



Building Models Design And Energy Simulation With Google Sketchup And Openstudio Ahmed Y Taha Al-Zubaydi

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Abstract

The necessity to approach the zero net building design and the improving of building thermal performance augmented the need to use the energy simulation programmes in order to estimate the building energy consumption and virtually modify the structure and the construction material. Energy Plus software from the US Department of Energy introduced a plug-in for Google SketchUp drawing software known as Open Studio, this tool can be considered as a free licences powerful simulation tool available for all engineers to estimate and modify the buildings energy consumption. In this paper we presented a step by step simulation procedure to explain the software capability and encourage the use of the tool by engineers interested in energy efficiency calculations.

Keywords: Energy, Simulation, Google Sketchup, openstudio.

1. Introduction

The energy efficient buildings are highly recommended to achieve an energy rating which lead to more energy saving and cleaner environment. Computer simulation is an important tool in assessment the building energetic performance. The energy assessment is required in the design of new buildings or the refurbishment of existence one. The computer simulation can cover multi tasks processes including building wall and roof layers, window and door types, selecting loads and equipments, selecting the control strategy, estimates loads and calculating payback periods for the suggested system or building modifications.

Though, the modelling may carry certain inaccuracy depending on the available information about the building and its varying with actual case, but the simulation results still considered very useful to decide the final design decisions.

Many building software tools for evaluating energy efficiency, renewable energy, and sustainability in buildings are available e.g. TRNSYS, EnergyPlus, DesignBuilder, etc. Usually, the cost of such software is too high, but the US Department of Energy (DOE) encouraging the use of building energy simulation, consequently the department supporting

some free software available to use by engineers (Weaver et al. 2012). In this paper we shall present the modelling and simulation of building energy using free software from the US Department of Energy and graphically supported by Google Sketch Up. It can be considered as a manual for researchers interested in the energy simulation.

Developed for the conceptual stages of design, GOOGLE Sketch Up is extremely powerful 3D software require basic skills to learn and easy to use. This software combines simple, powerful tools that simplify the 3D design on the computer.

The Open Studio is an open source plug-in for Google Sketch Up 3D drawing software from NREL (NREL). The plugin helps to create and edit the building geometry in Energy Plus input files. Add a number of great use tools for building design in 3D. The plugin also allows you to launch Energy Plus simulations and view results without leaving Sketch Up.

2. INFORMATION ON THE BUILDINGS USE

Building in this paper is an interactive office buildings, a typical office occupations and schedules are considered in this work. The Advanced Energy Design Guide procedure presented by Pacific Northwest National Laboratory under contract for the U.S. Department of Energy project to achieve 50% energy savings above the requirements of ANSI/ASHRAE/IESNA Standard 90.1-2004 for different building types (E. et al. 2012), included two office building type, i.e. Medium size benchmark office building of D.O.E. (Thornton et al. 2009) and Small size office building (Thornton et al. 2010), both will be used in this study.

Similar to (Thornton et al. 2009; Thornton et al. 2010) it was assumed that the buildings peak occupancy take time between 8 AM to 5 PM Weekdays, 10-30% of peak on Saturday, and limited to 5% on Sundays and public holidays. In the buildings in this study, the number of occupants, Lighting, equipments and HVAC scheduling are based on values from office schedules in the ASHRAE Standard 90.1-2004 (ANSI/ASHRAE/IESNA 2010).

3. INTERFERENCE OF GOOGLE SKETCHUP

The Google Sketchup and OpenStudio interface briefly presented in this section, with overview of toolbars, menus and dialog boxes. The purpose of this section is to present the complete operation of the drawing program and get to know all their tools and their use. Google Sketch 3D drawing software is free to download from Google Inc. (Google). On the program start up the following screen appears on Start using SketchUp (Figure 1).

To start a new OpenStudio project, go to the tool bar and click **T** to create a new Openstudio model from template, a list of US department of Energy (DOE) templates will be found in OpenStudio documentation to choose from as shown in Figure 2. In this study, basically we selected a medium office template, which later modified to match the building under study specifications.

