

Feasibility Study of Solar Power System in Residential Area

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Abstract

The present paper studied the feasibility of solar power system in the residential area in Kuching. Generally, the solar power system described in this paper is defined as a small-scale photovoltaic (PV) based system that can be installed within a housing compound or on the rooftop to generate sufficient power to support a household daily electricity usage. The required data was collected at the residential area at Sekama, Kuching by using two methods, which are an analytical and experimental method. Later, the acquired data obtained from the two methods used were converted in term of solar irradiation. Besides, analyses were carried out for the solar power system in terms of the potential, capacity and economic feasibility of the solar PV system. Overall, the solar PV system is found to be feasible to be installed in the residential area.

Keywords— Solar energy; photovoltaic; residential area; Kuching; solar panel; solar irradiation

1 Introduction

In today's world, the global energy consumption increased significantly due to the rapid growth of population, industrialization and development in developing countries. Being one of the developing countries, Malaysia utilized fossil fuels to generate 90% of electricity aside from other resources [1]. However, the use of fossil fuels to generate electricity are considered as non-renewable and non-sustainable as it is depleting when they are burnt to generate electricity. Besides, the burning of fossil fuels produces carbon dioxide which could damage our environment and cause global warming as well as the greenhouse effect. Therefore, the use of renewable energy to non-renewable energy is widely concerned about many developing and developed countries.

Renewable energy can be obtained from the natural resources which are sustainable and environmentally friendly. Currently, several types of renewable energy were utilized by many countries such as solar, wind, tidal, hydro and biomass. Among these renewable energy sources, solar energy gained more attention by researchers in the developing countries. From future prospects, the solar energy is said to be a promising renewable energy alternative as it converts sunlight directly to electrical energy.

Malaysia is claimed to have a high suitability for using solar energy as a source for electricity generation as Malaysia

was located entirely in the equatorial region. Malaysia is exposed to a constant high temperature ranging from 27°C to 33°C and average solar radiation of 4.5 kWh/m² daily [2]. However, the feasibility of using solar energy in Malaysia is still undergoing research and development. Therefore, this research was proposed to study the feasibility of installing the small-scale photovoltaic solar system in the residential area in Kuching, Sarawak.

Currently, the electricity that supplied to most of the households in Kuching is generated from hydropower and coal power plant. In order to minimize the electricity generation that depends on non-renewable energy, cut down the electric bill expenses of households and create a sustainable environment, the solar power system is considered to be studied in this research.

In addition, this research has highlighted the feasibility of installing the standalone solar PV system in the residential area of Sekama in Kuching. In order to approximate the possible solar energy production, solar radiation data will be collected. Furthermore, the potential of the implementation of solar energy in Kuching can be determined by conducting analysis using the estimated energy production. The experimental tools that will be used in measuring the solar radiation in Kuching including a light meter and a solar panel and multimeter. Apart from that, consultation will be conducted with local companies to obtain the information regarding the installation of the solar panel system in Kuching. Lastly, the analysis will be conducted based on all the results and findings to come out with the recommendation.

2 Literature Review

2.1 Study of Location

The location is very important for installing solar power system as it is related to the availability of the sunshine, light intensity and the tilt angle of solar module [3]. The selected research location, Kuching is located in Sarawak, Malaysia. Malaysia is a tropical country located close to the equator which exposed to abundant sunshine throughout the year. The average sunshine hours in Malaysia is about 4 to 8 hours daily and the monthly solar radiation is approximately 400 – 600 MJ/m² [4]. According to the official website of State Planning Unit, Sarawak experiences monsoonal changes twice in a year where the Northeast and Southwest Monsoon brings heavy rainfall [5]. Besides this monsoonal changes, the climate

condition in Sarawak is constant throughout the year. Also, the website reported that Kuching is having an average of 5 to 6 hours of sunshine every day.

According to Chua et al. in 2009, Germany have the largest solar power capacity being installed which is around half of the world market [6]. Although the average solar irradiance is quite low in Germany, the country is still the major player in solar energy production. This implied that Malaysia as a country at the equator has very high potential and opportunity to develop solar power system.

