Journal of Advanced Science and Engineering Research Vol 4, No 1 March (2014) 47-60

An Economic Evaluation of Grid-Connected Photovoltaic Generation System for Residential House in Malaysia

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Article Info

Received: 20/12/2013
Accepted: 20/1/ 2014
Published online: 1/3/2014

ISSN 2231-8844

Abstract

In term of renewable energy sources, solar energy is an option that is viable for Malaysia due to its location in the equatorial region. The Malaysian government is actively encouraging the public, the commercial and the industrial sectors to adopt solar technology to provide electrical energy to their premises. One of the initiatives to promote the implementation of PV system in Malaysia is the introduction of the Fit-In-Tariff (FiT) in 2011. In this paper, an economic evaluation of grid-connected photovoltaic (PV) generation system for residential houses in Malaysia is conducted. This research used quantitative method where actual data were taken from four residential houses fitted with the grid-connected PV system. This study also investigates the three factors that will affect the payback period of a grid-connected PV system such as solar irradiance, initial investment cost and the FiT rate. Finally the advantages of PV system installations in Malaysia are discussed in term of benefits to the society and the country. The outcome of this study will enable house owners to evaluate whether installing a grid-connected PV generation system is a sound financial investment and serve as a guideline for individuals when considering a PV system in Malaysia. The results revealed that the installation of grid-connected PV system will generate income for residential house owners in the long run and is beneficial to both the society and the country.

Keywords: solar energy, photovoltaic, payback period, FiT, Malaysia

1. Introduction

The solar energy generation has increased in popularity in Malaysia and the climatic condition of Malaysia makes solar energy a very viable form to generate electricity (Johari, Hafshar, Ramli and Hashim, 2011). Solar photovoltaic (PV), plays an important role in overcoming the problems of over dependant to the fossil fuels and the energy security issues in Malaysia (Ahmad and Byrd, 2013). There are two types of PV technology available for residential house. The first one is the grid-connected system where the residential house is connected to the low voltage power lines through single phase (230V) and three phase (400V). The grid connected system can be with or without storage facility. In October 1999, a bungalow in TNB Research Centre, Selangor was installed with 3.6kW of grid connected PV system making it one of the first in Malaysia (Hussin, Hasliza, Yaacob, Zain, Omar and Shaari, 2012). The other type of PV technology is the off-grid system. It is an independent system that supplies electricity to the load without being connected to the electric grid. This off-grid system offers great solution to remote or rural areas in terms of reducing costs, operation and maintenance (Idris, Omar and Shaari, 2010). Abdulateef, Sopian, Kader, Bais, Sirwan, Bakhtyar and Saadatian, (2013) proved that supplying electricity to a remote household using the off-grid PV systems is beneficial and suitable for long-term investments, especially if the initial prices of the PV systems are decreased and the efficiencies are increased.

Over the years, the number of grid connected PV installations in residential sectors has increased in Malaysia. Currently there are about 1738 of residential Feed-in-Approval-Holder (FiAH) which generate below 14kW that are connected to the grid system (TNB, 2013). The major barriers of PV system installation are its high capital cost and very low capacity factor (Rasheduzzaman, Stahlman, Chowdhury, 2011). Even though the cost of PV systems in the market is decreasing, the total cost of PV system installation is rather expensive in Malaysia as described by Tze and Chun, (2013) and many home owners are reluctant to make the initial investment in solar energy. Muhammad-Sukki, Ramirez-Iniguez, Abu-Bakar, McMeekin, Stewart and Chilukuri, (2011) conducted a survey and found that Malaysians still lack in awareness with regards to the government renewable energy (RE) initiatives and many are unwilling to invest in solar PV system due to the high installation cost.

The research objectives are to carry out the payback period analysis of grid-connected PV system for residential houses, to study the three factors that will affect the payback period and to discuss the benefits of PV system installation to the society. This study aims to enhance knowledge in grid-connected PV system investment for residential homes in Malaysia particularly with 10kW and less of output generation. This research will analyze four case studies of grid-connected PV system installed at four separate houses in Malaysia.

