Building Energy Simulation

A Workbook Using DesignBuilder[™]

Vishal Garg Jyotirmay Mathur Surekha Tetali Aviruch Bhatia



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Preface

The Building Energy Simulation: A Workbook Using DesignBuilderTM is an outcome of a series of training programs conducted for participants with varied backgrounds. The authors experimented with various teaching techniques and arrived at the conclusion that the most effective method of imparting these training programs is through tutorials and step-by-step instructions along with graphical illustrations.

The simulations in this workbook are performed using the DesignBuilderTM software for illustration purpose to help explain the aspects of a whole building energy simulation process. This workbook adopts the 'learning by doing' principle to explain the fundamentals of building physics and building services, and in turn help participants understand the concept of building energy performance. Based on participant feedback during the training programs, the authors decided to use EnergyPlusTM with DesignBuilder as the front end to explain the simulation process.

The book has been organized as follows:

• The first ten chapters of this workbook cover various aspects of simulation, such as creating the building geometry, assigning material and equipment and analysing the results.

- Chapter 11 explains simulation for the whole building performance method of the ASHRAE 90.1 standard.
- Chapters 12 through 14 provide exercises to simulate three different building projects.

The authors would highly appreciate any feedback or suggestions for improving this workbook.

Acknowledgements

The authors thank all those who helped during the research, writing, review and editing process, which immensely contributed in making this workbook a reality.

We would like to start by thanking all professionals, researchers and students from all over the globe for providing their feedback during the various building simulation training programs that were conducted in the past few years. This feedback helped us improve the building simulation teaching methodology and motivated us to create this workbook.

We thank Prof. N. K. Bansal who not only introduced us to this subject of building science but also served as our role model in learning the art and science of the teaching process.

We are also grateful to DesignBuilder Software Ltd., Stroud, UK for allowing us to develop this book and answering our queries during the writing process.

This workbook would not have been possible without all those reviewers who took time out to patiently go through the content and provide their valuable feedback. The authors would especially appreciate the contribution from Gaurav Choudhary, Hema Rallapalli, Ishita Sharma, Kopal Nihar, Sraavani Gundepudi, Shivraj Dhaka and all the students from International Institute of Information Technology (IIIT), Hyderabad, India and Malaviya National Institute of Technology (MNIT), Jaipur, India who reviewed this workbook and provided feedback on the technical content and its accuracy.

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Getting Started with Energy Simulation

This chapter is to acquaint you with energy simulation. It starts with the introduction of various components and requirements for simulation, and then gradually progresses to the concept of simulation using a ready example file. It establishes the impact of key simulation inputs such as lighting power density (LPD), activity, setpoint, window-to-wall ratio (WWR), orientation and fresh air intake on energy consumption.

There are 11 tutorials to help you navigate through the chapter. By the end of this chapter, you will get familiarized with key input parameters, output visualization, and overall simulation process.

Building energy simulation

Building energy simulation is performed using a computer to virtually represent a building design and perform physics-based calculations. The simulations can range from a building component to a cluster of buildings. For energy simulation, the building model along with the usage pattern and the weather of the location are required to determine various outputs, such as peak loads, system sizing, and energy consumption for any given period. This information can be utilized for estimating the utility bills, for evaluating cost–benefit analysis of various design strategies. Some of the uses for energy simulation tools are:

Early design decisions: In early design stage, decisions such as orientation and layout of the building are taken. Energy simulation can help in evaluating various design strategies. However, a detailed simulation may not be possible because of the limited information available at this stage.

Component or material selection: Simulation helps in the decision-making process while selecting individual components of building envelop or systems. It is quite commonly used to carry out cost–benefit analysis of various designs and components. Therefore, modelling at this stage needs to be performed with greater accuracy as compared to modelling for early design decisions.

Retrofitting decisions: For retrofit of existing buildings, energy simulation can help in selecting cost effective solutions. For an accurate analysis, simulation model should be calibrated using the measured performance data of the building.

What is needed for energy simulation

Energy simulation of buildings can be performed using a systematic approach. A lot of data is required. It is recommended that you collect the required data before you start the modelling.

The following basic information is required:

Location and weather file: Energy simulation tools need hourly ambient conditions (temperature, humidity, wind velocity, solar radiation, etc.) at the building location. This information is available in weather files. Simulation tools use these weather files to extract the hourly ambient conditions while carrying out the simulation. However, for some locations, the weather file may not be available. In such cases, the weather file of some other location with similar weather conditions can be used.

Weather files are available in different formats. Different simulation tools use different formats of weather files. Utilities are available on the web for converting a weather file from one format to another. **Building geometry:** Building elevation and floor plans are required to create the geometric model of a building. Architectural drawings may have many details that might not be directly useful for energy simulation. It is useful to simplify the drawings based on thermal zoning into a single line drawing by removing unnecessary details.

Envelope components: It is necessary to have construction details, such as thickness and thermophysical properties of materials used in each layer of building envelope. Besides the opaque components, it is very important to have properties of window glass, frame and shading devices.

Building services: Information about various services such as HVAC and lighting is required. This includes equipment capacities, energy efficiency, location and controls.

Usage of building: The hourly values of the following are required:

- Occupancy
- Lighting
- Equipment
- Thermostat setpoint
- · HVAC operation

How simulation software works

The simulation program enables simultaneous interaction of the geometric model with outdoor conditions, occupancy, and usage of building systems to predict various loads arising in the building on an hourly basis. Basic laws of physics and energy balance equations are used for calculations. The energy consumption for the operation of systems corresponding to the heat and other loads is also calculated on the same time scale. Results of the processing are passed to the calculations of next time slice and are also supplied to the output file. This process continues for the entire duration of the simulation, and the final output is seen as aggregated or on the same time slice for which calculation has been carried out. Most simulation tools are capable of simulating the energy flows through different building components on an hourly basis, including the transient effects of the envelope and systems.

BUILDING ENERGY SIMULATION

The advantage of energy simulation over classical method is that various effects of thermophysical properties of materials and the performance of various systems under varying external and internal environmental conditions are considered in energy calculations. Most energy simulation tools do not require any special computing power, as they can be run on commercially available desktop computers or laptops.

This chapter provides basic tutorials on creating simple geometry, analysing the impact of building orientation, WWR, internal loads and fresh air delivery with a special focus on analysing building energy performance and system sizing. The tutorials are followed by exercises. There are many energy simulation tools available. For this book, we will be using DesignBuilder. This can be downloaded from: https://www.designbuilder.co.uk/download/software/ previous-versions/49-designbuilder-v4-70-027-1.

TUTORIAL 1.1 Opening and simulating an example file

GOAL

To evaluate the energy performance of a building provided in an example file in DesignBuilder.

WHAT ARE YOU GOING TO LEARN?

- · Simulating an example file
- Viewing energy consumption results based on utility type or fuel, such as electricity and gas
- Viewing the end use energy consumption (lighting, equipment, fan, cooling, heating, pump and domestic hot water)
- Viewing results on a daily, monthly and annual basis
- Switching between Metric (SI) and English (IP) measurement units
- Finding energy use intensity (EUI)

PROBLEM STATEMENT

In this tutorial, you are going to simulate an existing template, **Courtyard with VAV Example**, from the DesignBuilder library and simulate it for the climate of London. You will learn how to view the daily, monthly, and annual energy consumptions in a graphical form. You will also learn how to view the annual fuel breakdown and fuel total.

SOLUTION

Step 1: Start **DesignBuilder**. The **DesignBuilder** main screen appears as shown in next step.

Programs (1)
🖉 DesignBuilder
Documents (49)
🕼 DesignBuilder Data
🕼 Backup
🔓 lt Autosave 3_15_2016_7_12_01_PM
🔓 lt Autosave 3_15_2016_6_55_45_PM
Lt Autosave 3_15_2016_6_45_45_PM
🚇 lt Archive 3_15_2016_6_35_44_PM
Files (54)
📄 Chapter 3 Material and construction
📠 lt
📄 Chapter 2 Geometry of buildings
🖄 Chapter 1 Getting Started
🖬 Chapter 1 Getting Started (deleted 60327e97e7161b43f9e0f5694
💼 Chapter 1 Getting Started (deleted d677bfec04b2da0f3b11fb810
₽ See more results
DesignBuilder × Shut down +
8 6 🔚 3 6

Step 2: Double-click **Courtyard with VAV Example** in the DesignBuilder templates under the Recent Files tab. A **New project Data** screen appears.

	9 🕒				
esignBuilder Data					Info, Help
Recent Files Component Libraries Template Lib	rafes				Help Data
Name	Folder /	Size (Last Modified V	Extension /	Recent and Example Files
DesignBuilder files					To open one of the recently opened files, select the
_IC:\Users\Neresh\Desktop					file in the main screen and click on 'Open selected file' below.
🔏 lt	C:\Users\Naresh\Des	1120	3/15/2016 12:59:11 PM	DesignBuilder files	
_D\DB Files\Chapter 2 DB files					Selected file: Courtyard with VAV Example
A 2.4	D:\DB Files\Chapter 2	1608	3/15/2016 11:21:46 AM	DesignBuilderfiles	fill Open selected site
DesignBuilder templates					X Delete selected site
LC\ProgramData\DesignBuilder\Temp					Clear recent files list (files are not deleted)
Simple HVAC night cooling	C:\ProgramData\Desi		12/14/2015 1:03:00 PM	DesignBuilder templates	If the file you want to open does not appear in the list
Plenum Example Buillding	C:\ProgramData\Desi	891	12/14/2015 1:03:00 PM	DesignBuilder templates	of recently used files you can also:
🔓 Green roof example	C:\ProgramData\Desi		12/14/2015 1:03:00 PM	DesignBuilder templates	Create new project
B Double Skin Facade Example		1009		DesignBuilder templates	
Courtyard with VAV Example					Open existing site
Atrium Example with Calc N				DesignBuilder templates	
Zone Multiplier Example	C:\ProgramData\Desi	953	12/14/2015 1:03:00 PM	DesignBuilder templates	Learning mode is ON Learning mode provides relevant information and
A PCM Example	C:\ProgramData\Desi			DesignBuilder templates	easy access to typical commands. New users often
Parametric Simulation Exam	. C:\ProgramData\Desi	946	12/14/2015 1:02:58 PM	DesignBuilder templates	find Learning mode particularly helpful. You can switch it off from the Program Options dialog
La Underfloor Heating Example	C:\ProgramData\Desi	748	12/14/2015 1:02:58 PM	DesignBuilder templates	switch it on from the program Options draiog
Trombe Wall Example	C:\ProgramData\Desi	878	12/14/2015 1:02:58 PM	DesignBuilder templates	Other tools:
Single Zone Example	C:\ProgramData\Desi			DesignBuilder templates	Web Tutorials
Model Geometry Example	C:\ProgramData\Desi			DesignBuilder templates	Web Tutonais
📓 CFD Internal Analysis Exam	C:\ProgramData\Desi			DesignBuilder templates	
Dehumidification example	C:\ProgramData\Desi	964		DesignBuildertemplates	
Atrium example base	C:\ProgramData\Desi			DesignBuilder templates	
🔓 CFD External Analysis Exa	C\/ProgramData\/Desi			DesignBuilder templates	
Arch Vent with Preheat	C\/ProgramData\/Desi			DesignBuilder templates	
Aixed Mode Example	C\/ProgramData\/Desi	934		DesignBuilder templates	
🖓 DesignBuilder Video Tutori		1024		DesignBuilder templates	
House Example 1	C:\ProgramData\Desi	820	12/14/2015 1:02:58 PM	DesignBuilder templates	

Courtyard with VAV Example is a DesignBuilder template file. A DesignBuilder template file helps in providing examples of various building typologies and systems such as geometry, HVAC system and passive strategies. Relevant data from the example files can be exported and imported into other DesignBuilder models.

Step 3: Click **CA-SAN FRANCISCO INTL**. Three dots (...) appear.

If you have installed DesignBuilder for the first time on your system, **CA-SAN FRANCISCO INTL** may appear as location. If you have used DesignBuilder earlier, you may get some other location based on your previous settings.

Select location for template-based new file		a set action of
New project Data		Help
Location Template		Info Data
Trile Trile Location Analysis Analysis type LEED/ASHRAE 90.1 Model ASHRAE 90.1 App G PRM	Unitiled S CA - SAN FRANCISCO INTL 1-EnergyPlus V	Site 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 data tab at \$ Site level.
Don't show this dialog next time		Help Cancel OK

Step 4: Click the three dots (...). The **Select the location template** screen appears.

Select location for template-based new file		the start section of	
New project Data		Help	
Location Template		Info Data	
Title Title Location	v Untitled	✓ ☑ + ि ☑ ◀ ► Location templates	1
Location Analysis	CA - SAN FRANCISCO IN T	CA - SACRAMENTO/EXECUTIV CA - SALINAS MUNI CA - SAN BERNARDINO INTL	
Analysis type LEED/ASHRAE 90.1 Model ASHRAE 90.1 App G PRM	1-EnergyPlus •	CA - SAN DIEGO/LINDBERGH CA - SAN FRANCISCO INTL CA - SAN LUIS CO RGNL Data Report (Not Editable)	
		General Name CA - SAN FRANCISCO INTL	1
		Country UNITED STA Source ASHRAE/TM WMO 724940 ASHRAE climate zone 3C	
Don't show this dialog next time]	Konnen classification Colo Help Cancel OK	

Step 5: Select LONDON/GATWICK ARPT. Click OK. The Select location for template-based new file screen appears.

LONDON/GATWICK ARPT is a weather file that comes along with the DesignBuilder installation. For all other locations, an Internet connection is needed to download the weather files.

Select the location template	
LEUCHARS	*
IINTON-ON-OUSE	
-Sa LITTLE RISSINGTON	
-S LOCH GLASCARNOCH	
Sa LONDON WEATHER CENT	
IONDON/GATWICK ARPT	
LONDON/HEATHROW AIR	
-S LOSSIEMOUTH	
LUTON	
Sa LYNEHAM	
Sa MADLEY	
S MIDDLE WALLOP	•
🕂 🔓 🗹 Sort	Cancel OK

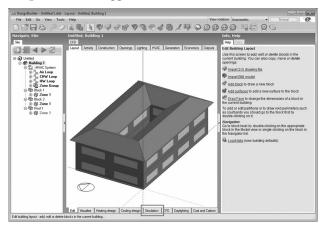
Step	6:	Click	OK.

elect location for template-based new file		
lew project Data		Help
Location Template		Info Data
Title	*	
Title	Untitled	Select the location template as a source of location and weather data for the site.
Location	*	The location defines the geographical location and
*Location	LONDON/GATWICK ARPT	weather data for all buildings on this site. You will be
Analysis	1-EnerovPlus	
Analysis type EED/ASHBAE 901 Model	1-EnergyPlus ·	
ASHRAE 90.1 App G PRM		
		•
Don't show this dialog next time		Help Cancel OK

The building layout appears with the following tabs at the bottom of the central display screen:

- Edit
- Visualise
- Heating design
- Cooling design
- Simulation
- CFD
- Daylighting
- Cost and carbon

Step 7: Select **Simulation** tab. The **Edit Calculation Options** screen appears.



Step 8: Enter the Simulation Period start date to **1 Jan** and the end date to **31 Dec**. Click **OK** to start the simulation.

Edit Calculation Options			
Calculation Options Data			Help
General Options Output Simulation Manager			Info Data
Calculation Description	×		Simulation Options
Simulation Period	×		These options control the simulation and the output produced.
From	×		Simulation Period Select the start and end days for the simulation, or
Start day	Jan •		select a typical period: • Annual simulation
Start month	Jan		Summer design week
End day	31		Summer typical week
End day	Dec •		Summer rypical week All summer
Output Intervals for Reporting	Dec		Winter design week
Monthly and annual			• Winter typical week
☑ Daily			All winter
☑ Hourly			- <u>All Waller</u>
Sub-hourty			Interval
		1	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 sub-hourly intervals can produce large amounts of data which slows processing and results in large file sizes.
			Auto-Update
		ľ	This dialog is always shown when you select 'Update' and will also be shown before all simulations if 'Don't show this dialog next time' at the bottom is cleared.
Don't show this dialog next time		(Help Cancel OK

A screen appears showing the simulation progress. Depending on the configuration of the system, it can take several minutes to complete the simulation.

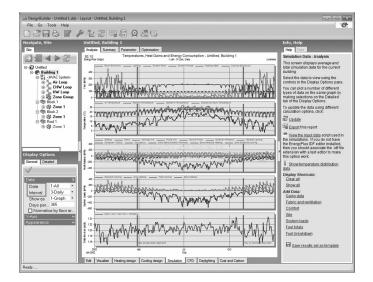
Cancel

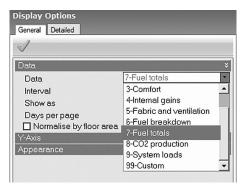
After the simulation is completed, results are displayed in the Analysis subtab of the Simulation tab.

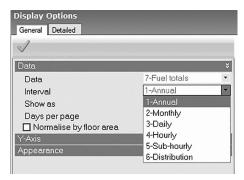
Step 9: Under **Display Options**, select **Fuel totals** from the **Data** drop-down list and **Annual** from the **Interval** drop-down list. A screen appears with a bar graph for annual fuel totals for electricity and gas.

Note: The results are either displayed in IP or SI units based on your configuration of DesignBuilder. The steps involved in switching between SI and IP units are explained in Step 15.

BUILDING ENERGY SIMULATION

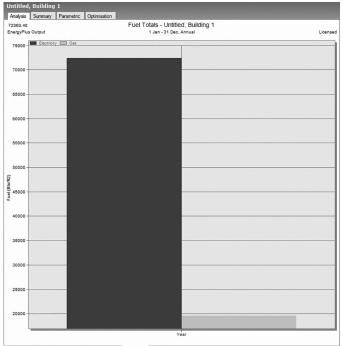






Step 10: Select the **Normalise by floor area** check box and **All floor area** from the **By** drop-down list to view the EUI of the building.

Display Options General Detailed		
\checkmark		
Data.		÷
Data	7-Fuel totals	
Interval	1-Annual	-
Show as	1-Graph	-
Days per page	365	
Normalise by floor area		
By	1-All floor area	*
Y-Axis		>
Appearance		>



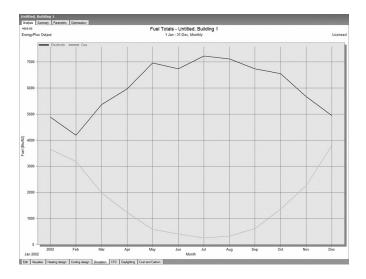
Edit Visualise Heating design Cooling design Simulation CFD Daylighting Cost and Carbon

Units for the Fuel totals can be seen on the *y*-axis of the graph.

The term EUI refers to the energy consumption of the building per unit area per annum. The same term, in some countries, is also named as Energy Performance Index (EPI). The EUI of a building is calculated by dividing the annual total energy (all fuel types) consumption of the building with its gross floor area. The unit of measurement is kWh/m² yr or kWh/ft² yr or Btu/ft² yr. A lower EUI means a better energy performance.

The gross floor area of a building is the total built-up area, which includes all conditioned and unconditioned enclosed spaces of the building.

Step 11: Change the Interval from Annual to **Monthly** to view monthly results. Refer to step 9.



Step 12: Select **Grid** from the **Show as** drop-down list to view results in a grid format.

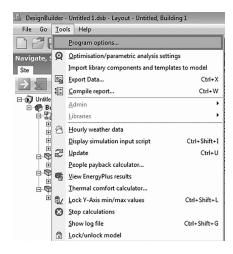
Navigate, Site			Untit	led, Buil	lding	g 1				
Site			Analy	sis Sum	mary	Parametric	Optimisation			
→ 2			Date/1	ime	E	lectricity (Btu/ft	2) Gas (Bt	u/ft2)		
			01-01	-2002	2	805.526	2093.2	95		
⊡ 🕡 Untitled	^		01-02	-2002	2	403.409	1832.7	74		- 1
Building 1	=		01-03	-2002	3	081.368	1137.4	47		- 1
E I <hvac system=""> E I Air Loop</hvac>			01-04	-2002	3	425.949	704.78	84		- 1
			01-05	-2002	3	998.149	331.74	08		- 1
⊕ ී∰ CH₩ Loop ⊕ Ŝ∰ H₩ Loop		Π	01-06	-2002	3	868.452	231.86	94		- 1
n 🛱 Zone Group	*	4	01-07	-2002	4	153.393	146.31	86		
Display Options			01-08	-2002	4	088.434	183.60	71		- 1
General Detailed		Ц	01-09	-2002	3	870.745	351.70	12		- 1
1	-	1	01-10	-2002	3	761.884	781.18	55		- 1
×			01-11	-2002	3	257.23	1293.0	05		- 1
Data ¥			01-12	-2002	2	839.737	2176.5	92		
Data 7-Fuel totals •										- 1
Interval 2-Monthly •										- 1
Show as 2-Grid										
Days per page 365										
	-		Edit	Visualise	Н	eating design	Cooling desig	n Simulation	CFD	Da

Step 13: Select **Fuel breakdown** from the **Data** dropdown list to view results for fuel breakdown.

Display Options		
General Detailed		
\checkmark		
Data		*
Data	6-Fuel breakdown	-
Interval	2-Monthly	•
Show as	2-Grid	•
Days per page	365	
Normalise by floor are	a	
By	1-All floor area	•
Y-Axis		»
Appearance		»

Analysis	Summary	Parametric Optimis	ation				
Date/Time	R	oom Electricity (Btu/ft2)	Lighting (Btu/ft2)	System Fans (Btu/ft2)	System Pumps (Btu/ft2)	Heating (Gas) (Btu/ft2)	Cooling (Electricity) (Btu/ft2)
01-01-200	12 6	92.0494	753.6227	706.4256	0.732569	2093.295	652.6954
01-02-200	12 6	04.6763	655.3242	638.0043	0.6495782	1832.774	504.7545
01-03-200	12 6	39.348	688.0903	704.7253	0.7171509	1137.447	1048.488
01-04-200	12 6	62.925	720.8566	682.9946	0.9475924	704.7684	1358.225
01-05-200	12 6	92.0494	753.6227	712.694	2.138696	331.7408	1837.644
01-06-200	12 6	10.2236	655.3242	688.6503	2.44445	231.8694	1911.81
01-07-200	12 6	92.0494	753.6227	719.0799	3.125918	146.3186	1985.515
01-08-200	12 6	65.6987	720.8566	716.4	2.905756	183.6071	1982.573
01-09-200	12 6	36.5743	688.0903	686.1201	2.144564	351.7012	1857.816
01-10-200	12 6	92.0494	753.6227	704.5274	1.369266	781.1855	1610.315
01-11-200	12 6	36.5743	688.0903	682.4278	0.9172565	1293.005	1249.221
01-12-200	12 6	65.6987	720.8566	706.832	0.8974392	2176.592	745.4519

In all the above steps, the results are in SI or IP units based on the existing configuration of DesignBuilder in your system. To change the units, perform the following step. Step 14: From the Tools menu, select **Program options**. The **Edit Program Options** screen appears.



Step 15: Select the **International** tab and select **Units** as per your requirement. Click **OK**. DesignBuilder updates all the values in the selected units. SI units will be used in this workbook.

Edit Program Options			
Program Options Data		Help	_
Interface Dialogs Files Developer EnergyPlus	Limits International		
	units International		_
Language		*	
Language	1-English	DesignBuilder can be used either with SI units (me	etric)
Units	[a	 or IP units. Because the program uses SI units internally, and because the databases which come 	
Units Currency	2-Inch-Pound (IP) 1-Metric (SI)	the program have been built up assuming SI units	US
El Currency	2-Inch-Pound (IP)	users may find some limitations with the data supp and with some aspects of the user interface. Thes	bied
Filters	TE man Found (ir)	be addressed in due course.	e wiii
Region	England and Wales	Region filter	
Show ASHBAE data	England and Wales	The region filter allows you to see only the data relevant to your particular region. Note that if you h	
Show NCM data		a file loaded then DesignBuilder will use the region	1
Show Spanish data		associated with the location of the site. The region this dialogue is only used when no file is loaded.	in
Show other regions data		Data tables which can be filtered in this way are:	
Show 'General' region data	2-Always	Constructions	
Show DesignBuilder 'Early' data	2-Always	Activity Templates	
Italian Law		Holidays	
		Sectors	
		Help Cancel OK	_
		Lancel UK	

Step 16: From the File menu, select Save to save this model.

Exercise 1.1

Compare the EUIs of residential and office buildings.

'Courtyard with VAV example' is for an office space. Simulate a file with residential usage and compare the results.

DesignBuilder can open only one file at a time.

Hint: Open the file **House example 1**. Ensure that the location is London Gatwick. Repeat the steps given in Tutorial 1.1 to find the EUI. Enter the EUI values in the last column of Table 1.1.

You can observe that even with the same location and building envelope, the EUIs of office buildings and residential buildings are different. This is mainly due to the difference in building usage that includes difference in timing and duration of use, occupancy density, nature of equipment used and other factors. Office buildings usually have a higher EUI, as they have higher internal loads (Table 1.1).

Table 1.1Energy use intensities for office and residentialbuildings

Energy use	Office building EUI (kWh/m ²)	Residential building EUI (kWh/m ²)
Electricity Gas		

TUTORIAL 1.2 Creating a single-zone model

GOAL

To create a single-zone model and find heating and cooling capacities.

WHAT ARE YOU GOING TO LEARN?

- Creating a new file
- Drawing a rectangular model
- Viewing the building model
- Rendering the building model
- Sizing runs for heating and cooling capacity
- · Performing annual energy simulations

PROBLEM STATEMENT

Create a new file and draw a 40 m \times 20 m rectangular building of height 3.5 m with location as LONDON/ GATWICK ARPT. Perform cooling and heating sizing and annual energy simulation. Use the Dynamic orbit option for different 3D views of the model.

SOLUTION

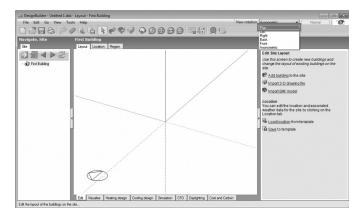
Step 1: Click **File** and select **New Project**. The **Add new project screen** appears.

210	Go Tools Help						
닆	New project Chir N						
-							Info, Help
	Save +	Template Libraries					Help Data
	[mport •		Folder /	Size (KB)	Last Modified T	Extension /	Recent and Example Files
	Export +			-			To open one of the recently opened files, sele
	Folders +	p					the file in the main screen and click on 'Open selected file below
		-	C.{Users\/Neresh\/Des.	1120	3/15/2016 12:59:11 PM	DesignBuilder files	Selected file: Courtward with VAV Example
	Print	Briles					
	Exit Alt+F4		D:\DB Files\Chapter 2.	1608	3/15/2016 11:21:46 AM	DesignBuilderfiles	Copen selected site
	1 lt.dsb	-					X Delete selected site
	2 2.4.dsb	Builder\Templates					Clear recent files list iffies are not deleted
_	-	it cooling		987	12/14/2015 1:03:00 PM	DesignBuilder templates	If the file you want to open does not appear in
	晶 Double Skin Fac		C.\ProgramData\Desi.	1009	12/14/2015 1:03:00 PM	DesignBuilder templates	the list of recently used files you can also:
	晶 Plenum Example		C.\ProgramData\Desi.		12/14/2015 1:03:00 PM	DesignBuilder templates	Create new project
	Courtyard with V/		C.\ProgramData\Desi.		12/14/2015 1:03:00 PM	DesignBuilder templates	
		with Calc Nat Vent	C.\ProgramData\Desi.		12/14/2015 1:03:00 PM	DesignBuilder templates	Cpen existing site
	晶 Zone Multiplier E		C:\ProgramData\Desi.		12/14/2015 1:03:00 PM	DesignBuilder templates	Learning mode is ON
	🚜 Green roof exam	ple	C:\ProgramData\Desi.		12/14/2015 1:03:00 PM	DesignBuilder templates	Learning mode provides relevant information
	PCM Example		C.\ProgramData\Desi.	2263	12/14/2015 1:03:00 PM	DesignBuilder templates	and easy access to typical commands. New
	晶 Underfloor Heati		C.\ProgramData\Desi.	748	12/14/2015 1.02.58 PM	DesignBuilder templates	users often find Learning mode particularly helpful. You can switch it off from the Program
	A Parametric Simul		C.\ProgramData\Desi.		12/14/2015 1:02:58 PM	DesignBuilder templates	Options dialog
	Trombe Wall Exe		C.\ProgramData\Desi.		12/14/2015 1:02:58 PM	DesignBuilder templates	
	📠 Single Zone Exa		C.\ProgramData\Desi.		12/14/2015 1:02:58 PM	DesignBuilder templates	Other tools:
	Addel Geometry		C.\ProgramData\Desi.		12/14/2015 1:02:58 PM	DesignBuilder templates	Web Tutorials
	CFD Internal Ana		C:\ProgramData\Desi.		12/14/2015 1:02:58 PM	DesignBuilder templates	
	Dehumidification		C:\ProgramData\Desi		12/14/2015 1:02:58 PM	DesignBuilder templates	
	Atrium example t			989	12/14/2015 1:02:58 PM	DesignBuilder templates	
	CFD External And		C:\ProgramData\Desi.	929	12/14/2015 1:02:58 PM	DesignBuilder templotes	
	A Mech Vent with P		C.\ProgramData\Desi.	755	12/14/2015 1:02:58 PM	DesignBuilder templates	
	Mixed Mode Exa			934	12/14/2015 1:02:58 PM	DesignBuilder templates	
		ideo Tutorials Exa		1024	12/14/2015 1:02:58 PM	DesignBuilder templates	
	House Example	1	C.\ProgramData\Desi.	820	12/14/2015 1:02:58 PM	DesignBuilder templates	

Step 2: Enter **First Building** in the Title text box and click **OK**. A blank building layout appears.

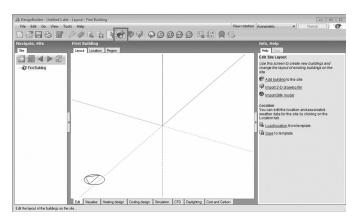
Add new project			
New project Data		Help	
Location Template		Info Data	
Title	* l	Site Location	
Title	First Building	Select the location template as	a source of location
Location	×	and weather data for the site.	
* Location	LONDON/GATWICK ARPT	The location defines the geogra	phical location and
Analysis	*	weather data for all buildings or able to load data from other loc	ation templates or
Analysis type	1-EnergyPlus ·	override the default data from the	e Location data tab at
LEED/ASHRAE 90.1 Model	*	one reven.	
ASHRAE 90.1 App G PRM			
		>	
Don't show this dialog next time		Help Cance	ОК



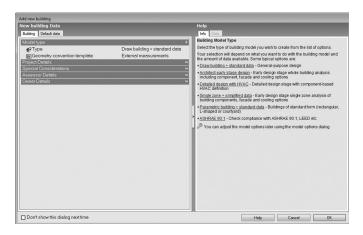


In the DesignBuilder display, the red line represents the *x*-axis, green the *y*-axis, and blue the *z*-axis.

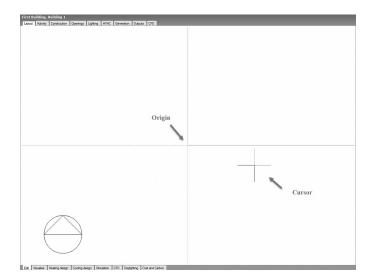
Step 4: Click the **Add new building** button. The **Add new building** screen appears.



Step 5: Click **OK**. The screen appears with a cursor to draw a building.



Step 6: Move pointer to the **Origin**. Left click, move on the positive *x*-axis. The length of the segment is shown. (In case of any mistake, you can choose to cancel the drawn line by pressing the ESC key and then try again).



Transfer South 1 The failing states 1 The fail the failing states 1 The failing state

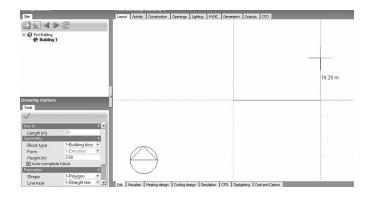
Step 7: Type **40**. The **Length** of the wall is set to **40** m. Ensure that the properties under the Geometry section are as follows:

- Block type Building Block
- Form Extruded
- Height 3.5 m

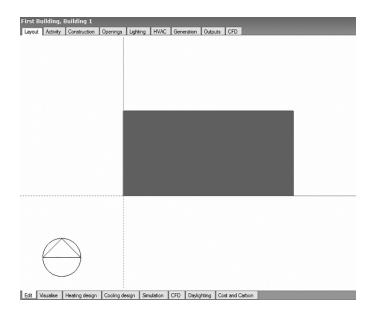
Press Enter.

Drawing Options		
\checkmark		
Key In		×
Length (m)	40	
Geometry		×
Block type	1-Building block	
Form	1-Extruded	
Height (m)	3.50	
Auto-complete block		
Perimeter		¥
Shape	1-Polygon	
Line type	1-Straight line	
Protractor		»
Direction Snaps		»
Point Snaps		»
Drawing Guides		»

Step 8: Rotate the mouse wheel to zoom in or zoom out. Move the pointer parallel to the positive *y*-axis. It snaps when a dashed vertical line appears. Type **20** to draw the second side of the rectangle. Press **Enter**.

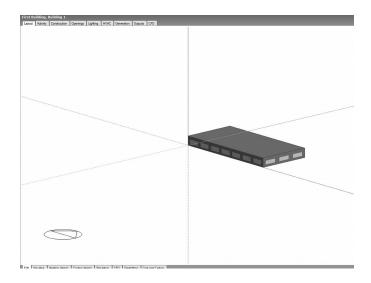


Step 9: Similarly draw other segments and complete the rectangular building block of dimensions 40 m \times 20 m. The following screen shows the completed block.



Step 10: Select the **Dynamic orbit** tab on the main menu bar. This shows the block in the orbit mode. Click and drag the mouse in the layout to view the block in the orbit mode.





Now you will learn to run the system sizing.

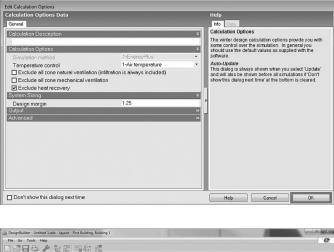
Step 11: Select the **Heating design** tab at the bottom of the screen. The **Edit Calculation Options** screen appears.

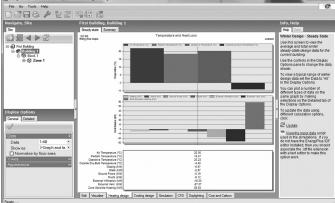
Edit Visualise Heating design Cooling design Simulation CFD Daylighting Cost and Carbon

Heating Design calculations show the heating system size in the worst conditions (no internal loads and solar heat gains) for a winter design day.

Steady-state simulations assume that the temperature across the envelope does not vary with time.

Step 12: Select **OK**. The screen appears with the average and total winter steady-state design data for the current building in graphical format.





This graph shows the heat balance to maintain the inside temperature of 22° C when the outdoor dry bulb temperature is -4.4° C. You can see that there is a heat flow from the inside to outside (shown as negative numbers; the convention is that a positive value is used for a heat flow from the outside to inside) through the envelop and due to infiltration and ventilation. To balance this heat loss, the required zone sensible heating is 58.53 kW.

The table also shows the air temperature, radiant temperature and operative temperature, where the operative temperature is calculated as the average of the radiant and air temperatures.

Steady-state heat loss is the total heat loss from the building. In other words, it is the amount of heat needed to maintain the given indoor comfort temperature.

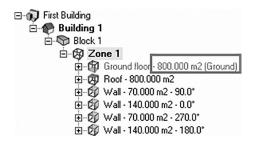
Step 13: Select the **Summary** tab. The Heating design data summary appears.



Design capacity is the total heat loss multiplied by the sizing factor.

Sizing factor is the safety factor considered in sizing the HVAC system. For example, the heating system is commonly oversized by 25%.

The design capacity of the building is 73.16 kW, which is calculated considering the sizing factor of 25% over the steady-state heat loss of 58.53 kW. The design capacity normalized by area is 95.60 W/m², which is calculated for the building floor area. In this case, the building dimensions are 40 m \times 20 m, and the building area is 800 m² (Net Floor area is 765.24 m²).

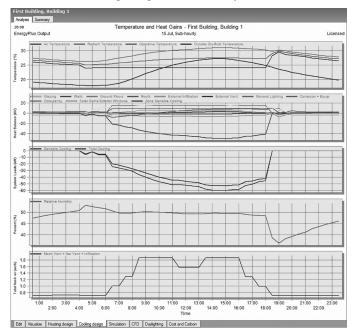


Step 14: Similarly select the **Cooling design** tab at the bottom of the screen. The **Calculation Options – Building 1** screen appears. Click **OK**. The temperature, heat gains and other parameters appear in graphical format.

Calculation Options - Building 1		
Calculation Options Data		Help
General		Info Data
Calculation Description		Calculation Options
		The summer design calculation options provide you with some control over the simulation. In general you
Calculation Options		should use the default values as supplied with the
Simulation method	1-EnergyPlus	 software.
Temperature control	1-Air temperature	Auto-Update This dialog is always shown when you select 'Update'
Summer Design Day		and will also be shown before all simulations if 'Don't
Day	15	 show this dialog next time' at the bottom is cleared.
Month	Jul	•
Day of week	9-SummerDesignDay	×
Exclude all zone natural ventilation (i	infiltration is always included)	P
Exclude all zone mechanical ventilat	tion	
Exclude heat recovery		
System Sizing		*
Design margin	1.15	
Sizing method	1-ASHRAE	
Airflow calculation method	1-Sensible only	
Output		>>
Solar		»
Advanced		»
Don't show this dialog next time		Help Cancel OK

A cooling system is commonly oversized by 15%.

Step 15: Select the **Summary** tab. The screen appears with the cooling design data summary.



Zone	Block 1: Zone
Design capacity (kW)	68.9
Design flow rate (m ³ /s)	4.2
Total cooling load (kW)	59.9
Sensible (kW)	52.9
Latent (kW)	7.0
Air temperature (°C)	24.0
Humidity (%)	49.5
Time of max cooling	Jul 15:00
Max op temp in day (°C)	29.9
Floor area (m ²)	765.3
Volume (m ³)	2,678.5
Flow/floor area (l/s-m ²)	5.5
Design cooling load per floor area (W/m ²)	90.1
Outside dry bulb temperature at time of peak cooling load (°C)	27.2

 Table 1.2
 Data for the single-zone model

irst Building, Buil											
Analysis Summary											
Zone	Design Capacity	(k.w) Design Flow Rate	[m3/s] Total Cooling Lo	ad (kW) Sensible (k	W] Latent (k)	Air Temperati.	re (°C) Hunidity (Time of Max Cook. 	Max Op Temp in Day ("C)	Floor Area (m2)	Volue
Building 1											
Block1:Zone1	68.94	4.2185	59.95	52.93	7.01	24.0	49.5	Jul 15:00	29.9	765.3	2678
Totals	68.94	4.2185	59.95	52.93	7.01	24.0	49.5	N/A	29.9	765.3	267

The screen data are provided in table format for a clear view (Table 1.2).

The load calculated in the building is 68.94 kW. Cooling load is also described in tons of refrigeration (TR). For this building, it is 19.64 TR. Enter the cooling and heating capacities in Table 1.4.

A ton of refrigeration (TR), describes the heat-extraction capacity of refrigeration and air conditioning equipment. It is defined as the rate of heat transfer that results in the melting of 1 short ton (907 kg) of pure ice at 0° C in 24 hours. A refrigeration ton is approximately equivalent to 3.5 kW of cooling effect.

Sensible versus latent heat:

Sensible heat is the energy required to change the temperature of a substance with no phase change. Sensible heat represents only the dry bulb temperature change.

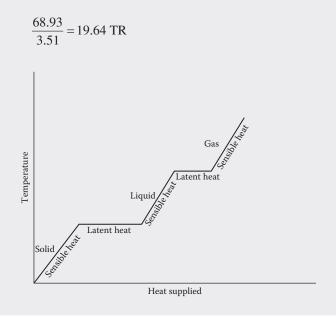
(Continued)

Latent heat, however, does not affect the temperature of a substance. Heat that causes a change of state with no change in temperature is called latent heat.

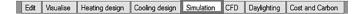
A cooling system should be capable of removing both the sensible and latent heat from the building. Therefore, the total cooling capacity of a system will be (sensible heat load + latent heat load) \times sizing factor.

In this tutorial, sensible heat is 52.93 kW and latent heat is 7.01 kW. The addition of both sensible and latent heat is 59.9. Therefore, the design capacity calculated by multiplying 59.9 with sizing factor (1.15) is 68.93.

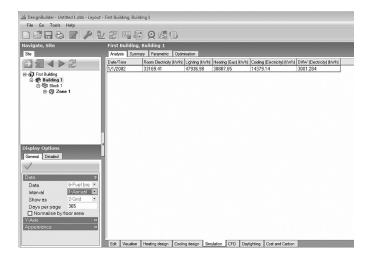
You can divide this by 3.51 to convert it into the unit of TR.



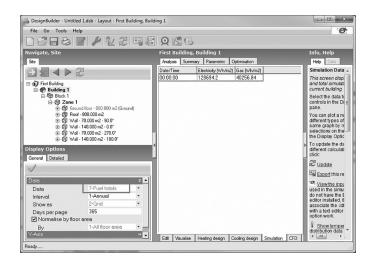
Step 16: Select the **Simulation** tab to perform the annual simulation. Select **Fuel breakdown** from the **Data** drop-down list, **Annual** from the **Interval** drop-down list and **Grid** from the **Show as** drop-down list.



BUILDING ENERGY SIMULATION



Step 17: Select the **Normalise by floor area** check box and **All floor area** from the **By** drop-down list to view the EUI of the building. Also select **Fuel totals** from the **Data** drop-down list. Enter the electricity EUI value in Table 1.3.



Step 18: Save the model as **First Building** on Desktop. You are going to use this model in forthcoming tutorials.

Jave File As		×
Save in Desktop	G 🖻 🖻 [.
Name	Size	Item t 🖍
词 Libraries		
🖓 Homegroup		
🖟 admin		
🛒 Computer		
📬 Network		-
•		Þ
File name: First Building		Save
Save as type: DesignBuilder files(*.dsb)	-	Cancel

Exercise 1.2

Create a larger building and compare the EUI with a smaller building. Repeat the tutorial to create an 80 m \times 40 m rectangular building. Compare the EUI of the larger building with the smaller building (the 40 m \times 20 m building created in Tutorial 1.2) and enter it in Table 1.3. Enter and compare the cooling and heating capacities of the larger building in Table 1.4. The method to calculate the EUI (kWh/m² yr) is explained in Tutorial 1.1.

 Table 1.3
 EUI for a large and small building

	Building with 40 m \times 20 m dimension kWh/m ² yr	Building with 80 m \times 40 m dimension kWh/m ² yr
Electricity Gas		

	Building with $40 \text{ m} \times 20 \text{ m}$ dimensions	Building with 80 m × 40 m dimensions
Capacity of cooling equipment (kW)		
Capacity of heating equipment (kW)		
Cooling capacity (kW/m ²)		
Heating capacity (kW/m ²)		

Table 1.4Cooling and heating capacity for a large and smallbuilding

The following observations can be made through the above exercise:

- 1. EUIs of both the buildings are different.
- 2. Cooling and heating equipment capacities are greater for the 80 m \times 40 m building compared to the 40 m \times 20 m building. Larger buildings require higher capacity equipment due to the greater envelope area, occupancy and internal loads.
- 3. Cooling/heating equipment capacities per unit area are different. A larger building has a lower capacity per unit area. The main reason behind such a difference is that although most of the internal loads, such as occupancy, lighting and equipment, vary linearly with area, the heat gain/loss through the building envelope does not follow the same trend due to a non-linear variation of the exposed surface area with the floor area or carpet area.

TUTORIAL 1.3 Evaluating the impact of building location and orientation

GOAL

To evaluate the impact of the building location and its orientation on the HVAC system sizing and building annual energy consumption.

WHAT ARE YOU GOING TO LEARN?

- Changing the location of a building
- Downloading a weather file
- Changing building orientation
- Analysing the impact of weather and orientation on the building's performance

PROBLEM STATEMENTS

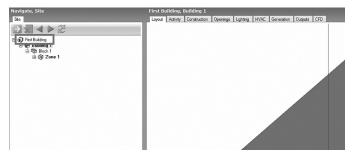
- 1. In Tutorial 1.2, a 40 m \times 20 m rectangular building was simulated for London. Simulate the same building model for New Delhi and compare the HVAC sizing, monthly energy consumption and annual energy consumption.
- 2. Rotate the building by 90° clockwise and simulate it for New Delhi. Compare the results of the two models (without rotation and with 90° rotation).

SOLUTION

Step 1: Open the model saved in Tutorial 1.2.

👍 Open File		for Designed by	- annati	×
Look in:	Desktop	•	G 🖻 🖻 🛙	
æ	Name		Size	Item type 🔺
Recent Places	📠 First Buildir	ng.dsb	1,617 KB	DesignBuilder , ≡
Desktop				
Libraries				
Computer	4			
	File name:		-	Open
Network	Files of type:	DesignBuilder files(*.dsb) Open as read-only	•	Cancel

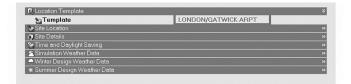
Step 2: Click **First Building**.



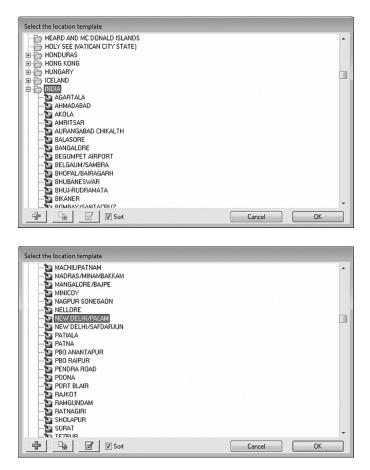
Step 3: Select the **Location** tab. The **Location Template** screen appears.

Navigate, Site	First Building
Ste	Layout Location Region
E → Building → Building → Building → Building → Block 1 → ⊕ 20 Zone 1	

Step 4: Click **LONDON/GATWICK ARPT**. Three dots (...) appear. Click the three dots. The **Select the location template** screen appears.



Step 5: Scroll to select **INDIA**. Double click **India** and select **NEW DELHI/PALAM**. Click **OK**.

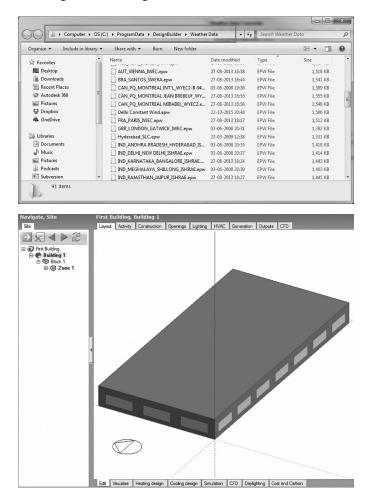


Step 6: Click Building 1.

Navigate, Site	First Building	
Ste	Layout Location Region	
2 2 4 ▶ 2	C. Location Template	×
- al First Ruilding	Template NEW DELL	HI/PALAM
🖻 🕐 Building 1	Site Location	»
E QU BIOCK I	👦 Site Details	»
ia-⊕ Zone 1	Time and Daylight Saving	»
	😤 Simulation Weather Data	»
	Service Context Contex	»
	* Summer Design Weather Data	**

Step 7: Select the **Simulation** tab. If your computer is connected to the Internet, DesignBuilder directly downloads the weather file. If, for some reason, DesignBuilder is not able to download the weather file, you can manually download the weather file from https://energyplus.net/weather.

Place the downloaded weather file in the folder C:\ ProgramData\DesignBuilder\Weather Data.



DesignBuilder uses hourly weather files with .epw extension. Weather files can be downloaded from the following link: https://energyplus.net/weather. Weather files that are downloaded directly from the website should be copied in the DesignBuilder weather data folder located at C:\ProgramData\DesignBuilder\ Weather Data.

Step 8: Compare the simulation results for London and New Delhi locations. Results for London location can be obtained from Tutorial 1.2.

The impact of location on building energy consumption can be seen from the results reported in Table 1.5.

You can observe that there is no change in room electricity and lighting. This is the result of the same internal loads, and as there is no daylight-based control, the change in location does not change these values.

From the results in Tables 1.5 and 1.6, the following observations can be made:

• The heating energy consumption is more in London than in New Delhi. This is because London has a colder climate compared to New Delhi.

Туре	London (kWh)	New Delhi (kWh)
	London (k (i i)	
Room electricity	33,169.41	33,169.41
Lighting	47,936.98	47,936.98
Heating (gas)	30,807.65	1,502.32
Cooling	14,379.14	101,945.7
DHW (electricity)	3,001.28	3,001.28

 Table 1.5
 Energy consumption with a change in location

	London	New Delhi
Capacity of cooling equipment (kW)	68.94	99.64
Capacity of heating equipment (kW)	73.16	43.56

Table 1.6Heating and cooling equipment capacity with achange in location

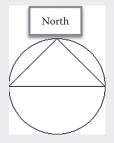
- For the cooling energy consumption, it is the reverse because New Delhi is warmer than London in summers.
- Similarly, there is a significant effect of location on the cooling and heating equipment capacity.

Next steps show how to change the orientation.

Step 9: Select the **Location** tab (refer to Steps 2 and 3 of this tutorial) and click **Site Details**. Enter **90** in the Site Orientation text box. Select the **Layout** tab. You can observe the change in the north arrow direction before and after changing the site orientation.



North is indicated by the direction of the north arrow in the sketch plan view.

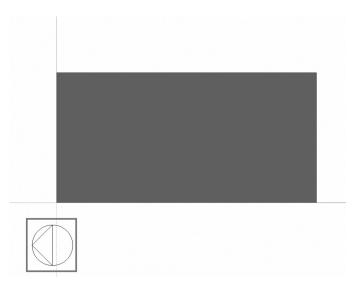


Working at the 'untitled' level (here First Building) of the tree means working at the site level. For example, if there are multiple buildings on a site that are to be modelled in DesignBuilder, after creating one building, return to the site level in the tree to start creating the next building.

Therefore, all site-specific information such as location and orientation can be assigned to the model only when the site level is selected in the navigation tree.

Site orientation (°) in DesignBuilder represents the alignment of the building(s) with respect to true north. However, since there could be multiple buildings on the site, this is called site orientation instead of building orientation.

Step 10: Select the **Simulation** tab to get the results.



The impact of building orientation on building energy consumption is shown in the results recorded in Table 1.7.

Туре	Orientation 0° (kWh)	Orientation 90° (kWh)
Room electricity	33,169.41	33,169.41
Lighting	47,936.98	47,936.98
Heating (gas)	1,502.32	1,644.22
Cooling (electricity)	101,945.7	103,836.7
DHW (electricity)	3,001.28	3,001.28

Table 1.7Annual energy consumption with a change inorientation

 Table 1.8
 Heating and cooling equipment capacity with change in orientation

Туре	Orientation 0° (kW)	Orientation 90° (kW)
Cooling	99.64	105.49
Heating	43.56	43.56

Changing the orientation of the building changes the heating and cooling energy consumption and also the system sizing. You may note that heating capacity does not get affected by the change in orientation due to the fact that peak requirement of heating occurs in non-sunshine hours. Hence, any orientation would require the same amount of heating (Table 1.8).

Exercise 1.3A

For New Delhi, run simulations for three more orientations -45° , 180° and 270° – and compare the results (Tables 1.9 and 1.10).

Annual fuel breakdown data					
Туре	0° (kWh)	45° (kWh)	90° (kWh)	180° (kWh)	270° (kWh)
Room electricity					
Lighting					
Heating (gas)					
Cooling (electricity)					
DHW (electricity)					

Table 1.9 Energy consumption with a change in orientation

 Table 1.10
 Heating and cooling equipment capacity with a change in orientation

Туре	0°	45°	90°	180°	270°
Heating capacity (kW) Cooling capacity (kW)					

Compare the energy consumption for 0° and 180° ; what do you observe?

It can be seen that the results for 0° and 180° are the same, and those of 90° and 270° are the same. This is due to symmetry in the shape and window distribution of the building due to which solar exposure for these two cases becomes similar.

A comparison of the energy consumption for 0° and 90° shows a difference in the cooling capacity as well as energy consumption due to the change in solar exposure.

Exercise 1.3B

Change the weather location of the model with New York and Singapore and enter the values in Tables 1.11 and 1.12.

 Table 1.11
 Energy consumption with a change in location

Annual fuel breakdown data			
Туре	New York (kWh)	Singapore (kWh)	
Room electricity			
Lighting			
Heating (gas)			
Cooling			
DHW (electricity)			

Table 1.12Heating and cooling equipment capacity with achange in location

Туре	New York (kW)	Singapore (kW)
Heating Cooling		

BUILDING ENERGY SIMULATION

Observe and write why energy consumption and system sizing changed?

It can be seen that the extent of variation is significantly less for orientation as compared to that of the change in location.

The change in energy consumption due to orientation may be more pronounced in buildings having a higher aspect ratio (the ratio of longer and shorter sides) due to the change in solar exposure of the building that influences heat gain.

The change in energy consumption with location is largely due to the change in harshness of climatic conditions. This can be proportional to the cooling degree days (CDDs) for cooling energy consumption and heating degree days (HDDs) for heating energy consumption.

Values of CDDs and HDDs can be found in weather files, design data books and references such as ASHRAE.

HDDs and CDDs are a common measure used to interpret the heating and cooling needs of a location. Degree days are the summation of the product of the difference in temperature (ΔT) between the average outdoor and the hypothetical average indoor temperature and the number of days the outdoor temperature above or below the hypothetical average indoor temperature.

The degree days are calculated in reference to a baseline line temperature that is commonly 18°C. Temperatures beyond 18°C need to be cooled and temperatures below 18°C need to be heated.

Example: To calculate CDDs for two consecutive days.

Baseline temperature = 18° C Daily average outdoor DBT on Day 1 = 20° C Daily average outdoor DBT on Day 2 = 17° C CDD on Day 1 = 20 - 18 = 2CDD on Day 2 = 17 - 18 = -1Total CDD = 2

The unit of measurement for CDD or HDD is degree days.

TUTORIAL 1.4 Evaluating the impact of opaque envelope components

GOAL

To understand the impact of thermal properties for opaque envelope components (the external wall and roof) on the HVAC system sizing and energy consumption.

WHAT ARE YOU GOING TO LEARN?

- Changing the wall construction in a building from the library of DesignBuilder
- Changing the roof construction in a building from the library of DesignBuilder

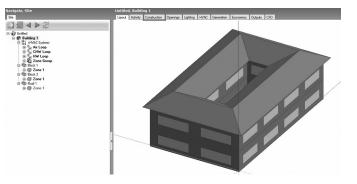
PROBLEM STATEMENT

For the Courtyard with VAV Example, change the external wall from 'Best practice wall, Medium weight' to 'Brickwork single leaf construction dense plaster' and record its impact on the building energy performance for the London weather file.

SOLUTION

Step 1: Open the **Courtyard with VAV Example** model from the template.

Name	Folder /	Size (KB)	Last Modified V	Extension /
DesignBuilderfiles				
-IC/Users/Naresh/Desktop				
- A R	C:\Users\Naresh\Desktop	1120	3/15/2016 12:59:11 PM	DesignBuilderfiles
_D\DB Files\Chapter 2 DB files				
Ja 2.4	D.\DB Files\Chapter 2 DB files	1608	3/15/2016 11:21:46 AM	DesignBuilder files
DesignBuilder templates				
- C\ProgramData\DesignBuilder\Templates				
Simple HVAC night cooling	C:\ProgramData\DesignBuil	987	12/14/2015 1:03:00 PM	DesignBuilder templates
A Plenum Example Buillding	C:\ProgramData\DesignBuil	891	12/14/2015 1:03:00 PM	DesignBuilder templates
Green roof example	C\ProgramData\DesignBuil	944	12/14/2015 1:03:00 PM	DesignBuilder templates
	C\ProgramData\DesignBuil	1009	12/14/2015 1:03:00 PM	DesignBuilder templates
Courtyard with VAV Example	C\ProgramData\DesignBuil	771	12/14/2015 1:03:00 PM	DesignBuilder templates
Atrium Example with Calc Nat Vent	C\ProgramData\DesignBuil	111	12/14/2015 1:03:00 PM	DesignBuilder templates
Zone Multiplier Example	C:\ProgramData\DesignBuil	953	12/14/2015 1:03:00 PM	DesignBuilder templates
PCM Example	C\ProgramData\DesignBuil	2263	12/14/2015 1:03:00 PM	DesignBuilder templates
A Parametric Simulation Example	C.\ProgramData\DesignBuil	946	12/14/2015 1:02:58 PM	DesignBuilder templates
Underfloor Heating Example	C\ProgramData\DesignBuil	748	12/14/2015 1:02:58 PM	DesignBuilder templates
Trombe Wall Example	C\ProgramData\DesignBuil	878	12/14/2015 1:02:58 PM	DesignBuilder templates
🝶 Single Zone Example	C.\ProgramData\DesignBuil	751	12/14/2015 1:02:58 PM	DesignBuilder templates
Model Geometry Example	C\ProgramData\DesignBuil	920	12/14/2015 1:02:58 PM	DesignBuilder templates
GED Internal Analysis Example	C.\ProgramData\DesignBuil	3115	12/14/2015 1:02:58 PM	DesignBuilder templates
Dehumidification example	C\ProgramData\DesignBuil	964	12/14/2015 1:02:58 PM	DesignBuilder templates
Atrium example base	C\ProgramData\DesignBuil	989	12/14/2015 1:02:58 PM	DesignBuilder templates
🝶 CFD External Analysis Example	C.\ProgramData\DesignBuil	929	12/14/2015 1:02:58 PM	DesignBuilder templates
A Mech Vent with Preheat	C:\ProgramData\DesignBuil	755	12/14/2015 1:02:58 PM	DesignBuilder templates
Mixed Mode Example	C\ProgramData\DesignBuil	934	12/14/2015 1:02:58 PM	DesignBuilder templates
🝶 DesignBuilder Video Tutorials Example	C:\ProgramData\DesignBuil	1024	12/14/2015 1:02:58 PM	DesignBuilder templates
House Example 1	C\ProgramData\DesignBuil	820	12/14/2015 1:02:58 PM	DesignBuilder templates

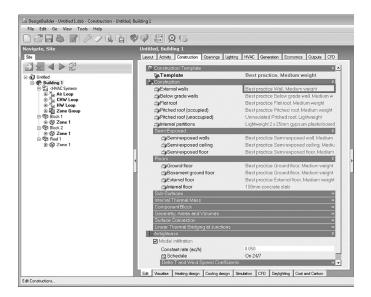


Step 2: Select the Construction tab.

DesignBuilder uses the tree structure for data organization. The 'Template' is the root and all the other fields are the branches. DesignBuilder Templates are databases of typical generic data.

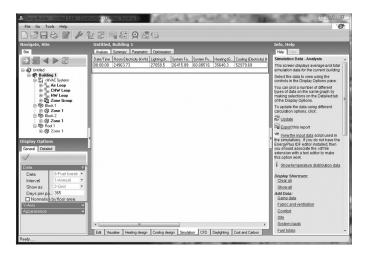
Therefore, when editing the template at the root level, it changes at all branches, but if changes are made at the branch level, root and other branches will not change.

Objects such as external walls in the construction template can also be edited individually without changing the complete root template. However, in that case, it is to be noted that this particular object will be decoupled from the root. This means that changing the roof object does not impact the value of this object. Step 3: Make sure that **Best practice Wall, Medium** weight is selected as **External walls**.



Step 4: Select the **Simulation** tab. The **Edit Calculation Options** screen appears. Click the **Annual simulation** link to set annual simulation period.

Edit Calculation Options		-	
Calculation Options Data		Help	
General Options Output Simulation M	lanager		Info Data
Calculation Description		×	Simulation Options
Simulation Period		Ţ	These options control the simulation and the output produced.
From			Simulation Period
Start day	1		Select the start and end days for the simulation, or select a typical period:
Start month	Jan		Annual simulation
То	international and	×	Summer design week
End day	31	•	Summer typical week
End month	Dec	۳	All summer
Output Intervals for Reporting		Ÿ	Winter design week
Monthly and annual			Winter typical week
☑ Daily			<u>All winter</u>
Hourly			
□ Sub-hourly		Interval Monthly and annual output is always generated and daily hourly and sub-hourly data can selected by	
Don't show this dialog next time			Help Cancel OK



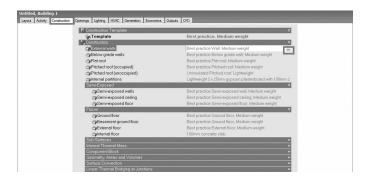
Step 5: Record the energy simulation results.

In the next steps, you are going to change the external wall construction.

Step 6: Click **Edit**. The **Construction Template** screen appears.

Edit Visualise Heating design Cooling design Simulation CFD Daylighting Cost and Carbon

Step 7: Click **External walls** under the **Construction** section. Three dots (...) appear. Click the three dots. The **Select the construction** screen appears.



Step 8: Select Brickwork single leaf construction dense plaster.





Step 9: Select the **Simulation** tab and perform annual energy simulation. View the energy simulation results in Tables 1.13 and 1.14 and compare.

It can be observed that changing the wall impacts the equipment sizing and energy consumption.

Table 1.13Energy consumption with a change in the externalwall construction

Annual fuel breakdown data			
Туре	Best practice wall, medium weight (kWh)	Brickwork single leaf construction dense plaster (kWh)	
Room electricity	24,963.73	24,963.73	
Lighting	27,058.50	27,058.50	
System fans	26,415.89	27,748.42	
System pumps	60.09	67.75	
Heating (gas)	35,640.30	78,542.51	
Cooling (electricity)	52,979.69	53,300.88	

Туре	Best practice wall, medium weight	Brickwork single leaf construction dense plaster
Cooling	73.77	76.55
Heating	56.04	92.32

Table 1.14Heating and cooling equipment capacity (kW) with
a change in the external wall construction

Exercise 1.4

Open the model prepared in Tutorial 1.2. Assign flat roof construction as shown in Tables 1.15 and 1.16. Simulate and compare the results for London.

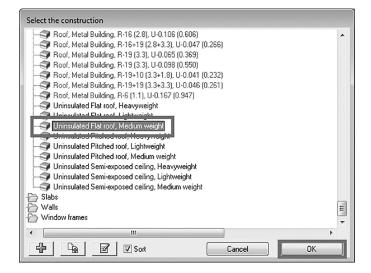
 Table 1.15
 Energy consumption with a change in roof construction

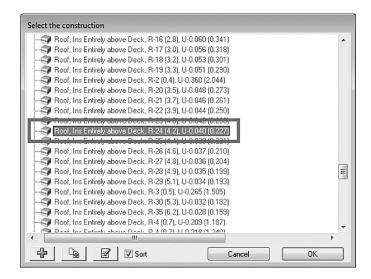
Туре	Roof, ins entirely above deck, R-24 (4.2), U-0.040 (0.227) (kWh)	Uninsulated flat roof, medium weight (kWh)		
Room electricity				
Lighting				
System fans				
System pumps				
Heating (electricity)				
Heating (gas)				
Cooling				

Table 1.16Heating and cooling sizing with a change in roofconstruction

Heating and cooling sizing (kW)				
Туре	Roof, ins entirely above deck, R-24 (4.2), U-0.040 (0.227)	Uninsulated flat roof, medium weight		
Heating Cooling				

Untitled, Building 1			
Layout Activity Construction Openings Lighting	HVAC Generation Economics Outputs CFD		
Construction Template	* 🔺		
Template	Best practice, Medium weight		
Construction	¥		
External walls	Best practice Wall, Medium weight		
Below grade walls	Best practice Below grade wall. Medium w		
Flat roof	Best practice Flat roof, Medium weight		
Pitched roof (occupied)	Best practice Pitched root, Medium weight		
Pitched roof (unoccupied)	Uninsulated Pitched roof, Lightweight		
Internal partitions	Lightweight 2 x 25mm gypsum plasterboard		
Semi-Exposed	¥		
Semi-exposed walls	Best practice Semi-exposed wall, Medium		
Semi-exposed ceiling	Best practice Semi-exposed ceiling, Mediu		
Semi-exposed floor	Best practice Semi-exposed floor, Medium		
Floors	¥		
Ground floor	Best practice Ground floor, Medium weight		
Basement ground floor	Best practice Ground floor, Medium weight		
External floor	Best practice External floor, Medium weight		
Internal floor	100mm concrete slab		
Sub-Surfaces	»		
Internal Thermal Mass	»		
Component Block	»		
Geometry, Areas and Volumes	<u> </u>		
Surface Convection	»		
Linear Thermal Bridging at Junctions	» *		
Airtightness	*		
Model infiltration			
Constant rate (ac/h)	0.050		
😭 Schedule	On 24/7		
Delta T and Wind Speed Coefficients	» v		





You can follow similar steps as you have performed for the external wall.

TUTORIAL 1.5 Evaluating the impact of WWR and glass type

GOAL

To evaluate the impact of glazing area and glazing properties on the energy performance of a building.

In the field of building energy simulations, glazing area is most commonly quantified in terms of WWR. WWR is the ratio of the total glazing area to the total external wall area in conditioned zones.

WHAT YOU ARE GOING TO LEARN?

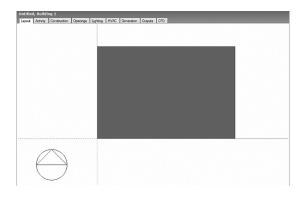
- · Creating zones in a building
- Changing WWR
- Changing glazing type

PROBLEM STATEMENT

Create a 60 m \times 40 m five-zone, single-story building model for London. Take WWR of 30% and 80% and evaluate the building energy performance. Compare cooling and heating equipment sizing of north and south zones.

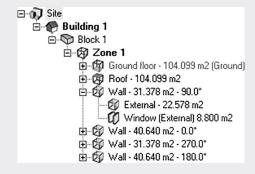
Similarly, compare sizing in east and west zones. Evaluate the impact of glazing by changing the single pane clear glazing (Sgl Clr 3 mm) to high-performance low SHGC dual pane glazing (Dbl Blue 6 mm/13 mm Air).

Step 1: Open a new project and draw a building with $60 \text{ m} \times 40 \text{ m}$.



Data structure hierarchy in DesignBuilder:

Site \rightarrow Building \rightarrow Floors/Levels \rightarrow Zones/Rooms \rightarrow Opaque Components \rightarrow Transparent \rightarrow Components



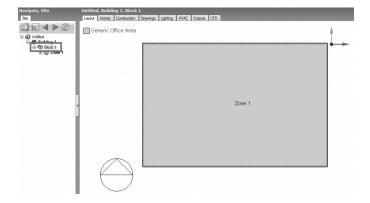
Assigning a template to the upper level branch will result in the same template for all the sub-branches. For example, if a construction template named 'Framed Construction' is assigned to the building, all floors and zones will have the same template – 'Framed Construction'.

When a particular sub-branch is edited, it is separated from the main branch resulting in a need for a separate edit from the main branch.

(*Continued*)

For example, if a particular zone (such as zone 1) of the first floor of the building is selected and the construction template is changed from 'Framed Construction' to 'Mass Construction', and later the whole building is selected and the construction template is changed from 'Framed Construction' to 'Steel Construction', construction template of zone 1 still retains 'Mass Construction'.

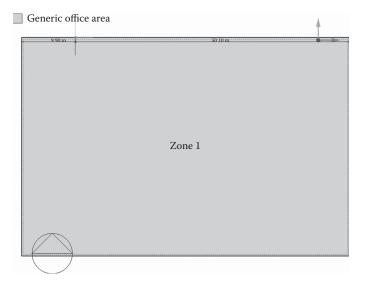
Step 2: Click **Block 1** in navigation tree. The display changes to **Zone 1**.



Step 3: Click the **draw construction line** button to mark lines on the zone. You need to draw an internal partition of 10 m offset.

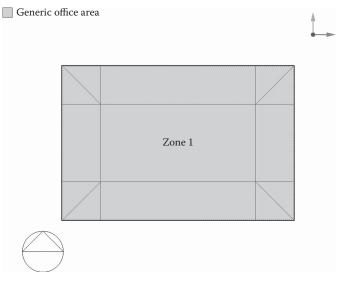


Similar to other drafting programs, DesignBuilder provides some important drafting options such as snap points, gridlines and direction snap. Make sure to select the relevant options while creating the custom geometry. Step 4: Place the pointer near the top-left corner. The pointer snaps to the corner (green square appears at the centre of the cross hair). Left click once the pointer has snapped, and then move the mouse in the right direction over the north wall of the building and type **10**. It draws a construction line of 10 m from the top-left corner on the north wall.

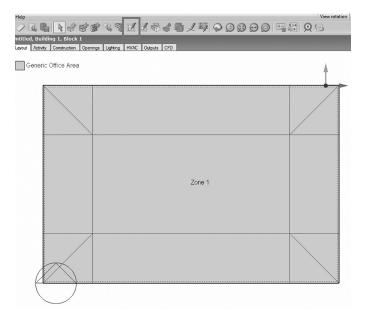


Step 5: Click the right end of the construction line. Now move the mouse vertically down parallel to the west wall of the building with an offset of 10 m (as achieved in the previous step) and snap to the south wall (this time cross hair will change to the red square because it will be edge snapping) and click. Cone 1

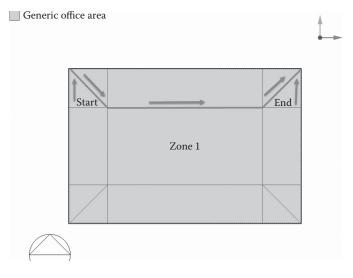
Step 6: Continue drawing all construction lines to mark core and perimeter zones.



Step 7: Click the **Draw partition** button. The screen appears with a cursor to draw the internal partitions.

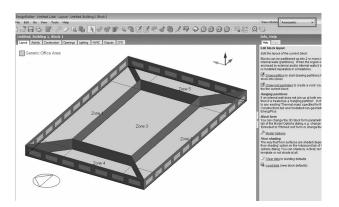


Step 8: Trace the construction line to draw a perimeter zone on the north.

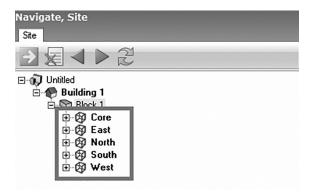


Step 9: Repeat Step 8 to draw other three zones. This step results in a total of five zones, four perimeters and one core as shown below with Axonometric View. (Note: No need to redraw the partition drawn in the previous steps.)

Perimeter and Core zoning is common in building energy simulations, especially when the internal layout of the building that is being modelled is not designed. The Perimeter and Core zoning is also practiced while modelling large open floor plans.



Step 10: Select and rename each zone based on its orientation. (For renaming you need to single click the zone name and wait for about 1 second, and then click again. A text box appears to enter a new name.)

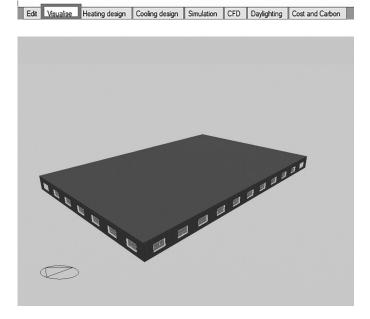


Step 11: Click **Building 1** in the navigation tree. Now you are going to set WWR for the whole building.

Step 12: Select the **Openings** tab. The **Glazing Template** screen appears.

yout Activity Construction Openings Lighting HVAC Outputs CFD			
C Glazing Template		¥	
Q. Template	Project glazing template		
 External Windows 		¥	
() Glazing type	Project external glazing		
Layout	Preferred height 1.5m, 30% glazed		
Dimensions		×	
Type	3-Preferred height		
Window to wall %	30.00		
Window height (m)	1.50		
Window spacing (m)	5.00		
Sill height (m)	0.80		
Reveal		»	
Frame and Dividers		»	
Shading		>>	
Airflow Control Windows		>>	
Free Aperture		»	
Internal Windows		**	
Sloped Roof Windows/Skylights		>>	
Doors		**	
Vents		»	

Step 13: Make sure that window to wall percentage is **30**. Step 14: Select the **Visualise** tab. Use the orbit tool for 3D visuals.



Step 15: Select the **Heating design** tab.



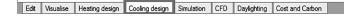
Step 16: Ensure **Air temperature** is selected in the **Temperature control** drop-down list. Click **OK**.

Edit Calculation Options	
Calculation Options Data	Help
General	Info Data
Calculation Description *	Calculation Options
	The winter design calculation options provide you with
Calculation Options ¥	some control over the simulation. In general you should use the default values as supplied with the
Simulation method 1-EnerovPlus •	software.
Temperature control	Auto-Update This dialog is always shown when you select 'Update'
Exclude all zone natural ventilation (infiltration is always included)	and will also be shown before all simulations if 'Don't
Exclude all zone mechanical ventilation	show this dialog next time' at the bottom is cleared.
Exclude heat recovery	
System Sizing **	•
Output » Advanced »	
Auvanceu	
Don't show this dialog next time	Help Cancel OK

Air temperature control means controlling the mean air temperature of the zone to the assigned setpoint temperatures. Other control types mainly include operative temperature and adjusting zone radiant temperature control fraction. These control types are mainly used in advanced research and comfort analysis studies.

Step 17: Select the **Summary** tab. The results are displayed in a grid view. For each zone, the heating capacity is shown in the table.

Step 18: Select the **Cooling design** tab. Ensure **Air temperature** is selected as temperature control. Click **OK**.



Calculation Options - Building 1			
Calculation Options Data			Help
General			Info Data
Calculation Description		×	Calculation Options
			The summer design calculation options provide you with some control over the simulation. In general you
Calculation Options		÷	should use the default values as supplied with the
Simulation method	1-EnergyPlus		software.
Temperature control	1-Air temperature		Auto-Update This dialog is always shown when you select 'Update'
Summer Design Day			and will also be shown before all simulations if 'Don't
Day	15	•	show this dialog next time' at the bottom is cleared.
Month	Jul	-	
Day of week	9-SummerDesignDay	-	
Exclude all zone natural ventilation (infil			
Exclude all zone mechanical ventilation	1		
 Exclude heat recovery System Sizing 			
Design margin	115	· ·	
Sizing method	1-ASHBAE		
Airflow calculation method	1-Sensible only		
Output		>>	
Solar		»	
Advanced		»	
Don't show this dialog next time			Help Cancel OK

Step 19: Select the **Summary** tab to view the cooling system sizing results of each zone (Table 1.17).

It can be seen that the peak cooling for the east zone is at 10:00 and for the west zone at 16:00. Further, note that the cooling capacity for the west zone is more than the east zone. Also, the design capacity for the south zone is more than the north zone. This is because London is located at 51.5° north latitude, resulting in more solar radiation on the south façade.

Step 20: Run energy simulation and record the results for fuel breakdown. Save the model to use in forthcoming tutorials.

Step 21: Repeat previous steps and set WWR to 80.

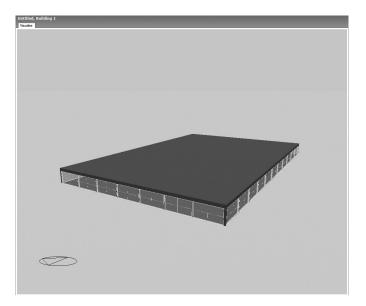
mensions		×
Туре	3-Droforred height	•
Window to wall %	80.00	
Window height (m)	1.50	
Window spacing (m)	5.00	
Sill height (m)	0.80	

Step 22: Select the **Visualise** tab. Use the orbit tool for 3D visuals.

Edi	Visualise	Heating design	Cooling design	Simulation	CFD	Daylighting	Cost and Carbon

Table (Table 1.17 Cooling design data for 30% WWR	esign data for 3	0% WWR						
Zone	Design capacity (kW)	Design flow rate (m ³ /s)	Total cooling load (kW)	Sensible (kW)	Latent (kW) (Air temperature (°C)	Humidity (%)	Time of max cooling	Max op temperature in day (°C)
West	31.97	1.99	27.8	24.99	2.81	24	49	Jul 16:00	31.5
North	35.92	2.16	31.23	27.11	4.13	24	50	Jul 15:00	28.6
East	26.18	1.60	22.77	20.1	2.67	24	49.3	Jul 10:00	28.7
South	53.95	3.21	46.92	40.32	6.59	24	50.3	Jul 15:00	28.1
Core	45.37	2.80	39.45	35.17	4.28	24	49.3	Jul 14:00	28.7
Total	193.39	11.77	168.17	147.69	20.48	24	49.7	N/A	31.5

WR
\geq
r 30% WWI
for
data
design
Cooling
1.17
ble



Step 23: Record the heating and cooling design data and fuel breakdown (Tables 1.18 and 1.20).

Now compare the results for each zone to gain a better understanding of the impact of WWR on sizing. The comparison is shown in Table 1.19.

Also compare the energy consumption of the two models (Table 1.20).

In the tutorial so far, you have learned to change WWR and its impact on sizing and energy consumption. Now you will see the impact of glazing by changing from a single pane clear glazing ('Sgl Clr 3mm') to a dual pane low SHGC high-performance glazing ('Dbl Blue 6mm/13mm Air') with 30% WWR. Before going to the next step, make sure that the WWR is 30% and you are at the building level in the navigation tree.

Untitled										
Layout	Activity	Construction	Openings	Lighting	HVAC	Generation	Outputs	CFD		
			GR	azing Ter	nnlate			-		×
				Templa				1.1	Project glazing template	
			Ex Ex	temal Wi	ndows					×
			Ø	Glazing	type				Sql Cir 3mm	
			Ø	Layout					Preferred height 1.5m, 30% glazed	

Zone	Design capacity (kW)	Design flow rate (m ³ /s)	Total cooling load (kW)	Sensible (kW)	Latent (kW)	Air temperature (°C)	Humidity (%)	Time of max cooling	Max op temperature in day (°C)
Vest	56.34	3.7411	48.99	46.94	2.05	24	47.7	Jul 17:00	37.8
North	42.65	2.6089	37.08	32.74	4.35	24	49.5	Jul 15:00	30.2
East	49.01	3.1683	42.62	39.75	2.87	24	48.2	Jul 09:00	30.8
outh	70.14	4.5091	60.99	56.58	4.41	24	48.4	Jul 13:30	30.1
Core	56.21	3.3603	48.87	42.16	6.71	24	50.2	Jul 15:00	28.4
otal	274.34	17.3878	238.56	218.17	20.38	24	49.1	N/A	37.8

<	
\leq	
~	
80%	
for	
data	
design c	
Cooling	
1.18	
ble	

	Heating si	izing (kW)	Cooling si	izing (kW)
	WWR 30%	WWR 80%	WWR 30%	WWR 80%
North	43.37	48.36	35.92	42.65
South	43.32	48.21	45.37	70.14
East	26.82	29.44	26.18	49.01
West	26.82	29.44	31.97	56.34
Core	52.6	66.41	53.95	56.21

 Table 1.19
 Heating and cooling sizing for 30% and 80% WWR

 Table 1.20
 Energy consumption with 30% and 80% WWR

	Annual fuel breakdown da	ata
Туре	WWR 30% (kWh)	WWR 80% (kWh)
Room electricity	99,994	99,993
Lighting	1,44,513	1,44,512
Heating	90,292	91,614
Cooling	36,454	63,526
DHW	9,048	9,048

Step 24: Select the **Openings** tab and select the **Sgl Clr 3mm** from the library and run the annual simulation.

Step 25: Now select the **Dbl Blue 6mm/13mm Air** from the library and run the annual simulation.

Untitled, Building 1		
Layout Activity Construction Openings Lighting HVAC Generation Outputs CFD		
C. Glazing Template		×
Ge Template	Project glazing template	
External Windows		¥
Glazing type	Dbl Blue 6mm/13mm Air	
Layout	Preferred height 1.5m, 30% glazed	

When you compare the results by changing the glazing from single glazing to double glazing, notice that there is a change in the consumption of electricity for cooling and gas for heating (Table 1.21).

	Annual fuel breakdown data	
Туре	Single glazing (Sgl Clr 3mm) kWh	Double glazing (Dbl Blue 6mm/13mm Air) kWh
Room electricity	99,994	99,994
Lighting	1,44,513	1,44,513
Heating (gas)	1,10,841	1,00,895
Cooling	35,809	30,798
DHW	9,048	9,048

Table 1.21 Annual energy consumption with a change in glasstype

Exercise 1.5

Repeat the above tutorial for Sydney, Australia.

a. Observe the effect when WWR is changed from 30% to 80% (Tables 1.22 and 1.23).

Table 1.22Energy consumption with 30% and 80% WWR

Annual fuel breakdown data		
Туре	WWR (30%) (kWh)	WWR (80%) (kWh)
Room electricity		
Lighting		
Heating (electricity)		
Heating (gas)		
Cooling (electricity)		

Table 1.23Heating and cooling sizing capacity with 30% and80% WWR

	Heating sizing (kW)		Cooling sizing (kW)	
	WWR 30%	WWR 80%	WWR 30%	WWR 80%
North				-
South				
East				
West				
Core				

It can be seen that cooling sizing, and cooling energy consumption increases with increase in WWR. This is because larger glass area results in larger solar gain. Further, as the U-value of the window is inferior to the U-value of the wall, larger window results in larger heat gain in summers. It is interesting to note that heating sizing and heating energy consumption also increases with the increase in WWR. Though an increased solar heat gain through the glass tends to reduce the requirement of heating during daytime, the heat loss through the glass due to conduction offsets this effect. At any given time, glass of only one or two orientations would allow solar radiation to enter, whereas glass of other orientations would lose more heat through conduction as compared to a façade with a smaller WWR, assuming that the walls are more insulated than the glass. Further, during off-sunshine hours, the entire glazed area results in more heat loss if the U-value of the glass is inferior to that of the wall.

However, in subsequent chapters, it will be seen that this effect is combined with a reduction in lighting energy consumption if artificial light is simulated with a dimming feature.

b. Observe the effect with the change in glass type for 30% WWR (Tables 1.24 and 1.25).

