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Electrical Energy Audit: Electrical Energy Audit at Block QB Faculty of Electrical and Electronic Engineering Universiti Tun Hussein Onn Malaysia

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Abstract: As the demand for energy continues to rise, organizations and individuals are increasingly realizing the importance of optimizing energy consumption to reduce costs, enhance operational efficiency, and minimize environmental impact. Several researchers who have done electrical energy audit on the designed location or building play crucial role in identifying potential areas of improvement and developing strategies for effective power management. This research is done for block QB University Tun Hussein Onn Malaysia in order to achieve effective power consumption or management. Three test is conducted by using different equipment which lux meter is for illuminance test, temperature and humidity data logger to record both the temperature and humidity in the area and lastly thermal imager camera to detect any problem related to air insulation in a specified room. These data were analyzed and energy saving measure (ESM) were proposed. Benefits derived from electrical energy audits, including cost savings, enhanced energy efficiency, and compliance with energy regulations. By identifying energy wastage and implementing appropriate measures, responsible electrical organization for block QB can achieve substantial energy savings, cost reduction and contribute to a more sustainable future.

Keywords: Energy Audit, Illuminance, Humidity and Temperature, Thermal Imager

1. Introduction

The increase in the number of buildings in Malaysia has a great impact on national development but it also increases the energy demand. Statistical record by Tenaga Malaysia shows that 94% of electricity generated in the country is by fossil fuels and it is expected that the figure will be unchanged over the next decade. Building consume total of 48% of the electricity generated in Malaysia.[1]. Author in [2] highlighted that existing building and its communities contribute over 40% of

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greenhouse gases emission to the environment. Chua and Oh [3] study reveals that the total electricity generation and consumption in Malaysia is expected to increase more in the near future. This is because of the country's increasing energy demand from 1243.7 to 2217.9 Pascal joules (PJ). Buildings consume a lot of energy for heating, cooling, lighting, and technological devices like computers purposes. According to the previous researches, energy consumption that will be used for the building is between 40% and 50%. While for the lighting, it consumes about 13% of energy, and the rate of energy consumption is increasing over time [4]. So electrical energy should be used wisely by avoiding of excessive use of the energy. When energy sources are used efficiently many benefits will be gain such as saving energy consumption. Plus, increasing in energy efficiency can lower the greenhouse effect, pollution thus reducing the monthly electricity bill.

The excessive use of electricity at Universiti Tun Hussein Onn Malaysia (UTHM) has been emphasized by electricity management which states that the monthly bill of the university is approximately RM 700,000 per month which is only the number for the main campus at UTHM Parit Raja. This work aims to identify any problem that related to electrical and mechanical equipment used in each main building such as air- conditioning, chiller and wiring system. Plus, high energy consumption occurs due to waste of electric power that consist of the usage of electrical and mechanical components are running for over long period of time without stopping although they are not being used. All the data need to meet the regulation (MS1525:2014) "Energy efficiency and use of renewable energy for non- residential buildings – Code of practice" made by department of Standards Malaysia (STANDARDS MALAYSIA), which is the national standards and accreditation body of Malaysia. By following the Commission, any private installation license holder or user whose net energy generation or overall consumption equals or exceeds 3,000,000 kWh will be sent a notice to designate or appoint an electricity manager licensed to carry out duties and obligations under Regulation 16 in the installation [5].

The objective of this study is to perform measurement for illuminance level, relative humidity, temperature and thermal imaging in the building area of Faculty of Electrical and Electronic Engineering, to analyze the measured illuminance level, humidity and temperature and thermal imaging data, to propose energy saving measure (ESM) for the building based on the finding from the analyzed measurement.

2. Materials and Methods

2.1 Materials

Table 1 listed three equipment used in order to conduct the measurement test which is lux meter (UNI-T UT381) for illuminance level, data logger (UNI-T UT330C) and thermal imager (XEAST XE-29).

