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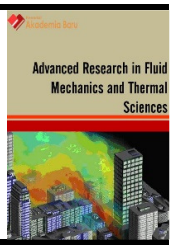

Building Energy Performance: A Case Study at G2 Building UTHM

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ABSTRACT

Improper energy consumption has become a concern among the building owners. To ensure proper energy consumption of the building, it has become a practice to conduct building energy performance study. The study allows the building owner to confirm possible ineffective energy utilization of the building. This paper presents a quantitative analysis of a building performance for G2 Building in Universiti Tun Hussein Onn Malaysia (UTHM) for a duration from August 2016 until March 2017. The study is based on collected electricity consumption data for the interval of 30 minutes every day throughout the study period. Building Energy Index (BEI) and Energy Intensity Index (EII) were used as building performance tools. The calculated BEI is 254.24 kWh/m^2/year which is far beyond a minimum of 150 kWh/m^2/year for non-residential building in order to achieve a point by Green Building Index (GBI) of Malaysia. Meanwhile, the results on EII shows that a monthly amount of electricity energy was inconsistently consumed throughout a semester break and lecture period at a G2 Building. The present study attempts to address the building energy performance in G2 Building, hence to build up awareness on energy saving among building users.

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1. Introduction

Theories on energy efficient building do depend on three main factors; building design, services design and occupant behaviour [1-3]. To determine if a building is energy efficient, building energy performance is commonly investigated. The characteristics of building performance varies based on its type and significantly affected by the significant energy user such as heating and cooling systems, lightings and office equipment [4,5]. Determining building energy performance often help researchers or building owner to properly outline the benchmark level for energy consumption [6-8]. It is also very useful in helping researchers to propose on potential energy saving strategies thus improving the building energy performance. Poor building energy performance always relates to high intensity of activities and occupancy rate [9-10].

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Several numbers of energy performance tools are available to assess building energy performance [11-13]. In the present study, Building Energy Index (BEI) and Energy Intensity Index (EII) are used to indicate the level of G2 Building energy performance. BEI represents the energy consume by each floor area throughout the year. Higher BEI represent high energy consumption and vice versa. On the other hand, (EII) is used to monitor the effectiveness of monthly energy consumption based on modelled energy consumption. Unity value of EII represents proper consumption of electricity while higher than unity EII represents over usage of energy and lower than unity EII represents low usage of energy.

The present paper aimed to investigate the building energy performance of G2 building UTHM. The findings of the study are very useful for the building owner to acknowledge the present energy performance of the building and to put in place proper strategies to improve building energy performance in the future.

2. Methodology

Figure 1 shows the overview of the methodology involves in the present study. The activities start with data collection on building information and energy consumption. Data required on building information includes building location, building orientation, building plan layout, major energy consumer information. Data collection of energy usage involves activities recording the energy consumption of the building before being utilized in the later stages of the study involving building energy index analysis and energy intensity index analysis.

