Study on Energy Consumptions for The Commercial Buildings Using Energyplus

Mohd Noor Ropiah Bin Abu Bakar, Khairulzan Bin Yahya

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Johor Bahru, 81310, Malaysia

Abstract

This paper presents the results of simulation for commercial building using Energyplus program and ASHREA database. The study is concerned on the factors that can enhance the energy efficiency in the existed building where there are a limited possibility in comparison with the new buildings. The construction of the building has been drawn in Sketch up 8 and the calculation has been made in energyplus however the communication between them has been accomplished using legacy open studio. The ASHREA database used in this paper is related to Kuala Lumpur region where there is no database for Johor in such organization. Three factors has been studied now: increasing of daylight control sensors, increasing the cover shadow of windows, effect of presence of trees infront of the buildings. The results show that there are a significant effects to the total energy used in the building with improving the above factors and therefore the energy efficiency is increased.

Keywords: Energyplus, simulation, Sketch up8, Legacy Open Studio.

1. Introduction

Energy efficiency is explicitly addressed in the Ninth Malaysia Plan. Energy efficiency programs at this plan will focus on energy saving features in the industrial and commercial sectors as well as the domestic sectors. Efficient Management of Electrical Energy Regulations are to be introduced, Uniform Building By-Laws to be amended to incorporate energy efficiency features, and specifications promulgated for accurate and informative electrical appliance labelling to be further enhanced. It has been reported that approximately thirty two percent of total energy consumption in Malaysia has been consumed by commercial sector (Saidur, 2009). In Malaysia, total demand of energy increased from 1,244 Petajoules (PJ) in 2000 to 2,218 PJ in 2010 in which thirteen percent of total demand of energy is contributed by commercial building (EPU, 2006). According to Ninth Malaysia Plan, commercial building has shown gradually increasing from 162 PJ in 2000 to 284.9 PJ in 2010 which almost eight percent per year. Commercial building alone, account for about thirteen percent of total energy consumption and forty eight percent of electricity consumption (Begum and Pereira, 2010).

Energy simulation tools are increasingly used for analysis of energy performance of buildings and the thermal comfort of their occupants. Today, there are many building performance simulation programs with different user interfaces and different simulation engines that are capable of these analyses. Given the significant variety of such simulation tools, it is crucial to understand limitations of the tools and the complexity of such simulations. The reliability of data exchange and straightforward, user-friendly interfaces are major aspects of the practical usage of these tools. Due to the huge amount of data that is to be input and the availability of rich 3D geometry rendering engines, effective data exchange and software interfaces are crucial to enable faster and reliable performance of the simulation tools.

Several building energy estimations have been done using Energyplus. Rejane M. L. et al has developed an Energyplus daylighting module – Detailed in Brazilian conditions. Energyplus results were compared with data measured in situ, of daylit room with windows on two parallel façades (Rejane M.L, 2009). Demir E. has studied many parameters that influence energy simulation outputs of buildings in Energyplus for the project so called “Holistic energy-efficient retrofitting of residential buildings” (HERB), financed by the European Union seventh framework program project (Demir E. 2014). Murat O. et.al has investigated the building heat transfer based on the thermal transmittance of the building fabric in Energyplus. He has determined the effect of temperature
reduction capacity of a phase change materials lining which is applied to a simple building under the weather conditions of Cyprus (Murat O. 2012).

2. Overview on Simulation Toolboxes

We have used three simulation softwares that are integrated together to perform professionally the calculation of energy consumption and estimations.

1- Sketch up8
2- Energy plus
3- Legacy OpenStudio Plug-in

The construction has been made by Sketch up8 and the calculation of the total build energy and thermal loads have been done using Energyplus. The communication between the previous programs has been accomplished using Legacy OpenStudio program.

2.1 Sketch up8

It is a 3D modeling computer program for applications such as architectural, interior design, civil and mechanical engineering, film, and video game design. Sketch up8 is owned by Trimble Navigation, a mapping, surveying, and navigation equipment company. Sketch Up8 was independent from 2000 to 2006 and then owned by Google from 2006 to 2012. The program claims to be easy to use. There is an online open source repository of free-of-charge model assemblies (e.g., windows, doors, automobiles, etc.), 3D Warehouse, to which users may contribute models. The program includes drawing layout functionality, allows surface rendering in variable "styles", supports third-party "plug-in" programs hosted on a site called Extension Warehouse to provide other capabilities (e.g., near photo-realistic rendering), and enables placement of its models within Google Earth.

2.2 Energyplus

It is developed by United States Department of Energy (DOE) which is a whole building energy simulation program that engineers, architects, and researchers use to model energy and water use in buildings. Modeling the performance of a building with Energyplus enables building professionals to optimize the building design to use less energy and water.