2. Policy and Previous Studies

The energy sector has become the main contributor towards the rapid growth of Malaysia's economy. The energy generating capacity has increased almost 20% from 13,000MW in 2000 to 15,500MW in 2009 (Mustapa, Peng, Hashim, 2010). The electricity generation capacity in 2011 was 21,817MW where Tenaga Nasional Berhad (TNB), the national electricity company generated 7,054MW and the remaining capacities were from Independent Power Producers (IPP). According to the Malaysian Energy Commission report in 2011, the highest daily energy demand was 318.4 GWh in 2011 compared to 311.5 GWh in 2010 (EC, 2011).

The electricity generation in Malaysia is powered mainly by natural gas (52.7%) and coal (38.9%). Malaysians are not paying the real cost of electricity as the tariffs are being subsidized by the Malaysian government and the main national natural gas producer, Petronas. The electricity is being subsidized through an imposed low gas price where Petronas is required to sell at a controlled price of RM15.20 per mmbtu where the price of natural gas in ASEAN is between RM45/mmbtu to RM 50/mmbtu (TIISD, 2013). The coal price has dropped by 19.3%; average USD83.6 per metric tonne (mt) in FY2013 compared to USD 103.6 per mt in FY 2012 (TNB, 2013). In total, the Malaysian government spent about RM23.5 Billion in 2009 for fuel and energy subsidy (PEMANDU, 2009). The energy subsidies are intended as a mechanism to keep energy affordable for Malaysians. However subsidies represent a financial burden to the Malaysian government.

In Malaysia, The National Energy Policy was introduced in 1979 with three main objectives; adequacy of supply, efficient utilization objective and minimize impact on environment. To achieve these objectives, the National Depletion Policy was introduced in 1980 to safeguard the natural oil reserves. In 1981, the Four Fuel Diversification Strategy policy was introduced to reduce over dependence on oil to other energy supply mix such as natural gas, coal and hydro. Currently Malaysia is adopting the Five Fuel Diversification Policy which was introduced in 2001 with the addition of the renewable energy as the fifth fuel source (Tan, Maragatham & Leong, 2013). Under the 10th Malaysia Plan, the Malaysian government set a target to achieve 5.5% of RE sources by 2015. The National Renewable Energy Policy and Action Plan was launched in 2009 with the vision to enhance the utilization of RE resources to contribute towards national supply security power generation mix and sustainable socioeconomic development.

One of the incentives offered by the Malaysian government to investors in the RE field is the FiT where the house owners are paid for electricity generated in kilowatt-hour (kWh). FiT works by paying a premium for electricity generated from non-fossil fuel sources such as geothermal, mini-hydro schemes, solar and biomass. The FiT scheme will be financed by the consumers themselves. This is achieved by increasing the electricity tariff by 1%, and that amount is pooled into the FIT fund and it will be available until 2030 (Muhammad-Sukki et al., 2011). The RE Fund is created to ensure the sustainable growth of renewable energy via the Renewable Energy Act 2011. However consumers with 300 kWh and less of electricity usage are exempted from RE Fund contribution (SEDA, 2013). On the 1st of January 2014, the surcharge on electricity bill for the RE Fund was revised from 1.0% to 1.6%. The FiT rates for all renewable resources (except for small hydropower) will decrease with time according to the respective yearly degression rates. The degression occurs at the start of each new calendar year onwards. Once the PV system is installed, the tariff payment remains constant over a long period of time despite tariff degression (Jacobs, 2010).

