POTENTIAL SAVING AND RETURN OF INVESTMENT OF SOLAR PANEL SYSTEM INSTALLATION FOR RESIDENTIAL IN MALAYSIA

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FACULTY OF ENGINEERING
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POTENTIAL SAVING AND RETURN OF INVESTMENT OF SOLAR PANEL SYSTEM INSTALLATION FOR RESIDENTIAL IN MALAYSIA

ABSTRACT

Nowadays, electrical demand is getting to increase in residential area. Annually, there are 3% of electrical consumption increase in residential. Therefore, the electrical price is followed to increase. Besides that, non-renewable energy source is gradually depleting. Hence, renewable energy had been introduced to replace the non-renewable energy source. Due to Malaysia is in a strategical location, solar photovoltaic (PV) system is the renewable energy to promote to implement in Malaysia. In addition, solar PV system is a suitable solution to reduce the household electricity bill by selling back the solar energy back to the electrical grid. Along the year, Malaysia government implemented several policies to expand the usage of renewable energy in Malaysia such as Feed In Tariff (FiT) scheme and Net Energy Metering (NEM). However, people still did not convince on the performance of the solar PV system. This research study provides the analysis of solar energy production in three different locations to illustrate the potential saving. The potential saving based on three different location is up to 50% from the initial electricity bill with assumption of 2% increment on the electrical tariff. The return of investment for the solar panel system is fall in between 33% to 38% based on three different locations.

Keywords: Solar Photovoltaic, Feed in Tariff, Net Energy Metering, Renewable Energy.

POTENTIAL SAVING AND RETURN OF INVESTMENT OF SOLAR PANEL SYSTEM INSTALLATION FOR RESIDENTIAL IN MALAYSIA

ABSTRAK

Pada masa ini, permintaan elektrik semakin meningkat di kawasan perumahan. Setiap tahun, terdapat 3% peningkatan penggunaan elektrik di kediaman. Oleh itu, harga elektrik diikuti untuk meningkat. Selain itu, sumber tenaga yang tidak boleh diperbaharui secara beransur-ansur habis. Oleh itu, tenaga boleh diperbaharui telah diperkenalkan untuk menggantikan sumber tenaga yang tidak boleh diperbaharui. Oleh kerana Malaysia berada di lokasi yang strategik, sistem solar photovoltaic (PV) adalah tenaga yang boleh diperbaharui untuk dipromosikan untuk dilaksanakan di Malaysia. Sebagai tambahan, sistem PV suria adalah penyelesaian yang sesuai untuk mengurangkan bil elektrik isi rumah dengan menjual kembali tenaga suria ke grid elektrik. Sepanjang tahun ini, kerajaan Malaysia melaksanakan beberapa dasar untuk memperluas penggunaan tenaga boleh diperbaharui di Malaysia seperti skema Feed In Tariff (FiT) dan Net Energy Metering (NEM). Namun, orang masih tidak yakin dengan prestasi sistem PV solar. Kajian penyelidikan ini memberikan analisis pengeluaran tenaga suria di tiga lokasi yang berbeza untuk menggambarkan potensi penjimatan. Potensi penjimatan berdasarkan tiga lokasi berbeza adalah hingga 50% dari bil elektrik awal dengan andaian kenaikan 2% pada tarif elektrik. Pulangan pelaburan untuk sistem panel suria adalah antara 33% hingga 38% berdasarkan tiga lokasi yang berbeza.

Keywords: Solar Photovoltaic, Feed in Tariff, Net Energy Metering, Renewable Energy.

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LIST OF SYMBOLS AND ABBREVIATIONS

MIDA	:	Malaysian Investment Development Authority
PV	:	Photovoltaic
MSW	:	Municipal Solid Waste
SREP	:	Small Renewable Energy Power
kW	:	Kilowatts
kWh	:	Kilowatts Hour
TNB	:	Tenaga Nasional Berhad
ROI	:	Return of Investment
NEM	:	Net Energy Metering

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CHAPTER 1: INTRODUCTION

1.1 Background

The uses of fossil fuels to generate electricity is one of the factors which create the global warning issues and climatic changes. Many countries are highly dependent on fossil fuels especially for the industrial sector. Following the increase of energy demand, government across the world are encouraging to invest in the renewable energy sector.

Clean and environmentally friendly renewable energy is becoming increasingly popular. With the growing demand for renewable energy, the progress on technology development is on the rise globally. Solar energy has become one of the importance sources of renewable energy. It could use for electricity generation, water heating and desalinating. Solar technology evidently produces almost no harmful emission with unlimited energy production due to the lifespan of the sun which predicts the use of renewable energy to increase exponentially. By using solar energy, it will help to reduces the emissions of greenhouse gases and fossil fuels. The main technology for the solar energy is Photovoltaics (PV) system. The main principle of the PV system is to convert the sunlight into electricity and distribute to the grid by collect sunlight from solar panel. The electricity bill can be reduced by contracting the solar energy into it.

The Malaysian Investment Development Authority (MIDA) under the National Renewable Energy Policy and Action Plan is aiming to accomplish 2,080 megawatts (MW) of renewable energy by 2025. The demand of solar energy is expected to rise as the government is moving toward to the renewable energy direction. However, there are some confusion and obstacles which is blocking the consumer to invest on the solar energy especially the cost of the solar panel installation. Nowadays, the technology to produce the solar panels is getting mature and the cost had been reduced drastically. It is one of the factor to increase the market share of solar technology in the world.

1.2 Problem Statement

Solar technology is getting famous and mature in current situation. However, the knowledge related to the solar technology is not widely spread in the community. Community do not have the awareness on the solar technology application. Solar technology such as photovoltaic (PV) system is one of the famous systems installed in the residential area. Solar PV is design to collect the solar energy from the sun and convert into the electricity for daily consumption. This research is to focus on the solar panel system install at the residential area. Study on the investment cost of the solar panel system by comparing to the electricity consumption before and after the installation of the solar panel system. In addition, the solar collection throughout the year (2020) to proof the solar energy sufficient for the electricity usage for a residential house. Community having the doubts of the performance from the solar panel system is not sufficient for the daily usage. Besides that, the potential saving from the solar panel system will be tabulated to proof the solar panel system is worth for investment. Discussion on the cost of the investment and potential saving in 10 years' time to encourage the installation of solar panel system.