	Single glazing (Sgl Clr 3mm)	Double glazing (Db Blue 6mm/13mm
Туре	kWh	Air) kWh
Room electricity		
Lighting		
Heating (electricity)		
Heating (gas)		
Cooling (electricity)		

 Table 1.24
 Energy consumption with a change in glass type

Table 1.25Heating and cooling sizing capacity with thechange in glass type

	Cooling and heating s	system sizing
Туре	Single glazing (Sgl Clr 3mm) kW	Double glazing (Dbl Blue 6mm/13mm Air) kW
Heating Cooling		

TUTORIAL 1.6 Evaluating the impact of occupancy density

GOAL

To evaluate the impact of occupancy density on cooling and heating loads, and the whole building energy consumption.

WHAT ARE YOU GOING TO LEARN?

Changing occupancy density

PROBLEM STATEMENT

Use the model created in Tutorial 1.5 ($60 \text{ m} \times 40 \text{ m}$ with five zones). Set WWR to 30%, minimum fresh air (l/s-person) to 2.5, Mech vent per area (l/s-m²) to 0.3, and model infiltration (ac/h) to 0.20. Run simulations with occupancy density (people/m²) set to 0.07 and 0.10. Analyse the change in energy consumption. Use the **AZ-PHOENIX/SKY HARBOR**, **USA** weather file.

SOLUTION

Step 1: Select the Activity tab, and under the Occupancy section, set the occupancy density (people/m²) to 0.1. Under the Minimum Fresh Air section, set Fresh air (l/s-person) to 2.5 and Mech vent per area (l/sm²) to 0.3.

tled, Building 1	
ut Activity Construction Openings Lighting HVAC Generation	Outputs CFD
 Activity Template 	¥
	Generic Office Area
Sector	B1 Offices and Workshop businesses
Zone multiplier	1
Include zone in thermal calcule	lations
Include zone in Radiance day	viahting calculations
Floor Areas and Volumes	20
60 Occupancy	8
Density (people/m2)	0.1
(2) Schedule	Office_OpenOff_Occ
Metabolic	»
Ceneric Contaminant Generation	on »
& Holidays	»
i, DHW	»
In Environmental Control	8
Heating Setpoint Temperatures	
Cooling Setpoint Temperatures	s »
Humidity Control	»
Ventilation Setpoint Temperatur	#86 *
Minimum Fresh Air	*
Fresh air (l/s-person)	2.5
Mech vent per area (l/s-n	-m2) 0.3
Ligning	»
Computers	*
Miscellaneous	* *
Catering	* *
i Colering i Process	" »

Step 2: Select the **Construction** tab. Under the Airtightness section, set Model Infiltration Constant rate as 0.200 ac/h.

Construction Template	
Se Template	Project construction template
Construction	
CEXternal walls	Project wall
Below grade walls	Project below grade wall
GFlat roof	Project flat roof
Pitched roof (occupied)	Project pitched roof
Pitched roof (unoccupied)	Project unoccupied pitched roof
Internal partitions	Project partition
Semi-Exposed	
Semi-exposed walls	Project semi-exposed wall
Semi-exposed ceiling	Project semi-exposed ceiling
Semi-exposed floor	Project semi-exposed floor
Floors	
Ground floor	Project ground floor
Basement ground floor	Project basement ground floor
CExternal floor	Project external floor
cainternal floor	Project internal floor
Sub-Surfaces	
Internal Thermal Mass	
Component Block	
Geometry, Areas and Volumes	
Surface Convection	
Linear Thermal Bridging at Junctions	
Airtightness	
Model infiltration	
Constant rate (ac/h)	0.200
ft) Schedule	On 24/7

Step 3: Perform the annual simulation and record the results.

Step 4: Set the occupancy density to **0.07** people/m². Perform the annual simulation and record the results (Table 1.26).

Here if you observe the results, they clearly show that a change in occupancy density has an impact on the total energy consumption.

The impact of occupancy density on energy consumption can be explained as follows:

• An increase in occupancy density increases cooling energy consumption due to the increased load (addition of sensible and latent loads from the occupants) in the zone air.

Туре	0.1 people/m ²	0.07 people/m ²
Room electricity	99,994	99,994
Lighting	1,44,513	1,44,513
Heating (gas)	1,045	1,096
Cooling (electricity)	2,02,307	1,92,100
DHW (electricity)	9,048	9,048

Table 1.26Annual energy consumption with the change inoccupancy density

- An increase in occupancy density decreases the heating energy consumption since the heat added by the occupants to the indoor air helps in reducing the heating loads. However, this effect is not straightforward since a higher occupancy would require a higher fresh air intake that would in turn increase heating energy consumption. Further, for blowing more air into the space, the increase in fan power is also a factor that cannot be neglected.
- Occupancy density has no impact on lighting or equipment energy consumption unless these are directly related to the occupancy.

Two important parameters are used to show the occupancy of a zone:

- 1. Occupancy density and schedule: As seen in the tutorial, occupancy density is the maximum number of people in a zone. Schedule of occupancy defines when a zone is occupied or unoccupied and by how many people.
- 2. Metabolic activity: The amount of heat given out by people depends on the activity they perform. For example, a person who is exercising gives out more heat as compared to a person who is sleeping.

Exercise 1.6

For the same tutorial, observe the effect on cooling and heating equipment sizing (Table 1.27).

It can be seen from the results that change in occupancy alters heating and cooling sizing as well. **Table 1.27**Heating and cooling sizing capacity with a changein occupancy density

Туре	0.1 people/m ²	0.07 people/m ²
Cooling Heating		

Increasing occupancy density results in additional sensible and latent heat into the space leading to higher cooling capacity and higher energy consumption.

Higher occupancy density leads to higher fresh air and supply air requirements. Hence, system capacity needs to be increased.

TUTORIAL 1.7 Evaluating the impact of space activity GOAL

To understand the impact of space activity on cooling and heating loads, and energy consumption.

WHAT ARE YOU GOING TO LEARN?

- Changing space activity
- Understanding various activity types
- Understanding the impact of activity type on sizing and energy consumption

PROBLEM STATEMENT

Create a 20 m \times 15 m single-zone model. Set the activity template to Office and Restaurant and compare. Study the effect on sizing and energy consumption for London.

SOLUTION

Step 1: Create a 20 m \times 15 m single-zone model. You can refer to Tutorial 1.2 to create a single-zone model.

Step 2: Select the Activity tab. The Activity Template appears.

Untitled, Building 1	
Layout Activity Construction Openings Lighting HVAC	Generation Outputs CFD
	×
C. Activity Template	Generic Office Area
ج Template	
Sector	B1 Offices and Workshop businesses
Zone multiplier	1
Include zone in thermal calculations	
Include zone in Radiance daylighting calculation	ons
🚡 Floor Areas and Volumes	»
to Occupancy	*
Density (people/m2)	0.1110
🛱 Schedule	Office_OpenOff_Occ
🤶 Metabolic	»
Ceneric Contaminant Generation	»
🏦 Holidays	»
K DHW	»
IIIEnvironmental Control	*
Heating Setpoint Temperatures	»
Cooling Setpoint Temperatures	»
Humidity Control	»
Ventilation Setpoint Temperatures	»
Minimum Fresh Air	»
Lighting	»
🚽 Computers	»
🔩 Office Equipment	»
Miscellaneous	»
Catering	»
l Process	»

Step 3: Simulate the model and record the results.

Step 4: Select the **Activity Template** as **Eating/drinking area**. It changes internal gains and schedules of the space.

Select the activity template
E G Offices / Workshop businesses
B Passenger terminals
Primary Health Care Buildings
E C Residential spaces
E-C Restaurants/Cales/Dinking Establishments/Hot Food takeaways
- Circulation area (contidors and statiwawa) - non nublic - For all non-nublic contidors and statiwawa. For nublic circulation spaces select Eatino/ditiking area
- A Eating/diriking area - Areas where food or dirik are consumed. This could include open conidors or stairs providing access to the main eating/diriking spaces.
- X Food preparation area - An area where food is prepared.
-3 Generic Office Area - Areas to perform office work including offices and meeting rooms. It can include internal contidors providing access to the office spaces, tea making facilities or kitchenne
-3% Light plant room - Areas containing the main HVAC equipment for the building eg. bolles/air conditioning plant. - g. [Pestomance area [stage] - For stages with dedicated lighting and equipment in]uddition to that within the remainder of the space. For stages within other activity areas which do not have speci-
-3 Store Room - Areas for un-chilled goods storage with low transient occupancy.
-3 Tollet - Any tollet areas.
E Commencial/Professional services
Secure Residential Institutions
E Constant alone utility block
E Storage or Distribution
E D Universities and colleges
P Pa Sot Cancel OK

out Activity Construction Openings Lighting HVAC Generation Outputs	CFD
C, Activity Template	×
	Eating/drinking area
Sector	A3/A4/A5 Restaurant and Cafes/Drinking Establishments
Zone multiplier	1
Include zone in thermal calculations	
Include zone in Radiance daylighting ca	liculations
R Floor Areas and Volumes	»

Step 5: Double click on **RestPub_EatDrink_Occ** schedule under the **Occupancy** tab. The **Edit schedule-RestPub_EatDrink_Occ** screen appears. (You can note the occupancy schedule for comparison with the other activity template as shown in Table 1.28.)

Schedules are used in DesignBuilder to define with respect to time the following:

- Occupancy
- Equipment, lighting HVAC operation
- Heating and cooling temperature setpoints
- Transparency of component blocks (usually seasonal)

Occupancy, equipment and lighting schedule are defined by a fraction (0-1). The maximum gain 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.

Source: http://www.designbuilder.co.uk/helpv4.7/ #Schedules_-_EnergyPlus_Compact_Schedules.htm

hedules Data		Help	
eneral		Info	
eneral		* Gene	
Name RestPub_EatD Description Building: REST/ Source	AURANT/BAR/PUBLIC HOUSE Area: EATING E UK NCM	R profil for ea Sche	nedule consists of one daily e for each day of the week, ach month of the year. dules are used when the
≧ Category ∰Region	Restaurants/Cafes/Drinking E General	-	el detail is set to 'Schedules pact Schedules
Schedule type rofiles Schedule:Compact.	2-Compact Schedule	Defin Com on th	e the schedule using pact Schedule script based e EnergyPlus dule:Compact dataset.
Schedule:Compact, RestPub_EatDrink_Occ, Fraction, Through: 31 Dec, For: Weekdays SummerDesic		3	Press F1 for more nation.
Unit: 07:00, 0, Unit: 07:00, 0, Unit: 10:00, 0.5, Unit: 12:00, 0.5, Unit: 14:00, 1, Unit: 15:00, 0.5, Unit: 15:00, 0.5, Unit: 22:00, 1, Unit: 22:00, 1, Unit: 22:00, 1, Unit: 22:00, 0, Unit: 22:00, 0, Unit: 22:00, 0,		► This edite dialo	ed Library Data library data cannot be d but you can close this g, create a copy of this and edit the copy
Uniti: 09:00, 0.25, Uniti: 12:00, 0.5, Uniti: 14:00, 1, Uniti: 15:00, 0.5, Uniti: 18:00, 0.25, Uniti: 19:00, 0.25, Uniti: 22:00, 1, Uniti: 23:00, 0.5, Uniti: 24:00, 0,			

 Table 1.28
 Workday schedules for a generic office and eating/ drinking area

Generic office area Office_OpenOff_Occ	Eating/drinking area RestPub_EatDrink_Occ
Schedule: Compact,	Schedule: Compact,
Office_OpenOff_Occ,	RestPub_FoodPrep_Occ,
Fraction,	Fraction,
Through: 31 Dec,	Through: 31 Dec,
For: Weekdays	For: Weekdays SummerDesignDay,
SummerDesignDay,	Until: 06:00, 0,
Until: 07:00, 0,	Until: 07:00, 0.25,
Until: 08:00, 0.25,	Until: 08:00, 0.75,
Until: 09:00, 0.5,	Until: 14:00, 1,
Until: 12:00, 1,	Until: 15:00, 0.75,
Until: 14:00, 0.75,	Until: 17:00, 0.25,
Until: 17:00, 1,	Until: 18:00, 0.75,
Until: 18:00, 0.5,	Until: 22:00, 1,
Until: 19:00, 0.25,	Until: 23:00, 0.75,
Until: 24:00, 0,	Until: 24:00, 0.25,
For: Weekends,	For: Weekends,
Until: 24:00, 0,	Until: 06:00, 0,
For: Holidays,	Until: 07:00, 0.25,
Until: 24:00, 0,	Until: 08:00, 0.75,
For: WinterDesignDay	Until: 14:00, 1,
AllOtherDays,	Until: 15:00, 0.75,
Until: 24:00, 0;	Until: 17:00, 0.25,
	Until: 18:00, 0.75,
	Until: 22:00, 1,
	Until: 23:00, 0.75,
	Until: 24:00, 0.25,
	For: Holidays,
	Until: 06:00, 0,
	Until: 07:00, 0.25,
	Until: 08:00, 0.75,
	Until: 14:00, 1,
	Until: 15:00, 0.75,
	Until: 17:00, 0.25,
	Until: 18:00, 0.75,
	Until: 22:00, 1,
	Until: 23:00, 0.75,
	Until: 24:00, 0.25,
	For: WinterDesignDay AllOtherDays
	Until: 24:00, 0;

Step 6: Click Cancel. The screen closes.

Step 7: Select the **Simulation** tab to get energy consumption results.

Compare both cases (Table 1.29).

The results show the impact of Activity type on energy consumption.

From the model, you can find out the interior load parameters (Table 1.30). You can get this data from the Activity and Lighting tabs. You can co-relate the change in energy consumption with the change in interior loads.

C Activity Template	Generic Office Area
Sector	B1 Offices and Workshop businesses
Zone multiplier	1
Include zone in thermal calculations	
Include zone in Radiance daylighting calculation	ations
Floor Areas and Volumes By Occupancy	
	0.1110
Density (people/m2) 😭 Schedule	Office_OpenOff_Occ
e Metabolic	olice_openoli_occ
Melabolic Contaminant Generation	
fo Holidays	
K DHW	
Consumption rate (l/m2-day)	0.200
III Environmental Control	
Heating Setpoint Temperatures	
Heating ("C)	22.0
Heating set back (°C)	12.0
Cooling Setpoint Temperatures	
Cooling (*C)	24.0
Cooling set back (°C)	28.0
Humidity Control	
Ventilation Setpoint Temperatures	
Minimum Fresh Air	
Lighting	400
Target Illuminance (lux)	0
Default display lighting density (W/m2) Computers	0
□ On	
Superior Sector	
☑ On	
	11.77
Gain (W/m2) 얇 Schedule	Uffice_OpenOff_Equip
Radiant fraction	0.200
Miscellaneous	0.200
On	
Catering	
* Process	

Туре	Generic office area (kWh)	Eating/drinking area (kWh)
Room electricity	12,131.16	32,225.33
Lighting	17,532.15	12,259.07
Heating (gas)	12,729.33	24,047.98
Cooling (electricity)	6,529.12	8,596.75
DHW (electricity)	1,097.67	43,672.32

 Table 1.29
 Annual energy consumption with a change in space activity

Table 1.30Internal load data for generic office and eating/
drinking area

Interior load	Unit	Generic office area	Eating/ drinking area
Occupancy	People/m ²	0.111	0.2
Target illuminance	Lux	400	150
Interior light	W/m ² per - 100 lux	5	5
Equipment	W/m ²	11.77	18.88
DHW	l/s-day	0.2	5.69

Exercise 1.7

Compare the cooling and heating energy consumption for a generic office area and classroom (Table 1.31).

Activity type: Classroom can be found under 'Universities and college' category.

From the model, you can find out the change in the internal load parameter (Table 1.32).

Table 1.31Annual energy consumption for a generic office and
eating/drinking area

Туре	Generic office area (kWh)	Class room area (kWh)
Room electricity		
Lighting		
Heating (Gas)		
Cooling (Electricity)		
DHW (Electricity)		

 Table 1.32
 Internal load for a generic office and eating/ drinking area

Unit	Generic office area	Classroom area
People/m ²		
lux		
W/m ² 100 lux		
W/m ²		
l/s-day		
	People/m ² lux W/m ² 100 lux W/m ²	Unit office area People/m ² lux W/m ² 100 lux W/m ²

BUILDING ENERGY SIMULATION

Compare office and class room schedules in Table 1.33.

Table 1.33Workday schedules for a generic office and classroom area

Generic office area Office_OpenOff_Occ Classroom area

TUTORIAL 1.8 Evaluating the impact of lighting and equipment power

GOAL

To understand the impact of lighting and equipment power density on HVAC system sizing and energy consumption.

WHAT ARE YOU GOING TO LEARN?

- Changing lighting power density (LPD)
- Changing equipment power density (EPD)

PROBLEM STATEMENT

Compare the energy consumption when you set the LPD as 13.13 and as 10.0 W/m². Use the **Courtyard with VAV Example** template for London.

SOLUTION

Step 1: Select the **Lighting** tab, and under the **General Lighting** section, set the LPD shown as Lighting energy (W/m²) to 13.13.

Lighting power density represents the load of any lighting equipment in any defined area or the watts per square meter of the lighting equipment. It can be obtained by dividing the total lighting load by the area.

Layout Activity Construction Openings Ughting HVAC Generation Outputs CFI		
C. Lighting Template		:
Q Template	Reference	
Seneral Lighting		
⊠ n Normalised power density (W/m2) ্রিষ্ণ Schedule	13.13 RestPub_EatDrink_Light	
Luminaire type	1-Suspended	
Radiant fraction	0.420	
Visible fraction	0.180	
Convective fraction	0.400	

Tip: Does your Lighting energy have units as W/m^2 - 100 lux rather than W/m^2 ?

If yes, change this to W/m² in the following way:

Go to: Edit \rightarrow Model Options Data \rightarrow Data \rightarrow Gain Data \rightarrow Lighting Gains Units, and change the lighting gain units to W/m².

Step 2: Click **Simulate** and click the **Annual simulation** link to perform annual simulation.

Edit Calculation Options		
Calculation Options Data		Help
General Options Output Simu	lation Manager	Info Data
Calculation Description		Simulation Options
Simulation Period		These options control the simulation and the output produced.
From		Simulation Period
Start day	1	 Select the start and end days for the simulation, or select a typical period:
Start month	Jan	Annual simulation
То		Summer design week
End day	31	Summer typical week
End month	Dec	All summer
Output Intervals for Reporting		Winter design week
Monthly and annual		Winter typical week
☑ Daily		All winter
Hourly		
Sub-hourly		Interval Monthly and annual output is always generatedand daily, hourly and sub-hourly data can selected by checking the
Don't show this dialog next t	ime	Help Cancel OK

Step 3: Repeat the steps to set the LPD to 10.00. Perform annual energy simulation. Compare the end use energy consumption for both cases (Table 1.34).

From the end use energy consumption shown in Table 1.34, it is clear that a reduction in LPD decreases the lighting energy consumption. Also, note the decrease in cooling and fans and pump energy consumption.

Туре	LPD – 13.13 W/m ² (kWh)	LPD - 10.0 W/m ² (kWh)
Room electricity	24,963.73	24,963.73
Lighting	23,685.21	18,039.00
System fans	25,854.88	24,916.21
System pumps	57.99	54.61
Heating (gas)	36,880.63	39,053.90
Cooling (electricity)	51,073.34	48,160.19

 Table 1.34
 Annual fuel breakdown with a change in LPD

Exercise 1.8

Set the equipment power density to 20 and 10 W/m^2 and study the impact on building energy consumption and sizing (Tables 1.35 and 1.36).

It can be clearly seen from the results that reducing the LPD and EPD not only results in the reduction of energy consumption for lighting, but it also helps reduce the cooling energy. This is because the energy consumed in lighting or operating equipment such as computers finally gets converted into heat and usually gets added into the space. This additional heat increases the energy consumption of the fans and pumps and also increases the system sizing. In cases of heating energy consumption, the reverse effect is observed since lighting and equipment add additional heat to the space, thereby reducing energy requirement for heating.

Туре	EPD (20 W/m ²) (kWh)	EPD (10 W/m ²) (kWh)
Room electricity		
Lighting		
System fans		
System pumps		
Heating (electricity)		
Heating (gas)		
Cooling (electricity)		

Table 1.35Energy consumption with a change in equipmentpower density

Table 1.36Heating and cooling sizing capacity with a changein equipment power density

Туре	EPD (20 W/m ²) (kW)	EPD (10 W/m ²) (kW)
Heating Cooling		

TUTORIAL 1.9 Evaluating the impact of daylight controls

GOAL

To evaluate the impact of daylight controls on energy consumption.

WHAT ARE YOU GOING TO LEARN?

- Specifying daylight controls in a building model
- Evaluating the impact of daylight controls on energy consumption

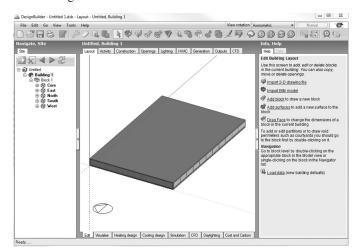
PROBLEM STATEMENT

Create a 60 m \times 40 m model with a core and four perimeter zones. Consider a perimeter depth of 5 m. (Refer Tutorial 1.5 for steps to create the model.) Set WWR to 60% and use 'Sgl Grey 3mm' glass (VLT ~ 60%). Perform annual energy simulation without daylight sensors, then install daylight control in the north zone. Compare the lighting energy consumption with and without daylight control for **London Gatwick location, United Kingdom**.

Tip: For single pane glass with 60% visible light transmittance, select 'Sgl Grey 3mm' with a light transmission value of 0.611 under the Single category of the glazing library.

SOLUTION

Step 1: Create a five-zone core and perimeter model of size $60 \text{ m} \times 40 \text{ m}$. Set WWR to 60% and select Sgl Grey 3mm glass.



Step 2: Select the **Simulation** tab. The **Edit Calculation Options** screen appears. Select the **Hourly** checkbox under Output Intervals for Reporting and then click **OK**. After simulation, hourly results appear under the Analysis tab.

Edit Calculation Options		
Calculation Options Data		Help
General Options Output Sim	ulation Manager	Info Data
Calculation Description		Simulation Options
Simulation Period		These options control the simulation and the output produced.
From	1	Simulation Period Select the start and end days for the simulation, or
Start day Start month	Jan	select a typical period: Annual simulation
То		Summer design week
End day	31	 Summer typical week
End month	Dec	All summer
Output Intervals for Reporting		 Winter design week
Monthly and annual		Winter typical week
Daily Hourly		• <u>All winter</u>
Sub-hourly		Interval Monthly and annual output is always generated and daily, hourly and sub-hourly data can selected by checking the appropriate boxes
Don't show this dialog next	time	Help Cancel OK

Step 3: Click the **Export data** icon to export the hourly energy consumption in the spreadsheet. (Ensure that Fuel breakdown, Hourly interval and Grid options are selected.)

łavigate, Site				ed, Build							
Ste		_	Analy	is Summa	ary Paramet						
→ ★ ▲ ▶ 22		- 1	Date/T		Room Elec	Lighting (k	Heating (G.	. Cooling (EL.	DHW (Ele		A
		-	01-01-	2002 01:	1.463186	0	0	0	0		
⊡ 🕡 Untitled			01-01-	2002 02:	1.463186	0	0.13655	0	0		
Building 1 Book 1			01-01-	2002 03:	1.463186	0	4.137133	0	0		
E Core			01-01-	2002 04:	1.463186	0	8.967437	0	0		
⊕ ∰ East			01-01-	2002 05:	1.463186	0	12.46369	0	0		
			01-01-	2002 06:	1.463186	0	206.2982	0	0		
E 🕼 South			01-01-	2002 07:	1.463186	0	157.356	0	0		
in 🕼 West			01-01-	2002 08:	27.12618	46.09377	94.77353	0	0.961962		
			01-01-	2002 09:	27.12618	46.09377	91.91863	0	1.923922		
			01-01-	2002 10:	27.12618	46.09377	100.9151	0	3.847842		
			01-01-	2002 11:	27.12618	46.09377	70.82156	0	3.847842		
		ſ	01-01-	2002 12:	27.12618	46.09377	47.08217	0	3.847842	1	
			01-01-	2002 13:	27.12618	46.09377	26.52744	0	2.885884		
splay Options			01-01-	2002 14:	27.12618	46.09377	21.73172	0	2.885884		
Seneral Detailed			01-01-	2002 15:	27.12618	46.09377	28.8499	0	3.847842		
1		-	01-01-	2002 16:	27.12618	46.09377	28.84281	0	3.847842		
/			01-01-	2002 17:	27.12618	46.09377	37.07107	0	3.847842		
Data		×	01-01-	2002 18:	27.12618	46.09377	27.90423	0	1.923922		
Data	6-Fuel breakdown	•	01-01-	2002 19:	27.12618	46.09377	25.54036	0	0.961962		
Interval	4-Hourly		01-01-	2002 20:	27.12618	0	0	0	0		
Show as	2-Grid		01-01-	2002 21:	1.463186	0	0	0	0		
Days per page	365	-11	01-01-	2002 22:	1.463186	0	0	0	0		
Normalise by floor area		- 11	01-01-	2002 23:	1.463186	0	0	0	0		
Avis		>>	02-01-	2002	1.463186	0	0	0	0		
			02-01-	2002 01:	1.463186	0	0	0	0		
- ppeorence			02-01-	2002 02:	1.463186	0	0	0	0		
			02-01-	2002 03:	1.463186	0	0	0	0		
						h.,		-		1	
			Edit	Visualise	Heating desig	n Cooling	design Sim	ulation CFD	Daylighting	Cost and Carbon	

Step 4: Select **File** from the **Export to** drop-down list. Select **CSV spreadsheet** from the **Format** drop-down list. Click **OK**. The **Export CSV file** screen appears.

😂 Export Re	sults Spreadsheet
Export Da	ta
	Export to: 1-File Format: CSV spreadsheet
	Help Cancel OK

Step 5: Enter the File name **Without daylight sensor** and save the file on Desktop.

3. Export CSV file			×
Save in: 📃 Desktop)	- G 🕸	₽
Name	Size	Item type	Date mor 📤
词 Libraries			=
🝓 Homegroup			
🔏 Naresh			
Real Computer			
Metwork			-
•	III		Þ
File name: Withou	t daylight sensor		Save
Save as type: CSV sp	oreadsheet files(*.csv	/) 🔹	Cancel

Step 6: Select Annual from the Interval drop-down list.

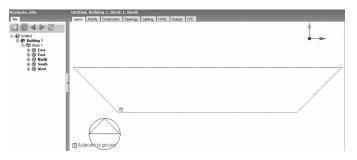
Navigate, Site	Untitled, Building 1
Site	Analysis Summary Parametric Optimisation
	Date/Time Room Electricity (kWh) Lighting (k Heating (G Cooling (EL. DHW (Ele
	01-01-2002 01: 99892.05 144365.7 136862.7 43744.28 9038.584
E-P Building 1	
Block 1	
terest Bast	
⊞-Ø North	
⊞-∰ South ⊞-∰ West	
1 1	
Display Options	
General Detailed	
1	
Data ¥	
Data 6-Fuel breakd *	
Interval 1-Annual	
Show as 2-Grid *	
Days per page 365	
V-Axis >>	
Appearance »	

Record the simulation results.

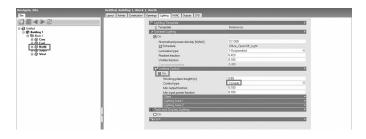
In the next step, you are going to install the daylight sensor in the north zone.

Step 7: Select the **Edit** tab. Click the **North** zone in the navigation tree. It shows the north zone in the Layout

tab. Select the **Lighting** tab. The Lighting properties are displayed.



Step 8: Expand the Lighting control section. Select the **On** check box. Select Linear from the **Control type** drop-down list.



Different types of lighting control options that exist in DesignBuilder are as follows:

- 1. Linear
- 2. Linear/off
- 3. Stepped

Linear control, also called as continuous control, reduces the power input of the luminaire continuously, thereby decreasing the output light from the lamp till it reaches the minimum input and output fraction provided as a user input. this is possible with continuously dimmable fixture and lamps. the decrease in the input power (proportionally the lighting output) depends on the daylight illuminance requirement in the space. as the daylight illuminance increases, the input power reduces till it reaches the minimum input power and light output fraction and remains at the minimum specified ratio with a further increase in daylight illuminance. Step 9: Select the **Layout** tab. The daylight sensor is displayed.



Step 10: Perform the simulation and record the annual and hourly results of the lighting energy consumption.

Step 11: Compare the results with and without lighting controls (Table 1.37).

Step 12: Draw the graph for hourly lighting energy consumption for 1 January with and without a daylight sensor by using the data exported using a spreadsheet program.

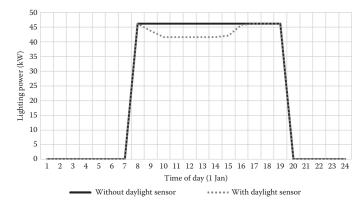


 Table 1.37
 Annual energy consumption with or without lighting control for the north zone

Туре	Without lighting controls (kWh)	With lighting controls (kWh)
Room electricity	99,892	99,892
Lighting	1,44,366	1,32,533
Heating (gas)	1,36,863	1,42,500
Cooling (electricity)	43,744	41,748
DHW (electricity)	9,039	9,039

The above figure shows the hourly lighting energy consumption for 1 January. It can be observed that there is a reduction in the energy consumption with the use of daylight sensor and dimmable luminaire.

The effect of daylight control is similar to that of reducing LPD as discussed in the previous exercise.

The daylight control reduces the artificial lighting load whenever daylight is available in the space. The lighting loads are reduced to the extent that the combined lux levels of artificial light and daylight equals the setpoint lux level.

This reduction in LPD reduces the lighting energy consumption. For example, east and south zones would have different extent and timing of availability of daylight, and hence these would have different energy savings too.

Exercise 1.9

Add daylight control in the south zone of the model and study the effect on the energy consumption (Table 1.38).

It can be observed that the deployment of lighting control increases the heating energy consumption and decreases the cooling energy consumption.

Туре	Without daylight controls (kWh)	With daylight control (kWh)
Room electricity		
Lighting		
System fans		
System pumps		
Heating (electricity)		
Heating (gas)		
Cooling (electricity)		

Table 1.38Annual energy consumption with or withoutlighting control for the south zone

TUTORIAL 1.10 Evaluating the impact of setpoint temperature

GOAL

To evaluate the impact of setpoint temperature on sizing and energy consumption.

WHAT ARE YOU GOING TO LEARN?

- Changing the setpoint for heating
- Changing the setpoint for cooling

PROBLEM STATEMENT

Create a 60 m \times 40 m model with a core and four perimeter zones. Consider a perimeter depth of 5 m. (Refer to Tutorial 1.5 for steps to create the model.) Set the heating setpoint to 20°C and 22°C. Simulate the model with the **PARIS-AEROPORT CHAR** weather file. Analyse the effect of setpoint on the energy consumption and HVAC system sizing.

SOLUTION

Step 1: Create a five-zone core and perimeter model of size $60 \text{ m} \times 40 \text{ m}$.

Step 2: Select the **Activity** tab and go to **Heating Setpoint Temperatures**. Enter **20.0** in Heating (°C) box.



Step 3: Perform the annual simulation and record all end use energy consumption.

Step 4: Repeat steps to set the heating temperature at 22°C. Simulate the model.

Annual fuel breakdown data				
	Heating temperature 20°C (kWh)	Heating temperature 22°C (kWh)		
Room electricity	99,895	99,895		
Lighting	1,44,369	1,44,369		
Heating (gas)	61,076	92,223		
Cooling (electricity)	51,646	52,776		
DHW (electricity)	9,039	9,039		

 Table 1.39
 Energy consumption with a change in heating setpoint temperature

Table 1.40Heating sizing capacity with a change in heatingsetpoint temperature

	Heating sizing	
Туре	With heating setpoint temperature 20°C (kW)	With heating setpoint temperature 22°C (kW)
Heating	161.45	175.05

Step 5: Compare result for both cases (Tables 1.39 and 1.40).

You can observe that increasing the heating setpoints increases the heating energy consumption and heating sizing (Table 1.40).

Exercise 1.10

Repeat the tutorial for the change in the cooling setpoint from 24°C to 25°C. Compare the results for cooling sizing and energy consumption. Set the weather location as Brisbane, Australia (Tables 1.41 and 1.42).

Annual fuel breakdown data			
Туре	With cooling setpoint 24°C (kWh)	With cooling setpoint 25°C (kWh)	
Room electricity			
Lighting			
System fans			
System pumps			
Heating (electricity)			
Heating (gas)			
Cooling (electricity)			

 Table 1.41
 Energy consumption with a change in cooling setpoint temperature

Table 1.42Cooling sizing capacity with change in coolingsetpoint temperature

Туре	With cooling setpoint 24°C (kW)	With cooling setpoint 25°C (kW)
Cooling		

The following can be observed:

- Increasing the heating setpoint results in an increase in energy consumption since more heat is to be added to the space for keeping a higher temperature. This also results in a higher system capacity since the rate of heat addition at an elevated temperature is to be matched with the higher rate of heat loss. In case of gas heaters using hot water panels, the energy consumption of the pump also increases with the increase in the setpoint.
- Similarly, a lower cooling setpoint demands the removal of more heat, thereby causing more energy consumption. This also results in a higher capacity of the cooling equipment and more pump and fan energy consumption.

TUTORIAL 1.11 Evaluating the impact of fresh air supply

GOAL

To evaluate the impact of the fresh air supply quantity on energy consumption.

WHAT ARE YOU GOING TO LEARN?

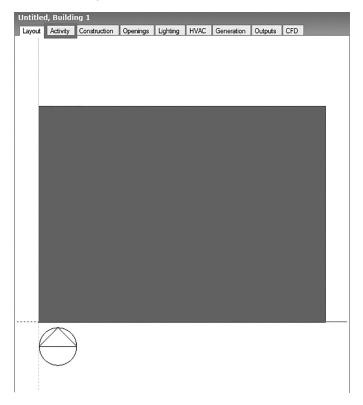
• Changing the fresh air flow rate

PROBLEM STATEMENT

Create a single-zone 20 m \times 15 m model. Set the fresh air supply rate (l/s-person) to 5 and 7.5 and compare. Study the effect on energy consumption for the **AZ-PHOENIX DEER VALLEY, USA** location.

SOLUTION

Step 1: Create a single-zone 20 m \times 15 m model. Select the **Activity** tab.



Step 2: Expand the **Minimum Fresh Air** section and enter **5** in the Fresh air (l/s-person).

C. Activity Template	
	Generic Office Area.
Sector	B1 Offices and Workshop businesses
Zone type	1-Standard
Zone multiplier	1
Include zone in thermal calculation	ns
Include zone in Radiance daylight	ting calculations
8g Occupancy	
👷 Metabolic	
Generic Contaminant Generation	
L _S DHW	
1 Environmental Control	
Heating Setpoint Temperatures	
Cooling Setpoint Temperatures	
Humidity Control	
Ventilation Setpoint Temperatures	
Minimum Fresh Air	
Fresh air (l/s-person)	5
Mech vent per area (l/s-m2)	0.000
Lighting	
Scomputers	
🔩 Office Equipment	
Niscellaneous	
of Catering 10 Process	

Step 3: Simulate the model and record the results.

Compare the end use energy consumption results for the fresh air supply of 5 and 7.5 l/s-person (Table 1.43).

It can be seen from the above table that with the increase in the fresh air rate, there is an increase in the cooling/ heating energy consumption.

Table 1.43 Energy consumption with a change in fresh airsupply quantity

Annual fuel breakdown data					
Туре	Fresh air supply of 5 l/s-person (kWh)	Fresh air supply of 7.5 l/s-person (kWh)			
Room electricity	12,131	12,131			
Lighting	17,532	17,532			
Heating (gas)	800	812			
Cooling (electricity)	31,124	31,442			
DHW (electricity)	1,098	1,098			

Exercise 1.11

Compare cooling and heating energy consumption for the change of fresh air supply volume from 5 to 9 l/s-person (Table 1.44).

An increase in the fresh air supply rate increases the energy consumption due to several factors:

- More fresh air brings in more sensible as well as latent load from outside. This in turn increases the load on the equipment, which increases the cooling/heating energy consumption.
- The energy consumption of the fan is proportional to the volumetric flow rate. With the increase in the flow rate because of the additional energy required to blow more supply air (for heating/cooling), the fan energy consumption increases.
- More heating/cooling load and higher air flow rate result in the requirement of more water flow as heat adding/ removal medium for a fixed change in temperature across the air handling unit since more heat is to be taken away per unit time. This requirement of a higher flow rate increases the pump rating and results in a higher energy consumption by the pump.

Table 1.44	Heating and cooling energy consumption by
changing the	e fresh air supply quantity

	Cooling energy consumption electricity (kWh)		Heating energy consumption gas (kWh)	
	5 l/s-person	9 l/s-person	5 l/s-person	9 l/s-person
Jan				
Feb				
Mar				
Apr				
May				
Jun				
Jul				
Aug				
Sept				
Oct				
Nov				
Dec				

Geometry of Buildings

In this chapter, we discuss the geometrical aspects, such as thermal zoning, aspect ratio, floor multiplier, and surface adjacency.

Usually buildings have several rooms; however, from modelling perspective, there may not be a requirement to model each room separately. If adjacent spaces have the same specifications, such as schedule, occupancy, and cooling and heating temperature setpoint, you can combine these spaces and model it as a single zone. By doing this, the complexity of the model and its simulation run time can be reduced without affecting the energy simulation results. Similarly, in cases of multi-storied buildings, with typical floors, the model can be simplified by modelling only three floors: ground, mid and top.

One of the important parameters that need to be considered while designing the building is aspect ratio, which is the ratio of the length to width of a building. The aspect ratio affects the envelope area. Increase in the envelope area leads to a higher heat gain/loss from the building. However, higher aspect ratio helps in better distribution of daylight and more access to windows for the occupants.

The impact of these aspects on building performance is explained through four tutorials in this chapter.

TUTORIAL 2.1 Defining thermal zoning for a building GOAL

To evaluate the effect of architectural and thermal zoning on the end use energy consumption and simulation run time.

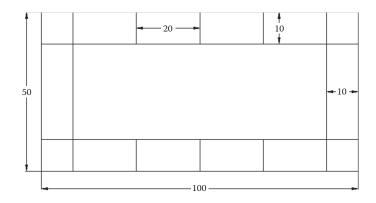
WHAT ARE YOU GOING TO LEARN?

- Defining thermal zoning
- Adding internal mass

PROBLEM STATEMENT

Create a multi-zone (15 zones as shown in the following figure) building with a rectangular footprint of 100 m \times 50 m. Find its energy performance and simulation run time. Create another model by combining similar spaces into thermal zones and compare the energy performance and run time duration with the previous model.

Use the **FRANKFURT MAIN ARPT**, Germany weather file.



All dimensions are in metre.

SOLUTION

Step 1: Open a **New Project** and create a $100 \text{ m} \times 50 \text{ m}$ block with internal partitions. (Use construction lines to facilitate easy snapping while creating the partitions.)

Novdpatro, Stle 20 30 30 30 40 40 50 50 50 50 50 50 50 50 50 5	New Building, Building J. Levat Adaty Contrustor	Openings Lighting HVAC	Outputs CFD		Ĺ	•
8: 00 Zeen 13 8: 00 Zeen 14 8: 00 Zeen 15 8: 00 Zeen 2 8: 00 Zeen 3 8: 00 Zeen 4 9: 00 Zeen 4	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Zone 2
 ○ Ø Συμ 6 ○ Ø Συμ 7 ○ Ø Συμ 7 ○ Ø Συμ 7 ○ Ø Συμ 8 	Zone 5			Zone 11		Zone 3
	Zone 4	Zone 15	Zone 14	Zone 13	Zone 12	Zone 1
)				

Step 2: Select the **Construction** tab and select **Outer volume** in the **Zone floor area calculation method** drop-down list.

Construction Template	¥
Template 🖓	Project construction template
Construction	¥
CyExternal walls	Project wall
Below grade walls	Project below grade wall
⇒Fletroof	Project flat roof
Pitched root (occupied)	Project pitched roof
Pitched root (unoccupied)	Project unoccupied pitched root
Internal partitions	Project partition
Semi-Exposed	»
Floors	»
Sub-Surfaces	»
Internal Thermal Mass	»
Component Block	»
Geometry, Areas and Volumes	*
Geometry convention template	External measurements
Zone geometry and surface areas	2-Outer volume
Zone volume calculation method	1-Innervolume
Zone floor area calculation method	2-Outer volume
Fixed Surface Thicknesses	»
Void Depths	······································
Surface Convection	»
Linear Thermal Bridging at Junctions Airtightness	30 30

Zone floor area calculation method

This setting dictates whether internal or external measurements (include external wall thickness inside the zone boundary or not) are used to calculate the zone floor area. This is required to calculate per m^2 values such as occupancy and other internal gains as well as floor area values for general reporting.

Inner – where the zone volume used in thermal calculations is derived from the zone inner geometry.

Outer – where the zone volume used in thermal calculations is derived from the zone outer geometry.

http://www.designbuilder.co.uk/helpv4.7/Content/ GeometryAreasAndVolumes.htm Step 3: Perform hourly simulation for the whole year and record the energy consumption and the run time.

Recording a run time:

After the simulation is complete, type the following path to open the eplusout.err file. You can use any text editor to open this file.

C:\Users\User\AppData\Local\DesignBuilder\ EnergyPlus\eplusout.err

The actual folder name on a computer depends on the language setting and your Windows user name. In the path given above, the Windows user name is 'User'.

Alternatively, you can open the EnergyPlus folder from the DesignBuilder file option.

P	Des	ignBuilder	-		1.000		-		
	<u>F</u> ile	Edit Go	Tools	Help					
		<u>N</u> ew projec	t		Ctrl+N	3	6		
	2	<u>O</u> pen proje	t		Ctrl+O				
i		<u>S</u> ave			•	prarie	es		
Γ		Import			•			Folder 🛆	
		<u>E</u> xport			•			C:\User	s\adı
		<u>F</u> olders					EnergyPlus folde	r	
		<u>P</u> rint					<u>R</u> adiance folder		adı adı
		Exit			Alt+F4		Weather data fold	der	
		1 a.dsb					Library data folde	er	adı
		2 T1.061.dsl	,				<u>T</u> emplate project	s folder	adı
		<u>3</u> T1.05.dsb				p===	Diagnostic files fo	older	adı

At the end of the file, you can find Elapsed Time.

You need to record the elapsed time.

Source: http://www.designbuilder.co.uk/ helpv4.7/Content/_DesignBuilder_files_ location_and_extensions.htm

Analysis Summary Parametric Optimisation					
Date/Time			Heating (Gas) (kWh)	Cooling (Electricity) (kWh)	DHW (Electricity) (kWh)
12:00:00 AM	216714.9	313200	238757.8	99456.46	19609.12

Step 4: Repeat step 1 while combining zones for spaces with similar activity, schedule and setpoints. In this example, let us assume that the north zones (zones 7, 8, 9 Generic office area

Generic office area

and 10), as shown in the following figure, are similar and can be combined into a single thermal zone. Similarly, the south zones (12, 13, 14 and 15) can be combined into a single thermal zone. Do note that zone numbers in your model might differ as zones are numbered in the sequence they are created.

You can select the internal partition and delete the internal partition by pressing the delete key. (Please ensure that you are at the block level.)

Zone 6Zone 7Zone 8Zone 9Zone 10Zone 2Zone 5Zone 11Zone 11Zone 3Zone 4Zone 15Zone 14Zone 13Zone 12Zone 1

Zone 6 Zone 7 Zone 2 Zone 5 Zone 8 Zone 3 Zone 4 Zone 9 Zone 1 A 'thermal zone', usually termed simply 'zone', is a virtual or real segment of a building that has a homogeneous, enclosed volume of air. In a simple approach, each physical space can be treated as one zone. However, to simplify the modeller's work, and to reduce the calculation time, areas having similar thermal and usage conditions such as occupancy, setpoint, and solar exposure, and those that are serviced by common mechanical equipment, can be clubbed to create one zone. Temperatures, supply units, and layout.

Step 5: Perform annual simulation and record the energy consumption and the run time.

Compare the energy simulation results and the simulation run time (Tables 2.1 and 2.2).

Туре	With architectural zoning (kWh)	With lumped thermal zones (kWh)
Room electricity	216,715	216,715
Lighting	313,200	313,200
Heating (gas)	238,755	238,281
Cooling (electricity)	99,454	99,166
DHW (electricity)	19,609	19,609

 Table 2.1
 Annual fuel breakdown energy with architectural zoning and lumped thermal zones

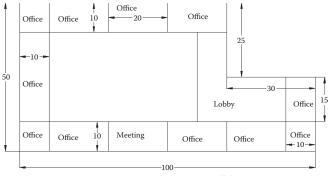
Table 2.2Simulation run time with architectural zoning andlumped thermal zones

	With architectural zoning	With lumped thermal zones
Simulation run time	48.04 seconds	31.03 seconds

As seen in the results, combining architectural zones to form thermal zones reduces the simulation run time. In this case, there is an approximately 37% decrease in the simulation run time. Note that because there is a difference in the models, there is a slight difference in the energy simulation results.

Exercise 2.1

Create thermal zoning for the plan shown in the following figure. Compare the simulation run time and energy consumption for the models with architectural and thermal zoning (Tables 2.3 and 2.4).



All dimensions are in metre

Table 2.3 Annual fuel breakdown energy with architecturalzoning and lumped thermal zones

Туре	With architectural zoning (kWh)	With lumped thermal zones (kWh)
Room electricity		
Lighting		
Heating (gas)		
Cooling (electricity)		
DHW (electricity)		

Table 2.4Simulation run time with architectural zoning andlumped thermal zones

	With architectural zoning (kWh)	With lumped thermal zones (kWh)
Run time		

TUTORIAL 2.2 Evaluating the effect of a zone multiplier

GOAL

To evaluate the effect of a zone multiplier on the energy consumption and simulation run time.

WHAT ARE YOU GOING TO LEARN?

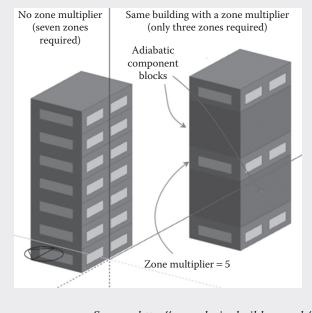
• Using zone multiplier

PROBLEM STATEMENT

Use the **Zone Multiplier Example** template file to evaluate the impact of a floor multiplier on the building energy consumption and simulation run time. This file contains two buildings with and without the floor multiplier. You need to select one building at a time and simulate for London Gatwick Airport, United Kingdom.

DesignBuilder has the concept of zone multiplier. The zone multiplier data allow 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 concept of zone multiplier when applied at the floor level multiplies all the zones on the given floor, effectively working as floor multiplier. Hence, in a building where there are several identical floors, you can model one floor and use a zone multiplier on that floor.

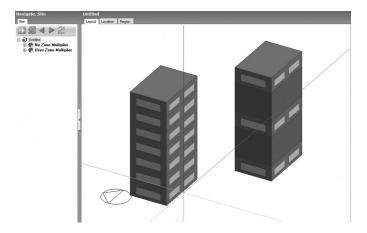
(Continued)



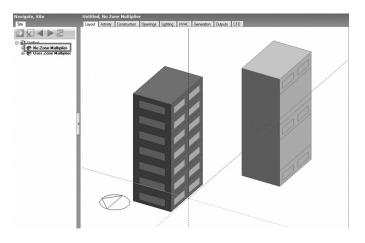
Source: http://www.designbuilder.co.uk/ helpv4.7/#Zone_Multiplier.htm

SOLUTION

Step 1: Open the **Zone Multiplier Example** template from DesignBuilder templates. The layout appears with two buildings.



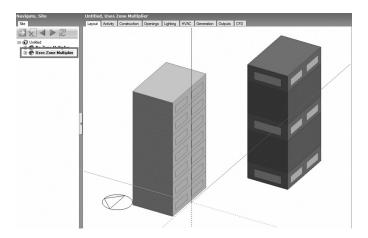
Step 2: Click the **No Zone Multiplier** building in the navigation tree. It selects the building that does not use a floor multiplier.



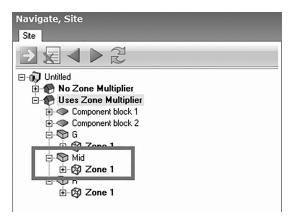
Step 3: Perform annual simulation. Record simulation run time. The results appear. Record the energy simulation results.

Untitled, No Zone Multiplier						
Analysis Summary Parametric Optimisation						
Date/Time	Room Electricity (kWh)	Lighting (kWh)	Heating (Gas) (kWh)	Cooling (Electricity) (kWh)	DHW (Gas) (kWh)	
12:00:00 AM	29238.68	52820.29	33237.48	22250.89	2998.367	

Step 4: Select the **Edit** tab. Click the **Uses Zone Multiplier** building in the navigation tree. Expand the **Uses Zone Multiplier**.



Step 5: Under Mid, click Zone 1.



Step 6: Select the **Activity** tab. Since the mid five floors are typical floors, the **Zone multiplier** for the whole floor is set to **5**.



When using a floor multiplier, calculations are performed only for one floor and multiplied by the zone multiplier. This helps in reducing the simulation run time.

Compare the results for the models with and without the zone multiplier (Table 2.5).

	Without floor multiplier	With floor multiplier
Туре	(kWh)	(kWh)
Room electricity	29,238.68	29,238.68
Lighting	52,820.29	52,820.29
Heating (gas)	33,237.48	33,203.70
Cooling (electricity)	22,250.89	21,744.07
DHW (gas)	2998.37	2998.37
Simulation time	25.13 seconds	13.67 seconds

 Table 2.5
 Impact of a zone multiplier

The results show that using a zone multiplier reduces the simulation run time. However, it has a slight impact on the energy consumption.

Exercise 2.2

Create a building with a total of 20 floors. First 10 floors have a floor plate of dimensions 50 m \times 50 m. Floors 11 to 20 have a floor plate of dimensions 25 m \times 25 m. Each floor has a height of 3 m. All floors are centrally aligned. Perform annual energy simulation of the building with and without floor multiplier. Compare energy and runtime of the simulation.

TUTORIAL 2.3 Evaluating the impact of the aspect ratio

GOAL

To evaluate the impact of building aspect ratio on energy performance.

WHAT ARE YOU GOING TO LEARN?

• Modelling building with different aspect ratio but same floor area

PROBLEM STATEMENT

In this tutorial, you are going to analyse the impact of the aspect ratio of the building on the energy performance. You need to create models with different aspect ratios for a floor plate of areas 64 m^2 and 625 m^2 . Simulate various cases as given below and compare their energy consumption for the London Gatwick weather location. Make sure that WWR is 30%.

For a rectangular building, aspect ratio is the ratio of the longest dimension of the building footprint to the narrowest dimension. An aspect ratio of 1.0 represents a square building footprint.

a. For a floor area of 64 m², Table 2.6 gives the length and breadth values for various aspect ratios

S. No.	U	Breadth <i>b</i> (m)	1		Façade area (window + wall) (m ²)	3
1	8.00	8.00	1	64	112.00	1.75
2	11.31	5.65	2	64	118.79	1.86
3	13.85	4.62	3	64	129.33	2.02
4	16.00	4.00	4	64	140.00	2.19

 Table 2.6
 Different aspect ratios for a 64 m² floor area

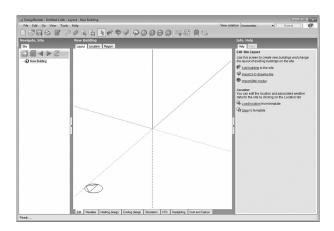
b. For a floor area of 625 m², Table 2.7 gives the length and breadth values for various aspect ratios

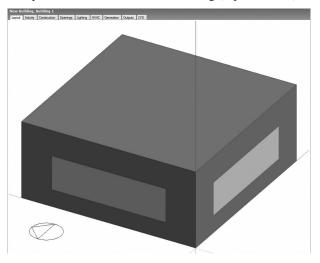
S. No.	0	Breadth <i>b</i> (m)			Façade area (window + wall area) (m ²)	Façade area/floor area
1	25.0	25.0	1	625	350.00	0.56
3	43.3	14.4	3	625	404.15	0.646
5	55.9	11.2	5	625	469.57	0.75
7	66.1	9.4	7	625	529.15	0.846

Table 2.7Different aspect ratios for a 625 m^2 floor area

SOLUTION

Step 1: Open a new project file.





Step 2: Create an $\mathbf{8} \mathbf{m} \times \mathbf{8} \mathbf{m}$ building (aspect ratio 1).

Step 3: Simulate the model and store the results (Table 2.8).

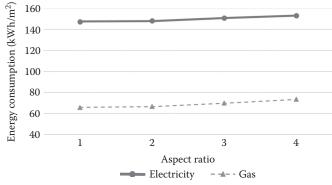
Table 2.8 Energy simulation results for an 8 m × 8 m model

Room electricity	Lighting	Heating (gas)	Cooling (electricity)	DHW (electricity)
Wh/m ²	Wh/m ²	Wh/m ²	Wh/m ²	Wh/m ²
43,342.96	62,639.97	65,691.39	37,698.21	3921.82

Step 4: Repeat steps 1 to 3 for aspect ratios 2, 3 and 4, respectively. Compare the energy simulation results for all cases (Table 2.9).

2 3 4 1 Aspect ratio (8 m × $(11.3 \text{ m} \times$ $(13.9 \text{ m} \times 10^{-1} \text{ m})$ (16 m × 8 m) 5.7 m) 4.6 m) 4 m) Room electricity 43,342.96 43,342.96 43,342.96 43,342.96 (Wh/m^2) Lighting (Wh/m²) 62,639.97 62,639.97 62,639.97 62,639.97 Heating (gas) 65,691.39 66,469.18 69,815.29 73,499.85 (Wh/m^2) Cooling 37,698.21 38,203.12 40,965.80 43,371.99 (electricity) (Wh/m2)DHW 3,921.82 3,921.82 3,921.82 3,921.82 (electricity) (Wh/m2)

 Table 2.9
 Energy consumption with different aspect ratios (without daylight sensor)

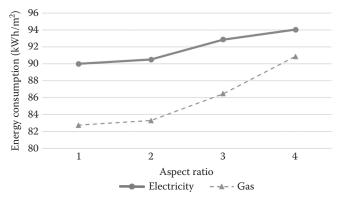


Energy consumption with varying aspect ratios when daylight sensors are not modelled

Step 5: Repeat all the above steps with daylight sensor (Table 2.10).

Aspect ratio	1	2	3	4	
	(8 m × 8 m)	(11.3 m × 5.7 m)	(13.9 m × 4.6 m)	× (16 m × 4 m)	
Room electricity (Wh/m ²)	43,342.96	43,342.96	43,342.96	43,342.96	
Lighting (Wh/m ²)	15,987.71	15,997.28	15,752.72	14,627.30	
Heating (gas) (Wh/m ²)	82,736.33	83,288.69	86,451.32	90,868.41	
Cooling (electricity) (Wh/m ²)	26,754.61	27,236.63	29,863.74	32,160.17	
DHW (electricity) (Wh/m ²)	3,921.82	3,921.82	3,921.82	3,921.82	

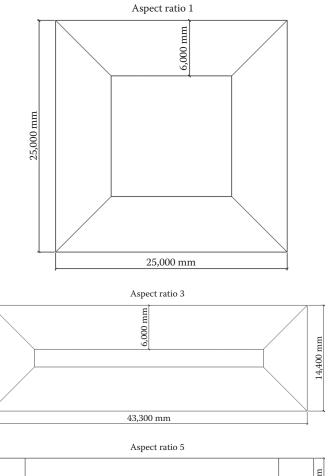
Table 2.10Energy consumption with varying aspect ratios (with
daylight sensor)



Energy consumption with varying aspect ratios when daylight sensor is modelled

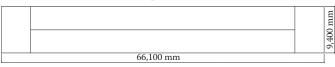
Step 6: Repeat all the above steps for the floor area of 625 m^2 (Tables 2.11 and 2.12).

You need to draw the model with the help of plans as shown in the following figures with aspect ratios 1, 3, 5 and 7.





Aspect ratio 7

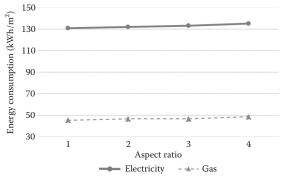


Aspect ratio	1	3	5	7
	(25 m × 25 m)	(43.3 m × 14.4 m)	(55.9 m × 11.2 m)	(66.1 m × 9.4 m)
Room electricity (Wh/m ²)	43,342	43,342	43,342	43,342
Lighting (Wh/m ²) Heating (gas)	62,640 45,401	62,639 46,695	62,639 46,654	62,640 48,641
(Wh/m ²) Cooling (electricity)	20,772	22,038	23,289	25,238
(Wh/m ²) DHW (electricity)	3,921	3,921	3,921	3,921
(Wh/m ²)				

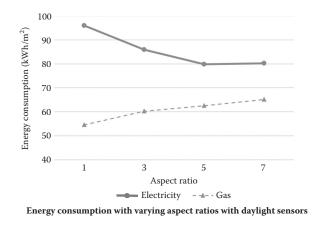
Table 2.11Energy consumption for different aspect ratios(without daylight sensor)

Table 2.12Energy consumption for different aspect ratios (with
daylight sensor)

Aspect ratio	1	3	5	7	
	(25 m × 25 m)	(43.3 m × 14.4 m)	(55.9 m × 11.2 m)	(66.1 m × 9.4 m)	
Room electricity (Wh/m ²)	43,342	43,342	43,342	43,342	
Lighting (Wh/m ²)	35,176	25,783	19,702	18,443	
Heating (gas) (Wh/m ²)	54,576	60,245	62,566	65,177	
Cooling (electricity) (Wh/m ²)	13,529	12,912	12,876	14,513	
DHW (electricity) (Wh/m ²)	3,921	3,921	3,921	3,921	



Energy consumption with varying aspect ratios when daylight sensors are not modelled



Exercise 2.3

- a. Analyse the effect of the aspect ratio for all cases described in the tutorial for the 90° orientation.
- b. Repeat the tutorial for the hot and dry climate (UAE) and observe the energy simulation results.

TUTORIAL 2.4 Evaluating the impact of adjacency of the surface

GOAL

To evaluate the impact of the ground surface on the energy performance.

WHAT ARE YOU GOING TO LEARN?

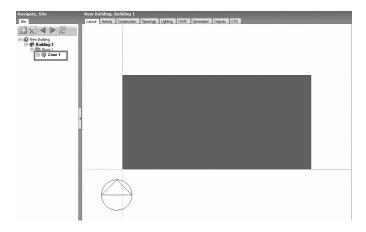
- Assigning surface adjacency
- Making surface adiabatic

PROBLEM STATEMENT

In this tutorial, you are going to create a 50 m \times 25 m single-zone model. Assign ground floor construction to a 200 mm aerated concrete slab. Set the ground floor surface adjacency to **Auto** and as **Adiabatic**. Compare the effect of the surface adjacency on the energy consumption for QC – Montreal/Mirabel INT'L A, Canada.

SOLUTION

Step 1: Create a **50 m** × **25 m single zone** model. Expand **Zone 1** in the navigation tree.



Step 2: Click Ground Floor.

Navigate, Site Ste	New Building, Building 1, Block 1, Zone 1, Ground floor - 1250.000 m2 (Ground)	
		-
曲 愛 Wal+175.000 m2-0.0* 曲 愛 Wal+375.000 m2-201* 曲 愛 Wal+175.000 m2-180.0*		
Drawing Options Tools Options x		
Creep default openings Protection 39 Diraction Snaps 39 Point Snaps 39 Drawing Guides 39 Drawing Grid 39	<u></u>	
	P Adjacent to ground	

Step 3: Select the **Construction** tab.

Navigate, Site	New Building, Building 1, Block 1, Zone 1, Ground floor - 1250.000 m2 (Ground)
Site	Layout Construction Openings Outputs CFD
2 2 4 ≥ 2	
⊕ - @ Wal - 175.000 m2 - 180.0*	
Drawing Options Tools	
Cottons * Cottons * Cottons * Protractor * Direction Shaps *	
Point Snaps *	
Drawing Guidas » Drawing Grid »	The second secon

Step 4: Under the Floors section, click **Ground floor**. Three dots (...) appear. Click the **dots**. The **Select the construction** screen appears.

	1, Zone 1, Ground floor - 1250.000 m2 (Gro	ound)	
Layout Construction Opening	ps Outputs CFD		
	C. Construction Template		
			· · · · · · · · · · · · · · · · · · ·
	Template	Project construction template	
	R Construction		8
	Floors		8
	Ground floor	Project ground floor	
	Basement ground floor	Project basement ground floor	
	Sub-Surfaces		**
	Adjacency		>>
	Geometry, Areas and Volumes		>>
	Surface Convection		>>
	Toost Cost		>>
	*# Cost		

Step 5: Click the **Add new data** button to create a new construction.

— Part L2 2010 Notional Ground floor, Heavyweight	
— Part L2 2010 Notional Ground floor, Lightweight	
— Part L2 2010 Notional Ground floor, Medium weight	
- Project basement ground floor	
- Project ground floor	
- I Reference Ground floor, Heavyweight	
- Reference Ground floor, Lightweight	
- Provide the second floor, Medium weight	
Slab-On-Grade Floor, Heated, F-0.688 (1.191)	
Slab-On-Grade Floor, Heated, F-0.843 (1.459)	
- Slab-On-Grade Floor, Heated, F-0.860 (1.489)	
- Slab-On-Grade Floor, Heated, F-0.900 (1.558)	
- Slab-On-Grade Floor, Heated, F-1.020 (1.766)	
-SIAb-On-Grade Floor, Unheated, F-0.510 (0.883)	
- Slab-On-Grade Floor, Unheated, F-0.520 (0.900)	
- Slab-On-Grade Floor, Unheated, F-0.540 (0.935)	
- Slab-On-Grade Floor, Unheated, F-0.730 (1.264)	
- Slab-On-Grade, Heated, Fully Insulated, R-10.0 (1.8), F-0.550 (0.95)	
- Slab-On-Grade, Heated, Fully Insulated, R-15.0 (2.6), F-0.440 (0.76)	
Club On Grada Masted Endstanded D 20 0 12 ELE 0 272 (0 CE)	

Step 6: Go to the **Layers** section and make sure that **Areated Concrete Slab** is the material and the thickness is **0.2000** m. Click **OK**.

Constructions Data Help Constructions Data Help Constructions Data Help Constructions Data Construction Layers Constructions Data Construction Layers Constructions Data Construction Layers Constructions Data Constructions Data Constrestres Data Constrestestructions Data	Edit construction - Floors (ground)		
Control Contraction Layers Name Fibors (around) Control Streamber of the material data framework Control Control	Constructions Data		Help
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Company Poors ground) © Margino General Definition 14.eyers Calculation Settings 1 Calculation Settings 1 Cystes <			and thickness for each layer.
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a layer hangs the highest r-value and requires that no bridging is used to be observed on the construction.			to meet the mandatory energy code U-value as set on
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Model date rear law Debt law Heb Cycel DK			Ed Set U-Value
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Model date rear two Date law Heb Carcel DK			
Model date rear law Debte law Hoto Carol DK			
Model data realizer Déte lave Heb Carcel DK			
Model date reseture Debte law Heb Carol DK			
Model data neet lave Date lave Heb Cancel DK			
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	Model data	Incert laver Delete lav	er Help Cancel DK

Step 7: Click the **Adjacency** section. It displays the Adjacency property of the selected surface.

Ensure Auto is selected in the adjacency drop-down list.

Untitled, Building 1, Block 1, Zone 1, Ground floor - 1250.000 m	2 (Ground)
Layout Construction Openings Outputs CFD	
C. Construction Template	*
Ge Template	Project construction template
F Construction	×
Floors	*
Ground floor	Floors (ground)
Basement ground floor	Project basement ground floor
Sub-Surfaces	»
Adjacency	×
Adjacency	1-Auto
Geometry, Areas and Volumes	»
Surface Convection	»
™ # Cost	»

Step 8: Perform annual energy simulation. Record the results for the end use energy consumption.

Analysis	Summar	y Parametric	Optin	isation			
Date/Time		Room Electricity	(k₩h)	Lighting (kWh)	Heating (Gas) (kWh)	Cooling (Electricity) (kWh)	DHW (Electricity) (kWh
12:00:00 A	M	52293.8		75575.88	50881.13	18437.18	4731.727

Step 9: Repeat step 6 to select **Adiabatic** from the **Adjacency** drop-down list.

Untitled, Building 1, Block 1, Zone 1, Ground floor - 1250.000 m2 (C Layout Construction Openings Outputs CFD	Sround)
C, Construction Template	*
Sep Template	Project construction template
To Construction	*
Floors	*
Ground floor	Floors (ground)
Basement ground floor	Project basement ground floor
Sub-Surfaces	**
Adjacency	¥
Adjacency	1-Auto
Geometry, Areas and Volumes	1-Auto
Surface Convection	2-Not adjacent to ground
I™⊒ Cost	3-Adjacent to ground
	4-Adiabatic

Step 10: Run simulation to view the results.

Compare the end use energy consumption breakdown (Table 2.13).

You can observe that there is a change in the cooling and heating energy consumption when the ground floor surface property is set to adiabatic.

Table 2.13 Annual fuel breakdown data for building withground floor adjacency set to adjacent to ground and adiabatic

Туре	Adjacent to the ground (kWh)	Adiabatic (kWh)
Room electricity	52,293.80	52,293.80
Lighting	75,575.88	75,575.88
Heating (gas)	159,140.60	160,616.20
Cooling (electricity)	23,653.23	26,540.71
DHW (electricity)	4,731.72	4,731.72

The EnergyPlus weather file provides ground temperatures for undisturbed sites. However, you should not use the ground temperatures in the EnergyPlus weather file header because these are for undisturbed sites.

The temperature beneath a building is significantly affected by the building itself – the EnergyPlus documentation recommends using a ground temperature of 2° C below average internal temperatures for large commercial buildings (where the 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 the use of the ground construction at the site level.

EnergyPlus cannot model very thick constructions, so it is necessary to use less thick constructions (2 m or smaller) combined with some assumptions about temperatures at about half a meter below the floor.

> Source: http://www.designbuilder.co.uk/ helpv4.7/Content/Ground_Modelling.htm

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 the ground. If an earth layer is not included, then you should increase the default site ground temperatures to values closer to those typically found just below the ground slab.

Source: http://www.designbuilder.co.uk/ helpv4.7/Content/Ground_Modelling.htm

Material and Construction

The aim of this chapter is to explain how to create a model while defining materials and constructions and to evaluate their impact on the energy consumption of buildings. The chapter starts with a tutorial on evaluating the impact of thermal mass in the envelope by comparing the performance of lightweight and heavyweight external wall construction. Learners can also find a method for calculating the thickness of insulation on the roof or external walls. The tutorials cover analysis of roof insulation location (overdeck or underdeck), use of a cool roof and radiant barrier.

TUTORIAL 3.1 Evaluating the effect of lightweight and heavyweight construction

GOAL

To evaluate the effect of thermal mass – the lightweight and heavyweight external wall construction in a building with night purge – on the thermal performance of the building.

WHAT ARE YOU GOING TO LEARN?

- · Assigning lightweight and heavyweight construction
- Getting zone temperatures

PROBLEM STATEMENT

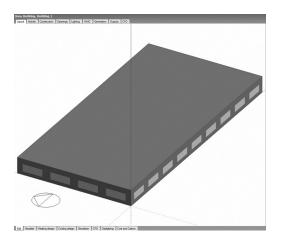
In this tutorial, you are going to use a 50 m \times 25 m model and set external wall construction to lightweight and heavyweight. Find out the air temperatures inside the zone for both the cases. You need to analyse it for the **DUBAI INTERNATIONAL**, **United Arab Emirates** weather location.

You are going to use the following construction for external walls:

- Uninsulated wall, lightweight (wood derivative plywood 15 mm)
- Uninsulated wall, heavyweight (stone granite, 450 mm)

SOLUTION

Step 1: Open a new project file. Create a $50 \text{ m} \times 25 \text{ m}$ building.



Step 2: Select the **Construction** tab.

New Building, I								
Layout Activity	Construction	Openings	Lighting	HVAC	Generation	Outputs	CFD	

Step 3: In the Construction section, click **Project** wall. External walls gets highlighted. Click the Add new item icon. The Edit construction-Wall screen appears.

ew Building, Building 1 ayout Activity Construction Openings Light	ng HVAC Generation Outputs CFD		Info, Data Help Data
Construction Template		×	V 2 + AZ
Se Template	Project construction template		Constructions
To Construction		×	Project wall
External walls	Project wall		Project wall sub-surface constr
Below grade walls	Project below grade wall		Reference Semi-exposed wall,
GFlat roof	Project flat roof		Reference Semi-exposed wall, Reference Semi-exposed wall,
Pitched roof (occupied)	roof (occupied) Project pitched roof		Reference Wall, Heavyweight
Pitched roof (unoccupied)	Project unoccupied pitched roof		Reference Wall, Lightweight
Internal partitions	Project partition		Reference Wall, Medium weig

Step 4: Enter **Light weight** as the Name. Go to the Layers section and select **Plywood** as material (you can find it under the **Wood** branch), and set the thickness to **0.025**. Click **OK**. A message box appears.

Edit construction - Wall Constructions Data		_	Help
Layers Surface properties Image Calculated	Cost Condensation analysis		Info Data
General		×	Construction Layers
Name Light Weight			Set the number of layers first, then select the material and thickness for each layer.
Category	Walls		Insert laver
@Region	General		× Delete layer
Definition Definition method Calculation Settings Layers Number of layers Single layer	1-Leyers 1	* • * • *	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 that bridging effects are NOT used in
⊗Material Thickness (m) ☐ Bridged?	Plywood (Lightweight) 0.025		Emerg/Plus, bit are used in energy code complexics check requires (L-values 1a be calculated according to 55 bit 50° 544 Emergy Code Compliance You can calculate the thickness of insulation required to meet the anadatory energy code L-values and on the Emergy This calculation (dentifies the insulation layer as the layer having the hiphest rivalues and requires that no budings is =

Step 5: Select Light Weight as the external wall.

ew Building, Building 1 Layout Activity Construction Openings Light	ing HVAC Generation Outputs CFD	
Construction Template		×
Se Template	Project construction template	
Construction		¥
😋 External walls	Light Weight	
Below grade walls	Project below grade wall	
Flat roof	Project flat roof	
Pitched roof (occupied)	Project pitched roof	
Pitched roof (unoccupied)	Project unoccupied pitched roof	Pitch
Internal partitions	Project partition	

Step 6: Go to the Airtightness section and enter **3.000** in the **Constant rate (ac/h)** box. Click **On 24/7** in the **Schedule** field. Three dots appear. Click the **dots**. The **Select the Schedule** screen appears.

Airtightness		*
Model infiltration		
Constant rate (ac/h)	3.000	
🚼 Schedule	On 24/7	
Delta T and Wind Speed Coefficients		"
The Cost		»

Step 7: Click the **Create copy of highlighted item** icon. Make sure that the copy of the item is highlighted.

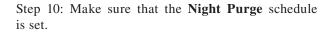
-63	Minimum outdoor ventilation air schedule: Always 1 ac/h		
-63	Mixed mode temperature control		
-6	Off 24/7		
-6	On 24/7		
-6	Opaque all time		
-64	Precool coil setpoint temperature: Always 22.00		
-6	Preheat coil setpoint temperature: Always 5.00		
-6	PV panel efficiency: Always 0.15		
	Real time pricing schedule		
-6	Relative humidity setpoint schedule: Always 50.00		
-6	ScheduledAmbientRH		
-64	ScheduledAmbientTemp		=
-6	ScheduledCompressorTemp		1
-64	Simple Airflow Control Type Schedule: Always 0		-
-6	Summer (Northern Hemisphere)		
-64	Summer (Southern Hemisphere)		
-6	Summer cooling work days (Northern Hemisphere)		
	Summer cooling work days (Southern Hemisphere)		
-6	Summer vent work days (Northern Hemisphere)		
-63	Summer vent work days (Southern Hemisphere)		
	Time of day orhedule		*
÷	Ba Sort	Cancel	0K

Step 8: Click the **Edit selected data** icon. The **Edit Schedule** screen appears.

Select the schedule	
- 🛱 Cooling high water temperature schedule: Always 15.00	
Cooling low control temperature schedule: Always 22.00	
Cooling low water temperature schedule: Always 10.00	
- Galino set point schedule	
- 1 Copy of On 24/7	=
- 1 Daty range multipliers for Design Days Deriver	
- G Default DB Temp hourly multipliers for Design Days	
- G Default months	
Default months Default outdoor CO2 levels 400 ppm (Source: NOAA ESRL)	
G D0AS supply at temperature. Always 18:00 G D0AS supply at temperature. Always 55:00 Fan operation mode - Continuous Fan operation mode - Londinuous Fan operation mode - Londinuous Fan of the Always 0.5 Fan of the Always 0.5 G Endinic containable: Always 0.5 G Endinic containable: Always 0.5 G Endinic containable: Always 0.5 Heating contail temperature. Always 11.0 Heat recovery cultet temperature. Always 11.0 Heating contail temperature. Always 12.0 Heating contail temperature. Always 12.0 Heating contail temperature. Always 12.0	
- Tai Domestic hot water setpoint temperature: Always 55.00	
- Fan operation mode - Continuous	
Fraction of outdoor air schedule: Always 0.5	
Gain distribution schedule: Always 0.5	
- Gale Generic contaminant setpoint: Always 0.5ppm	
Heat recovery heating setpoint temperature: Always 11	
- Always 11.0 C	
Heating control temperature schedule: Always 21.00	
- Heating Fanger comfort setpoint: Always -0.5	
- E3 Hastinn hinh control temperature orbedule: Alwaie 21.00	*
🕂 强 🗹 V Sort Cancel OK	

Step 9: In the **General** section, enter **Night Purge** in the **Name** box. Under the **Profiles** section, edit the schedule as shown below. Click **OK**.

Edit schedule - Copy of On 24/7			
Schedules Data		Help	
General		Info Data	
General		8 General	
Name Night Purge		A schedule consists of one daily profile for each day of the w month of the year.	leek, for each
Description		Schedules are used when the model detail is set to 'Schedu	les'
Source	Ceneral>	Compact Schedules	
Category Region	General	 Define the schedule using Compact Schedule script based of Schedule Compact dataset. 	in the EnergyPlus
Schedule type	2-Compact Schedule	Press F1 for more information.	
Profiles	c compactoricano	S Please I to mate monitority	
Schedule:Compact			
On,			
Any Number, Through: 12/31,			
For AliDavs.			
Until: 6:00, 1, Until: 22:00, 0.1,			
Unti: 22:00, 0.1, Unti: 24:00, 1:			
L			
Model data			
Model data		Help Cancel	OK.



Se Template	Project construction template
Construction	
Texternal walls	Light Weight
SBelow grade walls	Project below grade wall
SFlat roof	Project flat roof
Pitched roof (occupied)	Project pitched roof
Pitched roof (unoccupied)	Project unoccupied pitched roof
Internal partitions	Project partition
Semi-Exposed	
Semi-exposed walls	Project semi-exposed wall
Semi-exposed ceiling	Project semi-exposed ceiling
Semi-exposed floor	Project semi-exposed floor
Floors	
Contract and Second	Project ground floor
Basement ground floor	Project basement ground floor
SExternal floor	Project external floor
spinternal floor	Project internal floor
Sub-Surfaces	
Internal Thermal Mass	
Component Block	
Geometry, Areas and Volumes	
Surface Convection	
Linear Thermal Bridging at Junctions	
Airtightness	이 가지 않는 것 같아요. 것은 것 같아요. 집안 가 있는 것이 같아.
Model infiltration	
Constant rate (ac/h)	3.000

Night purge is a technique used in conditioned buildings in which during unoccupied night hours, cool ambient air is passed through the building to flush out the heat released/accumulated in the building.

Step 11: Click **Flat roof element - 1250.000** m^2 in the navigation tree and select **Adiabatic** from the **Adjacency** drop-down list. Click **Building 1** in the navigation tree.

	ew Building, Building 1, Block 1, Zone 1, Roof - 1 Layout Construction Openings Outputs CFD	250.000 m2	
D D New Bulding	C. Construction Template	Project construction template	¥
🗄 🕐 Building 1	Construction		×
i⊟-50 Block 1 i⊒-50 Zone 1	Flat roof	Project flat roof	
Ground Hoar - 1250.000 m2 (Ground) Ground 1007 - 1250.000 m2	Sub-Surfaces Adjacency		* *
- 20 Flat roof element - 1250.000 m2	Adjacency	1-Auto	•
a c war or soome soo	Geometry, Areas and Volumes	1-Auto	
⊕ - ∰ Wal - 175.000 m2 - 0.0*	Surface Convection	2-Not adjacent to ground	
⊕ 👰 Wall - 87.500 m2 - 270.0*	R Cost	3-Adjacent to around	- 10
i≟-Ø Wal+175.000 m2+180.0*		4-Adiabatic	

To understand the effect of the thermal mass of the external wall, we want to remove the heat gains and losses from the roof. To achieve this, the roof has been made adiabatic.

Adiabatic surface means that heat is not transferred across its external surface.

Source: http://www.designbuilder. co.uk/helpv4.7/#Adjacency.htm

Step 12: Go to the **Building 1** level. Select the **Activity** tab and select **Density** (**people/m**²) as **0.06** and **Office Equipment Gain** (W/m^2) as **1.00**. (The internal load has been reduced so that the effect of the thermal mass is clearly visible. If the internal loads are higher, then the inside zone temperature is dominated by the internal load and you cannot observe the effect of the thermal mass from the envelope.)

CHAPTER THREE MATERIAL AND CONSTRUCTION

New Building, Building 1	
Layout Activity Construction Openings Lighting HVAC Generation	Outputs CFD
xy Template	Generic Office Area A B1 Offices and Workshop businesses 1
 Include zone in Radiance daylighting calculations Floor Areas and Volumes Occupancy 	» *
Density (people/m2) ∰ Schedule ⊉ Metabolic	0.06 Office_OpenOff_Occ
MGeneric Contaminant Generation	33 33 35 34 35 35
Heating Setpoint Temperatures Heating (°C) Heating set back (°C)	22.0 12.0
Cooling Set Vack (C) Cooling (C) Cooling (C)	240 280
Humidity Control Ventilation Setpoint Temperatures Minimum Fresh Air	>> >> >> >>
Lighting Computers On	× V
♣ Office Equipment On Gain (W/m2)	*
(n) Schedule Radient fraction IV Miscellaneous	Office_OpenOff_Equip 0.200 ¥
🗖 On	-

Step 13: Select the **Openings** tab and ensure that **Preferred height** is selected and **window-to-wall per-centage** is set as **0.00**.

ew Building, Building 1		
ayout Activity Construction Openings Lighting H	IVAC Generation Outputs CFD	
C, Glazing Template		×
Template	Project glazing template	
🝵 External Windows		×
Glazing type	Project external glazing	
Layout	Preferred height 1.5m, 30% glazed	
Dimensions		×
Туре	3-Preferred height	-
Window to wall %	0.00	
Window height (m)	1.50	
Window spacing (m)	5.00	
Sill height (m)	0.80	

Step 14: Select the Lighting tab and select the Lighting energy (W/m²-100 lux) as 0.25.

🕵 Lighting Template		
🖓 Template	Reference	
 General Lighting 		¥
🗹 On		
Normalised power density (W/m2	2-100 lux) 0.25	
台 Schedule	Office_OpenOff_Light	
Luminaire type	1-Suspended	٣
Radiant fraction	0.420	
Visible fraction	0.180	
Convective fraction	0.400	
Lighting Control		×
🗖 On		
🖉 Task and Display Lighting		×
🗖 On		
Exterior Lighting		¥
🗖 On		
"# Cost		»

Step 15: Select the **HVAC** tab and select the **template** as **<None>** and clear **Mechanical Ventilation**, **Heating, Cooling, DHW** and **Natural Ventilation** check boxes.

New Building, Building 1		
Layout Activity Construction Openings Lighting HVAC	Generation Outputs CFD	
R. HVAC Template		×
	<none></none>	v l
Template	<none></none>	×
		×.
🗖 On		
Auxiliary Energy		×
Pump etc energy (W/m2)	0.0000	
123 Schedule	Office_OpenOff_Occ	
h Heating		×
Heated		
-X-Cooling		¥
Cooled		
Humidity Control		>>
DHW		¥
🗆 On		
Antural Ventilation		¥
🗖 On		
면/Larth Lube		>>
Air Temperature Distribution		>>
Recost		>>

Step 16: Simulate the model for hourly interval reporting.

Edit Calculation Options				
Calculation Options Data			Help	
General Options Output Simulation Manag	er i		Info Data	
Calculation Description	×	1	Simulation Options	
Simulation Period	*		These options control the simulation and the output produced.	
From			Simulation Period	
Start day	1 *		Select the start and end days for the simulation, or select a typical period:	ш
Start month	Jan 💌		<u>Annual simulation</u>	
To	*		Summer design week	=
End day	31 .		Summer typical week	
End month	Dec	П	All summer	
Output Intervals for Reporting	*		Winter design week	
Monthly and annual		$\ '\ $	Winter typical week	
☑ Daily		Н	<u>All winter</u>	
☑ Hourly □ Sub-hourly			Interval Monthly and annual output is always generatedand daily, hourly and sub-hourly data can selected by checking the appropriate boxes. Note that selecting output at hourly or sub-hourly intervals can produce large amounts of data which slows processing and results in large file alzes. Auto-Update This dialog is always shown when you select 'Update' and will also be shown before all simulations' ID ont show this dalog net time at the bottom is cleared.	
Don't show this dialog next time			Help Cancel OK	

Step 17: Click **OK**. The results are displayed in the grid. You need to click on **Zone 1** to get the results at the zone level.

