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A Case Study of an Office Building to Identify Energy Consumption and Carbon Management Solutions Using Physical Data and Simulation Software.

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Abstract. To measure the level of energy performance of a building, there are several categories of energy consumption to be calculated such as oil, natural gas and electricity. In order to significantly minimise the Greenhouse gas emission in an office, it is important to tap into the positive progress of energy efficiency of equipment which contributes to total energy performance of a building. Consequently, to enable accurate building energy consumption of a building, energy modelling method is applied to identify total consumption and cost of energy usage with effects of carbon emission. Hence, this will help to reduce the costing of energy inside building with differences of efficiency options. Therefore, this paper aims to analyse an office building in terms of the level of energy consumption and carbon emission as a case study. The first objective is to identify the amount of energy consumption and carbon emission inside the building using the simulation software. Secondly, to identify the differences between the data recorded through simulation software and physical data. Finally, to identify solutions to decrease the carbon emission by applying measures towards reducing energy consumption inside the building.

Keywords: Energy Performance, Simulation Software, Carbon Emission

1. Introduction

Building energy consumption referring to total energy usage by consumers inside buildings that contains the energy-use of space heating and cooling, lighting, water heating, refrigeration, wet cleaning, cooking, and electronics [1]. It is recorded that construction sector contributed global final energy use at 36% and energy-related CO2 emissions at 39% [2]. Besides that, 30 to 40 percent of total energy consumption were from building operations and 70 percent was by electricity consumption [3]. As building energy consumption tend to increase in future, energy modelling can be used to predict and reduce building energy consumption especially for office building. Office buildings are constructed fast in in both developed and developing countries as part of sustainable development [4; 5; 6] and to boost the economy of a country [7]. Therefore, energy modelling analysis need to be used to calculate and monitor energy and carbon emission inside building based on several efficiency options for reduction in energy costing. Energy modelling which uses building simulation tool is commonly used during the concept to initial stage of a construction project. [8]. Based on this research study, the first objective is to identify the amount of energy consumption and carbon emission inside the building using the simulation software. Identification of carbon emission inside the building is achievable based on amount of energy consumption. Secondly, to identify the differences between the data recorded through simulation software and physical data. Finally, to identify solutions to decrease the carbon emission by applying measures towards reducing energy consumption inside the building.

2. Materials and methods

An office building in Kelana Jaya with 2694.19 square meter was used as case study for this research study. Initially, building energy simulation software (IESVE) will be used to developed simulation model; base model to identify the amount of energy consumption and carbon emission inside the building. Then, the base model will be calibrated using the metered data. Metered data referring to electricity bills which was collected from January to December 2019. Thereafter, the amount of energy consumption inside the building was calculated in kilowatt per hour (kwh) and later converted to carbon emission in tonne carbon dioxide (tonne CO_2) by the simulation software based on ASHRAE carbon conversion factor. The formula is as follows:-

$$CO_2e = \frac{\sum_{f=1}^{n} F_f \times E_f \times C}{\mathrm{NG}}$$

Where

CO_2 = Carbon dioxide equivalent emissions, Ib/MW
F_f = Quantity of carbon emitting fuel at the power plant for the f^{th} energy form
E_f = Total emission rate for the f^{th} energy form, kWh/kWh
C = Conversion factor to change quads to MWh
NG = Net generation; f = index for the energy form
n = number of energy forms used to make electricity [9]

Finally, measures towards reducing energy consumption will be identified inside the building are identified to reduce the amount of energy consumption.

3. Results and Discussion

Based on the first objective, the amount of energy consumption (including solar energy) inside the building was identified using the simulation software. The findings are as stated in table 1.

Table 1. The Total Amount of Energy Consumption

Month and Days (Year 2019)	Amount of Electricity (MWh)
January 01-31	12.8008
February 01-28	11.2482
March 01-31	12.0178
April 01-30	12.7128
May 01-31	12.5941
June 01-30	12.1599
July 01-31	13.0386
August 01-31	11.8231
September 01-30	12.4821
October 01-31	12.7682
November 01-30	11.1114
December 01-31	12.5545
Summed Total	147.3114

The findings based on Table 1 shows the total amount of energy consumption from January to December 2019 using a simulation software. The total amount of energy consumption is calculated based on 10 energy breakdown which are,

i) Interior lighting
ii) Receptacle Equipment
iii) Refrigeration
iv) Other Process
v) Space Cooling
vi) Heat Rejection
vii) Interior Central Fans
viii) Interior Local Fans
ix) Pumps
x) Generated Electricity