2.2 Methods

Block diagram of the work is shown in Figure 1. Block QB is set as the building where the electrical energy audit is performed. Walkthrough audit is made in the building to locate the place to do the measurement test for illuminance, humidity and temperature and thermal energy. All the obtained data will be analyzed where the regulation of MS1525:2014 is used as a bench mark. Proposing energy saving measure (ESM) needs to be performed at the end of the work.

Illuminance level in an area can be expressed in (Eq.1) to compute luminous flux per unit area.

$$\mathrm{E} = \Phi \mathrm{l}\ \mathrm{Cu}\ \mathrm{LLF} / \mathrm{A} \quad (Eq.1)$$

where, E stand for illumination, Φ_l is luminance per lamp, C_u coefficient of utilization LLF is light loss factor and A is the area.

Table 1: List of Equipment

Type of Equipment	Function	Characteristic	Procedure
 Thermal Imager Camera	- Infrared camera, used to detect objects with infrared radiation.	- The data transformed into an electronic picture displaying the temperature of the object. - The temperature range is 20˚C to 400˚C. - Portable thermal imager.	- By pointing the laser point of the thermal imager to see the infrared radiation of the space along with the temperature.
 Lux Meter	- Use to determine the illumination level and for analyzing lighting requirements.	- Digital meter that used highly accurate visible light sensor. - Consist of 8-bit microprocessor to process data. - It is suitable to test illuminance within 0 to 20,000 lux.	- Sensor of the lux meter needs to be placed on the plane where light is bounced back to our eyes such as the table.
 Humidity/Temperature/ Pressure Datalogger	- It is a function to record humidity, temperature, and pressure.	- Record data measurement, use a non-volatile electronic memory. - Temperature range is -40˚C to 80 ˚C. - The relative humidity range is 0% to 100%. - The pressure range is 750hPa to 1100 hPa.	- Placing the datalogger in the desired area for some time in order to produce an accurate data output.

3. Results and Discussion

The measured and analyzed data will be shown below for building of faculty of electrical and electronic engineering block QB for illuminance level, humidity and temperature and thermal energy.

A. Illuminance Test

The test is performed in medical engineering laboratory where 7 point or location in the area is taken to take the measurement using the lux meter. The results are tabulated in Table 2.

The recorded illuminance level in medical engineering laboratory is a bit higher than recommended value in which the recommended value is 1000 Lux meanwhile the range of the recommended lux value recorded is from 1000 Lux to 1400 Lux. It can be said the illuminance provided in the area is a bit higher than the recommended value from MS 1525:2014.

B. Temperature and Humidity

Result of temperature and humidity as shows in Figure 2. The recorded data for humidity and temperature on the ground floor can be seen with temperature ranging 24 to 25 degrees Celsius which is in the range of the recommended value to MS 1525 (23℃-26℃). Humidity recorded is ranging where it increases by time from ranging value of 80 to 90. High value of humidity means has high moisture content in which can slow down sweat evaporation process. But with the temperature ranging in the value of 24 to 25 in an air-conditioned room, a person will feel cold and comfortable in the space.