Display Options		
General Detailed		
\checkmark		
Data		×
Data	3-Comfort	-
Interval	4-Hourly	-
Show as	2-Grid	•
Days per page	365	
🔲 Normalise by floor a	rea	
Y-Axis		»
Appearance		»

Date/Time	Air Temperature (*C)	Radiant Temperatur	Operative Temper	Outside Dry-Bulb Temperature (*C)	Relative H	
1/1/2002 1:00:		22.6021	21.27978	16.75	67.63126	
1/1/2002 2:00:	19.18021	22.02618	20.6032	15.7	66.78899	
1/1/2002 3:00:	18.66668	21.57833	20.1225	15.225	68.14468	
1/1/2002 4:00:	18.22894	21.16861	19.69877	14.875	69.80403	
1/1/2002 5:00:	17.87279	20.79552	19.33416	14.5	71.0724	
1/1/2002 6:00:	17.55365	20.44221	18.99793	14.25	71.93117	
1/1/2002 7:00:	18.83235	20.23939	19.53587	13.825	66.3064	
1/1/2002 8:00:	19.6931	20.51507	20.10408	14.675	63.28916	
1/1/2002 9:00:	21.09123	21.41099	21.25111	16.8	59.69363	
1/1/2002 10:00.	23.24645	22.57734	22.9119	19.275	55.82771	
1/1/2002 11:00.	24.56045	23.59703	24.07874	22.225	55.40805	
1/1/2002 12:00.	25.55275	24.4411	24.99692	23.675	55.85401	
1/1/2002 1:00:	26.19297	25.05903	25.626	24.575	56.92477	
1/1/2002 2:00:	26.72131	25.60482	26.16307	24.95	56.03124	
1/1/2002 3:00:	27.209	26.03543	26.62222	25.75	54.77247	
1/1/2002 4:00:	27.5598	26.31151	26.93565	25.25	54.39133	
1/1/2002 5:00:	27.46172	26.24494	26.85333	24.25	56.24974	
1/1/2002 6:00:	26.65441	25.5746	26.11451	22.5	59.41983	
1/1/2002 7:00:	25.61076	24.8751	25.24293	21.4	63.07595	
1/1/2002 8:00:	24.68477	24.42354	24.55416	20.3	65.70626	
1/1/2002 9:00:	23.87914	24.07538	23.97726	20	67.56403	
1/1/2002 10:00	23.21468	23.77383	23.49426	19.25	67.66705	
1/1/2002 11:00	21.53511	23.39924	22.46718	19	69.853	
1/2/2002	21.0864	22.99313	22.03977	19	69.28327	

Step 18: Click the **Export Data** icon. The **Export Results Spreadsheet** dialog box appears. You can save this results file on your desktop to retrieve it easily.

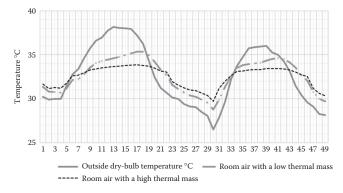
🔁 Export Results Spreadsheet	×
Export Data	
Output	
Export to: 1-File Format: CSV spreadsheet	
Help Cancel OK	

Step 19: Repeat the previous steps to create a high thermal mass external wall.

Edit construction - Wall			
Constructions Data			Help
Layers Surface properties Image Calcula	ted Cost Condensation analysis		Info Data
General		×	Construction Layers
Name Heavy Weight			Set the number of layers first, then select the material and thickness for each layer.
Category	Walls		P Insert layer
Begion	General		X Delete laver
Definition		×	E
Definition method Calculation Settings	1-Layers	•	Bridging You can also add bridging to any layer to model the effect of a relatively more conductive material bridging
Layers		*	a less conductive material. For example wooden joists briging an insulation layer.
Number of layers Single layer	1	*	Note that bridging effects are NOT used in EnergyPlus, but are used in energy code compliance checks requiring U-values to be calculated according to BS EN ISO 6946.
⊗Material Thickness (m) ☐ Bridged?	Stone - granite [0.4500]		Evalues to be calculated according to bs EN ISO 6946. Energy Code Compliance You can calculate the thickness of insulation required to meet the mandatory energy code U-value as set on the Energy Code lab at site level.
			This calculation identifies the "insulation layer" as the layer having the highest rvalue and requires that no bridging is used in the construction.
Model data	Insert layer	Delete layer	Help Cancel OK

Step 20: Perform hourly simulation and record the results.

Compare the indoor air temperature for both cases with the outside dry-bulb temperature.



- As shown in the above figure, the temperature difference between the indoor air and outside air is higher for high thermal mass buildings. This is because building walls with a high thermal mass tend to store and increase the time taken for the heat to transfer from the outside to inside.
- The room air temperature in a high thermal mass building has less swing as compared to the room air temperature of a low thermal mass building that follows the outside temperature pattern.
- The occurrence of the highest room air temperature in a high thermal mass building is not at the same time when the outside air temperature peaks. Rather, it is shifted to a later time of the day. This difference in time when the peaks are observed in room temperature and the outside air temperature is defined as the thermal lag.

Exercise 3.1

Repeat the tutorial with insulation on the lightweight external wall. Compare the results with and without insulation on the lightweight wall.

TUTORIAL 3.2 Evaluating the impact of roof insulation

GOAL

To study the effect of roof insulation on the building energy consumption.

WHAT ARE YOU GOING TO LEARN?

- Creating roof construction
- Setting the U-value of the roof

PROBLEM STATEMENT

In this tutorial, you are going to use a 50 m \times 25 m model. Construct a roof with a 100 mm Aerated concrete slab and glass fibre slab insulation of varying thicknesses. Achieve the U-values given in Table 3.1 by varying the insulation thickness. Find out the energy consumption for each variation. Use the weather file of **WIEN/SCHWECHAT-FLUG, AUSTRIA**.

S. No.	$\frac{\text{U-value}}{(\text{W/m}^2 \text{ K})}$	<i>R</i> -value (m ² K/W)	S. No.	$\frac{\text{U-value}}{(\text{W/m}^2 \text{ K})}$	<i>R</i> -value (m ² K/W)
1	1	1	10	0.31	3.25
2	0.8	1.25	11	0.29	3.5
3	0.67	1.5	12	0.27	3.75
4	0.57	1.75	13	0.25	4
5	0.5	2	14	0.24	4.25
6	0.44	2.25	15	0.22	4.5
7	0.4	2.5	16	0.21	4.75
8	0.36	2.75	17	0.2	5
9	0.33	3			

 Table 3.1
 U-values and R-values of the roof

*R***-value or thermal resistance (***R***) – The** *R***-value of any section having one or more layers with parallel surfaces is an indication of the resistance offered by the section to the heat flow. It is the reciprocal of thermal conductance. For a structure having plane parallel faces, the thermal resistance is equal to the thickness (***L***) of the structure divided by the thermal conductivity (***k***).**

$$R = \frac{L}{k} \tag{3.1}$$

The *R*-value of individual payers can be added to arrive at the total *R*-value of the section.

It is also expressed as the ratio of the temperature difference across an insulator and the heat flux (the heat transfer per unit area per unit time).

Thermal transmittance (U-factor) – thermal transmittance (U) – The thermal transmission in the unit time through the unit area of the given section divided by the temperature difference between the fluid on either side of the building unit in steady-state conditions. It is also called the U-value. Its unit is W/m² K. It can be treated as a measure of the heat loss through the unit area of a building section such as a wall, floor or roof. A low U-value generally indicates high levels of insulation.

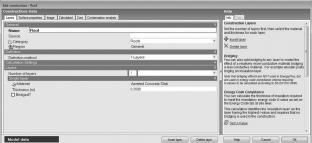
SOLUTION

Step 1: Open a new project and create a 50 m \times 25 m building.

Step 2: Select the Construction tab.

Step 3: Go to the Construction section, click **Flat roof**, and then click the **Add new item** icon. The **Edit construction – Roof** screen appears.

Outputs CFD		Hel	p Data	
Layout Activity Construction Ope	nings Lighting HVAC Generation			
Construction Template	× 🔺	Co	nstructions	×
Template	Project construction te			Wood-Framed, Adva
Tonstruction	×			Wood-Framed, Adva
External walls	Project wall			Wood-Framed, Adv
Below grade walls	Project below grade wall			Wood-Framed, Adva Wood-Framed, Adva
S. Flat roof	Project flat roof			Wood-Framed, Adva
Pitched roof (occupied)	Project pitched roof	1	[•
Pitched roof (unoccupi	Project unoccupied pitched			lot Editable) ×
Internal partitions	Project partition	G	ieneral	
Semi-Exposed	*		Project flat r	roof
Semi-exposed walls	Project semi-exposed wall		Source	
Semi-exposed ceili	Project semi-exposed ceili		Category	Roofs
Semi-exposed floor	Project semi-exposed floor		Region	AUSTRI
Floors	× 🕶	D	efinition	
			Definition meth	hod 1-Lavers



Step 5: Enter 0.1000 as the Thickness (m) in the Outermost layer section Select Class Fibre Slah from

Outermost layer section. Select **Glass Fibre Slab** from Insulating materials for the innermost layer.

Edit construction - Roof				
Constructions Data			Help	
Layers Surface properties Image Calculate	ed Cost Condensation analysis		Info Data	
General		¥		
Name Roof			Materials	× •
Source		-11	-S Foam - polyvinylchlorid	
Category	Roofs	•	Foam - urea formaldeh	
Region	General		- Foam Slag	
Definition	and the second	×	Glass Fibre Ouit	
Definition method	1-Layers	•	Glass Fibre Slab	- 3
Calculation Settings		>>	Glass fibre/wool - fibre	
Layers		×	Glace Rive Aunal . Rive	
Number of layers	2	• •	<	•
Outermost layer		×	Data Report (Not Editable)	¥
Material	Aerated Concrete Slab		General	
Thickness (m)	01000	18	Glass Fibre Slab	
Bridged?			Source	CIBSE Guide
Innermost layer		×	Category	Insulating mat
Material	Glass Fibre Slab		Region	General
Thickness (m)	0.2000	-	Material Layer Thickness	
Bridged?	0.2000	18	Force thickness	No
		- 11	Thermal Properties	
			Detailed properties Yes	
			Thermal Bulk Properties	
		_		
Model data	Insert layer Delete layer		Help Cancel	ОК

Step 6: Click anywhere in the blank space under the Innermost layer section to update the help section.

Edit construction - Roof			
Constructions Data		Help	
Layers Surface properties Image Calculated	Cost Condensation analysis	Info Data	
General	¥		
Name Roof		Materials	× •
Source		Foam · poly	
Category	Roofs ·	- Foam · poly	
Region	General		urethane, freon-filled
Definition	×	- Foam - poly	
Definition method	1-Layers •	Foam Slag	formaldehyde resin
Calculation Settings	»	- Glass Fibre	Quit
Layers	¥	Glass Fibre	
Number of layers	2	Glass fibre/	wool - fibre quit
Outermost layer	¥	Data Report (Not Ed	
Material	Aerated Concrete Slab	General	
Thickness (m)	01000	Glass Fibre Slab	
Bridged?		Source	CIBSE Guide
Innermostlayer	*	Category	Insulating mat
Material	Glass Fibre Slab	Region	General
Thickness (m)	0.2000	Material Layer This	
Bridged?		Eorce thickness	No
		Thermal Properties	5
		Detailed properties Y	
Clic		Thermal Bulk Pro	
Her	re	Conductivity (W/m-	
		Specific Heat (J/kg	
		Density (kg/m3)	25.00 💌
Model data	Insert layer Delete layer	Help	Cancel OK

Step 4: Select 2 from the Number of layers drop-down list.

Step 7: Click the **Set U-value** link. The **Set Construction U-value** screen appears.

Edit construction - Roof		
Constructions Data		Help
Layers Surface properties Image Calculated	Cost Condensation analysis	Info Data
General	×	Construction Layers
Name Roof		Set the number of layers first, then select the material and thickness for each layer.
Source		Insert laver
Category	Roofs ·	
Region Definition	General	X Delete laver
Definition method Colcutation Settings Loyets Number of layers Outermost layer SyMaterial Thickness (m) Bridged? Innermost layer SyMaterial Thickness (m) Bridged?	1-Layers r 2 2 Aeroted Concrete Stab 01000 Glass Fibre Stab 0.2000	Bridging You can also add bridging to any layer to model the affect of a reliatively more conductive malerial bridging bridging an inclusion layor. You be an also add bridging to any layer to model the affect of a reliatively more conductive malerial bridging and inclusion layor. Note the bridging effects are NOT used to Exercise quarter of a reliative document of the second to the se
Model data	Insert layer Delete layer	Help Cancel OK

Step 8: Enter the **U-value** (**W/m² K**) as **1.0**. Click **OK**. A confirmation message appears with the updated insulation thickness.

Set Construction U-Value		
Enter the U-value y	ou would like to use.	ОК
		Cancel
11-Value (W/m2-K)	Default Maximum U-values - Austria	
1.0	Flat roof = 0.220 W/m2-K Pitched roof = 0.220 W/m2-K	Help
	Roofspace floor = 0.220 W/m2-K	
	Use selected default	

Step 9: Click **OK**. The insulation thickness is updated.

DesignBui	der 🕱
Â	Confirm *REDUCE* insulation thickness 2 from 0.2000m of Glass Fibre Slab to 0.0082m of Glass Fibre Slab
	OK Cancel

Step 10: Select the **Calculated** tab. The updated **U-Value** of the construction appears.

Edit construction - Roof		
Constructions Data		Help
Layers Surface properties Image Calculated Cost Condensati	on analysis	Info Data
ture Suffice reporter Image Catalant Cat Condensation Enternant Example Report Particles Report Particles Report Particles Report Catalation Setings Loyers Outermost layer Sufficient Reyer Sufficient	Roots Ceneral 2 Ceneral 2 1Layers 4 Aeroted Concrete Stab 0 0.1000 2 Class Pibre Stab 0 0.002 2	In Construction Layer Construction Layer Sath an unable of layers fart, then select the material discusses for each layer.
Model data	Inset layer Delete layer	Help Cancel OK
moder data	Developer albeit	under OK

Step 11: Click OK.

onstructions Data		Help
Layers Surface properties Image Calculated Cost Con	densation analysis	Info Data
		Calculated Data
Convective heat transfer coefficient (W/m2-K)	4.460	This tab provides further information on the heat transmission properties of the construction.
Radiative heat transfer coefficient (W/m2-K)	5.540	This data is used in Simple calculation methods
Surface resistance (m2-K/W)	0.100	such as SBEM and generally NOT in EnergyPlus
		 simulation s.
Convective heat transfer coefficient (W/m2-K)	19.870	Exceptions are window frame U-values and use of fixed
Radiative heat transfer coefficient (W/m2-K)	5.130	CIBSE convective heat transfer coefficients (more below).
Surface resistance (m2-K/W)	0.040	U-values are shown including and excluding the effect
No Bridging		of surface resistance and are calculated with and
U-Value surface to surface (W/m2-K)	1.164	without bridging effects.
R-Value (m2-K/W)	0.999	Note that the outer surface resitance depends on the
U-Value (W/m2-K)	1.001	exposure to wind (on the Location tab at Site level).
With Bridging (BS EN ISO 6946)		Convective heat transfer coefficients The convective heat transfer coefficients displayed are
Thickness (m)	0.1082	used in EnergyPlus when the 'CIBSE' Inside/Outside
Km - Internal heat capacity (KJ/m2-K)	0.0000	convection algorithm is selected. Otherwise EnergyPlu uses its' own convection algorithm as set in the
Upper resistance limit (m2-K/W)	0.999	simulation options and the transmission data displayed
Lower resistance limit (m2-K/W)	0.999	here is not used.
U-Value surface to surface (W/m2-K)	1.164	
R-Value (m2-K/W)	0.999	
U-Value (W/m2-K)	1.001	

Step 12: Perform annual energy simulation and record the results.

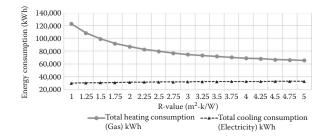
New Building, Building 1							
Analysis Su	ummary	Parametric	Optim	isation			
Date/Time	R	oom Electricity	k₩h)	Lighting (kWh)	Heating (Gas) (k₩h)	Cooling (Electricity) (kWh)	DHW (Electricity) (kWh)
12:00:00 AM	5	2293.8		75575.88	122679	30154.15	4731.727

Step 13: Repeat the previous steps to set the U-values as given in Table 3.1. For each U-value, simulate and record the results.

Compare the results for all simulations (Table 3.2).

S. No.	U-value (W/m ² K)	<i>R</i> -value (m ² K/W)	Total heating consumption (gas) (kWh)	Total cooling consumption (electricity) kWh
1	1	1	122,679.00	30,154.15
2	0.8	1.25	108,379.80	30,443.14
3	0.67	1.5	99,166.45	30,778.71
4	0.57	1.75	92,090.48	31,118.85
5	0.5	2	87,049.97	31,404.42
6	0.44	2.25	82,713.34	31,677.60
7	0.4	2.5	79,882.75	31,879.73
8	0.36	2.75	77,004.63	32,093.25
9	0.33	3	74,849.12	32,266.08
10	0.31	3.25	73,423.50	32,383.91
11	0.29	3.5	71,980.63	32,507.87
12	0.27	3.75	70,537.98	32,630.72
13	0.25	4	69,108.34	32,756.97
14	0.24	4.25	68,383.09	32,823.62
15	0.22	4.5	66,954.23	32,955.86
16	0.21	4.75	66,236.32	33,021.09
17	0.2	5	65,521.70	33,087.50

Table 3.2Heating and cooling energy consumption fordifferent U-values



- In this scenario, the impact of insulation on the heating energy consumption is more than that on the cooling energy consumption.
- The law of diminishing returns can be seen here, as the heating energy consumption does not proportionally decrease with the increase in the insulation thickness.

Exercise 3.2

Repeat the above with the Miami, Florida location.

TUTORIAL 3.3 Evaluating the impact of the position of roof insulation

GOAL

To evaluate the impact of the position of roof insulation (overdeck and underdeck).

WHAT ARE YOU GOING TO LEARN?

• Editing roof construction

PROBLEM STATEMENT

In this tutorial, you are going to use a 50 m \times 25 m model. Use the construction layers as given in the following table. Find out the energy consumption for each variation. Use the weather data for **FRANKFURT MAIN ARPT**, Germany and **DUBAI INTERNATIONAL**, United Arab Emirates (Table 3.3).

Table 3.3	Construction I	ayers
iubic 5.5	Construction	uyers

	Case I	Case II
Outermost layer	Concrete, medium density, 0.15 m	XPS extruded polystyrene - HFC blowing, 0.05 m
Innermost layer	XPS extruded polystyrene - HFC blowing, 0.05 m	Concrete, medium density, 0.15 m

In most of the locations, except for very high latitudes, the external surface of the roof is directly exposed to solar radiation for the longest duration as compared to other surfaces of the building. The solar radiation upon being absorbed by the external surface of the roof turns into heat, which subsequently gets transmitted into the rooms below through the roof slab. The slab, due to its thermal mass, also accumulates heat while transmitting it beneath, which continues to be transmitted even after sunset due to the temperature difference between the slab and room interiors. To avoid this transmission and *(Continued)* accumulation of heat, insulation on the top surface is required in the form of overdeck insulation. A reduction in heat transmission by using insulation results in low energy consumption for operating cooling devices.

If insulation is provided on the inner surface of the roof, it is termed as underdeck insulation. It results in decreasing energy consumption for cooling devices since it reduces the radiant heat from entering the rooms.

In locations requiring heating of buildings, the reverse is the approach. Insulation is provided on the inner side for reducing the heat flow from the inside to outside. As a concept insulation should be put as early as possible in the path of a heat flow, whether from outside to inside or from inside to outside.

SOLUTION

Step 1: Open a new project. Create a $50 \text{ m} \times 25 \text{ m}$ building. Change the weather location to Frankfurt, Germany.

Step 2: Select the Construction tab.

Step 3: Add a roof with underdeck insulation – 0.15 m of Concrete, Medium density (from Concretes materials), and 0.05 m of XPS Extruded Polystyrene - HFC Blowing (from Insulating materials).

Layers Surface properties Image Calculated Cost	Condensation analysis		Info Data
General		*	Set the number of layers first, then select the materia and thickness for each layer.
Name Project Roof			Finsert laver
Source			
Category	Roots	· · · · · · · · · · · · · · · · · · ·	X Delete layer
Region	General		
			Bridging You can also add bridging to any layer to model the
Definition method	1-Layers	* .	effect of a relatively more conductive material bridgin
		» 3	a less conductive material. For example wooden
			oists briging an insulation layer.
Number of layers	2	· .	Vote that bridging effects are NOT used in EnergyPlus, but are used in energy code compliance checks requiring
Outermost layer		×	I-values to be calculated according to BS EN ISO 6946.
Material	Concrete, Medium density		
Thickness (m)	0.15	5	Energy Code Compliance (ou can calculate the thickness of insulation required
Bridged?			o meet the mandatory energy code U-value as set or
Innermast løyer			he Energy Code tab at site level.
AMoterial	XPS Extruded Polystyrene -	HFC Blowing	This calculation identifies the 'insulation layer' as the aver having the highest r-value and requires that no
Thickness (m)	0.05		aver having the highest -value and requires that no pridging is used in the construction.
Bridged?			2 Set U-Value
			Contradice

Step 4: Perform the annual simulation and record the results.

Site, Building 1					
Analysis Summar	ry Parametric Optim	isation			
Date/Time	Room Electricity (kW/h)	Lighting (kWh)	Heating (Gas) (kW/h)	Cooling (Electricity) (kWh)	DHW (Electricity) (kWh)
12:00:00 AM	52293.8	75575.88	78150.55	25341.23	4731.727

Step 5: Repeat the tutorial for overdeck insulation.

Edit construction - Project Roof_1			
Constructions Data		Help	
Layers Surface properties Image Calculated 0	Cost Condensation analysis	Info Data	
General		Construction Layers	
Name Project Roof_1		Set the number of layers first, then select the mater and thickness for each layer.	rial 🗌
Source		Insert laver	
Category	Roofs		
强Region	General	× Delete laver	
Definition		* Bridaina	
Definition method	1-Layers	You can also add bridging to any layer to model the	
Colculation Settings		effect of a relatively more conductive material bridge	ing
Layers	and the second	 a less conductive material. For example wooden jo briging an insulation layer. 	lists
Number of layers	2	Note that bridging effects are NOT used in EnergyPlus, but	
Outermost layer		are used in energy code compliance checks requiring	U.L.
Addenial	XPS Extruded Polystyrene - HF	FC Blowin U-values to be calculated according to BS EN ISO 6946.	
Thickness (m)	0.0500	Energy Code Compliance	
Bridged?		You can calculate the thickness of insulation require	
Innermostlayer		to meet the mandatory energy code U-value as set the Energy Code tab at site level.	on
Material	Concrete, Medium density		
Thickness (m)	0.1500	This calculation identifies the "insulation layer' as the layer having the highest r-value and requires that no	e
Bridged?		bridging is used in the construction.	
		Z Set U-Value	
			-
Model data	Insert layer Del	lete layer Help Cancel OK	

Step 6: Simulate the model and compare the results for the two cases (Table 3.4).

Frankfurt requires predominantly heating and underdeck insulation, preventing the internal heat from being absorbed by the slab mass, thereby reducing the heating energy consumption.

Step 7: Change the weather location to **DUBAI INTERNATIONAL, United Arab Emirates** and compare the energy consumption for overdeck and underdeck insulation (Table 3.5).

Cooling is the predominant requirement in Dubai. Overdeck insulation prevents the external heat from being absorbed by the slab mass, thereby reducing cooling energy consumption.

	With underdeck roof insulation (kWh)	With overdeck roof insulation (kWh)
Room electricity	52,293.8	52,293.8
Lighting	75,575.8	75,575.8
Heating (gas)	78,150.5	83,534.8
Cooling (electricity)	25,341.2	21,440.5
DHW (electricity)	4,731.7	4,731.7

 Table 3.4
 Annual fuel breakdown for underdeck and overdeck roof insulation for Frankfurt location

	With underdeck roof insulation (kWh)	With overdeck roof insulation (kWh)
Room electricity	52,293.8	52,293.8
Lighting	75,575.8	75,575.8
Heating (gas)	659.4	71.2
Cooling (electricity)	171,781.6	169,637.4
DHW (electricity)	4,731.7	4,731.7

Table 3.5 Annual fuel breakdown for underdeck and overdeckroof insulation for Dubai location

Exercise 3.3

Repeat the above tutorial for the external wall. Use the weather data for **FRANKFURT MAIN ARPT**, **Germany** and **DUBAI INTERNATIONAL**, **United Arab Emirates** (Table 3.6).

	Case I	Case II
Outermost layer	Brickwork 230 mm	XPS extruded polystyrene - HFC blowing, 0.05 m
Innermost layer	XPS extruded polystyrene - HFC blowing, 0.05 m	Brickwork 230 mm

 Table 3.6
 Construction layers for external walls

TUTORIAL 3.4 Evaluating the impact of the air gap between roof layers

GOAL

To evaluate the effect of the air gap thickness in roof construction on the energy consumption.

WHAT ARE YOU GOING TO LEARN?

- Adding the air gap between the roof layers
- Changing the air gap thickness

PROBLEM STATEMENT

In this tutorial, you are going to use a 50 m \times 25 m model with a roof consisting of the following layers (starting with the outermost layer):

- 1. 0.01 m of cement/plaster/mortar-plaster
- 2. 0.15 m concrete, medium density
- 3. Air gap with varying thicknesses (as given below)
- 4. 0.01 m gypsum plasterboard

Thickness of the air gap:

- 1. No air gap
- 2. Air gap 15 mm (downwards)
- 3. Air gap 17 mm (downwards)
- 4. Air gap 25 mm (downwards)
- 5. Air gap 50 mm (downwards)
- 6. Air gap 100 mm (downwards)
- 7. Air gap 300 mm (downwards)

Find out the energy consumption for LONDON/GATWICK ARPT, United Kingdom.

An air gap is different from the air space layer. An air gap is enclosed on either side, whereas an air space is a gap left between exterior finish layers and interior insulation layers – as commonly practiced in the lightweight construction. The main role of the air space layer is to act as vapour and water drain/barrier, as compared to an air gap that improves the overall insulation properties of the wall/roof section.

SOLUTION

Step 1: Open a new project. Create a 50 m \times 25 m building.

Step 2: Select the Construction tab.

Step 3: Add a new roof with three layers. Select Cement/ plaster/mortar- cement plaster from Plaster materials with thickness (m) as 0.0100, Concrete, Medium density from Concretes materials with thickness (m) as 0.1500 m, and select Gypsum plasterboard from Plaster materials with thickness (m) as 0.0100 m.

nstructions Data		Help
ayers Surface properties Image Calculated	Cost Condensation analysis	Info Data
ieneral		Construction Layers
Name Project Roof_1 Source		Set the number of layers first, then select the material and thickness for each layer.
Category	Roofs	 Insert layer
Region	General	×
efinition		×
Definition method	1-Layers	- Bridaina
alculation Settings		You can also add bridging to any
ayers		ager to model the effect of a relatively more conductive material
Number of layers	3	bridging a less conductive material.
Outermost layer		For example wooden joists briging
Addrenial	Cement/plaster/mortar - cem	Note that bridging effects are NOT used
Thickness (m)	0.0100	in EnergyPlus, but are used in energy
Bridged?		code compliance checks requiring U-values to be calculated according to
Layer 2		BS EN ISO 6946.
S Material	Concrete, Medium density	Energy Code Compliance
Thickness (m)	0.1500	You can calculate the thickness of
Bridged?		insulation required to meet the mandatory energy code U-value as
Innermost layer	Cement/plaster/mortar - cen	set on the Energy Code tab at site
S Material	0.0100	level.
Thickness (m) Bridged?	0.0100	This calculation identifies the 'insulation layer' as the layer having
L) bridged r		insulation layer as the layer having the highest r-value and requires that no bridging is used in the construction

Step 4: Simulate the model and record the results.

Analaria	0	Description	0.1	in the second			
Analysis	Summary	/ Parametric	Optim	isation			
Date/Time		Room Electricity	(k₩h)	Lighting (kWh)	Heating (Gas) (kWh)	Cooling (Electricity) (kWh)	DHW (Electricity) (kWh)
12:00:00/	AM	52293.8		75575.88	210535	10037.76	4731.727

Step 5: Again select the **Construction** tab. Edit the roof construction.



Step 6: Select the **Thickness** of the **Innermost layer** (we want to insert a new layer above this layer; hence, we have to select this layer). Click **Insert layer**.

Edit construction - Project Roof_1		
Constructions Data		Help
Layers Surface properties Image Calculated	Cost Condensation analysis	Info Data
General		Construction Layers
General Name Project Roof_1 Source Celepson Definition method Celepsition Senings Logens Number of layers Outermost Royer Outermost Royer Colorencest (m) Bidged? Logyre Colorencest (m) Bidged? Dickness (m) Bidged? Dic	General	Bet the number of layers first than select. In metal and thickness for each layer. Insertianer Detete layer Detete layer Oroucan also add hidging to any layer to mode the effect of a relayed more conductive matrix. For example wooden iotis brigging ministration layer. Note that forouge effects are NOT and is
So Material Thickness (m) ☐ Bridged?	Cement/plaster/mortar - cement plaste 0.0100	I layer' as the layer having the highest rvalue and requires that no bridging is used in the construction.
Model data	Insert layer Delete layer	Help Cancel OK

Step 7: Select **Air gap 15mm (downwards)** from Gases materials for the newly inserted layer (Layer 3) and enter **0.001** as thickness (m).

lit construction - Project Roof_1		
onstructions Data		Help
Layers Surface properties Image Calculated Cost Co	ndensation analysis	Info Data
General	×	Construction Layers
Name Project Roof_1		Set the number of layers first, then select the material and thickness for each layer.
Source		Insert laver
Category	Roofs ·	
Region	General	X Delete layer
Definition	¥	
Definition method	1-Layers ·	Bridging You can also add bridging to any layer to
Calculation Settings	»	model the effect of a relatively more
Layers	*	conductive material bridging a less conductive material. For example wooden
Number of layers	4	joists briging an insulation layer.
Outermost layer	*	Note that bridging effects are NOT used in
Adderial	Cement/plaster/mortar - cement plaster	EnergyPlus, but are used in energy code compliance checks requiring U-values to be
Thickness (m)	0.0100	calculated according to BS EN ISO 6946.
Bridged?		
Layer 2	*	Energy Code Compliance You can calculate the thickness of
⊘Material	Concrete, Medium density	insulation required to meet the mandatory
Thickness (m)	0.1500	energy code U-value as set on the Energy Code tab at site level
Bridged?		This calculation identifies the 'insulation
Layer 3	*	laver' as the laver having the highest
Material	Air gap 15mm (downwards)	r-value and requires that no bridging is
Thickness (not used in thermal calcs) (m)	0.001	used in the construction.
Innermostlayer		Set U-Value
Material	Cement/plaster/mortar - cement plaster	
Thickness (m)	0.0100	
Bridged?		

Step 8: Simulate the model and record the results.

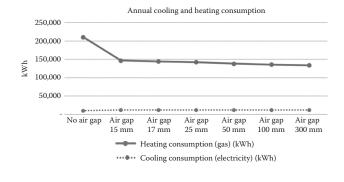
Analysis Sumr	nary Parametric	Optim	isation			
Date/Time	Room Electricity	(k₩h)	Lighting (kWh)	Heating (Gas) (kWh)	Cooling (Electricity) (kWh)	DHW (Electricity) (kWh)
12:00:00 AM	52293.8		75575.88	146784.7	11597.16	4731.727

Step 9: Repeat the previous steps for all the air gap thicknesses given in the problem statement.

Compare the results for all simulations (Table 3.7).

Table 3.7Comparison of annual fuel breakdown data for
various air gaps

Annual fuel breakdown data							
	Room electricity (kWh)	Lighting (kWh)	Heating (gas) (kWh)	Cooling (electricity) (kWh)	DHW (electricity) (kWh)		
No air gap	52,293.80	75,575.88	210,535.00	10,037.76	4,731.73		
Air gap 15 mm	52,293.80	75,575.88	146,784.70	11,597.16	4,731.73		
Air gap 17 mm	52,293.80	75,575.88	144,410.50	11,689.15	4,731.73		
Air gap 25 mm	52,293.80	75,575.88	142,125.00	11,780.55	4,731.73		
Air gap 50 mm	52,293.80	75,575.88	137,828.30	11,954.16	4,731.73		
Air gap 100 mm	52,293.80	75,575.88	135,788.40	12,042.50	4,731.73		
Air gap 300 mm	52,293.80	75,575.88	133,825.40	12,127.33	4,731.73		



TUTORIAL 3.5 Evaluating the impact of surface reflectance

GOAL

To evaluate the effect of surface reflectance on the energy performance of buildings.

WHAT ARE YOU GOING TO LEARN?

Changing surface reflectivity

PROBLEM STATEMENT

In this tutorial, you are going to use a 50 m \times 25 m model with a roof consisting of the following layers (starting with the outermost layer):

- 0.015 m cement/plaster/mortar-plaster
- 0.150 m concrete, medium density
- 0.015 m cement/plaster/mortar-plaster

Vary the roof solar reflectivity on the outermost material from 0.9 to 0.1 in steps of 0.1. Find out the impact of roof solar reflectivity on the energy consumption for **SINGAPORE/PAYA LEBA**.

Surface absorptance is the property of the surface material to absorb radiation, and it is the opposite to surface reflectance, which is the capability to reflect radiation. For opaque surfaces, surface absorptance and surface reflectance values are therefore ratios whose sum is always equal to 1.

Solar reflectivity = Solar absorptance -1

SOLUTION

Step 1: Open a new project. Create a 50 m × 25 m building.Step 2: Select the Construction tab.

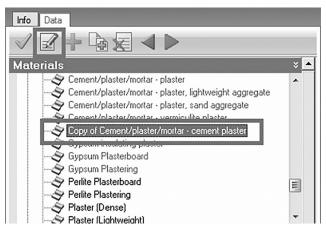
Step 3: Add a new roof with three layers. Select **Cement/ plaster/mortar - cement plaster** from Plaster materials with thickness (m) as **0.01**, **Concrete, Medium density** from Concretes materials with thickness (m) as **0.15** and **Cement/plaster/mortar-cement plaster** from Plaster materials with thickness (m) as 0.01.

ayers Surface properties Image Calculated	Cost Condensation analysis	Info Data
àener a l		Construction Layers
Name New Roof Source		Set the number of layers first, then select the materia and thickness for each layer.
Category	Roofs	
Region	General	× Delete laver
Definition		8
Definition method	1-Layers	 Bridging You can also add bridging to any layer to model the
Calculation Settings		effect of a relatively more conductive material bridging
		a less conductive material. For example wooden jois
Number of layers	3	 briging an insulation layer.
Outermost layer		Note that bridging effects are NOT used in EnergyPlus, but are used in energy code compliance checks requiring
Material	Cement/plaster/mortar - cement plas	ter U-values to be calculated according to BS EN ISO 6946.
Thickness (m)	0.01	Energy Code Compliance
Bridged?		You can calculate the thickness of insulation required
Layer 2		to meet the mandatory energy code U-value as set or
Material	Concrete, Medium density	the Energy Code tab at site level.
Thickness (m)	0.15	This calculation identifies the 'insulation layer' as the layer having the highest r-value and requires that no
Bridged?		bridging is used in the construction.
Innermostlayer		Set U-Value
AMaterial	Cement/plaster/mortar - cement plas	ter der of value
Thickness (m)	0.01	
Bridged?	E	

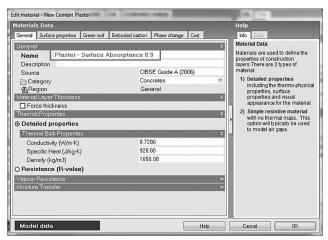
Step 4: Click **Cement/plaster/mortar - cement plaster** in the outermost layer and click the **Create copy of highlighted item** icon.

Edit construction - Project Roof_1			
Constructions Data		Help	
Layers Surface properties Image Calculated Cost	Condensation analysis	Info Data	
General	*		
Name Project Roof_1		Materials	* •
Source		1- Phase change	, i i i
Category	Roofs ·)- Plaster	
Region	General	- 3 0.5 in. (12.7 mm) gypsum	board
Definition	¥	- 9 0.625 in. gypsum board	
Definition method	1-Layers •	- 2010 NCM Plasterboard (- Cement/plaster/mortar - c	
Calculation Settings	»	Cement/plaster/mortar - c	
Layers	×	- Cement/plaster/mortar - c	
Number of layers	3	< III	•
Outermost laver	×*	Data Report (Not Editable	e) *
S Material	Cement/plaster/mortar - cement	General	
Thickness (m)	0.0100	Cement/plaster/morta	- cement p
Bridged?		Source	CIBSE Guid
Layer 2	×	Category	Plaster
Material	Concrete, Medium density	Region	General
Thickness (m)	0.1500	Material Layer Thicknes	s
Bridged?		Force thickness	No
Innermost layer	×	Thermal Properties	
SMaterial	Cement/plaster/mortar - cement pla	Detailed properties Yes	
Thickness (m)	0.0100	Thermal Bulk Propertie	es
Bridged?		Conductivity (W/m-K)	0.7200
		Specific Heat (I/kesk)	0.40.00
Model data	Insert layer Delete layer	Help Cancel	OK

Step 5: Select the **Copy of Cement/plaster/mortar - cement plaster** and click the **Edit highlighted item** icon.



Step 6: Enter **Plaster - Surface Absorptance 0.9** in the Name box.



Step 7: Select the **Surface Properties** tab and enter **Solar absorptance** as **0.900**.

Edit material - Copy of Cement/plaster/mo	ortar - cement plaster		
Materials Data			Неір
General Surface properties Green roof	Embodied carbon Phas	e change Cost	Info Data
Surface Properties		×	Surface properties
Thermal absorptance (emissivity)	0.900		Colour The colour data is used for
Solar absorptance	0.900		display purposes and only when
Visible absorptance	0.800		the texture is not available for any reason. It is not used in any of the
Roughness	3-Rough	•	calculations.
Colour			
Texture	GranulatedGra	xy453M	
Model data		Help	Cancel OK

Step 8: Click the **Select this data** icon.

Edit construction - Roof		
Constructions Data		Help
Layers Surface properties Image Calculated	Cost Condensation analysis	Info Data
General	*	
Name Roof		Materials *
Source		Materials *
Category	Roofs ·	Concrete, High density
Region	General	Concrete, Medium density
Definition	*	
Definition method	1-Layers *	Concrete, Reinforced (with 2% steel) Plaster - Surface Absorptance 0.9
Calculation Settings	*	Medium weight concrete
Layers	*	😽 Medium-weight concrete block, solid gi
Number of layers	3	A Minoral Shea
Outermost layer	*	Data Report (Not Editable) *
Material	Plaster - Surface Absorptance 0.9	General
Thickness (m)	0.2000	Plaster - Surface Absorptanc
Bridged?		Source CIBSE Gu
Layer 2	*	Category Concretes
Material	Concrete, Medium density	Region General
Thickness (m)	0.2000	Material Layer Thickness
Bridged?		Force thickness No
Innermost layer		Thermal Properties
Aterial	Cement/plaster/mortar - cement	Detailed properties Yes
Thickness (m)	0.2000	Thermal Bulk Properties
Bridged?		Conductivity (W/m+K) 0.7200
		Specific Heat (J/kg-K) 920.00
Model data	Insert layer Delete layer	Help Cancel OK

Step 9: Perform the annual simulation and record the results.

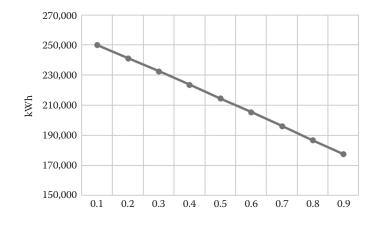
Analysis	Summar	ry Pa	arametric	Optim	isation			
Date/Time		Room	Electricity	(k₩h)	Lighting	(k₩h)	Cooling (Electricity) (kWh)	DHW (Electricity) (kWh)
12:00:00 A	١M	5229	3.8		75575.	.88	249997.2	4731.727

Step 10: Repeat the previous steps for all the values of solar absorptance given in the problem statement.

Compare the results for all simulations (Table 3.8).

 Table 3.8
 Annual fuel breakdown data for different surface absorptance

Surface absorptance	Surface reflectance	Room electricity (kWh)	Lighting (kWh)	Cooling (electricity) (kWh)	DHW (electricity) (kWh)
0.9	0.1	52,293.80	75,575.88	249,997.20	4,731.73
0.8	0.2	52,293.80	75,575.88	241,298.20	4,731.73
0.7	0.3	52,293.80	75,575.88	232,533.50	4,731.73
0.6	0.4	52,293.80	75,575.88	223,629.40	4,731.73
0.5	0.5	52,293.80	75,575.88	214,548.10	4,731.73
0.4	0.6	52,293.80	75,575.88	205,382.60	4,731.73
0.3	0.7	52,293.80	75,575.88	196,176.00	4,731.73
0.2	0.8	52,293.80	75,575.88	186,744.60	4,731.73
0.1	0.9	52,293.80	75,575.88	177,542.70	4,731.73



Exercise 3.5

Repeat the above tutorial for the **FRANKFURT MAIN ARPT, Germany** weather location (Table 3.9).

Table 3.9 Annual fuel I	nual fuel breakdow	breakdown data for different surface absorptance	ace absorptance			
Surface absorptance	Surface reflectance	Room electricity (kWh)	Lighting (kWh)	Heating (gas) (kWh)	Cooling (electricity) (kWh)	DHW (electricity) (kWh)
0.9	0.1					
0.8	0.2					
0.7	0.3					
0.6	0.4					
0.5	0.5					
0.4	0.6					
0.3	0.7					
0.2	0.8					
0.1	0.9					

TUTORIAL 3.6 Evaluating the impact of roof underdeck radiant barrier

GOAL

To evaluate the impact of underdeck radiant barrier on the energy performance.

WHAT ARE YOU GOING TO LEARN?

• Changing the emissivity of a material

PROBLEM STATEMENT

In this tutorial, you are going to use a 50 m \times 25 m model with a roof consisting of the following layers (starting with the outermost layer).

- 0.01 m cement/plaster/mortar-plaster
- 0.15 m concrete, medium density
- 0.01 m cement/plaster/mortar-plaster

Vary the thermal emittance on the innermost material of the roof (ceiling) from 0.1 to 0.9 in steps of 0.1. Find out the impact of roof thermal emittance on the energy consumption for **CA-SAN FRANCISCO INTL, USA**.

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).

http://www.designbuilder.co.uk/helpv4.7/Content/ SurfaceProperties.htm

Radiant barrier is the coating used under the roof deck to limit the heat transfer from the inside to outside and the outside to inside.

SOLUTION

Step 1: Open a new project. Create a 50 m \times 25 m building.

Step 2: Select the **Construction** tab.

Step 3: Add a new roof with three layers. Select **Cement/ plaster/mortar - cement plaster** from Plaster materials with thickness (m) as **0.01**, **Concrete**, **Medium density** from Concretes materials with thickness (m) as **0.1500** and select **Cement/plaster/mortar - cement plaster** from Plaster materials with thickness (m) as **0.0100**.

Edit construction - Project Roof_1		
Constructions Data		Help
Layers Surface properties Image Calculated Cost Condensation	on analysis	Info Data
Ceneral Name Project Roof Source ⊘ Category ∰Ragion Definition method	c Roofs ≁ General 1-Layers ≁	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 that bridging effects are NOT used in EnergyPlus, kot are used in energy code compliance checks desconferie to SE MISO 9946.
Calculation Settings Layers Number of layers Outermost layer - Material	» ≤ 3 ✓ Cement/blaster/mortar - cement plaster	Energy Code Compliance You can calculate the thickness c insulation required to meet the mandatory energy code U-value
Conductions Thickness (m) ☐ Bridged? Lover 2	0.0100	as set on the Energy Code tab at site level. This calculation identifies the insulation layer as the layer
⊘Material Thickness (m) ☐ Bridged?	Concrete, Medium density 0.1500	having the highest r-value and requires that no bridging is used in the construction.
Innermostlayer SyMaterial Thickness (m) Bridged?	≈ New Cernent/plaster/mortar - cernent plaster 0.0100	-
Model data	Insert layer Delete layer Help	Cancel OK

Step 4: Click **Cement/plaster/mortar - cement plaster** in the innermost layer, create a copy and rename it as **New Cement/plaster/mortar - cement plaster**.

ayers Surface properties Image Calculated	Cost Condensation analysis	Info Data	
ieneral	¥		
Name Project Roof		Materials	ž
Source		Phase change	
Category	Roofs ·	Plaster	
Region	General	- 🗢 0.5 in. (12.7 mm) gypsun	n board
Definition	¥	- 3 0.625 in. gypsum board - 3 2010 NCM Plasterboard	6
Definition method	1-Layers •	Cement/plaster/mortar -	
alculation Settings	**	- Cement/plaster/mortar -	
ayers	¥	- S Cement/plaster/mortar -	cement/lime plaste +
Number of layers	3 *	· · · · · · · · · · · · · · · · · · ·	•
Outermost layer	*	Data Report (Not Edita	ble) ×
Amaterial	Cement/plaster/mortar - cement plast	General	
Thickness (m)	0.0100	Cement/plaster/mor	tar - cement pl
Bridged?		Source	CIBSE Guid
Layer2	×	Category	Plaster
Material	Concrete, Medium density	Region	General
Thickness (m)	0.1500	Material Layer Thickn	ess
Bridged?		Force thickness	No
Innermost laver	×	Thermal Properties	
S Material	Cement/plaster/mortar - cement pl	Detailed properties Yes	
Thickness (m)	0.0100	Thermal Bulk Prope	rties
Bridged?		Conductivity (W/m-K)	0.7200

struction - Project Roof constructions Data Layers Surface properties Image Calculated Cost Co n analysis General Name Project Roof * Roofs General) Category Region 1-Layers × Data Report (N Ceme 0.0100 General New Cem Category Plast Region Gene Material Layer Thickness × Plaster Concrete. Mater Thickness (m) 0.1500 Maternal Layer Thickness Force thickness No Thermal Properties Detailed properties Yes Thermal Bulk Properties Conductivity (W/m-K) 0.7200 Soecific Heat (J/k.a., R4n nn Material Thirt 0.0100 Thickness (m) Bridged? Model data Insert layer Delete layer Help Cancel 0K

Step 6: Select the **Surface properties** tab and enter **0.900** as the **Thermal absorptance (emissivity)**.

laterials Data			Help
Seneral Surface properties Green roof Embodied carbo	n Phase change Cost		Info Data
Surface Properties		×l	Surface properties
Thermal absorptance (emissivity)	0.900		Colour The colour data is used for display
Solar absorptance	0.600	_	purposes and only when the texture
Visible absorptance	0.600		is not available for any reason. It is not used in any of the calculations.
Roughness	3-Rough		not used in any of the calculations.
Colour			
Texture	GranulatedGray453M		
Model data		Help	Cancel

Step 7: Simulate the model and record the results.

Analysis Summ	ary Parametric Optin	nisation			
Date/Time	Room Electricity (kWh)	Lighting (kWh)	Heating (Gas) (kWh)	Cooling (Electricity) (kWh)	DHW (Electricity) (kWh)
12:00:00 AM	52293.8	75575.88	62966.75	15490.71	4731.727

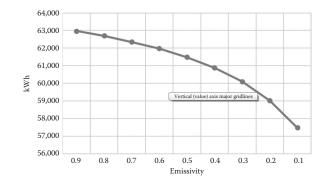
Step 8: Repeat the previous steps for all the values of thermal emissivity given in the problem statement.

Compare the results for all simulations (Table 3.10).

Step 5: Click the Edit highlighted item icon.

Thermal absorptance (emissivity)	5	Lighting (kWh)	Heating (gas) (kWh)	Cooling (electricity) (kWh)	DHW (electricity)
0.9	52,293.80	75,575.88	62,966.75	15,490.71	4,731.73
0.8	52,293.80	75,575.88	62,696.43	15,513.52	4,731.73
0.7	52,293.80	75,575.88	62,352.68	15,553.91	4,731.73
0.6	52,293.80	75,575.88	61,982.36	15,619.02	4,731.73
0.5	52,293.80	75,575.88	61,489.79	15,720.82	4,731.73
0.4	52,293.80	75,575.88	60,888.78	15,881.52	4,731.73
0.3	52,293.80	75,575.88	60,104.81	16,128.46	4,731.73
0.2	52,293.80	75,575.88	59,024.70	16,510.27	4,731.73
0.1	52,293.80	75,575.88	57,484.44	17,130.53	4,731.73

Table 3.10Comparison of annual fuel breakdown data for
thermal absorptance



Exercise 3.6

Repeat the tutorial for the **DUBAI INTERNATIONAL**, **United Arab Emirates** weather location (Table 3.11).

Thermal absorptance (emissivity)	0 0	(gas)	Cooling (electricity) (kWh)	DHW (electricity)
0.9				
0.8				
0.7				
0.6				
0.5				
0.4				
0.3				
0.2				
0.1				

 Table 3.11
 Annual fuel breakdown data

TUTORIAL 3.7 Evaluating the impact of a green roof

GOAL

To evaluate the impact of a green roof on the energy consumption.

WHAT ARE YOU GOING TO LEARN?

Creating a green roof

PROBLEM STATEMENT

In this tutorial, you are going to use a 50 m \times 25 m model with a roof consisting of the following layers (starting with the outermost layer):

- 0.01 m cement/plaster/mortar-plaster
- 0.15 m concrete, medium density
- 0.01 m cement/plaster/mortar-plaster

Add a green roof to the outermost layer of the roof. Find out the change in energy consumption with and without a green roof for **DUBAI INTERNATIONAL**, United Arab Emirates. A green roof or living roof is a roof of a building that is partially or completely covered with vegetation and a growing medium planted over a waterproofing membrane.

> http://www.designbuilder.co.uk/ helpv4.7/Content/GreenRoof.htm

SOLUTION

Step 1: Open a new project. Create a 50 m \times 25 m building.

Step 2: Select the **Construction** tab.

Step 3: Add a **New roof** with three layers. Select **Cement/ plaster/mortar - cement plaster** from Plaster materials with thickness (m) as **0.0100**, **Concrete, Medium density** from Concretes materials with thickness (m) as **0.1500**, and **Cement/plaster/mortar - cement plaster** from Plaster materials with thickness (m) as **0.0100**.

Sancted Name Now Roof Source Career Company C	onstructions Data Layers Surface properties Image Calculated Co	the Condensation analysis	Help Info Data
Source So	General		compliance checks requiring U-values to be calculated according to BS EN ISO
© Cetegory Pools Pools Paragram Paragr	Truine		6946.
Collegory Product Connected Set of the Product Connect Set of the Product Set o	Source		Enormy Code Compliance
Definition on the set of the set		1 10013	You can calculate the thickness of
Definition method I-Layers Information			
Definition method 1-Leyers Ievel: Definition method 1-Leyers Ievel: Availability 1 1 Availability 0.0100 1 Bindgaler? 1 1 Dischered (m) 0.1500 1 Bindgaler? 1 1 Michaela Connervlplaster/monter - cament plaster 1 Availability 1 1 Dischered (m) 0.1500 1 Bindgaler? 1 1 Thickness (m) 0.0100 1			set on the Energy Code tab at site
syster Syste		1 20/010	level.
Solution of layers 3 3 F Outermost System Construction of the product of the pr			
Number of styers 3 • Ordermost Syster Cement/plaster/monter - cement plaster • Didged? 0.0100 • Usyster 0 • SyMderial Concrete. Medium density • Didged? 0.1500 • Didged? • • Michaes (m) 0.1500 • Didged? • • Michaes (m) 0.500 • Thickness (m) 0.500 • Thickness (m) 0.0100 •	.ayers		the bished ruplus and requires that
SyMaterial Cement/plaster/montar - cement plaster Discrete		3 *	no bridging is used in the
Thickness (m) 0.0100 Bridged? S SyMaterial Concrete, Medium density Thickness (m) 0.1500 Bridged? S Material Concrete, Medium density Thickness (m) 0.1500 Bridged? S Thickness (m) 0.100 Thickness (m) 0.010		*	9
Thickness (m) 0.0100 Loyat 2 \$ SMderial Concrete, Medium density Thickness (m) 0.1500 Bridged* \$ Systematic concrete, Medium density \$ Intermost logut \$ Systematic concrete, Medium density \$ Thickness (m) 0.100	Addenial		E Set U-Value
Leyer 2 \$ \$Mdeeinal Concrete, Medium density Thickness (m) 0.1500 Bridged* Immemoral Hoyait \$ \$ \$ \$ \$ \$ Thickness (m) 0.0100	Thickness (m)	0.0100	
SyMaterial Concrete. Medium density Thickness (m) 0.1500 Brdged?	Bridged?		
Thickness (m) 0.1500 Bridged* 5 Schkeinial Cement/plaster/monter-cement plaster Thickness (m) 0.0100	Løyer 2	*	
☐ Bridged* [Intermostlyper S/Material Cement/plaster/montar - cement plaster Thickness (m)	Material	Concrete, Medium density	
Internet styler * SyMaterial Cement/plaster/monter-cement plaster Thickness (m) 0.0100	Thickness (m)	0.1500	
Material Cement/plaster/montar-cement plaster Thickness (m) 0.0100	Bridged?		- 18
Thickness (m) 0.0100	Innermostlayer	\$	
mediess (m)	Adderial	Cement/plaster/mortar - cement plaster	1
	Thickness (m)	0.0100	
	Bridged?		

Step 4: Simulate the model and record the results without a green roof.

Now you are going to add a green roof.

Step 5: Add a **New roof** with four layers. Select **12 in. Soil at R-0.104/ in.** from sands, stones and soil materials with thickness (m) as **0.305**, **Ethylene propylene diene monomer (EPDM)** from rubber materials with thickness (m) as **0.0015** and select **Concrete**, **Medium density** from concretes materials with thickness (m) as **0.1500**, and **Cement/plaster/mortar - cement plaster** from Plaster materials with thickness (m) as **0.0100**.

Edit construction - New Roof		
Constructions Data		Help
Layers Surface properties Image Calculated Cost Condensation	analysis	Info Data
General	*	Construction Layers
Name Green Roof_1		Set the number of layers first, then select the material and thickness for each layer.
Source		Insert laver
Category	Roofs ·	
强Region	General	× Delete layer
Definition Definition method Calculation Settings Layers	* 1-Läyers » *	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
Number of layers	4	joists briging an insulation layer.
Outermost layer SMaterial Thickness (not used in thermal calcs) (m) Layer 2	* 12 in. Soil at R-0.104/ in. 0.3048 *	Note that bridging effects are NOT used in EnergyPlus, but are used in energy code complement checks requiring U-values to be calculated according to BS EN ISO 6946.
Softward Thickness (m) ☐ Bridged? Layer 3	Ethylene propylene diene monomer (EPDM 0.0015	Energy Code Compliance You can calculate the thickness of insulation required to meet the mandatory energy code U-value as set on the Energy Code tab at site level.
Softeniel Thickness (m) ☐ Bridged? Innermostlayer	Concrete, Medium density 0.1500	This calculation identifies the "insulation layer" as the layer having the highest r-value and requires that no bridging is used in the construction. Z Set U-Value
ଙMaterial Thickness (m) ☐ Bridged?	Cement/plaster/morter - cement plaster 0.0100	
Model data	Insert layer Delete layer	lelp Cancel OK

Step 6: Click **12 in. Soil at R-0.104/ in.** In the outermost layer, it highlights and creates a copy.

Edit construction - Green Roof_1				
Constructions Data			Help	
Layers Surface properties Image Calculated Cost Conde	nsation analysis		Info Data	
General		× 🔺		_
Name Green Roof_1			Materials	*
Source			vds. stones and soils	<u> </u>
Category	Roofs	*	12 in Sol at R-0.104/ in	
Region	General		Alluvial clay, 40% Sands	
Definition		×	Artifitial stone	
Definition method	1-Layers	*	Basalt Clav or sit	
Calculation Settings		»	Crystalline rock	
Layers		¥	Cultivated Clay Soil 12.5%D.W. Moisture	
Number of layers	4	•	Cultivated Clay Soil 25.0%D.W. Moisture	-
Outermost layer			· · · · · · · · · · · · · · · · · · ·	•
Material	12 in. Soil at R-0.104/ in.		Data Report (Not Editable)	÷
Thickness (not used in thermal calcs) (m)	0.3048		General	
Layer 2	and the second	×	12 in. Soil at R-0.104/ in.	

Step 7: Select the **copy of 12 in. Soil at R-0.104/ in.** Rename it Green Roof Layer.

Edit material - Copy of 12 in. Soil at R-0.104/ in.		
Materials Data		Help
General Surface properties Green roof Embodied carbo	on Phase change Cost	Info Data
General	×	Material Data
Name Green Roof Layer		Materials are used to define the properties of construction
Description		layers. There are 2 types of
Source	ASHRAE Handbook	material:
Category	Sands, stones and soils	 Detailed properties including the thermo-physical
Region	US General	properties, surface properties
Material Layer Thickness	*	and visual appearance for the material
Force thickness		
Default thickness (m)	0.3048	 Simple resistive material with no thermal mass. This
Thermal Properties	×	option will typically be used
O Detailed properties		to model air gaps.
 Resistance (R-value) 		
Thermal resistance (m2-K/W)	0.2201	
Vapour Resistance	»	
Moisture Transfer	»	
L		
Model data	Help	Cancel OK

Step 8: Select the **Green roof** tab. Select the **Green roof** check box.

General Surface properties Green roof Embodied car	bon Phase change Cost	Info Data
Careen Root Green Root Green Root Height of plants (m) Leaf area index (LA) Leaf area index (LA) Leaf areasisty Minimum stomatal resistance (s/m) Max volumetric moisture content a saturation Min residual volumetric moisture content Initial volumetric moisture content	1-Simple 0.1000 2.2000 0.950 180.000 0.010 0.010 0.150	 Green Roof Green roofs can be used to reduce cooling loads by providing thermal mass and exportaive cooling this and exportaive cooling the maintain as a green roof in a roo construction check the 'Green roof in checkbox and enter the data. Note that the conductivity value defined on the first stand of the gree roof material is for earth when it is dry. Note also that the maximum thickness for the maximum thickness for the maximum thickness for the maximum

Step 9: Click **OK**. Green Roof Layer appears as the outermost layer.

Instructions Data avers Surface properties Image Calculated Cost Cond	ensation analysis	Help Mo Data
Seneral	÷ · ·	
Name Green Roof_1		
Source		Materials * Celular Rubber Underlay
Category	Roofs ·	Cloth/carpet/telt - carpet, simulated woo
@Region	General	Cloth/carpet/telt - carpet, Wilton
Definition	¥	Cloth/carpet/felt - felt, semi-rigid, organic
Definition method	1-Layers *	Cloth/carpet/felt - felt, semi-rigid, organic
Calculation Settings	, ,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	Cloth/carpet/let - jute feit, at 50C degre Cloth/carpet/let - jute fibre, at 50C degr
øyers		Cloth/carpet/felt - wool felt underlay
Number of layers	4 *	Cork floor tiles
Outermost layer	¥	A lindeum
Material	Green Roof Layer	Data Report (Not Editable)
Thickness (not used in thermal calcs) (m)	0.3048	General
Layer 2	*	Green Roof Layer
Addenial	Ethylene propylene diene monomer (EPDM)	Source ASHRAF
Thickness (m)	0.0015	Category Sands, st
Bridged?		Region US Gener
Layer 3	¥	Material Layer Thickness
Addenial	Concrete, Medium density	Force thickness Yes
Thickness (m)	0.1500	Default thickness (m) 0.3048
Bridged?		Thermal Properties
Innermostlayer	¥	Detailed properties No
Addenial	Cement/plaster/mortar - cement plaster	Resistance (R-value) Yes
Thickness (m)	0.0100	Thermal resistance (m 0.2201
Bridged?		Vapour Resistance
		Vapour resistance def 1-Factor

Step 10: Perform annual simulation and record the results.

Compare the results for both simulations (Table 3.12).

	Without a green roof (kWh)	With a green roof (kWh)
Room electricity	52,293.80	52,293.80
Lighting	75,575.88	75,575.88
Heating (gas)	2,483.94	470.05
Cooling (electricity)	196,202.30	188,443.40
DHW (electricity)	4,731.73	4,731.73

Table 3.12Annual fuel breakdown with and without agreen roof

Exercise 3.7

Repeat the above tutorial for the CA – San Francisco, USA weather file (Table 3.13).

Table 3.13Annual fuel breakdown consumption with andwithout a green roof

	Annual fuel breakdown consumption	
	Without a green roof (kWh)	With a green roof (kWh)
Room electricity		
Lighting		
Heating (gas)		
Cooling (electricity)		
DHW (electricity)		

Openings and Shading

Openings are required in buildings to bring daylight and fresh air, and provide outdoor views. The energy for artificial electric light can be reduced if there is sufficient daylight in the space. However, daylight increases the heat gain in a space. If the climate is hot/warm, it results in an increase in the airconditioning energy consumption. Hence, there is a need to optimize the window-to-wall ratio (WWR) to get the minimum energy consumption while getting sufficient daylight.

Choosing glass type is also important for buildings; building glass is specified by some important properties such as *U*-value, solar heat gain coefficient (SHGC) and visible light transmittance (VLT). Generally, VLT to SHGC ratio is taken as an indicator of glass performance in cooling dominated locations. Higher is this ratio, better is the glass. Building shades can be used to cut the direct solar radiation in buildings and get diffused daylight inside the perimeter space. Overhangs and fins are classified as fixed building shades. Operable shades can also be used to cut the direct radiation from windows.

In this chapter, through the three tutorials, you are going to learn how to analyse the impact of different glazing types, fixed shades and operable shades for a given climate. This can be useful in the analysis of different designs and approaches for reducing solar heat gains through windows.

TUTORIAL 4.1 Evaluating the impact of window wall ratio and glazing type

GOAL

To evaluate the impact of WWR and glazing type on the energy consumption.

Window-to-wall ratio (WWR), is the ratio of the total window area to the total gross exterior above grade wall area.

WHAT ARE YOU GOING TO LEARN?

- · Setting WWR
- Selecting glazing type

PROBLEM STATEMENT

In this tutorial, you are going to use a 50 m \times 25 m fivezone model with a 5 m perimeter depth. You are going to use the following glass types for the simulations (Table 4.1).

Find out energy consumption for all cases for **SINGAPORE/PAYA LEBA**.

Light-to-solar gain (L/S) is the ratio between the VLT and SHGC. It provides a gauge of the relative efficiency of different glass or glazing types in transmitting daylight while blocking heat gains. The higher the number, the more the light transmitted without adding excessive amounts of heat.

SOLUTION

Step 1: Create a 50 m \times 25 m five-zone model with a 5 m perimeter depth.

PART I: With Dbl Green 6mm/6mm Air glass.

Step 2: Select the Openings tab and select Glazing type as Dbl Green 6mm/6mm Air. Set WWR to 0.00%.

syout Activity Construction Openings Lighting	ng HVAC Outputs CFD	
C, Glazing Template		
Template	Project glazing template	
External Windows	the second s	
() Glazing type	Dbl Green 6mm/6mm Air	
Layout	Preferred height 1.5m, 30% glazed	
Dimensions		
Туре	3-Preferred height	
Window to wall %	0.00	
Window height (m)	1.50	
Window spacing (m)	5.00	
Sill height (m)	0.80	

Table 4.	Table 4.1 Glass types and their properties	their properties				
PART	Glass	Properties	Light-to-solar gain ratio (L/S)	WWR	Daylight controls	Shade
Ι	Double glazing	Green 6mm/6mm Air, SHGC-0.49, VLT-0.66	1.35	0% to 90% in steps of 10%	With and without	None
II	Single glazing	Sgl Clr 6mm, SHGC-0.81 and VLT-0.88	1.09	0% to 90% in steps of 10%	With and without	None
Ш	ASHRAE 90.1 equivalent glass	U-6.81 W/m ² K, SHGC-0.25 and VLT 0.53	2.12	0% to 90% in steps of 10%	With and without	None and with a 0.5 m overhang on all windows

Glass types and their properties	
pes and th	
Glass ty _l	
ble 4.1	

Step 3: Simulate the model and record the results.

Step 4: Repeat the previous steps to set WWR (from 10% to 90% in steps of 10%) as given in the problem statement.

Record the results for all WWRs without lighting control (Table 4.2).

Step 5: Select the **Lighting** tab. In the **Lighting Control** section, select the **ON** check box.

New Building, Building 1, Block 1		
Layout Activity Construction Openings Lighting HVAC	Outputs CFD	
C, Lighting Template		*
© Template	Reference	
General Lighting		¥
🗹 On		
Normalised power density (W/m2-100 lux)	5.0000	
😭 Schedule	Office_OpenOff_Light	
Luminaire type	1-Suspended	-
Radiant fraction	0.420	
Visible fraction	0.180	
Convective fraction	0.400	
🔊 Lighting Control		¥
🗹 On		
Working plane height (m)	0.80	
Control type	1-Linear	*
Min output fraction	0.100	
Min input power fraction	0.100	

When you select the ON check box, you get the daylight sensor placed in all zones. You can see that the lighting energy consumption for the daylit perimeter zones will decrease.

Table 4.2Annual energy consumption with a double glazingwindow without daylight controls

Double glazing without daylight controls (Dbl Green 6mm/6mm Air)

WWR (%)	Room electricity (kWh)	Lighting (kWh)	Cooling (electricity) (kWh)	DHW (electricity) (kWh)	Annual consumption (electricity) (kWh)
0	51,114.49	73,871.52	188,313.20	4,625.02	317,924.23
10	51,114.49	73,871.52	194,815.30	4,625.02	324,426.33
20	51,114.49	73,871.52	201,498.70	4,625.02	331,109.73
30	51,114.49	73,871.52	207,691.50	4,625.02	337,302.53
40	51,114.49	73,871.52	213,531.40	4,625.02	343,142.43
50	51,114.49	73,871.52	219,081.10	4,625.02	348,692.13
60	51,114.49	73,871.52	224,293.80	4,625.02	353,904.83
70	51,114.49	73,871.52	229,142.60	4,625.02	358,753.63
80	51,114.49	73,871.52	233,851.40	4,625.02	363,462.43
90	51,114.49	73,871.52	238,187.40	4,625.02	367,798.43

Step 6: Simulate the model and record the results.

Record the results for all WWRs with lighting control (Table 4.3).

Step 7: Compare the results with and without daylight controls (Table 4.4).

Table 4.3 Annual energy consumption with a double glazingwindow with daylight controls

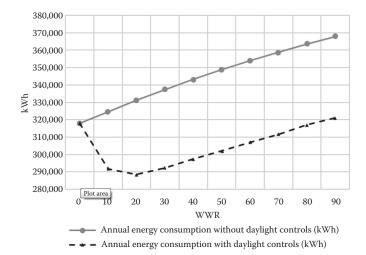
Double glazing with daylight controls (Dbl Green 6mm/6mm Air)

WWR (%)	Room electricity (kWh)	Lighting (kWh)	Cooling (electricity) (kWh)	DHW (electricity) (kWh)	Annual consumption (electricity) (kWh)
0	51,114.49	73,871.52	188,313.20	4,625.02	317,924.23
10	51,114.49	53,353.82	182,543.10	4,625.02	291,636.43
20	51,114.49	46,939.31	185,863.80	4,625.02	288,542.62
30	51,114.49	45,119.64	191,441.50	4,625.02	292,300.65
40	51,114.49	44,352.53	197,248.60	4,625.02	297,340.64
50	51,114.49	43,660.43	202,749.90	4,625.02	302,149.84
60	51,114.49	43,205.62	208,067.20	4,625.02	307,012.33
70	51,114.49	42,831.40	213,031.60	4,625.02	311,602.51
80	51,114.49	43,154.81	218,172.20	4,625.02	317,066.52
90	51,114.49	42,800.91	222,551.70	4,625.02	321,092.12

 Table 4.4
 Comparison of the total annual energy consumption

 for a double glazed window with and without daylight sensors

WWR (%)	Annual energy consumption without daylight controls (kWh)	Annual energy consumption with day light controls (kWh)
0	317,924.23	317,924.23
10	324,426.33	291,636.43
20	331,109.73	288,542.62
30	337,302.53	292,300.65
40	343,142.43	297,340.64
50	348,692.13	302,149.84
60	353,904.83	307,012.33
70	358,753.63	311,602.51
80	363,462.43	317,066.52
90	367,798.43	321,092.12



The results show that with double glazed glass, a building consumes the minimum energy at 20% WWR, when daylight controls are installed in the building in all its daylit perimeter spaces.

PART II: With Sgl Clr 6mm glass.

Step 8: Repeat the previous steps to get simulation results with **Sgl Clr 6mm** glass (Tables 4.5 through 4.7).

New Building, Building 1, Block 1		
Layout Activity Construction Openings Lighting HVAC	Outputs CFD	
C, Glazing Template	*	
Sector Se	Project glazing template	
Texternal Windows	*	
🕅 Glazing type	Sgl Clr 6mm	
Layout	Preferred height 1.5m, 30% glazed	
Dimensions	*	
Туре	3-Preferred height	
Window to wall %	0.00	_
Window height (m)	1.50 Window to wall 5	%
Window spacing (m)	5.00	
Sill height (m)	0.80	

Single glazing without daylight controls (Sgl Clr 6mn					
WWR (%)	Room electricity (kWh)	Lighting (kWh)	Cooling (electricity) (kWh)	DHW (electricity) (kWh)	Annual consumption (electricity) (kWh)
0	51,114.49	73,871.52	188,313.20	4,625.02	317,924.23
10	51,114.49	73,871.52	199,104.20	4,625.02	328,715.23
20	51,114.49	73,871.52	209,534.90	4,625.02	339,145.93
30	51,114.49	73,871.52	218,763.50	4,625.02	348,374.53
40	51,114.49	73,871.52	227,147.50	4,625.02	356,758.53
50	51,114.49	73,871.52	234,957.70	4,625.02	364,568.73
60	51,114.49	73,871.52	242,125.10	4,625.02	371,736.13
70	51,114.49	73,871.52	248,650.70	4,625.02	378,261.73
80	51,114.49	73,871.52	254,622.30	4,625.02	384,233.33
90	51,114.49	73,871.52	260,126.20	4,625.02	389,737.23

Table 4.5Annual energy consumption for a single glazedwindow without daylight controls

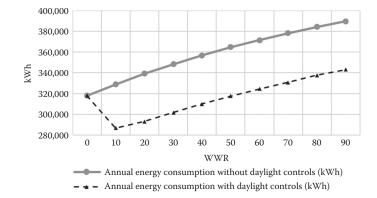
Table 4.6Annual energy consumption for a single glazedwindow with daylight controls

WWR (%)	Room electricity (kWh)	Lighting (kWh)	Cooling (electricity) (kWh)	DHW (electricity) (kWh)	Annual consumption (electricity) (kWh)
0	51,114.49	73,871.52	188,313.20	4,625.02	317,924.23
10	51,114.49	47,477.93	183,586.70	4,625.02	286,804.14
20	51,114.49	44,369.11	192,984.40	4,625.02	293,093.02
30	51,114.49	43,484.96	202,437.50	4,625.02	301,661.97
40	51,114.49	43,065.26	211,079.50	4,625.02	309,884.27
50	51,114.49	42,599.63	219,113.30	4,625.02	317,452.44
60	51,114.49	42,272.71	226,499.70	4,625.02	324,511.92
70	51,114.49	42,010.69	233,254.80	4,625.02	331,005.00
80	51,114.49	42,242.57	239,633.50	4,625.02	337,615.58
90	51,114.49	41,992.99	245,322.10	4,625.02	343,054.60

WWR (%)	Annual energy consumption without daylight controls (kWh)	Annual energy consumption with daylight controls (kWh)
0	317,924.23	317,924.23
10	328,715.23	286,804.14
20	339,145.93	293,093.02
30	348,374.53	301,661.97
40	356,758.53	309,884.27
50	364,568.73	317,452.44
60	371,736.13	324,511.92
70	378,261.73	331,005.00
80	384,233.33	337,615.58
90	389,737.23	343,054.60

 Table 4.7
 Comparison of the total annual energy consumption

 for a single glazed window with and without daylight sensors



The results show that with single glazed glass, a building consumes the minimum energy at 10% WWR when daylight controls are installed in the building in all its daylit perimeter spaces.

PART III A: With **ASHRAE 90.1-2007** equivalent glass (U-1.20 (6.81), SHGC-0.25 and VLT 53%).

Step 9: Now refer to the previous steps and get simulation results with ASHRAE 90.1 equivalent glass. Vertical glazing, 0%-40% of wall, U-1.20 (6.81) and SHGC-0.25 (Tables 4.8 and 4.9).

New Building, Building 1, Block 1			
Layout Activity Construction Openings Lighting HV	AC Outputs CFD		
🕵 Glazing Template	Ť		
Template	Project glazing template		
👕 External Windows	×		
Glazing type	Vertical glazing, 0%-40% of wall, U-1.20 (6.81),		
Layout	Preferred height 1.5m, 30% glazed		
Dimensions	*		
Туре	3-Preferred height		
Window to wall %	0.00		
Window height (m)	1.50		
Window spacing (m)	5.00		
Sill height (m)	0.80		

Table 4.8Annual energy consumption with ASHRAE 90.1equivalent glass without daylight controls

ASHRAE 90.1 Glass without daylight controls (vertical glazing, 0%-40% of wall, U-1.20 (6.81) and SHGC-0.25)

WWR (%)	Room electricity (kWh)	Lighting (kWh)	Cooling (electricity) (kWh)	DHW (electricity) (kWh)	Annual consumption (electricity) (kWh)
0	51,114.49	73,871.52	188,313.20	4,625.02	317,924.23
10	51,114.49	73,871.52	191,587.80	4,625.02	321,198.83
20	51,114.49	73,871.52	194,916.30	4,625.02	324,527.33
30	51,114.49	73,871.52	198,107.40	4,625.02	327,718.43
40	51,114.49	73,871.52	201,055.30	4,625.02	330,666.33
50	51,114.49	73,871.52	203,782.00	4,625.02	333,393.03
60	51,114.49	73,871.52	206,272.20	4,625.02	335,883.23
70	51,114.49	73,871.52	208,605.50	4,625.02	338,216.53
80	51,114.49	73,871.52	210,932.40	4,625.02	340,543.43
90	51,114.49	73,871.52	212,968.10	4,625.02	342,579.13

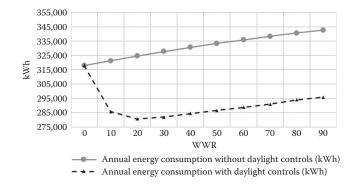
WWR (%)	Room electricity (kWh)	Lighting (kWh)	Cooling (electricity) (kWh)	DHW (electricity) (kWh)	Annual consumption (electricity) (kWh)
0	51,114.49	73,871.52	188,313.20	4,625.02	317,924.23
10	51,114.49	51,701.49	178,250.50	4,625.02	285,691.50
20	51,114.49	46,126.67	178,795.00	4,625.02	280,661.18
30	51,114.49	44,625.61	181,601.70	4,625.02	281,966.82
40	51,114.49	43,983.63	184,642.30	4,625.02	284,365.44
50	51,114.49	43,373.37	187,426.20	4,625.02	286,539.08
60	51,114.49	42,948.02	190,069.90	4,625.02	288,757.43
70	51,114.49	42,597.32	192,549.70	4,625.02	290,886.53
80	51,114.49	42,902.14	195,325.90	4,625.02	293,967.55
90	51,114.49	42,571.14	197,496.00	4,625.02	295,806.65

Table 4.9Annual energy consumption with ASHRAE 90.1equivalent glass with daylight controls

Step 10: Compare the results with and without daylight sensors (Table 4.10).

Table 4.10Comparison of simulation results of glass with andwithout daylight sensors

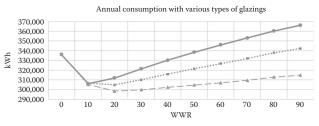
WWR (%)	Annual energy consumption without daylight controls (kWh)	Annual energy consumption with daylight controls (kWh)
0	317,924.23	317,924.23
10	321,198.83	285,691.50
20	324,527.33	280,661.18
30	327,718.43	281,966.82
40	330,666.33	284,365.44
50	333,393.03	286,539.08
60	335,883.23	288,757.43
70	338,216.53	290,886.53
80	340,543.43	293,967.55
90	342,579.13	295,806.65

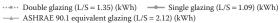


Step 11: Now compare the results for all simulations of double glazing glass, single glazing glass and ASHRAE 90.1 equivalent glass with lighting controls (Table 4.11).

Table 4.11	Comparison of the tota	l annua	energy	consumption
for all glass	types with daylight con	trols		

WWR (%)	Double glazing (L/S = 1.35) (kWh)	Single glazing (L/S = 1.09) (kWh)	ASHRAE 90.1 equivalent glazing (L/S = 2.12) (kWh)
0	336,004.18	336,004.18	336,004.18
10	306,612.44	306,036.66	305,364.20
20	304,903.64	311,950.44	298,535.13
30	310,044.69	321,242.29	299,836.25
40	315,943.50	330,149.92	302,380.69
50	321,484.33	338,323.96	304,731.91
60	326,813.57	345,953.19	307,113.99
70	331,942.46	353,023.54	309,480.51
80	337,800.03	360,149.95	312,833.83
90	342,264.91	366,045.43	314,854.56





PART III B: With **ASHRAE 90.1-2007** equivalent glass (U-1.20 [6.81], SHGC-0.25 and VLT 53%) with the shading of a 0.5 m overhang.

Step 12: Select the **Openings** tab, select the **Local shading** check box under the Shading section and select **0.5m Overhang** from the **Type** (Table 4.12).

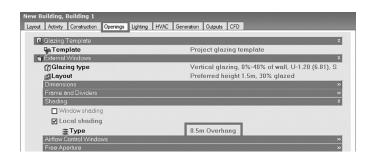


Table 4.12Annual energy consumption with ASHRAE 90.1equivalent glass, with fixed shade and daylight controls

Good glazing with daylight controls (vertical glazing, 0%–40% of wall, U-1.20 (6.81) and SHGC-0.25)

WWR (%)	Room electricity (kWh)	Lighting (kWh)	Cooling (electricity) (kWh)	DHW (electricity) (kWh)	Annual consumption (electricity) (kWh)
0	51,114.49	73,871.52	188,313.20	4,625.02	317,924.23
10	51,114.49	53,819.91	178,846.40	4,625.02	288,405.82
20	51,114.49	47,004.59	177,688.30	4,625.02	280,432.40
30	51,114.49	45,294.22	179,536.80	4,625.02	280,570.53
40	51,114.49	44,561.03	181,742.40	4,625.02	282,042.94
50	51,114.49	43,683.38	184,197.20	4,625.02	283,620.09
60	51,114.49	43,139.11	186,824.00	4,625.02	285,702.62
70	51,114.49	43,017.17	189,495.10	4,625.02	288,251.78
80	51,114.49	43,106.45	192,231.50	4,625.02	291,077.46
90	51,114.49	42,705.82	194,444.50	4,625.02	292,889.83

Compare the results for with and without shading controls for ASHRAE 90.1 equivalent glass (Table 4.13).

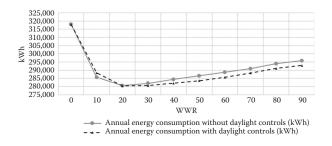


Table 4.13	Annual	energy consumption results for ASHRAE	90.1
equivalent g	glass with	and without shading	

WWR (%)	Annual energy consumption without daylight controls (kWh)	Annual energy consumption with daylight controls (kWh)
0	317,924.23	317,924.23
10	285,691.50	288,405.82
20	280,661.18	280,432.40
30	281,966.82	280,570.53
40	284,365.44	282,042.94
50	286,539.08	283,620.09
60	288,757.43	285,702.62
70	290,886.53	288,251.78
80	293,967.55	291,077.46
90	295,806.65	292,889.83

For warm/hot climates:

- If a building is without daylight controls, then the energy consumption increases with the increase in WWR. With the increase in WWR, heat gains through glass increase in the building and due to the absence of artificial lights dimming, the energy consumption increases.
- 2. If a building is having daylight sensors, then artificial lights can be dimmed when sufficient daylight is available. With the increase in WWR, more daylight is available to the perimeter spaces. Daylight sensors help in reducing the artificial lighting load and offset the heat gains through the glass. However, after a point when the perimeter spaces are daylit, an increase in WWR does not save the artificial lighting energy as the lamps are fully dimmed. After this point with the increase in WWR, the heat ingress increases, thereby increasing the overall energy consumption.
- 3. Glass with a higher visible light to solar gain (L/S) needs to be selected to get the maximum benefit from daylight.

Exercise 4.1

Repeat the above tutorial for WIEN/HOHE VARTE, Austria.

TUTORIAL 4.2 Evaluating the impact of overhangs and fins

GOAL

To evaluate the impact of window overhangs and fins on the energy performance.

WHAT ARE YOU GOING TO LEARN?

· Modelling overhangs and fins

PROBLEM STATEMENT

In this tutorial, you are going to use a $30 \text{ m} \times 30 \text{ m}$ model with a 5 m perimeter depth. You need to select the **split no fresh air** HVAC system to the simulation model.

You need to simulate the model with the following options:

- 1. No shades
- 2. Overhangs
- 3. Vertical fins

Use location **DUBAI INTERNATIONAL**, United Arab Emirates.

SOLUTION

Step 1: Open a new project and create a $30 \text{ m} \times 30 \text{ m}$ building with a 5 m perimeter depth.

Step 2: Select the **Openings** tab. Select the **Single glazing, clear, no shading** template. Select **Sgl Grey 6mm** in **Glazing type**.