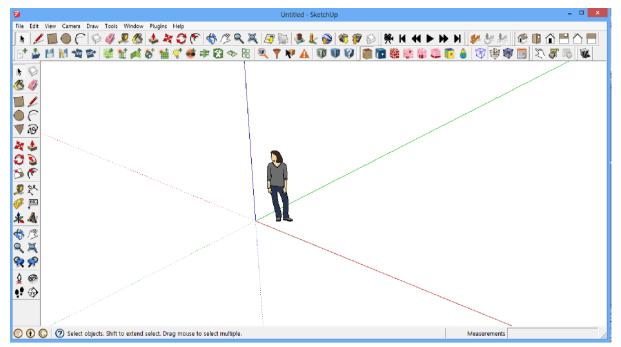
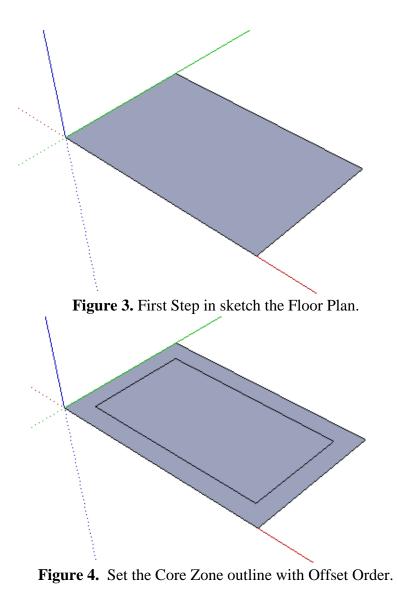


Figure 1. Display list to draw from Google SketchUp.

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Desktop	🛜 LargeHotel	25/08/2012 00	0:29 OSM File	725 KB		
F-	冠 LargeOffice	25/08/2012 00	0:29 OSM File	468 KB		
1	冠 MediumOffice	25/08/2012 00	0:29 OSM File	480 KB		
Libraries	冠 MidriseApartment	25/08/2012 00	0:29 OSM File	536 KB		
	冠 MinimalTemplate	25/08/2012 00	0:29 OSM File	113 KB		
000	🛜 OutPatient	25/08/2012 00	0:29 OSM File	964 KB		
Computer	🛜 PrimarySchool	25/08/2012 00	0:29 OSM File	695 KB		
	🛜 QuickServiceRestaurant	25/08/2012 00	0:29 OSM File	533 KB		
Network	🛜 SecondarySchool	25/08/2012 00	0:29 OSM File	741 KB		
Network	🛜 SmallHotel	25/08/2012 00	0:29 OSM File	765 KB		
	🛜 SmallOffice	25/08/2012 00	0:29 OSM File	460 KB		
	河 Stand-aloneRetail	25/08/2012 00	0:29 OSM File	523 KB		
	🛜 StripMall	25/08/2012 00	0:29 OSM File	458 KB		
	🛜 SuperMarket	25/08/2012 00	0:29 OSM File	537 KB		
	冠 Warehouse	25/08/2012 00	0:29 OSM File	494 KB		
	File name:				•	Open

Figure 2. OpenStudio Template Models

To start building modelling in 3D, we select draw rectangle key, and draw a rectangle with the assigned building outer dimensions ($55m \times 33 m$), as shown in Figure 3. With the offset key we select the core zone area (with 4.6 m offset from outer boundary), Figure 4. And complete the parameter zones drawing on the plan layout (Figure 5).



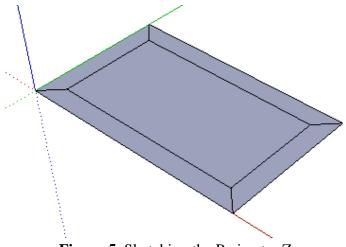


Figure 5. Sketching the Perimeter Zones.

Double click on any line on the diagram to select the whole plan layout, the press create space from diagram key, the window in Figure 6 will pop up, the data for the floor height and number of floors to be entered, in our case the floor height is 2.75, and 1 floor in each step in order to insert the plenum in a proper way as explained further.

Create Spaces From 2d Floor Plan				
Floor Height (SketchUp Units)	2.75			
Number of Floors	1			
OK Cancel				

Figure 6. Create Space From Floor Plan Window.

