates

Metabolic rate data defines a category of human metabolic output. The metabolic rate can be selected in Model data on the Activity tab by choosing a Metabolic rate component.

The metabolic rate per person data is supplied to EnergyPlus which multiplies it by the number of people in the zone as the starting point for occupancy heat emission calculations.

Metabolic rate data can be found in the ASHRAE Handbook of Fundamentals, Chapter 8, Table 5.

DesignBuilder data is derived from this data and is for adult males having typical surface area of 1.8m2. For women multiply the adult male value by 0.85 and for children multiply by 0.75.

Component data can be accessed:

- from the Components tab on the opening screen (to view/edit library components if no file is open),
- from the Components tab in the Navigator panel (to view/edit model components if a file is open),
- by clicking on the Edit button when selecting window gases from a list.

Background

Heat is generated in the human body by oxidation at a rate called the metabolic rate. This heat is dissipated from the body surface and respiratory tract by a combination of radiation, convection and evaporation. The relative proportions of sensible and latent heat from people is a complex function of the metabolic rate and the environmental conditions.

EnergyPlus uses a polynomial function to divide the heat gain into sensible and latent portions.
More details can be found in the EnergyPlus EngineeringDoc.pdf documentation.

5.12 Local Shading

General tab on Local Shading Dialog.

Local Shading Components are used to define simple generic shading devices to apply to the Windows in the model.

Enter the name and category for the local shading data set.

Overhangs, louvres and sidefins can be specified either individually (e.g. just overhangs) or in combination (e.g. sidefins combined with louvres).

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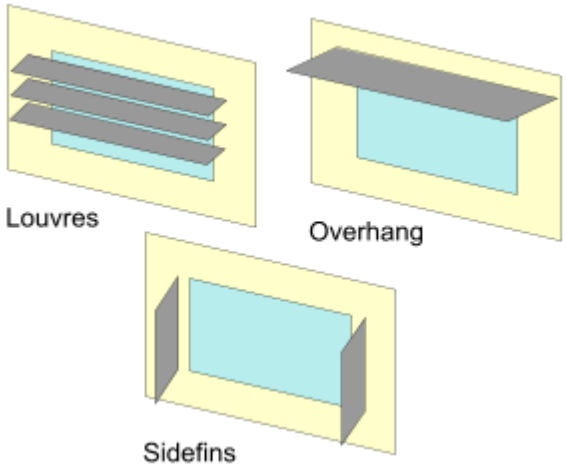

Local Shading component data can be selected from the Openings tab in Model Data and is applied to all windows on the surface, including custom windows.

The data applies only to external glazing - roof and internal glazing do not use local shading data.

Overhang, louvre and sidefin blades are all assumed to be 100% opaque and made of the material specified on this tab.

Note: the DesignBuilder Local shading devices allow a range of different overhangs, side fins and louvres to be defined, but if you need to model a shading device not covered by the standard mechanism, you can draw custom shading devices using Component blocks.

There are four tabs on the Local Shading dialog:

- General
- Louvres
- Sidefins
- Overhangs

Local shading data can be accessed:

- from the Components tab on the opening screen (to view/edit library components if no file is open),
- from the Components tab in the Navigator panel (to view/edit model components if a file is open),
- by double-clicking on the local shading icon on the Openings tab in the model data,
- by clicking on the Edit button when selecting local shading devices from a list.

5.12.2 Louvres

Louvres tab on Local Shading Dialog.

Enter details on the louvres, if fitted.

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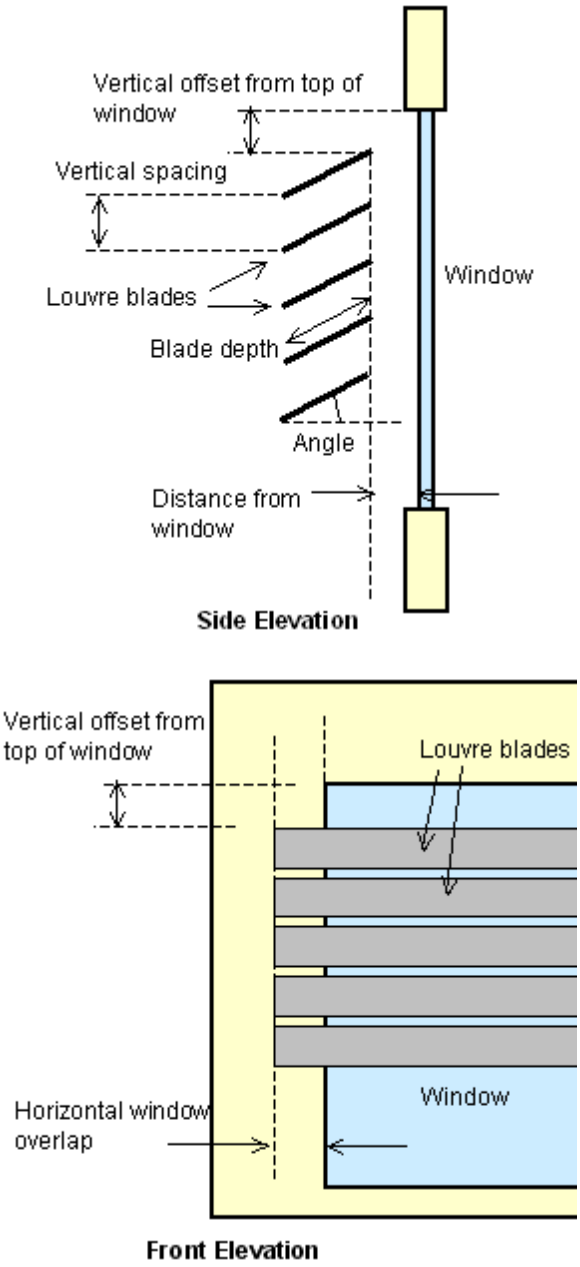

The number of louvres is a maximum value and if the window is not high enough to accommodate the requested number of louvres blades, any louvres blades which would be positioned below the window are not added.

5.12.3 Sidefins

Sidefins tab on Local Shading Dialog.

Enter details on the sidefins, if fitted.

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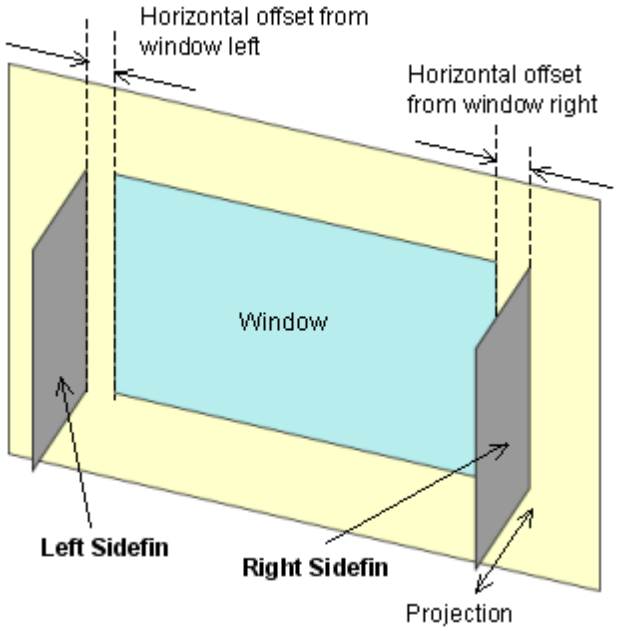
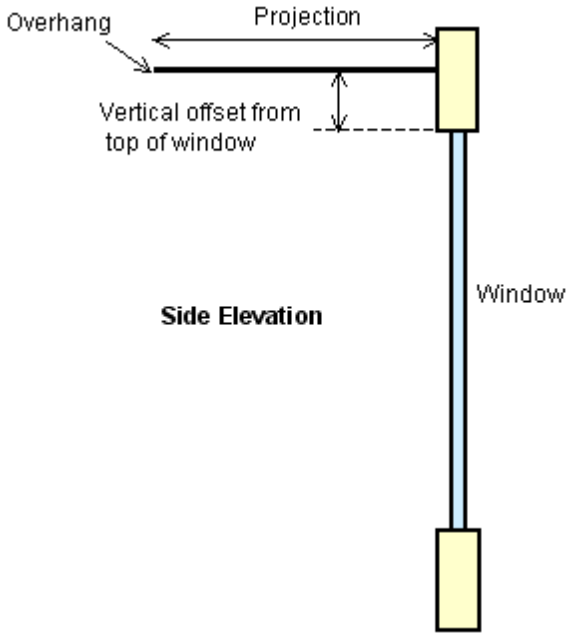


5.12.4 Overhangs

Overhangs tab on Local Shading Dialog.

Enter details on the overhangs if fitted.



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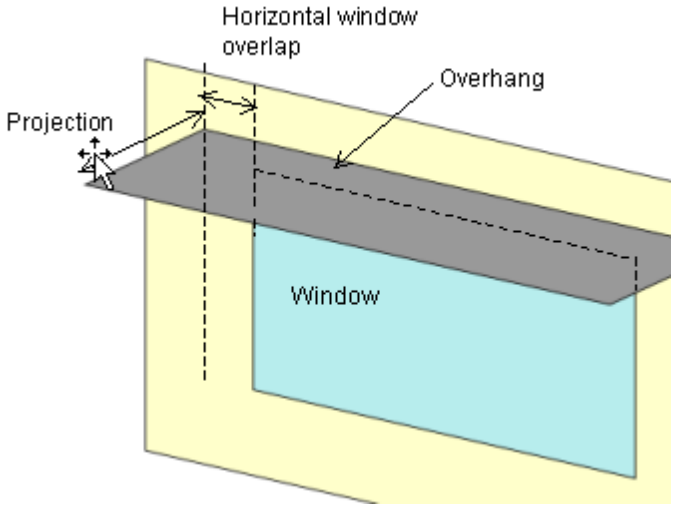

5.13 Window Blinds

Window blind components can be selected for external glazing, roof glazing and interior glazing from the Openings tab in the Model Data.

There are four types of window blinds, as selected in the Category data on the General tab:

- Slat - slatted blinds which have different transmission properties with solar position.
- Shade - assumed perfectly diffusing.
- Transparent insulation - transparent insulation material to be positioned on the outer surface of an external wall.
- Electrochromic switching - switchable visible and solar properties based on solar gain.

Window blind component data can be selected from the window shading data on the Openings tab in Model Data and is applied to all windows on the surface, including custom windows.

The data applies only to external and roof glazing, internal windows cannot have window blinds.

Window blinds component data can be accessed:

- from the Components tab on the opening screen (to view/edit library components if no file is open),
- from the Components tab in the Navigator panel (to view/edit model components if a file is open),
- by double-clicking on the window blinds icon on the Openings tab in the model data,
- by clicking on the Edit button when selecting window blinds from a list.

5.13.1 General

General tab on Window Blinds Dialog.

Enter the name and category for this Window blinds data set.

5.13.2 Slat Data

Slat data tab on Window Blinds Dialog.

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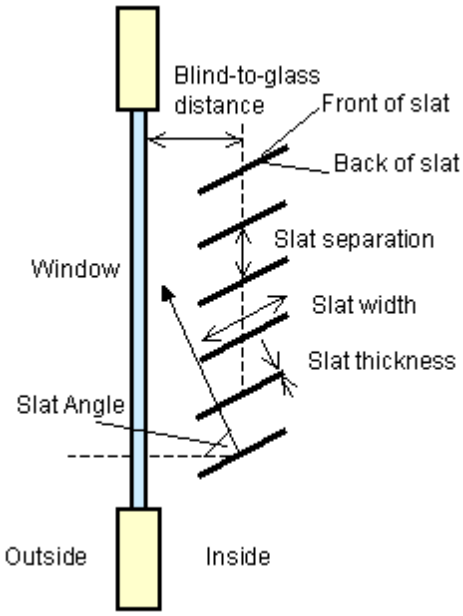
This object specifies the properties of a window blind consisting of flat, equally-spaced slats. Unlike window shades, which are modelled as perfect diffusers, window blinds have solar and visible transmission and reflection properties that strongly depend on slat angle and angle of incidence of solar radiation. When in place, the blind is assumed to cover all of the glazed part of the window, including dividers; it does not cover any of the window frame, if present. The plane of the blind is assumed to be parallel to the glazing. When the blind is retracted it is assumed to cover none of the window. The solar and thermal effects of the blind's support strings, tapes or rods are ignored. Slat curvature, if present, is ignored.



The slat angle is the angle between the glazing outward normal to the slat outward normal. A slat angle of 0° sets slats to be vertical and an angle of 90° sets them to be horizontal.

A slatted blind can be applied ***inside***, ***outside*** or ***mid-pane***.

SLAT PROPERTIES

Blind to Glass Distance

For interior and exterior blinds, the distance from the mid-plane of the blind to the adjacent glass (m). See schematic above. Not used for between-glass blinds. As for window shades this distance is used in calculating the natural convective air flow between glass and blind that is produced by buoyancy effects.

Slat Orientation

The choices are Horizontal and Vertical. "Horizontal" means the slats are parallel to the bottom of the window; this is the same as saying that the slats are parallel to the X-axis of the window. "Vertical" means the slats are parallel to Y-axis of the window.

Slat Width

The width of the slat measured from edge to edge.

Note: if the Blind is applied mid-pane, the gap between the inner pane and the second pane must be at least large enough to accommodate the slat width. The gap thickness is defined by the Window gas selected in the Glazing component.

Slat Separation

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The distance between the front of a slat and the back of the adjacent slat.

Slat Thickness

The distance between the faces of a slat.

Slat Angle

The angle (degrees) between the glazing outward normal and the slat outward normal, where the outward normal points away from the front face of the slat (degrees).

Minimum Slat Angle

The minimum allowed slat angle (degrees). Used only if WindowProperty:ShadingControl (for the window that incorporates this blind) varies the slat angle (i.e., the WindowProperty:ShadingControl has Type of Slat Angle Control for Blinds =ScheduledSlatAngle or BlockBeamSolar). In this case, if the program tries to select a slat angle less than Minimum Slat Angle it will be reset to Minimum Slat Angle. (Note that if the Minimum Slat Angle itself is less than the minimum allowed by Slat Width, Slat Separation and Slat Thickness, it will be reset to that minimum.)

Maximum Slat Angle

The maximum allowed slat angle (degrees). Used only if WindowProperty:ShadingControl (for the window that incorporates this blind) varies the slat angle (i.e., the WindowProperty:ShadingControl has Type of Slat Angle Control for Blinds = ScheduledSlatAngle or BlockBeamSolar). In this case, if the program tries to select a slat angle greater than Maximum Slat Angle the slat angle will be reset to Maximum Slat Angle. (Note that if the Maximum Slat Angle itself is greater than the maximum allowed by Slat Width, Slat Separation and Slat Thickness, it will be reset to that maximum.)

Slat Conductivity

The thermal conductivity of the slat.

SLAT BEAM SOLAR PROPERTIES

Slat Beam Solar Transmittance

The beam solar transmittance of the slat, assumed to be independent of angle of incidence on the slat. Any transmitted beam radiation is assumed to be 100% diffuse (i.e., slats are translucent).

Front Side Slat Beam Solar Reflectance

The beam solar reflectance of the front side of the slat, assumed to be independent of angle of incidence (matte finish). This means that slats with a large specularly-reflective component (shiny slats) are not well modelled.

Back Side Slat Beam Solar Reflectance

The beam solar reflectance of the back side of the slat, assumed to be independent of angle of incidence (matte finish). This means that slats with a large specularly-reflective component (shiny slats) are not well modelled.

SLAT DIFFUSE SOLAR PROPERTIES

Slat Diffuse Solar Transmittance

The slat transmittance for hemispherically diffuse solar radiation. This value should equal “Slat Beam Solar Transmittance.”

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Front Side Slat Diffuse Solar Reflectance

The front-side slat reflectance for hemispherically diffuse solar radiation. This value should equal “Front Side Slat Beam Solar Reflectance.”

Back Side Slat Diffuse Solar Reflectance

The back-side slat reflectance for hemispherically diffuse solar radiation. This value should equal “Back Side Slat Beam Solar Reflectance.”

SLAT BEAM VISIBLE PROPERTIES

Slat Beam Visible Transmittance

The beam visible transmittance of the slat, assumed to be independent of angle of incidence on the slat. Any transmitted visible radiation is assumed to be 100% diffuse (i.e., slats are translucent).

Front Side Slat Beam Visible Reflectance

The beam visible reflectance on the front side of the slat, assumed to be independent of angle of incidence (matte finish). This means that slats with a large specularly-reflective component (shiny slats) are not well modeled.

Back Side Slat Beam Visible Reflectance

The beam visible reflectance on the front side of the slat, assumed to be independent of angle of incidence (matte finish). This means that slats with a large specularly-reflective component (shiny slats) are not well modeled.

SLAT DIFFUSE VISIBLE PROPERTIES

Slat Diffuse Visible Transmittance

The slat transmittance for hemispherically diffuse visible radiation. This value should equal “Slat Beam Visible Transmittance.”

Front Side Slat Diffuse Visible Reflectance

The front-side slat reflectance for hemispherically diffuse visible radiation. This value should equal “Front Side Slat Beam Visible Reflectance.”

Back Side Slat Diffuse Visible Reflectance

The back-side slat reflectance for hemispherically diffuse visible radiation. This value should equal “Back Side Slat Beam Visible Reflectance..”

SLAT INFRARED PROPERTIES

Slat Infrared Hemispherical Transmittance

The slat Infrared transmittance. It is zero for solid metallic, wooden or glass slats, but may be non-zero in some cases (e.g., thin plastic slats).

Front Side Slat Infrared Hemispherical Emissivity

Front-side hemispherical emissivity of the slat. Approximately 0.9 for most materials. The most common

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exception is bare (unpainted) metal slats or slats finished with a metallic paint.

Back Side Slat Infrared Hemispherical Emissivity

Back-side hemispherical emissivity of the slat. Approximately 0.9 for most materials. The most common exception is bare (unpainted) metal slats or slats finished with a metallic paint.

OPENINGS

The openings data allows you to define the distance between the blind and the window and also define the fraction of the blind surface that is open to air flow on each side of the blind. The following opening multipliers are defined in the same way as for window shades. Note that, unlike window shades, there is no input for Air-Flow Permeability; this is automatically calculated by the program from slat angle, width and separation.

Blind Top Opening Multiplier

Defined as for Shades.

Blind Bottom Opening Multiplier

Defined as for Shades.

Blind Left-Side Opening Multiplier

Defined as for Shades.

Blind Right-Side Opening Multiplier

Defined as for Shades.

5.13.3 Shade/Transparent Insulation Data

Shade data tab on Window Blinds Dialog.

Shade blinds can be used for diffusing materials such as drapery and translucent roller shades. For slat-type shading devices, like Venetian blinds, that have a strong angular dependence of transmission, absorption and reflection, it is better to use the Slat option.

You can specify the properties of window shade materials. Reflectance and emissivity properties are assumed to be the same on both sides of the shade. Shades are considered to be perfect diffusers (all transmitted and reflected radiation is hemispherically-diffuse) with transmittance and reflectance independent of angle of incidence. When in place, the shade is assumed to cover all of the glazed part of the window, including dividers; it does not cover any of the window frame, if present. The plane of the shade is assumed to be parallel to the glazing.

Transmittance and reflectance values for drapery material with different colour and openness of weave can be obtained from manufacturers or determined from 2001 ASHRAE Fundamentals, Chapter 30, Fig. 31.

A diffusing blind can be applied inside, outside or mid-pane.

SHADE PROPERTIES

Thickness

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Thickness of the shade material. If the shade is not flat, such as for pleated pull-down shades or folded drapery, the average thickness normal to the plane of the shade should be used.

Note: if the Shade is applied *mid-pane*, the gap between the inner pane and the second pane must be at least large enough to accommodate the thickness. The gap thickness is defined by the Window gas selected in the Glazing component.

Conductivity

Shade material conductivity. Transmittance averaged over the solar spectrum. Assumed independent of incidence angle.

Solar reflectance

Reflectance averaged over the solar spectrum. Assumed same on both sides of shade and independent of incidence angle.

Visible transmittance

Transmittance averaged over the solar spectrum and weighted by the response of the human eye. Assumed independent of incidence angle.

Visible reflectance

Reflectance averaged over the solar spectrum and weighted by the response of the human eye. Assumed same on both side of shade and independent of incidence angle.

Thermal hemispherical emissivity

Effective long-wave emissivity. Assumed same on both sides of shade. We can approximate this effective emissivity, εeff, as follows. Let η be the “openness” the shade, i.e., the ratio of
the area of openings in the shade to the overall shade area (see Air-Flow Permeability, below). Let the emissivity of the shade material be ε. Then

$$\varepsilon_{eff} \approx \varepsilon .(1 - \eta)$$

For most non-metallic materials ε is about 0.9.

Thermal transmittance

Effective long-wave transmittance. Assumed independent of incidence angle. We can approximate this effective long-wave transmittance, τeff, as follows. Let η be the “openness” the shade, i.e., the ratio of the area of openings in the shade to the overall shade area. Let the long-wave transmittance of the shade material be τ. Then

$$T_{eff} \approx \eta + T.(1 - \eta)$$

For most materials τ is very close to zero, which gives

$$T_{eff} \approx \eta$$

OPENINGS

Shade to glass distance

Distance from shade to adjacent glass. This is denoted by s in Figures below. If the shade is not flat, such as for pleated pull-down shades or folded drapery, the average shade-to-glass distance should be used. (The shade-to-glass distance is used in calculating the natural convective air flow between glass and shade produced by buoyancy effects.). Note used for between-glass shades. In the following, H is the glazing height and W is the glazing width.

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Shade top opening multiplier

Effective area for air flow at the top of the shade divided by sW, the horizontal area between glass and shade (see Figures below).

Shade bottom opening multiplier

Effective area for air flow at the bottom of the shade divided by sW, the horizontal area between glass and shade (see Figures below).

Shade left-side opening multiplier

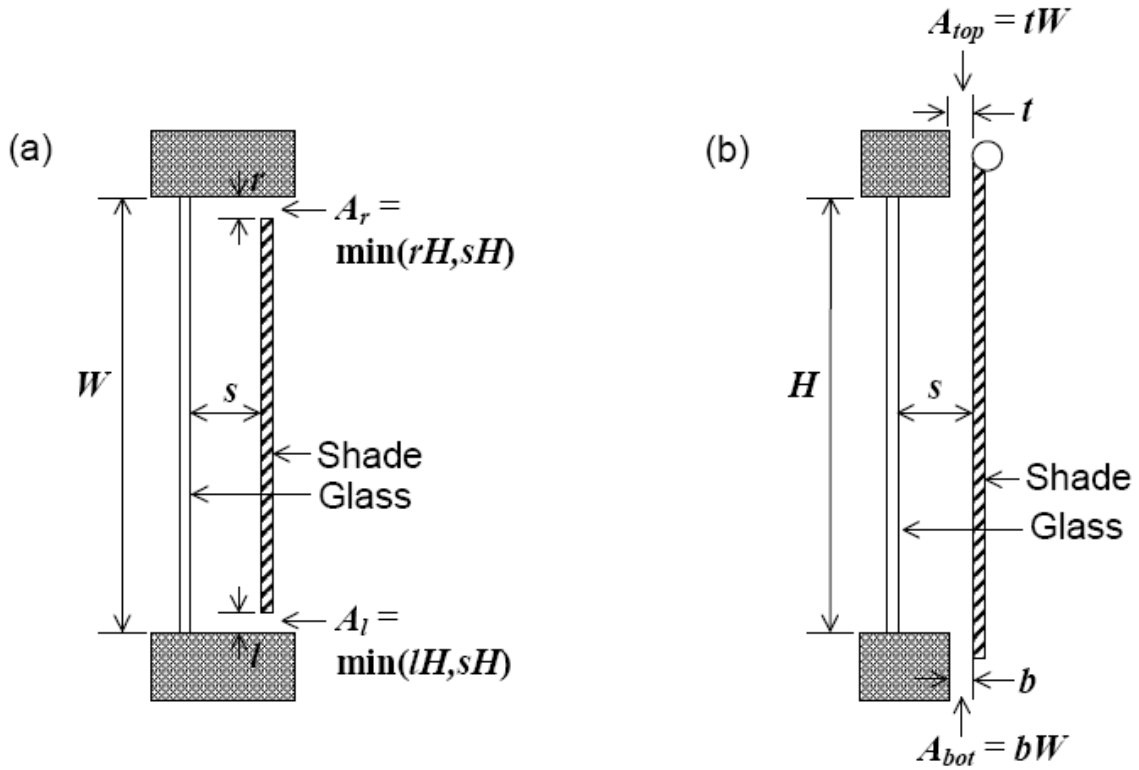
Effective area for air flow at the left side of the shade divided by sH, the vertical area between glass and shade (see Figures below).

Shade right-side opening multiplier

Effective area for air flow at the right side of the shade divided by sH, the vertical area between glass and shade (see Figures below).

Shade air-flow permeability

The fraction of the shade surface that is open to air flow, i.e., the total area of openings (“holes”) in the shade surface divided by the shade area, HW. If air cannot pass through the shade material, Air-Flow Permeability = 0. For drapery fabric and screens the Air-Flow Permeability can be taken as the “openness” of the fabric (see 2001 ASHRAE Fundamentals, Chapter 30, Fig. 31), which is 0.0 to 0.07 for closed weave, 0.07 to 0.25 for semi-open weave, and 0.25 and higher for open weave.



Vertical section (a) and perspective view (b) of glass and interior shade layers showing variables used in the gap air flow analysis. In (b), the air-flow opening areas Abot, Atop, Al, Ar and Ah are shown schematically. See Engineering Manual for definition of thermal variables.

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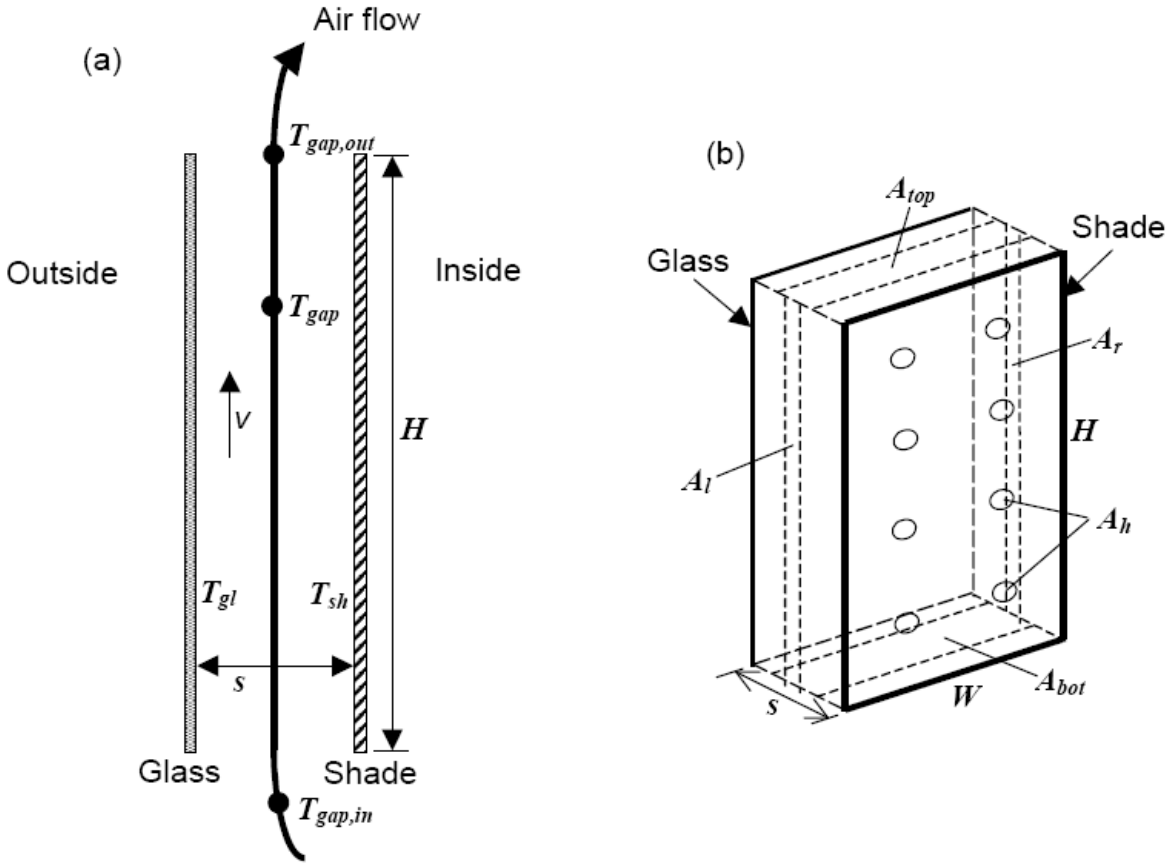

Examples of air-flow openings for an interior shade covering glass of height H and width W. Not to scale.
(a) Horizontal section through shade with openings on the left and right sides (top view).
(b) Vertical section through shade with openings at the top and bottom (side view).

In (a) Left-Side Opening Multiplier = Al /sH = min(l/s,1) and Right-Side Opening Multiplier = Ar /sH = min(r/s,1). In (b) Top Opening
Multiplier = Atop /sW = t/s and Bottom Opening Multiplier = Abot /sW = b/s.

5.13.4 Electrochromic Switching

Electrochromic tab on Window Blinds Dialog.

Enter the electrochromic switchable pane material.

This pane will be used in place of the standard outer glazing pane according to the control data in the Model Data.

More information on Electrochromic glazing.

Note: that the blind position in Openings Model Data must be 'Switchable' to use electrochromic switchable shading

5.14 Vents

Vent Components have a coefficient of discharge and a texture (used to represent a vent in the rendered view).

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More information about vents.

There are two tabs on the Vents dialog:

- General
- Airflow

Vent component data can be accessed:

- from the Components tab on the opening screen (to view/edit library components if no file is open),
- from the Components tab in the Navigator panel (to view/edit model components if a file is open),
- by double-clicking on the vent icon on the Openings tab in the model data,
- by clicking on the Edit button when selecting vents from a list.

5.14.1 General

General tab on Vents Dialog.

Enter the name and category for this vent component.

The texture is used to represent the vent in rendered views.

5.14.2 Airflow

Airflow tab on Vents Dialog.

Enter the discharge coefficient for this vent component.

You can select this vent from the Openings model data.

Note: The discharge coefficient is only used in thermal simulations when the Natural ventilation Model option is set to **Calculated**.

5.15 Holidays

A 'Holiday schedule' is a list of intervals of one or more day which identify the days the building may be unoccupied. The holiday intervals are listed in order, with holidays most likely to be taken at the top of the list. The Holidays per year Model data on the Activities tab at building level defines how many holidays are taken and this 'Holiday schedule' defines which days are holidays. Days are selected from the top of the list working downwards. The data is used to specify EnergyPlus 'SpecialDayPeriods'.

There are two tabs on the Holidays dialog:

- General
- List

Holiday data can be accessed:

- from the Components tab on the opening screen (to view/edit library components if no file is open),
- from the Components tab in the Navigator panel (to view/edit model components if a file is open),
- by double-clicking on the holidays icon on the Activity tab in the model data,
- by clicking on the Edit button when selecting holidays from a list.

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5.15.1 General

General tab on Holidays Dialog.

Enter the Region and Category for the Holiday Schedule.

5.15.2 Holiday List

List tab on Holidays Dialog.

Holidays are selected from the top of the list, so holidays which are most likely to be taken should be defined first (so they are positioned at the top of the list).

Use the controls in the Info panel to add, edit and delete holidays.

Valid holiday date formats are defined in Compact Schedules: EnergyPlus Date Definition

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6 Templates

DesignBuilder templates allow you to quickly load data into your model in bulk. If you often work with similar types of buildings you may find it useful to create your own templates. This will allow you to load the same data into any models you work with in the future.

DesignBuilder Templates are databases of typical generic data. The following templates are available:

- Activity templates
- Construction templates
- Glazing templates
- Facade templates
- HVAC templates
- Location Templates
- Hourly weather data
- Pressure coefficients
- Metabolic rates
- Cracks
- Legislative regions
- Energy codes
- Sectors
- World time zones (predefined, not editable)

Library Templates are loaded into the model at the time the dsb file is created and from then on, they are associated specifically with this model and so are known as **Model Templates.** Any changes made to the Library Templates do not affect existing building models because they reference their own set of Model Templates. The latest set of library templates can be loaded into a model using the Import library components and templates to model command.

Also templates are used for loading data into models, so ***a change to a template will not affect the model until the data is loaded***.

New Template functionality in version 1.3
Note that the behaviour of templates changed starting with version 1.3. In previous versions templates were always associated with the application and never with the model. In version 1.3 templates are loaded to the model in the same way that components are.

Managing template data

You can edit and move template data around in various ways:

1. Add, Edit, Delete, Import and Export Template library data from the Opening Screen - Template Libraries tab.
2. If a model file is loaded you can edit Model templates from the Templates tab in the Navigator panel (Learning mode switched off) or by using the Data management panel on the right of the screen (Learning mode switched on).
3. In either case, **to add a template**, open up the template type you wish to define by clicking on the + to the left of the template icon, then click on the category of template you wish to define. Now click on the Green '+' to add a template of the selected category.
4. Import/export Model template using the **File > Export > Library data** menu command to create a . ddf file with the .dsb model file open.
5. To import the previously exported Model template data to the Template library close the .dsb file and import the .ddf file to the library.
6. Load the latest library templates into your model using the **Import library components and templates to model** command from the Tools menu when a model is loaded. Any new data that has

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been added to the library since the model file was created will be imported to the model. Also if there have been any changes to library template data, this new data will overwrite the original data.

Important Note: any template you add while a model is open will be added to Model templates and not to the Template library. It will only be added to the library and hence to new models if you export the new component model data in .ddf form and import the .ddf file to the library before creating the new model.

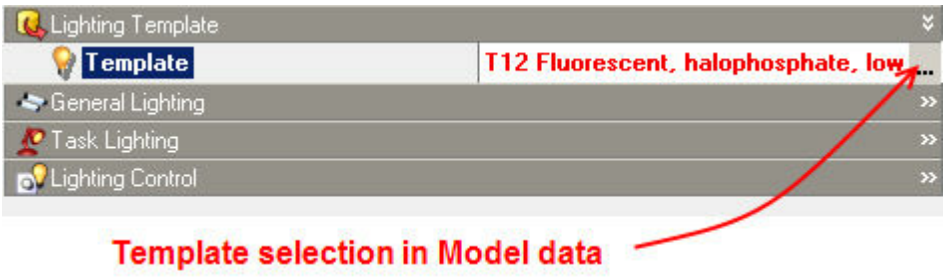
Loading to Model Data

Each tab in the Model data has the name of the template last used to load the data at the top (shown in bold). At the top of the HVAC tab is the HVAC Template, at the top of the Lighting tab is the Lighting Template etc. This is the template that was previously used to load the default data, but you can load different data from a different template by clicking on the template data, then clicking again on the '...' to the right of the template data and making a new selection. When you make the selection, the appropriate data is loaded from the template into the model.

Note 1: It is important to understand that the template data itself does not contribute to the model until it is loaded in.

Note 2: Changes to the model data relative to the data in the template last loaded are highlighted in bold to show that it overrides the template data previously loaded.

Note 3: Another way to load data to a model from templates is to use the Load Data From Template tool.



Colour code

Templates are coded by colour in the Navigator panel and selection lists as follows:

Red shows user data, i.e. data that was not supplied by DesignBuilder.
Green indicates that the data is derived from a reputable national or international source.
Blue indicates that the data is generated internally by DesignBuilder.
Black is used for other data.

6.1 Activity Templates

Activity templates are used as a source of default activity (building usage) data for building models.

The data covers occupancy, equipment usage and suitable design internal temperatures, illuminance levels and ventilation rates per person.

There are five tabs on the Activity Template dialog:

- General
- All gains
- Occupancy
- Other gains
- Environmental

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Template data can be accessed:

- from the Templates tab on the opening screen (if no file is open),
- from the Templates tab in the Navigator panel (if a file is open),
- by double-clicking on the template icon in the model data,
- by clicking on the Edit button when selecting templates from a list.

6.1.1 Activity Templates - General

General tab on Activity Templates Dialog.

Enter the name, category, sector and region for this activity template.

Enter the region as 'General' if you want the data to be generally available (i.e. not restricted to a particular region).

The floor shade colour is used to shade the floor of the model at block and zone levels to give a quick indication of the usage of the building in various areas.

6.1.2 Activity Templates - All Gains

All Gains tab on Activity Templates Dialog.

The lumped gains into the space from people, equipment, lights etc.
Data on this tab is only used when the Gains option is set to 'Lumped'.

6.1.3 Activity Templates - Occupancy

Occupancy tab on Activity Templates Dialog.

Occupancy levels and times, metabolic activity on this tab is used when the 'Gains' option is set to 'Early' or 'Detailed'.

Set the metabolic rate according to the level of activity within the space. The metabolic factor accounts for people of various sizes. Enter 1.00 for men, 0.85 for women, 0.75 for children, or you can use an average value if there is a mix of sizes.

The Workday profile is used when the 'Timing' option is set to 'Typical workday' and the Schedule data is used when the Timing option is set to '7/12 Schedules'.

6.1.4 Activity Templates - Other Gains

Other Gains tab on Activity Templates Dialog.

Data on this tab is used when the 'Gains' option is set to 'Early'. DHW Data is always used.

The default gains into the space from computers, office equipment, catering, process and miscellaneous equipment for this activity.

Also hot water consumption rate per person per day and the operation schedules are defined here.

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6.1.5 Activity Templates - DHW

Enter the Domestic Hot Water (DHW) volumetric consumption per unit of floor area per day and the operation schedule.

In DesignBuilder the amount of DHW consumed is considered to be a function of the activity. For example, there is a demand assumed to arise from the occupants of an office for activities such as washing hands and washing up cups. This demand is associated with the office rather than the toilet or tea room. Thus the demand from each space needs to be assigned to a DHW system even if the system itself is not present in the space.

6.1.6 Activity Templates - Environmental

Environmental tab on Activity Templates Dialog.

Enter the data related to the environmental and comfort requirements of this activity:

- Heating set-point temperature (if the space is heated).
- Cooling set-point temperature (if the spaces cooled).
- Ventilation set-point temperature
- Illuminance levels required.
- Fresh air levels required per person - defines mechanical ventilation air change rates.

If there is never any heating or cooling, you can leave these set-points.

See Environmental Control under Activity Model Data for more details.

6.2 Construction Templates

Construction templates are used as a source of generic construction data for loading into building models.

The template provides data on the construction of external walls, roofs, floors, partitions, roofs etc and air-tightness data.

There are four tabs on the Construction template dialog:

- General
- Simple
- Standard
- Airtightness

Template data can be accessed:

- from the Templates tab on the opening screen (if no file is open),
- from the Templates tab in the Navigator panel (if a file is open),
- by double-clicking on the template icon in the model data,
- by clicking on the Edit button when selecting templates from a list.

6.2.1 Construction Templates - General

General tab on Construction Templates Dialog.

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Enter the name, source, category and region for this construction template.

6.2.2 Construction Templates - Simple

Simple tab on Construction Templates Dialog.

Data on this tab is used when the Construction model detail is set to **Pre-design**.

Enter default levels of insulation and thermal mass for this construction type.

6.2.3 Construction Templates - Walls

Walls tab on Construction Templates Dialog.

Data on this tab is used when the Construction model detail is set to **Pre-design** or **General** (i.e. it is always used).

Select default walls, partitions for exposed and semi-exposed surfaces for this Constructions template.

You can also select the external and internal wall sub-surface constructions here.

6.2.4 Construction Templates - Roofs/Floors/Slabs/Ceilings

Roofs/Floors/Slabs/Ceilings tab on Construction Templates Dialog.

Data on this tab is used when the Construction model detail is set to **Pre-design** or **General** (i.e. it is always used).

Select default constructions for roofs, floors, slabs and ceiling surfaces for this Constructions template.

You can also select the roof sub-surface construction here.

6.2.5 Construction Templates - Doors

Doors tab on Construction Templates Dialog.

Data on this tab is used when the Construction model detail is set to **Pre-design** or **General** (i.e. it is always used).

Select default door constructions for internal and external doors for this Constructions template.

You can also select the external and internal wall sub-surface constructions here.

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6.2.6 Construction Templates - Airtightness

Airtightness tab on Construction Templates Dialog.

Cracks template

The Cracks template setting indicates the Cracks data template to use as a source for crack data when the Calculated Natural ventilation model option is selected.

Infiltration

The default infiltration rate used when the 'Natural ventilation' model detail level is 'Simple'.

6.2.7 Construction Templates - Thermal mass

Thermal mass tab on Construction Templates Dialog.

Data on this tab is used when the Construction model detail is set to **Pre-design** or **General** (i.e. it is always used).

Enter the default thermal mass construction for this construction template.

See Internal Thermal Mass for more information on defining thermal mass in a model.

6.3 Glazing Templates

Glazing templates are used as a source of default glazing, frame and shading construction data for building models.

There are three tabs on the Glazing Template dialog:

- General
- Glazing
- Shading

Template data can be accessed:

- from the Templates tab on the opening screen (if no file is open),
- from the Templates tab in the Navigator panel (if a file is open),
- by double-clicking on the template icon in the model data,
- by clicking on the Edit button when selecting templates from a list.

6.3.1 Glazing Templates - General

General tab on Glazing Templates Dialog.

Enter the name, category and region for this glazing template.

Enter the region as 'General' if you want the data to be generally available (i.e. not restricted to a particular region). Glazing templates with category '<System>' have their data set up at the time a file is created or when the Legislative region is changed.

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6.3.2 Glazing Templates - Glazing

Glazing tab on Glazing Templates Dialog.

Enter data on the glazing construction, frame and opening area for external glazing, internal glazing and roof glazing.

6.3.3 Glazing Templates - Shading

Shading tab on Glazing Templates Dialog.

Select any shading devices to be applied when this glazing templates is loaded to the model.

6.4 Facade Templates

Facade templates are used to provide a choice of typical simple facade layouts and frame definitions which can be easily loaded into a building model.

There are two tabs on the Facade Template dialog:

- General
- Openings

Template data can be accessed:

- from the Templates tab on the opening screen (if no file is open),
- from the Templates tab in the Navigator panel (if a file is open),
- by double-clicking on the template icon in the model data,
- by clicking on the Edit button when selecting templates from a list.

6.4.1 Facade Templates - General

General tab on Facade Templates Dialog.

Enter the name and category for this Facade Template.

6.4.2 Facade Templates - Openings

Openings tab on Facade Templates Dialog.

Enter the glazing and frame data for the facade. There are a number of standard facade types:

- None - there is no glazing.
- Continuous horizontal - glazing is generated in a continuous horizontal strip using sill height and % glazing.
- Fixed height - glazing is generated with a fixed height at the specified sill height, and width is calculated based on the % glazing. This option uses % glazing but prioritises window height.
- Preferred height - glazing is generated using the window height data and the % glazing, but the window height may be adjusted to achieve the required % glazing. This option uses window and sill

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height but prioritises % glazing.
- Fixed width and height - windows have fixed width and height. This option uses % glazing but prioritises window width and height.
- Fill surface (100%) - the entire surface is filled with glazing and there is no frame.
- If the glazing does not have a frame, uncheck the 'Has a frame?' box.

6.5 Lighting Templates

Lighting templates data sets are used as a source of generic lighting systems for loading into the building data.

There are three tabs on the Lighting Template dialog:

- General
- Output
- Control

Template data can be accessed:

- from the Templates tab on the opening screen (if no file is open),
- from the Templates tab in the Navigator panel (if a file is open),
- by double-clicking on the template icon in the model data,
- by clicking on the Edit button when selecting templates from a list.

6.5.1 Lighting Templates - General

General tab on Lighting Templates Dialog.

Enter the name, category and region for this Lighting Template.

Enter the region as 'General' if you want the data to be generally available (i.e. not restricted to a particular region).

See also Building Model Lighting Data for more information on the use of this template data in the model.

6.5.2 Lighting Templates - Output

Output tab on Lighting Templates Dialog.

Enter the lighting energy for task and general lighting in W/m2/100 lux (W/ft2/100 lux). This data is used for setting up the actual Lighting energy W/m2 data in each zone using:

Lighting energy (W/m2) = Lighting (W/m2/100 lux) x Design lux level (Activity tab) / 100

Substitute ft2 for m2 for equation in IP units.

The 'Output' data is used for generating default lighting loads based on lighting type and required illuminance levels as set in Activity data.

See General Lighting under Building Model Lighting Data for more information on the use of this template data in the model.

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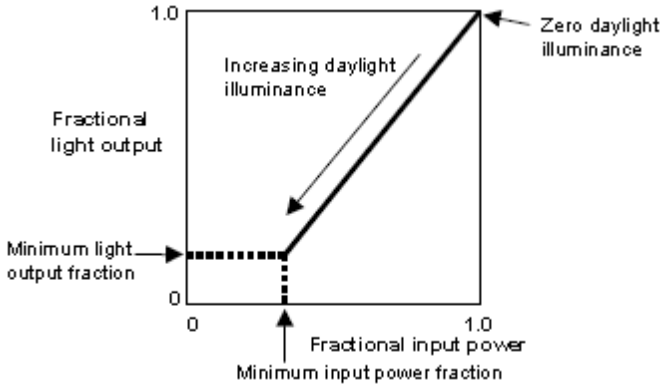
6.5.3 Lighting Templates - Control

Control tab on Lighting Templates Dialog.

If the lighting is to be controlled by the availability of natural daylight, check the 'control' option box and select the type of control.

Continuous Control

For 'continuous' control, the overhead lights dim continuously and linearly from maximum electric power, maximum light output to minimum electric power, minimum light output as the daylight illuminance increases. The lights stay at the minimum point with further increase in the daylight illuminance.



The minimum input power fraction for 'continuous' control type is the lowest power the lighting system can dim down to, expressed as a fraction of maximum input power. For 'continuous/off' lighting control, this is the power fraction reached just before the light switch off completely.
The minimum output fraction for 'continuous' control type, is the lowest lighting output the lighting system can dim down to, expressed as a fraction of maximum light output. This is the fractional light output that the system produces at minimum input power. For 'continuous/off' lighting control, this is the power fraction reached just before the light switch off completely.

Continuous/Off Control

'Continuous/off' control is the same as continuous control except that the lights switch off completely when the minimum dimming point is reached.

Stepped Control

For 'stepped' control, the electric power input and light output vary in discreet, equally spaced steps. The number of steps can be set.

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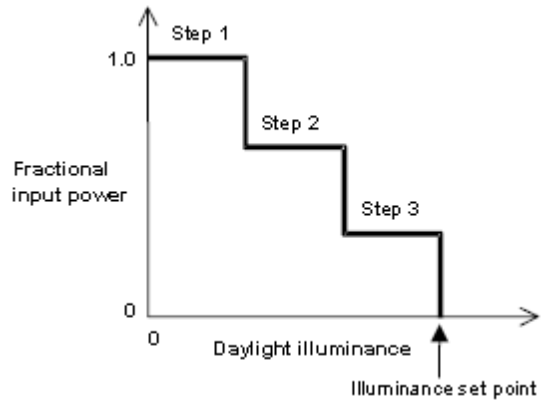

6.6 HVAC Templates

HVAC templates data sets are used as a source of generic heating/cooling and ventilation systems for loading into the building data.

There are four tabs on the HVAC Template dialog:

- General
- Ventilation
- System
- Air temperature distribution

Template data can be accessed:

- from the Templates tab on the opening screen (if no file is open),
- from the Templates tab in the Navigator panel (if a file is open),
- by double-clicking on the template icon in the model data,
- by clicking on the Edit button when selecting templates from a list.

6.6.1 HVAC Templates - General

General tab on HVAC Templates Dialog.

Enter the name, category, sector and region for this HVAC template.

Enter the region as 'General' if you want the data to be generally available (i.e. not restricted to a particular region).

The floor shade colour is used to shade the floor of the model at block and zone levels to give a quick indication of the system type fitted in various areas.

6.6.2 HVAC Templates - Ventilation

Ventilation tab on HVAC Templates Dialog.

Enter the maximum natural/mechanical ventilation rates as appropriate.

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6.6.3 HVAC Templates - System

System tab on HVAC Templates Dialog.

The data on this tab is divided into 'System' (i.e. whole system data), 'Heating' and 'Cooling'.

Auxiliary energy - defines the energy consumption of fans, pumps and other auxiliary equipment when using the 'Simple' HVAC model option. This energy is assumed to be consumed during periods when either heating or cooling systems are operating.

Type - defines the EnergyPlus compact system type when the 'Compact' HVAC model option is set. Select from:

- Unitary single zone - for modelling 'window' air conditioning units and any other system which does not use ducted air
- Unitary multizone - for modelling constant volume air conditioning systems.
- VAV - for modelling variable air volume air conditioning systems.

When using the VAV compact system type you can define the system in more detail using:

- Outside air control type - select either 'Fixed' or 'Proportional'. 'Fixed means that the minimum outside air flow rate is fixed no matter what the actual system flow rate is. Proportional means the minimum outside air flow rate varies in proportion to the total system air flow rate.
- Supply air min flow fraction - is the fraction that the zone VAV box can reduce to based on the supply air maximum flow rate.

Heating/cooling system CoP is the whole system seasonal coefficient of performance including distribution losses when using the 'Simple' HVAC model option.

Boiler/chiller CoP is the seasonal coefficient of performance of the boiler/chiller, excluding any energy consumption by fans, pumps etc and excluding distribution losses..

6.6.4 HVAC Templates - Air Temperature Distribution

Air temperature distribution tab on HVAC Templates Dialog.

By default EnergyPlus assumes that air temperature within a zone is completely uniform (i.e. the air is fully mixed). The data on this tab allows you to set up a temperature gradient which varies dynamically depending on:

- Outside temperature.
- Inside temperature.
- Inside-outside temperature difference.
- Heating load.
- Cooling load.

See Air Temperature Distribution for more information on defining vertical zone temperature profiles (temperature gradients).

6.7 Location Templates

Location Templates are a database of locations from around the world based on ASHRAE design weather data including daylight savings.

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Each Location data set is located within a 'Legislative Region'. Most Regions in Europe include some basic data on the energy codes which apply.

There are four tabs on the Location Template dialog:

- Location
- Winter design weather
- Summer design weather
- Simulation weather

Template data can be accessed:

- from the Templates tab on the opening screen (if no file is open),
- from the Templates tab in the Navigator panel (if a file is open),
- by double-clicking on the template icon in the model data,
- by clicking on the Edit button when selecting templates from a list.

6.7.1 Location Templates - Location

Location tab on Location Templates Dialog.

DesignBuilder Location Templates are located within 'Legislative Regions'. Most regions in Europe include some basic data on the energy codes which apply.

6.7.2 Location Templates - Winter Design Weather

Winter design weather tab on Location Templates Dialog.

The weather data used in winter design calculations is:

- Minimum outside dry-bulb temperature
- Co-incident wind speed and direction.

There are options for 99.6 or 99% confidence (i.e. 0.4 or 1% chance of more extreme winter weather occurring).

6.7.3 Location Templates - Summer Design Weather

Summer design weather tab on Location Templates Dialog.

The weather data used in summer design calculations is:

- Maximum outside dry-bulb temperature
- Minimum outside dry-bulb temperature
- Wet-bulb temperature at the time of the maximum dry-bulb temperature.

Risk can be specified based on dry or wet-bulb temperatures, for 99.6, 99 and 98% confidence (i.e. 0.4, 1 or 2% chance of more extreme weather occurring).

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6.7.4 Location Templates - Simulation Weather

Simulation weather tab on Location Templates Dialog.

DesignBuilder will only use hourly weather data for simulations (winter and summer design calculations use design weather data).

You can add your own Hourly Weather data.

6.8 Crack Templates

Crack data is used when the 'Calculated' natural ventilation option is set. In this case every surface in the model has a crack and its size (characterised by flow coefficient and exponent) is determined by Airtightness as set on the Constructions tab in the Model Data. The value of Airtightness is used as a key to look up corresponding crack sizes in the Cracks database.

The cracks database has been set up empirically to give typical air change rates for each of the five Airtightness categories in a range of building types.

There are five tabs on the Crack Template data dialog:

- General
- Openings
- Walls
- Floors/ceilings
- Roofs

6.8.1 Crack Templates - General

General tab on Crack Templates Dialog.

Tab contains the name and category of the crack template.

6.8.2 Crack Templates - Openings

Openings tab on Crack Templates Dialog.

Enter the characteristics of the cracks around internal and external windows, vents and doors.

Note that the opening crack characteristics are normalised by opening perimeter *lengths*.

6.8.3 Crack Templates - Walls

Walls tab on Crack Templates Dialog.

In reality the porosity of walls is caused by a very large number of small cracks and holes.

DesignBuilder models this porosity using a single equivalent crack. Enter the characteristics this equivalent single crack for internal and external walls.
Note that the crack characteristics are normalised by *surface area*.

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6.8.4 Crack Templates - Floors/Ceilings

Floors/Ceilings tab on Crack Templates Dialog.

In reality the porosity of floors is caused by a very large number of small cracks and holes.

DesignBuilder models this porosity using a single equivalent crack. Enter the characteristics this equivalent single crack for internal and external floors.

Note that the crack characteristics are normalised by *surface area*.

6.8.5 Crack Templates - Roofs

Roofs tab on Crack Templates Dialog.

In reality the porosity of roofs is caused by a very large number of small cracks and holes.

DesignBuilder models this porosity using a single equivalent crack. Enter the characteristics this equivalent single crack for roofs.

Note that the crack characteristics are normalised by *surface area*.

6.9 Legislative Region Templates

A Legislative region in DesignBuilder is typically a whole country or a region, province or state within a country which has its own building control powers.

In current versions of the software a Legislative Region contains information on:

- Local energy codes/building regulations.
- Carbon dioxide emission factors are provided for a range of fuels.

The current regions database is only sparsely populated with useful data (most of that is from countries within Europe). But we expect to expand this in time.

There are three tabs on the Legislative Region Template dialog:

- General
- Standard insulation
- Emissions

Template data can be accessed:

- from the Templates tab on the opening screen (if no file is open),
- from the Templates tab in the Navigator panel (if a file is open),
- by double-clicking on the template icon in the model data,
- by clicking on the Edit button when selecting templates from a list.

6.9.1 Legislative Region Templates - General

General tab on Legislative Region Templates Dialog.

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Enter the name of the Legislative region, the category (country) and a description of the Region.

6.9.2 Legislative Region Templates - Standard Insulation

Standard insulation tab on Legislative Region Templates Dialog.

Data on this type specifies 4 standard insulation levels which apply to this region:

- Uninsulated - typical U-values for buildings in the region which are not insulated
- Stock average - Average (estimated) insulation standards for real buildings in the region. This data is used in some asset rating calculations.
- Mandatory energy code - Defines the maximum U-values allowed in the energy code/building regulations in force in the region.
- Best practice - Defines the U-values to be expected in a state-of-the-art building in the region.

The data on this tab indicates the required maximum U-values.

6.9.3 Legislative Region Templates - Emissions

Emissions tab on Legislative Region Templates Dialog.

The factors on this tab define the amount of carbon dioxide emitted per unit of energy consumed for each of the major fuel types in the region. The CO2 emission factors depend on the mix of technology used to generated the electricity, the quality of the fuel and other factors such as production carbon cost.

6.10 Energy Code Templates

Energy code data is used within DesignBuilder to indicate the mandatory energy performance of building components and/or the whole building.

There are three types of heat transmission code:

1. Envelope component performance
2. Whole building envelope performance
3. Whole building energy performance

You can define the type of energy code by making selections on the next 3 tabs.
If this energy code requires for example that minimum component perforance and whole building energy performance then check both these options.

Template data can be accessed:

- from the Templates tab on the opening screen (if no file is open),
- from the Templates tab in the Navigator panel (if a file is open),
- by double-clicking on the template icon in the model data,
- by clicking on the Edit button when selecting templates from a list.

6.10.1 Energy Code Templates - General

General tab on Energy Code Templates Dialog.

Enter a name and description of this Energy code.

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6.10.2 Energy Code Templates - Envelope (component)

Envelope (component) tab on Energy Code Templates Dialog.

Specifies mandatory maximum U-values through the individual components (walls, windows, roofs etc.).

The data on this tab indicates the required maximum U-values.

6.10.3 Energy Code Templates - Envelope (building)

Envelope (building) tab on Energy Code Templates Dialog.

Sets a limit on the rate of heat transfer through the overall building envelope. The limit is typically set as an average U-value for the overall building envelope.

6.10.4 Energy Code Templates - Energy Performance

Energy performance tab on Energy Code Templates Dialog.

Sets a limit on the rate of heat transfer through the overall building envelope. The limit is typically set as an average U-value for the overall building envelope.

6.11 Sector Templates

Sectors are used to categorise buildings according to their use/activity.

A sector is located within a legislative region and can only be accessed if the building is situated within the region containing the sector.

The 'General' sector is an exception to this rule as it can be accessed from all regions if the 'List region data' Program Options setting is 'All or 'General+Local'.

You can also associate a holiday schedule with the sector.

Template data can be accessed:

- from the Templates tab on the opening screen (if no file is open),
- from the Templates tab in the Navigator panel (if a file is open),
- by double-clicking on the template icon in the model data,
- by clicking on the Edit button when selecting templates from a list.

6.12 Times Zone Templates

DesignBuilder comes with a database of all of the world's time zones including information on daylight savings. This data is sourced from ASHRAE.

If the time zone does not have daylight saving then the text **N/A** is entered in the **Daylight saving from** field.

The time zone is selected in model data under Time and Daylight Saving on the Location tab at site level.

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Note: you can override daylight savings to be off in the model data by unchecking the Use daylight saving.

Template data can be accessed:

- from the Templates tab on the opening screen (if no file is open),
- from the Templates tab in the Navigator panel (if a file is open),
- by double-clicking on the template icon in the model data,
- by clicking on the Edit button when selecting templates from a list.

6.13 Wind Pressure Coefficient Templates

Wind pressure coefficients are used when Natural ventilation model option is set to 'Calculated'. EnergyPlus/AIRNET uses pressure coefficients when calculating wind-induced pressure on each surface during simulations when the Calculated Natural ventilation option is selected.

DesignBuilder is supplied with a database of wind pressure coefficients based on data from AIVC Applications Guide: A guide to energy-efficient ventilation. The Cp data is buildings of 3 storeys or less, with square surfaces and for 3 levels of site exposure. The data is given in 45° increments.

Note: The AIVC wind pressure coefficient data provides a good first level of approximation for basic design purposes. However, ideally you would override this default data with pressure coefficient data specific to your application. This data might be calculated from CFD simulations or measured from wind tunnel studies using physical models.

Template data can be accessed:

- from the Templates tab on the opening screen (if no file is open),
- from the Templates tab in the Navigator panel (if a file is open),
- by double-clicking on the template icon in the model data,
- by clicking on the Edit button when selecting templates from a list.

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7 Calculations

There are four types of energy simulation:

- Heating design simulation
- Cooling design simulation
- Simulation using real weather (simply referred to as 'simulation' in DesignBuilder documentation)
- Energy Performance Indicator simulations (on the Check screen). This capability is still under development and is so far undocumented.

DesignBuilder has been set up to allow a choice of calculation method for each of these energy simulation types, but version 1.0 only allows EnergyPlus as the calculation method. The range of options will be expanded in future versions.

Display Options in the Panel in the bottom left of the screen allow you to change the data displayed and the presentation style.

Results can be exported in a variety of file formats or they can added as a Report topic.

7.1 Heating Design

Heating design calculations are carried out to determine the size of heating equipment required to meet the coldest winter design weather conditions likely to be encountered at the site location. These design calculations are traditionally carried out using steady-state methods such as those offered by ASHRAE and CIBSE. You can use DesignBuilder to carry out effectively the same calculation using the EnergyPlus dynamic thermal simulation engine.

Click on the Heating Screen tab to view Heating Design data. If the necessary data has not yet been generated, a Heating Design calculation is automatically started to generate the data.

Heating design simulations using EnergyPlus have the following characteristics:

- Constant (Steady-state) external temperature set to the winter design external temperature.
- Wind speed and direction set to design values.
- No solar gain.
- No internal gains (lighting, equipment, occupancy etc).
- Heated zones are heated constantly to achieve the heating temperature set point using a simple convective heating system.
- Includes consideration of heat conduction and convection between zones of different temperatures.

Simulation continues until temperatures/heat flows in each zone have converged. If convergence does not occur then simulation continues for the maximum number of days as specified in the calculation options.

The simulation calculates heating capacities required to maintain the temperature set points in each zone and displays the total heat loss broken down as:

- Glazing
- Walls
- Partitions
- Solid floors
- Roofs
- External infiltration
- Internal natural ventilation (i.e. heat lost to other cooler adjacent spaces through windows, vents,

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doors, holes)

The total heat loss in each zone is multiplied by a Safety factor (1.5 by default) to give a recommended heating Design Capacity. This heating capacity can be written directly into the **Heating capacity** model data depending on the setting of the Plant sizing model option on the Data tab under HVAC.

Customise the data displayed and display style using the Display Options panel.

Note: heating design calculations do not use any Natural ventilation data.

EnergyPlus IDF data

You can view the EnergyPlus IDF data used to carry out the calculation by clicking on the 'View the input data' link in the info panel (Learning mode only) or from the Tools menu.

7.1.1 Calculation Options

These calculation options can be accessed from the Heating design calculation options tab of the Model Options dialog and from the Heating design calculation options dialog.

- Calculation Options
- Heating system sizing
- Advanced Calculation Options

Calculation description

Enter some text to identify the calculation. This will be used in reports and in the filename for automatically generated ESO files.

Click on the OK button to start the Heating design calculation.

7.1.2 Display Options

You can review heating design output in 2 ways:

- **Heat loss breakdown** - on the Steady State tab.
- **Summary table** - heating capacity data for each zone on the Summary tab.

To update the data using different calculation options, click Update (Ctrl-U).

The General tab on the Display Options panel provides options for controlling the data displayed in the Heating design data display screen. General Display Options are grouped under three headers:

- Data - control the data displayed.
- Y-axis - for customising the layout of the Y-axis.
- Appearance - for customising the style and appearance of the graphics.

The Detailed tab on the Display Options panel provides controls which allow you to select exactly the data items you wish to display.

DATA OPTIONS

Data

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Select an option to indicate the data you wish to display:

- **1-All** - fabric and ventilation heat gains/losses, internal gains (not Heating Design), temperatures and outside dry-bulb air temperature.
- **2-Site data** - all site data.
- **3-Comfort** - inside air, the radiant and comfort temperatures.
- **4-Internal gains** - internal gains including equipment, lighting, occupancy, solar and HVAC heating/ cooling delivery.
- **5-Fabric and ventilation** - heat gains to the space from the surface element (walls, floors, ceilings etc.) and ventilation. Negative values indicate heat loss from the space.

Tip: to update the data using different calculation options, click Update (Ctrl-U).

Show as

You can display the data in one of four ways:

- Graph
- Grid
- Graph and table
- Table

Note: you must select the Grid option to export data in spreadsheet format.

Normalise by floor area

Check this option if you wish data to be displayed 'per floor area' i.e. /m2 or /ft2. You can select the area to use as the denominator from:

- **1-All areas** - Total area is used,
- **2-Occupied area** - just occupied areas are used.

Note: you can only select **1-All areas** if the building and block data *includes* occupied areas as set in **Include unoccupied zones in block and building totals and averages** option in Heating design Output options, Likewise you can only select **2-Occupied area** if the building and block data *excludes* occupied areas.

Y-AXIS OPTIONS

These options give you control over how the Y-axis is displayed.

Lock min/max

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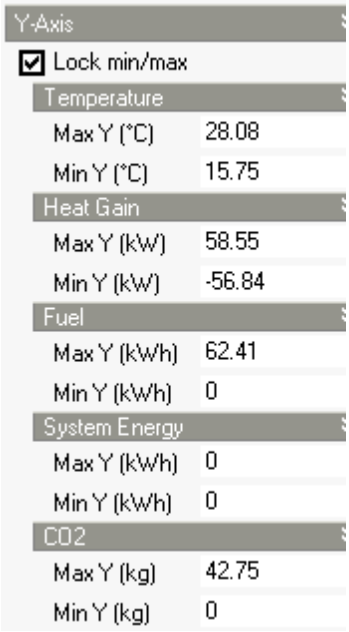

This option locks the extent of the Y-axes so that they keep their current maximum and minimum values. This allows consistent comparison with the future results display.

The Y-axis keeps its current settings until you unlock it again.

You can achieve the same effect by clicking on the 'Lock Y-axis min/max values' toolbar command.

When you lock the Y-axis the current settings are stored and displayed for each of the available Y-axes. You can edit any of these to get a more precise setting. Remember to click on the Apply button when you are ready to register a change to any numeric display option data.

Overlap multiple axes

Option allows you to save space on the Y-axis allowing different axes to overlap.

Separate axes

Check this option to add a vertical space between each of the displayed axes.

Normalise by floor area

Check this option if you wish data to be displayed 'per floor area' i.e. /m2 or /ft2.

APPEARANCE

You can control the details of the presentation of the graphical output by making selections on the Display Options panel under the Appearance header.

ENERGYPLUS SCRIPT

You can view the input data script used to calculate these results by selecting the 'Tools | Display simulation input script' menu option. If you do not have the EnergyPlus IDF editor installed, then you should associate the .idf file extension with a text editor to make this option work.

Note: this shows the script stored with the model just before the simulation *not* the in.idf file stored in the

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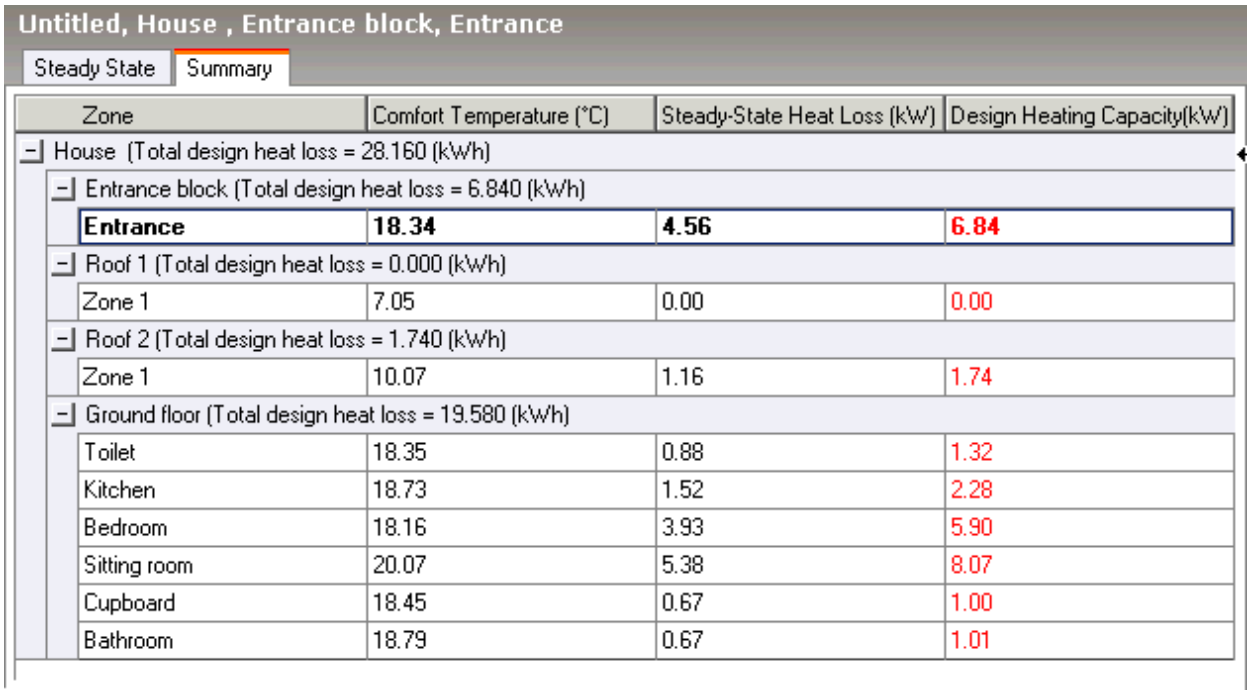
EnergyPlus folder.

7.1.3 Summary table

The Summary screen shows Comfort temperature, Steady state heat loss and Design heating capacity:

- **Comfort temperature** - The mean of the internal air and radiant temperatures (also known as the 'operational' temperature)
- **Steady-state heat loss** - same as 'Heating delivered' on the Steady State tab - heat delivered to maintain the internal heating design temperature.
- **Design capacity** - is the Steady-state heat loss multiplied by the **Design margin** to give the design heating capacity of the equipment.



Zone	Comfort Temperature (°C)	Steady-State Heat Loss (kW)	Design Heating Capacity(kW)
House (Total design heat loss = 28.160 (kWh)			
Entrance block (Total design heat loss = 6.840 (kWh)			
Entrance	**18.34**	**4.56**	**6.84**
Roof 1 (Total design heat loss = 0.000 (kWh)			
Zone 1	7.05	0.00	0.00
Roof 2 (Total design heat loss = 1.740 (kWh)			
Zone 1	10.07	1.16	1.74
Ground floor (Total design heat loss = 19.580 (kWh)			
Toilet	18.35	0.88	1.32
Kitchen	18.73	1.52	2.28
Bedroom	18.16	3.93	5.90
Sitting room	20.07	5.38	8.07
Cupboard	18.45	0.67	1.00
Bathroom	18.79	0.67	1.01

Use the Export command to export this data in spreadsheet format.

7.1.4 Heat loss breakdown results

The 'Steady-State' tab has detailed heating design results (displayed as a histogram and table by default).

For more on how the output is calculated see: Calculation of DesignBuilder Output from EnergyPlus Report Variables.

- **Air Temperature** - the calculated average temperature of the air.
- **Radiant Temperature** - the calculated average Mean Radiant Temperature (MRT) of the zone, calculated assuming that the person is in the centre of the zone, with no weighting for any particular surface.
- **Operative Temperature** - The mean of the internal air and radiant temperatures.
- **Outside Dry-Bulb Temperature.**
- **Glazing** - heat loss through all glazing.

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- **Walls** - heat loss through all external walls.
- **Ceilings (int)** - heat loss through internal ceilings (e.g. zone above is colder).
- **Floors (int)** - heat loss through internal floors (e.g. zone below is colder).
- **Floors (ext)** - heat loss through external floors (not ground floor, e.g. floor in cantilevered space, roof eaves etc).
- **Doors and Vents** - conduction heat loss through doors and vents.
- **Ground Floors** - heat loss through ground floors.
- **Partitions (int)** - heat loss through all internal partitions (e.g. adjacent zone is colder).
- **External Infiltration** - heat loss through air infiltration (non-unintentional air entry through cracks and holes in building fabric).
- **External Mechanical Ventilation** - is the heat loss due to the entry of outside air through the air distribution system. View can exclude mechanical ventilation from the heating design calculations by unchecking the 'Mechanical ventilation On' Model Data.
- **Internal Natural Ventilation** - heat loss due to air exchange through open internal windows, doors, vents, holes and virtual partitions to adjacent spaces.
- **Zone/Sys Sensible Heating** - heat delivered to maintain the internal heating design temperature.

Note: The **Heating delivered** is the sum of the component heat loss values.

Surface heat loss data (walls, ceilings, floors etc) refers to heat transfer from the zone to the inside surface of the building elements.

You can also customise the data displayed and display style using the Display Options panel.

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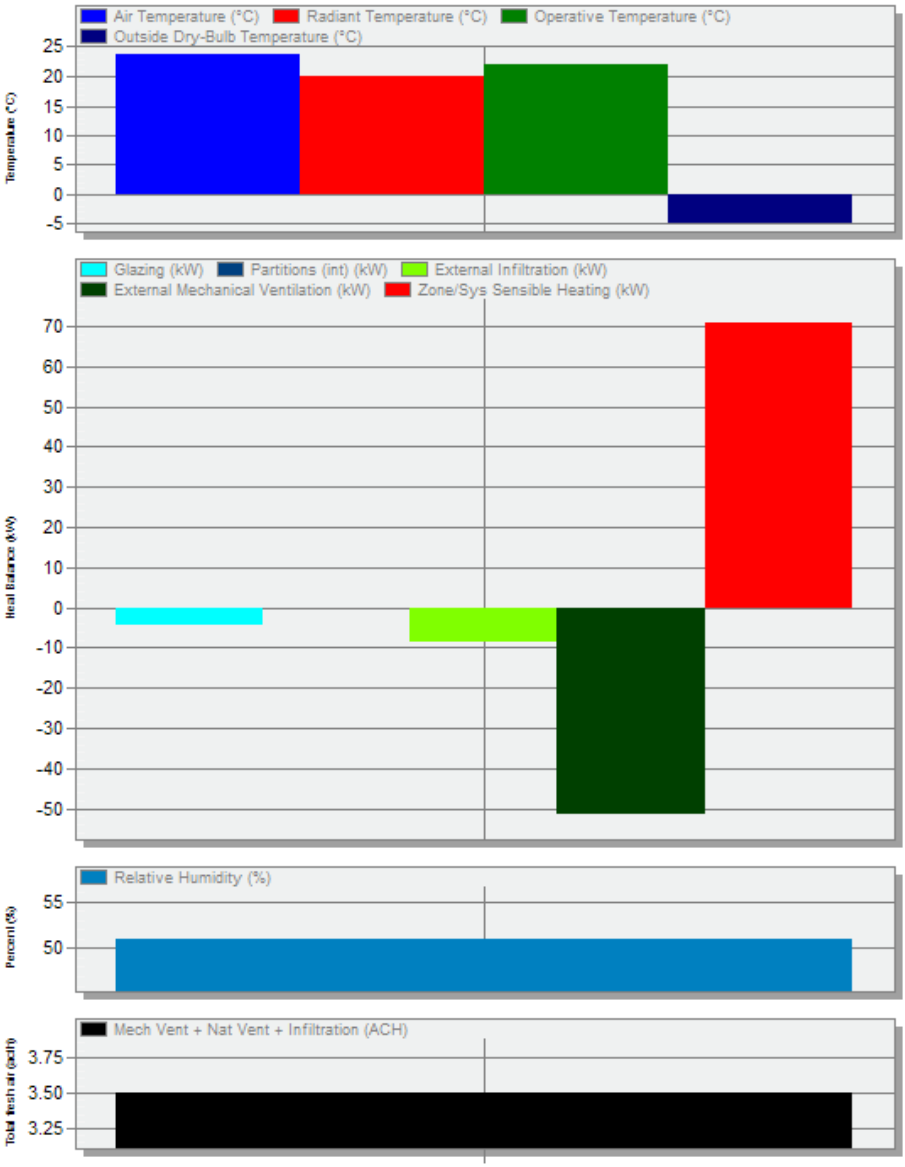
Temperature and Heat Loss

EnergyPlus Output Licensed



Air Temperature (°C)	23.96
Radiant Temperature (°C)	20.04
Operative Temperature (°C)	22.00
Outside Dry-Bulb Temperature (°C)	-4.80
Glazing (kW)	-4.53
Partitions (int) (kW)	0.01
External Infiltration (kW)	-8.54
External Mechanical Ventilation (kW)	-51.40
Zone/Sys Sensible Heating (kW)	70.78
Relative Humidity (%)	51.08
Mech Vent + Nat Vent + Infiltration (ACH)	3.50

7.2 Cooling Design

Cooling design calculations are carried out to determine the capacity of mechanical cooling equipment required to meet the hottest summer design weather conditions likely to be encountered at the site location. In zones which are not mechanically cooled free-floating temperatures are calculated including the effects

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of natural or mechanical ventilation if these options are selected on the zone HVAC tab. These design calculations are traditionally carried out using periodic steady-state methods such as the admittance and response factor methods provided by CIBSE and ASHRAE. You can use DesignBuilder to carry out effectively the same calculation using the EnergyPlus dynamic thermal simulation engine.

Click on the Cooling Screen tab to view Cooling Design data. If the necessary data has not yet been generated, a Cooling Design calculation is automatically started to generate the data.

Cooling design simulations using EnergyPlus have the following characteristics:

- Periodic steady-state external temperatures calculated using maximum and minimum design summer weather conditions.
- No wind.
- Includes solar gains through windows and scheduled natural ventilation.
- includes internal gains from occupants, lighting and other equipment.
- Includes consideration of heat conduction and convection between zones of different temperatures.

For buildings situated in the Northern Hemisphere, Cooling Design calculations are made for the month of July and for buildings in the Southern Hemisphere they are made for the month of January.

Simulation continues until temperatures/heat flows in each zone have converged. If convergence does not occur then simulation continues for the maximum number of days as specified in the calculation options.

The simulation calculates half-hourly temperatures and heat flows for each zone and determines cooling capacities required to maintain any cooling temperature set points in each zone.

The maximum cooling load in each zone is multiplied by a Safety factor (1.3 by default) to give a Design Cooling Capacity. This design cooling capacity can be written directly into the **Cooling capacity** model data depending on the setting of the Plant sizing model option on the Data tab under HVAC.

Customise the data displayed and display style using the Display Options panel.

Note: Cooling Design calculations use Scheduled Natural ventilation model data set on the HVAC tab even when the Calculated natural ventilation option is set. This is to help you to document the input data for your Cooling Design calculations. Calculated natural ventilation data input is too complex to be adequately summarised.

7.2.1 Calculation Options

These calculation options can also be accessed from the Cooling design calculation options tab of the Model Options dialog.

- Calculation Options
- Summer design day
- Cooling system sizing
- Solar Options
- Advanced Calculation Options

Calculation description

Enter some text to identify the calculation. This will be used in reports and in the filename for automatically generated ESO files.

Click on the OK button to start the Cooling design calculation.

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7.2.2 Detailed results

The 'Analysis' tab has detailed half-hourly cooling design results (displayed as a line graph by default).