Table 1: FiT Rates for Solar PV Up to 24kW (SEDA, 2013)

Basic FiT rates having installed capacity of:	FiT rates (RM/kWh)	
	2013	2014
i) up to and including 4kW	1.1316	1.0411
ii) above 4kW and up to and including 24kW	1.1040	1.0157
Bonus FiT rates having the following criteria		
i) use as installations in buildings or building structures	+0.2392	+0.2201
ii) use as building materials	+0.2300	+0.2116
iii) use of locally manufactured or assembled PV modules	+0.0300	+0.0300
iv) use of locally manufactured or assembled solar inverters	+0.0100	+0.0100

The Sustainable Energy Development Authority of Malaysia (SEDA) is the statutory body established to administer the implementation of the FiT mechanism. SEDA can only approve a limited number of applications every year due to the limited funds available from the RE Fund. Private investors for RE projects will have to sign the Renewable Energy Power Purchase Agreement (REPPA) which is the power purchase agreement between TNB and private investors. The RE electricity producers are given a license for a period of 21 years under REPPA, which is effective from the date of commissioning of the plant (SEDA, 2013).

The Malaysian government has taken some steps to promote and develop solar energy as one of the significant sources of renewable energy in the country by introducing policies and incentives (Johari et al., 2011). Among the strategies are the Malaysia Building Integrated Photovoltaic (MBIPV) and SURIA1000 projects (Mekhilef, Safari, Mustaffa, Saidur, Omar and Younis, 2012). According to Solangi, Lwin, Rahim, Hossain, Saidur and Fayaz, (2011), these projects are still insufficient and more developments are needed. The current contribution from RE remains very low and solar energy only contributes less than 0.03% of the electricity generation energy mix in Malaysia (EC, 2011).

Now, Malaysians with landed properties are able to generate electricity using their rooftops or available land area and get paid for it by TNB. In average, Malaysia gets around five to six hours of optimal sun hours every day for PV electricity generation. Under the FiT framework, it will guarantee all solar power producers an income for up to 21 years and it can function as a secondary income for house owners. SEDA launched the Solar Rooftop Programme on 24th September 2012 where 2MW of solar PV quota was released in the second half of 2012 and 6MW of solar in the first half of 2013. Each individual is allowed up to two applications and each is capped at 12kW (SEDA, 2012).

There are a few considerations that need to be made in advance before the installation of a grid-connected PV system at residential house. Firstly the owner must gauge the condition of the roof; whether the roof space is wide enough, whether it is able to withstand the weight of the PV system and whether it has an appropriate angle direction with less shading in order to get the most optimal solar energy. Secondly is to determine the size of the PV system for the house. Thirdly is to identify the electricity provider's requirements and the FiT application requirements from SEDA. Fourthly is to appoint the solar PV supplier that can offer the best PV installation and technical support service.

Generally there are two meters that will be installed to measure the total amount of import and export of energy to the grid. The first one is the kilowatt-hour meter which will measure power absorbed from the grid. The second one is the FiT meter which will measure power delivered from PV system to the grid. TNB will make monthly readings for both meters. The owner will have to pay for the normal electricity usage based on the first meter and the FiT payment will be paid by TNB based on the second meter.

2.1 Economic Evaluation of PV Systems

It is important to do an economic evaluation analysis to assist the decision on the PV system implementation. The main expectation of house owners is that the resulting benefits must exceed the investment costs. The most common methods used to examine the profitability of a PV project are payback period, net present value, net cash flow, and internal rate of return (Tze and Chun, 2013). Muhammad-Sukki et al., (2011) have performed the financial analysis to compare the return of investment and the payback period of 2.5 kW solar PV installations at various locations in Malaysia and found that the average annual return on investment varies from 3.24% to 11.93%, with a payback period of between 5.99 years and 12.49 years. Using the previous FiT rates, Abdullah et al., (2012) found that BIPV projects implemented in Malaysia are economical and environment friendly and it should be promoted to residential house owners.

Oliva and MacGill, (2012) showed that the economic value of a commercial PV system in Australia varies considerably and that payback periods for PV owners range from 8 to 10 years. El-Tous, (2012) presented an analysis for a grid-connected photovoltaic system for a residential house in Amman, Jordan and found that the payback period is less than 10 years. Sopitpan et al., (2000) did a study on three different configurations of PV systems in Bangkok, i.e. PV stand-alone, PV direct and PV connected to a grid. The grid-connected PV systems in city areas are still unpopular due to the high investment cost.