1.3 Objectives

The objective of this research is to investigate the potential saving from the solar panel system based on solar data from year 2020. To increase the accuracy of the solar energy production data analysis, this research study will find out the solar harvesting from the solar panel system at three different locations: Penang, Selangor, and Johor. Different location is exposure to different solar radiation and generate different output of solar energy. In this case, three different location which are from northern, central, and southern used as the baseline to investigate the estimation output of the solar panel system. This research study also investigates the analysis method of the solar energy production is capable to supply the demand of household electrical appliances. Meanwhile, the electricity consumption per residential house will be discussed and tabulated for analysis. Besides that, this research intends to validate the return of investment for the solar panel system and the payback period of the solar panel system investment.

1.4 Scope of Research Study

The research study will focus on three main areas in Malaysia: Penang (Southern), Selangor (Central), and Johor (Northern). Different area of locations provides the variance on the solar output. The solar data for year 2020 will extracted from the software and use for data analysis to determine the solar output of each location. The potential saving will be calculated based on a standard residential house electricity consumption to determine the annual saving after the implementation of the solar panel system for ten-year period. In addition, the assumption increase of inflation rate for the electricity tariff will also put into the consideration for the saving calculation. Maintenance cost of the solar panel system is unavoidable, and it will be affected the potential saving calculation. However, well maintained on the solar panel system will prolong the lifetime and it is providing the opportunity for a longer period of saving.

CHAPTER 2: LITERATURE REVIEW

2.1 Renewable Energy in Malaysia

Malaysia is a country which is still heavily depending on the non-renewable source such as fossil fuel and natural gases to generate the energy. In order to moving towards to the green technology, Malaysia government had developed various of policies and programs to promote the use of renewable energy. In addition, Malaysia government also developed the programs to increase the awareness of the importance of the role of renewable energy in current situation. To achieve the green environment goal, green technology application is widely promoted in Malaysia with the support by government. However, the support from the non-government agencies and public are strongly needed to helping Malaysia moving towards to a green environment country. Malaysia government taking proactive step to coordinate, promote and use energy generated from the renewable energy. The implementation of proactive action is not only limited to residential area, but also involve the industrial area to extend the development of the green technology.

The trend of using renewable energy source is increasing drastically among the worlds. This is due the depletion of the non-renewable energy sources among the worlds. Besides that, this is also because of the greenhouse gas reduction. Utilization of the non-renewable energy is increasing the greenhouse emission and creating the big impact on the environment. To reduce the consumption of the non-renewable energy, new energy source shall be discovered. Hence, the green technology application to generate the energy is strongly promoted to achieve the greenhouse emission reduction and environment friendly. Malaysia government also emphasis on the energy efficiency produced by renewable energy to ensure it is sufficient to support the daily electricity consumption and increase the utilization of renewable energy in residential house area. 2

Malaysia government is looking into possible renewable energy sources to implement such as hydropower system, solar PV system, hydrogen fuel cells energy system, wind power energy, energy generated from municipal solid waste (MSW) and nuclear power energy. The first renewable energy developed in Malaysia was hydropower system which listed in Four Fuel Diversification Policy in 1981 (Oh, Pang, & Chua, 2010).

Moreover, Malaysia has great potential for the solar energy system due to the strategically location near to the equator (Abdullah, Osman, Ab Kadir, & Verayiah, 2019). Ahmad, Kadir, and Shafie (2011) concluded that the condition of Malaysia is always hot and provide sufficient solar energy for all year long even there is rainy season during end of the year. Annually, total solar energy in between 1400 and 1900 kWh/m^2 will be available for the solar PV system based on a daily average of 12 hours of sunshine. Estimation of 6500MW will be generated from the solar energy. Malaysia has the highest to achieve this target due to the strategical location. In addition, solar irradiation in Malaysia is achieving the peak target during the Northeast monsoon. Generally, Malaysia is highly suitable for solar PV system due to the weather in Malaysia is hot and sunny all year long(Abdullah et al., 2019).

2.2 Government Initiatives

Several policies and programs had been rolled out by Malaysia government to promote the renewable energy. In year 2011, Renewable Energy Act had been developed and Feed-in-Tariffs (FiT) had been introduced to speed up the implementation of the renewable energy. Malaysia government target to have the achievement of 20% of renewable energy in the energy mix by year 2025. Total of five objectives had been populated to improve the utilization of the renewable energy in Malaysia which are (i) to increase renewable energy contribution in the national power generation mix, (ii) to facilitate the growth of the renewable energy industry, (iii) to ensure reasonable renewable generation cost, and (v) to enhance public awareness. In other research study, solar leasing program in Malaysia offer a great opportunity to the end user to implement the solar PV system. Most of the end user facing the problem to pay off the one times investment cost. Bank sectors offer zero percentage installment plan up to 36 months to encourage the end user to install the solar PV system. Besides that, the packages offered by solar company is providing end to end service when end user agree on the implementation. This help to reduce the risk of uncertainty happen during the implementation period. The electrical tariff rate in Malaysia have inflated at a rate of 4.5% year on year. This will help to promote the solar PV system which able to offset the electricity bill every month from the scheme and program provided by Malaysia government (Abdullah et al., 2019). In this aspect, the solar energy which could convert to electricity is providing the realized profit to the end user depending on which program they registered.

2.2.1 Feed-in-Tariff (FiT) Scheme

Malaysia government launched the Small Renewable Energy Power (SREP) program and implemented the small-scale FiT to encourage the uses of renewable energy in May 2001. FiT scheme is the renewable energy payments of electricity which simulate the exportation of electricity as a form of investment. Generally, there will be two meters require to install to differentiate the monthly consumption and monthly electricity exported to the distribution grid. From the monthly electricity exported meter, end users will receive the payment from the government. FiT scheme had proven successfully in other country to expedite the renewable energy implementation, reducing the carbon emissions and provide the job opportunity to the community. To ensure the succeed of FiT scheme, Chua, Oh, and Goh (2011) concluded several key factors: (i) stability of the scheme, (ii) long contract period, (iii) adequate energy prices, (iv) annual payments reduction to stimulate the rapid implementation of renewable energy and to be more competitive, (v) offer various payment based on the technology, project size and resource, (vi) incorporate the FiT into utility to ensure the payments. Solar energy application is expected to grow drastically due to the FiT scheme especially in the residential area.

2.2.2 Net Energy Metering (NEM) Program

During year 2018, NEM program was launched and replace the FiT scheme. The NEM program is to compensate the electricity bill by applying a net excess rate of 31sen/ kWh while the electricity selling cost is at 50sen/kWh. This NEM program target to promote the solar PV system in residential area. Malaysia government had set a quota of 500MW on NEM program. The NEM program is targeted to attract more user to invest on their own houses. Same selling price and buying price of electricity cost has been offered starting from year 2019. For the residential house, which is three phase system, the maximum capacity of solar PV system design is up to 10kWac. While the residential houses which is single phase system, the maximum capacity of solar PV system design is up to 4kWac.

