

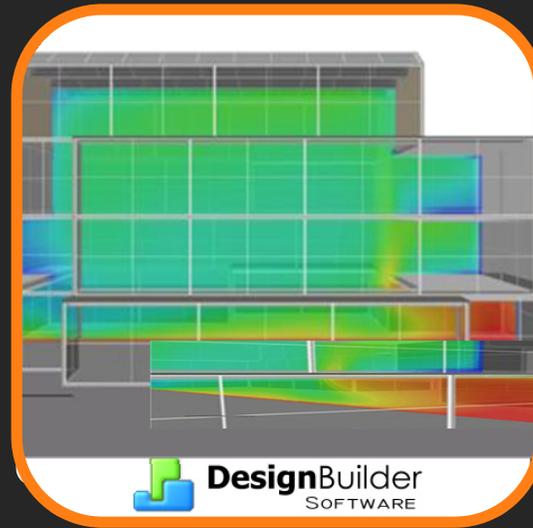
Building Performance Simulation for Designers - Energy
DesignBuilder // EnergyPlus

'Tutorial #3'

Construction Assemblies, Load Reduction & Shading



GEOMETRY



LOADS



RESULTS



Diego Ibarra | Christoph Reinhart
Harvard Graduate School of Design



OVERVIEW

- This document is the third document out of a series of tutorials created as a guide for building energy performance simulation beginners. Its focus audience are designers interested in studying the effect of early design decisions such as orientation, shape and façade layout on the energy efficiency of their projects. Throughout the document we will be using DesignBuilder/ EnergyPlus as our simulation tool.

OVERVIEW

This specific document, 'Tutorial #3 – Constructions Assemblies & Shading Devices', will help you to develop and quantitative understanding of:

- The impact of the envelope's thermal properties on indoor environmental conditions in a non-air conditioned space and in a fully conditioned space;
- The impact of the envelope's thermal properties on energy efficiency of a non-air conditioned space and in a fully conditioned space;
- The value of the reducing internal loads and designing shading devices as a mean to optimize both, the energy efficiency and the indoor environmental conditions of a space;

SET - UP

In case you do not have DesignBuilder already installed on your computer, please refer to the first document of this tutorial series. In that document you will find all the instructions required to set-up DesignBuilder on your computer. Make sure to pay close attention to all the steps and execute them carefully.



| **DesignBuilder™** |

You may download a FREE 30-day evaluation version of the latest DesignBuilder version from the 'DesignBuilder Software' website. This document is based on **DesignBuilder v.1.6.9.0003 BETA** (release date: 09/26/08).

<http://www.designbuilder.co.uk>

INFO

DesignBuilder Software requires you to provide some general information about yourself before you can download the evaluation version. You must be logged in before attempting to download. If you do not have a login and password, you will have to register first.

INDEX

- CONSTRUCTIONS
- OPTIMIZING INTERNAL LOADS
- SHADING DEVICES
- ANALYZE RESULTS

INFO

It is recommended that you work through the four sections in the order provided. Further information can be accessed through **// links /**distributed throughout the text.

CONSTRUCTIONS

The model to be used in this tutorial should be the last model you simulated in 'Tutorial 2 – Load Schedules' i.e. a scene with two shoebox models, one naturally ventilated the other fully conditioned with typical internal gains and built according to IECC standards.

- In this section you will modify the current envelope of your model to optimize its thermal properties for the selected climate (Boston, MA USA).
- You will further learn how to change existing constructions templates and how to create your own assemblies with existing or new materials.

CONSTRUCTIONS

- DesignBuilder uses construction components to model conduction through opaque areas of the building envelope. Constructions can be selected on the Constructions model data tab (below) to define the thermophysical properties of the various internal and external walls, floors, roofs etc 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. You can later modified one by one the assemblies and materials assigned for every surface.

INFO

Always remember that all the data is calculated at the surface level. It is a good-practice to check the model at the surface level before running a simulation to verified that the correct data is being used.

CONSTRUCTIONS

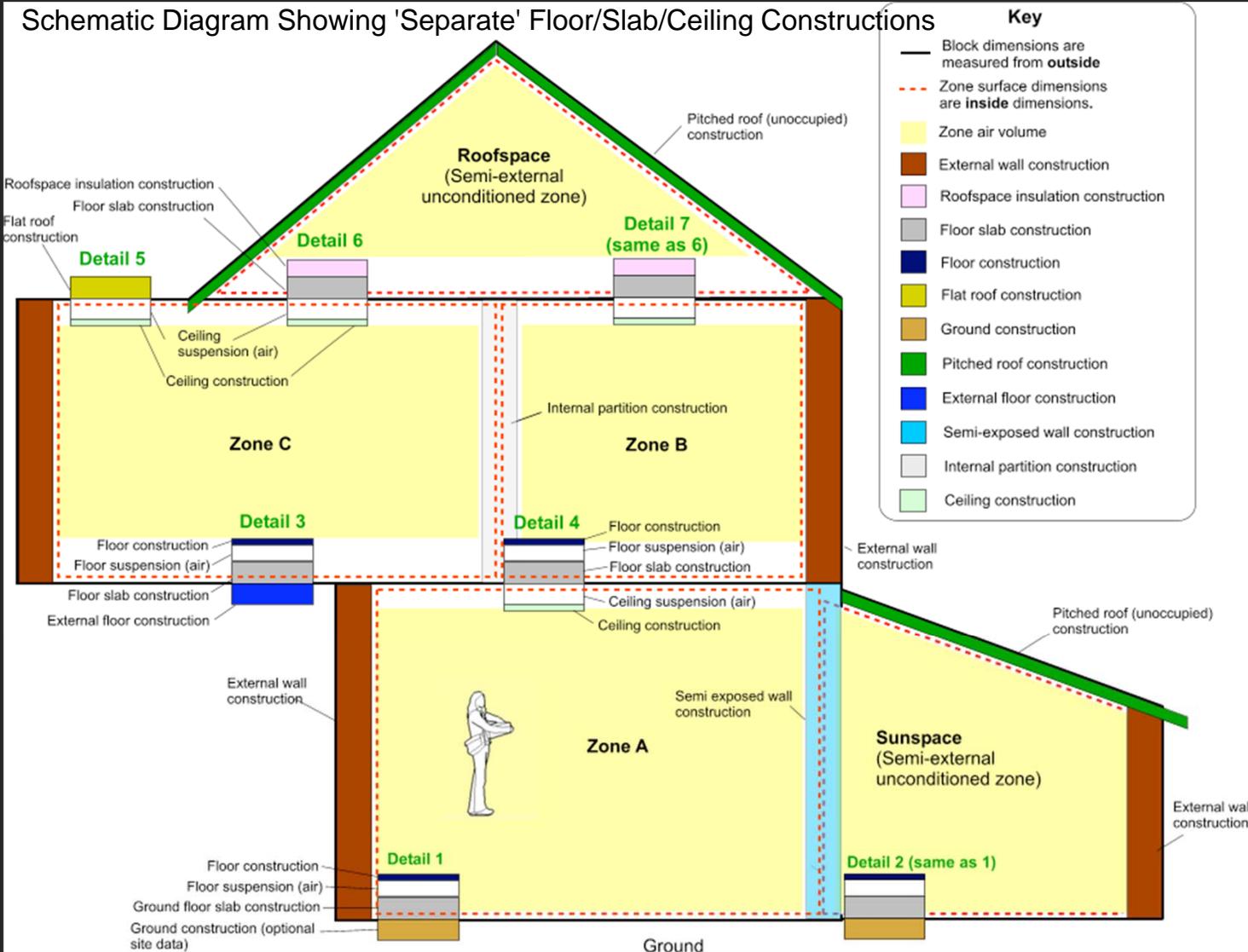
Before we proceed to modified the existing envelope, it is useful to visualize DesignBuilder's denomination of constructions and surfaces.

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 in the following slide.

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 definitions

CONSTRUCTIONS



INFO

CONSTRUCTIONS

- As mentioned earlier, it is important to understand that DesignBuilder's 'Constructions' data only define opaque elements, hence it does not define openings or glazing properties. All the data for defining opening properties and glazing types is located in a different tab, 'openings', and is not altered when changing the current 'construction template'

CONSTRUCTIONS

Selecting a Template

1.

To change the data for the whole 'Constructions' using the heritage properties, go to the "edit" tab go to "Building" level of the Nat Vent space > 'Constructions' > 'Template' and select 'Best practice Medium weight'.

Note that the description of each template can be found in the lower right side of the screen, in the 'Data Report' section.

The most noticeable variation you will see in this case is the 'Airtightness' or infiltration factor for the envelope. (from 0.7 to 0.3)

The screenshot shows the DesignBuilder software interface. The main window displays a list of construction templates for the 'Getting_Started_Tutorial_2_Shoebox_Nat_Vent' project. The 'Template' dropdown is set to 'IECC-1998, Lightweight'. The 'Data Report' section on the right provides detailed information for the selected template.