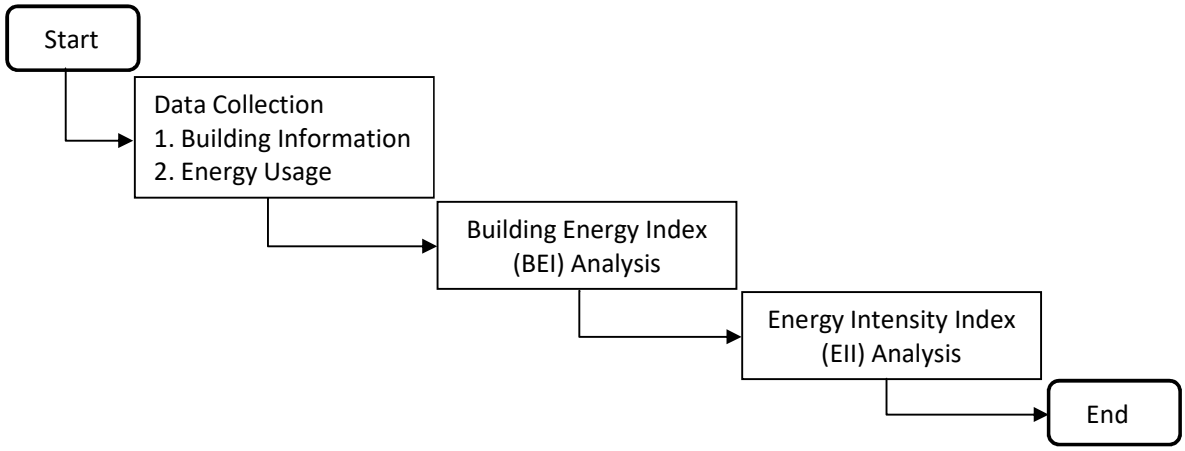

Fig. 1. Methodology of the present study

2.1 Data Collection

Figure 2 shows the location of G2 Building UTHM which is located at Universiti Tun Hussein Onn Malaysia in Parit Raja, Johor, Malaysia. The building GPS coordinate is 1° 51' 37.2744'' N, 103° 5' 17.88'' E.

G2 Building UTHM is the main building for Faculty of Mechanical and Manufacturing Engineering which integrates offices, classrooms, laboratories and general areas. The building consists 4 (four) wings with 2 (two) floors each and 4 (four) ground floor sub wings. It was commissioned in the year 2005 with gross floor area (GFA) excluded carpark of 9051.61 m2. In terms of energy source, the building consumed is fully powered by electricity during its operational. The building also equipped with centralized air-conditioning system.

Fig. 2. Location of G2 Building in Universiti Tun Hussein Onn Malaysia (UTHM)

Two sub-meterings have been installed in G2 Building. One for chiller consumption and another one for a total electricity consumption located at Main Switch Board (MSB). The sub-meterings are equiped with iSCADA Data Center system, which allow the electricity consumption to be recorded for the interval 30 minutes every day during the study period (August 2017 to March 2017). In addition to that, the recorded energy consumption also being segregated into peak and off-peak electricity consumption to monitor the electricity utilization within these two periods.

2.2 BEI Analysis

BEI represents the energy consume by each floor area throughout the year. The BEI for G2 Building UTHM was calculated based on the measured energy consumption and gross floor area of G2 Building UTHM before being compared with recommended BEI made available by Green Building Index (GBI) [11]. The recommended BEI value by GBI is 150 kWh/floor area/year. Equation (1) [14] shows the formulation for BEI which required total electricity consumption of the building for the period of 12 (twelve) months. However, due to inavalaibility of whole year data, the present study takes an average of six months (October 2016 until March 2017) and multiply by 12 (twelve) to obtain annual energy consumption. Such approach is reasonable due to the cyclic pattern of G2 Building UTHM energy consumption.

$$BEI = \frac{Total\ G2\ Electricity\ Consumption\ in\ a\ Year\ (kWh)}{Gross\ Floor\ Area\ (m^2)} \quad (1)$$

2.3 EII Analysis

EII is the most common tools used to investigate energy efficiency of a building [15-16]. Due to the nature of building's electricity consumption which involves ussually more than one independent variable, it is necessary to first determine the considered independent variables. In the present study, two independent variables have been considered; number of lecture hours and coling degree days (CDD). Both of these variables are correlated with building's electricity consumption to determine the expected energy consumption of G2 Building UTHM. Information on number of lecture hours has been extracted from the lectures timetable which can be access at UTHM Academic Management Office website.

Another independent variable which is cooling degree day is a measure of daily average temperature different in comparison with the base temperature which is set to be at 24 °C. The daily average temperatures were obtained from Malaysia Metrology Department (MetMalaysia) are used in determining degree Celsius CDD. Booth of these variables are correlated to the electricity consumption using multiple-regression analysis. The analysis provides an equation which will be used to determine predicted baseline electricity consumption for G2 Building UTHM. The results of predicted baseline electricity consumption are compared to the actual electricity consumption to determine the EII by using the formula as below.

$$\text{EII} = \frac{\text{Actual Electricity Consumption (kWh)}}{\text{Predicted Baseline Electricity Consumption (kWh)}} \quad (2)$$