Besides that, Malaysia government also launched the NEM program for the industrial area. This is very useful for the commercial building which have high load period during daytime. The solar energy produced from the solar PV system is directly consume by the building. Tan and Chow (2016) concluded that NEM scheme is more suitable to promote the solar PV system as the cost of PV is getting decrease. By comparing NEM and FiT, the potential saving is not having a big difference. The advantage of NEM is the monthly solar energy produced from the solar PV system excess the electricity consumption from the user can be stored as credit and used for the subsequent month in case of the solar energy produced is lower especially during the fourth quarter. The credit will be stored as kWh and it will not expired for up to 24 months. NEM is bringing the benefits of green environment and assure on the electrical tariff change in the future (Vaka, Walvekar, Rasheed, & Khalid, 2020). However, the low tariff rate of NEM is the challenges for Malaysia government to promote the solar PV panel system. Target of 20% increment on 11MW of solar energy was set by Malaysia government. The concept of the NEM is straight forward. The solar energy generated from the solar PV panel system will be consumed immediately to the household appliances. Then, the excess energy will only transfer back to the electrical grid and store as credit to deduct on subsequent month.

2.3 Solar PV System

To design the solar PV system, there are two main criteria to evaluate which are the surface area of the roof and determine the value of solar radiations. By providing the available space on the roof, an estimation of the solar PV capacity can be computed. And, the solar radiation will be computed the solar energy production (Ali, Shafiullah, & Urmee, 2018). To further simulate the result, the energy demand of the electrical appliances needs to be considered. List of electrical appliances with its power consumption and usage time required to tabulate (Ahsan, Javed, Rana, & Zeeshan, 2016). Typically, two key steps are used to perform the estimation of the solar PV system. The first step will be available space of roof area. The second step is to compute the solar radiation data based on the requirement to calculate the estimated potential solar energy could produce from the system (Ali et al., 2018). By prepared the required information, a solar PV system can be designed and proposed to the end user.

Few studies have focused on the solar energy production to ensure the sufficient solar energy to convert into electricity and supply to the end user. Malaysia is a country which have the great potential for the solar energy harvesting. Annually, the solar irradiation in Malaysia is 4.21 kWh/m^2 to 5.56 kWh/m^2. During August and November, the solar irradiation is the highest and estimated to reach 6.8 kWh/m^2(Shafie, Mahlia, Masjuki, & Andriyana, 2011). With this amount of solar irradiation, the solar PV system able to supply the electricity to the end user from the solar energy harvested. In addition, design and sizing of the solar PV array and battery storage for a solar PV system is a critical part of the system design. This requires the solar radiation data and energy consumption to populate the data. Generally, a solar PV system will require the components such as solar PV panels, solar converter, export meter, and battery storage (optional). The battery storage is not a must in the solar PV system design. The main reason is the solar energy will convert to the electricity and offset to the normal electricity consumption for NEM program. Before year 2019, the electricity generated from solar PV system will be sold back to the electrical grid and gain the realized profit to the end user.

2.3.1 Type of Solar PV Panel

There are three major type of solar PV panel used in residential area which are mono-crystalline type, poly-crystalline type, and thin film type. Akhter, Mekhilef, Mokhlis, Olatomiwa, and Muhammad (2020) had completed the performance assessment on different type of the solar PV panel. In term of performance, poly-crystalline type solar PV panel is the most suitable option for the solar PV system. However, the most cost-effective solar PV panel require further analysis. Due the demand on the solar PV panel, the technology on the solar PV panel has increased drastically. In the other research, Amin, Lung, and Sopian (2009) providing the analysis on the type of solar panel. Mono-crystalline type solar PV panel outpower increase with the solar irradiance and its power becomes highest among the other type of solar panel when the solar irradiance level is achieving 1000W/m^2. The output power from Poly-crystalline type solar PV panel increases with the change of solar irradiance level. When the solar irradiance level is high, the output power is become high. However, solar irradiance level will affect on the temperature of the solar PV panel and impact on the solar output when the temperature is high. For the thin film type solar PV panel, the output power is high even the solar irradiance level is low. It has the good light absorption feature, and the output power will not impact by the temperature of the solar PV panel. The average temperature of the solar panel installed in Malaysia is at a average of 42°C. As a conclusion, Malaysia is a country which is suitable to implement the solar PV system due to high availability of sun hours and stable weather condition. Based on the research, the thin film type solar panel is highly recommended to use in Malaysia followed by mono crystalline type and poly crystalline type of solar PV panel.

Total power generated from the PV panel can be calculated based on equation below:

$$P_{PV} = nVi$$

Where n is the number of the solar PV panel, V and I are the voltage and current of the PV panel. With this result, the number of solar panels will be calculated and the space required for the solar PV panel can be determine (Aghamolaei, Shamsi, & O'Donnell, 2020).

Besides that, the solar energy generated from the solar PV panel will be impacted by the angle of the solar panel installation. The optimum tilting angle of the solar angle provide the maximum solar energy absorption. To decide the optimum tilt angle, the maximum amount of direct beam radiation is equal to the site's latitude. Different type of the roof top require different type of the angle installation for the solar PV panel (Othman & Rushdi, 2014). In addition, different angle of the solar PV panel will affect on the electricity generation from the solar absorption. But the efficiency of the solar PV panel will not be impacted by the angle of the installation. Generally, the tilt angle of the solar PV panel will be set in between 20° to 60° to ensure the sufficient electricity power generation from the solar PV panel system. Figure 2.1 illustrated the different type of roof will have different type of the solar PV panel installation.

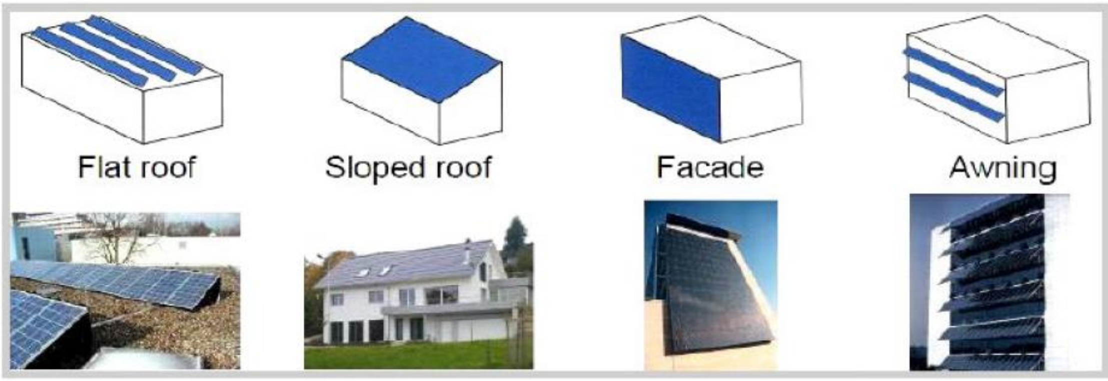

Figure 2-1 Type of the solar PV Panel Installation on roof

Maintenance on the solar PV panel is one of the considerations when the end users are making decision on the solar PV panel system investment. Typically, the solar PV panel is manufactured to withstand the difficult weather. Solar PV panel manufacturer is providing 20-25 years of warranty to safeguard the damage on the solar PV panel. However, there is a main concern on the dust accumulation on the solar PV panel. Hence, the angle of the solar PV panel is playing an important role to extend the life span. With the optimum angle of solar PV panel installation, system will provide the maximum solar absorption and prevent the dust accumulation on the solar PV panel.