The 3D diagram will be created with the medium office templates (Walls, Windows, Floors, Roofs and Ceiling) as shown in Figure 7.

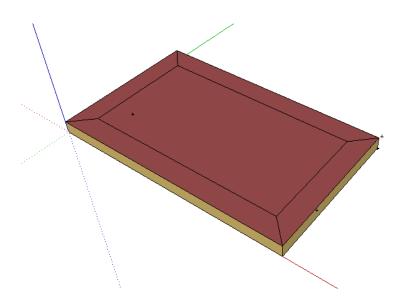


Figure 7. 3D Geometry for First Floor.

To add the Plenum, draw a new rectangle above the 3D diagram of the first floor (Figure 8), and create a new floor from the diagram (new rectangle) and specify the height to 1.25 m to create the plenum at the top of the first floor (Figure 9).

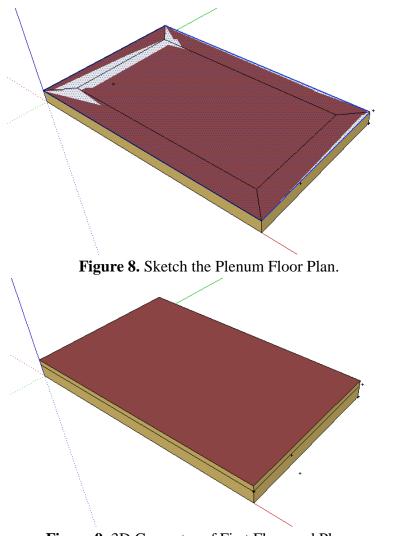


Figure 9. 3D Geometry of First Floor and Plenum.

Repeat the previous steps to create the second and third floors with plenum assigned for each floor (Figure 10).

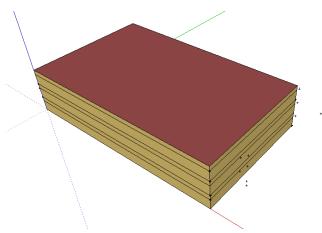


Figure 10. 3D Geometry of a Three Floors Building with Plenums.

Next step is to match the geometry surface, click the surface matching key, the window in Figure 11. will pop up, first intersect the zones surfaces by select "Intersect in Entire Model", the "Match in Entire Model" to match all the surfaces. To see the effect of surface matching view model in X-ray mode and render by construction type, each construction will be assigned a different colour (Figure 12.)

😥 Surfa	ace Matching 🛛 🗕 🗖 🗙
□ Intersect and Divide Inter-Z	one Surfaces (help)
Intersect in Entire Mode	
Surface Matching (help)	
Match in Entire Model	Match in Selection
Unmatch in Entire Mode	Unmatch in Selection

Figure 11. Surface Matching Window in OpenStudio.

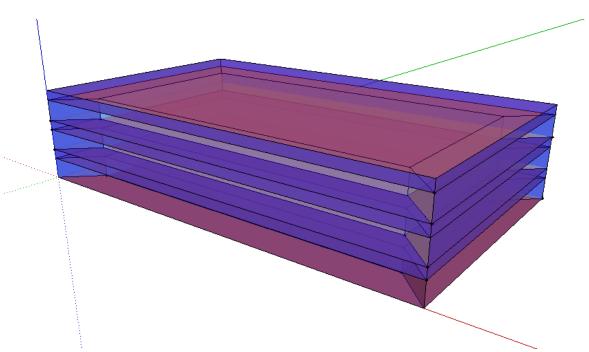


Figure 12. Office Building 3D Geometry in Construction Rending Mode.

The next step is to create fenestrations, return to the rending by surface type view and select "Hide Rest of Model" option, double click on any parameter zone, and then click on the external wall to be selected (Figure 13). From tool bar go to "plugins", "OpenStudio user scripts"," Alter or Add Model Elements" and then "Set Window to Wall Ratio" (Figure 14).

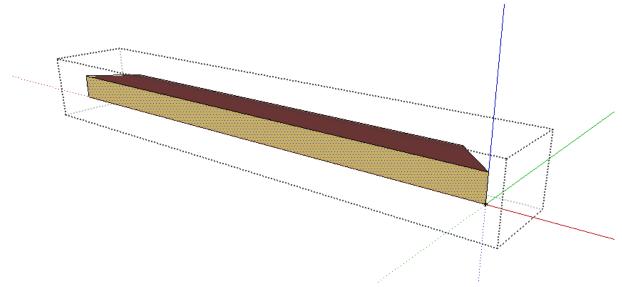


Figure 13. Single Space Selection View.