Energyplus models heating, cooling, lighting, ventilation, other energy flows, and water use. Energyplus includes many innovative simulation capabilities: time-steps less than an hour, modular systems and plant integrated with heat balance-based zone simulation, multi-zone air flow, thermal comfort, water use, natural ventilation, and photovoltaic systems. The following is a representative list of Energyplus capabilities:

- **Integrated, simultaneous solution** where the building response and the primary and secondary systems are tightly coupled (iteration performed when necessary)
- **Sub-hourly, user-definable time steps** for the interaction between the thermal zones and the environment; variable time steps for interactions between the thermal zones and the HVAC systems (automatically varied to ensure solution stability)
- **ASCII text based weather, input, and output files** that include hourly or sub-hourly environmental conditions, and standard and user definable reports, respectively
- **Heat balance based solution** technique for building thermal loads that allows for simultaneous calculation of radiant and convective effects at both in the interior and exterior surface during each time step
- **Transient heat conduction** through building elements such as walls, roofs, floors, etc. using conduction transfer functions
- **Improved ground heat transfer modeling** through links to three-dimensional finite difference ground models and simplified analytical techniques
• **Combined heat and mass transfer** model that accounts for moisture adsorption/desorption either as a layerby-layer integration into the conduction transfer functions or as an effective moisture penetration depth model (EMPD)

• **Thermal comfort models** based on activity, inside dry bulb, humidity, etc.

• **Anisotropic sky model** for improved calculation of diffuse solar on tilted surfaces

• **Advanced fenestration calculations** including controllable window blinds, electro-chromic glazing, layerby-layer heat balances that allow proper assignment of solar energy absorbed by window panes, and a performance library for numerous commercially available windows

• **Daylighting controls** including interior illuminance calculations, glare simulation and control, luminaire controls, and the effect of reduced artificial lighting on heating and cooling

• **Atmospheric pollution calculations** that predict CO2, SOx, NOx, CO, particulate matter, and hydrocarbon production for both on site and remote energy conversion

2.3 *Legacy OpenStudio Plug-in*

The *Legacy OpenStudio* Plug-in allows you to use the standard Sketch up8 tools to create and edit *Energyplus* zones and surfaces. You can explore your *Energyplus* input files by using all of the native Sketch up8 3D capabilities to view the geometry from any vantage point, apply different rendering styles, and perform shadowing studies. The plug-in allows you to mix *Energyplus* simulation content with decorative content such as background images, landscaping, people, and architectural finish details—all within the same Sketch up8 model. Highlights of *Legacy OpenStudio* Plug-in include the ability to:

• Create and edit *Energyplus* zones and surfaces

• Launch *Energyplus* and view the results without leaving Sketch up8

• Match inter zone surface boundary conditions

• Search for surfaces and sub surfaces by object name

• Add internal gains and simple outdoor air for load calculations

• Add the ideal HVAC system for load calculations.

• Set and change default constructions.

• Add daylighting controls and illuminance map.

• Get help from tutorials and documentation.

3. Simulation Setup and Results

We have used the ASHREA database of Kuala Lumpur since there are no available tables for Johor Bauru with such organization. We have performed the simulation on a commercial building that has approximately the same area of Angsana building which is 4 floors with 240m at length, 110m at width and 8m at height for each floor. We didn’t consider the details inside the building and maybe we can do it later. We have considered all interior boundary condition as surfaces without sun or wind exposed. We have settled the zones load in the whole program as shown in Fig. 2
3.1 Building Simulation Results and Discussion

- Daylighting calculations

Daylighting calculation is performed each time step that the sun is up for each zone that has one or two daylighting reference points specified. The exterior horizontal illuminance from the sun and sky is determined from solar irradiance data from the weather file. The interior illuminance at each reference point is found for each window by interpolating the daylight illuminance factors for the current sun position, then, for sky-related interior
illuminance, multiplying by the exterior horizontal illuminance from the appropriate sky types that time step, and, for sun-related interior illuminance, multiplying by the exterior horizontal solar illuminance that time step.

Two calculation has been accomplished: Day lighting reference point glare index as in Fig. 3 and Daylighting reference point illuminance as in Fig. 4. The glare index around reference point as in Fig. 3 are looked approximately similar in the whole months with value equal to 25 however there is an impact change in the value of luminance as in Fig.4 where it has the highest value equals to 3500 lux at Jan-Feb, 2500 lux at Mar-April, 1600 lux at May-Jun, 1500 lux at July-August, 2500 lux at Sep.-Oct. and 3000 lux at Nov.-Dec.