2.2 Solar Energy Trend in Malaysia

Currently, the solar PV system is applied in Malaysia mainly on providing electricity to the rural area, street and gardening lighting, and telecommunication [7]. Also, there are several industries that used solar water heater for heating purposes such as the hotels service provider, food and beverage industry and upper-class urban homes. The first trial for grid-connected PV system in Malaysia was conducted by the Tenaga Nasional Berhad (TNB) in July 1998. The first system was installed on top of a university. The results from the experiment showed that solar PV system in Malaysia is able to produce electricity that is 1.3 times more as compared to the similar installations in Germany. Additionally, Malaysia has an additional advantage for solar PV system as the weather is stable and the uniformly high ambient temperature throughout the year.

In 2001, Malaysian government started to implement the Fifth Fuel Policy to encourage the generation of electricity through renewable energy with the target of 5% within 5 years [8]. However, this target failed with the achievement of only 0.3% due to several reasons. The reasons included: market failures (limited buyers); economic, financial and technological constraints; lack of legal framework, institutional measures, and high installation cost. Later in 2005, the solar PV industry started to rise after the MBIPV Project was launched. At the end of this project on the 31st December 2010, there are 109 projects being conducted with 64 installed on residential houses [8]. Within this five years period, the cost of installation for PV system decreased by about 40% and there is an increment of about 13.2% of house owner who are willing to install the PV system.

In 2011, Malaysia started a Feed-in Tariff (FiT) scheme which focuses on PV system. The FiT concept had been used in many countries such as Germany, Italy, Spain and Thailand. The FiT was proven to be able to speed up the development of renewable energy sector [9]. The generated electricity through solar PV system can be exported back to the national grid with the rate of RM0.85 to RM1.23 per kWh. Also, some bonuses are introduced under the scheme where the seller will be paid for RM1.78 per kWh [8].

In 2012, a survey was conducted by Solangi et al. among the public in Malaysia to explore on their view and acceptance towards the solar energy [10]. The results showed that more than half of the participants is willing to purchase and install solar power system if the installation cost is 50% subsidies by the government. Also, around 80% of the participants will go for solar energy if the price is as close as the electricity generated from fossil fuel. The survey followed by the public awareness toward the incentives provided for renewable energy and more than half of the participants have no idea

about it [11]. Through this survey conducted, it is clearly that public perspective is focused on the installation cost and the lack of effectiveness in government awareness program. Thus, the reduction of the installation cost and government actions for increasing the awareness toward renewable energy will boost the development of solar energy in Malaysia.

2.3 Study of Building Integrated Photovoltaic (BIPV) system

Nowadays, the conventional fuel price is showing an increasing trend due to its decreasing availability [3]. This increasing trend of the price is predicted to be a continuous phenomenon in the future. For this reason, an early solar energy project, named Malaysia Building Integrated Photovoltaic (MBIPV) had been undertaken but the government of Malaysia [12]. This project was introduced to study the potential of solar energy and to encourage the development of the solar energy in Malaysia as a step to reduce dependency on the fossil fuel energy.

Under the MBIPV project, a study being conducted and the results showed that Malaysia is one of the countries in the whole world who has very high potential to produce electricity through solar PV system [12]. Eight cities within Malaysia (Kota Kinabalu, Penang, Kota Bharu, Kuching, Johor Bahru, Kuantan, Melaka and Kuala Lumpur) were selected in this study and used the same configurations for investigation. The results showed that Kuching ranged the fourth for the annual energy production for both roof-top system and facade system. Through the studies conducted under the MBIPV project, it is very clear that the solar energy has huge potential for supplying electricity in Malaysia.

Additionally, according to Ali, et al. [7], the BIPV system has a very high potential where it offers advantages. The advantages are that it required no extra land for locating the solar PV system and it reduces the transmission losses as the electricity is used at where it is generated. Recently, Malaysia is one of the countries with the fastest growing building industries around the world [3]. Thus, there will be an increasing demand for the electricity supply and the large available building space. These changes are indicating a huge potential for the implementation of BIPV technology in Malaysia.

