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Evaluation of Residential Grid-Connected Photovoltaic System as the Potential Energy Source in Malaysia

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Abstract

Application of solar energy in Malaysia has been started in 1998. This country has a large potential of solar energy due to its location at equatorial region. The current energy consumption and demand in Malaysia is describes in this paper. The potential of solar energy in Malaysia is described together with the suitable photovoltaic construction. It also explains the plans conducted by Malaysia involving solar energy that covers investments and also projects involved such as Malaysia Building Integrated Photovoltaic (MBIPV). Simulation of grid-connected photovoltaic system in this study is performed using HOMER software. Finally, the potential of having a grid-connected PV system in a residential area is analyzed. The positive and negative findings in terms of cost and suitability of the system are explained.

Keywords: *renewable energy, solar energy, solar photovoltaic, HOMER, cost of energy, energy demand, grid-connected photovoltaic, cost of energy, net present cost*

1. Introduction

Nowadays, experts in energy sector worldwide have been focusing on the various ways available in reducing the environmental effect throughout the process of producing energy [1]. The conventional way of generating electricity with fossil fuel as the main source such as oil has become a big concern since the greenhouse emission that includes carbon dioxide mainly has contributed a lot on the air pollution problem [2].

Besides the negative effect on the environment, the decreasing amount of fossil fuel reserves has urges the government and private sectors to reduce the dependency on them [3]. In low-income countries, energy security has become a critical issue as the vulnerabilities of supply and demand overlap [3].

Next, the volatility of global oil price has shown the threat it has on the energy sector of countries that depends mostly on the source. As a result from the Middle East and Africa crisis, the price of the oil has increased from $82 per barrel in November 2010 to more than $112 per barrel in April 2011 [3]. The increasing trend of oil price is expected to continue causing an alarm all over the world to start seeking for alternative source of energy. Since the catastrophe of Japanese Tsunami in 2011, countries worldwide have taken multiple actions in improving the safety measure on their nuclear plant facilities [4]. This caused the transition of the governments worldwide towards much greener source of energy with less environmental effect [5]. As a result, one of the actions taken in energy sector is by adopting renewable energy sources to produce electricity that is clean, mostly redundant and free such as solar, hydro and wind sources [1].

In Malaysia, as a country located in the equatorial region with high level of temperature, solar energy become one of the most potential sources of energy to be implemented [1]. The advantages of clean with no pollutant emissions and the free availability of the abundant source of solar energy have made it an ideal alternative to generate electricity for the country [1].

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2. Current Energy Scenario in Malaysia
2.1. Energy Consumption and Demand

The amount of population in Malaysian has reached 27 million in 2010 [6]. In the year 2020, about 75% will settle down in urban area [7]. An annual average consumption of 3300kWh for every household has been reported in [8] with 21% of the electricity generated is used by residential area in the first half of 2010. Figure 1 shows the same pattern of primary energy consumption and electricity consumption in Malaysia [9].

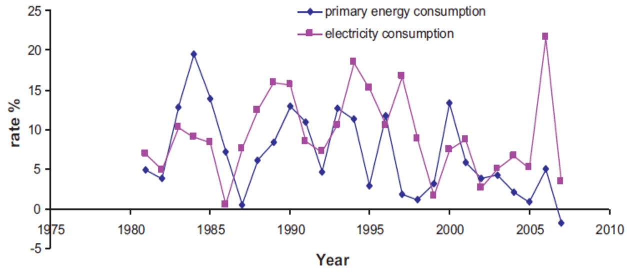

Figure 1. Rate of primary energy and electricity consumption in Malaysia by year [9]

In the past six years, the growth domestic product (GDP) grew at the rate of 5.7% [10]. In 2012, the government has predicted economic growth of 5 to 6% [11].The GDP is related directly with energy consumption and demand [10].

In Malaysia, gas and coal has been used most widely as the source of electricity generation. In addition, energy production is totally dependent on fossil fuel sources such as oil and also coal and gas as shown in Figure 2 [12].

