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Energy Audit of Building System by using Smart kWh Calculator and Building Simulation

Muhammad Akram Masoud[1], Nor Azuana Ramli[2], Shariah A[3]
[1,2,3]WahidUniversiti Kuala Lumpur British Malaysian Institute, Gombak, Selangor, Malaysia.
akram.masoud93@gmail.com[1], norazuana@unikl.edu.my[2], shariah@unikl.edu.my[3]

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Abstract

Energy audit is important in order to know the energy consumption in the building, hence, the energy consumption can be reduced without affecting the comfort and operation of the building. This paper presents an energy audit in Electrical Engineering Section at Universiti Kuala Lumpur British Malaysian Institute by using smart kWh calculator and building simulation software. The main objective of this study is to conduct energy audit in the case study area. Energy audit model is obtained through a walkthrough survey of the equipment such as electrical appliance, air conditioning, mechanical and ventilation (ACMV) and lighting. The survey identified energy consumption pattern in the case study area. Then, the calibration was carried out by using Sefaira and the results showed that the most of energy consumption comes from the cooling system which is 50% from the total energy. For energy audit, the total of energy used in the case study area is 426.39 kWh. To obtain the cost of the operation, smart kWh calculator is used and the cost is RM 155.63 per day. Finally, Energy Efficiency Measures Strategy are proposed to reduce the cost of energy consumption. By using energy efficient lighting, the total annual energy saving is 47.52 kWh and the return of investment is 7.8 months.

Keywords; *energy audit, building simulation, energy management, energy efficiency measures*

I. INTRODUCTION

Electricity is the most important energy in our daily life. The usage of the electricity is widely used in manufacturing,

residential, commercial building, education and transportation sector. The impact of the growing number of national developments also increase the energy demand. The increasing of energy demand is somehow terrifying as it contributes significantly to climate change by adding more carbon dioxide to the atmosphere.

To simulate sustainable building practice, The Code of Practice on Energy Efficiency and use of Renewable Energy for Non – Residential Buildings Malaysian Standard MS 1525:2007 have been introduced. The standards discuss about planning on how to design an optimize of the energy efficiency of a building for the engineering, architectural, landscaping and site planning aspects [1]. According to the Efficient Management of Electrical Energy Regulation 2008, the building that received the electrical supply from the supply authority with a total electricity consumption equal to or exceeding to 3,000,000 kWh as be measured at the metering point over any period of the consecutive months must comply with the requirement regulations.

The facts that the increasing of energy consumption in Malaysia has opened the eye of the government. Energy audit need to be carried out in order to discover performance of building and the facilities in that area to identify the potential of energy saving in the building. Additionally, the energy cost and energy tariffs has risen dramatically due to global

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limited fuel resource and increase the fuel costs [3]. In this study, energy audit is done by using the smart kWh calculator and building simulation software.

Studies involving energy audit are not something new. In fact, there are many previous studies that have been done related to energy audit. First, a previous study that is similar to our work where this research study is based on an energy consumption for Malaysian universities [2]. The similarity of this study is a preliminary or walk through energy audit. The study was carried out by three main stages which are pre-audit stage, the audit stage and post audit stage. The only different this study with our study is this research did not applied any software to do the energy performance. This research is only focus on analysis of the historical data such as utility bills and invoice. Besides, this research required walk through to identify the evidence by taking a meter reading and doing a simple interview with the in-charge site operation.

There is another study that stated energy audit can be one of the quick and inexpensive solutions to commute gap between energy demand and supply in the building [7] . Demand for electrical energy is increasing every day due to fastest development in growth population, industrial and urban. This study proved that energy audit is a cost effective method and a good approach for entire energy conservation and to sustain the environment. Another study that had been done in Malaysia is an energy audit that has been conducted at a government office building in Putrajaya. This research was developing a Graphical User Interface (GUI) of Energy Management System (EMS) tool for office building by using Microsoft Visual Basic Programming software [4]. The tools will display the thermal and electrical consumption of a building and operating hour. The consumption in the building will be calculated by using the Building Energy Index (BEI) and carbon emission based on the records that enter by the user. By using this software tools energy management system, it can assists the management to manage the energy consumption and carbon emission in a building every year.