Moreover, the properly sized BIPV system is able to cover the cost purchasing the electricity and it is possible to export the surplus back to the grid [3]. The authors also reported that a solar system with a capacity of 1kWp for every 10m² of rooftop area in either residential or commercial sectors, it is predicted that the system can generate the electricity at around 20% of the national energy demand.

2.4 Economic Feasibility of BIPV

According to the case study conducted in six different cases, the installation cost of a 2.5 kW solar PV system in Malaysia is around RM 47,800.00 [8]. This estimation is obtained through the results from the MBIPV project. Besides installation cost, the maintenance cost is estimated to be about RM478.00 annually. The average total revenue for all the six cases is between RM80,367.00 and RM167,517.00 for the operation of the solar panel within 21 years. The results showed that the annual return on investment ranged around

3% to 12% with the payback period of around 6 years to 13 years [8].

Moreover, a HOMER simulation is conducted by Heng et al. to determine the solar energy production for on grid system [13]. Before the simulation, the survey was conducted to obtain the monthly electricity consumption from 114 different participants. The simulation results showed that the monthly electricity consumption bills can be paid off by the electricity generated from the on-grid solar PV system and there will be an extra financial benefit. The profit for 1kW and 2 kW system for a 21-year full FiT contract are RM947.52 and RM1543.26 respectively [13]. As for 3kW and 4kW system, the revenue throughout the 21-year full FiT contract are much higher which is RM32408.46 and RM95382 respectively.

2.5 Types of Solar PV Panel

Three common types of solar PV panel available in today's market in Malaysia are monocrystalline, polycrystalline panel and amorphous thin film [14]. Although three of them are different in term of their appearance, efficiency, prices, and manufacturing process, but their working process is the same, which directly convert the solar radiation into electricity. Besides, all of these three types of panels are made of silicon. The best way to identify the type of panels is by observing the appearance. Generally, monocrystalline panels are black in color and octagonal in shape whereas the polycrystalline panels have inconsistent color and rectangular in shape [15].

The monocrystalline cells have been widely used in today's market due to they occupy 38% of all solar cell production in 2008 [16]. Monocrystalline panels are made by pure silicon which results in expensive price as compared to the other types of panels. However, the efficiency of the monocrystalline panels are considered as high due to the cells are aligned in one direction which enable the panels to catch most of the solar energy. Moreover, the monocrystalline panels generally produced by the smallest solar cells which are suitable to be installed on the rooftop [15].

Polycrystalline panels are the most widely produced solar cells in current solar cell production. Among these types of solar cells, the production of polycrystalline cells occupies 48% of world solar cell production in 2008 [16]. Polycrystalline panels have the cheapest price as compared to the other types of the panel due to they are made by polycrystalline cells. However, the efficiency of the polycrystalline panels are low due to the polycrystalline cells are aligned randomly in squares which enable the panels to catch the most of the solar energy as compared to monocrystalline panels. Furthermore, the polycrystalline panels are generally in rectangular blocks which are suitable to be used in large areas [15].

Amorphous silicon cells are made by a thin homogenous layer which consists of silicon atoms. As compare to the crystalline silicon, amorphous silicon is easier in absorbing light. However, the efficiency is low as compared to the crystalline solar cells [14].

Dobrzański, et al. [17] compared the electric characteristic of silicon solar cells. In this research, three different solar cells including monocrystalline, polycrystalline and amorphous have been tested on their efficiency, fill factor and maximum power output. The research found that the monocrystalline

silicon solar cell has the highest efficiency (22%), followed by the polycrystalline silicon solar cell (9%) and lastly is the amorphous silicon solar cell (8%). On the other hand, the maximum power output can be generated by monocrystalline, amorphous and polycrystalline at 130000 lx of radiation are 17.9 W/m², 14.12 W/m² and 6.29 W/m² respectively [17].