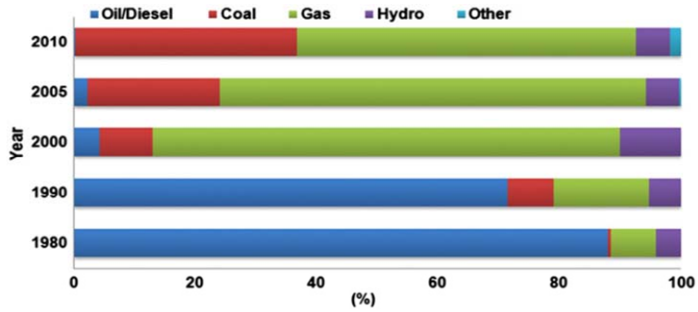

Figure 2. Source of electricity in Malaysia [12]

For oil source, in 2009, the total amount of petroleum production is 693,730 barrels per day (bbl/d) [9]. About 536,000 bbl/d has been consumed in this country, while the total export value is around 157,730 bbl/d. With the decreasing amount of oil reserves, oil and gas companies throughout Malaysia that includes *Petronas* and it's production sharing contracts (PSC) has started to search on offshore area reservoirs that will undoubtedly cause a large amount of cost allocation. In international level, Malaysia's oil reserves can be considered as small and insufficient as oil production is decreasing [9]. Furthermore, this fossil fuel source reserve has approaching the depletion period with decreasing amount of supply.

Malaysia's gas reserves of 88 trillion cubic feet (tcf) are much lesser compared to Russia (1680 tcf), Iran (1046 tcf) and Qatar (900 tcf) [9]. The production of natural gas in 2008 has shown an increment from 56 billion cubic feet in 1980 to 2023.55 billion cubic feet. However, according to [13], Malaysia can only produce electricity by using the natural gas as the sources for only 29 years although the size of the natural gas reserves is in 16th place highest as reported in [14].

Between 2000 and 2008, as a way to reduce the dependence on natural gas, Malaysia has introduced a policy that encouraged the transition of power production towards coal [15]. As for coal, Malaysia imported the supply mostly from Indonesia (84%) followed by Australia and South Africa [16].

In long-term period, fossil fuel sources is becoming less and less as the growth of economy worldwide requires more and more energy production. Governments worldwide should start to seek for another sustainable energy sources and one of the most preferable option is by implementing renewable energy as the source of energy [3].

2.2. Policy and Plan on Renewable Energy and PV System

In 2001, renewable energy has been highlighted in the 8th Malaysia Plan (2001-2005). Small Renewable Energy Program (SREP) was introduced to encourage the usage of renewable energy that includes solar, mini-hydroelectric, biomass and wind. Through this program, small power plants that use the renewable energy sources can sell their electricity to the utility via the distribution network. Besides, Fifth Fuel Policy 2000 (5FP2000) is also included in the plan with the purpose of focusing more on energy efficiency and sustainability that is much related to renewable energy.

Meanwhile, in the 9th Malaysia Plan (2006-2010), Malaysia has specified the solar energy or photovoltaic as the focus of renewable energy sector that is going to be developed. Malaysia Building Integrated Photovoltaic (MBIPV) project has been launched and planned to start on July 2005 and finish around December 2010 [17]. It involves the market development of PV cell in Malaysia, PV technologies and implementation of the capacities.

In August 2006, the Third Industrial Master Plan (IMP3, 2006–2020) was introduced. In these 15 years of industry development plan, solar energy has been chosen as the new growth area of energy. According to this report, in 2005, the worldwide sales of PV cells and modules has come to the total amount of USD 10 billion which is considered as a high growth. Government support to encourage the improvement in energy sector that surely can be achieved by the renewable energy implementation is highlighted in the National Green Technology Policy 2009 (NGTP2009).

Currently, in the 10th Malaysian Plan (2011-2015), the National RE Policy & Action Plan has been introduced and the MBIPV project is selected as a significant tool towards the RE development in Malaysia. The Prime Minister has stated that the government is planning in introducing a renewable energy law [18] that includes the feed-in tariff (FiT) for the benefit of the solar energy growth.