2.4 Return on Investment (ROI) and Payback Period

Saving from the solar PV panel system is the first consideration of the end user when they wanted to implement the solar PV system. ROI and payback period become the reference for the end user when they are making the decision. Annual potential saving can be calculated based on below:

$$Annual\ Saving = (E_m - E_{solar}) \times Tariff\ rate \times 12 months$$

Where E_m is the monthly energy consumption, E_{solar} is the solar energy produced from the solar PV panel system, and tariff rate is the electrical tariff rate in Malaysia. Formica and Pecht (2017) did the ROI analysis and minimum of 23.6 % of annual ROI is the expectation from the end user. The payback period can be calculated based on the total investment amount divided by the annual saving from the solar PV panel system. As a conclusion, solar PV panel system technology shall improve in the future to bring down the investment to increase the end user interest to invest on solar PV system. Besides that, to make the investment on solar PV system become more attractive, Lau, Muhamad, Arief, Tan, and Yatim (2016) found out that grid connected solar PV system is not advisable to install the battery storage. If the solar PV panel system is connected the grid under Malaysia government scheme, this might increase the cost of the investment on the solar PV panel system. This would be the additional cost impact on the ROI and increase the payback period.

CHAPTER 3: RESEARCH METHODOLOGY

A process flow to execute this research study had been developed and shown in Figure below. Several steps had been defined to perform the evaluation of the potential saving from the solar panel system.

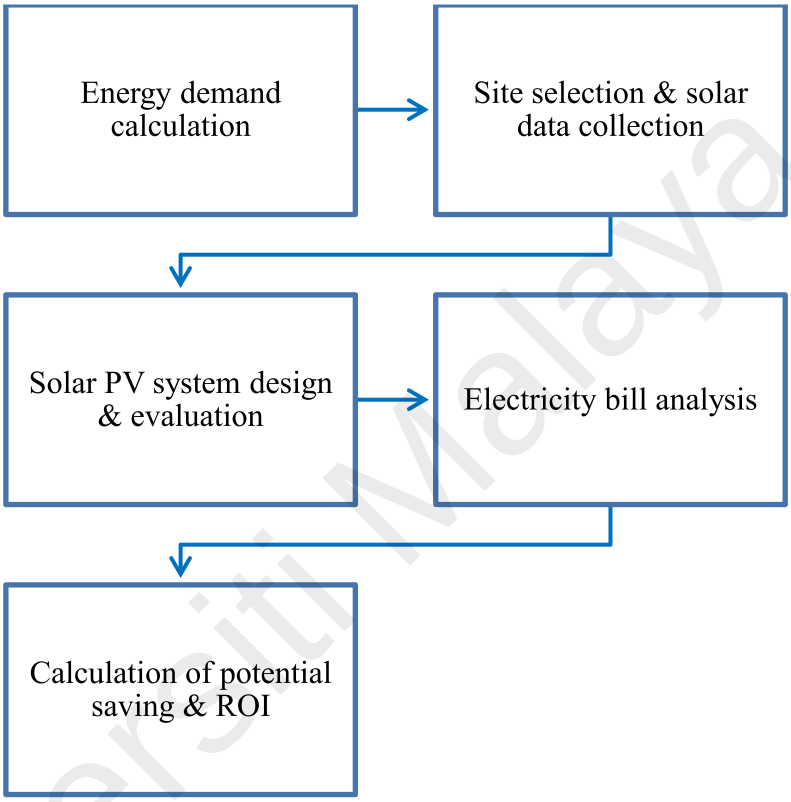

Figure 3-1 Flow Chart of Research Methodology

3.1 Electricity Demand for Residential House

For this research study, daily electrical consumption for a double storey house had been assumed to perform the analysis. Capacity of Solar PV system designed based on the electricity demand. In Malaysia, electrical supply to a double storey house is single phase system. Akhter et al. (2020) concluded the mathematical formulation to calculate the monthly energy demand. The monthly total energy demand is computed by using the equation below:

$$E_m = N \times P \times t \times d$$

Where E_m = monthly energy demand (kWh), N = number of equipment, P = power rating of electrical appliances, t = daily operating hours, d = number of days in a month. To simulate the energy demand for the residential house, a set of information for the electrical appliances has been populated in Table 3.1.

Table 3-1 Electrical Demand of Electrical Appliances

Electrical Appliances	Power (kW)	Quantit y	Time (hour)	Energy Demand (kWh)
Coffee maker	1	1	0.167	0.17
Microwave	0.9	1	0.167	0.15
Toaster	1	1	0.167	0.17
Washer	0.4	1	1.000	0.40
Dryer	3	1	0.250	0.75
Iron	1.2	1	0.333	0.40
Ceiling fan	0.1	4	4.000	1.60
Laptop	0.065	3	4.000	0.78
Monitor	0.15	1	4.000	0.60
Television 36"	0.1	2	4.000	0.80
Air conditioning	1.15	4	8.000	36.80
Light	0.02	15	4.000	1.20

Generally, a total of 43.81kWh of the energy usage will be required for a residential to consume in daily basis. The weather in Malaysia is sufficient for the solar energy production. Daily sun hour in Malaysia can achieve up to 12 hours and the peak sun hour is fall in between 4-5 hours. To further analysis the energy demand for each month. Day of the month had put into consideration and the details calculation for the energy demand for monthly usage had been shown in Table 3.2.

Table 3-2 Monthly Energy Consumption of Residential House

	Day of the Month	Energy Consumption per Month (kWh)
January	31	1358
February	29	1271
March	31	1358
April	30	1314
May	31	1358
June	30	1314
July	31	1358
August	31	1358
September	30	1314
October	31	1358
November	30	1314
December	31	1358
		16036

Total energy of 16036 kWh per year is require for a residential house. Details of consumption of each month had been tabulated. It will use for the analysis for solar power generated each month to have the overview on the energy savings.