New Building, Building 1	
Layout Activity Construction Openings Lighting HVAC	Generation Outputs CFD
C. Glazing Template	×
Template	Single glazing, clear, no shading
External Windows	single glazing, clear, no shaanig
Glazing type	Sgl Grey 6mm
Layout	Preferred height 1.5m, 30% glazed
Dimensions	¥
Туре	3-Preferred height
Window to wall %	30.00
Window height (m)	1.50
Window spacing (m)	5.00
Sill height (m)	0.80
Reveal	»
Frame and Dividers	»
Shading Airflow Control Windows	»
Free Aperture	» »
Internal Windows	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 Sloped Roof Windows/Skylights 	»
Doors	*
External	*
Auto generate	
Internal	¥
Auto generate	
Operation	»
Vents	»

Step 3: Select the **HVAC** tab. Select the **Split no fresh air** template. Clear the **Heated** check box under the **Heating** section and clear the **On** check box under DHW. Select the check box under **Cooling system** and enter **3.0** as **CoP**.

When you use the Split no fresh air template, you can get the cooling energy consumption for all zones separately.

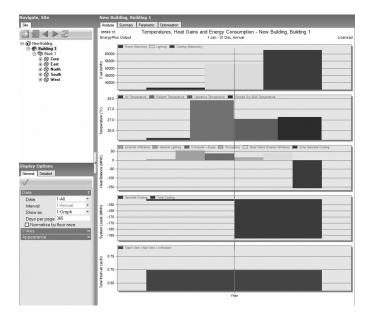
BUILDING ENERGY SIMULATION

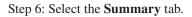
New Building, Building 1	
Layout Activity Construction Openings Lighting HVAC	Generation Outputs CFD
R, HVAC Template	¥
Template	Split no fresh air
Mechanical Ventilation	×
🗖 On	
Auxiliary Energy	×
Pump etc energy (W/m2)	0.0000
😭 Schedule	Office_OpenOff_Occ
N Heating	*
Heated	
-X- Cooling	×
Cooled	
Cooling system	Default
Fuel	1-Electricity from grid
Cooling system seasonal CoP	3.0
Supply Air Condition	»
Operation	×
A Schedule	Office_OpenOff_Cool
Humidity Control	» *
	Ŷ
Natural Ventilation	*
	Ŷ
Earth Tube Air Temperature Distribution	» »
Cost	* *
- Cost	<i>"</i>

Step 4: Select the **Simulation** tab and select the **Output** tab, expand **Summary Tables** and select the **All Summary** check box under the **Summary Annual Reports** section.

Calculation Options Data	
General Options Output Simulation Manager	
Output Data	×
Building and block output of zone data	
Include unoccupied zones in block and building	g totals and averages
Allow custom outputs	
Graphable Outputs	*
Energy	»
Comfort and Environmental	»
Detailed Daylight Outputs	»
Summary Tables	1-604/b
Summary output units (SI) Summary Annual Reports	1-kWh
All Summary	•
LEED Summary	
Annual Building Utility Performance Summary	(ABUPS)
Demand End Use Components Summary	((1001.0)
Sensible heat gain summary	
Input Verification and Results Summary	
Source Energy End Use Components Summ	arv
Adaptive Comfort Summary	
Zone Component Load Summary	
Standard 62.1 Summary	
Energy Meters	
Climatic Data Summary	
Equipment Summary	

Step 5: Perform annual simulation and view the data in graphical format.





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		-009/00/462, H4D-2010.03.19 00.10		Table of concents
abular Output Repo	t in Format: HTML			
uiding: Building				
invironment: NEW B	UILDING ** ABU DHA	BI - ARE IWEC Data WM0#=412170		
insulation Transforme	: 2016-03-19 00:16:	12		
inaacon rincatanp	. 2010 05 15 00.10.			
or: Entire Facility Imestamp: 2016-03				
alues gathered ov		Energy Per Total Building Area [kWh/m2]	Energy Per Conditioned Building Area [kWh/m2]	
		Energy Per Total Building Area [kWh/m2] 328.22	Energy Per Conditioned Building Area [kWh/m2] 328.22	
ite and Source En	Total Energy [kWh]			
ite and Source En	Total Energy [kWh] 277076.75 277076.75	328.22	328.22	

Step 7: Scroll down to read Annual and Peak Values – Other.

Annual and Peak Values - Other					
	Annual Value [GJ]	Minimum Value [W]	Timestamp of Minimum	Maximum Value [W]	Timestamp o Maximun
EnergyTransfer:Facility	564.16	0.00	01-JAN-00:30	82919.54	29-JUL-15:0
EnergyTransfer:Building	564.16	0.00	01-JAN-00:30	82919.54	29-JUL-15:0
EnergyTransfer:Zone:BLOCK1:CORE	185.83	0.00	01-JAN-00:30	26132.77	29-JUL-15:0
Heating:EnergyTransfer	0.00	0.00	01-JAN-00:30	43.82	25-SEP-05:30
Heating:EnergyTransfer:Zone:BLOCK1:CORE	0.00	0.00	01-JAN-00:30	18.33	25-SEP-05:30
Cooling:EnergyTransfer	564.16	0.00	01-JAN-00:30	82919.54	29-JUL-15:00
Cooling:EnergyTransfer:Zone:BLOCK1:CORE	185.83	0.00	01-JAN-00:30	26132.77	29-JUL-15:0
EnergyTransfer:Zone:BLOCK1:EAST	109.18	0.00	01-JAN-00:30	18522.09	29-JUL-10:0
Heating:EnergyTransfer:Zone:BLOCK1:EAST	0.00	0.00	01-JAN-00:30	8.31	25-SEP-05:3
Cooling:EnergyTransfer:Zone:BLOCK1:EAST	109.18	0.00	01-JAN-00:30	18522.09	29-JUL-10:0
EnergyTransfer:Zone:BLOCK1:WEST	96.75	0.00	01-JAN-00:30	17622.79	29-JUL-16:0
Heating:EnergyTransfer:Zone:BLOCK1:WEST	0.00	0.00	01-JAN-00:30	7.93	12-AUG-05:3
Cooling:EnergyTransfer:Zone:BLOCK1:WEST	96.75	0.00	01-JAN-00:30	17622.79	29-JUL-16:0
EnergyTransfer:Zone:BLOCK1:NORTH	73.95	0.00	01-JAN-00:30	12331.52	29-JUL-14:3
Heating:EnergyTransfer:Zone:BLOCK1:NORTH	0.00	0.00	01-JAN-00:30	5.51	25-SEP-05:3
Cooling:EnergyTransfer:Zone:BLOCK1:NORTH	73.95	0.00	01-JAN-00:30	12331.52	29-JUL-14:3
EnergyTransfer:Zone:BLOCK1:SOUTH	98.46	0.00	01-JAN-00:30	13531.62	14-0CT-13:3
Heating:EnergyTransfer:Zone:BLOCK1:SOUTH	0.00	0.00	01-JAN-00:30	5.86	25-SEP-05:3
Cooling:EnergyTransfer:Zone:BLOCK1:SOUTH	98.46	0.00	01-JAN-00:30	13531.62	14-0CT-13:3
DistrictHeating:Facility	0.00	0.00	01-JAN-00:30	0.00	01-JAN-00:3
DistrictHeating:HVAC	0.00	0.00	01-JAN-00:30	0.00	01-JAN-00:3
Heating:DistrictHeating	0.00	0.00	01-JAN-00:30	0.00	01-JAN-00:3

Step 8: Record the annual value for the energy transfer zone (GJ) for all perimeter zones (Table 4.14).

Save the simulation model for the next step.

Now you are going to model window overhangs.

Step 9: Select the **Openings** tab.

Step 10: Click the Shading section. Shading options appear.

🖲 Glazing Template		
Template	Project glazing template	
Texternal Windows		
🕼 Glazing type	Project external glazing	
Layout	Preferred height 1.5m, 30% glazed	
Dimensions		
Туре	3-Preferred height	
Window to wall %	30.00	
Window height (m)	1.50	
Window spacing (m)	5.00	
Sill height (m)	0.80	
Reveal		
Frame and Dividers		
Shading		

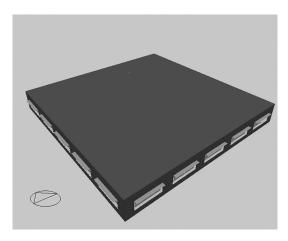
Table 4.14Annual value for the energy transfer for each zonewith no shading

Zone	Annual value for energy transfer (GJ)
North	73.95
East	109.18
West	96.75
South	98.46

Step 11: Select the **Local shading** check box. It displays shading type.



Step 12: Select the **Visualize** tab. It displays the rendering of the building. Make sure that all windows are modelled with an overhang.



Step 13: Repeat the previous steps to get simulation results (Table 4.15).

Save the simulation model with the name **DB_overhang**.

In the next steps you are going to model vertical fins.

Step 14: Open the saved simulation model.

Step 15: Select **Overhang + sidefins (0.5m projection)** and make a copy of the current selection and edit for changes.

Zone	Annual value (GJ)
North	72.30
East	100.23
West	88.33
South	87.45

 Table 4.15
 Annual value for energy transfer with overhangs

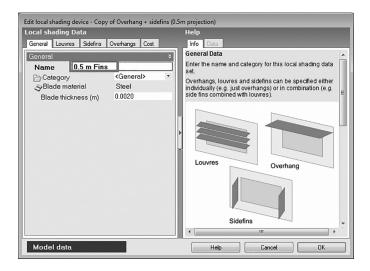
BUILDING ENERGY SIMULATION

Shading		¥
□ Window shading		
Local shading		_
Туре	0.5m Overhang	
Airflow Control Windows		

Step 16: Enter **0.5 m Fins** as the name.

Select the local shading device		
General> Louvre, 0.5m projection + 0.5m overhangs and sidefins Louvre, 1.0m projection + 1m overhangs and sidefins Overhang + sidefins (0.5m projection) vernang + sidefins (0.5m projection) Overhangs 1.0m Overhang 1.5m Overhang		
No shading	Cancel OK	

Step 17: Select the **Overhangs** tab.

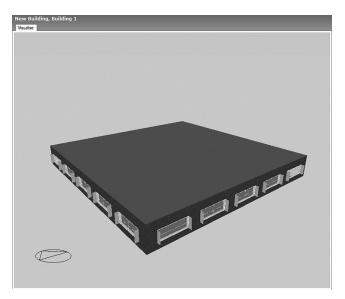


Step 18: Clear the **Overhangs** check box.

Edit local shading device - Overhang + sidefins (0.5m projection)	
Local shading Data	Help
General Louvres Sidefins Overhangs Cost	Info Data
Overhang Geometry ¥	Overhangs ^
☑ Overhangs	Enter details on the overhangs if fitted.
Vertical offset from window top 0.000	Overhang Projection
Projection (m) 0.500	overnang - Hojovion
Horizontel window overlap (m) 0.000	Vertical offset from
	Side Elevation
🛱 Locked Library data	Help Cancel OK

Edit local shading device - Copy of Overhang + sidefins (0.5	n projection)	
Local shading Data	Help	
General Louvres Sidefins Overhangs Cost	Info Data	
Overhang Geometry ×	Overhangs	*
Overhangs	Enter details on the overhangs if fitted.	
	Overhang Projection	
		=
	Vertical offset from	
	top of window	
	1.00	indow
	Side Elevation	
		-
	<	•
Model data	Help Cancel	OK

Step 19: **Visualize** the model. Make sure that all windows have side fins.



Step 20: Perform annual simulation and record the results (Table 4.16).

Compare the results for all the cases (Table 4.17).

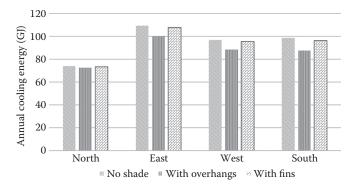
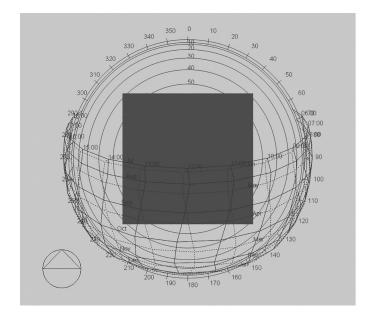


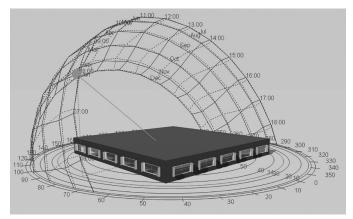
 Table 4.16
 Annual value of energy transfer for vertical fins

Annual value (GJ)
73.16
107.74
95.36
96.06

Annual cooling energy (GJ)					
Zone	No shade	With overhangs	With fins		
North	73.95	72.30	73.16		
East	109.18	100.23	107.74		
West	96.75	88.33	95.36		
South	98.46	87.45	96.06		

Table 4.17Comparison of the annual cooling energy for alltypes of shades





The following are the steps to get the sunpath diagram:

Step 1: Select the Visualize tab.

Step 2: Under the **Display options**, select the **Show sunpath diagram** check box.

Step 3: Click the Apply changes icon.

Exercise 4.2

Repeat the above tutorial for both overhangs and fins to observe the combined effect. Compare the energy consumption for all the perimeter zones.

TUTORIAL 4.3 Evaluating the impact of internal operable shades

GOAL

To evaluate the impact of window internal operable shades on the energy consumption.

WHAT ARE YOU GOING TO LEARN?

• Modelling operable shades

PROBLEM STATEMENT

In this tutorial, you are going to use the model created in Tutorial 4.2 (a 30 m \times 30 m model with a 5 m perimeter depth). Find the energy consumption and solar gain for all perimeter zones.

You need to simulate the model with the following options:

- 1. Overhang with a 0.5 m depth
- 2. Internal operable shades with solar control

Use the New Delhi/Palam, India weather location.

SOLUTION

Step 1: Open the model created in Tutorial 4.2 with a **0.5 m** overhang. Select the **Openings** tab and change window height to 1.00 m. Select the **Simulation** tab. The **Edit Calculation Options** screen appears.

CHAPTER FOUR OPENINGS AND SHADING

Site, Building 1	
Layout Activity Construction Openings Lighting HVAC	Generation Outputs CFD
9 AL - T	*
C. Glazing Template	
G Template	Single glazing, clear, no shading
 External Windows 	*
@Glazing type	Sgl Grey 6mm
DLayout .	Preferred height 1.5m, 30% glazed
Dimensions	*
Type	3-Preferred height
Window to wall %	30.00
Window height (m)	1.00
Window spacing (m)	5.00
Sill height (m)	0.80
Reveal	»
Frame and Dividers	»
Shading	*
Window shading	
☑ Local shading	
≣Type	0.5m Overhang
Airflow Control Windows	»
Free Aperture	»
📺 Internal Windows	»
Sloped Roof Windows/Skylights	»
Doors	»
Vents	»

Step 2: Simulate the model and select the **Sub-hourly** check box. Click **OK**. The results are displayed.

Edit Calculation Options						
Calculation Options Data				Help		
General Options Output Simul	ation Manager			Info Data		
Calculation Description		×		Simulation Options		
				These options control the simulation and the output produced.		
Simulation Period × From ×				Simulation Period		
Start day	1	Ţ		Select the start and end days for the simulation, or select a typical period:		
Start month	Jan	-	П	<u>Annual simulation</u>		
То		×		Summer design week		
End day	31	-		Summer typical week		
End month	Dec	-	H	<u>All summer</u>		
Output Intervals for Reporting				<u>Winter design week</u>		
Monthly and annual				Winter typical week		
🗹 Daily				<u>All winter</u>		
Hourly						
Sub-hourly				Interval		
				Monthly and annual output is always generated and daily, hourly and		
				sub-hourly data can selected by		
Don't show this dialog next ti	ne 📃	Help		Cancel OK		

Step 3: Select **Internal gains** from the **Data** drop-down list. Click **East** in the navigation tree. It shows internal gains for the east zone.

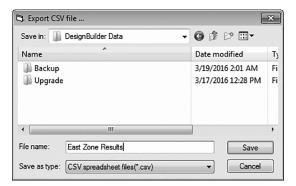
Site, Building 1, Block 1, East								
Analysis	Summary	Parametr	ric Optimisa	tion				
Date/Time	0	ieneral Li	Computer	Occupanc	Solar Gains Exterior Windows (kW)	Zone Sens	Zone Sens	
1/1/2002	12:30 0	1	7.167769	0	0	0	0	_
1/1/2002	1:00: 0		7.167769	0	0	0	0	
1/1/2002	1:30: 0		7.167769	0	0	0	0	
1/1/2002	2:00: 0		7.167769	0	0	0	0	
1/1/2002	2:30: 0		7.167769	0	0	0	0	
1/1/2002	3:00: 0		7.167769	0	0	0	0	
1/1/2002 3	3:30: 0		7.167769	0	0	0	0	
1/1/2002 -	4:00: 0		7.167769	0	0	0	0	
1/1/2002 -	4:30: 0		7.167769	0	0	0	0	
1/1/2002 9	5:00: 0		7.167769	0	0	0	0	
1/1/2002	5:30: 0		7.167769	0	0	4.726994	0	
1/1/2002	6:00: 0		7.167769	0	0	3.953504	0	
1/1/2002	6:30: 0		7.167769	0	0	3.97345	0	
1/1/2002	7:00: 0		7.167769	0	0	3.490388	0	
1/1/2002	7:30: 2	.258014	1.328841	0.2413183	0	0.9860969	0	
1/1/20021	8:00: 2	258014	1.328841	0.2413161	0.4062463	0.4909225	0	
1/1/20021	8:30: 2	258014	1.328841	0.482632	0.7145187	0	-0.19094	
1/1/2002 9	9:00: 2	258014	1.328841	0.482632	3.240368	0	-0.79035	
1/1/2002 9	9:30: 2	258014	1.328841	0.9362818	4.373629	0	-1.490301	
1/1/2002	10:00 2	258014	1.328841	0.89148	3.615113	0	-1.455245	
1/1/2002	10:30 2	258014	1.328841	0.8581443	2.657491	0	-1.756104	
1/1/2002			1.328841			0	-1.905412	
1/1/2002			1.328841	0.8580161	0.9179888	0	-1.96813	
1/1/2002	12:00 2	258014	1.328841	0.8580161	0.934961	0	-2.168585	
1/1/2002	12:30 2	258014	1.328841	0.643512	0.9972816	0	-2.207253	
1/1/2002	1:00: 2	258014	1.328841	0.643512	1.037724	0	-2.407031	
	JAnatysis Date/Time Diff/2002 1/1/2003 1/1/2004	Ange Distance Data/Tame C Data/Tame Data/Tame Data/Tame	Porter Energy Permet Dar/Toria Commutili Dar/Color 12:30 0 Dar/Color 2:30 0 D/R/Color 2:30 2 D/R/Color 2:30 0 D/R/Color 2:30 2 D/R/Color 2:30 2<	Portpl Summy Peamler: Optimizer Dard Taw Consult LL Consult LL Consult LL Consult LL Dard Taw Consult LL Consult LL Consult LL Consult LL Consult LL D1/2002 13:0 0 7157763 T167763 T167763 D1/2002 13:0 0 7157763 T167763 T167763 D1/2002 23:0 0 7157763 T167763 T167763 D1/2002 23:0 0 7157763 T167763 T167763 D1/2002 23:0 0 7157763 T167763 T167763 D1/2002 50:0 0 T157763 T167763 T167763 D1/2002 50:0 0 T167763 T167763 T167763 D1/2002 50:0 258014 126841 T167763 T167763 D1/2002 50:0 258014 126841 T167763 T167763 D1/2002 50:0 258014 126841 T17000 2000 258014 126841 D1/2002 10:0 258014 126841 T07000 10:0 <td>Particle Samera Parametric Consumera Dir/2002 0.00 2187780 Occasion: Dir/2002 0.00 7167780 Occasion: Dir/2002 0.00 0.7167780 Occasion: Dir/2002 0.00 2.556141 3.28444 0.241310 Dir/2002 0.00 2.556141 3.28444 0.241310 Dir/2002 0.00 2.</td> <td>Inverse Desense District Cocast. Cocast. Cocast. District Cocast. Cocast. Cocast. Cocast. District Cocast. Cocast. Cocast. Cocast. Cocast. District District Cocast. Cocast.</td> <td>Partner Sensor Parametric Concasor Casta Gan Estato Windows (bl 72 20) Concasor Conc</td> <td>Packet Same / Packet Operation Dist/Ten Oncore: Safe Care Oncore: Safe Care Oncore: Oncore: Safe Care Oncore: Oncore:</td>	Particle Samera Parametric Consumera Dir/2002 0.00 2187780 Occasion: Dir/2002 0.00 7167780 Occasion: Dir/2002 0.00 0.7167780 Occasion: Dir/2002 0.00 2.556141 3.28444 0.241310 Dir/2002 0.00 2.556141 3.28444 0.241310 Dir/2002 0.00 2.	Inverse Desense District Cocast. Cocast. Cocast. District Cocast. Cocast. Cocast. Cocast. District Cocast. Cocast. Cocast. Cocast. Cocast. District District Cocast. Cocast.	Partner Sensor Parametric Concasor Casta Gan Estato Windows (bl 72 20) Concasor Conc	Packet Same / Packet Operation Dist/Ten Oncore: Safe Care Oncore: Safe Care Oncore: Oncore: Safe Care Oncore: Oncore:

Step 4: Click the **Export data** button. The **Export Results Spreadsheet** screen appears.

Step 5: Select **File** from the **Export to** the drop-down list and **CSV spreadsheet** from the **Format** drop-down list. Click **OK**.

🔁 Export Results Spreadsheet	×
Export Data	
Output	
Export to: 1-File Format: CSV spreadsheet	
Help Cancel OK	

Step 6: Name the file as **East Zone Results** and save this for the comparison of results.



Similarly, repeat the previous step and save the results files for all the perimeter zones.

The next steps show how to model internal shades.

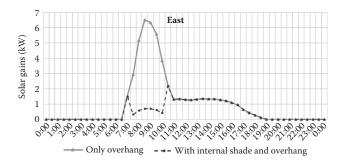
Step 7: Select the **Openings** tab. Select the **Window shading** check box under the **Shading** section. It displays shading type.

Step 8: Select High reflectance – low transmittance shade from the Type. Select 4-Solar from the Control type drop-down list. Set 250 as solar setpoint (W/m²).

t Activity Construction Openings Lighting H	IVAC Generation Outputs CFD
Glazing Template	*
Template	Single glazing, clear, no shading
External Windows	*
@Glazing type	Sgl Grey 6mm
DLayout .	Preferred height 1.5m, 30% glazed
Dimensions	*
Туре	3-Preferred height
Window to wall %	30.00
Window height (m)	1.00
Window spacing (m)	5.00
Sill height (m)	0.80
Reveal	»
Frame and Dividers	»
Shading	*
Window shading	
≣Туре	High reflectance - low transmittance shade
Position	1-Inside ·
Control type	4-Solar
Solar setpoint (W/m2)	250
Operation	¥
🏥 Operation schedule	Office_OpenOff_Occ
✓ Local shading	
≣Туре	0.5m Overhang
Airflow Control Windows	در در

Step 9: Simulate the model and record the results for all four zones.

Compare the results for two cases in each orientation: only overhang and overhang with internal shade for solar gains (kW) for 4 April.

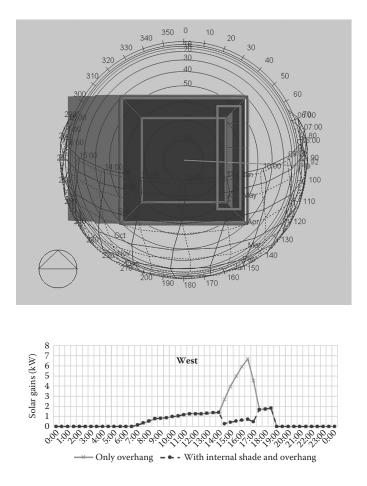


Solar control type operates the indoor shading devices based on the amount of radiation given in W/m^2 . In this example, the solar setpoint considered is 250 W/m^2 ; hence, whenever the solar radiation on the window is above this setpoint, the window shading will be down to reduce the incoming heat through radiation.

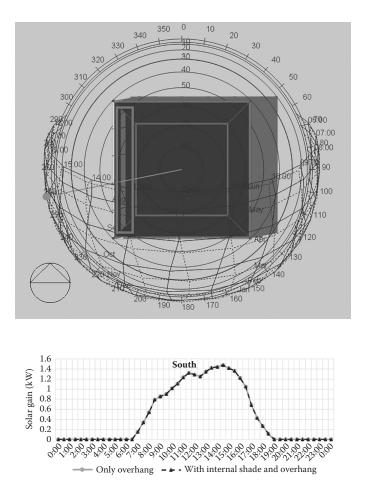
Indoor operable shades have other control types such as schedules and illuminance levels.

The previous graph shows the profile of solar gains through the window on the east façade with overhang and overhang + internal shades for a day (4 April); you can observe the reduction in solar gains due to internal shades between 7 AM and 10 AM.

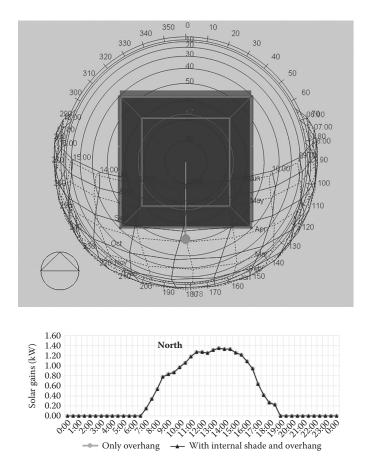
The following sunpath diagram shows direct radiation coming from the east window at 7 AM. Use of the internal shade can cut the direct solar radiation.



You can observe from the graph plotted above that the internal shade is effective on the west window from 14:00 to 19:00 on 4 April. This can also be seen from the following sunpath diagram that when there are no internal shades, west facing windows get direct solar radiation at 16:00 h.

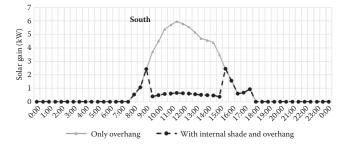


You can observe from the graph above that internal shades are not required on the south window on 4 April for this building. This can also be seen from the following sunpath diagram that the south zone is not getting any direct glare with an overhang of 0.5 m. This is due to the fact that the altitude of the sun in daytime, except for sunrise and sunset hours, is high enough on 4 April to not cause glare through windows.

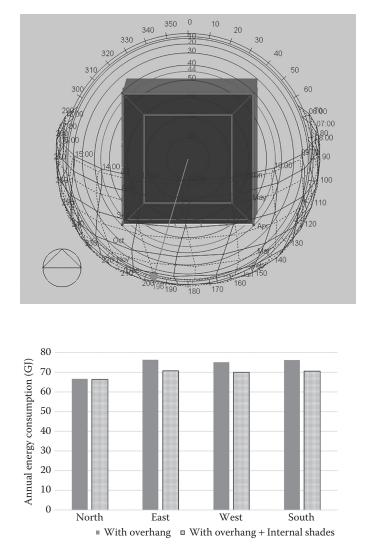


You can observe from the graph above that the internal shade is not required on the north façade on 4 April. This can also be seen from the sunpath diagram that the window in the north direction is shaded on 4 April.

Now plot the solar gains from the south window façade on 6 February when the sun is at a lower altitude.



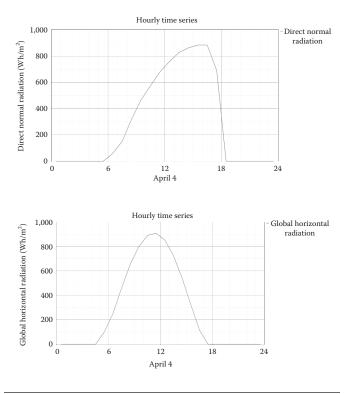
You can observe that with the internal shades there is a reduction in solar gains from the south window between 12:00 and 16:00 h.



Annual energy consumption with and without overhang in all directions

It is observed from the graph above that internal shades are more effective for the east, west and south zones for the New Delhi climate.

The following two graphs give the direct normal radiation and global horizontal radiation on 4th April. You can see that the solar radiation curve is smooth, implying that the sky is clear.



Exercise 4.3

Repeat the above tutorial for operable shade controlled **Outdoor air temp + Solar on window**. You can consider the outdoor temperature setpoint as 35°C for the **New Delhi/Palam**, **India** weather location.



Lighting and Controls

As daylight varies throughout the day, it cannot provide targeted illuminance levels the whole day. Sensors can be used to measure the deficit in the illuminance levels and can control the artificial lighting to provide the balance lumens. The operating level of artificial lights in daylit areas can be varied to achieve energy savings. Energy simulation tools are capable of handling this phenomenon. This is explained through two tutorials in this chapter.

TUTORIAL 5.1 Evaluating the impact of daylighting-based controls

GOAL

To evaluate the effect of daylighting-based controls on the energy consumption.

WHAT ARE YOU GOING TO LEARN?

· Modelling daylight controls

PROBLEM STATEMENT

In this tutorial, you are going to use a 50 m \times 25 m model with a 5 m perimeter depth.

You are going to evaluate the following lighting controls:

- a. No lighting control
- b. Linear/off

Use the WIEN/HOHE WARTE, Austria weather location.

SOLUTION

Step 1: Open a new project and create a 50 m \times 25 m building with a 5 m perimeter depth.

Step 2: Select the **Openings** tab and select **Dbl Grey 6mm/6mm Air** as the **Glazing type** from the drop-down list.

ite, Building 1	
Layout Activity Construction Openings Lighting	g HVAC Generation Outputs CFD
Clasing Townlate	× 🔺
C Glazing Template	
Template	Project glazing template
🝵 External Windows	*
🕜 Glazing type	Dbl Grey 6mm/6mm Air
Layout	Preferred height 1.5m, 30% glazed
Dimensions	×
Туре	3-Preferred height
Window to wall %	30.00
Window height (m)	1.50
Window spacing (m)	5.00
Sill height (m)	0.80

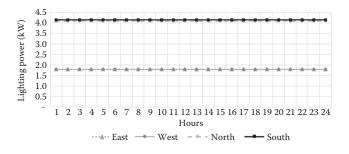
Step 3: Select the Activity tab. Select the 24×7 Generic Office Area template from the Miscellaneous 24hr activities folder.



Step 4: Select the **Lighting** tab. Make sure to clear the **On** check box under **Lighting Control**.

ite, Building 1 Layout Activity Construction Openings Lighting HVAC	Generation Outputs CFD		
Layout Activity Construction Openings Lighting HVAC	Generation Outputs CPD		
C Lighting Template			
© Template	Reference		
land General Lighting			
🗹 On			
Normalised power density (W/m2-100 lux)	5.0000		
fa Schedule	Ware_24x7CellOff_Light		
Luminaire type	1-Suspended		
Radiant fraction	0.420		
Visible fraction	0.180		
Convective fraction 0.400			
D Lighting Control			
🗖 On			
Task and Display Lighting			
🗖 On			

Step 5: Perform hourly simulation and record the results. For getting the results of each zone, go to the Navigation Tree on the left, select the zone and select **Internal gains** from the Data drop-down list and **Hourly** from the **Interval** drop-down list.



Step 6: Save the model using the **'Save as'** option. In the next steps, you are going to install daylight controls.

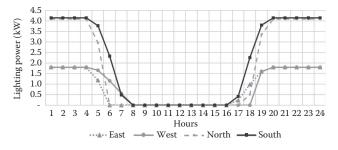
Step 7: Select the Lighting tab.

Step 8: Select the **On** check box under the **Lighting Control** section. Select **Linear** from the **Control type** drop-down list.

yout Activity Construction Openings Lighting HVAC	Outputs CFD	
C. Lighting Template		
© Template	Reference	
Seneral Lighting		
🗹 On		
Normalised power density (W/m2-100 lux)	5.0000	
A Schedule	Ware_24x7CellOff_Light	
Luminaire type	1-Suspended	
Radiant fraction	0.420	
Visible fraction	0.180	
Convective fraction	0.400	
DILighting Control		
🗹 On		
Working plane height (m)	0.80	
Cq Working plane height (m)	1-Linear	
Min output fraction	0.100	
Min input power fraction	0.100	

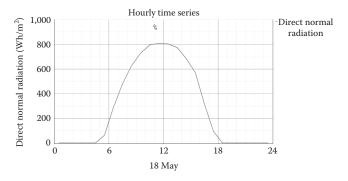
Based on the control type, lighting controls dim or turn off the internal lighting when the assigned illuminance level is met. This reduces the lighting energy consumption as well as the internal heat gain due to the artificial lighting. This reduction in heat gain decreases the cooling load and hence the cooling energy consumption. Step 9: Select the **Hourly Simulation** tab and record the results. For getting the results of each zone, go to the Navigation Tree on the left, select the zone and select **Internal gains** from the Data drop-down list and **Hourly** from the **Interval** drop-down list.

Step 10: Compare the hourly comparison of the lighting energy consumption for all options for 18 May. You can use a spreadsheet program to plot the comparative graphs.



From the above graph, it is clear that with the installation of controls, the lighting power consumption has reduced with the the lighting being automatically switched off between 06:00 and 18:00 h in different zones based on the daylight availability.

You can also get the solar radiation profile for 18 May by selecting **Site Data** from the **Data** drop-down list. Export the Direct Normal Solar and plot using a spreadsheet program.



The date of 18 May is selected for the simulation. The solar radiation curve is smooth with no perturbations due to clouds. Hence, it has been selected for the tutorial.

Exercise 5.1

Repeat the above tutorial and compare the energy consumption for stepped lighting controls.

TUTORIAL 5.2 Evaluating the impact of daylight sensor placement

GOAL

To evaluate the impact of daylight sensor positioning on the energy consumption.

WHAT ARE YOU GOING TO LEARN?

• Defining daylight sensors positioning

PROBLEM STATEMENT

In this tutorial, you are going to use a $10 \text{ m} \times 10 \text{ m}$ singlezone model with one window only on the south façade. Window area is 40% of gross south facade area. Find out the change in internal lighting gains in the zone with the use of a daylight sensor with linear/off.

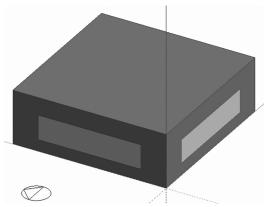
Place daylight sensor(s) at the following locations:

- 1. 2 m from the window
- 2. 8 m from the window
- 3. At 2 and 8 m from the window

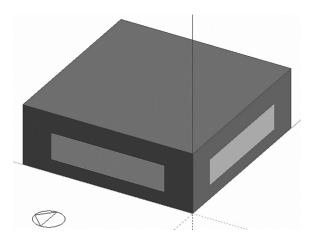
Use the New Delhi/Palam, India weather location.

SOLUTION

Step 1: Open a new project and create a $10 \text{ m} \times 10 \text{ m}$ single-zone model. Press the **ESC** button to get out from the **Edit mode**.



Step 2: Click on the west window; it highlights the window.

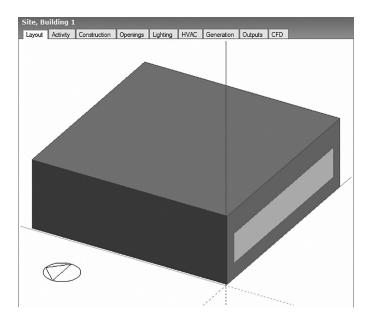


Step 3: Click **Delete selected object(s) (Del)**. Then click **Yes** on the message box. The window disappears. Similarly, you can delete windows on the north and east façade with the help of **Dynamic orbit**.





CHAPTER FIVE LIGHTING AND CONTROLS



Step 4: Select the **Openings** tab and select **Dbl Grey 6mm/6mm Air** from the glazing type. Set **Window to wall** % as **40.00**.

Site, Building 1		
Layout Activity Construction Openings Lighting	HVAC Generation Outputs CFD	
C, Glazing Template	*	
Template 🖓	Project glazing template	
🝵 External Windows	*	
Glazing type	Dbl Grey 6mm/6mm Air	
Layout	Preferred height 1.5m, 30% glazed	
Dimensions	*	
Туре	3-Preferred height	
Window to wall %	40.00	
Window height (m)	1.50	
Window spacing (m)	5.00	
Sill height (m)	0.80	

Step 5: Select the **Activity** tab. Select the **24×7 Generic Office Area** template from the **Miscellaneous 24hr activities** branch.

🕼 Activity Template		* 🔺
A Template	Generic Office Area	
Sector	B1 Offices and Workshop businesses	
Zone multiplier	1	

BUILDING ENERGY SIMULATION

Select the activity template	
e 🗁 Community/Day Centre	
Crown and County Courts	
Education (Non-residential)	
Education (Residential)	
Emergency services	
General Assembly/Leisure/Night Clubs/Theatres	
🖻 🗁 General Industrial / Special Industrial	1
B- C Hospitals/Care Homes	
B+ C→ Hotels	
P D Libraries/Museums/Galleries	
E A Miscellaneous 24hr activities	
9 24x7 Generic Office Area - Areas to perform 24 x7 hrs office work including offices and meeting rooms. It can include internal corridors providing ac	
 - 2 zak reception van alea olien containing a reception desk and reception stati with mansen occupancy. It also includes patient wating area. 	1
Heavy Plant Room - For heavy plant rooms with 24hr low-medium internal gains from equipment and transient occupancy. Server Hoom - For areas such as computer server spaces with 24hr low-medium internal gains from equipment and transient occupancy. For an area	
Contract A Markshop businesses	
The Car Dark Area docionated for matrice a new (analogical as underground)	
The Sort Cancel OK	

Step 6: Select the Lighting tab. Set the Normalised power density (W/m²-100 lux) to 3.

, Building 1. out Activity Construction Openings Lighting HVAC Gen	eration Outputs CED	
🕵 Lighting Template		¥
© Template	Reference	
Seneral Lighting		¥
🗹 On		
Normalised power density (W/m2-100 lux)	3	
Chedule Schedule	Ware_24x7CellOff_Light	
Luminaire type	1-Suspended	•
Radiant fraction	0.420	
Visible fraction	0.180	
Convective fraction	0.400	

Step 7: Make sure to clear the **ON** check box under the **Lighting Control** section.

€ Lighting Control	×
□ On	
🦉 nask and Uisplay Lighting	×
🗖 On	
Exterior Lighting	¥
🗆 On	
"" Cost	»

Step 8: Perform hourly simulation and record the results.

Analysis Summa	ary Parametric Optin	nisation			
Date/Time	Room Electricity (kWh)	Lighting (kWh)	Heating (Gas) (kWh)	Cooling (Electricity) (kWh)	DHW (Electricity) (kWh)
12:00:00 AM	6800.953	9319.256	26.28051	21729.27	923.8257

Now you are going to enable the daylight control in the model.

Step 9: Select the Lighting tab.

Step 10: Select the **ON** check box under the **Lighting Control** section and select **Linear/off** in the **Control type**. Set **100** for % **Zone covered by Lighting Area 1**. Select the **Layout** tab.

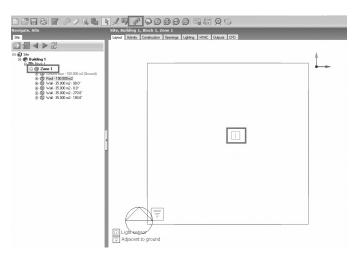
Site, Building 1			
Layout Activity Construction Openings Lighting HVAC G	eneration Outputs CFD		
	*		
C Lighting Template			
🖓 Template	Reference		
Seneral Lighting	¥		
🗹 On			
Normalised power density (W/m2-100 lux)	3.0000		
fill Schedule	Ware_24x7CellOff_Light		
Luminaire type	1-Suspended ·		
Radiant fraction	0.420		
Visible fraction	0.180		
Convective fraction	0.400		
🔊 Liahtina Control	*		
🗹 On			
Working plane height (m)	0.80		
Control type	2-Linear/off		
Min output fraction	0.100		
Min input power fraction	0.100		
Glare	»		
Lighting Area 1	*		
% Zone covered by Lighting Area 1	100.0		
Lighting Area 2	»		

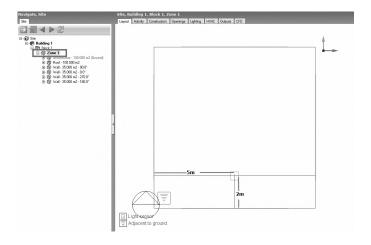
Step 11: Select the Activity tab and make sure that the target illuminance (lux) is **400**.

Layout	Activity	Construction	Openings	Lighting	HVAC	Generation	Outputs	CFD	
R.A	∖ctivity Te	mplate	-				-		×
- North Street S	t ⊁Templ				Gener	ic Office A	rea		
a Sector					B1 Offices and Workshop businesses				es
-	one multi	nlier			1				
		zone in them	nal calcula	tions					
_		zone in Radi			alculation	18			
	-	as and Volum		ignang oa		10	-		»
	ccupanc								
	/etabolic								»
		ontaminant G	eneration						»
ťe⊢	lolidays								**
)HW								»>
() x =	in∨ironme	ental Control							×
ŀ	leating S	etpoint Tem	peratures						»>
0	Cooling S	etpoint Temp	oeratures			bia no si			**
	Humidity (»>
		n Setpoint Te	emperature	s					**
	/linimum F	Fresh Air							**
	ighting.								×
	-	Illuminance		L	400				
_		t display light	ting density	y (W/m2)	0				
	Computers								**
)ffice Equ								» *
	liscellane	Bous							×
	On								
	atering								»
10 F	rocess								»

Step 12: Select **Zone 1** from the Navigation Tree. The daylight sensor can be seen in the layout.

Step 13: Select the **Sensor** and click the **Move selected object** icon. Click the daylight sensor and place it 2 m away from the window with the help of construction lines.

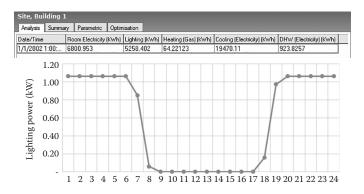




Step 14: Select the **Simulation** tab. The **Edit Calculation Options** screen appears. Select the **Output** tab and click the **Detailed Daylight Outputs** section. Select the **Daylight map output** check box. Click **OK**. Perform hourly simulation.

Calculation Options Data	Help	
General Options Output Simulation Manager	Info Data	
Output Data Dutput Data Comparing the second part of the second pa	Output Data Control the data generated Control the simulation com restrict the sim restrict the simulation com restrint the simulatin the	ou ort od er is clu on
Time Setpoints not Met Tolerances	statistics become more meaningful	

Step 15: Record the results. Plot hourly lighting data for 4 April.



In the above graph, you can observe that the lighting consumption is zero between 09:00 and 17:00 h. To get the lux level at this time, you need to get the illuminance map.

Step 16: Open the **eplusmap** file that exists in the **EnergyPlus** folder.

<u>F</u> ile	Edit Go View Tools Help)			
	New project Ctrl+1	v & G_1 ♥ ♥ ₽ \$			
2	Open project Ctrl+0	ite, Building 1			
	<u>C</u> lose Ctrl+F				
	<u>S</u> ave	>			
	Import	C Lighting Template			
	Export	General Lighting			
	<u>F</u> olders	EnergyPlus folder			
۵	<u>P</u> rint	<u>R</u> adiance folder			
	Exit Alt+F	4 Weather data folder			
	18.8 No heat recovery_New.dsb	Library data folder			
	2 8.6 Fixed Dry bulb_New.dsb	<u>T</u> emplate projects folder			
	<u>3</u> 1.11.dsb	<u>D</u> iagnostic files folder			

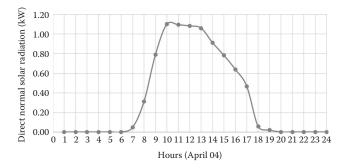
Irganize • Include	in library • Share with • Burn	New folder			- ==	4
R Favorites	Name	Date modified	Type	Size		
Desktop	L5_Actual	3/3/2016 1:34 PM	File folder			
Downloads	L5_Notional	3/3/2016 1:34 PM	File folder			
E Recent Places	L5_Reference	3/3/2016 1:34 PM	File folder			
🐺 Dropbax	🛋 compact	3/17/2016 11:09 AM	EP-Launch Docu	59 KB		
	3 dbrunep	3/17/2016 11:09 AM	Windows Batch File	1 KB		
🗟 Libraries	Energy+.idd	4/27/2015 8:49 AM	IDD File	3,653 KB		
Documents	Energy+	4/27/2015 8:49 AM	Configuration sett	1 KB		
Music	energyplusepi.dll	4/27/2015 8:49 AM	Application extens	24,074 KB		
E Pictures	Energy@lurA015h	4/27/2015 8-49 AM	1 12 File	7 88		
Videos	🕼 eplusmap	3/19/2016 2:09 PM	Microsoft Excel C	3,520 KB		
	eplusout.audit	3/19/2016 2:09 PM	AUDIT File	6 KB		
🖏 Homegroup	eplusout.bnd	3/19/2016 2:09 PM	BND File	9 KB		
	eplusout.dfs	3/19/2016 2:09 PM	DFS File	143 KB		
Computer	eplusout.dd	3/19/2016 2:09 PM	DXF File	22 KB		
Local Disk (C:)	eplusout.eio	3/19/2016 2:09 PM	EIO File	34 KB		
👝 Local Disk (D:)	eplusout.end	3/19/2016 2:09 PM	END File	1 KB		
👝 Local Disk (E:)	eplusout.err	3/19/2016 2:09 PM	ERR File	7 KB		
	eplusout.eso	3/19/2016 2:09 PM	ESO File	6,220 KB		
Wetwork Network	eplusout.mdd	3/19/2016 2:09 PM	MDD File	6 KB		
	eplusout.mtd	3/19/2016 2:09 PM	MTD File	12 KB		
	eplusout.mtr	3/19/2016 2:09 PM	MTR File	1,566 KB		
	eplusout.rdd	3/19/2016 2:09 PM	RDD File	46 KB		
	eplusout.shd	3/19/2016 2:09 PM	SHD File	3 KB		

Step 17: Get the data for 11:00 h.

Table 5.1 gives the Illuminance map when the sensor is placed near the window. In the map, each cell reports the illuminance (in lux) at the location specified by the (X;Y) coordinates in the column and row headers. These are XY pairs separated by a semi-colon for ease in importing into the spreadsheet. In **eplusmap** file, the Z coordinate of the map is shown in the title (the illuminance map is set in a plane) and the date and time are indicated in the upper left cell of the map. You can observe that at 09:00 h all artificial lights are off because of sufficient illuminance near the sensor. This leads to low illuminance in the interiors of the space.

Table 5.1 Illuminance m	inance map	1 April								
4/4/2016 9:00	(0.32; 0.20) =	(1.38; 0.20) =	(2.45; 0.20)=	(3.52; 0.20) =	(4.58; 0.20)=	(5.65; 0.20) =	(6.72; 0.20) =	(7.78; 0.20)=	(8.85; 0.20)=	(9.92; 0.20) =
(0.32; 0.20) =	5073	5940	5948	5948	5949	5951	5952	5951	1069	140
(0.32;1.27) =	462	652	715	730	732	726	704	628	435	226
(0.32;2.33) =	304	367	402	415	417	407	382	333	261	194
(0.32; 3.40) =	228	254	272	280	279	271	255	229	198	170
(0.32;4.47) =	187	200	208	212	211	206	196	183	168	153
(0.32;5.53) =	164	171	175	177	176	173	167	160	151	143
(0.32;6.60) =	152	156	158	159	159	156	153	148	143	138
(0.32;7.67) =	142	145	146	146	146	144	142	139	136	133
(0.32; 8.73) =	136	138	138	138	138	137	136	134	132	130
(0.32;9.80) =	132	133	133	133	133	132	131	130	129	127

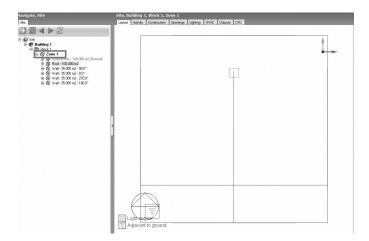
You can also get the solar radiation profile on 4 April by selecting **Site Data** from the **Data** drop-down list. Export the Direct Normal Solar and plot using a spreadsheet program.



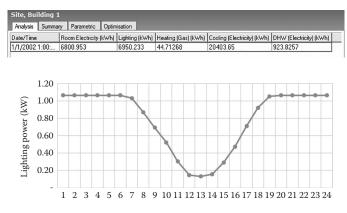
Step 18: Save the model using the Save as option.

Now, you are going to change the location of the daylight sensor at 8 m distance from the south window.

Step 19: Move the daylight sensor 8 m away from the window towards the north (as explained earlier).



Step 20: Perform hourly simulation. Record the annual results. Also record hourly lighting data for 4 April.



Hourly lighting load for 4 April (the daylight sensor at 8 m away from the window).

In the above graph, you can observe that lighting energy consumption between 08:00 and 17:30 h is higher compared to when the sensor is placed near the window. When the sensor is moved away from the window it gets into darker portion of the room and is triggered when more daylight enters the room. This increase in daylight might take some time thereby delaying the time when the lights are switched off. This increases the lighting energy consumption but ensures that sufficient light is available even in the interior areas of the room when the lights are switched off. However, this might lead to higher illuminance levels near the window, leading to visual discomfort.

So there is a need to place two sensors at different positions to get energy savings and visual comfort.

Step 21: Save the model using the Save as option.

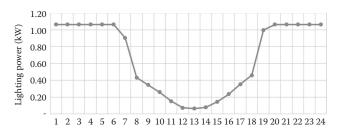
Now, you are going to install one more daylight sensor.

Step 22: Select the Lighting tab and select the Second lighting area check box. Enter 50.0 as the % Zone covered by Lighting Area 1 and % Zone covered by Lighting Area 2. Make sure the Target Illuminance (lux) is 400.

C Lighting Template	*
🖓 Template	Reference
land General Lighting	*
🗹 On	
Normalised power density (W/m2-100	. 3.0000
🛱 Schedule	Ware_24x7CellOff_Light
Luminaire type	1-Suspended ·
Radiant fraction	0.420
Visible fraction	0.180
Convective fraction	0.400
S Lighting Control	*
🗹 On	
Working plane height (m)	0.80
Control type	2-Linear/off •
Min output fraction	0.100
Min input power fraction	0.100
Glare	»
Lighting Area 1	*
% Zone covered by Lighting Area 1	50.0
Lighting Area 2	×
Second lighting area	
Target Illuminance (lux)	400
% Zone covered by Lighting Area 3	50.0

ite, Building 1, Block	ction Openings Lighting HVAC Outputs CFD	
Addition of the second se	citori operninga Lignang rivite ouputa ero	
		1
		•
	2	
Light sensor		
Adjacent to grou	und	

Step 23: Perform hourly energy simulation and record the results.



In the above graph, we can observe the lighting consumption between 08:00 and 17:30 h. The energy consumption is less compared to the case when the sensor is placed far from the window, as artificial lights are switched off near the window when there is sufficient daylight.

Get the data for 11:00 h for illuminance levels (Table 5.2).

Now compare the annual energy consumption for all three cases (Table 5.3).

	- 1	11dA 4 101 de 11								
04/04 09:00	(0.32;	(1.38;	(2.45;	(3.52;	(4.58;	(5.65;	(6.72;	(7.78;	(8.85;	(9.92;
	0.20) =	0.20) =	0.20) =	0.20) =	0.20) =	0.20) =	0.20) =	0.20) =	0.20) =	0.20) =
(0.32;0.20) =	5073	5940	5948	5948	5949	5951	5952	5951	1069	140
(0.32; 1.27) =	462	652	715	730	732	726	704	628	435	226
(0.32;2.33) =	304	367	402	415	417	407	382	333	261	194
(0.32;3.40) =	228	254	272	280	279	271	255	229	198	170
(0.32;4.47) =	187	200	208	212	211	206	196	183	168	153
(0.32;5.53) =	164	171	175	177	176	173	167	160	151	143
(0.32;6.60) =	152	156	158	159	159	156	153	148	143	138
(0.32;7.67) =	142	145	146	146	146	144	142	139	136	133
(0.32; 8.73) =	136	138	138	138	138	137	136	134	132	130
(0.32;9.80) =	132	133	133	133	133	132	131	130	129	127

 Table 5.2
 Illuminance map for 4 April

206

Sensor placement	Annual lighting energy consumption (kWh)
No sensor	9,319.25
Near to the window	5,258.40
Far from the window	6,950.23
With two sensors	6,056.55

 Table 5.3
 Annual lighting energy consumption

 with different sensor placements

It can be observed that the placement of the sensor affects the energy consumption. It is due to the fact that while using a single sensor, the controller assumes the same illuminance level in the entire zone as is found on the sensor. With this approach, when the sensor is placed close to the window, the model calculates the requirement of artificial light against a higher daylight level, as compared to the case of a lower daylight level when the sensor is placed far away. With two sensors, the space is divided into two zones independently controlled hence the energy consumption is between the two cases as discussed above. In practice, however, even while using a single sensor, different fixtures can be calibrated to adjust against different daylight levels at various depths.



Heating and Cooling Design

This chapter explains how to size and model the heating, ventilation and air conditioning (HVAC) systems. Out of the three tutorials, one explains the effect of HVAC operating criteria on energy consumption. Often, thermostats of HVAC are operated by sensing the air temperature, and the same criterion is also used for the evaluation of thermal comfort hours through simulation. This tutorial shows the difference in alternative approaches using the case of 'operative temperature', that is, a combination of air temperature and mean radiant temperature. The second tutorial explains the method of sizing HVAC systems, and the third one covers the effect of using different calculation algorithms for performing HVAC calculations in the simulation.

TUTORIAL 6.1 Evaluating the impact of temperature control types

GOAL

To evaluate the impact of temperature control types – air temperature and operative temperature on HVAC equipment sizing and energy consumption.

WHAT ARE YOU GOING TO LEARN?

• Changing temperature setpoint control types and evaluating its impact

PROBLEM STATEMENT

In this tutorial, you are going to use a 50 m \times 25 m model with a 5 m perimeter depth with the following specifications:

- Number of floors: G+1
- Window-to-wall ratio: 40%
- Glass type: Dbl Blue 6mm/13mm Air (U-value-2.70° W/m² K, SHGC-0.48, VLT-0.50)
- Roof construction: Roof, Ins Entirely above Deck, R-50(8.8), U-0.020(0.114)
- Activity template: 24×7 Generic Office Area

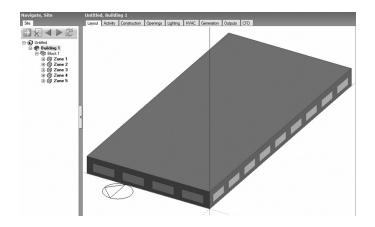
Find the cooling equipment sizing and energy consumption for the ground floor with the following two temperature controls:

- 1. Air temperature (AT)
- 2. Operative temperature (OT)

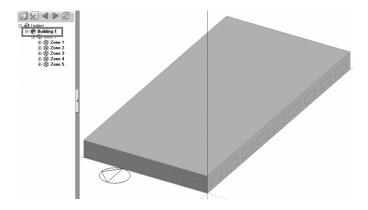
Use the New Delhi/Palam, India weather location.

SOLUTION

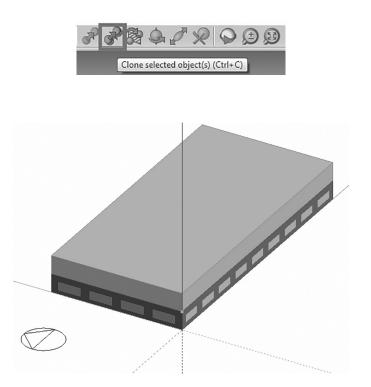
Step 1: Open a new project and create a 50 m \times 25 m building with a 5 m perimeter depth and select the template as 24 \times 7 Generic Office Area.

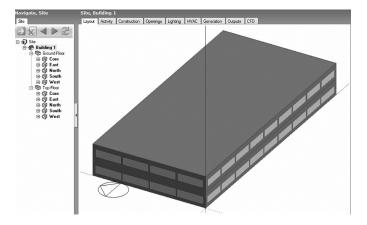


Step 2: Go to the **Building level** and select the **Building** on the edit screen.



Step 3: Click **Clone selected object(s)**. Click the origin of the floor, move the cursor to the top of the floor to paste the cloned floor.

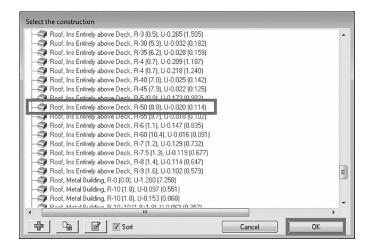




Step 4: Select the **Openings** tab. Select **Dbl Blue** 6mm/13mm Air as Glazing type and set the layout as **Preferred height 1.5m, 40% glazed**.

🕻 Glazing Template	
Template	Project glazing template
Fixternal Windows	, , , ,
🕜 Glazing type	Dbl Blue 6mm/13mm Air
Layout	Preferred height 1.5m, 30% glazed
Dimensions	
Туре	3-Preferred height
Window to wall %	40.00
Window height (m)	1.50
Window spacing (m)	5.00
Sill height (m)	0.80
Reveal	
Frame and Dividers	
Shading	
Airflow Control Windows	
Free Aperture	
🗊 Internal Windows	
Sloped Roof Windows/Skylights	

Step 5: Select the Construction tab and select Roof, Ins Entirely above Deck, R-50 (8.8), U-0.020 (0.114) as the Flat roof type.



Step 6: Select the **Cooling design** tab. The **Calculation Options** screen appears.

Step 7: Select **Air temperature** from the **Temperature control** drop-down list. Click **OK**. The results are displayed in the Analysis tab.

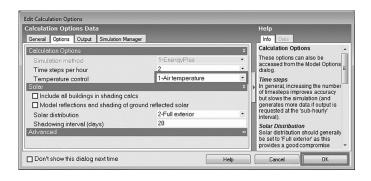
Calculation Options - Building 1			
Calculation Options Data			Help
General			Info Data
Calculation Description		¥	Calculation Options
			The summer design calculation
Calculation Options		×	options provide you with some control over the simulation. In
Simulation method	1-EnerovPlus	¥	general you should use the
Temperature control	1-Air temperature		default values as supplied with the software.
Summer Design Day		* I	Auto-Update
Day	15	•	This dialog is always shown when
Month	Jul	•	you select 'Update' and will also be shown before all simulations if
Day of week	9-SummerDesignDay	•	'Don't show this dialog next time'
Exclude all zone natural ventilation (infi			at the bottom is cleared.
Exclude all zone mechanical ventilatio	n		
Exclude heat recovery			-
System Sizing		×	
Design margin	1.15	_	
Sizing method	1-ASHRAE	*	
Airflow calculation method	1-Sensible only	•	
Output		<u> </u>	
Solar		>>	
Advanced		**	
Don't show this dialog next time	Help		Cancel OK

Day of week field is used to identify the appropriate daily profile within the schedules to use for the Cooling design calculations. The day type should be the day when the most extreme conditions and highest cooling loads are expected. You should normally keep the 9-SummerDesignDay default option, while running simulations.

Navigate, Site	Site, Building 1		
Site	Analysis Summary		
> 2 < > 2	Zone	Design Capacity (kW)	Design Flow Rate (m3/s)
	上Building 1		
🖃 🕡 Site	GroundFloor:Core	52.16	3.5644
E Building 1	GroundFloor:East	15.38	1.0623
⊡ 💱 Ground Floor ⊕ 🐼 Core	GroundFloor:West	17.31	1.1978
⊕-Öğ East ⊕-Öğ North ⊕-Öğ South ⊕-Öğ West ⊡-Öp Top Floor	GroundFloor:South	23.95	1.6433
	GroundFloor:North	23.66	1.6230
	TopFloor:Core	54.07	3.6958
	TopFloor:West	14.73	1.0169
	TopFloor:East	16.37	1.1323
⊕-⊗ Core ⊕-⊗ East	TopFloor:South	24.89	1.7084
⊡-Ø North	TopFloor:North	24.70	1.6957
🕀 😥 South	Totals	267.21	18.3398
⊡-Ø ₩est			

Step 8: Select the **Summary** tab. Record the results.

Step 9: Select the **Simulation** tab. In the **Edit Calculation Options** screen, select the **Options** tab. Ensure that the **Air temperature** is selected. Ensure that Hourly Simulation is selected in General tab. Click **OK**.



Step 10: Click **South** in the Ground Floor in the navigation tree. Record the air temperature and operative temperature for 4 April. (Data displayed on the screen is for the whole year; you can scroll to get the data for 27 March.)

Site			Analysis	Summar	y Parametric Op	otimisation	
→ 🗶 🔺 🕨	2	_	Date/Time		Air Temperature (*C)	Radiant Temperature (*C)	Operative Temperature (*C)
	5		1/1/2002	1:00:	24	26.1106	25.0553
🖃 🕡 Site		^	1/1/2002	2:00:	24	25.94206	24.97103
E Building 1	-		1/1/2002	3:00:	23.99903	25.79273	24.89588
E Cor		- 110	1/1/2002	4:00:	23.87952	25.66814	24.77383
⊞-∰ Eas			1/1/2002	5:00:	23.87762	25.55683	24.71722
B 🕲 Nor		E	1/1/2002	6:00:	23.89386	25.46838	24.68112
🕀 😰 Sou		- 110	1/1/2002	7:00:	23.90203	25.38713	24.64458
⊞-Ø We		- 110	1/1/2002	8:00:	23.97957	25.41829	24.69893
E Top Flo		- 111	1/1/2002	9:00:	23.9999	26.19025	25.09507
⊕ ⊕ Eas			1/1/2002	10:00	24	28.30153	26.15077
E 😥 Nor		-	1/1/2002	11:00	24	29.87432	26.93716
Display Options	_	-	1/1/2002	12:00	24.13863	31.33613	27.73738
			1/1/2002	1:00:	24.46738	31.78887	28.12813
General Detailed		_	1/1/2002	2:00:	24.32913	31.70047	28.0148
1			1/1/2002	3:00:	24.19638	31.5588	27.87759
			1/1/2002	4:00:	24.02085	30.64679	27.33382
Data		¥	1/1/2002	5:00:	24.00175	29.46	26.73088
Data.	3-Comfort		1/1/2002	6:00:	24.00011	28.38308	26.1916
Interval	4-Hourly		1/1/2002	7:00:	24.00001	27.80162	25.90081
Show as	2-Grid	•	1/1/2002	8:00:	24	27.41595	25.70798
Days per page	365	_	1/1/2002	9:00:	24	27.0708	25.5354
Normalise by	floor area		1/1/2002	10:00	24	26.76938	25.38469
Y-Axis		»	1/1/2002	11:00	24	26.51663	25.25832
Appearance		>>	1/2/2002		24	26.30649	25.15325

Step 11: Repeat the previous steps (the cooling design and simulation) by selecting the operative temperature control in place of the air temperature control.

Operative temperature is defined as follows:

A uniform temperature of a radiantly black enclosure in which an occupant would exchange the same amount of heat by radiation plus convection as in the actual non-uniform environment. It is the combined effect of the mean radiant temperature and air temperature calculated as the average of the two. It is also known as dry resultant temperature or resultant temperature. It can be calculated as follows:

$$t_o = \frac{\left(\left(t_a \times \sqrt{10\vartheta}\right) + t_{\rm mr}\right)}{1 + \sqrt{10\vartheta}}$$

where:

 ϑ = the air velocity

 t_a = the air temperature

 $t_{\rm mr}$ = the mean radiant temperature

The mean radiant temperature of an environment is defined as the uniform temperature of an imaginary black enclosure that would result in the same heat loss by radiation from the person as the actual enclosure. Step 12: Select **Operative temperature** from the **Temperature control** drop-down list. Click **OK** and get the summary of analysis.

Calculation Options - Building 1			
Calculation Options Data			Help
General			Info Data
Calculation Description	*	1	Calculation Options
			The summer design calculation
Calculation Options	*	1	options provide you with some control over the simulation. In
Simulation method	1-EnergyPlus ·		general you should use the default values as supplied with the
Temperature control	1-Air temperature		software.
Summer Design Day	1-Air temperature		Auto-Update
Day	2-Operative temperature		This dialog is always shown when you select 'Update' and will also be
Month			shown before all simulations if 'Don't
Day of week	9-SummerDesignDay		show this dialog next time' at the bottom is cleared.
Exclude all zone natural ventilation (infiltration is alway	ys included)	L	bollonnis cicultu.
Exclude all zone mechanical ventilation			
Exclude heat recovery System Sizing	*		
Design margin	1.15		
Sizing method	1-ASHBAF		
Airflow calculation method	1-Sensible only ·		
Output	»		
Solar			
Advanced	»		
Don't show this dialog next time	Help		Cancel OK

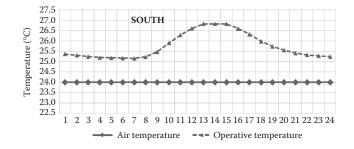
Step 13: Select the **Summary** tab. Record the results in a separate spreadsheet (hourly values for AT, OT on 27 March for all zones on the ground floor, cooling design data and annual energy consumption results).

Now compare the results for both the cases (Table 6.1).

Step 14: Plot AT and OT for the Ground Floor: South zone with the air temperature control for 27 March.

	Design capacity of cooling equipment (kW)		
Zone	Air temperature control	Operative temperature control	
Ground: East	15.49	20.19	
Ground: West	17.44	22.61	
Ground: North	23.71	26.43	
Ground: South	23.81	26.75	
Ground: Core	51.98	53.76	

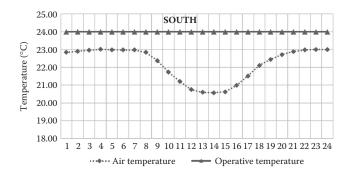
 Table 6.1
 Design capacity of cooling equipment



You can observe that the zone air temperature is maintained at 24°C. However, the operative temperature of the zone is not constant over the day. In this case, the operative temperature of the zone is higher than the zone air temperature due to the higher temperature of the exposed walls and windows. It can also be noted that this difference is highest during afternoon because the exposed surfaces of the south zone absorb solar radiation resulting in a higher surface temperature.

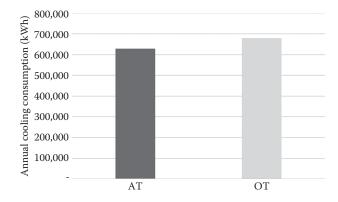
A higher operative temperature can cause discomfort despite the air temperature being maintained at 24°C. Hence, to get comfort in the zone, there is a need to set the thermostat based on the operative temperature.

Step 15: Now plot temperatures (AT and OT) for the Ground Floor: South zone with the operative temperature control.



It can be noted that for maintaining a constant operative temperature during the afternoon, the air temperature was reduced significantly to compensate for the higher surface temperature in the zones.

Step 16: Plot a chart for the annual cooling energy consumption for the air and operative temperature controls.



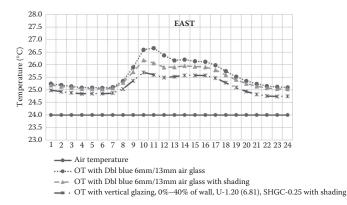
As discussed in the previous step, because the air temperature was reduced below 24°C to compensate for the higher surface temperature, the energy consumption in the operative temperature control mode is higher than that in the air temperature control mode.

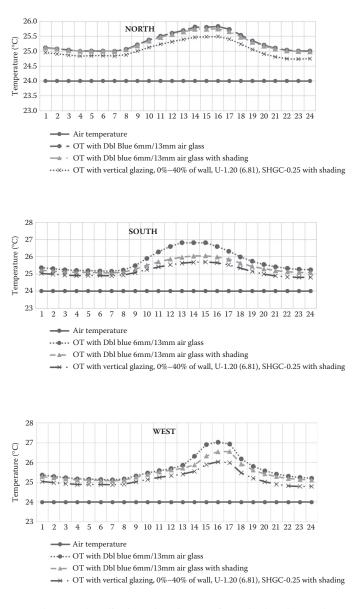
Now repeat the steps for the following two cases:

- Add a local shading 0.5 m overhang
- Use Vertical glazing, 0%-40% of wall, U-1.20 (6.81), SHGC-0.25 glass with local shading as a 0.5 m overhang

Simulate both the models for the air temperature based thermostat control. Record the results and plot the temperatures for all the zones on the ground floor. Also run annual simulations and observe the energy consumption.

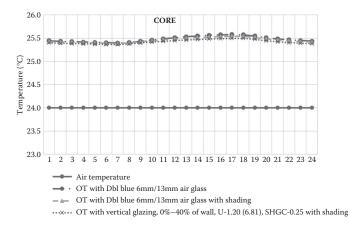
Step 17: Plot the temperatures for all zones on the ground floor with the air temperature for 4 April.





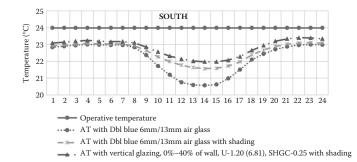
The results display that by putting shade above the opening reduces the operative temperature. Use of high performance glass also reduces the OT as the high performance glass surface tends to remain cooler then low performance glasses.

It can also be seen that the pattern of operative temperature is different for each zone. It is governed by the time of day when the zone receives solar radiation.

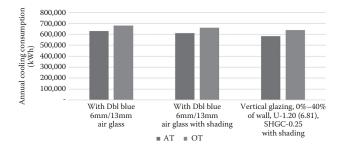


For the core zone it can be observed that the variation in OT is minimal since the walls are not receiving direct solar radiation and thus not getting heated up to the extent of the perimeter zones.

Step 18: Now, plot temperatures for the Ground Floor: South zone with the operative temperature control.



Step 19: Plot a chart for the annual cooling energy consumption for the air and operative temperature controls.



Analysis of results:

The thermostat control in conventional HVAC systems is activated as per the air temperature; however, human comfort is a function of operative temperature. Operative temperatures include the combined effect of air temperature and mean radiant temperature. During summer, perimeter spaces are uncomfortable due to higher operative temperatures. Therefore, there is an increase in the cooling equipment sizing of the system, because the operative temperature setpoint continues to condition the building until comfort conditions are met.

You can observe that the effect of the operative temperature setpoint is more noticeable in perimeter zones of the building compared to the core zone. This can be explained by the fact that the perimeter zones have more surfaces that are connected with the outdoor environment, whereas for the core zone, only the roof is connected to the outdoor environment.

Exercise 6.1

Repeat the above tutorial for 20% WWR (Table 6.2).

Table 6.2Comparison of the design capacity of cooling
equipment for air temperature and operative temperature
controls

	Design capacity of cooling equipment (kW)		
Zone	Air temperature control	Operative temperature control	
Ground: East			
Ground: West			
Ground: North			
Ground: South			
Ground: Core			

TUTORIAL 6.2 Evaluating the impact of design day selection

GOAL

To find the cooling equipment capacity using the designday and annual energy simulation approaches.

WHAT ARE YOU GOING TO LEARN?

• Sizing using two methods: design day and annual energy simulation methods

PROBLEM STATEMENT

In this tutorial, you are going to use a 50 m \times 25 m model with a 5 m perimeter depth.

Find the peak cooling load

- a. With the design day 15 July (as explained in Tutorial 6.1)
- b. Using annual energy simulations

Use the **New Delhi/Palam, India** weather file. Find the total cooling load for both options. Also note the time of occurrence of the maximum cooling load in each case.

COOLING DESIGN CALCULATION

Cooling design calculations are carried out to determine the capacity of the mechanical cooling equipment required to meet the hottest summer design weather conditions likely to be encountered at the site location.

Cooling design simulations using EnergyPlus have the following characteristics:

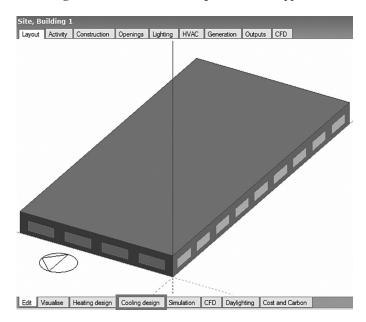
- Periodic steady-state external temperatures calculated using the maximum and minimum design summer weather conditions
- No wind
- Includes solar gains through windows and scheduled natural ventilation
- Includes internal gains from occupants, lighting and other equipment
- Includes consideration of 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.

> Source: http://www.designbuilder.co.uk/helpv4.7/ Content/_Cooling_design_simulation.htm

SOLUTION

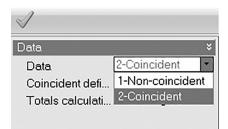
Step 1: Open a new model and create a $50 \text{ m} \times 25 \text{ m}$ building with a 5 m perimeter depth. Select the **Cooling design** tab. The **Calculation Options** screen appears.



Step 2: Click **OK**. The results are displayed on the Analysis tab.

Calculation Options - Building 1			
Calculation Options Data			Help
General			Info Data
Calculation Description		× 🔺	Calculation Options
			The summer design calculation options provide you with some
Calculation Options		×	control over the simulation. In
Simulation method	1-EnergyPlus	•	general you should use the default values as supplied with
Temperature control	1-Air temperature	¥	the software.
Summer Design Day		×	Auto-Update
Day	15	•	This dialog is always shown when
Month	Jul	•	you select 'Update' and will also be shown before all simulations if
Day of week	9-SummerDesignDay	- '	'Don't show this dialog next time'
Exclude all zone natural ventilation (infiltra	tion is always included)		at the bottom is cleared.
Exclude all zone mechanical ventilation			
Exclude heat recovery			
System Sizing		×	
Design margin	1.15	_	
Sizing method	1-ASHRAE		
Airflow calculation method	1-Sensible only	-	
Output		»	
Solar			
Advanced		» •	
Don't show this dialog next time	Hel	lp [Cancel OK

Step 3: Select the **Summary** tab. It shows the design capacity for 15 July. Select **Coincident** and record the results.



	ite, Building 1 Analysis Summary								
	Zone	Design Capacity (kW)	Design Flow Rate (m3/s)	Total Cooling Load (kW)	Sensible (kW)	Latent (kW)	Air Temperature (°C)	Humidity (%)	Time of Max Cook
E	Building 1								
	Block1:West	17.57	1.2106	15.28	14.88	0.39	24.0	47.8	Jul 15:30
	Block1:East	13.69	0.9411	11.91	11.57	0.34	24.0	48.0	Jul 15:30
	Block1:North	28.04	1.9224	24.38	23.64	0.74	24.0	48.2	Jul 15:30
	Block1:South	27.98	1.9190	24.33	23.59	0.74	24.0	48.2	Jul 15:30
	Block1:Core	63.69	4.3517	55.38	53.50	1.88	24.0	48.6	Jul 15:30
	Totals	150.96	10.3448	131.27	127.19	4.09	24.0	48.3	Jul 15:30

'Cooling design' does not require the weather data file for the calculation. DesignBuilder has all the required information in the 'ASHRAE_ 2005_Yearly_DesignConditions.xls' file. This file can be accessed at C:\ProgramData\DesignBuilder\ Weather Data path.

These details automatically get loaded in the DesignBuilder when the location is selected.

In the next steps, you are going to find out the cooling load using annual energy simulations.

Step 4: Select the **Simulation with Hourly** tab. After completion of the simulation, select **System loads** from the **Data** drop-down list.

Display Options General Detailed	
Data	×
Data	9-System loa 💌
Interval	4-Hourly 💌
Show as	2-Grid 💌
Days per page	365
Normalise by floo	r area
Y-Axis	»
Appearance	»

Navigate, Site	Site, Building 1			
Site	Analysis Summary	Parametric Optimi	sation	
> 2 ◀ ▶ 원	Date/Time S	Sensible Cooling (kW)	Total Cooling (kW)	Zone Heating (kW)
	1/1/2002 1:00: 0)	0	0
⊒-m il Site	1/1/2002 2:00: 0)	0	0
Building 1	1/1/2002 3:00: 0)	0	0
⊡-\$ Block 1 ⊕-\$ Zone 1	1/1/2002 4:00: 0)	0	0
⊕ 🛱 Zone 2	1/1/2002 5:00: 0)	0	0
⊞-∰ Zone 3 ⊞-∰ Zone 4	1/1/2002 6:00: 0)	0	21.95672
	1/1/2002 7:00: 0)	0	20.50932
⊡-@ Zone 5	1/1/2002 8:00: 0)	0	0.811373
	1/1/2002 9:00:	0.262392	-0.262392	0.078196
	1/1/2002 10:00	4.67382	-4.67382	0
	1/1/2002 11:00	16.34008	-16.34008	0
	1/1/2002 12:00	29.45524	-29.45524	0
	1/1/2002 1:00:	37.18619	-37.18619	0
	1/1/2002 2:00:	40.78593	-40.78593	0

Step 5: Click the **Export** icon to export the results to the spreadsheet (Table 6.3).

🛱 Export Results Spreadsheet
Export Data
Output
Export to: 3-Clipboard Format: CSV spreadsheet
Help Cancel OK

Day month	Time	Total cooling (kW)
19 June	4:00:00 PM	-158.2764
17 June	3:00:00 PM	-158.2065
19 June	5:00:00 PM	-158.1657
19 June	3:00:00 PM	-158.0092
17 June	4:00:00 PM	-157.7638
18 June	4:00:00 PM	-156.7041
18 June	3:00:00 PM	-156.598
17 June	12:00:00 PM	-156.2252
18 June	5:00:00 PM	-156.2232
21 June	5:00:00 PM	-156.0791
24 June	4:00:00 PM	-156.0511
17 June	5:00:00 PM	-156.0495
10 June	4:00:00 PM	-156.0368
17 June	11:00:00 AM	-156.0086
24 June	5:00:00 PM	-155.972
17 June	2:00:00 PM	-155.8881
9 July	5:00:00 PM	-155.832
20 June	3:00:00 PM	-155.7305

Table 6.3Total cooling load

Step 6: Open the spreadsheet and sort the results for the total cooling (kW) in decreasing order. This provides the peak total cooling (kW) of the building.

Compare the results for the building (Table 6.4).

The results show that there is a difference between the peak total cooling load of the building with the design day and without explicitly defining the design day. One should always be cautious while selecting the design day for cooling. Sometimes the design day might not represent the day of the maximum total cooling load.

Save the simulation model for use in next tutorials.

Table 6.4 Total cooling load for design day and annual energysimulation

With design day on 15 July		With annual e	energy simulation
Total cooling load (kW)	Date and time of peak	Total cooling load (kW)	Date and time of peak (building)
150.79	15 July at 15:00	158.27	19 June at 14:00

In some cases, design conditions, namely, max dry bulb, concurrent wet bulb and minimum dry bulb temperature are known to HVAC designers. As a third alternate, these conditions can directly be filled in DesignBuilder.

ayout Location Template * Image: Template NEW DELHI/PALAM Site Details * Time and Daylight Saving * Site Details * Winter Design Weather Data * Winter Design Weather Data * Outside design temperature (°C) 6.1 Wind speed (m/s) 8.0 Wind direction (°) 0.0 O Heating 99% coverage * Summer Design Weather Data * Temperature Range Modifiers * Wind Data * Design Temperature Period * O 99.6% coverage (based on dry-bulb temp.) 43.8 Max dry-bulb temperature (°C) 31.5 O 99% coverage (based on dry-bulb temp.) 99% coverage (based on dry-bulb temp.) O 99% coverage (based on dry-bulb temp.) 99% coverage (based on wet-bulb temp.) O 99% coverage (based on wet-bulb temp.) 99% coverage (based on wet-bulb temp.) O 99% coverage (based on wet-bulb temp.) 99% coverage (based on wet-bulb temp.) O 99% coverage (based on wet-bulb temp.) 99% coverage (based on wet-bulb temp.) O 99% coverage (based on wet-bulb temp.) 99% co	ite	
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Coincident wet-bulb temperature. 22.6 Min dry-bulb temperature (°C) 31.5 O 99% coverage (based on dry-bulb temp.) O 98.6% coverage (based on wet-bulb temp.) O 99.6% coverage (based on wet-bulb temp.) O 99% coverage (based on wet-bulb temp.)	● 99.6% coverage (based on dry-bu	ulb temp.)
Min dry-bulb temperature (°C) 31.5 O 99% coverage (based on dry-bulb temp.) O 98% coverage (based on dry-bulb temp.) O 99.6% coverage (based on wet-bulb temp.) O 99% coverage (based on wet-bulb temp.)	Max dry-bulb temperature (*C)	43.8
 99% coverage (based on dry-bulb temp.) 98% coverage (based on dry-bulb temp.) 99.6% coverage (based on wet-bulb temp.) 99% coverage (based on wet-bulb temp.) 	Coincident wet-bulb temperatur	22.6
 98% coverage (based on dry-bulb temp.) 99.6% coverage (based on wet-bulb temp.) 99% coverage (based on wet-bulb temp.) 	Min dry-bulb temperature (*C)	31.5
O 99.6% coverage (based on wet-bulb temp.) O 99% coverage (based on wet-bulb temp.)	O 99% coverage (based on dry-bulk	o temp.)
O 99% coverage (based on wet-bulb temp.)	O 98% coverage (based on dry-bulk	o temp.)
	O 99.6% coverage (based on wet-b	ulb temp.)
O 98% coverage (based on wet-bulb temp.)	O 99% coverage (based on wet-bull	b temp.)
	O 98% coverage (based on wet-bull	b temp.)

Exercise 6.2

Repeat the same steps as in the tutorial for London to find the heating design capacity.

You can use the heating sizing tab for this (Table 6.5).

With design day on 15 Jan		With annual energy simulation		
Total heating design capacity (kW)	Date and time of peak of heating load	Total heating design capacity (kW)	Date and time of peak heating load (building)	

 Table 6.5
 Total heating design capacity for design day and annual energy simulation

Heating design calculations are carried out to determine the size of the heating equipment required to meet the coldest winter design weather conditions likely to be encountered at the site location.

The simulation calculates the heating capacities required to maintain the temperature setpoints in each zone and displays the total heat loss broken down as follows:

- Glazing
- Walls
- Partitions
- Floors
- Roofs
- External infiltration
- Internal natural ventilation (i.e. the heat lost to other cooler adjacent spaces through windows, vents, doors and holes)

TUTORIAL 6.3 Evaluating the impact of the air flow calculation method

GOAL

To evaluate the impact of the air flow calculation method on HVAC equipment sizing.

WHAT ARE YOU GOING TO LEARN?

• Changing the air flow calculation method and finding the design air flow

PROBLEM STATEMENT

In this tutorial, you are going to use the simulation model used for Tutorial 6.2 ($50 \text{ m} \times 25 \text{ m}$ model with a 5 m perimeter depth) with building usage as classroom. Find the cooling equipment sizing, and design flow rates, for the following airflow calculation methods:

- 1. Sensible
- 2. Sensible + latent

Use the AZ - PHOENIX/SKY HARBOR, USA weather file.