3. PV Installation in Malaysia

3.1. Climate Potential

Malaysia lies entirely on the equatorial region. On average, Malaysia receives around 6 hours of sunlight per day [19]. Throughout the year, the temperature ranges between 22^{o}C and 33^{o}C (72~91^{o}F) and the average daily temperature is 26.5^{o}C. The annual average daily solar irradiations for Malaysia were from 4.21 kWh/m^2 to 5.56 kWh/m^2. The highest solar radiation was estimated at 6.8 kWh/m^2 in August and November while the lowest was 0.61 kWh/m^2 in December [20]. The monthly solar radiation in Malaysia is approximately around 400–600 MJ/m^2 [1]. The average daily global solar irradiation is approximately 4.5 kWh/m^2.

3.2. PV Construction

Solar PV connections can be obtained either in on-grid or off- grid connection [3]. An on-grid connection refers to one with interconnection between the building and the national grid that will enable electricity transfer towards the grid network of the utility. It is usually related to the feed-in tariff (FiT) introduced by the government. Meanwhile, an off-grid connection does not connected to the national grid. This type of connection is often connected to a storage bank which includes battery that will store the electricity. It is much suitable to be implemented in rural area.

In Malaysian PV market, four types of solar panels are mono-crystalline silicon, poly-crystalline silicon, copper-indium-diselenide (CIS) and thin film silicon (using amorphous silicon) [21]. Mono-crystalline silicon and poly-crystalline silicon show the best result under hot sun, whereas on cloudy days CIS and thin film silicon performed better. The most efficient PV module is mono-crystalline silicon followed by poly-crystalline silicon type. Crystalline silicon is popular for performing higher cell efficiency than the thin film technology. CIS compared to the amorphous silicon solar panel, has shown higher module efficiency. In Malaysia, main factories involve in PV capital equipment production, cell and panel manufacturing and installations of solar system are First Solar, Q-Cells and Sun Power [1].

Compared to the countries in Europe, the orientation of BIPV in Malaysia is less important. A tilt angle of 2° to 7° and true South direction for PV array is the perfect orientation of the PV installation [22]. In order to enable the natural cleaning process of the PV array surface with the help of rain drops, PV installation with an inclination angle of around 5° to 15° is much preferable [23].

3.3. Projects and Development of PV

In Malaysia, the first grid-connected PV was installed in July 1998 on the rooftop of College of Engineering, *Universiti Tenaga Nasional* (UNITEN) [29]. The installation was initiated by TNB Research Sdn Bhd (TNBR) as part of a pilot research project funded by Malaysia Electricity Supply Industry Trust Account (MESITA) and Tenaga Nasional Berhad (TNB). The system capacity is 3.15kWp and is connected to a 3-phase electricity system of the building. This installation provided the first Malaysian practical experience on grid-connected PV, and as such the system was simple and basic. The system is still working.

During the same year, two further grid-connected PV systems were installed by BP Malaysia and *Universiti Kebangsaan Malaysia* (UKM). An 8kWp PV system was installed at a BP petrol station along the KESAS highway, and a 5.5kWp PV at the Solar Energy Research Park in UKM. The PV system at the BP petrol station was officiated by HM Queen of England. However, today, both the UKM and BP PV systems have been removed. A family of a TNB senior officer became the first Malaysian family to experience BIPV at their home in August 2000 when a 3.15kWp BIPV system was installed at their house in Port Dickson. Subsequently, two further BIPVs were installed at public residences in Shah Alam (3.24kWp in November 2000) and Subang Jaya (2.8kWp in November 2001).

More recently in late 2005, the roof of a bungalow in Semenyih was integrated with a 5.25kWp BIPV system. By making the house energy efficient, the requirement for BIPV capacity (and investment) is reduced and the PV produced electricity will become more significant. Today, there are almost 500kWp of grid-connected BIPVs installed in Peninsular Malaysia, most notably the 362kWp BIPV at Technology Park Malaysia (TPM). The PV installation at TPM demonstrated Malaysian capability to handle and manage large PV installations.