2.6 Potential of Solar PV in Malaysia

Malaysia is rich in renewable energy sources such as solar, hydro, the wind, biomass and tidal [18]. Other than hydropower, all the other renewable energy sources were built in small scale to generate electricity and supply to the rural area and for the small applications usage. Solar is one of the potential renewable energy sources that has not been fully developed in Malaysia. According to Borhanazad, et al. [2], Malaysia is located entirely in the equatorial region, making it a hot and humid country with the average ambient temperature ranged from 27 °C to 33 °C and average solar radiation of 4500 Wh/m² daily. With this natural conditions, several researchers were interested in developing the solar energy in some rural areas in Malaysia.

Borhanazad, et al. [2], studied the feasibility of implementing three sources of renewable energy which are solar, wind and hydropower in some poorest states (Sabah, Sarawak, Perlis, and Kedah) in Malaysia. The research found that the solar energy can be received in Sabah is between 4.25 kWh/m² and 5.29 kWh/m² per day, followed by Kedah, Perlis, and Sarawak, the average received solar energy is about 5.48 kWh/m², 5.26 kWh/m² and 5.12 kWh/m² respectively. Besides, the research also found that the maximum solar radiation received in Sabah and Sarawak is about 6.027 kWh/m² and 5.303 kWh/m² per day and therefore, there is a high potential of implementing the solar PV system in both states in Malaysia [2].

In addition, Kadirgama, et al. [19] studied and estimated the solar radiation in East Coast Malaysia. In this research, the location of solar radiation forecasting is located in Pekan, Pahang. Also, a period of one year is utilized to measure the solar radiation and solar energy. According to Kadirgama, et al. [19], the average solar radiation received in Pekan is about 982 W/m² per day and the solar energy produced is about 400 Ly per day (= 193.8 W/m²). Furthermore, this research also shows that a maximum of 1200 W/m² solar radiation can be received in Pekan, Pahang [19].

Azhari, et al. [20], also studied the solar radiation in Malaysia by using satellite images. The research showed that there is no significant different of solar radiation received in both East and Peninsular Malaysia. A maximum solar radiation around 5.56 kW/m² is received mostly in the Northern region of Peninsular Malaysia and Southern region of East Malaysia [20]. In this research, it shows that the solar energy has the highest potential to be used in the Northern region of Peninsular Malaysia due to this area receive the most solar radiation every month as compared to East Malaysia. However, it is found that some areas in East Malaysia also have the potential to apply solar energy system due to they are exposed to high solar radiation between May until November, whereas the lowest solar radiation is received from December to January [20-31].

Furthermore, Mekhilef, et al. [4] claimed that Malaysia has strong potential to implement large scale of solar power due to

Malaysia is located near to the equator. Moreover, this research also shows that Kuching has a yearly average solar radiation of 1470 kWh/m².

Jakhrani, et al. [21] also investigated the accessibility and potential of solar energy at five typical locations in Sarawak. In his works, it is claimed that Kuching can receive 15.44 MJ/m² (= 4.29 kWh/m²) of daily global solar irradiation which is measured at Kuching Weather Station.

Besides, Engel-Cox, et al. [22] evaluated the solar and meteorological data in eight cities located in Malaysia. From his work, it stated that Kuching has a mean daily global solar radiation of 4.19 kWh/m² per day.

2.7 Developing and Existing Solar Power System in Sarawak

A local energy development company, Sarawak Energy Berhad, has implemented the project of the solar home system (SHS) and expanded the solar freezer system (SFS) in a remote area at Batang Ai in Sarawak. In December 2014, Sarawak Energy has implemented the first phase of the SHS project at Rh Kino and Rh Manggat in Menyang. Besides, the second phase of the SHS project has been completed in February 2016, where the project is expanded to Rh Griffin, Rh Jangong, and Rh Ninting in Nanga Jengin and Ulu Delok. [32-41] These two phases have cost around RM 2 million were a total of 63 households have been installed with the SHS which benefiting more than 300 residents. Furthermore, with the succeed of the project and positive acceptance by the villagers, the third phase of the SHS project will be started in April 2016 where the project will cover Engkari area for Rh. Brown, Ng. Stapang to benefit 16 households and 80 residents [23][42-45].

3 Methodology

In this study, the methodology is divided into two different section for obtaining all the information required for conducting the feasibility study of the solar PV system in the residential area.