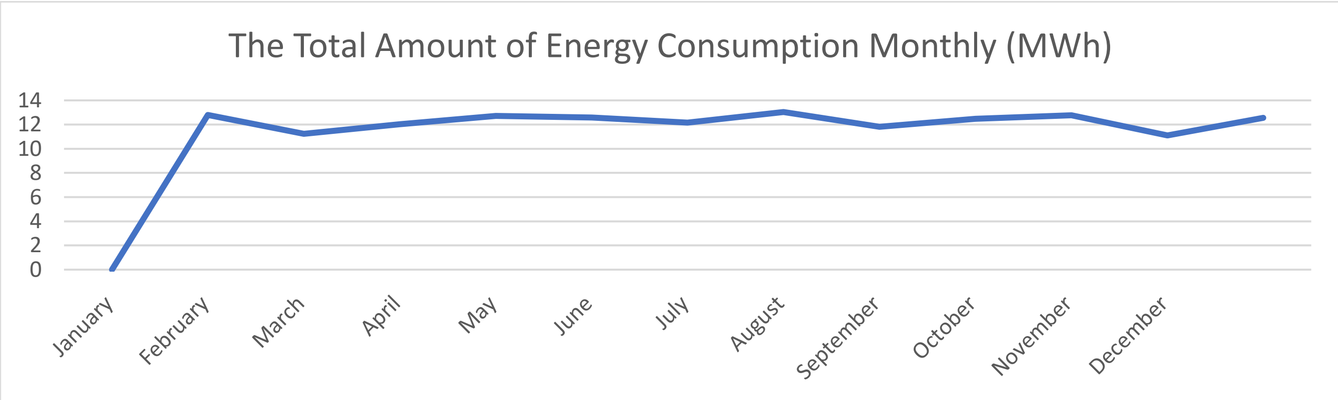

Figure. 1. The Total Amount of Energy Consumption Monthly

Table 2. The Total Amount of Grid Displaced Electricity

Month and Days (Year 2019)	Amount of Energy (MWh)
January 01-31	2.2132
February 01-28	2.1419
March 01-31	2.4727
April 01-30	2.3104
May 01-31	2.2142
June 01-30	2.1657
July 01-31	2.2464
August 01-31	2.3203
September 01-30	2.2763
October 01-31	2.2574
November 01-30	2.0979
December 01-31	2.0745
Summed Total	26.7909

The findings based on Table 2 shows the total amount of energy generated from January to December 2019 using a simulation software. The month of March recorded the highest amount of energy usage at 2.4727 MWh while the lowest amount of energy usage in December at 2.0745 MWh. The summed total of energy recorded at 26.7909 MWh yearly.

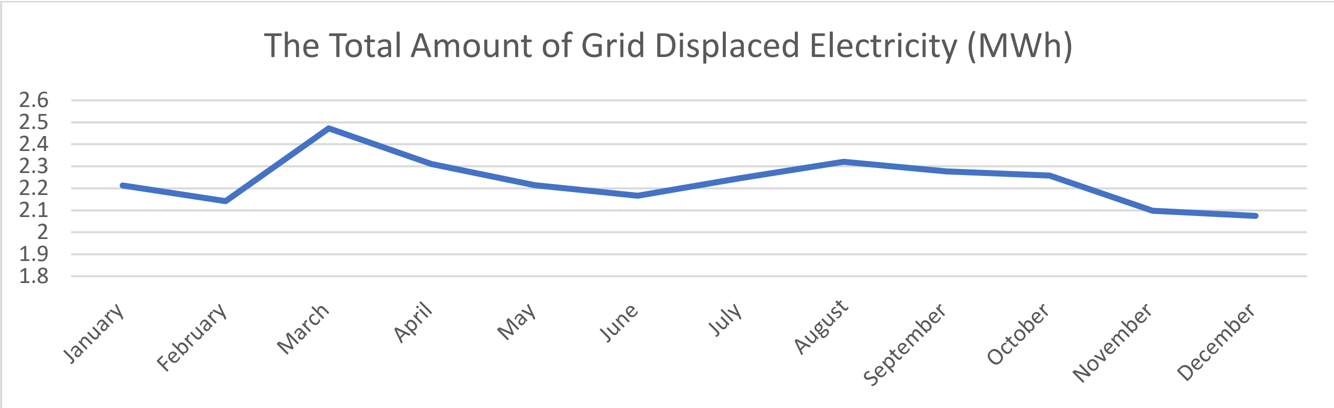

Figure.2. The Total Amount of Grid Displaced Electricity Monthly

Table 3. Total Amount of Carbon Emission from Usage of Energy Consumption

Month and Days (Year 2019)	Total Carbon (KgCO_2)
January 01-31	5495
February 01-28	4726
March 01-31	4954
April 01-30	5399
May 01-31	5387
June 01-30	5187
July 01-31	5601
August 01-31	4932
September 01-30	5297
October 01-31	5455
November 01-30	4678
December 01-31	5439
Summed Total	62551

The findings based on Table 3 shows the total amount of carbon emission from usage of energy consumption inside the building. The month of July recorded the highest amount of carbon emission at 5601 kgCO_2 while November the lowest at 4678 kgCO_2. The summed total of carbon emission recorded at 62,551 kgCO_2 yearly.