For more on how the output is calculated see: Calculation of DesignBuilder Output from EnergyPlus Report Variables.

- **Air Temperature** - the calculated average temperature of the air.
- **Radiant Temperature** - the calculated average Mean Radiant Temperature (MRT) of the zone, calculated assuming that the person is in the centre of the zone, with no weighting for any particular surface.
- **Operative Temperature** - The mean of the mean internal air and mean radiant temperatures.
- **Outside Dry-Bulb Temperature.**
- **Glazing** - the total heat flow to the zone from the glazing, frame and divider of exterior glazing excluding transmitted short-wave solar radiation (which is accounted for in **Solar Gains Exterior Windows** below).

  For windows **without an interior shading device** this heat flow is equal to:

  + [Convective heat flow to the zone from the zone side of the glazing]
  + [Net IR heat flow to the zone from zone side of the glazing]
  – [Short-wave radiation from zone transmitted back out the window]
  + [Conduction to zone from window frame and divider, if present]

  Here, short-wave radiation is that from lights and diffuse interior solar radiation.

  For windows **with an interior shading device** this heat flow is equal to:

  [Convective heat flow to the zone from the air flowing through the gap between glazing and shading device]
  + [Convective heat flow to the zone from the zone side of the shading device]
  + [Net IR heat flow to the zone from the zone side of the glazing]
  + [Net IR heat flow to the zone from the zone side of the shading device]
  – [Short-wave radiation from zone transmitted back out the window]
  + [Conduction to zone from window frame and divider, if present]

- **Walls** - heat gain due to conduction through all external walls, including the effect of solar radiation and longwave radiation to the sky.
- **Roofs** - heat gain due to conduction through all external roofs, including the effect of solar radiation and longwave radiation to the sky.
- **Ceilings (int)** - heat conduction gain through internal ceilings (e.g. zone above is colder).
- **Floors (int)** - heat conduction gain through internal floors (e.g. zone below is colder).
- **Floors (ext)** - heat conduction gain through external floors (not ground floor, e.g. floor in cantilevered space, roof eaves etc).
- **Ground floors** - heat conduction gain through ground floors.
- **Partitions (int)** - heat conduction gain due to heat conduction through all internal partitions from adjacent zones at different temperatures.
- **Doors and vents** - conduction heat gain through doors and vents.
- **External Infiltration** - heat gain through air infiltration (non-unintentional air entry through cracks and holes in building fabric).
- **External Natural Ventilation** - heat gain due to the entry of outside air through natural ventilation (as defined on the HVAC tab).
- **Internal Natural Ventilation** - heat gain from other zones due to air exchange through open internal windows, doors, vents, holes and virtual partitions.
- **External Mechanical Ventilation** - heat gain due to the entry of outside air through the air distribution system. You can exclude mechanical ventilation from the cooling design calculations by

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unchecking the 'Mechanical ventilation On' Model data.
- **Task Lighting** - heat gain due to task lighting.
- **General Lighting** - heat gain due to general lighting.
- **Miscellaneous** - heat gain due to miscellaneous equipment.
- **Process** - heat gain due to process equipment.
- **Catering** - heat gain due to cooking.
- **Computer and Equipment** - heat gain due to computer and other IT-related equipment.
- **Occupancy** - sensible gain due to occupants. Please note that this can vary depending on the internal conditions. With very high temperatures the sensible gain can drop to zero with all cooling effects taking place through latent heat transfer.
- **Solar Gains Exterior Windows** - (used to be called 'Transmitted solar gains'). Short-wave solar radiation transmission through *external* windows. For a bare window, this transmitted radiation consists of solar radiation passing through the glass and diffuse radiation from solar reflected from the outside window reveal, if present. For windows with a shade, this transmitted radiation is totally diffuse (shades are assumed to be perfect diffusers). For windows with a blind, this transmitted radiation consists of beam + diffuse radiation that passes between the slats and diffuse radiation from beam-to-diffuse reflection from the slats. *Solar re-reflected back out of the external window and transmitted through interior windows is not subtracted.*
  Solar Gains Interior Windows - Total beam + diffuse solar radiation transmission through *interior* windows. Requires the 3-Full interior and exterior solar model option to be set.
- **Zone/Sys sensible cooling** - is the sensible cooling effect *on the zone* of any air introduced into the zone through the HVAC system. It includes any 'free cooling' due to introduction of relatively cool outside air. Cooling always shows as a negative heat gain in the results. *It is best thought of as part of the zone heat balance.*

Airflow

- **Mech Vent + Nat Vent + Infiltration** - The sum of ***outside air*** (in ac/h) flowing into the zone through:
  - The HVAC air distribution system +
  - Infiltration +
  - Natural ventilation

System Heat Flows (Compact HVAC only)

These heat flows are plotted on the System Energy axes:

- **Zone Heating** - energy supplied by local room heaters and reheat coils to maintain room internal heating temperature setpoint temperature when using Compact HVAC data.
- **Total Cooling -** depending on the Sizing method:
  - for the default ASHRAE sizing method **Total Cooling** is the rate at which total energy (sensible and latent) is removed from the mixed outside and return air stream in order to bring the mixed air stream to the specified temperature and humidity ratio of the supply air stream.
  - for Compact HVAC sizing method - at *building level:* sensible + latent cooling transfer to the supply air from the AHU cooling coil + any single zone unitary and fan coil units in the building. At *zone level:* sensible + latent cooling transfer to the supply air from a single zone unitary or fan coil unit.
- **Sensible Cooling** - depending on the Sizing method:
  - for ASHRAE sizing method **Sensible Cooling** is the rate at which sensible energy is removed from the mixed outside and return air stream in order to lower its temperature to the specified temperature of the supply air stream. Any energy needed for moisture addition or removal is ignored.
  - for Compact HVAC sizing method **Sensible Cooling** is sensible only cooling heat transfer from the cooling coil to the supply air. Latent coil heat can be calculated as the difference: **Total Cooling - Sensible Cooling.**

Surface heat gain data refers to heat transfer from the inside surface of the building elements to the zone.

You can also customise the data and the way it is displayed using the Display Options panel.

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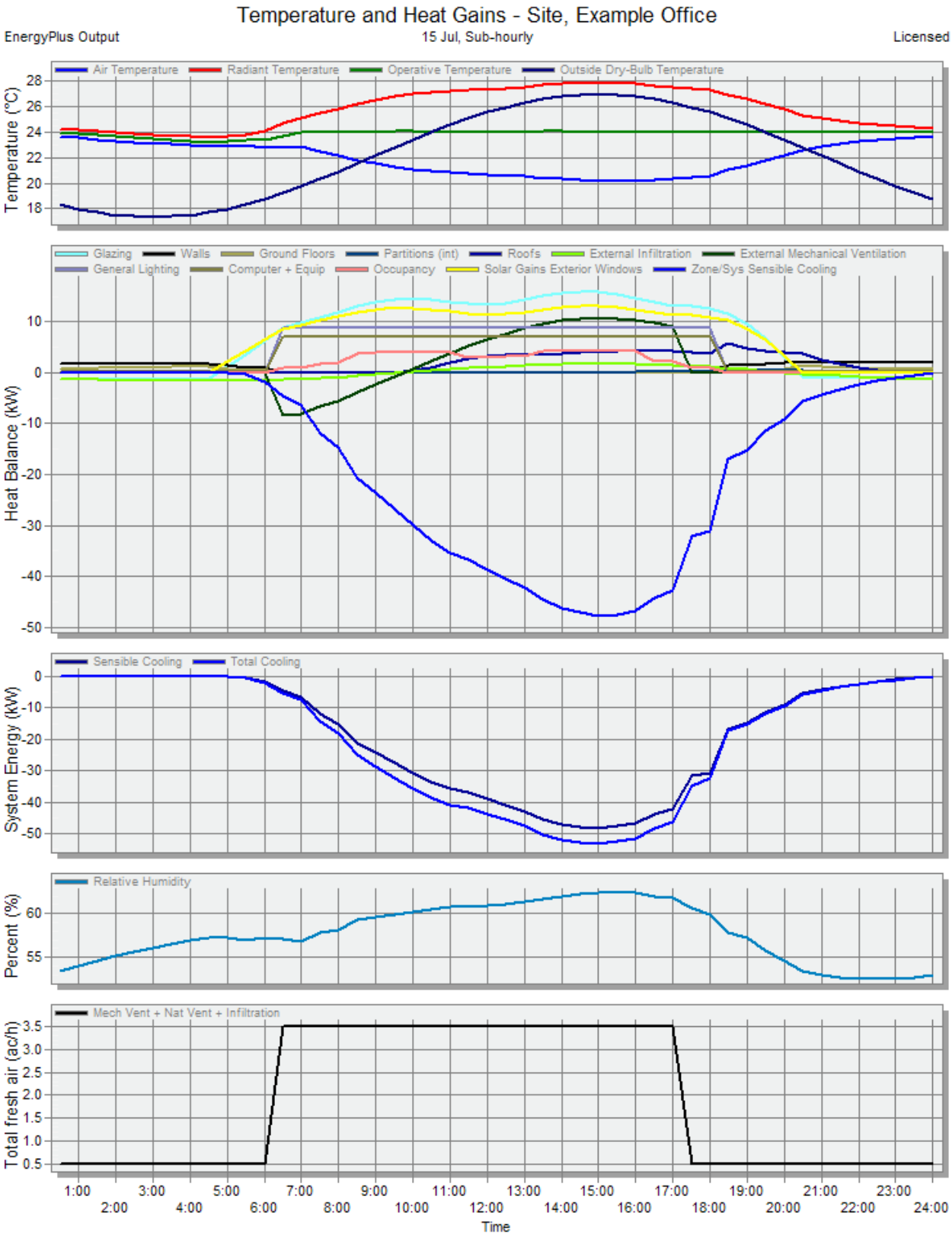

7.2.3 Display Options

You can review Cooling design output in 2 ways:

- **Detailed results** - half-hourly heat balance and inside conditions displayed on 'Analysis' tab.

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- **Summary table** - cooling capacity data for each zone on the Summary tab.

To update the data using different calculation options, click Update (Ctrl-U).Data Options

The General tab on the Cooling design Display options panel provides options for controlling the data displayed in the Simulation data display screen. General Display options are grouped under three headers:

- Data - control the data displayed.
- Y-axis - for customising the layout of the Y-axis.
- Appearance - for customising the style and appearance of the graphics.

The Detailed tab on the Display Options panel provides controls which allow you to select exactly the data items you wish to display.

DATA OPTIONS

Data

Select an option to indicate the data you wish to display:

- **1-All** - fabric and ventilation heat gains/losses, internal gains (not Heating Design), temperatures and outside dry-bulb air temperature.
- **2-Site data** - all site data.
- **3-Comfort** - inside air, the radiant and comfort temperatures, relative humidity, ASHRAE 55 and various comfort indices.
- **4-Internal gains** - internal gains including equipment, lighting, occupancy, solar and HVAC heating/ cooling delivery.
- **5-Fabric and ventilation** - heat gains to the space from the surface element (walls, floors, ceilings etc.) and ventilation. Negative values indicate heat loss from the space.

Tip: to update the data using different calculation options, click Update (Ctrl-U).

Show as

You can display the data in one of four ways:

- Graph
- Grid
- Graph and table
- Table

Note: you must select the Grid option to export data in spreadsheet format.

Normalise by floor area

Check this option if you wish data to be displayed 'per floor area' i.e. /m2 or /ft2. You can select the area to use as the denominator from:

- **1-All areas** - Total area is used,
- **2-Occupied area** - just occupied areas are used.

Note: you can only select **1-All areas** if the building and block data *includes* occupied areas as set in **Include unoccupied zones in block and building totals and averages** option in Cooling design Output options, Likewise you can only select **2-Occupied area** if the building and block data *excludes* occupied areas.

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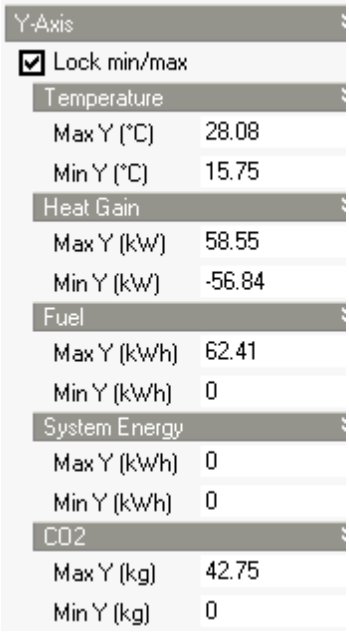
Y-AXIS OPTIONS

These options give you control over how the Y-axis is displayed.

Lock min/max



This option locks the extent of the Y-axes so that they keep their current maximum and minimum values. This allows consistent comparison with the future results display. The Y-axis keeps its current settings until you unlock it again.

You can achieve the same effect by clicking on the 'Lock Y-axis min/max values' toolbar command.

When you lock the Y-axis the current settings are stored and displayed for each of the available Y-axes. You can edit any of these to get a more precise setting. Remember to click on the Apply button when you are ready to register a change to any numeric display option data.

Overlap multiple axes

Option allows you to save space on the Y-axis allowing different axes to overlap.

Separate axes

Check this option to add a vertical space between each of the displayed axes.

Normalise by floor area

Check this option if you wish data to be displayed 'per floor area' i.e. /m2 or /ft2.

APPEARANCE

You can control the details of the presentation of the graphical output by making selections on the Display Options panel under the Appearance header.

ENERGYPLUS SCRIPT

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You can view the input data script used to calculate these results by selecting the 'Tools | Display simulation input script' menu option. If you do not have the EnergyPlus IDF editor installed, then you should associate the .idf file extension with a text editor to make this option work.

Note: this shows the script stored with the model just before the simulation *not* the in.idf file stored in the EnergyPlus folder.

7.2.4 Summary table

The Summary screen shows design cooling loads and flow rates for each zone plus other related data.

- **Design Capacity**, shown in bold, is the maximum value of **Total Cooling Load** and **Sensible** multiplied by the **Design margin** to give the design cooling capacity of the equipment. This value is written into the Cooling capacity Model Data on the HVAC tab if the appropriate Plant sizing Model Option is set.
- **Design Flow Rate**, shown in bold, is the flow rate required to deliver the **Sensible** cooling load using the **Design supply temperature** and the zone air temperature at the time of the maximum load multiplied by the **Design margin**.
- **Total Cooling Load** is the total maximum **Sensible** + **Latent** loads for the zone at the time of maximum Sensible Cooling load. If latent load is negative then it is ignored here and the Total Cooling Load is the same as the Sensible load.
- **Sensible** is the maximum Sensible Cooling load for the zone in the Design day.
- **Latent** is the latent load for the zone at the time of maximum Sensible load, calculated as Total Cooling - Sensible Cooling.
- **Air Temperature** is the Air temperature in the zone at the time of maximum Sensible load.
- **Humidity** is the humidity (%) in the zone at the time of maximum Sensible load.
- **Time of Max Cooling** - the time at which the maximum sensible cooling occurs.
- **Max Op Temp in Day** is the maximum operative temperature in the zone (using radiant fraction = 0.5) over the design day including periods when the zone may be unconditioned.
- **Floor area** is the floor area of the zone.
- **Volume** is the volume of the zone.
- **Flow/Floor area** (**MBH/ft2** in IP units) is the **Design Flow Rate** divided by the **Floor area** of the zone. It provides a useful check for the flow rates calculated.

Zone	Design Capacity (kW)	Design Flow Rate (m3/s)	Total Cooling...	Sensible (kW)	Latent (kW)	Air Temper...	Humidity (%)	Time of Max ...	Max Op Temp in Day (°C)	Floor Area (m2)	Volu...	Flow/Floor ...
1 System Plenum Total Design Cooling Requirement = 24.070 (kW)												
Block 1 Total Design Cooling Requirement = 24.070 (kW)												
Zone 2	**10.62**	**1.01**	8.17	7.75	0.42	20.3	61.6	13:30	27.0	70.6	247.0	14.35
Zone 1	**13.45**	**1.43**	10.35	9.80	0.54	19.4	64.7	16:00	28.9	70.6	247.0	20.30
Plenum Total Design Cooling Requirement = 0.000 (kW)												
Plenum	0.00	0.00	0.00	0.00	0.00	-	-	-	29.5	141.2	70.6	0.00

Use the Export command to export this data in spreadsheet format.

7.3 Simulation

You can generate detailed building energy performance data based on simulations using real weather data.

Click on the Simulation Screen tab to view simulation data. If the necessary data has not yet been generated, a simulation is automatically started to generate the data.

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Simulations using EnergyPlus have the following characteristics:

- Weather data comes from Hourly weather data file.
- Includes consideration of heat conduction and convection between zones of different temperatures.
- Includes solar gain through windows.
- Simulation of HVAC equipment (options)
- Includes one or more 'warmup' days to ensure correct distribution of heat in building thermal mass and the start of the simulation. Warmup continues until temperatures/heat flows in each zone have converged. If convergence does not occur then simulation continues for the maximum number of days as specified in the calculation options.

Customise the data displayed and display style using the Display Options panel.

7.3.1 Calculation Options

These options control the simulation and the output produced.

Click on the OK button to start the Simulation.

GENERAL

Calculation description

Enter some text to identify the calculation. This will be used in reports and in the filename for automatically generated ESO files.

Simulation Period

The simulation period is described in the help for the Model options.

Interval

Selecting Monthly is required to obtain annual output. Monthly, daily, hourly and sub-hourly data can selected by checking the appropriate boxes.

Note: selecting output at hourly or sub-hourly intervals can produce large amounts of data which slows processing and results in large file sizes. If you want to generate hourly or sub-hourly data you may wish to consider switching off some of the Output options to ensure you are only generating the data you require.

Auto-Update

This dialog is always shown when you select 'Update' and will also be shown before all simulations if 'Don't show this dialog' at the bottom is cleared.

OPTIONS

See Help for Simulation calculation options tab of the Model Options dialog.

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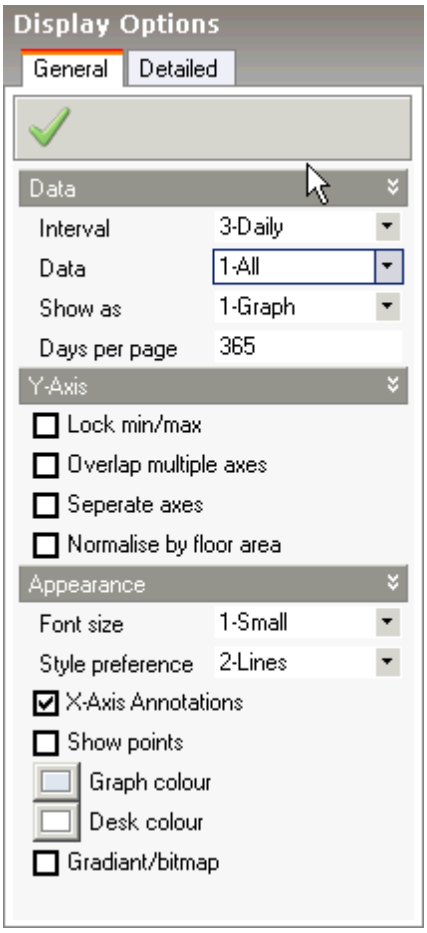
7.3.2 Display Options



The General tab on the Simulation Display Options Panel provides options for controlling the data displayed in the Simulation data display screen. General Display Options are grouped under three headers:

- Data - control the data displayed.
- Y-axis - for customising the layout of the Y-axis.
- Appearance - for customising the style and appearance of the graphics.

The Detailed tab on the Display Options panel provides controls which allow you to select exactly the data items you wish to display.

DATA OPTIONS

Interval

Select an interval from the list:

- **1-Annual** - show data for the entire simulation.
- **2-Monthly** - show data broken down by month.
- **3-Daily** - show data broken down by day.
- **4-Hourly** - show hourly data. Useful for checking operation of equipment and comfort conditions for particular design periods.
- **5-Sub-hourly** - show data recorded at time step intervals (2 and 6 intervals per hour depending on the 'Time steps per hour' calculation option). Useful for detailed checking of building performance.

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- **6-Distribution** - temperature distribution curves showing 'hours at', 'hours below' and 'hours above' temperature levels in 1°C temperature intervals during the occupied period. Note that 'Data' (below) should be set to **3-Comfort** to get temperature distribution curves.

Note: be aware that requesting Hourly and Sub-hourly results in large buildings and/or long simulation periods can result in very large data sets which take a long time to read in after the simulation.

Data

Select an option to indicate the data you wish to display:

- **1-All** - fabric and ventilation heat gains/losses, internal gains (not Heating Design), temperatures and outside dry-bulb air temperature.
- **2-Site data** - all site data.
- **3-Comfort** - inside air, the radiant and comfort temperatures, relative humidity, ASHRAE 55 and various comfort indices. If you set Interval to **6-Distribution** you get temperature distribution curves.
- **4-Internal gains** - internal gains including equipment, lighting, occupancy, solar and HVAC heating/ cooling delivery.
- **5-Fabric and ventilation** - heat gains to the space from the surface element (walls, floors, ceilings etc.) and ventilation. Negative values indicate heat loss from the space.
- **6-Fuel breakdown** - fuel consumption broken down by system category (***building level only***).
- **7-Fuel totals** - fuel consumption broken down by fuel (***building level only***)
- **8-CO2 production** - CO2 production by weight (***building level only***)

Click here for information on the meaning of the data.

Tip: to update the data using different calculation options, click Update (Ctrl-U).

Show as

You can display the data in one of four ways:

- Graph
- Grid
- Graph and table
- Table

Note: you must select the Grid option to export data in spreadsheet format.

Days per Page (Simulation only)

DesignBuilder displays all simulation results together, but you can select how many days are displayed at any one time using The 'Days displayed per page' option. A value of 365 means you will show all simulation data on the same screen and a value of 1 means you see each day on a separate screen.

Note: you can use the horizontal scroll bar at the bottom of the graph to see simulation results not currently displayed.

Normalise by floor area

Check this option if you wish data to be displayed 'per floor area' i.e. /m2 or /ft2. You can select the area to use as the denominator from:

- **1-All areas** - Total area is used,
- **2-Occupied area** - just occupied areas are used.

Note: you can only select **1-All areas** if the building and block data *includes* occupied areas as set in **Include unoccupied zones in block and building totals and averages** option in Simulation Output

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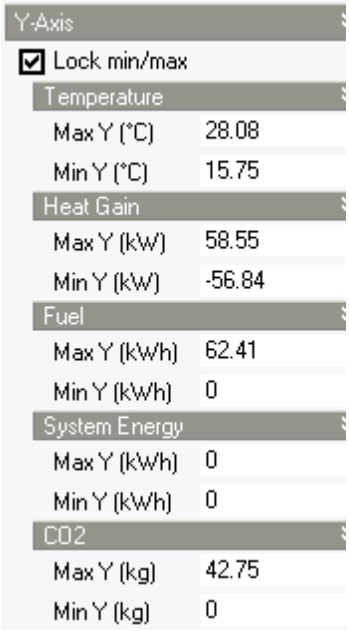
options, Likewise you can only select **2-Occupied area** if the building and block data *excludes* occupied areas.

Y-AXIS OPTIONS

These options give you control over how the Y-axis is displayed.

Lock min/max



This option locks the extent of the Y-axes so that they keep their current maximum and minimum values. This allows consistent comparison with the future results display. The Y-axis keeps its current settings until you unlock it again.

You can achieve the same effect by clicking on the 'Lock Y-axis min/max values' toolbar command.

When you lock the Y-axis the current settings are stored and displayed for each of the available Y-axes. You can edit any of these to get a more precise setting. Remember to click on the Apply button when you are ready to register a change to any numeric display option data.

Overlap multiple axes

Option allows you to save space on the Y-axis allowing different axes to overlap.

Separate axes

Check this option to add a vertical space between each of the displayed axes.

APPEARANCE

You can control the details of the presentation of the graphical output by making selections on the Display Options panel under the Appearance header.

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7.3.3 Detailed Results

The main Display options are in the bottom left of the screen. They allow you to control the content of the Detailed data and also the Display style.

The 'Analysis' tab has detailed simulation results (displayed as a line graph by default).

For more on how the output is calculated see: Calculation of DesignBuilder Output from EnergyPlus Report Variables.

Environmental/Comfort Output

- **Air Temperature** - the calculated average temperature of the zone air.
- **Radiant Temperature** - the average zone Mean Radiant Temperature (MRT) of the zone, calculated assuming that the person is in the centre of the zone, with no weighting for any particular surface.
- **Operative Temperature** - The mean of the zone air and radiant temperatures.
- **Outside Dry-Bulb Temperature.**
- **Relative Humidity** - the calculated average relative humidity of the air.
- **Fanger PMV** - Fanger Predicted Mean Vote calculated according to ISO 7730.
- **Pierce PMV ET** - the Predicted Mean Vote (PMV) calculated using the effective temperature and the Pierce two-node thermal comfort model.
- **Pierce PMV SET** - the Predicted Mean Vote (PMV) calculated using the 'Standard' effective temperature and the Pierce two-node thermal comfort model.
- **Pierce Discomfort Index (DISC)** - the Discomfort index calculated using the Pierce two-node thermal comfort model.
- **Pierce Thermal Sens. Index (TSENS)** - the Thermal Sensation Index (PMV) calculated using the Pierce two-node thermal comfort model.
- **Kansas Uni TSV** - the Thermal Sensation Vote (TSV) calculated using the KSU two-node thermal comfort model.
- **Discomfort hrs (summer clothing)** - the time when the zone is occupied that the combination of humidity ratio and operative temperature is not in the ASHRAE 55-2004 ***summer*** clothes region.
- **Discomfort hrs (winter clothing)** - the time when the zone is occupied that the combination of humidity ratio and operative temperature is not in the ASHRAE 55-2004 ***winter*** clothes region.
- **Discomfort hrs (all clothing)** - the time when the zone is occupied that the combination of humidity ratio and operative temperature is not in the ASHRAE 55-2004 ***summer or winter*** clothes region.

More on **Comfort Analysis**...

Fabric and ventilation

- **Glazing** - the total heat flow to the zone from the glazing, frame and divider of exterior glazing excluding transmitted short-wave solar radiation (which is accounted for in **Solar Gains Exterior Windows** below).

  For windows **without an interior shading device** this heat flow is equal to:

  + [Convective heat flow to the zone from the zone side of the glazing]
  + [Net IR heat flow to the zone from zone side of the glazing]
  – [Short-wave radiation from zone transmitted back out the window]
  + [Conduction to zone from window frame and divider, if present]

  Here, short-wave radiation is that from lights and diffuse interior solar radiation.

  For windows **with an interior shading device** this heat flow is equal to:

  [Convective heat flow to the zone from the air flowing through the gap between glazing and shading device]
  + [Convective heat flow to the zone from the zone side of the shading device]

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+ [Net IR heat flow to the zone from the zone side of the glazing]
+ [Net IR heat flow to the zone from the zone side of the shading device]
– [Short-wave radiation from zone transmitted back out the window]
+ [Conduction to zone from window frame and divider, if present]

- **Walls** - heat gain due to conduction through all external walls, including the effect of solar radiation and longwave radiation to the sky.
- **Roofs** - heat gain due to conduction through all external roofs, including the effect of solar radiation and longwave radiation to the sky.
- **Ceilings (int)** - heat conduction gain through internal ceilings (e.g. zone above is colder).
- **Floors (int)** - heat conduction gain through internal floors (e.g. zone below is colder).
- **Floors (ext)** - heat conduction gain through external floors (not ground floor, e.g. floor in cantilevered space, roof eaves etc).
- **Ground floors** - heat conduction gain through ground floors.
- **Partitions (int)** - heat conduction gain through all internal partitions (e.g. adjacent zone is colder).
- **Doors and Vents** - conduction heat gain through doors and vents.
- **External Infiltration** - heat gain through air infiltration (non-unintentional air entry through cracks and holes in building fabric) when using Simple natural ventilation option.
- **External Natural Ventilation** - heat gain due to the entry of outside air through natural ventilation, as defined on the HVAC tab, when using Simple natural ventilation option.
- **Internal Natural Ventilation** - heat gain from other zones due to air exchange through open internal windows, doors, vents, holes and virtual partitions.
- **External Mechanical Ventilation** - heat gain due to the entry of outside air through the air distribution system. You can exclude mechanical ventilation from the cooling design calculations by unchecking the 'Air Distribution On' Model Data.
- **External Air** - heat gain due to the entry of outside air through external windows, vents, doors, holes and cracks when using Calculated natural ventilation option.
- **Mixing Air** - heat gain due to the entry of inside mixing air through internal windows, vents, doors and holes when using Scheduled natural ventilation option.

Surface conduction data for Walls, Roofs, Ceilings, Floors, Partitions and Doors and Vents

The surface conduction data represents the heat conduction flow *just below the surface* of the construction and so includes all surface heat transfer mechanisms (convection, long and short-wave radiation).

Airflow

- **Mech Vent + Nat Vent + Infiltration** - The sum of ***outside air*** (in ac/h) flowing into the zone through:
  - The HVAC air distribution system +
  - Infiltration +
  - Natural ventilation

Internal Gains

- **Task Lighting** - heat gain due to task lighting.
- **General Lighting** - heat gain due to general lighting.
- **Miscellaneous** - heat gain due to miscellaneous equipment.
- **Process** - heat gain due to process equipment.
- **Catering** - heat gain due to cooking.
- **Computer and Equipment** - heat gain due to computer and other IT-related equipment.
- **Occupancy** - sensible gain due to occupants. Please note that this can vary depending on the internal conditions. With very high temperatures the sensible gain can drop to zero with all cooling effects taking place through latent heat transfer.
- **Solar Gains Exterior Windows** - (used to be called 'Transmitted solar gains'). Short-wave solar

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radiation transmission through all *external* windows. For a bare window, this transmitted radiation consists of solar radiation passing through the glass and diffuse radiation from solar reflected from the outside window reveal, if present. For windows with a shade, this transmitted radiation is totally diffuse (shades are assumed to be perfect diffusers). For windows with a blind, this transmitted radiation consists of beam + diffuse short-wave radiation that passes between the slats and diffuse radiation from beam-to-diffuse reflection from the slats. The heating effect of solar radiation on opaque roofs and walls is accounted for in the Roofs and Walls fabric heat conduction data. *Solar re-reflected back out of the external window and transmitted through interior windows is not subtracted*.

- **Solar Gains Interior Windows** - Total beam + diffuse solar radiation transmission through *interior* windows. Requires the 3-Full interior and exterior solar model option to be set.
- **Zone/Sys Sensible Cooling** - is the sensible cooling effect *on the zone* of any air introduced into the zone through the HVAC system. It includes any 'free cooling' due to introduction of relatively cool outside air and the heating effect of any fans present. Cooling always shows as a negative heat gain in the results. *It is therefore not the same as a cooling coil energy delivery* when mechanical ventilation is involved. ***It is best thought of as the HVAC cooling contribution to the zone heat balance.***
- **Zone/Sys Sensible Heating** - is the sensible heating effect of any air introduced into the zone through the HVAC system including any 'free heating' due to introduction of relatively warm outside air and the heating effects of fans. *It is therefore not the same as a heating coil energy delivery* when mechanical ventilation is involved. ***It is best thought of as the HVAC heating contribution to the zone heat balance.***

Surface heat gain data refers to heat transfer from the inside surface of the building elements to the zone.

Note: taken together the **Internal gains** and the **Fabric and ventilation** data above give an *approximate* **Zone Heat Balance**, i.e. the data represents all of the heat flows into and out of the zone.

Technical Note

It is important to understand when looking at the 'Zone heat balance' data that the values do not necessarily add to zero because:

1. Solar radiation values reported by EnergyPlus are *gross* values and do not account for the radiation re-reflected back out of internal and external windows. EnergyPlus tracks solar radiation in full detail but does not report all of the calculated values. It is not currently possible to generate *net* solar radiation gains from EnergyPlus.
2. Heat transfer gains between the zone and the surfaces cannot be added directly to ventilation gains because they are to different 'points' in the zone heat balance (surface heat transfer is to the 'rad-air' point and ventilation is to the 'air' point).
3. Minor EnergyPlus inaccuracy in reporting of conduction through window frames causes a minor error (~1%) in Glazing heat gain reported values. This does not affect the rest of the simulation, it is just in the Glazing heat gain report.

System Heat Flows

These heat flows are plotted on the System Energy axes:

Simple HVAC

Zone Heating - energy supplied by local room heaters and reheat coils to maintain room internal heating temperature setpoint temperature when using Compact HVAC data.

Total Cooling is the rate at which total energy (sensible and latent) is removed from the mixed outside and return air stream in order to bring the mixed air stream to the specified temperature and humidity ratio of the supply air stream.

Sensible Cooling is the rate at which sensible energy is removed from the mixed outside and return air stream in order to lower its temperature to the specified temperature of the supply air stream. Any energy

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needed for moisture addition or removal is ignored.

Compact HVAC

- **Zone Heating** - energy supplied by local room heaters and reheat coils to maintain room internal heating temperature setpoint temperature when using Compact HVAC data.
- **Preheat** - energy supplied by preheat coils to temper the outside air before it enters the outside air mixing box when using Compact HVAC data.
- **AHU Heating** - energy supplied by the AHU heating coil when using Compact HVAC data.
- **Total Cooling** - at *building level:* sensible + latent cooling transfer to the supply air from the AHU cooling coil + any single zone unitary and fan coil units in the building. At *zone level:* sensible + latent cooling transfer to the supply air from a single zone unitary or fan coil unit.
- **Sensible Cooling** - sensible only cooling transfer from the cooling coil to the supply air. Latent coil heat can be calculated as the difference: **Total Cooling - Sensible Cooling.**
- **Heat Recovery Sensible Cooling** - the *sensible* cooling rate of the supply air by the heat exchanger. This rate is determined using the supply air mass flow rate through the heat exchanger unit, the supply air inlet and outlet conditions, and the specific heat of the inlet supply air. A positive value is reported if the supply air is cooled by the heat exchanger, else the rate is set to zero.
- **Heat Recovery Total Cooling** - the *total* cooling rate of the supply air by the heat exchanger. This rate is determined using the supply air mass flow rate through the heat exchanger unit, and the enthalpy of the supply air entering and leaving the unit. A positive value is reported if the enthalpy of the supply air is decreased by the heat exchanger, else the rate is set to zero.
- **Heat Recovery Sensible Heating** - the *sensible* heating rate of the supply air by the heat exchanger. This rate is determined using the supply air mass flow rate through the heat exchanger unit, the supply air inlet and outlet conditions, and the specific heat of the inlet supply air. A positive value is reported if the supply air is heated by the heat exchanger, else the rate is set to zero.
- **Heat Recovery Total Heating** - the *total* heating energy added to the supply air by the heat exchanger.

BUILDING LEVEL ONLY

Fuel breakdown

The data for fuel consumption for building level broken down by end-use:

- **Heat Generation** - total fuel consumption due to operation of heat generators such as boilers and heat pumps.
- **Chiller** - total chiller fuel consumption.
- **Fans** - total electrical energy consumed by HVAC fans.
- **Pumps** - total electrical energy consumed by HVAC pumps.
- **Preheat** - heating energy transferred from main plant preheat coils to HVAC system air when using Compact HVAC data.
- **Lighting** - electricity consumed by general and task/display lights.
- **Room Electricity** - electricity consumed by room equipment other than lights (computers, equipment, process etc).
- **Room Gas** - gas consumed by room equipment (miscellaneous, process and catering)
- **Room Oil** - oil consumed by room equipment (miscellaneous, process and catering)
- **Room Solid** - solid fuel (such as coal) consumed by room equipment (miscellaneous, process and catering)
- **Room Bottled gas** - bottled gas (propane) consumed by room equipment (miscellaneous, process and catering)
- **Room Other** - other fuel consumed by room equipment (miscellaneous, process and catering)

Fuel totals

Total fuel consumption for building, data available at building level only:

- **Electricity** - total building electricity consumption.

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- **Gas** - fuel consumption total building gas consumption.
- **Oil** - total building or oil consumption.
- **Solid** - total building solid fuel consumption.
- **Bottled gas** - total building gas consumption.
- **Other fuel consumption** - total consumption of all other fuels.

CO2 production

Total carbon dioxide emission for building, data available at building level only:

- **CO2** - total CO2 emissions mass.

Site Weather data

Weather data stored at the site level and derived from the hourly weather file:

- **Outside Dry-Bulb Temperature**
- **Outside Dew-Point Temperature**
- **Direct Normal Solar**
- **Diffuse Horizontal Solar**
- **Wind Speed**
- **Wind Direction**
- **Atmospheric Pressure**
- **Solar Altitude**
- **Solar Azimuth**

Note: although Site weather data is stored at the Site level, it can be displayed at Building, Block and Zone levels too.

7.3.4 Comfort Analysis

DesignBuilder can generate extensive data on environmental conditions within the building and resultant occupant comfort levels. The following comfort-related output is available:

- **Internal air temperature** - the calculated average temperature of the air.
- **Internal radiant temperature** - the average Mean Radiant Temperature (MRT) of the zone, calculated assuming that the person is in the centre of the zone, with no weighting for any particular surface.
- **Internal operative temperature** - The mean of the internal air and radiant temperatures.
- **Outside dry-bulb temperature -** site data.
- **Relative Humidity** - the calculated average relative humidity of the air.
- **Fanger PMV** - Fanger Predicted Mean Vote
- **Pierce PMV ET** - the Predicted Mean Vote (PMV) calculated using the effective temperature and the Pierce two-node thermal comfort model.
- **Pierce PMV SET** - the Predicted Mean Vote (PMV) calculated using the 'Standard' effective temperature and the Pierce two-node thermal comfort model.
- **Pierce Discomfort Index (DISC)** - the Discomfort index calculated using the Pierce two-node thermal comfort model.
- **Pierce Thermal Sens. Index (TSENS)** - the Thermal Sensation Index (PMV) calculated using the Pierce two-node thermal comfort model.
- **Kansas Uni TSV** - the Thermal Sensation Vote (TSV) calculated using the KSU two-node thermal comfort model.
- **Discomfort hrs (summer clothing)** - the time when the combination of zone humidity ratio and operative temperature is not in the ASHRAE 55-2004 ***summer*** clothes region.
- **Discomfort hrs (winter clothing)** - the time when the combination of zone humidity ratio and operative temperature is not in the ASHRAE 55-2004 ***winter*** clothes region.

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- **Discomfort hrs (all clothing)** - the time when the combination of zone humidity ratio and operative temperature is not in the ASHRAE 55-2004 ***summer or winter*** clothes region.
- **Mech Vent + Nat Vent + Infiltration** - The sum of ***outside air*** (in ac/h) flowing into the zone through:
  - The HVAC air distribution system +
  - Infiltration +
  - Natural ventilation

The **Discomfort hrs** data above is equivalent to ASHRAE 'unmet load hours'.

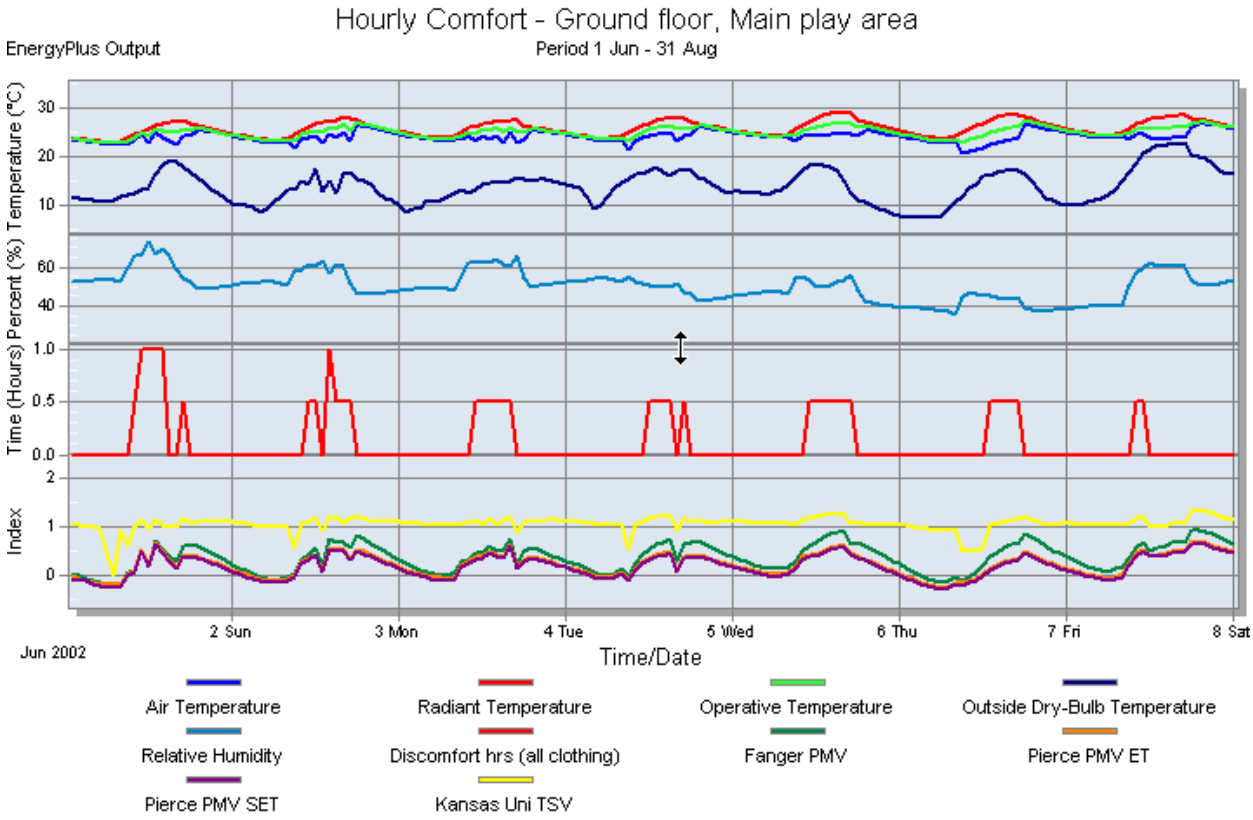
The above data can be displayed at all time increments. In addition, air, radiant and operative temperatures can be displayed as distribution curves (below).

You can find more detailed information about Fanger, Pierce and Kansas State University Thermal comfort prediction algorithms in the EnergyPlus Background Section.

The **Mech Vent + Nat Vent + Infiltration** data is the sum of fresh air delivered through the HVAC system, infiltration and natural ventilation outside airflow in air changes per hour (ac/h). When used together with the other environmental output it can be very useful in checking for occupant discomfort.

Note 1: It is possible to display comfort data for occupied periods only by selecting **2-Just occupied periods** as **Zone environmental and comfort reports** on the Output tab of the simulation options dialog. This option applies to all data described in this Comfort Analysis help section.

Note 2: Comfort data are not generated when the Gains data model option is set to **Lumped**. This is because in EnergyPlus the request for comfort calculations is made in the 'PEOPLE' statement and this is not used with Lumped gains.



Block and Building comfort level data

The comfort data listed above is calculated for blocks using *floor area weighted averages* of the zones in the block. For example:

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Block average Air temperature (T_a) = (A_1 x T_{az1} + A_1 x T_{az2} + A_3 x T_{az3} + ...) / (A_1 + A_2 + A_3 + ...)

Where:

A_n is floor area of zone n,
T_{azn} is the air temperature of zone n

There is one exception, **Mech Vent + Nat Vent + Infiltration**, which is calculated in a similar way but using *volume-weighted averages*, i.e. using zone volumes instead of floor areas in the above equation.

Building data is calculated in the same way but including all blocks.

if the **Include unoccupied zones in block and building totals and averages** option is not set then unoccupied zones are not included in the above equation.

Note: if all zones in the block/building are unoccupied and the option is not set the denominator is zero and an error message is shown and results are deleted.

TEMPERATURE DISTRIBUTION

If you requested Temperature distribution data prior to the simulation, you can generate temperature distribution curves showing 'hours at', 'hours below' and 'hours above' temperature levels in 1°C temperature intervals during the occupied period. To view temperature distribution data set the Interval in the Display Options panel to "Distribution". This data can be useful for getting an overview of the levels of comfort (or otherwise) provided by the building over time. The results can be compared with benchmark comfort criteria.

For example, CIBSE provides recommended benchmark summertime peak temperatures and overheating criteria as follows:

Offices, schools, dwellings (living areas) should have no more than 1% of the annual occupied hours over operative temperature of 28°C. Bedrooms in dwellings should have no more than 1% of the annual occupied hours over operative temperature of 26°C.

UK DfES Building Bulletin BB87 recommends an allowable overheating criteria of 80 occupied hours in a year over and air temperature of 28°C.

Note 1: Temperature distribution data is only available at **zone level**.

Note 2: This data will not be available when using Lumped gains model option as the data is tied in with the EnergyPlus 'People' data set and this is not generated for Lumped gains.

Note 3: This data will also not be available if the 1 time step per hour option is selected

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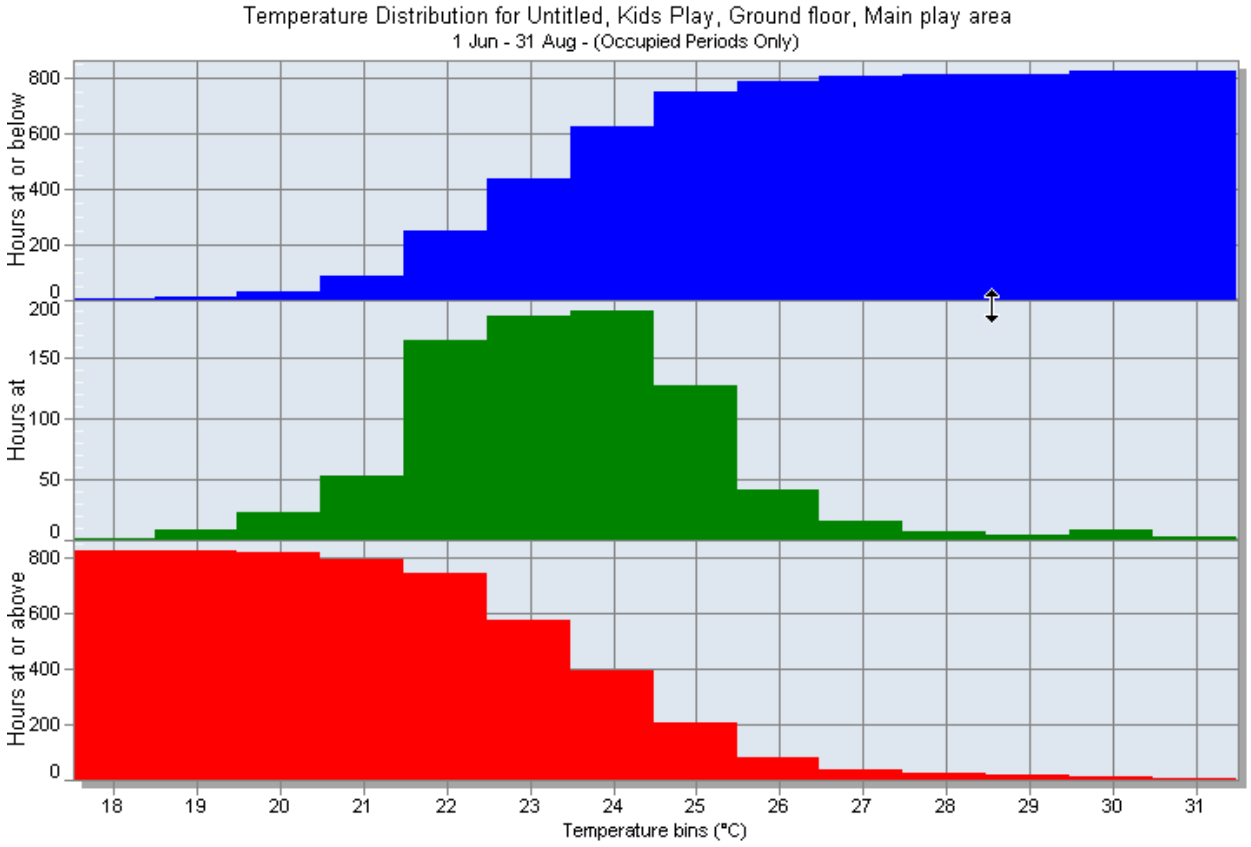

Example Temperature Distribution Output

SIMPLIFIED ASHRAE 55-2004 GRAPH RELATED OUTPUTS

The Discomfort hours data is based on whether the humidity ratio and the operative temperature is within the region shown in ASHRAE Standard 55-2004 in Figure 5.2.1.1. For these outputs the operative temperature is simplified to be the average of the air temperature and the mean radiant temperature. For summer, the 0.5 Clo level is used and, for winter, the 1.0 Clo level is used. The graphs below are based on the following tables which extend the ASHRAE values to zero humidity ratio.

In some cases you may find a large number of discomfort hours for a particular zone even though the air temperature in the space is within normal ranges. If this happens you should check:

1. Operative temperatures which can be very different in highly glazed spaces in the summer or poorly insulated spaces in the winter.
2. Humidity levels are within range - you may find very high or very low humidity caused by inadequate ventilation. Note that the minimum comfort temperature with winter clothes when the air is very dry is 21.7°C / 71°F which may be lower than some heating temperature setpoints. Likewise in the summer when the air is very humid operative temperatures above 26.8°C / 80.2°F are considered too hot with summer clothes.

Winter Clothes

Air Temp (deg C)	Humidity Ratio
19.6	0.012
23.9	0.012
26.3	0.000
21.7	0.000

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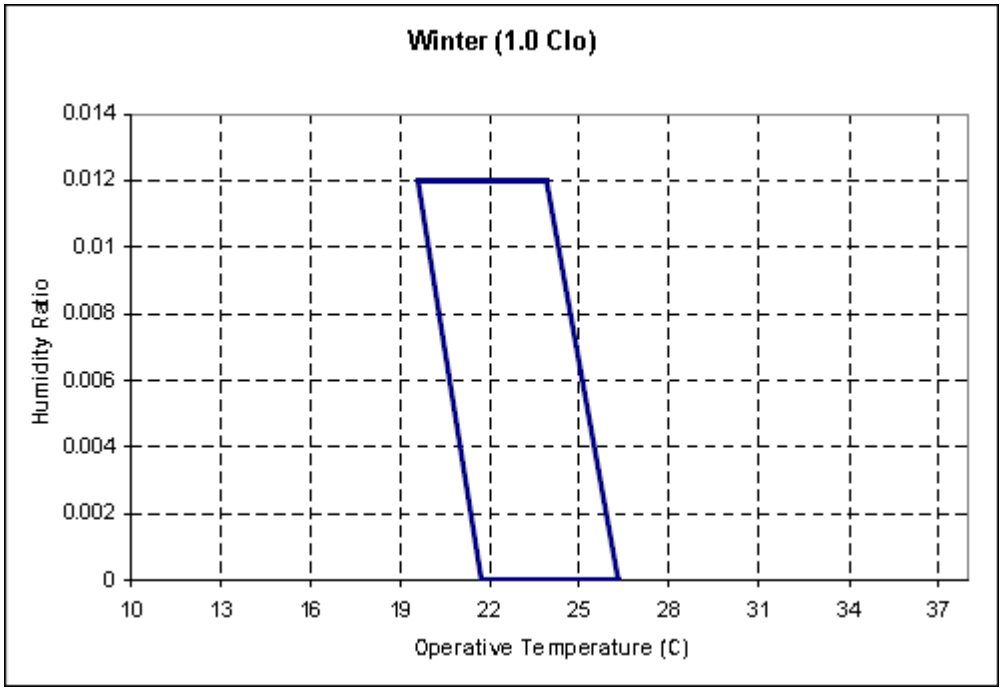
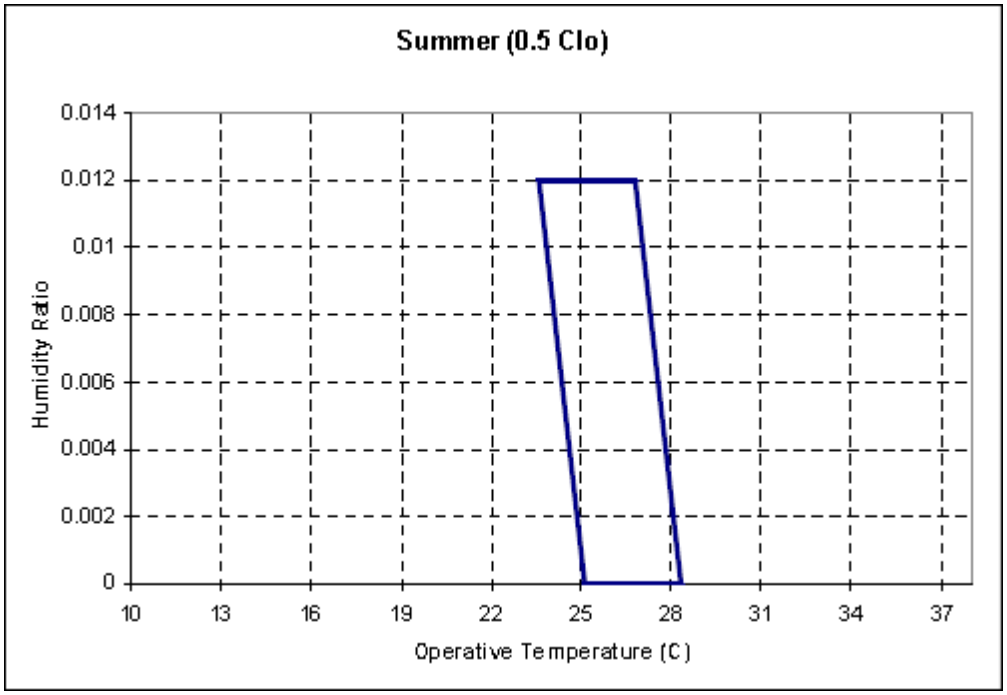


Summer Clothes

Air Temp (deg C)	Humidity Ratio
23.6	0.012
26.8	0.012
28.3	0.000
25.1	0.000



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7.4 CFD

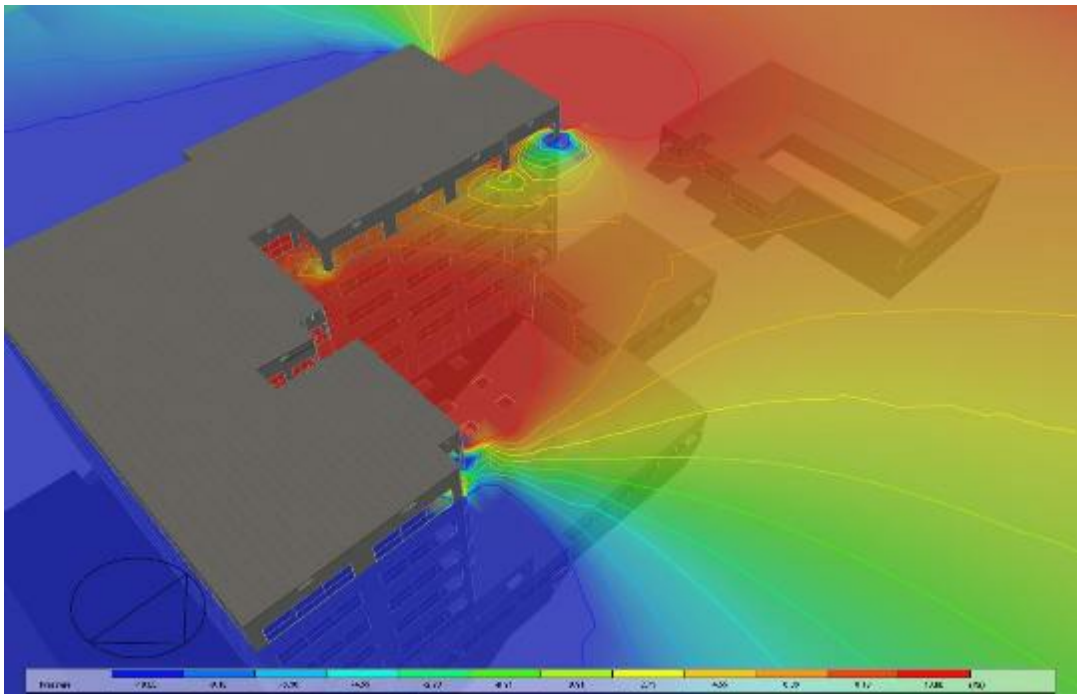
This section covers the processes involved in running CFD calculations in DesignBuilder.

What is CFD?

Computational Fluid Dynamics (CFD) is the term used to describe a family of numerical methods used to calculate the temperature, velocity and various other fluid properties throughout a region of space.

CFD when applied to buildings can provide the designer with information on probable air velocities, pressures and temperatures that will occur at any point through a predefined air volume in and around building spaces. Boundary conditions are specified which may include the effects of climate, internal heat gains and HVAC systems. DesignBuilder CFD can be used for both external and internal analyses.

External analyses provide the distribution of air velocity and pressure around building structures due to the wind effect and this information can be used to assess pedestrian comfort, determine local pressures for positioning HVAC intakes/exhausts and to calculate more accurate pressure coefficients for EnergyPlus calculated natural ventilation simulations.



Example External CFD Analysis Output - Wind Pressure Study

Internal analyses provide the distribution of air velocity, pressure and temperature (and several other calculated parameters) throughout the inside of building spaces. Also calculated is 'age of air' to indicate the relative 'freshness' of the air through the domain and also a comfort index. This information can be used to assess the effectiveness of various HVAC and natural ventilation system designs and to evaluate consequent interior comfort conditions.

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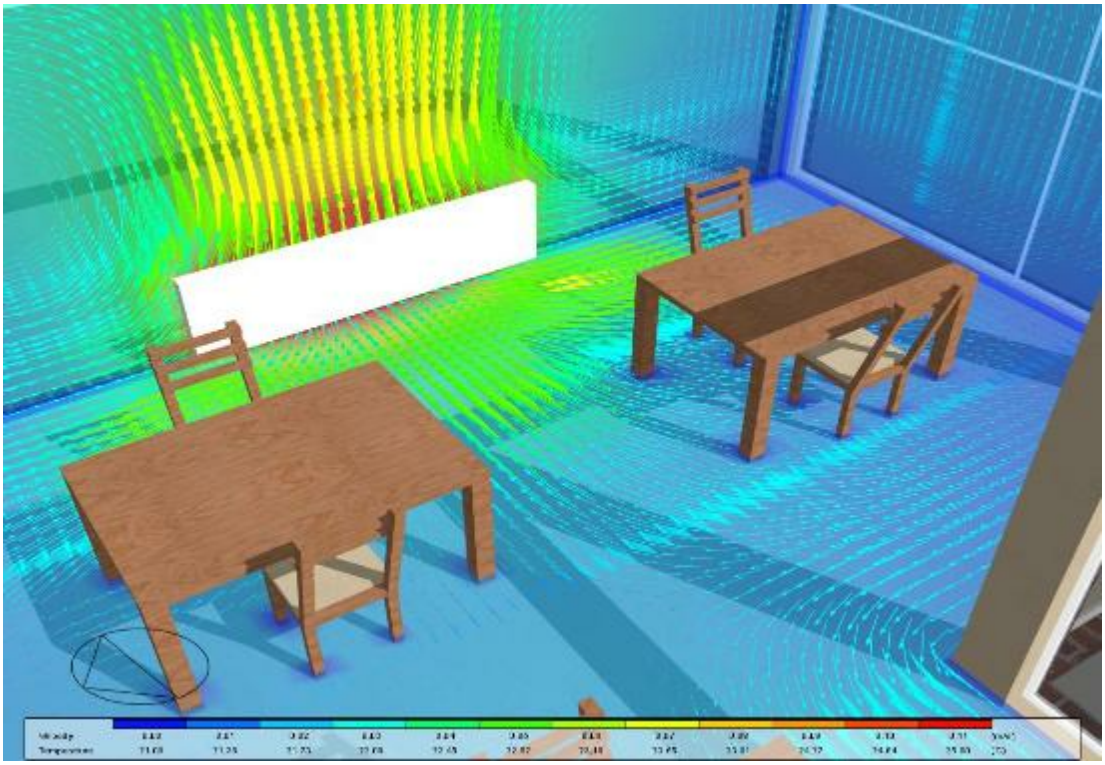

Example Internal CFD Analysis Output - Occupant Comfort

CFD Calculations Topics Contents

- CFD Calculations and Convergence
- The Iterative Nature of the Procedure
- Finite Volume Grid and Geometric Modelling Considerations
- Building Levels and CFD Analyses
- CFD Boundary Conditions
- Boundary Conditions for Internal CFD Analyses
- Component Blocks and Assemblies as CFD Boundaries
- Setting Up a New External CFD Analysis
- Setting Up a New Internal CFD Analysis
- Editing the CFD Grid
- CFD Grid Information
- Setting Up CFD Cell Monitor Points
- CFD Calculation Options
- Residuals and Cell Monitor Graphs
- Convergence Difficulties and Troubleshooting
- Displaying Results
- Conducting CFD Comfort Calculations
- CFD Results Manager

7.4.1 Creating Model Geometry for CFD

If you have already created a model for the purpose of an additional analysis (e.g. thermal simulation or SBEM calculation), you can use exactly the same model for CFD, although you should first read the Finite volume grid and geometric considerations section.

On the other hand, if you intend to conduct a CFD analysis from scratch, you should refer to the Building Models section for information on creating models.

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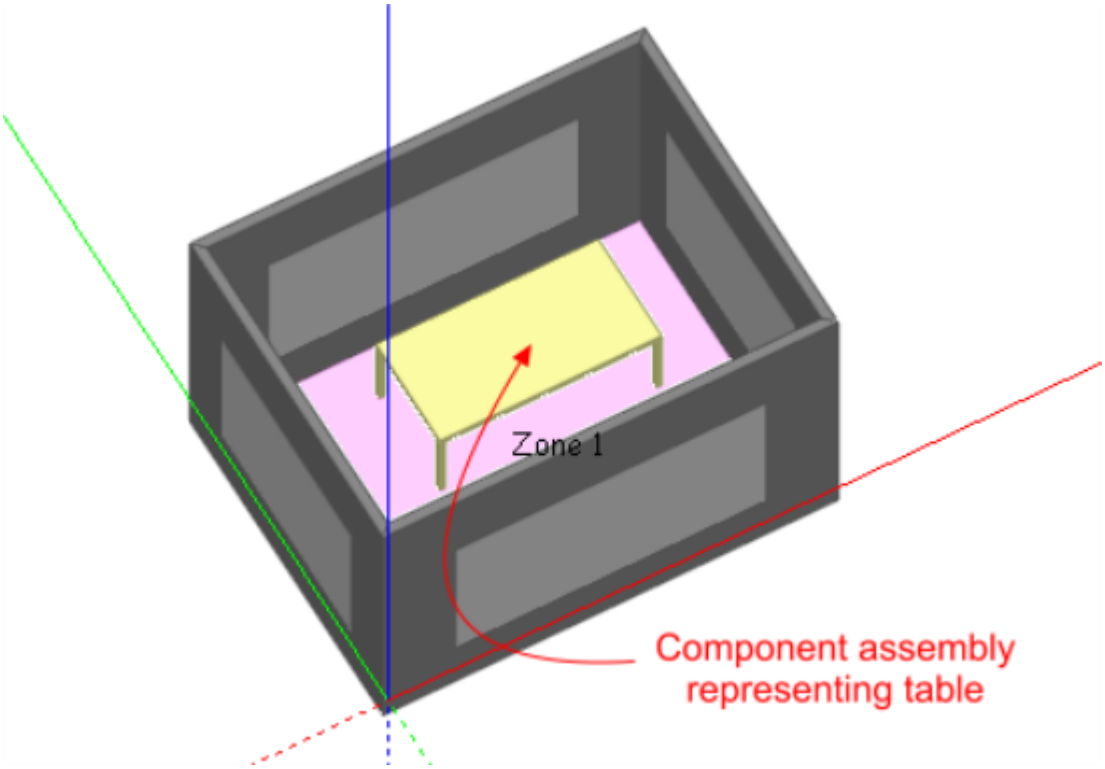
7.4.2 Finite Volume Grid and Geometric Modelling Considerations

The calculation method requires that the geometric space across which the calculations are to be conducted is first divided into a number of non-overlapping adjoining cells which are collectively known as the finite volume grid.

When a CFD project is created, a grid is automatically generated for the required model domain by identifying all contained model object vertices and then generating key coordinates from these vertices along the major grid axes. These key coordinates, extended from the X, Y and Z-axes across the width, depth and height of the domain respectively are known as 'grid lines'. The distance between grid lines along each axis is known as a grid 'region' and these regions are initially spaced employing user-defined default grid spacing in order to complete the grid generation. The grid used by DesignBuilder CFD is a non-uniform rectilinear Cartesian grid, which means that the grid lines are parallel with the major axes and the spacing between the grid lines enables non-uniformity.

For example, looking at a simple building block with a single component assembly representing a table:



The resulting grid, generated with 0.3m default grid spacing would be as follows:

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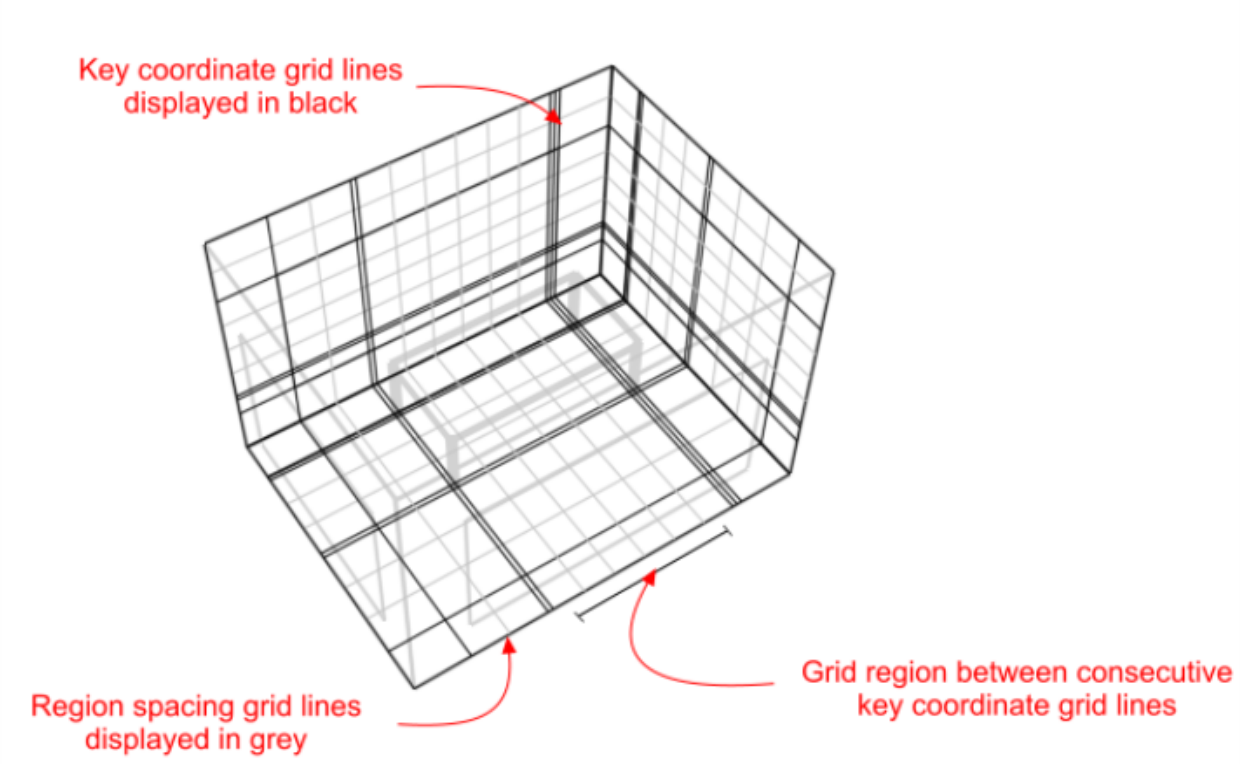

By default, grid regions are spaced uniformly using a spacing that is calculated to be as close to the user-defined default grid spacing as possible. Notice the narrow regions created between key coordinates associated with the tabletop and table legs. In this case, the distance between these key coordinates is of an acceptable value. However, very narrow regions resulting in long narrow grid cells or cells having a high aspect ratio should be avoided, as they tend to result in unstable solutions that can fail to converge. Highly detailed component assemblies can result in very large numbers of closely spaced key coordinates resulting in cells having high aspect ratios. Large numbers of key coordinates can also lead to overly complex grids and correspondingly high calculation run times and excessive memory usage which can be avoided by replacing very detailed assemblies with cruder representations for the purpose of the CFD calculation. However, where very narrow grid regions are unavoidable, adjacent grid lines formed from key coordinates can be merged together using the merge tolerance setting which is accessed through the new CFD analysis dialogs (see the Setting Up a New External CFD Analysis and 'Setting Up a New Internal CFD Analysis' sections). For instance, in the above example, if the table assembly had been located closer to the edge of the adjacent window, this could result in unacceptably close grid lines:

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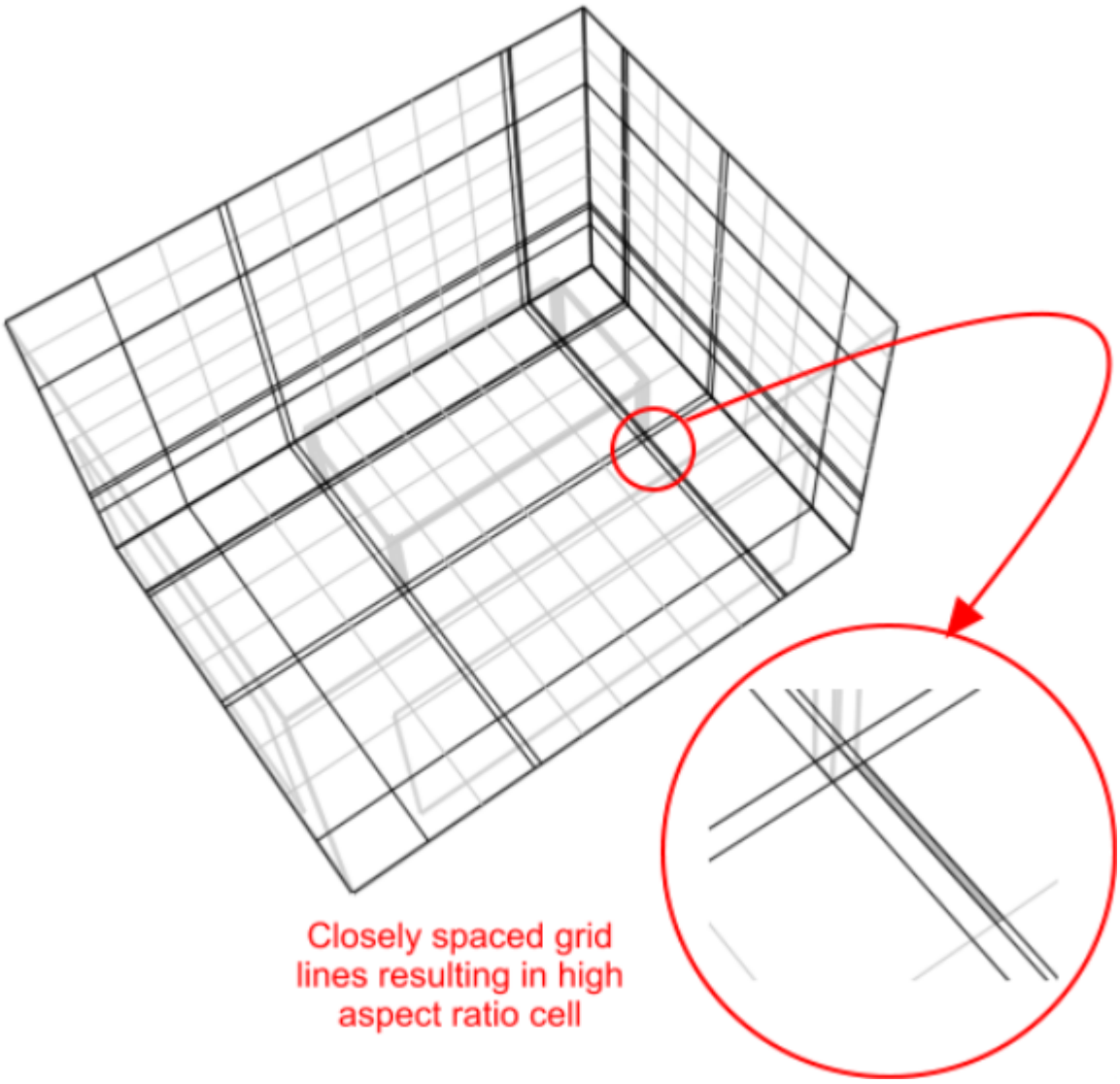

These closely spaced grid lines can be merged by creating a new analysis and increasing the grid line merge tolerance setting to say 0.025m:

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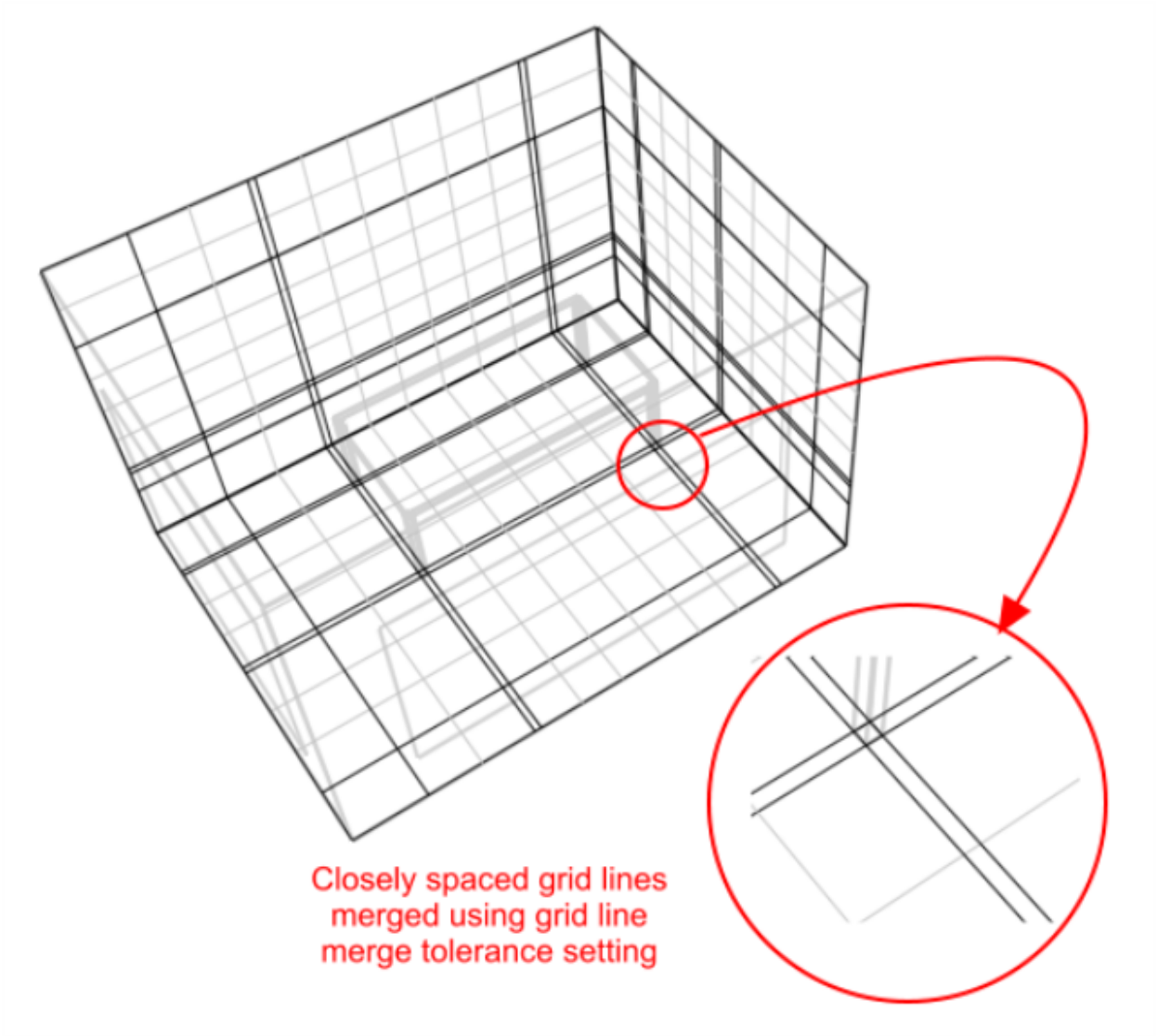

Due to the strict rectilinear nature of the grid, grid cells that lie in regions outside of the domain required for calculation are 'blocked-off' in order to cater for irregular geometries. It is important to take this into account when creating a model in order to maximise the efficiency of grid generation and/or to ensure that surface CFD boundaries will lie in the plane of a major grid axis to achieve accuracy of boundary representation. In some cases, the model may be rotated in order to ensure that most of the wall surfaces are orthogonal with respect to the grid axes. To take an extreme example, if a simple rectangular space has been drawn at a 45° angle to the Z-axis:

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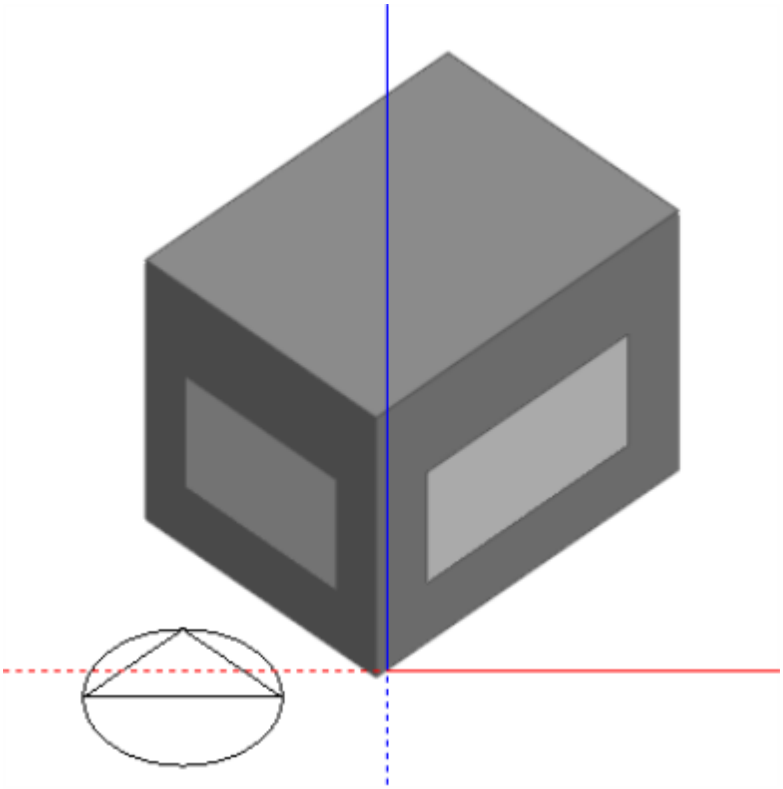
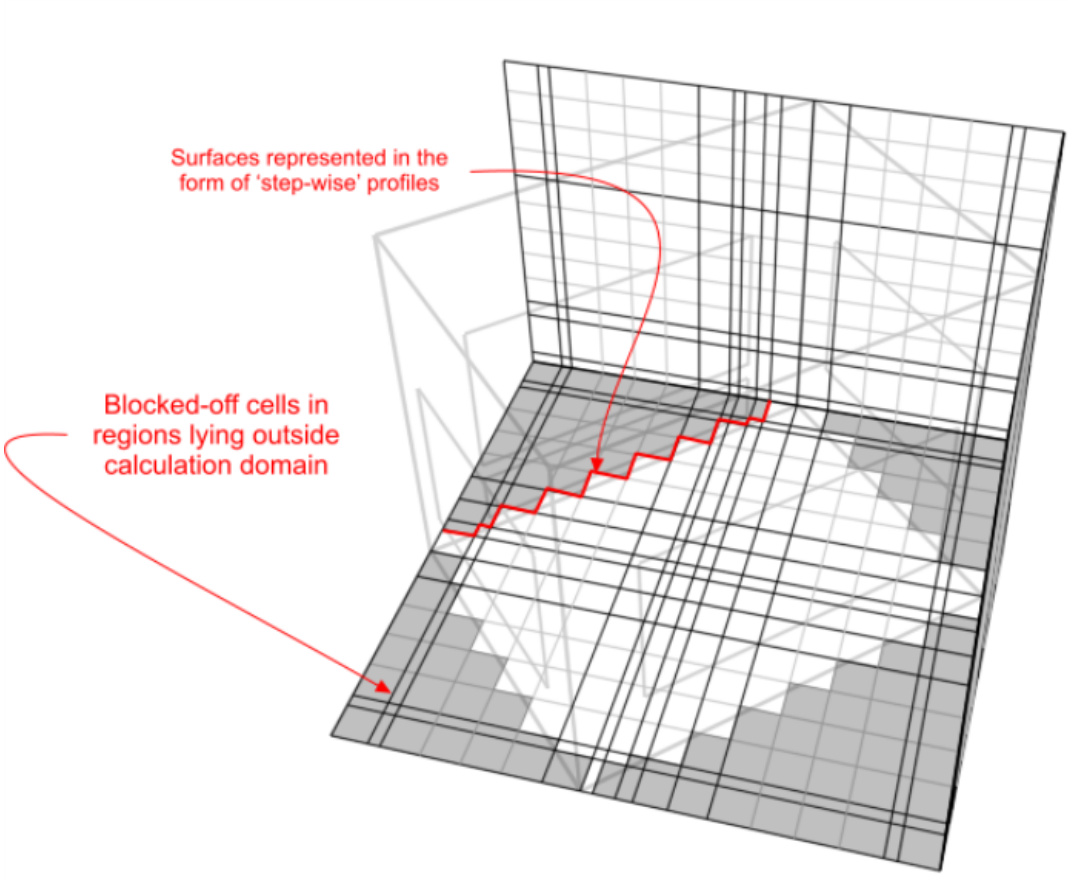


The resulting grid, generated using 0.3m default grid spacing, contains a great deal of redundancy in the form of blocked-off regions and inaccuracy of surface representation:



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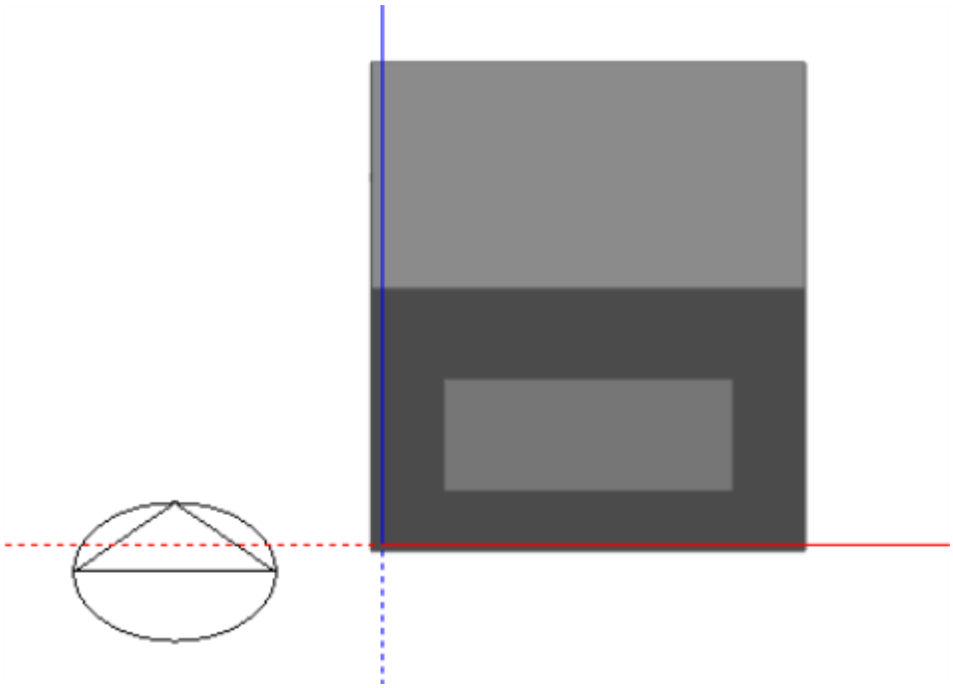
If the block is first rotated, to be aligned with the X-axis:



The resulting grid exhibits no redundancy and there is no inaccuracy in surface representation:

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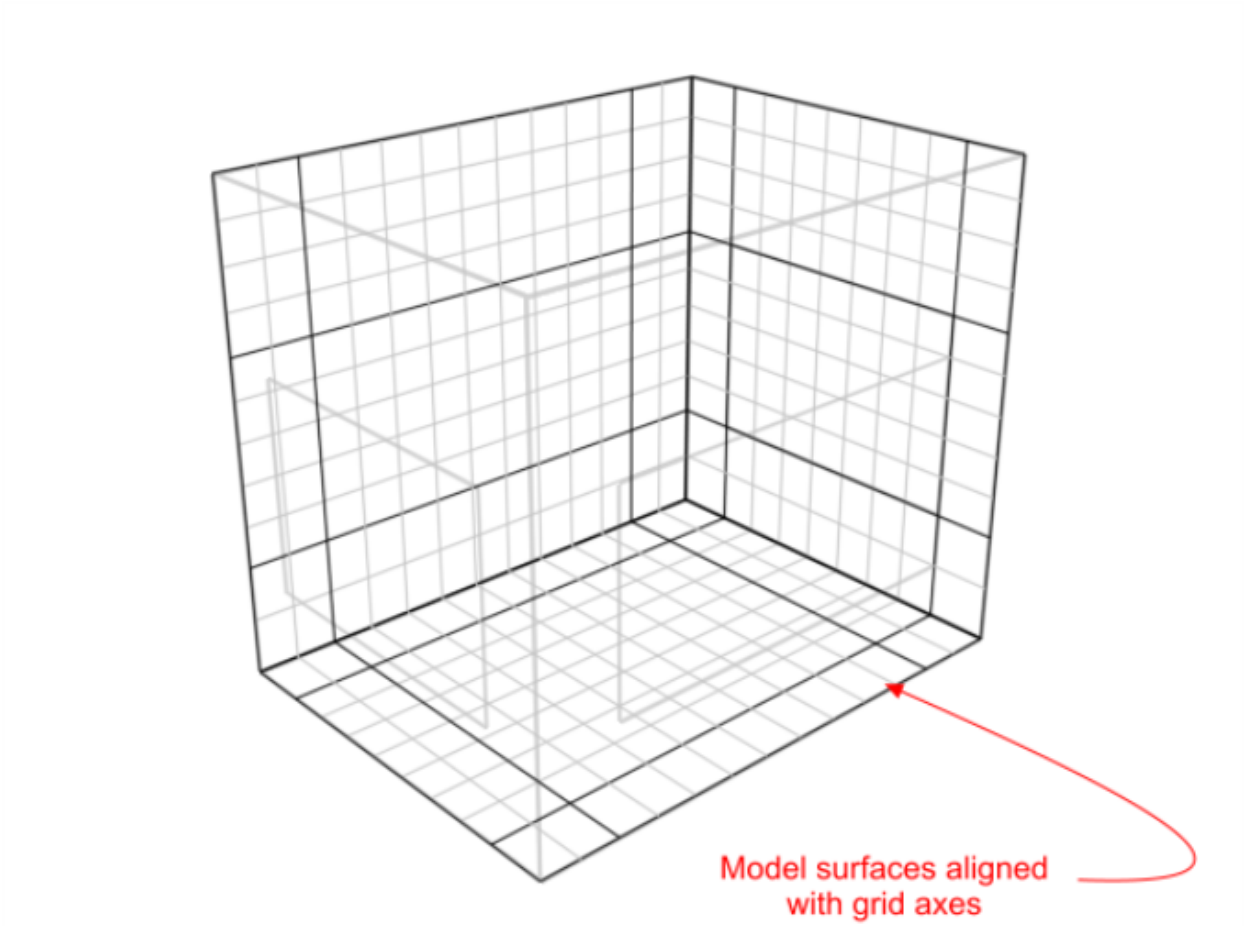
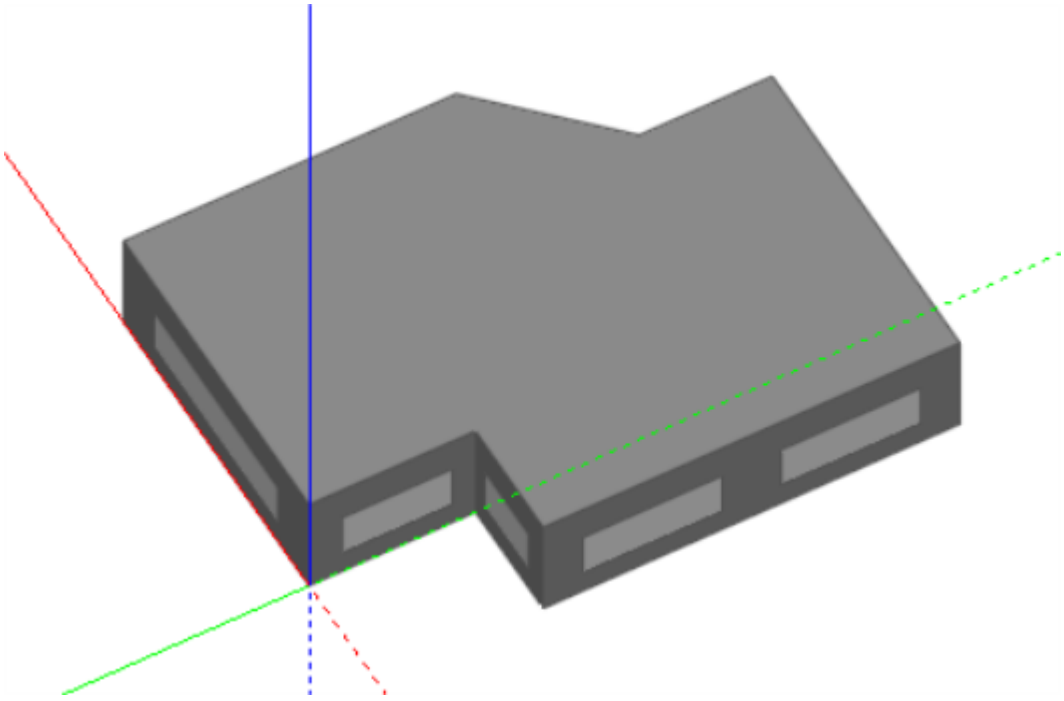


The accuracy of the representation of non-orthogonal surfaces can be improved by using smaller default grid spacing and in some cases specific grid regions can be modified to increase accuracy in a more localised fashion as illustrated by the following example:



Grid generated using default 0.3m grid spacing:

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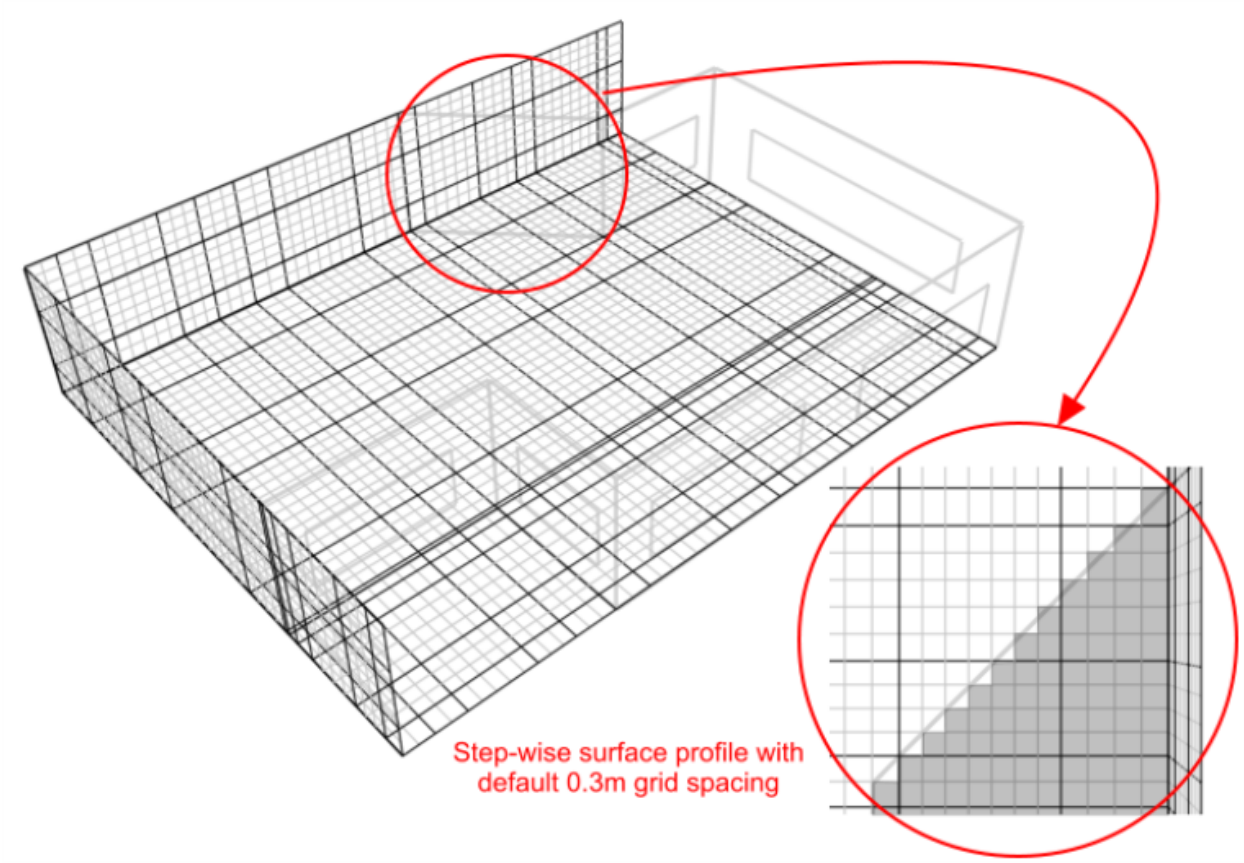

Using the 'Edit CFD Grid' tool, the grid spacing within just the regions spanning the angled section is reduced to 0.2m to improve the representation:

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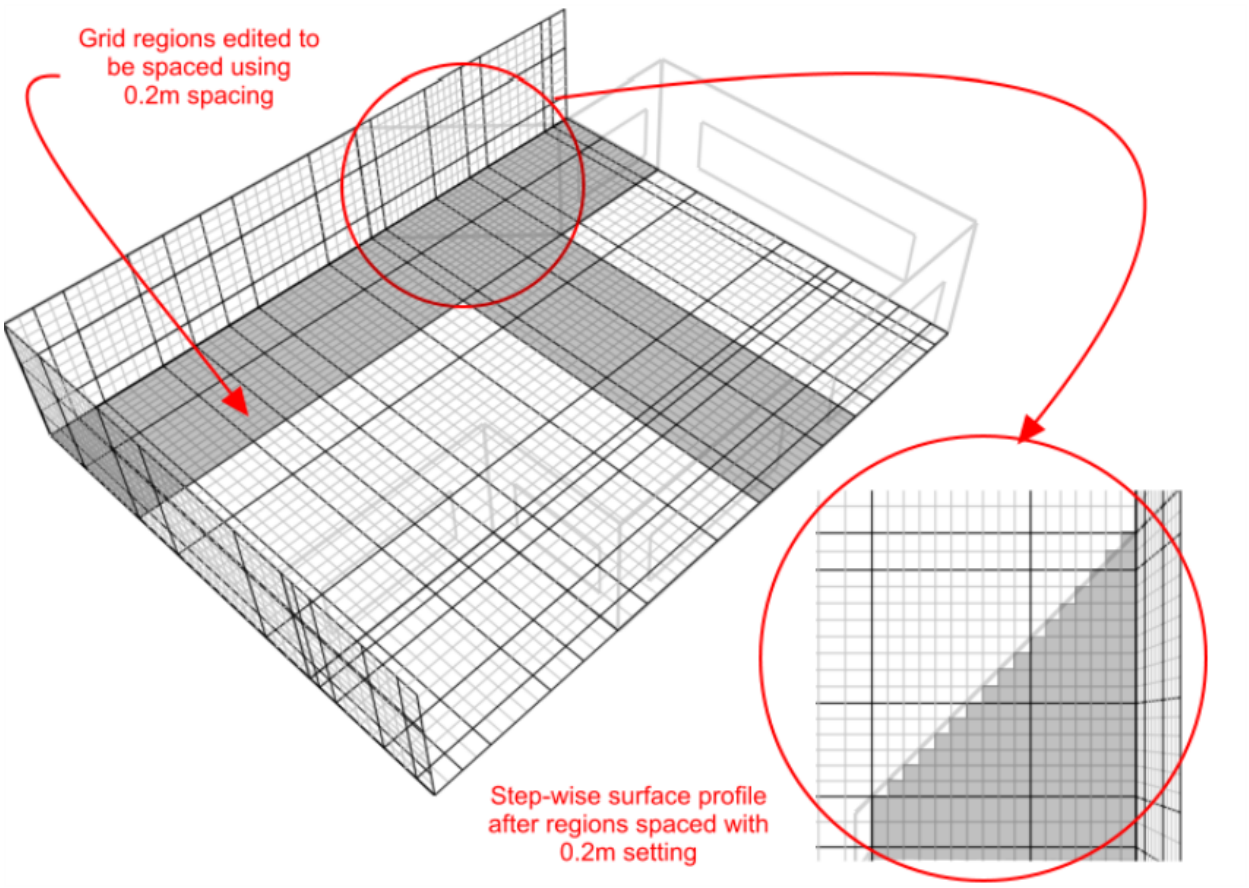

Grid regions between key coordinates can also be spaced using non-uniform spacing options and additional key coordinate regions can be added. Further information is provided on grid modification in the 'Editing the CFD Grid' section.

7.4.3 Building Levels and CFD Analyses

Internal CFD analyses can be conducted at zone, building block and building levels. Calculations can also be conducted for single zones that span several blocks by connecting them with holes and using the Merge zones connected by holes model option setting.

External analyses can only be conducted at the site level.

The level you are at when you create the CFD Analysis defines both the type of the CFD analysis (internal or external) and also the extent of the CFD domain. If you are at building level then the domain is the whole building, if you are at block level the domain will be the block and if you are at zone level the domain is the current zone.

7.4.4 CFD Boundary Conditions

An important initial concept for CFD analyses is that of boundary conditions. Each of the dependent variable equations requires meaningful values at the boundary of the calculation domain in order for the calculations to generate meaningful values throughout the domain. These values are known as boundary conditions and can be specified in a number of ways.

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The specification of boundary conditions for external analyses is relatively straightforward because it is an isothermal calculation and so it only requires the building exposure, wind velocity and wind direction to be set and this is done in the **New CFD Analysis** dialog box.

Internal analysis boundary conditions tend to be more involved and can require the addition of zone surface boundaries such as supply diffusers, extract grilles, temperature and heat flux patches and also the incorporation of model assemblies representing occupants, radiators, fan-coil units, etc. DesignBuilder provides default wall and window boundary temperatures automatically but it is important that you check that these defaults are appropriate and that you correctly specify any additional boundary conditions required for your project.

You can also calculate the internal surface temperature for each surface in the domain using EnergyPlus simulation by switching on the appropriate options. You can also calculate airflow rates through open windows, vents, doors and holes using the Calculated natural ventilation option.

See also:

- Boundary Conditions for Internal CFD Analyses
- CFD Model Data
- Component Blocks Assemblies as CFD Boundaries

7.4.5 Boundary Conditions for Internal CFD Analyses

Internal boundary conditions can be defined in three ways:

1. Surface temperatures can be defined for all zone surfaces including windows and other openings.
2. Zone surface boundary conditions including supply diffusers, extract grilles, temperatures and heat fluxes can be added in the form of surface patches using a similar method to that used for adding windows and doors.
3. Component blocks and component assemblies can be defined as temperature or heat flux boundaries or they can also have boundary condition patches added as described above for Zone surfaces.

In all cases the CFD boundary conditions can be edited on the CFD Model data tab.

DEFAULT WALL AND WINDOW TEMPERATURES

All zone surfaces within a model have default wall and window boundary temperatures. These boundary temperatures are inherited from the building level down to the zone surface level and may be set at any intermediate level. This mechanism provides a convenient method for defining wall and window temperature boundary conditions throughout a building model in the absence of imported EnergyPlus boundary data.

Default inside and outside wall and window boundary temperatures can be accessed under the **CFD Boundary** header on the CFD tab:

ZONE AND COMPONENT BLOCK SURFACE BOUNDARIES

Supply diffusers, extract grilles, temperature and heat flux patches can be added to zone and component block surfaces using the **Add CFD boundary** tool.

To add a surface boundary, move down to the surface on which you want to locate the boundary, either by selecting it from the model navigator or by navigating to it in the Edit screen. At the surface level, you can then select the **Add CFD boundary** tool from the toolbar:

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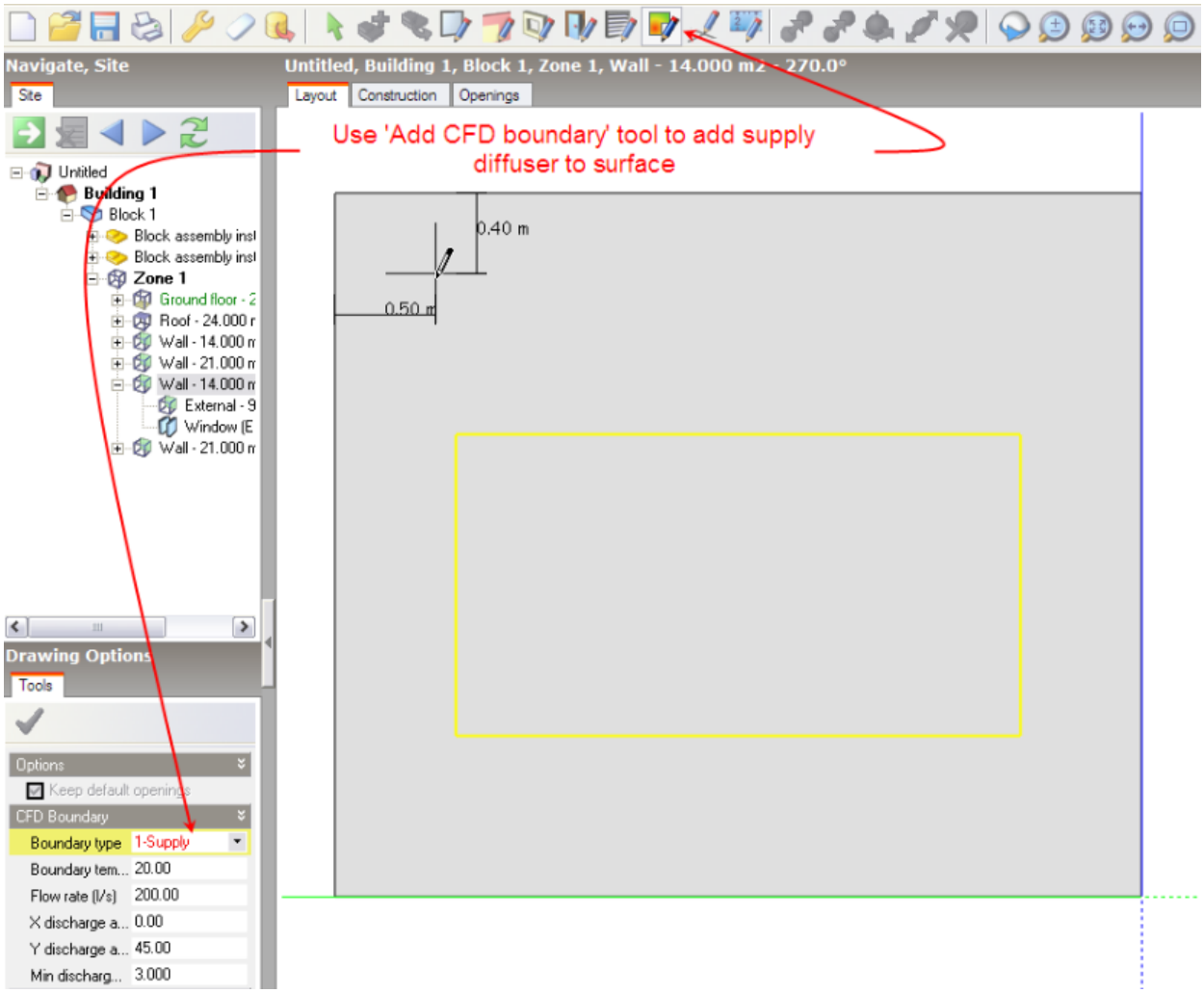

You can draw a CFD boundary on to the surface in exactly the same way that you would draw a window. Refer to the Draw Window section for details of drawing windows.

After selecting the **Add CFD boundary** tool, the boundary settings are displayed on the Drawing options data panel. You can select the required boundary type from the **Boundary type** drop list. The following boundary types are available for surfaces of all orientations:

- **1–Supply** (general purpose HVAC supply diffuser)
- **4–Extract** (HVAC extract grille)
- **5–Temperature** (surface temperature patch)
- **6–Flux** (surface heat flux patch)

The following additional boundary types for multi-directional diffusers will appear for ceiling and other downward-facing surfaces only:

- **2–Four-way** (four-way supply diffuser)
- **3–Two-way** (two-way supply diffuser)

Various settings are available depending on the boundary type:

1-Supply:

- **Boundary temperature** - the temperature of the air entering the space.
- **Flow rate** - the supply volume flow rate.

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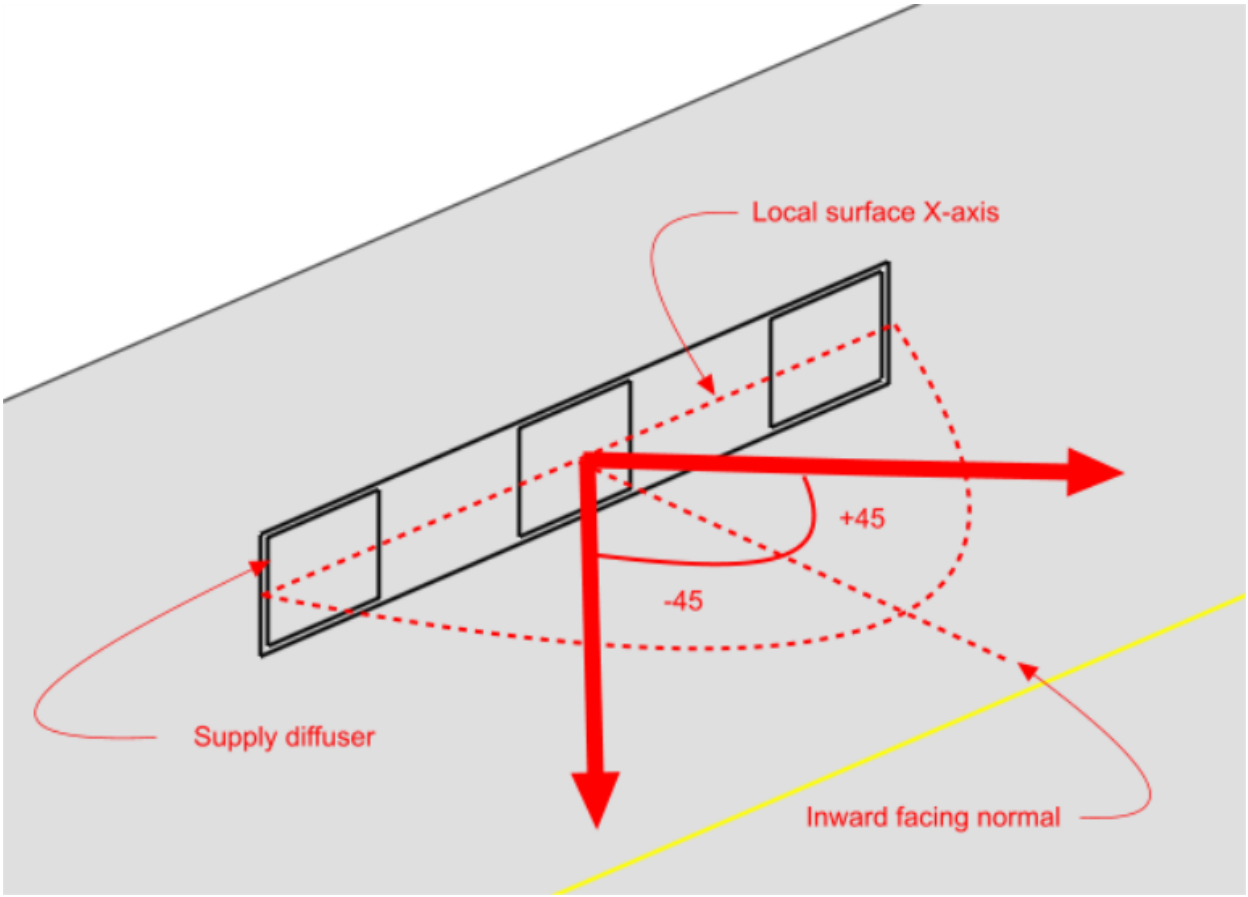
- **X-discharge angle (°)** - the discharge angle between the local surface X-axis and an inward facing normal to the surface. At the surface level, taking a normal view from the inside of the zone to the surface, the X-axis discharge angle is positive between the normal and the positive X-axis (i.e. the axis pointing towards the right) and negative between the normal and the negative X-axis (i.e. the axis pointing towards the left). For example to define a discharge angle of 45° pointing towards the left of the centre of a diffuser, looking at it from the inside of the zone, you would enter –45. On the other hand, to define a discharge angle of 45° pointing towards the right of the centre, you would enter 45:



- **Y-discharge angle (°)** - the discharge angle between the local surface Y-axis and an inward facing normal to the surface. At the surface level, taking a normal view from the inside of the zone to the surface, the Y-axis discharge angle is positive between the normal and the positive Y-axis (i.e. the axis pointing upwards) and negative between the normal and the negative Y-axis (i.e. the axis pointing downwards). For example to define a discharge angle of 45° pointing downwards from the centre of a diffuser, looking at it from the inside of the zone, you would enter –45. On the other hand, to define a discharge angle of 45°, pointing upwards from the centre, you would enter 45:

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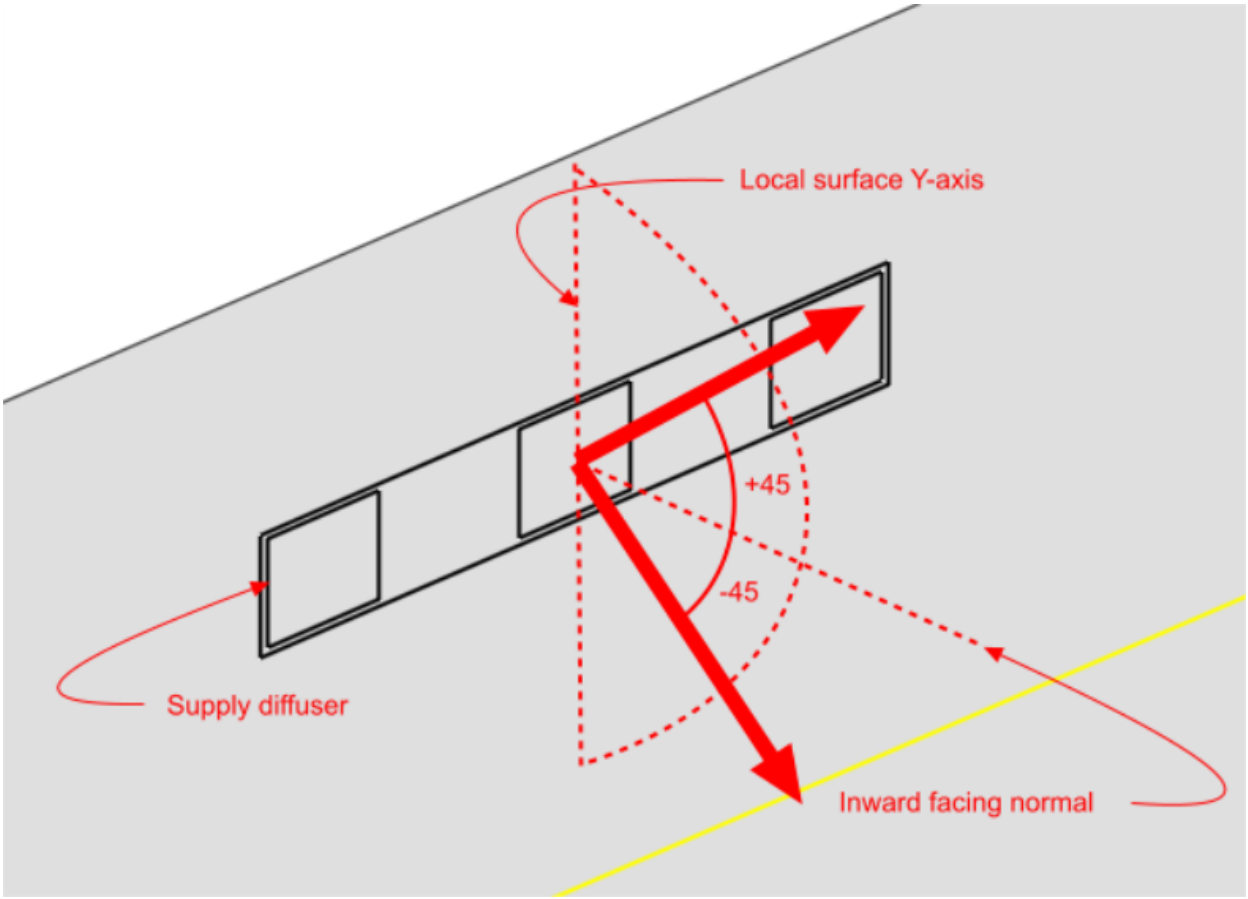

- **Minimum discharge velocity** - the minimum required velocity at the face of the diffuser. Supply diffusers are created using a number of elements, the areas of which are determined by combining the specified volume flow rate together with the minimum discharge velocity. The maximum linear dimension of each component element is currently 'hard-set' at 0.2m.

2–Four-way

- **Boundary temperature** - temperature of the air entering the space.
- **Flow rate** - the supply flow rate.
- **Multi-way diffuser discharge angle (°)** - the discharge angle is the angle between the downward pointing normal and the diffuser jet.
- **Minimum discharge velocity** - the minimum required velocity at the face of the diffuser. Four-way diffusers are created using four separate elements, one located at each edge of the diffuser, the area of each being determined by combining the specified volume flow rate together with the minimum discharge velocity.

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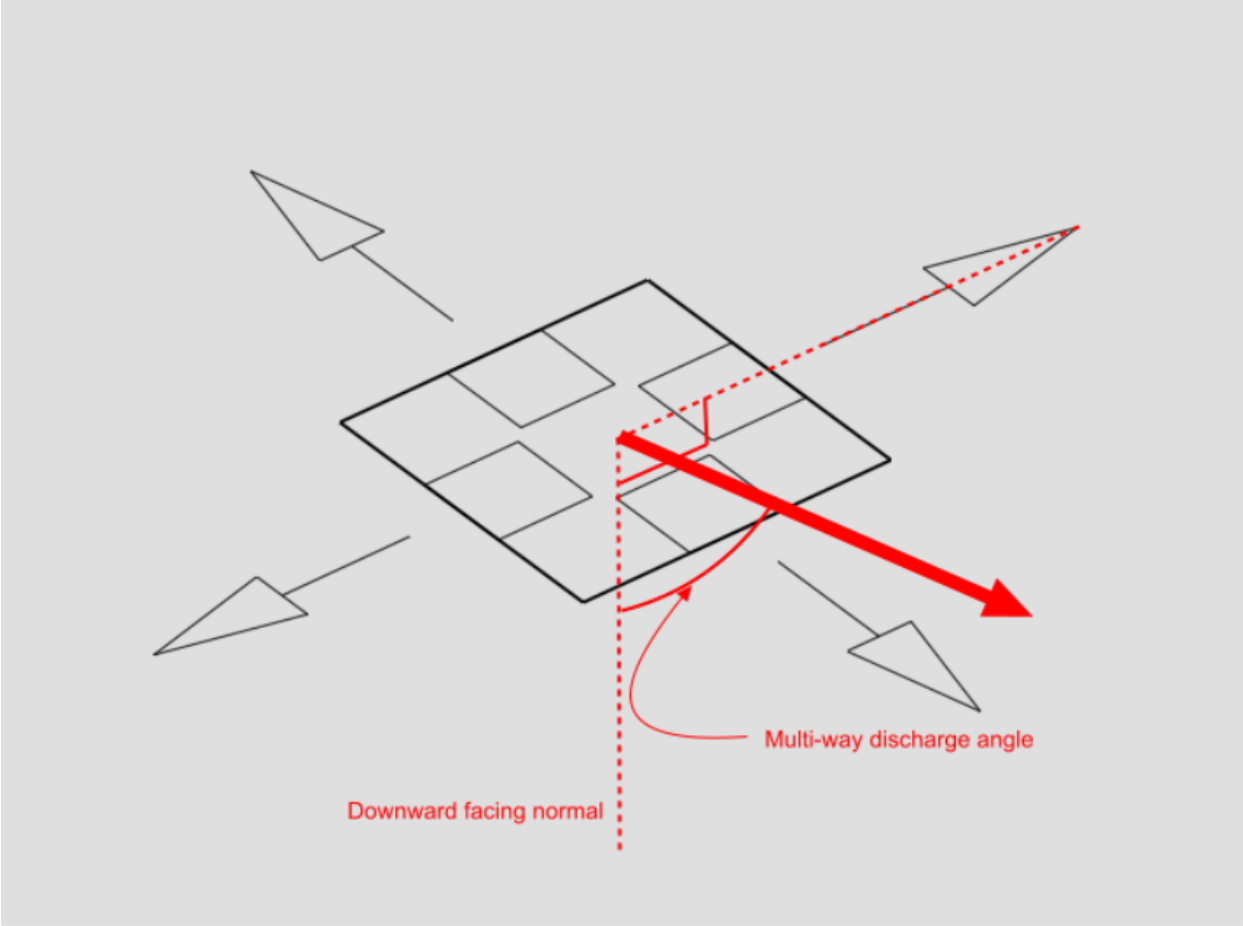

3–Two-way

- **Boundary temperature** - the temperature of the air entering the space.
- **Flow rate** - enter the supply flow rate.
- **Multi-way diffuser discharge angle (°)** - the angle between the downward pointing normal and the diffuser jet (see illustration in 'Four-way' section).
- **2-way diffuser discharge direction** - the local surface axis along which the diffuser is to discharge.
- **Minimum discharge velocity** - the minimum required velocity at the face of the diffuser. Two-way diffusers are created using two separate elements, one on either side of the diffuser along the discharge axis, the area of each being determined by combining the specified volume flow rate together with the minimum discharge velocity.

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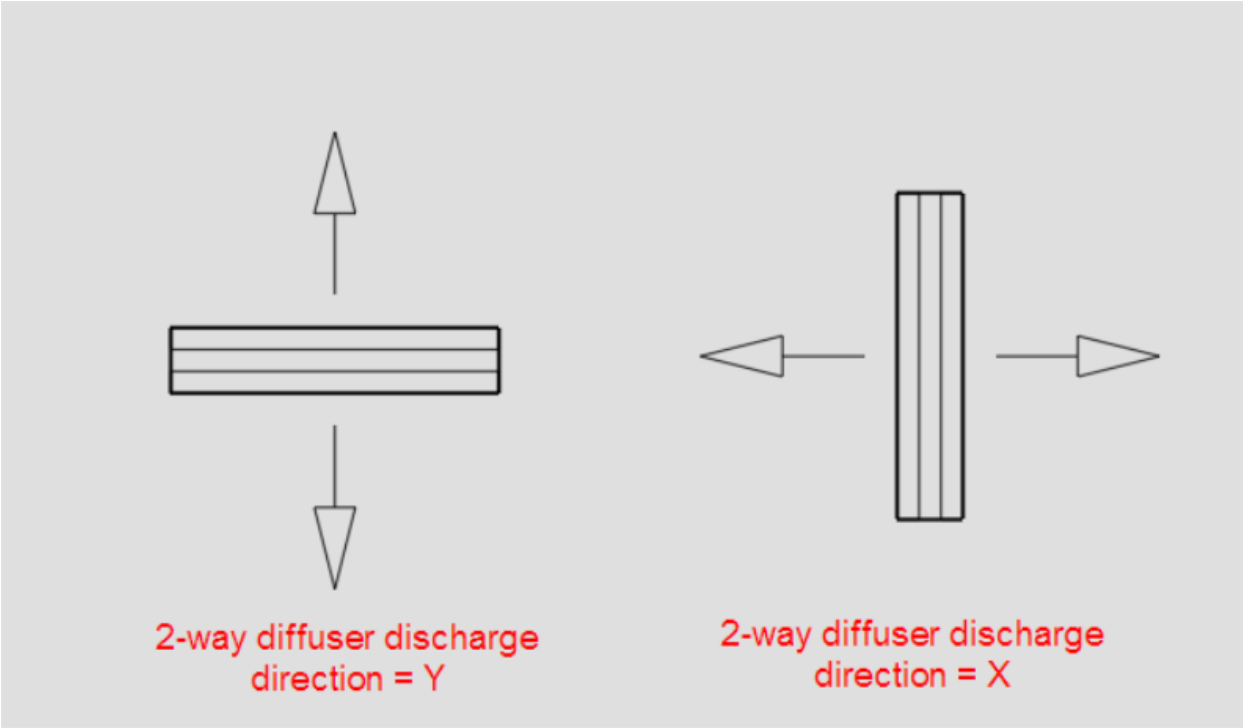

4–Extract

- **Flow rate** - the extract flow rate.

5–Temperature

- **Boundary temperature** - temperature for the patch.

6– Flux

- **Heat flux** - heat flux for the patch.

7.4.6 Component Blocks and Assemblies as CFD Boundaries

Component blocks and assemblies can be used for CFD analyses to simply allow for the effect of obstructions on the airflow. However, they also allow the definition of CFD boundary attributes to enable them to act as constant temperature surfaces or heat flux sources and can also be modified to behave as non-solids to allow air to pass through them.

Component Blocks

CFD attributes for component blocks are inherited down from the building level to component blocks located at both building and building block levels. CFD attributes for component blocks are accessed on the CFD model data tab:

Assemblies

The CFD assembly library that is provided with DesignBuilder contains a number of pre-defined assemblies that can be used to add items such as occupants, radiators and furniture. Some of these pre-defined assemblies already have CFD boundary attributes associated with them, e.g. occupant assemblies have a defined heat flux of 90W. You can also define your own assemblies for use in CFD analyses and you will find details of how to do this in the 'Assemblies' Help section.

CFD attributes for component assemblies are inherited from the parent assembly to instances of the

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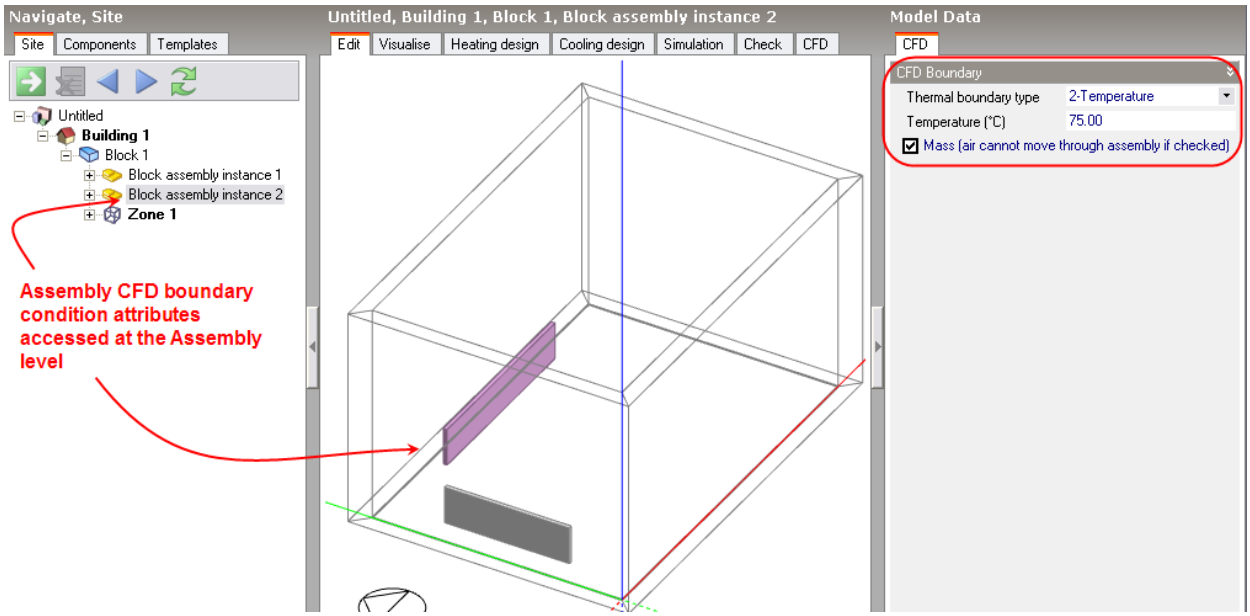
assembly at the building and building block levels. CFD attributes for assemblies are accessed from the CFD tab after moving down to an assembly instance level by clicking on it in the navigator or double-clicking on it in the Edit screen. It is important to understand that if you change an attribute for a specific instance of an assembly, the attributes will be changed for all other instances of the same assembly.



The following CFD boundary settings are available for both component blocks and component assemblies:

Thermal boundary type: The thermal boundary type can be set to one of the following:

- **1–None** - component block does not act as a CFD boundary condition.
- **2–Temperature** - component block acts as a fixed temperature CFD boundary condition (enter temperature below)
- **3 – Flux** - Component block supplies a fixed heat flux to the surroundings (enter the flux below).

Temperature

If the thermal boundary type has been set to **Temperature**, enter the temperature of the block.

Flux

If the thermal boundary type has been set to **Flux**, enter the heat emission of the block.

Mass

Determines whether or not the block will act as a physical obstruction to the surrounding flow. In some cases, it may be desirable to fix the temperature or flux of the component but allow air to pass through the block, e.g. to represent an occupancy flux throughout a large volume without needing to locate individual occupants.

7.4.7 Setting Up a New External CFD Analysis

To create a new external CFD analysis, first make sure that you have selected the Site object in the model navigator and then click on the CFD tab:

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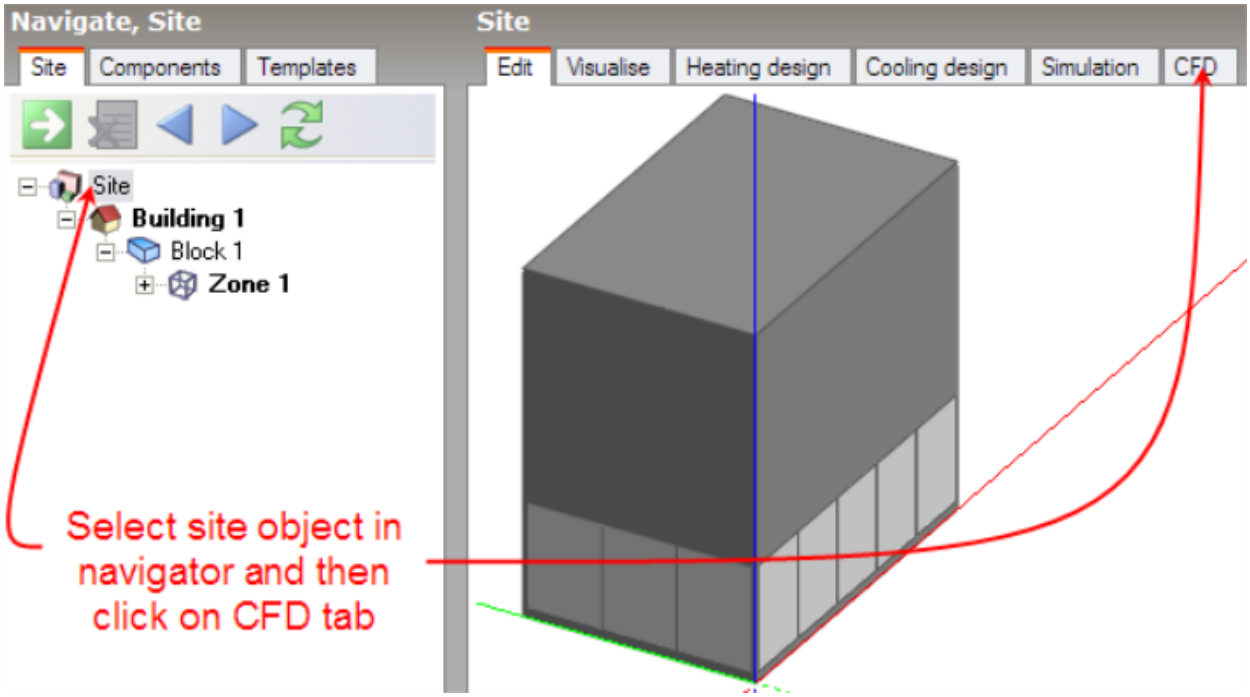
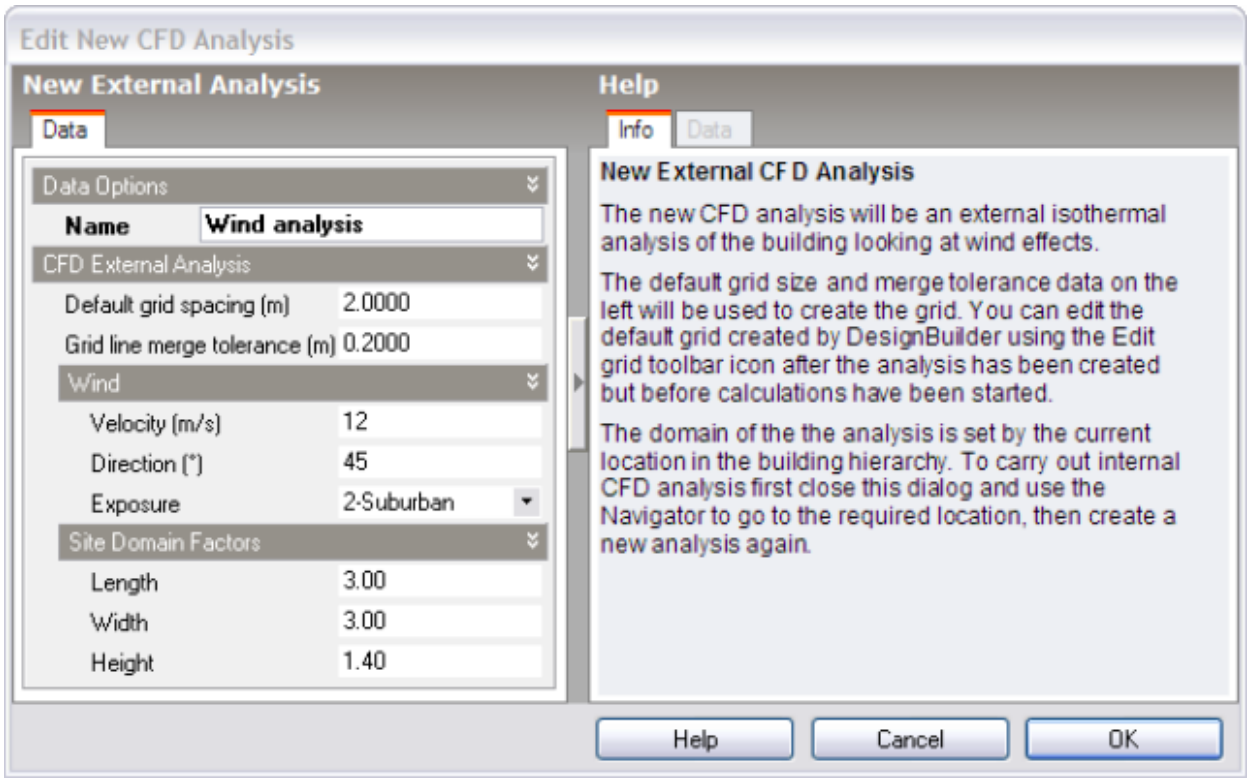


The 'New CFD Analysis Data' dialog is displayed which allows you to name the analysis, define grid generation variables, wind data and the extents of the domain to be included in the analysis:



Default Grid Spacing

On entry to the CFD screen after completing and closing the new CFD analysis dialog, the CFD grid is automatically generated throughout the overall external domain extents. The grid is created by first determining key points obtained from constituent model blocks along the major axes, the distance between each of these key points being known as regions. Each CFD grid region along each major axis is

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automatically spaced using the ‘default grid spacing’ dimension.

Grid Line Merge Tolerance

A potential problem when generating the grid is the creation of cells with a high aspect ratio that can lead to instability in the equation solver. In order to avoid such cells, grid lines that are very close together can be merged. The ‘grid line merge tolerance’ is the maximum dimension that will be used in determining whether or not to automatically merge grid lines.

Wind Velocity

Enter the required free stream wind velocity in m/s (measured at 10m above ground).

Wind Direction

The wind direction is defined clockwise from North. The default direction is 270°, i.e. Westerly.

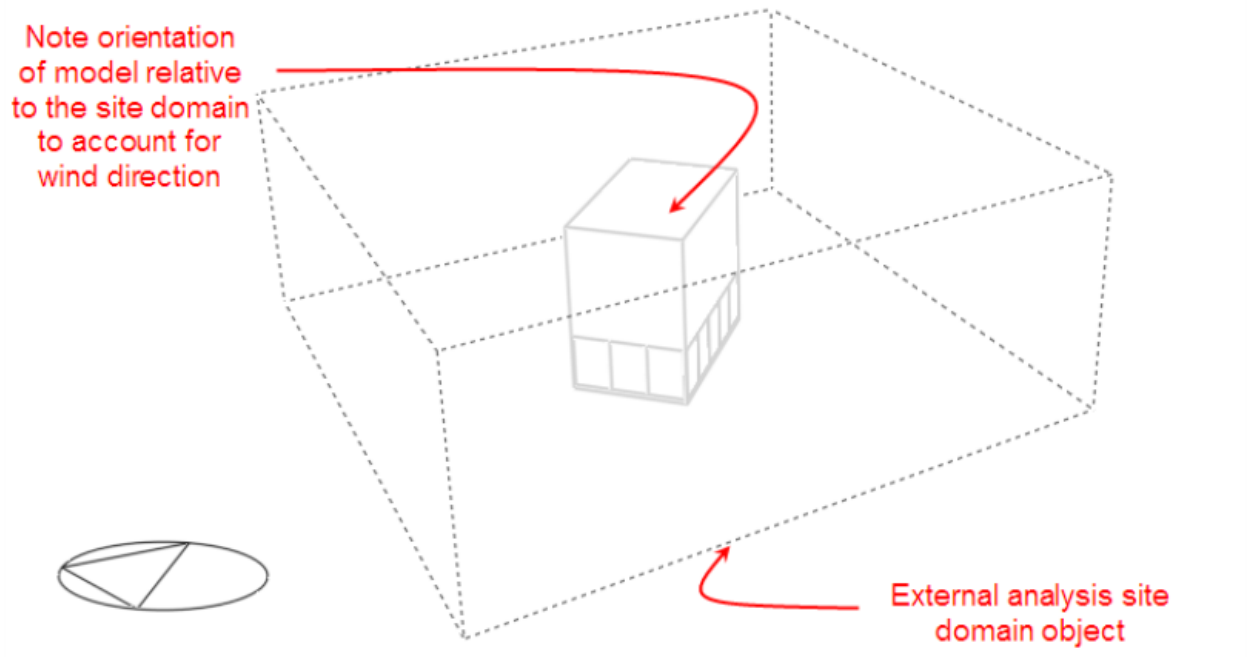
Wind Exposure

The free stream wind velocity is corrected for height above ground and surrounding terrain using an empirical relationship. Urban, suburban and open country exposures can be selected.

Site Domain Factors

The length, width and height site domain factors are multipliers that are applied to the overall dimensions of the building model in order to arrive at an external volume or domain across which the analysis is carried out. The default factors are 3.0 applied to the length and width and a factor of 2.0 that is applied to the model height.

After clicking on the OK button, the CFD screen is displayed showing the model in conjunction with the site domain object:



7.4.8 Setting Up a New Internal CFD Analysis

To create a new internal CFD analysis, first make sure that you have selected the appropriate level object (building, block or zone) in the model navigator and then click on the CFD tab:

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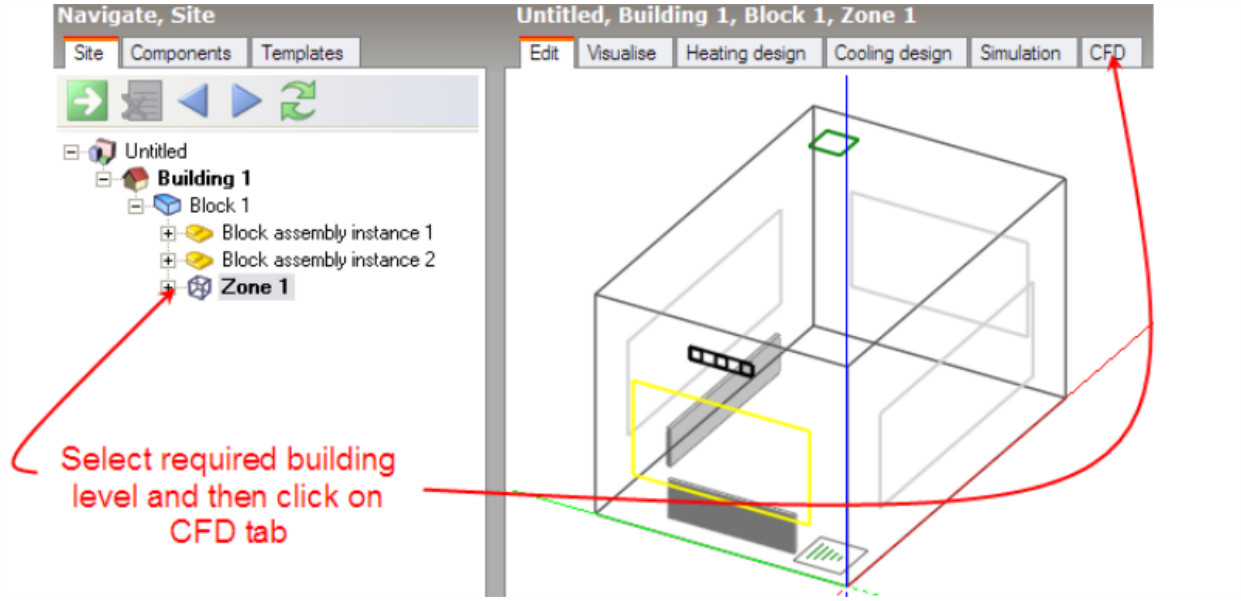
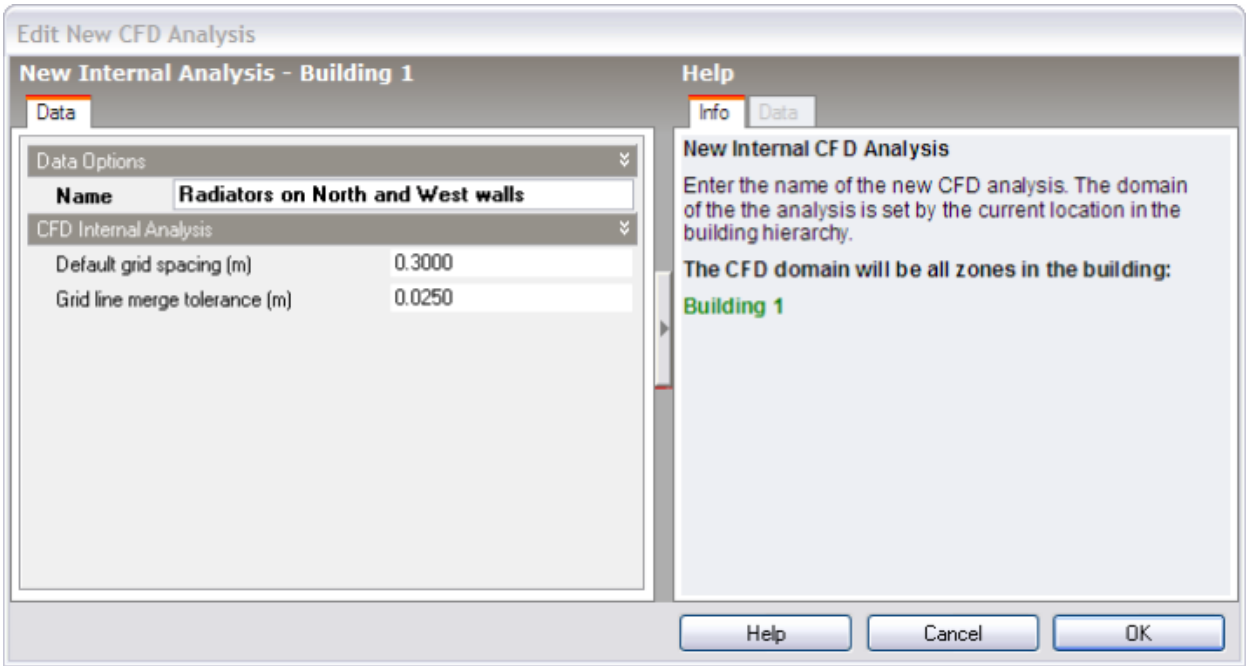


The 'New CFD Analysis Data' dialog is displayed which allows you to name the analysis and define grid generation variables:



Default Grid Spacing

On entry to the CFD screen after completing and closing the new CFD analysis dialog, the CFD grid is automatically generated throughout the overall external domain extents. The grid is created by first determining key points obtained from constituent model blocks along the major axes, the distance between each of these key points being known as regions. Each CFD grid region along each major axis is automatically spaced using the 'default grid spacing' dimension.

Grid Line Merge Tolerance

A potential problem when generating the grid is the creation of cells with a high aspect ratio that can lead to instability in the equation solver. In order to avoid such cells, grid lines that are very close together can be

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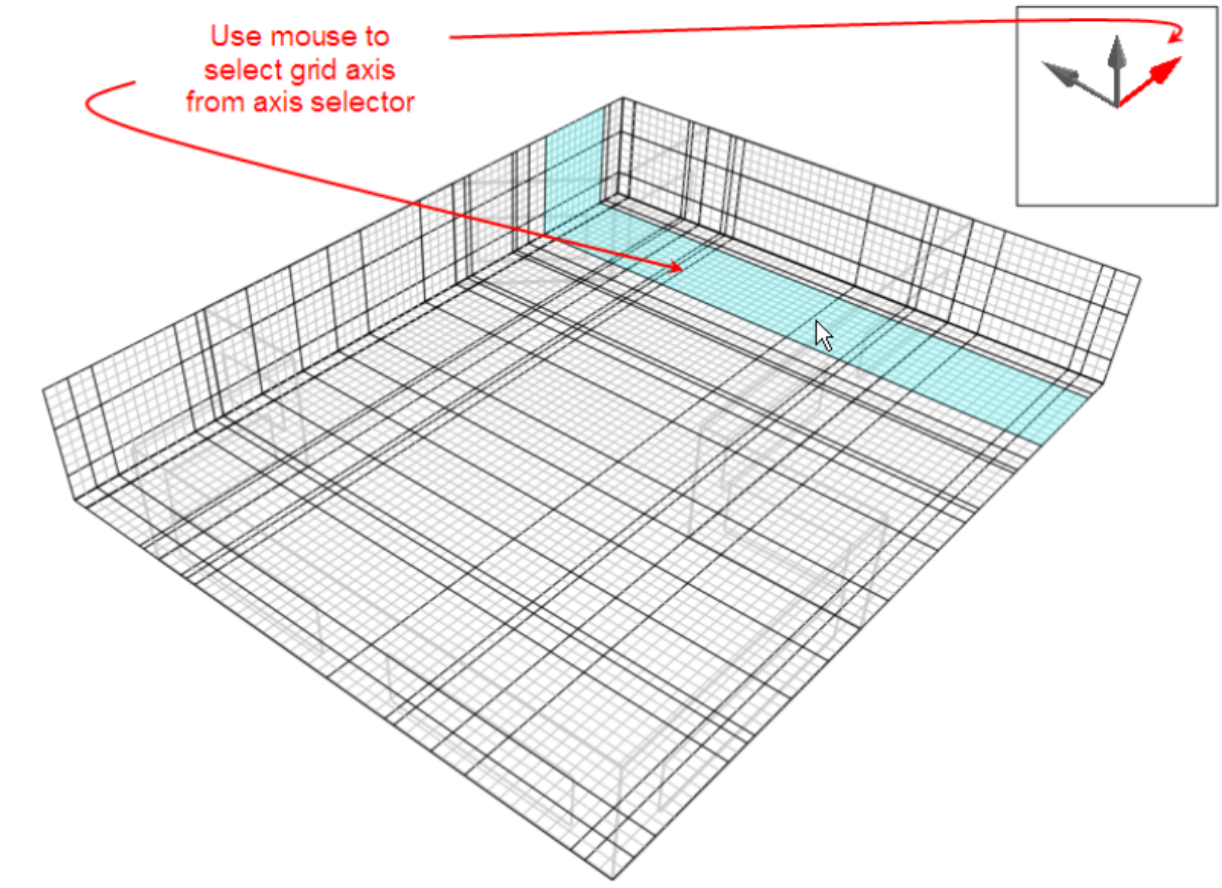
merged. The ‘grid line merge tolerance’ is the maximum dimension that will be used in determining whether or not to automatically merge grid lines.

7.4.9 Editing the CFD Grid

As soon as a new analysis data set has been created, a default CFD grid is generated using the default grid spacing defined as part of the data set. The default grid may be edited using the ‘Edit CFD Grid’ tool which allows you to change the spacing used for default regions, insert additional regions or remove previously inserted regions.

When you select the ‘Edit CFD Grid’ tool, the grid is displayed with the building outline overlaid as a ghosted wire frame. Grid regions are displayed along the major axes bounded by dark grey lines, the auto-generated grid region spacing lines being displayed in a lighter grey. The currently selected grid region is selected in cyan or yellow if the region is a non-default inserted region. To select regions on one of the other major axes, you can change the axis by clicking on the required axis of the axis selector displayed at the top right of the screen:



To edit a grid region, move the mouse cursor across the grid to the required region that will highlight to indicate that it has been selected and then click the mouse button. The selected region will then highlight in red and the ‘Edit CFD Grid’ data panel will be displayed at the bottom left of the screen:

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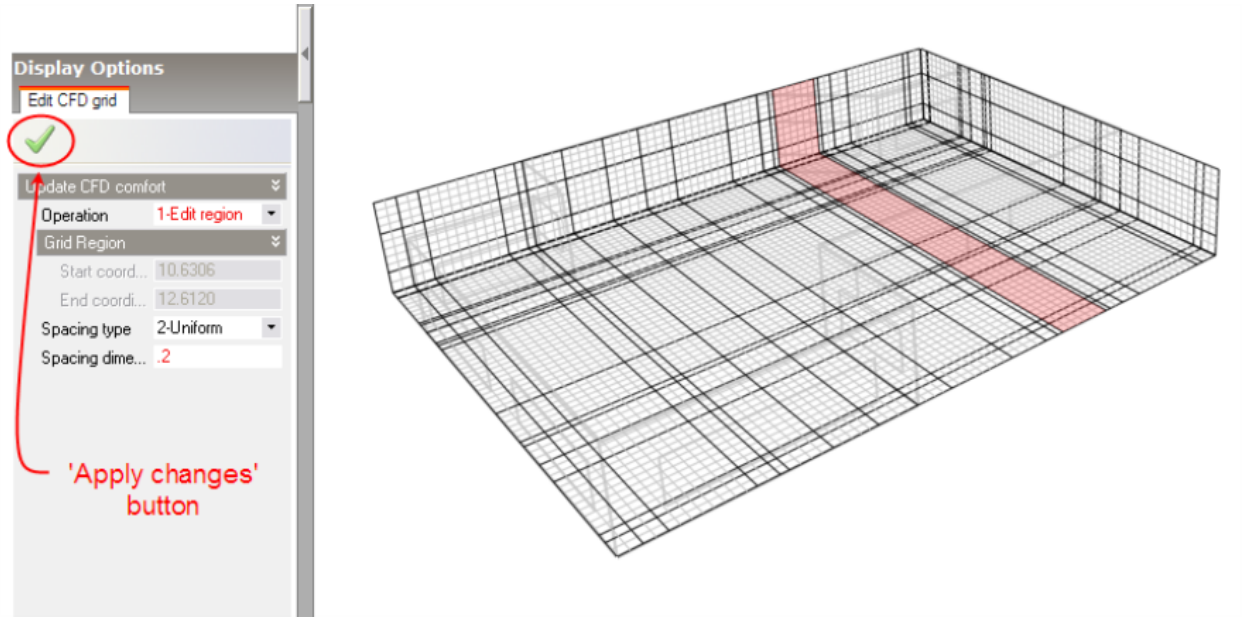

The following settings are available on the **Edit CFD Grid** data panel:

Operation:

- **1–Edit Region** - change the spacing of the currently selected region.
- **2–Insert Region-** insert a new custom key coordinate at a defined point in the current region to form an additional region.
- **3–Remove Region -** this option is only available if the current region has been previously inserted and allows you to remove it.

New coordinate (m)

If the 'Insert Region' operation has been selected, this setting is displayed allowing you to define a custom coordinate within the current region. Note that the coordinate must lie in the range defined by the displayed start and end coordinates.

Spacing Type

The spacing type can be set to one of the following:

- **1-None** - the region is not sub-divided.
- **2-Uniform** - the region is sub-divided into a number of equal sub-divisions, the dimension of which is calculated to be as close to the specified 'Spacing dimension' as possible.
- **3-Increasing power-law** - the location of each sub-division grid line within the region increases as the power of the spacing number, which starts at the beginning of the region. So that if i represents the index number of the grid line counted from the start of the region, the coordinate of the i^{th} sub-division grid line is calculated using the following relationship: $x_i=(\text{region dimension})(i/n)^{power}+x_s$
- **4-Decreasing power-law** - the location of each sub-division grid line within the region decreases as the power of the spacing number, which starts at the end of the region. So that if i represents the index number of the grid line counted from the start of the region, the coordinate of the i^{th} sub-division grid line is calculated using the following relationship: $x_i=(\text{region dimension})[1-(i/n)^{power}]+x_s$
- **5-Symmetric power-law** - the coordinate of the i^{th} sub-division grid line is calculated using both increasing and decreasing power-law relationships that meet at the middle of the region:

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For i <= n/2: $x_i=[(\text{region dimension})/2](2i/n)^{power}+x_s$

For i >= n/2: $x_i=[(\text{region dimension})/2][2-(2i/n))^{power}]+x_s$

Spacing dimension (m)

If the uniform spacing type has been selected, this setting is displayed and allows you to enter the dimension used for sub-dividing the region.

Spacing power

If the Increasing/Decreasing/Symmetric power law spacing type has been selected, this setting is displayed and allows you to enter the power used in the associated power-law spacing relationship.

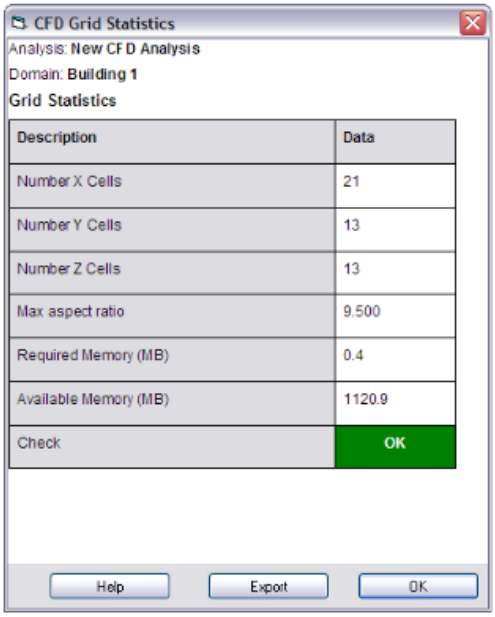
Number of divisions

If the Increasing/Decreasing/Symmetric power law spacing type has been selected, this setting is displayed and allows you to enter the number of divisions used in the associated power-law spacing relationship.

After selecting an operation and adjusting the required settings, you then need to click on the 'Apply changes' button to update the selected grid region with the current settings.

7.4.10 CFD Grid Information

Information about the CFD grid can be obtained using the 'Show CFD grid statistics' tool, which displays the CFD grid statistics dialog:



If the maximum cell aspect ratio exceeds the allowable limit of 50 or the required memory exceeds the physical memory available, the 'Check' will indicate a failure:

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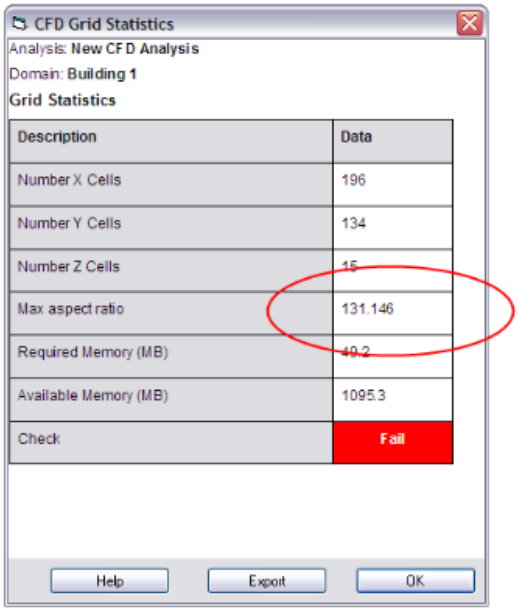

7.4.11 Setting Up CFD Cell Monitor Points

The CFD calculation process is iterative and is considered to have completed once 'convergence' has been achieved. The main indicator for convergence is the point at which the finite difference equations for all cells are satisfied by the current values of the appropriate dependent variables. However, it can be very useful in many cases to monitor the variation of the dependent variables at specific locations throughout the calculation domain in order to observe the point at which they stabilise. It may be acceptable, in many cases, to terminate a calculation as soon as the dependent variables have achieved adequate stability but before the residuals have arrived at their defined termination values

When a project is first created, a default central cell monitor point is automatically added to the domain. The Define CFD monitor points tool enables you to identify up to ten cells throughout the calculation domain at which you want to monitor the variation of the calculated variables.