3.1 Site Analysis

The first thing to be considered in the feasibility study of an installation of solar PV system is the site analysis. The site analysis includes the collection of meteorological data and the structural layout of the roof space as well as the average household energy usage at the residential area.

Firstly, the meteorological data is related to the weather and climate of the location. This involves the study of the availability of the sunlight and any information that can be used for the calculation of the energy that can potentially be produced. In this section, two methods are being applied for obtaining the data regarding the potential of solar power system in residential Kuching. Both methods are calculated based on the 1W rating polycrystalline solar cell with a dimension of 120mm x 74mm. The solar irradiance obtained can be used to calculate the peak sun hours (PSH). PSH refer to the amount of time that the solar system received the peak level of solar irradiance at 1kW/m².

3.1.1 Method 1: Analytical Data

For this method, the light meter is used to measure the light intensity under the sun as shown in Fig. 1(a). After that,

the light intensity is converted to the solar irradiance by multiplying with a constant. Then, the solar irradiance is used for calculation of the power output by using the area of the solar cell.

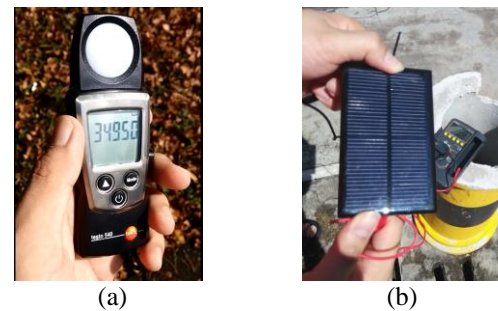


Fig. 1. (a) Light Intensity Collection by Light Meter (b) Measurement of Voltage and Current Output

3.1.2 Method 2: Experimental Data

For this method, the multimeter is used to measure the voltage and current output from a solar cell exposed the sun as shown in Fig. 1(b). By using the data collected, the power output of the solar cell is determined. Also, the power output is converted back to the solar irradiance.

Secondly, the analysis of the structural area of the rooftop is required for determination of the possible area for placements for solar panels and also the consideration of the possible obstacle and shadow problems that might affect the output of the solar PV system.

Lastly, the estimation of the average household electricity usage in a residential area is conducted to decide the size of solar PV system that is suitable for supplying the electricity and also the bill saving.

3.2 Economic Feasibility

After the site analysis, another main concern for the feasibility study of solar PV system is the economic feasibility. Economic feasibility depends on the capability of local people to invest for new installation and return of investment. In this section, the mathematical analysis was conducted for estimating the installation cost and the economic values.

For carrying out the estimation, the consultations were conducted with two companies locally in order to obtain all the basic information regarding the installation of solar PV system. The consulted companies are The Solar Energy Co. and the Ecogreen Solar Engineering Sdn. Bhd. The information obtained from the company consists of the area and price for a 1kWp solar PV system as well as some outcome information regarding the solar projects that have been carried out by them. The details of the calculation of economic feasibility have been discussed in the next sections.

4 Results and observations

4.1 Meteorological Data

Due to the limitation of time frame for this research project, the meteorological data was collected within a four weeks period starting from the 5th April to 2th May 2016 whereby the data was collected in the residential area in Sekama, Kuching.

4.1.1 Analytical Results (Method 1)

The light intensity was collected using the light meter at the selected location. The data collected was then converted to solar irradiance using an approximate value of 0.0079 W/m² per Lux. The conversion value is approximated because there is no direct conversion between light intensity and solar irradiance as light varies with its own wavelength and color. The calculated average daily solar irradiance in Kuching was plotted in Fig. 2. Based on the plotted graph, it can be clearly seen that the daily solar irradiance fluctuates around the 600 W/m² to 750 W/m² except for some data that was collected during the cloudy and rainy day. The orange line in the graph indicates the average solar irradiance in Kuching which is 636.19 W/m².