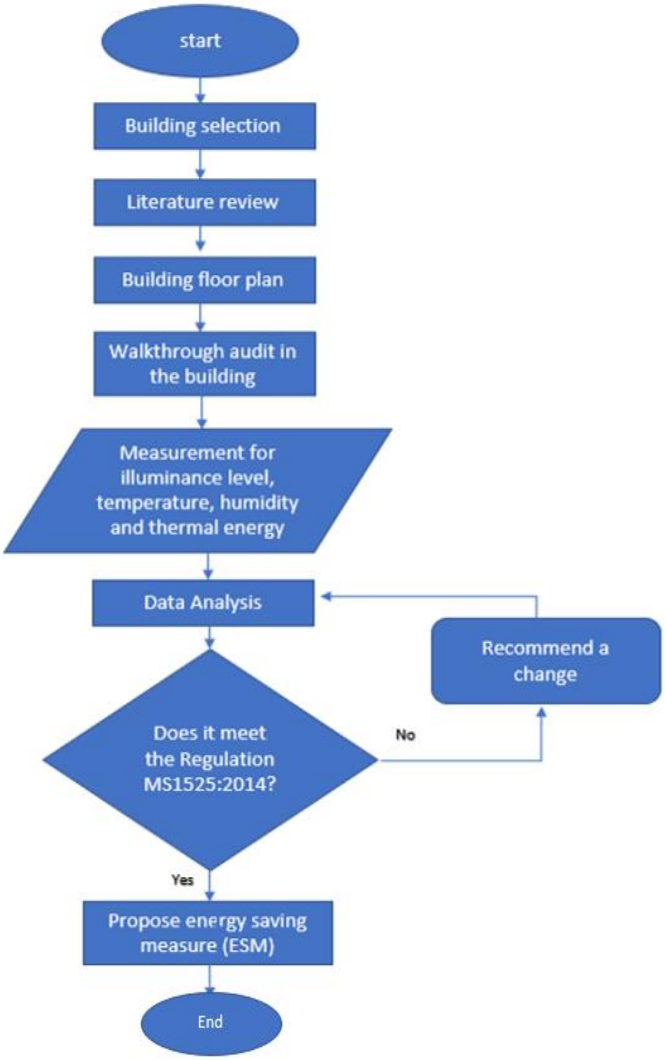

Figure 1: Flowchart diagram of the work

Table 2: Recorded Illuminance level

Place number	Illuminance level (Lux)	Recommended Average Illuminance (Lux)
1	1150	1000
2	1248	
3	1218	
4	1204	
5	1285	
6	1057	
7	1397	

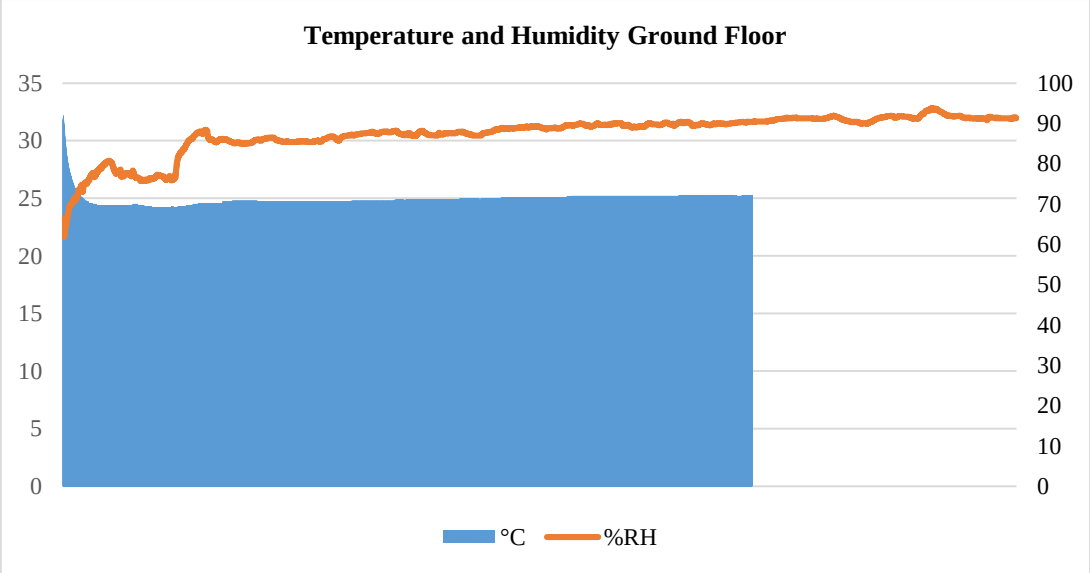

Figure 2: Results of Temperature and Humidity

C. Thermal Imager

Result of thermal imager as shown in Figure 3. Based on Figure 3, the image displays the hot spot within the class area which is located at third floor of the building where heat is being transferred from outside into the structure and known as thermal energy. This happens due to the increase in the temperature and humidity that occurs outside the building area that tries to enter the building through the windows aid of air.