Plugins Help				
Cost	•			
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OpenStudio	•			
OpenStudio User Scripts	•	Load User Scripts		
		Hello World	_	
		Alter or Add Model Elements	÷	Add Overhangs by Projection Factor
		Building Component Library	•	Assign Building Stories
		Create Standard Building Shapes	•	Assign Unique Zones To Untagged Spaces
		Reports	•	Export Selected Spaces to a new External Model
		SketchUp Visualization	•	Merge Spaces From External Model
		-11-		Make Selected Surfaces Adiabatic and Assign a Construction
				Move Selected Surfaces to New Space
				Remove Hard Assigned Constructions
				Remove Loads Directly Assigned to Spaces
				Remove Orphan SubSurfaces
				Rename Thermal Zones Based On Space Names
			1	Set Interior Partition Height Above Floor
				Set Window to Wall Ratio

Figure 14. Set Window to Wall Ratio Tool Bar Access.

The window in Figure 15 will pop up, set the values to 0.4 (40% Window to Wall Ratio) and the offset to 0.76 m above floor. Repeat the same step for each external wall until we get the final shape of the building geometry (Figure 16).

Use	r input.
Window to Wall Ratio (Fraction	n) 0.4
Offset (meters)	0.76
Application Type	Above Floor 🔹
OK Cancel	

Figure 15. Set Window to Wall Ratio Window.

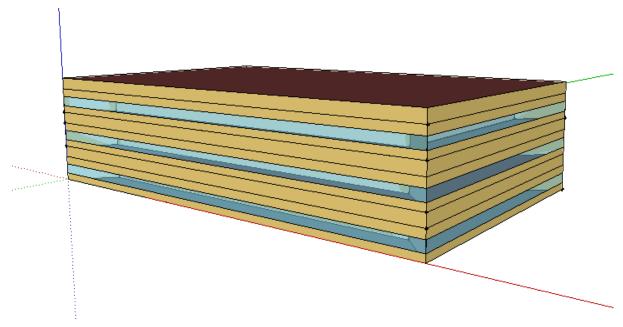


Figure 16. 3D Geometry of Office Building with External Windows.

The next step after the creation of the building 3D geometry is to apply the air condition zones to each space. First we select the space, by click the "Set Attributes for Selected Space" key the window in Figure 17 will appear, were we can select the space type, building story of selected space, construction set, thermal zone number, ideal load status and thermostat. The same step to be done for each space, until we get all Spaces assigned to 3 Story each with Core space , 4 parameter spaces and a plenum. The building will have 15 thermal zones (3 Core zones and 12 Parameter zones).

Set Attributes f	Set Attributes for Selected Spaces							
Ѕрасе Туре	ASHRAE_189.1-2009_ClimateZone 4-8_MediumOffice 💌							
Building Story	Building Story 1							
Construction Set	ASHRAE_189.1-2009_ClimateZone 4-5 (mdoff)_ConstSe 💌							
Thermal Zone	<new thermal="" zone=""></new>							
Set Parent Thermal Zone's - Ideal Air Loads Status	Yes							
Set Parent Thermal Zone's - Thermostat	Medium Office_Thermostat							
OK Cancel								

Figure 17. Set Attributes for Selected Space Window.

OpenOffice Inspector window (Figure 18) enables the user to change the building geometry in for ASHRAE standard to the construction layers described for each building. The previously described materials may not be found in the materials library, thus it's should be entered manually, then use the materials to create the constructions of each layer (External Walls, Interior Walls, Fenestration, Slab Floor, Interior Floors, Interior Ceiling and Roof). Similar steps required to create Space Loads and Scheduling. It will be more advantage to check each surface construction name.