After selecting the **Define CFD monitor points** tool, the cell monitor screen is displayed which includes the model view together with a cell selection frame, perpendicular to the currently selected axis. You can select a plane along the current axis by moving the mouse cursor across the model in the direction of the axis. To change the axis, click on the required axis on the axis selector tool, which is located at the top right of the screen:

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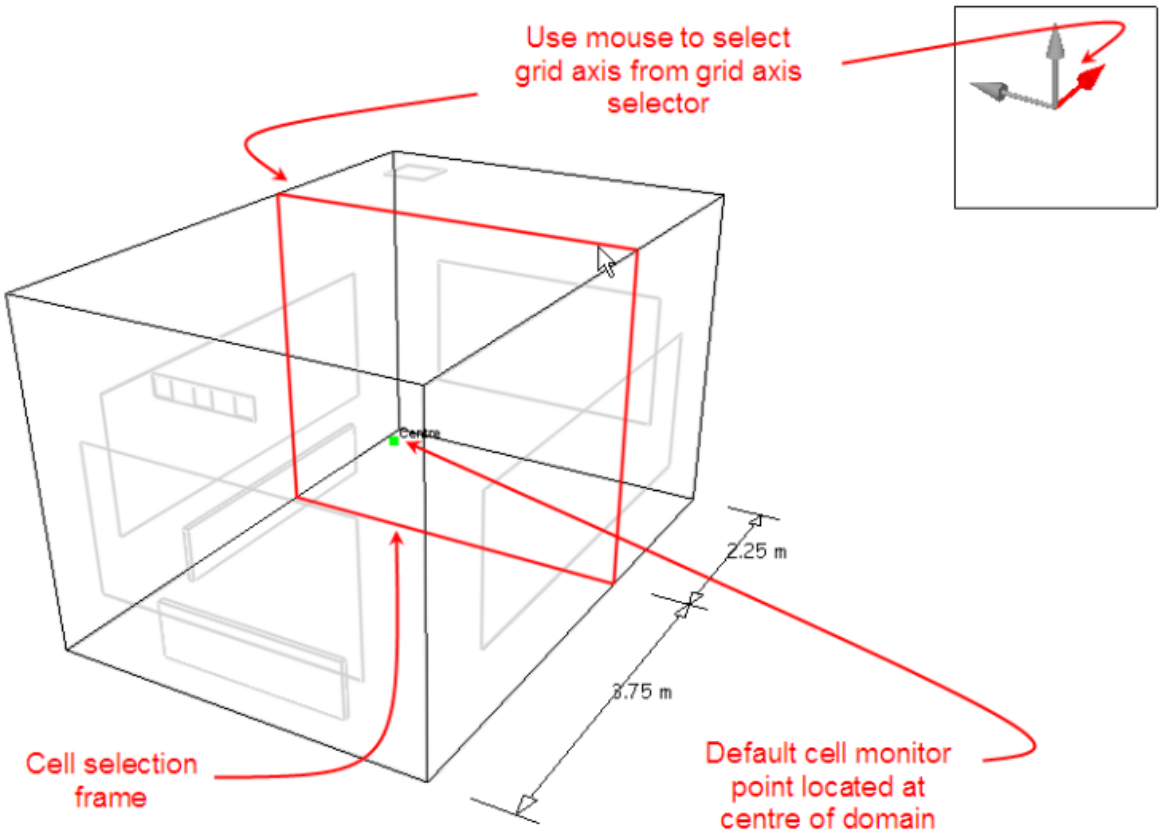
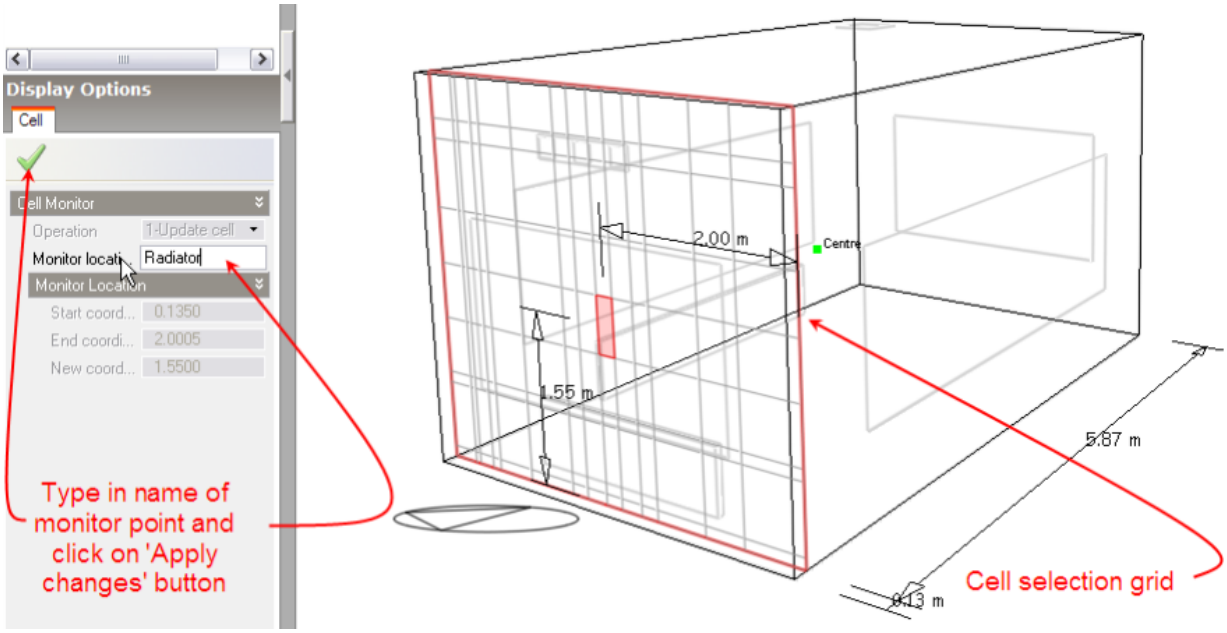


After selecting the required axis, move the cell selection frame along the axis, and then click the mouse button to select a plane at the required distance along the axis. A cell selection grid is then displayed in the selected plane allowing you to move the mouse cursor to the required cell in that plane:



After moving the mouse cursor to the required cell, click the mouse button to display the cell monitor data panel at the bottom left of the screen.

The following settings are available on the cell monitor data panel:

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Operation

This control is only active if you have selected a cell for which a monitor point has already been defined. The following options are available:

- **1–Update cell** - add a monitor point or edit the name of a previously defined point.
- **2–Remove cell** - remove a previously defined monitor point.

Monitor location name

Enter a name for monitor point - this is used later when selecting data for the monitor point to be displayed on the CFD Calculation Options dialog.

After changing the required settings, click on the 'Apply changes' button to update the selected cell. You can cancel the Define CFD monitor points command by pressing the <Esc> key or by selecting another tool.

7.4.12 CFD Calculation Options

To run the calculations, click on the Update calculated data tool. If a problem is found with the grid generation, the CFD Grid Statistics dialog is displayed showing the error. There are three possible error conditions:

1. **Maximum cell aspect ratio exceeds the limit** - you will need to delete the existing project and create a new one either reducing the default grid spacing dimension or increasing the grid line merge tolerance by a suitable amount (see the CFD Results Manager section).
2. **Required memory exceeds the available memory** - you will need to delete the existing project and create a new project with larger default grid spacing or consider simplifying the problem definition in terms of complexity of assemblies, etc.
3. **Flow imbalance** – the total flow rate specified for supply diffusers does not balance with the total flow rate specified for extract grilles. You will need to add supply diffusers or extract grilles or edit the existing flow rates to establish the correct balance

If no problem is encountered in creating the grid, the 'Edit Calculation Options' dialog will be displayed:

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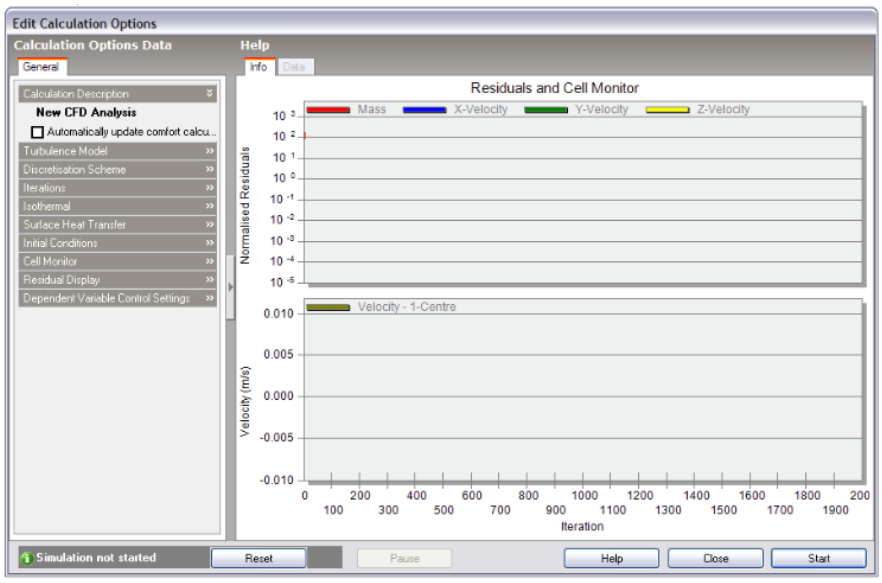

The Edit Calculation Options dialog is divided into two main sections, the Residuals and Cell Monitor graphs and the Calculation Options Data panel.

BUTTONS

There are also a group of buttons at the bottom of the dialog, which allow you to control the calculations:

Start

Start, or if the calculations have been paused, re-start the calculations.

Pause

Interrupt or pause the calculations. Once the calculations have been paused, the calculation dialog can be temporarily closed in order to review the results.

Reset

After pausing the calculations, the calculations may then be re-initialised to start from scratch. If the solution is found to diverge and you pause the calculations to decrease the velocity false time steps, you will then need to reset the calculations before re-starting.

The calculation settings panel incorporates the following settings:

TURBULENCE MODEL

The following turbulence model options are available:

- **1–k-e**: This model is one of the most widely used and tested of all turbulence models, belonging to the so-called RANS (Reynolds Averaged Navier-Stokes) family of models. These models involve replacing the instantaneous velocity in the Navier-Stokes and energy equations with a mean and fluctuating component. The resulting equations give rise to additional terms known as Reynolds stresses and turbulent heat flux components. Reynolds stresses are replaced with terms involving instantaneous velocities where molecular viscosities are substituted for effective viscosities and a similar substitution is conducted for the energy equation. The effective viscosity is the sum of the molecular viscosity and a turbulent viscosity, which is derived from the turbulence kinetic energy and the dissipation rate of turbulence kinetic energy:

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where k= turbulence kinetic energy and e = dissipation rate of turbulence kinetic energy
k and e are both derived from partial differential equations which are in turn derived from a manipulation of the Navier-Stokes equations.

- **2 – Constant effective viscosity**: The constant effective viscosity model is a much simpler approach and involves the replacement of the molecular viscosity in the Navier-Stokes equations with a constant effective viscosity (typically in the order of 100-1000). Although this model is incapable of modelling local turbulence or the transport of turbulence, it is computationally much less expensive than the k-e model and can be numerically much more stable.

DISCRETISATION SCHEME

The following discretisation schemes are available:

- **1-Upwind** - The calculation process involves replacing the defining set of partial differential equations with a set of finite difference equations. The conventional approach to this is to use a Taylor's series formulation, which leads to a set of central difference equations. However, although this approach is physically realistic for diffusion, it is not found to be realistic for convection because of its one-way nature, i.e. upwind conditions affect downwind conditions but not the reverse. The upwind scheme allows the convective term to be calculated assuming that the value of the dependent variable at a cell interface is equal to the value at the cell on the upwind side of the interface.

- **2–Hybrid** – a more computationally expensive approach than the upwind scheme but it reduces numerical diffusion at high values of Pe number.

- **3–Power-Law** - The power-law scheme is arguably more accurate than the hybrid scheme but is more computationally expensive.

ITERATIONS

This is the maximum number of iterations conducted by the outer iterative calculation loop (see 'CFD Calculations and Convergence' section). The calculations will terminate when the number of iterations reaches this value regardless of whether or not the solution has converged.

ISOTHERMAL

Temperature is assumed to be constant throughout the calculation domain and the energy equation is removed from the calculations.

Surface heat transfer

The following surface heat transfer options are available:

- **1–Calculated** - Surface heat transfer coefficients are calculated by the CFD calculation scheme if the k-e turbulence model has been selected.

- **2–User-defined** - Surface heat transfer coefficients can be defined for ceilings, wall and floors.

INITIAL CONDITIONS

In some cases, a faster solution can be achieved by setting the initial conditions closer to the final expected conditions.

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CELL MONITOR

Select any defined cell monitor point and associated dependent variable to be displayed on the cell monitor (see Setting Up CFD Cell Monitor Points section).

RESIDUAL DISPLAY

Select the dependent variables and/or mass for which residuals are to be displayed in the residuals monitor. The mass residual is similar to the dependent variable residuals but is extracted from a continuity equation mass balance for each cell and is the most significant residual in terms of indicating a successfully converged solution.

DEPENDENT VARIABLE CONTROL SETTINGS

The calculations involve a nested iterative scheme whereby dependent variable equations are solved iteratively within an overall outer iterative loop (see CFD Calculations and Convergence section). The dependent variable control settings enable control inner iterative dependent variable calculations.

Inner Iteration

The number of iterations used for the calculation of the dependent variable.

False Time Step

The finite difference equation set is formulated in the form of a transient equation set although the calculations are essentially a 'snap-shot' in time. The reason for this formulation is that the transient term behaves as a very effective relaxation method, which can slow the change in dependent variables in order to arrive at a more stable solution. The false time step is the time step used in the pseudo-transient term of the dependent variable equation. For forced convection flows, a 'best-guess' optimal false time step is automatically calculated for velocities, however for buoyancy driven flows, a default value of 0.2 is used. Reducing the false time step has the effect of slowing down the change in the dependent variable and can be a helpful remedy for unstable solutions.

Relaxation Factor

This is the 'text book' relaxation method, which can be used to allow only a proportion of the calculated value of the current iteration dependent variable to be assigned to the variable. However, the false time step is normally the preferred method of achieving under-relaxation.

- Termination Residual: The outer iterative calculation loop is repeated until the finite difference equations for all cells are satisfied by the current values of the appropriate dependent variables, at which point the scheme is said to have 'converged'. The dependent variable residual is the maximum residual quantity for the equation balance across all cells in the domain. The solution is deemed to have converged for each dependent variable when the residual is less than the termination residual.

The CFD Calculations and Convergence section for an overview of the calculation methodology that will help in understanding the concepts used to initialise, control and monitor the calculations.

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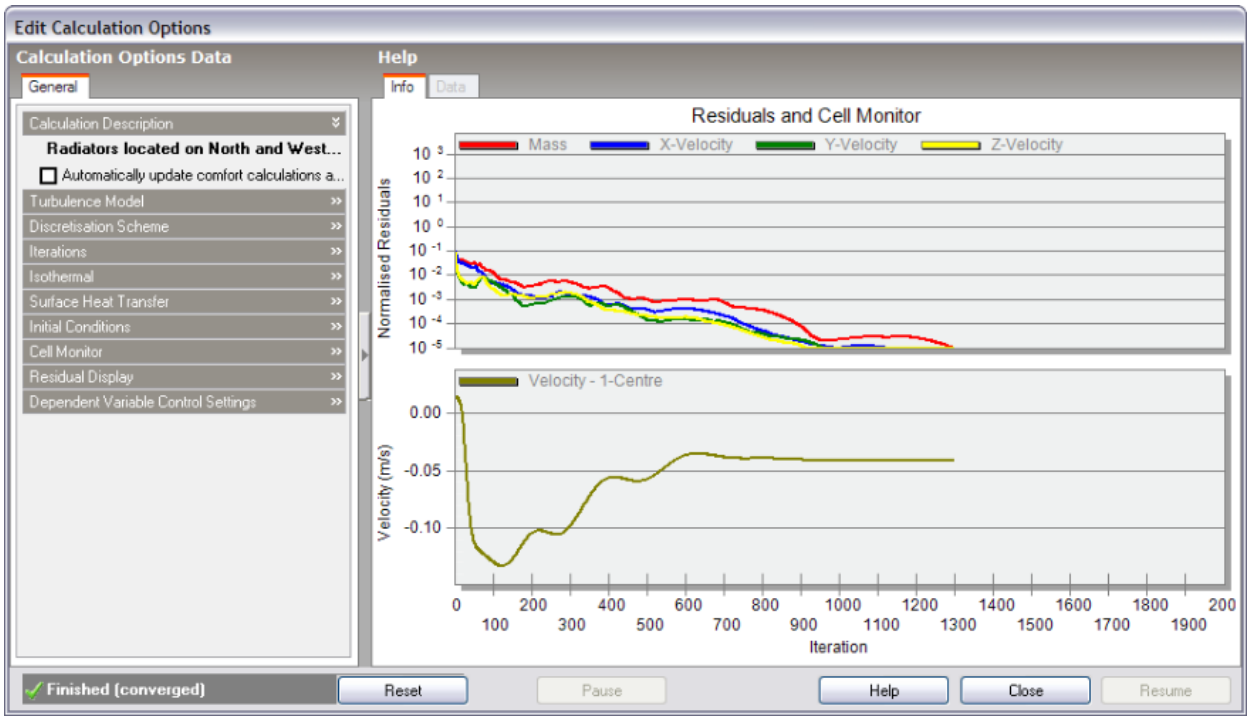
7.4.13 Residuals and Cell Monitor Graphs

During the CFD simulation, the value of each dependent variable residual together with the mass residual is plotted on the residuals graph, at the end of each outer iteration of the calculation. You can use the residuals plot to monitor the overall convergence of the solution and to determine whether or not any remedial action is required.

When considering the residual plots, you should bear in mind that the residuals can fluctuate quite markedly throughout the period of the calculations and in some cases rise appreciably before falling and so you need to get an idea of the overall trend after several hundred iterations. The following screenshot shows a plot of residuals and a default centrally located monitor cell plot for the internal analysis illustrated in the Displaying Results section. Notice that the monitored velocity has reached a steady final value.



If you notice that the residuals are fluctuating wildly or steadily increasing over several hundred iterations, you should pause the calculations and take remedial action (see Convergence Difficulties and Troubleshooting section).

The cell monitor graph displays the variation in the selected dependent variable for the currently selected monitor cell (see Setting Up CFD Cell Monitor Points section and **Cell Monitor** setting in the CFD Calculation Options section). The variation of monitored cell point variables provides a good indication of solution convergence, i.e. when the variation of the variable stabilises.

7.4.14 Convergence Difficulties and Troubleshooting

If the plotted residuals are found to diverge or fluctuate significantly, in many cases you will find that the situation can be improved by reducing the false time steps for the velocity components. The recommended procedure is to continuously half the time steps until a more stable solution is found.

However, in some cases a solution can be very difficult, if not impossible, to achieve using the standard k-e

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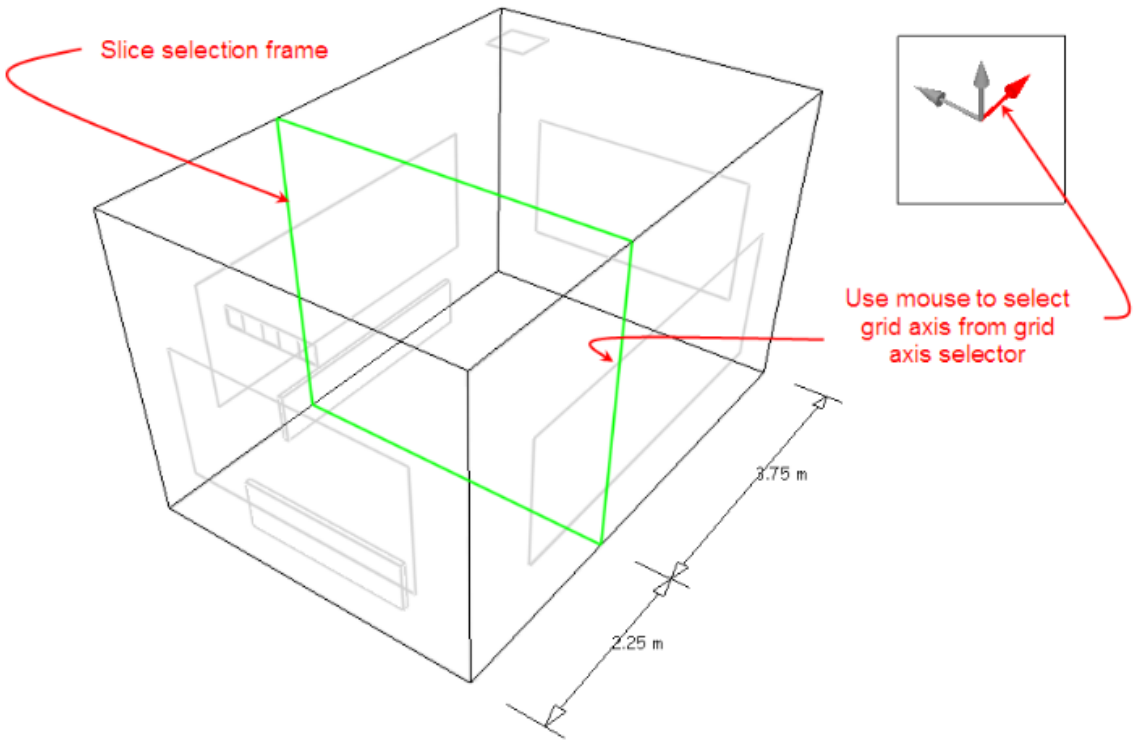
turbulence model. Particularly difficult problems involve very low velocity buoyancy-driven flows where diffusion is dominated by convection and this can cause velocities to fluctuate around a mean value. In these cases, reducing false time steps may not improve the situation. In order to force a solution, you may consider introducing additional boundary conditions such as occupants, which can change the flow sufficiently to obtain a solution without the problem necessarily becoming unrealistic.

Alternatively, you may consider using the constant effective viscosity turbulence model with a relatively high turbulent viscosity or turbulent viscosity multiplier but bear in mind that this will introduce an artificially high level of diffusion into the flow and also, the constant effective viscosity model is incapable of modelling the transport of turbulence.

7.4.15 Displaying Results

After completing or pausing the calculations, the CFD Display Options data panel is shown in the bottom left of the screen and the **Select CFD slice** tool becomes enabled (above). This is the main mechanism for displaying results. It allows you to select a slice along one of the main grid axes and perpendicular to it, within which any of the selected results can be displayed.

After selecting the **Select CFD slice** tool, the CFD results screen is displayed which includes the model view together with a slice selection frame, perpendicular to the currently selected axis. You can select a slice along the current axis by moving the mouse cursor across the model in the direction of the axis. To change the axis, click on the required axis on the axis selector tool, which is located at the top right of the screen:



After selecting the required axis and moving the slice selector frame to the required position along the axis, click the mouse button to add the slice to the display. Notice that as you move the slice selection frame to a slice that was previously added to the display, the frame colour changes from green to red and if you click

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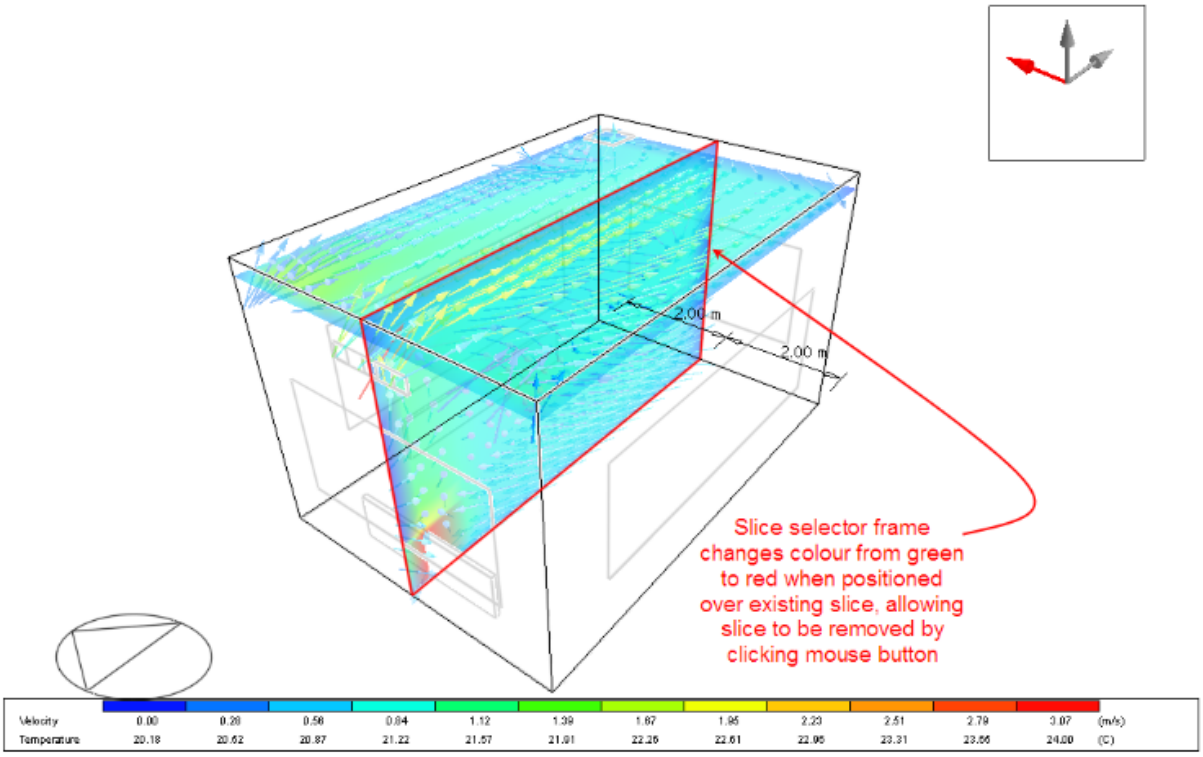
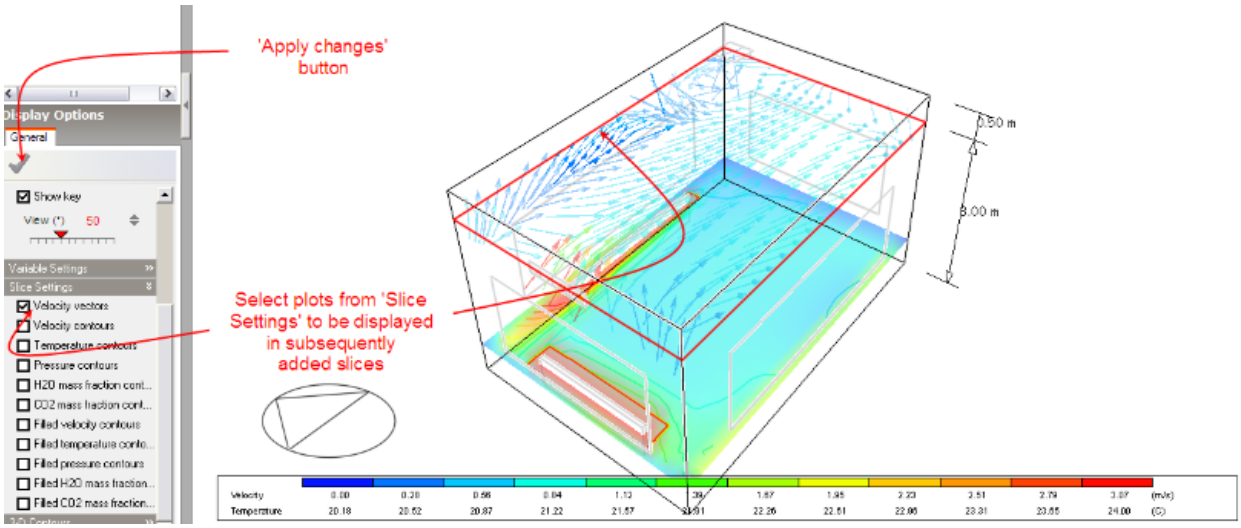
the mouse button, the slice is removed from the display:



Slice variable plots are selected under the 'Slice Settings' header on the Display Options data panel and controlled under the 'Variable Settings' header:



Note that any modifications made to items on the Display Options data panel will only come into effect after clicking on the 'Apply changes' button.

The 'Variable Settings' group contains groups of variable banding data for velocity, temperature and pressure variables. Also, under the variable settings 'Velocity' header, there are two velocity vector settings, 'Maximum vector length' and 'Velocity scale factor'. Velocity vectors are displayed as arrows, the length of which corresponds to the magnitude of the velocity and with the default vector scale factor of 1.0, a length of 1.0m corresponds to a magnitude of 1.0m/s. The maximum vector length is the maximum length of a vector

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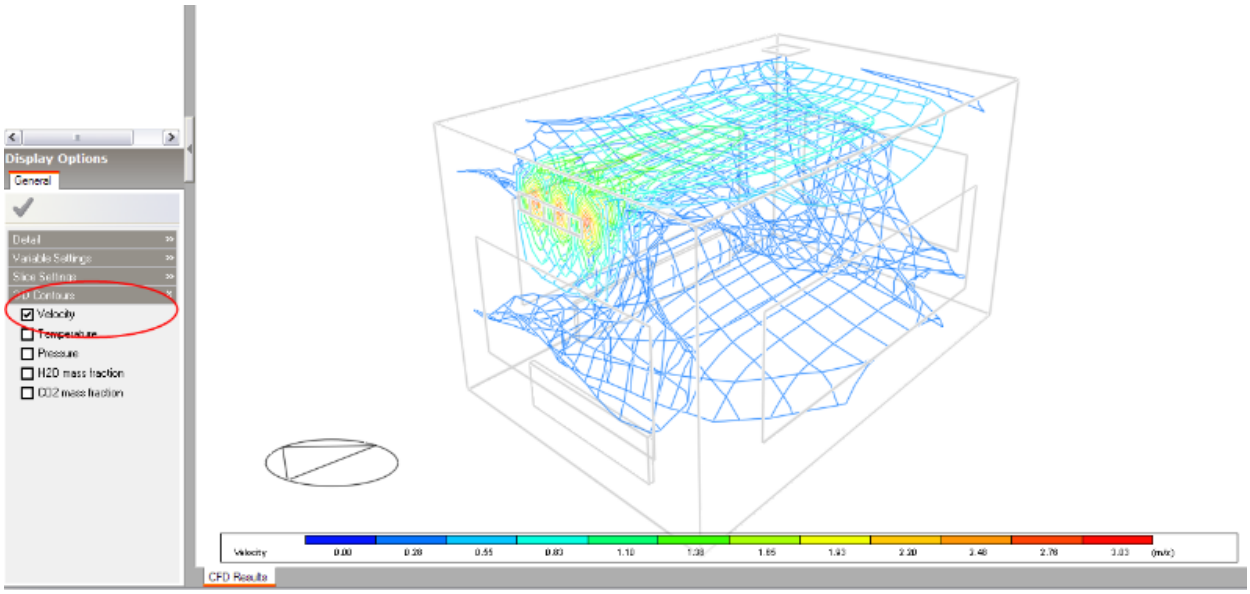
that will be displayed to prevent the display from becoming cluttered with excessively large vectors. Any vector, which has a magnitude greater than this maximum, will be displayed translucently to distinguish it from vectors with lengths that do represent magnitude.

The variable banding data comprises the defined band range, followed by twelve contour band values within the defined range. The band range defines the minimum and maximum variable values between which data will be displayed and the band values are the actual values within that range that are displayed in the form of contours or in the case of velocity vectors, vector colours. The default minimum and maximum variable display values are extracted from the calculated values and this range is then divided into twelve equal increments in order to arrive at the dependent variable contour bands. Each contour band can be edited or switched off altogether. When the band range values are modified, the individual band values are automatically re-calculated.

The 'Slice Settings' group is used to select the plots required to be included in subsequently added slices.

The last item on the Display Options data panel is the 3-D contours group that allows you to select any of the available variables for which a 3-D contour plot is required:



7.4.16 Conducting CFD Comfort Calculations

After completing or pausing the CFD the **Update CFD comfort** tool will become enabled. After selecting this tool, a progress bar will be displayed indicating that mean radiant temperature (MRT) calculations are in progress, followed by another progress bar for the comfort calculations themselves.

Comfort calculation metabolic rates and clothing levels are obtained from the data entered under the 'Metabolic' header on the 'Activity' tab of the model data panel.

After completing the calculations, some additional comfort display variables are available on the Display Options data panel:

- PMV
- PPD

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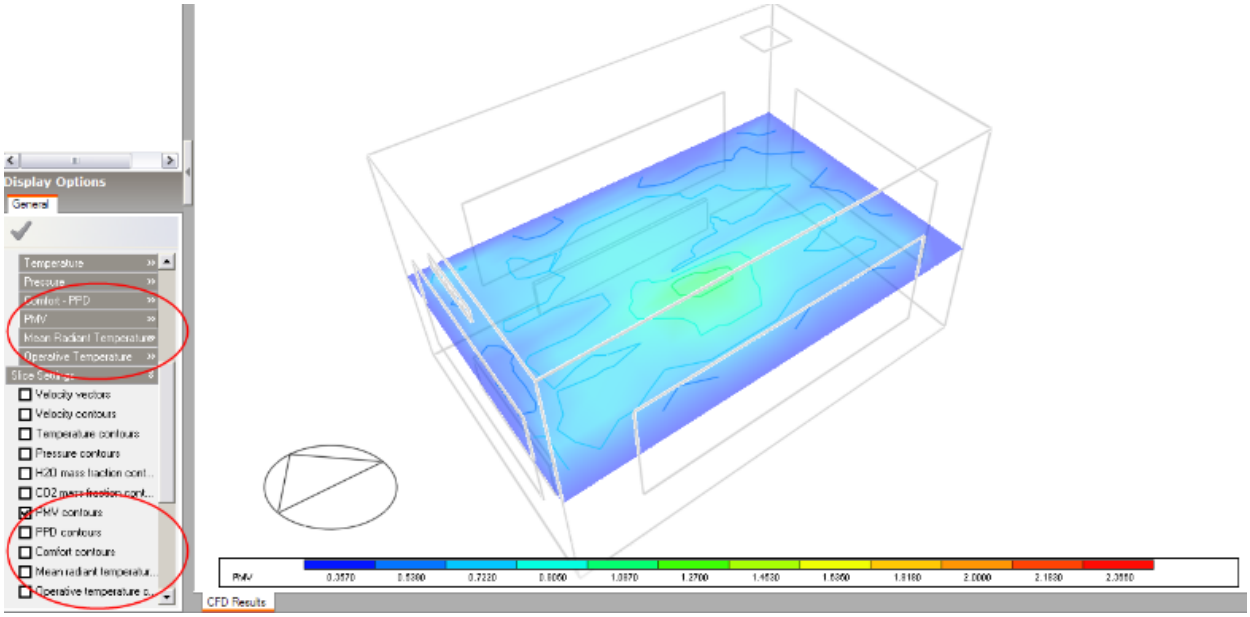
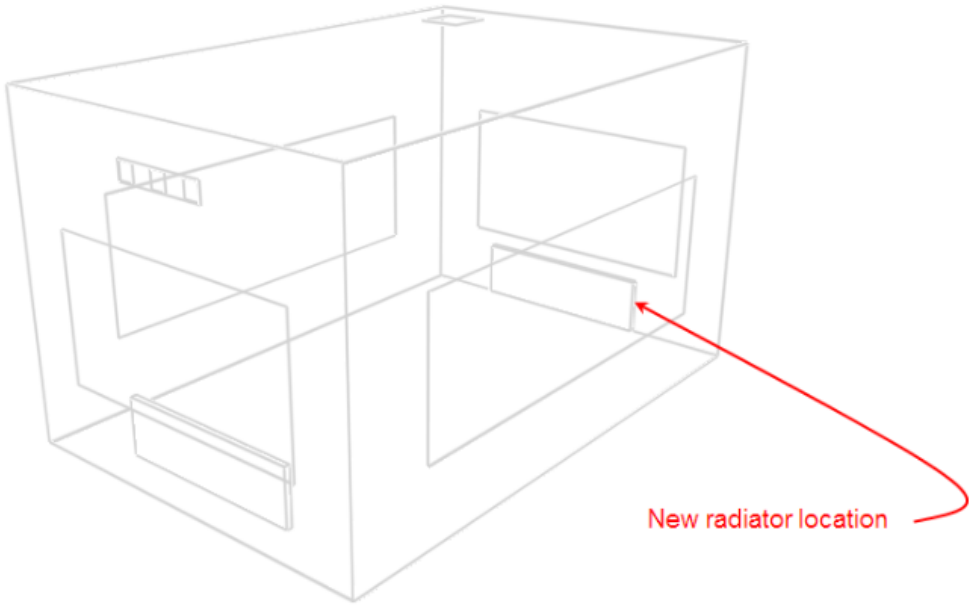
- Comfort Indices
- Mean Radiant Temperature
- Operative Temperature



7.4.17 CFD Results Manager

The CFD results manager tool allows you to create new CFD projects, open existing projects or remove existing projects. For example, considering the internal analysis example illustrated in the Displaying Results section, you may want to conduct another analysis after moving the position of a radiator in order to look at the effect on air distribution. You would first go to the Edit screen and modify the radiator layout:



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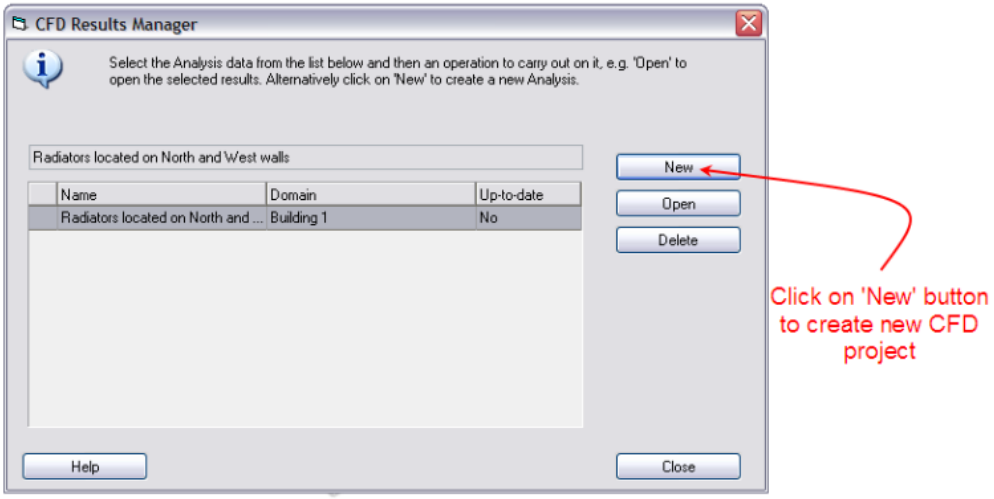
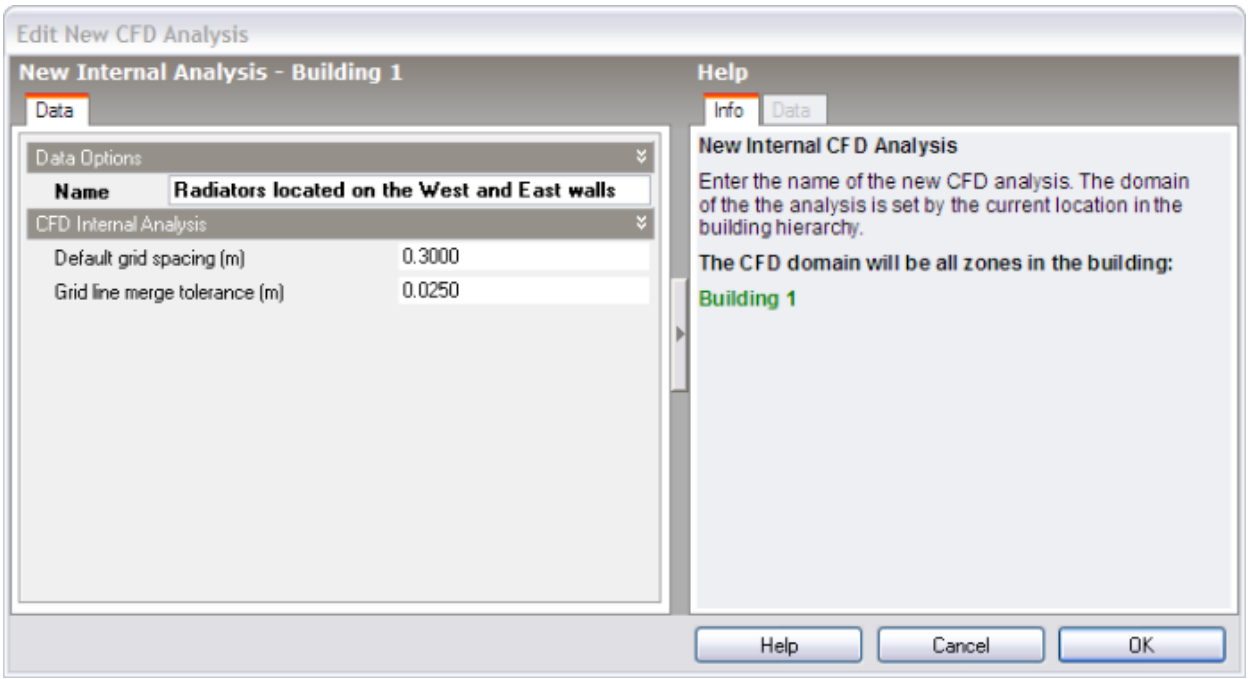
After returning to the CFD screen, you can then click on the CFD results manager tool to open the CFD Results Manager dialog:



The CFD Results Manger dialog incorporates a list of all available projects together with buttons that allow you to create a new project, open a project or delete a project. For each project entry in the list, the first column indicates the project name, the second column the model domain object used for the calculations (site, building, building block, zone) and the third column indicates whether or not the model geometry contained within the results is up-to-date. In this case, you would click on the 'New' button to create a new project:



See the 'Setting Up a New Internal CFD Analysis' section for details of creating a new internal analysis.

After creating the new analysis, you can then conduct the calculations:

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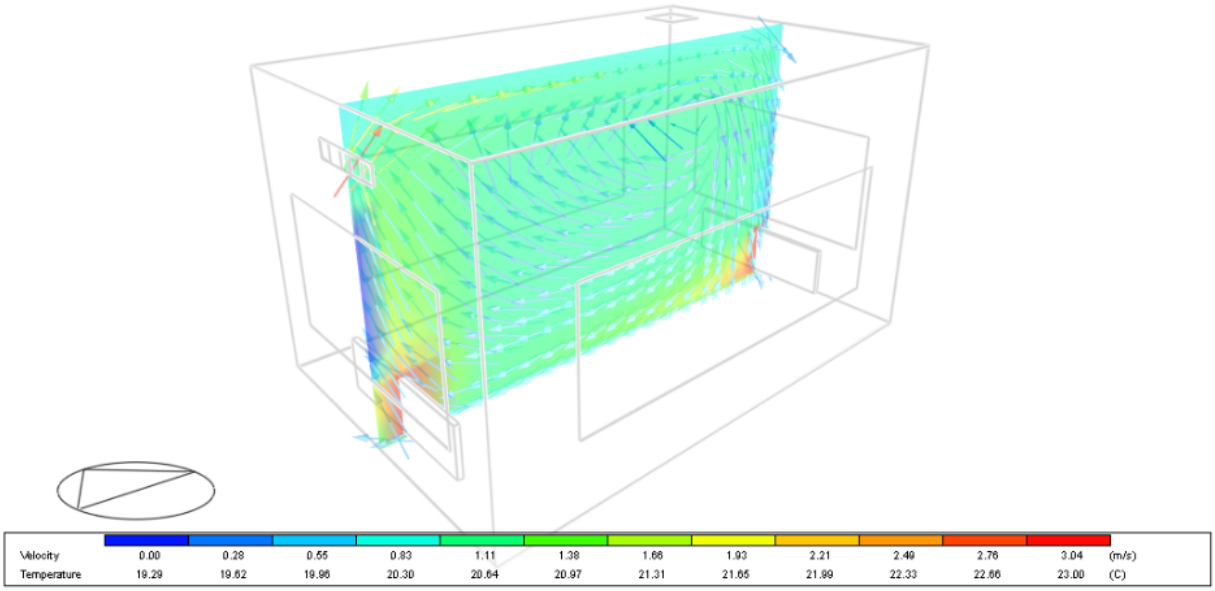
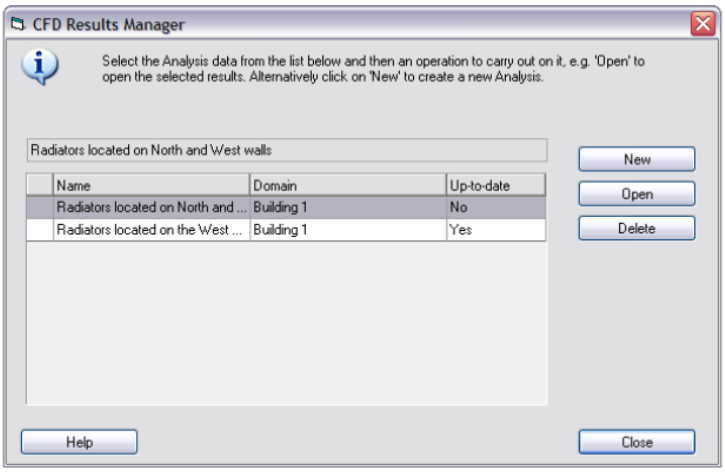


You can then use the CFD Results Manager to open the previous project in order to compare results:



7.4.18 Example CFD External Analysis

This CFD example will go through the steps required for a typical external CFD analysis:

- Create model for external analysis.
- Switch to the CFD screen and create a new CFD analysis.
- Perform the CFD calculation.
- Review the results.

External analyses are simpler than internal analyses in that you do not need to define any internal boundary conditions. Also they are isothermal and take account principally of only velocity and pressure.

Refer to internal analysis for details of grid editing and monitor cell selection.

CREATING THE MODEL

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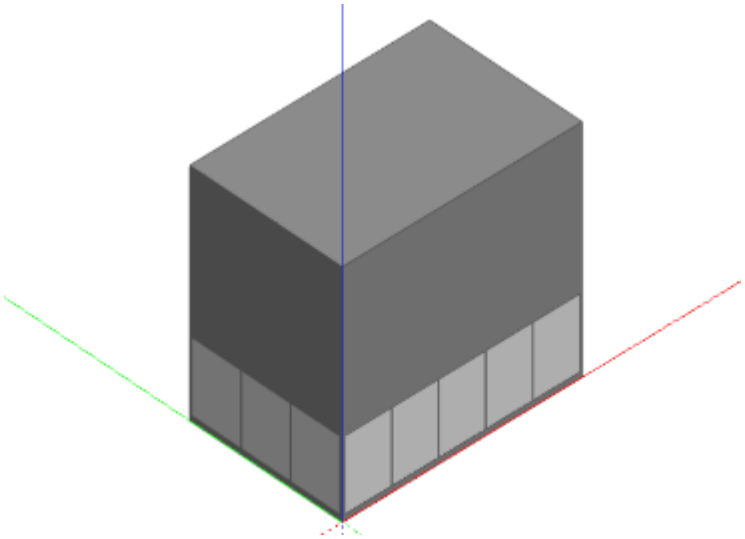
The model comprises a simple rectangular block with dimensions 30.0m x 20.0m x 30.0m.

Click on the Add new block tool and change the Block type to Building block and the Height to 30.0m. To place the origin of the building at the site origin, type in 0 0 and press the <Return> key. To then create the block with a 30.0m x 20.0m perimeter, type in 30 20 and press the <Return> key. A block will be created with the required dimensions. Alternatively create the block by drawing the base perimeter in the normal way.



CREATING A NEW CFD EXTERNAL ANALYSIS

Each DesignBuilder project can have one or more CFD analyses. Each CFD Analysis can be a different set of results for a different variation on the model. Unlike simulation data, CFD Analyses are not deleted automatically when the model is modified on the Edit screen.

1. Click on the site in the navigator to move to the site level.

   External CFD analyses can only be conducted at the site level.
2. Click on the CFD tab to set up an external CFD analysis.
3. After clicking on the CFD tab, the New CFD analysis dialog is displayed. Enter Wind analysis in the Name field and leave the grid spacing and grid line merge tolerance in their default settings.
4. Default grid spacing and grid line merge tolerance settings are covered later.
5. Under the Wind header, change the free-stream velocity to 12.0m/s, the Direction to 45° and the Exposure to Urban. The wind direction is defined clockwise from North, so the default of 270° represents a westerly and a setting of 45° a North-easterly.
6. The Site Domain Factors are multipliers that are applied to the overall model extent in the X (length), Y (width) and Z (height) dimensions to derive a site domain across which the calculations will be carried out. Keep the defaults of 3, 3 and 2.
7. After clicking on OK to create the analysis data set, the CFD screen displays the model in wire-frame together with the site domain, which is outlined in dotted lines.

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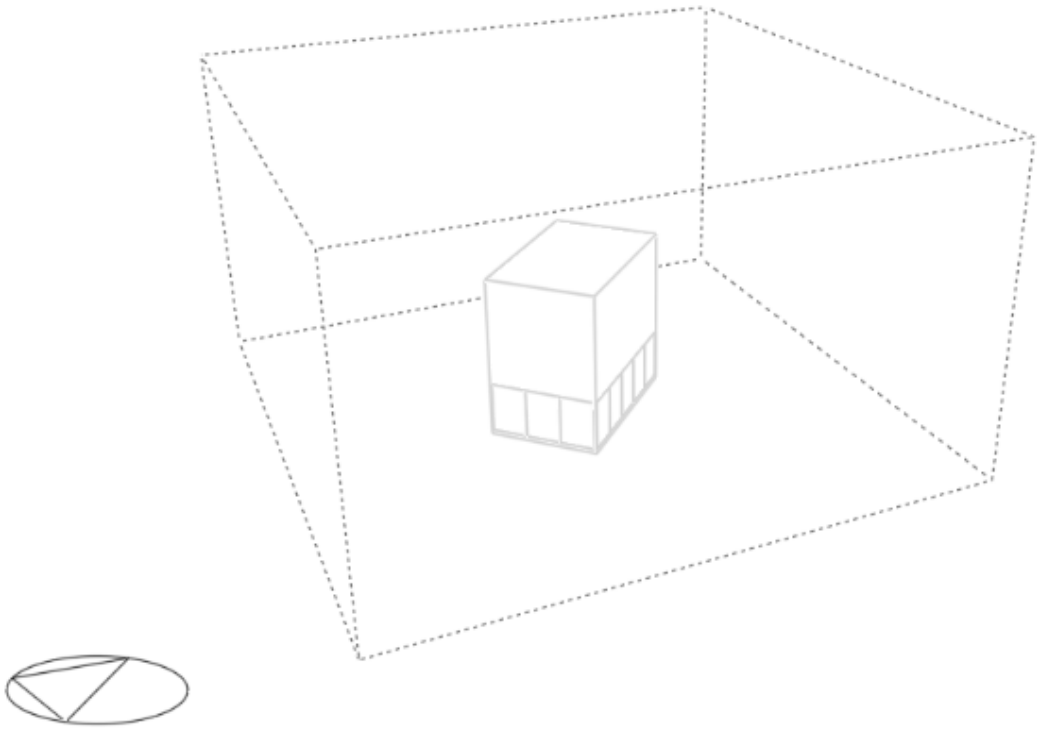

Notice the rotation of the domain with respect to the building to account for the wind direction.

SETTING UP MONITOR CELLS

It is usually a good idea to display the state of one or more monitor cells in the domain so that you can 'monitor' the extent to which the calculations have settled down to a final converged solution. DesignBuilder automatically sets up a single monitor cell at the centre of the domain. You can add new monitor points at any time as follows.
Click on the Define CFD monitor points tool and select the Z grid axis using the grid axis selector tool. Move the cursor along the axis to select a plane a couple of grid cells above the building and then move the cursor across the selected plane and select a cell roughly above the centre of the building. The Cell monitor data panel is displayed at the bottom left of the screen. Enter the name Roof into the Monitor location name field and click on the green tick Apply changes button.

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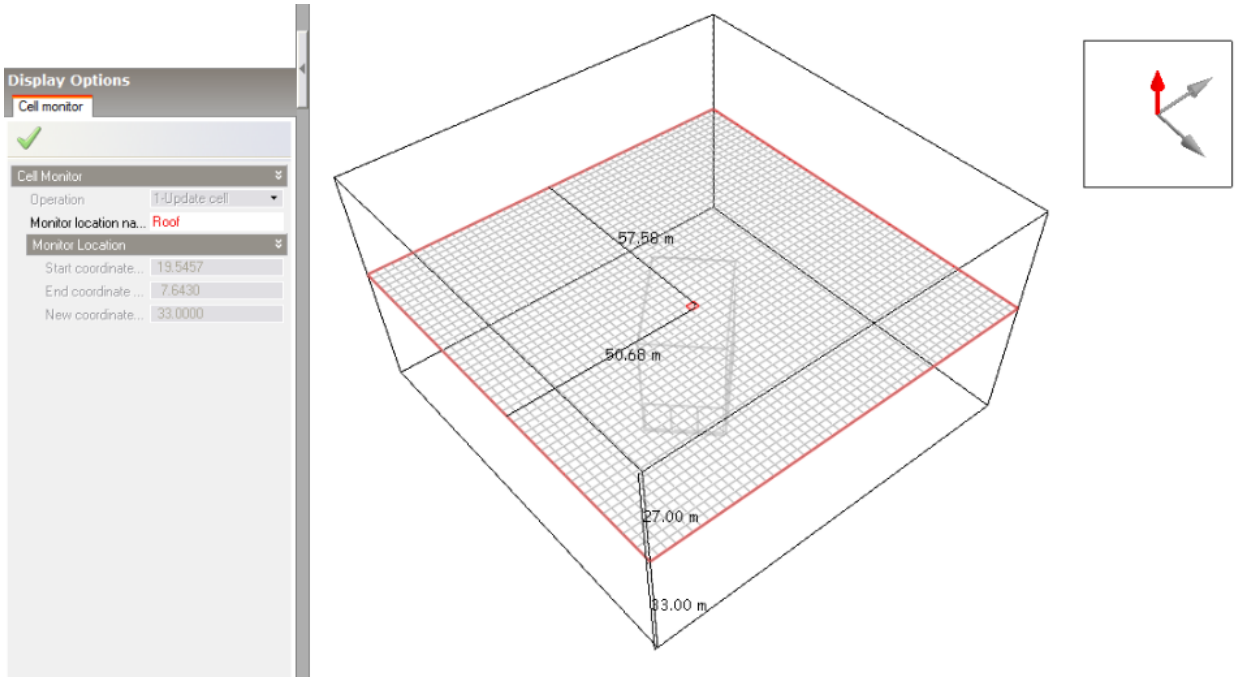

Press <Esc> to cancel the Define CFD monitor points tool.

RUNNING THE CFD CALCULATIONS

To set up calculation data and run the CFD calculations, click on the Update calculated data button, which will bring up the CFD Calculation options dialog. The left hand side of the calculation dialog contains various calculation options.

Keep the default options except for Iterations which should be set to 5000 and under the Residual Display header, switch on the X, Y and Z-axis velocity residuals.

Click on the Start button to begin the calculations. Wait until the calculation is fully converged when the residuals have reached the specified minimum and the “Finished (Converged)” indicator is displayed at the bottom left of the dialog. Notice that the displayed velocity for the supply monitor point becomes constant.

Press the Cancel button to close the calculation dialog.

DISPLAYING CFD RESULTS

1. Go to the Display Options panel and open the Velocity header under the Variable Settings header and set the Vector scale factor to 2.0 and the Maximum vector length to 5m.

2. Under the Slice Settings header, make sure that only Velocity vectors is switched on.

3. Click on the green tick Apply changes button.

4. Click on the Select CFD slice tool. Use the grid axis selector to change the current axis to the Z-axis and then move the mouse across one of the side surfaces of the site domain along the Z-axis until the slice selection frame is located 25m above the ground plane. Click on the mouse to add the currently selected slice to the display.

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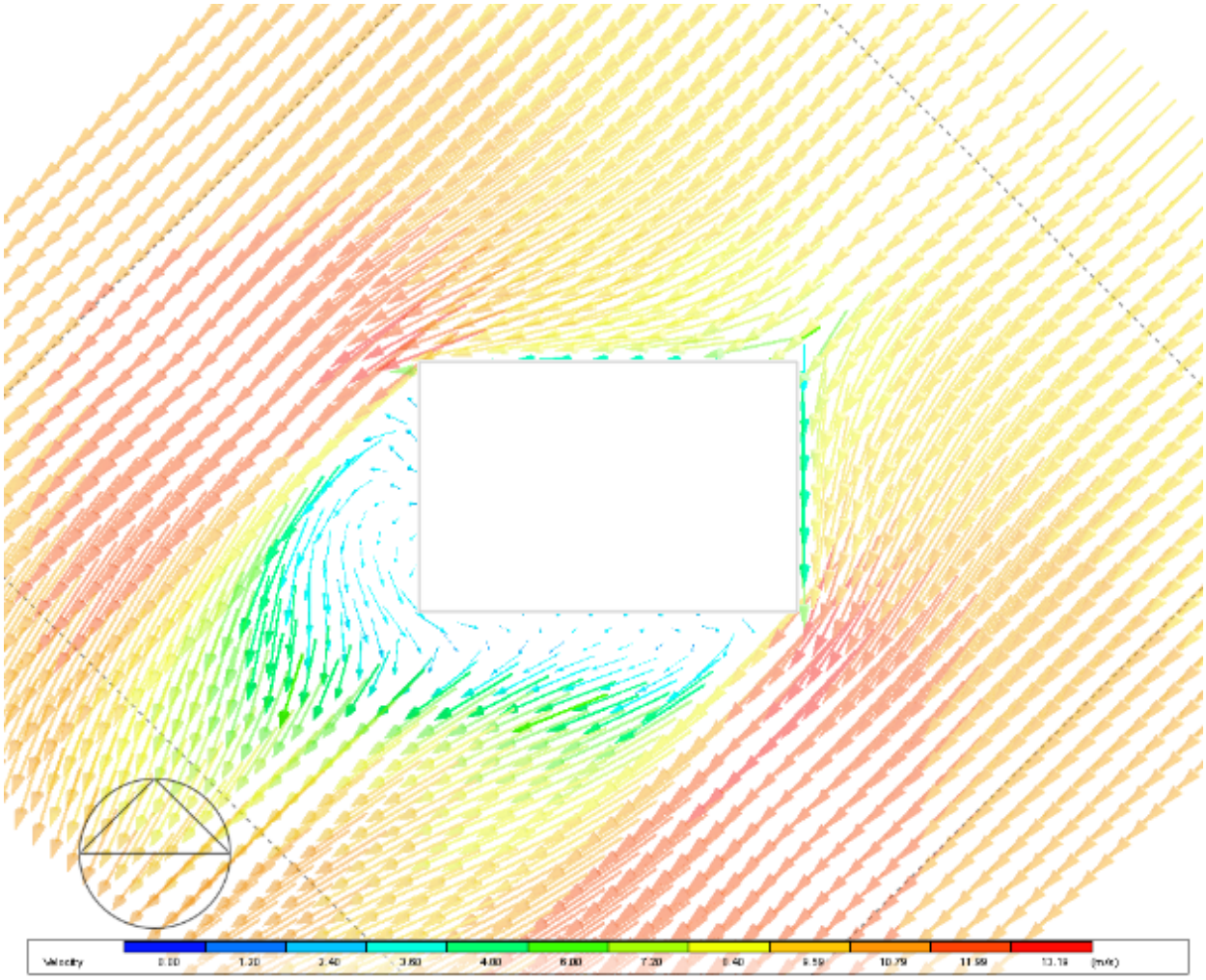

1. Clear the current slice from the display using the Clear all slices tool.
2. Switch off Velocity vectors under the Slice Settings header on the Display Options panel and switch on the Velocity contours and Filled Velocity contours.
3. Click on the green tick Apply changes button.
4. Select the Y-axis from the grid axis selector and move the cursor over the top surface of the site domain along the Y-axis until the slice selection frame is 50.68m from the origin and click the mouse to add the slice to the display.
5. To add a horizontal slice 5m from the ground, select the Z-axis from the grid axis selector and move the cursor over one of the side surfaces of the site domain along the Z-axis until the slice selection frame is 5.0m above the ground plane and click the mouse to add the slice to the display.

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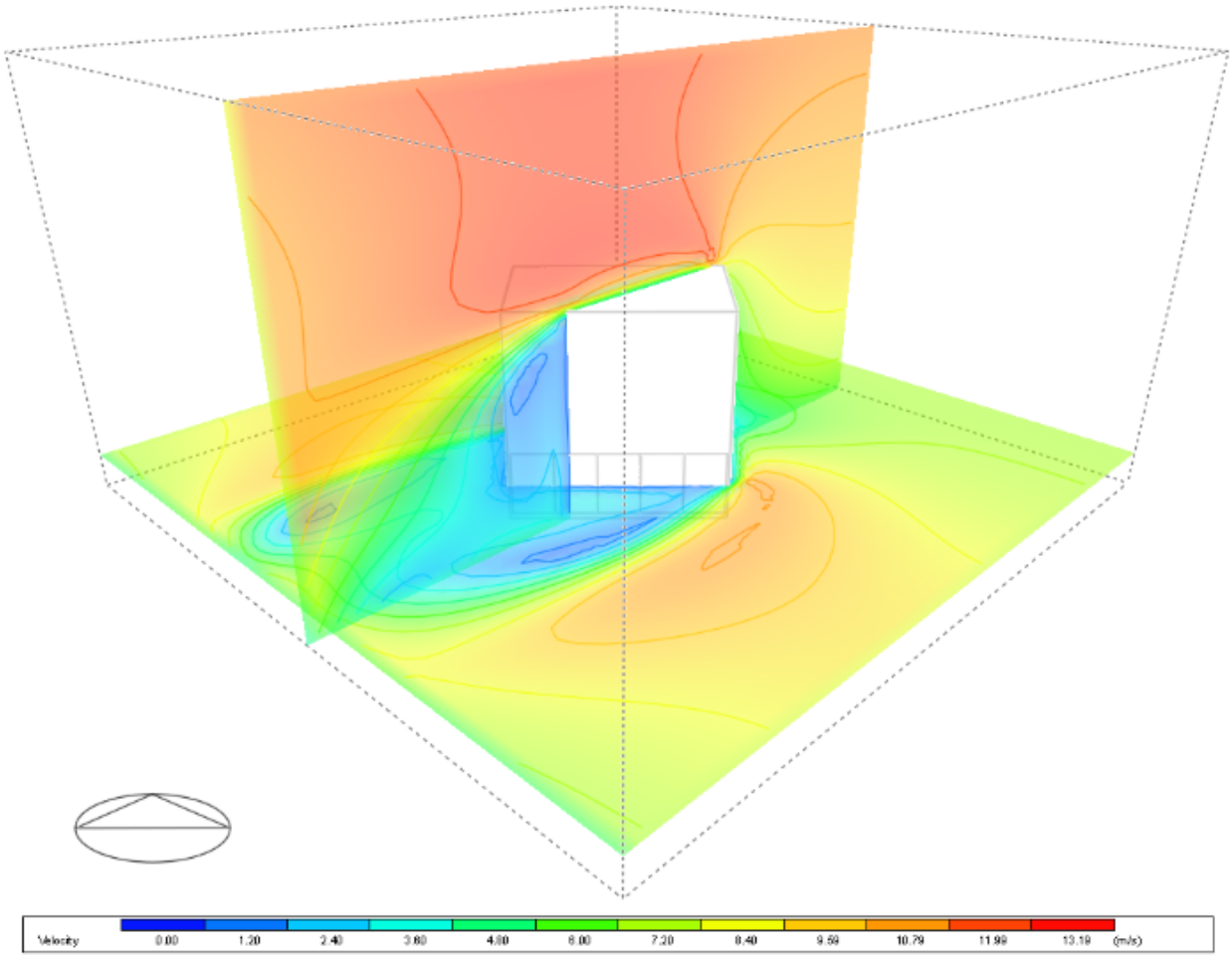

DISPLAY 3-D CONTOURS

3-D contours can be displayed to show the values of a variable throughout the domain. 3-D contours can display a lot of data:

1. Clear the current slice from the display using the Tools > Clear all slices menu option.
2. Under the 3-D Contours header on the Display Options data panel, switch on Pressure. Click on the green tick Apply changes button.

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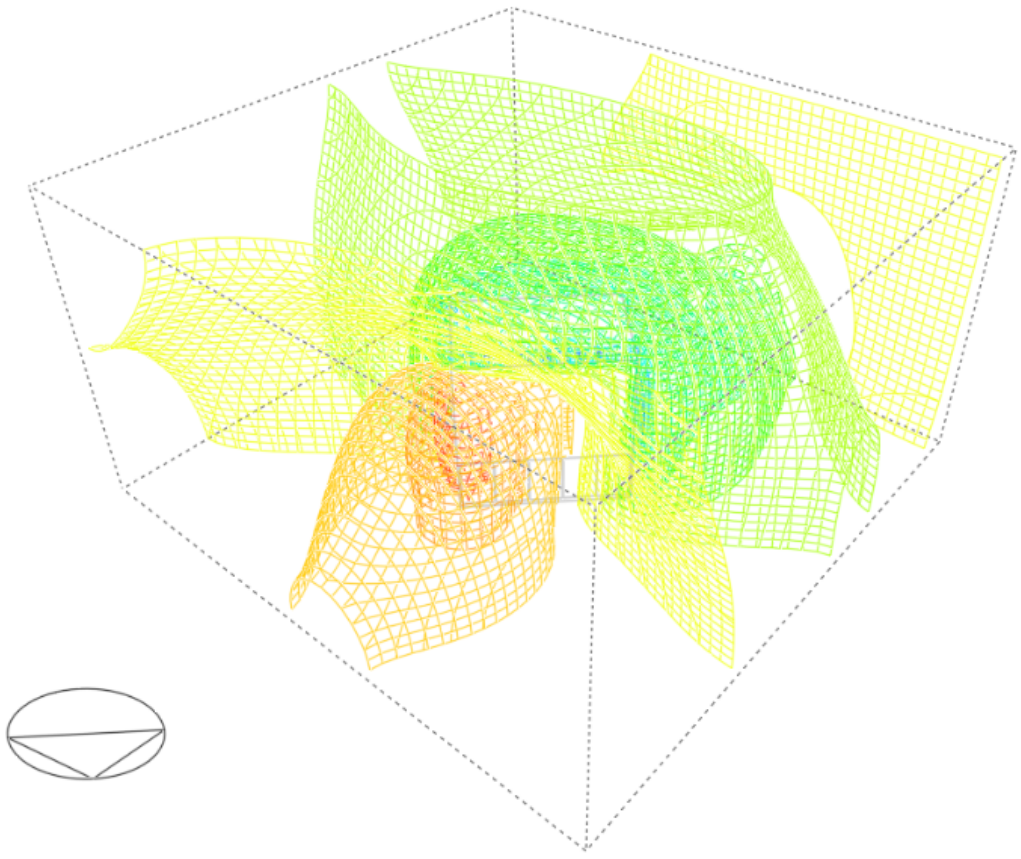

7.4.19 Example CFD Internal Analysis Basics

This internal CFD example will guide you through the basic minimum steps required for an internal CFD analysis:

- Create a simple single zone model.
- Add CFD surface boundaries to the model including a simple sidewall supply diffuser and ceiling mounted extract grille.
- Switch to the CFD screen and create a new CFD analysis.
- Perform a CFD calculation using default calculation options and grid.
- Review the results.

CREATING THE MODEL

The model comprises a simple rectangular block housing a zone with dimensions 6.0m x 4.0m x 3.5m.

Create a new site and add a new building using default settings. From the building level Click on the ‘Add new block’ tool and change the “Block type” to “Building block”, the “Height” to 3.5m and set the wall thickness to 0.25m.

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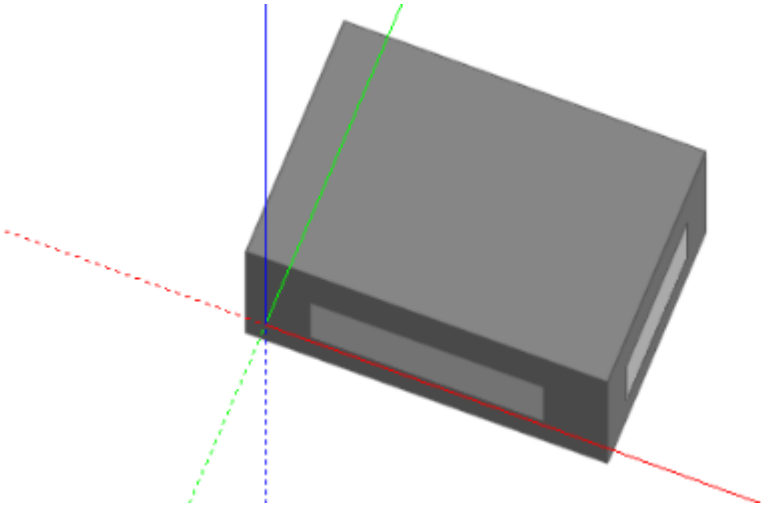
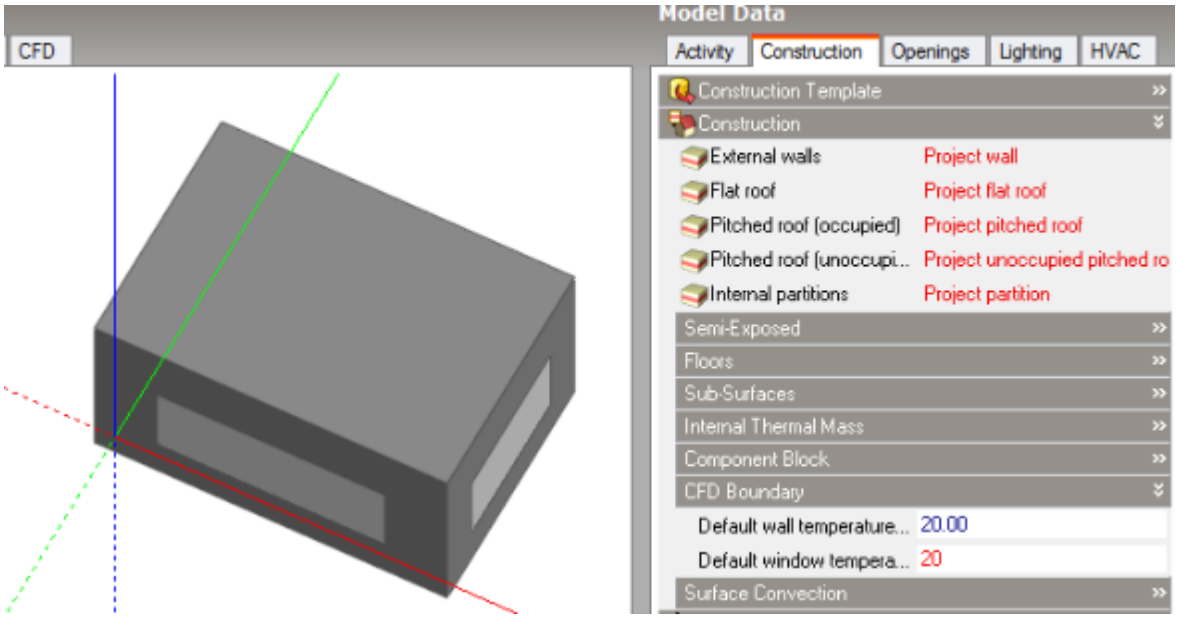


DEFAULT WALL AND WINDOW BOUNDARY TEMPERATURES

Default wall and window boundary temperatures can be defined from the building level down to the surface level. As with other DesignBuilder attribute data, these attributes are inherited from the level above unless deliberately overwritten.

The default wall and window boundary temperatures can be accessed under the CFD Boundary header under the Construction header on the Construction tab of the Model data panel.

At the building level, change the default window temperature to 20°C.



Boundary conditions shown on a display with “Learning mode” switched off.

Go down to the zone surface facing North and change the default wall temperature to 18°C and the default window temperature to 10°C. Go through the same procedure for the west facing zone surface.

ADDING SURFACE SUPPLY DIFFUSER AND EXTRACT GRILLE

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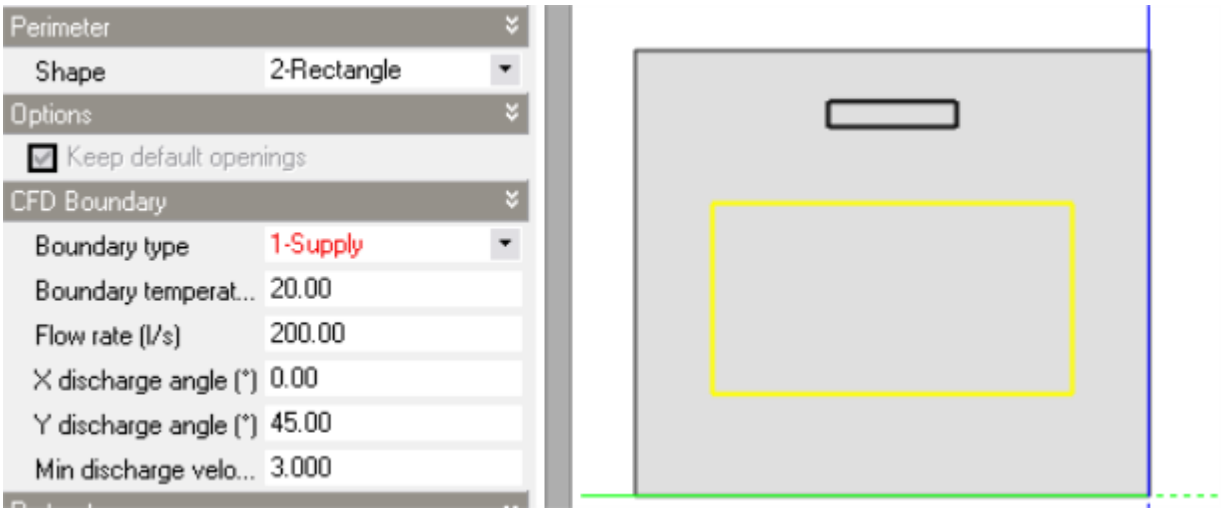
Supply grille

1. Click on the zone in the navigator and select the North-facing surface in the Edit screen. Double-click to drop down to the surface level.
2. Click on the Normal view button to obtain a normal view of the surface.
3. Click on the Add CFD boundary tool. The CFD boundary data panel is displayed at the bottom left of the screen.
4. Select Supply from the Boundary type drop list. Keep all of the remaining boundary defaults but change the Y discharge angle to 45° in order that the supply jet will be projected upwards at an angle of 45° from the horizontal.
5. The supply diffuser is to be 1.0m x 0.2m and is to be located midway between the North and South surface edges, 0.4m from the top edge of the surface. With the Increment snap switched on, move the cursor to the top left corner of the surface and press <SHIFT> to lock the origin to the surface corner, move the cursor away from the corner until the cursor is snapped 0.4m from the top edge and 1.5m from the left edge and click the mouse button to place the top left corner of the boundary. Move the cursor to place the bottom right corner of the boundary 1.0m to the right and 0.2m below the top left corner and click the mouse to place the supply.



Extract grille

A 0.5m x 0.5m extract grille is to be located in the corner of the ceiling 0.5 m from the North and east surface edges.

1. Click on the zone roof surface in the navigator and again click on the Normal view button to obtain a normal view.
2. Click on the Add CFD boundary tool and select Extract from the Boundary type drop list. Keep the default flow rate of 200 l/s to match the supply flow rate.
3. Move the cursor until it is snapped 0.5m from the top edge of the surface and 0.5m from the right edge and click the mouse to place the top right corner of the extract, move the mouse 0.5m to the left and 0.5m below the top right corner of the extract and click the mouse to place it.

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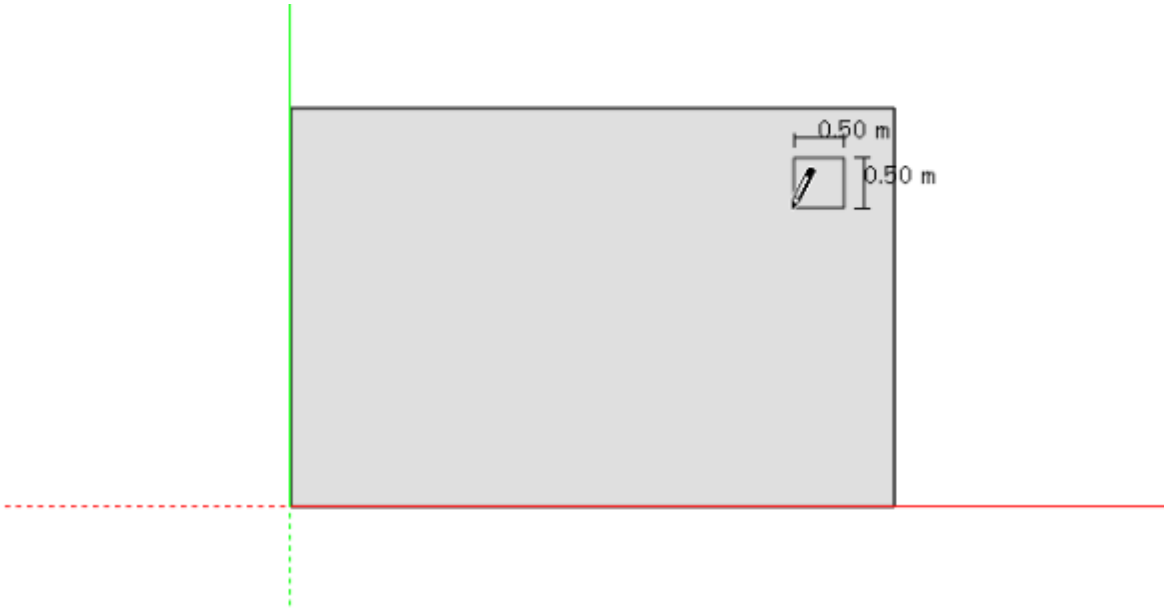

CREATING A NEW CFD INTERNAL ANALYSIS

Click on the building in the navigator to move to the building level and click on the CFD tab to set up an internal CFD analysis. An internal analysis can be set up for any level from a single zone up to the whole building. In this case, because we are dealing with a single zone building, the analyses for each level would be identical. After clicking on the CFD tab, the New CFD analysis dialog is displayed. Enter Basic Vent in the Name field and leave the grid spacing and grid line merge tolerance at their default settings. More on grids in the next exercise.