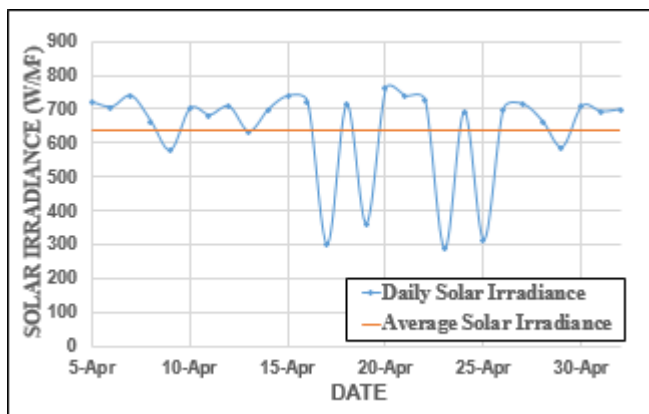


Fig. 2. Average Daily Solar Irradiance In Kuching (5th April – 2nd May 2016)

Besides, the average solar irradiance is also converted to the power output by multiplying with the area of the 1W rating solar cell so that the value can be compared against the experimental results. The area of the 1W rating solar cell and the output power are computed as shown in the equation (1) and (2).

$$\text{Area} = 0.12 \text{ m} \times 0.074 \text{ m} = 0.00888 \text{ m}^2 \quad (1)$$

$$\text{Output Power} = 636.19 \text{ W/m}^2 \times 0.00888 \text{ m}^2 = 5.65 \text{ W} \quad (2)$$

4.1.2 Experimental Results (Method 2)

Similarly, as the method 1, the output voltage and current of the solar cell are measured by using the multimeter at the same location. The measurement for daily output voltage and the current was plotted in the Fig. 3. Moreover, the output power of the solar cell was calculated according to the measurement of the output voltage and current and the results were plotted in the Fig. 4.

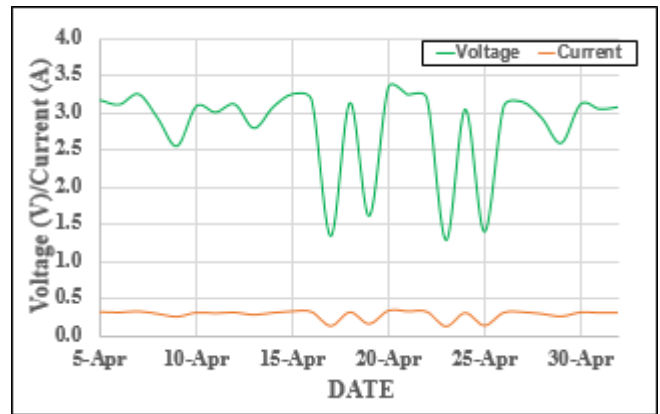


Fig. 3. Average Daily Output Voltage and Current for the Solar Cell in Kuching (5th April – 2nd May 2016)

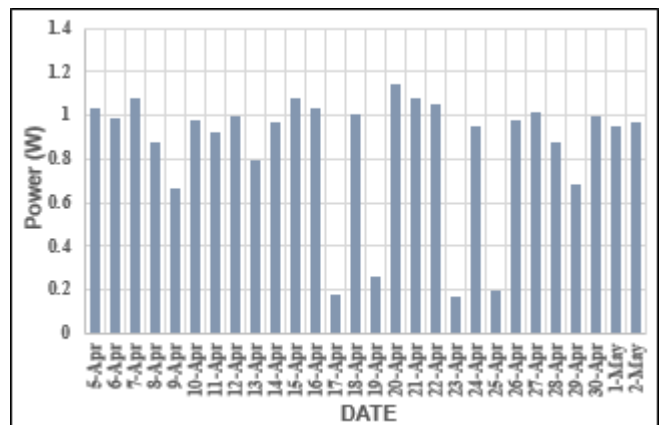


Fig. 4. Average Output Power for the Solar Cell in Kuching (5th April – 2nd May 2016)

After the data being collected for both output voltage and current from the solar cell, the average power output of the solar cell is calculated as 0.85 W. Then, the power output is converted back to solar irradiance by using the ratio method to map the area of the solar cell to 1 m². The calculation is shown in the equation (3).

$$\text{Solar Irradiance} = 0.85 \text{ W} \div 0.00888 \text{ m}^2 = 95.72 \text{ W/m}^2 \quad (3)$$

Through the results obtained from both analytical and experimental method, there is a huge different in the solar irradiance and power output. The possible reason for this observation is that the solar cell used in the experiment is limited to the only 1W rating. Another possible reason is that the solar cell does not utilize the overall surface area as there are conductors and separators located on top of the solar cell

and this reduces the amount of solar irradiance received by the solar cell. Thus, the solar irradiance calculated from the experimental result is not suitable for further calculation of the PSH.