2.2 Solar Radiation

A grid-connected PV system converts the energy from the sun light into electrical energy and the electricity is converted into grid compliant AC by an inverter (Anwari et al., 2011). Malaysia received about 1643 kWh/m2 average solar irradiance annually (Solangi et al., 2011). According to Mekhilef et al., (2012), the monthly solar radiation in Malaysia is approximately 4 to 6kWh/m^2 and the average sunshine duration is in the range of 4-8hrs/day. The annual variation between maximum and minimum is about 25 %. Malaysia has a steady solar radiation which is not seasonal in nature. However, the rainy and humid climate means almost half of the sunlight received is diffused (Mohamad et al., 2009). The northern states in Peninsular Malaysia and a few places in eastern Malaysia have high solar radiation throughout the year and the highest potential for solar energy application (Kamaruzzaman et al., 2010).

The output power of PV panels is affected by the amount of solar radiation, temperature and weather factors (Zhou and Zhu, 2011). In a study conducted by Muhida et al., (2010), PV electricity output is proportional to solar irradiation energy received by the PV modules. Therefore the amount of solar energy converted to electric energy will differ at different regions and weather conditions.

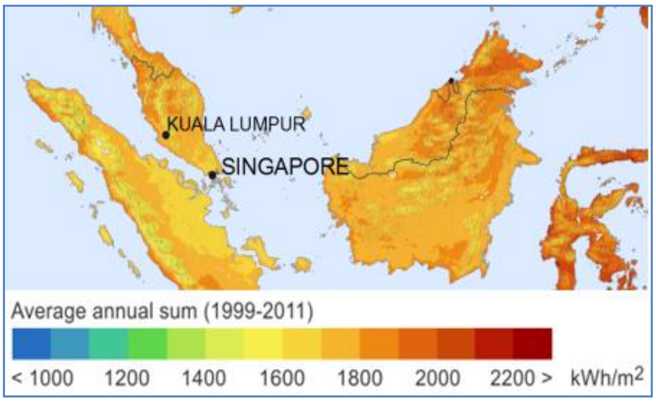

Fig. 2: South East Radiation Map (Solargis, http://solargis.info)

2.3 Initial Investment Cost

A grid-connected PV system consists of solar array, mounting structure, PV inverter, cables and PV meter. The initial investment includes the equipment price and the installation cost. Generally, there are four types of solar panels available in the Malaysia PV market. They are Mono-crystalline Silicon, Poly-crystalline, Thin film Silicon and Copper Indium Selenide (CIS). The mono-crystalline silicon is the most efficient PV module followed by poly-crystalline silicon type (Mekhilef et al., 2012). The price of PV system is highly dependent on the price of PV modules which contribute between 50% and 60% of the total cost. The range of unit cost of a solar PV system used to be RM 24,000-30,000 per kW according to (Tze and Chun, 2013). Nowadays, the price of grid-connected PV system for a residential house has decreased to about RM10,000 per kW (KETTHA, 2013).

Interested house owners can opt to apply for personal loans with various financial institutions in Malaysia for the initial investment. Many have been delaying their plans to install the PV system due to the difficulty in getting loans and high interest rates. Fortunately, there are a few banks in Malaysia that are offering loans to individuals who wanted to install solar PV system at their homes. SEDA also collaborated with some of the banks which aim to give affordable financing scheme for solar PV system at a lower interest rate (Solar System Malaysia, 2014).