9	OpenStudio Inspector
Select Type	Edit Object
OpenStudio Constructions OS:Construction (288) OS:Construction:Cfactor/UndergroundWall (0) OS:Construction:FfactorGroundFloor (0) OS:Construction:InfanaSource (0) OS:Construction:WindowDataFile (0)	OS:Building Name Medum Office Building Type
Osc.onstructione window/Datarile (0) OpenStudio Geometry ØsShading (1) Osfracility (1) Osfracility (1) OsfinterioPartitionSurface(0) OsfradingSurface (0) OsfshadingSurface(0) OsfshadingSurface(0) OsfshadingSurface(0)	Commercial North Axis O North Axis North Axis Nominal Floor to Floor Height
Osspare (18) Osspare (18) Ossuface (12) Ossuface (12)	3.0 m Space Type Name ASHRAE_189.1-2009_ClimateZone 4-8_MediumOffice Default Construction Set Name
OS:Building	AH_Default Constructions_ConstSet
Name Comment	MedumOffice_Schedules
•	

Figure 18. OpenStudio Inspector Window.

The Glazing material properties values (i.e. U-Factor, SHGC and the visible transmittance) can be edit from the OpenOffice inspector window. In Figure 19 the parameters of the glass properties stated. These values reduced to 2.5 W/m^2 .K (U-Factor) and 0.26 SHGC for modified glazing.

S:WindowMaterial:SimpleGlazingSys	tem	
Name		
AH- NonRes Fixed Assembly Window		
U-Factor		
3.23646	W	//m²•ł
Solar Heat Gain Coefficient		
0.39		
Visible Transmittance		
0.22		

Figure 19. Glazing Material Specification Editing Window in OpenStudio Inspection.

Further modification for the building in this study is to add a hangovers for external windows (Figure 20), the same procedure for adding windows to external wall shall be recalled here, go to "Plugins", "OpenStudio User Scripts", "Alter or Add Model Elements" then select "Add Overhangs by Projection Factor" (Figure 21), repeat the procedure for all windows till we get all windows with overhangs.

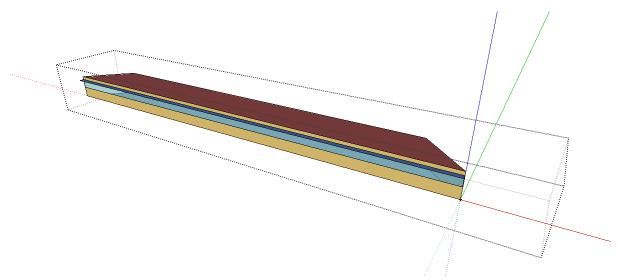


Figure 20. Adding an Overhang for External Window.

Plugins Help	7	
Cost Select OpenStudio Version OpenStudio		Ì ☆ ∦ H H H ► H H # & # [] 1 ☆ # # @ @ @ @ @ @ @ @ @ @]]
OpenStudio User Scripts	Load User Scripts	
	Hello World	/
	Alter or Add Model Elements	Add Overhangs by Projection Factor
	Building Component Library	Assign Building Stories
	Create Standard Building Shapes	Assign Unique Zones To Untagged Spaces
	Reports +	Export Selected Spaces to a new External Model
	SketchUp Visualization	Merge Spaces From External Model
		Make Selected Surfaces Adiabatic and Assign a Construction
		Move Selected Surfaces to New Space
		Remove Hard Assigned Constructions
		Remove Loads Directly Assigned to Spaces
		Remove Orphan SubSurfaces
		Rename Thermal Zones Based On Space Names
		Set Interior Partition Height Above Floor
		Set Window to Wall Ratio

Figure 21. Toolbar Access to Add Overhang by Projection Factor in OpenStudio Plug-in.

BUILDING ENERGY SIMULATION WITH OPENSTUDIO

This section shall subject the building to the simulation using the Openstudio, used in this project for the calculation of loads and demonstrate how they have been introducing the input parameters according to the study done earlier enclosure. The scenarios to be simulated are:

- 1. Basic conditions.
- 2. Improved glazing with solar filter film.
- 3. Improved window with Overhangs.
- 4. Mixed condition (Solar film and Overhangs).

The "Launch to OpenStudio" option will open the OpenStudio exe. File (Figure 22), the toolbar on the left side help to set and modify building geometry specification, internal loads and operating schedules, add HVAC units, run simulation and results viewing, in addition to more detailed options.