Next, a study involving the energy audit process for universities accommodation in Malaysia that stated by comparing the energy implementation process of selected Malaysian universities through the investigation of energy consumption behavior and the number of electrical appliances, machinery and buildings activities that have an impact on energy consumption that can improve energy efficiency in building to fulfil significant criteria in energy audit can be found [5]. This research suggested application of HOMER software to obtain solution and possible improvement of energy consumption during energy audit implementation and the Energy Efficiency Index (EEI) has been used as an indicator. By doing the documentation analysis, it can be a best practice to select the energy consumption. The results of this research can be used as a recommendation for other universities in order to help improving the implementation of energy audit process in their universities.

Lastly, a study that used energy audit method by gathering electricity bills and analyzed the usage of electricity in the building in order to focus on electricity services performance [6]. This research also applied Normalized Performance Indicator (NPI) as a guidance to calculate the energy performance. The NPI is compared with the practice of benchmark in the building. The result of this research stated that major energy consumption in the building is caused by the air condition, electric lightning and ventilation. Most of the old buildings are using the fluorescent tubes, tungsten halogen lamps and track light. The research suggests an energy saving light bulbs to control the energy consumption on lightning.

This study also used energy audit method to analyze energy consumption at level 6 officeUniversiti Kuala Lumpur British Malaysian Institute (UniKL BMI). However, since it is hard to obtain the electricity bills by level of the building, hence, smart

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kWh calculator is used to determine the cost of electricity usage. Building simulation software also will be applied in order to know the building energy consumption. All the methodologies applied in this study will be explained further in the next section before the discussion on all the results that were obtained from this study. At the end of this paper, all the findings will be concluded and further recommendations for future study will be provided.

II. RESEARCH METHODOLOGY

To begin this research, a constructive process flow is designed. All the processes involved in this study are illustrated as in Fig. 1 below:

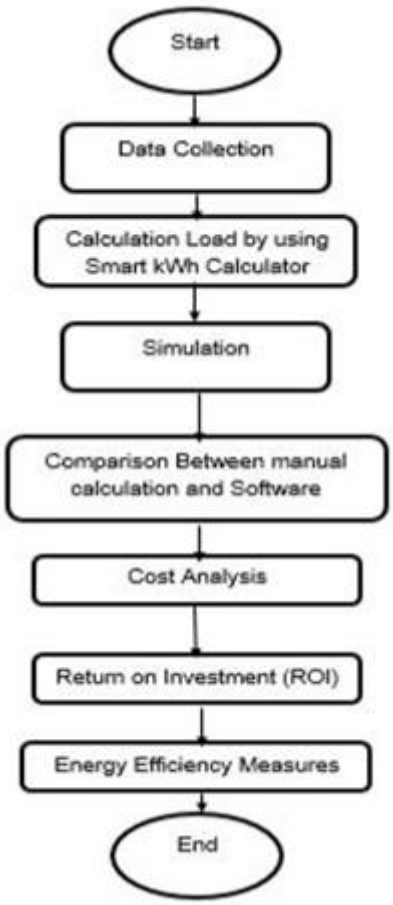

Fig. 1. Process flow chart for this study

The first step of this research is to collect data by evaluating the utility data, system building and facility information. From the data collection, the energy used from electrical equipment is calculated by using smart kWh calculator. The step to obtain the result by using smart kWh calculator as shown in Fig. 2.Through data collection, a benchmark of the data that against the energy usage in the building can be drawn.

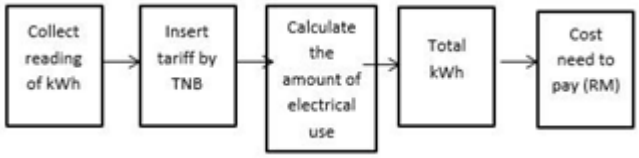

Fig. 2. Block diagram for smart kWh calculator

Then, the simulation can be started after all the data collection part is done. The process of simulation is started with the drawing of baseline of the building by using AutoCAD as shown in Fig. 3. The 3D model for this section in the building is built and exported to SketchUp software. The design tools used in this study are SketchUp and Sefaira that is integrated with the SketchUp software. Sefaira is an integrated apps that using EnergyPlus as its primary simulation engine.