Click OK to create the analysis data set.

You will see the model in wire-frame mode by default and at this stage the CFD analysis has been created including the default grid and the model is ready for calculations. If you were going to edit the grid now is the time – before starting the calculations, but for now we will use the default grid.

RUNNING THE CFD CALCULATIONS

To set up calculation data and run the CFD calculations, click on the “Update calculated data” button, which will bring up the CFD Calculation options dialog. The left hand side of the calculation dialog contains various calculation options. Keep the default options except under the Residual Display header, switch on the X, Y and Z-axis velocity residuals.

Click on the Start button to begin the calculations. Wait until the calculation is fully converged when the residuals have reached the specified minimum ($1x10^{-5}$ is the default for all variables) and the Finished (Converged) indicator is displayed at the bottom left of the dialog. Notice that the displayed velocity for the default Centre monitor point becomes constant (bottom graph).

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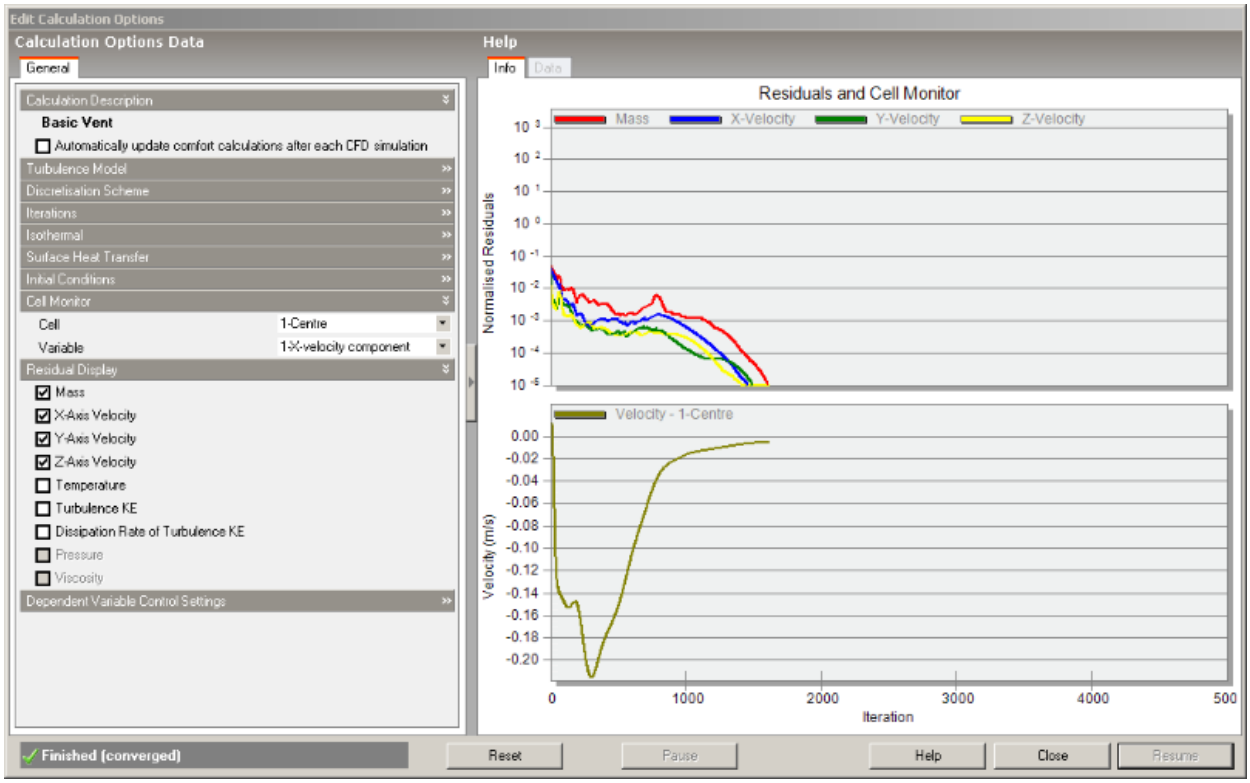

Press the Cancel button to close the calculation dialog.

DISPLAYING CFD RESULTS

After the calculations have been completed, the CFD results display options data panel is enabled allowing you to set various results display options. Use default Display options.

Click on the Select CFD slice tool. Click on the Y-axis of the grid axis selector (top right of screen) and then move the cursor over the ceiling surface along the Y-axis to move the slice selection frame midway between the North and South-facing walls, 2.0m from each wall and click the mouse button to add the currently selected slice to the display.

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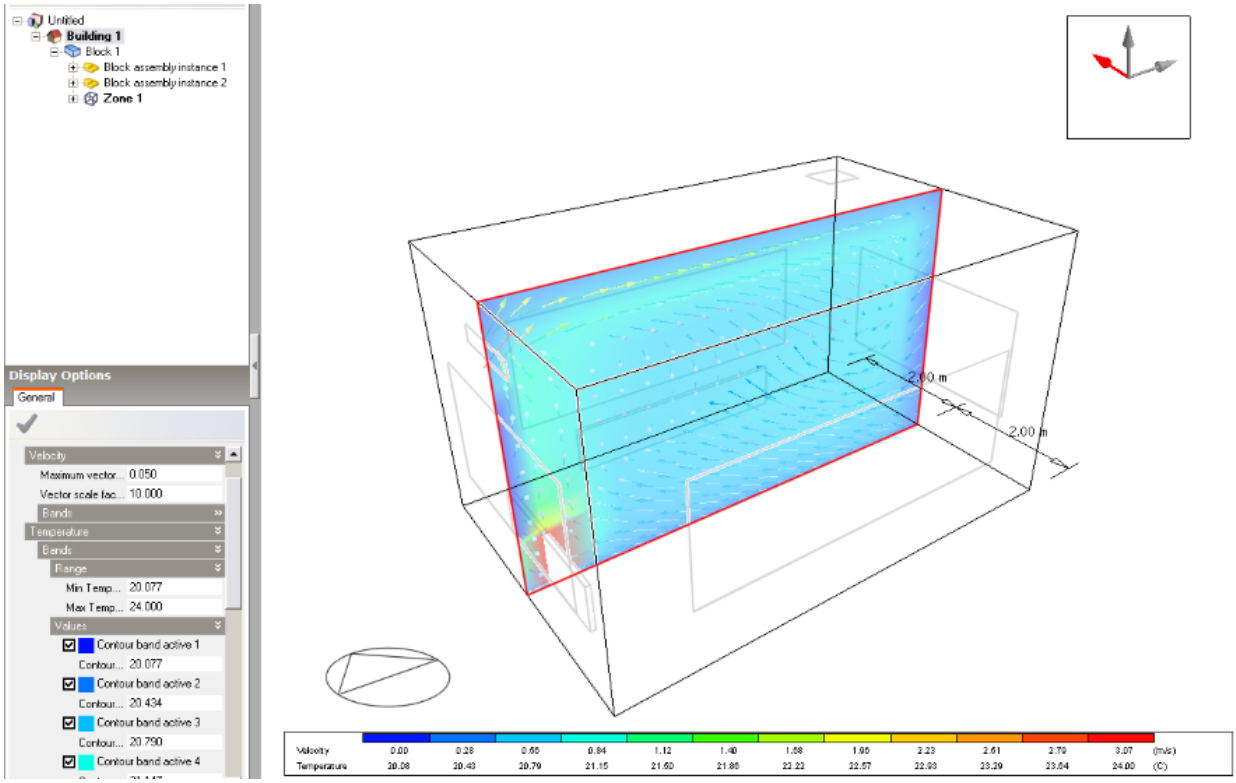

Notice that as you move the slice selection frame to a slice that was previously added to the display, the frame colour changes from green to red and if you click the mouse button, the slice is removed from the display.

Try adding more slices in other planes to see the key characteristics of temperature and velocity distribution in the zone.

Press the ESC key to cancel Select CFD slice tool.

7.4.20 Example CFD Internal Analysis Including Assemblies

In this second internal CFD exercise, the model is modified to include radiators as well as the supply and extract vents entered in the first tutorial. Also some more advanced features of the CFD calculations and display are explored. You will learn how to:

- Create a component representing a constant temperature radiator, convert the component to an assembly, assign CFD boundary conditions to the assembly and add the assembly to the model assembly library.
- Place the previously created radiator assembly within the zone.
- Edit the CFD grid.
- Add cell monitor points for calculation monitoring purposes.
- Edit the CFD Calculation options.
- Deal with common errors and non-convergence.
- Perform comfort calculations.

CREATING THE RADIATOR ASSEMBLY

Assemblies consist of 1 or more component blocks combined and are used to create boundary conditions inside or outside blocks. They can be used to create furniture, heat generating equipment, airflow supply

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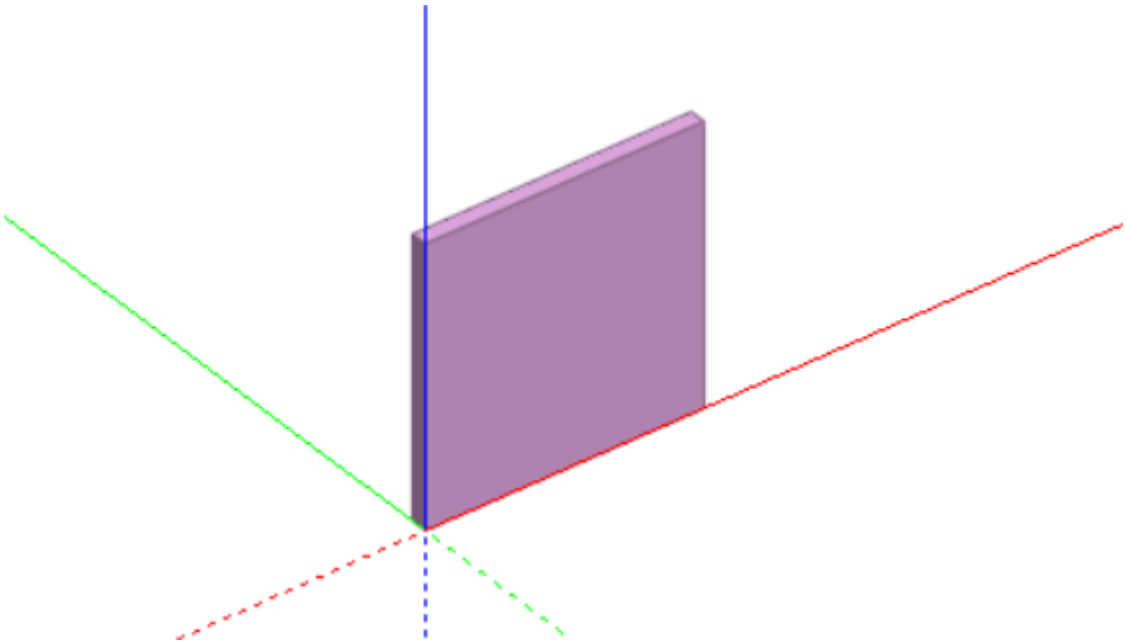
and extract etc.

In this exercise a radiator assembly is to be created from a single component block, which is to be drawn using a rectangular extrusion.

1. Click on the Add new block tool and change the Block type on the Drawing Options panel to Component block and the Height to 1.0m.
2. To place the origin of the radiator component block at the site origin, type in 0 0 and press the return key.
3. Now to create the radiator component with a length of 1.0m and say a thickness of 60mm to represent a single panel convector type radiator, type in 1.0 0.06. The component block will then appear with the specified dimensions. Alternatively use the mouse to define the component block dimensions in the usual way.



To convert the component block to an assembly and add the resulting assembly to the model assembly library:

1. First select the component block and then click on the Add assembly to library tool. The selected component block will be displayed with a wire frame bounding-box and the Add assembly to library data panel is displayed at the bottom left of the screen.
2. Set the Assembly creation mode to Delete because the original component block will not be needed after the conversion and type the name Radiator into the Name field.
3. Set the Thermal boundary type to Temperature in order to create a constant temperature radiator and set the Temperature to 75.0°C.
4. Make sure that the Mass check box is checked to ensure that the assembly will represent a solid boundary and that air will not be able to pass through it.
5. The next stage is to select the attachment plane for the assembly, which is the surface plane of the assembly that will be used when attaching the assembly to a model surface during the assembly placement process. In this case, the base (bottom) surface of the radiator should be selected as the attachment plane. To select the attachment plane, move the cursor over the radiator assembly and as you do so, each surface of the assembly bounding-box will highlight in yellow, move the cursor to the base surface of the bounding-box and click the mouse. The assembly will then be automatically added to the model assembly library and because the Delete creation mode has been selected, the original component will be deleted.

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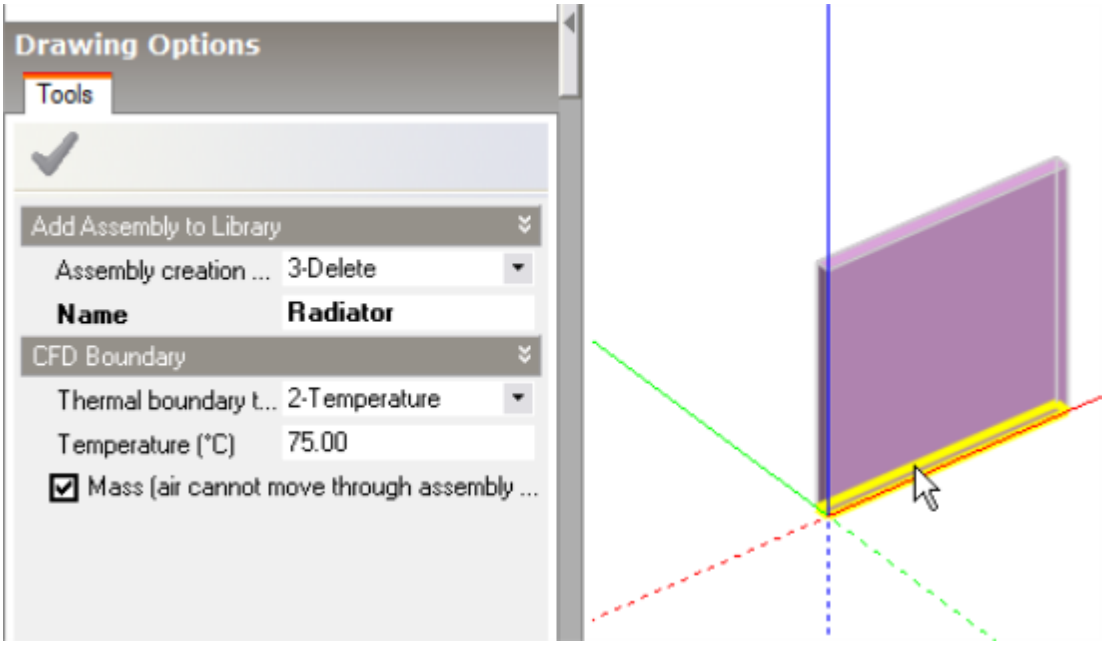

POSITIONING RADIATORS WITHIN THE BLOCK

Assemblies inside the building must be placed at Block level (not zone level) so to place a radiator assembly first click on the block in the navigator to move down to the block level.

To position assemblies accurately you must use construction lines.

To do this, orbit the model to get a clear view of the west-facing end wall from the inside of the block and then click on the Place construction line tool.

To position the construction line accurately, switch on the Increment snap under Point Snaps on the Drawing Options data panel. Move the cursor to snap to the lower surface edge at the bottom of the North-facing wall and move the cursor to obtain an edge snap 0.3m from the end nearest the west-facing wall. Click the mouse to start the construction line and move the mouse to the opposite edge at the bottom of the South-facing wall, snapped to the Y-axis and click the mouse once the edge snap is established on the opposite edge to place the construction line.

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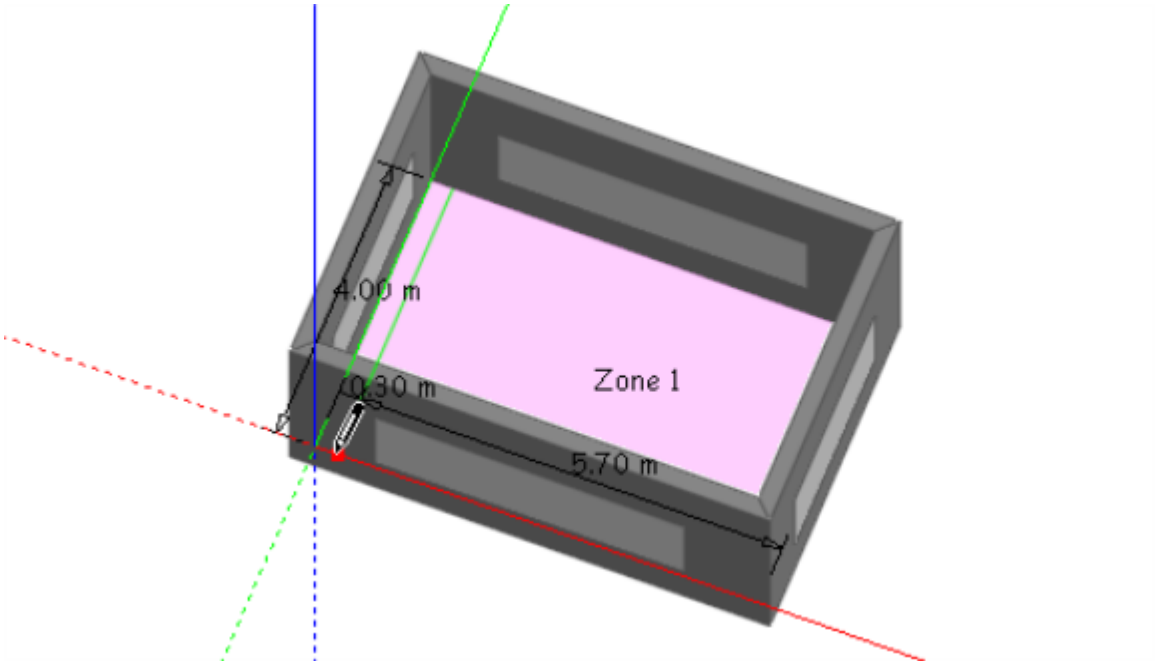
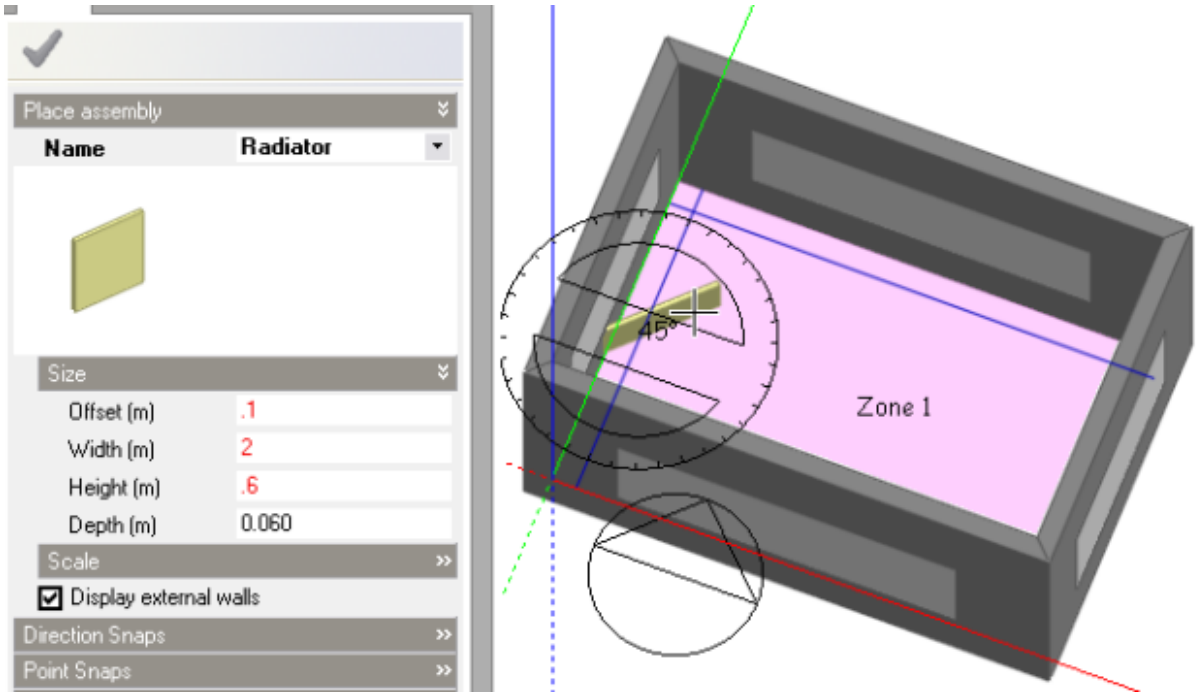


Click on the Place assembly tool and as you move the cursor back across the Edit screen, you will see that a copy of the previously created radiator assembly is attached to the cursor and the Place assembly data panel is displayed at the bottom left of the screen. Set the Offset to 0.1m to offset the base of the radiator 0.1m above the floor level, set the Width to 2.0m, the height to 0.6m and leave the Depth at 0.06m. Move the cursor to establish a snap on the construction line and click the mouse to place the radiator origin. Once the radiator has been placed, a protractor is displayed at the assembly origin enabling you to define the rotation. Rotate the radiator assembly until it is parallel with the nearest wall and then click the mouse to set the rotation.



Repeat this procedure to place a 3.0m radiator adjacent to the North-facing wall.

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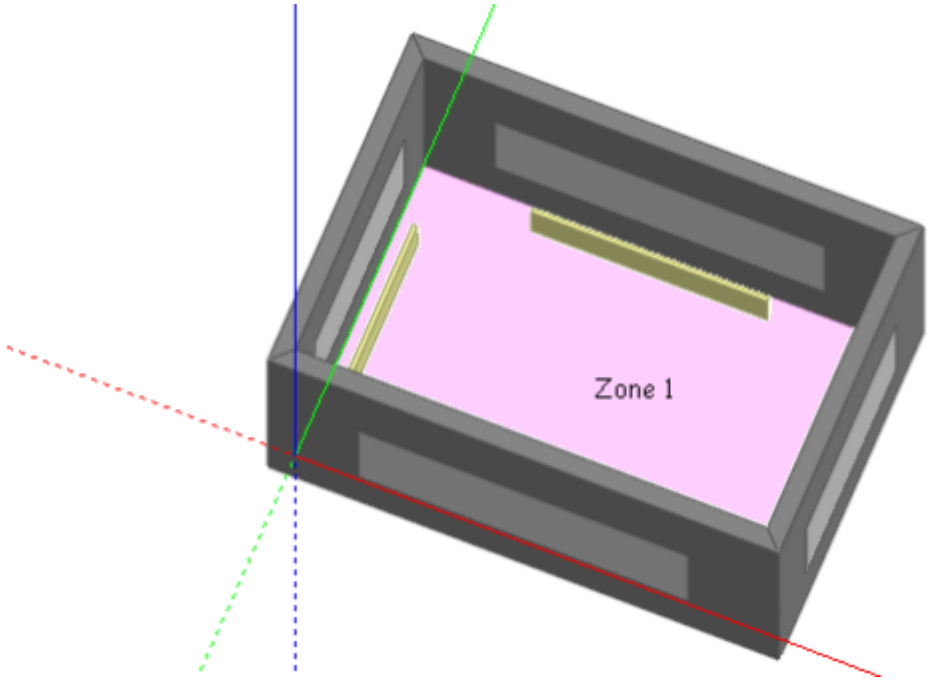
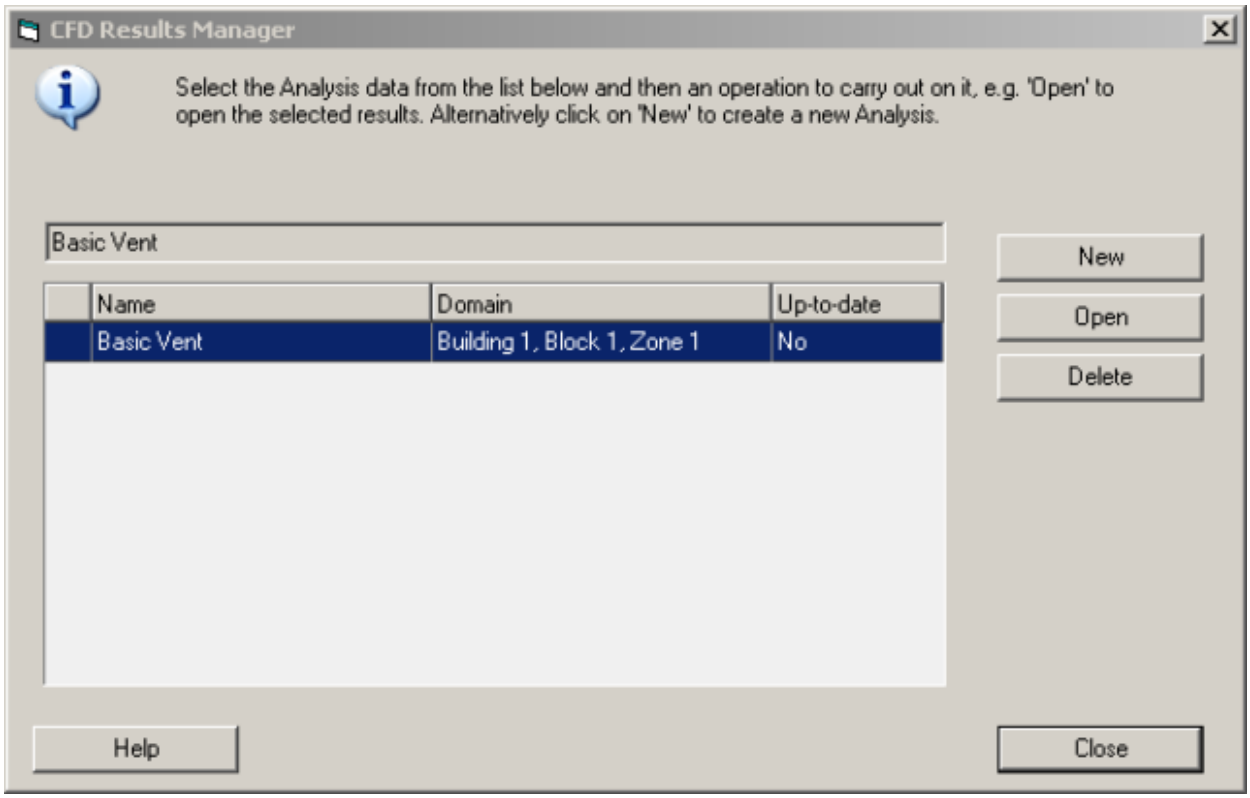


CREATING A NEW CFD INTERNAL ANALYSIS

We are now ready to start a new CFD calculation so again click on the building in the navigator to move to the building level and click on the CFD tab. If you have just finished the first CFD exercise, the analysis results for these calculations will be displayed. You should now create a new analysis because the model has changed with the addition of the radiators. To do this click on the CFD Results Manager toolbar icon. This displays the dialog below.



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Note that the first Basic Vent analysis is flagged as not up-to-date. This is because the model has been edited since the last calculation was made.

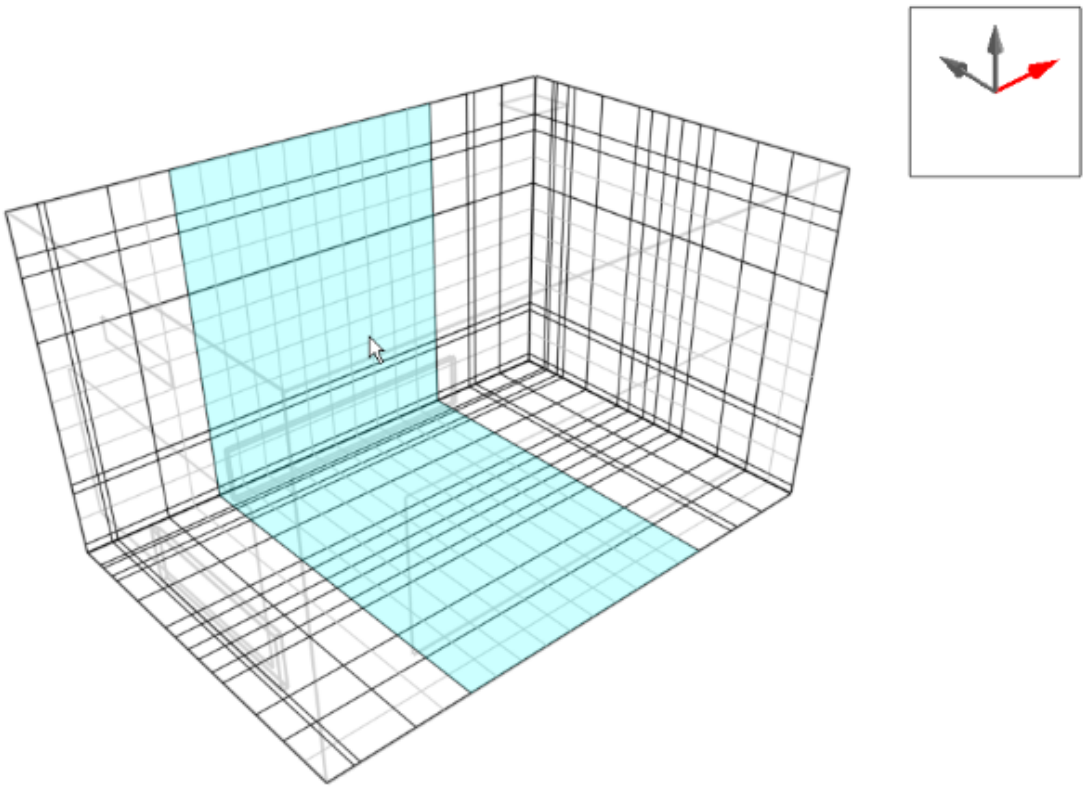
Click on the New button to create a new analysis using the model in its current state. The New CFD analysis dialog is displayed. Enter Radiators and Vent in the Name field and leave the default grid spacing and grid line merge tolerance at their default settings. The default grid spacing and grid line merge tolerance are used in generating the CFD grid. During the process of creating a new CFD analysis data set, a 3-D CFD grid is automatically generated by extracting key points from the model geometry along each of the major axes. The spaces between the key points are known as grid regions and are automatically divided into sub-regions using the default grid spacing entered on the Calculation options dialog. The grid line merge tolerance enables key point grid lines that are very close together to be merged in order to prevent very high aspect ratio cells from being created which can lead to calculation instability.

Click OK to create the analysis data set.

You will see the model in wire-frame mode by default and at this stage the CFD analysis has been created including the default grid and the model is ready for calculations.

EDITING THE CFD GRID

But before starting the calculations we will explore the edit grid capability. First click on the Edit CFD grid tool. Move the cursor across the displayed CFD grid to select grid regions along the current grid axis. Selected grid regions are highlighted in cyan.



To change the current grid axis, click on one of the major axes in the grid axis selector tool that is displayed at the top right of the CFD screen. To edit a selected region, click the mouse on the currently selected region. The selected region will turn red and the Edit CFD grid region data panel will be displayed at the bottom left of the screen. You can select Edit region from the Operation drop list to change the default spacing of the region or Insert region to create a new region and in the case of a previously inserted region, you can select Remove region to remove it.

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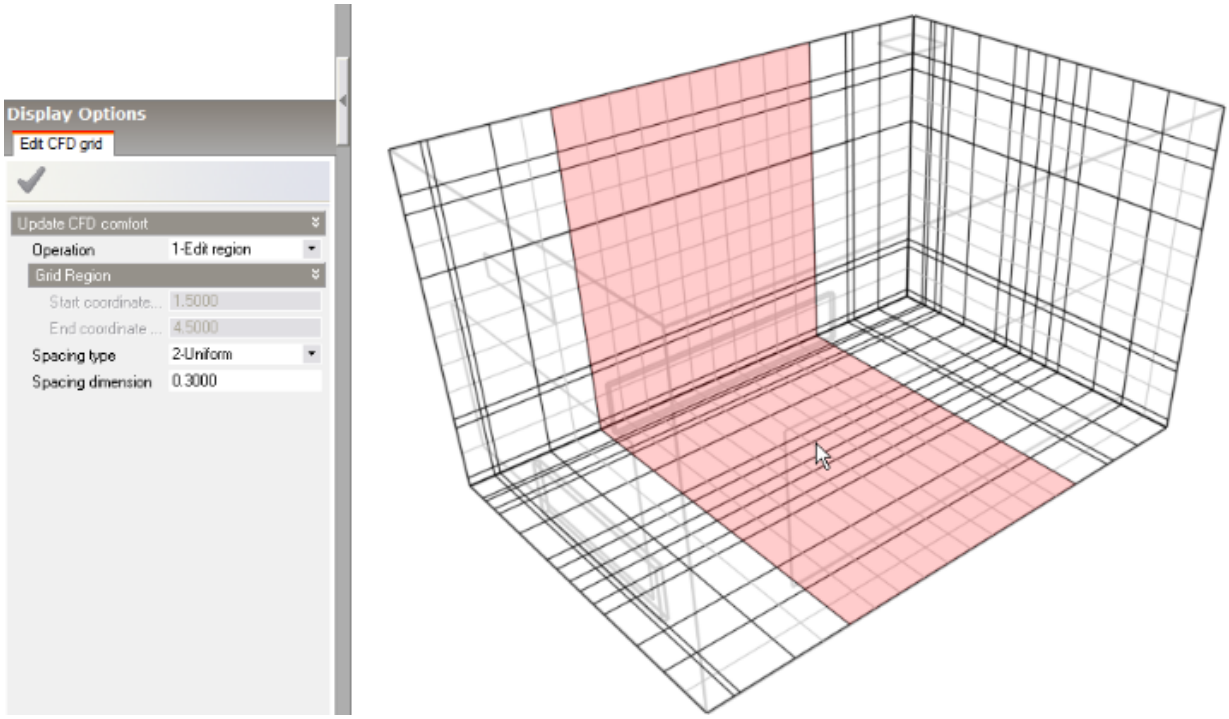

To cancel the Edit CFD grid tool press the <Esc> key.

After editing the default grid, you can reset it to the default by clicking on the Reset CFD grid tool. Also, to obtain information about the grid, you can click on the Show CFD grid statistics tool which brings up a dialog indicating the number of cells, required memory, available memory and maximum cell aspect ratio.

For the purpose of this tutorial, the default grid will be used.

SETTING UP MONITOR CELLS

In order to monitor the convergence of the solution, it can be useful to set up a number of monitor points throughout the calculation domain. During the calculation it is then possible to enable a plot of the variation of the various dependent variables for each of the defined monitor points in order to see if the variables have reached a constant value as the CFD calculation proceed.

1. To set up a monitor point, click on the Define CFD monitor points tool.
2. Move the cursor along the current grid axis to select the plane in which the monitor cell is to be selected. You can change the current grid axis using the grid axis selector tool as before.
3. Once the plane has been selected, you can the move the cursor to select the required cell in that plane. With the current grid axis set to the default X axis, move the cursor along the axis to select a plane about 1.0m from the supply diffuser and then move the cursor across the selected plane and select a cell directly in front of the diffuser.
4. The Cell monitor data panel is displayed at the bottom left of the screen. Enter the name Supply in the Monitor location name field and click on the green tick Apply changes button

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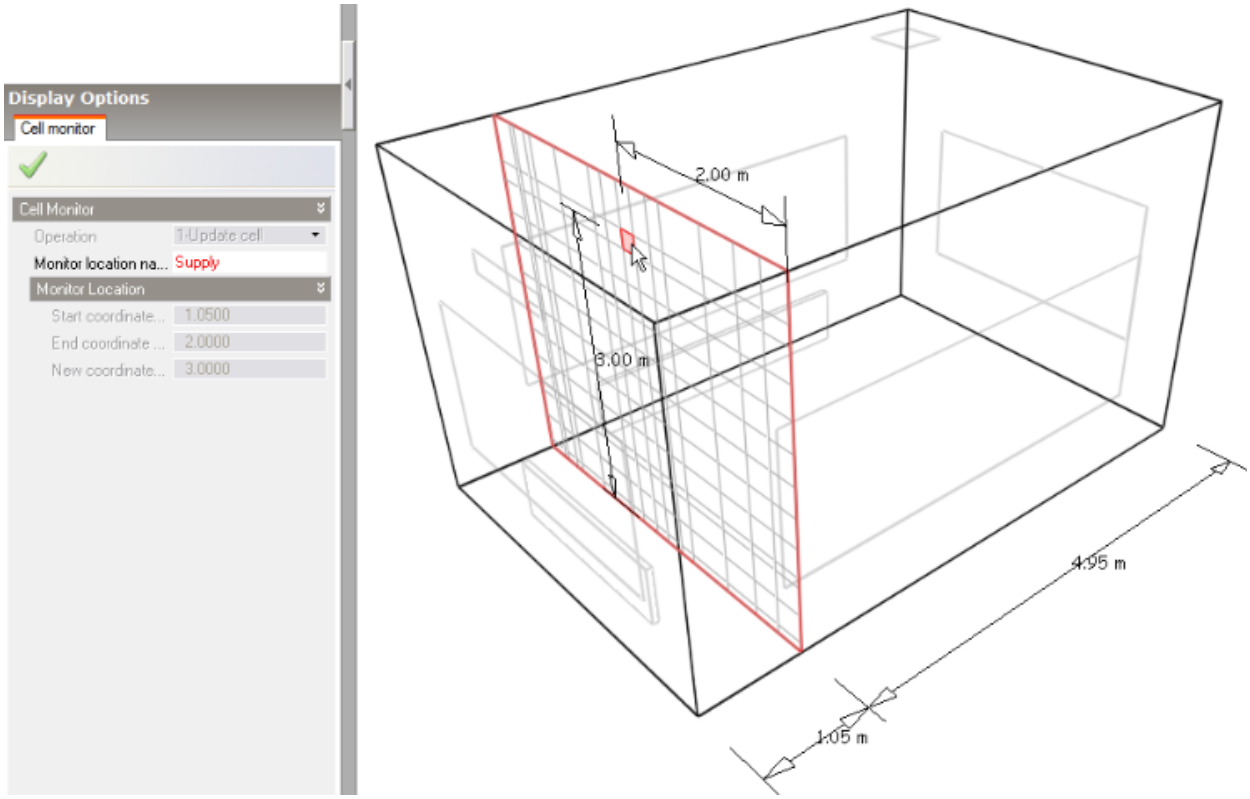
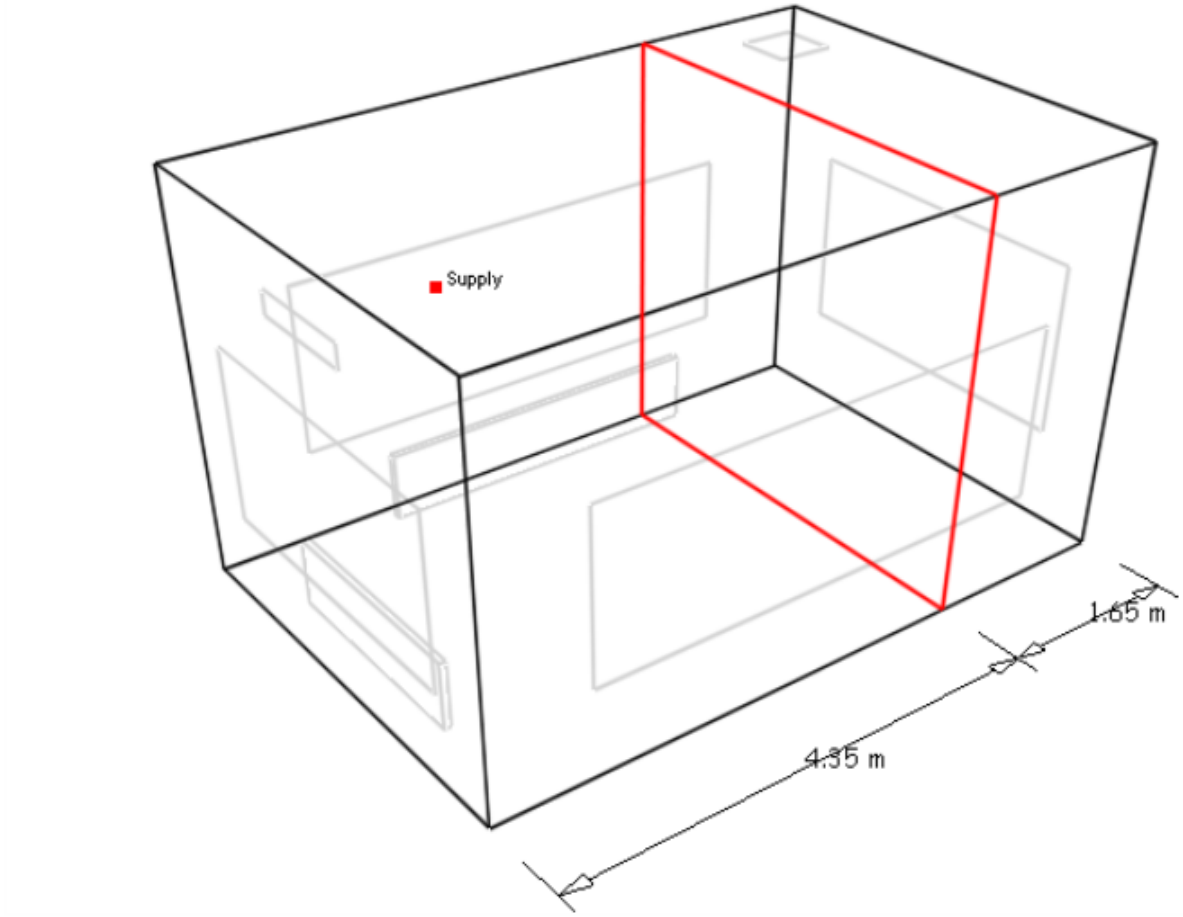


When a monitor cell has been added, a cell marker is displayed together with the cell name.



You can press <Esc> to cancel the Define CFD monitor points tool.

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RUNNING THE CFD CALCULATIONS

To set up calculation data and run the CFD calculations, click on the Update calculated data button, which will bring up the CFD Calculation options dialog. The left hand side of the calculation dialog contains various calculation options. Keep the default options except under the Residual Display header, switch on the X, Y and Z-axis velocity residuals.

Click on the Start button to begin the calculations. Wait until the calculation is fully converged when the residuals have reached the specified minimum and the “Finished (Converged)” indicator is displayed at the bottom left of the dialog. Notice that the displayed velocity for the default Centre monitor point becomes constant (bottom graph).

CFD DISPLAY OPTIONS

In the CFD results slices, velocity vectors are displayed as arrows, the length of which corresponds to the magnitude of the velocity and with the default vector scale factor of 1.0, a length of 1.0m corresponds to a magnitude of 1.0m/s. The maximum vector length is the maximum length of a vector that will be displayed to prevent the display from becoming cluttered with excessively large vectors. Any vector, which has a magnitude greater than this maximum, will be displayed translucently to distinguish it from vectors with lengths that do represent magnitude.

The default minimum and maximum dependent variable values are extracted from the minimum and maximum values found in the domain and this range is then divided into twelve equal increments in order to arrive at the dependent variable contour bands. Each contour band can be edited or switched off altogether.

In this tutorial the maximum temperature will be 75.0°C (the temperature of the radiators), which is well above the mean temperature of the space, and consequently the default contour bands would be far from the mean and the resulting display would not be very informative. So in order to compress the contour bands to be within the likely temperature range throughout the domain DesignBuilder automatically sets the Maximum Temperature under temperature bands range to 24.0°C and the minimum value to 18°C.

You can manually change these maximum and minimum values in the Display options panel. Note that you need to click on the green tick Apply changes button in order for the display attributes to take effect. Notice also that the temperature contour bands are updated using the new temperature range.

You can revert to the absolute minimum and maximum values in the model by using the Tools > Reset CFD display variables menu command.

COMFORT CALCULATIONS

Click on the Update CFD comfort tool to carry out comfort calculations. After the calculations have been completed, various comfort variables are available for display, PMV, PPD, operative temperature and mean radiant temperature. Clear all slices from the display using the Clear all slices tool. Switch off Velocity vectors and Filled temperature contours under the Slice Settings header on the Display options panel and switch on the PMV contours and Filled PMV contours. Click on the green tick Apply changes button.

Click on the Select CFD slice tool and click on the Y-axis of the grid axis selector. Move the cursor over the ceiling surface along the Y-axis to move the slice selection frame again to be midway between the North and South-facing walls and click the mouse button to add the slice to the display.

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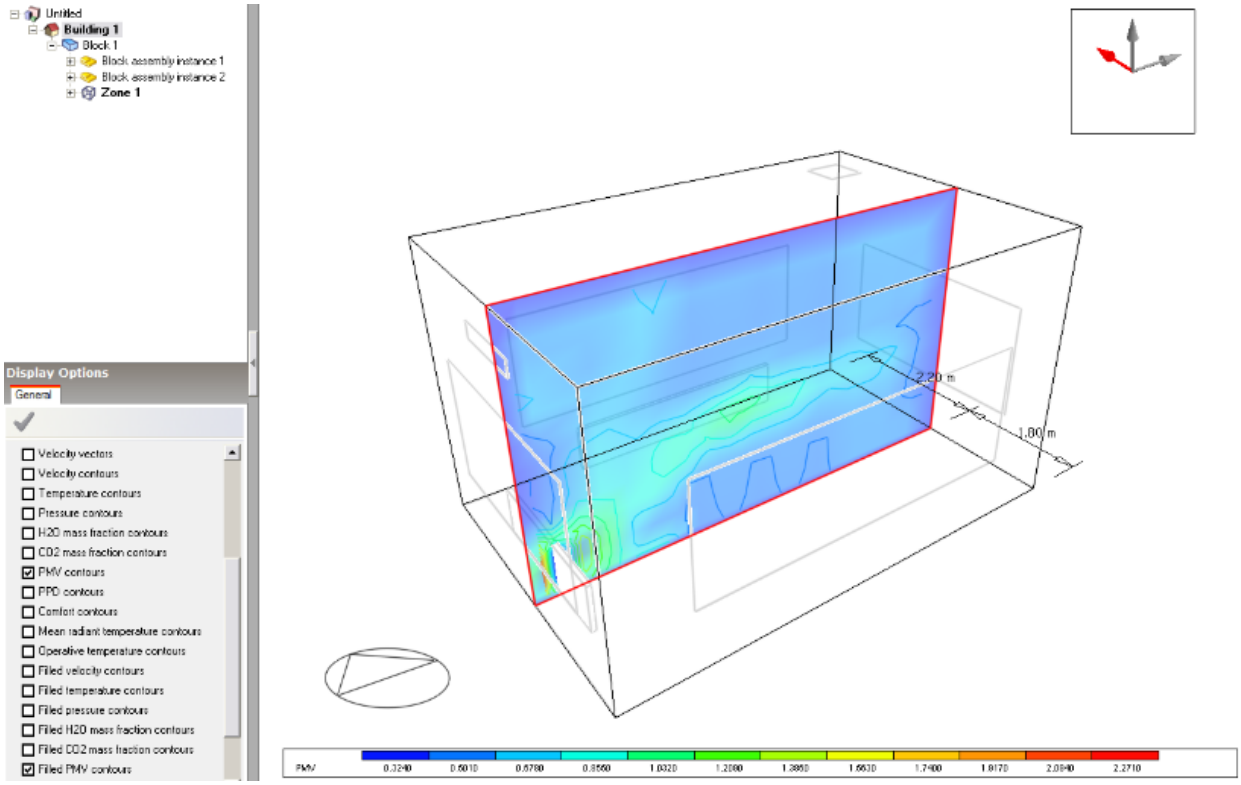

CHANGE CFD ANALYSIS

You can now switch between the 2 CFD analyses you have carried out using the CFD Result Manager dialog. Select the analysis you wish to switch to and use the Open button to load results. Any slices associated with the analysis will be restored. These 2 analyses will be stored in the dsb file by default and are not deleted when changes are made to the model.

7.4.21 Appendix - CFD Calculations and Convergence

The numerical method used by DesignBuilder CFD is known as a primitive variable method, which involves the solution of a set of equations that describe the conservation of heat, mass and momentum. The equation set includes the three velocity component momentum equations (known as the Navier-Stokes equations), the temperature equation and where the k-e turbulence model is used, equations for turbulence kinetic energy and the dissipation rate of turbulence kinetic energy. The equations comprise a set of coupled non-linear second-order partial differential equations having the following general form, in which f represents the dependent variables:

$$\underset{1}{\frac{\partial}{\partial t}(\rho\phi)} + \underset{2}{\operatorname{div}(\rho u\phi)} = \underset{3}{\operatorname{div}(\Gamma \operatorname{grad}\phi)} + \underset{4}{S}$$

Term 1 represents the rate of change, term 2 represents convection, term 3 represents diffusion and S is a source term.

Due to its non-linearity, the equation set cannot be solved using analytical techniques, which necessitates the requirement for a numerical method. The numerical method employed by DesignBuilder involves re-

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casting the differential equations into the form of a set of finite difference equations by sub-dividing the required building space (or calculation domain) into a set of non-overlapping adjoining rectilinear volumes or cells, which is collectively known as a finite volume grid. The equation set is then expressed in the form of a set of linear algebraic equations for each cell within the grid and the overall set of equations is solved using an iterative scheme. The non-linearity of the equation set is accounted for by the use of a nested iterative scheme whereby each dependent variable equation set (velocity components, temperature, etc.) are themselves solved iteratively within an overall outer iterative loop and at the termination of each outer iteration, the most recent values of the dependent variables are fed back into the dependent variable coefficients. The outer iterative loop is repeated until the finite difference equations for all cells are satisfied by the current values of the appropriate dependent variables, at which point the scheme is said to have 'converged'. An appreciation of the requirement for convergence and the nested iterative procedure used to achieve it will help in understanding the meaning of the various calculation options that are described in the 'Conducting CFD Calculations' section.

The Iterative Nature of the Procedure

The calculation procedure has been developed to ensure that the iterative solution of the equation set would be guaranteed to converge if the equation coefficients were constant. However, the equation set is non-linear and the coefficients actually contain the dependent variables themselves, and consequently convergence cannot be guaranteed in all cases. Although in the majority of cases, as long as the dependent variables and particularly the velocities only change slowly, a converged solution is normally achieved.

The main mechanism to ensure that the variables change slowly is that of false time steps. The finite difference equation set is formulated in the form of a transient equation set although the calculations are steady state, i.e. essentially a 'snap-shot' in time. The reason for this formulation is that the transient term behaves as a very effective relaxation method, which can slow the change in dependent variables in order to arrive at a more stable solution. The false time step is the time step used in the pseudo-transient term of the dependent variable equation.

You can find more details on the calculation method used in the CFD Technical online document.

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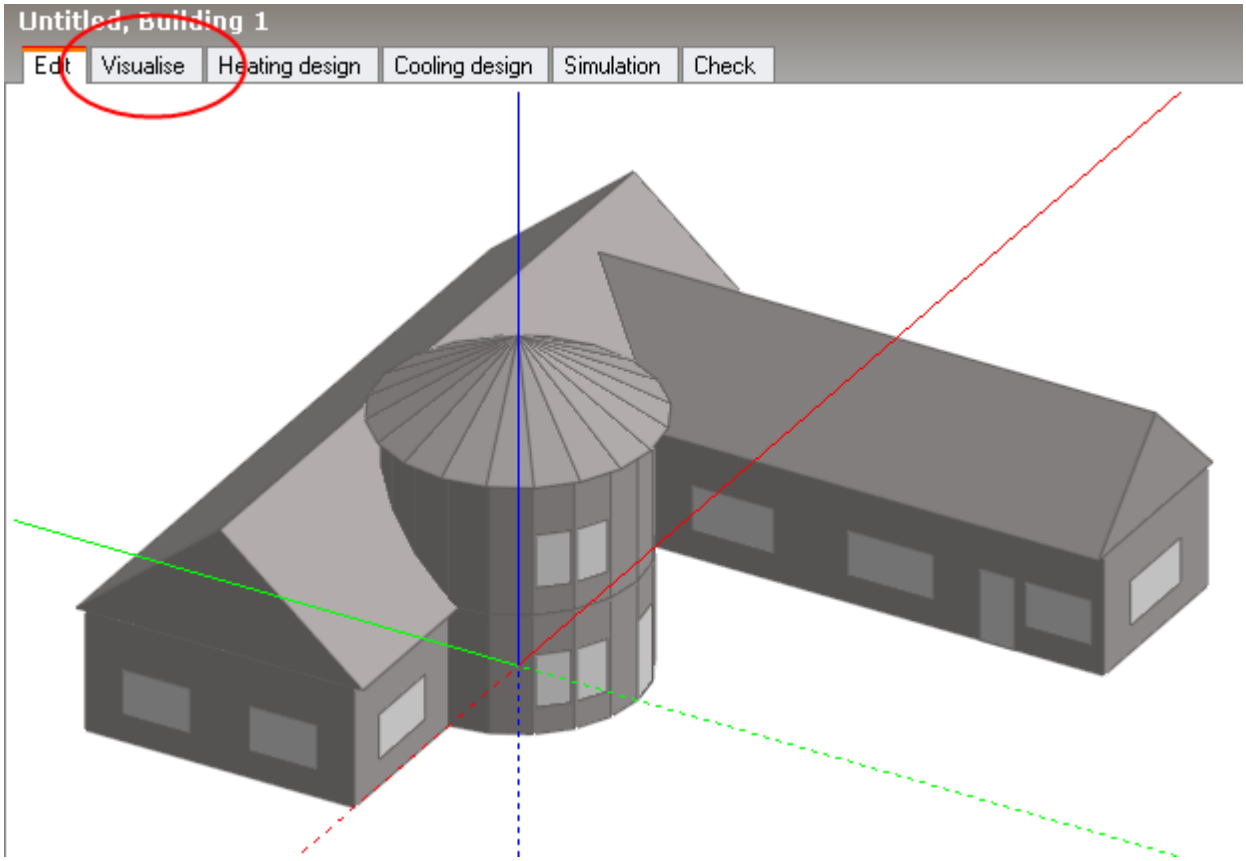
8 Visualisation

The Visualisation screen allows you to view the model in full 3-D rendered mode. This section describes the process of creating and controlling rendered images.

From the Visualisation screen you can export rendered images in various formats and also generate AVI movies of the scene.

To render a model, click on the Visualisation tab:



which takes you to the Visualisation screen:

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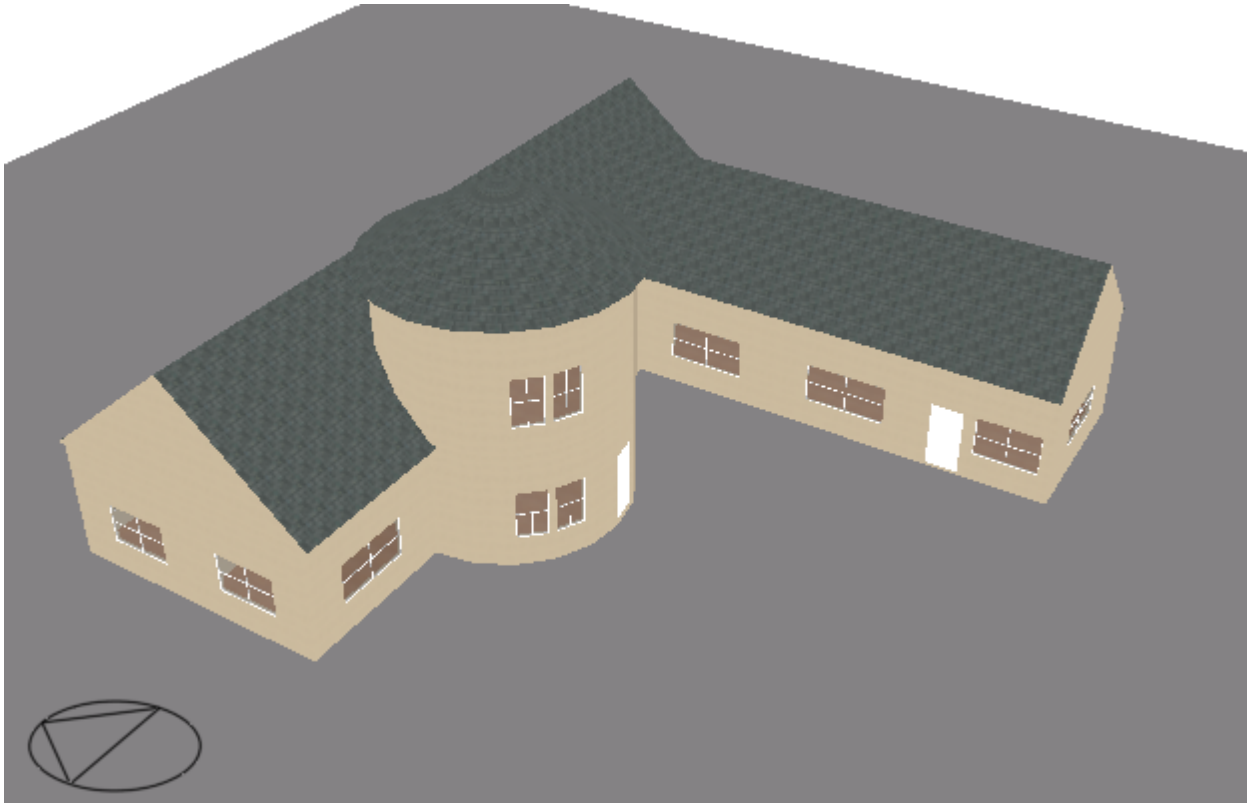

8.1 Controls

The following controls are available to customise the view:

- View Rotation
- Orbit
- Zoom
- Fit view
- Pan view
- Zoom window

Controls are also provided to customise the rendered image:

- Show shadows
- Antialiasing
- Show north arrow
- Dynamics

These controls are accessed from the Display Options panel on the Visualisation screen:

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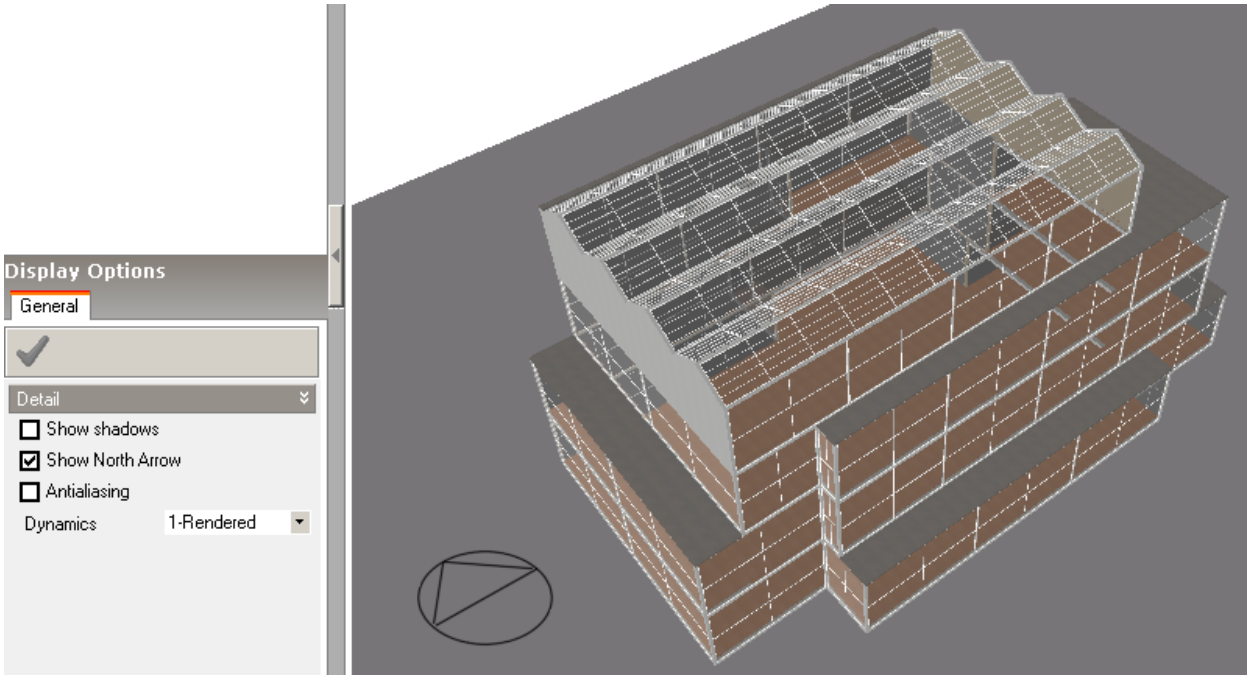
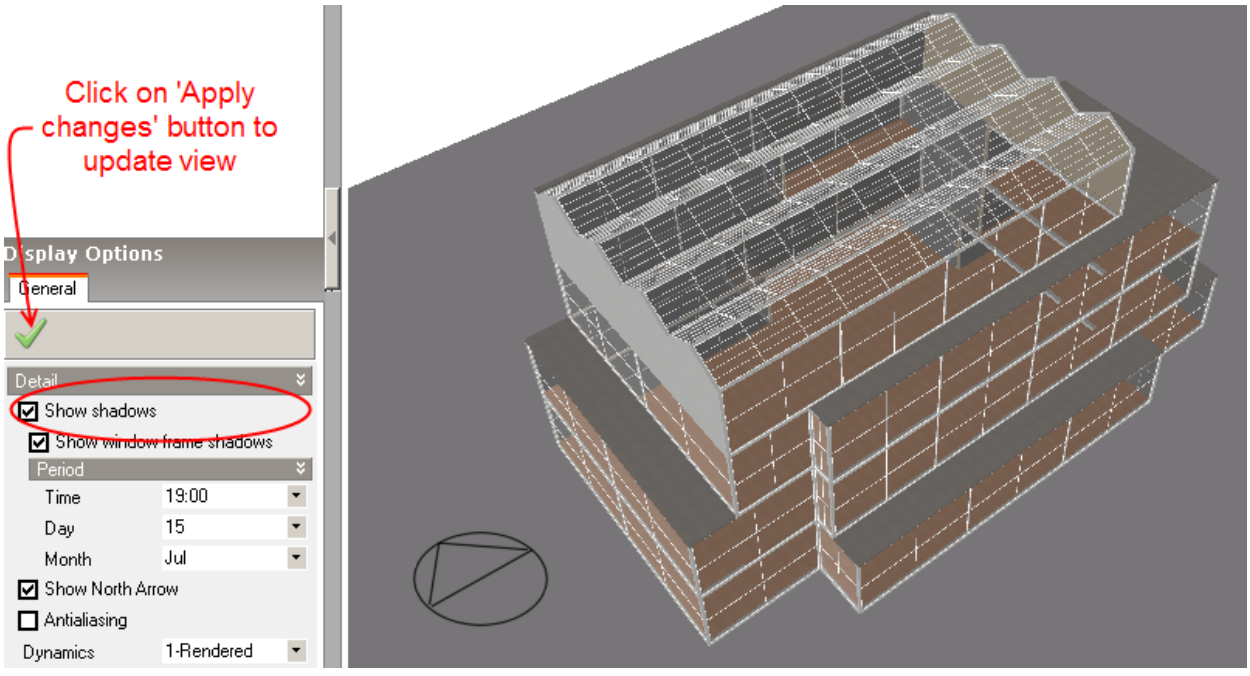


8.1.1 Show Shadows, Time, Day, Month

Display options on Visualisation screen

You can incorporate solar shading within the rendered model view by switching the 'Show shadows' check box on and then clicking on the 'Apply' button:



After clicking on the 'Apply' button, a progress control appears to inform of shadow generation and then the view is updated:

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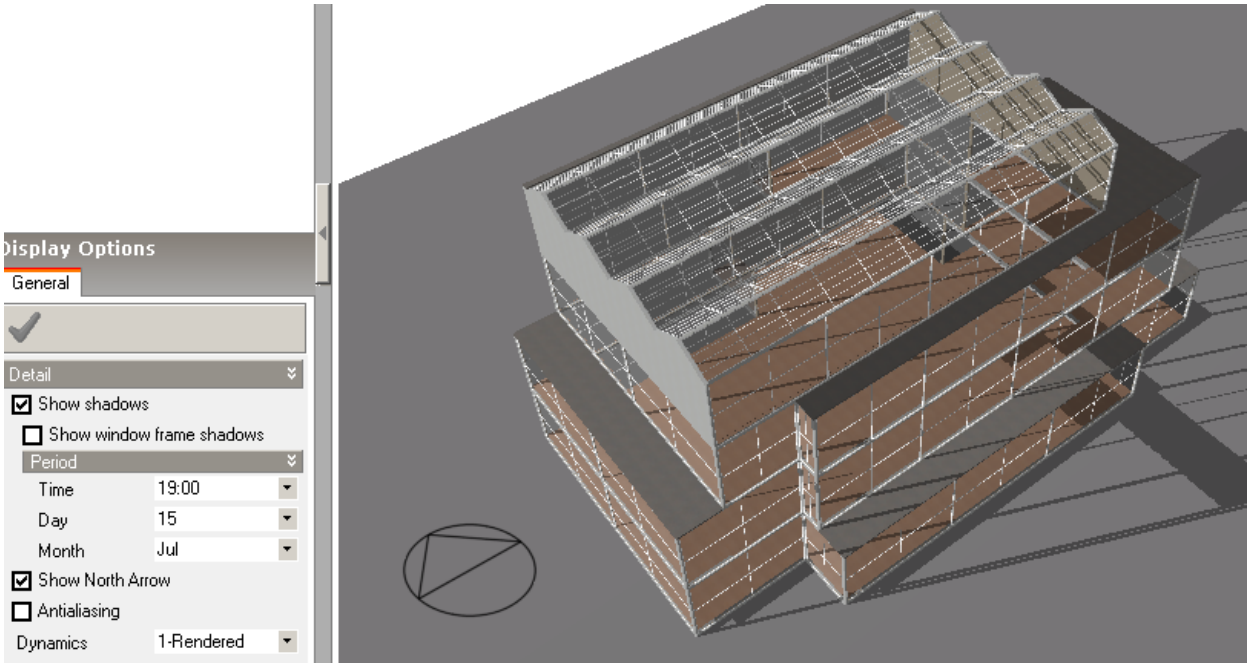
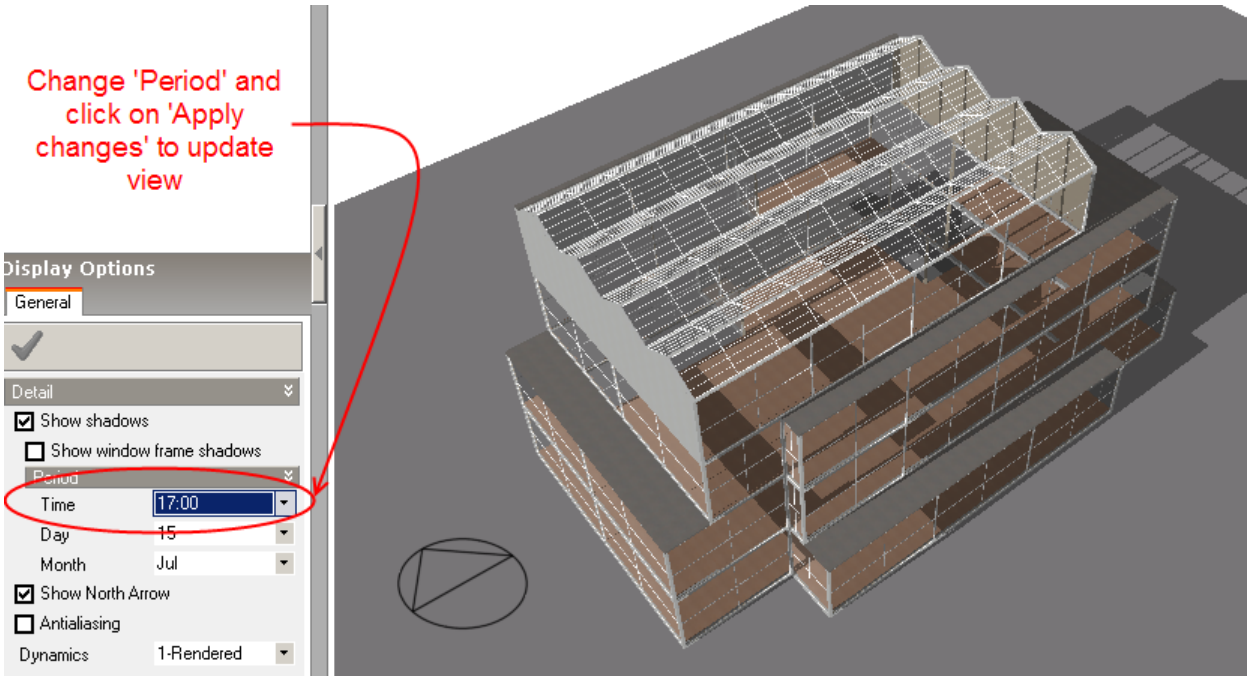


The month, day and time-of-day can be controlled using the 'Period' controls. Note that the time specified here is local mean time excluding any daylight saving. You can account for daylight saving time by adding 1 hour to the local mean time during summer months to see shading for clock time.

Note in versions 1.3.4 and later, time is defined in decimal hours, e.g. '10.5' is the same as 10:30am.



If you want to look at much more detailed shading, you can include the window frame dividers in the shading calculations by switching on the 'Show window frame shadows' check box and clicking the 'Apply' button:

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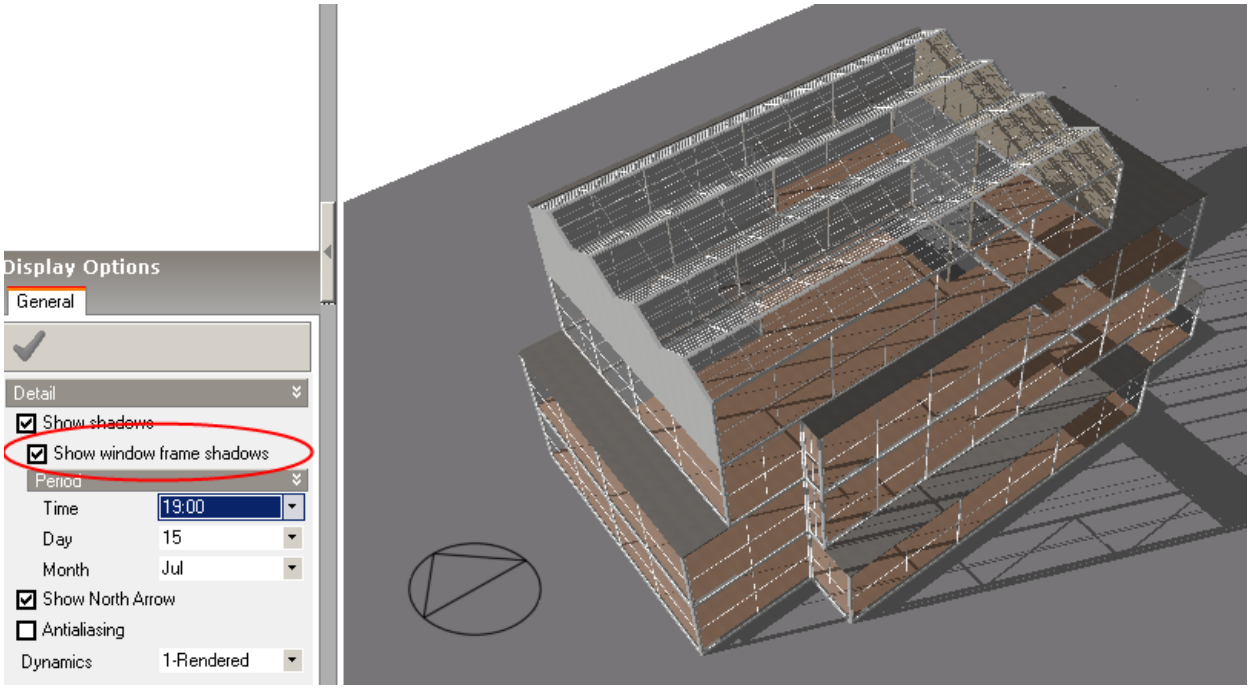

8.1.2 Show North Arrow

Display options on Visualisation screen

Use this control to switch the display of the North direction arrow on or off.

8.1.3 Antialiasing

Display options on Visualisation screen

The antialiasing option can be used to improve image quality. You may need to experiment with antialiasing to confirm whether or not the graphics card fitted to your computer will facilitate this feature - with some earlier cards, antialiasing can be very slow.

Tip: more advanced graphics cards can provide hardware antialiasing and in this case this software antialiasing option may only provide marginal benefit.

To enable antialiasing, switch the **Antialiasing** check box on and click on the **Apply** button:

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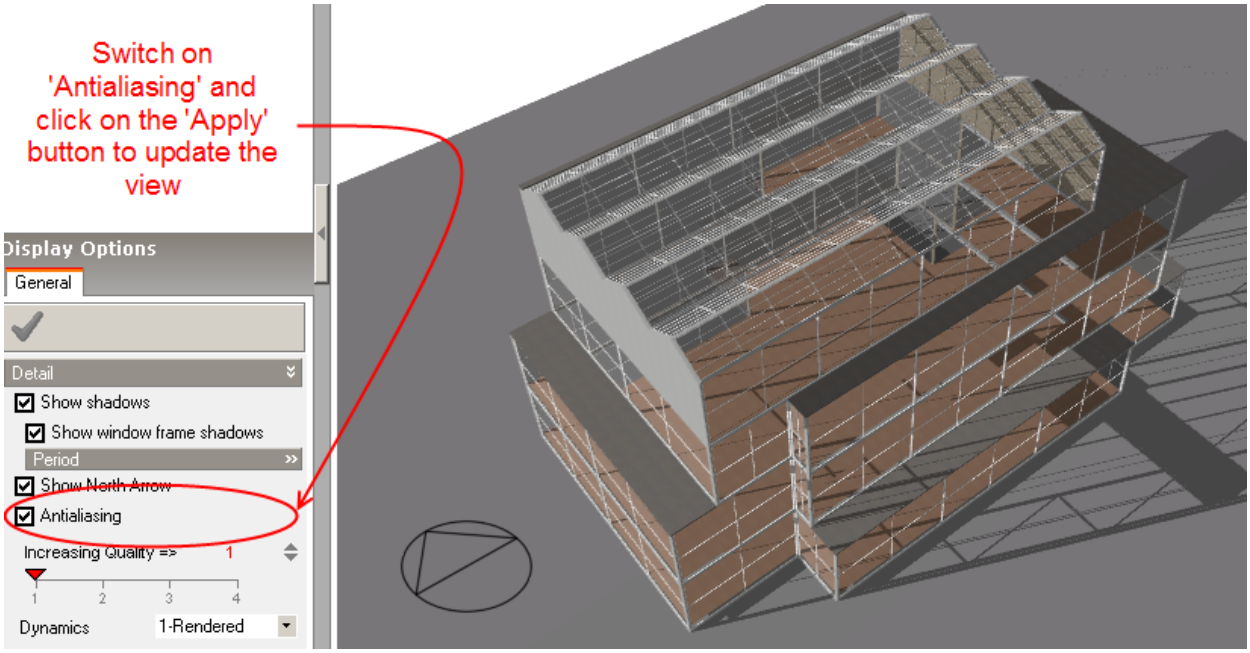
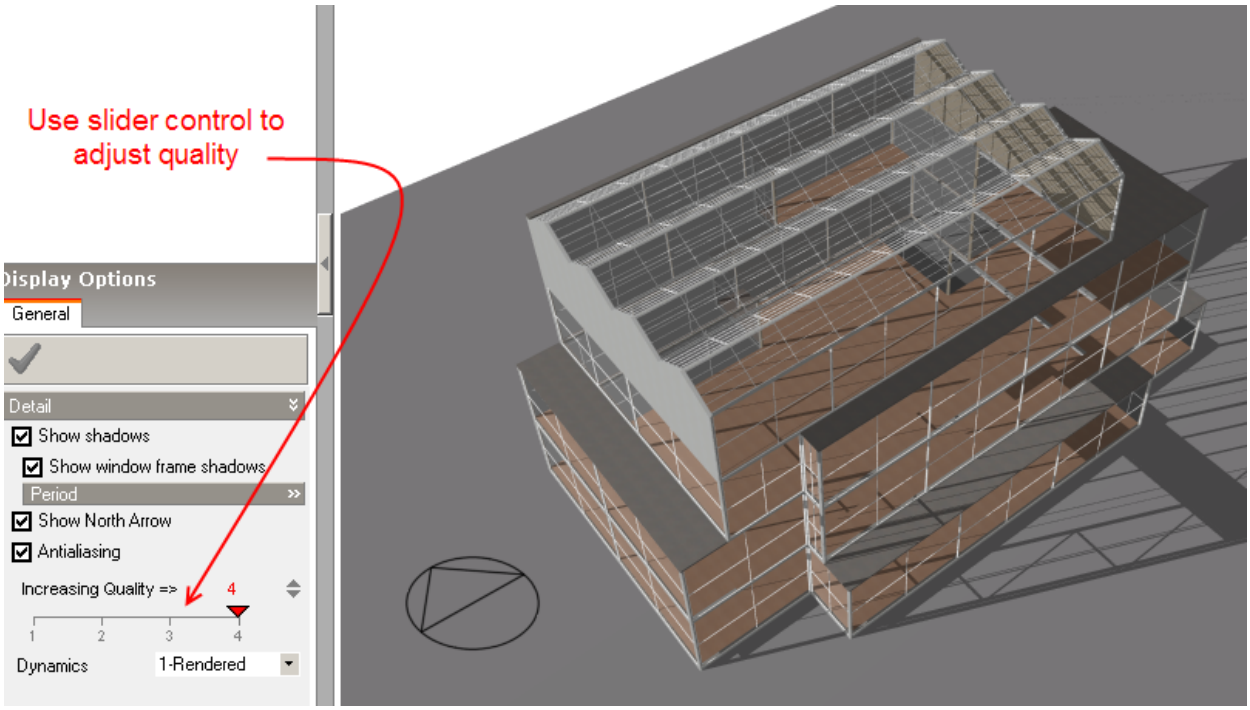


You can improve the quality of the image using the **Increasing Quality** slider control:



Bear in mind that as you increase image quality, the display speed will decrease.