Category	Item	Description
Construction Templates	Best practice, Lightweight	Best practice, Lightweight
	Best practice, Medium weight	Best practice, Medium weight
	IECC-1998, Heavyweight	IECC-1998, Heavyweight
	IECC-1998, Lightweight	IECC-1998, Lightweight
	IECC-1998, Medium weight	IECC-1998, Medium weight
	IECC-2000, Heavyweight	IECC-2000, Heavyweight
	IECC-2000, Medium weight	IECC-2000, Medium weight
	Uninsulated, Heavyweight	Uninsulated, Heavyweight
	Uninsulated, Lightweight	Uninsulated, Lightweight
	Uninsulated, Medium weight	Uninsulated, Medium weight

Data Report (Not Editable)	
General	
IECC-1998, Medium weight	
Source	Early Design
Category	General
Region	General
Simplified Constructions	
Thermal mass	1
Insulation	1
Walls	
External	IECC-1998 Wall, M
Internal	Lightweight 2 x 25
Semi-exposed	IECC-1998 Semi-ex
Sub surfaces	
External wall sub surface	100mm concrete sl
Internal wall sub surface	100mm concrete sl
Separate Floors/Slabs/Ceilings	
Flat roofs	IECC-1998 Flat roof
Ceilings	
Fitted?	Yes
Ceiling	10mm Ceiling tiles
Suspension height	0.2
Floors	

CONSTRUCTIONS

Selecting a Template

2.

One can now review the properties for each construction element type by clicking in the selected template. (i.e. 'External Walls' > 'Best Practice Wall Medium Weight'. If you scroll down the 'Data Report' section on the right of your screen you will find all the detail properties of the selected construction assembly for external walls. (i.e. layer dimensions, graphic section, R-value (m² K/W), U-value (W/m² K), etc).

The screenshot shows the DesignBuilder interface with the 'Construction' tab selected. The 'Template' list on the left includes 'Best practice, Medium weight' and 'Best practice Wall, Medium weight'. The 'Data Report' on the right provides a detailed breakdown of the wall assembly layers and their properties.

Layer	Material	Thickness (m)	Bridged?
Outermost layer	Brickwork (Outer Leaf)	0.1050	No
Layer 2	XPS Extruded Polystyrene	0.0790	No
Layer 3	Concrete Block (Medium)	0.1000	No
Innermost layer	Gypsum Plastering (not to scale)	0.0130	No

Inner surface

Convective heat transfer coefficient (W/m ² K)	2.152
Radiative heat transfer coefficient (W/m ² K)	5.540
Surface resistance (m ² K/W)	0.130

Outer surface

CONSTRUCTIONS

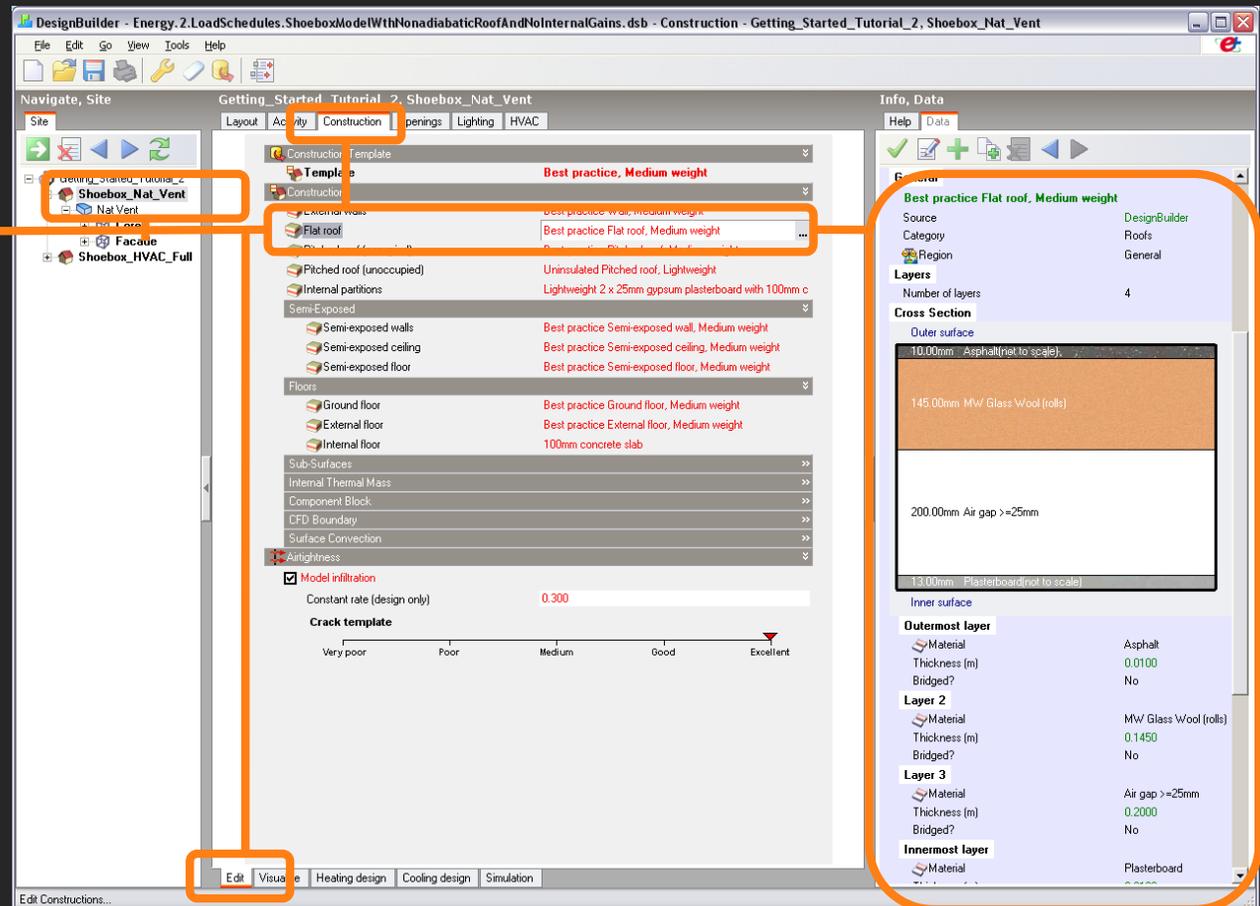
Modifying a construction assembly

3.

Now we will improve the thermal properties defined by the 'Best Practice Medium weight' for a 'Flat roof'

In the 'Data Report' section one can find the current properties for that construction assembly. It contains 4 layers and a U-value of 0.25 W/m²K.

We will now modify this assembly to optimize its thermal performance to a higher standard of 0.18 W/m²K.



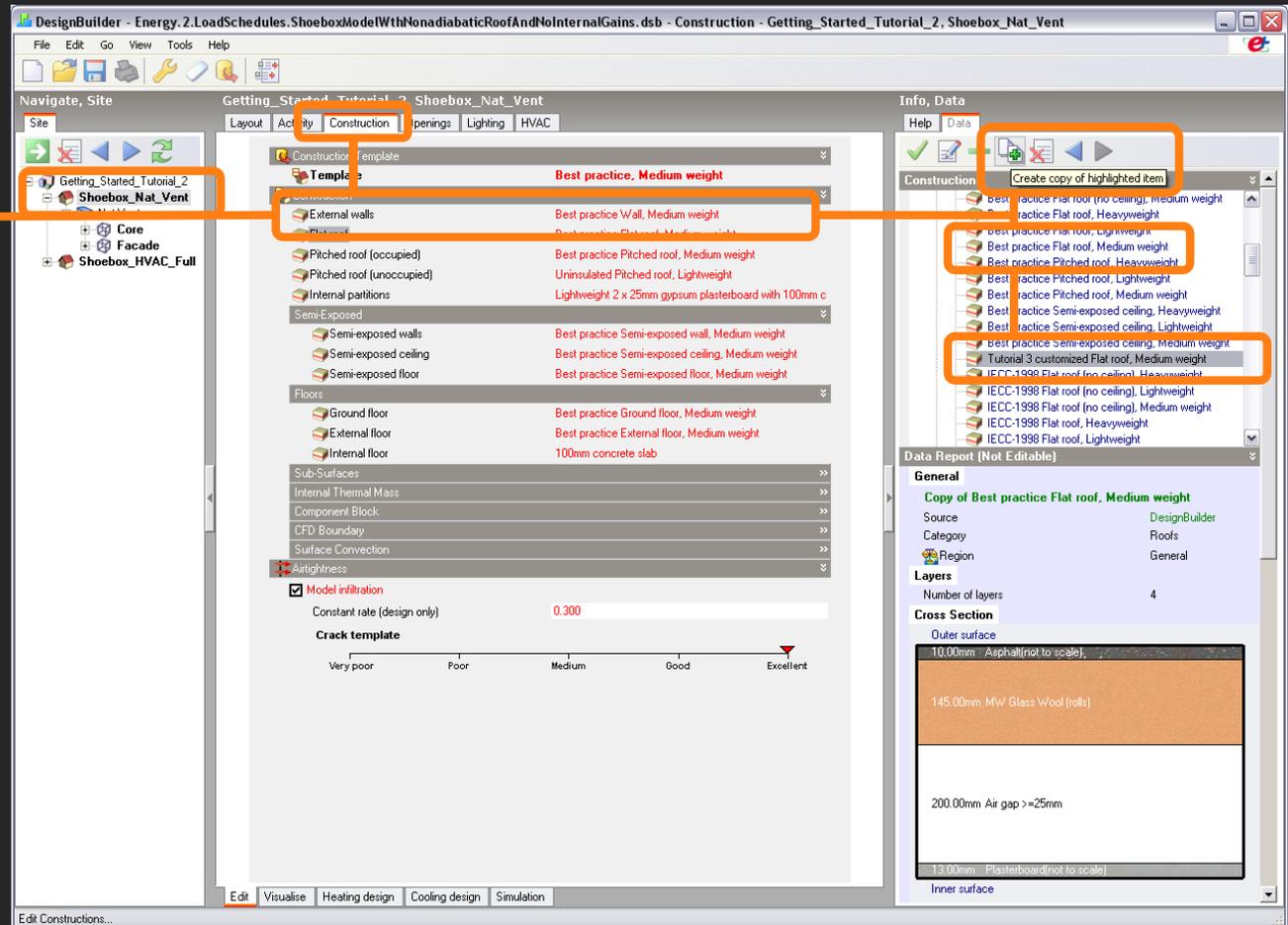
CONSTRUCTIONS

Modifying a construction assembly

4.