3.2 Site Location

Due to different areas will provided variance on the solar radiation. For this research, three locations had been selected to perform the three scenario of case study for the output solar PV system. Three selected locations are Penang, Selangor, and Johor. The selected locations are distributed at southern, northern, and central. The main reason of the different area is to obtain the different solar radiation data to proof that every location in Malaysia is suitable for the solar PV system installation. The latitude and longitude for Penang are 5.269507, 100.429239. The latitude and longitude for Selangor are 2.819615, 101.512641. The latitude and longitude for Johor are 2.378996, 103.016508.

3.3 Solar PV System and Design Specification

In Malaysia, the electricity supply for a residential house is single phase system. With this requirement, a solar PV system with capacity of 5.01kWp had been selected to perform the analysis. The components for the solar PV system are PV panels, solar inverter, PV meter, and Battery Storage (optional). Solar PV system design illustrated as Figure 3.1.

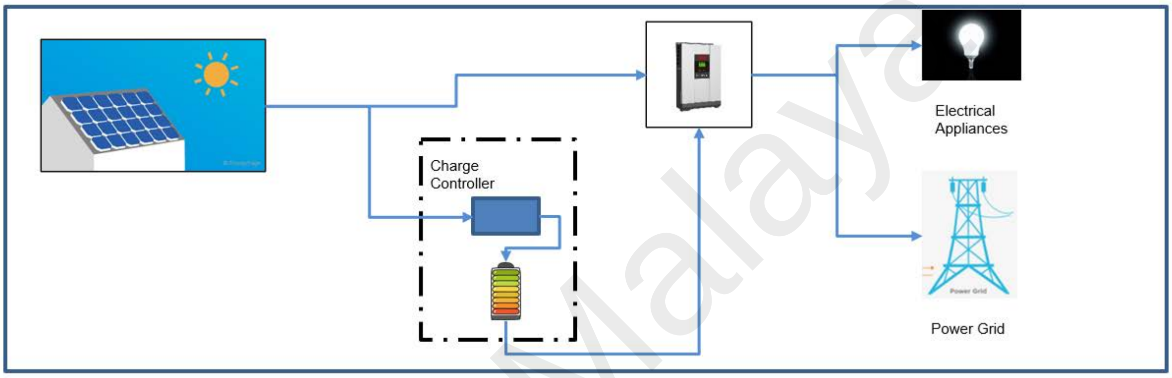

Figure 3-2 Solar PV System

Solar panel from QCELLS had been selected for the study. The data specification for the solar panel as follows:

- Dimension: 2080mm x 1030mm x 35mm (including frame)
- Weight: 24.5 kg
- Cell: 6 x 24 monocrystalline Q.ANTUM solar half cells
- Power: 430 Watts (W)
- Panel yield: 20.1%

To design a solar PV system of 5.1 kWp based on the data specification of solar panel, total of 12 pieces of solar panel is required and the total surface area for the solar panel installation is 26 m^2. Theoretically, Malaysia has total of 6 hours of direct sunlight with the solar radiation in average of 140-170 $kWh/m^2/month$. With this amount of solar radiation, the total estimated energy could generate from the solar PV system is 16.49 kWh and this is consider good to implement the solar PV system (Amin et al., 2009). To be more accurate on the solar production data, solar radiation data is tabulated for the solar energy calculation.

Generally, each location is provided different solar radiation data which will impact on the energy generated from the solar energy. Some of the location will have the lowest solar radiation data when comparing to the other locations. Typically, solar radiation data at the fourth quarter is lower compared to the first quarter in Malaysia. This is due to end of the year is the raining season in Malaysia. Besides that, the tilt angle of the solar panel is one of the factors impacts on the solar energy output. Due to Malaysia is located in the Northern Hemisphere, the optimum tilt angle of solar panel is generally set at less than 20°. Anang, Syd Nur Azman, Muda, Dagang, and Daud (2021) provided the analysis on the solar panel tilt angle shall set at 5°. Highest the tilt angle, lowest the solar energy generated. This should be one of the considerations for the property developer to consider the flat roof in the future to maximum the roof exposure to sun to extend the utilization of the solar PV system.

3.4 Electricity Bill Calculation based on TNB Tariff

Based on the assumptions of the energy demand for residential house, electrical bill is calculated based on current electrical tariff set by TNB under the domestic category. The electrical tariff rate under domestic category is illustrated in Figure 3.3.

TNB tariff rates are set out as follows:-

	TARIFF CATEGORY	UNIT	CURRENT
1	**Domestic Category**		
	Tariff A - Domestic Tariff		
	For the first 200 kWh (1 - 200 kWh) per month	sen/kWh	**21.8**
	For the next 100 kWh (201 - 300 kWh) per month	sen/kWh	**33.4**
	For the next 300 kWh (301 - 600 kWh) per month	sen/kWh	**51.6**
	For the next 300 kWh (601 - 900 kWh) per month	sen/kWh	**54.6**
	For the next kWh (901 kWh onwards) per month	sen/kWh	**57.1**
	The minimum monthly charge is RM3.00		

Figure 3-3 Electrical Tariff Rate from TNB

TNB had provided the domestic electrical tariff into five different charging blocks. The first charging block is from 1 to 200 kWh per month. The second charging block is from 201 to 300 kWh per month. The third charging block is from 301 to 600 kWh per month. The fourth charging block is from 601 to 900 kWh per month. Lastly, the fifth charging block is from 901 kWh onward. Based on current electrical tariff rate, an average of the electrical tariff rate is 43.7 sen/kWh. Sulaima et al. (2019) had populated the historical information on the electrical tariff rate from 2011 to 2016 for the domestic category. Based on the information, an average inflation rate of 3% occurs for every year. With the inflation rate increment, solar PV system is provided the huge potential saving on the total electricity bill.

3.5 Solar PV System Energy Analysis

Energy produced from the solar PV system is based on the several criteria such as solar radiation of the site, solar PV panel yield, total surface area of solar PV panel, and performance ratio. Energy equation below is to compute the solar energy.

$$E_m = A \times r \times SR \times PR$$

Where E_m = total energy of the month in kWh per month, A = total surface area of the solar PV panel in m^2, r = solar panel yield in percentage, SR = solar radiation in $kWh/m^2/month$, and PR = performance ratio – system losses.