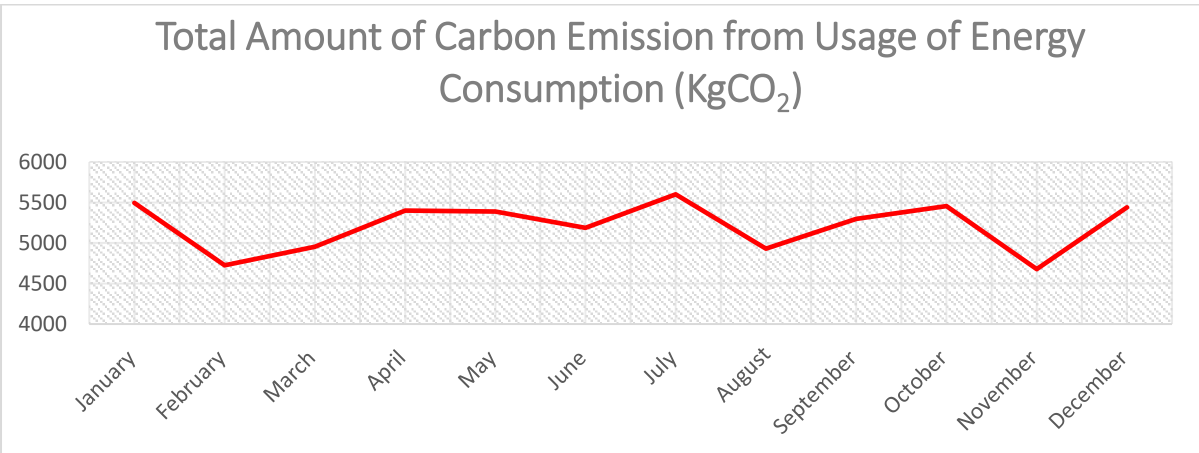

Figure.3. Total Amount of Carbon Emission from Usage of Energy Consumption Monthly

Table 4. Total Amount of Carbon Emission from Grid Displaced Electricity

Month and Days (Year 2019)	Total Carbon ($KgCO_2$)
January 01-31	1149
February 01-28	1112
March 01-31	1283
April 01-30	1199
May 01-31	1149
June 01-30	1124
July 01-31	1166
August 01-31	1204
September 01-30	1181
October 01-31	1172
November 01-30	1089
December 01-31	1077
Summed Total	13904

The findings based on Table 4 shows the total amount of carbon emission from usage of grid displaced electricity inside the building. The month of March recorded the highest amount of carbon emission at 1283 $kgCO_2$ while December the lowest at 1077 $kgCO_2$. The summed total of carbon emission recorded at 13,904 $kgC0_2$ yearly.

Based on Table 1, the total amount of energy usage was recorded at 147.3114 MWh including the amount of grid displaced electricity at 26.7909. Thereafter, using the metered or physical data (electricity bills), the amount of energy consumption was recorded at 141.1109 MWh where with differences of 4.39% when compared with simulate energy data. This is considered as acceptable as simulation works not considering the real scenario of energy usage inside the building. Therefore, considered fulfilled the second objective.