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	Site Weather File & Design Days Utility Rates		My Model Library Edit
	Weather File		
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	files/AUS_NSW.Sydney.947670_IWEC.epw	Browse	
	Download weather files at <u>www.energyplus.gov</u>		
	Design Days		
	DDY File Path		
		Browse	
	Location		
	Name: SYDNEY		
n.	Latitude: -33.95		
	Longitude: 151.18		
B	Elevation: 3		
	Time Zone: 10		
	Number of Design Days: 18		
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0 1 1			
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Figure 22. OpenStudio Panel Window.

The run simulation window will perform the building simulation with EnergyPlus software; EnergyPlus has its roots in two programs, BLAST and DOE-2. BLAST, Building Loads Analysis and System Thermodynamics and DOE-2 were developed and released in late 1970 and early 1980 as a tool for energy load simulation. Like original programs, EnergyPlus is a program of energy analysis and thermal load simulation. Based on the description of a building user-defined from the perspective of the physical (construction), mechanical systems, etc..

EnergyPlus calculates the heating and cooling loads necessary to maintain control set points thermal conditions in an HVAC system, and the energy consumption of primary plant equipment, and many details of other simulations that are necessary to check that the simulation is running as desired.

At the end of simulation process (Figure 23), we can view the result on "Results Summary" page (Figure 24). Detailed Electricity and Gas consumption for simulated building are listed and graphed. To get more detailed results for each space we can choose to open the "Results Viewer" (Figure 25), were the annual performance report for whole building is available. Double click on any Variable(s) on the left will plot the selected zone(s) annual variables on hourly bases (Figure 26).

Ŭ	Medium Office D AC glazed + Hangover.osm — OpenStudio		- 🗆 🗙
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		100%	Open RunManager
Run	Finished		for Multiple Runs
1			
	Use Radiance for Daylighting Calculations. Ruby and Radiance are required.		
100	Warnings: 36		
9 <u>1</u>	Errors: 0		
	Output		
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1997 - C	EnergyPlus Starting		
	EnergyPlus-64-WP 7.1.0.012, 25/12/2012 16:13 Processing Data Dictionary		
	Processing Justa Juctonary Processing Justa Juctonary		
	Initializing Response Factors		
1	Calculating CTFs for "ASHRAE_189, 1-2009_EXTWALL_MASS_CLIMATEZONE 4", Construction #1		
	Calculating CTFs for "CBECS_1980-2004_EXTROOF_ATTICFLOOR_CLIMATEZONE 8", Construction #2 Calculating CTFs for "CBECS_1980-2004_EXTROOF_METAL_CLIMATEZONE 1", Construction #3		
	Calculating CTFs for "ASHRAE" 189.1-2009 EXTWALL MASS CLIMATEZONE 5, Construction #4		
B	Calculating CTFs for "CBECS_BEFORE-1980_EXTROOF_IEAD_CLIMATEZONE 4Å", Construction #6		
	Calculating CTFs for "CBECS_1980-2004_EXTROOF_IEAD_CLIMATEZONE 59", Construction #7		
r+1	Calculating CTFs for "ASHRAE_189.1-2009_EXTWALL_STEELFRAME_CLIMATEZONE 4-8", Construction #8 Calculating CTFs for "ASHRAE_189.1-2009_EXTWALL_METAL_CLIMATEZONE 4-8", Construction #9		
(Feel	Calculating CTFs for "CBECS_1980-2004_EXTWALL_MASS_CLIMATEZONE 68", Construction #10		
	Calculating CTFs for "CBECS_1980-2004_EXTROOF_METAL_CLIMATEZONE 68", Construction #11		
X	Calculating CTFs for "CBECS_BEFORE-1980_EXTWALL_MASS_CLIMATEZONE 1-2", Construction #12 Calculating CTFs for "CBECS_1980-2004_EXTWALL_METAL_CLIMATEZONE 8", Construction #13		
	Calculating CTFs for "ASHRAE_189.1-2009 EXTIVAL_MASS_CLIMATEZONE_ALTRES 5", Construction #14		
65	Calculating CTFs for "CBECS_BEFORE-1980_EXTROOF_ATTICFLOOR_CLIMATEZONE 6", Construction #15		
200 - C	Calculating CTFs for "ASHRAE_90.1-2004_EXTWALL_MASS_CLIMATEZONE_ALT-RES 3", Construction #16 Calculating CTFs for "CBECS_1980-2004_EXTROOF_IEAD_CLIMATEZONE 1", Construction #17		
\sim	Calculating CTFs for "CBECS 1980-2004 EXTROOM_EAN/AMTEZONE 3.", Construction #18		
8	Calculating CTFs for "ASHRAE_90.1-2004_EXTWALL_METAL_CLIMATEZONE 6-8", Construction #19		
	Calculating CTFs for "CBECS_1980-2004_EXTROOF_IEAD_CLIMATEZONE 6A", Construction #20		
	Calculating CTFs for "CBECS_1980-2004_EXTWALL_METAL_CLIMATEZONE 2A", Construction #21 Calculating CTFs for "ASHRAE 189,1-2009 EXTROOF IEAD CLIMATEZONE 2-5", Construction #22		
	Calculating CTFs for "CBECS_1980-2004 EXTROOF_IEAD_CLIMATEZONE 3.", Construction #24		
	Calculating CTFs for "CBECS_1980-2004_EXTWALL_METAL_CLIMATEZONE 38_LAS", Construction #25		
	Calculating CTFs for "CBECS_BEFORE-1980_EXTWALL_STEELFRAME_CLIMATEZONE 1-38", CONStruction #26 Calculating CTFs for "CBECS_BEFORE-1980_EXTWALL_STEELFRAME_CLIMATEZONE 1-38", CONStruction #26		
	Calculating CTFs for "CBECS_BEFORE-1980_EXTWALL_MASS_CLIMATEZONE 8", Construction #27 Calculating CTFs for "CBECS_1980-2004_EXTROOF_ATTICFLOOR_CLIMATEZONE 3A", Construction #28		
	Calculating CTFs for "CBECS_1980-2004_EXTWALL_WOODFRAME_CLIMATEZONE 3B_LAX", Construction #29		
	Calculating CTFs for "ASHRAE 90.1-2004 EXTWALL_STEELFRANGE CLIMATEZONE_ALT-RES 8", Construction #30 Calculating CTFs for "MURE ICONTIGNES". Constructions #31	v .	
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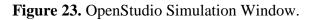