2.4 Operation and Maintenance Cost

The life cycle of the solar panel is around 15 to 25 years and the PV system need to be maintained properly to ensure the sustainability (Rahim et al., 2012). The solar array requires minimal maintenance and the main concern is the dust accumulation on the surface of the panel. Nevertheless, cleaning and maintenance work as well as minor repairs and replacement of the inverter need to be included in the calculation of economic analysis. Usually, the manufacturers will provide inverter product warranty for at least 5 years and owners can extend the warranty period with additional cost. The Peninsular of Malaysia receives average rainfall of about 2,500mm (World Weather and Climate Information, 2013). The usual downpour helps to clean the PV panel naturally. Generally the operation and maintenance cost of solar PV system of <1MW is between 1% to 5% (EPRI, 2010).

3. Data Collection and Analysis

There are two types of data used in this study. The first type of data was obtained from the utility company and the residential customers with grid-connected PV system installed. The data acquired are the actual monthly bill, the electricity production recorded and the amount of energy sold to the utility company. The second type of data was obtained from various sources on the internet for example the annual solar radiation, the statistic of household income in Malaysia and the Malaysia expenditure on fuel subsidies.

In the first part of this study, the payback period is chosen for the economic analysis of the PV system implementation at four separate residential houses in Malaysia. Payback period can be defined as the expected number of years required to recover the original investment. The payback period is calculated using the Excel model and then the selected components are varied for comparison. The initial investment made to install the PV system is assumed to be RM10,000 per kWh. In this study, the dimensions of energy consumption in a household and the current electricity tariff are not taken into consideration in the annual benefits calculation. In the second part of this study, three factors that may affect the payback period are compared and analyzed. Finally this study will discuss the benefits of the grid-connected PV system to the society in Malaysia.

4. Results & Discussions

In Case Study 1, the residential house is installed with a 3.9kW system and generated about 393kWh of energy per month. In Case Study 2, the bungalow house is installed with 4.8kW system and generated in average 464kWh of energy per month. In Case Study 3, the residential house is installed with 10.6kW system and generated about 1031kWh per month. In Case Study 4, the PV system installed is 3.6kW and generated about 356kWh per month. The FiT rates for all case studies are the actual rate for the four houses.

In Figure 3, the monthly energy generated throughout the year for the four case studies are tabulated into graphical form and analyzed. The monthly energy production can be seen varies throughout the year. In Case Study 1, the highest energy produced was in November 2013, while the lowest was in June 2013. In Case Study 2, the highest energy production was also in November 2013 and the lowest was in September 2013. In Case Study 3, the energy production was fairly constant with the highest recorded in March 2013. In Case Study 4, the highest energy production was also in November 2013 and the lowest was in February 2013.