4. Grid-Connected PV System Calculation

4.1. Introduction

The proposed grid-connected PV cell in a small residential area involves a total of 10 units of houses located at Johor Bahru, Johor, Malaysia as a case study.

4.2. Size of PV Array

First, the size of the PV array required is calculated by using equation (1) as stated in [28].

$$PV\ Area = \frac{E_L}{G_{av}\ x\ \eta_{PV}\ x\ TCF\ x\ \eta_{out}} \quad (1)$$

Where E_L is the average daily load demand
G_{av} is average solar input per day
TCF is temperature correction factor
η_{PV} is PV efficiency
η_{out} is battery efficiency η_B × inverter efficiency η_{inv}

In average, a typical house has a daily load demand of 8.427 kWh [24]. Therefore, for 10 units of houses, the average daily load demand is 84.27 kWh. From the HOMER software, the average solar input per day for Johor Bahru is 4.921 KWh/m^2/day. Meanwhile the value of temperature correction factor (TCF) is 0.578 [25].

In this project, the PV array use is of the mono-crystalline (SC0155) type manufactured by Sorigin. The efficiency of this PV module is 14.62% [26]. Next, the inverter chosen to be implemented is produced by AIMS of type PWRINV500012W 5000 Watt power inverter with and efficiency of 90% [27].

After calculating, the size of the array needed for 10 units of a house in the residential area is 225 m^2. The PV peak power under illumination of 1 kW/m^2 at a cell temperature of 25°C was determined with the help of equation (2) [28].

$$\text{PV Peak Power} = \text{PV area x PSI x } \eta_{PV} \quad (2)$$

PSI takes the value of 1000. Therefore, the PV peak power computed for the residential area is 32895 Wp.

4.3. Size of Inverter

The inverter rating must be higher than the total watts of appliances. The inverter plays a big role in the system as it converts the DC input into AC at the output.

In the project, the rating of the inverter chosen must be 25% to 30% bigger than total watts of appliances. The inverter must be able to sustain the total amount of watts that will be used at a time for a standalone system. This project, the inverter is selected considering the rating to be 25% higher than total watts of appliances which takes the value of 4375 W. Therefore, a 500 W inverter has been chosen.

5. Simulation

The simulation of the PV system is done by using the HOMER software. After obtaining the values required for the components in the PV system, the data is inserted into the PV and inverter windows as the input. The description of the input for both PV module and inverter can be obtained in Figure 3 and 4 respectively.

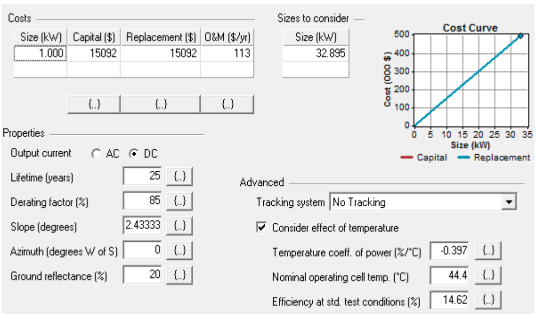

Figure 3. Input window for PV module

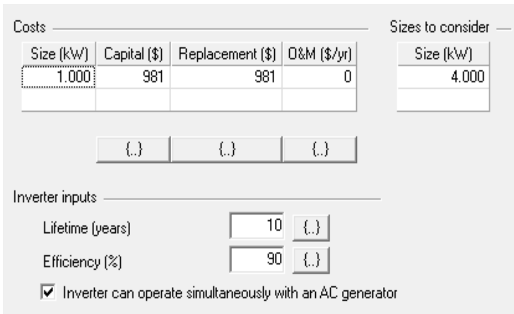

Figure 4. Input window for inverter

From Figure 4, it can be observed that the input for the size of the PV module to be considered is inserted as 32.895 kW which is calculated above. Besides, from [26], the input values for nominal operating cell temperature and the efficiency are 44.4ºC and 14.62% respectively. The lifetime for this simulation is chosen to be 25 years.