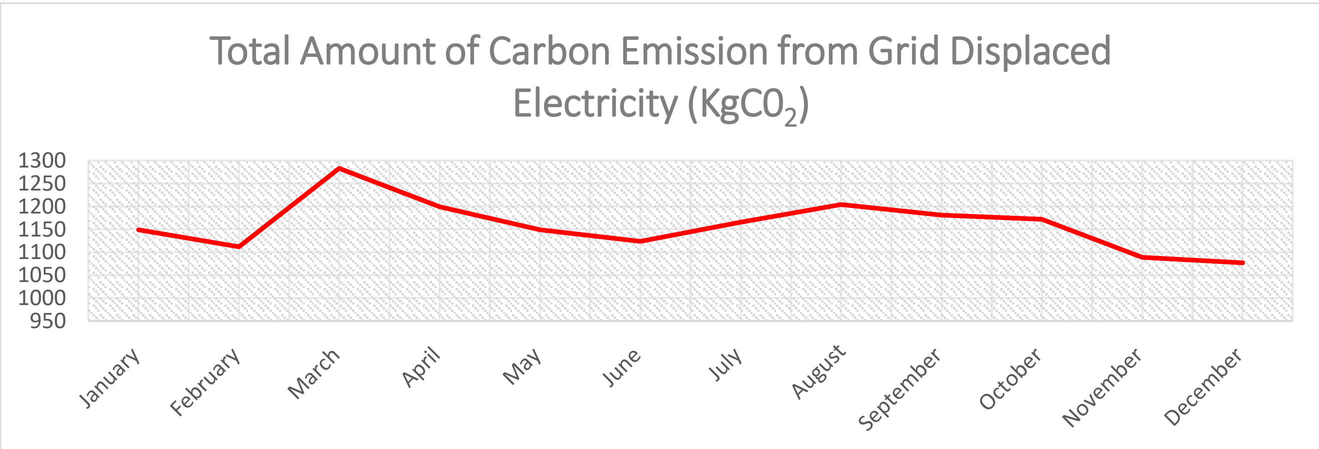

Figure. 4. The Amount of Carbon Emission from Grid Displaced Electricity Monthly

Several measures or solution are identified to reduce the amount of carbon emission inside the office building by reducing energy consumption inside the building. For this research study three measures or solutions are identified to reduce energy consumption inside the building. The first solution is based on lighting system inside the office building. The lighting power density inside the building is between 8-10 w/m^2 which is as required in MS1525:2019 at 14 W/m^2 [10] and by GreenRE at 25 W/m^2 [11] for a baseline model. Although the lighting power density is lower compared to MS1525:2019 and GreenRE requirement, further improvement in lightings can be carried to reduce the overall energy consumption as lighting systems account for approximately 50–70% of the total electricity consumption in commercial buildings [12]. The lighting power density can be reduced by using high efficiency lighting with less than 5 W/m² lighting power density. This high efficiency lighting can be chosen based on several criteria such as types of solution, level of performance, pricing lifespan and warranty.

Secondly, smart lighting with integration of sensors can be used for controlling air conditioning and mechanical ventilation. Lighting that is part of internet of things (IOT) can be integrated with infrared sensors so that it can sense the present of people inside a room and adjust the flowrate or the temperature accordingly. Infrared sensors referring to device which control the movement of electrons that assess and capture the infrared radiation in its surrounding location. A BAS (Building Automation System) can be installed where usage of sensors for data collection on the building's appearance and uses actuators to identify physical movement. A BAS system is capable to store data such as temperature, power, flow rate and pressure, control signals, and states of equipment in its database [13].

Lastly, not only the rooftop can be equipped with PV panel. The glazing can also be part of the renewable energy generation by using building integrated photovoltaic panels. This will in turn increase the renewable energy generation with less space required. Basically, there are two types of photovoltaic modules used in the construction field, BAPV (building applied photovoltaic) and BIPV (building integrated photovoltaic) [14]. Basically, BAPV is located on the building roof [15] while BIPV is accommodated as a part of the building envelope, which provides additional functions such as insulation, weather barrier, or sun shading besides electricity generation [16]. Therefore, the concentrator-PV type glazing technology through BIPV is an important element that smartly adopts the optical concentrators to maximise the usage of solar energy for renewable electricity generation and provide daylighting parallelly [17].

4. Conclusion

Data were gathered in order to obtain the amount of energy consumption and carbon emission inside the commercial building. It is clearly drawn that the total amount of energy consumption at 147.3114 MWh was recorded using simulation compared to 141.1109 MWh using the metered or physical data (electricity bills). This is equivalent to total of carbon emission recorded at 62,551 $kgCO_2$ yearly. Thus, it can be interpreted that the amount of energy usage and emission of carbon inside the building were able to be identified using the simulation software. The differences between physical and simulation data are mere 4.39% as not fully applying energy consumption inside building. Based on the amount of energy and carbon emission recorded through the simulation, a new proposed model can be developed using the several suggestions given. Firstly, by reducing the lighting power density by using a high efficiency lighting with less than 5 W/m² lighting power density. Secondly, by installation of smart lighting with integration of sensors for controlling air conditioning and mechanical ventilation. Finally, applying glazing as part of the renewable energy generation by using building integrated photovoltaic panels. Therefore, this research study recommends improving the findings in future by developing a new proposed model for energy consumption by applying the suggested measures.

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