3.6 Return on Investment (ROI) and Payback Period

This research study simulates the ROI of a solar PV system installation at three locations in Malaysia with the consideration of TNB electrical tariff inflation, maintenance fees, and investment cost. The average energy consumption for a residential house in Malaysia is computed and the electricity bill is calculated based on year 2020 electrical tariff rate. These are the important values to compute the saving amount by using the solar system. Equation used to calculate the ROI as shown below:

$$ROI = \frac{Annual\ Saving - Maintenance\ Cost}{Initial\ Investment\ Cost}$$

Where Annual Saving is the saving from the yearly electrical bill, Maintenance Cost is the yearly cost to maintain the Solar PV system and Initial Investment Cost is the capital for the solar PV system installation. The ROI calculation for this research study is based on the ten-year periods after the solar PV system. Typically, maintenance cost always is one of the concerns from the end-user when they considering the installation of the solar PV system. ROI analysis is one of the methodologies that widely use in the project investment to express the average annual profit as a percentage of the initial investment.

Payback period is the most common justification used in the project investment. The payback period is defined as the total time required for the repayment of the investment. It is easy to calculate and understand. Payback period is focusing on the true timing of the project benefits and costs. Equation to calculate the payback period as shown in below.

$$Payback\ Period = \frac{Investment\ amount}{Annual\ profit}$$

Where, investment amount is the initial cost of the system, annual profit is the profit gain from the system. The profitability of the system is unable to measure through the payback period method. It is mainly use for illustrated the time required to get back the investment cost.

CHAPTER 4: RESULTS

4.1 Solar PV System Cost and Installment Plan

In this research study, solar PV system of 5.1kWp which is equal to 4kWac was selected. The installation package for the solar PV system consists of solar inverter, solar PV Panel, export meter, and mobilization cost. The total cost required for the solar PV system as shown in Table 4.1.

Table 4-1 Solar PV System Package

No	Item	Quantity	Unit Price (RM)	Amount (RM)
1	Solar Inverter	1	7,200.00	7,200.00
2	Export Meter	1	300.00	300.00
3	Solar PV panel	12	1,250.00	15,000.00
4	Mobilization	1	500.00	500.00
			Total:	23,000.00

In Malaysia, bank sector had implemented the 0% interest free repayment period up to 36 months to encourage the public to invest in the residential area. This is one of the key drivers to attract the residential users to invest on the solar PV system.

4.2 Solar Energy Production

Solar energy production is the important key to determine the saving of the solar PV system. In many cases, end-user do not have enough information to justify the investment of the solar PV system due to lack of knowledge on the solar PV system. The advantage of Malaysia is the sun peak hours availability is higher compared to other country which have four seasons. The historical solar radiation data was taken to perform the analysis. Solar radiation data on year 2020 was selected and shown in Figure 4.1.

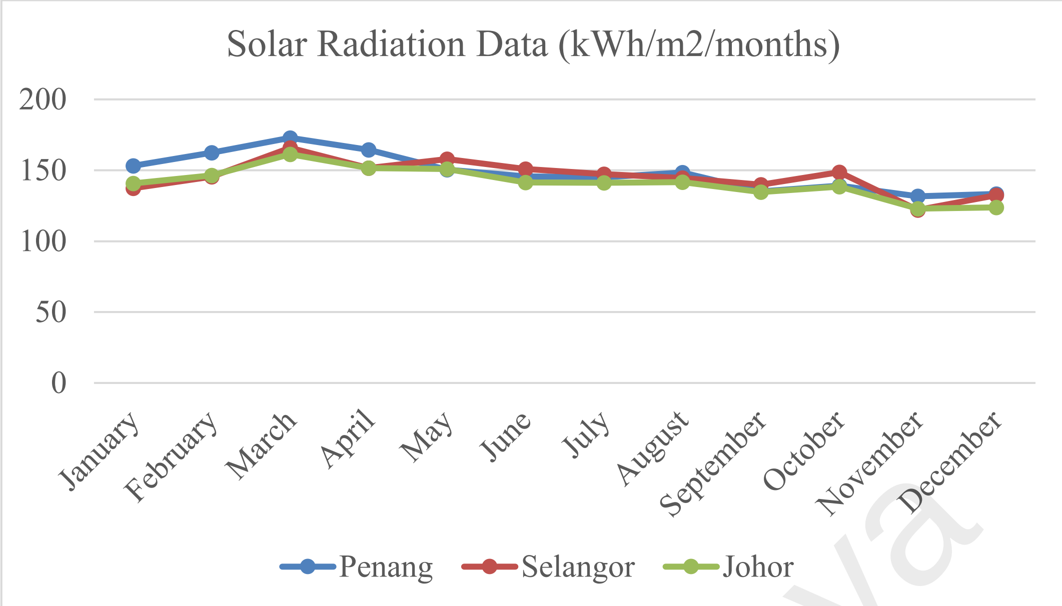

Figure 4-1 Solar Radiation Data for Penang, Selangor, and Johor

To compute solar energy produced from the solar PV system, solar radiation data is one of the key data to generate the results. Besides that, the performance ratio of the solar PV panel is also one of the important data to compute the solar energy. The performance ratio is based on the selected solar PV panel data specification. Table 4.1 shown the solar radiation data for each location.

Table 4-2 Solar Radiation Data for Year 2020

Month	Solar Radiation Penang ($kWh/m^2/month$)	Solar Radiation Selangor ($kWh/m^2/month$)	Solar Radiation Johor ($kWh/m^2/month$)
January	153.16	137.38	140.78
February	162.36	145.59	146.46
March	172.9	165.85	161.32
April	164.47	151.54	151.52
May	150.5	157.93	150.89
June	145.65	150.82	141.52
July	144.95	147.32	141.23
August	148.46	144.54	141.58
September	135.22	139.96	134.68
October	139.1	148.66	138.59
November	131.64	122.06	122.98
December	133.37	132.35	123.91
Total	1781.78	1744.00	1695.46

Figure 4.2 shown the chart of solar energy produce from the solar PV system. Location in Penang have the highest solar production in the first quarter and location in Johor have the lowest solar energy production. Location in Selangor provide the average solar energy production.