SOLUTION

Step 1: Open the model saved in Tutorial 6.2 (a 50 m \times 25 m building with a 5 m perimeter depth).

Step 2: Select the **Activity** tab. Select **Classroom** in the Universities and colleges section.

Untitled, Building 1	
Layout Activity Construction Openings Lighting HVAC G	eneration Outputs CFD
R Activity Template	*
プ <mark>Template</mark>	Classroom
Sector	C2 Residential Institutions - Universities and colleges
Zone multiplier	1
Include zone in thermal calculations	
Include zone in Radiance daylighting calculations	

Step 3: Select the **Cooling design** tab. The **Calculation Options** screen appears.

Step 4: Select **Sensible only** from the **Airflow calculation method** drop-down list. Click **OK**. The results are displayed in the Analysis tab.

Calculation Options - Building 1			
Calculation Options Data			Help
General			Info Data
Calculation Description		× •	Calculation Options The summer design calculation options provide you with some
Simulation method		÷.	control over the simulation. In general you should use the
Temperature control	1-Air temperature	•	default values as supplied with the software.
Summer Design Day		×	Auto-Update
Day		•	This dialog is always shown when
Month	Jul	-	you select 'Update' and will also be shown before all simulations if
Day of week	9-SummerDesignDay	•	'Don't show this dialog next time'
Exclude all zone natural ventilation (infiltra	tion is always included)		at the bottom is cleared.
Exclude all zone mechanical ventilation			
Exclude heat recovery			
System Sizing		×	
Design margin	1.15		
Sizing method	1-ASHRAE	-	
Airflow calculation method	1-Sensible only	-	
Output		»	
Solar		»» T	۰ III ا
Don't show this dialog next time	Help		Cancel OK

The supply air for cooling

$$Q_{\rm s} = \frac{q_{\rm s}}{C_1(t_{\rm R} - t_{\rm s})}$$

The supply air for dehumidification

$$Q_{\rm L} = \frac{q_{\rm L}}{C_2(W_{\rm R} - W_{\rm s})}$$

where:

 $Q_{\rm s}$ = supply air volume required to satisfy the peak sensible load

 $Q_{\rm L}$ = supply air volume required to satisfy the peak latent load

 $q_s = \text{peak sensible load}$

 $q_{\rm L} = \text{peak latent load}$

 $t_{\rm R}$ = room air temperature

 $t_{\rm s}$ = supply air temperature

 $W_{\rm R}$ = room humidity ratio

 $W_{\rm s}$ = humidity ratio of the dehumidified supply air

 $C_1 = 1.23$ (For calculation in SI units)

 $C_2 = 3010$ (For calculation in SI units)

Step 3: Select the **Summary** tab. Record the results.

Zone	Design Capacity (kW)	Design Flow Rate (m3/s)	Total Cooling Load (kW)	Sensible (kW)	Latent (kW)	Air Temperature (*C)	Humidity (%)
Building 1							
Block1:Core	60.43	4.7209	52.55	52.55	0.00	23.0	49.1
Block1:East	13.65	1.0665	11.87	11.87	0.00	23.0	47.5
Block1:West	16.38	1.2798	14.25	14.25	0.00	23.0	48.0
Block1:North	27.17	2.1224	23.63	23.63	0.00	23.0	48.5
Block1:South	28.09	2.1944	24.43	24.43	0.00	23.0	48.4
Totals	145.73	11.3841	126.72	126.72	0.00	23.0	48.6

Step 4: Repeat the previous steps to select **Sensible+latent** from the **Airflow calculation method** drop-down list. Click **OK**.

BUILDING ENERGY SIMULATION

Calculation Options - Building 1							
Calculation Options Data			Help				
General			Info Data				
Calculation Description		× 🔺	Calculation Options				
			The summer design calculation options provide you				
Calculation Options		¥	with some control over the simulation. In general you should use the default values as supplied with the				
Simulation method	1-EnergyPlus	•	software.				
Temperature control	1-Air temperature	*	Auto-Update				
Summer Design Day		¥	This dialog is always shown when you select 'Update' and will also be shown before all simulations if 'Don't				
Day	15	*	show this dialog next time' at the bottom is cleared.				
Month	Jul	*					
Day of week	9-SummerDesignDay	•					
Exclude all zone natural ventilation (infiltration	on is always included)		P				
Exclude all zone mechanical ventilation							
Exclude heat recovery							
System Sizing		¥					
Design margin	Design margin 1.15						
Sizing method 1-ASHRAE •							
Airflow calculation method 2-Sensible + latent							
Output 1-Sensible only							
Store surface output	2-Sensible + latent						
Include unoccupied zones in block and build	ding totals and averages						
Solar		» •					
Ad aread							
Don't show this dialog next time			Help Cancel OK				

Step 5: Select the **Summary** tab. Record the results.

Untitled, Building :							
Analysis Summary							
Zone	Design Capacity (kW)	Design Flow Rate (m3/s)	Total Cooling Load (kW)	Sensible (kW)	Latent (kW)	Air Temperature (*C)	Humidity (%)
Building 1							
Block1:Core	60.43	3.6367	52.55	52.55	0.00	23.0	49.1
Block1:East	13.65	0.8644	11.87	11.87	0.00	23.0	47.5
Block1:West	16.38	1.0212	14.25	14.25	0.00	23.0	48.0
Block1:North	27.17	1.6676	23.63	23.63	0.00	23.0	48.5
Block1:South	28.09	1.7286	24.43	24.43	0.00	23.0	48.4
Totals	145.73	8,9185	126.72	126.72	0.00	23.0	48.6

Compare both cases (Table 6.6).

Zone		Design flow rate (m ³ /s)			
	Design capacity (kW)	Sensible only	Sensible + latent		
Core	15.88	4.72	3.64		
East	26.94	1.07	0.86		
West	13.38	1.28	1.02		
North	61.03	2.12	1.67		
South	27.94	2.19	1.73		
Total	145.16	11.38	8.92		

Table 6.6 Design capacity and design flow rate for each zone

Factors that influence the sensible cooling load	Factors that influence the latent cooling load
 Glass, windows or doors Solar radiation striking windows, skylights or glass doors Thermal resistance of exterior walls Partitions (that separate spaces of different temperatures) Ceilings under an attic Thermal resistance of roofs and floors Air infiltration through cracks/ gaps in the building, doors and windows Building occupants Equipment and appliances operated in the summer Light 	 Moisture is introduced into a structure through: Building occupants Equipment and appliances that release vapour in space, such as tea kettle Air infiltration through cracks/gaps in the building, doors and windows and frequent doors opening to the ambience

Exercise 6.3

Repeat the above tutorial for the London Getwick Airport, UK (Table 6.7).

Zone		Design flow rate (m ³ /s)			
	Design capacity (kW)	Sensible only	Sensible + latent		
Core					
East					
West					
North					
South					
Total					

 Table 6.7
 Design capacity and design flow rate for each zone



Unitary HVAC Systems

In most unitary HVAC systems, coefficient of performance (COP) and fan properties are the two key aspects that govern their energy consumption. Higher COP is associated with a reduction in energy consumption. Unitary systems require a fan for blowing air over the condenser as well as evaporator tubes. A fan is characterized by its static pressure and volumetric air flow rate. High static pressure and flow rate help in achieving setpoint faster, however, they are also associated with higher energy consumption. If these parameters are not specified properly, results of the energy model could significantly deviate from the actual performance. This chapter explains the method of modelling unitary systems by specifying COP and fan properties.

TUTORIAL 7.1 Evaluating the impact of unitary air conditioner COP

GOAL

To evaluate the impact of unitary air conditioner COP on building energy performance.

WHAT ARE YOU GOING TO LEARN?

- Modelling the unitary HVAC system
- Changing the cooling system COP

PROBLEM STATEMENT

In this tutorial, you are going to create a $50 \text{ m} \times 25 \text{ m} \text{ 5-zone}$ model with 5 m perimeter depth. You need to model the unitary HVAC system and then change the COP of the system. You need to change the cooling COP from 1.5 to 3.5 with increments of 0.5.

Use **FL** – **MIAMI**, **USA** weather file. Find energy consumption for all COP values.

COP = desired effect/work input

For cooling:

$$COP_{cooling} = \frac{Q_o}{W}$$
(7.1)

For heating:

$$COP_{Heating} = \frac{Q_k}{W}$$
(7.2)

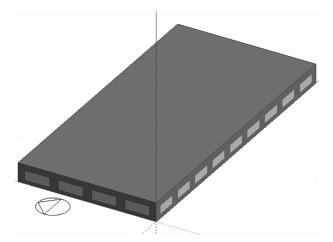
where:

 Q_{o} = heat absorbed in the evaporator Q_{k} = heat rejected in the condenser W = compressor work

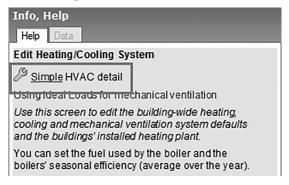
The COP of the refrigeration cycle is a dimensionless index used to indicate the performance of a thermodynamic cycle or the thermal system. The magnitude of COP is usually greater than 1.

SOLUTION

Step 1: Open a new project and create a 50 m \times 25 m building with five zones and consider a 5 m perimeter depth. Select the HVAC tab.



Step 2: Make sure **Simple HVAC detail** is displayed under the **Help** tab.



There are three HVAC model options available in DesignBuilder:

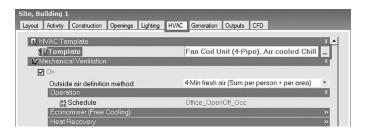
Simple HVAC is suitable for use at early design stages. The heating/cooling system is modelled using basic loads calculation algorithms.

Compact HVAC – the heating/cooling systems are defined in DesignBuilder using moderately basic HVAC descriptions that are expanded into detailed HVAC definitions and modelled in EnergyPlus including boiler, chiller and fan part-load characteristics. Compact HVAC is now a deprecated feature and may not be supported in future releases.

Detailed HVAC – the HVAC system is modelled in full detail using EnergyPlus air and water-side components linked together on a schematic layout drawing. This option will usually involve more work in setting up the setpoints, etc. especially for large models, but there is increased flexibility.

Source: http://www.designbuilder.co.uk/helpv4.7/ Content/_HVAC_model_detail.htm

Step 3: Click **Template** under the **HVAC Template** section. It displays three (...) dots. Click the three dots. The **Select the HVAC template** screen appears.





-	🚛 Cooled beams, DOAS, displacement ventilation	
-	🚛 Electric Convectors, Nat Vent	
-	🚛 Electric storage heaters, Nat Vent	
-	📲 Fan Coil Unit (4-Pipe) with District Heating + Cooling	
-	📲 Fan Coil Unit (4-Pipe), Air cooled Chiller	
-	📲 Fan Coil Unit (4-Pipe), Air cooled Chiller, DOAS	ſ
-	📲 Fan Coil Unit (4-Pipe), Water cooled Chiller, Water-side economiser	
-	📲 GSHP Unitary Water-to-air Heat Pump	
-	📲 GSHP Water to Water heat Pump, Heated Floor, Chilled Beams, Nat Vent	
-	🚛 GSHP Water to Water heat Pump, Heated Floor, Nat Vent	
-	📲 Heated floor, Boiler HW, Nat Vent	
-	📲 Heated floor, Solar Assisted Boiler HW, Nat Vent	
-	📲 Heating and Ventilation Ducted Supply + Extract	
-	📲 HW Convectors, Nat Vent	
-	Natural ventilation - No Heating/Cooling	
-	Packaged DX	
-	TAC Electric Heating	
-	PTAC HW Heating	
-	PTHP	
-	Radiator heating, Boiler HW, Mech vent Supply + Extract	
-	Radiator heating, Boiler HW, Mixed mode Nat Vent, Local comfort cooling	
-	Radiator heating, Boiler HW, Nat Vent	
1 -	Radiators Electric, Nat Vent	

The screen appears showing the selected template as Packaged DX:

Site, Building 1	
Layout Activity Construction Openings Lighting H	VAC Generation Outputs CFD
R HVAC Template	*
Template	Packaged DX
Contract Mechanical Ventilation	*
🗹 On	
Outside air definition method	4-Min fresh air (Sum per person + per area) 🔹
Operation	*
14 Schedule	Office_OpenOff_Occ
Economiser (Free Cooling)	»
Heat Recovery	»

A unitary system combines heating, cooling and fan sections all in one or a few assemblies for simplified application and installation and are used in most classes of buildings, particularly where low initial cost and simplified installation are important.

In DesignBuilder, the Unitary single zone option allows you to model simple single constant volume direct expansion (DX)-based HVAC configurations with several heating options. Direct expansion includes single-packaged rooftop systems commonly seen in commercial buildings and split systems commonly seen in residential buildings.

> Source: http://www.designbuilder.co.uk/ helpv4.7/#_Unitary_single_zone.htm

Step 5: Enter **1.5** as the **Cooling system seasonal CoP** in the **Cooling** section.

* Cooling		¥
🗹 Cooled		
Cooling system	Default	
Fuel	1-Electricity from grid	•
Cooling system seasonal CoP	1.5	

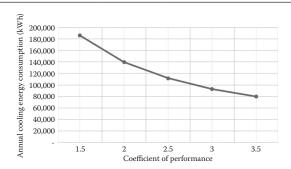
Step 6: Perform annual simulation and record the results.

Step 7: Repeat the previous steps for all other COP values and record the results (Table 7.1).

Compare the results.

			СОР		
End-use category	1.5	2	2.5	3	3.5
Room electricity	51,114.94	51,114.94	51,114.94	51,114.94	51,114.94
Lighting	73,872.16	73,872.16	73,872.16	73,872.16	73,872.16
Cooling (electricity)	186,137.60	139,603.20	111,682.60	93,068.80	79,773.26
DHW (electricity)	4,625.06	4,625.06	4,625.06	4,625.06	4,625.06

 Table 7.1
 Variation in annual energy consumption (kWh) with COP



Results show that there is a decrease in energy consumption with the increase in COP of the system. Systems with higher COP require lesser energy input to remove the same amount of heat from the thermal zone.

Save the model to use in the subsequent tutorial.

Exercise 7.1

	An	nual energ	al energy consumption (kWh)		h)
End-use category	COP 1.5	COP 2.0	COP 2.5	COP 3.0	COP 3.5
Room electricity					
Lighting					
System fans					
Heating (electricity)					
Cooling (electricity)					
DHW (electricity)					

Repeat the above tutorial for the heating system COP. Use CA-SAN FRANCISCO INTL, USA weather data.

TUTORIAL 7.2 Evaluating the impact of the fan efficiency of a unitary air conditioning system

GOAL

To evaluate the impact of the fan efficiency of a unitary air conditioning system on energy performance.

WHAT ARE YOU GOING TO LEARN?

• Changing the fan efficiency

PROBLEM STATEMENT

In this tutorial, you are going to use a 50 m \times 25 m fivezone model with 5 m perimeter depth.

Model the unitary HVAC system with the following three fan efficiencies:

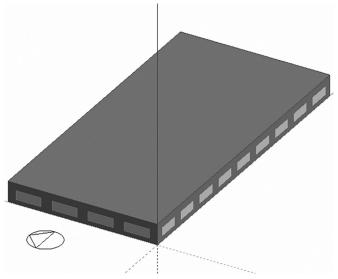
- 1. 0.600
- 2. 0.700
- 3. 0.800

Find change in energy consumption for all the cases.

Use Rio de Janeiro (AERO), Brazil location.

SOLUTION

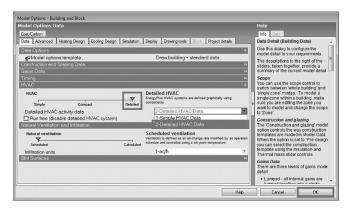
Step 1: Open a new project and create a $50 \text{ m} \times 25 \text{ m}$ building with 5 m perimeter depth.



Step 2: Select the **HVAC** tab. Click **Simple** link under the **Help** tab. The **Model Options – Building and Block** screen appears.



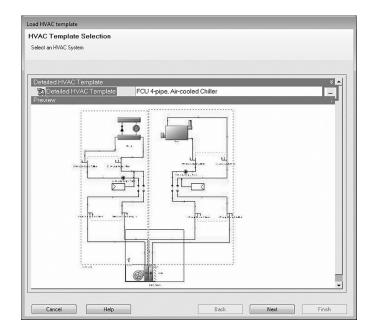
Step 3: Click **Detailed** under the HVAC slider. Select **Detailed HVAC Data** from the Detailed HVAC dropdown list. Click **OK**. It displays the <HVAC system> option under Building 1.



Step 4: Click **<HVAC System>**. It displays initializing HVAC progress bar and subsequently the **Load HVAC template** screen appears.

Navigate, Site
Site
⊡-ŵ Site
Puilding 1 (HVAC System> Block 1
in the second s
⊡ - 🔀 Zone 3 ⊡ - 🛱 Zone 4
E S Zone 5

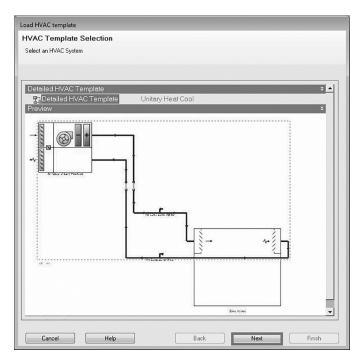
Step 5: Click **Detailed HVAC Template**. It displays three (...) dots. Click the three dots. The **Select the Detailed HVAC Template** screen appears.



Step 6: Select **Unitary Heat Cool** under Select Detailed HVAC Template. The **Load HVAC template** screen appears.

	FCU 4-pipe, Water-cooled Chiller, Waterside Economiser FCU with DOAS, Air-cooled Chiller		
	Ground Heat Exchanger, Chilled Ceiling		
	GSHP In-zone Water-to-air Heat Pump		
	GSHP Unitary Water-to-air Heat Pump		
	GSHP Water-to-water HP, Heated Floor		
	GSHP Water-to-water HP, Heated Floor, Chilled Beams		
5	Heated Floor, Boiler HW, Nat Vent		
	PTAC Electric Heating		-
5	PTAC HW Heating		
29292	PTHP		
5	Radiator Electric, Nat Vent		
-5	Radiator heating, Boiler HW, Nat Vent		
	Cultur Aminta di Hausta di Floor		
	Unitary Heat Cool		
	VAV Reheat, Air-cooled Chiller		L
2	VAV Reheat, Air-cooled Chiller, Steam Humidifier		
-51	VAV Reheat, Chiller Cooled by Fluid Cooler		
	VAV Reheat, DX cooling with Dehumidification		
	VAV Rahast Wstercooled Chiller		
4	Ga Sort	Cancel	OK

Step 7: Click Next. It displays all the zones.

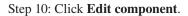


Step 8: Select the **Building 1** check box and click **Finish**.

Load HVAC template
Unitary Heat Cool: Select the zones served by this HVAC System
Use the check boxes to select the zones to be served by this HVAC system.
Znnes¥
Zone 1
└──☑段 Zone 5
Cancel Help Back Next Finish

Step 9: In the navigation tree, select **Air Loop Unitary HeatCool Supply Fan** from the <HVAC System> tree. You need to click + to expand the tree.

Navigate, Site
Site
⊡-ŵ Site
🗄 🕐 Building 1
🖮 🏣 <hvac system=""></hvac>
🖻 🐐 Air Loop
🚎 Air Loop Demand Side
🖻 🚎 Air Loop Supply Side
🖻 🛂 Air Loop Unitary HeatCool
- Air Loop Unitary HeatCool DX Cooling Coil
Air Loon Unitern HeatCool Heating Coil
- International Contemporation of the Arrivan Arrivation of the Arrivatio of the Arr
🖻 🗗 Zone Group
E Slock 1
🗄 🚳 Zone 1
⊡ 🚱 Zone 2
⊡ 🚱 Zone 3
🕀 🚱 Zone 4
⊡® Zone 5



DesignBuilder - 7.2.dsb - Layout - Site, Building 1		
File Edit Go View Tools Help		View rotation Autonometric Normal
Navigate, Site	Site, Building 1	Info, Help
Ste	Layout	Help Data
B I I I I I I I I I I		Supply Fan - AHU Component
Source State State Source State		The type of this fan is find as "Constant volume" because the Air loop AVI have been differed as Over. We constant the send differed as Over. We constant the send difference of the send based on costing/beatanty lead of other control based on costing/beatanty lead of other control and a mode pressure rule to calculate fan endormance.
Beady	Edit Visualise Heating design Cooling d	esign Simula
Triddy		

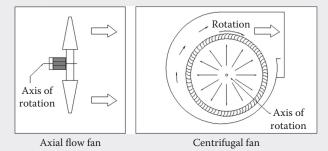


an Data		Help
Fan		Info Data
General		Constant Volume Fan
Name	Air Loop Unitary HeatCool Supply	The type of this fan is fixed as "Constant volume" because the Air
Туре	1-Constant volume	loop AHU has been defined as
Fan total efficiency	0.600	CAV.
Pressure rise (Pa)	600.0	Constant volume fans operate
End-use subcategory	General	continuously based on a time schedule and will not cycle on and
Flow Rates	*	off based on cooling/heating load
Maximum flow rate (m3/s)	Autosize	or other control signals.
Motor		Constant volume fans use total efficiency rating and a rated
Motor efficiency	0.900	pressure rise to calculate fan
Motor in airstream fraction	1.000	performance.
Operation	*	s
Availability schedule	On 24/7	
🛱 Model data <admin></admin>	Help	Cancel OK

A fan is a power-driven rotary machine that causes a continuous flow of air.

A fan is a machine that causes flow of air.

There are two broad categories of fans – axial and centrifugal.



In axial flow fans, air moves parallel to the shaft. This type is used in many applications such as a cooling fan for electronics and wind tunnel.

A centrifugal fan blows air at 90° to the intake of the fan. Mostly, it is used for HVAC applications.

Fan Efficiency

The fan efficiency is the ratio between the power transferred to the air flow and the power used by the fan.

$$\eta = \frac{\Delta P.Q}{W_{\text{fan}}}$$
(7.3)

where:

 η = fan efficiency (values between 0 and 1) ΔP = total pressure (*Pa*) Q = air volume delivered by the fan (m³/s)

 $W_{\text{fan}} = \text{power used by the fan (Watt)}$

Step 12: In the navigation tree, click **Building 1**. Perform annual simulation and record the results.

Analysis S	ummary	Parametric	Optimisat	tion		
Date/Time	R	oom Electricity	(k₩h)	Lighting (kWh)	System Fans (kWh)	Cooling (Electricity) (kWh)
12:00:00 AM	1 5	1114.3		73871.25	23220.41	84774.2

	Annual energy consumption (kWh)			
End use	0.60	0.70	0.80	
Room electricity	51,114.30	51,114.30	51,114.30	
Lighting	73,871.25	73,871.25	73,871.25	
System fans	23,220.41	19,903.21	17,415.31	
Cooling (electricity)	84,774.20	83,792.05	83,051.09	

Table 7.2Variation of annual energy consumption with fanefficiency

Step 13: Repeat the previous steps for 0.700 and 0.800 fan efficiency.

Compare the results (Table 7.2).

It can be seen that in addition to the reduction in energy consumption under system fans, there is a decrease in cooling (electricity) with the increase in fan efficiency. It is due to the fact that with a high-efficiency fan, lesser heat is added to the air while it passes over the fan motor, thus requiring a lesser cooling effect to be delivered by the system.

Save the simulation model with 0.7 fan efficiency to use in the next tutorial.

Exercise 7.2

Repeat the above tutorial for fan efficiency varying from 0.3 to 0.9 with steps of 0.1 for climate Melbourne, Australia.

TUTORIAL 7.3 Evaluating the impact of fan pressure rise

GOAL

To evaluate the impact of fan pressure on building energy performance.

WHAT ARE YOU GOING TO LEARN?

· Changing fan pressure rise

PROBLEM STATEMENT

In this tutorial, you are going to use the simulation model created in Tutorial 7.2 (50 m \times 25 m model with 5 m perimeter depth).

Model the unitary HVAC system with the following two fan pressures:

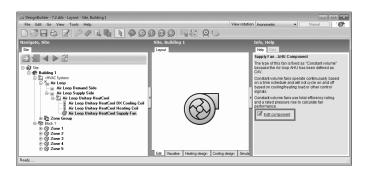
- 1. 500 Pa
- 2. 750 Pa

Find the change in energy consumption for both cases.

Use Rio de Janeiro (AERO), Brazil weather location.

SOLUTION

Step 1: Open the project file used in Tutorial 7.2. In the navigation tree select **Air Loop Unitary HeatCool Supply Fan.** Click **Edit component**.



Step 2: Enter **500** for Pressure rise (Pa). Click **OK**.

an Data		Help
Fan		Info Data
General Name Type Fan total efficiency Pressure rise (Pa) End-use subcategory Flow Rates Maximum flow rate (m3/s) Motor Motor efficiency Motor efficiency Motor in airstream fraction Operation ✓ Availability schedule	Air Loop Unitary HeatCool Suppl 1-Constant volume 0.700 500 General 4.utosize 0.900 1.000 3 On 24/7	Constant Volume Fan The type of this fan is fixed as 'Constant volume' because the Air loop AHU has been defined as CAV. Constant volume fans operate continuously based on a time schedule and will not cycle on and of based on coling/heating load or other control signals. Constant volume fans use total efficiency rating and a rated pressure fase to calculate fan performance.
🖌 Model data <admin></admin>	Help	Cancel OK

Fans provide energy to air that helps the air to move through the ducts and other parts of the air side of an HVAC system, such as grills, diffusers, air filters, humidifiers and dampers.

All these components impose resistance to the flow of air. To overcome such resistance, an increase in pressure is required.

As seen in Tutorial 7.2, fan power is inversely proportional to pressure rise:

• A typical fan running at a fixed speed can provide a greater volumetric flow rate for systems with smaller total pressure drops (if we are to the right of the peak in the fan curve).

Static pressure is used to overcome the pressure drop due to various ventilation system components on the airflow path within a given system. For mechanical ventilation systems, the fans create positive static pressure to move air through a given system.

The positive static pressure created by the fans equals the negative static pressure created by resistance as air navigates obstacles in the ventilation path plus the head required to impart sufficient kinetic energy to air for getting spread into the space.

Proper air filtration results in better conditions and air quality for occupants of the building as well as increases the longevity of the HVAC system. However, due to high negative pressure or resistance to flow with filtration devices, their use results in the rise in the static pressure requirement of the fan for maintaining the same flow rate.

Step 3: In the navigation tree, click **Building 1**. Perform annual simulation and record the results.

Analysis	Summa	ry Parametric	Optimisat	ion		
) ate/Time		Room Electricity	(k₩h)	Lighting (kWh)	System Fans (kWh)	Cooling (Electricity) (kWh
12:00:00 /	١M	51114.3		73871.25	16586.01	82802.66

	Annual energy consumption (kWh)		
End-use categories	500 Pa	750 Pa	
Room electricity	51,114.30	51,114.30	
Lighting	73,871.25	73,871.25	
System fans	16,586.01	24,879.01	
Cooling (electricity)	82,802.66	85,262.43	

Table 7.3Variation of annual energy consumption with fanpressure rise

Step 4: Repeat the previous steps for **750 Pa** fan pressure.

Compare the results (Table 7.3).

From the results, you can observe that there is an increase in fan energy consumption due to the rise in fan pressure. Also you can observe that there is an increase in cooling energy consumption with the increase in pressure rise due to the addition of more heat to the air passing over a fan motor of higher power rating.

Exercise 7.3

In the tutorial, make Motor in airstream fraction as 0 and observe the effect on the cooling and fan energy consumption. Use the same Rio de Janeiro (AERO), Brazil weather file (Table 7.4).

Edit Fan -		
Fan Data		Help
Fan		Info Data
General	÷	Constant Volume Fan
Name Type	Air Loop Unitary HeatCool Supply 1-Constant volume	The type of this fan is fixed as "Constant volume" because the Air loop AHU has been defined as
Fan total efficiency	0.700	CAV.
Pressure rise (Pa)	750.0	Constant volume fans operate continuously based on a time
End-use subcategory	General	schedule and will not cycle on and
Flow Rates	*	off based on cooling/heating load or other control signals.
Maximum flow rate (m3/s)	Autosize	Constant volume fans use total
Motor	*	efficiency rating and a rated
Motor efficiency	0.900	pressure rise to calculate fan
Motor in airstream fraction	0	performance.
operation	* I	
Availability schedule	On 24/7	
🛍 Model data <admin></admin>	Help	Cancel OK

Table 7.4Variation of annual energy consumption with
fan efficiency

	Annual energy consumption (kWh)		
End-use categories	500 Pa	750 Pa	
Room electricity			
Lighting			
System fans			
Cooling (electricity)			



Central HVAC System

Energy consumption of the centralized HVAC (Heating, Ventilating and Air Conditioning) system depends on the selection of individual components and their integration in the entire system. Major variations include the type of condenser for heat rejection, chilled water-pumping scheme, efficiency of the air distribution system, waste heat recovery and efficiency of the chiller and boiler. This chapter, through its tutorials, explains the method of modelling central HVAC systems. Different variations of systems are explained, such as types of chillers, cooling towers and the use of variable speed drives in HVAC components. The impact of each variation on energy consumption is also explained.

TUTORIAL 8.1 Evaluating the impact of air-cooled and water-cooled chillers

GOAL

To evaluate the impact of air-cooled and water-cooled chillers on the building energy consumption.

WHAT ARE YOU GOING TO LEARN?

- Modelling the central HVAC system
- · Modelling the air-cooled chiller
- Modelling the water-cooled chiller

PROBLEM STATEMENT

In this tutorial, you are going to use a G+5 floor building model. Each floor has a 50 m \times 25 m area and five zones with 5 m perimeter depth. You need to make use of the floor/zone multiplier option to model the building. Model HVAC systems having **VAV with reheat**.

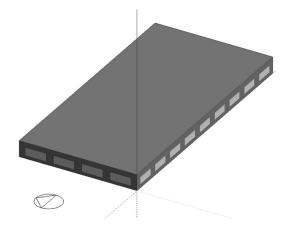
Use the following two options for a chiller in the HVAC system:

- 1. Air cooled
- 2. Water cooled

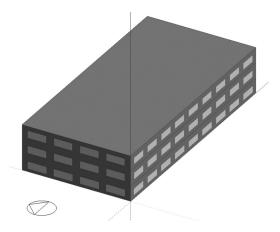
Compare the energy consumption of the two chillers for **AZ-PHOENIX/SKY HARBOR, USA** weather location. Phoenix has long, very hot summers and short, mild winters. The climate is arid, with plenty of sunshine and clear skies.

SOLUTION

Step 1: Open a new project and create a building with ground floor having a $50 \text{ m} \times 25 \text{ m}$ area and five zones with 5 m perimeter depth.



Step 2: Copy ground floor and create two other floors. (You can refer to Tutorial 6.1 to copy/clone floors.)



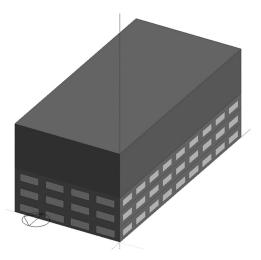
Step 3: Select **Plan** from View rotation drop-down. Click the **add block** icon.



Before drafting, select Block type as **Component block** and **Adiabatic** in the Component block type and enter **10.50** in Height (m).

Drawing Options		
Tools		
\checkmark		
Geometry		×
Block type	3-Component block	۳
Component block ty	3-Adiabatic	۳
Form	1-Extruded	•
Height (m)	10.50	
Auto-complete blo	ск	
Perimeter		×
Shape	1-Polygon	•
Line type	1-Straight line	•
Protractor		»
Direction Snaps		»
Point Snaps		»
Drawing Guides		»

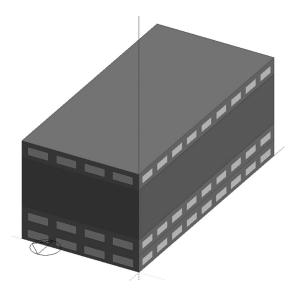
Go to Axonometric view, click in the corner and make sure that the roof is selected, when you click the point.



With the help of **Move Selected Object** icon, it can be adjusted.



(You can also refer to Chapter 2 for floor/zone multiplier.)



Step 4: Select the **HVAC** tab. Click **Simple** link under **Help** tab. The **Model Options – Building and Block** screen appears.



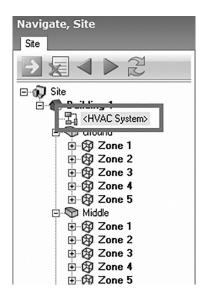
Step 5: Click **Detailed** under HVAC slider. Select **Detailed HVAC Data** from the Detailed HVAC dropdown list. Click **OK**. It displays <HVAC system> option under Building 1.

CHAPTER EIGHT CENTRAL HVAC SYSTEM

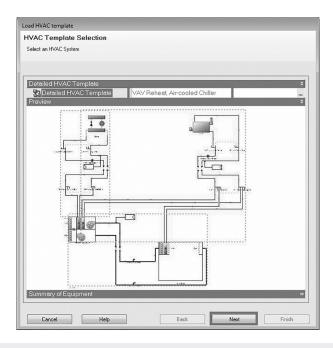
Model Options Data		Help
Cost/Carbon		Info Data
Data Advanced Heating Design Cooling Design 5	imulation Display Drawing tools Block Project details	Data Detail (Building Data)
Data Options PModel options template Construction and Glazing Data	v ⇒ Draw building + standard data. >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>	Use this dialog to configure the model detail to your requirements. The descriptions to the right of the sliders, taken together, provide a
Gains Data Timing HVAC	>> >> ¥	summary of the current model detail Scope You can use the scope control to switch between whole building and 'single zone' modes. To model a sinde-zone
HVAC Simple Compact Detailed HVAC activity data	Detailed UPAC EnergyPlus HVAC systems are defined graphically using components 2-Detailed HVAC Data	within a building, make sure you are editing the zone you want to model and change the scope to 'Zone'
Run free (disable detailed HVAC system)		Construction and glazing The 'Construction and glazing' model
Natural Ventilation and Infiltration	*	option controls the way construction templates are loaded in Model Data.
Natural ventilation	Scheduled ventilation Ventilation is defined as an air-change rate modified by an operation schedule and controlled using a set-point temperature.	When the option is set to 'Pre-design' you can select the construction template using the Insulation and Thermal mass
Infiltration units	1-ac/h 🔹	slider controls.
BIM Surfaces	>	Gains Data There are three levels of gains model detait
	Hab	Cancel OK

Detailed HVAC – The HVAC system is modelled in detail using EnergyPlus air- and water-side components linked together on a schematic layout drawing. In this case, HVAC data is accessed by clicking on the <HVAC System> navigator node.

Step 6: Click **<HVAC System>**. It displays the initializing HVAC progress bar and subsequently the **Load HVAC template** screen appears.



Step 7: Select VAV Reheat, Air-cooled Chiller from Detailed HVAC Template. Click Next.



In medium to large air conditioning systems, chilled water from the central plant is used to cool the air at the coils in an air handling unit (AHU).

Based on the condenser cooling, chillers are of two types:

- An air-cooled chiller has a condenser that is cooled by ambient air. Air-cooled chillers are preferred for small or medium installations and are preferred in cases where there is not enough water.
- A water-cooled chiller has a condenser connected with a cooling tower. Cold water is obtained through partial evaporation of water through ambient air that is used to facilitate heat rejection from the condenser. The use of a cooling tower to cool the condenser increases the efficiency of water-cooled chillers over air-cooled systems in which ambient air cools the condenser.

	Air cooled	Water cooled
Efficiency	Less	High
Cost	Less	High
Maintenance	Less	High

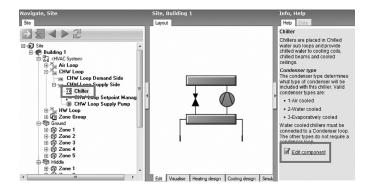
Step 8: Select all the check boxes from the **Zones** section. Click **Finish**. It displays the system layout.

Load HVAC template	
VAV Reheat, Air-cooled Chiller: Select the zones served by this HVAC System	
Use the check boxes to select the zones to be served by this HVAC system.	
Zones	×
E Building 1	
Ground	
₩ Zone 4	
□ □ □ □ 0 0 Zone 5 □ - □ □ Middle	
⊡tt Zone 1	
─────────────────────────────────────	
·····································	
Zone 5	
⊡-⊡ூ Top - ⊡ Ø Zone 1	
────────────────────────────────────	
v ⊗ Zone 5	
	_11
Options	×
Replace all existing HVAC systems	
Override template defaults	
Cancel Help Back Next Finish	

Step 9: In the navigation bar, expand **CHW Loop**.

Navigato, Site Ste Ste Ste Ste Ste Statuto HVAC System HVAC System HVAC System	Site, Building 1
	Edt Visualise Heating design Cooling design Simulation CFD Daylighting Cost and Carbon

Step 10: Expand **CHW Loop Supply Side** and click **Chiller**. The Chiller layout appears. Click **Edit component** under the **Help** tab. The Chiller data appears.

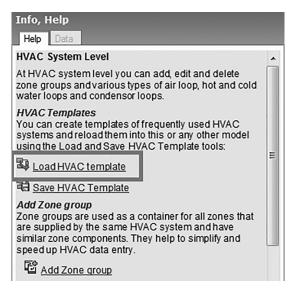


Step 11: Make sure that **Air Cooled Default** is selected for **Chiller template**.

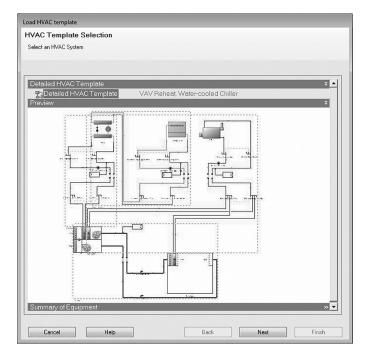
eneral	
Name	Chiller
	Air Cooled Default
Chiller type	2-Electric EIR
Reference capacity (W)	Autosize
Reference COP	5.500
Compressor motor efficiency	1.000
Chiller flow mode	3-Not modulated
Sizing factor	1.00
Condenser	
Condensertype	1-Air cooled
Condenser fan power ratio	0.035
emperatures	
Reference leaving chilled water temperature (*C)	6.670
Reference entering condenser fluid temperature (*C)	29.400
Leaving chilled water temperature limit (*C)	5.000
low Rates	
Reference chilled water flow rate (m3/s)	Autosize
Performance Curves	
Cooling capacity function of temperature curve	Air cooled CentCapFT
Electric input to cooling output ratio function of tem	Air cooled CentEIRFT
Electric input to cooling output ratio function of part	. Air cooled CentEIRFPLR
Part Load Settings	
Minimum part load ratio	0.000
Maximum part load ratio	1.000
Optimum part load ratio	1.000
Minimum unloading ratio	0.250

Step 12: Simulate the model and record Annual Fuel Breakdown results.

Step 13: Select the Edit tab. In the navigation tree click <**HVAC System>** and select Load **HVAC Template**.



Step 14: Repeat the previous steps to select VAV Reheat, Water-cooled Chiller from Select the Detailed HVAC Template.



eneral	
Name	Chiller
‰ Chiller template	DOE-2 Centrifugal/5.50COP
Chiller type	2-Electric EIR
Reference capacity (W)	Autosize
Reference COP	5.500
Compressor motor efficiency	1.000
Chiller flow mode	3-Not modulated
Sizing factor	1.00
ondenser	
Condensertype	2-Water cooled
emperatures	
Reference leaving chilled water temperature (*C)	6.670
Reference entering condenser fluid temperature (*C)	29.400
Leaving chilled water temperature limit (*C)	2.000
ow Rates	
Reference chilled water flow rate (m3/s)	Autosize
Reference condenser water flow rate (m3/s)	Autosize
erformance Curves	
Cooling capacity function of temperature curve	DOE-2 Centrifugal/5.50COP CAPFT
Electric input to cooling output ratio function of tempera	
Electric input to cooling output ratio function of part loa	DOE-2 Centrifugal/5.50COP EIRFPLR
Part Load Settings	
Minimum part load ratio	0.100
Maximum part load ratio	1.000
Optimum part load ratio	1.000
Minimum unloading ratio	0.200

Step 15: Select **DOE-2 Centrifugal/5.50COP** in the chiller template field.

Step 16: Perform annual energy simulation and compare results for both cases (Table 8.1).

	Annual energy consumption (k	
End-use categories	Air-cooled chiller	Water-cooled chiller
Room electricity	153,342.90	153,342.90
Lighting	221,613.80	221,613.80
System fans	168,257.40	168,257.40
System pumps	1,275.77	8,569.14
Heating (gas)	100,853.20	100,853.20
Cooling (electricity)	494,753.60	253,026.60
Heat rejection	Not applicable	55,257.56

Table 8.1 Energy consumption for air- and water-cooled chillers

Air-cooled chillers do not have a cooling tower for condenser cooling. In DesignBuilder, a heat rejection term is used for reporting cooling tower energy consumption. Hence, for the air-cooled chiller in the end-use category – heat rejection – there is no value.

You can also observe that the cooling energy consumption with the water-cooled chiller is less compared with the air-cooled chiller. The use of water instead of air increases the efficiency of heat transfer from the condenser, thereby increasing the efficiency of the chiller.

However, due to the addition of a water loop, a circulation pump called condenser water pump is required, which increases the energy consumption under system pumps.

Save the simulation model with the water-cooled chiller to use in subsequent tutorials.

TUTORIAL 8.2 Evaluating the impact of variable speed drive (VSD) on a chiller

GOAL

To evaluate the impact of VSD on a centrifugal chiller on building energy consumption.

WHAT ARE YOU GOING TO LEARN?

Modelling the chiller with VSD

PROBLEM STATEMENT

In this tutorial, you are going to use the water-cooled chiller model saved in Tutorial 8.1 (50 m \times 25 m model with 5 m perimeter depth, six floors).

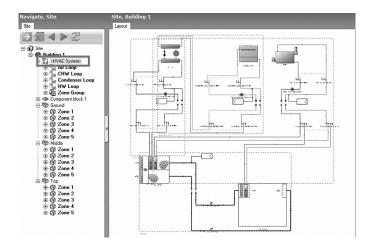
You need to select the following two chillers and find out energy consumption in both cases:

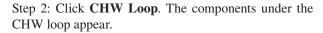
- 1. EIRchiller Centrifugal Carrier 19XR 1213kW/ 7.78COP/Vanes
- EIRchiller Centrifugal Carrier 19XR 1143kW/ 6.57COP/VSD

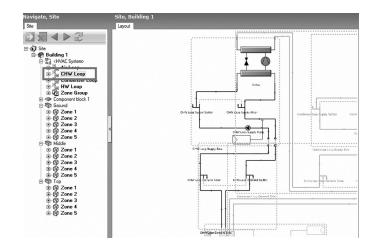
Use **AZ-PHOENIX/SKY HARBOR**, USA weather location.

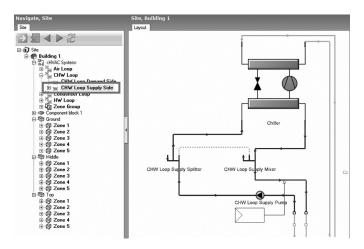
SOLUTION

Step 1: Open the simulation model saved in Tutorial 8.1. Click **<HVAC System>** in the navigation pane.



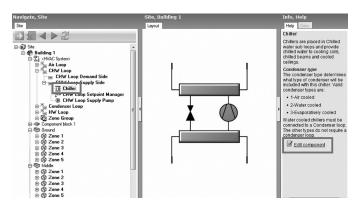






Step 3: Click CHW Loop Supply Side.

Step 4: Click **Chiller**. The chiller layout appears on the **Layout** tab. Click **Edit component** under the **Help** tab. The **Edit Chiller** screen appears.



Step 5: Click **DOE-2 Centrifugal/5.5COP**. Three dots (...) appear. Click the three dots. The **Select the Chiller** screen appears.

General	v
	Chiller
Name 22 Chillestanulute	
2 Chiller template	DOE-2 Centrifugal/5.50COP
Chiller type	2-Electric EIR
Reference capacity (W)	Autosize
Reference COP	5.500
Compressor motor efficiency	1.000
Chiller flow mode	3-Not modulated
Sizing factor	1.00
Condenser	×
Condenser type	2-Water cooled 🔹
Temperatures	*
Reference leaving chilled water temperature (*C)	6.670
Reference entering condenser fluid temperature (*C)	29.400
Leaving chilled water temperature limit (*C)	2.000
Flow Rates	*
Reference chilled water flow rate (m3/s)	Autosize
Reference condenser water flow rate (m3/s)	Autosize
Performance Curves	×
Cooling capacity function of temperature curve	DOE-2 Centrifugal/5.50COP CAPFT
Electric input to cooling output ratio function of temperat.	DOE-2 Centrifugal/5.50COP EIRFT
Electric input to cooling output ratio function of part load.	. DOE-2 Centrifugal/5.50COP EIRFPLR
Part Load Settings	×
Minimum part load ratio	0.100
Maximum part load ratio	1.000
Optimum part load ratio	1.000
Minimum unloading ratio	0.200
Heat Recovery	*
Heat recovery	

Step 6: Click ElectricEIRChiller Centrifugal Carrier 19XR 1213kW/7.78COP/Vanes.

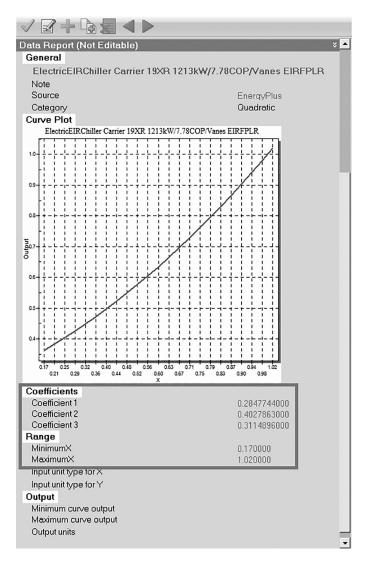
Select the Chiller	
ElectricEIRChiller Centrifugal Carrier 19XL 1871kW/6.49C0P/Vanes	<u>^</u>
ElectricEIRChiller Centrifugal Carrier 19XL 2057kW/6.05C0P/Vanes	
ElectricEIRChiller Centrifugal Carrier 19XR 1076kW/5.52C0P/Vanes	
ElectricEIRChiller Centrifugal Carrier 19XR 1143kW/6.57C0P/VSD	
ElectricEIRChiller Centrifugal Carrier 19XR 1157kW/5.62C0P/VSD	
ElectricEIRChiller Centrifugal Carrier 19/R 1196/W//6 50C0PA/anec	
ElectricEIRChiller Centrifugal Carrier 19XR 1213kW/7.78C0P/Vanes	
Electrice IRChiller Centrifugal Carrier 13XH 1234KW75.33CUP7V5D	
ElectricEIRChiller Centrifugal Carrier 19XR 1259kW/6.26C0P/Vanes	
ElectricEIRChiller Centrifugal Carrier 19XR 1284kW/6.20C0P/Vanes	
ElectricEIRChiller Centrifugal Carrier 19XR 1294kW/7.61C0P/Vanes	
ElectricEIRChiller Centrifugal Carrier 19XR 1350kW/7.90C0P/VSD	
ElectricEIRChiller Centrifugal Carrier 19XR 1403kW/7.09C0P/VSD	
ElectricEIRChiller Centrifugal Carrier 19XR 1407kW/6.04C0P/VSD	
ElectricEIRChiller Centrifugal Carrier 19XR 1410kW/8.54C0P/VSD	
ElectricEIRChiller Centrifugal Carrier 19XR 1558kW/5.81C0P/VSD	
ElectricEIRChiller Centrifugal Carrier 19XR 1586kW/5.53COP/VSD	
ElectricEIRChiller Centrifugal Carrier 19XR 1635kW/6.36C0P/Vanes	
ElectricEIRChiller Centrifugal Carrier 19XR 1656kW/8.24CDP/VSD	
ElectricElRChiller Centrifugal Carrier 19/R 1723/W//8 32C0P/VSD	-
Grance OK	•

Step 7: Click **Electric input to cooling output ratio function of part load ratio curve**. EIR vs part load curve is displayed on the right side.

Numerically, EIR (energy input ratio) is the inverse of COP. The part-load ratio is the ratio of actual cooling load delivered at any point of time compared to the chiller's cooling capacity.

Contract op in the second se	General	
Contract op in the second se	Name	Chiller
Parterines cepacity (M) 121200.000 Parterines cepacity (M) 121200.000 Comprises motor efficiency 700 Comprises motor efficiency 1000 Stating floct 100 Conditionate flops 100 Conditionate flops 100 Conditionate flops 100 Partering centres 100 Conditionate flops 100 Partering centres	# Chiller template	ElectricEIRChiller Centrifugal Carrier 19XR 1213kW/7.78COP/Vane
Partners CDP 100 Compress mode of Bioley, O 0.00 Stating factor 1.00 Contrainer for mode of Bioley, O 1.00 Partner colleging, Contrainer find Imprestrue (°C) 6.110 Reference leaving childed webrit fremperstrue (°C) 2.000 Facterization 0.022403 Reference contrain (Contrainer find)) 0.022403 Reference contrainer contrainer (Contrainer find)) 0.027203 Contrainer for the (Contrainer find) 0.027203 Contrainer find) function of the partner contrainer contrainer the contrainer contrainer the contrain	Chiller type	2-Electric EIR
Compression motor efficiency 1.00 Delating from modulated 3-Vector modulated Stating floor modulated 100 Conditionare type 2-Vector modulated Conditionare type 2-Vector modulated Reference temperature (C) 6.110 Reference contenders fluid event temperature (C) 12.290 Lawing childel weet from reference million 2000 Profession 2000 Reference contender (mS) 0.012:230 Reference contender vector (mS) 0.017:230 Reference contender vector (mS) 0.017:00	Reference capacity (W)	1213200.000
Other forwards 3-Hot modulated Steing factor 100 Condense rybe	Reference COP	7.780
Chile for mode 3Hot modulent Sing factor and Sing factor and S	Compressor motor efficiency	1.000
Condenses in 2014 Condenses in 2014 Temperatures in 2014 Reference leaving chiled weet remperature (C) Reference entrong condense reference condenses Reference entrong condense reference (C) Reference entrong condense reference (C) Reference childs weet four rate (m,1y) Reference childs weet four rate (m,1y) Reference condenses weet four rate (m,1y) Referen		3-Not modulated
Continent type PAMeter cooled Reference tensors 6110 Reference tensors 6110 Reference tensors 12.280 Lawing childed water temperature (°C) 12.290 Reference centers 2000 Reference centers of (n) 0.012.430 Reference controls water temperature (n) 0.012.430 Reference controls water from refs (n) 0.012.230 Reference controls water (n) 10.012.230 Reference controls water (n) 10.012.030 Reference controls water (n) 10.012.030 Reference controls water (n) 10.010 Reference controls water (n) 10.000 Reference controls water (n) 10.000 Reference controls water (n) 10.000	Sizing factor	1.00
Temperatures ² 6.110 Reference leaving childed wetter temperature (°C) 6.110 Reference leaving childed wetter temperature (°C) 12.780 Leaving childed wetter temperature (°C) 2.000 Reference classifier 0.002430 Reference classifier 0.002430 Reference classifier 0.047820 Choine for or die (rh.3/s) 0.047820 Reference classifier 0.047820 Choine for or die (rh.3/s) 0.047820 Reference childer wetter for or die (rh.3/s) 0.047820 Childer Choine for or die (rh.3/s) 0.047820 Reference childer wetter for or die (rh.3/s) 0.047820 Childer Choine for or die (rh.3/s) 0.047820 Reference childer wetter for on die (rh.3/s) 0.047820 Childer Chenier for on die (rh.3/s) 0.047820 Reference childer wetter for on die (rh.3/s) 0.0170 Minimum per load relo 1.020	Condenser	
Parternova terming chilled valet temperature (*) 6 110 Leaving chilled valet temperature (*) 12 290 Leaving chilled valet temperature (*) 2000 Prover basis	Condensertype	2-Water cooled
Peterse centering condenser fluid emperature (°C) 12.780 Leaving childrel weber temperature fluid (°C) 2.000 2012/001 2000 Defension childrel weber temperature fluid (°C) 0.022/00 Reference conclusion value floor rate (roll) 0.047200 Reference conclusion value floor rate (roll roll) 0.000	Temperatures	
Learling childs where temperature limit (C) 2000 Final Reserve Conference Con	Reference leaving chilled water temperature (*C)	6.110
Erge Floet Enterinse of line (min) 002400 Reference of line (min) 0047800 Reference of line (min) 0047800 Reference of line (min) ElectricEIRChiller Conier 1987;1213W/77800P/Verse CAPFT Reference of line (min) ElectricEIRChiller Conier 1987;1213W/77800P/Verse EIRFT Reference of line (min) ElectricEIRChiller Conier 1987;1213W/77800P/Verse EIRFT Reference of line (min) 0.0170 Minimum peri load relio 0.170 Meximum peri load relio 1.000	Reference entering condenser fluid temperature ("C)	12.780
Patersonic onlined water for very (m3) 0.02240 Patersonic onlined water for very (m3) 0.07250 Patersonic onlined water for very (m3) 0.07260 Patersonic onlined water for very (m3) 0.07260 Patersonic onlined water for very (m3) 0.07260 Patersonic onlined water for very (m3) ElectricEPCNIIIer Comier 15-R1 213.WU7 7800P/Vanes CAPPT Patersonic onlined water for very (m3) ElectricEPCNIIIer Comier 15-R1 213.WU7 7800P/Vanes ERPFLF Patersonic onlined water for very (m3) ElectricEPCNIIIer Comier 15-R1 213.WU7 7800P/Vanes ERPFLF Patersonic onlined water for very (m3) 0.170 Minimum part load relio 0.170 Meximum part load relio 1.000	Leaving chilled water temperature limit ("C)	2.000
Participation consider an under flow rate (m3/s) 0.47820 Constraintschware Electrication constraints and constraint constraints and constraint constraints and co	Flow Rates	
Performance Lances Performance Perfor	Reference chilled water flow rate (m3/s)	0.032430
Cloning capacity function of temperature curve ElectricEFicAlier Comier 1984 1213W/77800P/venes EFFT Minimum part load ratio Minimum part load ratio 100		0.047820
Tellectric input to control contruct include from of the measurement on control Tellectric input to control contruct include incline of the measurement on control Tellectric input to control control on the measurement on control Tellectric input to control control on the measurement on control Tellectric input to control on the measurement on control Tellectric input to control on the measurement on control Tellectric input to control on the measurement on control Tellectric input to control on the measurement on control Tellectric input to control on the measurement on control Tellectric input to control on the measurement on control Tellectric input to control on the measurement on control Tellectric input to control on the measurement on control Tellectric input to control on the measurement on control Tellectric input to control on the measurement on control Tellectric input to control on control Tellectric input to control Tellectritectric input to control Tellectric input to control Telle		
Electrical input to cooling output ratio function of port load ratio annel Electrical RCAliter Center 159R 1213/W/77800F/Varies ERFPLE Minimum part load ratio 0.170 Minimum part load ratio 1.020 Optimum part load ratio 1.000	Cooling capacity function of temperature curve	ElectricEIRChiller Carrier 19XR 1213kW/7.78COP/Vanes CAPFT
Minimum part load ratio 0.170 Moinnum part load ratio 1.020 Optimum part load ratio 1.030	Electric input to cooling output ratio function of temperature curve	ElectricEIRChiller Carrier 19XR 1213kW/7.78COP/Vanes EIRFT
Minimum part load ratio 0170 Makimum part load ratio 1020 Optimum part load ratio 1000	Electric input to cooling output ratio function of part load ratio curve	ElectricEIRChiller Carrier 19XR 1213kW/7.78COP/Vanes EIRFPLP
Maximum part load ratio 1,020 Optimum part load ratio 1,000	Plant Load Clowings	
Optimum part load ratio 1.000	Minimum part load ratio	0.170
opinium particular data	Maximum part load ratio	1.020
Minimum unloading ratio 0170	Optimum part load ratio	1.000
Heat Recovery	Minimum unloading ratio	0.170

You can also view the curve coefficients.



Performance Curves

Cooling capacity function of temperature curve

The biquadratic performance curve parameterizes the variation of the cooling capacity as a function of the leaving chilled water temperature and the entering condenser fluid temperature. The output of this curve is multiplied by the reference capacity to give the cooling capacity at specific temperature operating conditions (i.e. at temperatures different from the reference temperatures). The curve should have a value of 1.0 at the reference temperatures and flow rates specified above. The biquadratic curve should be valid for the range of water temperatures anticipated for the simulation.

Electric input to cooling output ratio function of temperature curve

The biquadratic performance curve parameterizes the variation of the energy input to cooling output ratio (EIR) as a function of the leaving chilled water temperature and the entering condenser fluid temperature. The output of this curve is multiplied by the reference EIR (inverse of the reference COP) to give the EIR at specific temperature operating conditions (i.e. at temperatures different from the reference temperatures). The curve should have a value of 1.0 at the reference temperatures and flow rates specified above. The biquadratic curve should be valid for the range of water temperatures anticipated for the simulation.

Electric input to cooling output ratio function of part load ratio curve

The quadratic performance curve parameterizes the variation of the EIR as a function of the part load ratio. The output of this curve is multiplied by the reference EIR (inverse of the reference COP) and the energy input to cooling output ratio function of temperature curve to give the EIR at the specific temperatures and part load ratio at which the chiller is operating. This curve should have a value of 1.0 when the part load ratio equals 1.0. The quadratic curve should be valid for the range of part load ratios anticipated for the simulation.

> Source: http://www.designbuilder.co.uk/ helpv4.7/Content/Performance_Curves.htm

Step 8: Perform annual simulation and record the results.

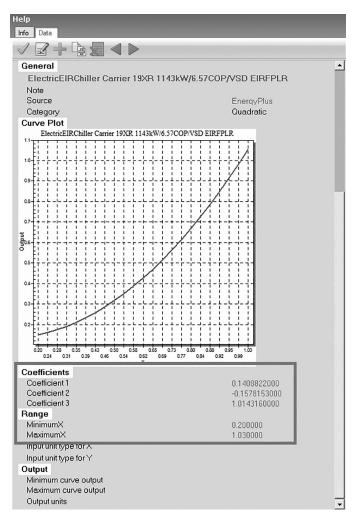
Step 9: Repeat the previous steps to select ElectricEIRChiller Centrifugal Carrier 19XR 1143kW/6.57COP/VSD.

Select the Chiller	
ElectricEIRChiller Centrifugal Carrier 19EX 4997kW/6.40C0P/Vanes ElectricEIRChiller Centrifugal Carrier 19EX 5148kW/6.34C0P/Vanes ElectricEIRChiller Centrifugal Carrier 19EX 5208kW/6.88C0P/Vanes ElectricEIRChiller Centrifugal Carrier 19FA 5651kW/5.50C0P/Vanes ElectricEIRChiller Centrifugal Carrier 19KL 1674kW/7.89C0P/Vanes ElectricEIRChiller Centrifugal Carrier 19KL 1674kW/7.618C0P/Vanes	-
ElectricEIRChiller Centrifugal Carrier 19xL 1797kW75.69C0P/Vanes ElectricEIRChiller Centrifugal Carrier 19xL 1871kW75.69C0P/Vanes ElectricEIRChiller Centrifugal Carrier 19xL 2057kW76.05C0P/Vanes ElectricEIRChiller Centrifugal Carrier 19xL 2057kW76.05C0P/Vanes ElectricEIRChiller Centrifugal Carrier 19xR 1143kW76.57C0P/VSD	
ElectricEIRChiller Centrifugal Carrier 13xR 1196kW/6.50C0P/Vanes ElectricEIRChiller Centrifugal Carrier 13xR 1196kW/6.50C0P/Vanes ElectricEIRChiller Centrifugal Carrier 13xR 123kkW/5.39C0P/VSD ElectricEIRChiller Centrifugal Carrier 13xR 125kW/6.26C0P/Vanes ElectricEIRChiller Centrifugal Carrier 13xR 125kW/6.20C0P/Vanes	

General	Chiller
Name	
% Chiller template	ElectricEIRChiller Centrifugal Carrier 19XR 1143kW/6.57COP/VSD
Chillertype	2-Electric EIR
Reference capacity (W)	1142900.000
Reference COP	6.570
Compressor motor efficiency	1.000
Chiller flow mode	3-Not modulated
Sizing factor	1.00
Condenser	
Condensertype	2-Water cooled
Temperatures	
Reference leaving chilled water temperature ("C)	10.000
Reference entering condenser fluid temperature (°C)	26.670
Leaving chilled water temperature limit (*C)	2.000
Flow Rates	
Reference chilled water flow rate (m3/s)	0.025930
Reference condenser water flow rate (m3/s)	0.051420
Performance Curves	
Cooling capacity function of temperature curve	ElectricEIRChiller Carrier 19XR 1143kW/6.57COP/VSD CAPFT
Electric input to cooling output ratio function of temperature curve	ElectricEIRChiller Carrier 19XR 1143kW/6.57COP/VSD EIRFT
Electric input to cooling output ratio function of part load ratio curve	ElectricEIRChiller Carrier 19XR 1143kW/6.57COP/VSD EIRFPLR
Part Load Settings	
Minimum part load ratio	0.200
Maximum part load ratio	1.030
Optimum part load ratio	1.000
Minimum unloading ratio	0.200

VSD on the chiller provides you better efficiency while operating in part-load conditions.

You can also view the curve coefficients.



Step 10: Simulate the model and record the results.

Compare the energy consumption for both cases (Table 8.2).

	Annual energy consumption (kWh)		
	Chiller without VSD	Chiller with VSD	
Room electricity	153,342.90	153,342.90	
Lighting	221,613.80	221,613.80	
System fans	168,257.40	168,257.40	
System pumps	13,138.87	14,004.84	
Heating (gas)	100,853.20	100,853.20	
Cooling (electricity)	302,814.30	115,774.90	
Heat rejection	80,947.34	82,738.82	

 Table 8.2
 Effect of VSD on the chiller

There is a significant reduction in cooling energy consumption with the VSD chiller. If you want to analyse the results, you need to look at the cooling load profile of the building.

Installing VSD on the chiller provides you better efficiency while operating in part load conditions.

TUTORIAL 8.3 Evaluating the impact of VSD on a chilled water pump

GOAL

To evaluate the impact of VSD on a chilled water pump on the building energy consumption.

WHAT ARE YOU GOING TO LEARN?

• Modelling the variable speed chilled water pump

PROBLEM STATEMENT

In this tutorial, you are going to use the water-cooled chiller model saved in Tutorial 8.1 (50 m \times 25 m model with 5 m perimeter depth, six floors).

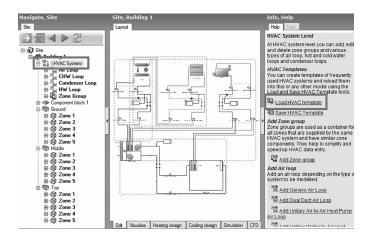
You need to select the following two configurations of the chilled water pump and compare energy consumption in both cases:

- 1. Constant flow
- 2. Variable flow

Use **FL** – **MIAMI, USA** weather location. Miami has a tropical monsoon climate with hot, humid summers and short, warm winters, with a marked drier season in the winter.

SOLUTION

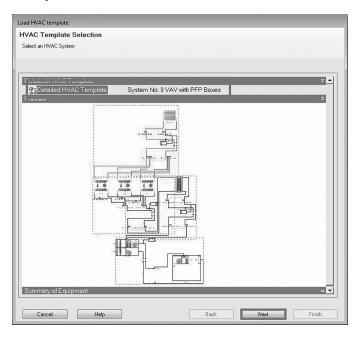
Step 1: Open the simulation model saved in Tutorial 8.1. Click **<HVAC System>** in the navigation pane. Click **Load HVAC template**.



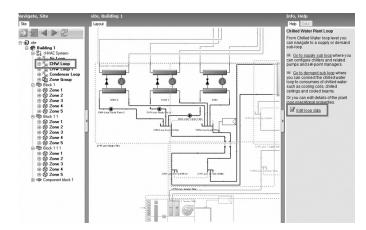
Step 2: Select **System No. 8 VAV with PFP Boxes** from ASHRAE 90.1 Appendix G baseline. Click **OK**. The **Load HVAC template** appears.

Select the Detailed HVAC Template	
⊡-/→ ASHRAE 90.1 Appendix G baseline	
System No. 1 PTAC	
- 📳 System No. 10 Heating (Electric) and Ventilation	
System No. 2 PTHP	
System No. 3 PSZ-AC	Ξ
System No. 4 PSZ-HP	
System No. 5 Packaged VAV with Reheat	
PI Custon No. 71/AL (with Pohon)	
System No. 9 Heating (Furnace) and Ventilation	
⊕ 🦳 DHW	
🖕 🦳 Heating and Cooling Systems	
ASHP Air-to-water Heat Pump, Integrated Boiler, Water Convector	
ASHP Air-to-water Heat Pump, Water Convector	
In the work of the second chiller	
CAV with 4-Pipe Induction Units	
In the second contract of the second chiller	
Land Convector Heating Electric Nat Vent	
Cancel OK	

Step 3: Click **Next**. Select all the check boxes from the **Zones** section. Click **Finish**. It displays the system layout.



Step 4: Select **CHW Loop**. Click **Edit loop data** under the **Help** tab. The **Edit Plant loop** screen appears.



Step 5: Select **Constant flow** from the Plant loop flow type.

lant loop Data			Help
General Plant Equipment Operation			Info Data
General		×	Chilled Water Loop
Name	CHW Loop		The Chilled water loop consists of:
Fluid type	1-Water	•	 Supply sub loop which contains one or more chillers, a pump and a setpoint controller.
Plant loop volume (m3)	Autocalculate		Demand sub loop which distributes the chilled
Tow Type		×	 Demand sub loop which distributes the chilled water to water cooling coils, chilled ceilings, cooled
Plant loop flow type	1-Constant flow		beams etc."
Femperature		~	This dialog covers the sizing and operation details of
Maximum loop temperature ("C)	80.00		the overall loop.
Minimum loop temperature (°C)	0.00		Load Distribution Scheme The Load Distribution Scheme selects the algorithm
Tow Rate		×	used to sequence equipment operation in order to
Maximum loop flow rate (m3/s)	Autosize		meet the plant loop demand. There are 3 options:
Minimum loop flow rate (m3/s)	0.000000		 'Sequential' uses each piece of equipment to its maximum part load ratio and will operate the last
Load distribution scheme	1-Sequential		required piece of equipment between its minimum
Plant loop demand calculation scheme	1-SingleSetPoint		and maximum part load ratio in order to meet the
Sizing		¥	loop demand.
Design loop exit temperature ("C)	6.67		 'Optimal operates each piece of equipment at its optimal part load ratio and will operate the last
Loop design temperature difference (deltaC)	6.67		component between its minimum and maximum
Operation		¥	part load ratio in order to meet the loop demand.
Availability schedule	On 24/7		 'Uniform' evenly distributes the loop demand amongst all available components on the
Outside Temperature Operation		¥	equipment list for a given load range.
Outside temperature operation			

Step 6: Perform annual energy simulation and record the results.

Step 7: Repeat the previous steps for **Variable flow** CHW Loop.

lant loop Data			Help
General Plant Equipment Operation			Info Data
General		× I	Chilled Water Loop
Name	CHW Loop		The Chilled water loop consists of:
Fluid type	1-Water		 Supply sub loop which contains one or more chillers, a pump and a setpoint controller.
Plant loop volume (m3)	Autocalculate		Chillers, a pump and a setpoint controller. Demand sub loop which distributes the chilled
Tow Type		×1	 Demand sub loop which distributes the chilled water to water cooling coils, chilled ceilings, cooled
Plant loop flow type	2-Variable flow		beams etc."
l'emperature		*	This dialog covers the sizing and operation details of the overall loop.
Maximum loop temperature ("C)	80.00		I ned Distribution Scheme
Minimum loop temperature ("C)	0.00		The Load Distribution Scheme selects the algorithm
Tow Rate		×	used to sequence equipment operation in order to
Maximum loop flow rate (m3/s)	Autosize		meet the plant loop demand. There are 3 options:
Minimum loop flow rate (m3/s)	0.000000		 'Sequential' uses each piece of equipment to its maximum part load ratio and will operate the last
Load distribution scheme	1-Sequential	•	required piece of equipment between its minimum
Plant loop demand calculation scheme	1-SingleSetPoint	•	and maximum part load ratio in order to meet the loop demand.
Sizing		¥	 'Optimal operates each piece of equipment at its
Design loop exit temperature ("C)	6.67		optimal part load ratio and will operate the last
Loop design temperature difference (deltaC)	6.67		component between its minimum and maximum part load ratio in order to meet the loop demand.
Operation		¥	'Uniform' evenly distributes the loop demand
Availability schedule	On 24/7		amongst all available components on the
Outside Temperature Operation		×	equipment list for a given load range.
Outside temperature operation			

Step 8: Perform annual energy simulation and record the results.

Save the simulation model to use in subsequent tutorials.

Compare the energy consumption in both cases (Table 8.3).

	Annual energy consumption (kWh)				
End-use category	Constant flow	Variable flow			
Room electricity	153,342.90	153,342.90			
Lighting	221,613.80	221,613.80			
System fans	72,965.29	72,965.28			
System pumps	255,151.10	235,740.20			
Heating (electricity)	8,253.35	8,253.35			
Cooling (electricity)	297,860.90	296,225.90			
Heat rejection	117,246.00	117,093.10			

Table 8.3Energy consumption for constant and
variable flow on the chilled water pump

You can observe that there is a reduction in pump energy, cooling energy and energy consumption for heat rejection. Where variable flow is used, it can be clearly seen that there is less energy consumption for system pumps. Also there is a small decrease in cooling energy consumption of chiller and heat rejection due to the change in operating conditions of the chiller.

TUTORIAL 8.4 Evaluating the impact of a cooling tower fan type

GOAL

To evaluate the impact of a cooling tower fan type on the building energy consumption.

WHAT ARE YOU GOING TO LEARN?

- Modelling the cooling tower with a single speed fan
- Modelling the cooling tower with a double speed fan

PROBLEM STATEMENT

In this tutorial, you are going to use the variable flow model saved in Tutorial 8.3 (50 m \times 25 m model with 5 m perimeter depth, six floors).

You need to select the following two configurations of the chilled water pump and find out energy consumption in both cases:

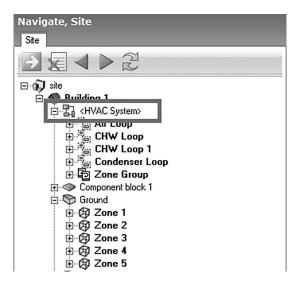
- 1. Single speed fan cooling tower
- 2. Double speed fan cooling tower

Use AZ-PHOENIX/SKY HARBOR, USA weather location.

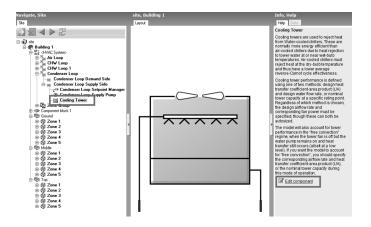
A cooling tower is an equipment that rejects heat extracted from the building to the atmosphere by the evaporation of water. Cooling tower fans help in governing the air flow and rate of evaporation.

SOLUTION

Step 1: Open the variable flow model saved in Tutorial 8.3. Expand **<HVAC System>** in the navigation pane.



Step 2: Select **Cooling Tower** under **Condenser Loop Supply Side**. Click **Edit component** under the **Help** tab. The **Edit Cooling Tower** screen appears.



Step 3: Select **Single speed** for cooling tower type.

Name	_ Cooling Tower
Cooling tower type	1-Single speed
Design air flow rate (m3/s)	Autosize
Fan power at design air flow rate (W)	Autosize
Air flow rate in free convection regime (m3/s)	Autosize
Evaporation loss mode	1-Saturated exit
Drift loss percent	0.008
Heating sizing factor	1.00
Performance Input Method	
Performance input method	2-UA and design water flow rate
Design water flow rate (m3/s)	Autosize
UA at design air flow rate (W/K)	Autosize
UA at free convection air flow rate (W/K)	Autosize
Free convection air flow rate sizing factor	0.100
Basin Heater Settings	
Basin heater capacity (W/K)	0.0
Basin heater setpoint temperature (*C)	2.00
🙀 Basin heater operating schedule	On 24/7
Blowdown	
Blowdown calculation mode	1-Concentration ratio
Blowdown concentration ratio	3.000
Capacity Control	
Capacity control	1-Fan cycling
Multi-Cell Tower Settings	

Step 4: Simulate the model and record the results.

Step 5: Repeat the previous steps to select **Double speed** cooling tower type.

CHAPTER EIGHT CENTRAL HVAC SYSTEM

Cooling tower type 2-Double speed Design air flow rate (m3/s) Autosize Fan power at design air flow rate (W) Autosize Air flow rate in free convection regime (m3/s) Autosize Evaporation loss mode 1-Saturated exit Drift loss percent 0.008 Heating sizing factor 1.00 enformance Input Method 2-UA and design water flow rate Performance Input Method 2-UA and design water flow rate Low fan speed UA value Autosize Star flow rate (m3/s) Autosize Low fan speed UA value Autosize Low fan speed UA sizing factor 0.000 Design water flow rate (m3/s) Autosize Free convection air flow rate sizing factor 0.100 asin heater capacity (W/K)	eneral	
Design air flow rate (m3/s) Autosize Fan power at design air flow rate (W) Autosize Air flow rate in free convection regime (m3/s) Autosize Evaporation loss mode 1-Saturated exit Drift loss percent 0.008 Heating sizing factor 1.00 erformance Input Method 2-UA and design water flow rate Performance input method 2-UA and design water flow rate Low fan speed UA value Autosize Low fan speed UA value Autosize Low fan speed UA value Autosize UA at design air flow rate (m3/s) Autosize UA at design air flow rate (m3/s) Autosize UA at design air flow rate (m3/s) Autosize UA at free convection air flow rate (W/K) Autosize Free convection air flow rate (W/K) Autosize Basin heater capacity (W/K) 0.0 Basin heater capacity (W/K) 0.0 Basin heater operating schedule On 24/7 Blowdown calculation mode 1-Concentration ratio Blowdown calculation mode 1-Concentration ratio Blowdown concentration ratio 3.000	Name	Coolina Tower
Fan power at design air flow rate (W) Autosize Air flow rate in free convection regime (m3/s) Autosize Evaporation loss mode 1-Saturated exit Drift loss percent 0.008 Heating sizing factor 1.00 Performance input Method 2-UA and design water flow rate High fan speed UA value Autosize Low fan speed UA value Autosize UA at design air flow rate (m3/s) Autosize UA at design air flow rate (W/K) Autosize UA at free convection air flow rate (W/K) Autosize UA at free convection air flow rate sizing factor 0.100 Iosin heater capacity (W/K) 0.0 Basin heater capacity (W/K) 0.0 Basin heater capacity (W/K) 0.0 Blowdown calculation mode 1-Concentration ratio Blowdown concentration ratio 3.000 Capacity Control Io	Cooling tower type	2-Double speed
Fair flow rate in free convection regime (m3/s) Autosize Evaporation loss mode 1-Saturated exit Drift loss percent 0.008 Heating sizing factor 1.00 Performance Input Method 2-UA and design water flow rate High fan speed UA value Autosize Low fan speed UA value Autosize Low fan speed UA value Autosize Design water flow rate (m3/s) Autosize UA at design air flow rate (m3/s) Autosize UA at design air flow rate (W/K) Autosize UA at free convection air flow rate (W/K) Autosize UA at free convection air flow rate sizing factor 0.100 Josin heater capacity (W/K) 0.0 Basin heater capacity (W/K) 0.0 Basin heater operating schedule On 24/7 Blowdown concentration mode 1-Concentration ratio Blowdown concentration ratio 3.000 Capacity Control Control	Design air flow rate (m3/s)	Autosize
Surfaction loss mode 1-Saturated exit Drift loss percent 0.008 Heating sizing factor 1.00 Performance Input Method 2-UA and design water flow rate High fan speed UA value Autosize Low fan speed UA value 0.000 Design water flow rate (m3/s) Autosize UA at design air flow rate (m3/s) Autosize UA at free convection air flow rate (W/K) Autosize UA at free convection air flow rate (W/K) Autosize Basin heater capacity (W/K) 0.0 Blowdown calculation mode 1-Concentration ratio Blowdown concentration ratio 3.000 Capacity Control 0.00	Fan power at design air flow rate (W)	Autosize
Even point loss percent 0.008 Heating sizing factor 1.00 Performance Input Method 2-UA and design water flow rate High fan speed UA value Autosize Low fan speed UA value 0.000 Low fan speed UA value 0.000 Design water flow rate (m3/s) Autosize UA at design air flow rate (W/K) Autosize UA at design air flow rate (W/K) Autosize UA at design air flow rate (W/K) Autosize UA at free convection air flow rate (W/K) Autosize Basin heater capacity (W/K) 0.00 Basin heater setpoint temperature (*C) 2.00 (#) Basin heater operating schedule On 24/7 Blowdown calculation mode 1-Concentration ratio Blowdown concentration ratio 3.000 Capacity Control Image: design	Air flow rate in free convection regime (m3/s)	Autosize
Performance input Method 1.00 Performance input Method 2-UA and design water flow rate High fan speed UA value Autosize Low fan speed UA value Autosize UA at design air flow rate (W/K) Autosize UA at free convection air flow rate (W/K) Autosize Free convection air flow rate (W/K) Autosize Basin heater capacity (W/K) 0.0 Basin heater capacity (W/K) 0.0 Basin heater setpoint temperature (°C) 2.00 (#] Basin heater operating schedule On 24/7 Nowdown I-Concentration ratio Blowdown calculation mode 1-Concentration ratio Blowdown concentration ratio 3.000	Evaporation loss mode	1-Saturated exit
Performance Input Method 2-UA and design water flow rate High fan speed UA value Autosize Low fan speed UA value Autosize UA at design air flow rate (W/K) Autosize UA at free convection air flow rate sizing factor 0.100 Basin heater capacity (W/K) 0.0 Basin heater capacity (W/K) 0.0 Basin heater setoint temperature (°C) 2.00 [#] Basin heater operating schedule On 24/7 Blowdown 1-Concentration ratio Blowdown calculation mode 1-Concentration ratio Blowdown concentration ratio 3.000 Capacity Control Control	Drift loss percent	0.008
Performance input method 2-UA and design water flow rate High fan speed UA value Autosize Low fan speed UA value Autosize Low fan speed UA value Autosize Low fan speed UA sizing factor 0.000 Design water flow rate (m3/s) Autosize UA at design air flow rate (W/K) Autosize UA at free convection air flow rate (W/K) Autosize Basin heater capacity (W/K) 0.100 Basin heater capacity (W/K) 0.0 Basin heater setpoint temperature (°C) 2.00 Mit Blowdown 0n 24/7 Blowdown calculation mode 1-Concentration ratio Blowdown concentration ratio 3.000	Heating sizing factor	1.00
High fan speed UA value Autosize Low fan speed UA value Autosize Low fan speed UA value Autosize Low fan speed UA sizing factor 0.000 Design water flow rate (m3/s) Autosize UA at design air flow rate (W/K) Autosize UA at free convection air flow rate (W/K) Autosize Eree convection air flow rate sizing factor 0.100 Dasin heater capacity (W/K) 0.0 Basin heater capacity (W/K) 0.0 Basin heater setpoint temperature (°C) 2.00 (*) Basin heater operating schedule 0n 24/7 Blowdown 1-Concentration ratio Blowdown concentration mode 1-Concentration ratio Blowdown concentration ratio 3.000	Performance Input Method	
Ingrin Process of Value Autosize Low fan speed UA value Autosize Low fan speed UA sizing factor 0.000 Design water flow rate (m3/s) Autosize UA at design air flow rate (W/K) Autosize UA at design air flow rate (W/K) Autosize UA at free convection air flow rate sizing factor 0.100 Basin heater capacity (W/K) 0.0 Basin heater capacity (W/K) 0.0 Basin heater operating schedule 0n 24/7 Blowdown calculation mode 1-Concentration ratio Blowdown concentration ratio 3.000	Performance input method	2-UA and design water flow rate
Low fan speed UA sizing factor 0.000 Design water flow rate (m3/s) Autosize UA at design air flow rate (m3/s) Autosize UA at design air flow rate (W/K) Autosize UA at free convection air flow rate (W/K) Autosize Free convection air flow rate sizing factor 0.100 Jasin heater capacity (W/K) 0.0 Basin heater capacity (W/K) 0.0 Basin heater operating schedule 0n 24/7 Jowdown Jowdown Blowdown calculation mode 1-Concentration ratio Blowdown concentration ratio 3.000	High fan speed UA value	Autosize
Design water flow rate (m3/s) Autosize UA at design air flow rate (W/K) Autosize UA at free convection air flow rate (W/K) Autosize UA at free convection air flow rate sizing factor 0.100 Jasin Heater Settings 0.0 Basin heater capacity (W/K) 0.0 Basin heater capacity (W/K) 0.0 Basin heater operating schedule 0n 24/7 Jowdown 1-Concentration ratio Blowdown concentration mode 1-Concentration ratio Blowdown concentration ratio 3.000	Low fan speed UA value	Autosize
Design rate index (indys) Autosize UA at design air flow rate (W/K) Autosize UA at free convection air flow rate (W/K) Autosize Free convection air flow rate (W/K) Autosize Basin heater capacity (W/K) 0.0 Basin heater capacity (W/K) 0.0 Basin heater operating schedule On 24/7 Blowdown I-Concentration ratio Blowdown concentration ratio 3.000 Capacity Control Image: Control	Low fan speed UA sizing factor	0.000
UA at free convection air flow rate (W/K) Autosize Free convection air flow rate sizing factor 0.100 Basin Heater Settings Basin heater capacity (W/K) 0.0 Basin heater capacity (W/K) 0.0 Basin heater setpoint temperature (°C) 2.00 Basin heater operating schedule 0n 24/7 Blowdown Blowdown calculation mode 1-Concentration ratio Blowdown concentration ratio 3.000 Capacity Control	Design water flow rate (m3/s)	Autosize
Basin Heater Settings 0.100 Basin Heater Settings 0.0 Basin heater capacity (W/K) 0.0 Basin heater setpoint temperature (*C) 2.00 (****) Basin heater operating schedule On 24/7 Bowdown 1-Concentration ratio Blowdown calculation mode 1-Concentration ratio Blowdown concentration ratio 3.000	UA at design air flow rate (W/K)	Autosize
Basin Heater Capacity (W/K) 0.0 Bowdown 0n 24/7 Blowdown calculation mode 1-Concentration ratio Blowdown concentration ratio 3.000 Capacity Control 0	UA at free convection air flow rate (W/K)	Autosize
Basin heater capacity (W/K) 0.0 Basin heater setpoint temperature (°C) 2.00 (***) Basin heater operating schedule On 24/7 Blowdown	Free convection air flow rate sizing factor	0.100
Basin heater setpoint temperature (°C) 2.00 (***********************************	Basin Heater Settings	
Basin heater operating schedule On 24/7 Blowdown Inconcentration ratio Blowdown calculation mode 1-Concentration ratio Blowdown concentration ratio 3.000 Capacity Control Inconcentration ratio	Basin heater capacity (W/K)	0.0
Blowdown Blowdown calculation mode 1-Concentration ratio Blowdown concentration ratio 3.000 Papacity Control	Basin heater setpoint temperature (°C)	2.00
Blowdown calculation mode 1-Concentration ratio Blowdown concentration ratio 3.000 Capacity Control	😭 Basin heater operating schedule	On 24/7
Blowdown concentration ratio 3.000 Capacity Control	Blowdown	
Capacity Control	Blowdown calculation mode	1-Concentration ratio
	Blowdown concentration ratio	3.000
Capacity control 1-Fan cycling	Capacity Control	
	Capacity control	1-Fan cycling
	Multi-cell tower	

Multi-speed/Variable Speed Drive (VSD) fan is the preferred method of capacity control for cooling towers. By matching the fan motor speeds to the required heat rejection, multi-speed/VSD cooling towers can significantly reduce energy consumption for heat rejection.