Figure 24. OpenStudio Basic Results Viewer.

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Zone Mean Air Temperature	PERIMETER_TOP_ZN_1 THERMAL ZONE	Hourly	3-EnergyPlu	s-0 R					
Zone Mean Air Temperature	PERIMETER_BOT_ZN_2 THERMAL ZONE	Hourly	3-EnergyPlu	s-0 R		Site and Source En	ergy		
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Zone Mean Air Temperature	PERIMETER_TOP_ZN_2 THERMAL ZONE	Hourly	3-EnergyPlu	s-0 R		Total Site Energy	1927.91	389.48	389.48
Zone Mean Air Temperature	BOT_PLENUM_THERMAL ZONE	Hourly	3-EnergyPlu	s-0 R		Net Site Energy	1927.91	389.48	389.48
Zone Mean Air Temperature	PERIMETER_TOP_ZN_3 THERMAL ZONE	Hourly	3-EnergyPlu	s-0 R		Total Source Energy	5704.87	1152.50	1152.50
Zone Mean Air Temperature	PERIMETER_MID_ZN_1 THERMAL ZONE	Hourly	3-EnergyPlu	s-0 R		Net Source Energy	5704.87	1152.50	1152.50
Zone Mean Air Temperature	PERIMETER_BOT_ZN_1 THERMAL ZONE	Hourly	3-EnergyPlu	s-0 R		Site to Source Ene	rgy Conversion Fa	ctors	
Zone Mean Air Temperature	PERIMETER_BOT_ZN_3 THERMAL ZONE	Hourly	3-EnergyPlu	s-0 R		Site	=>Source Conversi	on Factor	
Zone Mean Air Temperature	PERIMETER_MID_ZN_2 THERMAL ZONE	Hourly	3-EnergyPlu	s-0 R		Electricity		3.167	
Zone Mean Air Temperature	CORE_MID_THERMAL ZONE	Hourly	3-EnergyPlu	s-0 R		Natural Gas		1.084	
Zone Mean Air Temperature	TOP_PLENUM_THERMAL ZONE	Hourly	3-EnergyPlu	s-0 R		District Cooling		1.056	
Zone Mean Air Temperature	PERIMETER MID ZN 3 THERMAL ZONE		3-EnergyPlu			District Heating Steam		3.613	
		,				Gasoline		1.050	
Zone Mean Air Temperature	PERIMETER_BOT_ZN_4 THERMAL ZONE	Hourly	3-EnergyPlu	s-0 R		Diesel		1.050	
Zone Mean Air Temperature	PERIMETER_TOP_ZN_4 THERMAL ZONE	Hourly	3-EnergyPlu	s-0 R		Coal		1.050	
Zone Mean Air Temperature	PERIMETER_MID_ZN_4 THERMAL ZONE	Hourly	3-EnergyPlu	s-0 R		Fuel Oil #1		1.050	
Zone Mean Air Temperature	CORE_BOT_THERMAL ZONE	Hourly	3-EnergyPlu	s-0 R	~	Fuel Oil #2		1.050	

