Feasibility Analysis of Solar Power Generation System for Office Building in Academic Institution

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Abstract. This paper study the potential of energy-saving through lighting located at the office building in an academic institution known as Politeknik Sultan Azlan Shah (PSAS). Exercise through energy audit has been conducted at 3 main academic building to identify energy usage of lighting. 3 academic building involved is Mechanical Engineering Department (MED), Civil Engineering Department (CED), and the Electrical Engineering Department (EED). This study analysis 5 types of lighting to identify which types of lighting use the highest amount of energy in academic buildings. The 5 types of lighting involved in this study are Fluorescent T8 36W, Fluorescent T8 18W, Compact Fluorescent (CFL) 24W, Metal halide (MH) 400W and Ttube 18W. Energy savings are calculated based on the installation of hybrid solar in 3 related buildings. From an energy audit, the energy-saving at-least 5% from previous data has been estimated through the installation of a solar photovoltaic (PV) system. Through feasibility analysis, it is found that energy-saving potential obtained in the year 2019 for MED, CED and EED are about 4299 kWh, 2,319 kWh and 3,269 kWh respectively. Besides, the energy bill saving obtained is about RM 1,569, RM 846 and RM 3,269 respectively for MED, CED, and EED.

1. Introduction
Global warming is a real challenge and accepted as a global issue. An active action to handle this challenge must be taken. One of the methods to achieve the target of reducing the carbon emissions by buildings in Malaysia with encouraging renewable energy source use, which also known as a clean energy source. Using this source in the power system can reduce greenhouse gas emissions, which is identified as a major contributing factor to global warming [1]. In Malaysia, the lighting is identified as one of the major energy consumers in the buildings [2] where is for an academic building, an energy consumption approximately 19% [3]. However, in the academic building in PSAS, there are 5 types of
lighting with different power rated and specification. A study conducted by Alajmi [4] on higher institution learning building in Kuwait using energy audit strategy to gather information about energy usage and calculate the potential energy saving that can be achieved. Azucena et al [5] conducted the study at university of Mexico and only focus their research on energy consumption per equipment such as lighting, research equipment, cooling, and water heating only. Another study by Mohammad Ahsan et al [6] focuses their energy audit on lamps, motors and other equipment. Based on a literature review [4-7] using an energy audit is the best strategy to collect data about high energy-consuming equipment in the educational building. In this study, an energy audit has been conducted on lighting only and this setting is acceptable because a lot of literature review mention about the lighting is one of their research target. Analyse and identify energy-consuming of each lighting will show which types of lighting that need to be focus for purpose of energy-saving. Energy audit findings of facilitate the use of energy and the potential of energy savings for lighting is calculated [7] for PSAS. In effort to reduce the energy consumption of in the academic building, the implementation of solar power generation system is currently the most widely installed in the building sector [8]. The research by Clara et al [9] has been present a case study involving an office building installed an integrated PV solar system in Norway. While, Ruben et al [10] mentioned most universities in Indonesia applied solar energy with off-grid system. The author presents the feasibility analysis of photovoltaic power installation using HOMER software. However, relying only on solar energy cannot meet electricity demand effectively because the supplied it is inefficient and variable. Solar power system depends on weather and requires backed up by traditional fossil fuel energy [11]. Installing a hybrid solar system is one of the practical solutions for stand-alone or off-grid power generation systems. This paper will analyses follow the previous work by [9] but using a different methodology to analyse the data. Based on the energy audit data, the energy forecast is done but not using the HOMER [10]. The aim of this study to analyse the potential of energy savings through lighting located at the office building. The 5 types categories of lighting involved in this study such as Fluorescent T8 36W, Fluorescent T8 18W, Compact Fluorescent (CFL) 24W, Metal halide (MH) 400W and Ttube 18W. Through the energy audit data of lighting, the feasibility analysis has been calculated by installing a rooftop solar power generation system in Politeknik Sultan Azlan Shah. The total energy consumption of lighting in 3 main academic buildings in PSAS is about 21% of whole energy consumption at 3 departments involved. Focusing on the lighting for energy-saving purposes through feasibility analysis has been confirmed gives a significant impact on the PSAS.