8.1.4 Dynamics

Display option on Visualisation screen

With larger and more complex models, orbit and zoom control speed can be increased very significantly by selecting 'Wireframe' from the 'Dynamics' control drop list.

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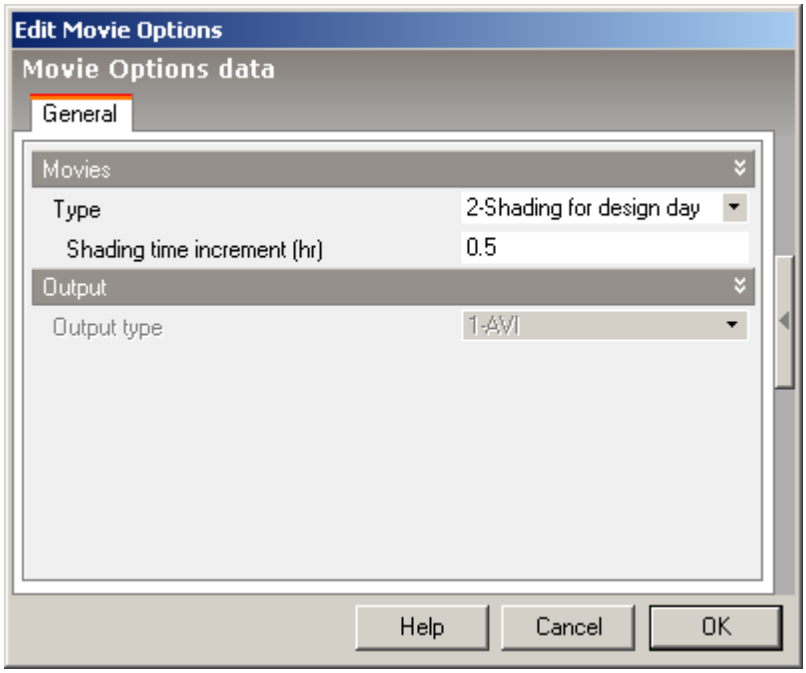
8.1.5 Visualisation Limitations

Visualisations are based on the same model as that used for the calculations but you may notice some slight differences in the way the model is displayed vis-a-vis the floor constructions and Zone volume calculation options.

1. DesignBuilder uses a single floor 'slab' for each block even when some floors in the block may have different constructions. This is done for simplicity and also to ensure the most realistic images are produced without step changes in the floor level throughout the block. So there is only limited scope for adjusting the height of floor level in the visualisation.
2. Where there is external floor and internal floor in the same block you will notice that the internal floor slab used to represent the floor in the rendered view is the same no matter what settings are used in the Zone volume options. You will also notice that the floor slab takes on the texture of the internal floor even for areas of the floor that are actually external floor and may have a different texture.
3. Where the **Ground floor construction is below ground and is not subtracted from zone volume** option is selected, the top of the ground floor will be shown in the visualisation screen as being at ground level - this is consistent with the data. However you will not be able to see the ground construction below the ground if you adjust the camera level to be below ground.

8.2 Creating Movies

You can create AVI movies of your model using this feature. To create a movie, click on the 'Generate AVI movie' tool which opens the 'Movie options data' dialogue box:



Use the 'Type' drop list to select either:

- **Shading for design day** - fixed camera position, varying the solar position over the design day as

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specified on the Visualisation Data Options panel.
- **Orbit** - 360° orbit movie.

Click on the OK button to generate the movie. After the movie generation has completed, a file save dialogue will be displayed to allow you to save the movie file to any required location.

Note: smaller 'Shading time increments' and 'Orbit increments' can generate a lot of data and take a long time to complete movie generation, especially when software antialiasing is switched on.

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9 Reporting

You can use DesignBuilder to generate reports using the Compile Reports and Report topic mechanism or you can Export individual report content to file, clipboard (for pasting into word processors) or directly to the printer.

9.1 Export Data

You can export data from DesignBuilder **screens:**

- **Edit Screen** - exports a non-rendered 3-D image of the building. Alternatively a 3-D DXF file can be exported.
- **Visualisation Screen** - exports a rendered 3-D image of the building optionally including shading and antialiasing..
- **Heating and Cooling Design Screens** - exports design data (graphical, tabular, spreadsheet).
- **Simulation Screen** - exports simulation data (graphical, tabular, spreadsheet).

You can export to a range of **destinations** (depending on the nature of the data):

- File - store output in a file which can be imported into your documents/e-mails.
- Printer - sends output directly to the printer.
- Clipboard - for pasting directly into word processors etc.
- Report topic - for generating reports using the Compile Reports feature.

Export **format** options depend on the nature of the data. The full range of options is:

- **Bitmap** - best bitmap based output quality but very large file sizes.
- **PNG** - better quality compression than JPEG but sometimes have larger file sizes.
- **TIFF** - best bitmap based output quality but very large file sizes.
- **GIF** - good compression but black and white only.
- **JPEG** - recommended for 3-D images of the model because of its good quality combined with small file sizes.
- **DXF** - generate 3-D DXF data of the model - only available from Edit and Visualisation Screens. The 3-D DXF file generated by DesignBuilder is suitable for reading into other CAD software. Two options are available:
  - **1-Whole model with details** which includes all of the details of the model as seen on the Visualisation tab, and,
  - **2-Zones** which generates the internal surfaces as used in simulations and other energy calculations.
- **Windows metafile** - results graphs only - scalable so graphs can be resized without losing quality.
- **CSV spreadsheet** - grid results and library data only.
- **Text** - reports only.

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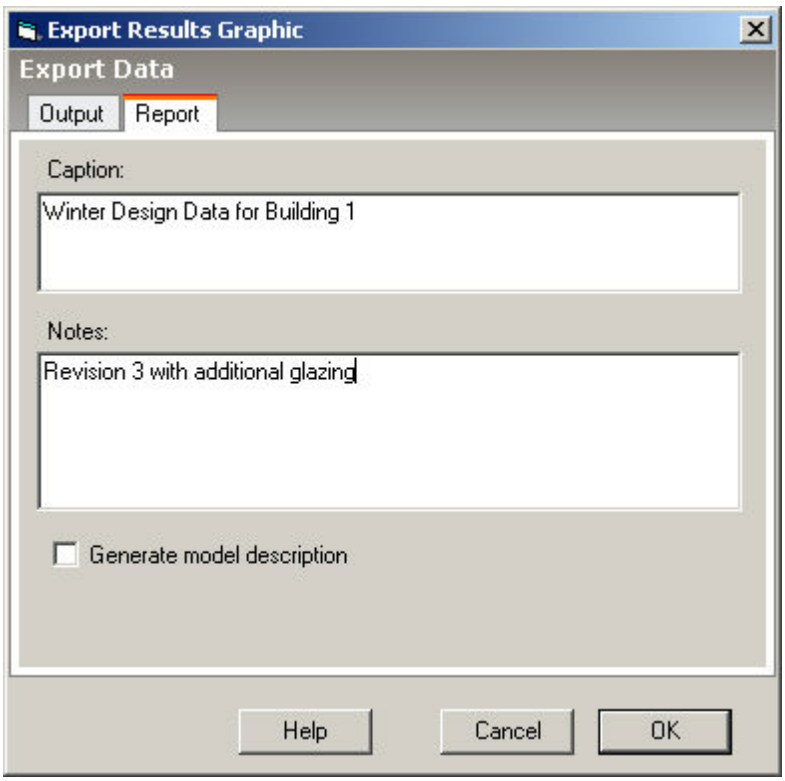
9.2 Report Topics

Report topics are used to store snapshots of model data including model descriptions, graphic images of the model and results.

You can export to a report topic by selecting 'Report topic' from the 'Export to' option on the Export Data dialog. When Report topic is selected, a second tab becomes available called Report on which you can enter a title and caption for the topic. You can also choose to include a model description with the topic. This allows a building description to be included alongside the data when the report is compiled using the Compile Report dialog.



Report topics are retained within the dsb file and are available for compiling into a report if the file is saved and reloaded.

9.3 Compile Reports

The Compile Reports dialog allows you to control the generation of a report based on previously created Report topics. Available report topics are listed and can be previewed by clicking on them.

The Title entered on this dialog is displayed in a table at the top of the report.

Check the checkbox to the left of the report topics to be included in the report and click on OK.

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10 Program Options

The Program options dialog is accessed from the Tools menu.

The Program options apply to the overall application no matter which file is loaded. There are six tabs:

- User interface
- Dialogs
- Files
- EnergyPlus
- Limits
- International

10.1 User Interface

User Interface tab of the Program options dialog

Learning

You should generally select **Learning** mode while you gain experience with DesignBuilder. In Learning mode, the Info panel is shown to the right of the main screen, providing additional information and commonly used tools relevant to each screen. Model Data is accessed from tabs along to the top of the screen.

With Learning mode switched off, the Info window is not shown and Model data is shown on the right of the screen alongside the Model edit screen. This allows you to see the effects of updates to data as they are made.

Help System

Select one of:

- **1-Web-help** - the default option where the latest help is displayed from the DesignBuilder servers using the **Web Help** system. This option has the advantage of providing the most up-to-date help but it requires an Internet connection and is slower than...
- **2-Local help** - a chm format help file is downloaded and displayed. Once the help file is downloaded no Internet connection is required. The help file is called Manual.chm and is downloaded and stored in the folder "Local settings\Application data\DesignBuilder\Help" on Windows XP or AppData\Local\DesignBuilder\Help\V2.0.

Use Slider controls

Some significant data items are (by default) controlled using a 'slider' which allows rapid selection of typical values. If however you need to enter precise values (for example when modelling an existing building) or if you need to enter values outside the slider range you may prefer to type this data in a text box. In this case uncheck the 'Use slider controls' data. Common reasons for this are to enter Computer gain densities for IT suites or dealing rooms.

Note: when using DesignBuilder with IP units, slider controls are always switched off regardless of this setting.

Sort lists

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By default DesignBuilder automatically sorts navigator and other data lists alphabetically. This can make it easier to find the data you are looking for but also increases the time taken to generate lists and so slows some program operations requiring lists to be generated. You can request unsorted lists by unchecking this option.

Automatically refresh site navigator lists

By default DesignBuilder automatically refreshes the contents of the site navigator list on the left of the screen as the building is modified. In large models frequent rebuilding of the navigator list can slow progress especially when drawing partitions. Uncheck this option to avoid this problem.

You can manually refresh the navigator lists by clicking on the **refresh list** icon above the Navigator panel (below).

Double-click to navigate site hierarchy

By default you can navigate to an object in the site hierarchy (building, block, zone etc) by single-clicking in the Navigator. You can change this behaviour by checking **Double-click to navigate site hierarchy.** In this case you must double-click to go to objects in the Navigator and a single click highlights the object in the Edit view (if you are already at the level above). For example if you are at block level and you single click on one of the zones in the block the zone is highlighted in red in the Edit view.

Note: disabling this option can be useful for identifying blocks, zones, surfaces by single-clicking in the Navigator.

Show 'Load data from template' dialog when template selected

When you select a new template by clicking on the browse button in the Model data, by default the data in the template is loaded directly to the current object. However if this option the 'Load data from template' dialog is opened giving you the opportunity to select various options and load other templates. This option is switched off by default.

Show model data departures from template in bold

Select this option to show any differences in model data relative to the selected template in bold. This option is switched on by default.

Default surface normal view

When working at surface level it can be useful to get a normal view of the surface by clicking on the Normal button in the top right of the screen. By default this will show a normal view of the surface as viewed from **outside**. You can use the **Default surface normal view** program option to instead view from the **inside**.

Maximum characters shown in data display lists

You can control the number of characters displayed in data lists on the right hand panel. This provides a workaround to a problem with the list component used in DesignBuilder which always scroll to the right when an item with a long name is selected. This scrolling can be inconvenient so we have implemented the option to control the amount of text displayed. By default this is set to 35 characters but you can use a larger value if you prefer.

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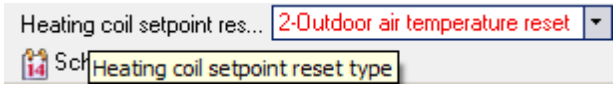
Show tooltips in Model data

With small window sizes or when Learning mode is switched off there is not always enough space to display the caption for each Model data item so DesignBuilder provides the option for tooltips to appear when the mouse hovers over a truncated caption. See screenshot below.



10.2 Dialogs

Dialogs tab of the Program options dialog

Calculation dialogs

These options control whether a calculation option dialog appears by default before every calculation. Note that a dialog always appears when you press Update.

New object dialogs

When you create a new site or building, a dialog box appears by default allowing you to enter basic data on the new object. If you prefer not to see these dialogs and just use default data, uncheck these two check boxes.

10.3 Files

Files tab of the Program options dialog

Backup

DesignBuilder will by default make automatic backups of your current working file. Check the **Automatic backup** option box and select a backup interval to enable this option.
If for any reason DesignBuilder does not close down cleanly and is unable to save, a skh backup file will remain in the same folder as the dsb file and DesignBuilder will ask whether you want to recover this data the next time you open the dsb file.

In addition DesignBuilder copies the auto backup file to the Backup folder below DesignBuilder Data folder.

Note: DesignBuilder keeps files in the Backup folder for up to 30 days and removes old backups each time the program is run.

Default folders

DesignBuilder stores the most recently used folders for:

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- Data file storage
- Picture file export
- AVI file export
- Report file export
- DXF file import/export

You can edit these default folders on this tab.

10.4 EnergyPlus

EnergyPlus tab of the Program options dialog

EnergyPlus

You can select the version of EnergyPlus to use in your simulations. This can be useful to target a specific DOE version you may wish to use or when a new version becomes available which might provide new functionality or address previous problems.

You should generally select the recommended DLL option as it is more tightly integrated within DesignBuilder and provides progress feedback.

DesignBuilder comes with 2 internal versions of EnergyPlus:

- DLL - the default option, runs the internal version of EnergyPlus supplied with the program asynchronously giving visual feedback of progress and allowing interaction with the computer during the simulation.
- Executable - an executable version of the program running in a command window.

...or you can select an executable version of EnergyPlus supplied by DOE. If you are exporting IDF data for use outside DesignBuilder you should select the appropriate DOE version to avoid incompatibilities.

Note: the EnergyPlus version selected here is used for simulations within DesignBuilder but also as the target version when exporting IDF data for use outside DesignBuilder.

Mode

If you select an executable version (internal or DOE) there are four options available to control the way EnergyPlus is executed when simulating within DesignBuilder:

- **1-Executable (minimised)** - runs the executable invisibly - you will just see a minimised window on the Task bar but not the EnergyPlus command window.
- **2-Executable (visible)** - runs the executable showing EnergyPlus screen output in a command window.
- **3-Executable (debug)** - runs the executable showing EnergyPlus screen output in a command window and pauses after simulation - intended for advanced EnergyPlus users who may want to see the stack dump following a crash.
- **4-Executable (EP-Launch)** - runs the DOE-supplied EP-Launch program, waiting until this is closed before loading results. This option is only possible if you have selected a DOE-supplied version of the EnergyPlus executable. This option can be useful for making quick minor changes to the IDF data prior to simulation. Any changes made to the IDF data from within EP-Launch will be included in the simulation but will not be retained for future simulations. **Info on the EP-Launch option.**

  The screenshot below shows EP-Launch being used to control EnergyPlus simulations from DesignBuilder.

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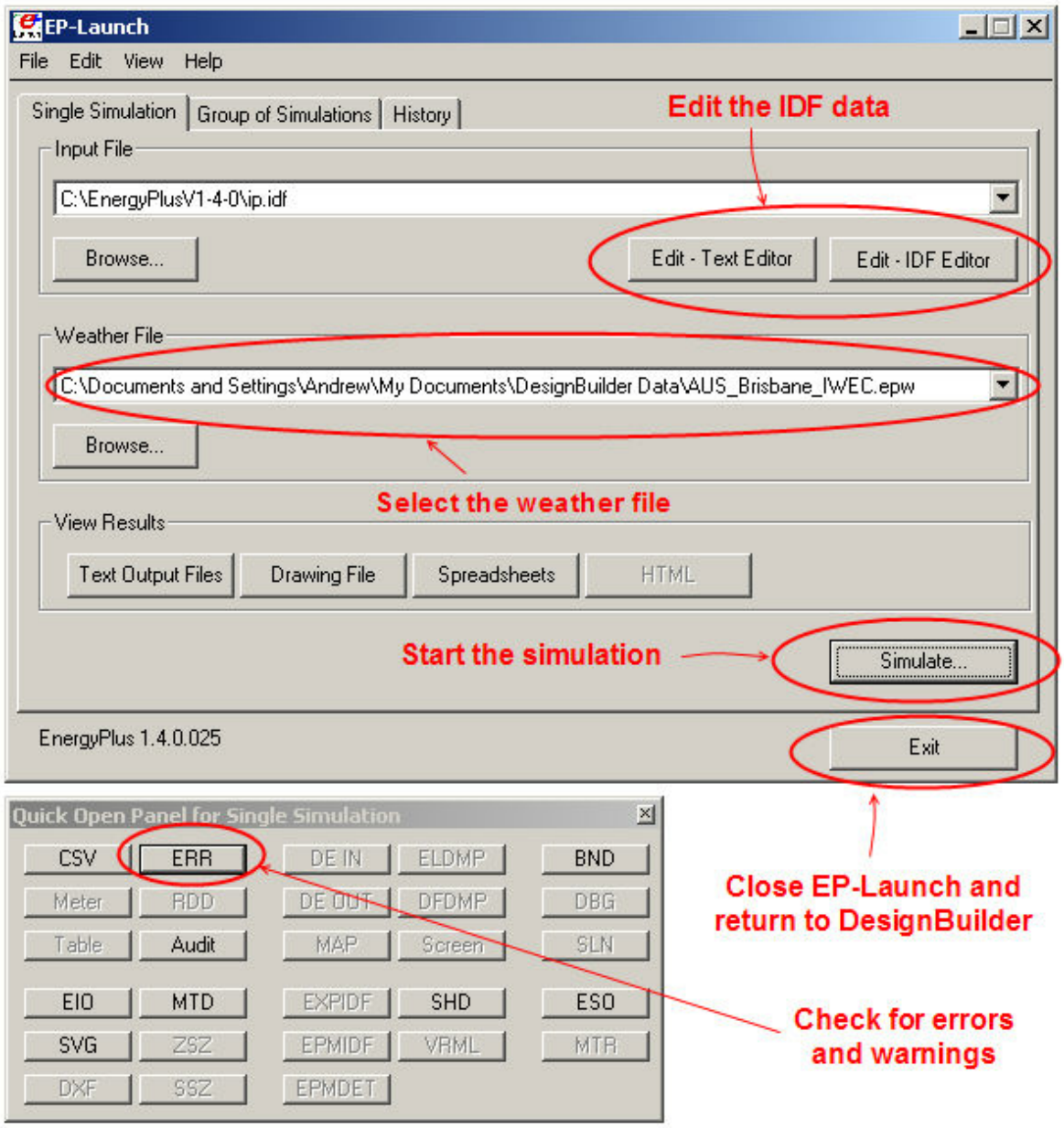

Note 1: If you use this method you must make sure to set the correct weather file manually.

Note 2: Any changes you make to the IDF data, either in the IDF Editor or using a text editor, will be saved in a file called ip.inp in the EnergyPlus folder. This file will be overwritten the next time a simulation is requested so if you wish to save the any changes you make to IDF data you should use the File > Export option and edit the data and make simulations outside DesignBuilder.

Note 3: If you want to run EnergyPlus without DesignBuilder then use the File > Export > Export EnergyPlus IDf file > Simulation option to generate the idf file and load this using EP-Launch outside DesignBuilder.

EnergyPlus export folder

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When using a DOE EnergyPlus executable version you must also select the folder where the selected version is installed. You can scan the disk for DOE installations by clicking on the link in the Info help panel..

When you select any option other than the default DLL option, the necessary EnergyPlus files are downloaded seamlessly prior to the first simulation following the change.

Note: If you wish to install a different DLL version of EnergyPlus to that which is recommended, you must have administrative rights on the computer.

DesignBuilder are licensed distributors of EnergyPlus. All versions of EnergyPlus supplied by DesignBuilder have been compiled by the DOE.

ESO Output

You can generate ESO output files containing Heating design, Cooling design and Simulation results. The files can be loaded later using the File > Load results file menu option, provided the model hasn't changed too much.

Rules:

1. The DesignBuilder model must still have same zones and surfaces it had at the time the simulation data was generated
2. If you have modified these files and carried out further simulations in EnergyPlus you should find that the results will read in OK provided you haven't changed zone or surface names in the IDF data.
3. You cannot read in ESO files generated from IDF data which was entered by hand (or by other software) because the zone and surface references will be different.
4. Results must be loaded to the correct screen - you can't for example read Heating design results into the Simulation screen.
5. *Simulation only:* the results to be read in must have been generated using the same simulation period and number of timesteps currently set in the Simulation options.

If you choose to **Save ESO simulation output** then you can also select options to **Prompt for filename** and **Auto load ESO** described below.

Prompt for filename

Tell DesignBuilder whether you wish to be prompted for a filename after each simulation. If you choose not to be prompted then DesignBuilder will automatically generate output filenames based on the name of the dsb file, the calculation type, the calculation description and the date. It places the file in the EnergyPlus folder. If you choose to be prompted the file can be stored anywhere on your computer system.

Auto load ESO

Check this option to automatically load the ESO results file after simulations. If you have been warned that there will be a lot of data and the program may crash on reading results you may wish to switch this option off and reload the results later. It is often possible to read in very large ESO files after DesignBuilder has restarted following a simulation and this can be a useful for avoiding a crash due to too much data. You may also wish to switch the option off to avoid waiting for the results to read in when carrying out parametric simulations.

This option only refers to Simulation results no Heating/Cooling Design results.

IDF OPTIONS

Display extra warnings

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Requesting Display extra warnings causes the statement:

```
Diagnostics,DisplayExtraWarnings;
```

to be included in the IDF data. This option is for experienced EnergyPlus users who understand the significance of the extra warning messages generated.

IDF Formatting

The IDF data can be formatted using the options:

- **1-Full** - indentation and comments are included in the IDF data
- **2-Basic** - just indentation and comments required to reference the IDF objects with data in the DesignBuilder model.
- **3-Compressed** - the IDF data is fully compressed. Choose this option if your model is very large and you wish to reduce the amount of IDF text being processed. When the IDF data uses more than about 10MB of disk space DesignBuilder is unable to process the quantity of text involved and if this happens when the **1-Full** or **2-Basic** options are set it will attempt to regenerate the IDF data using the **3-Compressed** option to reduce the memory requirement. If IDF data is being generated twice before your simulations you can speed the process by selecting this option from the start ensuring that IDF data is only generated once.

Options will be made available in future versions to ease reading of IDF data generated by DesignBuilder.

10.5 Limits

Limits tab of the Program options dialog

You can enter the maximum number of arc and circle segments if you have a special requirement.

10.6 International

International tab of the Program options dialog

Language

DesignBuilder currently supports 4 languages:

- English (native language)
- Italian (available from Evolvente only)
- French
- Spanish (still under development)

When you change the language you must restart DesignBuilder to see the full effect.

Units

DesignBuilder can be used either with SI units (metric) or IP units. Because the program uses SI units internally, and because the databases which come with the program have been built up assuming SI units, US users may find some limitations with the data supplied and with some aspects of the user interface. These will be addressed in due course.

Region filter

The region filter allows you to see only the data relevant to your particular region. Note that if you have a file loaded then DesignBuilder will use the region associated with the location of the site. The region in this

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dialogue is only used when no file is loaded. Data tables which can be filtered in this way are:

- Constructions
- Glazing
- Materials
- Metabolic rates
- Schedules
- Holidays
- Activity templates
- Construction templates
- Glazing templates
- Lighting templates
- HVAC templates
- DHW templates
- Sectors

Show other region data

Use this option to display/hide component and template data from other regions.

Show 'General' data

Use this option to display/hide component and template data from the 'General' region. Options are:

1-Never - Never show General data
2-Always - always show General data
3-When no region specific data - only show General data when the is no region specific data available.

Show program 'Early' data

Use this option to display/hide special 'Early' and other 'broad-brush' typical system component and template data. Options are:

1-Never - Never show 'Early' data
2-Always - always show 'Early' data
3-When no region specific data - only show 'Early' data when the is no region specific data available.

Note when categories of data are hidden this does not mean they are deleted from the database - the data is still there but it does not appear on lists.

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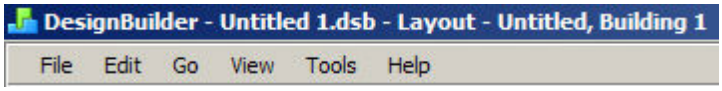
11 Menu

The DesignBuilder menu is located at the top of the screen and provides a full reference of all the currently available commands.



The following sub-menus are available:

- **File** - access file operations
- **Edit** - options for editing the model
- **Go** - options for navigating and obtaining data
- **View** - options for adjusting the view of the model
- **Tools** - miscellaneous tools
- **Help** - documentation and other support resources on use of the program.

11.1 File Menu

The File menu can be accessed from the horizontal top bar menu at the top of the screen. The following options are available when a file is open:

General

- **New project** (Ctrl+N) - create a new DesignBuilder dsb file.
- **Open project** (Ctrl+O) - Open an existing DesignBuilder dsb file.
- **Close** (Ctrl+F4) - close the currently open DesignBuilder dsb file and returned to the opening screen.
- **Print** - Print current view
- **Load results file** - load a previously generated ESO file.

Save

- **Save** (Ctrl+S) - Save currently open DesignBuilder dsb file. If no file is currently loaded then this command saves the libraries.
- **Save without output results** - save the current DesignBuilder dsb file without output results reducing the file size. Use this option if you plan to send the dsb file by e-mail or to the support forums.
- **Save as** (F12) - save the DesignBuilder dsb file using a different name/location.
- **Save as template** - save the DesignBuilder dsb file as a template so it can be used as a starting point for subsequent new projects.

Import

- **Import 2-D DXF floorplan** - import a 2-D DXF floorplan into the model for tracing over.
- **Import detailed survey data** - import a survey data file into the model (advanced option - contact DesignBuilder support for more information on this)
- **Import building from external file** - import a building into the current model from an external file. The option assumes that there is only one building in the external file.
- **Import library data** - import library data from an existing DDF file.

Export

- **Export EnergyPlus Heating design IDF file** - export an IDF file using options for heating design calculations.
- **Export EnergyPlus Cooling design IDF file** - export an IDF file using options for cooling design calculations.

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- **Export EnergyPlus Simulation design IDF file** - export an IDF file using options for simulation using hourly weather data.
- **Export model image** - export the currently displayed image of the model.
- **Export 3-D DXF model** - export the model in 3-D DXF format.
- **Export CSV** - export a summary of the model in spreadsheet format
- **Export library data** - export library data in DDF format.

11.2 Edit Menu

The Edit menu can be accessed from the horizontal top bar menu at the top of the screen.

General

- **Undo** (Ctrl+Z) - undo last operation
- **Redo** (Ctrl+R) - redo last operation
- **End stream** (Enter) - end the partition stream creating a floating partition
- **Cancel current operation** (Escape) - cancel the current operation returning to select mode
- **Undo last point** (Escape) - undo the last point drawn when creating a block or when drawing partitions
- **Clear to default** - clear model data to defaults
- **Load data from template** (Ctrl+L) - loads data from template
- **Reload non-default templates** - loads data from template throughout model where template is non-default
- **Transfer blocks** - transfers blocks from one building to another
- **Convert selected outlines to blocks** - convert any selected outlines to component or building blocks
- **Drag block face** -start the drag face operation on the currently selected block
- **Divide block** - divide the currently selected block using the cutting tool
- **Measure** (Ctrl+M) - measure length, angles or areas in the model

Draw

- **Draw block** – add a new block (building level only)
- **Draw internal perimeter**- draw a void/courtyard (block level only)
- **Draw partition** - draw partition streams (block level only)
- **Draw window** - draw windows (surface level only)
- **Draw sub-surface** - draw sub-surface (surface level only)
- **Draw door** - draw doors (surface level only)
- **Draw hole** - draw holes (surface level only)
- **Draw vent** - draw vents (surface level only)
- **Draw construction line** - draw one or more construction lines

Remove

- **Remove DXF data** - remove all current DXF data
- **Remove all construction lines** - remove all construction lines
- **Remove all outlines** - remove all outline blocks

General

- **Select** - returned to select mode
- **Select all** - select all objects in current view

Equipment (zone level, Equipment tab when Detailed gains model option selected)

- **Add** - at an item of equipment
- **Edit** - edit currently selected equipment
- **Delete** - delete currently selected equipment

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Opening screen component and template edit

- **Add** - add a new component/template as per currently selected item
- **Edit** - edit currently selected component/template
- **Delete** - delete currently selected component/template

Edit currently selected model objects

- **Move** (Ctrl+V) - move selected objects
- **Clone** (Ctrl+C) - clone (copy) selected objects
- **Rotate** (Ctrl+T) - rotate selected objects
- **Stretch** (Ctrl+J) - stretch selected objects
- **Delete** (DEL) - delete selected objects

General

- **Building model options** (F11) - open Model options dialog
- **Add building** (Ctrl+A) - add a new building (site level only)

11.3 Go Menu

The Go menu can be accessed from the horizontal top bar menu at the top of the screen.

11.4 View Menu

The View menu can be accessed from the horizontal top bar menu at the top of the screen.

11.5 Tools Menu

The Tools menu can be accessed from the horizontal top bar menu at the top of the screen.

General

- **Program options** - open program options dialog.
- **Rebuild** - recalculate the zone, surface and adjacency geometry from the base building elements.
- **Rezone block** - refresh the zoning in the current block.
- **Import library components to model** - import current component and template libraries to the model replacing existing ones.
- **Export data** - export results/graphics results from the current screen.
- **Compile report** - generation of a report based on previously created Report topics.
- **Hourly weather data** - open the hourly weather data dialog.
- **Show log file** - show a log file containing information on your computer and all significant actions taken during the current DesignBuilder session.

Results screens

- **Update calculated data** - refreshes the results first opening the Calculation options dialog allowing you to enter new options.
- **Lock Y-axis min/max values** - locks the extent of the Y-axes so that they keep their current maximum and minimum values allowing consistent comparison with the future results display.

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Libraries (opening screen)

- **Backup libraries** - backup component and template libraries
- **Restore libraries** - restore previous component and template library backups

11.6 Help Menu

The Help menu can be accessed from the horizontal top bar menu at the top of the screen.

- **Index** - access program help using the Index.
- **Search** - access program help using the Search facility.
- **Contents** - access program help using the hierarchical Contents.
- **Licence** - enter serial number and licence keys
- **Tutorials** - access DesignBuilder web tutorials
- **About** - DesignBuilder version number

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12 Modelling Advice

Modelling advice topics:

- Working with large models
- Natural ventilation modelling
- Ground modelling
- Adjacent Buildings
- Defining setpoint temperature schedules
- Electrochromic Glazing
- Trombe Walls
- Autosizing Heating and Cooling Equipment
- Daylight Saving and Local Time
- Mixed mode
- Double Facades
- Solar Radiation Distribution
- Solar Technology Solutions
- Warehouse with Office

12.1 Natural Ventilation Modelling

Natural ventilation
There are two general approaches to natural ventilation and infiltration modelling in DesignBuilder depending on the setting of the Natural ventilation model option:

- **Scheduled** in which the natural ventilation change rate is explicitly defined for each zone in terms of a maximum ACH value and a schedule and infiltration air change rate is defined by a constant ACH value.
- **Calculated** where natural ventilation and infiltration are calculated based on window openings, cracks, buoyancy and wind driven pressure differences crack dimensions etc.

You should generally choose Scheduled natural ventilation if you are able to make a reasonable estimate of the natural ventilation rates and infiltration rates in the building. Some airflow scenarios are more difficult to estimate and it may be necessary to calculate airflows.

SCHEDULED NATURAL VENTILATION AND INFILTRATION

Scheduled Natural Ventilation flow rate and schedule data is accessed on the HVAC tab. The flow is switched off if the zone air temperature falls below the Ventilation setpoint temperature set under Environmental Control on the Activity tab.

Infiltration is defined by a constant ACH value under Airtightness on the Construction tab.

Airflow through *Exterior* Windows, Vents and Doors is considered to be included in the Natural ventilation outside air ac/h value set on the HVAC tab.

Airflow through *Interior* Windows, Vents and Doors is modelled using the concept of mixing where equal amounts of air are transferred from one zone to another and vice-versa. The flow rate is directly proportional to the opening area using Airflow rate per opening area data accessed from the Model Options dialog. There is no way in v.1 to set airflows between zones using Scheduled Natural ventilation.

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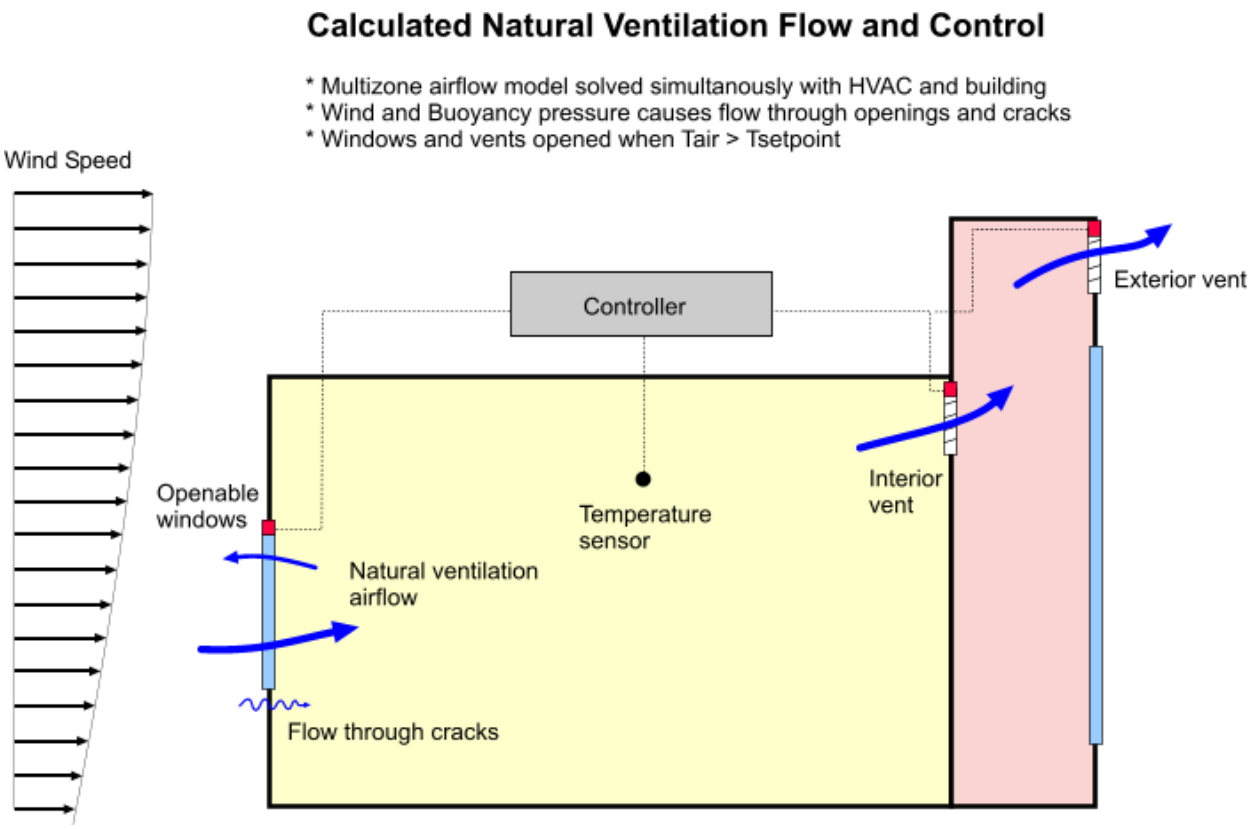
CALCULATED NATURAL VENTILATION AND INFILTRATION



By default Calculated natural ventilation is controlled by timer (window and vent data on the Operation header on the Openings tab) and by Ventilation setpoint temperature on the Activity tab.

The Crack data under Airtightness on the Constructions tab is used in EnergyPlus/AIRNET to calculate infiltration.

Note 1: Using the **Calculated** option increases the complexity of the model and slows simulations down. You should aim to simplify the model as appropriate to the requirements of the calculations. For example if you are carrying out a summertime simulation of a naturally ventilated building you could consider switching off infiltration modelling if infiltration heat flow is only a very small part of summertime heat balance.

Note 2: In Version 1 the calculated airflows through external windows, vents, doors, holes and cracks are all lumped into 'External air' data on the Simulation results screen.

Calculations

The ventilation rate (q) through each opening and crack in the model is calculated based on the pressure difference using wind and stack pressure effects:

$$q = C.(DP)^{n}$$

Where:

q is the volumetric flow through the opening.

DP is the pressure difference across the opening/crack.

n is the flow exponent varying between 0.5 for fully turbulent flow and 1.0 for fully laminar flow.

C is the flow coefficient, related to the size of the opening/crack.

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Wind-Driven Ventilation

When wind impinges on the surface of a rectangular building, a positive pressure is induced on the upwind face. The flow separates at the corners resulting in negative pressure regions on the side of the building and a negative pressure distribution on the leeward facade. The pressure distribution on the roof varies according to pitch - the pressure on the upwind face being negative for roof pitches of 30° and positive for steeper pitches.
The pressure on any point on the surface of a building facade can be represented by:

$$P_w = 0.5 \,.rho.\, C_p \,.\, v_z^2$$

Where:

P_w is the surface pressure due to wind,
rho is the density of air,
C_p is the wind pressure coefficient at a given position on the surface and
v_z is the mean wind velocity at height z.

The wind pressure coefficient, *Cp*, is a function of wind direction, position on the building surface and side exposure. Some typical approximate values for buildings subjected to varying degrees of shelter and wind directions is given in an AIVC publication A guide to energy-efficient ventilation. This data is also quoted in the CIBSE A Guide. DesignBuilder uses this data to populate the Pressure Coefficients templates and provide default pressure coefficients suitable for use in basic design calculations for buildings having no more than three stories.

For more detailed analysis, or for buildings having 4 or more stories you should obtain specific pressure coefficient data from CFD analysis of from wind tunnel measurements and enter it for each surface under the Pressure Coefficients header on the Openings tab.

Excluding Wind-Effects

When carrying out conservative design calculations you may prefer to exclude (or reduce) the effects of wind from Calculated natural ventilation. To exclude wind-driven airflow from the analysis altogether set the Wind factor on the Advanced tab of the Model Options dialog to 0. For full treatment of wind effects set it to 1 and for intermediate treatment of wind set to a number between 0 and 1.

Limitations

DesignBuilder uses the EnergyPlus AIRNET method to calculate air flow rates. You should be aware of some restrictions:

- **Large horizontal openings** are only modelled very approximately. The opening algorithm in AIRNET assumes that openings are vertical or near vertical. Horizontal openings have no 'opening height' and so 'cross-mixing' (i.e. simultaneous inflow and outflow) does not occur.
- EnergyPlus AIRNET simulations take considerably longer than the equivalent simulations with Scheduled natural ventilation.

Modulation

You can modulate the opening sizes to reduce the large temperature swings that can occur if the windows/ doors are too far open when they are venting, especially when there is a large inside-outside temperature difference. Use the Modulation settings on the Advanced tab of the Model Options dialog to control this. *By default modulation is on* and opening sizes are reduced to 5% of full values when the outside is 15°C or more colder than inside. This models the fact that occupants are unlikely to throw the windows wide open when it is very cold outside (for manual control systems).

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Modelling Infiltration

Normally when Calculated natural ventilation is set DesignBuilder includes a single crack in each surface in the simulation to account for infiltration. The size and properties of this crack depend on the setting of the Airtightness slider.

Tip: The effects of infiltration in some areas of the building and in some calculation types can be minor and in these cases infiltration can be switched off. This can be done by unchecking the Model infiltration checkbox on the Construction model data tab for the areas of the building where infiltration in not to be modelled. For example you may wish to switch off infiltration in roof blocks (and include the roofspace ventilation using a smaller number of vents or holes instead) or you could switch it off in the whole building for Summertime simulations where the effects of infiltration would be minimal relative to the much larger flow rates due to open windows, vents, holes and doors.

Airtightness slider

The setting of the Airtightness slider indicates the Crack template applied when setting crack properties:

- Very poor
- Poor
- Medium
- Good
- Excellent

See also Mixed mode.

12.2 Working with Large Models

It is possible to create very large, complex building models using DesignBuilder but you should consider what you're trying to achieve by your modelling exercise before diving in and including every detail of the building design. Otherwise you may find you have created a beautiful model which is impractical to simulate because it takes too long or causes the simulation engine to fail. You can should consider the following points.

EnergyPlus simulations are slowed down by:

1. Lots of windows
2. Lots of zones
3. Lots of windows per zone
4. Lots of surfaces
5. VAV Compact HVAC descriptions
6. Radiant heating systems (Simple HVAC)
7. Calculated natural ventilation using AIRNET
8. Calculating solar reflections
9. Reading hourly or sub-hourly results for extended simulation periods
10. Not enough computer memory (RAM)
11. Lots of output (quantity of data and number of reports)

You can speed up simulations by using these techniques:

1. Reduce the number of windows in the model by increasing the Window spacing. Shading issues

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aside, modelling a small number of large Windows has the same effect as a large number of small Windows provided you get the frame area right.

2. Avoid unnecessary wiggles and indents in block perimeters and partitions - keep it as simple as possible. The larger the model the more important it is to follow this advice. Where an indent in the perimeter gives shading then you could instead model this using a single flat surface without indent and use local shading devices with sidefins to model local window shading.
3. Use the Lump similar windows on surfaceoption to speed up simulations with many similar windows per surface. Note that switching this option on has no effect for zones using Daylight lighting control or if the Full interior and exterior solar distribution option is selected.
4. Wherever possible lump similar adjacent zones together. Only create zones to model areas of the building with specific environmental conditions, and HVAC systems or internal gains schedules. A common mistake made by the beginners is to model each room as a separate zone. This is generally not necessary for building energy simulations because most rooms will have very similar operating conditions. In this case you may want to use one of the DesignBuilder Merging features to reduce the number of zones.
5. If there are multiple identical zones then you can use the Zone multiplier to reduce the number of zones processed.
6. When you first create a building model you may want to carry out simulations before partitioning the blocks into zones. If your un-partitioned blocks are very large there could be an enormous number of windows in the single zone making up a block and this can slow down EnergyPlus simulations especially if carrying out daylighting analysis. In this case you should try to reduce the number of windows in the model as recommended above.
7. Try to use the smallest number of blocks possible to keep the number of surfaces down.
8. Exclude semi-exterior unconditioned zones from the model and replace them with an R-Value.
9. Use Simple, (convective heating) HVAC descriptions.
10. Use the Scheduled Natural ventilation option.
11. If you need to use Calculated natural ventilation in your simulations then you should aim to minimise the number of cracks and openings involved in the airflow calculations. One way to do this is to switch off infiltration calculations. Normally DesignBuilder includes a single crack in each surface in the simulation to simulate infiltration. If you have other openings such as vents, windows, doors etc in a particular block/zone you can switch off infiltration. This approach can be used in roof blocks or calculations such as cooling design where infiltration is relatively insignificant.
12. Switching off calculation of solar reflections in the Model options dialog
13. Restricting hourly and sub-hourly results to short simulations for investigation of detailed building operation. You should not attempt to generate hourly or sub-hourly results for long periods (such as a whole year) unless your model is simple.
14. If you are interested in analysing a single zone within a much larger model, you could consider using the single zone option to carry out simulations just on the zone, excluding consideration of the rest of the building.
15. If you want to model a only a group of zones then you can use the Include zone model option.
16. Fit as much memory (RAM) to your computer as possible (2-4 GB ideally). Paging memory to disk during simulations of large models can cause EnergyPlus to grind to a halt.
17. Only request the output you really need. This will speed up simulation initialisation and reading of output (especially hourly and sub-hourly) at the end. If you are only looking at hourly results then you can get noticeably faster initialisation and simulations by switching off monthly and daily results. For example, simulation times for a test winter week simulation on a real model were:

    17.1. - With hourly, daily, monthly outputs: **39 min**
    17.2. - Only hourly outputs: **14 min**
    17.3. - Only hourly outputs and checking 'Internal surface as adiabatic': **12 min**
18. If you don't need surface data (Walls, Windows etc. heat transfer) switch the Surface heat transfer incl solar output option off.
19. Note that if you request large volumes of data this can result is a program crash when results are being loaded into DesignBuilder.
20. If all else fails then you can model very large buildings by splitting them into smaller units and summing results outside DesignBuilder.

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12.3 Mixed mode

In mixed mode buildings natural ventilation is used as the primary means of providing cooling and, when this is inadequate to provide comfort conditions, active cooling is introduced.

Definition of a mixed mode building:

> "It is a building in which occupants can open windows, and which is designed with effective passive strategies for limiting the effects of the external climate. The passively designed building is utilised to provide acceptable conditions for the majority of the year, and is supplemented by a mechanical system, either on an 'as and when required' basis, or on a seasonal basis."
>
> ***Source:*** *Cooper, V.A., "Occupancy Comfort and Energy Consumption in Naturally Ventilated and Mixed Mode Office Buildings", PhD thesis, UMIST, 1998*
>
> "Mixed-mode refers to a hybrid approach to space conditioning that uses a combination of natural ventilation from operable windows (either manually or automatically controlled), and mechanical systems that include air distribution equipment and refrigeration equipment for cooling. A well-designed mixed-mode building begins with intelligent facade design to minimize cooling loads. It then integrates the use of air-conditioning when and where it is necessary, with the use of natural ventilation whenever it is feasible or desirable, to maximize comfort while avoiding the significant energy use and operating costs of year-round air conditioning."
>
> ***Source****: Mixed mode page on Center for Built Environment website, contains background, case studies*
> *and a database of 150 mixed mode buildings.*
>
> Some useful background documents on mixed mode design and simulation:
>
> 1. www.cbe.berkeley.edu/mixedmode
> 2. www.ibpsa.org/proceedings/BS1999/BS99_D-07.pdf

DesignBuilder can model all three types of mixed mode system defined by CBE in the above reference.

1. **Concurrent** *(Same space, same time)*
   Concurrent mixed-mode operation is the most prevalent design strategy in practice today, in which the air-conditioning system and operable windows operate in the same space and at the same time. The HVAC system may serve as supplemental or "background" ventilation and cooling while occupants are free to open windows based on individual preference. Typical examples include open-plan office space with standard VAV air-conditioning systems and operable windows, where perhaps perimeter VAV zones may go to minimum air when sensor indicates that a window has been opened.
2. **Change-over** *(Same space, different times)*
   Change-over designs are becoming increasingly common, where the building "changes-over" between natural ventilation and air-conditioning on a seasonal or even daily basis. The building automation system may determine the mode of operating based on outdoor temperature, an occupancy sensor, a window (open or closed) sensor, or based on operator commands. Typical examples include individual offices with operable windows and personal air conditioning units that shut down for a given office anytime a sensor indicates that a window has been opened; or a building envelope where automatic louvers open to provide natural ventilation when the HVAC system is in economizer mode, and then close when the system is in cooling or heating mode.
3. **Zoned** *(Different spaces, same time)*
   Zoned systems are also common, where different zones within the building have different conditioning strategies. Typical examples include naturally ventilated office buildings with operable windows and a

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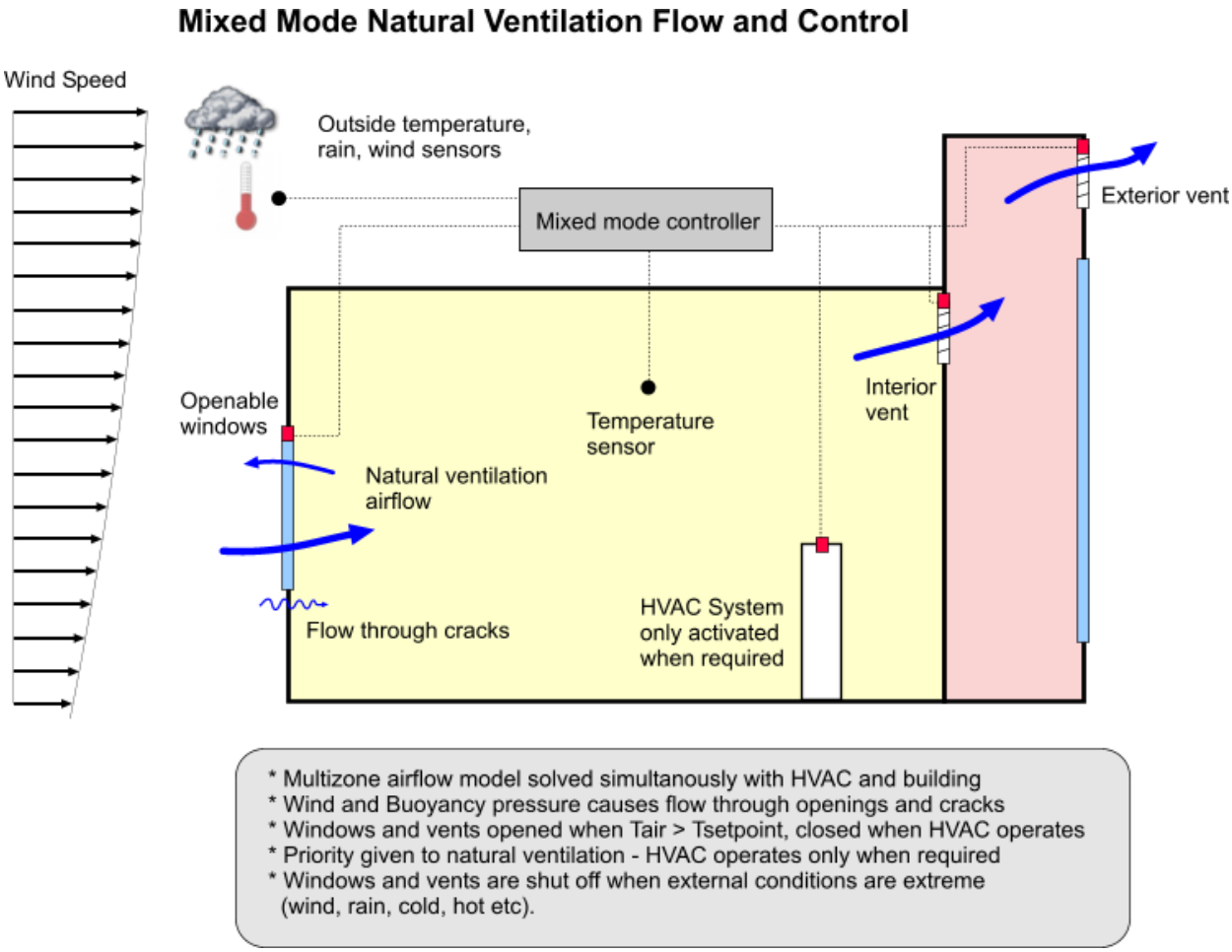
ducted heating/ventilation system, or supplemental mechanical cooling provided only to conference rooms. For many mixed-mode buildings, operating conditions sometimes deviate somewhat from their original design intent (e.g., a building originally designed for seasonal changeover between air-conditioning and natural ventilation may, in practice, operate both systems concurrently).

Concurrent and **Zoned** systems can be modelled without using DesignBuilder mixed mode control. In DesignBuilder 'mixed mode' specifically refers to **Change-over** systems where the HVAC and the natural ventilation do not take place at the same time.



When modelling mixed mode systems in DesignBuilder you should use Calculated natural ventilation and Compact HVAC.

The steps to setting up a change-over mixed mode model in DesignBuilder are:

1. Include active cooling and natural ventilation by switching on the 'Natural ventilation on' and 'Cooling on' options on the HVAC tab.
2. Also, include mechanical ventilation if there is outside air introduced through the HVAC system.
3. Ensure that the setpoints for natural ventilation and cooling operation are correct. The natural ventilation (window/vent opening) setpoint should ideally be 2°C lower than the cooling setpoint to ensure maximum use of natural ventilation and to avoid the active cooling system being used unnecessarily and also 2°C higher than the heating .temperature. Typical values might be heating setpoint temperature = 20°C, natural ventilation setpoint temperature = 22°C, cooling setpoint temperature = 26°C. Heating should ideally be switched off in the summer to avoid unnecessary heating caused by natural ventilation overcooling the space.
4. See the mixed mode section on the HVAC help for detailed information on the data that can be set, including conditions that require windows and vents to be closed such as rain, wind and low outside air temperature.

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12.4 Ground Modelling

How it works

In EnergyPlus, heat is transferred between zones and the ground through one-dimensional ground floor surface elements. The 2-D and 3-D effects in the ground heat conduction that occur in reality are not treated by default. EnergyPlus uses ground construction data to model the storage of heat in the ground and it can accurately model heat transfer processes over several days (so it can model the effect of say a warm week followed by a cool week) but it cannot directly model long-term ground thermal storage effects (periods measured in months). For more on advanced ground modelling see bottom of this topic.

EnergyPlus applies a constant temperature boundary condition for each month on the lower surfaces of ground adjacent elements.

There are 3 ways to create an adjacency to ground in DesignBuilder:

1. Using DesignBuilder's Auto adjacency detection where ground adjacency is set for all surfaces at or below ground level. By default, all external surfaces which are at or below ground level are considered to be adjacent to ground. Surfaces that are partly above ground (z=0) and partly below, are modelled as entirely adjacent to outside (if the Adjacency setting is **1-Auto** - see below).
2. Using Ground component blocks - any surfaces (or part of surfaces) touching a ground component block are considered to be adjacent to ground.
3. Using the Adjacency model data on the Construction tab at block, zone and surface levels where external surfaces can be defined as being adjacent to ground by changing the Adjacency model data on the Construction tab from **1-Auto** to **3-Adjacent to Ground**. If a surface is below ground level but is not adjacent to ground you can select **2-Not adjacent to ground**.

When using Separate constructions, and when the Add ground construction layers to surfaces in contact with ground option is selected, DesignBuilder automatically combines the site ground construction (0.5m of earth by default) with the main construction (typically ground floor or wall) set on the Constructions tab. With Combined constructions the earth layers must be explicitly included in the ground floor/wall constructions if you wish to define ground temperatures within the earth.

Ground temperatures

Monthly ground temperatures are defined at the site level under Site details.

Note: You should not use the ground temperatures in the EnergyPlus weather file header because these are for undisturbed sites. The temperature beneath buildings is significantly affected by the building itself - the EnergyPlus documentation recommends using ground temperatures of 2°C below average internal temperatures for large commercial buildings (where perimeter heat loss is relatively less important). *Note that this temperature should be applied directly below the slab* and should not include ground material - so if you use this approach to ground temperature definition, you should switch off use of the ground construction at the site level.

EnergyPlus cannot model very thick constructions so it is necessary to use less thick constructions (2m or smaller) combined with some assumptions about temperatures at about half a metre below the floor.

Many modellers prefer to define the ground temperature just below the slab and exclude the earth layers from the model. This has the advantage of simplicity and clarity and the approach recommended by EnergyPlus developers.

Note: the default ground temperatures provided in DesignBuilder assume that an earth layer is included in the constructions adjacent to ground. If an earth layer is not included then you should increase the default

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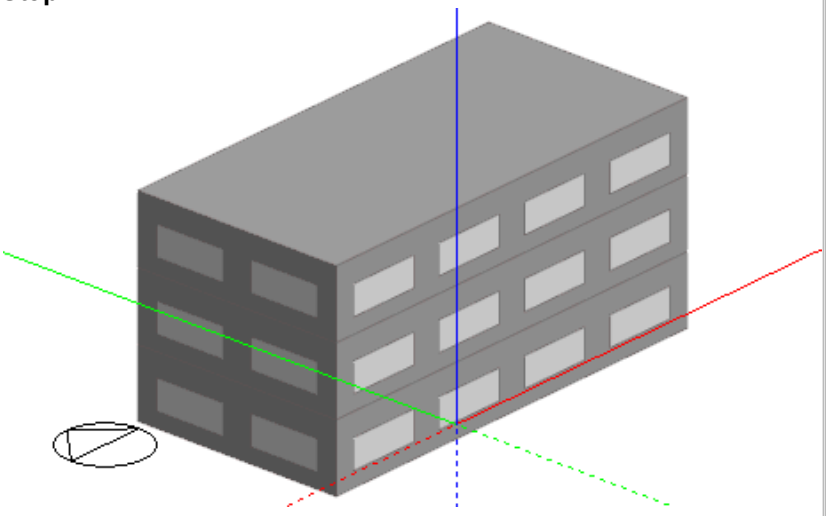
site ground temperatures to values closer to those typically found just below the ground slab (as described in note above).

Example Application - Basement or Cellar under inclined ground slope

This example illustrates how to create a simple 3 storey rectangular building model with:

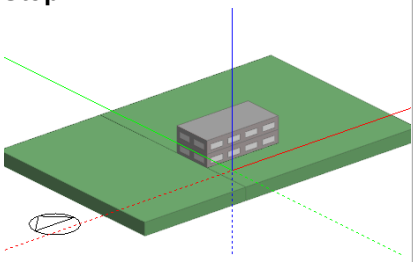
- Basement which is fully below ground and
- Ground floor is partially buried under an inclined ground plane.

Step 1



Draw 3 blocks on the z=0 ground plane. The lowest block will be the basement (completely buried), the middle block will be the ground level block, partially buried and the top block will be the second level. So far only the bottom surface is adjacent to ground because it sits on the z=0 plane.

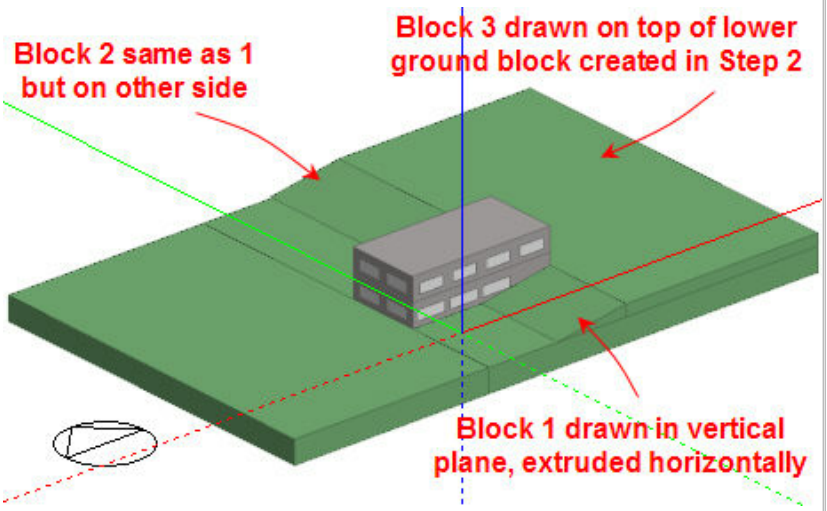
Step 2



Draw 2 ground component blocks around the basement building block to give it's surfaces ground adjacency.

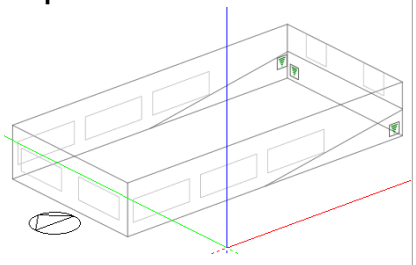
Note this step could be avoided by moving the whole building down so that the basement is fully below ground. To do this go to building level, select all the blocks, select the move command, click on one of the bottom corners of the middle block to create a reference point then click on a blank part of the screen to move the reference point down to z=0.

Step 3



Draw three new ground component blocks to create the sloping ground and the upper ground levels.

Step 4



The zone of the middle block is shown above. Notice how 3 of the surfaces have been split into external and ground adjacencies (ground adjacencies are flagged by green ground symbols). Note also that the portions of the surfaces touching the ground component block cannot have windows but DesignBuilder attempts to set up the correct % glazing for the remaining external parts of the

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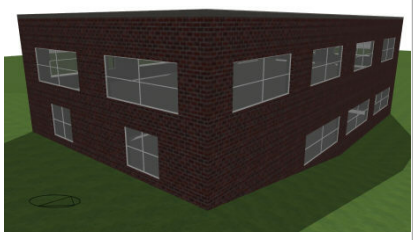
	surface.
Step 5 The ground component blocks probably do not need to shade this model as they are mainly below all surfaces that can receive solar radiation/light, but if you are modelling reflections you will probably need to include the reflection of solar radiation and light from the ground blocks during simulations. In other cases you may prefer to switch off the generation of the component blocks shading/reflection surfaces to speed simulations. Do this on the Constructions model data tab under Component Block.	**Step 6**  The finished model. The texture of Ground component blocks is defined by the material set under Component blocks on the Constructions tab.

3-D Modelling Using the EnergyPlus Slab Preprocessor (Advanced)

To accurately model long-term ground thermal storage you may wish to consider using an external 2 or 3-D conduction tool such as the 'Slab' utility supplied with EnergyPlus. This can be used to calculate the temperatures applied to the underside of the ground floor surface elements.

The EnergyPlus slab program produces temperature profiles for the outside surface at the core and at the perimeter of the slab. It also produces the average based on the perimeter and core areas used in the calculation. EnergyPlus has a single GroundTemperatures object that is used for twelve monthly average ground temperature values - see the Input Output Reference document. Because of this, there are two options for dealing with the ground temperatures:

1. Use the average temperatures produced by the slab program for the GroundTemperatures object. This will provide an average ground temperature at the outside face of any heat transfer surface whose OutsideFaceEnvironment field is 'ground'.
2. If two or more ground temperature conditions are desired, it is necessary to utilize the ground temperature modification feature of other side coefficients (OtherSideCoef field in OutsideFaceEnvironment). Then, for example, if core and perimeter temperatures are wanted, the perimeter temperatures from the slab program should be specified in the GroundTemperatures object, and the surface associated with that condition is treated as in Option 1 above. The surface that is to be exposed to the core temperature should be given the OtherSideCoef designation, and the OtherSideCoefficients object should be used to specify the temperatures. To do this, all of the numerical fields in this object should be zero except field N5. This field should contain the ratio of the average annual core temperatures and average annual perimeter temperatures. In other words, the resulting core profile values will be N5 times the perimeter values. This same procedure can be used to generate as many profiles as needed. However, it should be noted that they will all have the same profile as the GroundTemperatures object values.

Detailed ground modelling may only give a marginal difference in results and you might want to carry out a sensitivity study to check the influence of ground temperatures on simulation results before deciding on the most appropriate level of detail.

DesignBuilder version 1 does not account for 2-D and 3-D thermal bridging effects but future versions will.

12.5 Adjacent Buildings

Adjacent buildings (i.e. other buildings that are touching the modelled building) usually modify the boundary conditions relative to external and also provide shade.

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There is no explicit way in DesignBuilder 1.2 to model temperatures and heat flows in 2 buildings simultaneously and account for energy transfer between them. Future versions may allow this, but in the meantime there are two options:

1. Model the adjacent building using component blocks (for shading/reflection) and adiabatic surfaces between the buildings. This is the usual way to treat an adjacent building not requiring full simulation and is accurate if the temperature of the adjacent and actual buildings are similar or if there is insulation between the two buildings.
2. If the adjacent building does require simulation then model it as part of the actual building and separate simulation results at the end.

You can set adiabatic adjacent condition data under Constructions on the Constructions tab at surface level.

Merging buildings

Where two separate buildings have been created inadvertently, the blocks of one building can be transferred to the other building using the Transfer blocks command from the Edit menu.

Airflow

If there is airflow between the two buildings and the adjacent building is at the same temperature as the modelled building then you could probably ignore its effect. To model the effect of the airflow through an opening between buildings in detail you should model both buildings as one DB building using the Calculated natural ventilation model option. If you do it this way and the adjacent building uses energy you must separate results for the two buildings at the end. You can use different boiler and chiller fuels to differentiate fuel consumption between the two buildings.

If you use the Simple natural ventilation instead of Calculated, DesignBuilder uses an assumed mixing of air between the two buildings based on 'flow per opening area' as set on the Model options dialog on the Advanced tab under Natural Ventilation.

12.6 Electrochromic Glazing

Electrochromic windows are part of a new generation of technologies called switchable glazing-or 'smart' windows. Switchable glazing can change the light transmittance, transparency, or shading of windows in response to an environmental signal such as sunlight, temperature or an electrical control. Electrochromic windows change from transparent to tinted by applying an electrical current. Potential uses for electrochromic technology include daylighting control, glare control, solar heat control, and fading protection in windows and skylights. By automatically controlling the amount of light and solar energy that can pass through the window, electrochromic windows can help save energy in buildings.

A variety of electrochromic technologies and media have been developed. One type is darkened by applying a small electrical voltage to the windows and lightened by reversing the voltage. Light transmittance during operation varies from five to 80 percent. Once the change in tint has been initiated, the electrochromic glazing has 'memory' and does not need constant voltage to maintain the tinting. Further, the film can be tuned to block certain wavelengths, such as infrared (heat) energy.

Another switchable technology, the liquid crystal suspended particle device (SPD), contains molecular particles suspended in a solution between plates of glass. In their natural state, the particles move randomly and collide, blocking the direct passage of light. When energized, the particles align rapidly and the glazing becomes transparent. This type of switchable glazing can block up to about 90 percent of light.

You can easily model electrochromic glazing in DesignBuilder using the Window shading data and defining the properties of the outer Window Pane to be used when the shading is active. The procedure is:

1. Specify the glazing type to be used when the electrochromic glazing system is clear (bleached) in

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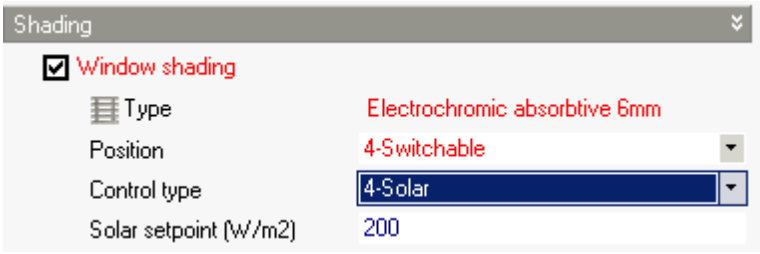
the standard way on the Openings tab under External glazing.
2. Under External Glazing and Shading headers, check the 'Window shading' option.
3. Select the Type as 'Electrochromic absorptive 6mm' (for example).
4. Select the Position as 4-Switchable.
5. The Shading Type defines the properties of the pane which is to be used in place of the standard outer glazing pane according to the control data in the Control type.
6. Set the Control type together with any supplementary setpoint data.



A model using the data in the above screenshot would enter its' darkened state whenever the solar radiation incident on the outside of the window is greater than 200 W/m2..

12.7 Trombe Walls

Trombe walls are passive solar devices designed for thermal storage and delivery. A Trombe wall consists of a thick wall (150mm to 300mm) [8" to 16"] faced with a selective surface solar absorber, air gap, and high transmissivity glass pane. Trombe walls are usually South facing (in the Northern Hemisphere) for maximum sun exposure. An overhang above the wall is used to decrease exposure in the summer when the sun is high in the sky and heating is not required, yet still allows for full exposure in the winter when the sun is low in the sky and heating is desirable. In DesignBuilder, there is no Trombe wall object per se; rather, it is composed of other standard building components. This approach provides flexibility in specifying the various wall parameters and allows the freedom to explore unusual configurations.

To simulate the Trombe wall, a very narrow zone is coupled to the desired surface via an interzone partition. The depth of the zone corresponds to the size of the air space usually 18mm to 150mm (¾" to 6"). In most cases the Trombe zone will be a sealed zone with no ventilation. The exterior wall of the Trombe zone contains a single or double-pane window. Optimally, the window covers nearly all of the wall area and has a very high transmissivity to allow the maximum amount of solar flux into the Trombe zone. Frames and dividers can be defined as usual for the window. The interior wall is usually constructed of very thick masonry materials with a solar absorber surface as the innermost layer of the wall. The absorber is a selective surface material with very high absorptivity and very low emissivity, e.g. copper with a special black surface treatment. It is important to make sure the Solar Distribution is set to **3-Full Interior and Exterior** so that the majority of the solar flux is directed on the absorber surface and not just on the very small area of the Trombe zone floor.

The Zone type on the Activity tab should be set to **3-Cavity** and this causes the following changes to be made to the model:

- The zone is set as unoccupied by loading **<None>** Activity, HVAC and Lighting template data.
- Suspended floors and ceilings are switched off when using Separate constructions.
- The **5-Cavity** Internal convection algorithm is set for Cooling design, Heating design and simulation calculations to correctly model the air space.
- The **3-Full interior and exterior** Solar distribution algorithm is set for Cooling design and simulation calculations because it allows solar radiation to be accurately distributed onto zone internal surfaces. The default option **2-Full exterior** assumes all solar radiation falls on floor which is not good for modelling solar absorption by a Trombe wall.

Finally, an overhang should be attached to the Trombe zone to control the amount of seasonal sun exposure. There is considerable freedom to experiment with different materials, sizes, and configurations.

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Passive Trombe wall

Passive Trombe walls perform without the assistance of any additional mechanical equipment. Most Trombe walls are passive Trombe walls. They can be either sealed or naturally ventilated. For a sealed or unvented Trombe wall, the Zone Inside Convection Algorithm should be set to **5-Cavity**. This algorithm correctly calculates the convection coefficients for a narrow sealed vertical cavity based on the ISO 15099 standard.

The EnergyPlus modeling approach for the sealed passive Trombe wall has been validated with experimental data (Ellis 2003). For a naturally ventilated Trombe wall, there is no built-in algorithm for calculating the correct convection coefficients on the inside of the cavity walls. One option is to use the **1-Detailed** Inside convection algorithm. This algorithm takes into account some natural convection effects but is intended for a normal sized room.

You can define holes and vents through the Trombe wall by drawing them on at surface level. Vent openings can be scheduled and controlled by internal temperature.

Mechanically ventilated Trombe wall

You can also model mechanically ventilated Trombe walls by using Compact HVAC and specifying the Trombe wall cavity zone as a plenum zone.

12.8 Autosizing Heating and Cooling Equipment

The Heating Capacity and Cooling Capacity Model Data is found on the HVAC tab at zone level.

If the Plant sizing building model option is set to **4-Autosize when not set** these heating and cooling capacities can be automatically calculated by the software.

Note: if you change heating or cooling capacities by hand you should be aware that the data will be overwritten if Model Options change.

To keep the heating and cooling capacities fixed, change the Plant sizing model option to **2-Manual**. You may choose to use this option if you are already satisfied with the autosized capacities and wish to keep them as they are regardless of future changes to the model.

COMPACT HVAC AUTOSIZING

Winter and summer design day simulations are automatically carried out as required for autosizing heating and cooling equipment prior to a Compact HVAC simulation. There are some considerations you should be aware of regarding autosizing.

1. Internal gains should normally be excluded from Winter design day calculations.
2. You therefore shouldn't use the same schedule for equipment, occupancy and HVAC operation because equipment and occupancy should be off for heating autosizing and HVAC should be on.
3. Typical workday gives the easiest route to defining autosizing operation - the appropriate Winter Design Day schedule data settings are used.
4. Summer design day schedules are normally the same as the general ones so are easier to deal with.
5. If you are using Compact schedules then you should ensure that a specific line of WinterDesignDay data is included for all schedule periods.
6. If you are using 7/12 Schedules then there are 2 options: **End-use defaults** and **Profiles.**
7. You can include intermittent operation by using a time-varying Heating demand or HVAC schedule. This would normally provide heating equipment sizes with higher capacity than a steady-state calculation where the heating is on all day.

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12.9 Daylight Saving and Local Time

DesignBuilder allows you to model the effect of daylight saving time where the clocks are moved forward one hour in the summer months in most non-equatorial countries. The timing of this is handled automatically using DesignBuilders' time zones database when you load data from one of the Location templates supplied with the program.

You can set the Time zone at the Site level on the Location tab:

There are however some factors you should be aware of:

- Simulation results are displayed in 'local mean time'. This means that during the summer, occupancy will appear to start 1 hour earlier in the day than it does in the winter. To help you pinpoint this, DesignBuilder prints the times when daylight saving starts and ends on the graph.
- Visualisations use local mean time when setting the position of the sun for site shading analysis. Again you should add 1 hour to the time to see shading for local time.

12.10 Double Facades

Background

A ventilated double facade can be defined as a traditional single facade doubled inside or outside by a second, essentially glazed facade. Each of these two facades is commonly called a skin . A ventilated cavity - having a width which can range from several centimetres at the narrowest to several metres for the widest accessible cavities - is located between these two skins. There exist facade concepts where the ventilation of the cavity is controllable, by fans and/or openings, and other facade concepts where this ventilation is not controllable . The indoor and outdoor skins are not necessarily airtight (see, for example, the "louvre" type facades). Automated equipment, such as shading devices, motorised openings or fans, are most often integrated into the facade. The main difference between a ventilated double facade and an airtight multiple glazing, whether or not integrating a shading device in the cavity separating the panes, lies in the intentional and possibly controlled ventilation of the cavity of the double facade.

The standard prEN 13119, specifies the terminology associated with curtain walls and of a double-skin facade. These are defined as:

Curtain walling	External building facade produced with framing made mainly of metal, timber or PVC-U, usually consisting of vertical and horizontal structural members, connected together and anchored to the supporting structure of the building, which provides, by itself or in conjunction with the building construction, all the normal functions of an external wall, but does not contribute to the load bearing characteristics of the building structure.
Double-Skin Facade	A curtain wall construction comprising an outer skin of glass and an inner wall constructed as a curtain wall that together with the outer skin provide the full function of a wall.

This definition includes only references to the constructive and structural aspects of the facade. No reference is made to the ventilation of the cavity. Thus formally, the term "double-skin facade" does not

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designate a ventilated double facade. It is for this reason that the term ´Ventilated Double-Skin Facade´ is proposed as the generic term to designate these facades.

Double facades can be categorised according to the type of ventilation.

Type of ventilation	Name of the facade concept
Natural	Passive facade
Mechanical	Active facade
Hybrid	Interactive facade

This table contains the commonly used names referring (only) to the type of ventilation and thus giving no indication about the partitioning of the facade or the ventilation modes. In the literature, the double facades adopting the *air supply* ventilation mode are called *airflow window* or also *ventilated window*. The facades adopting the air exhaust ventilation mode are also called *extract air* or *exhaust airflow*.

Modelling Considerations

There are some important considerations when using DesignBuilder to model double facades.

1. If you are using a zone to model the cavity in the double facade then the inner glazing is 'interior' and so requires the Full interior and exterior solar distribution option to get solar radiation to pass through exterior and then through interior windows. You should read the information about the restrictions associated with this option before using it.
2. Take care when comparing the exterior solar radiation transmitted into the double facade zone with the interior solar radiation transmitted into the occupied zone. These do not include the re-reflection of solar back out of the external windows. Read the definitions for the output data.
3. It is possible to set the double facade zone as a return plenum.

To be extended...

Source of background information:

http://www.bbri.be/activefacades/new/content/1_home/en.html

12.11 Solar Radiation Distribution

This topic summarises the methods used in calculation of solar radiation in EnergyPlus.

Sky Radiance Model

In EnergyPlus the calculation of diffuse solar radiation from the sky incident on an exterior surface takes into account the anisotropic (non-uniform) radiance distribution of the sky. For this distribution, the diffuse sky irradiance on a surface is given by:

*AnisoSkyMult * DifSolarRad*

where:

DifSolarRad is the diffuse solar irradiance from the sky on the ground and *AnisoSkyMult* is determined by surface orientation and sky radiance distribution, and accounts for the effects of shading of sky diffuse radiation by shadowing surfaces such as overhangs. It does not account for reflection of sky diffuse radiation from shadowing surfaces.

The sky radiance distribution is based on an empirical model based on radiance measurements of real skies, as described in Perez et al., 1990. In this model the radiance of the sky is determined by three

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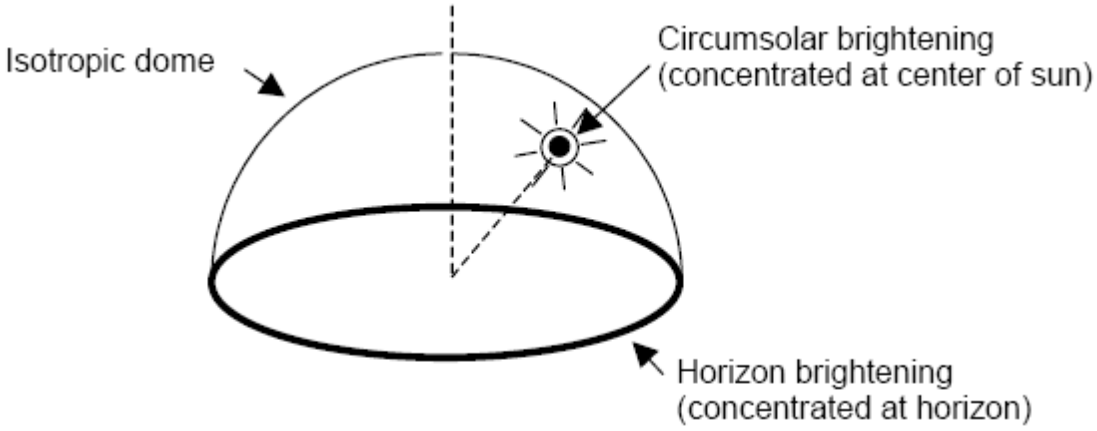
distributions that are superimposed (see Figure 33)

1. An isotropic distribution that covers the entire sky dome;
2. A circumsolar brightening centered at the position of the sun;
3. A horizon brightening.