3. Results and Discussion

3.1 Overall Consumption

Figure 3 shows the monthly electricity consumption of G2 Building UTHM from August 2016 until March 2017. The bars represent the portion of electricity consume by the chillers and others noted in terms of percentage. The variation throughout 8 months exhibits the cyclical pattern where the overall electricity consumption towards semester break (August 2016, January 2017 and February 2017) is descending and is ascending towards the lecture period (September 2016, October 2016, November 2016, December and March 2017). The maximum consumption has been recorded in the month of March 2017 (214,031.08 kWh) while the lowest consumption has been recorded in the month of February 2017 (167, 312.73 kWh). In terms of distribution between chillers and other energy consumption, consistent pattern has been recorded throughout the 8 (eight) months. In average, 25.27 % of the electricity has been consumed by the chillers and 74.73 % by the other. Other inclusive of lighting, power socket, compressed air system etc.

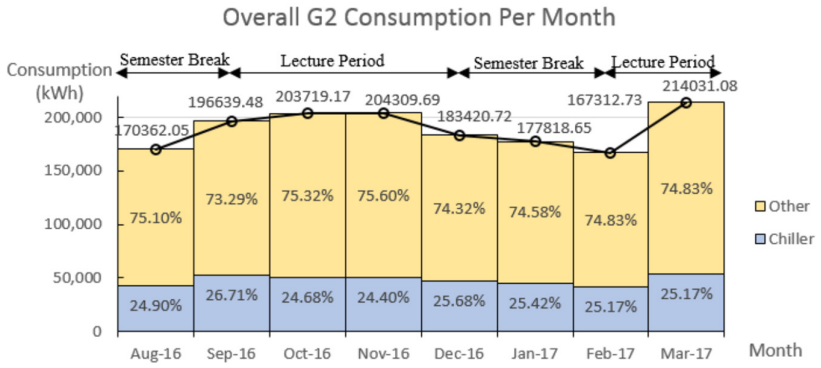

Fig. 3. Overall electricity consumption in G2 Building UTHM over the period from August 2016 until March 2017

3.2 Peak vs Off-Peak Consumption

Figure 4 shows the comparison between the electricity consumption during peak and off-peak hour in G2 Building UTHM. The average peak hour electricity consumption is 152,342.34 kWh and average off-peak hour electricity consumption is 223,52.60 kWh. The highest electricity consumption during peak hour is in the month of March 2017 (179,564.27 kWh) equivalent to 89.93 % of overall

monthly consumption and lowest during February 2017 (137330.34 kWh) equivalent to 90.24 % of the overall monthly consumption. On the different note, the highest electricity consumption during off-peak hour is during September 2016 (38,794.62 kWh) equivalent to 21.78 % of overall monthly consumption and lowest during February 2017 (14,845.89 kWh) equivalent to 9.76 % of overall monthly consumption.

Generally, the consumption during the peak hour and off-peak hour recorded consistent distribution between 88 to 91 % and 9 to 12% respectively except for the month September 2016. Further inquiry on the exceptional pattern of electricity consumption in September 2016 reveals the unusual operational hour of the chillers system due to maintenance activities during off-peak hour.

Figure 4 also indicates the average peak consumption with all month during the lecture period recorded higher consumption. Vice versa, all month during the semester break period recorded lower consumption in comparison with the average value. In terms of consumption in off-peak hour, only consumption in September 2016 exceed the average off-peak hour consumption. The patterns conclude that the off-peak consumption is not influence by the lecture or semester break period whereby the peak consumption is significantly influence by the factor.