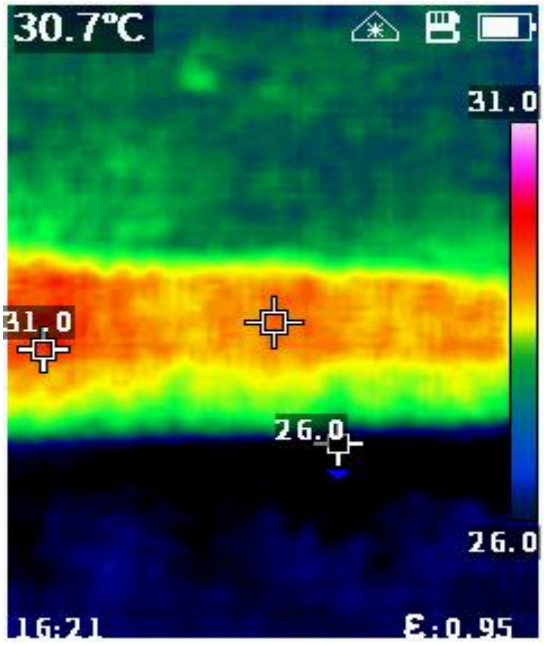

Figure 3: Thermal Imager in Tutorial Room 5

D. Building Load Profile

i) Energy Consumption During Online Class and Face to Face Class

Graph in Figure 4 and 5 shown the energy consumption or electrical energy (kWh) used for block QA and QB for faculty of electrical and electronic engineering (FKEE) University Tun Hussein Onn Malaysia for main switch board. Data taken is 17 days for online classes from 1 April 2023 until 17

April 2023. Meanwhile for face-to-face classes data recorded is from 14 May to 31 May. Based on both graphs, the similarity that can be spotted is value for energy used for Friday and Saturday is low as it is in weekend, except for the date of 26 May and 27 May where the energy use is higher than other days and the peak value of highest consumption is on the 26 May at 1182.5 kWh. Meanwhile the peak value of energy consumption during online classes is 1453.09 on 9 April. From the graph we can obtained the average daily electrical consumption needed for main switch board. During online classes around 5990.89 kWh needed per day which is lower comparing to electrical consumption during face-to-face classes which at 6005.82 kWh. From the data for electrical energy needed per day during online classes and face to face classes it can be said that the usage of electrical appliances in block QB during face-to-face classes is utilized more than during online classes. Electrical cost for block QA and QB for a day of operation by referring to Table 3.