First we will create a new construction assembly by duplicating the existing template (original templates are not editable and will appear as 'locked library data').

Select the current template 'Best Practice Flat Roof Medium Weight' > click on the icon to 'create a copy of highlighted item'. Find the newly created construction assembly and rename it to 'Tutorial 3 customized flat roof' (the new assembly will always start with the word 'copy of').



CONSTRUCTIONS

Modifying a construction assembly

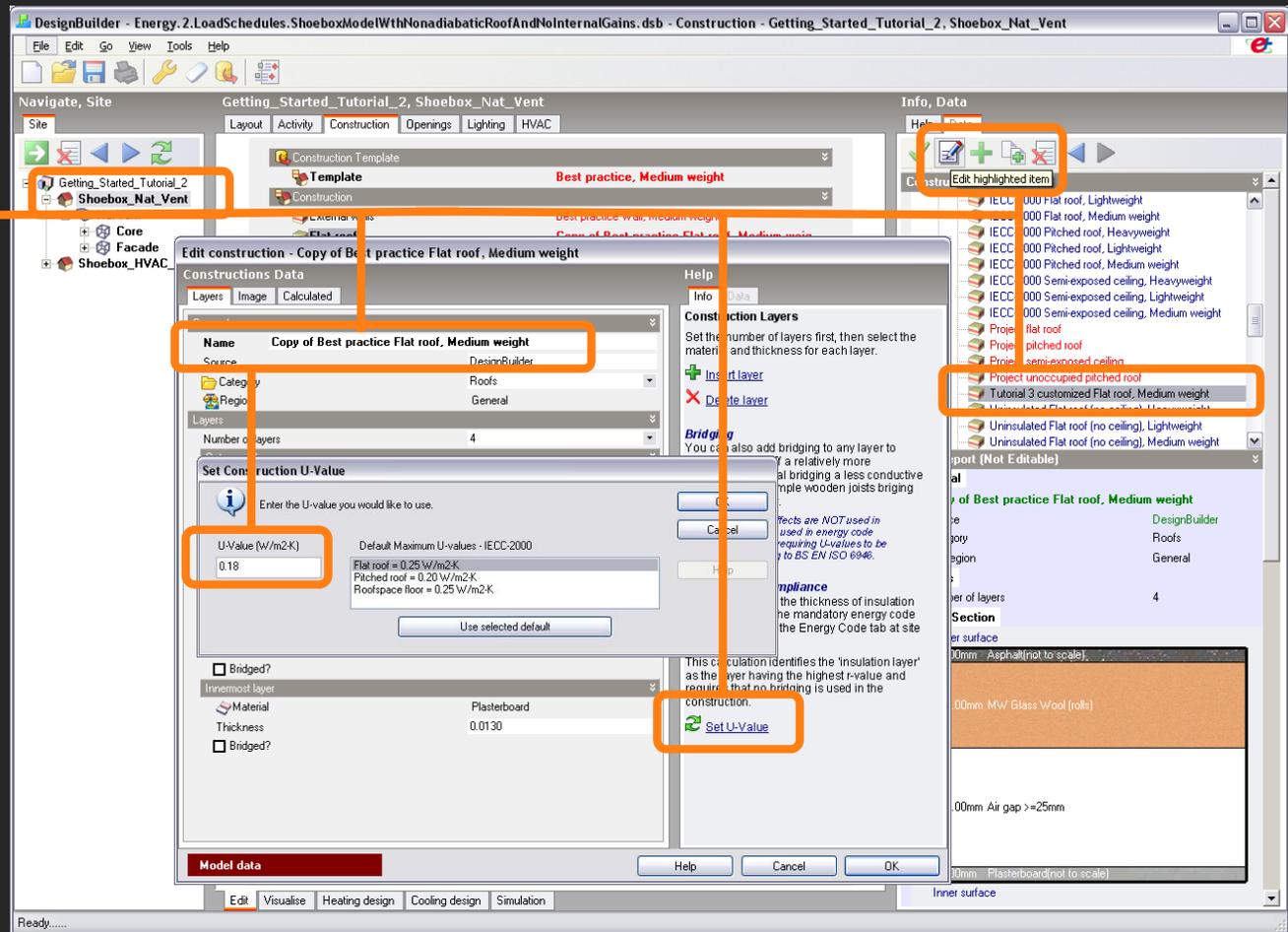
5.

Select the new customized flat roof assembly and 'click' on the 'edit the highlighted item' icon.

Change the name again to the already used, 'Tutorial 3 customized flat roof'.

Select the 'Set a U-Value' option and change the current value to 0.18 W/m²K.

A window will pop-up asking if you want to increase the insulation thickness to meet the current U-value requirements.



CONSTRUCTIONS

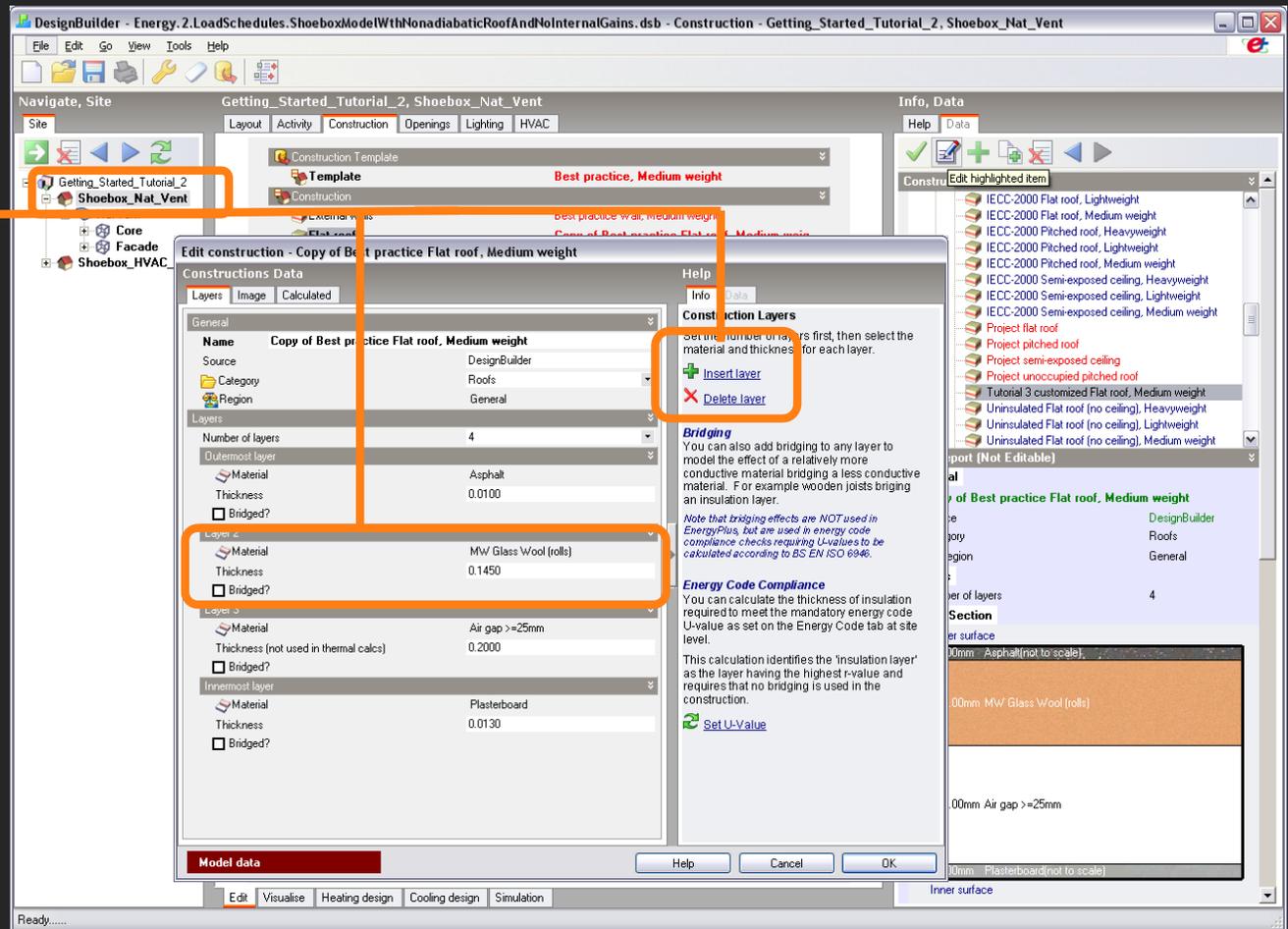
Changing Materials in a Construction Assembly

6.