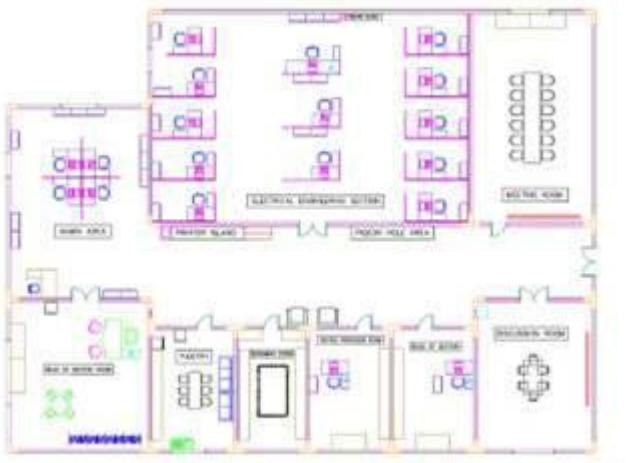

Fig. 3. Floor plan of Electrical Engineering Section by using AutoCAD

After collecting the simulation data and real data, the baseline analysis can be done. By doing the baseline analysis, the energy usage and cost analysis for the building can be calculated. For the energy usage analysis, the Energy Efficiency Measures (EEMs) is used as an important practicable solution for the equipment. It will identify the equipment that

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produce higher energy consumption. Lastly, cost analysis will focus on the present energy cost, potential saving and measure the implementation costs. The data from previous step is calculated to reduce the energy consumption that obtained from the actual data. In order to know the benefit of this energy audit, return of investment (ROI) is calculated to know the simple payback period.

$$\text{Return of Investment (ROI)} = \frac{\text{Annual Retrofit Savings - Project Cost (1) Project Cost}}{}$$

III. RESULTS AND DISCUSSION

Results of this study are presented by parts. The first part is a discussion on the calculation load that were obtained through walkthrough survey in the Electrical Engineering Section in UniKL BMI.

A. Calculation Load

Table 1 shows the area of electrical appliance load in the Electrical Engineering Section. To obtain the total kWh that has been used for operation, the number of lamps, the wattage and time of operation hour need to be included in the calculation. Every part of the section in the department have differences type of electrical equipment. Some of the equipment operate in difference hours.

Table I. Calculation load of electrical equipment

Meeting Room					
No	Appliance	Nos	Watts	Time Operation/hours	kWh
1	Fluorescent Lamp	15	36	10	5.4
2	Aircond	2	2798	10	55.95
Total Energy Consumption					61.35
Discussion Room					
No	Appliance	Nos	Watts	Time Operation/hours	kWh
1	Fluorescent Lamp	6	36	10	2.16
2	Aircond	1	2484	10	24.84
Total Energy Consumption					27
Head of Section					
No	Appliance	Nos	Watts	Time Operation/hours	kWh
1	Fluorescent Lamp	3	36	10	1.08
2	Aircond	1	2798	10	27.98
Total Energy Consumption					29.06
Visiting Professor					
No	Appliance	Nos	Watts	Time Operation/hours	kWh
1	Fluorescent Lamp	3	36	10	1.08
Total Energy Consumption					1.08

Document Store					
No	Appliance	Nos	Watts	Time Operation/hours	kWh
1	Fluorescent Lamp	6	36	10	2.16
Total Energy Consumption					2.16
Pantry					
No	Appliance	Nos	Watts	Time Operation/hours	kWh
1	Fluorescent Lamp	6	36	10	2.16
2	Aircond	1	2798	10	27.98
3	Refrigerator	1	1120	24	26.88
4	Water Dispenser	1	620	24	14.88
5	Coffee Maker	1	1000	10	10