Next, for inverter as shown in Figure 4, since the inverter size calculated is 4375W, the input value for the simulation is selected to be 4000W.The inverter efficiency is inserted as 90%.

The PV system is constructed in the software and the schematic diagram of the system can be seen in Figure 5. From the Figure 5, the system consists of equipment such as PV module, converter, primary load representing the total load for the 10 units of houses and grid. Inverter plays the role of converting the DC supply produced by PV module from the sun into AC supply that will be consumed by the load. The AC supply will also be transferred to the grid network since the PV system for the residential area project is grid-connected.

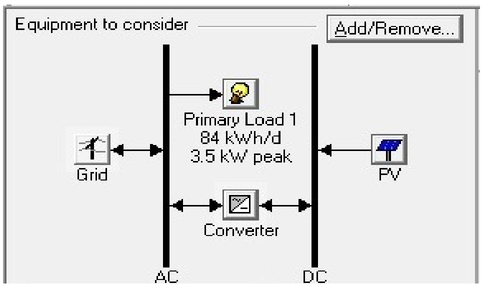

Figure 5. Schematic Diagram for Grid-Connected PV system

6. Simulation Result

After the simulation has been done, the output result obtained is shown in Figure 6. From Figure 6, it can be observed that for the PV system with 25 years of lifetime simulated in HOMER, the initial capital is RM 500,375. Besides, the operating cost is calculated to be RM5559 per year whereas the cost of energy (COE) is RM1.115 per kWh.

Double click on a system below for simulation results.

	PV (kW)	Conv. (kW)	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.
	32....	4	1000	$ 500,375	5,559	$ 597,181	1.115	0.76

Figure 6. Output result from HOMER simulation

Therefore, it is obvious that a very big amount of investment has to be allocated to initiate this grid-connected PV system which is RM 500,375 that requires a very strong support by the government and the private sectors as well. Furthermore, it is not easy to gain confidence among them in order to ask for such a very big investment not forgetting that there is an amount of RM 5,559 operating cost per year involved. A wide awareness about the solar energy as the clean and green renewable energy must be spread via education and also commercialization in order to gain the confidence among the key players.

According to the current TNB tariff for residential user that falls into the domestic category [30], the rate for the first 200 kWh per month is RM0.218 per kWh which is very much lower compared to the cost of energy (COE) computed in HOMER which is RM1.115 per kWh. Furthermore, the payback period for solar energy is quite long. However, in the long term, PV system will definitely be a source of energy that is able to provide the energy security with less environmental effect. Another aspect that needed to be considered is the area for the PV installation will require a very wide space which is less practical and will cause more money expansion. Therefore, as an option the implementation of building integrated PV system is much preferable.

7. Conclusion

Solar energy has high potential in Malaysia. Since 2000, solar PV installations have grown significantly in this country. The Malaysia Building Integrated Photovoltaic MBIPV project was one of the important tools to increase solar PV penetration in residential sector. Solar could become one of the major renewable sources for electricity generation in Malaysia since the financial resources for research and development programs and various government policies have shown a positive growth recently. The implementation of FiT undoubtedly will boost the solar PV industry in Malaysia. However, the total return from solar investment is not considered good enough. The implementation of PV system has to cope with the low level of understanding of government policies in Malaysia as well as the important awareness among users. A green energy of solar is only possible when there are complete awareness, sufficient investment, stable market and solid commitment.