2. Methodology

2.1. Baseline Data

The baseline data is referred to data of energy consumption is measured using power meter was installed in each academic building PSAS. This reference value will compare with the calculated energy consumption to minimize the error percentage between measured and calculated data. Baseline data is referring to measured data for energy consumption (kWh) in 2019. Based on baseline data, the prediction of energy consumption and energy saving in PSAS for future years has been estimated. The data collected is referring to average energy consumption data (kWh) for 12 months in 2018. All the data has been extracting via the online Energy Monitoring System (EMS) owned by PSAS. Table 1 shows the baseline data for energy consumption in the year 2018 is imported from EMS involving 3 main academic buildings.

| Building                             | Energy Consumption (kWh)/Year |
|--------------------------------------|------------------------------|
| Mechanical Engineering Department (MED) | 327,324                      |
| Civil Engineering Department (CED)    | 173,468                       |
2.2. Data collection through energy audit

The gather of data follows the methodology implement by [6] where energy audit has been conducted in 3 main academic department at PSAS. 3 academic building involved is Mechanical Engineering Department (MED), Civil Engineering Department (CED), and the Electrical Engineering Department (EED). Most researchers [12-14] implement the energy audit methodology to identify which types of equipment consuming the highest energy. In this research, types of lighting use the highest amount of energy in academic buildings has been identified. The walk-through energy audit collect the information about types of lighting, quantity, power rated and operating hours. The lighting is divided into 5 types of categories such as Fluorescent T8 36W, Fluorescent T8 18W, Compact Fluorescent (CFL) 24W, Metal halide (MH) 400W and Ttube 18W. Table 2, Table 3 and Table 4 show the types of lighting, a total of quantity, rating power and operating hours based on academic calendar PSAS 2018 and normal routine activity at MED, CED and EED.

### Table 2. Types of lighting, total of quantity, rating power and operating hours for normal routine activity at MED.

| No | Types of Lighting | Quantity | Power rated (kW) | Operating Hours (h/year) |
|----|-------------------|----------|------------------|-------------------------|
| 1  | T8 36W           | 1209     | 0.036            | 708                     |
| 2  | T8 18W           | 204      | 0.018            | 708                     |
| 3  | CFL 24W          | 23       | 0.024            | 708                     |
| 4  | MH 400W          | 155      | 0.4              | 708                     |
| 5  | Ttube 18W        | 650      | 0.018            | 708                     |
|    | TOTAL             | 2241     | 0.496            | 708                     |

### Table 3. Types of lighting, total of quantity, rating power and operating hours for normal routine activity at CED.

| No | Types of Lighting | Quantity | Power rated (kW) | Operating Hours (h/year) |
|----|-------------------|----------|------------------|-------------------------|
| 1  | T8 36W           | 404      | 0.036            | 708                     |
| 2  | T8 18W           | 52       | 0.018            | 708                     |
| 3  | CFL 24W          | 35       | 0.024            | 828                     |
| 4  | MH 400W          | 75       | 0.4              | 828                     |
| 5  | Ttube 18W        | 775      | 0.018            | 708                     |
|    | TOTAL             | 1341     | 0.496            | 756                     |

### Table 4. Types of lighting, total of quantity, rating power and operating hours for normal routine activity at EED.

| No | Types of Lighting | Quantity | Power rated (kW) | Operating Hours (h/year) |
|----|-------------------|----------|------------------|-------------------------|
| 1  | T8 36W           | 1260     | 0.036            | 828                     |
| 2  | T8 18W           | 135      | 0.018            | 708                     |
| 3  | CFL 24W          | 13       | 0.024            | 828                     |
| 4  | MH 400W          | 42       | 0.4              | 828                     |
| 5  | Ttube 18W        | 800      | 0.018            | 828                     |
2.3. Equations

The estimation of energy consumption by the lighting in the PSAS is calculated using as the following equation (1) [6, 7].

\[ E_{CL} = P_r \times O_h \times L_f \]  

where \( E_{CL} \) is the annual energy consumption of lighting (kWh), \( P_r \) is power rated (kW), \( O_h \) is annual operating hours, \( L_f \) is the loading factor. The loading factor for lighting considered in ideal condition and set as 1 [7]. The estimated operating hours for lighting has been calculated by considering the total operating hour per day in normal routine is 8 hour. The number of days the lighting in ON condition for 1 year is calculated based on 32 weeks of lectures and plus others 4 weeks for the final examination.

The estimation of annual energy saving for lighting in the PSAS is calculated using as the following equation (2)

\[ AES_L = P_r \times H_{avg} \times R_p \]  

where \( AES_L \) is the energy-saving estimation of per year (kWh), \( Pr \) is power rated of lighting, \( H_y \) is representing an operating hour operation by year, \( L \) is the loading factor of lighting and \( R_p \) is a percentage of lighting replacement. Energy-saving for each type of lighting in this research has been calculated based on the percentage of lamps quantities is replaced. Annual bill savings in annually using new lighting are calculated using the following equation in (3) [6]

\[ ABS = AES_L \times E_c \]  

Where \( ABS \) is annual bill savings (RM), \( AES_L \) is energy saving per year (kWh) and \( E_c \) is the energy cost (RM/kWh). Tariff rate for PSAS refer to tariff C1 for medium voltage general commercial tariff.