Schematic view of sky showing solar radiance distribution as a superposition of three components: dome with isotropic radiance, circumsolar brightening represented as a point source at the sun, and horizon brightening represented as a line source at the horizon.

The proportions of these distributions depend on the sky condition, which is characterized by two quantities, clearness factor and brightness factor, defined below, which are determined from sun position and solar quantities from the weather file.
The **circumsolar brightening** is assumed to be concentrated at a point source at the center of the sun although this region actually begins at the periphery of the solar disk and falls off in intensity with increasing angular distance from the periphery.
The **horizon brightening** is assumed to be a linear source at the horizon and to be independent of azimuth. In reality, for clear skies, the horizon brightening is highest at the horizon and decreases in intensity away from the horizon. For overcast skies the horizon brightening has a negative value since for such skies the sky radiance increases rather than decreases away from the horizon.

Shadowing of Sky Long-Wave Radiation

EnergyPlus calculates the sky long-wave radiation incident on exterior surfaces assuming that the sky long-wave radiance distribution is isotropic. If obstructions such as overhangs are present the sky long-wave incident on a surface is multiplied by an isotropic shading factor. The long-wave radiation from these obstructions is added to the long-wave radiation from the ground; in this calculation both obstructions and ground are assumed to be at the outside air temperature and to have an emissivity of 0.9.

Solar Gains

The total solar gain on any exterior surface is a combination of the absorption of direct and diffuse solar radiation given by

$$Q_{so} = \alpha \bullet \left(I_b \bullet \cos\theta \bullet \frac{S_s}{S} + I_s \bullet F_{ss} + I_g \bullet F_{sg} \right)$$

where:

a =solar absorptance of the surface
A =angle of incidence of the sun's rays
S =area of the surface

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S_s = sunlit area

I_b =intensity of beam (direct) radiation

I_s =intensity of sky diffuse radiation

I_g =intensity of ground reflected diffuse radiation

F_{ss} = angle factor between the surface and the sky

F_{sg} = angle factor between the surface and the ground

If the surface is shaded the program modifies Fss by a correction factor that takes into account the radiance distribution of the sky (see “Shadowing of Sky Diffuse Solar Radiation”). Shading of ground diffuse solar radiation is not calculated by the program. It is up to the user to estimate the effect of this shading and modify the input value of Fsg accordingly.

SOLAR DISTRIBUTION

As discussed in the Solar Model options section, the Solar Distribution determines how EnergyPlus will treat beam solar radiation entering a zone through exterior windows. The three choices: **1-Minimal shadowing**, **2-Full exterior** and **3-Full Interior and exterior** are discussed in the Solar options topic.

EnergyPlus calculates the distribution of short-wave radiation in the interior of each thermal zone. This radiation consists of beam solar radiation, diffuse solar radiation, and short-wave radiation from electric lights. The program determines the amount of this radiation that is (1) absorbed on the inside face of opaque surfaces, (2) absorbed in the glass and shading device layers of the zone’s exterior and interior windows, (3) transmitted through the zone’s interior windows to adjacent zones, and (4) transmitted back out of the exterior windows. The effects of movable shading devices on the exterior windows are taken into account.

Initial Distribution of Diffuse Solar Transmitted through Exterior and Interior Windows

As of Version 2.1 the treatment of diffuse solar transmitted first through exterior windows and subsequently through interior windows has been improved. Diffuse solar (from sky and ground sources) transmitted through exterior windows is first distributed to the interior heat transfer surfaces in the zone containing the exterior windows. This initial distribution apportions the transmitted diffuse solar to interior surfaces using the approximate view factors described above in “LW Radiation Exchange Among Zone Surfaces.” The amount of this initially distributed diffuse solar absorbed by each interior surface, and each window material layer, is calculated and later added to the “short-wave radiation absorbed” values described below. The amount of this initially distributed diffuse solar that is reflected is accumulated for each zone and redistributed uniformly to the other surfaces. The amount of this initially distributed diffuse solar that is transmitted by interior windows to adjacent zones is initially distributed to the interior heat transfer surfaces in the adjacent zone in the same manner as just described.

This new treatment of diffuse solar is intended to more accurately account for the initial absorption, transmittance, and reflection of short-wave radiation prior to the uniform distribution described below.

Interior Solar Radiation Absorbed by Opaque Surfaces

The short-wave radiation absorbed on the inside face of an opaque surface (floor, wall or ceiling) is given by:

Ground surface reflectance

Ground reflectance values are used to calculate the ground reflected solar amount. This fractional amount (entered monthly) is used in the following equation:

GroundReflectedSolar = (BeamSolar x COS(SunZenithAngle) + DiffuseSolar) x GroundReflectance

The Ground Reflected Solar is never allowed to be negative. The Snow Ground Reflectance Modifier can

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further modify the ground reflectance when snow is on the ground. If the user enters 0.0 for each month, no ground reflected solar is used.

Ground Reflectances (Snow)

When snow is on the ground, ground reflectances may change. The user can specify two values, Snow reflected solar modifier and Snow reflected daylight modifier.

Snow reflected solar modifier

A number between 0.0 and 10.0 which is used to modify the basic ground surface reflectance when snow is on the ground. Note that the value of $GroundReflectance_{Used}$ (below) must be <=1.

$$GroundReflectance_{Used} = GroundReflectance \times Modifier_{Snow}$$

During simulations, the ground is considered to be snow-covered when the SnowDepth data in the hourly weather file is > 0.

Snow reflected daylight modifier

A number between 0.0 and 10.0 which is used to modify the basic ground surface reflectance when snow is on the ground. Note that the value of $DaylightingGroundReflectance_{Used}$ (below) must be <=1.

$$DaylightingGroundReflectance_{Used} = GroundReflectance \times Modifier_{Snow}$$

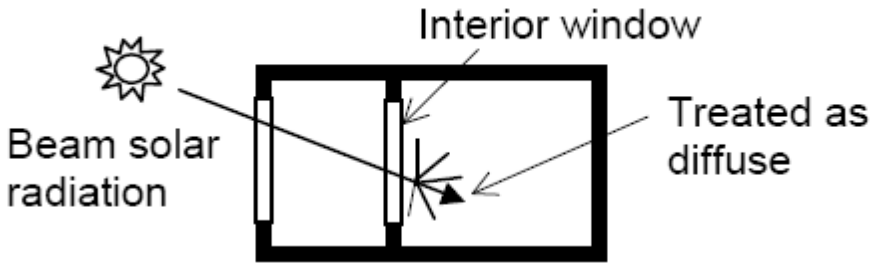
During simulations, the ground is considered to be snow-covered when the SnowDepth data in the hourly weather file is > 0.

Beam distribution

If the Solar Distribution option is **Minimal shadowing** or **Full exterior**, it is assumed that all beam solar from exterior windows falls on the floor. If Solar Distribution is **Full Interior and Exterior** the program tracks where beam solar from exterior windows falls inside the zone, and wall as well as floor surfaces can receive beam radiation.

Diffuse distribution

Diffuse solar transmitted through exterior and interior windows is distributed according to the approximate view factors between the transmitting window and all other heat transfer surfaces in the zone. This variable is the amount of transmitted diffuse solar that is initially absorbed on the inside of each heat transfer surface. The portion of this diffuse solar that is reflected by all surfaces in the zone is subsequently redistributed uniformly to all heat transfer surfaces in the zone, along with interior reflected beam solar and shortwave radiation from lights. The total absorbed shortwave radiation is given by the next variable.



Solar radiation reflected from exterior surfaces

EnergyPlus has an option to calculate beam and sky solar radiation that is reflected from exterior surfaces and then strikes the building. For zones with detailed daylighting, these reflections are also considered in

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the daylight illuminance calculations. The reflecting surfaces fall into three categories:

1. **Shadowing surfaces**. These are surfaces like overhangs, component blocks or surfaces of the building Examples are shown in Solar Options. These surfaces can have diffuse and/or specular (beam-to-beam) reflectance values that are specified with the based on the material surface properties.
2. **Exterior building surfaces**. In this case one section of the building reflects solar radiation onto another section (and vice-versa). See Figure 47. Opaque building surfaces (walls, for example) are assumed to be diffusely reflecting. Windows and glass doors are assumed to be specularly reflecting. The reflectance values for opaque surfaces are calculated by the program from the Absorptance:Solar and Absorptance:Visible values of the outer material layer of the surface's construction. The reflectance values for windows and glass doors are calculated by the program from the reflectance properties of the individual glass layers that make up surface's construction assuming no shading device is present and taking into account interreflections among the layers.
3. **The ground surface**. Beam solar and sky solar reflection from the ground is calculated even if the Reflections option is not used (the default). But in this case the ground plane is considered unobstructed, i.e., the shadowing of the ground by the building itself or by obstructions such as component blocks is ignored. This shadowing is taken into account only if the Reflections option is used. In this case the ground view factor calculated by DesignBuilder is not used.

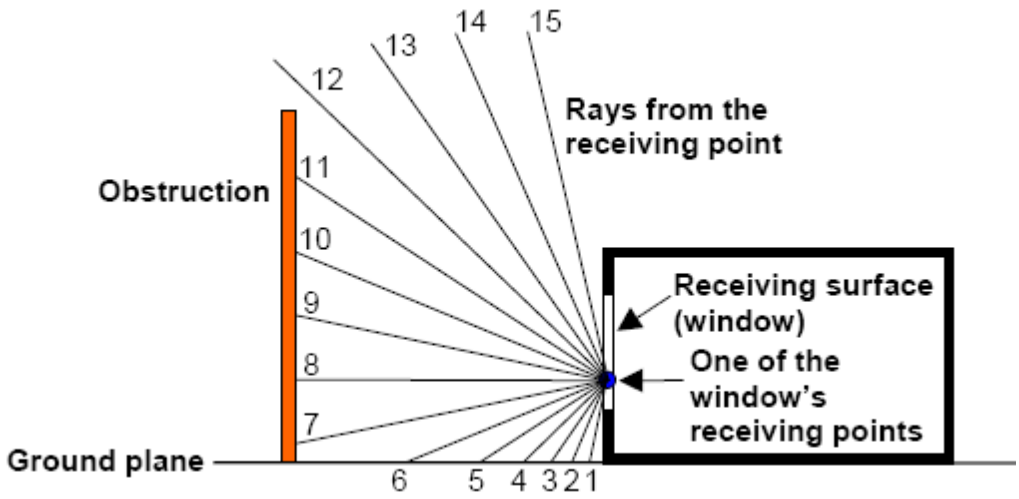
See Solar Options,

Diffuse reflection of beam solar and sky solar radiation

A ray-tracing method is used to calculate beam solar and sky solar radiation that is diffusely reflected onto each of a building's exterior surfaces (walls, roofs, windows and doors), called here "receiving surfaces". The calculation begins by generating a set of rays proceeding into the outward hemisphere at each receiving point on a receiving surface. Then it determines whether each ray hits the sky, ground or an obstruction. The radiance at the hit point from reflection of incident beam or sky solar is determined and the contribution of this radiance to the receiving surface is calculated, added to the contribution from other hit points, and averaged over the receiving points. Separate calculations are done for beam-to-diffuse and sky solar reflection from all obstructions and beam-to-diffuse and sky solar reflection from the ground. (For beam-to-beam reflection see **Beam solar radiation specularly reflected from obstructions** below.)

Rays

A total of 90 rays are sent out into the exterior hemisphere surrounding each receiving point. An upgoing ray may hit an obstruction or the sky. A downgoing ray may hit an obstruction or the ground. See diagram below.



Two-dimensional schematic showing rays going outward from a point on a receiving surface. Rays 1-6 hit

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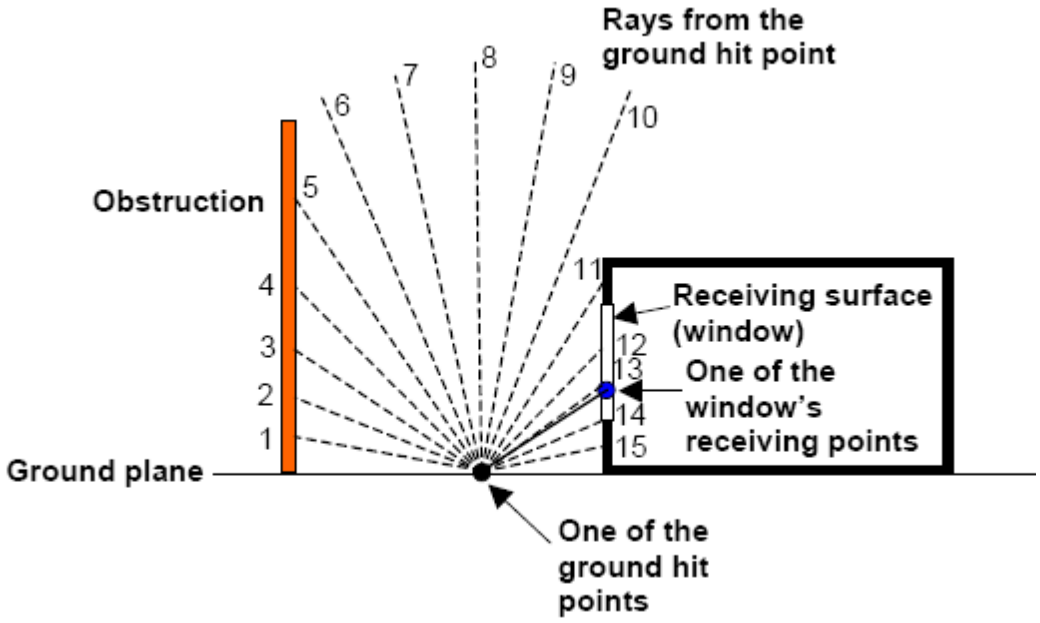
the ground, rays 7-11 hit an obstruction, and rays 12-15 hit the sky.

Sky Solar Radiation Diffusely Reflected from the Ground

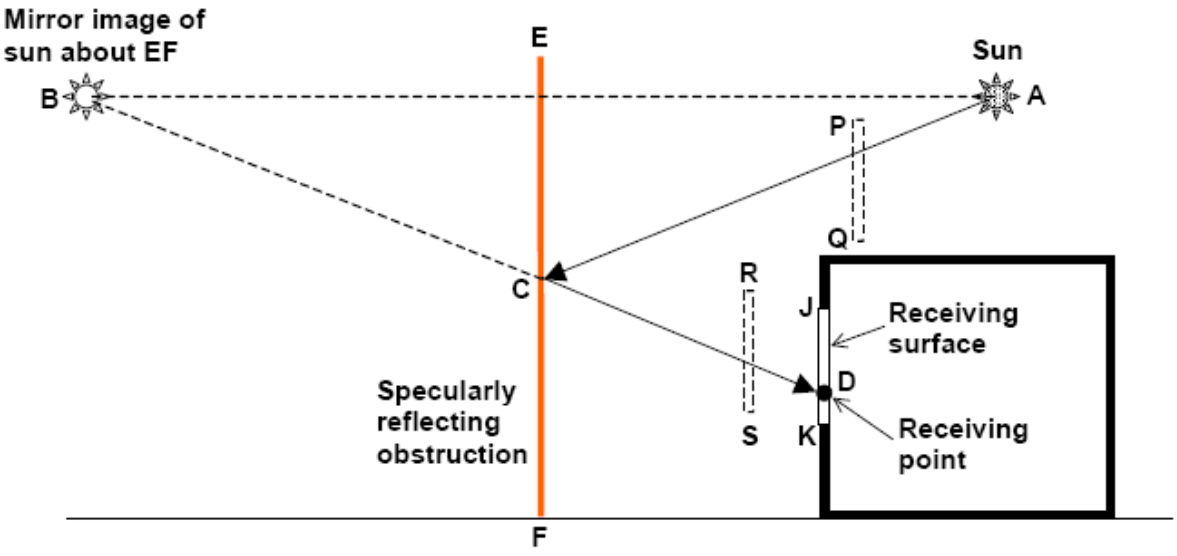
If a downgoing ray from a receiving point hits the ground (for example, rays 1-6 in diagram below), the program calculates the radiance at the ground hit point due to sky diffuse solar reaching that point. To do this, rays are sent upward from the ground hit point and it is determined which of these rays are unobstructed and so go to the sky (for example, rays 6-10 below). For this calculation it is assumed that the radiance of the sky is uniform.



Two-dimensional schematic showing rays going upward from a ground hit point.

Beam Solar Radiation Specularly Reflected from Obstructions

The diagram below shows schematically how specular (beam-to-beam) reflection from an obstruction is calculated.



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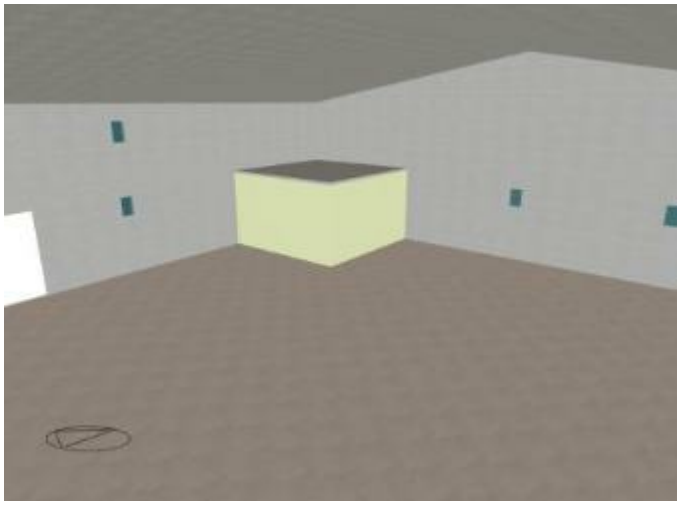
Two-dimensional schematic showing specular reflection from an obstruction such as the glazed façade of a neighboring building. The receiving point receives specularly reflected beam solar radiation if (1) DB passes through specularly reflecting surface EF, (2) CD does not hit any obstructions (such as RS), and (3) AC does not hit any obstructions (such as PQ).

*More detailed information on can be found in the EnergyPlus **EngineeringReference.pdf** document.*

12.12 Warehouse with Office

Sometimes it is necessary to create a smaller zone such as an office within a larger zone (e.g. a large warehouse space). This tutorial explains how to set up a simple 2 zone model such as that illustrated in the screenshots below where a small office is located in bottom corner of a larger warehouse space.



The steps involved are:

1. Draw the ground floor block including both office and warehouse. The block should be the height of the office space as the top of the block will form the ceiling of the office.

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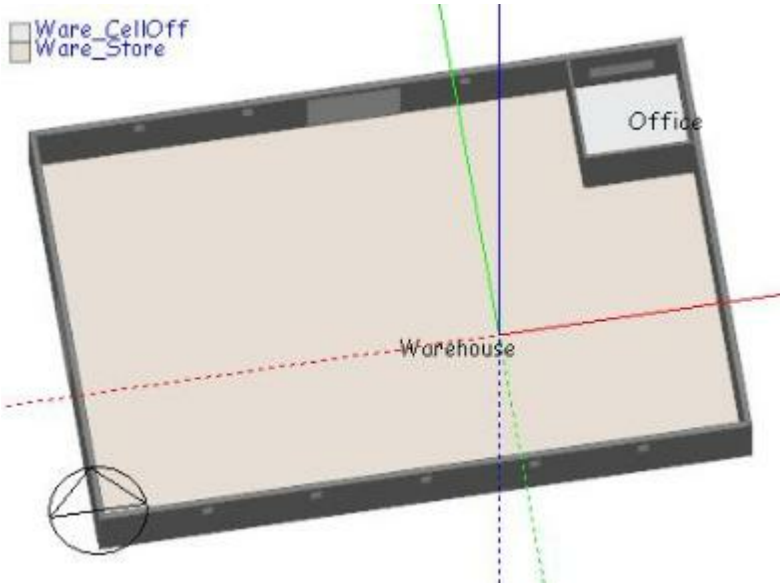
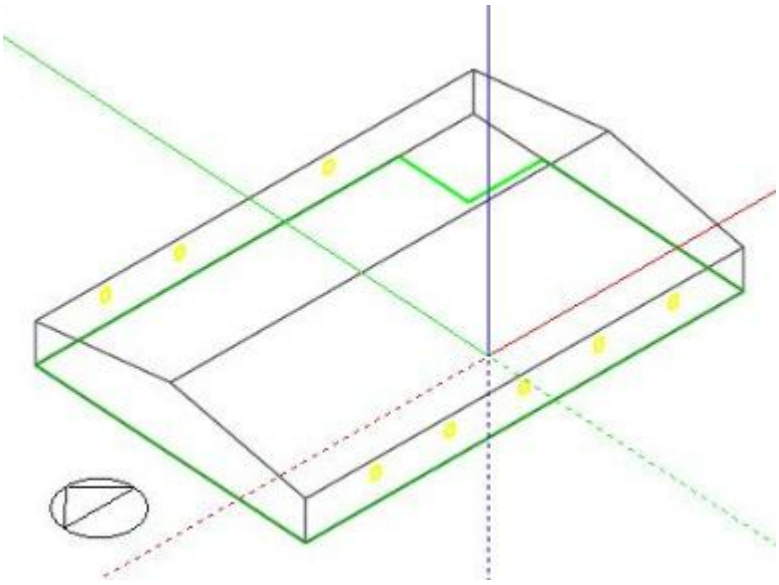


2. Draw the 1st floor block representing the high-level warehouse space.

3. Draw a hole in the floor of the 1st floor block to connect the upper and lower warehouse zones together. The upper warehouse zone should look something like the screenshot below. The green line shows the perimeter of the hole.



4. Select the Merge zones connected by holes model option to merge the upper and lower parts of the warehouse into a single zone.

5. The 'floor' on top of the office zone is not usable floor area so go to this floor surface and select the **Exclude this surface from total zone floor area** option. This indicates that the surface is not part of the building useable floor area. This step ensures that this floor area is not counted in the floor area provided to certification tools such as SBEM. This step is not currently required for EnergyPlus simulations.

Note: if the excluded floor surface contains some external adjacencies as well as internal ones these **external areas will not be subtracted from the zone floor area**.

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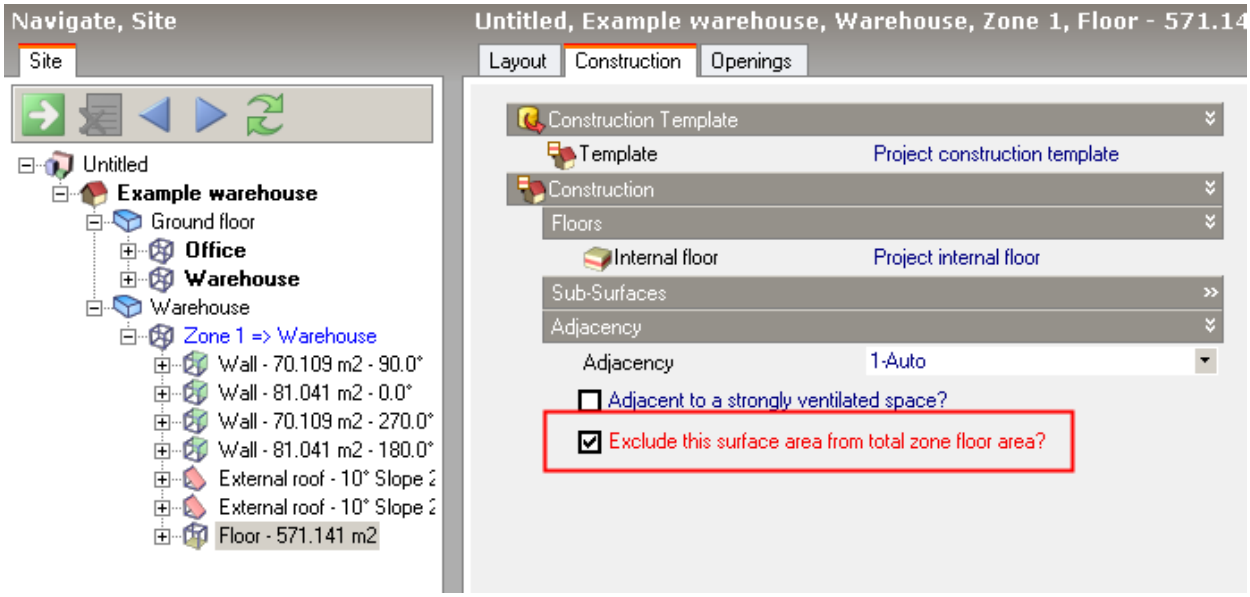

So the building now consists of 2 zones - an Office and a Warehouse zone. This model is available as one of the DesignBuilder example templates.

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13 Reference

Reference sections:

- DesignBuilder files, locations and extensions
- Licensing and activation
- Hardware requirements
- Diagnostics
- Model Geometry Example
- Surface Types
- Calculation of Air Density
- Pitched Roof Geometry - Technical Description
- Triangulation
- Calculation of HVAC Energy Consumption

13.1 DesignBuilder Files, Location and Extensions

Filename/ Extension	Folder	Description
.dsb	DesignBuilder Data folder (default)	DesignBuilder model description file. Note that dsb files are already compressed so don't need to be 'zipped' before sending in emails.
.ddf		DesignBuilder exported component/template data
.dat	Library folder	Construction and Template exported files.
.lif	Any	DesignBuilder Licence file for activating licences when Internet access is not available
.idf	EnergyPlus folder	EnergyPlus input script file.
.stat	Weather data folder	EnergyPlus hourly weather data statistics file used by DesignBuilder to automatically load location and weather statistics to the Hourly weather data dialog when the epw file is selected. stat files are supplied with DesignBuilder and are automatically generated by the Hourly weather data translation process when creating custom weather data.
.epw	Weather data folder	EnergyPlus hourly weather data. a database of hourly weather data is supplied by automatic download or you can create your own hourly weather data.
Compact.idf	EnergyPlus folder	Compact.idf is generated when using Compact HVAC. It is the full input data with HVAC in compact form, i.e. prior to being expanded into detailed form.
Expanded.idf	EnergyPlus folder	Expanded.idf is generated when using Compact HVAC. It is the full input data with HVAC in expanded form, i.e. after being expanded into detailed form. It is copied
ip.idf	EnergyPlus folder	The EnergyPlus input file when using DOE version in EP-Launch - it is necessary because EP-Launch cannot accept in.idf as an input filename. You can make minor changes to ip.idf in EP-Launch and see

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		the effects in the DB results.
in.idf	EnergyPlus folder	Temporary file generated by DesignBuilder used as input to EnergyPlus - this file is overwritten before each simulation. Note when using DOE version in EP-Launch, in.idf is generated by EP-Launch.
Energy+.idd	EnergyPlus folder	EnergyPlus data definition dictionary (see EnergyPlus documentation for information on this).
Eplusout.err	EnergyPlus folder	EnergyPlus error message file.
Eplusout.eso	EnergyPlus folder	Standard eso Output File - contains detailed results to be read in by DesignBuilder.
Eplusout.eio	EnergyPlus folder	EnergyPlus model summary configuration output file. Note there is a free utility called xESOView that can be used to quickly view EnergyPlus eso output files. Download it from: http://sourceforge.net/projects/xesoview.
Eplusout.rdd	EnergyPlus folder	Report Variable Data Dictionary - list all possible EnergyPlus output reports for a particular idf input file.
Eplusout.bnd	EnergyPlus folder	HVAC layout summary file - shows details about the branches, nodes, and other elements of the flow connections. It is intended for use in debugging potential problems and supports the EnergyPlus diagramming tool.
Eplusout.dxf	EnergyPlus folder	DXF file (from Report,Surfaces,DXF;)
Eplusout.mtr	EnergyPlus folder	Similar to .eso but only has Report Meter outputs.
Eplusout.end	EnergyPlus folder	A one line summary of success or failure used by DesignBuilder to indicate whether the simulation was successful or not.
Eplusout.dbg	EnergyPlus folder	From Debug Output object – may be useful to support to help track down problems.
Eplusout.csv	EnergyPlus folder	Not directly from EnergyPlus - produced by EnergyPlus utility program that reads the .eso file and produces output files for spreadsheet programs.

Compact HVAC file translation process

When using Compact HVAC, the EnergyPlus input file generation process is as follows:

1. DesignBuilder first creates **in.idf** using Compact HVAC notation.
2. **in.idf** is copied to **Compact.idf** as a backup/record - this file is not used in the simulation process
3. **in.idf** is processed by ExpandObjects.exe to generate **expanded.idf -** the full HVAC data set that can be read by EnergyPlus.
4. **expanded.idf** is copied to **in.idf** as a backup/record and plays no further part.
5. **in.idf** is used as input to EnergyPlus simulation.

All above files are stored in the EnergyPlus folder.

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in.idf

Folders

Folder	Typical Location*	Use
DesignBuilder Data	My Documents\DesignBuilder Data	Storing DesignBuilder dsb data files.
DesignBuilder Data\Backup	My Documents\DesignBuilder Data\Backup	DesignBuilder automatic backup files and file copies made when opening existing files.
EnergyPlus	C:\Documents and Settings**User**\LocalSettings\Application Data\DesignBuilder\EnergyPlus	Storing files related to EnergyPlus simulations.
Library data	C:\Documents and Settings**User**\LocalSettings\Application Data\DesignBuilder\Data	Library data and .dat files currently being used by DesignBuilder
Library data	C:\Documents and Settings**User**\LocalSettings\Application Data\DesignBuilder\Data	Library data including backups and .dat files.
Template projects	C:\Documents and Settings\All Users\Application Data\DesignBuilder\Templates	DesignBuilder dsb files stored in this folder can be used as templates for future models. Click on the Templates tab on the Create New Site dialog for a list of available template files.
Weather data	C:\Documents and Settings**User**\LocalSettings\Application Data\DesignBuilder\Weather Data	EnergyPlus hourly weather data is stored in this folder. The data may have been automatically downloaded from the DesignBuilder website or it can be added manually.

* The actual names of the folders will depend on the language used on your computer and on your Windows user name. The above locations assume English as the language and Windows user name '**User**'.

Tip: the above folders can be accessed from the **File | Folders** menu commands.

13.2 Hardware Requirements

DesignBuilder is a professional graphics application and requires a high standard of computer hardware for successful use. This page contains information on the minimum system requirements and also the recommended specification. The main areas you should pay attention to if you are buying or upgrading your computer system to run DesignBuilder are:

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- **Graphics adapter** - a good 100% OpenGL compatible graphics adapter is required to run DesignBuilder. The mid-range and better NVIDIA cards seem to be the most reliable. Some graphics adapters integrated with the motherboard we have tested are unable to run DesignBuilder. See also note below.
- **Memory** - DesignBuilder will use all the memory you can throw at it - at least 2 GB is recommended for serious modelling or more if you are running under Windows Vista which itself uses 1 GB.
- **CPU speed** - get as fast as you can afford.
- **Cores** - having more than one processor core does not necessarily speed up simulations in DesignBuilder version 1 but it does allow you to continue using your computer while simulations are running. Dual core processors also make the software more responsive in use.

Minimum Requirements

- Windows 7, Vista, XP or Windows 2000 running on
- 1000 MHz processor
- 800x600 pixel screen
- 1 GB RAM
- 200 MB free disk space
- Pointing device
- 100% OpenGL compatible 3D graphics adapter with hardware acceleration running in 32-bit color mode

The above specification will allow you to successfully model small buildings using DesignBuilder but we recommend a more powerful computer for best results especially when working with larger building models.

Recommended

- Windows XP SP2
- 2.4 GHz dual core processor or faster. Dual Core processors are recommended as they allow you to continue using your computer while simulations are carried out.
- 4 GB (or more) RAM.
- 5 GB free disk space
- Pointing device
- 100% OpenGL compatible 3-D graphics adapter with hardware acceleration running in 32-bit color mode
- 1280x1024 pixels or larger screens for efficiency during the modelling process and for displaying high-quality visualisation images and walk-throughs of DesignBuilder models and CFD results. DesignBuilder works well with wide screens.

Windows Vista

DesignBuilder works under Windows Vista, but you must ensure that you follow the advice on the support knowledgebase to switch off desktop composition and set XP-compatibility mode.

Graphics Card Settings

If you plan to purchase a computer we recommend choosing an NVIDIA graphics adapter as these, in our experience, have more reliable drivers for use with OpenGL. ATI graphics cards are generally not recommended for use with DesignBuilder as they often have bugs in their OpenGL driver software, especially new releases.

Many graphics cards allow you to customise driver settings. The example screenshot below is for an NVIDIA card showing recommended settings. Note antialiasing, anisotropic filtering and unified back/depth buffer have been changed from default settings to provide **hardware accelerated** optimal visualisations. The antialiasing option provides sharp lines without slowing program operation and unified back/depth buffer gives best results for dragging selection rectangles on some graphics cards allowing double buffering to be used for cursor dynamics.

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13.3 DesignBuilder Licensing

DesignBuilder v.2 has different licensing systems for single user and site licences. This page gives further details on these beyond the basics described in the Licensing and Activation section.

SINGLE USER LICENSES

A single user licence allows you install DesignBuilder onto a maximum of 2 computers for personal use, for example one on a desktop and one on a laptop. If you need to use the software on a third computer then you must first deactivate one of the other 2 computers.

When you purchase a DesignBuilder v.2 license from the website, you will receive an 8-digit activation code. To use this enter it in the License dialog accessed from the Help menu within DesignBuilder and press the Activate button. This will cause DesignBuilder to automatically download licences for all modules associated with the activation code and activate them. You will then be able to use the software and run functionality associated with each activated license.

DesignBuilder also periodically checks to ensure that the licence is still valid. To do this it must connect to our servers over the Internet. If DesignBuilder hasn't been able to check licences for 2 days then it will request that you connect to the Internet so it can check license status. If it still fails to connect after another 24 hours, then the licenses will be deactivated on that computer. To reactivate simply connect to the Internet and press the Activate button on the License dialog.

You can also deactivate activation codes either from within DesignBuilder by pressing the Remove activation code from this computer button or from the deactivate webpage:

http://www.designbuilder.com/deactivate

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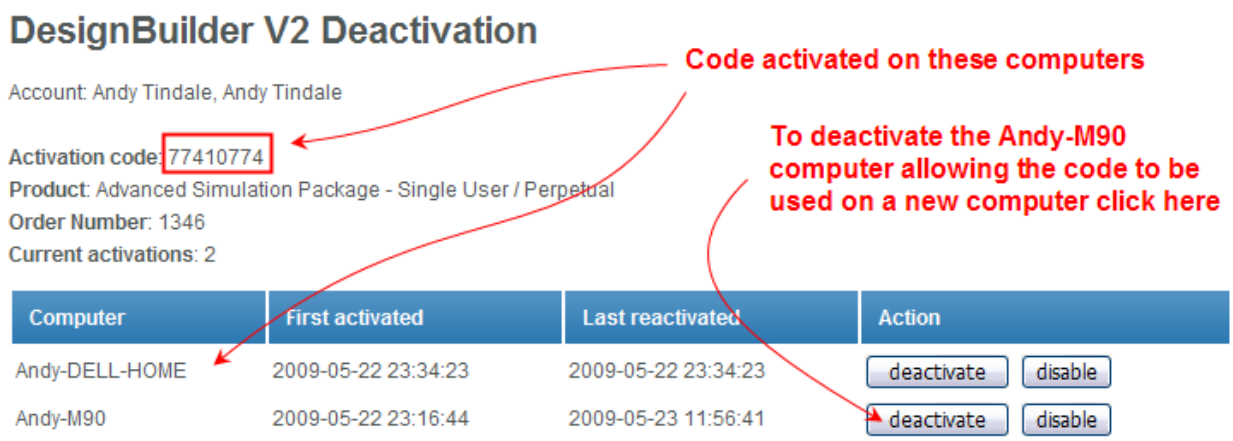

From this webpage you can also permanently cancel activations to prevent users no longer entitled to use the software from using it. For example if an employee leaves the company but still has a copy of the software activated at home then this can easily be cancelled allowing the activation code to be used by someone else. To cancel an activation click on the disable button on the Deactivation webpage.

SITE LICENSES

Site licenses require a single license server to be installed and run on the network and for each client computer using DesignBuilder an environment variable must be set to tell DesignBuilder where on the network to find the license server.

Summary of Process

In summary, the steps to set up DesignBuilder Site Licenses are:

1. Download the **designb_rlm.zip** file from the Downloads > Software area of the DesignBuilder website
2. Extract the files in the **designb_rlm.zip** file to the folder on the server to be used to store DesignBuilder site license files (e.g. c:\RLMSERVER)
3. Obtain the License file by clicking on activate.cmd, following instructions on the webpage and saving the license file to the site license folder.
4. Run the RLM server as a service and start the service.
5. On client machines which are to run the DesignBuilder software, set the environment variable **DB_SITE_SERVER** to the IP address of the site license server on the network.

The above steps are detailed below.

Obtaining your License File

Before you run the rlm server you will need to obtain your license file and save it into the rlm installation folder. That's the folder containing rlm.exe and other files listed above. You should have received an activation code from your site license purchase,
this is an 8-digit number and is needed to activate the license. Open the rlm installation folder in Windows Explorer and
double click on **activate.cmd** This loads a web page at www.designbuilder.co.uk with a form for you to enter your activation code. Other values in the form such as Hostid are automatically filled in for you. After entering your activation code click **Activate License** and if successful you will be presented with a download link for your activated license file. Download the license file and save in your rlm installation folder.

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Running the RLM Server

The server can be run directly by double clicking **rlm.exe**. This runs a command window and logs activity to the window. This is useful when you first run the license server as you'll be able to see the license server starting up correctly and loading the license file as well as DesignBuilder clients obtaining licenses from the server.

Running RLM as a Service

It is best to set rlm up to run as a Windows service rather than in the command window, otherwise you'll need to remember to manually restart the license server when the computer reboots. If you are running rlm in a command window please close that before starting up rlm as a service. To create the Windows service to run rlm automatically double click on **service_install.cmd** or use **Manage Windows Service** in the admin interface.

Note: The service will be added to Windows services but not started.

Use Control Panel > Services to start **DesignBuilder License Server.**

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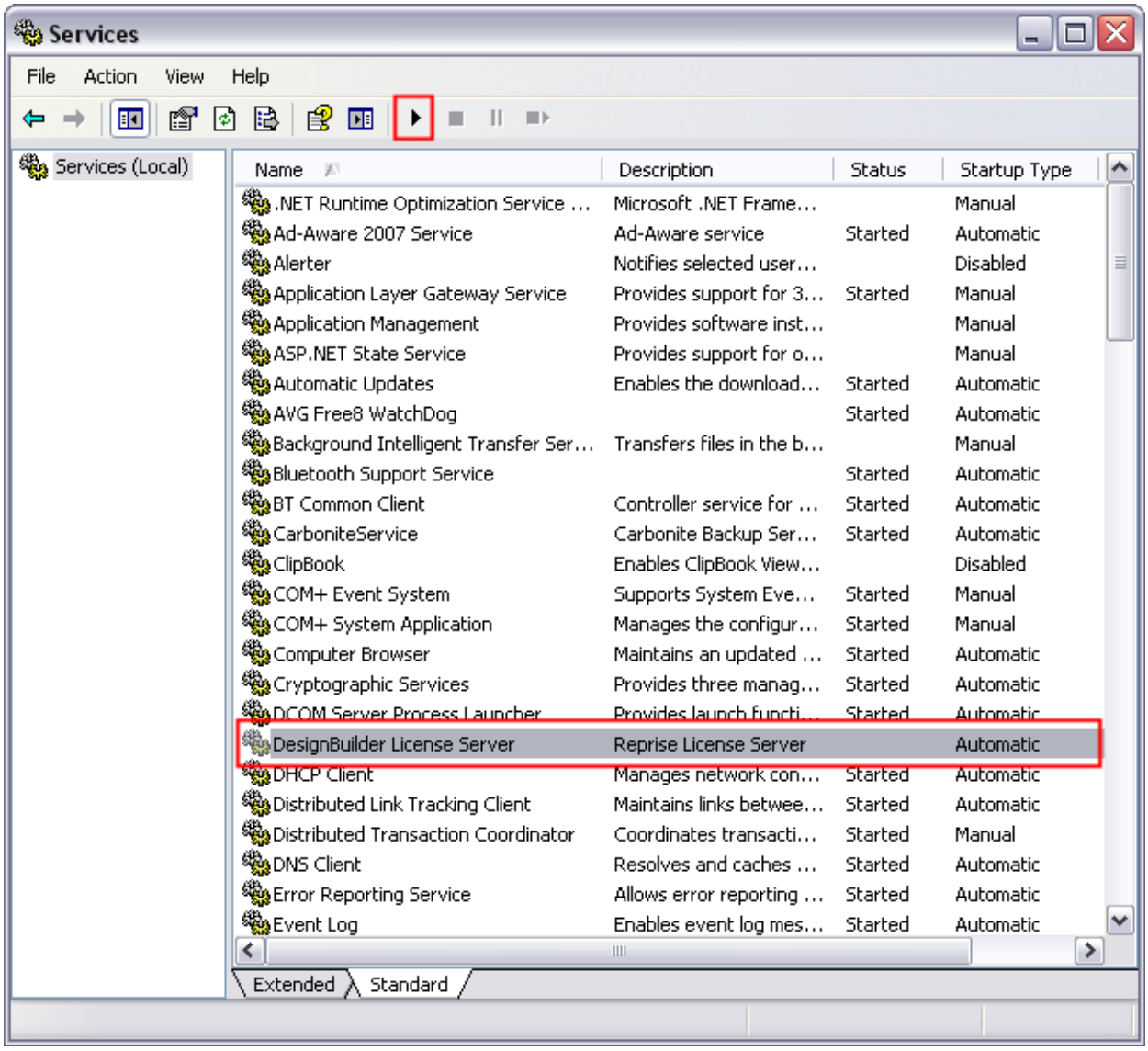

Once started in this way the service will restart automatically if the computer is rebooted. By default the service will write a log file **designb_rlm.log** into the rlm installation folder. If you want this in a different location you can use the admin interface (below) to set up the service then you can specify the service name and the log file location. On Vista you may have problems with permissions when setting up the service. You can either disable the UAC or try right clicking service_install.cmd and choosing "Run as administrator"

Setting up Client Machines

DesignBuilder will examine the environment variable DB_SITE_SERVER to decide whether to look for site licenses or single user licenses. If DB_SITE_SERVER is set then DesignBuilder will try to 'check out' licenses from the server at start up. If DB_SITE_SERVER is not set this DesignBuilder will use single user licenses. The environment variable DB_SITE_SERVER should be set to port@host where port is 5053 and host is the license server hostname (in your DNS system) or IP address.

For example:

DB_SITE_SERVER=5053@192.168.1.99

or:

DB_SITE_SERVER=5053@OUR_SYSTEM_SERVER

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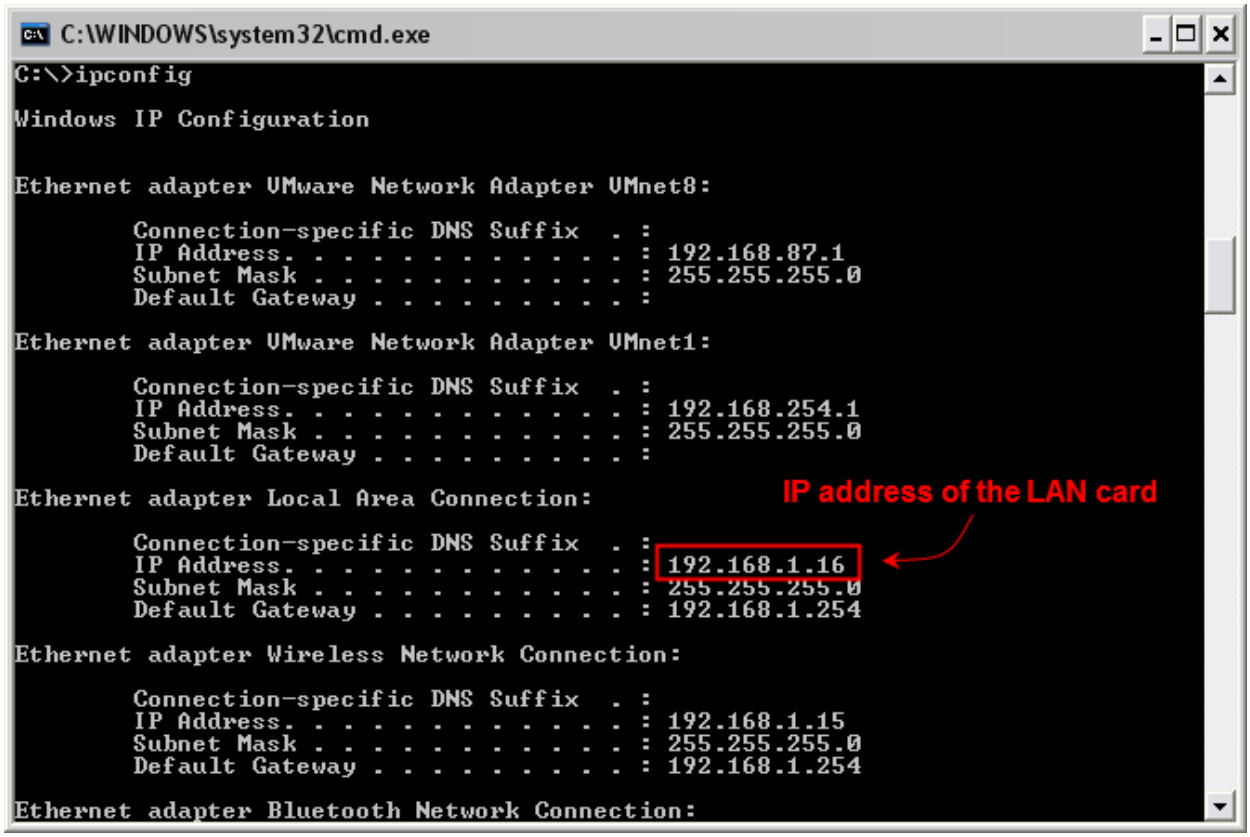
To set environment variables use the **Environment Variables** button on the Advanced tab of **Systems Properties** which can be accessed from the Windows Control panel.

You can find the IP address of your server by typing **ipconfig** in the Windows Command box on the server machine.



Once DesignBuilder is running you can check out or check back in module licenses using the License dialog which can be accessed from the DesignBuilder Help menu.

RLM Server Admin Interface

RLM provides a browser-based administration interface to the license server. To run this, double click on the **admin_interface.cmd** file in the RLM folder using Windows Explorer.

Refer to the RLM End User Manual (double click **online_manual.cmd**) for more details on using the admin interface.

Note: DesignBuilder does not use the Activation page of the admin interface.

13.4 Diagnostics

DesignBuilder creates a new **diagnostics file** on startup called Diagnostics_xxxx.log where xxxx is the date and time. The file is generated in the folder above the Library data folder.

Diagnostic files contain information about the operating system settings, hardware configuration and settings within the program. You may be requested to supply this file to DesignBuilder Support if you have problems with program operation on your computer.

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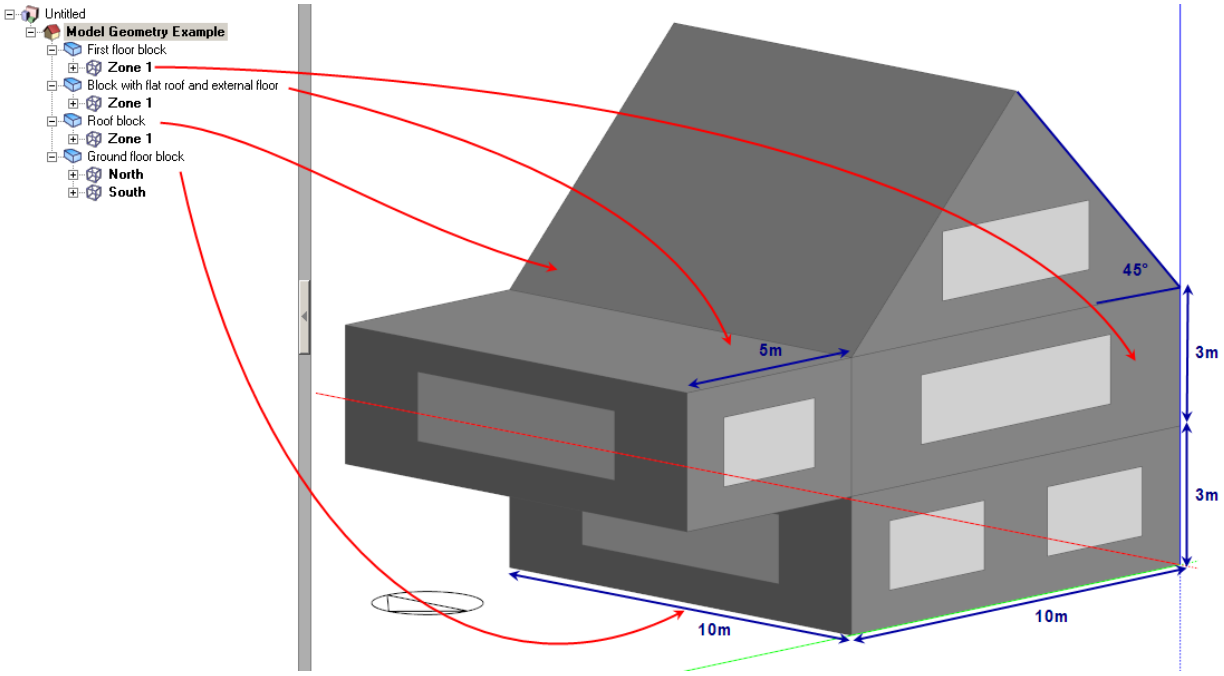
13.5 Model Geometry Example

This section documents the way the DesignBuilder model geometry you define is used in the calculations and visualisations. The description is based on the **Model Geometry Example.dsb** example building shown below. The file **Model Geometry Example.dsb** is supplied with DesignBuilder. The model consists of 4 blocks, each block containing a single zone, except the Ground floor block which is divided into equal sized North and South zones.



and Visualisation view:

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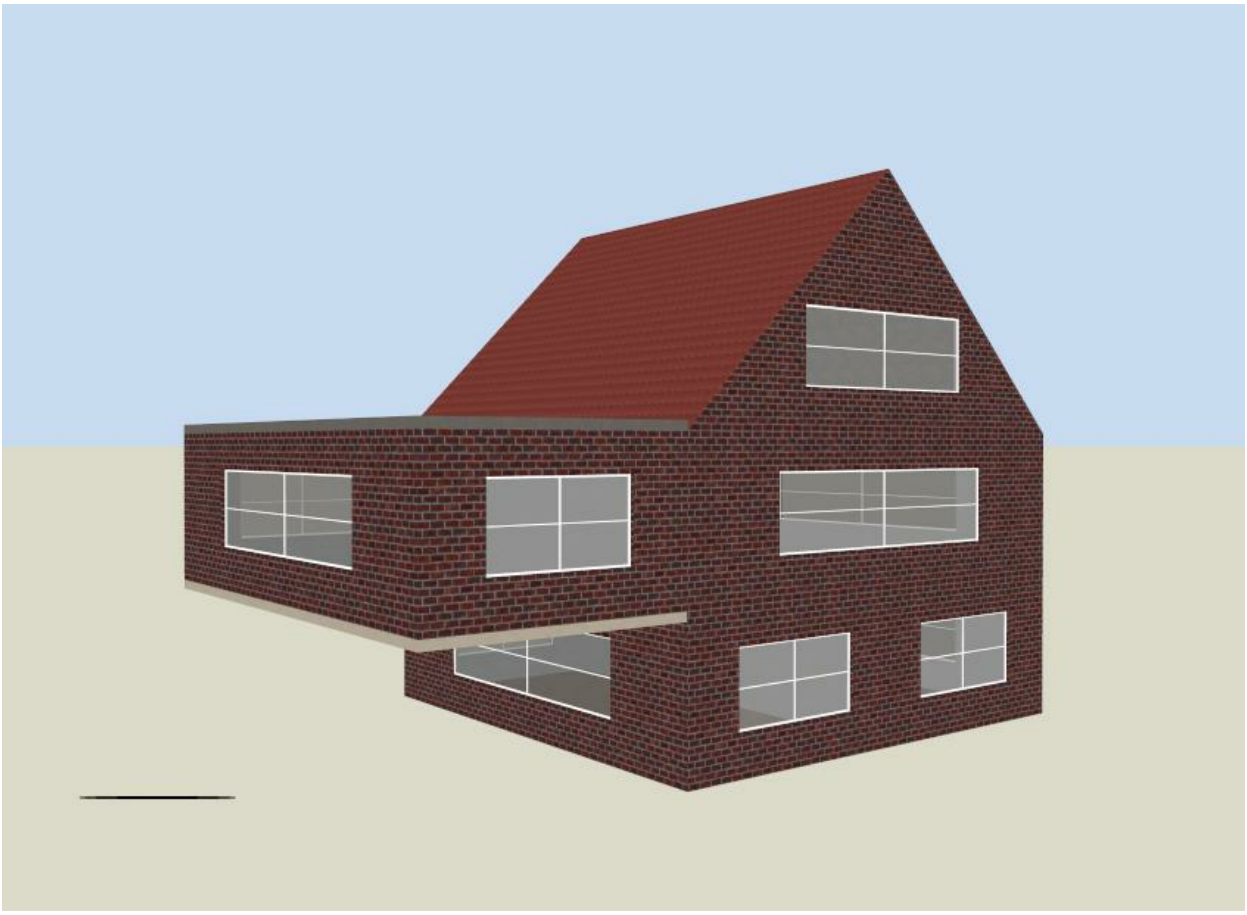

See the Visualisation Limitations section for information on some minor differences in the rendered images and the model used in the calculations.

The model consists of:

1 x 10m x 10m **Ground floor block** partitioned into equal size North and South zones using partition of thickness 0.05m.
1 x 10m x 10m **First floor block** stacked on ground block.
1 x 10m x 5m **Block with flat roof and external floor** connects with the First floor block on the North side.
1 x 10m x 10m **Roof block** with 45° roof slope drawn in the vertical plane and extruded horizontally, i.e. it is not defined as a Pitched roof block form. The **Roof block** is stacked on top of the **First floor block**.

Above are *external* block dimensions.
Block wall thickness = 0.2m for all blocks.
30% Glazing ratio for all blocks, all glazing uses default facades (i.e. no windows or doors have been drawn).
Model uses default Zone volume calculation options - **Internal floor constructions not subtracted from zone volume, External floor constructions not subtracted from zone volume** and **Ground floor construction is below ground and is not subtracted from zone volume**.

When exported to 3-D DXF using the Whole model with details option and dimensioned the model looks like this:

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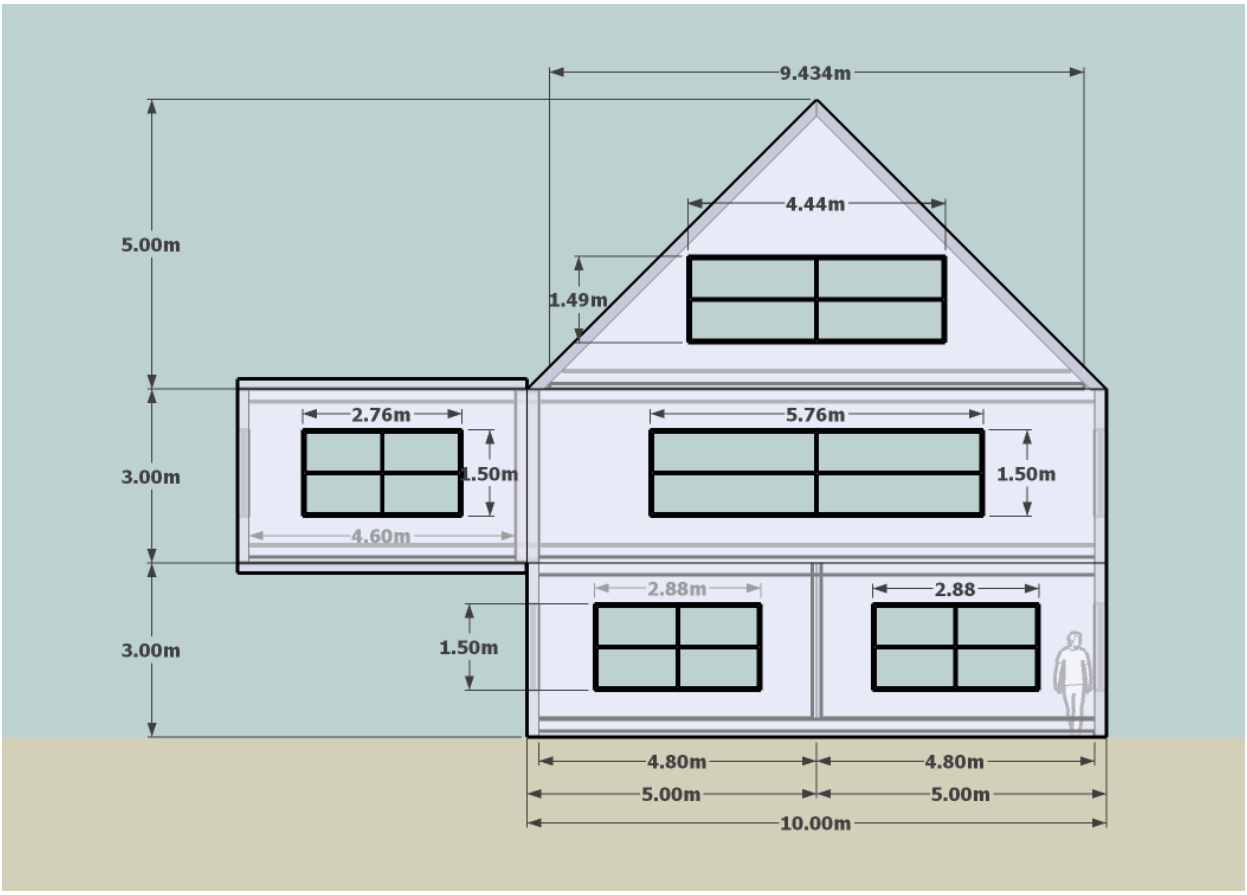
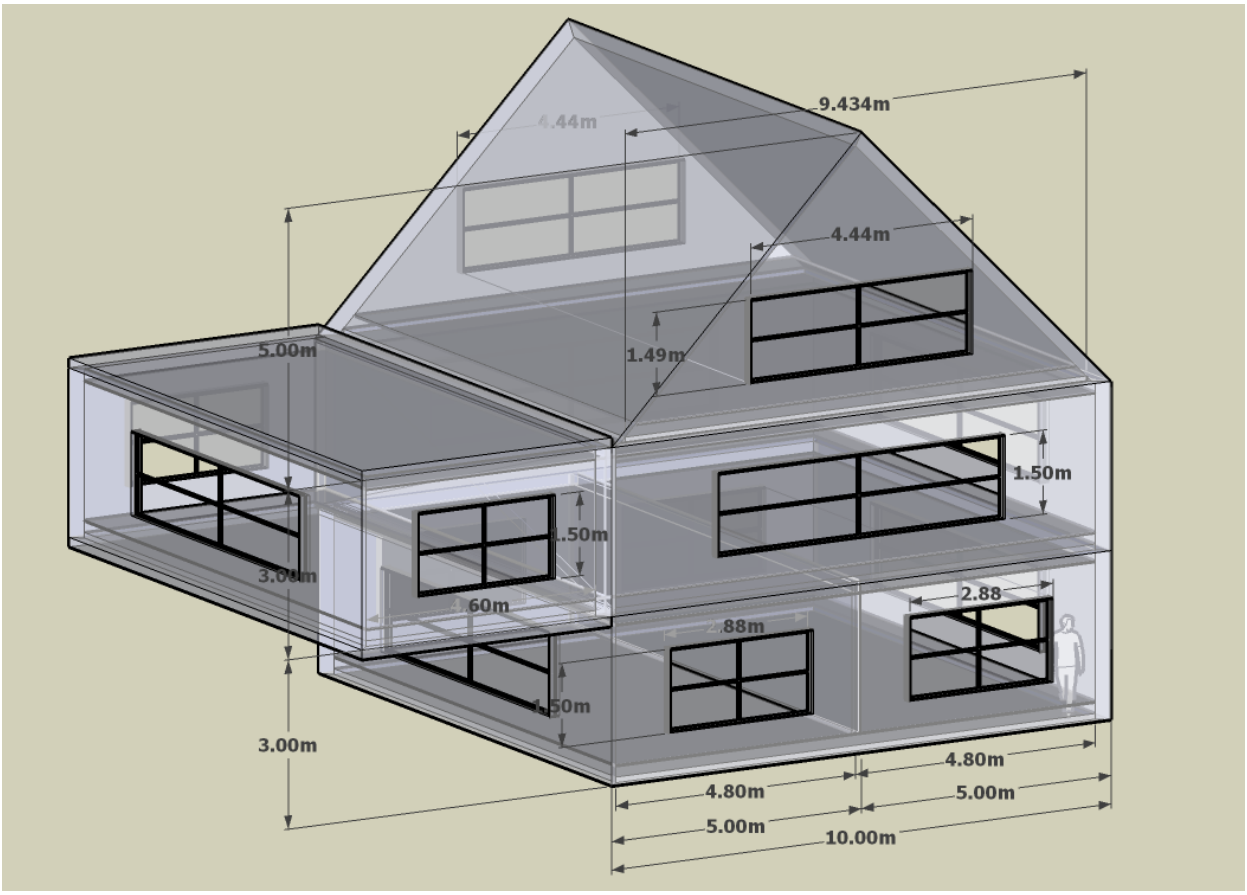


The same model in 3-D view looks like this:



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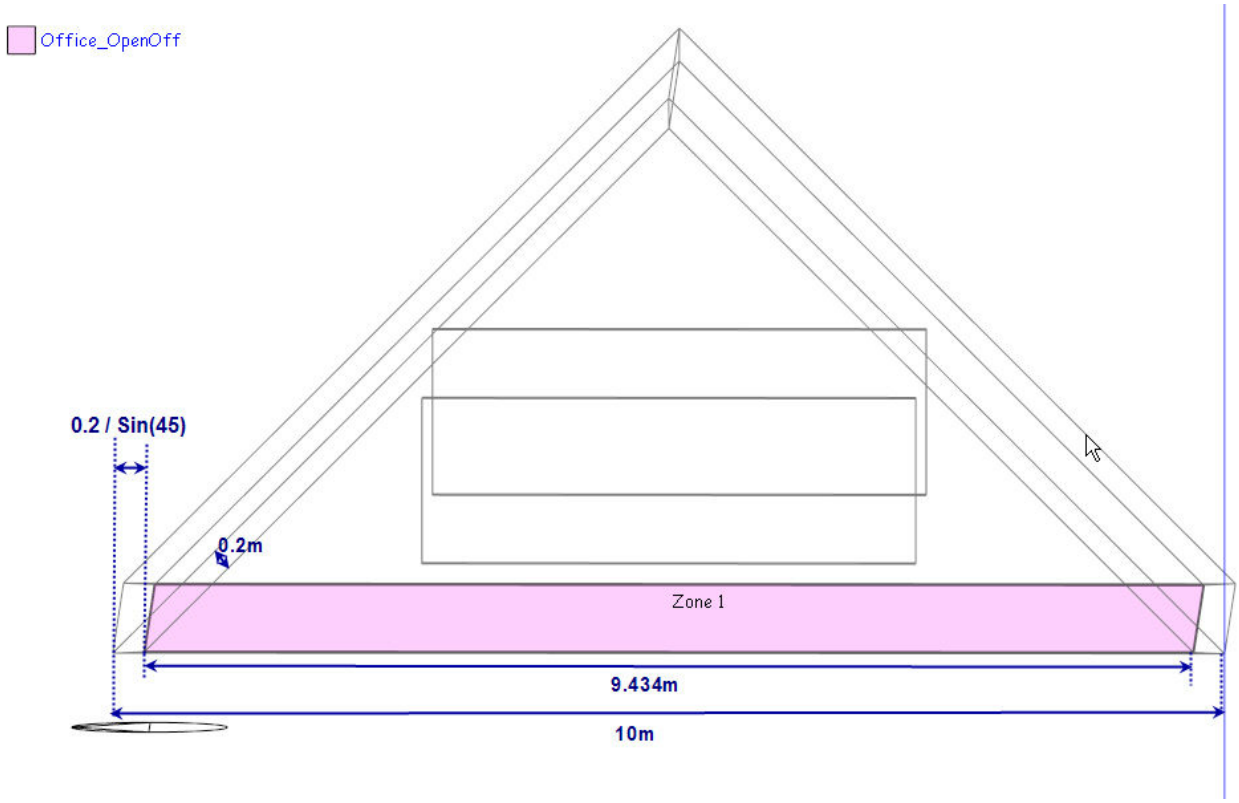
The ceiling / floor surface between **First floor block - Zone 1** and **Roof block - Zone 1** has area 9.6m x (9.6 - 2 x 0.2 / sin 45°) where the 0.2 / sin 45° term is the Roof block wall thickness (0.2m) adjusted to account for the roof slope (45°) as shown in the diagram below.



The dimension data for the zones, surfaces and openings used in the calculations can be seen in the Navigator and can also be obtained by exporting a csv report file.

The general principles used in DesignBuilder are:

- Internal zone surface areas are used in calculations and these are derived from block outer dimensions accounting for block wall thickness.
- Full block height is used when calculating wall areas
- Zone volume is calculated accurately even for very complex shaped zones but for a simple 'shoebox' model the zone volume is simply zone floor area x block height.
- If one of the Zone volume calculation options is not selected then the volume of appropriate floor constructions is subtracted from the basic zone volumes. The volume of the floor construction is the Thickness of the construction x the surface area.

The tables below list the most important geometric data and show how each item is calculated. Note that surfaces with glazing have area of glazing subtracted. The areas below are consistent with EnergyPlus and SBEM calculations. Klima Europa calculations have modifications to wall area and volume calculations to ensure internal heights are used.

Zone Ground floor block - North		**Calculation Note**
Floor area (m2)	46.08	4.8m x 9.6m
Volume (m3)	138.24	46.08m2 x 3m (subtract volume of ground floor if Ground floor construction is below ground and is not subtracted from zone zolume model option set)

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Surface	Area (m2)	Area Calculation Note	Adjacency (Orientation / adjacent zone)
Ground floor	46.08	4.8m x 9.6m	Ground
Ceiling	46.08	4.8m x 9.6m	First floor block - Zone 1
Wall Outside	10.08	4.8m x 3m - glazing area on surface (2.88m x 1.5m)	90
Glazing Outside	4.32	2.88m x 1.5m	90
Wall Outside	20.16	9.6m x 3m - glazing area on surface (5.76m x 1.5m)	0
Glazing Outside	8.64	5.76m x 1.5m	0
Wall Outside	10.08	4.8m x 3m - glazing area on surface (2.88m x 1.5m)	270
Glazing Outside	4.32	2.88m x 1.5m	270
Partition	28.8	9.6m x 3m	Ground floor block - South

Zone Ground floor block - South		Calculation Note
Floor area (m2)	46.08	4.8m x 9.6m
Volume (m3)	138.24	46.08m2 x 3m (subtract volume of ground floor if Ground floor construction is below ground and is not subtracted from zone volume model option set)

Surface	Area (m2)	Area Calculation Note	Adjacency (Orientation / adjacent zone)
Ground floor	46.08	4.8m x 9.6m	Ground
Ceiling	46.08	4.8m x 9.6m	First floor block - Zone 1
Wall Outside	10.08	4.8m x 3m - glazing area on surface (2.88m x 1.5m)	90
Glazing Outside	4.32	2.88m x 1.5m	90
Wall Outside	20.16	9.6m x 3m - glazing area on surface (5.76m x 1.5m)	180
Glazing Outside	8.64	5.76m x 1.5m	180
Wall Outside	10.08	4.8m x 3m - glazing area on surface (2.88m x 1.5m)	270
Glazing Outside	4.32	2.88m x 1.5m	270
Partition	28.8	9.6m x 3m	Ground floor block - North

First floor block - Zone 1		Calculation Note
Floor area (m2)	92.16	9.6m x 9.6m
Volume (m3)	276.48	92.16m2 x 3m (subtract volume of ground floor if Ground floor construction is below ground and is not subtracted from zone volume model option set)

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Surface	Area (m2)	Area Calculation Note	Adjacency (Orientation / adjacent zone)
Floor	46.08	4.8m x 9.6m	Ground floor block - North
Floor	46.08	4.8m x 9.6m	Ground floor block - South
Ceiling	90.569	9.434m x 9.6m (9.434m = 10 - 2 x 0.2 / sin 45°)	Roof block - Zone 1
Wall Outside	20.16	9.6m x 3m - glazing area on surface (5.76m x 1.5m)	90
Glazing Outside	8.64	5.76m x 1.5m	90
Wall Outside	20.16	9.6m x 3m - glazing area on surface (5.76m x 1.5m)	180
Glazing Outside	8.64	5.76m x 1.5m	180
Wall Outside	10.08	9.6m x 3m - glazing area on surface (5.76m x 1.5m)	270
Glazing Outside	8.64	5.76m x 1.5m	270
Wall (with hole)	0.201	Necessary surround for interblock partition	0
Interblock partition	28.649	Interblock partition 9.6m x 3m - wall (with hole) (0.201m2)	Block with flat roof and external floor - Zone 1

Block with flat roof and external floor - Zone 1		**Calculation Note**
Floor area (m2)	44.16	4.6m x 9.6m
Volume (m3)	132.48	44.16m2 x 3m (subtract volume of external floor if Internal and external floor construction is below ground and is not subtracted from zone volume model option set)

Surface	Area (m2)	Area Calculation Note	Adjacency (Orientation / adjacent zone)
Floor	44.16	4.6m x 9.6m	Outside
Flat roof	44.16	4.6m x 9.6m	Outside
Wall Outside	9.66	4.6m x 3m - glazing area on surface (2.76m x 1.5m)	90
Glazing Outside	4.14	2.76m x 1.5m	90
Wall Outside	20.16	9.6m x 3m - glazing area on surface (5.76m x 1.5m)	0
Glazing Outside	8.64	5.76m x 1.5m	0
Wall Outside	9.66	4.6m x 3m - glazing area on surface (2.76m x 1.5m)	270
Glazing Outside	4.14	2.76m x 1.5m	270
Wall (with hole)	0.201	Necessary surround for interblock partition	180
Interblock partition	28.649	Interblock partition 9.6m x 3m - wall (with hole) (0.201m2)	First floor block - Zone 1

Roof block - Zone 1		**Calculation Note**
Floor area (m2)	90.569	9.434m x 9.6m (9.434m = 10 - 2 x 0.2 / sin 45°)
Volume (m3)	213.615	90.569m2 x (5m - 0.2 / cos 45°) x 0.5

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Surface	Area (m2)	Area Calculation Note	Adjacency (Orientation / adjacent zone)
Floor	90.569	9.434m x 9.6m (9.434m = 10 - 2 x 0.2 / sin 45°)	First floor block - Zone 1
Wall Outside	15.576	9.434m x (5m - 0.2 / cos 45°) x 0.5 - glazing area (6.676)	90
Glazing Outside	6.676	4.45m x 1.5m	90
Wall Outside	15.576	9.434m x (5m - 0.2 / cos 45°) x 0.5 - glazing area (6.676)	270
Glazing Outside	6.676	4.45m x 1.5m	270
Roof (slope 45°)	64.042	6.671m x 9.6m, 6.671 is the *internal* eaves to apex length = (5 - 0.2 / cos 45) / sin 45	90
Roof (slope 45°)	64.042	6.671m x 9.6m, 6.671 is the *internal* eaves to apex length = (5 - 0.2 / cos 45) / sin 45	270

Additional information for Klima Europa users

The DesignBuilder interface to Klima Europa works slightly differently. With Klima Europa, calculations have modifications to wall area and volume calculations to ensure internal heights are used. A ratio is used to do this:

InnerVolumeToOuterVolumeRatio = (Volume - ConstructionVolumeForSubtraction) / Volume

The area of all vertical walls is multiplied by the above factor to ensure that only internal wall areas are used in calculations. Also the volume is reduced to account for internal and external floor constructions (but not by default for ground floors as these are by default taken as being below ground).

To achieve this Klima users should make the Zone volume calculation settings before running Klima Europa:

Zone volume calculation option	Recommended Setting for Klima Europa
Internal floor constructions not subtracted from zone volume	No
External floor constructions not subtracted from zone volume	Yes
Ground floor construction is below ground and is not subtracted from zone volume	Yes

These settings may be enforced when in Klima analysis mode in future versions.

Other related information

1. Block and Zone Dimensions is an introductory section explaining how to enter blocks and the relationship with zones.
2. Also see Constructions for how to edit the construction configuration.
3. See Combined Constructions for information on the meaning of the Construction Model data.

13.6 Surface Types

The meaning of most surface types listed in the Navigator should be obvious. This section provides further information on the meaning of 3 less obvious surface types:

- Inter-block partition
- Wall (with hole)

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- Link body edge surfaces

These special surfaces are required because DesignBuilder uses 3-D surface slabs to represent building fabric. Using 3-D surface slabs allows accurate calculation of zone volumes, definition of blocks using external dimensions and realistic rendered images. Zones for EnergyPlus simulations and other calculations provided by DesignBuilder are generated from the interior faces of the block geometry.

Cutaway of DesignBuilder Zone showing 3D-slabs

Inter-block partition

An Inter-block partition surface is the shared partition wall between 2 zones in different blocks. Inter-block partition surfaces are generated whenever 2 blocks touch along a plane. They are listed in the Navigator twice, once in each of the 2 zones in which they appear. They are however a single partition object within DesignBuilder and in the thermal calculations. So if, for example, you change the Partition construction model data for an inter-block partition (or draw windows) the change will also be reflected in the equivalent inter-block partition surface in the adjacent zone.

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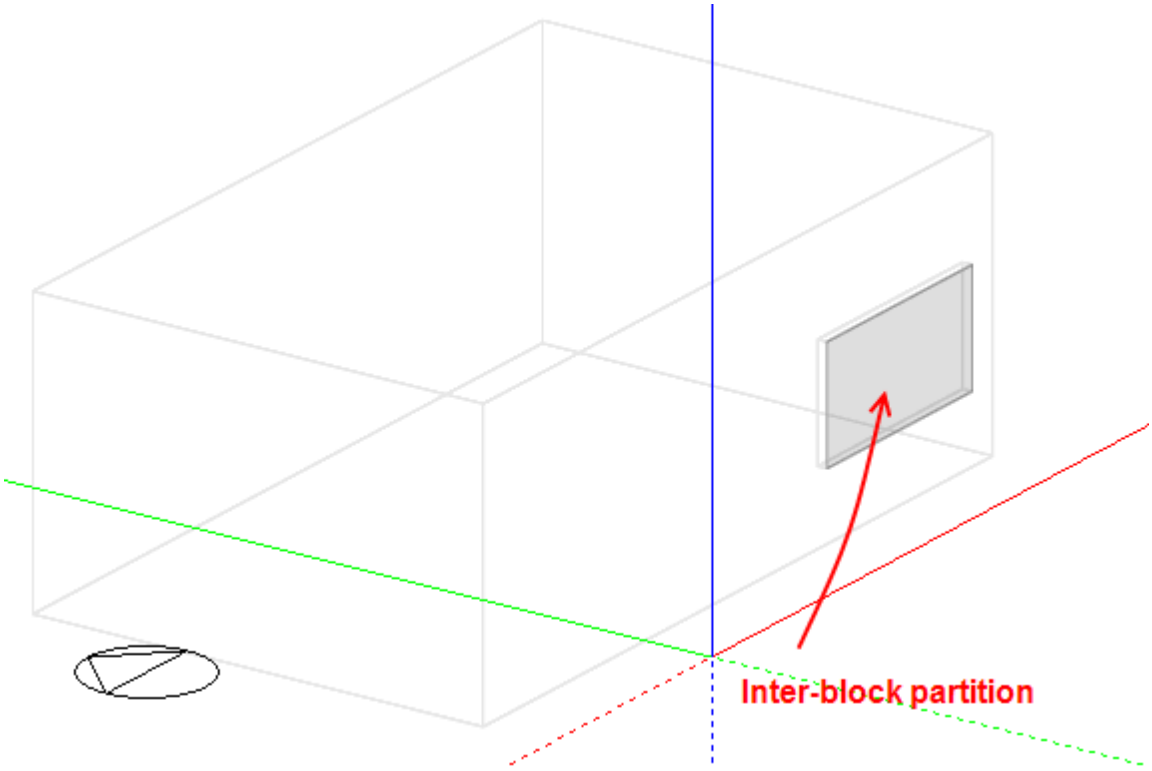
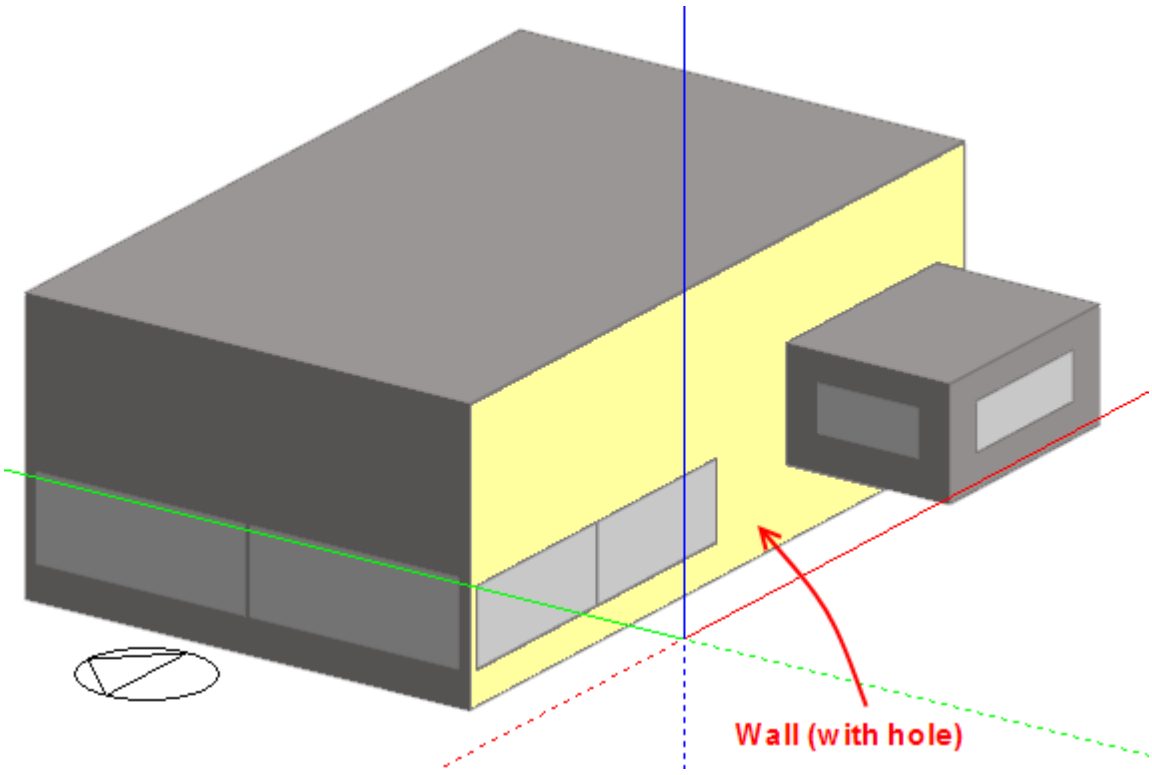


Wall (with hole)

Surfaces marked **Wall (with hole)** in the navigator are external surfaces on the same block face as an inter-block partition surface (see above). The 'hole' is where the inter-block partition goes. So 'Wall (with hole)' is the part of the block face that is adjacent to outside. The partition with the adjacent block is in a separate surface called **inter-block partition** (it is separated from the rest of the wall because it has a different adjacency). So the sum of the inter-block partition(s) and the wall with the hole make up the actual surface. The figures below illustrate.