- **Heat balance method**

Energy Plus follows the “ASHRAE heat balance method” principles for heating and cooling load calculations. This method is based on balancing all energy flows into a thermal zone. This involves solving a set of equations, which are energy balance equations with two methods: Surface inside Face Temperature as in Fig. 5 and Surface outside Face Temperature as in Fig. 6. The inside surfaces have approximately the same values max =34 $^\circ$C, Min = 24 $^\circ$C and mean value = 26$^\circ$C. The same is happened with outside surface where max = 60 $^\circ$C, Min = 19 $^\circ$C and mean value=26$^\circ$C.

![Fig.3 Day lighting reference point glare index](image)
Fig. 4 Daylighting reference point luminance

• **Zone Ideal Loads Supply Air Sensible Cooling Rate**

It represents the sensible heating energy in Watt that is actually supplied by the system to that zone for the *timestep* reported which actually equal to the sensible heating rate multiplied by the simulation *time-step*. As shown in Fig. 7, it has the same values around 120kw for Jan-Feb, March-April, May-June and July-August, however it has a value equal to 100kw for Sep-Oct. and Nov- Dec.

• **Zone Ideal loads Supply Air total Cooling Rate**

*It can be defined as* the total (sensible plus latent) cooling energy required to cool the supplied air to the zone exhaust air temperature and humidity ratio. It has approximately the same values in the whole months as it is shown in Fig. 8 with max value equal to 200KW and Min value equal to 1kw.

• **Zone mean radiant temperature**

The Mean Radiant Temperature (MRT) in degrees Celsius of a space is a measure of the combined effects of temperatures of surfaces within that space. Specifically it is the surface area multiplied by emissivity weighted average of the zone inside surface temperatures where emissivity is the Thermal Absorbance of the inside material layer of each surface. The range of radiant temperature as shown in Fig. 9 is located between 30c⁰ and 24.5 c⁰.
Fig. 5: Surface inside Face Temperature

Fig. 6: Surface outside Face Temperature

Fig. 7: Zone Ideal Loads Supply Air Sensible Cooling Rate

Fig. 8: Zone Ideal loads Supply Air total Cooling Rate
3.2 The effects of some Factors on the Total Energy Consumption

Three factors have been studied: increasing of daylight control sensors, increasing the cover shadow of windows, effect of presence of trees in front of the buildings. The building with windows shadow and trees shadow are illustrated in Fig. 10 and 11. The Annual Building Utility Performance Summary report as in tables 1, 2 and 3 indicates that there is a significant difference between energy needed without shadow and with windows shadow however the decreasing in the energy needed that earned in the case trees shadow is small. We will review here only 1416 hours, January-February period and for the others months it looks similar.
Table 1: Site and source energy for January-February (1416 hours) without shadow

|                      | Total Energy [GJ] | Energy Per Total Building Area [MJ/m²] | Energy Per Conditioned Building Area [MJ/m²] |
|----------------------|-------------------|----------------------------------------|--------------------------------------------|
| Total Site Energy    | 18784.54          | 183.17                                  | 183.17                                     |
| Net Site Energy      | 18784.54          | 183.17                                  | 183.17                                     |
| Total Source Energy  | 28932.21          | 282.12                                  | 282.12                                     |
| Net Source Energy    | 28932.21          | 282.12                                  | 282.12                                     |

Table 2: Site and source energy for January-February (1416 hours) with windows shadow

|                      | Total Energy [GJ] | Energy Per Total Building Area [MJ/m²] | Energy Per Conditioned Building Area [MJ/m²] |
|----------------------|-------------------|----------------------------------------|--------------------------------------------|
| Total Site Energy    | 17645.32          | 174.62                                  | 174.62                                     |
| Net Site Energy      | 17645.32          | 174.62                                  | 174.62                                     |
| Total Source Energy  | 26868.51          | 273.78                                  | 273.78                                     |
| Net Source Energy    | 26868.51          | 273.78                                  | 273.78                                     |

Table 3: Site and source energy for January-February (1416 hours) with trees shadow

|                      | Total Energy [GJ] | Energy Per Total Building Area [MJ/m²] | Energy Per Conditioned Building Area [MJ/m²] |
|----------------------|-------------------|----------------------------------------|--------------------------------------------|
| Total Site Energy    | 18365.38          | 179.69                                  | 179.69                                     |
4. Conclusions

A simulation study for commercial building has been performed in this paper using Energyplus, Legacy OpenStudio and Sketch up8. The ASHREA database of Kuala Lumpur has been used with the energy calculations and estimations. The study has been accomplished with several conditions, which have been compared with each other. The results show that we can increase the energy efficiency for the existed building using some factors. Future work is to develop a cost analysis system for the energy calculation coming from simulation. Enhancing the simulation with many other factors will also be another task for the future work.

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