The average solar irradiance obtained from the analytical result is used to calculate the PSH. The calculation is made based on a consideration of six hours daily sunlight exposed as shown in the equation (4).

$$PSH = 636.19 \text{ W/m}^2 \times 6 \text{ hours} = 3.820 \text{ kWh/m}^2 = 3.82 \quad (4)$$

4.2 Rooftop Structural Area Data

The most common type of home in Malaysia is a terraced house. Through some study, it was found that the available rooftop area for a terraced house ranges from 50m² to 150m². This surface area is considered large enough for installation of the small scale solar PV system in the residential area. However, there are also some important factors to be considered in order to determine the suitability for the installation. The factors are including the design consideration of the rooftop, possible shading or obstacles issues and also the ability to carry the additional weight of the solar system.

4.3 Household Electricity Usage Data

By asking some questions from the households in the residential area, it was found that the average household electricity usage ranges from RM 60 to RM 150.

4.4 Solar PV System Data

4.4.1 Information Obtained through Consultation

The information collected through the consultation with the Solar Energy Co. was tabulated in the TABLE I. below.

TABLE I. INFORMATION REGARDING 1kWp SOLAR PV SYSTEM

For 1kWp Solar PV System	
Rooftop Area Required	8 ~ 9m ²
Pricing	
Grid Connected System	RM 8000 ~ RM 10000
Off Grid System	RM 28000 ~ RM 40000
Peak Sun Hours In Kuching	3.7 PSH

From the TABLE I. above, it was observable that the price for off-grid solar PV system is much higher as compared to the grid connected system. According to Mr. Lawrence Tan, the huge difference in price for both systems is due to the requirement of battery and charge controller in the off-grid solar PV system [24]. Also, the PSH used by the company in designing the solar PV system in Kuching is 3.7 hours.

Besides, Mr. Tan also shared some information regarding the 4kWp grid connected solar PV system that was installed in his own house four years ago. At that time, the installation cost is about four times more expensive than the current pricing. The electricity generated from the solar PV system is sold back to the grid at the same rate as what have been consuming for daily activities. At the end of the consultation, Mr. Tan told us that the bill saving for the 4kWp solar system installed was around RM150.00 a month.

The second consultation was conducted with the Ecogreen Solar Engineering Sdn. Bhd. and the information regarding the solar energy system was tabulated in TABLE II. .

TABLE II. BASIC INFORMATION REGARDING SOLAR PV SYSTEM

For 1kWp Solar PV System	
Rooftop Area Required	Solar Panel = 6m ² Walkway = 3m ² Total = 9m ²
Pricing	
Grid Connected System	RM 10 per 1Wp
Off Grid System	Depend upon the type of battery and the load of the system
Peak Sun Hours In Kuching	4.0 PSH (NASA)

Based on the information obtained, it can be seen that the rooftop area required and the current pricing for the 1kWp grid-connected solar system are almost the same for both companies. According to Mr. Alex Ling, the price for off-grid system varies with the type of batteries and the load of the system [25]. Also, the PSH value used by the company is 4.0 and this value was obtained from NASA.

During the consultation, Mr. Ling shared the 10kWp Hybrid Solar System that was installed as the rooftop for their carpark. The system cost around RM 200k. The hybrid system is a combination of the features from both on-grid and off-grid system where it has a battery storage. This means that the system can provide electricity even if there is a power blackout.