Admin Area					
No	Appliance	Nos	Watts	Time Operation/hours	kWh
1	Fluorescent lamp	21	36	10	7.56
2	Aircond	1	2798	10	27.98
3	Aircond	1	2484	10	24.84
Total Energy Consumption					60.38
Lecturer Office					
No	Appliance	Nos	Watts	Time Operation/hours	kWh
1	Fluorescent lamp	15	36	10	5.4
2	Aircond	4	2798	10	111.92
3	Laptop	11	60	10	6.6
Total Energy Consumption					123.92
Walkway					
No	Appliance	Nos	Watts	Time Operation/hours	kWh
1	Fluorescent lamp	8	36	10	2.88
Total Energy Consumption					2.88

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B. Calculation of Electrical Bills by using Smart kWh Calculator

To calculate the cost of electricity, the tariff rate for educational building that has been designated by TNB is used where the rate is RM 0.365/kWh. To have an effective load factor improvement in the building, the load shape profile of the building need to be analyzed as shown in Table 2. This will be done by using the smart calculator as shown in Fig. 4 and Fig. 5 which has been designed in portable version to help calculates the amount of electricity cost.

Table II. Total energy consumption and total cost of the

No	Section	Total energy consumption (kWh/per day)	RM
1	Meeting Room	61.35	22.39
2	Discussion Room	27	9.85
3	Head of Section	29.06	10.60
4	Visiting Professor	1.08	0.39
5	Document Store	2.16	0.78
6	Pantry	89.4	32.63
7	Head of Section	29.16	10.64
8	Admin Area	60.38	21.90
9	Lecturer Office	123.92	45.23
10	Walkway	2.88	1.05
		426.39 kWh	155.63

Fig. 4. Key in current kWh value

Fig. 5. Total cost of electricity in Ringgit Malaysia

C. Simulation Results

The Electrical Engineering Section was developed by using Sketchup software from scratch based on the drawing plan of the building. The 2D model is developed from AutoCAD drawings. Fig. 6 shows the 3D drawing from the Sketchup.

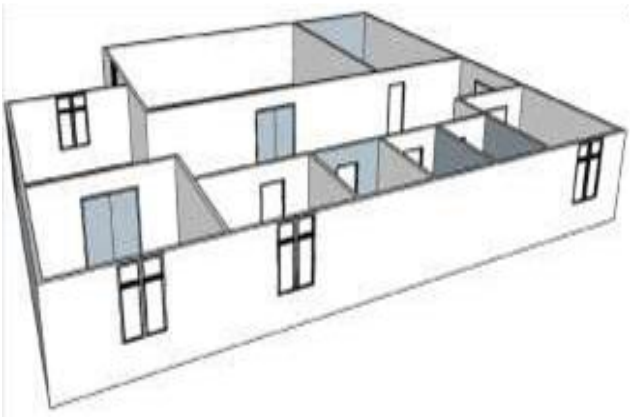

Fig. 6. 3D model from SketchUp

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From Sketchup, energy calibration is done by using Sefaira to obtain the result as shown in Fig. 7. The energy performance is simulated by using the Sefaira Architecture that can be operated as a cloud-based software by uploading the data of baseline building in Sketchup. The other details of the building that have been filled is the angle of building orientation, design temperature, diversity schedule, ventilation and outside air and zoning strategy. The value for infiltration rate and equipment power density are referred from the ASHRAE 90.1:2010 while the value for glazing properties are referred from Pilkington Glass Handbook 2010. The standard value for lighting power density are obtained from MS1525:2014.

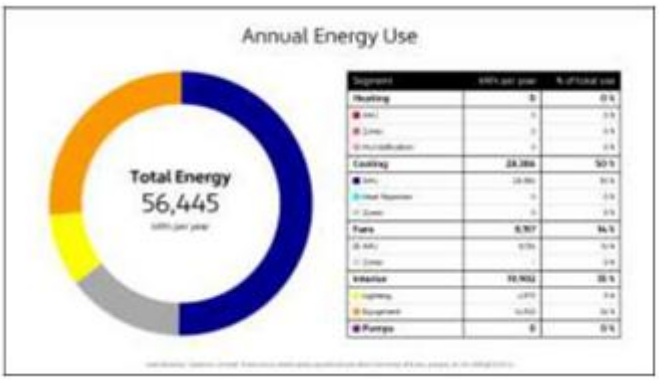

Fig. 7. Annual energy use

From Fig. 7, the results showed that total energy consumption for the commercial building per year is 56,445 kWh. The cooling system has the highest energy consumption which is 28,386 kWh. It is 50% of the energy consumption in the commercial building. The second highest of the energy consumptions in the building is 35% from the interior which is 19,902 kWh per year. The interior section consists of two sections which are 26% from equipment that is 14,923 kWh per year and 9% from lighting that is 4,979 kWh per year. Lastly, the third highest of the energy consumption is from fans which is 14% that is from AHU that consists 8,157 kWh per year.