3. Results and Discussion

Analysis of energy audit data for lighting has been conducted in 3 main academic building. The number of lamps or quantity, power rated, operating hours, energy consumption and energy bill are also recorded and calculated. The energy consumption and energy bill for all types of lighting in 3 academic buildings have been calculated by year by using Equation (1). The calculation estimation of energy bills using the TNB tariff rates category C1. The tariff under category medium voltage general commercial using one rate for all kWh per month at a charge rate of RM0.365 [15].

3.1. Energy consumption and energy bill at MED

By using the data from Tables 2, 3 and 4 and calculated using equation (1) then the details of total energy consumption and energy bills for 5 types of lighting are shown in Tables 5, 6 and 7 respectively for MED, CED, EED.

| No | Types of Lighting | Energy consumption/year (kWh) | Energy bill/year (RM) |
|----|------------------|-------------------------------|-----------------------|
| 1  | T8 36W           | 30,815                        | 11,247                |
| 2  | T8 18W           | 2,600                         | 949                   |
| 3  | CFL 24W          | 391                           | 143                   |
| 4  | MH 400W          | 43,896                        | 16,022                |
| 5  | Tube 18W         | 8,284                         | 3,024                 |
| TOTAL |                   | 85,985                        | 31,385                |

Table 5. Energy consumption and energy bill for lighting at MED

| No | Types of Lighting | Energy consumption/year (kWh) | Energy bill/year (RM) |
|----|------------------|-------------------------------|-----------------------|
|    |                  |                               |                       |

Table 6. Energy consumption and energy bill for lighting at CED

| No | Types of Lighting | Energy consumption/year (kWh) | Energy bill/year (RM) |
|----|------------------|-------------------------------|-----------------------|
|    |                  |                               |                       |
The feasibility analysis of the solar power generation using a rooftop solar photovoltaic (PV) system was conducted and the energy-saving potential in MED, CED and EED has been calculated. By assuming the power generated by solar PV for self-consumption [16] where electricity generated is entirely for own use and not exported to the grid [17], energy-saving (kWh) and bill saving (RM) per year for lighting have been calculated. The feasibility analysis has been conducted using solar PV monocrystalline module 250W. By assuming the average of the peak sun hour for Malaysia is 4 hours means one solar panel is generating 1 kWh per day and about 30 kWh per month. According to Table 5, the annual energy consumption for lighting in MED is 85,985 kWh per year and the energy bill is RM 31,385 per year. Means energy demand for lighting in MED is approximate 60 kW per day and the energy consumption is about 239 kWh per day.

Referring to Table 6, the annual energy consumption for lighting in CED is 46,372 kWh per year and the energy bill is RM 16,926 per year. The energy demand for lighting in CED is approximate 32 kW per day and the energy consumption is about 129 kWh per day. The energy demand for CED is approximate 60 kW per day and the energy consumption is about 239 kWh per day. The energy demand for CED is about 129 kW per day.

### Table 7. Energy consumption and energy bill for lighting at EED

| No | Types of Lighting | Energy consumption/year (kWh) | Energy bill/year (RM) |
|----|------------------|-------------------------------|-----------------------|
| 1  | T8 36W           | 10,297                        | 3,758                 |
| 2  | T8 18W           | 663                           | 242                   |
| 3  | CFL 24W          | 696                           | 254                   |
| 4  | MH 400W          | 24,840                        | 9,067                 |
| 5  | Tube 18W         | 9,877                         | 3,605                 |
|    | TOTAL            | 46,372                        | 16,926                |

### Table 8. The percentage of apportionment for the lighting in 3 main department

| Building  | Total (kWh/year for whole building (A)) | Total (kWh/year lighting only (B)) | Percentage B/A (%) |
|-----------|----------------------------------------|-----------------------------------|--------------------|
| MED       | 327,324                                | 85,985                            | 26                 |
| CED       | 173,468                                | 46,372                            | 27                 |
| EED       | 442,349                                | 65,370                            | 15                 |
| (MED + CED + EED) | 943,141                        | 197,727                            | 21                 |

### 3.2. Percentage of apportionment for the lighting in each department

The percentage of apportionment for the lighting is shown in Table 8 where the energy consumption for the whole building in PSAS obtains from measured data using a power meter and stated in (A) column. Total energy consumption for lighting obtain from an estimation calculation through energy audit data and is represented in (B) column. Based on the result shows in Table 8, the lighting using about 21% of whole energy consumption at 3 departments involved.
less almost half compared with MED. In EED, the annual energy consumption for lighting is 65,370 kWh per year and the energy bill is RM 23,860 per year as shown in Table 7. The energy demand for lighting in EED about 45 kW per day and the energy consumption is about 182 kWh per day. The information about the value of energy demand will help in determining the number of solar PV panel need to be installed to meet the requirement of energy goal. By using the data from Tables 2, 3 and 4 and calculated using equation (2) and (3) then the total energy saving and energy bills are shown in Tables 9, 10 and 11 respectively for MED, CED, EED. The forecast for energy-saving and bill saving has been calculated based on an increment of the percentage due to of the energy supplied by solar PV. That percentage of increment for energy supplied by solar PV (5%, 10%, and 15%) based on Malaysian Polytechnic POLYGreen Blueprint 2015 [18]. This document stated all the polytechnic institutions need to reduce their utility costs minimum by 5% per year. The percentage represents the savings will gained for each year from 2019 to 2021.