To add or change the materials in any construction assembly you should select the 'add layer' or 'delete layer' icons.

When adding a layer you may select the material from the 'Data' tab located on the right-side of the screen. You may set the dimensions for each material layer.

Now modified the 'External Wall' assembly for the whole building. First change the "Concrete Block (lightweight)" to "Concrete Block (heavyweight)". Then set the 'U-value' to 0.3 W/m²K.



CONSTRUCTIONS

Apply all changes to the 'Shoebox HVAC Full' Building

- Proceed to make the same exact changes for the 'Shoebox HVAC Full' Building, so that both buildings have the same envelope properties.

Note that this time you don't have to create a new construction assembly. Select the already created 'tutorial 3 customize flat roof'.

CONSTRUCTIONS

Run an annual simulation

- Once you have applied all the changes to both spaces, the naturally ventilated and the fully conditioned, proceed to run an annual simulation for both buildings.
- Review the results and compare each space to the annual simulation results from tutorial 2. Present results in a customized monthly graph displayed as 'bar stacked'.

INTERNAL LOADS

In this section you will now optimize the internal loads for both spaces, run an annual simulation again, and review the impact that optimizing internal loads may have in the building.

- The internal loads to be optimized are:
 - Artificial Lighting: will reduce the Lighting Power Density (LPD) for the space and incorporate daylight controls to optimize the use of artificial lighting according to the availability of daylight.
 - Plug Loads (Computers, screens, task lights, etc): will reduce the installed power for plug loads assuming high efficiency artifacts.

INFO

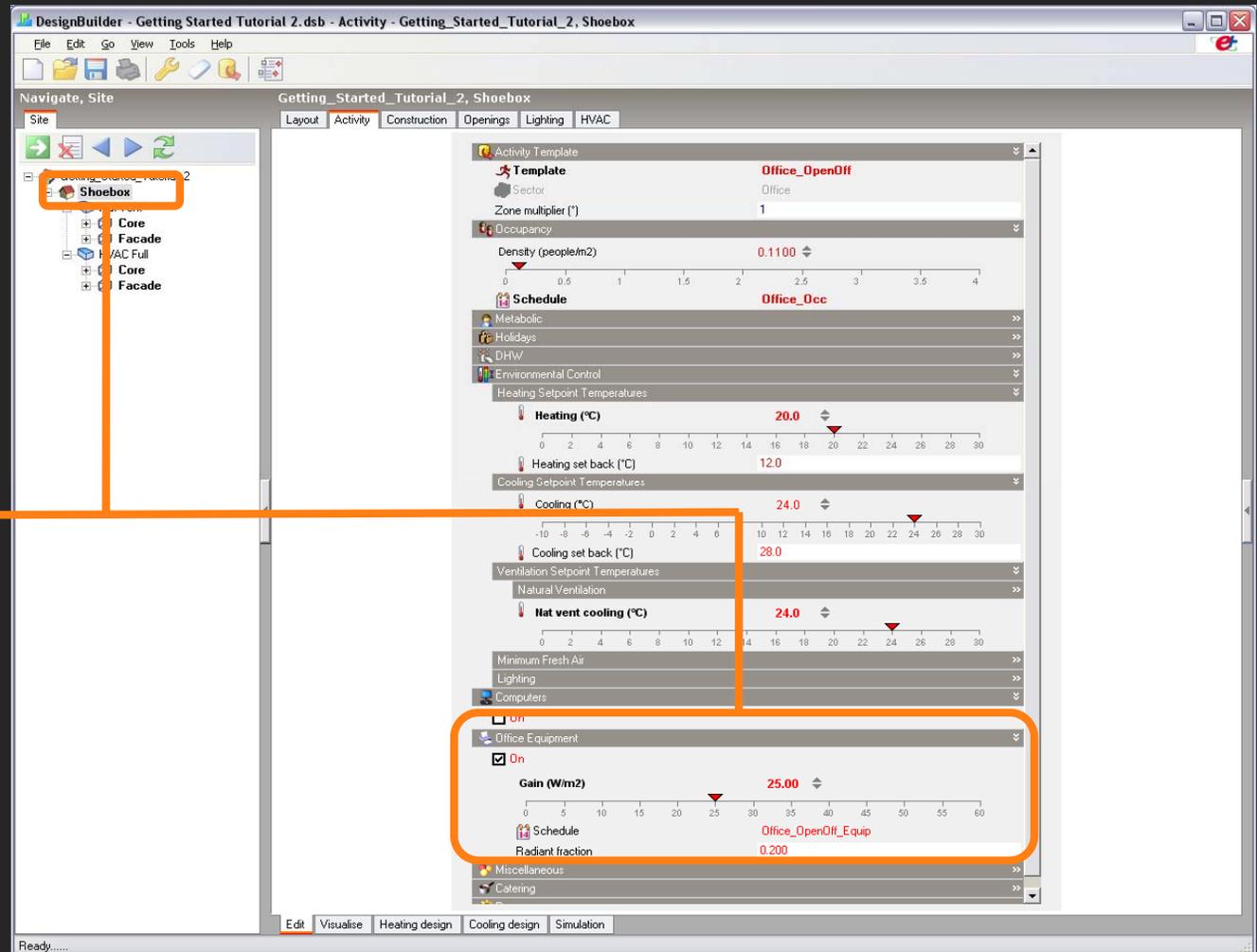
The use of shading devices as an ECM to reduce solar gains is addressed later on in this document.

INTERNAL LOADS

Optimizing Plug Loads

7.

In 'Office equipment' reduce the load to '15W/m²' (this is an optimized value for all plug loads. All plug loads are lumped together into this value (Computers, screens, task lights, etc))

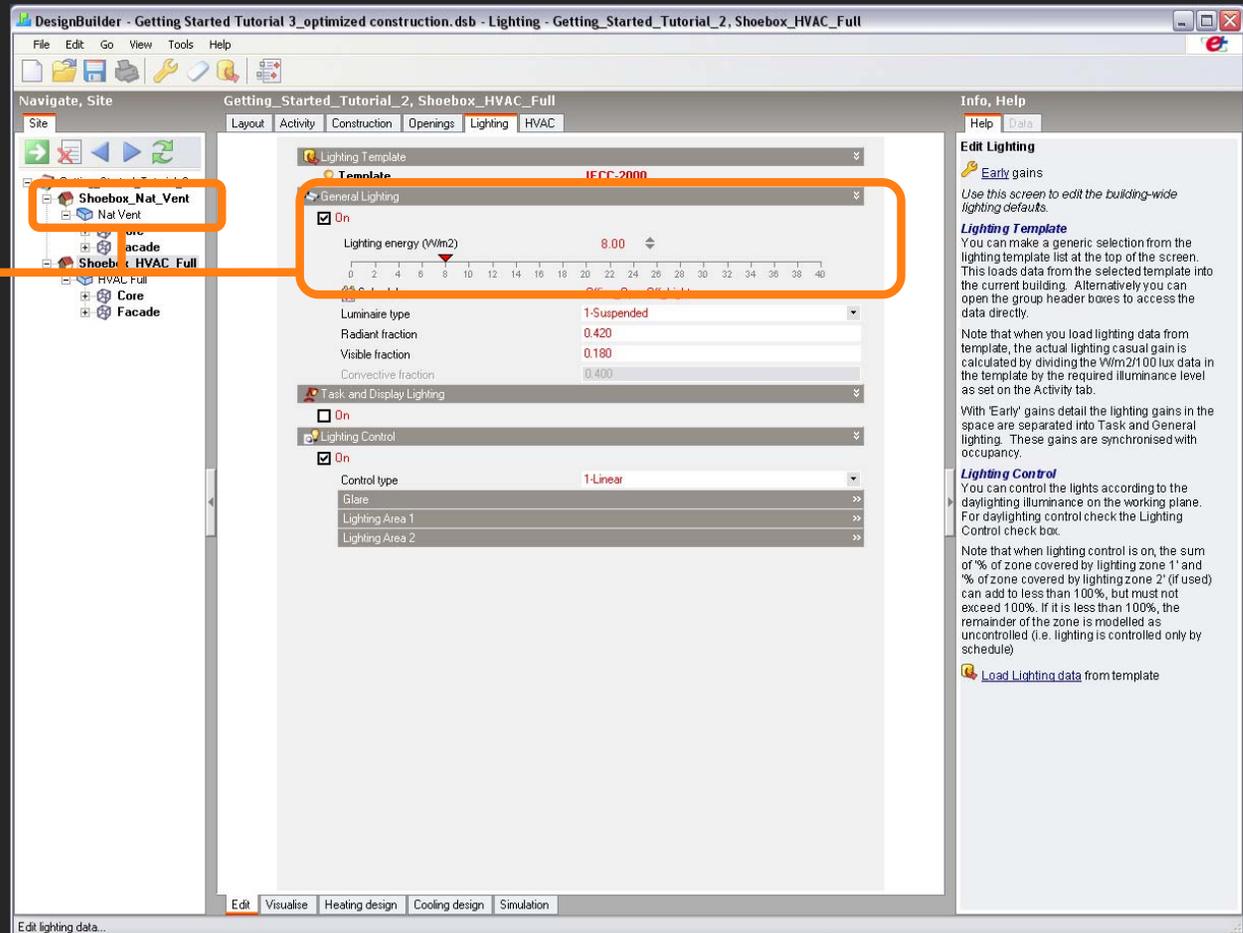


INTERNAL LOADS

Optimizing Lighting Loads

8.