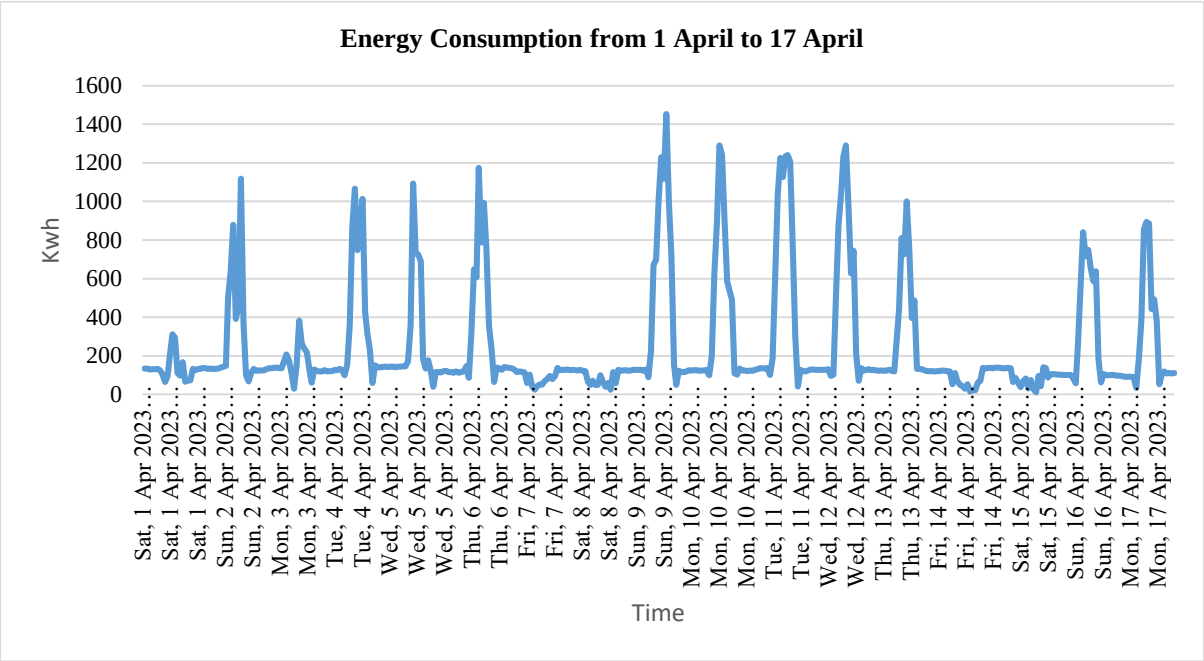

Figure 4: Energy Consumption (online class)

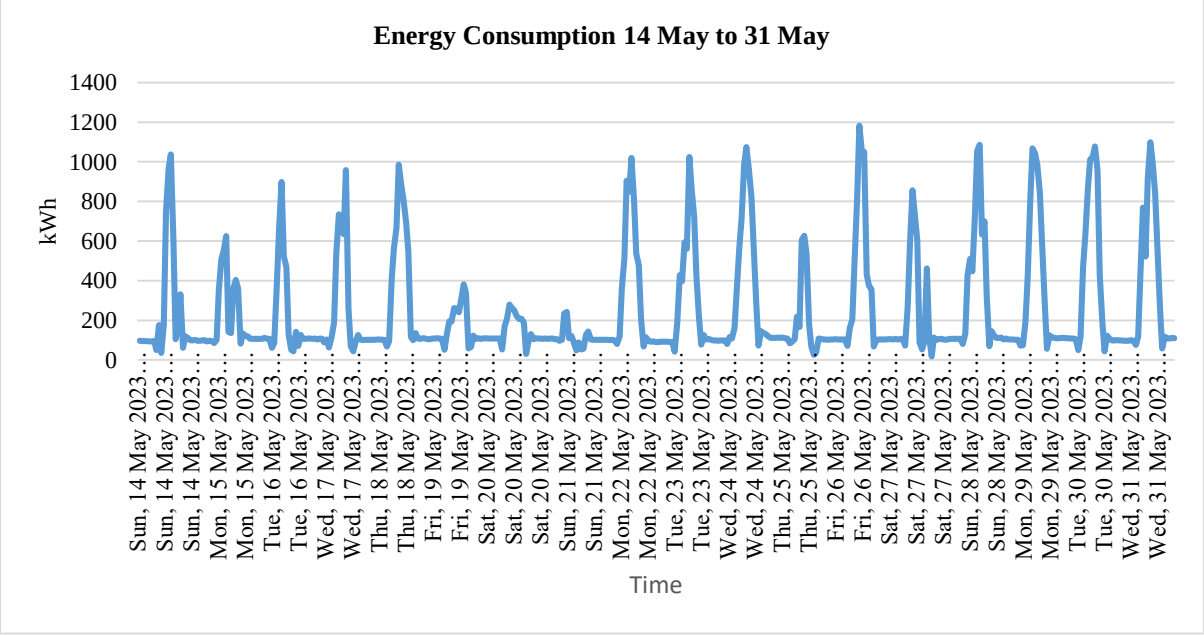

Figure 5: Energy Consumption (Face-to-Face Class)