Figure 1 and 2 shows the graph of a forecast for energy-saving and bill saving per year respectively at MED, CED, and EED if install solar photovoltaic for self-consumption. The results in Figures 1 and 2 show that increment of the total energy supplied by solar will decrease energy consumption supplied by TNB and proportionally increase the amount of bill saving. The solar power generation system also involves PWM solar charge controller 12/24V and the energy produced by solar PV will be stored in the battery sealed lead acid 12V 330Ah. The output of direct current from the battery will convert to the alternating current through 3000W inverter 12V 330 Ah. The output of the inverter will be used to operating the lighting system.

Table 9. Forecast for energy and bill saving per year at MED if install solar photovoltaic for self-consumption

| Energy supplied by solar PV | Energy saving per year (kWh) | Bill saving per year (RM) |
|-----------------------------|-----------------------------|--------------------------|
| 5%                          | 4,299                       | 1,569                    |
| 10%                         | 8,599                       | 3,138                    |
| 15%                         | 12,898                      | 4,708                    |

Table 10. Forecast for energy and bill saving per year at CED if install solar photovoltaic for self-consumption

| Energy supplied by solar PV | Energy saving per year (kWh) | Bill saving per year (RM) |
|-----------------------------|-----------------------------|--------------------------|
| 5%                          | 2,319                       | 846                      |
| 10%                         | 4,637                       | 1,693                    |
| 15%                         | 6,956                       | 2,539                    |

Figure 1. Forecast for energy saving per year at MED, CED, and EED if install solar photovoltaic for self-consumption
Figure 2. Forecast for bill saving per year at MED, CED, and EED if install solar photovoltaic for self-consumption

Table 11. Forecast for energy and bill saving per year at EED if install solar photovoltaic for self-consumption

| Energy supplied by solar PV | Energy saving per year (kWh) | Bill saving per year (RM) |
|-----------------------------|------------------------------|--------------------------|
| 5%                          | 3,269                        | 1,193                    |
| 10%                         | 6,537                        | 2,386                    |
| 15%                         | 9,806                        | 3,579                    |

3.4. Carbon Emission Reduction

The installation of rooftop solar PV power generation produces carbon emission reduction. The estimated value on the potential of carbon emission CO2 which has been eliminated due to installing the solar PV power generation system is shown in Table 12, 13 and 14 for MED, CED, and EED respectively. The energy produced by solar PV is equal to energy-saving obtained by departments. To calculate the CO2 reduction, the energy-saving per year multiplying with an emission factor of 0.693 kg of CO2 per kWh [19].

Table 12. CO2 reduction per year for MED

| Energy saving per year (kWh) | Carbon emission reduction (kg of CO2) |
|------------------------------|--------------------------------------|
| 4,299                        | 2,979                                |
| 8,599                        | 5,959                                |
| 12,898                       | 8,938                                |

Table 13. CO2 reduction per year for CED

| Energy saving per year (kWh) | Carbon emission reduction (kg of CO2) |
|------------------------------|--------------------------------------|
| 2,319                        | 1,607                                |
| 4,637                        | 3,214                                |
| 6,956                        | 4,820                                |

Table 14. CO2 reduction per year for EED

| Energy saving per year (kWh) | Carbon emission reduction (kg of CO2) |
|------------------------------|--------------------------------------|
| 3,269                        | 2,265                                |
| 6,537                        | 4,530                                |
| 9,806                        | 6,795                                |
4. Conclusion

Based on the research, the total energy consumption of lighting in 3 main academic buildings in PSAS is 197,727 kWh. It is about 21% of whole energy consumption at 3 departments involved. The estimation of energy consumption per year is about 85,985 kWh, 46,372 kWh, and 65,370 kWh while energy bill per year is about RM 31,385, RM 16,926, and RM 23,860. The energy consumption and energy bill above refer respectively for MED, CED, and EED. Through feasibility analysis, it is found that energy-saving potential obtained in the year 2019 for MED, CED, and EED are about 4299 kWh, 2,319 kWh, and 3,269 kWh respectively. Besides, the energy bill saving obtained is about RM 1,569, RM 846, and RM 3,269 respectively for MED, CED, and EED.

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