At the building level go to the 'Lighting' tab > 'General Lighting', reduce the Lighting Power Density (LPD) to 8W/m².



INFO

General lighting accounts for the main lighting in the room. It can be configured to replace artificial lighting by daylight through lighting control, if this option is selected. This is explained the following slide.

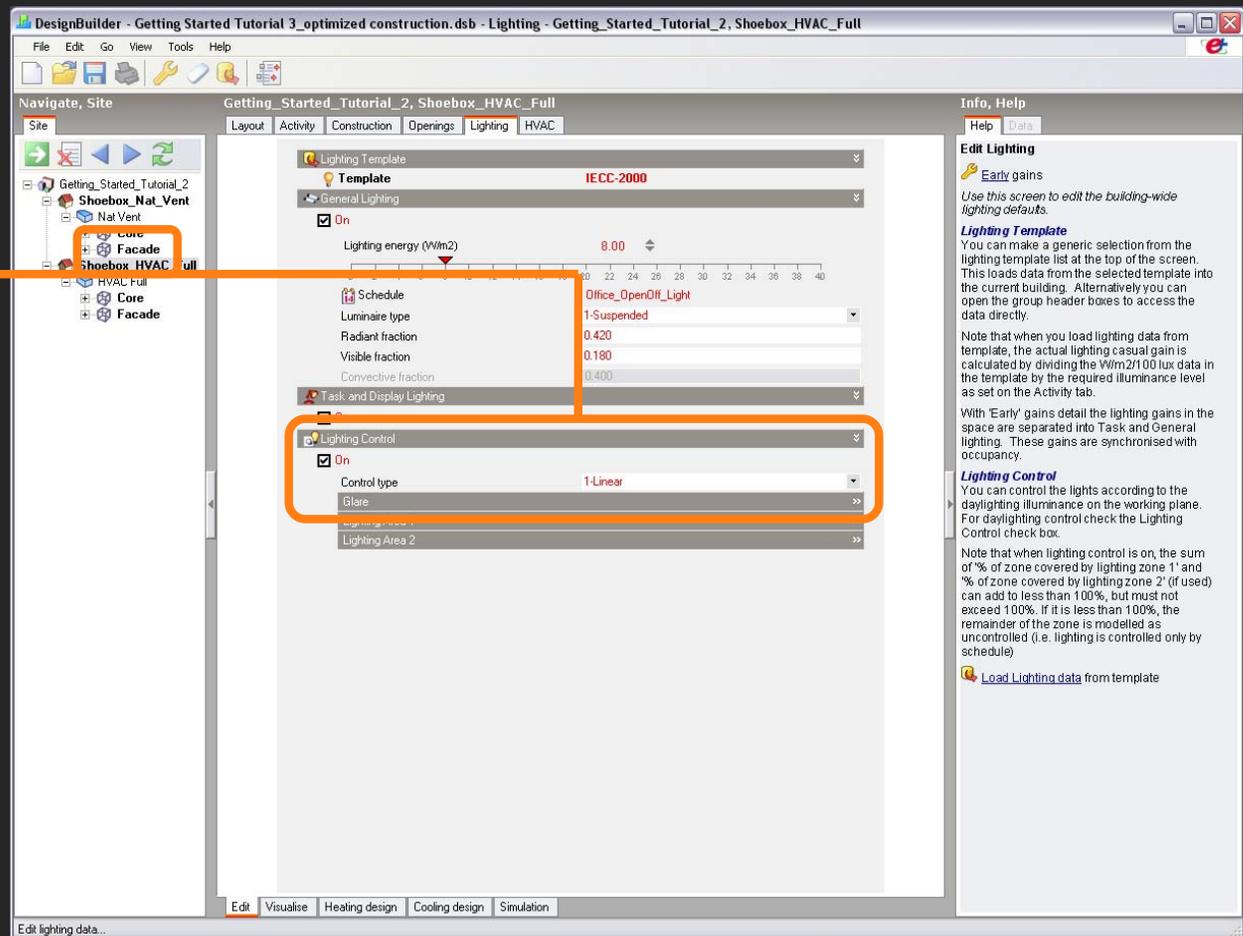
INTERNAL LOADS

Daylight Controls

8.

At the **Zone level 'Façade'**, go to the 'Lighting' tab > Turn "Lighting Controls" ON, and keep the default '1-Linear' control type.

Please note:
For DesignBuilder v1.6.9.003 and lower, an error will occur when setting Daylighting Controls at the Building level, if the building contains zones without windows.



INFO

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.

INTERNAL LOADS

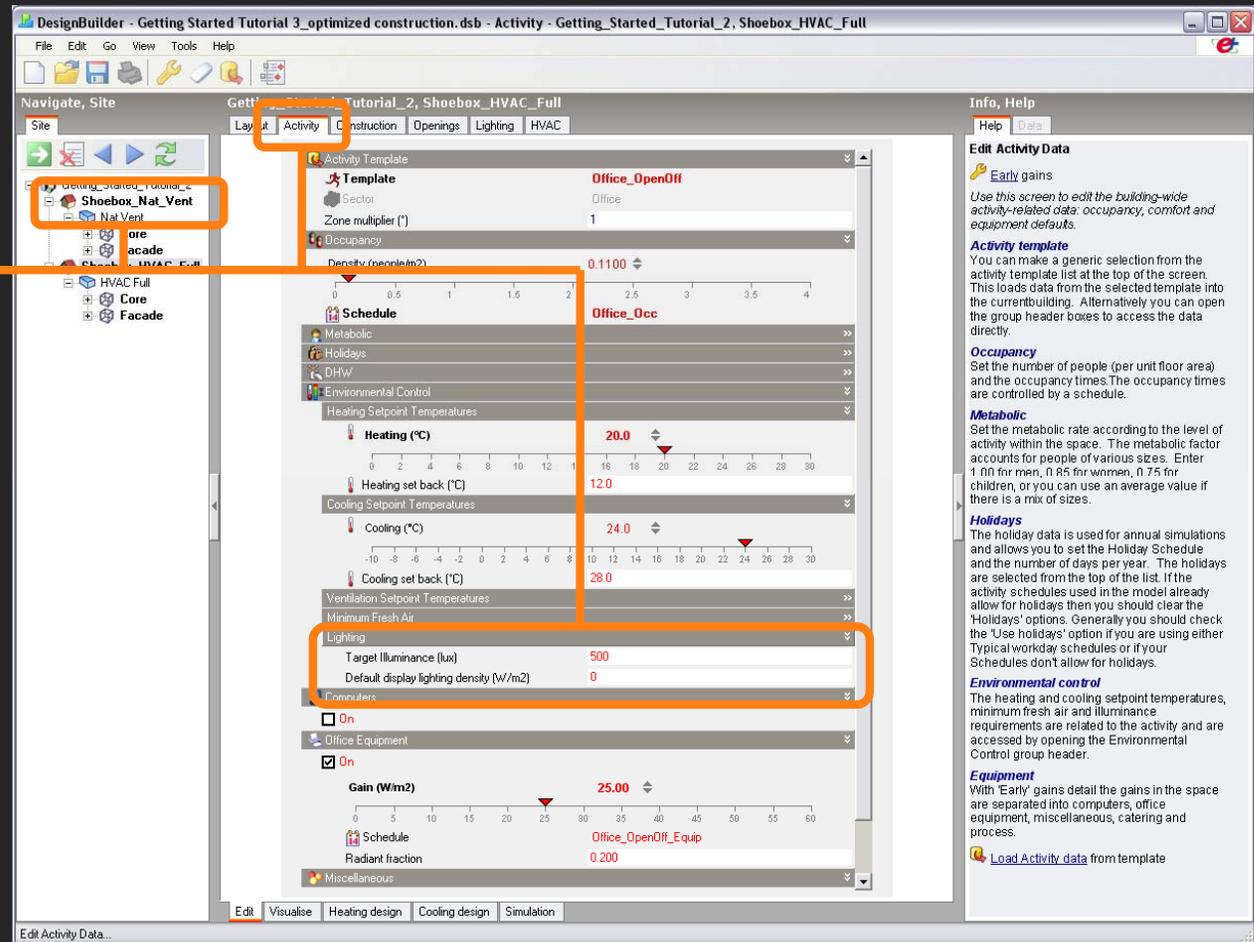
Optimizing Lighting Loads

8.