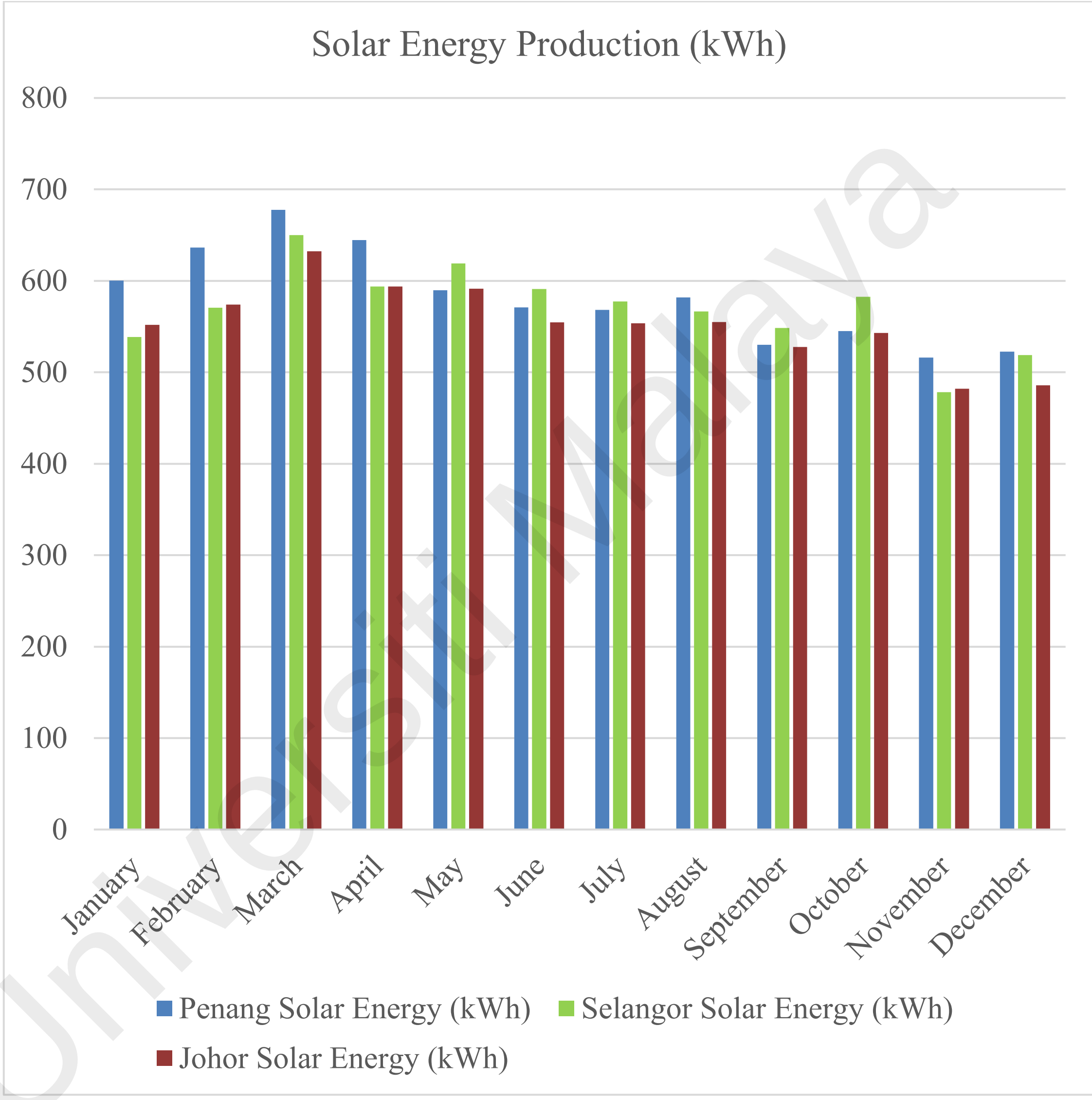

Figure 4-2 Solar Energy Production for Penang, Selangor, and Johor

4.3 Electrical Bill Calculation and Saving

In addition, the electrical bill for a residential house had been simulated for year 2020 to have the overview on the electrical bill payment. The result populated used as the baseline to calculate the saving gain after the solar PV implementation.

Table 4-3 Electrical Bill Consumption on Year 2020

Month	Energy Consumption per Month (kWh)	Total Electricity Bill (RM)
January	1358.21	657.24
February	1270.59	607.20
March	1358.21	657.24
April	1314.40	632.22
May	1358.21	657.24
June	1314.40	632.22
July	1358.21	657.24
August	1358.21	657.24
September	1314.40	632.22
October	1358.21	657.24
November	1314.40	632.22
December	1358.21	657.24
	16035.68	7,736.77

Based on the result calculation from Table 4.2, the total electricity bill for year 2020 is RM 7,736.77. Based on the NEM program in Malaysia, the solar energy produced is one to one basis deduction into the electricity meter record. In this case, the solar energy produced is directly deduct to the electricity consumption. The result had been tabulated in Table 4.3.

Table 4-4 Energy Consumption after Solar Energy Deduction

	Energy Consumption per Month (kWh)	Penang-New Energy Consumption (kWh)	Selangor-New Energy Consumption (kWh)	Johor-New Energy Consumption (kWh)
January	1358	758	820	806
February	1271	634	700	697
March	1358	681	708	726
April	1314	670	720	721
May	1358	768	739	767
June	1314	744	723	760
July	1358	790	781	805
August	1358	776	792	803
September	1314	784	766	787
October	1358	813	776	815
November	1314	798	836	832
December	1358	835	839	873

After computed the new energy consumption for each location, the revised electricity is calculated to illustrate the bill amount after the solar energy deduction. Figure 4.3 shown the bill amount for each month and there is a significantly drop after the installation of the solar PV system.