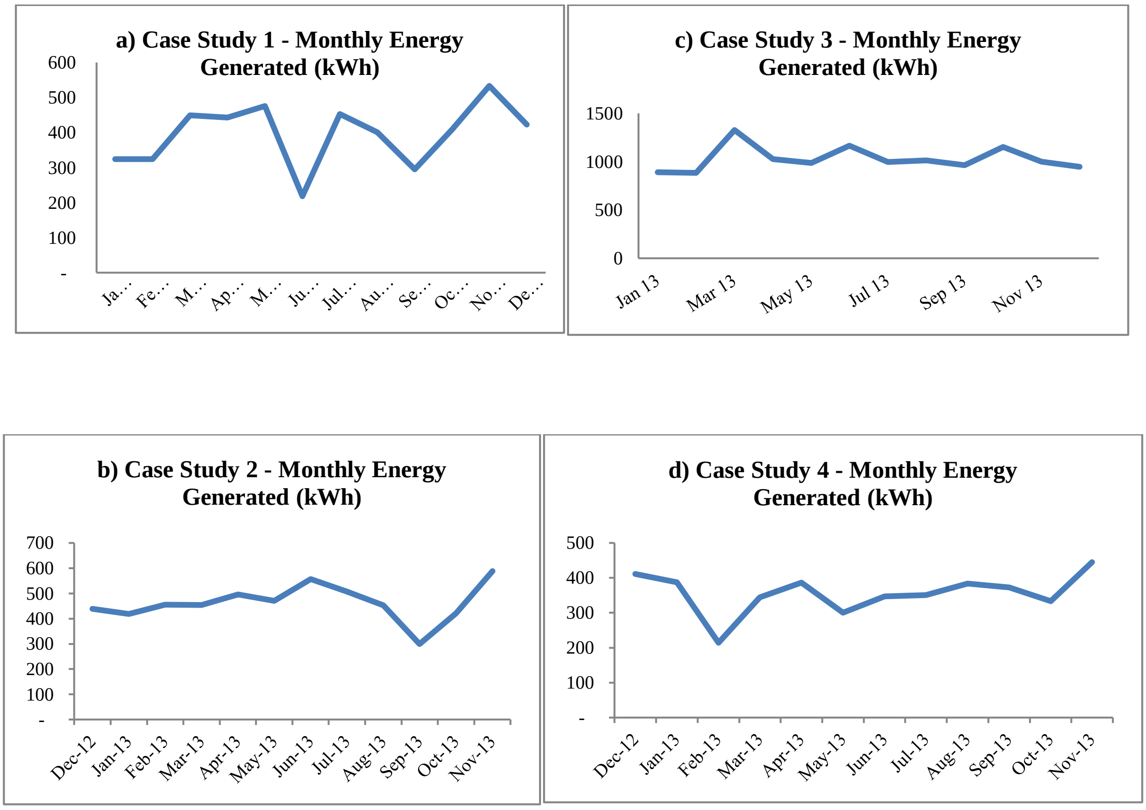

Fig. 3: Energy Production from the Case Studies

Using the data obtained from the utility company, the payback periods were calculated for the four case studies. The payback period is the number of years required for invested capital to be paid back by the resulting benefits.

$$Eq. 1 : \ Payback \ Period = \frac{Initial \ Investment}{Net \ annual \ benefit}$$

Where:-
Initial investment cost = PV module +Inverter + Installation cost + others
Net Annual Benefit = Revenue – Operation and Maintenance cost
Revenue = Income from selling power to the utility
Operation and Maintenance (O&M) cost is assumed to be 1% of the capital cost

In Table 2, the payback period for the case studies varies between 5.88 years to 6.67 years. The payback periods for the four houses are considered good with regards to the PV system installation.

Table 2 – Case Study Data

	Case Study 1	Case Study 2	Case Study 3	Case Study 4
Maximum Output Capacity	3.9kW	4.8kW	10.6kW	3.6kW
Location	Selangor	Selangor	Johor Bahru	Muar
Initial Investment (RM10,000/kWh)	RM39,000	RM48,000	RM106,000	RM36,000
O&M Cost	RM390	RM480	RM1,060	RM360
Annual Revenue	RM7,023	RM8,120	RM24,739	RM6,371
FiT Rate	RM1.49/kWh	RM1.46/kWh	RM1.37/kWh	RM1.49/kWh
Payback Period	5.88 Years	6.28 Years	6.67 Years	5.99Years

4.1 Solar Radiation Comparison

The output power of PV panels is affected by the amount of solar radiation, temperature, weather factors and the performance of the module. The amount of sun the PV panel receives can be affected by the direction of the solar panels, the geographical location and whether the roof is shady or not.

Figure 4 shows the average daily electricity production from Case Study 1 in the month of December 2013. It can be seen that the electricity production varies with the time of the day. The maximum power produced is about 1.7kW which occurs around mid day. The daily average is about 465W.