Remember the Target Illuminance levels are set in the 'Activity' tab.

The CIBSE Code for Lighting recommends a maintained illuminance of 500 lux for general offices (e.g. writing, typing, reading, data processing, etc.) and for CAD work stations and conference/meetings rooms. Where the main task is less demanding, e.g. filing, a lower level of 300 lux is recommended.

Keep the target level at 500lux.



INFO

The Chartered Institution of Building Services Engineers (CIBSE) received its Royal Charter in 1976. It is the professional body that exists to: 'Engineer a Sustainable Built Environment'.

<http://www.cibse.org/>

INTERNAL LOADS

Apply all changes to the 'Shoebox HVAC Full' Building

- Proceed to make the same exact changes for the 'Shoebox HVAC Full' Building, so that both buildings have the same internal loads and lighting controls.

Run an annual simulation

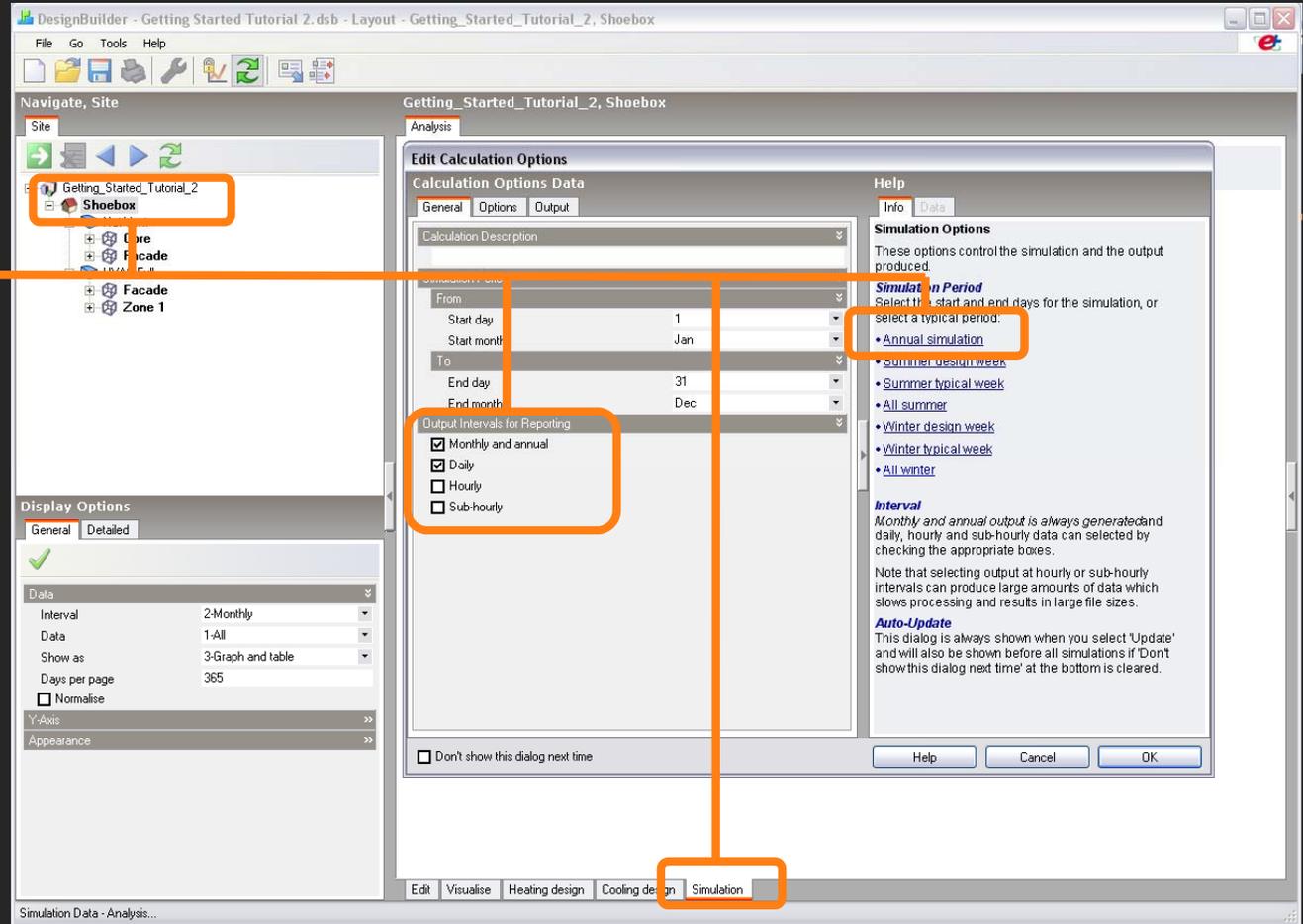
- Once you have applied all the changes to both spaces, the naturally ventilated and the fully conditioned, proceed to run an annual simulation for both buildings.
- Review the results and compare each space to the annual simulation results from tutorial 2. Present results in a customized monthly graph displayed as 'bar stacked'.

INTERNAL LOADS

Running an annual simulation with loads

10.

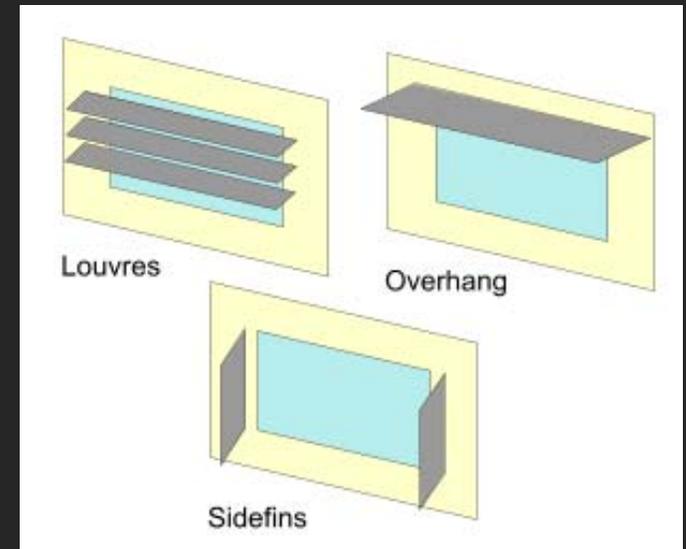
Select the “Building” level within the naturally ventilated space and start an annual simulation.



SHADING DEVICES

In this section you reduce the solar gains received by both spaces by adding an fixed external shading device to the South-facing facades.

DesignBuilder supports three types shading components, overhangs, louvres and sidefins, which can be specified either individually or in combination (e.g. sidefins combined with louvres).



SHADING DEVICES

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.

INFO

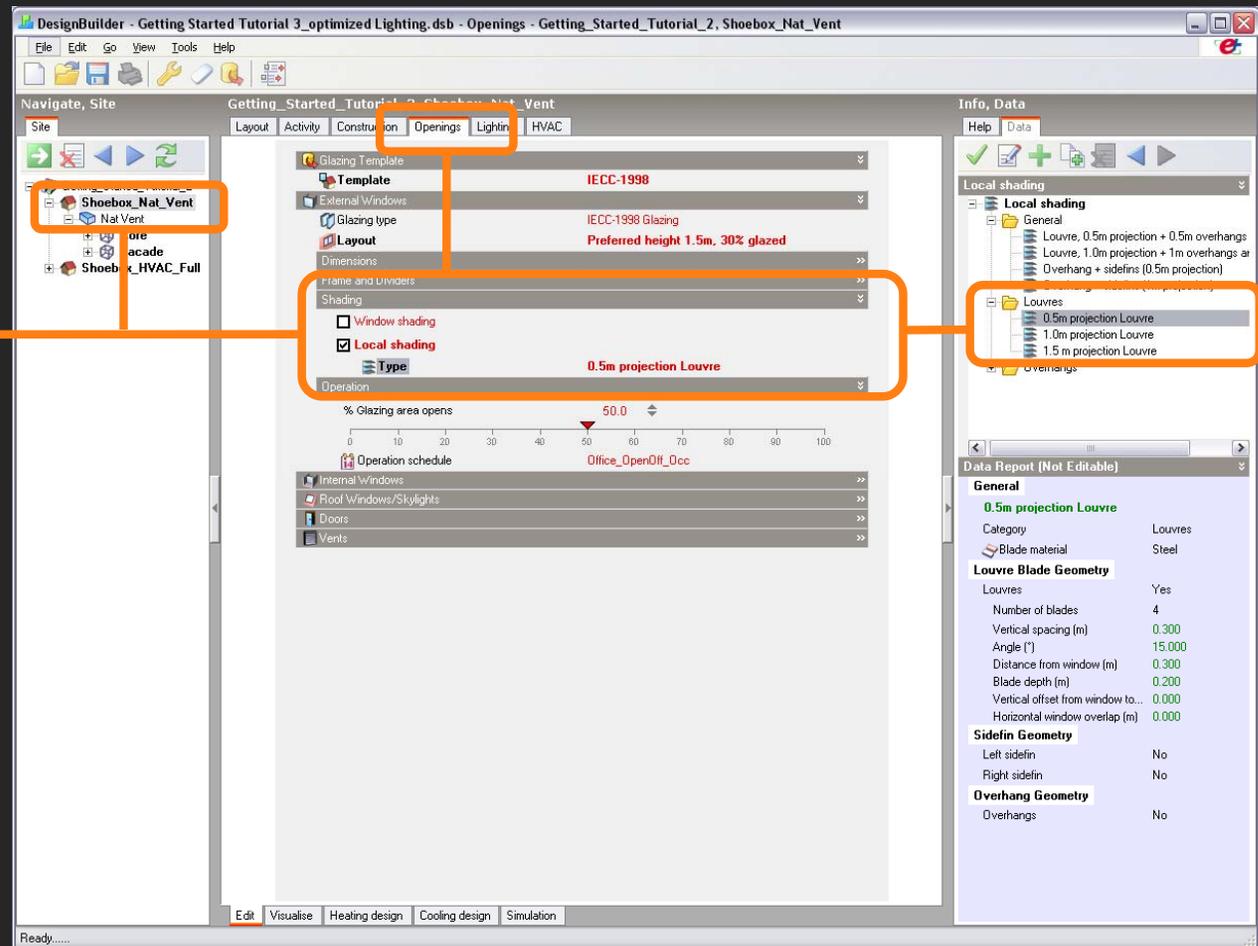
DesignBuilder Local shading devices allow a range of different overhangs, side fins and louvres to be defined, but if you need to model a shading device not covered by the standard mechanism, you can draw custom shading devices using Component blocks. Source: <http://www.designbuilder.co.uk/helpv1/>