Figure 25. Results Viewer Window in OpenStudio Package.

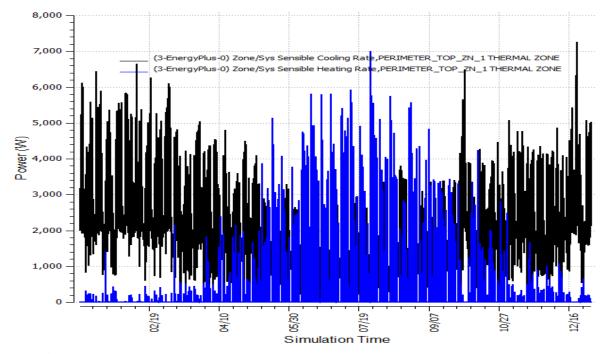


Figure 26. Perimeter Zone 1 Annual Cooling and Heating Loads on Hourly Bases.

The simulation results for the two building under study were given in the buildings simulation result section in this chapter to compare between results obtained from OpenStudio and these obtained from TRNSYS software package simulation. The OpenStudio results are used to estimate the HVAC systems electricity consumption for cooling.

CONCLUSION

The simulation with the Energy Plus OpenStudio plug in utilize the graphical interference with Google SketchUp presented in this work in the form of step by step manual guide. The software flexibility and accuracy promoted it as one of the best available options for energy calculation.

REFERNCES

- ANSI/ASHRAE/IESNA 2010, User's Manual for ANSI/ASHRAE/IESNA Standard 90.1-2010, Energy Standard for Buildings Except Low-Rise Residential Buildings., American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, Georgia.
- E., B., M., L., S., P., B., L., W., W., B., T. & J., W. 2012, '50% Advanced Energy Design Guides', paper presented to the ACEEE Summer Study on Energy Efficiency in Buildings, August 12-17, 2012., Pacific Grove, California, August 12-17, 2012.
- Google, *Google SketchUp*, viewed 24/12 2012, http://www.sketchup.com/intl/en/index.html.
- NREL, National Renewable Energy Laboratory, viewed 24/12 2012, ">http://www.nrel.gov/>.
- Thornton, B.A., Wang, W., Lane, M.D., Rosenberg, M.I. & Liu, B. 2009, Technical Support Document: 50% Energy Savings Design Technology Packages for Medium Office Buildings, PNNL-19004; Other: BT0201000, Pacific Northwest National Laboratory, Richland, WA.
- Thornton, B.A., Wang, W., Lane, M.D., Y., H. & Liu, B. 2010, Technical Support Document: 50% Energy Savings for Small Office Buildings, PNNL-19341, Pacific Northwest National Laboratory, Richland, WA.
- Weaver, E., Long, N., Fleming, K., Schott, M., Benne, K. & Hale, E. 2012, 'Rapid Application Development with OpenStudio', paper presented to the 2012 ACEEE Summer Study on Energy Efficiency in Buildings, Pacific Grove, CA.