Table 3: Electrical Energy Consumption and Electrical Cost

Time	Average Electrical Consumption (kWh) online class	Average Electrical Consumption (kWh) face-to-face class	Electrical Cost (RM) online class	Electric Cost (RM) face-to-face class
Day	5990.89	6005.817	2186.67	2192.12
Month	179726.7	180174.5	65600.1	65763.7
Year	2156720.4	2162094	787201.2	789164.35

ii) Overall Recommended Energy Saving Measures

In this part will shows on the recommended ways to save energy saving measures as listed in Table 4. There will be 2 parts on the recommendation which the first one is no cost where there will be no need to spend money on doing the implementation. The second one will be a mid-cost measure where a money spend on it is acceptable.

Table 4: Energy Saving Measure.

		No	Recommendation Measures
a.	No cost	1.	De-lamping of Fluorescent Lamp
b.	Mid Cost	2.	Retrofitting Led tube to replace fluorescent tube.
		3.	Awning/Top Hung Window installation

a) Delamping of fluorescent 36W lamp (remove one tube)

Table 5: Delamping Cost Reduction

Fluorescent Delamping	**Assuming 5 hours, 9 housing x 3 tube**	**Assuming 8 hours, 9 housing x 3 tube**
Total original Quantity (tubes)	27	27
Reduce quantity 1 tube per housing	18	18
Lamp Power per tube, Watt	36	36
Operation hours, hrs	5	8
Tnb C1 tariff usage rate, RM/kWh	0.365	0.365
Avoided energy calculation		
Daily Avoided energy, kWh	1.62	2.592
Monthly Avoided energy, kWh (20 days)	32.4	51.84
Yearly Avoided energy, kWh (240 days)	388.8	622.08
Electric Cost Saving Calculation		
Monthly Energy Cost Saving, RM	11.826	18.9216
Monthly Elec Cost Saving, RM	11.826	18.9216
Yearly Elec Cost Saving, RM	141.91	227.06

Table 5 tabulated delamping cost reduction. Based on Table 5, the number of fluorescent lamps is reduced to get the desired range of value for illuminance level in the area for classroom (300 to 500 Lux) from 27 tube to 18 tube. The number of tubes determined after doing the calculation as shown above. Two set of time is used to perform the measurement for electric cost which is 5 hours and 8 hours of use. After implementing delamping of the fluorescent tube, daily avoided energy is 1.62 kWh and then can obtained for monthly and yearly avoided energy. Lastly, we can calculate the electrical cost saving in a year where for 5 hours of use, electric cost saving is RM 141.91 and for 8 hours of use, electric cost saving is RM 227.06. It can be concluded that the process or the implementation of

delamping in tutorial room 5 does save electric cost and energy consumption to meet up with the energy saving measure (ESM).

b) Retrofitting Led Lamp to Replace Fluorescent Lamp

Table 6 tabulated retrofitting cost of LED tube. The intercept of an ROI graph in Figure 6 represents the point where the ROI is zero, indicating that there is neither a gain nor a loss. It is the break-even point where the initial investment is recovered. It is crucial because it helps determine the breakeven point for an investment. Any ROI value above the intercept indicates a positive return, while values below the intercept indicates a negative return. The intercept value represents the initial investment amount. After calculating the delamping of fluorescent lamp, retrofitting the fluorescent to led tube is performed to save energy which will be benefitable over time. Time utilized for the lamp taken is 8 hours. By referring to the return-on-investment graph figure 4.39, electrical cost for led is higher than fluorescent due to early investment that need to be done where a single led tube cost around RM 20. By changing all the tube, the first month for the cost of investment is RM 360. The calculation is performed for 24 month or 2 years in order to observe the difference of electrical cost between the two types of tube. The line will intercept around month 19 or a year and 7 months to start become profitable. The electrical cost after 19 4months after using LED tube will be lower rather than using fluorescent tube.