SHADING DEVICES

Setting a Local Shading Device

11.

At the building level go to the 'Opening' tab > 'Shading', turn ON the 'Local Shading', then select under 'Louvres' > '0.5m projection Louvre'.



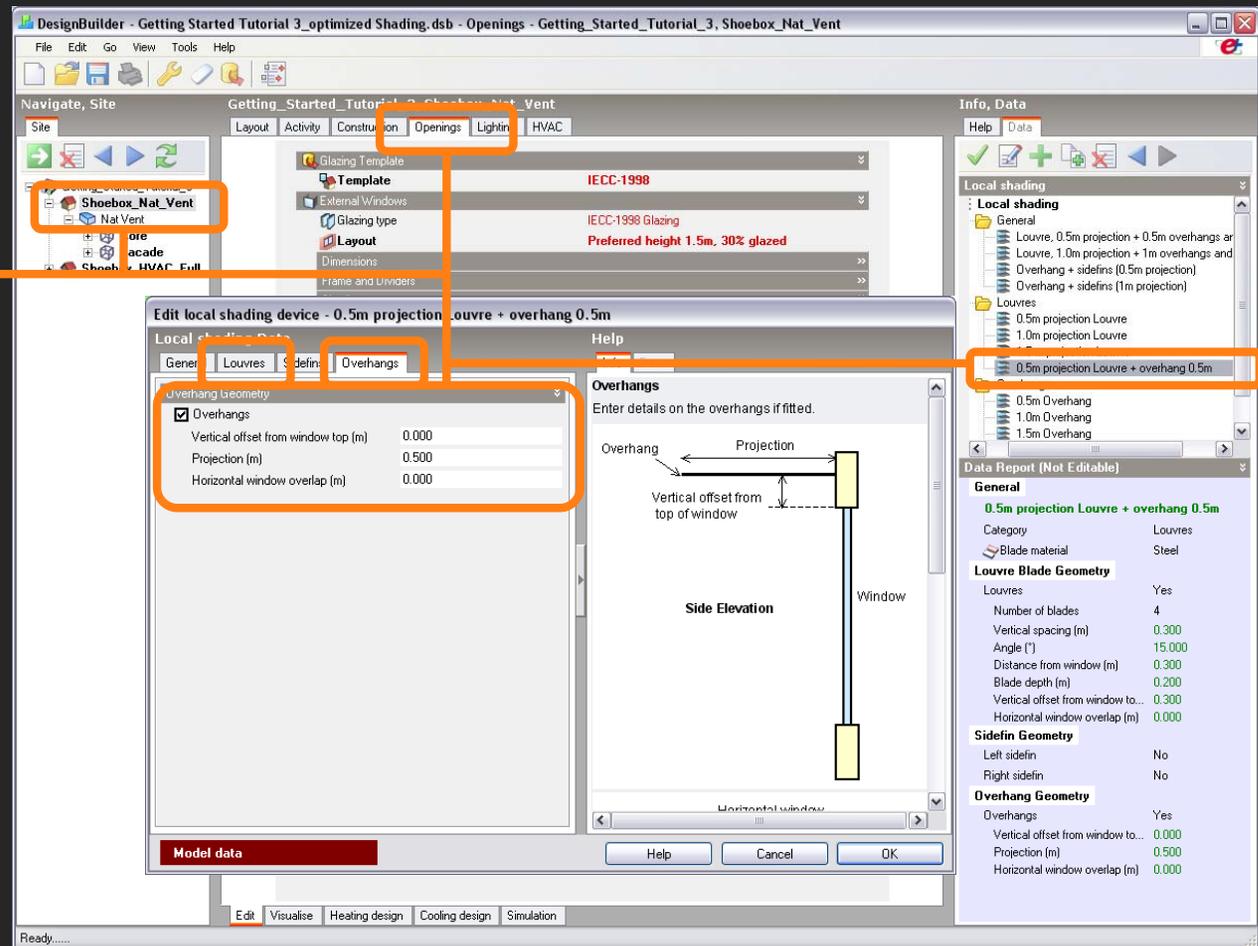
SHADING DEVICES

Customize a Local Shading Device

12.

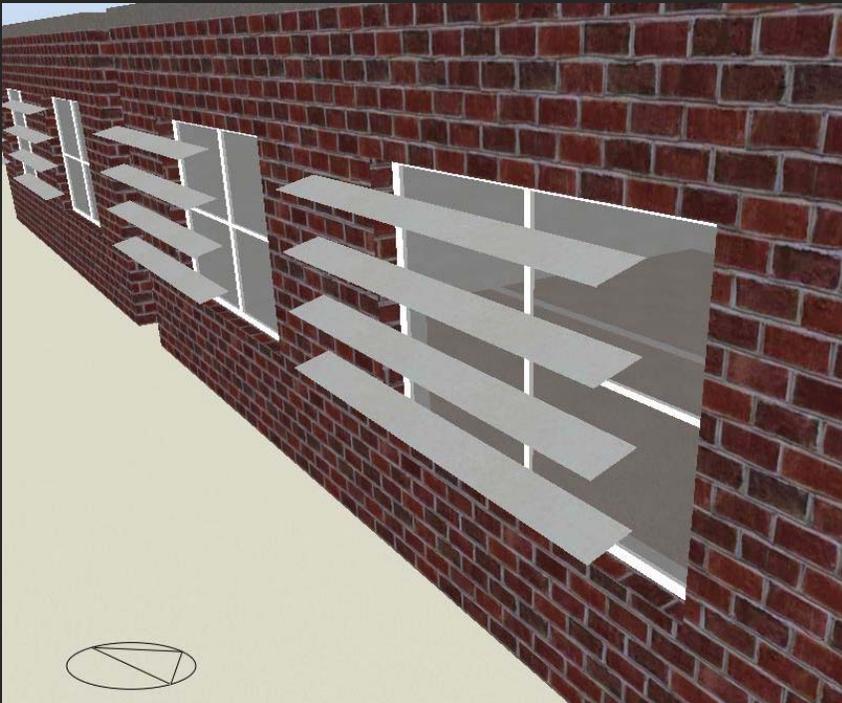
Now we will customize the Local Shading Device by adding an overhang to avoid the direct sun passing through the 0.3m gap that remains between the window and the shading device at the top of the window. (i.e. the 0.5m projection Louvre has a blade depth of 0.2m and is offset from the window 0.3m.)

Create a new shading component by duplicating the existing template. Then click on the 'Edit' icon > 'Overhang' tab > and turn ON 'Overhang'. In the 'Louvres' tab set the 'Vertical offset from window top' to 0.3m. Remember to rename the new shading component.