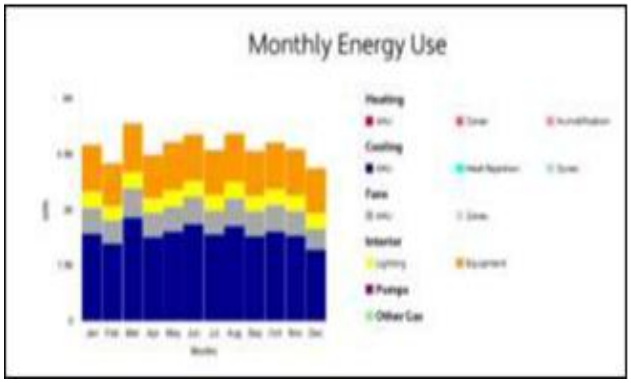

Fig. 8. Monthly energy use

Fig. 8 shows the result of the impact of the monthly energy consumption on energy segment of the building overall month from January to December. From the histogram, maximum energy consumption is in March where it is more than 5,000 kWh. This is probably caused by air conditioning that had to be operated on minimum temperature due to hot weather.

D. Comparison between Manual Calculation and Software

Table 3 shows the manual calculation by using smart kWh calculator that has sum up the total load calculation. Load calculation need to be multiplied with 10 hours because the operation of the Electrical Engineering Section is from 8.00 A.M to 6.00 P.M every day except weekend.

Table III. Manual calculation load and sefaira software

Manual Calculation (load calculation)/month	Sefaira
8527.8 kWh	4700 kWh
RM 3112.64	RM 1715.50

To make a valid comparison, results from August is taken from Sefaira (refer to Fig. 8) as the manual calculation was done in the last August. There is difference 3,827.8 kWh between manual calculation with simulation results. This is because some of the parameters did not put into consideration such as partition or rooms and actual loads in the department.

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E. Cost Analysis

In order to practicable the Energy Efficiency Measures (EEMs), the lighting system has been upgraded in the Electrical Engineering Section where the cost is stated in Table 4.

Table IV. Cost analysis to replace conventional

Fluorescent Lamp To Led Lamp

Lighting System Description	Fluorescent Lamp (T8 36W)	Fluorescent LED Lamp (T8 18W)
The Quantity of Lamp	95	95
Price for Each Lamp	RM15	RM12
Total Cost to Change the Lamp	RM1,425	RM1,140
Total Energy Consumption 10hours per day	34.2kWh	17.1kWh
Total Cost Operation a day in tariff C1	RM12.48	RM6.24

F. Return of Investment

From the cost analysis that has been shown in Table 4, calculation of return of investment (ROI) is provided to show the investment that can be done by management in the future. The formula that will be used is from the equation (1).

$$= \frac{\text{Total anual retrofit - Total project cost}}{\text{Total cost project}}$$

$$= \frac{\text{RM 1,647.30 - RM 1,140}}{\text{RM 1,1140}}$$

= 0.45 return on investment
= ROI x 100
= 0.45 x 100
= 45%

IV. CONCLUSION

By doing the energy audit, it will create an awareness among the staff to improve the energy efficiency and provide an opportunity for management to reduce the cost of operational of the building. The process of energy calibration plays an important role to understand the energy use, environmental impact and occupant experience on the building.

Additionally, the strategies of Energy Efficiency Measures (EEMs) is an important practicable solution to upgrade the lighting system in the building. The efficiency of the lighting LED which is long lifespan and low maintenance cost. An awareness among the staff is important to keep the electrical usage is use in effective ways. For future study, it is hoped that the energy audit can be done in the whole building instead of a section/department only.

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