Step 6: Perform annual energy simulation and record the results.

Save the simulation model to be used in the next tutorial. Compare results for both cases (Table 8.4).

	Annual energy consumption (kWh)			
End-use components	Single speed cooling tower fan	Double speed cooling tower fan		
Room electricity	153,342.90	153,342.90		
Lighting	221,613.80	221,613.80		
System fans	95,181.46	95,181.46		
System pumps	165,284.00	165,284.00		
Heating (electricity)	52,254.34	52,254.34		
Cooling (electricity)	202,158.00	202,158.00		
Heat rejection	82,768.20	28,458.18		

Table 8.4Energy consumption for single speed and doublespeed cooling tower fans

You can observe from the results that there is a significant reduction in energy consumption under heat rejection.

TUTORIAL 8.5 Evaluating the impact of condenser water pump with VSD

GOAL

To evaluate the impact of using VSD with a condenser water pump on the building energy consumption.

WHAT ARE YOU GOING TO LEARN?

Modelling VSD on the condenser water pump

PROBLEM STATEMENT

In this tutorial, you are going to use the double speed model saved in Tutorial 8.4 (50 m \times 25 m model with 5 m perimeter depth, six floors).

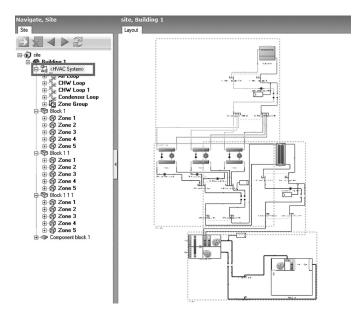
You need to select the following two configurations of the condenser water pump and find out energy consumption in both cases:

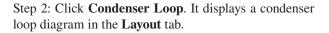
- 1. One speed condenser water pump
- 2. Variable speed condenser water pump

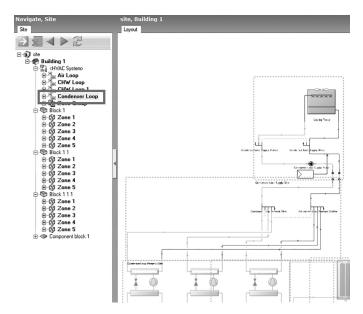
Use FL – MIAMI, USA weather location.

SOLUTION

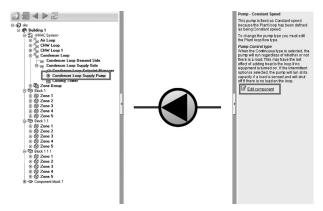
Step 1: Open the double speed model saved in Tutorial 8.4. Expand **<HVAC System>** in the navigation pane.







Step 3: Click **Condenser Loop Supply Pump**. Click **Edit component** under the **Help** tab. The **Edit Pump** screen appears.



Step 4: Select **Constant speed** from the **Type** drop-down list. Click **OK**.

ump Data			Help
General			Info Data
General		×	Pump - Constant Speed
Name	Condenser Loop Suppl	v Pum	This pump is fixed as Constant speed
Туре	1-Constant speed		because the Plant loop has been defined as being Constant speed.
Pump Settlings		× II	To change the pump type you must edit
Rated power consumption (W)	Autosize		the Plant loop flow type.
Rated pump head (Pa)	235241.37		Pump Control type
Motor efficiency	0.90	1	When the Continuous type is selected, the pump will run regardless of whether
Fraction of motor inefficiencies to fluid stre	0.00		or not there is a load. This may have the
Pump control type	2-Intermittent	٠	net effect of adding heat to the loop if no equipment is turned on. If the
			Intermittent option is selected, the pump
			will run at its capacity if a load is sensed and will shut off if there is no load on the

Step 5: Simulate the model and record the results.

Step 6: Repeat the previous steps to select **Variable speed** from the **Type** drop-down list.

mp Data			Help
eneral			Info Data
eneral		¥	Pump - Variable Speed
Name	Condenser Loon Supply Pump		This pump is fixed as Variable speed
Туре	2-Variable speed	•	because the Plant loop has been defined as being Variable speed.
ump Settlings		×١	To change the pump type you must edit the
Rated power consumption (W)	Autosize		Plant loop flow type.
Rated pump head (Pa)	235241.37		Pump Control type
Motor efficiency	0.90		There is a choice of Continuous or Intermittent operation. A variable speed pump
Fraction of motor inefficiencies to fluid stream	0.00		is defined with maximum and minimum flow
Minimum flow rate (m3/s)	0.000000		rates that are the physical limits of the device. If there is no load on the loop and the pump is
Pump control type	2-Intermittent	•	operating intermittently, then the pump can
art Load Performance		¥	shutdown. For any other condition such as the loop having a load and the pump is
Performance curve template	Pump Part-Load Power, Default	V	operating intermittently or the pump is
Pump Coefficients		¥	continuously operating (regardless of the
Pump coefficient 1	0.0000000		loading condition), the pump will operate and select a flow somewhere between the
Pump coefficient 2	1.0000000		minimum and maximum limits. In these cases
Pump coefficient 3	0.0000000		where the pump is running, it will try to meet the flow request made by demand side
Pump coefficient 4	0.0000000		components.
			Autosizable data is shown in blue. This can either have the text 'autosize' or numeric data

Step 7: Simulate the model and record the results.

Annual energy consumption (kWh)			
Single speed condenser water pump	Variable speed condenser water pump		
153,342.90	153,342.90		
221,613.80	221,613.80		
72,965.28	72,965.28		
235,740.20	110,578.00		
8,253.35	8,253.35		
296,225.90	295,302.80		
117,093.10	110,880.00		
	Single speed condenser water pump 153,342.90 221,613.80 72,965.28 235,740.20 8,253.35 296,225.90		

Table 8.5Energy consumption for the single speed andvariable speed condenser water pumps

Compare energy consumption for both cases (Table 8.5).

A reduction in energy consumption under system pumps can be seen in the case of a variable speed condenser water pump. A small reduction in energy consumption for heat rejection can also be seen.

TUTORIAL 8.6 Evaluating the impact of an air-side economiser

GOAL

To evaluate the impact of an air-side economiser on building energy performance.

WHAT ARE YOU GOING TO LEARN?

• Modelling the air-side economiser (free cooling system)

PROBLEM STATEMENT

In this tutorial, you are going to use the variable flow model saved in Tutorial 8.3 (50 m \times 25 m model with 5 m perimeter depth, six floors).

Model the unitary HVAC system with the following options for the air-side economiser:

- 1. None
- 2. Fixed dry bulb temperature based
- 3. Fixed enthalpy based

Find the change in energy consumption for all three cases.

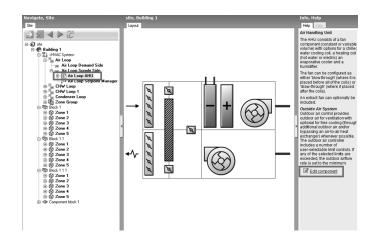
Use **New Delhi/Palam, India** weather location. The climate of New Delhi is a monsoon-influenced humid subtropical climate with high variation between summer and winter in terms of both temperature and rainfall. The temperature varies from 46°C in summers to around 0°C in winters.

An economiser is an adjustable fresh air intake unit that can draw up to 100% outside air when the outside air is cooler than the temperature inside the building and not humid, thereby providing free cooling.

Air-side economisers in HVAC can save energy in buildings by using cool outside air to cool the indoor space. When the temperature and/or enthalpy of the outside air is less than the temperature/enthalpy of the recirculated air, conditioning the outside air is more energy efficient than conditioning recirculated air. When the outside air is both sufficiently cool and dry (depending on the climate), no additional conditioning is required; this portion of the air-side economiser control scheme is called free cooling.

SOLUTION

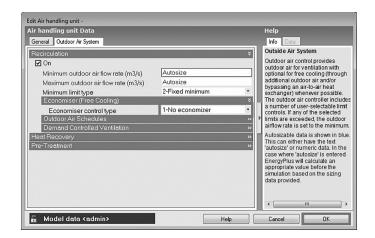
Step 1: Open the variable flow model saved in Tutorial 8.3. Step 2: Click **Air Loop AHU**. Click **Edit component** under the **Help** tab. The **Air handling unit Data** screen appears.



Step 3: Select the **Outdoor Air System** tab.

ecirculation		
🗹 On		
Minimum outdoor air flow rate (m3/s)	Autosize	
Maximum outdoor air flow rate (m3/s)	Autosize	
Minimum limit type	2-Fixed minimum	
Economiser (Free Cooling)		
Economiser control type	2-Fixed dry bulb	
Lockout type	1-No lockout	
Economiser control action type	1-Modulate flow	
Outdoor Dry-Bulb Temperature Low Limit Control		
Outdoor dry-bulb temperature low limit control	bl	
Outdoor Dry-Bulb Temperature High Limit Contro		
Outdoor dry-bulb temperature high limit contr	ol	
Economiser maximum limit dry bulb tempera	ture (* 21.11	
Outdoor Enthalpy High Limit Control		
Outdoor enthalpy high limit control		
Outdoor Dew Point Temperature High Limit Contr		
Outdoor dew point temperature high limit con		
Time of Day Economiser Override Control Scheo	dule	
🗋 On		
Humidity Control		
High humidity control	1-No	
Outdoor Air Schedules		
Demand Controlled Ventilation eat Recovery		

Step 4: Select **No economiser** from the **Economiser control type** drop-down menu under **Economiser** (Free Cooling).



Step 5: Simulate the model and record the results.

Repeat the previous steps to select the fixed dry bulb air-side economiser control type.

Step 6: Select **Fixed dry bulb** from the Economiser control type drop-down menu under Economiser (Free Cooling).

randling unit Data reral Outdoor Ar System			Help
circulation		*1	Outside Air System
1 On			Outdoor air control provides outdoo
Minimum outdoor air flow rate (m3/s)	Autosize		air for ventilation with optional for free cooling (through additional
Maximum outdoor air flow rate (m3/s)	Autosize		outdoor air and/or bypassing an
Minimum limit type	2-Eixed minimum		air-to-air heat exchanger) wheneve possible. The outdoor air controller
Economiser (Free Cooling)		×1	includes a number of
Economiser control type	2-Fixed dry bulb		user-selectable limit controls. If any of the selected limits are exceeded
Lockouttype	1-No lockout	•	the outdoor airflow rate is set to the
Economiser control action type	1-Modulate flow		minimum.
Outdoor Dry-Bulb Temperature Low Limit Control		×	Autosizable data is shown in blue. This can either have the text
Outdoor dry-bulb temperature low limit control			'autosize' or numeric data. In the
Outdoor Dry-Bulb Temperature High Limit Control		×	case where 'autosize' is entered EnergyPlus will calculate an
Outdoor dry-bulb temperature high limit control		,	appropriate value before the
Economiser maximum limit dry bulb temperature ("C)	21.11		simulation based on the sizing data
Outdoor Enthalpy High Limit Control		¥ 1	provided.
Outdoor enthalpy high limit control			
Outdoor Dew Point Temperature High Limit Control		×	
Outdoor dew point temperature high limit control			
Time of Day Economiser Override Control Schedule		¥	
🗆 On		1000	
Humidity Control		×	
High humidity control	1-No		
Outdoor Air Schedules		**	
Demand Controlled Ventilation		**	
		»	
e-Treatment		»	

Step 7: Simulate the model and record the results.

Repeat the previous steps to select fixed enthalpy air-side economiser control type.

Step 8: Select **Fixed enthalpy** from the Economiser control type drop-down menu under Economiser (Free Cooling).

Enthalpy is the total heat content of the air. This covers the combined effect of temperature and humidity.

r handling unit Data			Help
ieneral Outdoor Air System			Info Data
Recirculation		×	Outside Air System
☑ On			Outdoor air control provides outdoor air for ventilation with
Minimum outdoor air flow rate (m3/s)	Autosize		optional for free cooling (through
Maximum outdoor air flow rate (m3/s)	Autosize		additional outdoor air and/or bypassing an air-to-air heat
Minimum limit type	2-Fixed minimum	•	exchanger) whenever possible
Economiser (Free Cooling)		×	The outdoor air controller inclu
Economiser control type	4-Fixed enthalpy	•	a number of user-selectable lin controls. If any of the selected
Lockout type	1-No lockout		limits are exceeded, the outdo
Economiser control action type	1-Modulate flow	•	airflow rate is set to the minimu
Outdoor Dry-Bulb Temperature Low Limit Contro	l	¥	Autosizable data is shown in b This can either have the text
Outdoor dry-bulb temperature low limit contr			'autosize' or numeric data. In th
Outdoor Dry-Bulb Temperature High Limit Contri		¥	case where 'autosize' is entere EnerovPlus will calculate an
Outdoor dry-bulb temperature high limit cont	trol		appropriate value before the
Economiser maximum limit dry bulb tempera	ature (*C) 21.11		simulation based on the sizing data provided.
Outdoor Enthalpy High Limit Control		¥	data provided.
Outdoor enthalpy high limit control			
Economiser maximum limit enthalpy (J/kg)	50000.00		
Outdoor Dew Point Temperature High Limit Con		¥	
Outdoor dew point temperature high limit co			
Time of Day Economiser Override Control Sche	dule	¥	
🗖 On			
Humidity Control		¥	
High humidity control	1-No	•	
Outdoor Air Schedules		**	
Demand Controlled Ventilation		>>	
feat Recovery		»	
Pre-Treatment		»	

	Annu	on (kWh)	
End-use category	No economiser	Fixed dry bulb temperature-based economiser	Fixed enthalpy-based economiser
Room electricity	153,342.90	153,342.90	153,342.90
Lighting	221,613.80	221,613.80	221,613.80
System fans	92,796.03	92,794.31	92,793.84
System pumps	244,590.30	196,796.50	196,773.80
Heating (electricity)	29,138.51	33,129.39	33,129.37
Cooling (electricity)	313,250.80	289,159.50	288,984.30
Heat rejection	80,399.58	80,292.47	80,233.80

Table 8.6Energy consumption for no, fixed DBT and fixedenthalpy-based economisers

Step 9: Simulate the model and record the results. Compare the results (Table 8.6).

You can observe that application of free cooling leads to reduction in annual cooling energy consumption. Enthalpy type air-side economiser leads to higher energy savings as compared to a dry bulb type economiser. There is a reduction in energy consumption of all the HVAC components, namely, cooling, pumps and heat rejection.

Save the model with no economiser for use in further tutorials.

Exercise

Compare the energy savings in **Miami**, **Florida** and **London Gatwick** using both types of air-side economisers.

TUTORIAL 8.7 Evaluating the impact of supply air fan operation mode during unoccupied hours

GOAL

To evaluate the impact of fan operation mode during unoccupied hours on energy consumption.

WHAT ARE YOU GOING TO LEARN?

· Changing fan operation mode during unoccupied hours

PROBLEM STATEMENT

In this tutorial, you are going to use the No economiser model saved in Tutorial 8.6 (50 m \times 25 m model with 5 m perimeter depth, six floors).

You need to simulate the model with the following two options for **New Delhi/Palam, India** weather location for supply air fan operation:

- 1. Stay off
- 2. Cycle on any

Find energy consumption in both cases.

Applicability schedule (night cycle)

This schedule determines whether or not for a given time period this mechanism is to be applied. Schedule values greater than zero (usually 1 is used) indicate the night cycle mechanism is to be applied, whereas schedule values less than or equal to zero (usually 0 is used) denote that it is not used for this time period.

Control type

The possible inputs are as follows:

- Stay off means that the night cycle mechanism will have no effect AHU on/off will be determined by the fan schedule.
- Cycle on any means that if any zone served by the air loop incorporating this AHU has an air temperature outside the cooling or heating setpoints, the central fan will turn on even though the fan schedule indicates the fan is off.

This setting is used to enable cycling of an air system when one or more zones become too hot or too cold. A common requirement for this mechanism is where the AHU 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 either a specified control thermostat or any thermostat shows a zone temperature of less than a nighttime setpoint. Similarly, there might be a concern about a building getting too hot. Again the control system is programmed to turn the AHU back on if one or any zone temperature exceeds a nighttime cooling setpoint.

This mechanism offers considerable flexibility in determining how the nighttime on/off decision will be made. The temperature in one specific zone may be used or the temperatures in all the zones connected to the AHU may be sampled. You can specify a temperature tolerance and a run time for the system once it switches on. There is also an applicability schedule for scheduling when this mechanism may be applied.

> Source: http://www.designbuilder.co.uk/ helpv4.7/#Generic_AHU.htm?Highlight=Generic Air Handling Unit (AHU)

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 from becoming too cold and to reduce peak heating requirements at start-up. Enter the setpoint temperature to be used at nighttime, weekends and other holidays during the heating season.

Cooling setback setpoint temperature

Some buildings require a low level of cooling during unoccupied periods to prevent the building from becoming too hot and to reduce the start-up cooling load the next morning. Enter the setpoint temperature to be used at nighttime, weekends and other holidays during the cooling season.

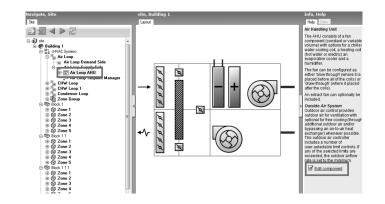
> Source: http://www.designbuilder.co.uk/helpv4.7/ Content/_Environmental_comfort.htm

SOLUTION

Step 1: Open the fixed dry bulb model saved in Tutorial 8.6. Enter **8.0** in Heating set back (°C) and **35.0** in Cooling set back (°C) text boxes in the **Activity** tab.

Layout Activity Construction Openings Light	nting HVAC Generation Economics Outputs CF
C. Activity Template	× 🔺
	Generic Office Area
Sector	B1 Offices and Workshop businesses
	1
Zone multiplier	
Include zone in thermal calculations	
Include zone in Radiance daylightir	ng calculations
Floor Areas and Volumes	»
€g Occupancy	×
Density (people/m2)	0.1110
😭 Schedule	Office_OpenOff_Occ
€ Metabolic	<u> </u>
Generic Contaminant Generation	<u> </u>
6 Holidays	»
It Environmental Control	¥ ×
Heating Setpoint Temperatures	
Heating (*C)	22.0
Heating set back (*C)	8.0
Cooling Setpoint Temperatures	
Cooling (*C)	24.0
Cooling set back (*C)	35.0
Humidity Control	»
Ventilation Setpoint Temperatures Minimum Fresh Air	»
Lighting	* *
Computers	<u> </u>
☐ On	
Soffice Equipment	× 🗸

Step 2: Click **Air Loop AHU** in the navigation tree. Click **Edit component** under the **Help** tab. The **Edit Air** handling unit screen appears.



Step 3: Under the Night Cycle section, select **Stay off** from the **Control type** drop down menu and select **8:00** - **18:00 Mon - Fri** under the **Operation** section and make sure **Heat Recovery** check box is clear under **Outdoor Air System** tab.

Edit Air handling unit -			
Air handling unit Data			Help
General Outdoor Air System			Info Data
General Name Fon type Design supply air flow rate (m3/s) Optication (f) Availability schedule Night Cycle On (f) Applicability schedule Control type Thermostal tolerance (deltaC) Oycling an time (s) Extract Fon Minclude extract fon Mixed Mode Cone Equipment Mixed Mode on	Air Loop AHU 2:-Veriable volume Autosize 8:00 - 18:00 Mon - Fri 0n 24/7 1:Stay off 1:000 1:600.000	* * * * * * * *	Air Handling Unit (AHU) The AHU consists of a fain component options for a a bind water cooling only a healing col (hot water or cellectrc) an exaporative cooler and a humiditer. The fain coils or draw through (where all of the coils)
🛱 Model data <admin></admin>		Help	Cancel OK

Step 4: Simulate the model and record the results.

Step 5: Repeat the previous steps to select **Cycle on any** from the **Control type** drop down menu and select **8:00 - 18:00 Mon - Fri** under the **Operation** section.

General Journal General AirLoop AHU Name AirLoop AHU Fan type 22vanible volume Design supply oir flow rate (m3/s) Autosize Operation (3) Availability schedule 800-1800 Mon - Fri 800-1800 Mon - Fri	× Air Ha The Al (const option a heat	Data andling Unit (AHU) HU consists of a fan componer tant or variable volume) with is for a chilled water cooling coi
Name Air Loop AHU Fan type Design supply air flow rate (m3/s) Operation	 The Al (const option a heat 	HU consists of a fan componer tant or variable volume) with is for a chilled water cooling coi
Fan type 2-Variable volume Design supply air flow rate (m3/s) Autosize Operation	 (const option a heat 	tant or variable volume) with is for a chilled water cooling coi
Design supply air flow rate (m3/s) Autosize Operation	option a heat	is for a chilled water cooling coi
Operation		
		ting coil (hot water or electric) a rative cooler and a humidifier.
63 Availability schedule 8:00 - 18:00 Mon - Eri	The fe	an can be configured as either
		an can be configured as either through' (where it is placed
Night Cycle	> before	e all of the coils) or
🗹 On	In the co	through' (where it placed after ills)
Applicability schedule On 24/7		tract fan can optionally be
Control type 2-Cycle on any	 include 	
Thermostat tolerance (deltaC) 1.000		izable data is shown in blue.
Cycling run time (s) 1800.000		an either have the text 'autosizi meric data. In the case where
	autos	ize' is entered EnergyPlus will
☑ Include extract fan	calculation	ate an appropriate value before mulation based on the sizing
Mixed Mode Zone Equipment	ata p	nuration based on the sizing
Mixed mode on		

Step 6: Simulate the model and record the results.

Compare the results (Table 8.7).

You can observe that there is an increase in systems fans, cooling and heating energy consumption. This is due to the reason that when the **Cycle on any** option is selected, fan runs for additional duration in unoccupied hours.

	Annual energy consumption (kWh)		
End-use categories	Stay off	Cycle on any	
Room electricity	153,342.90	153,342.90	
Lighting	221,613.80	221,613.80	
System fans	36,524.22	61,160.97	
System pumps	4,894.60	11,862.04	
Heating (electricity)	161.73	32,574.40	
Cooling (electricity)	149,971.20	258,275.00	
Heat rejection	17,444.70	40,430.50	

Table 8.7Energy consumption in changing supply air fanoperating mode

Codes such as ASHRAE 90.1-2010 Appendix G, requires that schedules for HVAC fans, which provide outdoor air for ventilation, shall run continuously whenever spaces are occupied and shall be cycled on and off to meet heating and cooling loads during unoccupied hours.

TUTORIAL 8.8 Evaluating the impact of heat recovery between fresh and exhaust air

GOAL

To evaluate the impact of recovering heat between fresh air intake and exhaust on building energy performance.

WHAT ARE YOU GOING TO LEARN?

• Modelling the heat recovery system

PROBLEM STATEMENT

In this tutorial, you are going to use the air-cooled chiller model saved in Tutorial 8.1 (50 m \times 25 m model with 5 m perimeter depth, six floors).

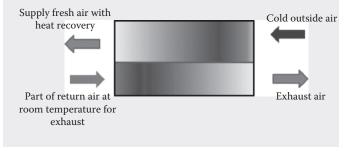
You need to simulate the model with the following three options:

- 1. No heat recovery
- 2. Sensible heat recovery
- 3. Enthalpy-based heat recovery

Find out energy for all the cases.

Use New Delhi/Palam, India weather location.

Energy recovery ventilation is the energy recovery process of exchanging the energy contained in air exhausted from building or space air and using it to treat (precondition) the incoming outdoor ventilation air in HVAC systems. Air-to-air energy recovery reduces energy use and can significantly reduce heating and cooling system sizes. The driving force behind the exchange is the difference in temperatures between the opposing air streams, which is also called the thermal gradient.



There are two types of heat recovery:

- 1. Sensible
- 2. Enthalpy (The enthalpy of moist and humid air includes the enthalpy of the dry air the sensible heat and the enthalpy of the evaporated water the latent heat.)

Sensible heat recovery is possible by the use of fixed plate heat exchangers. A fixed plate heat exchanger has no moving parts, and consists of alternating layers of plates that are separated and sealed. Typical flow is cross current, and since the majority of plates are solid and non-permeable, sensible only transfer is the result. Sensible heat recovery is also possible through a rotating wheel heat exchanger.

Enthalpy heat recovery is possible by the use of a rotating wheel heat exchanger. Rotating wheel heat exchanger is composed of a rotating cylinder filled with an air permeable material resulting in a large surface area. The surface area is the medium for the sensible energy transfer. As the wheel (*Continued*) rotates between the ventilation and exhaust air streams, it picks up heat energy and releases it into the colder air stream.

The enthalpy exchange is accomplished through the use of desiccants. Desiccants transfer moisture through the process of adsorption that is predominantly driven by the difference in the partial pressure of vapour within the opposing air streams. Typical desiccants consist of silica gel and molecular sieves.

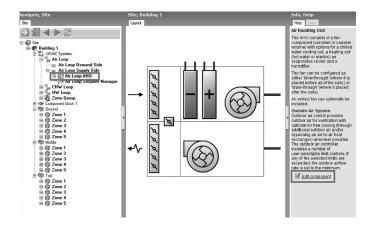
> Source: http://www.designbuilder.co.uk/helpv4.7/ Content/Unitary_Heat_Recovery.htm

SOLUTION

Step 1: Open the air-cooled chiller model saved in Tutorial 8.1. Select the **Activity** tab. Enter **7.100** in the **Fresh air** (**l/s-person**) text box in the **Minimum Fresh Air** tab and select **24×7 Generic Office Area** as Template.

大Template	24x7 Generic Office Area
Sector	Others - Miscellaneous 24hr activities
Zone multiplier	1
Include zone in thermal calculations	
☑ Include zone in Radiance daylighting	calculations
R Floor Areas and Volumes	
f Occupancy	
Density (people/m2)	0.0951
14 Schedule	Ware_24x7CellOff_Occ
👷 Metabolic	
MGeneric Contaminant Generation	
🏠 Holidays	
Environmental Control	그는 그 말을 하는 것 같은 것 같
Heating Setpoint Temperatures	
🖁 Heating (*C)	22.0
🖁 Heating set back (°C)	12.0
Cooling Setpoint Temperatures	
Cooling (*C)	24.0
📱 Cooling set back (*C)	28.0
Humidity Control	
Ventilation Setpoint Temperatures	
Minimum Fresh Air	
Fresh air (I/s-person)	7.100
Mech vent per area (l/s-m2)	0.000
Lighting	
2 Computers	
🗖 On	

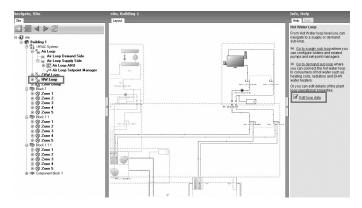
Step 2: Click **Air Loop AHU** in the navigation tree. Click **Edit component** under the **Help** tab. The **Edit Air Handling Unit Data** screen appears.

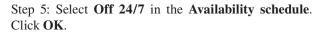


Step 3: Select the **Outdoor Air System** tab. Select the **On** checkbox under **Heat Recovery**. Make sure that **Plate** is selected from the **Heat exchanger type** drop-down list.

neral Outdoor Air System		
ecirculation		:
2 On		
Minimum outdoor air flow rate (m3/s)	Autosize	
Maximum outdoor air flow rate (m3/s)	Autosize	
Minimum limit type	2-Fixed minimum	
Economiser (Free Cooling)		:
Economiser control type	1-No economizer	
Outdoor Air Schedules		,
Demand Controlled Ventilation		\$
ant Recovery		
On		
General		
Nominal supply air flow rate (m3/s)	Autosize	
Nominal electric power (W)	0.000	
Supply air outlet temperature control	1-No	
Heat exchanger type	1-Plate	
Economiser lockout	1-Yes	
Effectiveness		:
Sensible	0.350	
at 75% Heating air flow	0.750	
at 75% Cooling air flow	0.750	
at 100% Heating air flow	0.700	
at 100% Cooling air flow	0.700	
Latent		
at 75% Heating air flow	0.000	
at 75% Cooling air flow	0.000	
at 100% Heating air flow	0.000	
at 100% Cooling air flow	0.000	
Frost Control		
Frost control type	1-None	
Heat Recovery Operation	On 24/7	

Step 4: Click **HW Loop** in the navigation tree. Click **Edit loop data** under the **Help** tab. The **Edit Plant loop** screen appears.





lant loop Data			Help	
General Plant Equipment Operation		_	Info Data	
General		×	Hot Water Loop	
Name	HW Loop		The Hot water loop consists of:	
Fluid type	1-Water		 Supply sub loop which contains one or more boilers. 	
Plant loop volume (m3)	Autocalculate		a pump and a setpoint	
Flow Type		¥	controller	
Plant loop flow type	2-Variable flow	•	 Demand sub loop which distributes the hot water to 	
Temperature		¥	water heating coils, heated	
Maximum loop temperature (*C)	100.00		floors, radiators etc.	
Minimum loop temperature (*C)	10.00		This dialog covers the sizing an operation details of the overall	
Flow Rate			operation details of the overall loop.	
Maximum loop flow rate (m3/s)	Autosize		loop.	
Minimum loop flow rate (m3/s)	0.000000		The Load Distribution Scheme	
Load distribution scheme	1-Sequential		selects the algorithm used to sequence equipment operation in	
Plant loop demand calculation scheme	1-SingleSetPoint	•	order to meet the plant loop	
Sizing		¥	demand. There are 3 options:	
Design loop exit temperature (*C)	80.00		 'Sequential' uses each piece of equipment to its maximum 	
Loop design temperature difference (deltaC)	10.00		part load ratio and will operat	
Operation	and the second second second second	¥	the last required piece of	
Availability schedule	Off 24/7		equipment between its minimum and maximum part	
Outside Temperature Operation		×	load ratio in order to meet the	
Outside temperature operation			loop demand.	
			Optimal operates each piece	
🛱 Model data <admin></admin>		Help	Cancel OK	

Step 6: Simulate the model and record the results.

Step 7: Select **Rotary** from the **Heat exchanger type** drop-down list. Enter **0.70** under **Latent effectiveness**. Click **OK**.

CHAPTER EIGHT CENTRAL HVAC SYSTEM

circulation		
On		
	Autosize	
Minimum outdoor air flow rate (m3/s)	Autosize	
Maximum outdoor air flow rate (m3/s)	2-Fixed minimum	
Minimum limit type Economiser (Free Cooling)	2-Fixed minimum	
	1-No economizer	
Economiser control type Outdoor Air Schedules	1-140 economizer	_
Demand Controlled Ventilation		
at Recovery		
On		
General		
Nominal supply air flow rate (m3/s)	Autosize	
Nominal electric power (W)	0.000	
Supply air outlet temperature control	1-No	
Heat exchanger type	2-Rotary	
Economiser lockout	I-Yes	
Effectiveness		
Sensible		
at 75% Heating air flow	0.750	
at 75% Cooling air flow	0.750	
at 100% Heating air flow	0.700	
at 100% Cooling air flow	0.700	
Latent		
at 75% Heating air flow	0.70	
at 75% Cooling air flow	0.70	
at 100% Heating air flow	0.70	
at 100% Cooling air flow	0.70	
Frost Control		
Frost control type	1-None	
Heat Recovery Operation		
Availability schedule	On 24/7	

Step 8: Simulate the model and record the results.

Step 9: Simulate the model and record the results without heat recovery. You can do it by clearing the **On** check box under the **Heat Recovery** section. Click **OK**. Compare the results (Table 8.8).

		Help		
		Info Data		
	¥	Outside Air System		
		Outdoor air control provides outdoor air for ventilation with optional for free cooling		
Autosize		(through additional outdoor air and/or		
Autosize		bypassing an air-to-air heat exchanger)		
2-Fixed minimum	•	whenever possible. The outdoor air controlle includes a number of user-selectable limit		
	¥	controls. If any of the selected limits are		
1-No economizer	*	exceeded, the outdoor airflow rate is set to the minimum		
	»	Autosizable data is shown in blue. This can		
		either have the text 'autosize' or numeric		
	¥	data. In the case where 'autosize' is entere EnergyPlus will calculate an appropriate		
		value before the simulation based on the		
	»	sizing data provided.		
	Autosize 2-Fixed minimum	Autosize Autosize 2-Fixed minimum * 3 1-No economizer * 2 2 Statustica (Statustica (Status		

	Annual energy consumption (KWh)			
_	None	Sensible heat recovery	Enthalpy heat recovery	
Room electricity	271,405.70	271,405.70	271,405.70	
Lighting	619,839.30	619,839.30	619,839.30	
System fans	186,069.30	186,036.80	186,031.70	
System pumps	2,306.85	2,264.16	1,989.80	
Cooling (electricity)	630,411.30	613,200.20	578,378.80	

 Table 8.8
 Effect of exhaust air heat recovery in the HVAC system

Annual anamatican (I-W/h)

You can observe that there is a decrease in cooling energy consumption with sensible heat recovery. Use of enthalpy heat recovery gives higher savings.

Generally, there is an increase in fan energy consumption with the heat recovery system. This is due to the increase in static pressure of the fan for the heat recovery wheel. To model this effect in the compact option, you need to change the fan pressure rise.

Building an air conditioning system requires fresh air supply to maintain indoor air quality. There are different standards such as ASHRAE 60.1-2010 that specify minimum fresh air requirements in different space types. In a cold climate, the temperature of fresh air is lower than the exhaust air (which is nearly at the room temperature). Bringing fresh air temperature from low to room temperature requires heating energy. Similarly, in hot climates bringing fresh air temperature from hot to room temperature requires cooling energy. Recovering heat/coolth from outgoing air offers energy saving opportunity.

Nominal electric power

This is the electric consumption rate of the device (W). Electric power is considered constant whenever the unit operates. This numeric input can be used to model electric power consumption by controls (transformers, relays, etc.) and/or a motor for a rotary heat exchanger. None of this electric power contributes thermal load to the supply or exhaust air streams. The default value for this field is 0.

Economiser lockout

This input denotes whether the heat exchanger unit is locked out (bypassed for plate type heat exchangers or the rotation is suspended for rotary type heat exchangers) when the air-side economiser is operating. Both the economiser and high humidity control activate the heat exchanger lockout as specified by this input. The input choices are **Yes** (meaning locked out) or **No**.

Sensible effectiveness at 100% heating air flow

The sensible heat exchange effectiveness at the heating condition defined in the above table with both the supply and exhaust air volume flow rates is equal to 100% of the nominal supply air flow rate specified in the previous input field. The default value for this field is 0.

Latent effectiveness at 100% heating air flow

The latent heat exchange effectiveness at the heating condition defined in the Operating Conditions for Defining Heat Exchanger Performance table with both the supply and exhaust air volume flow rates is equal to 100% of the nominal supply air flow rate. Specify this value as 0.0 if the heat exchanger does not transfer latent energy. The default value for this field is 0.

Sensible effectiveness at 75% heating air flow

The sensible heat exchange effectiveness at the heating condition defined in the Operating Conditions for Defining Heat Exchanger Performance table with both the supply and exhaust air volume flow rates is equal to 75% of the nominal supply air flow rate. The default value for this field is 0.

Latent effectiveness at 75% heating air flow

The latent heat exchange effectiveness at the heating condition defined in the Operating Conditions for Defining

(*Continued*)

Heat Exchanger Performance table with both the supply and exhaust air volume flow rates is equal to 75% of the nominal supply air flow rate. Specify this value as 0.0 if the heat exchanger does not transfer latent energy. The default value for this field is 0.

Sensible effectiveness at 100% cooling air flow

The sensible heat exchange effectiveness at the cooling condition defined in the Operating Conditions for Defining Heat Exchanger Performance table with both the supply and exhaust air volume flow rates is equal to 100% of the nominal supply air flow rate. The default value for this setting is 0.

Latent effectiveness at 100% cooling air flow

The latent heat exchange effectiveness at the cooling condition defined in the Operating Conditions for Defining Heat Exchanger Performance table with both the supply and exhaust air volume flow rates is equal to 100% of the nominal supply air flow rate. Specify this value as 0.0 if the heat exchanger does not transfer latent energy. The default value for this setting is 0.

Sensible effectiveness at 75% cooling air flow

The sensible heat exchange effectiveness at the cooling condition defined in the Operating Conditions for Defining Heat Exchanger Performance table with both the supply and exhaust air volume flow rates is equal to 75% of the nominal supply air flow rate. The default value for this setting is 0.

Latent effectiveness at 75% cooling air flow

The latent heat exchange effectiveness at the cooling condition defined in the Operating Conditions for Defining Heat Exchanger Performance table with both the supply and exhaust air volume flow rates is equal to 75% of the nominal supply air flow rate. Specify this value as 0.0 if the heat exchanger does not transfer latent energy. The default value for this field is 0.

> Source: http://www.designbuilder. co.uk/helpv4.7/#Generic_AHU. htm?Highlight=Generic AHU.htm

Exercise

Repeat the tutorial for Montreal, Canada climate.

TUTORIAL 8.9 Evaluating the impact of boiler nominal thermal efficiency

GOAL

To evaluate the impact of boiler efficiency on building energy performance.

WHAT ARE YOU GOING TO LEARN?

· Changing boiler efficiency

PROBLEM STATEMENT

In this tutorial, you are going to use the air-cooled chiller model saved in Tutorial 8.1 (50 m \times 25 m model with 5 m perimeter depth, six floors).

You need to simulate the model with the following boiler efficiencies ranging from 0.89 to 0.95 in increment of 0.02. Find out energy consumption for all the cases.

Use PARIS-AEROPORT CHAR, France weather location.

Nominal thermal efficiency

This is the heating efficiency (as a fraction between 0 and 1) of the boiler's burner relative to the higher heating value (HHV) of fuel at a part load ratio of 1.0. Manufacturers typically specify the efficiency of a boiler using the higher heating value of the fuel. For the rare occurrences when a manufacturer's (or particular data set) thermal efficiency is based on the lower heating value (LHV) of the fuel, multiply the thermal efficiency by the lower-to-higher heating value ratio. For example, assume that a fuel's lower and higher heating values are approximately 45,450 and 50,000 kJ/kg, respectively. For a manufacturer's thermal efficiency rating of 0.90 (based on the LHV), the nominal thermal efficiency entered here is 0.82 (i.e. 0.9 multiplied by 45,450/50,000).

Heating value: The amount of heat produced by a complete combustion of fuel and it is measured as a unit of energy per unit mass or volume of substance (e.g. kcal/kg, kJ/kg, J/mol and Btu/m³).

(Continued)

HHV is defined as the gross calorific value, defined as the amount of heat released when fuel is combusted and the products have returned to a temperature of 25°C. The heat of condensation of the water is included in the total measured heat.

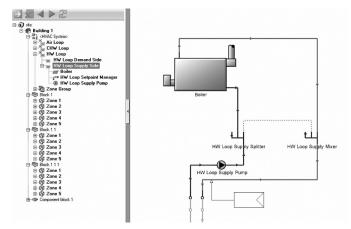
The LHV is defined as the net calorific value and is determined by subtracting the heat of vaporization of water vapour (generated during combustion of fuel) from the HHV.

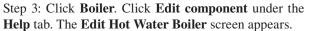
> Source: http://www.designbuilder. co.uk/helpv4.7/#Boilers.htm

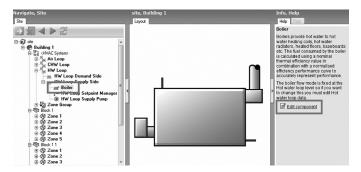
SOLUTION

Step 1: Open the simulation model created in Tutorial 8.1 with an air-cooled chiller. Click **HW Loop**.

Step 2: Click HW Loop Supply Side.





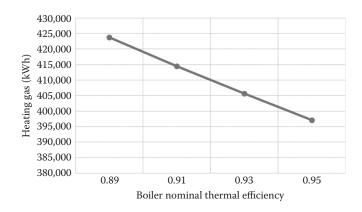


Step 4: Enter **0.890** in the **Nominal thermal efficiency** text box under the **Efficiency** subtab.

Edit Hot Water Boiler - Boiler Data			Help
Hot Water Boller			Info Data
			Boiler
General		×	
Name	Boiler		Boilers provide hot water to hot water heating coils, hot water radiators,
b Boiler template	Gas-fired condensing boiler		heated floors, baseboards etc. The
Fuel type	1-Natural gas	-	fuel consumed by the boiler is calculated using a nominal thermal
Nominal capacity (W)	Autosize		efficiency value in combination with a
Boiler flow mode	3-Not modulated		normalised efficiency performance
Parasitic electric load (W)	25.000		curve to accurately represent performance.
Sizing factor	1.00		The boiler flow mode is fixed at the
Efficiency		×	Hot water loop level so if you want to
Nominal thermal efficiency	0.890		change this you must edit Hot water loop data.
Efficiency curve temperature evaluation varia	able LeavingBoiler	•	Autosizable data is shown in blue
Normalized boiler efficiency curve	CondensingBoilerEff		This can either have the text
Water Outlet		×	'autosize' or numeric data. In the case where 'autosize' is entered
Design water flow rate (m3/s)	Autosize		EnergyPlus will calculate an
Part Load Ratios		×	appropriate value before the
Minimum part load ratio	0.000		simulation based on the sizing data provided.
Maximum part load ratio	1.000		
Optimum part load ratio	1.000		
🛱 Model data <admin></admin>		lelp	Cancel OK

Step 5: Simulate the model and record the results.

Step 6: Repeat the previous steps to simulate the model with **0.91**, **0.93** and **0.95** nominal thermal efficiencies (Table 8.9).



	Annual energy consumption (kWh)				
End-use category	0.89	0.91	0.93	0.95	
Room electricity	153,342.90	153,342.90	153,342.90	153,342.90	
Lighting	221,613.80	221,613.80	221,613.80	221,613.80	
System fans	128,277.70	128,277.70	128,277.70	128,277.70	
System pumps	419.34	419.34	419.34	419.34	
Heating (gas)	423,825.50	414,510.70	405,596.40	397,057.60	
Cooling (electricity)	255,680.80	255,680.80	255,680.80	255,680.80	

Table 8.9Energy consumption with change in nominal thermalefficiency

Simulation Parameters

This chapter will help you to understand the nuances of simulation engine settings that not only affect the accuracy of calculations but also affect the run time of a model. This becomes very important especially for large building models. Three concepts covered in this chapter are time step, which may be treated analogous to the least count of the model, method of calculation for energy balance and the algorithm for convective heat transfer in various building components. Simulation tools offer freedom to choose a smaller time step at the cost of a significant increase in running time. Similarly, the calculation method and convection algorithm are also associated with the accuracy of calculation at the cost of run time. These tutorials help in understanding the methods as well as the extent of difference that is obtained in the results while using different approaches. This information can be useful to the simulator to decide the appropriate simulation setting as per the availability of computing power, time and requirement of accuracy.

TUTORIAL 9.1 Evaluating the impact of time steps per hour on run time

GOAL

To evaluate the change in simulation run time with the change in time steps per hour.

WHAT ARE YOU GOING TO LEARN?

Changing time steps per hour

PROBLEM STATEMENT

In this tutorial, you are going to use the water-cooled chiller model saved in Tutorial 8.1 (50 m \times 25 m model with 5 m perimeter depth, six floors).

You are going to use the following time steps per hour:

2, 10, 30 and 60.

Find the change in energy consumption and run time for all cases.

Use Brisbane Aero, Australia weather location.

Simulation time steps define the interval at which the heat transfer calculations are performed. In EnergyPlus (which is the simulation engine of DesignBuilder), this minimum time step is 1, which means that the heat transfer and load calculation are performed on an hourly basis. The maximum number of time steps that can be assigned is 60, which means the calculations are performed for every minute. The allowed options for time steps are 1, 2, 3, 4, 5, 6, 10, 15, 20, 30 and 60. The higher the number of time steps, the more precise are the results.

Source: http://www.designbuilder.co.uk/ helpv4.7/Content/Calculation_Options.htm

Caution: Note the difference between simulation time steps, simulation period (also called run period) and run time. A run period is the time of the year for which the calculation should be performed, whereas time step is the frequency at which these calculations are performed. Further, run time is the time taken for performing energy simulation. Run time depends on several factors such as the complexity of the model, the speed of the computer hardware, run period and the time step.

SOLUTION

Step 1: Open the simulation model saved in Tutorial 8.1. Select the **Simulation** tab. The **Edit Calculation Options** screen appears.

Calculation Options Data		Help	
	on Manager	Info Data	
Calculation Description		Simulation Options	^
Simulation Period		These options control the simulation and the output produced.	
From		Simulation Period Select the start and end days for the simulation	on, _
Start day Start month	1 Jan	or select a typical period: Annual simulation	
To Start month	Jan	Summer design week	
End day	31	Summer typical week	L
End month	Dec	All summer	
Output Intervals for Reporting		Winter design week	
Monthly and annual		<u>Winter typical week</u>	
☑ Daily		<u>All winter</u>	
☐ Hourly ☐ Sub-hourly		Interval Monthly and annual output is always generaledand daily, houth's and sub-hourly da can selected by checking the appropriate box	
		Note that selecting output at hourty or sub-ho intervals can produce large amounts of data	urly -
Don't show this dialog next time		Help Cancel OK	

Step 2: Select the **Options** tab.

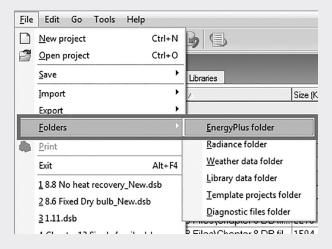
Step 3: Select 2 from the **Time steps per hour** dropdown list and click **OK**.

Edit Calculation Options					
Calculation Options Data			Help		
General Options Output Simulation Manage	r	_	Info Data		
Calculation Options		×	Calculation Options	^	
Simulation method	1-Enerm/Plus	•	These options can also be accessed from the		
Time steps per hour	2		Model Options dialog. Time steps	11	
Temperature control	1-Air temperature	•	In general, increasing the number of timesteps		
Solar ¥		¥	improves accuracy but slows the simulation (and generates more data if output is requested at the	=	
Include all buildings in shading calcs			sub-hourly interval).		
Model reflections and shading of group	Model reflections and shading of ground reflected solar		Solar Distribution		
Solar distribution	2-Full exterior	•	Solar distribution should generally be set to 'Full exterior' as this provides a good compromise		
Shadowing interval (days)	20		between accuracy and versatility.		
Detailed HVAC Autosizing		**	Note that the 'Full interior and exterior' option		
Advanced		»	only works for convex shaped zones (zones whose surfaces can all 'see' each other).		
			Include all buildings		
			Check the Include all buildings in shading calcs' if		
			you want to use the surfaces of other buildings on the site to shade the current building in the		
			simulation.		
				<u> </u>	
Don't show this dialog next time		[Help Cancel OK		

Step 4: Perform annual simulation and note down the results for energy and run time.

How to record the run time:

After the simulation is complete, open the **eplusout.err** file from the **EnergyPlus folder**. You can use any text editor to view this file.



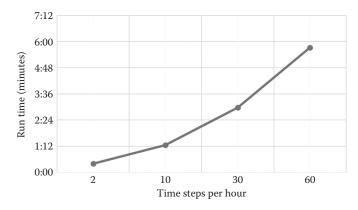
At the end of the file, you can find Elapsed Time.

You need to record the elapsed time.

Source: http://www.designbuilder.co.uk/ helpv4.7/Content/_DesignBuilder_files_ location_and_extensions.htm

Step 5: Repeat the previous steps for the time steps 10, 30 and 60.

Compare the run time for all the cases (Table 9.1).



	Time steps 2 per hour	Time steps 10 per hour	Time steps 30 per hour	Time steps 60 per hour
Run time (min)	0:24	1:15	2:59	5:43
Room electricity	153,342.9	153,342.9	153,342.9	153,342.9
Lighting	221,613.8	221,613.8	221,613.8	221,613.8
System fans	132,544	133,927.5	134,233.3	134,310.2
System pumps	8,179.506	8,246.28	8,260.38	8,264.02
Heating (gas)	80,341.41	85,960.33	87,098.55	87,375.35
Cooling (electricity)	231,246.2	232,903.3	233,253.2	233,372.8
Heat rejection	53,253.13	55,180.27	55,330.14	55,359.05

Table 9.1Variation of annual energy consumption with
variation in time steps

You can observe from the results that as the number of time steps per hour increases, the simulation run time also increases. You can also observe a slight change in the HVAC energy consumption due to the change in the resolution of energy calculations. Please note that since the above-mentioned run times depend on the system configuration, your results might differ from the ones shown above. However, the trend would remain the same. In most cases, the difference in the results is very less, of the order of 1%; hence, unless necessary, use of smaller time steps is not recommended.

Save the simulation model with time steps 2 per hour to use in subsequent tutorials.

TUTORIAL 9.2 Evaluating the impact of the solar distribution algorithm

GOAL

To evaluate the impact of the solar distribution algorithm on energy consumption and simulation run time.

WHAT ARE YOU GOING TO LEARN?

· Changing the solar distribution algorithm

PROBLEM STATEMENT

In this tutorial, you are going to use the time steps 2 per hour as the model saved in Tutorial 9.1 (50 m \times 25 m model with 5 m perimeter depth, six floors). Add 1 m overhang on all the windows.

You need to select the following solar distribution:

- a. Full exterior
- b. Minimal shading

Find the change in energy consumption for both cases.

Use AZ – PHOENIX/SKY HARBOR, Arizona, USA weather location.

This option determines how EnergyPlus treats beam solar radiation and reflectance from exterior surfaces that strike the building and, ultimately, enter the zone.

(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.

(Continued)

(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.

(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.

Source: http://www.designbuilder.co.uk/ helpv4.7/#Solar_Options.htm

SOLUTION

Step 1: Open the simulation model saved in Tutorial 9.1 with time steps per hour as 2.

Step 2: Select the **Openings** tab. Select the **Local Shading** check box in the **Shading** section. Select **1.0** m **Overhang** as Type.

BUILDING ENERGY SIMULATION

Site, Building 1	
Layout Activity Construction Openings Lighting	HVAC Generation Economics Outputs CFD
	*
C, Glazing Template	
Template	Project glazing template
🝵 External Windows	*
🕼 Glazing type	Project external glazing
Layout	Preferred height 1.5m, 30% glazed
Dimensions	¥
Туре	3-Preferred height
Window to wall %	30.00
Window height (m)	1.50
Window spacing (m)	5.00
Sill height (m)	0.80
Reveal	»
Frame and Dividers	»
Shading	¥
Window shading	
☑ Local shading	
≣Туре	1.0m Overhang
Amow Control windows	»
Free Aperture	»
📺 Internal Windows	»
Sloped Roof Windows/Skylights	»
Doors	»
Vents	»

Step 3: Select the **HVAC** tab and select **Detailed HVAC detail** under Info, Help.

Info, Help Help Data
HVAC Data
Detailed HVAC detail
When using Detailed HVAC the HVAC system is defined using components and the data on the HVAC tab is used for:
To access HVAC data click on the <hvac System> navigator node</hvac
Detailed HVAC Activity Data The "Detailed HVAC Activity data" model option set to "2-Detailed HVAC", so the data on the HVAC tab is used as follows:
Heating and Cooling design calculations
 Natural ventilation and Temperatute distribution data are used for Simulations

Step 4: Click **Simple** under the HVAC slider.

Model Options	Data		ſ				
Cost/Carbon							
Data Advanced	Heating Design	Cooling Design	Simulatio	n Display	Drawing tools	Block	Project details
Data Options							×
Model opt	ions template			Draw b	ouilding + star	dard da	ata
Construction ar	nd Glazing Data						>>
Gains Data							»
Timing							»>
HVAC							¥
HVAC			Detailed		AC s are modelled usin calculated from lo		
Simple	Compac	t L	Jetailed	efficiencies 3-Autos	nino		-
HVAC sizing							•
	Cautosize metho			1-Ener	gyPlus		•
	nple/Design HV/			2.0			-
	nergy calculation				arate fans and	pumps	
	l ventilation meth			2-Ideal	loads		•
Natural Ventila	tion and Infiltratio	n					*
Natural ventila	ation				d ventilation efined as an air-cha		addied by an
Scheduled		C	alculated		dule and controlled		
Infiltration unit	s			1-ac/h			•
BIM Surfaces							*

Step 5: Select the **Simulation** tab. The **Edit Calculation Options** screen appears.

Step 6: Select the **Options** tab. Expand the **Solar** section. Select **Full exterior** from the **Solar distribution** dropdown list. Click **OK**.

Edit Calculation Options			
Calculation Options Data			Help
General Options Output Simulation Manager			Info Data
Calculation Options		¥	Calculation Options
Simulation method	1-EnergyPlus	*	These options can also be accessed from the Model Option _
Time steps per hour	2	-	dialog.
Temperature control	1-Air temperature	-	Time steps
Solar		×	In general, increasing the numbion of timesteps improves accuracy
Include all buildings in shading calcs			but slows the simulation (and
Model reflections and shading of ground			generates more data if output is requested at the 'sub-houriy'
Solar distribution	2-Full exterior	*	interval).
Shadowing interval (days)	20		Solar Distribution
Advanced		»	Solar distribution should genera be set to 'Full exterior' as this
			de secto Pullexterior as uns
L			
Don't show this dialog next time	Help		Cancel OK

Step 7: Simulate the model and record the results for energy and simulation run time.

Step 8: Select the **Summary** tab and click **Table of Contents**.

BUILDING ENERGY SIMULATION

Site, Building 1
Analysis Summary Parametric Optimisation
Program Version:EnergyPlus, Version 8.3.0-6d97d074ea, YMD=2016.04.07 09:49
Tabular Output Report in Format: HTML
Building: Building
Environment: SITE (01-01:31-12) ** Phoenix Sky Harbor Intl Ap AZ USA TMY3 WMO#=722780
Simulation Timestamp: 2016-04-07 09:49:46

Step 9: Click the Sensible Heat Gain Summary link.

Site, Bu	ilding 1			
Analysis	Summary	Parametric	Optimisation	
Table o	f Content	s		
Input V Demand Compor Climatic Envelop Lighting Equipme HVAC S System Outdoo	erification a	nd Results S components Summary nary ry ry ary ary many		

Step 10: Copy the table **Annual Building Sensible Heat Gain Components** to a spreadsheet program. (You need to select the table and right click and select copy and paste in the spreadsheet.)

leport: Sensible I	Heat Gain S	lummary													1	able of Content
or: Entire Facility	v															
mestamp: 2016	-05-17 21:	42:13														
Annual Building Sensible Heat Gain Components																
undai bolioing																
	HVAC Input Sensible Air Heating [GJ]	HVAC Input Sensible Air Cooling [GJ]	HVAC Input Heated Surface Heating [GJ]	HVAC Input Cooled Surface Cooling [GJ]	People Sensible Heat Addition [GJ]	Lights Sensible Heat Addition [GJ]	Equipment Sensible Heat Addition [GJ]	Window Heat Addition [GJ]	Interzone Air Transfer Heat Addition [G]	Infiltration Heat Addition [GJ]	Opaque Surface Conduction and Other Heat Addition [G]	Equipment Sensible Heat Removal [GJ]	Window Heat Removal [GJ]	Interzone Air Transfer Heat Removal [G]]	Infiltration Heat Removal [GJ]	Opaque Surface Conduction and Other Heat Removal [GJ]
GROUND:20NE4	0.935	-59.790	0.000	0.000	5.839	20.288	14.038	48.823	0.000	5.175	0.000	0.000	-12.018	0.000	-9.870	-13.421
GROUND:ZONE1	3.177	-102.430	0.000	0.000	13.359	46.265	32.012	51.966	0.000	12.843	0.001	0.000	-20.180	0.000	-19.208	-17.80
GROUND:ZONE5	0.994	-61.908	0.000	0.000	5.817	20.288	14.038	48.210	0.000	5.281	0.003	0.000	-10.466	0.000	-9.710	-12.54
GROUND:ZONE2	1.170	-129.029	0.000	0.000	13.236	46.265	32.012	97.236	0.000	12.734	0.002	0.000	-23.379	0.000	-23.452	-26.792
GROUND:ZONE3	3.451	-228.154	0.000	0.000	38.090	132.831	91.911	0.000	0.000	40.023	0.005	0.000	0.000	0.000	-58.774	-19.378
MIDDLE:20NE4	0.778	-59.941	0.000	0.000	5.839	20.288	14.038	47.105	0.000	4.981	0.001	0.000	-12.602	0.000	-9.999	-10.483
MIDDLE:ZONE1	2.786	-108.596	0.000	0.000	13.359	46.265	32.012	49.763	0.000	12.168	0.001	0.000	-21.480	0.000	-19.662	-6.613
MIDDLE:20NE5	0.865	-62.243	0.000	0.000	5.823	20.288	14.038	46.435	0.000	5.030	0.002	0.000	-11.050	0.000	-9.728	-9,448
MIDDLE:ZONE2	0.915	-130.121	0.000	0.000	13.249	46.265	32.012	93.901	0.000	12.071	0.007	0.000	-24.713	0.000	-23.564	-20.016
MIDDLE:ZONE3	2.613	-242.561	0.000	0.000	38.076	132.831	91.911	0.000	0.000	37.862	0.005	0.000	0.000	0.000	-59.957	-0.774
TOP:ZONE4	1.280	-64.072	0.000	0.000	5.850	20.288	14.038	46.102	0.000	4.682	0.000	0.000	-13.220	0.000	-10.251	-4.696
TOP:ZONE1	4.127	-117.750	0.000	0.000	13.377	46.265	32.012	47.919	0.000	11.295	4.891	0.000	-22.267	0.000	-19.870	-0.001
TOP:ZONE5	1.379	-66.824	0.000	0.000	5.831	20.288	14.038	45.255	0.000	4.737	0.000	0.000	-11.431	0.000	-9.875	-3.397
TOP:ZONE2	1.789	-139.895	0.000	0.000	13.275	46.265	32.012	91.596	0.000	11.217	0.000	0.000	-25.633	0.000	-23.789	-6.837
TOP:ZONE3	4.537	-268.817	0.000	0.000	38.156	132.831	91.911	0.000	0.000	33.877	28.293	0.000	0.000	0.000	-60.786	-0.00
Total Facility	30.796	-1842.132	0.000	0.000	229.175	797.810	552.034	714.311	0.000	213.975	33.212	0.000	-208.450	0.000	-368.495	-152,208

Step 11: Repeat the previous steps to select **Minimal shad**owing from the **Solar distribution** drop-down list.

Calculation Options Data		
General Options Output Simulation Manager		
Calculation Options		×
Simulation method	1-EnergyPlus	•
Time steps per hour	2	•
Temperature control	1-Air temperature	-
Solar		×
Include all buildings in shading calcs		
Model reflections and shading of ground re	eflected solar	
Solar distribution	1-Minimal shadowing	-
Shadowing interval (days)	20	
Advanced		»

Step 12: Click **OK**. Record the results.

Compare results for both simulations (Tables 9.2 and 9.3).

It can be observed from the results that with the Minimal shading option, there is an increase in the HVAC energy consumption, as there is no exterior shadowing considered in the calculations except from window and door reveals.

The results also show that the window heat gain is lesser with Full exterior. This is because the shadow patterns on the exterior surface caused by overhangs and exterior surfaces are taken into account for calculations.

	Annual fuel breakdown consumption (kWh)			
	Full exterior	Minimal shading		
Run time	0:16	0:14		
Room electricity	153,342.90	153,342.90		
Lighting	221,613.80	221,613.80		
Heating (gas)	10,616.47	8,836.53		
Cooling (electricity)	256,906.00	287,547.30		
DHW (electricity)	13,875.00	13,875.00		

Table 9.2Variation of annual energy consumption with
variation in local shading

	Window heat addition (GJ)		
	Minimal	Full exterior	
Ground: West	72.42	48.44	
Ground: North	57.40	51.35	
Ground: East	71.50	47.74	
Ground: South	169.90	96.46	
Ground: Core	_	_	
Middle: West	68.29	45.60	
Middle: North	53.42	47.73	
Middle: East	67.08	44.72	
Middle: South	161.26	91.53	
Middle: Core	_	_	
Top: West	69.19	46.11	
Top: North	54.05	47.96	
Top: East	68.17	45.24	
Top: South	162.27	91.54	
Top: Core	-	_	
Total facility	1,074.94	704.41	

 Table 9.3
 Heat gains from window

Save the model to use in the next tutorial.

Exercise 9.1

Repeat the above tutorial for the Full interior and exterior solar distribution algorithm.

TUTORIAL 9.3 Evaluating the impact of the solution algorithm

GOAL

To evaluate the building energy performance and the run time with the change in the solution algorithm.

WHAT ARE YOU GOING TO LEARN?

• Changing the solution algorithm

PROBLEM STATEMENT

In this tutorial, you are going to use the simulation model saved in Tutorial 9.1 with time steps per hour as 2.

You need to select the following algorithms:

- 1. Conduction Transfer Function
- 2. Finite Difference

Find the change in energy consumption with both cases.

Use AZ – PHOENIX/SKY HARBOR, Arizona, USA weather location.

CTF: the default method used in EnergyPlus for CTF calculations is known as the state space method. CTF is a sensible heat-only solution not taking into account moisture storage or diffusion in the construction elements.

Finite Difference: this solution technique uses a 1-D finite difference solution in the construction elements. It is a sensible heat-only solution and does not take into account moisture storage or diffusion in the construction elements.

Finite Difference Settings

The settings below are required when the general solution algorithm is set to 2-Finite Difference or if any constructions used in the simulation override the general setting to use the Finite Difference algorithm.

Difference Scheme

This field determines the solution scheme used by the Conduction Finite Difference model.

There are two options:

(1) Fully implicit first-order scheme, which is first order in time and is more stable over time. But it may be slower than option 2.

(2) Crank Nicholson second order, which is second order in time and may be faster than option 1, but it can be unstable over time when boundary conditions change abruptly and severely.

> Source: http://www.designbuilder.co.uk/helpv4.7/ Content/Advanced_Calculation_Options.htm

SOLUTION

Step 1: Open the simulation model saved in Tutorial 9.1 with time steps per hour as 2. Select the **Simulation** tab.

Step 2: Select the **Options** tab and expand the **Advanced** section.

BUILDING ENERGY SIMULATION

Calculation Options		
Simulation method	1-EnergyPlus	
Time steps per hour	2	
Temperature control	1-Air temperature	
Solar		
Include all buildings in shading calcs		
Model reflections and shading of grou	nd reflected solar	
Solar distribution	2-Full exterior	
Shadowing interval (days)	20	
Detailed HVAC Autosizing		
Advanced		

Step 3: Select Conduction Transfer Function from the Solution algorithm drop-down list.

alculation Options		1
Simulation method	1-EnergyPlus	•
Time steps per hour	2	
Temperature control	1-Air temperature	
lolar		
Include all buildings in shading calcs		
Model reflections and shading of ground reflected solar		
Solar distribution	2-Full exterior	
Shadowing interval (days)	20	
)etailed HVAC Autosizing		
General Solution		
Solution algorithm	1-Conduction Transfer Function	
Allow individual constructions to override solution method		
Finite Difference Settings		:
Finite difference scheme	1-Fully implicit first order	
Space discretization constant	3.00	
Relexation factor	1.000	
Inside face surface temperature convergence criteria	0.0020	
Airflow Network		
Maximum iterations	1000	
Absolute airflow convergence tolerance (kg/s)	0.000001000	
Relative airflow convergence tolerance	0.000100000	
Convection		
Inside convection algorithm	6-TARP	
Outside convection algorithm	6-DOE-2	

Step 4: Simulate the model and record the results.

Step 5: Repeat previous steps and select **Finite Differ**ence from the **Solution algorithm** drop-down list.

Calculation Options		
Simulation method	1-EnergyPlus	*
Time steps per hour	2	•
Temperature control	1-Air temperature	•
Solar		×
Include all buildings in shading calcs		
Model reflections and shading of ground reflected solar		
Solar distribution	2-Full exterior	•
Shadowing interval (days)	20	
Detailed HVAC Autosizing		**
Advanced		×
General Solution		×
Solution algorithm	2-Finite Difference	•
Allow individual constructions to override solution method		
Finite Difference Settings		×
Finite difference scheme	1-Fully implicit first order	•
Space discretization constant	3.00	
Relaxation factor	1.000	
Inside face surface temperature convergence criteria	0.0020	
Airflow Network		×
Maximum iterations	1000	
Absolute airflow convergence tolerance (kg/s)	0.000001000	
Relative airflow convergence tolerance	0.000100000	
Convection		×
Inside convection algorithm	6-TARP	*
Outside convection algorithm	6-DOE-2	*

	Annual fuel breakdown consumption (kWh)	
	Conduction Transfer Function	Finite Difference (fully implicit first order)
Run time	0:27	3:57
Room electricity	153,342.90	153,342.90
Lighting	221,613.30	221,613.80
System fans	155,002.60	156,511.60
System pumps	7,939.26	8,021.31
Heating (electricity)	101,686.90	106,023.80
Cooling (electricity)	230,764.70	232,707.50
Heat rejection	51,146.54	51,847.43

Table 9.4Variation in simulation run time with variation in thesolution algorithm

Step 6: Simulate the model and record the results. Compare the results for both simulations (Table 9.4). It can be seen from the results that with the Finite Difference method there is an increase in the simulation run time.

TUTORIAL 9.4 Evaluating the effect of the inside convection algorithm

GOAL

To evaluate building energy performance with the change in the inside convection algorithm.

WHAT ARE YOU GOING TO LEARN?

· Changing the inside convection algorithm

PROBLEM STATEMENT

In this tutorial, you are going to use the simulation model saved in Tutorial 9.1 with time steps per hour as 2.

You are going to select the following algorithms:

- 1. Adaptive convection
- 2. Simple
- 3. CIBSE
- 4. TARP

Find the change in energy consumption for all cases.

Use PARIS-AEROPORT CHAR, France weather location.

Inside convection algorithm

You can select from six main EnergyPlus inside convection algorithms for calculating the convection between internal zone surfaces and the rest of the zone air in the simulation calculations. Unless you have a good reason to do so, you are advised to use the default TARP convection algorithm.

- 1-Adaptive convection algorithm: this advanced option provides a dynamic selection of convection models based on conditions. Beausoleil-Morrison (2000, 2002) developed a methodology for dynamically managing the selection of h_c equations, called the adaptive convection algorithm. The algorithm is used to select among the available h_c equations for the one that is most appropriate for a given surface at a given time. As Beausoleil-Morrison notes, the adaptive convection algorithm is intended to be expanded and altered to reflect different classification schemes and/or new h_c equations. The adaptive convection algorithm implemented in EnergyPlus for the inside face has a total of 45 different categories for surfaces and 29 different options for h_c equation selections. The tables provided in the Engineering document summarize the categories and the default assignments for h_c equations.
- 2-Simple: the simple convection model uses constant coefficients for different heat transfer configurations, using the criteria to determine reduced and enhanced convections. The coefficients are taken directly from Walton (1983). Walton derived his coefficients from the surface conductance for $\varepsilon = 0.90$ 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 = 0.918BTU/h ft² F and then subtracted off. Finally, the coefficients were converted to SI units to yield the following values. For a vertical surface, $h_c = 3.076$. For a horizontal surface with reduced convection, $h_c = 0.948$. For a horizontal surface with enhanced convection, $h_c = 4.040$. For a tilted surface with (*Continued*)

reduced convection, $h_c = 2.281$. For a tilted surface with enhanced convection, $h_c = 3.870$.

- **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, $h_c = 3.873 + 0.082 \times ACH ^0.98$. For ceilings, $h_c = 2.234 + 4.099 \times ACH ^0.503$. For walls, $h_c = 1.208 + 1.012 \times ACH ^0.604$.
- 5-Cavity: this algorithm was developed to model convection in a 'Trombe wall zone' that is 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 multipane 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 and 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. See also the note below.
- **6-TARP**: based on variable natural convection based on the temperature difference from ASHRAE algorithms. This is the same as the old 'Detailed' Inside convection algorithm provided in earlier versions of DesignBuilder.

Source: http://www.designbuilder.co.uk/ helpv4.7/Content/Surface_Convection.htm

SOLUTION

Step 1: Open the simulation model saved in Tutorial 9.1 with time steps per hour as 2.

Step 2: Select the **Simulation** tab.

Step 3: Select the **Options** tab and expand the **Advanced** section.

Calculation Options Data		
General Options Output Simulation Manager		
Calculation Options		×
Simulation method	1-EnergyPlus	•
Time steps per hour	2	•
Temperature control	1-Air temperature	•
Solar		¥
Include all buildings in shading calcs		
Model reflections and shading of groun	d reflected solar	
Solar distribution	2-Full exterior	-
Shadowing interval (days)	20	
Detailed HVAC Autosizing		»
Advanced		»

Step 4: Select Adaptive Convection Algorithm from the Inside convection algorithm drop-down list in the Convection section.

Solar distribution	2-Full exterior	
	20	
Shadowing interval (days) etailed HVAC Autosizing	20	»
dvanced		
General Solution		*
Solution algorithm	1-Conduction Transfer Function	
Allow individual constructions to override solution method		
Finite Difference Settings		÷
Finite difference scheme	1-Fully implicit first order	
Space discretization constant	3.00	-
Space discretization constant Relaxation factor	1,000	
	0.0020	
Inside face surface temperature convergence criteria Airflow Network	0.0020	
	1000	Ŷ
Maximum iterations		
Absolute airflow convergence tolerance (kg/s)	0.000001000	
Relative airflow convergence tolerance	0.000100000	
Convection		×
Inside convection algorithm	1-AdaptiveConvectionAlgorithm	*
Outside convection algorithm	6-DOE-2	٣
Warmup		÷
Minimum number of warmup days	6	
Maximum number of warmup days	25	
Temperature convergence tolerance	0.400000	
Loads convergence tolerance	0.040000	

Step 5: Click **OK** and note down the results.

	Annual fuel breakdown consumption (kWh)			
	Adaptive convection algorithm	Simple	CIBSE	TARP
Run time (min)	0.27	0.22	0.19	0.20
Room	153,342.90	153,342.90	153,342.90	153,342.90
electricity				
Lighting	221,613.80	221,613.80	221,613.80	221,613.80
System fans	122,129.20	131,199.00	134,431.30	128,277.70
System pumps	4,215.91	4,841.64	5,136.61	4,664.57
Heating (gas)	417,841.00	437,897.80	440,730.00	423,825.50
Cooling	86,390.53	98,280.73	102,366.10	94,650.77
(electricity)				
Heat rejection	26,360.16	30,413.91	31,752.80	29,144.83

Table 9.5Variation in simulation run time with variation in theinside convection algorithm

Step 6: Repeat the previous steps for **Simple, CIBSE** and **TARP** from the Inside convection algorithm drop-down list.

Compare the results for simulations (Table 9.5).

Difference in the HVAC energy consumption and the run time while using different algorithms can be noted from the above table.

Exercise 9.2

Repeat the above tutorial to evaluate the building energy performance with the change in the outside convection algorithm.

You need to select the following algorithms:

- 1. Adaptive convection
- 2. Simple combined
- 3. TARP
- 4. DOE-2

Use PARIS-AEROPORT CHAR, France weather location.

TUTORIAL 9.5 Evaluating the impact of the shadowing interval

GOAL

To evaluate the impact of the shadowing interval on the building energy consumption.

WHAT ARE YOU GOING TO LEARN?

Changing the shadowing interval

PROBLEM STATEMENT

In this tutorial, you are going to use the simulation model saved in Tutorial 9.2 with Full exterior.

You are going to simulate the model for the following intervals:

5, 10, 20 and 30 days

Use New Delhi/Palam, India weather location.

Shadowing interval is important for determining the amount of sun entering your building and by inference the amount of cooling or heating load needed for maintaining the building. Though termed 'shadowing' calculations, it in effect determines the sun's position on a particular day in a weather file period simulation. (Each design day will use the date of the design day object.) Even though weather file data contain the amount of solar radiation, the internal calculation of the sun's position will govern how it affects various parts of the building.

By default, the calculations are done for every 20 days throughout a weather run period; an average solar position is chosen and the solar factors (such as sunlit areas of surfaces) remain the same for that number of days. More integrated calculations are needed for controlling dynamic windows or shades.

Source: EnergyPlus InputOutput Reference

SOLUTION

Step 1: Open the simulation model saved in Tutorial 9.2.

Step 2: Select the **Simulation** tab.

Step 3: Select the **Options** tab.

Calculation Options Data

General Options Output Simulation Manage	er	
Calculation Options		¥
Simulation method	1-EnergyPlus	•
Time steps per hour	2	•
Temperature control	1-Air temperature	*
Solar		¥
Include all buildings in shading calcs		
Model reflections and shading of gro	und reflected solar	
Solar distribution	2-Full exterior	-
Shadowing interval (days)	20	

Step 4: Type 5 in the Shadowing interval (days).

Edit Calculation Options			
Calculation Options Data			Неір
General Options Output Simulation	Manager		Info Data
Calculation Options		×	Calculation Options
Simulation method	1-EnergyPlus	-	These options can also be accessed from the Model Options dialog.
Time steps per hour	2		Time steps
Temperature control	1-Air temperature	•	In general, increasing the number of
Solar		×)	timesteps improves accuracy but slows the simulation (and generates
🔲 🔲 Include all buildings in shading	g calcs		more data if output is requested at the
Model reflections and shading	of ground reflected	solar	'sub-hourly' interval).
Solar distribution	2-Full exterior		Solar Distribution
Shadowing interval (days)	5		Solar distribution should generally be set to 'Full exterior' as this provides a
Advanced		"	good compromise between accuracy
			and versatility. 👻
Don't show this dialog next time		Help	Cancel OK

Step 5: Simulate the model and record the results.

Step 6: Repeat previous steps for shading intervals of 10, 20 and 30 days.

Compare the data for all the cases (Table 9.6).

Table 9.6 Variation in simulation run time with variation in the shadowing interval

Annual fuel breakdown data				
	Shading interval			
End use component	5 days	10 days	20 days	30 days
Run time (min)	0:18	0.15	0.14	0.13
Room electricity	153,342.90	153,342.90	153,342.90	153,342.90
Lighting	221,613.80	221,613.80	221,613.80	221,613.80
Heating (gas)	10,568.76	10,578.89	10,616.47	10,658.09
Cooling (electricity)	256,742.50	256,770.60	256,906.00	256,897.60
DHW (electricity)	13,875.00	13,875.00	13,875.00	13,875.00

Natural Ventilation

The method of simulating natural ventilation is somewhat different from that of simulating HVAC components. Natural ventilation is often achieved either using windows or using ventilation fans. Simulation tools can model both the cases and can predict the thermal conditions of indoors. Mixedmode buildings, which use both natural ventilation when ambient conditions are moderate and HVAC system when it is harsh, can also be modelled by defining the opening of windows and operation of HVAC in the simulation model. In this chapter, the method of modelling naturally ventilated buildings is explained through six tutorials. Various aspects of modelling of natural ventilation, such as how to define window opening, how to define scheduled opening and closing of windows and the impact of window opening on indoor conditions are explained. Design issues such as the size of the openable window and the temperature-controlled automatic opening of windows are also discussed.

TUTORIAL 10.1 Evaluating the impact of wind speed on natural ventilation

GOAL

To evaluate the impact of the change in wind speed on ventilation rate.

WHAT ARE YOU GOING TO LEARN?

- Modelling natural ventilation
- Defining glazing area openings for 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. A range of control options are provided.
- **Calculated** where natural ventilation and infiltration are calculated based on window openings, cracks, buoyancy and wind-driven pressure differences, crack dimensions and so on. Control options are provided.

Source: http://www.designbuilder.co.uk/helpv4.7/ Content/_Natural_ventilation_modelling.htm

PROBLEM STATEMENT

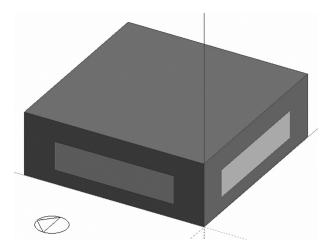
In this tutorial, you are going to use a $10 \text{ m} \times 10 \text{ m}$ singlezone model.

Find zone air changes for the model with natural ventilation.

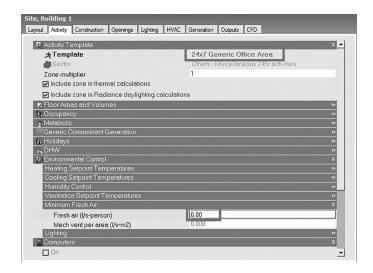
Use New Delhi/Safdarjung, India weather location.

SOLUTION

Step 1: Open a new blank project file and create a $10 \text{ m} \times 10 \text{ m}$ single-zone building. Select the **Activity** tab.



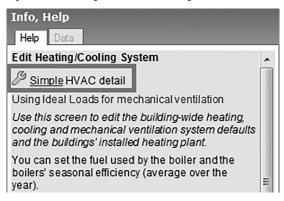
Step 2: Select the 24×7 Generic Office Area template. Set Fresh air (l/s-person) and Mech vent per area (l/s- m^2) to 0.



Step 3: Select the **HVAC** tab. Select the **Natural** ventilation – No Heating/Cooling template.

Site, Building 1 Layout Activity Construction Openings Lighting H	VAC Generation Outputs CFD
R HVAC Template	*
1 Template	Natural ventilation - No Heating/Cooling
Mechanical Ventilation	*
🗖 On	
TAuxiliary Energy	×
Pump etc energy (W/m2)	0.0000
Chedule Schedule	Office_OpenOff_Occ

Step 4: Click Simple under the Help tab.



Step 5: Click **Calculated** under Natural ventilation. Click **OK**.

Model Options - Building and Block		
Model Options Data		Нер
Cost/Carbon		Info Data
Data Advanced Heating Design Cooling Design Simul	ation Display Drawing tools Block Project details	Data Detail (Building Data)
Data Options	Drew building + standard data	Use this dialog to configure the model detail to your requirements.
Construction and Glazing Data Gains Data	Draw building + standard dala	The descriptions to the right of the sliders, taken together, provide a summary of the current model detail
Timing HVAC HVAC Simple Compact Dr	Simple HVAC HVAC systems are modelled using Ideal Loads, fuel consumption adultude from loads using seasonal efficiencies	zone you want to model and change the
HVAC sizing		scope to 'Zone'
Simple HVAC autosize method Specify Simple/Design HVAC details	1-EnergyPlus	 Construction and glazing The 'Construction and glazing' model option controls the way construction
Auxiliary energy calculations	2-Separate fans and pumps	 templates are loaded in Model Data. When the option is set to 'Pre-design'
Mechanical ventilation method	2-Ideal loads	 you can select the construction template
Natural Ventilation and Infiltration		 using the Insulation and Thermal mass slider controls.
	Calculated ventilation Natural ventilation and infiltration air flow rates are calculated base on opening and crack sizes, buoyancy and wind pressures.	d Gains Data There are three levels of gains model detail
Infiltration units		Lumped - all internal gains are
Airtightness method		 Lumped - all internal gains are lumped together into a single value.
BIM Surfaces		 Early - gains can be defined separately under various categories
		Help Cancel OK

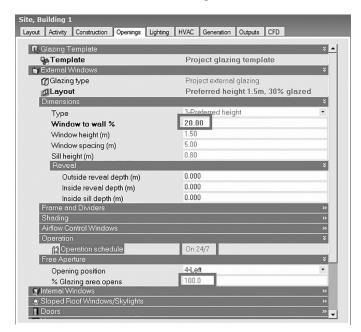
Step 6: Click the **Options** sub-section in the **Natural Ventilation** section and select **Constant** for the External control mode and Internal control mode drop-down lists.

Outside air definition method	1-By zone	
Outside air (ac/h)	5.000	
Operation		
台 Schedule	Ware_24x7CellOff_Occ	
Outdoor Temperature Limits		
Delta T Limits		
Delta T and Wind Speed Coefficients		
Options		
Wind factor	1.00	
External control mode	4-Constant	
Internal control mode	4-Constant	
Modulate opening areas		
Mixed Mode Zone Equipment		

Constant – Whenever an opening's operation schedule allows venting, all of the zone's openable windows and doors are open, independent of indoor or outdoor conditions. Note that 'Constant' here means that the size of each opening is fixed while venting; the air flow through each opening can, of course, vary from time step to time step. This option allows modelling of a window that is opened for fresh air regardless of inside/outside temperature/enthalpy.