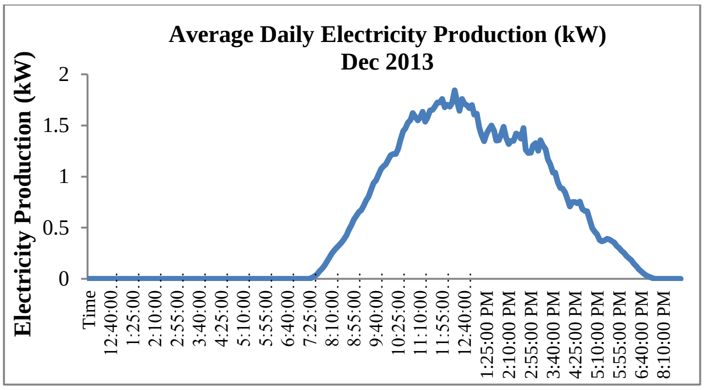

Fig. 4: Electricity Production from the Case Study 1

The estimated energy production can be calculated using the solar radiation data and Equation 2 and 3. Figure 5 shows the annual solar radiation in different cities in Malaysia. In order to analyze the solar radiation effect on the payback period, the electricity generation of PV system at three separate cities in Malaysia are calculated and compared. The dimensions of initial investment, sun hour, PV efficiency, FiT rate, roof area and operating and maintenance costs are set fixed for calculation.

Eq. 2
Energy generated (kWh/day) = Annual Solar Radiation x Sun Hours x PV Efficiency x Area

Eq.3
Annual Revenue = Energy generated x Days in a Year x FiT rate

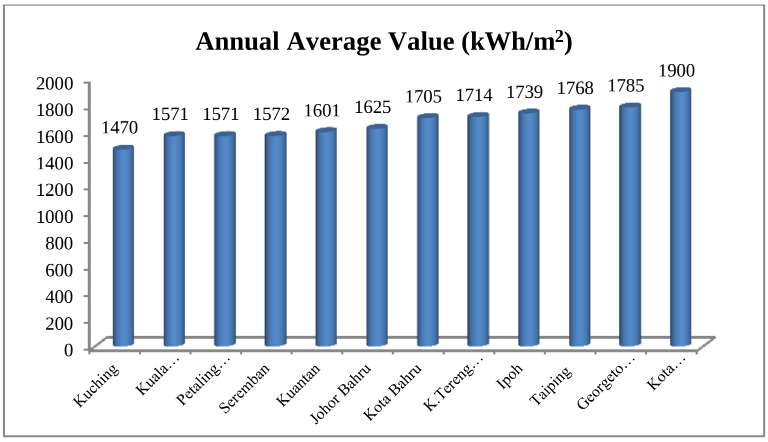

Fig. 5: Annual solar radiation in different cities in Malaysia (Haris, 2008)

From the results shown in Table 3, the amount of energy generated at a house located in Georgetown is the highest compared to the ones located in Kuala Lumpur and Johor Bahru as it receives the highest solar radiation among the three. The payback period for the house located in Georgetown is 5.66 years compared to 6.25 years in Johor Bahru and 6.48 years in Kuala Lumpur.

Table 3 – Comparison of PV systems at three different cities in Malaysia

	Kuala Lumpur	Johor Bahru	Georgetown
Initial Investment	RM39,000	RM39,000	RM39,000
Solar Radiation	1,571kWh/m^2	1,625kWh/m^2	1,785kWh/m^2
Sun Hour (Hours)	5	5	5
Roof Area (m^2)	10	10	10
PV Module Efficiency	15%	15%	15%
FiT Rate	RM1.49/kWh	RM1.49/kWh	RM1.49/kWh
Revenue Per Year	RM6,408	RM6,628	RM7,281
O&M Cost	RM390	RM390	RM390
Annual Benefits	RM6,018	RM6,238	RM6,891
Payback Period	6.48 Years	6.25 Years	5.66 Years

4.2 Initial Investment Comparison

The comparison of payback period for the initial investment of the PV system is made using Case Study 1 where the owner use; a) his or her own money; b) 90% bank loan with an interest rate of 7% per annum and c) 100% bank loan with 5% interest rate for a period of 10 years. In Table 4, the payback period resulted from the initial investment using the owner's own money is better than using the bank loan. Practically, using the bank loan is a good option for house owners without the initial capital and they can manage their loan payment through installment method. The payback period will get shorter as the interest rate gets lower or the loan period gets shorter. Therefore, the faster the PV system is paid off, the lower the total investment cost to the owner. As the PV system price is decreasing, house owners can choose to find the best solution offered by the service provider for his or her house particularly affordable price, good performance, good technical service and good warranty period.