4.4.2 Calculation by using Experimental Results

The experimental result is used to calculate the amount of electricity that can be generated. In order to compare against the data obtained from Mr. Lawrence Tan, the calculation was made for a 4kWp grid connected solar system. According to Mr. Tan, the electricity generated can be calculated by multiplying the solar system capacity with the PSH. Thus, the calculation was made by using the experimental result of 3.82PSH as shown in the equation (5).

$$\text{Energy Generated} = 4\text{kWp} \times 3.82\text{PSH} = 15.28 \text{ kWh/day} \quad (5)$$

$$\text{Energy Generated} = 458.4 \text{ kWh/month}$$

From the website of Sarawak Energy Berhad, the electricity rate per unit for residential area is 29.5 cent for 1 to 500 units per month. Thus, the monthly bill saving can be calculated as shown in the equation (6).

$$\text{Bill Saving} = 458.4 \text{ kWh} \times 29.5 \text{ cent} = \text{RM } 135.23 \quad (6)$$

The calculated amount is slightly lesser than the information given by Mr. Tan. The reason is that this value is calculated by considering only the peak sun hours and there is still a little amount of energy generated during the off-peak hours.

5 Discussions

5.1 Analysis of the Potential of Solar System

From the analytical data collected, it can be seen that the solar irradiance is quite stable throughout the four weeks' period unless there is the cloudy or rainy day. By analyzing all the results obtained in this research, the available solar irradiance and peak sun hours in Kuching are enough for generating the electricity that can cover the daily energy usage.

5.2 Analysis of Rooftop Area

Both Mr. Tan [24] and Mr. Ling have mentioned that an approximate of 9m² of rooftop area is required for a 1kWp solar PV system. As the terraced houses located at Sekama residential area were found mostly to be a terraced house, therefore, the capacity of the solar PV system can be calculated from the rooftop area of the terraced house. Generally, the minimum rooftop area of the terraced house is approximate 50m². Since 9m² of the rooftop area is able to generate 1 kWp of solar PV system, therefore a small scale solar PV system with the capacity ranged from 1 kWp to 5 kWp can be installed at the terraced house at Sekama residential area. The capacity of solar PV system can be increased as the area of rooftop increased due to more solar irradiation can be received by the solar PV panel. This result shows that the solar PV system is suitable to be installed in a terraced house in Sekama residential area.

5.3 Analysis of Economic Feasibility

A consultation was conducted with Solar Energy Co. to obtain the performance, capacity and installation cost of the rooftop solar PV system for payback period calculation purpose. With the information, the economic value of the solar PV system with capacity ranged from 1 kWp to 5kWp had been evaluated. The findings showed that the economic value generated is similar for all the different system capacity.

Therefore, in this research, a 4 kWp of solar PV system is taken to calculate the payback period. From the solar consultation company, the installation cost of a 4 kWp solar PV system with grid connected system is rated at around RM 40,000. According to Mr.Tan [24], this 4 kWp is able to save around RM 150.00 per month of the electricity expenses. Therefore, it is calculated that the payback period of the entire 4 kWp solar PV system is around 22.22 years. This result shows that the solar PV system is considered as long term investment. However, the payback period is still considered as acceptable and reasonable as it can lower the electric bills and carbon footprints for the entire lifetime of the solar power system. The investment turns positive right after 22 years. This value will drop if the installed system manages to join the FiT system by Sustainable Energy Development Authority (SEDA) Malaysia. For system up to 4kWp, the FiT Rates would be RM 0.82 per kWh produced.

Last but not least, the recommendation was made based on the findings where the installation of grid-connected solar PV system at a residential area in Kuching is encouraged. The reasons include the bill saving per month and the profit that can be generated right after the investment turns positive.

6 Conclusion

To conclude, the solar power system is feasible to be installed at the Sekama residential area due to this area is able to receive sufficient solar irradiation from sunlight. Besides, a consultation with a solar expert has been done to obtain the information such as performance, capacity and installation cost of the solar PV system. Throughout the experimental results and consultation, the capacity of the solar PV system that can be installed in Sekama residential area was calculated. Moreover, the payback period of the solar PV system is calculated and considered as reasonable and worth to invest by the residents in Sekama residential area. Overall, the grid-

connected solar PV system is found to be feasible for installation at Sekama residential area.

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