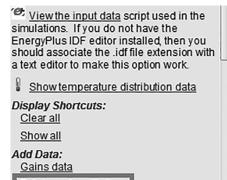
> Source: http://www.designbuilder.co.uk/ helpv4.7/Content/CalculatedNatVent.htm

Step 7: Select the **Opening** tab. Set Window to wall % to **20.00**. Click the **Free Aperture** section. Set % Glazing area opens to **100.0** and select **On 24/7** in Operation schedule.



Step 8: Perform hourly simulation. After simulation, click **Clear all**.

Step 9: Now click the links **Fabric and ventilation** and **Site** from **Add Data** to record the results for Wind speed and Mechanical ventilation. Select **Grid** in the Show as dropdown list.



Fabric and ventilation

<u>Comfort</u>

<u>Site</u>

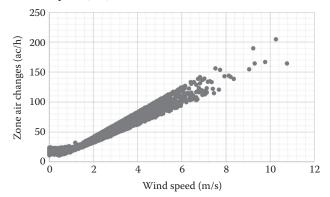
System loads

Fuel totals

Fuel breakdown

Analysis Sun	mary Paramet	ric Optimisat	tion			
Date/Time	Outside Dr	Outside De	External Air.	Mech Vent + Nat Vent + Infiltration (ac/h)	Wind Speed (m/s)	√ir
1/1/2002 1:00:		4.5	-6.200551			29
1/1/2002 2:00:	6.625	4.375	-6.508322	30.55686	1.625	27.
1/1/2002 3:00:	6.55	3.85	-6.239213	33.94604	1.925	261
1/1/2002 4:00:	6.225	3.25	-6.185522	33.839	1.925	25;
1/1/2002 5:00:	6.925	2.65	-5.269088	30.90661	1.75	26
1/1/2002 6:00:	7.35	1.75	-5.143509	40.09126	2.375	27.
1/1/2002 7:00:	7.925	1.575	-4.733286	50.04868	3.125	27!
1/1/2002 8:00:	9.225	1.825	-4.245484	63.02525	3.75	28!
1/1/2002 9:00:	11.25	2.725	-3.668017	69.73933	3.9	29;
1/1/2002 10:0	D 13.9	3.525	-3.206588	72.39957	3.9	291
1/1/2002 11:0	J 16.7	3.775	-2.612462	70.12128	3.9	29:
1/1/2002 12:0	0 19.05	3.125	-2.062108	77.15937	4.275	29
1/1/2002 1:00:	20.425	2.3	-1.85321	80.52464	4.625	29
1/1/2002 2:00:	20.775	1.125	-2.247421	86.45415	4.925	29

Export the results to a spreadsheet and plot a scatter graph between Mech Vent + Nat Vent + Infiltration (ac/h) and Wind speed (m/s).



You can observe that with an increase in wind speed, there is an increase in zone air change.

Step 10: Repeat the above tutorial with **Scheduled** under Natural ventilation.

Model Options Data	
Block Project details Cost/Carbon	
Data Advanced Heating Design Cooling Design	Simulation Display Drawing tools
Data Options	*
Model options template	Draw building + standard data
Construction and Glazing Data	»
Gains Data	»
Timing	»
HVAC	*
HVAC Simple Compact Detailed	Simple HVAC HVAC systems are modelled using Ideal Loads, fuel consumption is calculated from loads using seasonal efficiencies
HVAC sizing	3-Autosize
Simple HVAC autosize method	1-EnergyPlus
Specify Simple/Design HVAC details	
Auxiliary energy calculations	2-Separate fans and pumps 🔹
Mechanical ventilation method	2-Ideal loads
Natural Ventilation and Infiltration	*
Natural ventilation Scheduled Infiltration units	Scheduled ventilation Ventilation is defined as an air-change rate modified by an operation schedule and controlled using a «±-noint temperature 1-ac/h
BIM Surfaces	»

Scheduled – the ventilation rates are predefined using a maximum air change rate modified by operation schedules.

Source: http://www.designbuilder.co.uk/helpv4.7/ Content/_Ventilation_model_detail.htm

Step 11: Select the **Activity** tab. Clear both **Indoor min and max temperature control** checkboxes in the Natural Ventilation section.

BUILDING ENERGY SIMULATION

Site, Building 1		
Layout Activity Construction Openings Lighting	HVAC Generation Outputs CFD	
C Asti it Tourslate		×
R Activity Template	24x7 Generic Office Area	×
्र Template		
Sector	Others - Miscellaneous 24hr activities	
Zone multiplier	1	
Include zone in thermal calculations		
Include zone in Radiance daylighting c	alculations	
🚡 Floor Areas and Volumes	에는 것 같아? 이는 것은 것은 것 같아. 가지는 것 같아.	>>
0 ₆ Occupancy		>>
netabolic		>>
MGeneric Contaminant Generation		>>
🏠 Holidays		>>
The second se		>>
Environmental Control		*
Heating Setpoint Temperatures		>>
Cooling Setpoint Temperatures		»
Humidity Control		>>
Ventilation Setpoint Temperatures		*
Natural Ventilation		×
Indoor min temperature control		
Indoor max temperature control		
Minimum Fresh Air		×
Fresh air (l/s-person)	0.000	
Mech vent per area (I/s-m2)	0.000	
Lighting		>>
💂 Computers		>>
🔩 Office Equipment		>>

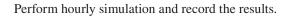
Step 12: Select the **Construction** tab. Clear **Model infiltration** in the Airtightness section.

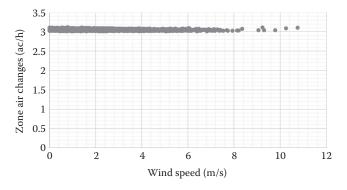
Construction Template	
Se Template	Project construction template
Construction	
Texternal walls	Project wall
🗊 Below grade walls	Project below grade wall
Tlat roof	Project flat roof
Pitched roof (occupied)	Project pitched roof
Pitched roof (unoccupied)	Project unoccupied pitched roof
Internal partitions	Project partition
Semi-Exposed	
Floors	
Sub-Surfaces	
Internal Thermal Mass	
Component Block	
Geometry, Areas and Volumes	
Surface Convection	
Linear Thermal Bridging at Junctions	
Airtiahtness	

Step 13: Enter **3.000** for **Outside air** (**ac/h**) under the Natural Ventilation section and select **On 24/7** in the Operation section.

CHAPTER TEN NATURAL VENTILATION

Site, Building 1	
Layout Activity Construction Openings Lighting	HVAC Generation Outputs CFD
R HVAC Template	*
Template	Natural ventilation - No Heating/Cooli
Mechanical Ventilation	Natural Ventilation - No Fleating/Cooli
On	
Tuxiliary Energy	×
Pump etc energy (W/m2)	0.0000
Chedule	Office OpenOff Occ
N Heating	*
Heated	
*Cooling	¥
Cooled	
Humidity Control	»
is DHW	*
🗖 On	
Natural Ventilation	*
🔽 On	
Outside air definition method	1-By zone 🔹
Outside air (ac/h)	3.000
Operation	¥
않 Schedule	On 24/7
Outdoor Temperature Limits Delta T Limits	» »
Delta T Limits Delta T and Wind Speed Coefficients	
Mixed Mode Zone Equipment	» *
mittea meao zono zquipment	





You may note that there is no change in ventilation rate with wind speed, since in this option, the ventilation is fixed.

Exercise 10.1

Repeat the above tutorial for % Glazing area opens to 50. Plot the chart between zone air changes (ac/h) with Wind speed (m/s). Observe the change in Air changes per hour.

TUTORIAL 10.2 Evaluating the impact of natural ventilation with constant wind speed and direction

GOAL

To understand the impact of natural ventilation with constant wind and direction.

WHAT ARE YOU GOING TO LEARN?

• Changing the weather data file for wind speed and direction

PROBLEM STATEMENT

In this tutorial, you are going to use a $10 \text{ m} \times 10 \text{ m}$ singlezone model with a window on the north and south façades. You are going to change wind velocity and direction in the weather file.

- Wind velocity 1 and 2 m/s
- Wind direction 0° (wind from the north to south)

Then simulate the weather file and observe the effect on Air changes per hour.

Use New Delhi/Safdarjung, India weather location.

SOLUTION

First, you are going to modify the weather data file for wind speed and direction.

Step 1: Download the weather data for New Delhi from the following link and download the .epw file.*

Or

Copy from the Weather data folder.

Step 2: Download the following CSV editor tool.[†] (You can use any csv editor.)

(For this tutorial, we have used CSVed 2.4.)

Step 3: Open the CSV editor tool and select the downloaded .epw file of New Delhi weather location.

^{*} https://energyplus.net/weather-location/asia_wmo_region_2/IND//IND_ New. Delhi.421820_ISHRAE

[†] http://csved.sjfrancke.nl (by Sam Francke)

CHAPTER TEN NATURAL VENTILATION

File Edit View Tools Help	8768 × 10 [1][1]					
	000200		BDX0II0	0		
Navigation Clipboard	Column 1	Column 2	Column 3	Column 4	Column 5	Col
So to Column:	LOCATION	New Delhi	Delhi	IND	ISHRAE	421
1	DESIGN CONDITIONS	1	Climate Design		Heating	1
olumn 1	TYPICAL/EXTREM	8	Wet Season - W	Typical	8/14	8/2
iolumn 2 iolumn 3	GROUND TEMPERA	3	.5			
iolumn 3	HOLIDAYS/DAYLI	No	0	0	0	
iolumn 5 iolumn 6	COMMENTS 1	ISHRAE India W				
olumn 7	COMMENTS 2	Ground temp				
	DATA PERIODS	1	1	Data	Sunday	1/
Column 8 Column 9 Column 10	1990	1	1	1	60	292
	1990	1	1	2	60	292
	•					F
io to Row:	CSVed version	on 2.4 2016				
1	Start an Colum Colu	m Date T Join an Le	adin Modify Proper	Filter a Save Searc	h XML Fixed L	Sort .
*		Row	Edit Item	Hide - Unhide Columns		
> Start and Item Edit		Start Row (skip rows): 1	Edit	Select Columns to hide:	Column Width for unhide:	
> Column Edit 1		Jse Value at every File	East	Column 1	A 150	
b - Column Edit 2	Tab	Use Start Row as Column Captio	Insert	Column 2 Column 3		
Date Thousands Decimal	© Pipe	with Number Prefix		Column 3 Column 4	Unhide all Columns	
Join and Split		Column Name: Add	Add	Column 5	E	
 Leading Zeros or Spaces Modify 	Col			Column 6 Column 7		
- Proper Strings		Inser	Delete	Column 8	* Hide Columns	
 Filter and Dups 	Set New Column (Column 9	* Hoe coumris	
	Set New Column C	Jrder				
b. Save						

Source: From http://csved.sjfrancke.nl/.

Step 4: After opening the file, go to **Set Start Row** in **Start and Item Edit** tab. Set **Start Row** to **9**.

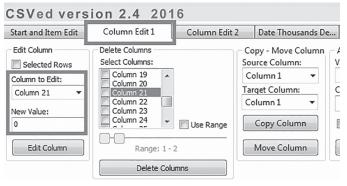
Set Separator (a) , Comma (b) ; Semi Colon (c) Tab (c) Pipe	Start Row Set Start Row (skip rows): Use Value at every File Use Start Row as Colum with Number Prefix	
Other	New Column Name: Column 👻	Add Insert

In the .epw file, Columns 21 and 22 represent the Wind direction and speed, respectively.

Column 18	Column 19	Column 20	Column 21	Column 22	Column 23	Column 24
0	0	0	289	1.4	0	5
0	0	0	270	1.7	0	5
0	0	0	265	2.0	0	1
0	0	0	248	1.9	0	7
0	0	0	270	1.7	0	5
0	0	0	276	2.6	1	7
0	0	0	280	3.3	2	8
0	0	0	292	3.9	3	4
0	0	0	293	3.9	5	9
0	0	0	297	3.9	6	0
0	0	0	292	3.9	6	8
0	0	0	294	4.4	6	4
0	0	0	290	4.7	6	0
0	0	0	292	5.0	5	8
0	0	0	287	4.5	3	2
0	0	0	291	3.9	2	4
0	0	0	292	2.8	1	6
0	0	0	304	2.3	1	4
0	0	0	308	1.9	1	2
0	0	0	315	2.2	2	9
0	0	0	306	2.4	2	2
0	0	0	302	2.9	2	1
0	0	0	292	2.8	1	4
0	0	0	294	2.7	1	8
0	0	0	290	2.1	0	6
0	0	0	292	1.7	0	2
0	0	0	282	1.2	0	5
0	0	0	278	1.3	0	2
0	0	0	247	2.2	1	8
0	0	0	231	1.8	1	8

Source: From http://csved.sjfrancke.nl/.

Step 5: For changing the wind direction to 0° , select Column Edit 1 tab and select Column 21 from the drop-down and enter 0 in the New Value text box. Click Edit Column.



Source: From http://csved.sjfrancke.nl/.

Step 6: Similarly, for changing the wind speed to 1 m/s, select **Column 22** and enter **1** in the **New Value** text box. Click **Edit Column**.

•				
CSVed versi	ion 2.4 20	16		
Start and Item Edit	Column Edit 1	Column Edit :	2	Date Thousands De
Edit Column Selected Rows Column to Edit: Column 22 New Value: 1 Edit Column Edit Column	Delete Columns Select Columns: Column 19 Column 20 Column 21 Column 21 Column 23 Column 24 Range: 1	Use Range	Sou Co Tar Co	py - Move Column rrce Column: Jumn 1 get Column: Jumn 1 Copy Column Move Column

Source: From http://csved.sjfrancke.nl/.

Step 7: Save the file with the name **Delhi Constant Wind.epw** on Desktop.

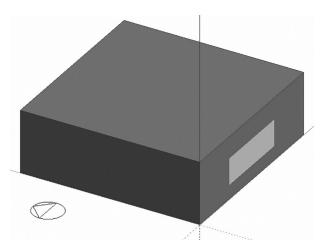
Open DesignBuilder.

Select the **File > Folders > Weather data** folder and paste it as the **Delhi Constant Wind.epw** weather file.

<u>_</u>	Des	ignBuilder		
	<u>F</u> ile	Go Tools Help		
		<u>N</u> ew project	Ctrl+N	
	2	<u>O</u> pen project	Ctrl+0	
		<u>S</u> ave	•	ate Libraries
Γ		Import	•	r 🛆 Size (Ki
		<u>E</u> xport	•	B Files\Chapter 2 DB 1631
		<u>F</u> olders		EnergyPlus folder
		Print		<u>R</u> adiance folder
		Exit	Alt+F4	Weather data folder
		1 2.4.dsb		Library data folder
		2 5.2 8m sensor.dsb		Template projects folder
		3 2.3 625.dsb		<u>D</u> iagnostic files folder

Source: From http://csved.sjfrancke.nl/.

Step 8: Open the project file saved in Tutorial 10.1 with calculated Natural ventilation and delete both east and west façades.



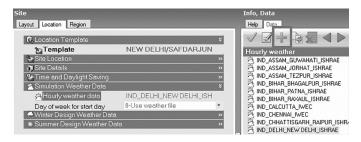
Step 9: Select the **Construction** tab. Select **Outer** for the **Zone volume calculation method** and **Zone floor area calculation method** in the **Geometry**, **Areas and Volumes** section.

	× *
External measurements	
2-Outer	
2-Outer	•
2-Outer	•
	2-Outer 2-Outer

Step 10: Select the Location tab and select Hourly weather data under the Simulation Weather Data section.

C. Location Template		
Template	NEW DELHI/SAFDARJUN	11111
Site Location		
🔊 Site Details		
Time and Daylight Saving		
🛎 Simulation Weather Data		
😤 Hourly weather data	IND_DELHI_NEW DELHI_ISHRAE	
Day of week for start day	a-Use weather life	

Step 11: Click the **Add new item** icon under the **Help** tab.



Step 12: In the **Edit hourly weather - Delhi Constant Wind** screen, rename with your custom weather file and search for the file by clicking **Filename**. Click **OK** to successfully select the file.

lourly weather Data			Help		
General Statistics			Info Data		
General		×1	Hourly Weather Data Templates		
Name Delhi Constant Wi	nd	11	Hourly weather data templates are a database of hourly weather		
Source	ISHRAE		files from around the world.		
Country	INDIA		If you select an hourly weather file		
Filename	Delhi Constant Wind.epw		from the DesignBuilder database		
Details		≈ III	which does not yet exist on your computer, DesignBuilder will		
Latitude (")	28.58		automatically download it from the		
Longitude (")	77.20	Ш	website.		
WMO station identifier	421820	Ш			
ASHRAE climate zone	Unknown	Ш			
Model data	Help		Cancel OK		

Step 13: Select **Exposed** from the **Exposure to wind** drop-down list under the **Site Details** section.

CHAPTER TEN NATURAL VENTILATION

Site		
Layout Location Region		
C Location Template	그렇게 회사 물건을 수 있는 것을 많이 많다.	×
Template	NEW DELHI/SAFDARJUN	
Site Location		»
🔊 Site Details		×
Elevation above sea level (m)	216.0	
Exposure to wind	3-Exposed	•
Site orientation (*)	0	
Ground		»
Sky	: 2011년년 - 1112 (M. 2011년 - 201	**

Step 14: Simulate the model and record the results. Observe the results in Wind Speed, Wind Direction and Mech Vent + Nat Vent + Infiltration (ac/h).

Site							
Analysis Sun	nmary Parametr	ic Optimisa	tion				
Date/Time	Outside Dr	Outside De	Wind Speed (m/s)	Wind Direction (*)	Solar Altitu	Solar Azim	Atmospł 🔺
1/1/2002	12.85833	2.604167	1	U	0	0	10100 =
1/2/2002	12.625	3.745833	1	0	0	0	101000
1/3/2002	13.59167	5.854167	1	0	0	0	101125
1/4/2002	14.44167	7.483334	1	0	0	0	101250
1/5/2002	14.20833	9.566667	1	0	0	0	101000
1/6/2002	14.7125	9.779166	1	0	0	0	10108(
1/7/2002	15.2375	10.30417	1	0	0	0	10150(
1/8/2002	14.92917	10.7125	1	0	0	0	10116
1/9/2002	15.21667	11.19167	1	0	0	0	101000
1/10/2002	16.4	11.18333	1	0	0	0	10108
1/11/2002	14.47083	12.5375	1	0	0	0	101416
1/12/2002	15.37083	10.95	1	0	0	0	101458
1/13/2002	15.8875	11.46667	1	0	0	0	101625
1/14/2002	14.05417	10.075	1	0	0	0	101416
1/15/2002	13.64167	9.120833	1	0	0	0	10154
1/16/2002	11.27917	9.870833	1	0	0	0	10129
1/17/2002	13.00833	9.6	1	0	0	0	10154
1/18/2002	12.0625	9.825	1	0	0	0	101375
1/19/2002	10.98333	9.620833	1	0	0	0	102000
1/20/2002	13.4625	8.683333	1	0	0	0	101375
1/21/2002	13.42917	7.5125	1	0	0	0	101208
1/22/2002	13.36667	7.8875	1	0	0	0	101208
1/23/2002	13.5125	7.454166	1	0	0	0	101666

Date/Time	Lighting (k.	. Air Temper	Radiant Te	Operative	Outside Dr	External Air	General Li	Solar Gain	Mech Vent + Nat Vent + Infiltration (ac/n)
1/1/2002 1:00:.	. 2	9.721354	15.95517	12.83826	7.55	-5.58922	2	0	21.14309
1/1/2002 2:00:.	. 2	8.878499	15.32376	12.10113	6.625	-5.81512	2	0	21.1334
1/1/2002 3:00:.	. 2	8.655287	14.7548	11.70504	6.55	-5.440234	2	0	21.13978
1/1/2002 4:00:.	. 2	8.325451	14.36089	11.34317	6.225	-5.423567	2	0	21.09971
1/1/2002 5:00:.	. 2	8.727758	14.01154	11.36965	6.925	-4.665512	2	0	21.1813
/1/2002 6:00:.	. 2	9.013419	13.89292	11.45317	7.35	-4.298749	2	0	21.16726
1/1/2002 7:00:.	. 2	9.397363	13.78261	11.58999	7.925	-3.807067	2	0	21.20516
1/1/2002 8:00:.	. 2	10.37359	13.82569	12.09964	9.225	-2.960361	2	0.0634592	21.20729
1/1/2002 9:00:.	. 2	12.0175	14.30534	13.16142	11.25	-1.967999	2	0.7034124	21.20846
1/1/2002 10:00	2	14.37079	15.51845	14.94462	13.9	-1.198257	2	2.221532	21.19323
1/1/2002 11:00	2	16.97026	16.94967	16.95996	16.7	-0.683357	2	3.019037	21.18478
1/1/2002 12:00	2	19.15695	18.5511	18.85402	19.05	-0.270792	2	3.73964	21.17654
1/1/2002 1:00:.	. 2	20.48458	19.6929	20.08874	20.425	-0.151862	2	3.244034	21.17348
1/1/2002 2:00:.	. 2	20.94652	20.46544	20.70598	20.775	-0.428918	2	2.770406	21.17048
1/1/2002 3:00:.	. 2	20.58341	20.94597	20.76469	20.2	-0.954946	2	2.426734	21.17159
1/1/2002 4:00:.	. 2	19.68828	20.88714	20.28771	19.1	-1.46861	2	1.552328	21.18874
1/1/2002 5:00:.	. 2	18.60686	20.44795	19.52741	17.9	-1.77064	2	0.6678638	21.19156
1/1/2002 6:00:.	. 2	17.64022	19.86421	18.75222	16.85	-1.985715	2	5.720396	21.19304
1/1/2002 7:00:.	. 2	16.69375	19.36917	18.03146	15.775	-2.315656	2	0	21.19326
1/1/2002 8:00:.	. 2	15.74891	18.92001	17.33446	14.675	-2.714459	2	0	21.19031
1/1/2002 9:00:.	. 2	14.58615	18.45519	16.52067	13.275	-3.324424	2	0	21.17896
1/1/2002 10:00	2	13.2744	17.9086	15.5915	11.7	-4.010018	2	0	21.18154
1/1/2002 11:00	2	11.88151	17.28456	14.58303	10.025	-4.748003	2	0	21.16785
1/2/2002	2	10.68913	16.60165	13.64539	8.625	-5.291909	2	0	21.13069
1/2/2002 1:00:	. 2	9.826315	15.9473	12.88681	7.7	-5.472719	2	0	21.14835
1/2/2002 2:00:.	. 2	9.357215	15.3782	12.36771	7.275	-5.362625	2	0	21,11966

You can observe that Air changes per hour are almost constant throughout the year.

Step 15: Modify the weather data with Wind speed as **2 m/s** and Wind direction as **0**° with the help of previous steps.

Step 16: Simulate the model and note down the results. Observe the results in Wind Speed, Wind Direction and Mech Vent + Nat Vent + Infiltration (ac/h).

Date/Time	Outside Dr	Outside De.	Wind Speed (m/s)	Wind Direction (*)	Solar Altitu	Solar Azim	Atmospheri	Direct Nor.
1/1/2002	12.85833	2.604167	2	0	-14.77771	177.6181	101000	5.58675
1/2/2002	12.62292	3.732292	2	0	-14.73057	177.5012	101000	5.796
1/3/2002	13.56458	5.822917	2	0	-14.679	177.3857	101125	5.565
1/4/2002	14.44375	7.479167	2	0	-14.62301	177.2715	101250	4.794
1/5/2002	14,19792	9.55625	2	0	-14.56261	177,159	101000	3.252
1/6/2002	14.71771	9.784375	2	0	-14.49779	177.0482	101083.3	3.968
1/7/2002	15.24271	10.30625	2	0	-14.42856	176.9393	101489.6	5.029
1/8/2002	14.92188	10.70417	2	0	-14.35493	176.8323	101177.1	4.499
1/9/2002	15.19167	11.16979	2	0	-14.27691	176.7273	101000	3.015
1/10/2002	16.41042	11.19583	2	0	-14.1945	176.6246	101083.3	2.69575
1/11/2002	14.48958	12.54375	2	0	-14.10772	176.5241	101406.3	1.041
1/12/2002	15.33958	10.93437	2	0	-14.01657	176.426	101458.3	3.1395
1/13/2002	15.89063	11.46667	2	0	-13.92108	176.3304	101625	3.504
1/14/2002	14.08125	10.10312	2	0	-13.82125	176.2413	101416.7	3.609
1/15/2002	13.65521	9.14375	2	0	-13.71711	176.1782	101541.7	4.135
1/16/2002	11.27917	9.847917	2	0	-13.60867	176.1158	101302.1	0.43
1/17/2002	13.00417	9.6	2	0	-13.49596	176.0542	101531.3	2.3445
1/18/2002	12.06667	9.825	2	0	-13.37899	175.9934	101375	1.818
1/19/2002	10.99167	9.628125	2	0	-13.25779	175.9336	102000	1.084
1/20/2002	13.45625	8.692708	2	0	-13.13239	175.875	101385.4	4.5675
1/21/2002	13.42708	7.504167	2	0	-13.00281	175.8176	101208.3	5.16375
1/22/2002	13.37604	7.890625	2	0	-12.8691	175.7617	101208.3	4.905
1/23/2002	13.49375	7.451042	2	0	-12.73127	175.7073	101656.3	5.745
1/24/2002	13.84896	5.819792	2	0	-12.58937	175.6545	101468.8	6.68275
1/25/2002	13.79688	5.7375	2	0	-12.44343	175.6036	101166.7	6.17425
1/26/2002	13.975	6.060417	2	0	-12.29349	175.5545	101281.3	5.36675
1/27/2002	13.97917	9.466666	2	0	-12.1396	175.5075	101458.3	3.841
1/28/2002	14.92396	9.523958	2	0	-11.98179	175.4626	101416.7	5.445
1/29/2002	15.26667	10.61875	2	0	-11.82012	175.4199	101302.1	4.9165
1/30/2002	15.43333	11.53021	2	0	-11.65463	175.3795	101333.3	3.978
1/31/2002	15.64167	11.60729	2	0	-11.48538	175.3415	101333.3	3.67575

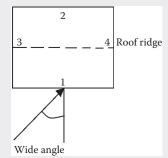
Analysis Su	mmary Paramet	ric Optimisa	tion						
Date/Time	Lighting (k	Air Temper	Radiant Te.	Operative	Outside Dr	External Air	General Li	Solar Gain	Mech Vent + Nat Vent + Infiltration (ac/h)
1/1/2002	48	13.43512	16.55211	14.99361	12.85833	-71.44456	48	20.46565	42.40253
1/2/2002	48	13.23312	16.53766	14.88539	12.62292	-75.60387	48	20.65007	42.40345
1/3/2002	48	14.06458	16.67644	15.37051	13.56458	-61.96915	48	20.30718	42.39244
1/4/2002	48	14.95918	17.58778	16.27348	14.44375	-63.888	48	18.74929	42.40048
1/5/2002	48	14.71339	17.58712	16.15026	14.19792	-63.2599	48	15.46985	42.39462
1/6/2002	48	15.22552	17.87527	16.55039	14.71771	-62.55011	48	17.15997	42.39699
1/7/2002	48	15.74263	18.36096	17.0518	15.24271	-61.86818	48	19.3339	42.39691
1/8/2002	48	15.45935	18.2917	16.87553	14.92188	-66.27816	48	17.81438	42.40128
1/9/2002	48	15.674	18.23991	16.95695	15.19167	-59.18798	48	14.79877	42.39451
1/10/2002	48	16.87027	19.20712	18.0387	16.41042	-56.2439	48	14.10314	42.39755
1/11/2002	48	15.03912	18.25718	16.64815	14.48958	-67.45989	48	9.394398	42.39695
1/12/2002	48	15.76976	17.99518	16.88247	15.33958	-53.10181	48	15.38769	42.38715
1/13/2002	48	16.38739	19.07148	17.72943	15.89063	-61.21595	48	16.23146	42.39942
1/14/2002	48	14.70097	18.33269	16.51683	14.08125	-76.21751	48	16.33938	42.41026
1/15/2002	48	14.23923	17.53168	15.88546	13.65521	-72.29655	48	17.44697	42.4035
1/16/2002	48	11.87076	15.40755	13.63916	11.27917	-73.19688	48	5.370644	42.39591
1/17/2002	48	13.43093	15.73781	14.58437	13.00417	-52.94247	48	12.20812	42.38873
1/18/2002	48	12.58444	15.64777	14.1161	12.06667	-64.07486	48	11.81416	42.39665
1/19/2002	48	11.53574	14.75872	13.14723	10.99167	-67.99506	48	9.737206	42.39683
1/20/2002	48	13.86004	15.90719	14.88362	13.45625	-50.12586	48	18.38432	42.38223
1/21/2002	48	13.95228	16.73211	15.3422	13.42708	-65.14606	48	18.80874	42.39901
1/22/2002	48	13.91903	16.74391	15.33147	13.37604	-67.50484	48	17.40286	42.40156
1/23/2002	48	14.01518	16.79054	15.40286	13.49375	-65.02526	48	19.85939	42.39923
1/24/2002	48	14.39279	17.35601	15.8744	13.84896	-67.47822	48	21.5369	42.39879
1/25/2002	48	14.40482	17.66574	16.03528	13.79688	-75.24442	48	20.63347	42.40715
1/26/2002	48	14.53029	17.48887	16.00958	13.975	-68.70015	48	19.1846	42.40103
1/27/2002	48	14.50237	17.18624	15.8443	13.97917	-65.14906	48	16.17116	42.40168
1/28/2002	48	15.42192	17.92839	16.67516	14.92396	-61,99186	48	19.29823	42.39928

You can calculate the Air changes per hour for two windows with the following equation:*

$$Q = U_{w} * \sqrt{\frac{\frac{C_{p1} - C_{p2}}{2}}{\frac{1}{(A_{1} * C_{1})}^{2} + \frac{1}{(A_{2} * C_{2})}^{2}}}$$

where C_p is the pressure drag coefficient, C is the discharge coefficient, U is the wind speed and A is the area of the opening.

Wind pressure coefficient data



Low-rise buildings (up to three storeys)

Length-to-width ratio: 1:1

Shielding condition: exposed

Wind speed reference level = building height

Wind angle (Table 10.1)

 Table 10.1
 Wind pressure coefficient data

Location	0	45	90	135	180	225	270	315
Face 1	0.7	0.35	-0.5	-0.4	-0.2	-0.4	-0.5	0.35
Face 2	-0.2	-0.4	-0.5	0.35	0.7	0.35	-0.5	-0.4
Face 3	-0.5	0.35	0.7	0.35	-0.5	-0.4	-0.2	-0.4
Face 4	-0.5	-0.4	-0.2	-0.4	-0.5	0.35	0.7	0.35

Source: http://www.designbuilder.co.uk/downloads/ AIVCWindPressureCoefficientData.pdf

> http://www.designbuilder.co.uk/helpv4.7/ Content/Pressure_Coefficients_Data.htm

^{*} ASHRAE Handbook of Fundamentals – 2015. ©ASHRAE, www.ashrae. org. (2015) ASHRAE Handbook—(Fundamentals).

Wind pressure coefficient templates

Wind pressure coefficients are used when the Natural ventilation model option is set to 'Calculated'. The EnergyPlus Airflow Network calculations use 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 the data from Martin Liddament, Air Infiltration Calculation Techniques, An Applications Guide, AIVC. The C_p data are buildings of three storeys or less, with square surfaces and for three levels of site exposure. The data are given in 45° increments.

http://www.designbuilder.co.uk/downloadsv1/ AIVCWindPressureCoefficientData.pdf

http://www.designbuilder.co.uk/helpv4.7/ Content/Pressure_Coefficients_Data.htm

Wind speed provided in the weather file is for 10-m height. You can use the following formula to calculate the wind speed at 2-m height:

$$u = u_r \left(\frac{z}{z_r}\right)^{\alpha}$$

 α is approximately 1/7, or 0.143 (it varies with local topography).

Tables 10.2 and 10.3 gives the calculation for natural ventilation in the zone.

0.72	m/s
6.59	m^2
0.7	
-0.2	
0.65	
0.65	
2.07	m ³ /s
7,442	m ³ /h
350	m ³
21.26	ac/h
	$ \begin{array}{r} 6.59\\ 0.7\\ -0.2\\ 0.65\\ 0.65\\ 2.07\\ 7,442\\ 350\\ \end{array} $

Table 10.2Calculation of zone air changes per hourat a wind speed of 1 m/s at 10-m height

Table 10.3	Calculation of zone air changes per hour
at a wind sp	eed of 2 m/s at 10 m-height

Wind speed at 2 m	1.44	m/s
Area of window	6.59	m ²
C_{p1}	0.7	
C_{p2}	-0.2	
C_1	0.65	
C_2	0.65	
Q	4.13	m ³ /s
Q	14,885	m³/h
Zone volume	350	m ³
Air changes	42.53	ac/h

Exercise 10.2

Repeat the above tutorial for the window area 16 m².

TUTORIAL 10.3 Evaluating the impact of window opening and closing schedule

GOAL

To evaluate the impact of window opening and closing schedule.

WHAT ARE YOU GOING TO LEARN?

• Defining window opening and closing schedule for natural ventilation

PROBLEM STATEMENT

In this tutorial, you are going to use the model saved in Tutorial 10.2 and add windows in remaining two directions.

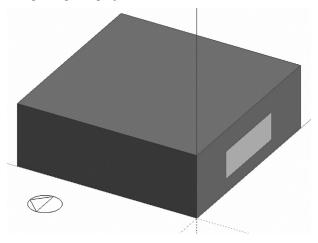
You need to simulate the model for the following two window operation schedules:

- 1. On (windows are always open)
- 2. 8:00-18:00 Mon-Sat

Use New Delhi/Safdarjung, India weather location.

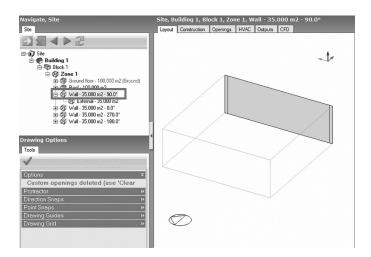
SOLUTION

Step 1: Open a project saved in Tutorial 10.2.

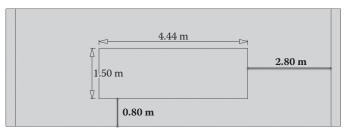


Step 2: In the navigation tree select East facing wall by selecting Wall – $35.000 \text{ m}^2 - 90.0^\circ$.

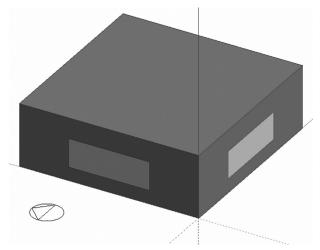
CHAPTER TEN NATURAL VENTILATION



Step 3: Select **Left** in the View rotation dropdown list then select **Draw window** in the **Help** tab to draw a window with the same dimensions as that on the north or south side.



Step 4: Similarly, draw the west window.



Step 5: Select the **Openings** tab. Click the **Operation** section. Make sure that Operation schedule is **On 24**/7.

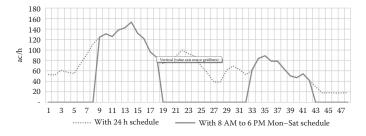
e, Building 1	
yout Activity Construction Openings Lig	hting HVAC Generation Outputs CFD
C Glazing Template	
Template	Project glazing template
🝵 External Windows	
🕼 Glazing type	Project external glazing
Layout	Preferred height 1.5m, 30% glazed
Dimensions	
Туре	3-Preferred height
Window to wall %	20.00
Window height (m)	1.50
Window spacing (m)	5.00
Sill height (m)	0.80
Reveal	· · · · · · · · · · · · · · · · · · ·
Frame and Dividers	
Shading	·
Airflow Control Windows	, ,
Operation	
Coperation schedule	On 24/7
Free Aperture	,
🝵 Internal Windows	۵

Simulate the model and record the results by exporting them to the spreadsheet.

Step 6: Repeat the above steps for Operation schedule 8:00 - 18:00 Mon - Sat.

Airflow Control Windows		»
Operation		¥
😭 Operation schedule	8:00 - 18:00 Mon - Sat	
Free Aperture		>>

Simulate the model and record the results. Plot the graph for January 1 and 2 for Mech Vent + Nat Vent + Infiltration (Air changes per hour, ac/h).



You can observe the impact of window opening and closing on air change rate.

TUTORIAL 10.4 Evaluating the impact of window opening control based on temperature

GOAL

To evaluate the impact of window opening control based on zone and outdoor air temperature.

WHAT ARE YOU GOING TO LEARN?

• Defining window operation control for natural ventilation

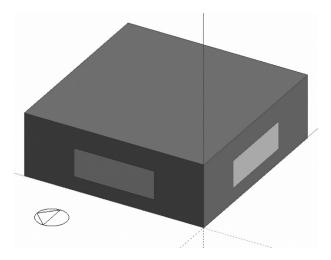
PROBLEM STATEMENT

In this tutorial, you are going to use the calculated model saved in Tutorial 10.1. You are going to simulate the model for Temperature control mode.

Use New Delhi/Safdarjung, India weather location.

SOLUTION

Step 1: Open the model saved in Tutorial 10.1 with natural ventilation set to calculate.



Step 2: Select the Activity tab. Set Min temperature to 20.0.

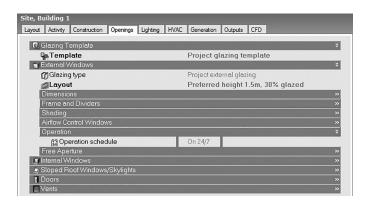
Site, Building 1	
Layout Activity Construction Openings Lighting HVA	C Generation Outputs CFD
 Activity Template 	*
	24x7 Generic Office Area
Sector	Others - Miscellaneous 24hr activities
	1
Zone multiplier	1
Include zone in thermal calculations	
Include zone in Radiance daylighting calculation	tions
💫 Floor Areas and Volumes	»
€ Occupancy	»
👷 Metabolic	»
Ceneric Contaminant Generation	»
f Holidays	»
is DHW	»
III Environmental Control	*
Heating Setpoint Temperatures	»
Cooling Setpoint Temperatures	»
Humidity Control	»
Ventilation Setpoint Temperatures	*
Natural Ventilation	*
Indoor min temperature control	
Min temperature definition	1-Bv value
Min temperature (*C)	20.0
Indoor max temperature control	
Minimum Fresh Air	»

Natural ventilation min temperature

This is the fixed indoor temperature below which ventilation is shut off. The control is visible when the 1-By value option is selected for Min temperature definition. It can be thought of as the cooling setpoint temperature which 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.

> http://www.designbuilder.co.uk/helpv4.7/ Content/_Environmental_comfort.htm

Step 3: Select the **Openings** tab. Click the **Operation** section. Make sure that Operation schedule is **On 24**/7.



Step 4: Select the **HVAC** tab. Enter Outside air (ac/h) as **3.000**. Select **Temperature** for the **External and Internal Control mode** drop-down lists.

BUILDING ENERGY SIMULATION

Site, Building 1	
Layout Activity Construction Openings Lighting HVAC	Generation Outputs CFD
🔃 HVAC Template	× 🔺
Template	Natural ventilation - No Heating/Cooling
C Mechanical Ventilation	×
🗖 On	
Auxiliary Energy	×
Pump etc energy (W/m2)	0.0000
M Schedule	Office_OpenOff_Occ
L Heating	*
Heated	*
* Cooling	*
	»
Purility Control	**************************************
□ On	·
A Natural Ventilation	×
☑ On	
Outside air definition method	1-By zone
Outside air (ac/h)	3.000
Operation	»
Outdoor Temperature Limits	»
Delta T Limits	»
Delta T and Wind Speed Coefficients	»
Options	×
Wind factor	
External control mode	2-Temperature
Internal control mode	2-remperature
Mixed Mode Zone Equipment	*
Mixed mode zone Equipment	· · · · ·
	_

To see the effect of window opening controls, we need the following:

- 1. Generate and view the results at system time steps instead of fixed user defined time steps. This can be achieved by selecting the 'detailed' frequency option on an HVAC output variable (e.g. Zone Air Temperature).
- 2. Generate more output variables such as window opening factor, zone infiltration and zone air temperature.

Field: Ventilation Control Mode

Specifies the type of zone-level natural ventilation control. The windows are 'open' when:

 $T_{\text{zone}_air} > T_{\text{setpoint}} \text{ AND } T_{\text{zone}_air} > T_{\text{outside}_air} \text{ AND the}$ schedule value = 1

where $T_{\text{outside_air}}$ is equal to the outdoor air temperature, $T_{\text{zone_air}}$ is equal to the previous time step's zone air temperature, T_{setpoint} is equal to the Vent Temperature Schedule value.

http://www.designbuilder.co.uk/helpv4.7/ Content/_Operation2.htm

System time step is a variable-length time step that governs the driving time step for HVAC and Plant system modelling. The user cannot directly control the system time step (except by use of the ConvergenceLimits object). When the HVAC portion of the simulation begins its solution for the current zone time step, it uses the zone time step as its maximum length but can then reduce the time step, as necessary, to improve the solution.

Users can see the system time step used if they select the 'detailed' frequency option on an HVAC output variable (e.g. Zone Air Temperature). In contrast, the 'Zone' variables will only be reported on the zone time step (e.g. Zone Mean Air Temperature).

Note that hourly data (such as outdoor conditions expressed by Design Days or Weather data) are interpolated to the Zone Time step.

Source: EnergyPlus InputOutput Reference

Zone Mean Air Temperature (°C)

Zone Mean Air Temperature is the average temperature of the air temperatures at the system time step. Remember that the zone heat balance represents a 'well-stirred' model for a zone; therefore, there is only one mean air temperature to represent the air temperature for the zone. This is reported only at the zone time step.

Zone Air Temperature (°C)

This is very similar to the mean air temperature. The 'well-stirred' model for the zone is the basis, but this temperature is also available at the 'detailed' system time step.

Source: EnergyPlus InputOutput Reference

Step 5: Minimize the DesignBuilder window. Create a new file named **output.idf**. Write additional output variables as follows:

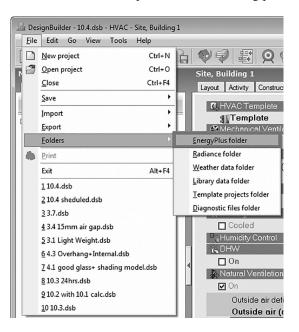
Output:Variable, *, Zone Air Temperature, Detailed;

Output:Variable, *, AFN Surface Venting Window or Door Opening Factor, Detailed;

Output:Variable, *, AFN Zone Infiltration, Detailed;

🗄 Output.idf 🖸

```
    Output:Variable, *, Zone Air Temperature, Detailed;
    Output:Variable, *, AFN Surface Venting Window or Door Opening Factor, Detailed;
    Output:Variable, *, AFN Zone Infiltration, Detailed;
```



This .idf file needs to be placed in the following path:

You can use any text editor such as Notepad++ and Editplus.

Step 6: Maximize the DesignBuilder window and select the **HVAC** tab. Click **Simple** under the **Help** tab. The **Model Options – Building and Block** screen appears.



Step 7: Select the **Simulation** tab. Click the **Advanced** section.

Simulation Options From Start day 1 Start month Jan To Image: Constraint of the start month End day 31 End day 31 End month Dec Calculation Options Image: Constraint of the start month Simulation method 1-EnergyPlus Time steps per hour 2 Temperature control 1-Air temperature Solar Model reflections and shading of ground reflected solar Solar distribution 2-Full exterior Shadowing interval (days) 20	Data Advanced Heating Design Cooling De	ign Simulation	Display	Drawing tools	Block	Project details
From Start day 1 Start month Jan To Image: Start month To Image: Start month End day 31 End day 31 End month Dec Calculation Options Image: Start month Simulation method 1-Energy/Plus Time steps per hour 2 Temperature control 1-Air temperature Solar Model reflections and shading of ground reflected solar Solar distribution 2-Full exterior Shadowing interval (days) 20	Simulation Options					
Start month Jan To Image: Start month End day 31 End month Dec Calculation Options Image: Simulation method Simulation method 1-EnergyPlus Time steps per hour 2 Temperature control 1-Air temperature Solar Include all buildings in shading calcs Model reflections and shading of ground reflected solar Solar distribution 2-Full exterior Shadowing interval (days) 20						
To To End day 31 End month Dec Calculation Options I+EnerqvPlus Simulation method I+EnerqvPlus Time steps per hour [2 Temperature control 1-Air temperature Solar Solar distribution Solar distribution 2-Full exterior Shadowing interval (days) 20	Start day		1			
End day 31 End month Dec Calculation Options I-Energy/Plus Simulation method 1-Energy/Plus Time steps per hour [2 Temperature control 1-Air temperature Solar Include all buildings in shading calcs Model reflections and shading of ground reflected solar Solar distribution Solar distribution 2-Full exterior Shadowing interval (days) 20	Start month		Jan			
End month Dec Calculation Options Calculation Options Simulation method 1-EnergyPlus Time steps per hour 2 Temperature control 1-Air temperature Solar Model reflections and shading calcs Model reflections and shading of ground reflected solar Solar distribution 2-Full exterior Shadowing interval (days) 20	То					
Calculation Options Calculation Options Simulation method Time steps per hour Temperature control In-Air temperature Control Include all buildings in shading calcs Include all buildings in shading of ground reflected solar Solar distribution Solar distribution 2-Full exterior Shadowing interval (days) 20	End day		31			
Simulation method 1-EnergyPlus Time steps per hour 2 Temperature control 1-Air temperature Solar	End month		Dec			
Time steps per hour 2 Temperature control 1-Air temperature Solar Include all buildings in shading calcs Model reflections and shading of ground reflected solar Solar distribution 2-Full exterior Shadowing interval (days) 20	Calculation Options					
Temperature control 1-Air temperature I molude all buildings in shading calcs Model reflections and shading of ground reflected solar Solar distribution 2-Full exterior Shadowing interval (days) 20	Simulation method		1-En	erqyPlus		•
Solar Solar Model reflections and shading calcs Model reflections and shading of ground reflected solar Solar distribution 2-Full exterior Shadowing interval (days) 20	Time steps per hour		2			
☐ Include all buildings in shading calcs ☐ Model reflections and shading of ground reflected solar Solar distribution 2-Full exterior Shadowing interval (days) 20	Temperature control		1-Air	temperature		
Model reflections and shading of ground reflected solar Solar distribution 2-Full exterior Shadowing interval (days) 20	Solar					
Solar distribution 2-Full exterior Shadowing interval (days) 20	Include all buildings in shading calcs					
Shadowing interval (days) 20	Model reflections and shading of grou	nd reflected so	ar			
enddening mertar (ddyo)	Solar distribution		2-Ful	l exterior		
Detailed HVAC Autosizing			20			
	Detailed HVAC Autosizing					

Step 8: Select the **IDF File 1** check box and select the Output.idf file from the EnergyPlus folder. Click **OK**.

Model Options - Building and Block	
Model Options Data	Help
Cost/Carbon	Info Data
Data Advanced Heating Design Cooling Design Simulation Display Drawing tools Block Project details	Simulation Calculation Options
Simulation Options »	Data on this tab allows you to
Calculation Options *	control the simulations.
Solar »	This data is also shown before simulations
Detailed HVAC Autosizing ****	
Advanced ×	
General Solution *	
Airflow Network *	
Convection » Wermup »	
Warmup » Shading »	
Include IDE Data	
☑ IDF File 1	
Filename Output.idf	
Other *	
□ 'Surfaces within zone' treated as adiabatic	
Air velocity for comfort calculations (m/s) 0.1370	
Output »	
Help	Cancel OK

Step 9: Select the **Simulation** tab. The **Edit Calculation Options** screen appears. Click **OK**.

Edit Calculation Options				
Calculation Options Data				Help
General Options Output Simulati	on Manager			Info Data
Calculation Description		×		Simulation Options
				These options control the simulation and the output produced.
Simulation Period From		*		Simulation Period
Start day	1	×		Select the start and end days for the simulation, or select a typical period:
Start month	Jan	•		Annual simulation
То		×		• Summer design week
End day	31	•		Summer typical week
End month	Dec	•	1	• <u>All summer</u>
Output Intervals for Reporting		×	Ц	Winter design week
Monthly and annual				Winter typical week
☑ Daily				<u>All winter</u>
✓ Hourly				
Sub-hourly				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
				sub-hourly intervals can produce large +
Don't show this dialog next time	9	Help		Cancel OK

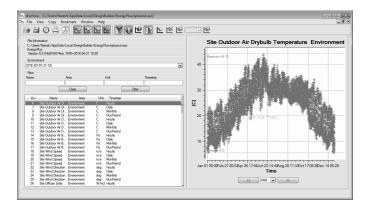
After simulation, the results on the screen appear, but DesignBuilder does not support viewing 'Detailed' reporting frequency.

After simulation, an ESO file is generated in the EnergyPlus folder which contains results at detailed reporting frequency. You can view this in the **xESOView** tool.

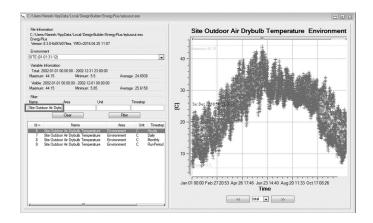
xESOView can be downloaded from http://xesoview. sourceforge.net/.

Step 10: Click the **View EnergyPlus results** icon. From the EnergyPlus folder, select the **eplusout.eso** file. xESOView tool will open.

File Go Tools He		명 왕	Q	1
Lis Solect frie Look n: Recent Place Destop Libraries Computer	EnergyPus Auno Status Statu	C C C C C C C C C C C C C C C C C C C	E3 File folder File folder File folder Eile folder eso - Ene	



Step 11: Enter **Site Outdoor Air Drybulb Temperature** in the Name field of the Filter section to view the variable. From the filtered list select the variable with hourly Timestep.



You can copy the variable data to view in a spreadsheet.

. File	View	Сору	Bookmark	Window	Help	
	30	🗊 Cop	oy graphic		Ctrl+Shift+C	
CI- I	1	D Cop	oy variable d	ata	Ctrl+C	
C:/Us	nformatic ers/Nare	🗸 Cop	by include tir	ne data		ut.eso
	yPlus on 8.3.0	D Cop	by file inform	ation		
Envir	onment	Cop	oy variable in	formation		
SITE (01-01:31	-12)				-
Tota			0:00 - 2002-12 Minimum: 5.) Average: 24.693	8
Visib	le: 2002-	01-01 00:	00:00 - 2002-1	12-01 00:00:	00	
Maxim	um: 44.1	5	Minimum: 5.	85	Average: 25.615	8
Filter						
ritter		Area		Unit	Timestep	
Name						
Name	utdoor Air	Dr				

Step 12: Click **Copy** and select **Copy variable data**.

You can copy only one variable at a time.

Step 13: Open a spreadsheet program and paste the data as shown in the below screen.

1	A	В	с	D	E	F	G
				AFN Surface Venting	AFN Surface Venting	AFN Surface Venting	AFN Zone
			AFN Surface Venting Window	Window or Door	Window or Door Opening	Window or Door	Infiltration Air
		Site Outdoor Air	or Door Opening Factor	Opening Factor	Factor	Opening Factor	Change Rate
		Drybulb Temperature	BLOCK1:ZONE1_WALL_2_0_0_	BLOCK1:ZONE1_WALL_3	BLOCK1:ZONE1_WALL_4_	BLOCK1:ZONE1_WALL	BLOCK1:ZONE1
1	Date/Time	Environment [C]	0_0_0_WIN []	_0_0_0_0_WIN []	0_0_0_0_WIN []	_5_0_0_0_0_WIN []	[ach]
2	1/1/22 12:: AM	7.55	0.868534	0.868534	0.868534	0.868534	0.01
3	1/1/22 12:2: AM	7.55	0	0	0	0	0.01
4	1/1/22 12:4: AM	7.55	0	0	0	0	0.01
5	1/1/22 12:6: AM	7.55	0	0	0	0	0.01
б	1/1/22 12:9: AM	7.55	0	0	0	0	0.01
7	1/1/22 12:11: AM	7.55	0	0	0	0	0.01
8	1/1/22 12:13: AM	7.55	0	0	0	0	0.01
9	1/1/22 12:16: AM	7.55	0	0	0	0	0.01
10	1/1/22 12:18: AM	7.55	0	0	0	0	0.01
11	1/1/22 12:2: AM	7.55	0	0	0	0	0.01
12	1/1/22 12:23: AM	7.55	0	0	0	0	0.01
13	1/1/22 12:25: AM	7.55	0	0	0	0	0.01
14	1/1/22 12:27: AM	7.55	0.87345	0.87345	0.87345	0.87345	0.01
15	1/1/22 12:3: AM	7.55	0	0	0	0	0.01
	1/1/22 12:32: AM		0	0	0	0	0.01
17	1/1/22 12:35: AM	7.55	0	0	0	0	0.01
18	1/1/22 12:38: AM	7.55	0	0	0	0	0.01
19	1/1/22 12:4: AM	7.55	0	0	0	0	0.01

Similarly, copy and paste the below variables with time step as hourly:

- AFN Surface Venting Window or Door Opening Factor BLOCK1:ZONE1_WALL_ 2_0_0_0_0_WIN []
- AFN Surface Venting Window or Door Opening Factor BLOCK1:ZONE1_WALL_ 3_0_0_0_0_WIN []

- AFN Surface Venting Window or Door Opening Factor BLOCK1:ZONE1_WALL_ 4_0_0_0_0_0_WIN []
- AFN Surface Venting Window or Door Opening Factor BLOCK1:ZONE1_WALL_ 5_0_0_0_0_WIN []
- AFN Zone Infiltration Air Change Rate BLOCK1: ZONE1 [ach]

	1379 • (* 🎉 ==F(AND(H379>\$8\$379,H379>20),TRUE,FALSE)											
4	A	в	c	D	E	F	G	н	1			
				AFN Surface Venting	AFN Surface Venting	AFN Surface Venting	AFN Zone					
			AFN Surface Venting Window	Window or Door		Window or Door	APN Zone Infiltration Air	Zone Air	Check if			
		Site Outdoor Air	or Door Opening Factor			Opening Factor	Change Rate		Tzone > To			
				Opening Factor	Factor			Temperature				
		Drybulb Temperature	BLOCK1/2ONE1_WALL_2_0_0_					BLOCK1/ZONE1	and			
	Date/Time	Environment [C]		0_0_0_0_WIN []	_0_0_0_0_WIN []	_5_0_0_0_0_WIN []		[C]	Tzone>20			
	1/1/22 4:42: PM		0.971402	0.971402	0.971402	0.971402		19.3989	FALSE			
	1/1/22 4:48: PM		0					20.6136	TRUE			
	1/1/22 4:54: PM		0.969861	0.969861	0.969861	0.969861	1.00E-02	19.3941	FALSE			
78	1/1/22 4: PM	17.	1.00E-02	1.00E-02	1.00E-02	1.00E-02		1.00E-02	FALSE			
79	1/1/22 5: PM		a	c	0	0	1.00E-02	20.477	TRUE			
80	1/1/22 5:2: PM		0.966227	0.966227	0.966227	0.955227	1.005-02	19.6049	FALSE			
81	1/1/22 5:4: PM		a	0	0	0	1.00E-02	19.702	FALSE			
82	1/1/22 5:6: PM		0	0	0	0	1.00E-02	20.5935	TRUE			
99	1/1/22 5:4: PM		0	0	0	0	1.00E-02	20.259	TRUE			
00	1/1/22 5:42: PM		0.963407	0.963407	0.963407	0.963407	1.00E-02	19.3331	FALSE			
01	1/1/22 5:45: PM		a	c	0	0	1.00E-02	19.3737	FALSE			
02	1/1/22 5:47: PM		a	c	0	0	1.005-02	20.2602	TRUE			
03	1/1/22 5:49: PM		0.963394	0.963394	0.963394	0.953394	1.00E-02	19.3339	FALSE			
04	1/1/22 5:51: PM		0	0	0	0	1.00E-02	19.3771	FALSE			
05	1/1/22 5:53: PM		0	0	0	0	1.00E-02	20.2648	TRUE			
06	1/1/22 5:55: PM		0.963349	0.963349	0.963349	0.963349	1.00E-02	19.3365	FALSE			
07	1/1/22 5:57: PM		G	0	0	0	1.005-02	19.5781	FALSE			
	1/1/22 5: PM	16.8	1.007-02	1.00F-02	1.007-02	1.005-02	15 3434	1.005-02	ENSE			
	1/1/22 6: PM				0	0	1.005-02	20.2575	TRUE			
	1/1/22 6-2: PM		0.957921	0.957921	0.957921	0.957921	1.00E-02	18.9839	FALSE			
	1/1/22 65: PM		0					18.9261	FALSE			

• Zone Air Temperature BLOCK1:ZONE1 [C]

You can observe from the above that if the following conditions are true, then there is natural ventilation.

 $T_{\text{zone}_air} > T_{\text{setpoint}}$ AND $T_{\text{zone}_air} > T_{\text{outside}_air}$

Please note that the zone setpoint is 20°C. You can see that the windows open in the succeeding time step after the above mentioned condition is met. Please note that the Zone infiltration air change rate is reported hourly and not on the system timestep. Hence, even when the windows are open the zone ventilation will not be reported in that timestep, it will be reported in the hourly time step.

TUTORIAL 10.5 Evaluating the impact of window opening area modulation on natural ventilation

GOAL

To evaluate the impact of window opening area modulation based on zone and outdoor air temperature.

WHAT ARE YOU GOING TO LEARN?

· Defining window opening area modulation

PROBLEM STATEMENT

In this tutorial, you are going to use the model saved in Tutorial 10.4.

You are going to simulate the model for Temperature control mode.

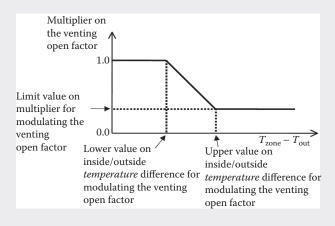
Use New Delhi/Safdarjung, India weather location.

The modulation takes the following form when Ventilation Control Mode = Temperature.

 $T_{\text{zone}} - T_{\text{out}} =$ [Lower value on inside/outside temperature difference for modulating the venting open factor]; then multiplication factor = 1.0.

[Lower value on inside/outside temperature difference for modulating the venting open factor] $< T_{zone} - T_{out} <$ [upper value on inside/outside temperature difference for modulating the venting open factor]; then multiplication factor varies linearly from 1.0 to [limit value on multiplier for modulating the venting open factor].

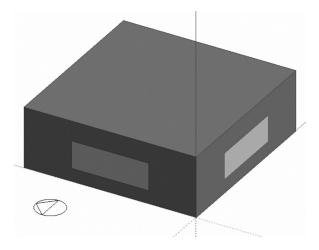
 $T_{\text{zone}} - T_{\text{out}} =$ [upper value on inside/outside temperature difference for modulating the venting open factor]; then multiplication factor = [limit value on multiplier for modulating the venting open factor].



Ref: EnergyPlus InputOutput Reference.

SOLUTION

Step 1: Open the project saved in Tutorial 10.4.



Step 2: Select the **HVAC** tab. Expand the **Natural Ventilation** section.

Site, Building 1		
Layout Activity Construction Openings Lighting	HVAC Generation Outputs CFD	
Auxiliary Energy	× 🔺	
Pump etc energy (W/m2) ft Schedule V Hesting	0.0000 Office_OpenOff_Occ ¥	
Heated		
*Cooling	¥	
Cooled		
■ Humidity Control	» ¥	
⊡ On	*	
Natural Ventilation	*	
☑ On		
Outside air definition method Outside air (ac/h)	1-By zone • 3.000	
Operation	»	
Outdoor Temperature Limits	»	
Delta T Limits	»	
Delta T and Wind Speed Coefficients		
Options	×	

Step 3: Select the **Modulate opening areas** check box. Enter the lower value of $T_{in} - T_{out}$ as **5.0** and the upper value as **15**.

On				
Outside air definition method	1-By zone			
Outside air (ac/h)	3.000			
Operation				
Outdoor Temperature Limits				
Delta T Limits				
Delta T and Wind Speed Coefficients	Delta T and Wind Speed Coefficients			
Options				
Wind factor	1.00			
External control mode	2-Temperature			
internal control mode	2-Temperature			
Modulate opening areas				
Lower value of Tin-Tout (deltaC)	5.0			
Upper value of Tin-Tout (deltaC)	15			
	0.010			

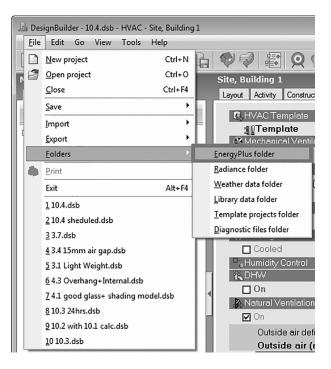
Step 4: Minimize the DesignBuilder window. Create an output.idf file. Write additional output variables:

Output: Variable, *, Zone Air Temperature, Detailed;

Output: Variable, *, AFN Surface Venting Window or Door Opening Factor, Detailed;

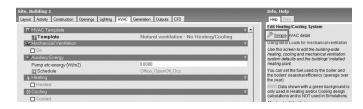
Output: Variable, *, AFN Zone Infiltration, Detailed;

	Edit Search View Encoding Language Settings Macro Run Plugins Window ?		Х
lo di) = 4 ° ° ° 4 / 4 h h > c # ½ < < 5 5 5 1 Eg 🛛 (
📄 Outp	tput idf 🖾		
1	Output:Variable, *, Zone Air Temperature, Detailed;		*
2	Output:Variable, *, AFN Surface Venting Window or Door Opening Fact	or, Detailed;	=
3	Output:Variable, *, AFN Zone Infiltration, Detailed;		-
4			
<u>د</u>			•
Normal	al length:191 lines:5 Ln:3 Col:53 Sel:0 0 Dos\Windows	UTF-8	INS



This .idf file needs to be placed in the following path:

Step 5: Maximize the DesignBuilder window and select the **HVAC** tab. Click **Simple** under the **Help** tab. The **Model Options – Building and Block** screen appears.



Step 6: Select the **Simulation** tab. Click the **Advanced** section.

Data Advanced Heating Design Cooling Des	ign Simulation	Display	Drawing tools	Block	Project detail
Simulation Options					
From					
Start day		1			
Start month		Jan			•
То					
End day		31			
End month		Dec			
Calculation Options					
Simulation method			rqyPlus		-
Time steps per hour		2			
Temperature control		1-Air te	emperature		
Solar					
Include all buildings in shading calcs					
Model reflections and shading of group	nd reflected sol				
Solar distribution		2-Full	exterior		•
Shadowing interval (days) Detailed HVAC Autosizing		20			

Step 7: Select the **IDF File 1** check box and select the Output.idf file from the EnergyPlus folder. Click **OK**.

Model Options - Building and Block	
Model Options Data	Help
Cost/Carbon	Info Data
Data Advanced Heating Design Cooling Design Simulation Display Drawing tools Block Project details	Simulation Calculation Options
Simulation Options »	Data on this tab allows you to control the simulations.
Calculation Options *	control the simulations. This data is also shown before
Solar »	simulations.
Detailed HVAC Autosizing »	
Advanced ×	
General Solution *	
Airflow Network *	7
Convection *	
Warmup » Shading »	1
snading *	-
IDF File 1	
Filosomo	
Other *	
□ 'Surfaces within zone' treated as adiabatic	
Air velocity for comfort calculations (m/s) 0.1370	
Output »	
Help	Cancel OK
Trop	

Step 8: Select the **Simulation** tab. The **Edit Calculation Options** screen appears. Click **OK**.

Edit Calculation Options			
Calculation Options Data			Неір
General Options Output Simu		Info Data	
Calculation Description		¥	Simulation Options
Simulation Period		Ĵ	These options control the simulation and the output produced.
From		*	Simulation Period Select the start and end days for the
Start day	1	•	simulation, or select a typical period: ≡
Start month	Jan	•	Annual simulation
То		¥	Summer design week
End day	31	•	Summer typical week
End month	Dec	•	All summer
Output Intervals for Reporting		×	Winter design week
Monthly and annual			Winter typical week
🗹 Daily			All winter
✓ Hourly			
Sub-hourly			Interval Monthly and annual output is always generatedand daily, hourly and sub-hourly data can selected by checking the appropriate boxes.
			Note that selecting output at hourly or sub-hourly intervals can produce large -
Don't show this dialog next ti	me	Help	Cancel OK

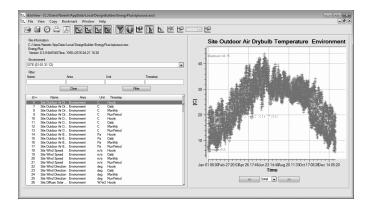
Step 9: Select the EnergyPlus results. Select **eplusout** file, so that the file will automatically open in the xESO-View tool.

File		Tools			_	
	31		1	2	Ň	B
Navig	ate,	Site	Site,	Building 1		

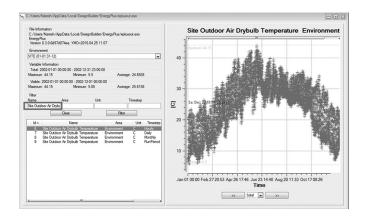
CHAPTER TEN NATURAL VENTILATION

🕍 Select file				X
Look in:	📗 EnergyPlus	•	ĝ ĝ Þ° ∷ ∙	
œ	Name	*	Date modified	Туре
-	ASHRAE901		4/1/2016 5:05 PM	File folder
Recent Places	L5_Actual		3/3/2016 1:34 PM	File folder
and a	L5_Notional		3/3/2016 1:34 PM	File folder
a	15 Reference	e	3/3/2016 1:34 PM	File folder
Desktop	te, eplusout		4/21/2016 6:30 PM	eso - Ener
Libraries				
Computer				
(h)	•			۲
Network	File name:	eplusout		Open
NELWOIK	Files of type:	EnergyPlus ESO files	_	Cancel
		Open as read-only		

The xEsoView screen appears:



Step 10: Enter **Site Outdoor Air Drybulb Temperature** in the Name field of the Filter section to view the variable.



You can copy the variable data to view in a spreadsheet. Step 11: Click **Copy** and select **Copy variable data**.

. File Viev	v Сору	Bookmark	Window	Help	
	C 🗊 Ca	opy graphic		Ctrl+Shift+C	
File-Informa	tic	opy variable d		Ctrl+C	
C:/Users/N	iare	opy include tir	ne data		_ut.eso
EnergyPlus Version 8.3		opy file inform	nation		
Environmer	nt D Ca	opy variable in	formation		
SITE (01-01	_				-
Maximum: 4 Visible: 20	2-01-01 00: 4.15 02-01-01 0	00:00 - 2002-12 Minimum: 5. 0:00:00 - 2002-1 Minimum: 5.	5 12-01 00:00:	Average: 24.69	
Maximum. 4	4.15	Miriinum. 5.	65	Average: 25.01	50
Filter					
Name	Area	3	Unit	Timestep	
Site Outdoor	r Air Dr				

1	A	В	с	D	E	F	G
				AFN Surface Venting	AFN Surface Venting	AFN Surface Venting	AFN Zone
			AFN Surface Venting Window	Window or Door	Window or Door Opening	Window or Door	Infiltration Air
		Site Outdoor Air	or Door Opening Factor	Opening Factor	Factor	Opening Factor	Change Rate
		Drybulb Temperature	BLOCK1:ZONE1_WALL_2_0_0_	BLOCK1:ZONE1_WALL_3	BLOCK1:ZONE1_WALL_4_	BLOCK1:ZONE1_WALL	BLOCK1:ZONE1
1	Date/Time	Environment [C]	0_0_0_WIN []	_0_0_0_0_WIN []	0_0_0_0_0_WIN []	_5_0_0_0_0_WIN []	[ach]
2	1/1/22 12:: AM	7.55	0.868534	0.868534	0.868534	0.868534	0.01
3	1/1/22 12:2: AM	7.55	0	0	0	0	0.01
4	1/1/22 12:4: AM	7.55	0	0	0	0	0.01
	1/1/22 12:6: AM	7.55	0	0	0	0	0.03
	1/1/22 12:9: AM	7.55	0	0	0	0	0.01
	1/1/22 12:11: AM		0	0	0	0	0.01
	1/1/22 12:13: AM		0	0	0	0	0.01
	1/1/22 12:16: AM		0	0	0	0	0.03
			0	0	0	0	0.01
	1/1/22 12:2: AM	7.55	0	0	0	0	0.01
	1/1/22 12:23: AM		0	0	0	0	0.01
	1/1/22 12:25: AM		0	0	0	0	0.01
	1/1/22 12:27: AM		0.87345	0.87345	0.87345	0.87345	0.03
	1/1/22 12:3: AM	7.55	0	0	0	0	0.01
	1/1/22 12:32: AM		0	0	0	0	0.01
	1/1/22 12:35: AM		0	0	0	0	0.01
	1/1/22 12:38: AM		0	0	0	0	0.01
19	1/1/22 12:4: AM	7.55	0	0	0	0	0.01

Step 12: Open a spreadsheet and paste the data.

You can check if natural ventilation is working as per the controls applied.

	1248	• 🗇 🎜 ====(A	ND(H248>B248,H248>20),TRUE,	FALSE)					
4	A	B	С	D	E	F	G	н	1
				AFN Surface Venting	AFN Surface Venting	AFN Surface Venting	AFN Zone		Check if
			AFN Surface Venting Window		Window or Door Opening	Window or Door	Infiltration Air	Zone Air	Tzone >
		Site Outdoor Air	or Door Opening Factor	Opening Factor	Factor	Opening Factor	Change Rate	Temperature	Tout an
		Drybulb Temperature	BLOCK1:ZONE1 WALL 2 0 0						Tzone
1	Date/Time	Environment [C]	0 0 0 WIN []	0 0 0 0 0 WIN []	0 0 0 0 0 WIN []		[ach]	[C]	>20
47	1/1/22 9:15: AM	11.25	0	0	0	0	1.00E-02	19.4544	FALS
48	1/1/22 9:17: AM	11.25	0	0	0	0	1.00E-02	20.5136	TRUE
49	1/1/22 9:19: AM	11.25	0.926861	0.926861	0.926851	0.926861	1.00E-02	16.969	FALS
50	1/1/22 9:21: AM	11.25	0	0	0	0	1.00E-02	15.6437	FALS
58	1/1/22 9:37: AM	11.25	0	0	0	0	1.00E-02	16.7314	FALS
59	1/1/22 9:38: AM	11.25	0	0	0	0	1.00E-02	17.1751	FALS
60	1/1/22 9:4: AM	11.25	0	0	0	0	1.00E-02	18.2332	FALS
61	1/1/22 9:42: AM	11.25	0	0	0	0	1.00E-02	19.337	FALS
62	1/1/22 9:44: AM	11.25	0	0	0	0	1.00E-02	20.2929	TRUE
63	1/1/22 9:45: AM	11.25	0.943068	0.943068	0.943068	0.943068	1.00E-02	17.7963	FALS
64	1/1/22 9:47: AM	11.25	0	0	0	0	1.00E-02	16.7258	FALS
65	1/1/22 9:49: AM	11.25	0	0	0	0	1.00E-02	17.1582	FALS
66	1/1/22 9:51: AM	11.25	0	0	0	0	1.00E-02	18.2154	FALS
67	1/1/22 9:52: AM	11.25	0	0	0	0	1.00E-02	19.3217	FALS
68	1/1/22 9:54: AM	11.25	0	0	0	0	1.00E-02	20.2802	TRUE
69	1/1/22 9:56: AM	11.25	0.943195	0.943195	0.943195	0.943195	1.00E-02	17.7908	FALS
70	1/1/22 9:58: AM	11.25	0	0	0	0	1.00E-02	16.7245	FALS
71	1/1/22 9:: AM	13.9	1.00E-02	1.00E-02	1.00E-02	1.00E-02	10.8368	1.00E-02	FALS
72	1/1/22 1:: AM		0	0	0	0	1.00E-02	19.0569	FALS

You can observe from the above that if the following conditions are true, then there is natural ventilation

 $T_{\text{zone_air}} > T_{\text{setpoint}}$ AND $T_{\text{zone_air}} > T_{\text{outside_air}}$

and Window opening fraction is dependent on the $T_{\text{zone}} - T_{\text{out}}$.

TUTORIAL 10.6 Evaluating the impact of mixed mode operation

GOAL

To evaluate the impact of mixed mode operation on energy performance.

WHAT ARE YOU GOING TO LEARN?

• Modelling mixed-mode ventilation

PROBLEM STATEMENT

In this tutorial, you are going to use the model saved in Tutorial 10.4.

Find out the energy consumption for the following two cases:

- 1. With mixed mode
- 2. Fully air conditioned

Use the New Delhi/Safdarjung, India weather location.

Mixed-Mode Cooling

In mixed-mode buildings, natural ventilation is used as the primary means of providing cooling, and active cooling is introduced when this is inadequate to provide comfort conditions.

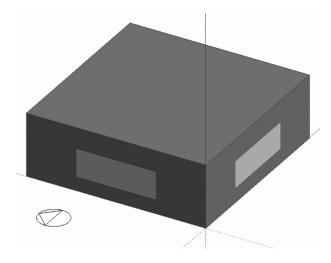
Mixed-Mode Building

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 an intelligent façade design to minimize cooling loads. It then integrates the use of air conditioning when and where 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: http://www.cbe.berkeley.edu/mixedmode

SOLUTION

Step 1: Open the file saved in Tutorial 10.4.



Step 2: Select the **HVAC** tab. Select the HVAC template as **Radiator heating**, **Boiler HW**, **Mixed mode Nat Vent**, **Local comfort cooling**.

- 📲 GSHP Water to Water heat Pump, H	leated Floor, Nat Vent	
-10 Heated floor, Boiler HW, Nat Vent		
📲 📲 Heated floor, Solar Assisted Boiler H	W, Nat Vent	
🚽 📲 Heating and Ventilation Ducted Supp	ply + Extract	
- 🗐 HW Convectors, Nat Vent		
🚽 📲 Natural ventilation - No Heating/Coo	ling	
	mode Nat Vent, Local comfort cooling	
Badiator heating Boiler HW/ Nat Ver	ht	
🚽 📲 Split + Separate Mechanical Ventilati	ion	
	Reheat (Parallel PIU)	
VAV, Air-cooled Chiller, HR, Outdoor	air reset	
WAV Aircooled Chiller HB Outdoor	air react a mixed mode	

Step 3: Clear the **Heated** checkbox in the Heating section and make sure Outside air (ac/h) is **3.000**.

Building 1	
t Activity Construction Openings Lighting HV	AC Generation Outputs CFD
🕻 HVAC Template	×
Template	Radiator heating, Boiler HW, Mixed mode Nat
Mechanical Ventilation	¥
🗖 On	
🖅 Auxiliary Energy	×
Pump etc energy (W/m2)	0.0000
貸 Schedule	Office_OpenOff_Occ
L Heating	×
□ Heated	
*Cooling	¥
✓ Cooled	
een Cooling system	Default
Fuel	1-Electricity from grid
Cooling system seasonal CoP	1.800
Supply Air Condition	
Operation	¥
fal Schedule	Ware_24x7CellOff_Cool
Humidity Control	» *
□ On	· · · · · · · · · · · · · · · · · · ·
Natural Ventilation	
On	· · · · · · · · · · · · · · · · · · ·
Outside air definition method	1-By zone •
Outside air (ac/h) Operation	3.000
Schedule	↓ Ware 24x7CellOff Occ
Outdoor Temperature Limits	ware_z4x/ceiion_occ »
Delta T Limits	»
Delta Tand Mind Speed Coefficients	

Step 4: Ensure the **Mixed mode on** check box is selected.

Mixed Mode Zone Equipment		¥
Mixed mode on		
Wind and Rain		»
Temperature Control		¥
Min outdoor temperature (*C)	0.0	
Max outdoor temperature (*C)	100.0	
Enthalpy Control		»
Dew Point Control		»
Advanced		»

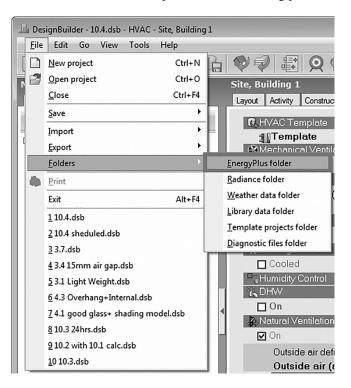
Step 5: Minimize the DesignBuilder window. Create an output.idf file. Write additional output variables as follows:

Output: Variable, *, Zone Air Temperature, Detailed;

Output: Variable, *, AFN Surface Venting Window or Door Opening Factor, Detailed;

Output: Variable, *, AFN Zone Infiltration Air Change Rate, Detailed;

Output: Variable, *, Zone Ideal Loads Supply Air Total Cooling Rate, Detailed;



This .idf file needs to be placed in the following path:

	File E	dit Search View Encoding Language Settings Macro Run Plugins Window ?	X
ť	0	8 € 6 6 8 % 6 9 € # %	
E	Outp	ut lef 🖸	
IΓ	1	Output:Variable, *, Zone Air Temperature, Detailed;	
	2	Output:Variable, *, AFN Surface Venting Window or Door Opening Factor, Detailed;	- 11
ш	3	Output:Variable, *, AFN Zone Infiltration Air Change Rate, Detailed;	- 11
ш	4	Output:Variable, *, Zone Ideal Loads Supply Air Total Cooling Rate, Detailed;	
ш	5		
	6		

Step 6: Maximize the DesignBuilder window and select the **HVAC** tab. Click **Simple** under the **Help** tab. The **Model Options – Building and Block** screen appears.



Step 7: Select the **Simulation** tab. Click the **Advanced** section.

Data Advanced Heating Design Cooling Des	Simulation Display Drawing tools Block Project details
	ennarettern eneprety erenning toole energit
Simulation Options	
From	
Start day	1
Start month	Jan
То	
End day	31
End month	Dec
Calculation Options	
Simulation method	1-EnergyPlus
Time steps per hour	2
Temperature control	1-Air temperature
Solar	
Include all buildings in shading calcs	
Model reflections and shading of ground	flected solar
Solar distribution	2-Full exterior
Shadowing interval (days)	20
Detailed HVAC Autosizing	
Advanced	

Step 8: Select the **IDF File 1** check box and select the Output.idf file from the EnergyPlus folder. Click **OK**.

Model Options - Building and Block	
Model Options Data	Help
Cost/Carbon	Info Data
Data Advanced Heating Design Cooling Design Simulation Display Drawing tools Block Project details	Simulation Calculation Options
Simulation Options »	Data on this tab allows you to
Calculation Options *	control the simulations.
Solar »	This data is also shown before simulations
Detailed HVAC Autosizing ****	
Advanced ×	
General Solution *	
Airflow Network *	
Convection » Wermup »	
Warmup » Shading »	
Include IDE Data	
☑ IDF File 1	
Filename Output.idf	
Other *	
□ 'Surfaces within zone' treated as adiabatic	
Air velocity for comfort calculations (m/s) 0.1370	
Output »	
Help	Cancel OK

Step 9: Select the **Simulation** tab. The **Edit Calculation Options** screen appears. Click **OK**.

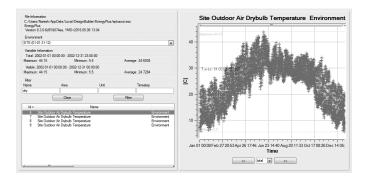
Edit Calculation Options			
Calculation Options Data			Help
General Options Output Simula	ation Manager		Info Data
Calculation Description		¥	Simulation Options
Simulation Period			These options control the simulation and the output produced.
From		×	Simulation Period Select the start and end days for the
Start day	1	•	simulation, or select a typical period: ≡
Start month	Jan	•	Annual simulation
То		¥	Summer design week
End day	31	•	Summer typical week
End month	Dec	•	• <u>All summer</u>
Output Intervals for Reporting		¥	Winter design week
Monthly and annual			Winter typical week
🗹 Daily			All winter
Hourly			
☐ Sub-hourly			Interval Monthly and annual output is always generatedand daily, hourly and sub-hourly data can selected by checking the appropriate boxes. Note that selecting output at hourly or sub-hourly intervals can produce large e
Don't show this dialog next tir	ne	Help	Cancel OK

Step 10: Select the **EnergyPlus** results. Select **eplusout** file, so that the file will automatically open in the xESO-View tool.

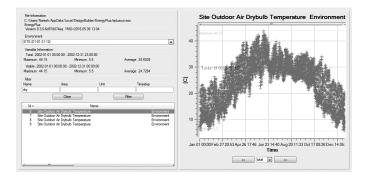
File				Help						-		
	21	-	0		S		RN	멱	\mathbf{Q}	Ň	B	
Navi	gate,	Site	;			Site,	Build	ing 1				

🔟 Select file			23
Look in:	🕼 EnergyPlus 👻	G 🖻 🖻 🖽 -	
æ	Name	Date modified	Туре
2	ASHRAE901	4/1/2016 5:05 PM	File folder
Recent Places	L5_Actual	3/3/2016 1:34 PM	File folder
	L5_Notional	3/3/2016 1:34 PM	File folder
	15 Reference	3/3/2016 1:34 PM	File folder
Desktop	1º, eplusout	4/21/2016 6:30 PM	eso - Ener
Libraries Computer			
0	< III		۴.
	File name: eplusout	- I	Open
Network			
	Files of type: EnergyPlus ESO files	-	Cancel
	Open as read-only		

The xEsoView screen appears:



Step 11: Enter **Site Outdoor Air Drybulb Temperature** in the Name field of the Filter section to view the variable.