Table 4 – Own Money Vs Bank Loan

	a) Own Money	b) 90%Bank Loan. Interest Rate 7%	c) 100%Bank Loan. Interest Rate 5%
Total Investment	RM39,000	RM63,570	RM58,500
Loan Period	-	10 Years	10 Years
Revenue Per Year	RM7,023	RM7,023	RM7,023
Annual O&M Cost	RM390	RM390	RM390
Annual Benefits	RM6,633	RM6,633	RM6,633
Payback Period	5.88 Years	9.58 Years	8.82 Years

4.3 FiT Rate Comparison

In order to analyze the payback period due to FiT rate, Case Study 1 is used where the FiT rate is RM1.49/kWh. On 1st January 2014, the FiT rate in Malaysia has decreased with respect to the annual degression rate. The comparison of FiT rate is shown in Table 5. With the new FiT rate, the payback period is longer which is 6.43 years compared to 5.88 years.

Therefore, the earlier the PV system is installed, the better the FiT rate is to the home owners and more annual revenue generated.

Table 5 – Comparison of FiT Rates

	Previous FiT Rate 2013 (RM1.49/kWh)	New FiT Rate 2014 (RM1.37/kWh)
Initial Investment	RM39,000	RM39,000
Annual Revenue	RM7,023	RM6,458
O&M Cost	RM390	RM390
Annual Benefits	RM6,633	RM6,068
Payback Period	5.88 Years	6.43 Years

4.4 Benefits of PV System to Society

The number of household in Malaysia is about 4.9Million (Wikipedia, 2014). Currently only about 0.04% of household has rooftop PV system. The government has set PV quota which limit the PV system application to about 2,000 houses per year. According to Green Prospect Asia, (2012) a household can generate an average of 4kW of power. It is expected that the total capacity generated by the PV system in 10 years time is about 80MW. By then, about 22,000 household will be able to generate electricity from solar power. As the capacity of PV generation from residential houses increases, it is predicted to reduce the government expenditure in fuel subsidy for electricity generation.

For a 4kW system, the initial investment cost for a PV system is estimated about RM40,000 and it can generate an income about RM600 per month. Assuming that the average household energy consumption is about RM150 per month. The savings on energy per household is about RM450 a month and about RM5,400 annually. As there will be about 2000 household that will be installed with the PV system annually, the savings will become RM10.8 Million per year. In 10 years, this will be translated into RM108 Million of savings.

The findings from the Household Income Survey 2012 revealed that the mean monthly household income for Malaysians increased from RM4,025 in 2009 to RM5,000 in year 2012. It was an increase of 7.2% per annum. By installing the PV system, the house owners can generate extra income and this will help to increase the household income by 9% - 11%. In order to facilitate individual house owners, the government can offer financing options that may provide the owners with the option to pay the PV system in installments with interest.

5. Conclusion

In conclusion, the installation of grid-connected PV system will generate income for residential house owners in the long run. Residential PV generation system is one of the most effective ways to earn extra income while playing an important role in the development of renewable energy in Malaysia. The payback period of grid-connected PV system for residential houses varies from 5.88 years to 9.58 years. The earlier the house owners install their PV system; the better the payback period is due to the decreasing FiT rates. When net metering is implemented in Malaysia, the calculation for payback period should also include the energy consumption of a household and the latest electricity tariff to calculate the annual net benefits.

The implementation of grid-connected PV system will give benefits to both the society and the country. House owners can improve their annual household income by 9%-11% and the government can benefit from the reduction in expenditure in fuel subsidy for electricity generation. Solar energy is sustainable and will play a significant role to reduce dependency on fossil fuels.

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