At building level

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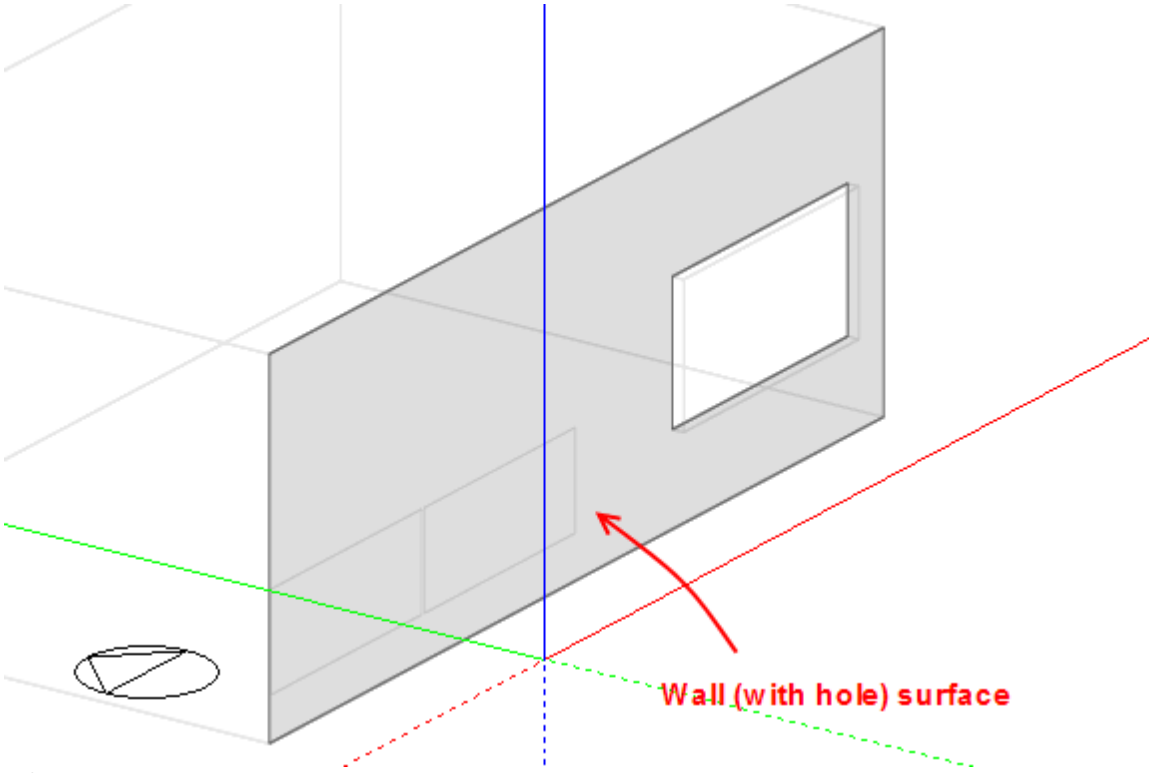
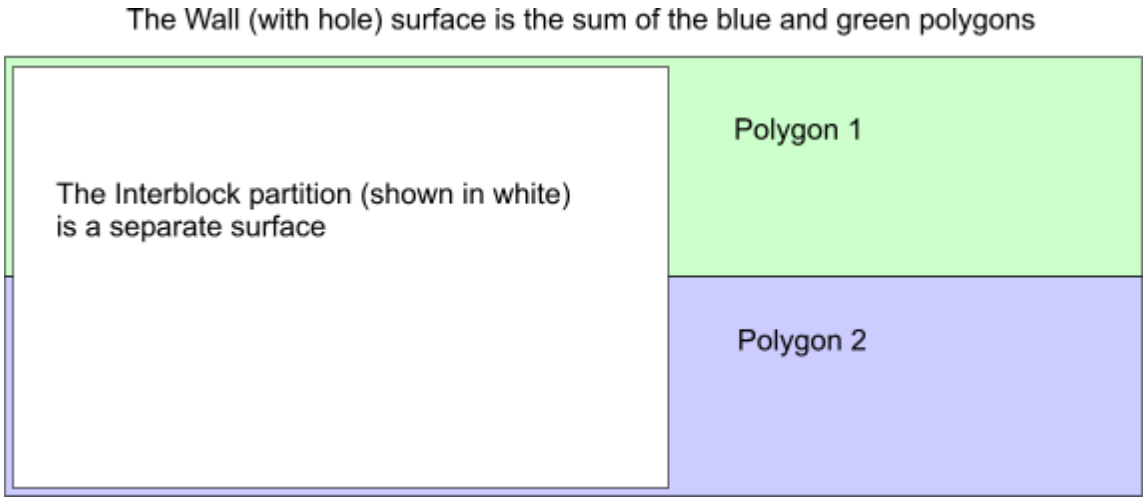


At surface level

Note that at surface level you can only draw openings on the grey areas of the surface. The white 'hole' is actually the inter-block partition (above).

Wall (with hole) representation in EnergyPlus

Because EnergyPlus does not allow surfaces to be defined with holes (i.e. surfaces are defined using a single set of vertices) DesignBuilder generates 2 or more valid sub-polygons to represent the surface in EnergyPlus. The diagram below illustrates the procedure used for a typical Wall (with hole) surface.



The surface is split into 2 (often equal area) polygons that, together, enclose the 'hole' left by the interblock partition. You should bear this in mind when looking at EnergyPlus IDF data.

Link body edge surfaces

Link body edge surfaces are used to connect the Wall (with hole) and the Inter-block partition surfaces to

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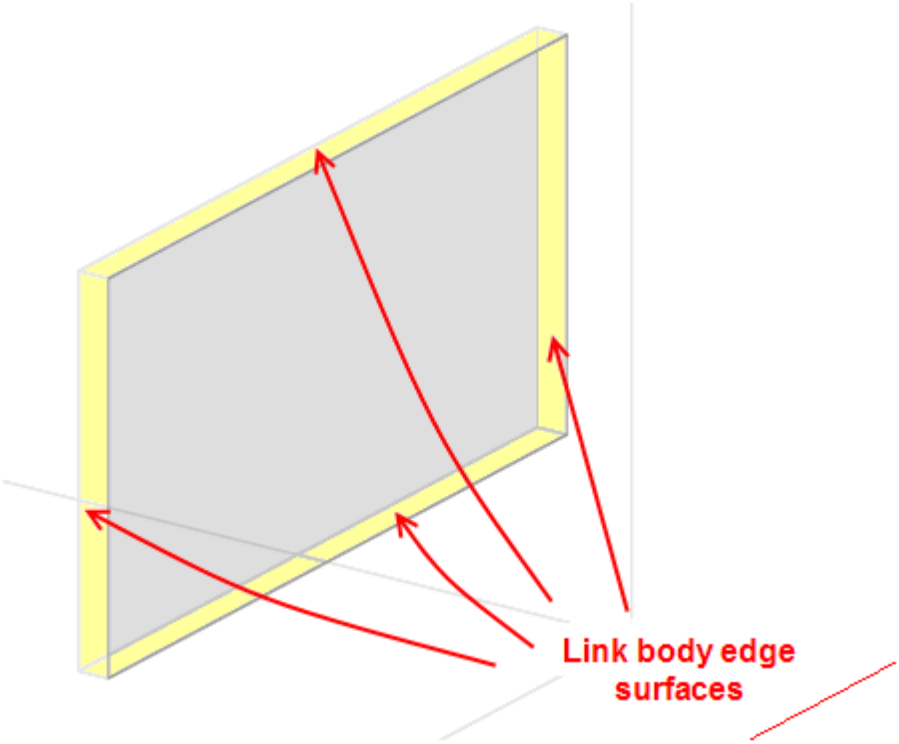
ensure that zones are fully enclosed. They are required because zones in adjacent blocks are separated from each other due to the thickness of the walls of the 2 blocks. The link body edge surfaces bridge the gap between the (internal) zone shell and the (external) block shell. The link body is the volume between the link edge surfaces and the inter-block partition.



Link body edge surfaces are excluded from the calculations by default to keep the size of models down but you can change the setting under Miscellaneous Edit on the Advanced tab of the Model options dialog to include them. When included, these surfaces are modelled using very high resistance zero mass elements and their contribution is to:

- Allow EnergyPlus to calculate zone volumes avoiding warning messages about volume mismatches. This does not actually affect the results because EnergyPlus uses the accurately calculated zone volumes supplied by DesignBuilder.
- Provide a slightly more accurate picture of the actual internal zone surface area and so potentially provide a more accurate convective/radiant calculation.

The pictures below show how the link body edge surfaces are used to connect the 2 blocks and ensure that zones are enclosed.

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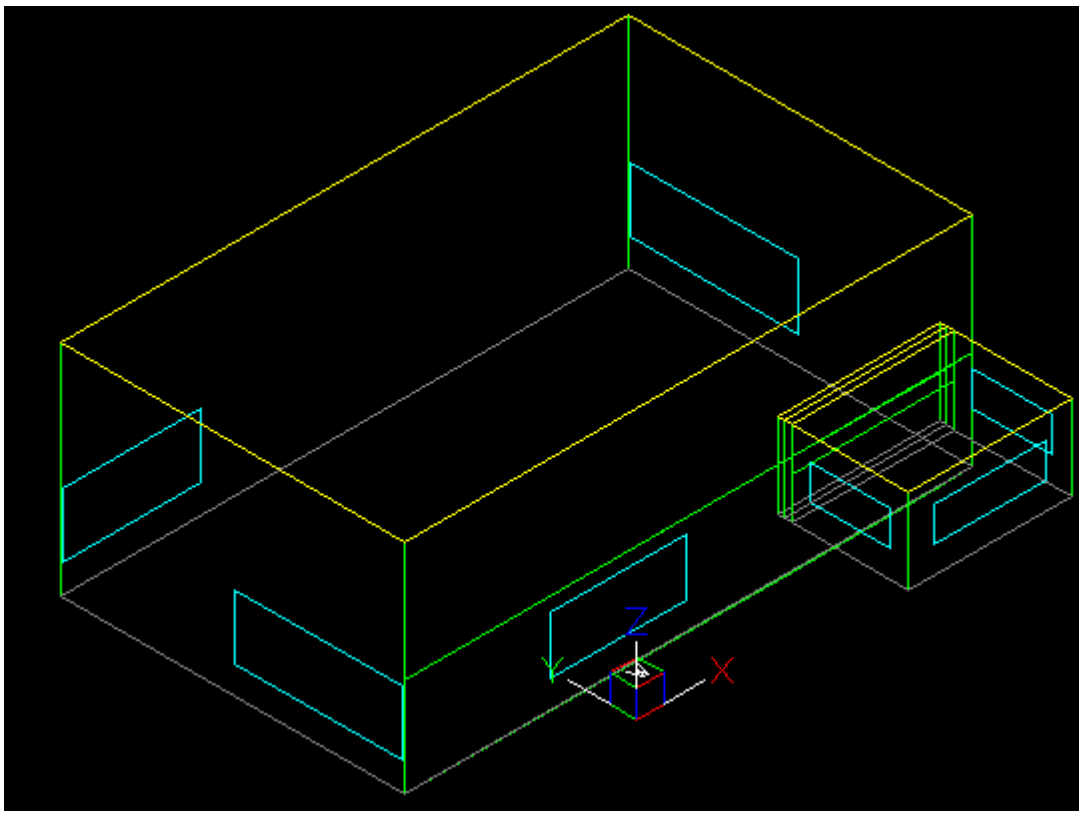
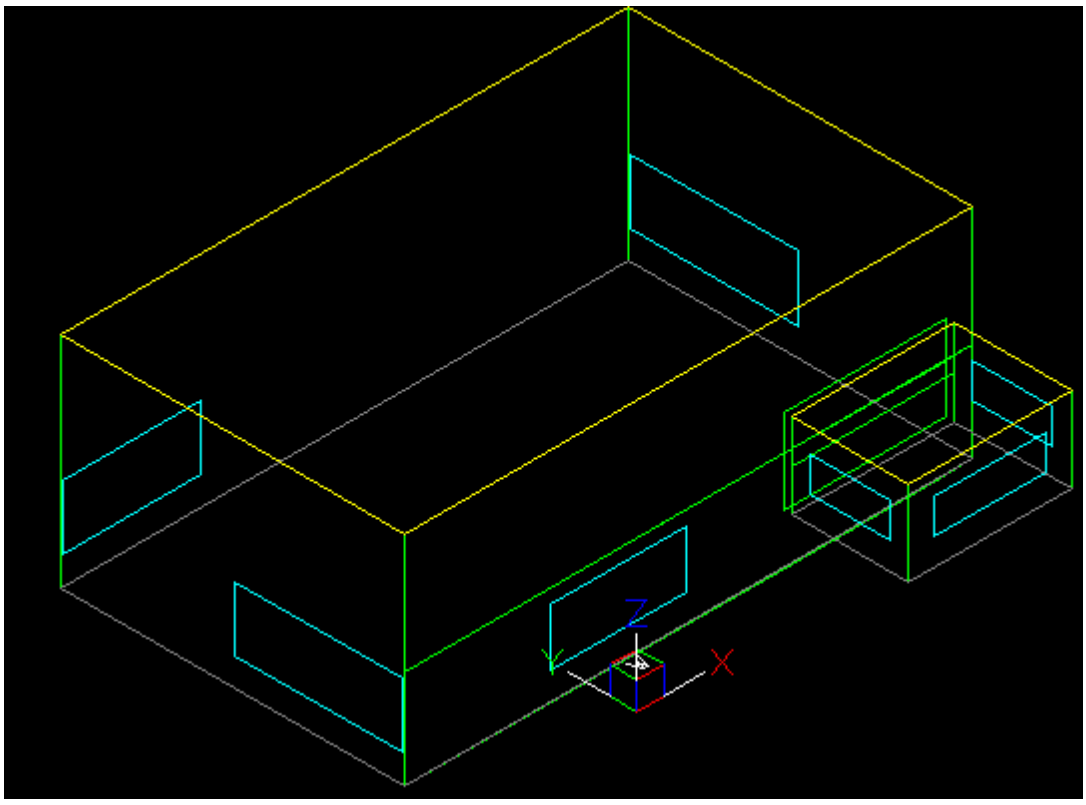


EnergyPlus Model *with* link body edge surfaces - zones are enclosed and the zone volume includes the volume enclosed by the link surfaces and the inter-block partition. This volume is the thickness of the block wall x inter-block partition area).



Equivalent EnergyPlus Model *without* Link body edge surfaces - zones are *not* enclosed and the zone volume excludes the link body (volume enclosed by the link surfaces and the inter-block partition).

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13.7 Calculation of Air Density

The air density is used for calculating the air volumetric flow rate from air mass flows as part of the loads calculation procedure.

The method used in DesignBuilder is the same as that in EnergyPlus for consistency. Air is assumed to be dry and at 20°C. The site elevation is used to calculate standard atmospheric pressure using the equation for 'standard atmospheric' pressure on p 6.1 of the ASHRAE 1997 HOF.

```
Density = P / (R * T)
```

Where:

`R` is the Gas constant = 287.05 J/kg-K
`T` is the temperature in K. Air is assumed to be at 20°C so, T = (20 + 273.15)
`P` is standard pressure:

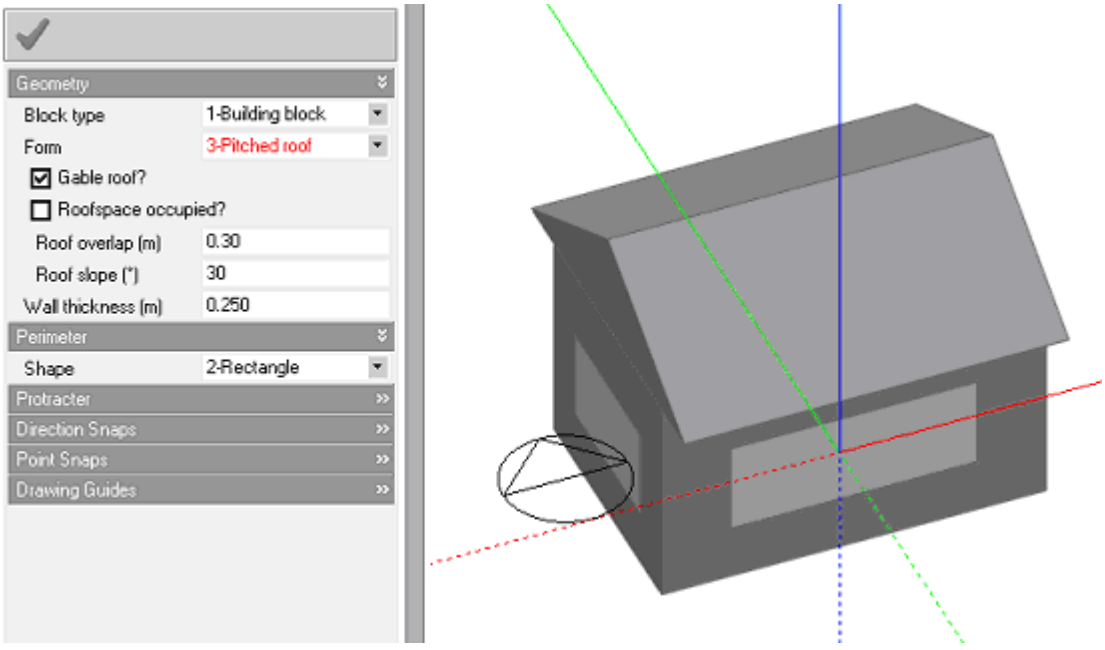
$$P = 101325 \times (1.0 - Z \times 0.0000225577)^{5.2559}$$

where:

`Z` = Elevation above sea level (m)

13.8 Pitched Roof Geometry - Technical Description

This page describes DesignBuilder pitched roof geometry generation with reference an example roof created by drawing a rectangular perimeter with an offset of 0.3m and an external wall thickness of 0.25m:



Roof perimeter blocks are created behind the scenes by first generating a conventional plan extrusion using the current external wall thickness and then generating the roof inner profile topology from the resulting block outer perimeter:

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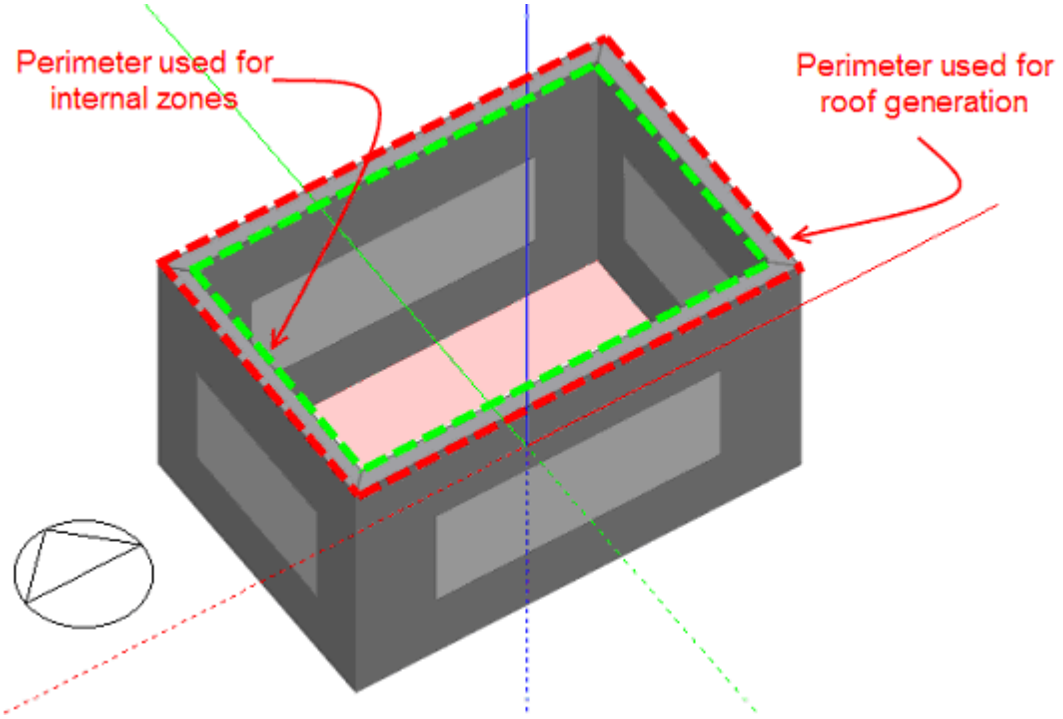
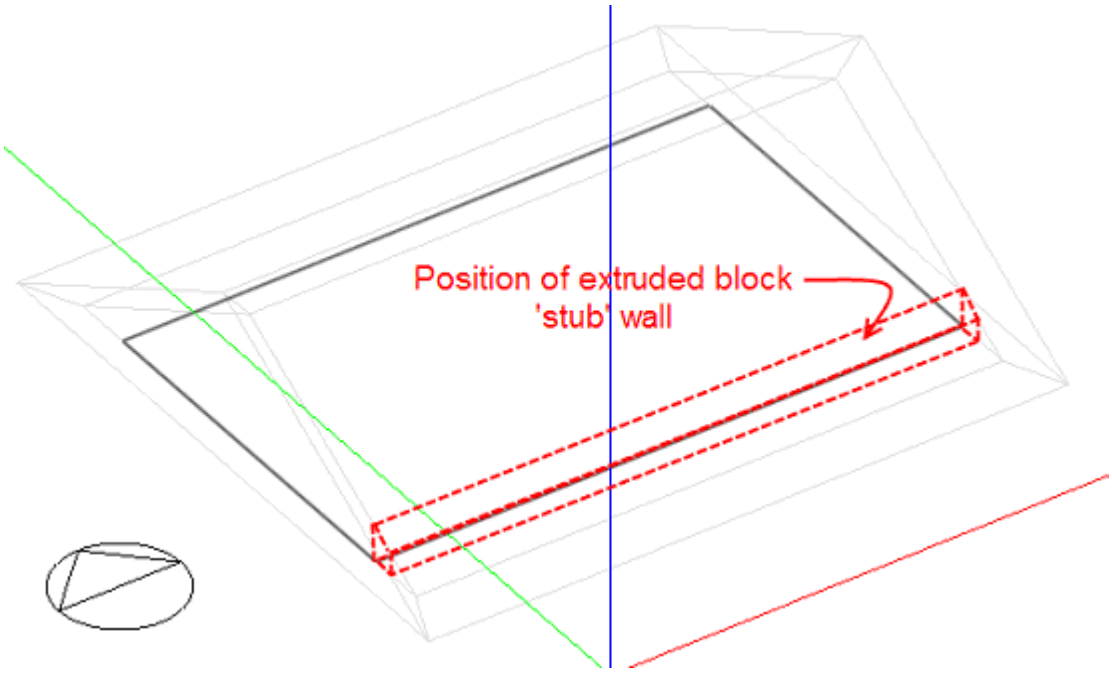


The roof geometry is created as if a stub wall existed from the original extrusion, cut to fit within the roof space and on top of which the roof assembly sits:



The resulting roof block is composed of a polyhedron representing the inner zone, which is created from the original inner block perimeter and is cut to fit within the roof space and a number of slabs that represent the actual roof construction. The roof slabs are generated from the inner roof profile and an outer profile created using the roof construction thickness.

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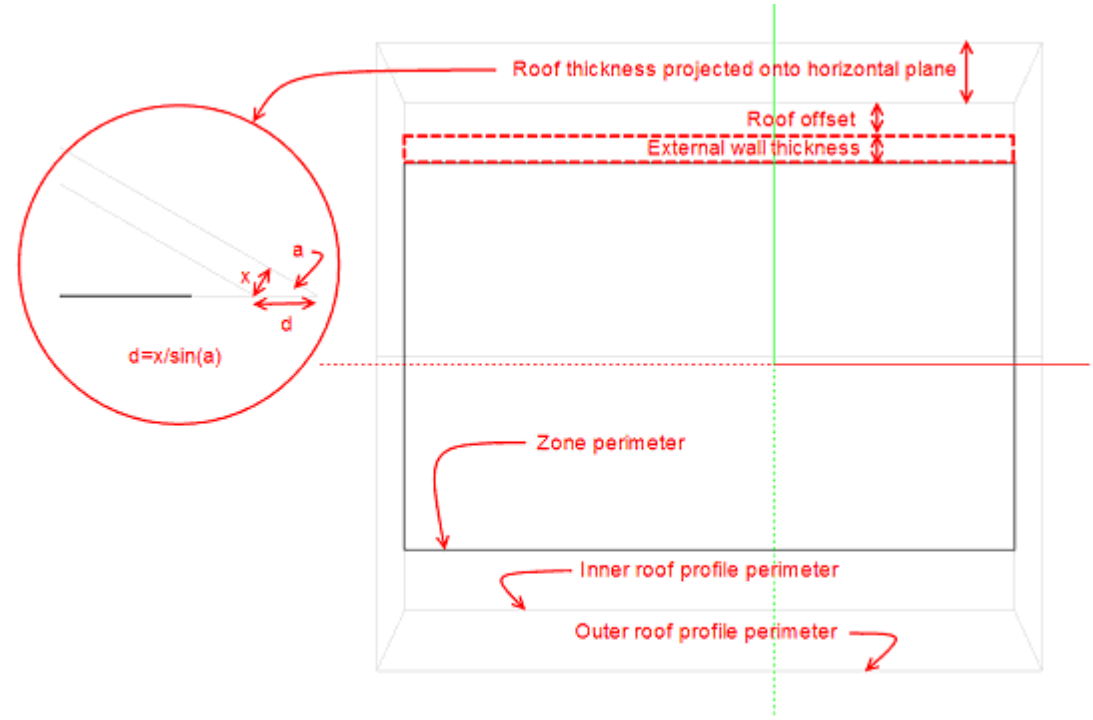

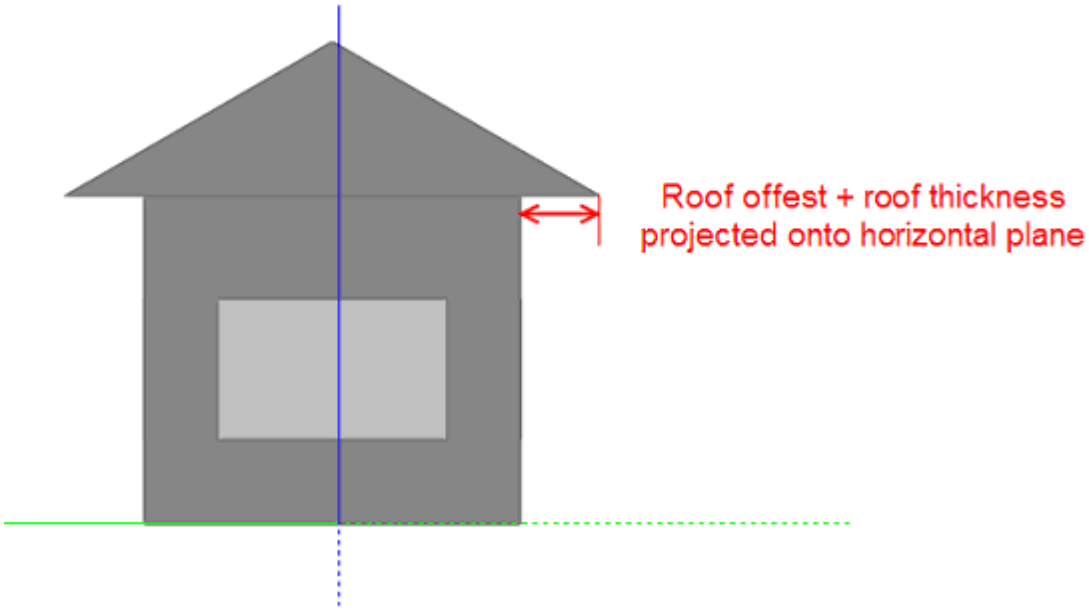

EnergyPlus model

DesignBuilder automatically generates overhangs for Pitched roof block types using EnergyPlus shading devices. The diagram below shows EnergyPlus DXF output of the building model generated using the above data. It shows the overhangs in grey.

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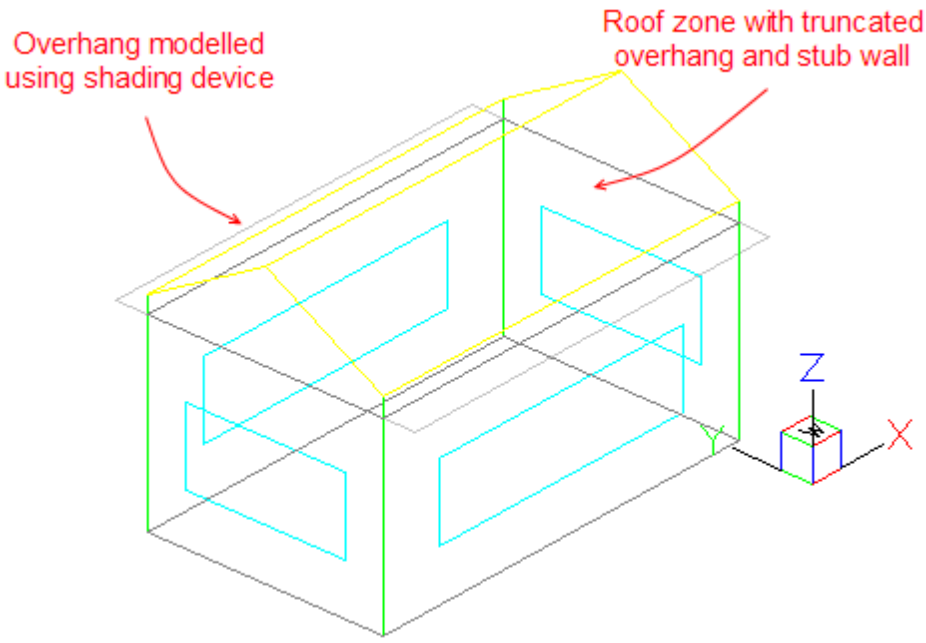

13.9 Triangulation

***** STARTING WITH VERSION 1.2 DESIGNBUILDER OPTIMISES FOR TRIANGULATION SO THE ADVICE BELOW SHOULD NOT APPLY IN MOST CASES *****

Triangulation is the process of breaking up polygons of complex shape into simple triangles which can be easily be manipulated by computers. This is routinely done behind the scenes in DesignBuilder for generating optimal surfaces in the OpenGL display routines, but is also sometimes necessary when generating EnergyPlus surfaces.

There is an option on the Advanced tab of the Model Options dialog which allows triangulation to be switched on/off explicitly. You should leave this switched off as it is intended for developer testing, but if you do switch it on all surface polygons (apart from triangular and rectangular ones) are triangulated.

You should however be aware of some situations requiring EnergyPlus surfaces to be triangulated even when this option is switched off:

1. When two blocks are adjacent and one of the adjacent faces is larger than the other and has glazing (see EnergyPlus DXF output below). This situation requires triangulation because EnergyPlus cannot handle surfaces with holes. You should try to avoid this situation wherever possible, especially if the surface involved is large or has a large number of windows because the large number of triangulated surfaces can slow simulations significantly

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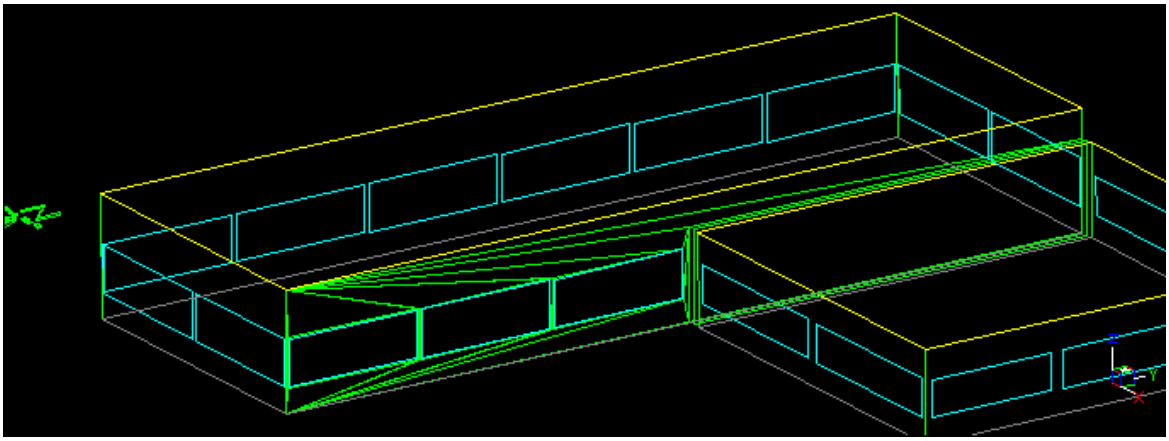
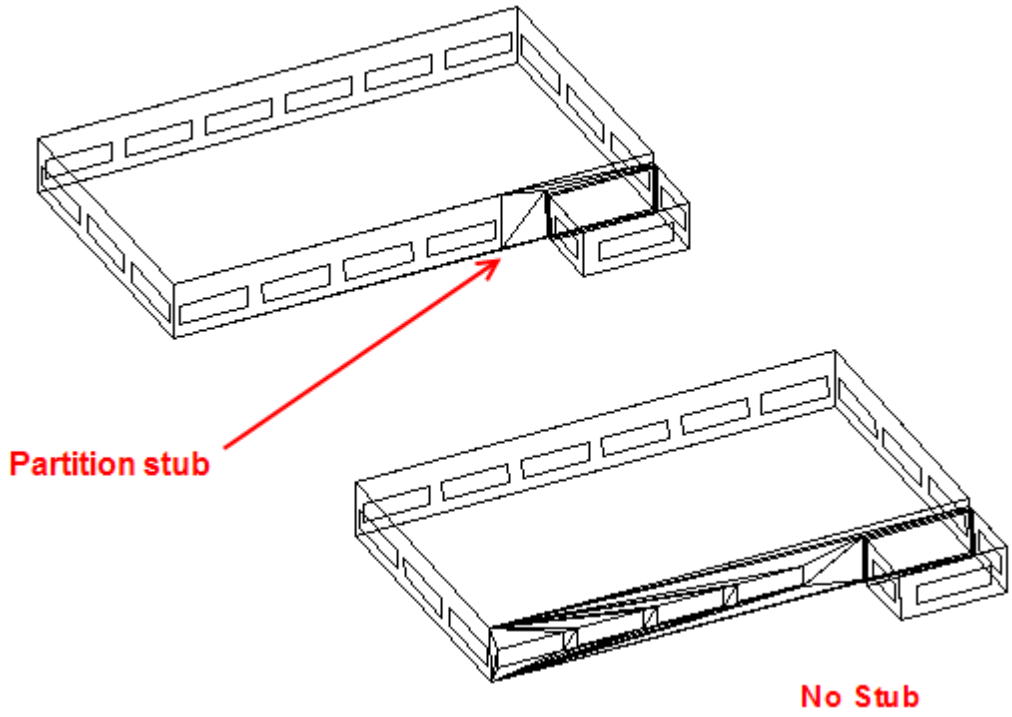


Illustration of triangulation in inter-block connection surfaces

- Windows which are neither triangular nor rectangular must be triangulated to fit with EnergyPlus requirements.
- If a surface, shading surface or opening has more vertices than is allowed from the IDD definition then it must be triangulated.

TIP TO REDUCE NUMBER OF TRIANGLES WHEN TRIANGULATION IS REQUIRED

You can reduce the number of triangles required when a smaller block is placed adjacent to a large one and the larger block has Windows by drawing a partitions stub to separate the block connection area from the window area as shown the diagram below.



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13.10 Calculation of HVAC Energy Consumption

DesignBuilder calculates boiler, chiller, DHW fuel consumption from the loads calculated by EnergyPlus using the CoP data at the building level on the HVAC tab as follows:

Simple HVAC

Boiler energy = *EnergyPlus heating loads* / **Heating system CoP**
Chiller energy = *EnergyPlus cooling loads* / **Cooling system CoP**

Compact HVAC

Boiler energy = (*EnergyPlus heating loads* x Heating distribution loss factor) / **Boiler CoP**
Chiller energy = (*EnergyPlus cooling loads* x Cooling distribution loss factor) / **Chiller CoP**

Where:

Heating distribution loss factor = 1 + (**Heating Distribution Loss**) / 100
Cooling distribution loss factor = 1 + (**Cooling Distribution Loss**) / 100

DHW (Simple and Compact HVAC)

DHW energy (kWh) = **DHW CoP** x 1000 (kg/m3) x 4.187 (KJ/kg-K) x (*EnergyPlus DHW m3 loads*) x (**Delivery water temperature** - **Mains water temperature**)

Where:

DHW CoP is **Heating system CoP** when using '1-Central heating boiler' DHW type

Data shown in **blue** is HVAC model data.
Data shown in *italics* is read from the EnergyPlus results eso file .

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14 EnergyPlus Background Information

EnergyPlus is the U.S. DOE building energy simulation program for modelling building heating, cooling, lighting, ventilating, and other energy flows. It builds on the most popular features and capabilities of BLAST and DOE-2 but also includes many innovative simulation capabilities such as time steps of less than an hour, modular systems and plant integrated with heat balance-based zone simulation, multizone air flow, thermal comfort, and photovoltaic systems.

EnergyPlus is a stand-alone simulation program without a 'user friendly' graphical interface – which is where DesignBuilder comes in. We have integrated EnergyPlus tightly within the DesignBuilder environment to allow you to carry out simulations without any fuss – just define your building model, request data and let the EnergyPlus simulation engine take care of the details.

DesignBuilder has been specifically developed around EnergyPlus allowing most of the EnergyPlus fabric and glazing data to be input. Databases of building materials, constructions, window panes, window gas, glazing units and blinds are provided.

HVAC is modelled using the Compact HVAC descriptions. A range of commonly used HVAC system types can be defined parametrically without the need for complex system layouts. These compact descriptions are automatically expanded behind-the-scenes into full HVAC simulation data sets prior to simulation.

You can use DesignBuilder to generate IDF files and work with these outside DesignBuilder to access system functionality not provided by DesignBuilder.

There is a range of EnergyPlus simulators to choose from including the current DOE executable release, the current DLL release and any interim releases made available by DOE. You can carry out DesignBuilder simulations via EP-Launch.

See also:

- EnergyPlus Program options
- Exporting EnergyPlus IDF Files
- EnergyPlus Version Compatibility
- EnergyPlus IDF Window Dimensions
- Calculation of DesignBuilder Output from EnergyPlus Report Variables
- EnergyPlus Errors and Warnings
- EnergyPlus Daylight Calculations
- EnergyPlus Thermal Comfort
- EnergyPlus Date Definition
- DOE EnergyPlus website
- Simulation Hourly Weather Data
- DesignBuilder Files, Location and Extensions
- Licensing & Activation
- EnergyPlus Documentation
- EnergyPlus Hourly Weather Data

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14.1 Exporting EnergyPlus IDF Files

You can use DesignBuilder to generate EnergyPlus idf files for use in external simulation environments such as EP-Launch. There are 4 alternative procedures for doing this:

1. From the File | Export menu option (*preferred method*).
2. By copying the intermediate in.idf file in the EnergyPlus folder.
3. Tools | Display simulation input script from Simulation or Heating/Cooling design screens.
4. Using the DOE executable EnergyPlus simulation option to open the EP-launch application before simulation.

Note that DesignBuilder will automatically generate compatible IDF files with the target version of EnergyPlus as set on the Program options dialog.

It is important to set the EnergyPlus version you intend to use before exporting the IDF data.

1. File > Export menu option

1. Open your DesignBuilder dsb model file.
2. Make sure you are at building level or below.
3. Click on **File > Export > EnergyPlus IDF file > Simulation**. DesignBuilder will warn you if the currently selected version of EnergyPlus is not a DOE one and give you an opportunity to change it.

2. Copy in.idf in the EnergyPlus folder

An alternative way to generate IDF files is to use the intermediate file in.idf in the EnergyPlus folder which is generated prior to each DesignBuilder EnergyPlus simulation. You should copy this file to a different filename/location before using it.

Important: You should not make any changes to **in.idf** itself because this file will get overwritten before the next DesignBuilder EnergyPlus simulation.

3. Tools > Display menu option

You can view the input data script used to calculate these results by selecting the Tools > Display simulation input script menu option. If you do not have the EnergyPlus IDF editor installed, then you should associate the .idf file extension with a text editor to make this option work.

Note: this shows the script stored with the model just before the simulation *not* the in.idf file stored in the EnergyPlus folder.

4. DOE executable EnergyPlus simulation option

In the Program options dialog you can select an executable EnergyPlus option and set the execution mode to **4-Executable (EP-Launch)**. This gives you some control over the IDF data before the simulation. Any changes made to the IDF data from within EP-Launch will be included in the simulation but will not be retained for future simulations. See Program options > EnergyPlus for more info on this.

Reading ESO results files back into DesignBuilder

Provided you haven't changed the zone and surface names in the IDF data you can read ESO results files generated from your modified data back into DesignBuilder for display and analysis.

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Tip: If you are already familiar with the EnergyPlus data structure you may find it most convenient to edit DesignBuilder IDF data using a text editor as it shows more clearly the comments included to help reference IDF data back to the DesignBuilder model.

14.2 EnergyPlus Version Compatibility

You should ensure that you have the correct version of EnergyPlus set before exporting IDF data for use outside DesignBuilder.

DesignBuilder will automatically generate compatible IDF files with the target version of EnergyPlus as set on the EnergyPlus tab Program options dialog. If you are generating IDF files for simulation outside DesignBuilder you should note that, by default, DesignBuilder targets an internal version of EnergyPlus which has an extended IDD data definition file to allow:

1. Surfaces of up to 330 vertices.
2. Shading surfaces of up to 33 vertices.
3. Up to 400 zones in compact HVAC systems.

So if you attempt to use IDF files generated for internal versions of EnergyPlus in a version of EnergyPlus supplied by DOE, you may find some surface or HVAC data errors related to the above changes. To avoid this situation you should either:

1. Explicitly target your DOE EnergyPlus installation by making the appropriate setting on the Program options dialog (preferred option), or
2. Carry the DesignBuilder IDD extensions over to your standalone version of EnergyPlus by copying Energy+.idd from the DesignBuilder EnergyPlus folder (use the File > Folder > EnergyPlus folder menu command) to your standalone EnergyPlus folder (e.g. C:\EnergyPlusV2-0-0).

14.3 EnergyPlus IDF Window Dimensions

The window dimensions supplied to EnergyPlus are the total opening size (window size including the frame), but deflated by an amount equal to the width of the window frame. The deflation is required because EnergyPlus expects window dimensions *excluding* the frame whereas DesignBuilder openings *include* the frame. DesignBuilder takes this approach because it is usually more convenient to enter the size of the opening in the fabric.

The default window areas generated by DB should correspond with the Window to wall % (WWR) setting on the Openings tab , provided you are using either **Continuous horizontal** or **Preferred height** facade types.

Tip: switching off frames on the Openings tab causes EnergyPlus windows of the expected dimensions to be generated given the simplistic 'window area divided by total wall area' calculation.

14.4 Calculation of DesignBuilder Output from EnergyPlus Report Variables

At the end of an EnergyPlus simulation DesignBuilder reads the EnergyPlus output file eplusout.eso. The format of this file is described in EnergyPlus documentation. The table below explains how the raw EnergyPlus output is processed to create DesignBuilder output. The **Environmental/Comfort Output** column refers to the data shown in DesignBuilder output screens. EnergyPlus Report variable column data shows report variable names with the units in square brackets. The units should be omitted when using the

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report variables in IDF data. The **Area** column indicates the zone, surface, component etc.

Environmental/ Comfort Output	EnergyPlus Report Variable	Area	Notes*
Internal air temperature	Zone Mean Air Temperature [C]	ZoneId	
Internal radiant temperature	Zone Mean Radiant Temperature [C]	ZoneId	
Internal operative temperature		ZoneId	0.5 x (Zone Mean Air Temperature + Zone Mean Radiant Temperature)
Relative Humidity	Zone Air Relative Humidity [%]	ZoneId	
Fanger PMV	FangerPMV	PEOPLE ZoneId	
Pierce PMV ET	PiercePMVET	PEOPLE ZoneId	
Pierce PMV SET	PiercePMVSET	PEOPLE ZoneId	
Pierce Discomfort Index (DISC)	PierceDISC	PEOPLE ZoneId	
Pierce Thermal Sens. Index (TSENS)	PierceTSENS	PEOPLE ZoneId	
Kansas Uni TSV	KsuTSV	PEOPLE ZoneId	
Discomfort hrs (summer clothing)	Time Not Comfortable Summer Clothes [hr]	PEOPLE ZoneId	
Discomfort hrs (winter clothing)	Time Not Comfortable Winter Clothes [hr]	PEOPLE ZoneId	
Discomfort hrs (all clothing)	Time Not Comfortable Summer or Winter Clothes [hr]	PEOPLE ZoneId	
Fabric and ventilation			
Glazing heat gain	Window Heat Gain [W] - Window Heat Loss [W] - Window Transmitted Solar [W]	SurfaceId	Window Transmitted Solar is subtracted so that Glazing heat gain represents the transfer of all heat through the window *excluding beam and diffuse short-wave solar heat* effects.
Walls, Roofs, Ceilings (int), Floors (int), Floors (ext), Ground floors, Partitions (int), Doors and vents	Opaque Surface Inside Face Conduction [W]	SurfaceId	
External infiltration	Zone Infiltration Sensible Heat Loss [J] + Zone Infiltration Sensible Heat Gain [J]	ZoneId	Scheduled Natural ventilation only
External natural ventilation	Zone Ventilation Sensible Heat Gain [J] + Zone Ventilation Sensible Heat	ZoneId	Scheduled Natural ventilation only

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	Loss [J]		
External mechanical ventilation	Zone Ventilation Sensible Heat Gain [J] + Zone Ventilation Sensible Heat Loss [J]	ZoneId	Scheduled Natural ventilation only
Internal Air	AirflowNetwork Mixing Sensible Loss Rate [W] + AirflowNetwork Mixing Sensible Gain Rate [W]	ZoneId	Calculated Natural ventilation only
External Air	AirflowNetwork Infiltration Sensible Loss Rate [W]+ AirflowNetwork Infiltration Sensible Gain Rate [W]	ZoneId	Calculated Natural ventilation only
Airflow			
Mech Vent + Nat Vent + Infiltration	Zone Mechanical Ventilation Air Change Rate [ach]	ZoneId	Summed across blocks and building using volume-weighted average
Mech Vent + Nat Vent + Infiltration	Zone Ventilation Air Change Rate [ach]	ZoneId	Summed across blocks and building using volume-weighted average
Mech Vent + Nat Vent + Infiltration	Zone Infiltration Air Change Rate [ach]	ZoneId	Summed across blocks and building using volume-weighted average
Internal Gains			
Task lighting gains	ELECTRIC EQUIPMENT#ZoneId#TaskLights* [J]	-	
General lighting gains	ELECTRIC EQUIPMENT#ZoneId#GeneralLights* [J]	-	The 'GeneralLights' ELECTRIC EQUIPMENT EnergyPlus output is a lighting *fuel* consumption and is summed to give the Lighting fuel consumption (below). The gain to the zone is calculated from this in each zone by multiplying by (1 - Return air fraction).
Miscellaneous gains	ELECTRIC EQUIPMENT#ZoneId#02: InteriorEquipment* [J]	-	The '02' ELECTRIC EQUIPMENT EnergyPlus output is the miscellaneous internal gains fuel consumption and is summed to give the Room fuel consumption (below). The gain to the zone is calculated from this in each zone by multiplying by (1 - Fraction lost).
Process gains	ELECTRIC	-	The '03' ELECTRIC

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	EQUIPMENT#ZoneId#03: InteriorEquipment* [J]		EQUIPMENT EnergyPlus output is the process internal gains fuel consumption and is summed to give the Room fuel consumption (below). The gain to the zone is calculated from this in each zone by multiplying by (1 - Fraction lost).
Catering gains	ELECTRIC EQUIPMENT#ZoneId#04: InteriorEquipment* [J]	-	The '04' ELECTRIC EQUIPMENT EnergyPlus output is the catering internal gains fuel consumption and is summed to give the Room fuel consumption (below). The gain to the zone is calculated from this in each zone by multiplying by (1 - Fraction lost).
Computer and equipment gains	ELECTRIC EQUIPMENT#ZoneId#05: InteriorEquipment* [J]	-	
Occupancy gains	Zone People Sensible Heat Gain [J]	ZoneId	
Solar Gains Exterior Windows	Zone Transmitted Solar [W]	ZoneId	
Solar Gains Interior Windows	Zone Diff Solar from Interior Windows [W] + Zone Beam Solar from Interior Windows [W]	ZoneId	
Zone/Sys sensible cooling	Zone/Sys Sensible Cooling Rate [W]	ZoneId	Cooling energy to the zone from the HVAC system (not energy consumption)
Zone/Sys sensible heating	Zone/Sys Sensible Heating Rate [W]	ZoneId	Heating energy to the zone from the HVAC system (not energy consumption)
System Heat Flows			
Zone Heating	Total Water Heating Coil Rate [W]	ZoneId REHEAT COIL	VAV/CAV Hot water reheat coils
Zone Heating	Heating Coil Rate [W]	ZoneId REHEAT COIL	VAV/CAV Electric reheat coils
Zone Heating	Heating Coil Rate [W]	ZoneId AHU HEATING COIL	Unitary single zone
Zone Heating	Total Water Heating Coil Rate [W]	ZoneId HEATING COIL	Fan coil
Preheat	Heating Coil Rate [W]	AHU PREHEAT COIL	VAV/CAV Gas/Electric preheat coils
AHU Heating	Total Water Heating Coil Rate [W]	AHU HEATING COIL	VAV/CAV Hot water coils
AHU Heating	Heating Coil Rate [W]	AHU HEATING COIL	VAV/CAV with Gas/ Electric AHU heating coils and Unitary multizone

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Total Cooling	Purchased Air Total Cooling Rate [W]	ZONE ZoneId PURCHASED AIR	Simple HVAC convective and ASHRAE Cooling design
Total Cooling	Total Water Cooling Coil Rate [W]	AHU COOLING COIL	VAV/CAV with Chilled water coils
Total Cooling	DX Coil Total Cooling Rate [W]	AHU COOLING COIL	Unitary Multizone
Total Cooling	DX Coil Total Cooling Rate [W]	ZoneId AHU COOLING COIL	Unitary single zone
Total Cooling	Total Water Cooling Coil Rate [W]	ZoneId COOLING COIL	Fan coil
Sensible Cooling	Purchased Air Sensible Cooling Rate [W]	ZONE ZoneId PURCHASED AIR	Simple HVAC convective and ASHRAE Cooling design
Sensible Cooling	Sensible Water Cooling Coil Rate [W]	AHU COOLING COIL	VAV/CAV with Chiller water
Sensible Cooling	DX Coil Sensible Cooling Rate [W]	AHU COOLING COIL	Unitary multizone
Sensible Cooling	DX Coil Sensible Cooling Rate [W]	ZoneId AHU COOLING COIL	Unitary single zone
Sensible Cooling	Sensible Water Cooling Coil Rate [W]	ZoneId COOLING COIL	Fan coil
Fuel breakdown (building level)			
Heat generator		Compact HVAC	The fuel consumption for each heating load is calculated based on the efficiency of the heat generation and distribution loss: Heat generator fuel = (Heating Load x Heating distribution loss factor) / Heat generator CoP Where: Heating distribution loss factor = 1 + (Heating Distribution Loss) / 100 **Note 1:** distribution loss is 0 for direct electric and gas heating coils. **Note 2:** CoP for direct gas coils is assumed to be 0.8 and direct electric coils 1.0.
Heat generator		Simple HVAC	Heat generator fuel = Heating load / Heating system CoP

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			Note: the Heating system CoP is defined separately for each zone.
Chiller		Compact HVAC	The fuel consumption for each cooling load is calculated based on the efficiency of the chiller and distribution loss: Chiller fuel = (Cooling Load x Cooling distribution loss factor) / Chiller CoP Where: Cooling distribution loss factor = 1 + (Cooling Distribution Loss) / 100
Chiller		Simple HVAC	Chiller fuel = Cooling load / Cooling system CoP **Note:** the Cooling system CoP is defined separately for each zone.
System fan	Fan Electric Consumption [J]	AHU SUPPLY FAN	VAV/CAV with Chiller water, Unitary multizone
System fan	Fan Electric Consumption [J]	ZoneId AHU SUPPLY FAN	Unitary single zone
System fan	Fan Electric Consumption [J]	ZoneId SUPPLY FAN	Fan coil
System pumps	Pump Electric Consumption [J]	HOT WATER LOOP HW SUPPLY PUMP + CHILLED WATER LOOP CHW SUPPLY PUMP + CHILLED WATER LOOP CNDW SUPPLY PUMP	
DHW	Domestic Hot Water Consumption [m3]	ZoneId DHW 1	DHW energy (kWh) = 1000 (kg/m3) x 4.187 (KJ/kg-K) x (Domestic Hot Water Consumption [m3]) x (Delivery water temperature - Mains water temperature) / DHW CoP Where: DHW CoP is Heat generator CoP when using 1-Central heating boiler DHW type.
Preheat energy			(Preheat Heating Coil Rate + Distr loss if appropriate) / Preheat CoP
Lighting			

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Room electricity			
Room gas			
Room oil			
Room solid			
Room bottled gas			
Room other			
Fuel totals (building level)			
Electricity			1-Electricity from grid
Gas			2-Natural gas
Oil			3-Oil
Solid			4-Coal + 7-Anthracite + 8-Smokeless fuel (including coke)
Bottled gas			5-LPG + 6-Biogas
Other fuel consumption			9-Dual fuel appliances (mineral + wood) + 10-Biomass + 11-Waste heat
CO2 production (building level)			
CO2			Calculated from Fuel totals above using locally published CO2 emission factors from the Emissions tab on the Legislative regions dialog accessed from the Site level on the Regions model data tab.
Site Weather data			
Outside dry-bulb temperature	Outdoor Dry Bulb	*Simulation*: Direct from EPW - spot value, *Cooling design*: Outdoor Dry Bulb - spot value.	For Cooling design, value is initialised from user input before calculation is run but is updated with E+ value after the calculation.
Outside dew-point temperature	Outdoor Dew Point	*Simulation:* Direct from EPW - spot value, *Cooling design*: Outdoor Dew Point - spot value.	
Direct normal solar	Direct Solar	*Simulation*: Direct from EPW - preceding hour, *Cooling design:* Direct Solar - preceding hour.	
Diffuse horizontal solar	Diffuse Solar	*Simulation:* Direct from EPW - preceding hour, *Cooling design*: Diffuse Solar - preceding hour.	

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Wind speed	Wind Speed	*Simulation:* Direct from EPW - spot value, *Cooling design:* Wind Speed - preceding hour.	
Wind direction	Wind Direction	*Simulation:* Direct from EPW - spot value, *Cooling design:* Assumed wind is from North.	
Atmospheric pressure	Outdoor Barometric Pressure	*Simulation:* Direct from EPW - spot value, *Cooling design:*Outdoor Barometric Pressure - preceding hour.	Estimated from elevation before cooling design calc is run but E+ value used after calculation.
Solar altitude	Solar Altitude Angle	*Simulation*: Calculated - spot value, *Cooling design:*Solar Altitude Angle - preceding hour.	For Cooling design, solar positions are initialised with calculated values before calculation is run but are updated with E+ values after the calculation. Calculated simulation data is based on 'spot values' on the hour so in this case the value for 12:00 is the value exactly at midday.
Solar azimuth	Solar Azimuth Angle	*Simulation:* Calculated - spot value, *Cooling design:*Solar Azimuth Angle - preceding hour.	

* Variables shown in green represent EnergyPlus output.
'Direct from EPW' means that the values in the hourly weather file itself are displayed.
EnergyPlus hourly output always represents totals and averages over the preceding hour so data for 12:00 is for the period 11:01 to 12:00.

14.5 EnergyPlus Errors and Warnings

A file eplusout.err is generated following each EnergyPlus simulation in the EnergyPlus folder. It may contain three levels of errors (Warning, Severe, Fatal) as well as the possibility of just message lines. These errors may be duplicated in other files (such as the standard output file) and are described more completely in the EnergyPlus Output Details and Examples documents.

ERRORS

1
```
** Severe  ** Did not find "Until:  22:00" in list of Objects
```

You may have entered a semi-colon character (;) at the end of one of the lines in a Compact schedule when you meant to enter a comma (,).

2
```
** Severe  ** Problem in interior solar distribution calculation (CHKBKS)
**   ~~~   **    Solar Distribution = FullInteriorExterior will not work in
```

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```
Zone=78474
**   ~~~   **    because vertex 3 of back surface=W_73536_2_0_0 is in front
of receiving surface=W_78474_3_0_0
**   ~~~   **    (Dot Product indicator=1.4966)
**   ~~~   **    Check surface geometry; if OK, use Solar Distribution =
FullExterior instead.
```

The 3-Full interior and exterior solar distribution option is selected but one or more zone in the model is non-convex. Note that DesignBuilder is configured by default to check for this condition and provides more friendly error messages.

3
```
** Severe ** For Purchased Air ZONE 21438 PURCHASED AIR serving Zone 21438
** ~~~ ** ..the supply air temperature for cooling [10.00] is greater than
the zone cooling setpoint [8.99].
```

This severe error can occur when using Simple HVAC, or Cooling design calculations with Operative control in zones with strong radiant heat gains causing high radiant temperatures (e.g. un-insulated roof or zone is highly glazed). The supply air temperature is fixed (to 10°C in the above example) but the zone air temperature must be cooled lower than this (8.99°C in the above example) to give the required operative setpoint (.e.g. 24 °C). Operative temperature, T_{op}, is calculated as:

$$T_{op} = 0.5 \times (T_a + T_r)$$

where:

T_{op} is the operative temperature.
T_s is the air supply temperature.
T_a is the zone air temperature (T_a must be > T_s).
T_r is the zone radiant temperature.

So there is a requirement:

$$T_{r\ max} <= 2\ T_{op} - T_s$$

If the zone radiant temperature is higher than $T_{r\ max}$ and Operative temperature control is used then this severe error will occur.
The solution may be to use Air temperature control and to reduce the radiant temperatures using solar shading/insulation as appropriate.

See the discussion on Operative temperature control under Calculation options for more on this.

4
```
** Severe  ** Problem in interior solar distribution calculation (CHKBKS)
   **   ~~~   **    Solar Distribution = FullInteriorExterior will not work
in Zone=42272
   **   ~~~   **    because vertex 6 of back surface=F_42272_10106_0_10277
is in front of receiving surface=W_42272_9_0_0
   **   ~~~   **    (Dot Product indicator=7.3314)
   **   ~~~   **    Check surface geometry; if OK, use Solar Distribution =
FullExterior instead.
```

One or more zones is non-convex which makes the model incompatible with the 3-Full interior and exterior solar distribution algorithm. This error can also lead to temperature out of bounds errors.

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```
5 ** Severe  ** Temperature out of bounds (637.89) for surface=W_43311_4_0_0
   **   ~~~   ** in Zone=43276
   **   ~~~   **  Occurrence info=BRUSSELS - BEL IWEC DATA WMO#=064510,
01/04 13:30 - 13:32
   **   ~~~   ** A temperature out of bounds problem can be caused by
several things.  The user
   **   ~~~   ** should check the weather environment, the level of internal
gains with respect
   **   ~~~   ** to the zone, and the thermal properties of their materials
among other things.
   **   ~~~   ** A common cause is a building with no thermal mass -- all
materials with
   **   ~~~   ** Regular-R definitions.
```

A temperature of a surface has become too high, during the simulation. Possible causes are:

1. Highly glazed zone with a small floor or other surface area (e.g. double facade cavity zone floor, solar chimney solar floor).
2. Some form of geometric error in the simulation, sometimes related to unrealistic amounts of solar radiation falling on small surfaces.
3. Use of the finite-difference solution method.
4. Very high/low heating/cooling setpoint temperature.

WARNINGS

```
** Warning ** GetHTSubSurfaceData: A Multiplier > 1.0 for window/glass door
1 W_67_4_0_0_0_0
**   ~~~   ** in conjunction with SolarDistribution = FullExterior or
FullInteriorExterior
**   ~~~   ** can cause inaccurate shadowing on the window and/or
**   ~~~   ** inaccurate interior solar distribution from the window.
```

The Lump similar windows on surface model option has been selected which causes DesignBuilder to use the EnergyPlus Window Multiplier option to speed up simulations. The message is warning that the Window Multiplier option, when used in conjunction with the Full exterior or Full interior and exterior calculation options can lead to inaccurate distributions of solar radiation around the room.

```
** Warning ** GetSurfaceData:The total number of floors, walls, roofs and
2 internal mass surfaces in Zone 59
**   ~~~   ** is < 6. This may cause an inaccurate zone heat balance
calculation.
```

This warning is often generated for pitched roofs and for interior zones separated by virtual partitions and can safely be ignored.

```
** Warning ** GetGroundTemps: Some values for "GroundTemperatures" fall
3 outside the range of 15-25C.
**   ~~~   ** These values may be inappropriate.  Please consult the Input
Output Reference for more details.
```

The default ground temperatures used in DesignBuilder is 14degC. This may be inappropriate in some cases and EnergyPlus is warning about this. You should take care to enter realistic ground temperatures bearing in mind the advice given in the Ground Modelling section.

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```
** Warning ** DXFOut: Could not triangulate surface="W_7469_0_0_1",
type="Wall", check surface vertex order(entry)
```

Caused by a minor bug in EnergyPlus when creating a DXF representation of the model - it is not always able to fully triangulate all surfaces and generate a full set of surfaces. You can ignore the message for the purposes of simulation results.

```
** Warning ** Base surface does not surround subsurface (CHKSBS), Overlap
Status=No-Overlap
**   ~~~   **   The base surround errors occurred 3 times.
**   ~~~   ** Surface "W_7376_3_0_0" misses SubSurface "W_7376_3_0_0_0_0"
```

These warnings are usually a reporting bug in EnergyPlus v.2.0 and earlier.

```
** Warning ** Calculated design cooling/heating load for zone=78474 is zero.
**   ~~~   ** Check ZONE SIZING and ZONE CONTROL:THERMOSTATIC inputs.
```

Cooling/heating may have been switched off in this zone or there is no cooling/heating load (i.e. the zone does not require any cooling/heating).

```
For a zone sizing run, there must be at least 1 Zone Sizing object input.
```

Can usually be ignored.

```
 ** Severe  ** CAUTION -- Interzone surfaces are usually in different zones
   **   ~~~   ** Surface=F_59604_10071_0_10046, Zone=59604
   **   ~~~   ** Surface=C_72917_1_0_0, Zone=59604
```

This warning can be safely ignored. These messages can be prevented by switching on the Surfaces within zone treated as adiabatic option in Simulation Advanced Calculation Options

14.6 EnergyPlus Daylight Calculations

The EnergyPlus daylighting model, in conjunction with the thermal analysis, determines the energy impact of daylighting strategies based on analysis of daylight availability, site conditions, window management in response to solar gain and glare, and various lighting control strategies.

The daylighting calculations are carried out during the simulation in 3 main steps:

1. Daylight factors, which are ratios of interior illuminance or luminance to exterior horizontal illuminance, are calculated and stored. The user specifies the coordinates of one or two reference points in each daylit zone. EnergyPlus then integrates over the area of each exterior window in the zone to obtain the contribution of direct light from the window to the illuminance at the reference points, and the contribution of light that reflects from the walls, floor and ceiling before reaching the reference points. Window luminance and window background luminance, which are used to determine glare, are also calculated. Taken into account are such factors as sky luminance distribution, window

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size and orientation, glazing transmittance, inside surface reflectances, sun control devices such as movable window shades, and external obstructions. Dividing daylight illuminance or luminance by exterior illuminance yields daylight factors. These factors are calculated for the hourly sun positions on sun-paths for representative days of the run period.

2. A daylighting calculation is performed each heat-balance time step when the sun is up. In this calculation the illuminance at the reference points in each zone is found by interpolating the stored daylight factors using the current time step's sun position and sky condition, then multiplying by the exterior horizontal illuminance. If glare control has been specified, the program will automatically deploy window shading, if available, to decrease glare below a specified comfort level. A similar option uses window shades to automatically control solar gain.
3. The electric lighting control system is simulated to determine the lighting energy needed to make up the difference between the daylighting illuminance level and the design illuminance. Finally, the zone lighting electric reduction factor is passed to the thermal calculation, which uses this factor to reduce the heat gain from lights. The EnergyPlus daylighting calculation is derived from the daylighting calculation in DOE-2.1E, which is described in [Winkelmann, 1983] and [Winkelmann and Selkowitz, 1985]. There are two major differences between the two implementations: (1) In EnergyPlus daylight factors are calculated for four different sky types—clear, clear turbid, intermediate, and overcast; in DOE-2 only two sky types are used—clear and overcast. (2) In EnergyPlus the clear-sky daylight factors are calculated for hourly sun-path sun positions several times a year whereas in DOE-2 these daylight factors are calculated for a set of 20 sun positions that span the annual range of sun positions for a given geographical location.

14.7 EnergyPlus Thermal Comfort

The integration of a sophisticated building thermal analysis tool with thermal comfort models will allow us to perform an energy analysis on a zone and simultaneously determine if the environmental control strategy will be sufficient for the occupants to be thermally comfortable. This chapter is intended to provide background on thermal comfort, present an overview of state of the art thermal comfort models and present the mathematical models that have been incorporated into Energy Plus.

Background on Thermal Comfort Models

Throughout the last few decades, researchers have been exploring the thermal, physiological and psychological response of people in their environment in order to develop mathematical models to predict these responses. Researchers have empirically debated building occupants' thermal responses to the combined thermal effect of the personal, environmental and physiological variables that influence the condition of thermal comfort.
There are two personal variables that influence the condition of thermal comfort: the thermal resistance of the clothing (Icl), and the metabolic rate (H/ADu). The thermal resistance of the clothing (Icl) is measured in units of "clo." The 1985 ASHRAE Handbook of Fundamentals (3) suggests multiplying the summation of the individual clothing items clo value by a factor of 0.82 for clothing ensembles.

The environmental variables that influence the conditions of thermal comfort include:

1. Air Temperature (Ta),
2. Mean Radiant Temperature (Tr),
3. Relative air velocity (v),
4. Water vapor pressure in ambient air (Pa)

The Air Temperature (Ta), a direct environmental index, is the dry-bulb temperature of the environment. The Mean Radiant Temperature (Tr) is a rationally derived environmental index defined as the uniform black-body temperature that would result in the same radiant energy exchange as in the actual environment. The Relative air velocity (v) a direct environmental index is a measure of the air motion obtainable via a hot wire or vane anemometers. The Water vapor pressure in ambient air (Pa) is a direct environmental index.

The physiological variables that influence the conditions of thermal comfort include:

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1. Skin Temperature (Tsk),
2. Core or Internal Temperature (Tcr),
3. Sweat Rate,
4. Skin Wettedness (w),
5. Thermal Conductance (K) between the core and skin.

Where the Skin Temperature (Tsk), the Core Temperature (Tcr) and the Sweat Rate are physiological indices. The Skin Wettedness (w) is a rationally derived physiological index defined as the ratio of the actual sweating rate to the maximum rate of sweating that would occur if the skin were completely wet. One more consideration is important in dealing with thermal comfort - the effect of asymmetrical heating or cooling. This could occur when there is a draft or when there is a radiant flux incident on a person (which is what is of primary interest to us here). Fanger (5) noted that the human regulatory system is quite tolerant of asymmetrical radiant flux. A reasonable upper limit on the difference in mean radiant temperature (Tr) from one direction to the opposing direction is 15_ (1). This limit is lower if there is a high air velocity in the zone.

Mathematical Models for Predicting Thermal Comfort

Many researchers have been exploring ways to predict the thermal sensation of people in their environment based on the personal, environmental and physiological variables that influence thermal comfort. From the research done, some mathematical models that simulate occupants' thermal response to their environment have been developed. Most thermal comfort prediction models use a seven or nine point thermal sensation scale, as in the following tables.

Seven point Thermal Sensation Scale:

3 hot
2 warm
1 slightly warm
0 neutral
-1 slightly cool
-2 cool
-3 cold

Nine point Thermal Sensation Scale:

4 very hot
3 hot
2 warm
1 slightly warm
0 neutral
-1 slightly cool
-2 cool
-3 cold
-4 very cold

The most notable models have been developed by P.O. Fanger (the Fanger Comfort Model), the J. B. Pierce Foundation (the Pierce Two-Node Model), and researchers at Kansas State University (the KSU Two-Node Model). Berglund (6) presents a detailed description of the theory behind these three models.

Note: for all Thermal Comfort reporting: Though the published values for thermal comfort “vote” have a discrete scale (e.g. –3 to +3 or –4 to +4), the calculations in EnergyPlus are carried out on a continuous scale and, thus, reporting may be “off the scale” with specific conditions encountered in the space. This is not necessarily an error in EnergyPlus – rather a different approach that does not take the “limits” of the discrete scale values into account.

The main similarity of the three models is that all three apply an energy balance to a person and use the energy exchange mechanisms along with experimentally derived physiological parameters to predict the

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thermal sensation and the physiological response of a person due to their environment. The models differ somewhat in the physiological models that represent the human passive system (heat transfer through and from the body) and the human control system (the neural control of shivering, sweating and skin blood flow). The models also differ in the criteria used to predict thermal sensation.

FANGER COMFORT MODEL

Fanger's Comfort model was the first one developed. It was published first in 1967 (7) and then in 1972 (2), and helped set the stage for the other two models. The mathematical model developed by P.O. Fanger is probably the most well known of the three models and is the easiest to use because it has been put in both chart and graph form.
Description of the model and algorithm

Fanger developed the model based on the research he performed at Kansas State University and the Technical University of Denmark. Fanger used the seven-point form of a thermal sensation scale along with numerous experiments involving human subjects in various environments. He related the subjects in response to the variables, which influence the condition of thermal comfort. Fanger's model is based upon an energy analysis that takes into account all the modes of energy loss (L) from the body, including: the convection and radiant heat loss from the outer surface of the clothing, the heat loss by water vapor diffusion through the skin, the heat loss by evaporation of sweat from the skin surface, the latent and dry respiration heat loss and the heat transfer from the skin to the outer surface of the clothing. The model assumes that the person is thermally at steady state with his environment.

By determining the skin temperature and evaporative sweat rate that a thermally comfortable person would have in a given set of conditions, the model calculates the energy loss (L). Then, using the thermal sensation votes from subjects at KSU and Denmark, a Predicted Mean Vote (PMV) thermal sensation scale is based on how the energy loss (L) deviates from the metabolic rate (M) in the following form:

PIERCE TWO-NODE MODEL

The Pierce Two-Node model was developed at the John B. Pierce Foundation at Yale University. The model has been continually expanding since its first publication in 1970 (8). The most recent version on the model appears in the 1986 ASHRAE Transactions (9).

The Pierce model thermally lumps the human body as two isothermal, concentric compartments, one representing the internal section or core (where all the metabolic heat is assumed to be generated and the skin comprising the other compartment). This allows the passive heat conduction from the core compartment to the skin to be accounted for. The boundary line between two compartments changes with respect to skin blood flow rate per unit skin surface area (SKBF in L/h•m2) and is described by alpha – the fraction of total body mass attributed to the skin compartment (13).
Furthermore, the model takes into account the deviations of the core, skin, and mean body temperature weighted by alpha from their respective set points. Thermoregulatory effector mechanisms (Regulatory sweating, skin blood flow, and shivering) are defined in terms of thermal signals from the core, skin and body (13).

The latest version of the Pierce model (15) discusses the concepts of SET* and ET*. The Pierce model converts the actual environment into a "standard environment" at a Standard Effective Temperature, SET*. SET* is the dry-bulb temperature of a hypothetical environment at 50% relative humidity for subjects wearing clothing that would be standard for the given activity in the real environment. Furthermore, in this standard environment, the same physiological strain, i.e. the same skin temperature and skin wettedness and heat loss to the environment, would exist as in the real environment. The Pierce model also converts the actual environment into a environment at an Effective Temperature, ET*, that is the dry-bulb temperature of a hypothetical environment at 50% relative humidity and uniform temperature (Ta = MRT) where the subjects would experience the same physiological strain as in the real environment.

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In the latest version of the model it is suggested that the classical Fanged PMV be modified by using ET* or SET* instead of the operative temperature. This gives a new index PMV* which is proposed for dry or humid environments. It is also suggested that PMV* is very responsive to the changes in vapor permeation efficiency of the occupants clothing.
Besides PMV*, the Pierce Two Node Model uses the indices TSENS and DISC as predictors of thermal comfort. Where TSENS is the classical index used by the Pierce foundation, and is a function of the mean body temperature. DISC is defined as the relative thermoregulatory strain that is needed to bring about a state of comfort and thermal equilibrium. DISC is a function of the heat stress and heat strain in hot environments and equal to TSENS in cold environments. In summary, the Pierce Model, for our purposes, uses four thermal comfort indices; PMVET-a function of ET*, PMVSET- a function of SET*, TSENS and DISC.

KSU TWO-NODE MODEL

The KSU two-node model, developed at Kansas State University, was published in 1977 (10). The KSU model is quite similar to that of the Pierce Foundation. The main difference between the two models is that the KSU model predicts thermal sensation (TSV) differently for warm and cold environment.

The KSU two-node model is based on the changes that occur in the thermal conductance between the core and the skin temperature in cold environments, and in warm environments it is based on changes in the skin wettedness. In this model metabolic heat production is generated in the core which exchanges energy with the environment by respiration and the skin exchanges energy by convection and radiation. In addition, body heat is dissipated through evaporation of sweat and/or water vapor diffusion through the skin. These principles are used in following passive system equations.
Here, control signals, based on set point temperatures in the skin and core, are introduced into passive system equations and these equations are integrated numerically for small time increments or small increments in core and skin temperature. The control signals modulate the thermoregulatory mechanism and regulate the peripheral blood flow, the sweat rate, and the increase of metabolic heat by active muscle shivering. The development of the controlling functions of skin conductance (KS), sweat rate (Esw), and shivering (Mshiv) is based on their correlation with the deviations in skin and core temperatures from their set points.
The KSU model's TSV was developed from experimental conditions in all temperature ranges and from clo levels between .05 clo to 0.7 clo and from activities levels of 1 to 6 mets (6).

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14.8 EnergyPlus Date Definition

Field Contents	Interpretation	Example
<Number> / <Number>	Month / Day	12 / 31
<Number> / Month	Day and Month	31 Dec
Month / <Number>	Day and Month	Dec 31
<Number> Weekday in Month	Numbered weekday of month	1st Saturday in April
Last Weekday in Month	Last weekday of month	Last Sunday in October

Notes

Month can be one of:

- January,
- February,
- March,
- April,
- May,
- June,
- July,
- August,
- September,
- October,
- November,
- December.

Abbreviations of the first three characters are also valid.

Weekday can be one of:

- Sunday,
- Monday,
- Tuesday,
- Wednesday,
- Thursday,
- Friday,
- Saturday.

Abbreviations of the first three characters are also valid.

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14.9 EnergyPlus Documentation

You can get the EnergyPlus user guides:

- Getting Started and Overview
- Input/Output Reference
- Output Details and Examples
- Engineering Reference
- Auxiliary Programs

Free from the EnergyPlus website:

http://www.eere.energy.gov/buildings/energyplus/documentation.cfm

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15 Support - Getting Help

If you need information that you could not find in this help file you should **first check the FAQ and Support Forum** on the Website:

http://www.designbuilder.co.uk/support

If this does not give you the information you need you can send us a support request using a Support Request Form and DesignBuilder team will endeavour to answer your question by email.

15.1 Frequently Asked Questions

An up-to-date Knowledgebase is available in the Support section of the DesignBuilder web site.

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