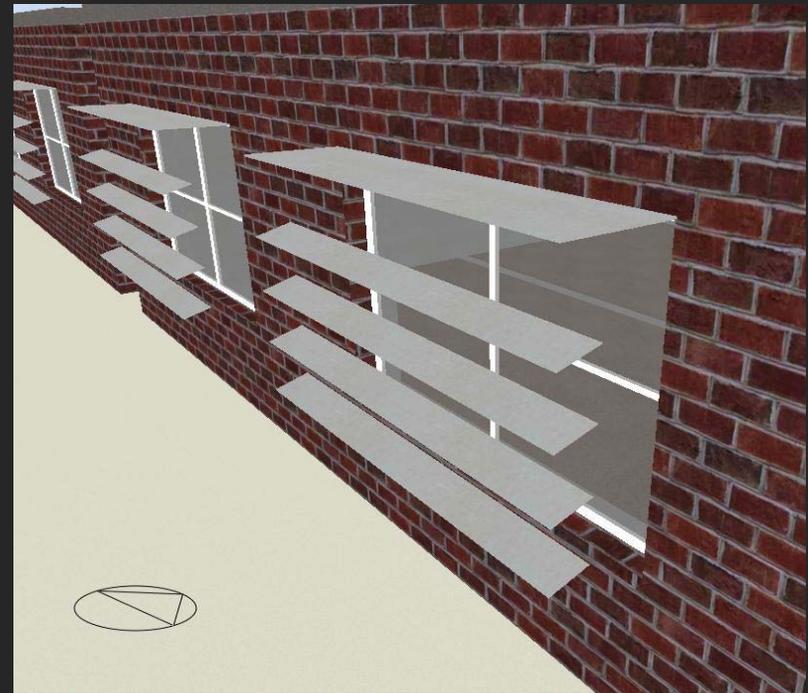


SHADING DEVICES

Customize a Local Shading Device



Default '0.5m projection Louvre' Local shading component.



Customized '0.5m projection Louvre + 0.5m overhang' Local shading component.

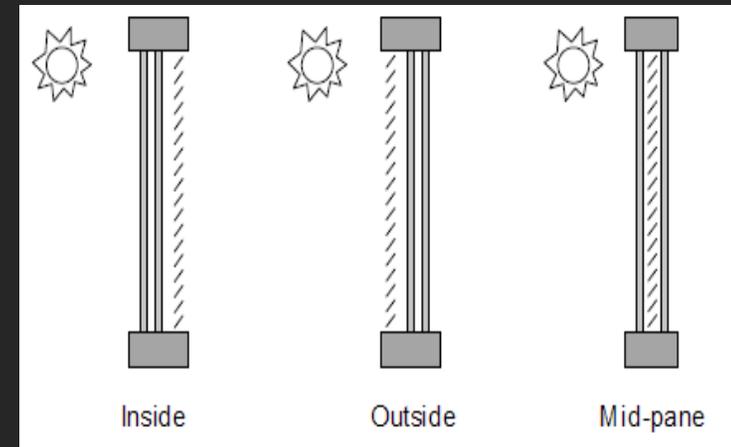
SHADING DEVICES

Additional Information on Window Shading

DesignBuilder also gives the option to include blinds, transparent insulation or electrochromic glazings by selecting the 'Window shading' checkbox. **Do not include Window Shading Devices at this point.**

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).



INFO

For more information on Window Shading and Shading Control Types go to <http://www.designbuilder.co.uk/helpv1/>

SHADING DEVICES

Apply all changes to the 'Shoebox HVAC Full' Building

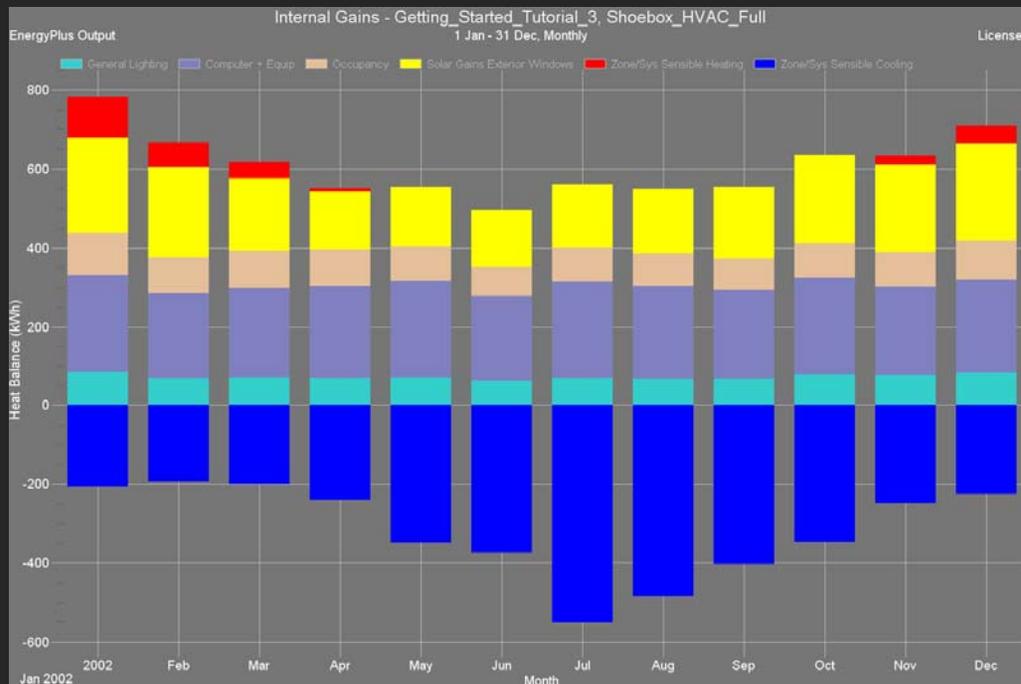
- Proceed to make the same exact changes for the 'Shoebox HVAC Full' Building, so that both buildings have the same Local Shading Devices.

Run an annual simulation

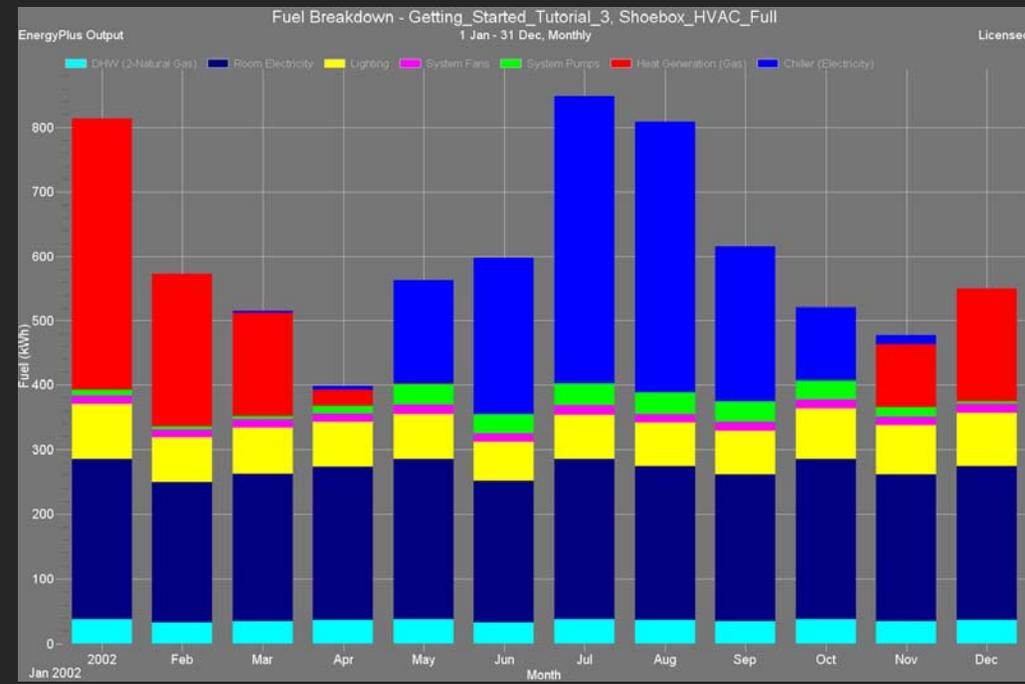
- Once you have applied all the changes to both spaces, the naturally ventilated and the fully conditioned, proceed to run an annual simulation for both buildings.
- Review the results and compare each space to the annual simulation results from tutorial 2. Present results in a customized monthly graph displayed as 'bar stacked'.

SIMULATIONS

Example of Monthly Simulation Results for Optimized 'Shoebox Full HVAC Building



Shoebox HVAC Full - Internal Gains



Shoebox HVAC Full - Fuel Breakdown

CONCLUSION

This document provided a quick, non-exhaustive overview of the building energy performance simulation capabilities offered by DesignBuilder/EnergyPlus. Should you decide to use this tool in the future consult the REFERENCE section for further reading. Remember:

- It is your responsibility to **learn the assumptions and limitations** of the programs you are using.
- Preparing and running a simulation take time. Before rushing into doing a simulation you should **have a clear idea of how the simulations results can help you resolve a specific design question** that you could not answer otherwise.

ACKNOWLEDGEMENT

The development of this document has been supported by the following organizations.

Harvard Graduate School of Design: The GSD has been putting special attention to the advancement of environmental building performance, supporting a number of researches in the matter. (www.gsd.harvard.com).

The Presidential Instructional Technology Fellows : The Presidential Instructional Technology Fellows (PITFs) program was established to recruit and train fellows in conjunction with the Schools to work with faculty to develop digital course materials with immediate educational benefits. PITFs leverage existing software tools developed here at Harvard and provide outreach(<http://isites.harvard.edu/icb/icb.do?keyword=k2526&pageid=icb.page12917>).