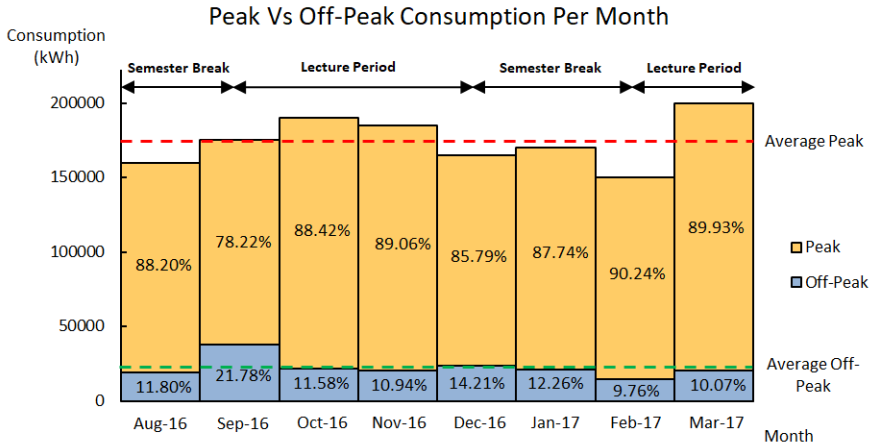

Fig. 4. Peak versus off-peak electricity consumption in G2 Building UTHM

3.3 Building Energy Index (BEI) of G2 Building

BEI is evaluated to determine building performance of G2 Building UTHM. The availability of actual data on the overall electricity consumption from iSCADA Data Centre helps to calculate an actual BEI. Table I shows the amount of electricity consumption monthly, average of six months electricity consumption and gross floor area (GFA) excluded carpark area. The total energy consumption of G2 Building UTHM can be expressed as below.

$$\text{Total G2 Energy Consumption} = 191768.67 \text{ x } 12 = 2301224.06 \text{ kWh} \quad (3)$$

Based on the determine Gross Floor Area in Table 1, the BEI of G2 Building UTHM is 254.23 kWh/m2/year. The recorded BEI value of G2 Building UTHM is significantly higher than recommended BEI value from Green Building Index (GBI) for Non-Residential Building at maximum of 150 kWh/m2/year6. The discrepancy between the values indicates large room of improvement in terms energy saving measures and energy efficiency that can be carried out at G2 Building UTHM. However, due to the nature of activities of the building describe in earlier in the writing which also involves

laboratory activities, the 150 kWh/m2/year value might be impractical since it has been specifically designated for offices.

Table 1
Amount of electricity consumption from October 2016 until March 2017 and GFA of the G2 Building

Month	Overall Consumption (kWh)	Average 6 Months Consumption (kWh)	Gross Floor Area (m^2)
Oct-16	203,719.17	191,768.67	9,051.61
Nov-16	204,309.69		
Dec-16	183,420,72		
Jan-17	177,818.65		
Feb-17	167,312.73		
Mar-17	214,031.08		

3.4 Multi Regression

To established predicted baseline electricity consumption which used in determining EII, a multi regression analysis has been carried out. Two independent variables have been determined to associate with the overall electricity consumption in G2 Building UTHM which are lecture hours and Cooling Degree Days (CDD) respectively. Table 2 tabulates the lecture hours and cooling degree day in degree Celsius from August 2016 to March 2017.

Table 2 obviously indicates higher lecture hours during lecture period and vice versa during semester break. Highest lecture hours have been recorded in the month of November 2016 (3697 hours) while lowest lecture hours have been recorded in the month of January 2017 (235 hours). CDD values in the other hand shows fluctuated value throughout the considered months. The variation represents the tropical rainforest climate of Malaysia. Highest CDD has been recorded in the month of November 2016 (411.00 CDD) and highest in the month of August 2016 (651 CDD).

Table 3 shows the summary output from multi regression analysis between electricity consumption and two independent variables; lecture hours and CDD. The R-squared value of the analysis is recorded to be at 0.73 indicates strong relationship between lecture hours and CDD toward electricity consumption. The summary output also indicates very high confidence level at 94% represented by the Significance F value at 0.0375 as shown in Table 4. The predicted baseline electricity consumption can be obtained from the given multi regression equation expressed below.

$$\text{Predicted Baseline Electricity Consumption (kWh)} = 133868.6 + (12.92\text{x Lecture Hours}) + (94.77\text{ x CDD}) \quad (4)$$

Table 2
Number of lecture hours and CDD distribution

Month	Lecture Hours	CDD
Aug-16	733	651
Sep-16	2,913	522
Oct-16	2,913	539.4
Nov-16	3,697	441
Dec-16	2,129	455.7
Jan-17	235	511.5
Feb-17	1,707	487.2
Mar-17	3,187	567.3