Table 6: Retrofitting Cost of LED Tube

Fluorescent Lamp		Led Lamp	
Total tubes	18	Total tubes	18
Lamp power per tube, Watt	36	Lamp power per tube, Watt	18
Operation hours, hrs.	8	Operation hours, hrs.	8
TNB C1 tariff usage rate, RM/kWh	0.365	TNB C1 tariff usage rate, RM/kWh	0.365
Electric Cost Calculation		**Electric Cost Calculation**	
Daily Electric Cost, RM	1.89	Daily Electric Cost, RM	0.95
Monthly Electric Cost, RM	37.8	Monthly Electric Cost, RM	19
Yearly Electric Cost, RM	453.6	Yearly Electric Cost, RM	228
		Investment In First Month	
		Total cost buying led tubes, RM	360

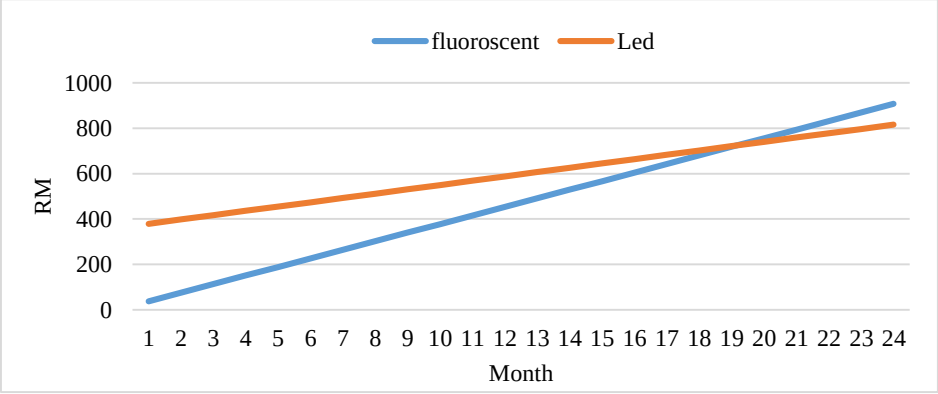

Figure 6: Return of Investment Graph

C) Window Installation

On the open spot on the first floor, implementation that can be done in order to make sure that the air insulation in the area is better is to install an awning or top hung windows. Table below shows the investment that need to be done from construction company (Pangkin Teguh SDN BHD) in order to install the window in the desired area are tabulated in Table 7.

Table 7: Window installation

No.	Spaciousness (meter-square)	Item	Unit	Price
1	3.528	a. window awning/top hung	1 set	RM 299.88

4. Conclusion

Energy audit is a systematic process that evaluates the energy usage and efficiency of a building or facility. It involves collecting data on energy consumption, conducting on-site inspection, analyzing the information and providing recommendation for energy-saving measures. The goal from energy audit it to identify areas of energy waste, suggest improvement and prioritize action to reduce energy costs and enhance sustainability. Energy audits help individuals and organizations optimize energy usage, and achieve significant savings.

Energy audit is a powerful tool to achieve interesting energy savings. In this paper the energy audit is limited to the illuminance level, temperature and humidity, and thermal imager in block QB. In a nutshell, air conditioning system in FKEE building consume the highest energy followed by lighting and office equipment usage. Throughout the energy audit program three major measurement is taken and analyze which is illuminance level, temperature and humidity and thermal imager for certain areas. Three major energy saving measure is performed which are delamping of fluorescent lamp, retrofitting of LED lighting and window installation were targeted to achieve energy saving. Last but not least, block QB have room for improvement in terms of energy saving and energy consumption especially in illuminance efficiency and equipment. All the energy saving measure proposed are provided with the calculation in order to have a better vision and understanding of the implementation.

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