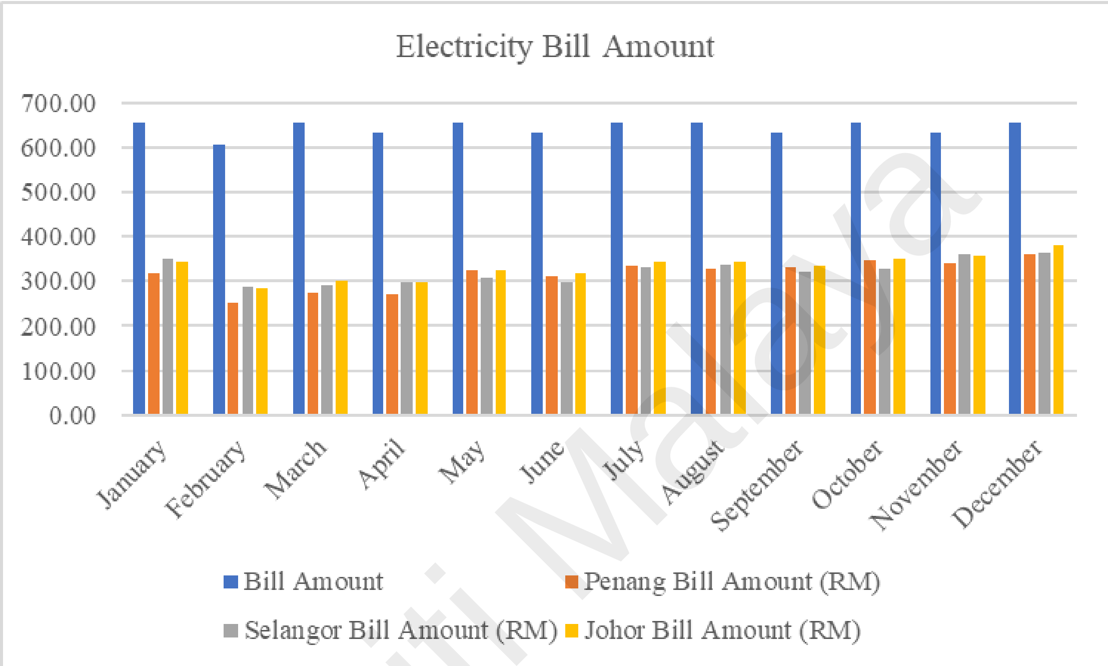

Figure 4-3 Electricity Bill for Penang, Selangor, and Johor

4.4 Potential Saving, ROI, and Payback Period Analysis

This research study had computed the potential saving, ROI, and the payback period by used a ten-year period as a case study. From Figure 4.3, clearly see that after the solar PV system installation, the electricity bill had been reduced around 40% to 60 % depend on the location. It shown that the huge potential saving from the solar PV system. By added the electrical tariff rate inflation factor and the maintenance cost, the saving from the solar PV system become obvious and attractive for investment. The details saving in ten-years period had been populated in the Table 4.4.

Table 4-5 Yearly Saving

	Yearly Savings		
Year	Penang	Selangor	Johor
0	3792.79	3873.64	3977.52
1	3906.57	3989.85	4096.84
2	4023.77	4109.54	4219.75
3	4144.48	4232.83	4346.34
4	4268.82	4359.82	4476.73
5	4396.88	4490.61	4611.03
6	4528.79	4625.33	4749.36
7	4664.65	4764.09	4891.84
8	4804.59	4907.01	5038.60
9	4948.73	5054.22	5189.76

With the NEM program, the payback period for Penang, Selangor and Johor is 5.8 years, 5.9 years, and 6.1 years. In addition, it provides the saving for the ten-year period for Penang, Selangor, and Johor are RM 43,480.07, RM 44,406.93, and RM45,597.78 respectively. The saving for the first ten-years is significant and attractive. Basically, end-user is earning additional profit after the payback period. With this result, the ROI had been populated for Penang, Selangor, and Johor are 38%, 36%, and 33% respectively.

CHAPTER 5: DISCUSSION

Based on the results obtained, solar PV system provided a huge potential saving for residential houses. The total of investment cost is RM 23,000 and the annual saving can achieve up to RM 4,000.00 per year. The annual saving and payback period are justified to install a solar PV system in residential houses. Besides that, there are several packages from the bank sector to support the implementation of the solar PV system. They partner with the solar energy contractor to allow the end-user to purchase the solar PV system with the instalment plan. Not only this, but they also provided the credit card 0 % installment plan to encourage the public to implement the solar PV system. By compared the result, the annual saving from the solar PV system can achieve up to 55% in different location. Hence, solar PV system is a good choice for the residential investment. Based on the research, Malik and Ayop (2020) concluded that the acceptance to use the solar PV energy was high in Malaysia from their survey. With this result, Malaysia government should put more efforts in developing the renewable energy source policy and program to expand the renewable energy usage. Besides that, residential household are playing important role to help the country in the decarbonization of our economy (Petrovich, Carattini, & Wüstenhagen, 2021). Malaysia government had phased out the FiT scheme by replaced with NEM program which is still maintaining the benefits of solar PV system investment.

In addition, Ozcan and Ersoz (2019) concluded that the potential risk on the payback period is minimal and the ROI is high enough compare to other type of investment. To make the solar PV system more attractive to the public, proactive action should take place from the Malaysia government and non-government party to promote the use of solar PV panel system. This is related to the solar PV system design, annual solar energy production, solar PV equipment and technology, and solar radiation data. These are the consideration to decide the path of implementation of solar PV system in the residential area.

Moreover, the solar irradiance is the most impacting on the solar energy production. It makes the NEM program more attractive to the end-user if the solar irradiance is strong during high peak of the months (Tan & Chow, 2016). Generally, Malaysia has the huge potential for solar energy collection and the implementation of the solar technology have significant growth since year 2000. Various policies and program developed by Malaysia government are the important booster to expand the solar PV implementation in Malaysia (Muhammad-Sukki, Ramirez-Iniguez, Abu-Bakar, McMeekin, & Stewart, 2011).

Malaysia government is playing important role on development of various policies and programs to promote the renewable energy to public and increase the awareness on the renewable energy system (Rahman Mohamed & Lee, 2006). Solar PV system is one of the main focuses of Malaysia government to promote the uses of renewable energy to gradually detach from non-renewable energy. Besides that, Malaysia government should engage with the property developer to launch the implementation of the solar PV system during the construction phase. The cost of the implementation could include into the price of the property. This will help to reduce the risk on the space of installation and the roof structure of support for the solar PV panel installation.

The method of investigating the solar energy production is providing the data for potential savings analysis. Based on the solar production output in three different locations, the solar energy which convert to the electricity and supply to household appliances able to achieve the saving in the electrical monthly bill and generate additional passive income.

CHAPTER 6: CONCLUSION

This research study had examined the potential savings and return on investment for solar PV system with capacity of 5.1 kWp installed in three location which are Penang (Northern), Selangor (Central), and Johor (Southern). Results shown that the three locations provide similar result on the potential saving up to 50 % from the electricity bill. The return of investment on solar panel system is fall in between 33% to 38%. This result further increases the interest of investing on solar PV system. In addition, compared the solar energy production from Penang, Selangor, and Johor, it proved that the Malaysia is having huge potential for the solar energy development. Sufficient solar energy to supply to the household electrical appliances even there is a raining season at the fourth quarter of the year. Malaysia government shall take proactive action to promote the use of solar energy and further improves on providing the awareness of importance of the role of renewable energy in the future.

With the support from Malaysia government, the quota to apply for NEM program is available and open for public. The NEM program stimulate the high potential saving on the electricity bill based on the assumption of household energy demand. Generally, the payback period of the investment on solar PV system is the most concerns from the investor and end-user. Results calculated shows that the payback period from the solar PV system is around 5.8 years to 6.1 years depend on the location in Malaysia. With these respects, the gap of the payback period in different location is small.

In a nutshell, the solar energy production analysis had proof that the energy from the solar panel system is sufficient to supply to the household and generate the potential saving from the monthly electricity bill. Based on the results calculated, the objectives of this research study are achieved.

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