Table 3
Summary output of the multi regression based on the lecture hours and CDD as the independent variables

Regression Statistic	
Multiple R	0.854970181
R Square	0.73097401
Adjusted R Square	0.623363614
Standard Error	10644.59014
Observation	8

Table 4
Confidence level b the Significance F value

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	133868.6293	37398.30963	3.579537	0.015883	37733.2139	230004.0447
Number of class hours	12.92228976	3.543783834	3.646467	0.014803	3.812703407	22.03187611
Deg. Celsius CDD	94.77485896	116.1869237	0.81571	0.451759	-203.893136	393.4428546

3.5 Energy Intensity Index (EII)

EII is another approach in monitoring the building performance hence to further investigate the energy saving. EII is obtained from the ratio between actual electricity consumption and predicted baseline of electricity consumption as prescribed in Equation (2). Table 5 shows the values of actual electricity consumption, predicted baseline electricity consumption (Equation (4)), and Energy Intensity Index (EII). The distributions of EII are also presented in terms of graph as shown in Figure 5. From the monitoring of EII accordingly, three months exceed the predicted baseline value, four months lower than predicted baseline value and only one month satisfied the predicted baseline value. January 2017 is the highest month that passed the predicted baseline with +0.09 and February is the lowest month to exceed the predicted baseline with -0.08. The values of EII suggest high electricity consumption during January 2017 although low number of lecture period and average CDD. On the other note, EII also suggest that electricity has been consumed most effectively during February 2017 to not exceed the predicted baseline consumption.

Table 5
The values of overall actual and predicted baseline of electricity consumption as well as the EII

Month	Actual Electricity Consumption (kWh)	Predicted Baseline of Electricity Consumption (kWh)	EII
Aug-16	170362.05	178131.14	0.96
Sep-16	196639.48	198985.47	0.99
Oct-16	203719.17	199901.58	1.02
Nov-16	204309.69	204852.92	1.00
Dec-16	183420.72	185362.67	0.99
Jan-17	177818.65	163838.74	1.09
Feb-17	167312.73	181576.57	0.92
Mar-17	214031.08	204913.02	1.04

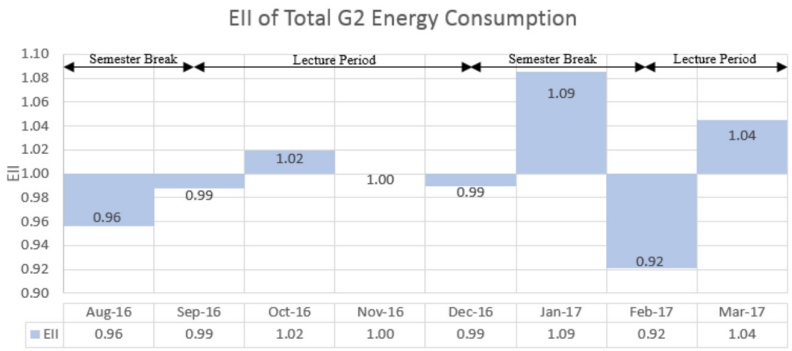

Fig. 5. EII of overall G2 electricity consumption for a duration of eight months. Only one month satisfied the predicted baseline of electricity consumption which is November 2016

4. Conclusion

The present study focuses on evaluating building energy performance of G2 Building UTHM. From the study, several conclusions can be made.

a) The semester break and lecture period indicating clear cyclic pattern of electricity energy consumption of the building with higher consumption during the lecture period and vice versa.

b) In average the chillers system of the building consumes 25.27 % of the total electricity while the balance of 74.73% is consumes by other inclusive of lighting, power socket, air compressor system etc.

c) The off-peak consumption is not influence by the semester break or lecture period while the peak hour consumption is significantly affected.

d) The BEI value which is at 254.23 kWh/m2/year is significantly higher than 150 kWh/m2/year which is recommended by GBI for Non-Residential Building indicates large room of improvement in terms of energy saving measures and energy efficiency.

e) Number of lecture hours and CDD provides strong correlation electricity consumption of the building.

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