You can copy the variable data to view it in a spreadsheet.

e View	Сору	Bookmark	Window	Help	
	D Co	py graphic		Ctrl+Shift+C	
	D Co	py variable d	ata	Ctrl+C	
/Users/Nar	110	py include tir	me data		ut.es
ergyPlus ersion 8.3.0	D Co	py file inform	nation		
vironment	D Co	py variable in	formation		
E (01-01:3	1-12)				
otal: 2002-0 ximum: 44. sible: 2002	01-01 00:0 15 -01-01 00	Minimum: 5.	5 12-01 00:00:	Average: 24.693	38
ximum: 44.	15	Minimum: 5.	85	Average: 25.61	58
	Area		Unit	Timesten	
	, nea		UTIN.	intestep	
	e-Information (Users/Nar ergyPlus ersion 8.3.0 vironment E (01-01:3) niable Informotal: 2002-0 ximum: 44. sible: 2002	Control Contro Control Control Control Control Control Control Control Control Co	Copy graphic Copy variable d Copy variable d Copy variable d Copy variable d Copy variable in Copy variable in Sible 2002-01-01 00:00:00 - 2002-12 ximum: 44.15 Minimum: 5. Sible: 2002-01-01 00:00:00 - 2002-12 ximum: 44.15 Minimum: 5.	Copy graphic Copy variable data Copy include time data regyPlus ersion 8.3.0 Vironment Copy variable information Copy variable information E (01-01:31-12) riable Information otal: 2002-01-01 00:00:00 - 2002-12-31 23:00:0 ximum: 44.15 Minimum: 5.5 sible: 2002-01-01 00:00:00 - 2002-12-01 00:00: ximum: 44.15 Minimum: 5.85 ref	Copy graphic Ctrl+Shift+C Copy variable data Ctrl+C Copy include time data ergyPlus ersion 8.3.0 Copy file information Copy variable information Source Variable Copy variable information Source Variable Copy variable information copy v

Step 12: Click **Copy**; then select **Copy variable data**.

Step 13: Open a spreadsheet and paste the data.

.4	A	B	C	D	E	F	G	н	I
				AFN Surface				I .	
			AFN Surface Venting		AFN Surface Venting Window	AFN Surface Venting			Zone Ideal Loads
			Window or Door	Door Opening	or Door Opening	Window or Door	AFN Zone		Supply Air Total
			Opening Factor	Factor	Factor	Opening Factor	Infiltration Air	Zone Air	Cooling Rate
		Site Outdoor Air				BLOCK1:ZONE1 WALL		Zone Air Temperature	BLOCK1-ZONF1
							BLOCK1:ZONE1	BLOCK1:ZONE	IDEAL LOADS AIR
	Date/Time	Environment [C]	D	IN[]	WIN []		[ach]	1 [C]	IW]
2	3/12/2002 8:00	21.33	1				[acn] 10.94	22.20	[w]
3	3/12/2002 8:05	21.33	1	1			16.36	22.20	
6	3/12/2002 8:05	21.55	1	1			19.26	22.76	
• 5	3/12/2002 8:10	21.33	1				19.26	22.71	
5	3/12/2002 8:20	21.33	1	1			18.24	22.53	
7	3/12/2002 8:20	21.55	1	1			18.24	22.52	
8	3/12/2002 8:23	21.33	0				0.02	23.91	
2 2	3/12/2002 8:35	21.33	1	1			19.20	23.91	
0	3/12/2002 8:55	21.55	1				19.20	24.10	
1	3/12/2002 8:40	21.33	0				0.02	24.01	
2	3/12/2002 8:45	21.33	0				0.02	24.00	
3	3/12/2002 8:55	21.33	0				0.02	24.00	
4	3/12/2002 9:00	23.33	0					24.00	
41 5	3/12/2002 9:00	23.33	0					24.00	
6	3/12/2002 9:00	23.33	0					24.00	3.716.2
7	3/12/2002 10:00	25.55	0					24.00	3,716.2
8	3/12/2002 10:00	25.15	0					24.00	3.716.2
9	3/12/2002 10:30	25.15	0					24.00	4,206.3
9	3/12/2002 10:00	25.15	0					24.00	4,206.3
1	3/12/2002 11:30		0					24.00	4,206.3
2	3/12/2002 11:30	26.43	0					24.00	4,208.5
3	3/12/2002 12:00	27.45	0					24.00	4,699.5
u l	3/12/2002 12:30	27.45	0					24.00	4,699.5
.4 15	3/12/2002 12:30	27.45	0					24.00	5.047.9
5	3/12/2002 12:00	27.45	0					24.00	5.047.9
7	3/12/2002 13:30	28.08	0					24.00	5.047.9
8	3/12/2002 13:30		0					24.00	5.543.8
9	3/12/2002 13:00	28.58	0					24.00	5,543.8
0	3/12/2002 14:30	28.58	0					24.00	5,543.8
1	3/12/2002 14:00		0					24.00	5,844.5
12	3/12/2002 14:00		0					24.00	5,844.5
3	3/12/2002 15:30	28.48	0					24.00	5,844.5

You can observe from the above that if the following conditions are true, then there is natural ventilation.

$$T_{\text{zone_air}} > T_{\text{setpoint}}$$
 AND $T_{\text{zone_air}} > T_{\text{outside_ain}}$

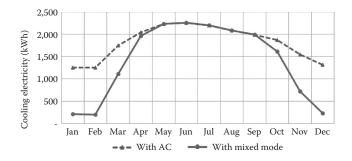
When the outside temperature is more than zone temperature, natural ventilation in OFF and mechanical cooling takes place.

Step 14: Clear the **On** check box to switch off the natural ventilation, so that the zone runs in the air condition mode.

Site, Building 1	
Layout Activity Construction Openings Lighting	HVAC Generation Outputs CFD
R HVAC Template	×
Template	Radiator heating, Boiler HW, Mixed mo
Mechanical Ventilation	
🗖 On	
Auxiliary Energy	*
Pump etc energy (W/m2)	0.0000
14 Schedule	Office_OpenOff_Occ
Heating	*
Heated	
* Cooling	¥
🗹 Cooled	
Cooling system	Default
Fuel	1-Electricity from grid
Cooling system seasonal CoP	1.800
Supply Air Condition	»
Operation	*
(論 Schedule	Ware_24x7CellOff_Cool
Humidity Control	»
C DHW	¥
🗋 On	
Atural `entilation	*
🗋 On	
Temperature Distribution	»
Read Cost	»

Simulate the model and record the monthly energy consumption results.

Compare the results in both cases.



You can observe that natural ventilation is effective in climate of New Delhi from January to March and October to December.

Exercise 10.6

Repeat the above tutorial for the window area modulation based on zone and outdoor air temperature.



Building Energy Code Compliance

Building energy code compliance in most countries has the following two paths:

- 1. Prescriptive
- 2. Performance-based

Prescriptive path give specific requirements for all the building components and all the requirements have to be met for compliance. This generally limits design freedom.

Performance-based path provides more design freedom and can lead to innovative design but involves more complex energy simulations and trade-offs between systems. Residential and smaller commercial buildings with singular heating ventilation and air conditioning (HVAC), service hot water and lighting systems are more likely to be designed by using a prescriptive approach. Larger commercial buildings that have multiple systems or varied uses and loads may find it more advantageous to follow a performance-based path for code compliance.*

The performance-based path requires the whole building energy simulation.

ASHRAE 90.1-2010 has two methods for the whole building simulation:

- a. Energy cost budget (ECB) method
- b. Performance rating method given in ASHRAE 90.1 Appendix G

^{*} https://www.energycodes.gov/resource-center/ace/enforcement/step2

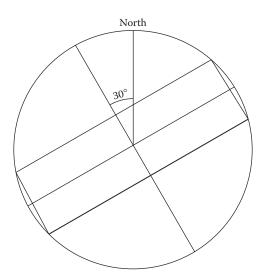
Both methods require energy simulation of the proposed building design and the budget building design.

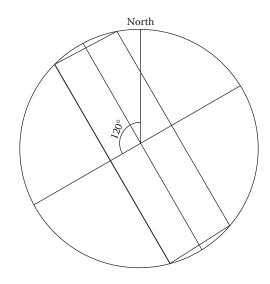
TUTORIAL 11.1 Simulating building performance in four orientations

The baseline building performance shall be generated by simulating the building with its actual orientation and again after rotating the entire building by 90°, 180° and 270° , and then deriving the average from the results. This is illustrated by the following example. The field Site orientation can be use for achieving the desired orientation.

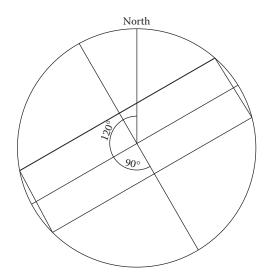


The building face is 150° from the north. (The rectangle inside the circle is the building, and the face is shown with the bold line.)

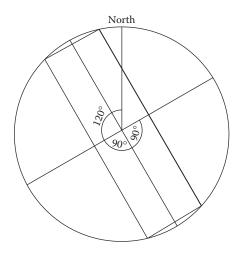




With 90° rotation from the building face.



With 180° rotation from the building face.



With 270° rotation from the building face.

TUTORIAL 11.2 Creating the base case external wall for ASHRAE 90.1-2010 Appendix G

The ECB method requires modelling of opaque assemblies such as roof and walls with the same heat capacity as of the proposed design, whereas in Appendix G, the performancebased method requires these to be modelled as lightweight/ steel-framed.

ASHRAE 90.1-2010 Appendix G requires that the external wall be steel-framed. You can refer to TABLE 5.5-1 of ASHRAE 90.1 for the U-value.

In this tutorial you need to create a steel-framed external wall with a U-value of $0.705 \text{ W/m}^2\text{-K}$.

Step 1: Create a new external wall and select Wall, Steel-Framed, R-13 (2.3), U-0.124 (0.70) - 16 in. (400mm) On Center, 3.5 in. (89mm) Depth Framing.

- 🗇 Wall, Metal Building, R-6+R-13 (1.1+2.3), U-0.070 (0.40)	
- 🌍 Wall, Steel-Framed, R-0 (0.0), U-0.338 (1.92) - 24 in. (600mm) On Center, 3.5 in. (89mm) Depth Framing,	
- 🜍 Wall, Steel-Framed, R-0 (0.0), U-0.352 (2.00) - 16 in. (400mm) On Center, 3.5 in. (89mm) Depth Framing,	
- 🕼 Wall, Steel-Framed, R-11 (1.9), U-0.116 (0.66) - 24 in. (600mm) On Center, 3.5 in. (89mm) Depth Framing,	
Wall, Steel-Framed, R-11 (1.9), U-0.132 (0.75) - 16 in. (400mm) On Center, 3.5 in. (89mm) Depth Framing,	
- 🕼 Wall, Steel-Framed, R-13 (2.3), U-0.108 (0.61) - 24 in. (600mm) On Center, 3.5 in. (89mm) Depth Framing,	
— 😴 Wall, Steel-Framed, R-13 (2.3), U-0.124 (0.70) - 16 in. (400 mm) On Center, 3.5 in. (89 mm) Depth Framing,	
Wall, Steel-Framed, R-13+R-15c.i. (2.3+2.7c.i.), U-0.042 (0.240) - 16 in. (400mm) On Center, 3.5 in. (89mm) Depth Frami	ng,
Wall, Steel-Framed, R-13+R-19c.i. (2.3+3.3c.i.), U-0.037 (0.212) - 16 in. (400mm) On Center, 3.5 in. (89mm) Depth Frami	ng,
Wall, Steel-Framed, B-13+B-4c.i (2,3+0.7c.i.), U-0.084 (0,479) - 16 in. (400mm) On Center, 3.5 in. (89mm) Deoth Framin	a.
Wall, Steel-Framed, R-13+R-7c.i. (2,3+1.3c.i.), U-0.064 (0.365) - 16 in. (400mm) On Center, 3.5 in. (89mm) Depth Framin	a.
- Wall, Steel-Framed, R-15 (2.6), U-0.102 (0.58) - 24 in. (600mm) On Center, 3.5 in. (89mm) Depth Framing,	
Wall, Steel-Framed, R-15 (2.6), U-0.118 (0.67) - 16 in, (400mm) On Center, 3.5 in, (89mm) Depth Framing,	
- Wall, Steel-Framed, R-19 (3.3), U-0.094 (0.53) - 24 in, (600mm) On Center, 6.0 in, (152mm) Depth Framing,	
Wall. Steel-Framed. B-19 (3.3). U-0.109 (0.62) • 16 in. (400mm) On Center. 6.0 in. (152mm) Depth Framing.	
Wall, Steel-Framed, R-21 (3.7), U-0.090 (0.51) · 24 in. (600mm) On Center, 6.0 in. (152mm) Depth Framing,	
- Wall, Steel-Framed, R-21 (3.7), U-0.106 (0.60) - 16 in. (400mm) On Center, 6.0 in. (152mm) Depth Framing,	
- Wall, Wood-Framed, R-0 (0.0), U-0.292 (1.66) - Studs 16 in. (400mm) On Center, 3.5 in. (89mm) Framing Depth,	[
- 3 Wall, Wood-Framed, R-0 (0.0), U-0.298 (1.69) - Studis 24 in. (600mm) On Center, 3.5 in. (89mm) Framing Depth,	
wait, wood rained, his (co), co.c.so (r.co) - situas 24 in (polonini) on center, s.s.in (commin raining cent), (a) (r.d) biological consistency of (r.d)	
m	F.

Step 2: Edit the construction to view properties.

ayers Surface properties Image Calc	sulated Cost Internal source Condensation analysis
General	
Name Wall, Steel-Frame	d, R-13 (2.3), U-0.124 (0.70)
Source	ASHRAE Standard 90.1 (Appendix A)
Category	Walls
Region	General
Definition	
Definition method	1-Layers
Calculation Settings	
ayers	
Number of layers	4
Outermost layer	
Aterial	0.75 in. Stucco
Thickness (m)	0.0190
Bridged?	
Layer 2	
Amaterial	0.625 in. gypsum board
Thickness (m)	0.0159
Bridged? Layer 3	
A Material	Board insulation (Glass fiber board)
*	0.0381
Thickness (m) Bridged?	0.0301
Innermost laver	
Amaterial	0.625 in. gypsum board
Thickness (m)	0.0159
Bridged?	

Step 3: Select the **Calculated** tab. It displays all construction properties.

Constructions Data		
Layers Surface properties Image Calculated Cost In	temal source Condensation analysis	
Inner surface		
Convective heat transfer coefficient (W/m2-K)	2.793	
Radiative heat transfer coefficient (W/m2-K)	5.540	
Surface resistance (m2-K/W)	0.120	
Outer surface		
Convective heat transfer coefficient (W/m2-K)	27.793	
Radiative heat transfer coefficient (W/m2-K)	5.540	
Surface resistance (m2-K/W)	0.030	
No Bridging		
U-Value surface to surface (W/m2-K)	0.788	
R-Value (m2-K/W)	1.418	
U-Value (W/m2-K)	0.705	
With Bridging (BS EN ISO 6946)		
Thickness (m)	0.0888	
Km - Internal heat capacity (KJ/m2-K)	15.5395	
Upper resistance limit (m2-K/W)	1.421	
Lower resistance limit (m2-K/W)	1.421	
U-Value surface to surface (W/m2-K)	0.787	
R-Value (m2-K/W)	1.421	
U-Value (W/m2-K)	0.704	

Please refer to Tutorial 3.1 to understand the effect of steel-framed and mass walls.

TUTORIAL 11.3 Modelling flush windows for the base case

As per ASHRAE 90.1-2010 Appendix G Table G 3.1, you must not model shading projections on the fenestration of the base case building. The fenestration needs to be modelled as flush with the exterior wall or roof.

CHAPTER ELEVEN BUILDING ENERGY CODE COMPLIANCE

Glazing Template	
Template	Project glazing template
External Windows	
🕅 Glazing type	Dbl Grey 6mm/6mm Air
Layout	Preferred height 1.5m, 30% glazed
Dimensions	
Туре	3-Preferred height
Window to wall %	40.00
Window height (m)	1.50
Window spacing (m)	5.00
Sill height (m)	0.80
Reveal	성업은 영향이 있는 것 같은 것 같은 것은 것이 있는 것이 없는 것이 없다.
Frame and Dividers	
Shading	
Window shading	
Local shading	
Airflow Control Windows	
Free Aperture	
Internal Windows	
Sloped Roof Windows/Skylights	
🕼 Glazing type	Project roof glazing
Layout	No roof glazing
Dimensions	
Frame and Dividers	
Shading	
Free Aperture	

In the **Reveal** section, make sure that the **Outside reveal depth** (**m**) is zero for the base case.

Window shading and Local shading must not be modelled.

TUTORIAL 11.4 Selecting HVAC system for the base case

As per ASHRAE 90.1-2010 Section G3.1.3, building type can be determined based on the conditioned floor area, number of floors and the fuel type.

In DesignBuilder, you can select ASHRAE 90.1 Appendix G baseline systems from the template.

Select the Detailed HVAC Template	
⊡-/→ ASHRAE 90.1 Appendix G baseline	
System No. 1 PTAC	
- 🕎 System No. 10 Heating (Electric) and Ventilation	
System No. 2 PTHP	
System No. 3 PSZ-AC	E
System No. 4 PSZ-HP	
ter- C→ DHW	
🛱 🗁 Heating and Cooling Systems	
ASHP Air-to-water Heat Pump, Integrated Boiler, Water Convector	
ASHP Air-to-water Heat Pump, Supplementary Boiler, Water Convector	
Chilled Ceiling, Air-cooled Chiller	
Convector Heating, Boiler HW, Nat Vent	-
I I Donvertor Heating Flactric Nat Vent	_
🕂 🔤 🗹 Sort Cancel OK	

TUTORIAL 11.5 Calculating fan power for the base case

As per ASHRAE 90.1-2010 Section G3.1.2.10, for the base case system fan electrical power for supply, return, exhaust and relief (excluding power to fan-powered VAV boxes) needs to be calculated with the following formulae:

For systems 1 and 2, P_{fan} (watts) = CFM_s × 0.3 For systems 3 and 4, Baseline fan motor brake horsepower = CFM_s × 0.00094 + A Baseline fan motor brake horsepower = CFM_s × 0.0013 + A Where A = sum of (PD × CFM_D/4131) CFM_s = The maximum design supply air flow rate to conditioned spaces served by the system in cubic feet per minute CFM_D = the design airflow through each applicable device in cubic feet per minute PD = each applicable pressure prop adjustment (Please refer to Table 6.5.3.1.1B of ASHRAE 90.1 for PD adjustment values.) Modelling in DesignBuilder^{*}

Delta $P = 1000 \times SFP \times Fan$ total efficiency

^{*} http://www.designbuilder.co.uk/helpv4.7/Content/Fans.htm

The Specific Fan Power (SFP) is a function of the volume flow of the fan and the electrical power input and is quoted for a particular flow rate.

 $SFP = P_e (W)/V (1/s)$

where:

V is volume flow (1/s)

 $P_{\rm e}$ is electrical power input (W) to the fan system or complete air movement installation

an Data		Help	
Fan		Info Data	
General	¥		
Name	Air Loop AHU Supply Fan	Curves	
Type	2-Variable volume	Curves	
Fan total efficiency	0.700	E Curves	
Pressure rise (Pa)	600.0	Fan Part-Load Powe	r, ASHRAE 90.1-2007 Appendix G
End-use subcategory	General	- Fan Part-Load Powe	
Flow Rotes	¥	Fan Part-Load Powe	r, Good Static Pressure Reset VSD
Minimum flow rate input method for fan power	1-Fraction		r, Variable Speed Motor
Minimum flow fraction for fan power	0.3	-	
Maximum flow rate (m3/s)	Autosize		
	*		
Motor efficiency	0.900	Data Report (Not Edital General	ole) 🌣
Motor in airstream fraction	1.000		
Part Load Performance	*		r, Inlet Vane Dampers
Performance curve template	Fan Part-Load Power, Inlet Vane Damp	Note Spurce	EnergyPlus
Fan Coefficients	*	Category	EnergyHus Quartic
Fan coefficient 1	0.3507122300	Calegory Curve Plot	Cluarac
Fan coefficient 2	0.3085053500		d Power, Inlet Vane Dampers
Fan coefficient 3	-0.5413736400	10	a contra dance danapers
Fan coefficient 4	0.8719882300		
Fan coefficient 5	0.000000000		
Operation	*	03	
Availability schedule	On 24/7	0.00	

In this tutorial you will calculate the base case power (kW) requirement for the AHU having the supply air volume 4000 CFM (2.359 m³/s) (1888 l/s) for system 8. (Assume that air-filtering system's pressure drop is less than 1 inch WG when filters are clean.)

Variable volume systems 5–8 Baseline fan motor brake horsepower = CFMs × 0.0013 + A Where $A = \text{sum of (PD × CFM_D/4131)}$ PD = each applicable pressure drop adjustment A = 0.97Baseline fan motor brake horsepower = 6.17 BHP = 4601.54 W SFP = P_e (W)/V (1/s) SFP = 4601.54/1888 = 2.4 W/(1/s) Let fan efficiency be 0.6 Delta $P = 1000 \times \text{SFP} \times \text{fan total efficiency}$ Delta $P = 1000 \times 2.4 \times 0.6$ Delta P = 1440 Pa

TUTORIAL 11.6 Understanding fan cycling

As per ASHRAE 90.1-2010 Section G3.1.2.5, Fan System Operation, supply and return fans shall operate continuously whenever spaces are occupied and shall be cycled to meet heating and cooling loads during unoccupied hours. Supply, return and/or exhaust fans will remain on during occupied and unoccupied hours in spaces that have healthand safety-mandated minimum ventilation requirements during unoccupied hours.

You can refer to Tutorial 8.7 for more details.

TUTORIAL 11.7 Specifying room air to supply air temperature difference

As per ASHRAE 90.1-2010 Section G3.1.2.5, System Types 1 through 8, system's supply air flow rates for the baseline building design shall be based on a supply-air-to-room-air temperature difference of 11°C (20°F), or the minimum outdoor air flow rate, or on the air flow rate required to comply with applicable codes or accreditation standards, whichever is greater.

Edit Air loop -		
Air Loop Data		
Air Loop		
General	×	
Name	Air Loop	
Sizing	×	
Design outdoor air flow rate (m3/s)	Autosize	
Minimum system air flow ratio	0.300	
Sizing option	2-Coincident ·	
Type of load to size on	1-Sensible ·	
System outdoor air method	1-Zone sum 🔹	
Zone maximum outdoor air fraction	1.000	
Heating	×	
Preheat design temperature (*C)	5.00	
Preheat design humidity ratio	0.0080	
Central heating design supply air te	16.00	
100% outdoor air in heating	1-No -	
Central heating design supply air hu	0.008	ľ
Heating design air flow method	1-Design day 🔹	
Cooling	×	
Precool design temperature (*C)	11.00	
Precool design humidity ratio	0.0080	
Central cooling design supply air te	13	
100% outdoor air in cooling	1-No •	
Central cooling design supply air hu	0.0080	
Cooling design air flow method	1-Design day 🔹	

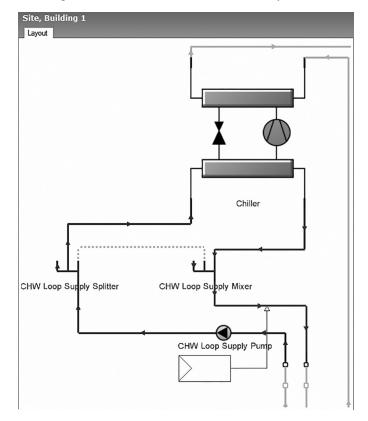
For example, if your room's air temperature setpoint is 24° C, then for the base case, you need to set the supply air temperature to 13° C.

TUTORIAL 11.8 Number of chillers in the base case

As per ASHRAE 90.1-2010 Section G3.1.3.7, Type and Number of Chillers (Systems 7 and 8), electric chillers shall be used in the baseline building design regardless of the cooling energy source.

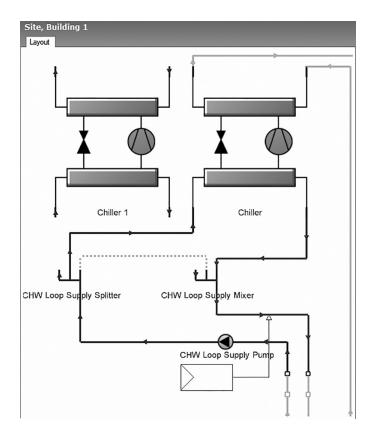
To choose the number of chillers in the base case, you need to find out the building peak cooling load. Based on the building cooling load you can refer to Table G3.1.3.7 of ASHRAE 90.1 to know about the numbers and type of the chillers.

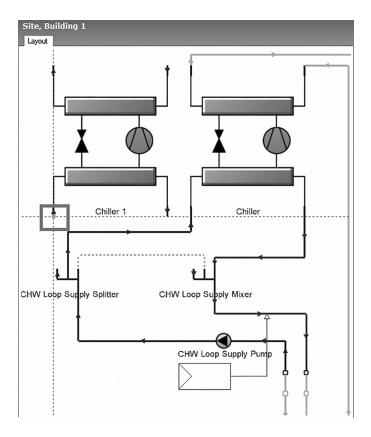
In DesignBuilder, you can add chillers with the following steps:



Step 1: Click Chiller. It shows the chiller layout.

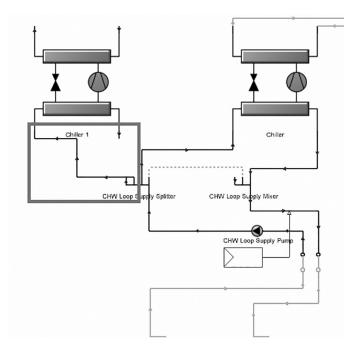
Step 2: Click the **Add Chiller** link. It displays one more chiller on the layout screen.



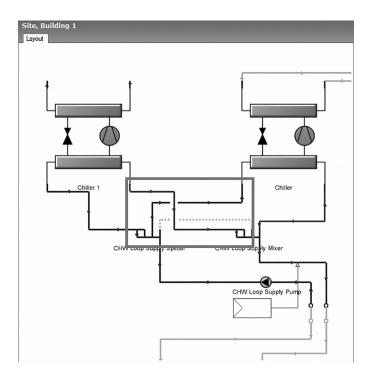


Step 3: Click **Connect components**. It shows a green dot when you click on the node of the chiller.

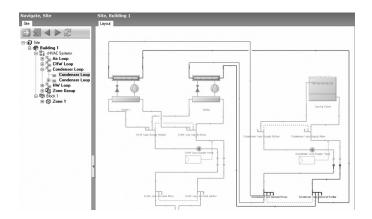
Step 4: Connect **connector** to the chilled-water loop splitter.



Step 5: Repeat step 4 to connect the chilled-water output loop.



Step 6: Connect the **condenser water loop** nodes.



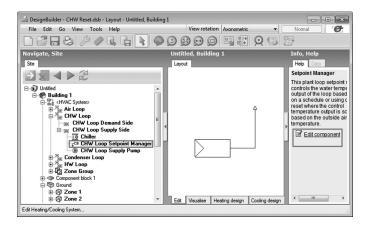
You can change the type of chiller by clicking on **Edit** component.

Electric encoder and the second se	, bailding 1		10. Help Her Her Her Her Her Her Her Her
Chiller Data Chiller General			<u> </u>
			Ý
Name		ller 1	
ℜ Chiller template		E-2 Centrifugal/5.50	ICOP
Chiller type	1-0	ionstant COP	-
Nominal capacity (W)	Aut	osize	
Nominal CoP	5.5	00	
Chiller flow mode	3-N	ot modulated	-
Sizing factor	1.0)	
Condenser			×
Condenser type	2-V	Vater cooled	*
Flow Rates			×
Design chilled water flow rate (m3/s	a) Aut	osize	
Design condenser water flow rate (osize	
Basin Heater	iner of		×
Basin heater capacity (W/K)	0.0	00	
Basin heater setpoint temperature			
Dasin nedler selpoint lemperature	.0) 2.0		

TUTORIAL 11.9 Defining chilled-water supply temperature reset for the base case

As per ASHRAE 90.1-2010 Section G3.1.3.9, Systems 7 and 8, the chilled-water supply temperature shall be reset based on the outdoor dry-bulb temperature by using the following schedule:

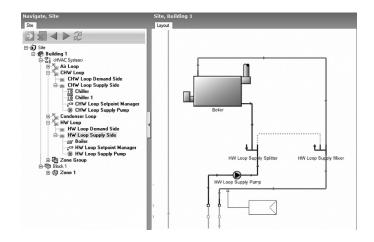
- Chilled-water temperature 7°C at DBT 27°C and above
- Chilled-water temperature 12°C at DBT 16°C and below
- Chilled-water temperature ramped linearly between 7°C and 12°C at outdoor dry-bulb temperatures between 27°C and 16°C



Setpoint Manager Data Setpoint Manager	
General	¥
Name	CHW Loop Setpoint Manager
Туре	10-Outdoor air reset 🔹
Control variable	1-Temperature 👻
Outdoor Air Temperatures vs Supply Temper	ature Relationship 🛛 🗧 🗧
Setpoint at outdoor low temperature (*C)	12
Outdoor low temperature (*C)	16
Setpoint at outdoor high temperature (*C)	7
Outdoor high temperature (*C)	27
Second Reset Rule	×
Second reset rule	

TUTORIAL 11.10 Type and number of boilers for the base case

As per ASHRAE 90.1-2010 Section G3.1.3.2 for Systems 1, 5 and 7, the boiler plant shall use the same fuel as the proposed design and shall be a natural draft, except as noted in Section G3.1.1.1 (Purchase Heat). The baseline building design boiler plant shall be modelled as having a single boiler if the baseline building design plant serves a conditioned floor area of 1400 m² or less and has two equal-sized boilers for plants serving more than 1400 m². Boilers shall be staged as required by the load.



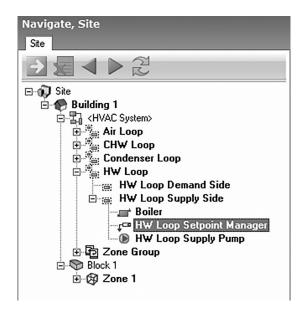
Hot Water Boiler		
General		1
Name	Boiler	
& Boiler template	Gas-fired condensing boiler	_
Fuel type	1-Natural gas	
Nominal capacity (W)	Autosize	
Boiler flow mode	3-Not modulated	•
Parasitic electric load (W)	25.000	
Sizing factor	1.00	
Efficiency		1
Nominal thermal efficiency	0.890	
Efficiency curve temperature evaluation variab	LeavingBoiler	•
Normalized boiler efficiency curve	CondensingBoilerEff	
Water Outlet		8
Design water flow rate (m3/s)	Autosize	
Part Load Ratios		1
Minimum part load ratio	0.000	
Maximum part load ratio	1.000	
Optimum part load ratio	1.000	

Fuel type should be the same as used in the proposed design.

TUTORIAL 11.11 Defining hot-water supply temperature reset

As per ASHRAE 90.1-2010 Section G3.1.3.4 Hot-water Supply Temperature Reset (Systems 1, 5 and 7), the hotwater supply temperature shall be reset based on the outdoor dry-bulb temperature by using the following schedule:

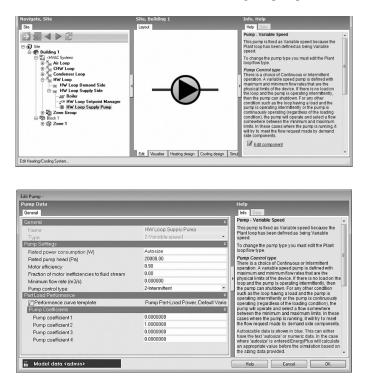
- 82°C at –7°C and below
- 66°C at 10°C and above
- Ramped linearly between 82°C and 66°C at temperatures between -7°C and 10°C



Setpoint Manager Data	
Setpoint Manager	
General	*
Name	HW Loop Setpoint Manager
Туре	10-Outdoor air reset 🔹
Control variable	1-Temperature
Outdoor Air Temperatures vs Supply Temperature Re	
Setpoint at outdoor low temperature (*C)	82
Outdoor low temperature (*C)	-7
Setpoint at outdoor high temperature (*C)	66
Outdoor high temperature (°C)	10
Second Reset Rule	×
Second reset rule	

TUTORIAL 11.12 Hot-water pumps

As per ASHRAE 90.1-2010 Section G3.1.3.5, Hot-water Pumps, the baseline building design hot-water pump power shall be 301 kW/1000 L/s. The pumping system shall be modelled as primary-only, with a continuous variable flow. Hot-water systems serving 11,148 m² or more shall be modelled with variable-speed drives, and systems serving less than 11,148 m² shall be modelled as riding the pump curve.^{*}



TUTORIAL 11.13 Defining exhaust air energy recovery parameters

As per ASHRAE 90.1-2010 Section 6.5.6.1, each fan system shall have an energy recovery system when the system's supply airflow rate exceeds the value listed in Table 6.5.6.1, based on the climate zone and the percentage of outdoor airflow rate at design conditions.

^{*} http://www.designbuilder.co.uk/helpv4.7/#Pump_-_Variable_Speed.htm

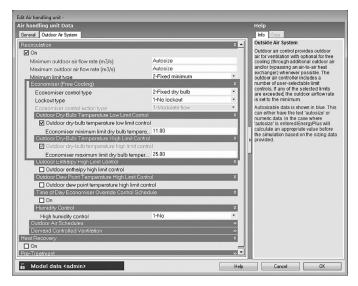
Energy recovery systems required by this section shall have at least 50% energy recovery effectiveness. Fifty percent energy recovery effectiveness shall mean a change in the enthalpy of the outdoor air supply equal to 50% of the difference between the outdoor air and return air enthalpies at design conditions. Provision shall be made to bypass or control the energy recovery system to permit air economiser operation, as required by Section 6.5.1.1. There are some exceptions to this, which you can refer to in Section 6.5.6.1.

You can refer to Tutorial 8.8 for modelling a heat recovery system.

TUTORIAL 11.14 Defining economiser parameters

As per ASHRAE 90.1-2010 Section G3.1.2.7, Economisers, outdoor air economisers shall not be included in baseline HVAC systems 1, 2, 9 and 10. Outdoor air economisers shall be included in baseline HVAC systems 3 through 8 based on climate, as specified in Table G3.1.2.6A. Exceptions can be referred to in the relevant section.

The high-limit shutoff shall be a dry-bulb switch with setpoint temperatures in accordance with the values in Table G3.1.2.6B.



You can refer to Tutorial 8.6 for more details.

TUTORIAL 11.15 Finding unmet hours after simulation

As per ASHRAE 90.1-2010 Section G3.1.2.3, unmet load hours for the proposed or baseline building designs shall not exceed 300 (of the 8760 simulated hours). You can get unmet hours in the **Summary** tab after simulation of the building.

Setpoint Not Met Criteria		
	Degrees [deltaC]	
Tolerance for Zone Heating Setpoint Not Met Time	1.11	
Tolerance for Zone Cooling Setpoint Not Met Time	1.11	
	1.11 Facility [Hours	1
	Facility [Hours	-
comfort and Setpoint Not Met Summary	Facility [Hours	0

TUTORIAL 11.16 Generating the performance rating method compliance report in DesignBuilder

You can get the LEED summary in DesignBuilder by selecting the LEED Summary checkbox.

Calculation Options Data	
General Options Output Simulation Manager	
Output Data	× 🔺
Building and block output of zone data	
Include unoccupied zones in block and building totals and averages	
Allow custom outputs	
Graphable Outputs	×
Energy	»
Comfort and Environmental	»
Detailed Daylight Outputs	»
Summary Tables	×
Summary output units (SI) 1-KWh	•
Summary Annual Reports	
✓ All Summary ✓ LEED Summary	
Annual Building Unity Performance Summary (ABUPS)	
Demand End Use Components Summary	
Sensible heat gain summary	
Input Verification and Results Summary	
Source Energy End Use Components Summary	
Adaptive Comfort Summary	
Zone Component Load Summary	-

After simulation, you can get the LEED summary in the **Summary** tab.

Site, Building 1	
Analysis Summary Parametric Optimisation	
Table of Contents	
Top Annual Building Utility Performance Summary	
Input Verification and Results Summary	
Demand End Use Components Summary	(⊞)
Source Energy End Use Components Summary	
Component Sizing Summary Surface Shadowing Summary	
Climatic Data Summary	
Envelope Summary	
Shading Summary	
Lighting Summary Equipment Summary	
HVAC Sizing Summary	
System Summary	
Outdoor Air Summary	
Object Count Summary Energy Meters	
Sensible Heat Gain Summary	
Standard 62.1 Summary	
LEED Summary	
Report: Input Verification and Results Summary Table of Contents	
For: Entire Facility	
Timestamp: 2016-04-23 14:17:57	

Report: LEED Sum	nmary					Table of Contents	
For: Entire Facility	/						
Timestamp: 2016-	-04-23 14:17:5	7					
Sec1.1A-General	Information						
					Data		
		01-01:31-12) ** New Delhi D	elhi IND ISHRAE WMO#=4			
HDD and CDD dat				Weather F			
Total gross floor a					88.65		
Principal Heating	a Source			Natu	ural Gas		
Principal Heating	g Source			Natu	Iral Gas		
				Nati	ural Gas		
	sage Type	Regularly C	Occupied Area [m2]	Vatu Unconditioned Area [m2]		Hours/Week in Operation [hr/wk]	
Ap2-1. Space U	sage Type Space Area	Regularly C		Unconditioned Area		Hours/Week in Operation [hr/wk] 168.00	
Principal Heating EAp2-1. Space Us BLOCK1:ZONE1 Totals	sage Type Space Area [m2]	Regularly C	[m2]	Unconditioned Area [m2]		[hr/wk]	Į.
EAp2-1. Space Us BLOCK1:ZONE1 Totals	sage Type Space Area [m2] 88.65 88.65	Regularly C	[m2] 88.65	Unconditioned Area [m2] 0.00		[hr/wk]	
EAp2-1. Space Us BLOCK1:ZONE1 Totals	sage Type Space Area [m2] 88.65 88.65	Regularly C Data	[m2] 88.65	Unconditioned Area [m2] 0.00		[hr/wk]	
EAp2-1. Space Us BLOCK1:ZONE1 Totals	sage Type Space Area [m2] 88.65 88.65 y Messages	Data	[m2] 88.65	Unconditioned Area [m2] 0.00		[hr/wk]	
EAp2-1. Space Us BLOCK1:ZONE1 Totals EAp2-2. Advisory	sage Type Space Area [m2] 88.65 88.65 / Messages heating loads not	Data met 0.00	[m2] 88.65	Unconditioned Area [m2] 0.00		[hr/wk]	

	Electric Energy Use [GJ]	Electric Demand [W]	Natural Gas Energy Use [GJ]	Natural Gas Demand [W]	Additional Energy Use [GJ]	Additional Demand [W]
Interior Lighting	21.80	1063.84	0.00	0.00	0.00	0.00
Exterior Lighting	0.00	0.00	0.00	0.00	0.00	0.00
Space Heating	0.00	0.00	0.15	1040.01	0.00	0.00
Space Cooling	0.00	0.00	0.00	0.00	0.00	0.00
Pumps	0.23	9.11	0.00	0.00	0.00	0.00
Heat Rejection	0.00	0.00	0.00	0.00	0.00	0.00
Fans-Interior	14.16	610.94	0.00	0.00	0.00	0.00
Fans-Parking Garage	0.00	0.00	0.00	0.00	0.00	0.00
Service Water Heating	0.00	0.00	0.00	0.00	0.00	0.00
Receptacle Equipment	24.48	1064.73	0.00	0.00	0.00	0.00
Interior Lighting (process)	0.00	0.00	0.00	0.00	0.00	0.00
Refrigeration Equipment	0.00	0.00	0.00	0.00	0.00	0.00
Cooking	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Process	0.00	0.00	0.00	0.00	0.00	0.00
Elevators and Escalators	0.00	0.00	0.00	0.00	0.00	0.00
Total Line	60.67		0.15		0.00	

TUTORIAL 11.17 Finding process load for the base case

Process loads must be identical for both the baseline building and the proposed building. However, project teams may follow the exceptional calculation method (ANSI/ ASHRAE/IESNA Standard 90.1-2010 G 2.5) to document measures that reduce process loads. Documentation of process load energy savings must include a list of assumptions made for both the baseline and the proposed design and theoretical or empirical supporting information.

The total process energy cost must be equal to at least 25% of the baseline building performance. For buildings where the process energy cost is less than 25% of the baseline building energy cost, you should include the documentation substantiating that the process energy inputs are appropriate.

BUILDING ENERGY SIMULATION

Ap2-17b. Er	nergy Us	e Intensity - N	atural G	as
		Natural Gas [MJ/m2]	
Space	Heating		1.68]
Service Water	Heating		0.00	1
Misco	ellaneous		0.00]
	Subtotal		1.68	
	Additio	nal [MJ/m2]		
	Additio	mal[M1/m2]		
Misselbreeue	Additio			
	Additio	0.00		
Miscellaneous Subtotal	Additio			
Subtotal		0.00		
		0.00		
Subtotal		0.00		
Subtotal E Ap2-18. Enc		0.00 0.00		
Subtotal E Ap2-18. Enc Interior	l Use Per	0.00 0.00 rcentage Percent [%]		
Subtotal EAp2-18. Enc Interior Space	i Use Pe r	0.00 0.00 rcentage Percent [%] 35.85		
Subtotal EAp2-18. Enc Interior Space Space	I Use Per Lighting Heating	0.00 0.00 centage Percent [%] 35.85 0.25		
Subtotal EAp2-18. Enc Interior Space Space	i Use Per Lighting Heating Cooling s-Interior	0.00 0.00 centage Percent [%] 35.85 0.25 0.00		
Subtotal EAp2-18. Enc Interior Space Space Fan:	I Use Per Lighting Heating Cooling s-Interior Heating	0.00 0.00 centage Percent [%] 35.85 0.25 0.00 23.28	1	

TUTORIAL 11.18 Getting ASHRAE 62.1 standard summary in DesignBuilder

Many rating systems require meeting the minimum requirements of Sections 4 through 7 of ASHRAE Standard 62.1-2007, Ventilation for Acceptable Indoor Air Quality. You can get this summary from the DesignBuilder output.

Site,	Bui	lding 1								
Anal	/sis	Summa	ry F	Parametri	c (Optimisatio	n			
Tab	le o	f Conte	ents							
Top										
						e Summ	ary			
				l Results						
				nponen						
					pone	ents Sum	nmary			
		ent Sizir								
				ummary	<u></u>					
		Data Su		Y						
		e Summ								
		Summa								
		Summa								
		nt Sum								
		ziną Sur		Ł						
		Summar								
		Air Sun								
		Count Su	umma	ary						
Ene	rqy I	<u>deters</u>								
<u>-Con</u>	cible.	Heeb G	Dist. Co	<u></u>						
<u>Sta</u>	ndaro	62.1 S	umm	ary						
LLL	o su	пппату								
Rep	ort:	Input \	/erifi	cation	and	Results	Summa	ry		
For:	Ent	ire Faci	lity							
Tim	octor	mn. 201	16-0	4-23 14	1.17	.57				
	coca			. 25 1						
ne Ventilation P	rameters									
	AirLoop	People Outdoor Air Rate - Rp [m3/s-	Zone Population - Pz	Area Outdoor Air Rate - Ra [m3/is-m2]	Zone Floor Area - Az [m2]	Breathing Zone Outdoor Airflow- Vbz [m3/s]	Cooling Zone Air Distribution Effectiveness - E2-clg	Cooling Zone Outdoor Ainflow - Voz-clg [m3/5]	Heating Zone Air Distribution Effectiveness - Ez-htg	Heating Zone Out Airflow- Voc [r
	Name	[margan]		-	fuel (fura al	LEGE		TS- IR\$	
LOCK1-ZONE2	Name	person] 0.009440	65.31	0.000000	588.36	0.6165	1.000	0.6165	1.000	
	Name	person]	65.31 10.02	0.000000	588.36 90.30	0.6165	1.000	0.6165	1.000	0.6
ILOCK1-ZONE4	AIR LOOP	person] 0.009440								0.61
RLOCK 1 ZONE2 RLOCK 1 ZONE4 RLOCK 1 ZONE5 RLOCK 1 ZONE1	Name AIR LOOP AIR LOOP	person] 0.009440 0.009440	10.02	0.000000	90.30	0.0946	1.000	0.0946	1.000	0.61

Reference

0.009

130.90

0.00

AIR LOOP

ASHRAE, ASHRAE Standard 90.1-2010: Energy Standard for Buildings Except Low-Rise Residential Buildings. Atlanta, GA: ASHRAE, www.ashrae.org.

People Outdoor Air Rate - Rp Sam of Zone Population - Area Outdoor Air Rate - Ra Samof Zone Floor Area - Breating Zone Outdoor Airflow - [ml > m2] As sam [m2] Ver [ml > h] Vec dg [ml > m2] Vec hg [ml > m2]

1179.30

1.2357

1.2357

1.2357



Project: Small Office

Project goal

The goal of this project is to create a DesignBuilder model of a small office building. The office is located in Jaipur, India, which is climate Zone 1A: Hot and Dry, as defined by ASHRAE 90.1-2010. This project will help you learn to model a small office and analyse the key results of a whole building energy simulation.

Overview

The building is a small office with three floors. An overview of the building is provided in Table 12.1.

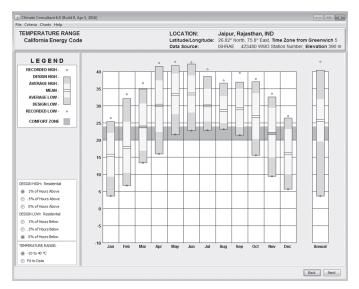
Climate and location

The building is located in Jaipur, India. In this particular climate zone, the maximum daytime temperature in summers is in the range of $32^{\circ}C-44^{\circ}C$ and night temperature ranges from $27^{\circ}C$ to $32^{\circ}C$. In winters, the values are between $10^{\circ}C$ and $25^{\circ}C$ during the day and between $4^{\circ}C$ and $10^{\circ}C$ at night. The relative humidity is about 20-25% in dry periods and 55-95% in the monsoon season.

Variable	Value
Built-up area	11,306 m ²
Total air conditioned area	9,959 m ²
Building use	Office
Number of above-grade floors	3 (G+2)
Wintow-to-wall ratio	27% distributed equal in all
	directions in horizontal strips
Heating	None
Cooling	Variable refrigerant volume (VRV) system
Average utility costs	
Electricity	\$0.12/kWh

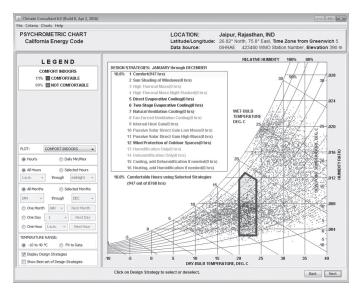
Table 12.1Building overview

The following figures provide the temperatures range (in degree Celsius) and Psychrometric chart for Jaipur climate, generated using Climate Consultant.



Source: From http://www.energydesign-tools.aud.ucla.edu/ climate-consultant/.

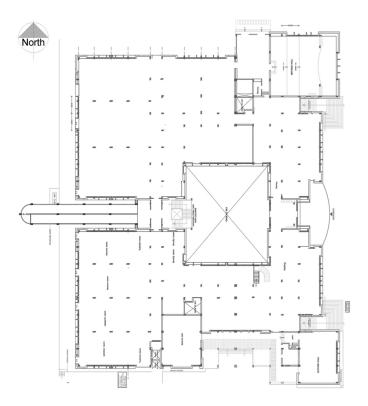
CHAPTER TWELVE PROJECT: SMALL OFFICE

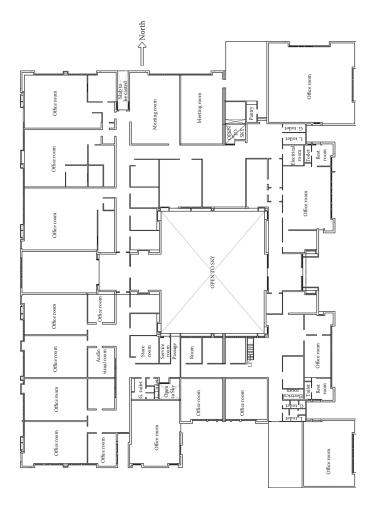


Source: From http://www.energydesign-tools.aud.ucla.edu/ climate-consultant/.

Floor plans

For creating any energy simulation model, it is important to have all floor plans. The following two figures give the floor plans for the ground and the first floor. A soft copy of CAD is provided with the book for import in DesignBuilder (https://www.crcpress.com/9781498744515).





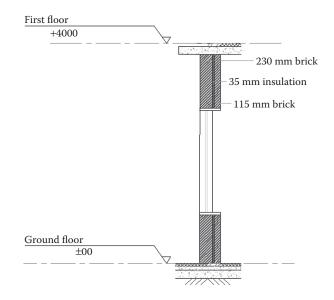
Building envelope

This small office is proposed to be constructed with parameters as shown in Table 12.2.

BUILDING ENERGY SIMULATION

S. No.	Model input parameter	Details
1.	Exterior wall construction	Assembly U-0.72 W/m ² -K 230 mm brick + 35 mm XPS insulation + 115 mm brick
2.	Roof construction	Assembly U-value – 0.35 W/m ² -K 125 mm RCC with underdeck
		75 mm XPS insulation
3.	Glazing	Double-glazed glass with low-heat gain and high visible transmittance U-value: 1.9 W/m ² -K SC (all): 0.28 & VLT: 39%
4.	Window-to-wall ratio (%)	27
5.	Roof reflectance	0.7
6.	Infiltration through envelope (ac/h)	0.5

 Table 12.2
 Construction parameters

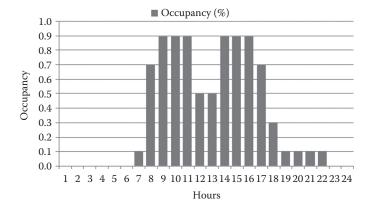


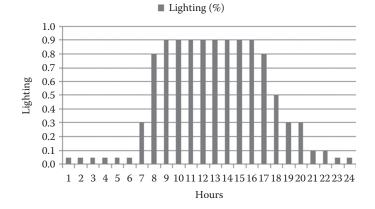
Internal loads and schedules

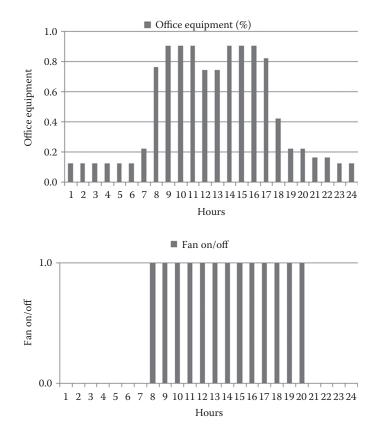
The building is a small office. Details of activity, equipment and lighting loads in each room are provided in Table 12.3.

S. No.	Model input parameter	Details
1.	Equipment power density (W/m ²)	23
2.	Occupancy (m ² /person)	5.4
3.	Lighting power density (W/m ²)	4.6
4.	Shading devices	Overhang 0.15 m on all windows
5.	Occupancy sensors	Installed in all areas
6.	Daylight sensors	Installed in daylit areas
7.	Fresh air	30% over ASHRAE 62.1-2010

 Table 12.3
 Internal loads and schedule details







Mechanical systems

The building is cooled and heated by a ducted VRV system. Details of the HVAC systems are provided in Tables 12.4 and 12.5.

 Table 12.4
 HVAC efficiency details

S. No.	Model input parameter	Value
1.	HVAC system type	VRV system
2.	AHU fan power	1.5 inch WG
3.	Demand control ventilation	CO ₂ sensors installed to modulate fresh air
4.	Heat recovery wheel	Enthalpy wheel type with 75% rated efficiency
5.	Winter heating source	None

COP	3.75
Capacity	9.6 TR
Input power	8.93 kW
Refrigerant	R410A

 Table 12.5
 VRV specifications details

You need to find base case parameters from ASHRAE 90.1-2010.

Simulate and compare the base case and design case models in Desgin Builder.

You can get more information about modelling VRF system from: https://www.designbuilder.co.uk/helpv4.7/ Content/VRFOutdoorUnit.htm

On this page you will also get a link to a webinar -VRF System Design and Simulation, presented by DesignBuilder, Mitsubishi and Building Performance Team, recorded on 01.09.15.



Project: Single-Family Residence

Project goal

The goal of this project is to create a DesignBuilder model of a single-family detached house located in the United States. The house is located in Chicago, Illinois, which is climate Zone 5A: Cool and Humid. You will learn to model a real-world example building and analyse the key results of a whole building energy simulation.

Overview

A single-family home with two floors and one basement will be modelled in this project. An introduction of the building is provided in Table 13.1.

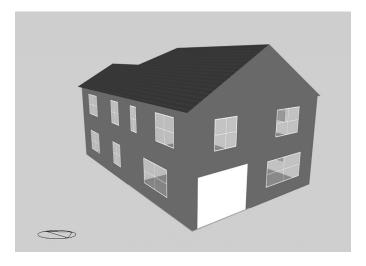


Table 13.1Building overview

Variable	Value
Year of construction	2015
Total built-up area	280 m ²
Building use	Single-family detached
Number of floors	2 + basement
Number of above-grade floors	2
Number of floors below grade	1
Construction type	Wood-framed: advance framing
Window-to-wall ratio	20%
Heating	Gas furnace
Cooling	Air conditioner – ducted split
Domestic hot water	system Gas boiler with storage tank
Average utility costs	
Natural gas	\$0.785/therm
Electricity	\$0.113/kWh

Variable	Value
City/state	Chicago, Illinois
Climate zone	5A (cool-humid)
Latitude	N 41°50′13″
Longitude	W 87°41′05″
Elevation	100 m
Heating design days (18.3°C baseline)	3506
Cooling design days (10°C baseline)	1689
Building orientation	0° from the true north

 Table 13.2
 Building location and orientation

Climate and location

The house is located in Chicago, Illinois. Chicago has a cool and humid climate, with hot and humid summers and cold winters. Therefore, in such climates, buildings are designed to meet both the cooling and heating needs.

Table 13.2 provides information on the geography and climate of Chicago. The building is oriented to the true north, with the slopes of the roofs facing north and south.

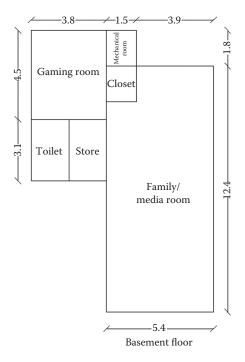
Floor plans

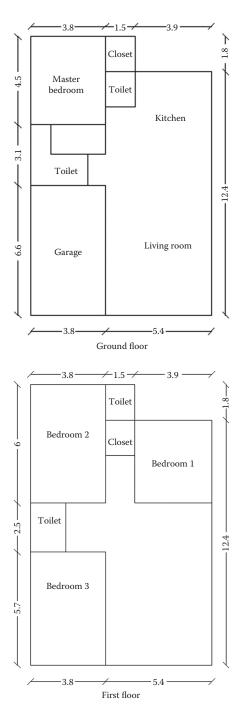
For creating any energy simulation model, it is important to define the area of the building within the thermal boundary. In this home, all the rooms within the building, including the attic area, are insulated, except the garage.

The figures that follow show the floor plans of the house. The first-level floor plan shows the kitchen, master bedroom and living room. On the second level of the home there are three bedrooms. The basement floor comprises a family room, game room, laundry room and mechanical room.

As seen in the 3D image, the building has a sloped roof and an attic under the sloped roof. The home is insulated at the ceiling level, and, hence, the attic is also a conditioned space. However, the garage on the first level is unconditioned.

Therefore, the thermal boundary of the building, is as shown in the plan and cross-section. The complete home is centrally conditioned and is controlled with a single thermostat.





All measurements are in metre.

Internal loads and schedules

The building is a single-family residence. The occupancy of the home is five people. Details of activity, maximum occupancy, equipment load and lighting loads in each of the room are provided in Table 13.3.

Equipment load radiant fraction is 0.2.

Occupancy, equipment, lighting, and mechanical equipment schedules are provided in Tables 13.4 and 13.5.

Room	Activity/ MET	Maximum occupancy	Equipment load (W/m ²)	Lighting load (W/m ²)
Living/dining room	Eating & drinking	5	10.8	5
Master bedroom	Sleeping	2	3.3	3
Bedrooms 1, 2 & 3	Sleeping	1 per room	3.3	3
Kitchen	Cooking	2	4.3	5
Game room	Light manual work	5	10.8	5
Family room	Seated quiet	5	16.1	5
Bathrooms	Standing/ walking	1 per room	2.2	2

 Table 13.3
 Activities and schedules

Table 13.4	l Occupancie	Table 13.4 Occupancies and operating schedule				
		Occupancy		Equipment		Lighting
Type Month		Fraction Jan-Dec		Fraction Jan-Dec		Fraction Jan-Dec
Days	Weekdays	Sunday and holidays	Weekdays	Weekends and holidays	Weekdays	Weekends and holidays
0:00	-	1	0.2	0.2	0.2	0.2
1:00	1	1	0.2	0.2	0	0
2:00	1	1	0.2	0.2	0	0
3:00	1	1	0.2	0.2	0	0
4:00	1	1	0.2	0.2	0	0
5:00	1	1	0.5	0.5	0.5	0.2
6:00	1	1	0.8	0.8	0.5	0.2
7:00	0.8	1	1	1	0.8	0.5
8:00	0.4	1	1	1	0.5	0.5
9:00	0	1	0.5	1	0	0.2
10:00	0	1	0.2	08	0	02
11:00	0	0	0.2	0.2	0	0
						(Continued)

operating sche
Occupancies and operatir
Table 13.4

		Occupancy		Equipment		Lighting
Type		Fraction		Fraction		Fraction
Month		Jan-Dec		Jan-Dec		Jan-Dec
Days	Weekdays	Sunday and holidays	Weekdays	Weekends and holidays	Weekdays	Weekends and holidays
12:00	0	0	0.2	0.2	0	0
13:00	0	0	0.2	0.2	0	0
14:00	0	0	0.2	0.2	0	0
15:00	0	0	0.2	0.2	0	0
16:00	0.8	1	0.5	0.5	0.2	0.2
17:00	0.8	1	0.8	0.8	0.5	0.5
18:00	0.8	1	0.8	0.8	1	0.8
19:00	1	1	1	0.5	1	1
20:00	1	1	1	0.5	1	1
21:00	1	1	0.8	0.5	0.8	0.8
22:00	1	1	0.5	0.5	0.5	0.5
23:00	1	1	0.5	0.2	0.5	0.5

Occupancies and operating schedule
Table 13.4 (Continued)

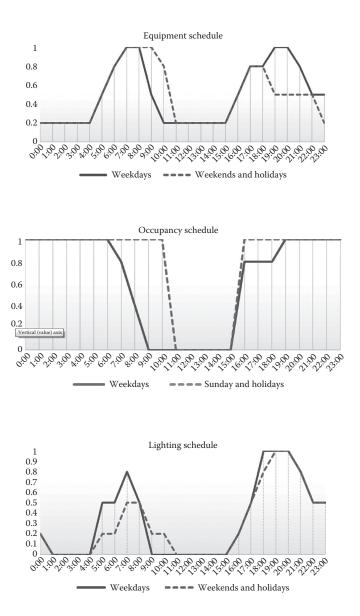
	Coolir	ling setpoint	Heat	Heating setpoint	Cool	Cooling system	Heatin	Heating system
Type Month	L.	Temperature Jan-Dec	Je	Temperature Jan-Dec		On/Off Jun-Sep	Oct O	On/Off Oct–May
Days	Weekdays	Weekends and holidays	Weekdays	Weekends and holidays	Weekdays	Weekends and holidays	Weekdays	Weekends and holidays
0:00	24	24	21	21	1	1	-	1
1:00	24	24	21	21	1	1	1	1
2:00	24	24	21	21	1	1	1	1
3:00	24	24	21	21	1	1	1	1
4:00	24	24	21	21	1	1	1	1
5:00	24	24	21	21	1	1	1	1
6:00	24	24	21	21	1	1	1	1
7:00	24	24	21	21	1	1	1	1
8:00	24	24	21	21	1	1	1	1
9:00	30	24	16	21	0	1	0	1
10:00	30	24	16	21	0	1	0	1
11:00	30	30	16	16	0	0	0	0
								(Continued)

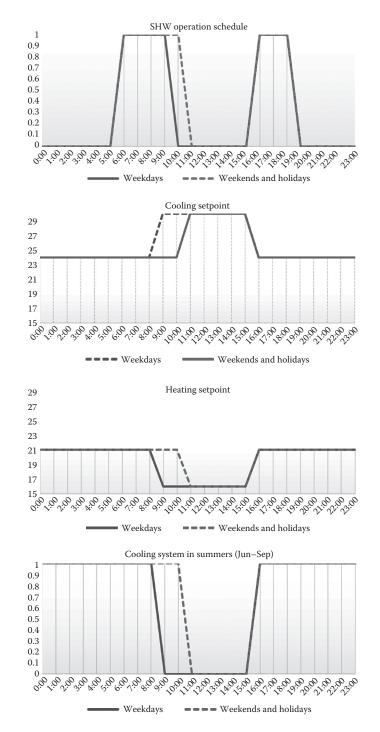
 Table 13.5
 Operating schedules for mechanical equipment

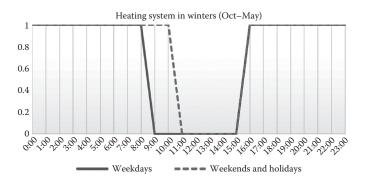
	Cooli	ling setpoint	Heat	Heating setpoint	Cool	Cooling system	Heating	Heating system
Type Month	Je	Temperature Jan-Dec	Je	Temperature Jan-Dec		On/Off Jun-Sep	On Oct-	On/Off Oct–May
Days	Weekdays	Weekends and holidays	Weekdays	Weekends and holidays	Weekdays	Weekends and holidays	Weekdays	Weekends and holidays
12:00	30	30	16	16	0	0	0	0
13:00	30	30	16	16	0	0	0	0
14:00	30	30	16	16	0	0	0	0
15:00	30	30	16	16	0	0	0	0
16:00	24	24	21	21	1	1	1	1
17:00	24	24	21	21	1	1	1	1
18:00	24	24	21	21	1	1	1	1
19:00	24	24	21	21	1	1	1	1
20:00	24	24	21	21	1	1	1	1
21:00	24	24	21	21	1	1	1	1
22:00	24	24	21	21	1	1	1	1
23:00	24	24	21	21	1	1	1	1

Table 13.5 (Continued) Operating schedules for mechanical equipment

The following figures give the 24 hours schedules for various parameters.

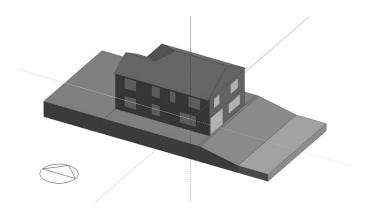






Building envelope

This home is constructed using advanced framing techniques. Layer-by-layer details of the wall, roof and floors is provided. Using these details, create custom layers and, if necessary, materials under the DesignBuilder construction tab. The Window-to-wall ratio of the home is 25%, with most of the glazing on the north and south (Table 13.6).



Component	Description	Construction layers (Some layers such as vapour and air barriers are not shown to maintain simplicity) outside to inside
Opaque assembly Roof	Unvented $\&$ insulated at roof	20 mm wood siding + 100 mm expanded polystyrene + 50 mm closed-cell spray foam + 15 mm gypsum board
Ceiling	Uninsulated	10 mm gypsum board
Above-grade exterior walls	Wood-framed	20 mm wood siding + 50 mm closed-cell spray foam + 100 mm fibre glass batt + 10 mm gypsum board
Interior floors	Wood-framed	20 mm wooden flooring
Partition wall	Interior walls	15 mm gypsum board + 20 mm air gap + 15 mm gypsum board
Below-grade walls	Insulated masonry wall	100 mm concrete masonry block + 100 mm closed-cell spray foam + 15 mm gypsum board
Slab on grade floors	Insulated concrete floor	150 mm concrete slab + 50 mm extruded polystyrene + 20 mm wooden flooring
		(Continued)

 Table 13.6
 Building envelope construction details

Component	Description	Construction layers (Some layers such as vapour and air barriers are not shown to maintain simplicity) outside to inside
Transparent assembly		
Window-to-wall ratio	7% on north + 10% on south + 5% on east + 3%	7% on north + 10% on south + 5% on east + 3% on
	on west	west
Glass solar heat gain coefficient (SHGC)	Double-pane low-E glazing (700 R/SL Slider LoE-180 from WASCO WINDOWS)	0.29
Solar heat gain coefficient (SHGC)	Advanced framing: $50 \text{ mm} \times 150 \text{ mm}$ framing, with 600 mm spacing centre to centre	0.49
Visible transmittance (VT)		0.62
Others		
Roof reflectance	Grey roof	0.3
Infiltration through envelope	Tight envelope	0.5 ac/h

Hint: Windows are only on the conditioned walls, and the building is completely conditioned. With the knowledge from previous examples and exercises in other chapters, should the windows be modelled in detail with exact dimensions and locations?

Tip: Using the area-weighted average method, calculate the effective R value of the insulation (fibre glass batt) used in the wall, considering 16% area for advanced framing.

The above-grade walls of the home are designed to use flash and batt insulation. Open-cell spray foam used in the cavities above dense-packed cellulose is installed.

Mechanical systems

The building is centrally heated and cooled. The heating is provided through a gas furnace, and the cooling system is a central split system. Efficiency details of the HVAC and SHW systems are provided in the following table. Both the heating and cooling systems are connected to the same air handling unit with a constant volume fan (Table 13.7).

Variable	Value
Heating	
System type	Furnace
Fuel type	Natural gas
Heating system efficiency (AFUE)	80%
Maximum supply air temperature	30°C
Maximum supply air humidity ratio	0.0156
Heating system capacity	26 kW
Cooling	
System type	Central air conditioning
	using split system
Fuel type	Electricity
Cooling system EER	12.00
Cooling system SEER	17.50
Cooling system capacity	14 kW
Domestic hot-water system	
System type	A storage hot-water system
	(standalone)
System fuel	Natural gas
Energy factor	0.82
Hot-water delivery temperature	75°C
Mains supply temperature	10°C

Table 13.7Mechanical system details

IECC 2015 compliance

You are required to run simulation for IECC 2015 compliance.



Project: Large Office

Project goal

The goal of this project is to create a DesignBuilder model of a large office building located in Ulsan, South Korea. The office is located in climate Zone 4A: Mixed Humid, as defined by ASHRAE 90.1-2010. You will learn to model a large office building and analyse the key results of a whole building energy simulation.

Overview

The building is a large office with five floors. An introduction of the building is provided in Table 14.1.

Climate and location

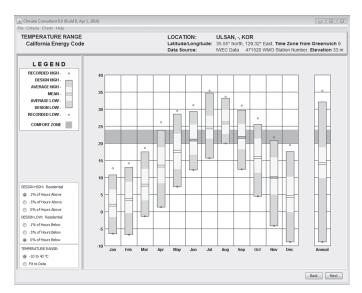
The building is located in Ulsan, Korea. Ulsan has a monsooninfluenced humid subtropical climate, with somewhat cold but dry winters and hot, humid summers (Table 14.2).

Variable	Value
Total built-up area	54.317 m ²
Building use	Office
Number of above-grade floors	2
Window-to-wall ratio	35%
Heating	Natural gas-fired steam boiler
Cooling	Water-cooled centrifugal chillers
Average utility costs	
Natural gas	\$1.7/therm
Electricity	\$0.08/kWh

Table 14.1 Building overview

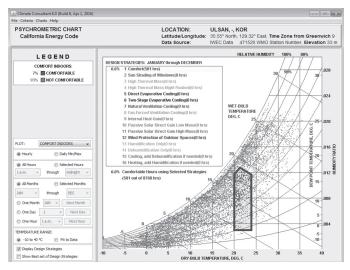
Table 14.2 Building location and orientation

Variable	Value
City/state	Ulsan, Korea
Climate zone	4A (mixed-humid)
Building orientation	0° from the true north



Source: From http://www.energydesign-tools.aud.ucla.edu/ climate-consultant/.

CHAPTER FOURTEEN PROJECT: LARGE OFFICE

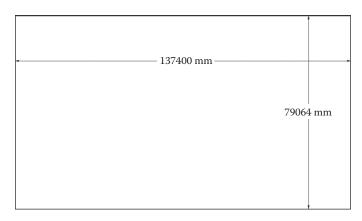


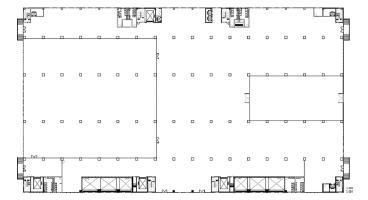
Source: From http://www.energydesign-tools.aud.ucla.edu/ climate-consultant/.

Floor plans

Following figures give the plan and elevations of the building.

A soft copy of CAD is provided with the book (https://www. crcpress.com/9781498744515).





PLAN



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REAR ELEVATION

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SIDE ELEVATION-1

SIDE ELEVATION-2

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Building envelope

This large office is proposed to be constructed with parameters as shown in Table 14.3.

Internal loads and schedules

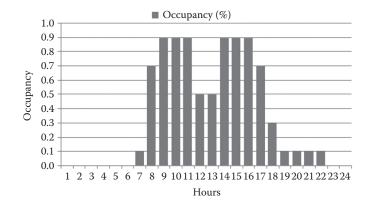
Details of activity, equipment load and lighting load in each of the room are provided in Table 14.4.

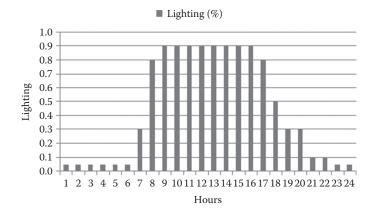
S. No.	Model input parameter	Details
1.	Exterior wall	Assembly U-0.340 W/m ² -K
	construction	Metal panel 50 mm + 75 mm PUF thickness
2.	Roof construction	Assembly U-value: 0.340 W/m ² -K (100 mm concrete + 75 mm PUF)
3.	Glazing	U-value: 3.463 W/m ² -K
		SC (all): 0.6 & VLT: 50%
		Window frame U-value:
		6.41 W/m ² -K
4.	Window-to-wall ratio	35%
5.	Roof reflectance	0.8
6.	Infiltration through envelope	0.5 ac/h
7.	Shading devices	None

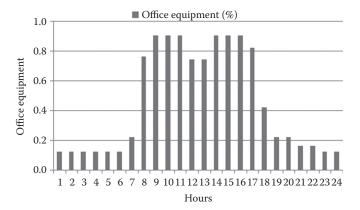
 Table 14.3
 Building envelope parameters

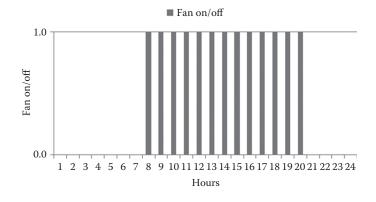
 Table 14.4
 Parameters related to internal loads

S. No.	Model input parameter	Details
1.	Fresh air C.F.M./person	30% over ASHRAE 62.1-2007
2.	Equipment power density (W/m ²)	15
3.	Occupancy (m ² /person)	9.30
4.	Lighting power density (W/m ²)	7
5.	Occupancy sensors	Installed in all areas
6.	Daylight sensors	None









Mechanical systems

The building is centrally heated and cooled. Efficiency details of the HVAC systems are provided in Table 14.5.

HVAC	parameters
	HVAC

S. No.	Model input parameter	Value
1.	HVAC system type	VAV system
2.	AHU fan power	4 in WG
3.	Demand control ventilation	CO ₂ sensors installed to modulate fresh air
4.	Heat recovery wheel	Enthalpy wheel type with 75% rated efficiency
5.	Airside economiser (100% fresh air system)	None
6.	Chiller parameter	3 numbers of 1000 TR water-cooled centrifugal chillers with COP 6.17
7.	Chilled water loop	Variable secondary flow CHW out = 6.66° C & CHW in = 12.22° C
8.	Winter heating source	Natural gas-fired steam boiler
9.	Boiler efficiency	96%
10.	Pump motor class	Standard
11.	Cooling tower fan	Variable speed

Show compliance for ASHRAE 90.1-2010

You need to find base case parameters as per ASHRAE 90.1-2010.

Prepare the DesignBuilder model for the base case and design case. Then compare energy savings (Table 14.6).

Table 14	Table 14.6 Model input parameters for base case and as design case	se case and as design case	
S. No.	Model input parameter	Baseline case as per ASHRAE 90.1-2007	As design case
1.	Exterior wall construction	Steel frame, 11-factor = 0 363 W/m ² -K	Assembly U-0.340 W/m ² -K Metal nanel 50 mm + 75 mm PUF thickness
2.	Roof construction	U-factor = 0.272 W/m ² -K insulation entirely above deck	Assembly U-value: 0.340 W/m ² -K (100 mm concrete + 75 mm PUF)
з.	Glazing	U-value: 2.83 W/m ² -K SC (all): 0.46 For fenestration assembly	U-value: 3.46 W/m ² -K SC (all): 0.6 & VLT: 50% Window frame U-value: 6.40 W/m ² -K
4.	Window-to-wall ratio (%)	35	35
5.	Fresh air C.F.M./person	30% over ASHRAE 62.1-2007	Same as base case
6.	Equipment power density (W/m ²)	0.18	Same as base case
7.	Occupancy (m ² /person)	13.94	Same as base case
8.	Lighting power density (W/m ²)	As per ASHRAE 90.1-2007 Space by Space	7
9.	Shading devices	None	None
10.	Occupancy sensors	None	Installed
11.	Daylight sensors	None	None
12.	HVAC system type	Table G3.1.1.B System 7 – VAV with reheat (total conditioned area is 4.17.400 Soft in five floors)	VAV system
			(Continued)

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Table 14	Table 14.6 (Continued) Model input parar	Model input parameters for base case and as design case	
S. No.	Model input parameter	Baseline case as per ASHRAE 90.1-2007	As design case
13.	AHU fan power	0.0011 kW/C.FM.	4 inch WG
14.	Demand control ventilation	None	CO ₂ sensors installed to modulate fresh air
15.	Heat recovery wheel	None	Enthalpy wheel type with 75% efficiency
16.	Airside economiser (100% fresh air system)	None	None
17.	Chiller parameter	2 nos water-cooled centrifugal chiller, COP 6.1	3 nos water-cooled centrifugal chiller, COP 6.17
18.	Chilled water loop	Variable secondary flow	Variable secondary flow & chilled water
			$\Delta I = 10^{-F}$ CHW out = 6.66°C CHW in = 12.22°C
19.	Winter heating source	Natural gas-fired steam boiler	Natural gas-fired steam boiler
20.	Boiler efficiency	80%	96%
21.	Pump motor class	Standard	Standard
22.	Cooling tower fan	Two speeds	Variable speed
23.	Energy rates	Electricity \$0.08/kWh Natural gas \$1.7/therm	Same as base case

Appendix A: Working of EnergyPlus[™] Simulation

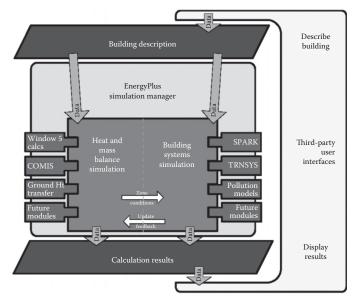
EnergyPlusTM is a whole building energy simulation program used by engineers, architects and researchers to model energy consumption for heating, cooling, ventilation, lighting and plug and process loads. EnergyPlus can also be used for simulating water use in buildings. Some of the features and capabilities of EnergyPlus include (Source: https://www.energyplus.net):

- *Integrated, simultaneous solution* of thermal zone conditions and HVAC system response that does not assume that the HVAC system can meet zone loads and can simulate un-conditioned and under-conditioned spaces.
- *Heat balance-based solution* of radiant and convective effects that produce surface temperatures thermal comfort and condensation calculations.
- Sub-hourly, user-definable time steps for interaction between thermal zones and the environment; with automatically varied time steps for interactions between thermal zones and HVAC systems. These allow EnergyPlus to model systems with fast dynamics while also tradingoff simulation speed for precision.
- *Combined heat and mass transfer model* that accounts for air movement between zones.
- Advanced fenestration models including controllable window blinds, electrochromic glazings and layer-by-layer heat balances that calculate solar energy absorbed by window panes.
- *Illuminance and glare calculations* for reporting visual comfort and driving lighting controls.

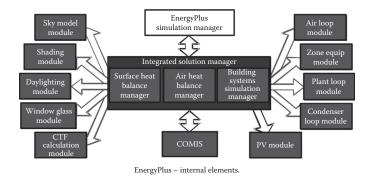
- *Component-based HVAC* that supports both standard and novel system configurations.
- A large number of built-in HVAC and lighting control strategies and an extensible runtime scripting system for user-defined control.
- *Functional Mockup Interface* import and export for co-simulation with other engines.
- *Standard summary and detailed output reports* as well as user definable reports with selectable time-resolution from annual to sub-hourly, all with energy source multipliers.

EnergyPlus is a console-based program that reads input and writes output to text files. It ships with a number of utilities including IDF-Editor for creating input files using a simple spreadsheet-like interface, EP-Launch for managing input and output files and performing batch simulations, and EP-Compare for graphically comparing the results of two or more simulations. Several comprehensive graphical interfaces for EnergyPlus are also available (https://energyplus.net/ interfaces). One of the interfaces is DesignBuilder.

One of the strong points of EnergyPlus is the integration of all aspects of the simulation – loads, systems and plants. Based on a research version of the Building Loads Analysis and System Thermodynamics (BLAST) program called IBLAST, system and plant output is allowed to directly impact the building thermal response rather than calculating all loads first, then simulating systems and plants. The simulation is coupled allowing the designer to more accurately investigate the effect of undersizing fans and equipment, and what impact that might have on the thermal comfort of occupants within the building. The figures below show the big picture and a basic overview of the integration of these important elements of a building energy simulation.



EnergyPlus - the big picture.



More information on EnergyPlus can be found in the Getting Started manual available at https://energyplus.net/sites/all/modules/custom/nrel_custom/pdfs/pdfs_v8.6.0/GettingStarted.pdf.



Appendix B: Weather Data and Tools

For simulating a building, its model and weather data for the location are required. There are various formats for storing the hourly weather data. EnergyPlus uses .epw format.

In a .epw file, all the data are in SI units. The format is textbased and comma-separated. The data file format contains commas to facilitate data reading and analysis with spreadsheet programs.

More information on the .epw format is given at http:// bigladdersoftware.com/epx/docs/8-2/auxiliary-programs/epwcsv-format-inout.html#epw-csv-format-inout.

Weather data for more than 2100 locations are now available in EnergyPlus weather format at https://energyplus.net/weather.

Weather data analysis tools

Climate It was developed by the Department of Architecture and Urban Design, University of California, Los Angeles. Graphically, it displays climate data in either metric or imperial units in dozens of ways useful to architects.

Benefits

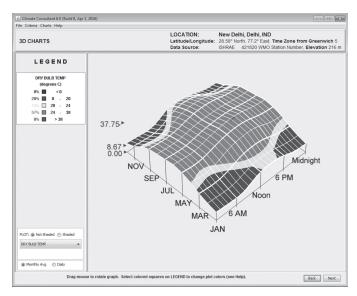
- Easier to identify unique patterns and subtle details that characterize each different climate.
- · Thresholds and comfort zones are more flexible.
- In contrast to the Weather Tool, detailed technical information about the passive strategies criteria is documented and is freely available.

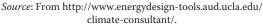
- The 'Wind Wheel' graphics show velocity and direction correlated with temperature and humidity and can be animated hourly, daily or monthly.
- The psychometric analysis recommends the most appropriate passive design strategies, as outlined in Givoni's *Man, Climate and Architecture.*

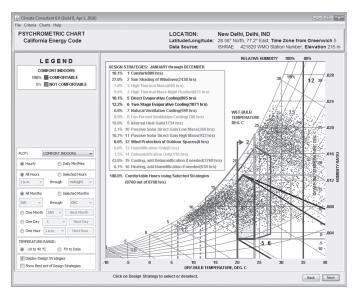
Climate Consultant is free to download from the website http:// www.energy-design-tools.aud.ucla.edu/.

Climate Consultant 6.0			
File Criteria Charts Help SELECT WEATHER DATA			LOCATION: Latitude/Longitude: Data Source:
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	SELECT UNITS:	Metric	
	SELECT WEATHER DATA:	Metic	
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Source: From http://www.energydesign-tools.aud.ucla.edu/ climate-consultant/.







Source: From http://www.energydesign-tools.aud.ucla.edu/ climate-consultant/.

SurrogateIt is developed by the Centre for IT in Building Science (CBS),City FinderInternational Institute of Information Technology, Hyderabad,
India. This is a web-based tool that shortlists the best-matched
weather based on parameters such as the latitude, altitude and
temperature range.

The Surrogate City Finder (SCF) tool has been tested by analysing the annual energy consumption of 16 reference-building models simulated for eight locations from different international climate zones and their surrogate cities to find that the deviation in annual energy consumption was mostly within the range of $\pm 2\%$.

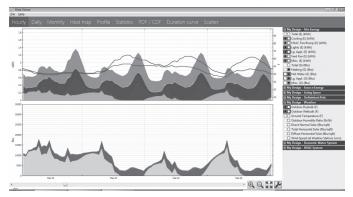
The tool can be accessed at cityfinder.cbs.iiit.ac.in.

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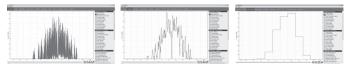
DView DView is used by BEopt for visualizing time-series weather data at any time step (e.g. hourly and subhourly). DView opens CSV files and also recognizes several weather data file formats, including TMY2, TMY3 and EPW files.

The hourly, daily and monthly graphs allow you to turn variables on or off with a single click and to zoom and pan very easily. DView has the ability to display simultaneous line and stacked areas, as demonstrated in the hourly graph below.



Source: From https://beopt.nrel.gov/downloadDView.

Daily and monthly time series graphs are automatically created by averaging or summing the hourly data:



Source: From https://beopt.nrel.gov/downloadDView.

DView is free to download from the website https://beopt.nrel. gov/downloadDView.



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