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References

[1] S Mekhilef, A Safari, W Mustaffa, R Saidur, R Omar, M Younis. Solar energy in Malaysia: current state and prospects. *Renewable and Sustainable Energy Reviews.* 2012; 16: 386-396.
[2] D Van Vuuren, N Nakicenovic, K Riahi, A Brew-Hammond, D Kammen, V Modi, et al. An energy vision: the transformation towards sustainability-interconnected challenges and solutions. *Current Opinion in Environmental Sustainability.* 2012; 4: 18-34.
[3] F Muhammad-Sukki, AB Munir, R Ramirez-Iniguez, SH Abu-Bakar, SHM Yasin, SG McMeekin, et al. Solar photovoltaic in Malaysia: the way forward. *Renewable and Sustainable Energy Reviews.* 2012; 16: 5232-5244.
[4] M Grimston. Fukushima: What Happened and What Needs to Be Done. BBC News. 2011.
[5] Z Nawawi, A Aziz, Z Buntat, M Sidik, H Kareem, M Aziz, et al. Performance Analysis of a VPV/FC Hybrid System for Generating Electricity in Iraq's Remote Areas. *TELKOMNIKA Telecommunication Computing Electronics and Control,* 2016; 14(2): 411-422.
[6] Department of Statistics. Population Clock. 2011. Available: https://www.statistics.gov.my/.
[7] PY Gan, Z Li. An econometric study on long-term energy outlook and the implications of renewable energy utilization in Malaysia. *Energy Policy.* 2008; 36: 890-899.
[8] E Commission. Interim report on the performance of the electricity supply services in Malaysia (for the first half year of 2010). Putrajaya, Malaysia: Energy Commission.. 2010.
[9] S Shafie, T Mahlia, H Masjuki, A Andriyana. Current energy usage and sustainable energy in Malaysia: a review. *Renewable and Sustainable Energy Reviews.* 2011; 15: 4370-4377.
[10] H Ong, T Mahlia, H Masjuki. A review on energy scenario and sustainable energy in Malaysia. *Renewable and Sustainable Energy Reviews.* 2011; 15: 639-647.
[11] Ministry of Finance. The 2012 Budget Speech. 2011.
[12] EP Unit. Tenth Malaysia Plan. E. P. Unit, Ed. Malaysia. 2010.
[13] S Ahmad, MZA Ab Kadir, S Shafie. Current perspective of the renewable energy development in Malaysia. *Renewable and Sustainable Energy Reviews.* 2011; 15: 897-904.
[14] CIA. The World Fact Book. 2011. Available: https://www.cia.gov/library/publications/download/download-2011/.
[15] A Jaffar. *Outlook of coal demand/supply & policy in Malaysia*. Cleaner Coal: Moving Towards Zero Emissions, APEC. Incheon, South Korea. 2009.
[16] MBIPMP Portal. 2010. Available: http://www.mbipv.net.my
[17] M Hussin, A Yaacob, R Rahman, Z Zain, S Shaari, A Omar. Monitoring results of Malaysian building integrated PV Project in Grid-connected photovoltaic system in Malaysia. *Energy and Power.* 2012; 2: 39-45.
[18] AW Azhari, K Sopian, A Zaharim, M Al Ghoul. A new approach for predicting solar radiation in tropical environment using satellite images-case study of Malaysia. *WSEAS Transactions on Environment and Development.* 2008; 4: 373-378.
[19] LY Seng, G Lalchand, GMS Lin. Economical, environmental and technical analysis of building integrated photovoltaic systems in Malaysia. *Energy Policy.* 2008; 36: 2130-2142.
[20] S Shaari, A Omar, A Haris, S Sulaiman. Solar Photovoltaic power: designing Grid-Connected systems. Putrajaya: Kementerian Tenaga, Teknologi Hijau dan Air. 2010.
[21] A Haris. Grid-connected and building integrated photovoltaic: application status & prospect for Malaysia. *Master Builders Journal.* 2006; 3: 91-95.
[22] S Kirmani, M Jamil, C Kumar, MJ Ahmed. Techno economic feasibility analysis of a stand-alone PV system to electrify a rural area household in India. *International Journal of Engineering Science and Technology.* 2010; 2: 5231-5237.
[23] V Applasamy. *Cost evaluation of a stand-alone residential photovoltaic power system in Malaysia.* In Business, Engineering and Industrial Applications (ISBEIA), 2011 IEEE Symposium on. 2011: 214-218.
[24] C Wang, MH Nehrir. Power management of a stand-alone wind/photovoltaic/fuel cell energy system. *IEEE transactions on energy conversion.* 2008; 23: 957-967.