Annualized Electricity Cost of Residential Solar PV System under Malaysia's NEM Scheme

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Abstract: Net energy metering (NEM) is a financial scheme that allows a consumer to generate, use and sell their excess energy to the grid. The main purpose of NEM is for self-consumption to reduce demand from the grid. It will allow customer to avoid being charged with expensive electricity tariff and hence reducing their monthly electricity bill. In other words, the annualized electricity cost could be reduced. NEM is commonly offered to residential solar photovoltaic (PV) system. Different PV size will determine the amount of energy that can be generated. This paper compares the annualized electricity cost of different residential customer types (large, medium and small) for different PV size under Malaysia's net energy metering (NEM) scheme. This paper utilizes the load profile and solar irradiation data for Malaysia. The results show that high PV size does not guarantee reduction in annualized electricity cost especially for medium customers as the excess PV generation can only be accumulated for 24 months. Large customers may have benefited the most with lower annualized cost with larger PV system, while small customers may not have benefited at all.

1. INTRODUCTION

Feed-in-Tariff (FIT) and Net Energy Metering (NEM) are two financial mechanisms used by many countries around the world to encourage renewable energy generation among residential customers. Most countries started with the FIT scheme where consumers receive payment from the utility for the amount of renewable energy they generate. The price they receive depends on the FIT price set by a country. In Malaysia, FIT was introduced in 2011 and the starting price for FIT is around RM 1.23 per kWh (up to and including 4 kWp) [1] of energy generated from solar PV. Residential customers can generate income by installing PV solar panel system at their home and selling it to the utility (such as TNB) and the customers will be paid monthly based on the amount of kWh generated by their PV system each month. They will receive this payment over a 21 years' contract period.

Although this FIT scheme is very attractive, it does require a huge financial cost for the utility to pay the PV owners. To cover the FIT cost, Malaysian government originally implemented a 1.0% and later, increased to 1.6% the tariff on electricity consumption [2]. This amount may need to be increased further if the FIT scheme continues. In 2016, the FIT scheme in Malaysia was discontinued and replaced with the NEM scheme.

Conceptually, NEM is a financial scheme for renewable energy owners, where they will be rewarded in terms of net kWh consumption not gross kWh generation. Net kWh consumption is defined here as the amount of kWh consumed minus the amount of kWh generated by the customer in one month. In other words, owners of renewable energy sources such as solar PV systems need to utilize the generated energy first. They were only being charged for the remaining energy supplied by the grid. Unlike FIT scheme, in NEM the utility does not pay for the kWh generated. However, solar PV owners are rewarded in a form of reduction in electricity bills due to the net metering concept. If the amount of kWh generated exceeds kWh consumption, the net generation will be carried over to the following month. This net generation can be carried over to next months for up to 24 months before it expires. If it remains unused for 24 months, the PV system owner will not receive any benefit from this net generation. Therefore, it can be said that under the NEM scheme, generating to much kWh may result in financial loss.

This paper will study the amount of financial returns that PV system owners can receive for different PV sizes. Three types of user will be used in the case study; large, medium and small. Existing electricity tariffs and NEM schemes for Malaysia will be used. This paper is organized as follows; the next section will discuss the NEM scheme and brief the NEM schemes introduced in various countries. The next section will present the data used for the case study. The financial returns for each PV size will be compared by using annualized electricity cost. The later section will present the results of the analysis.

Generally, most countries have higher sell rates of net excess generation rate price compared to Malaysia, since the price of sell rates are reflected from retail rates of electricity.

3. CASE STUDY

This section will be explained about the data will be used in case studies.

3.1 Residential Load Profile, Solar Output for Malaysia

The residential consumer has more specific trend for load profile, since most people work on office hours and not much different of lifestyle. The overall trend will be low at midnight until early morning since most of them are sleeping. Then, the trend become medium on early morning until late evening, time the people going to work. At night, the trend will be higher since the people are resting and spend time with family. Therefore, one load profile trend has been chosen to use for the research which reflect the average residents load profile specifically in Malaysia [13]. From the original trend, the graph was modified to develop three different residential consumption sizes, small, medium and large which are consume 300 kWh, 600kWh and 900kWh per month respectively. The load profile for small, medium and large residents as shown in figure 1. Assume that all types of resident will produce same load profile for every day.
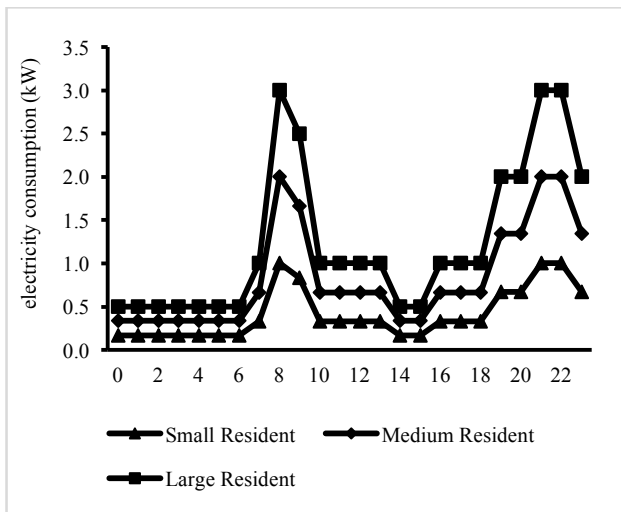

Figure 1. Energy Consumption for Different Size of Residents

Malaysia as a tropical country, receive sunlight more consistently throughout the year. Figure 2 shows the PV output for the daily PV output trends for 2kWp, 4kWp, 6kWp and 8kWp, which is based on 1kWp PV panel presented in [14, 15]. In this paper, it is assumed that every day the PV output will be the same. Therefore, daily PV output for 2kWp, 4kWp, 6kWp and 8kWp are 7.08kWh, 14.16kWh, 21.24kWh and 28.32kWh per day. The details as shown in table 2.

Next, the capital costs of PV panels for 2kWp, 4kWp, 6kWp and 8kWp are RM 13,900, RM 26,000, RM 35,000 and RM 42,000 respectively [16]. While the maintenance costs are RM 150, RM 200, RM 250 and RM 300 respectively. The detail as shown in table 3.
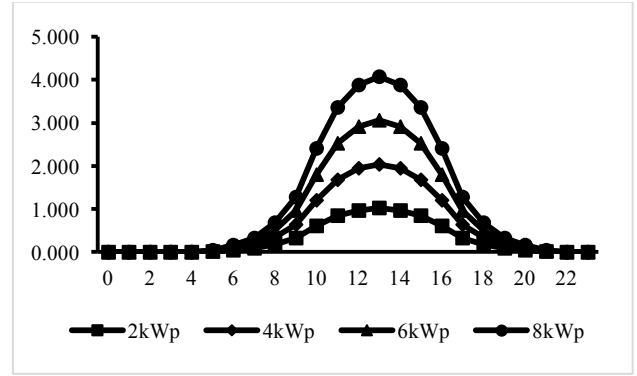
Figure 2. Daily PV Output for Different Size of PV Panels

Table 2. Daily PV output for different PV panel size

Time	PV Output					
	1kW	2kW	4kW	6kW	8kW	12kW
0	0.000	0.000	0.000	0.000	0.000	0.000
1	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000	0.000	0.000
5	0.005	0.010	0.020	0.030	0.040	0.060
6	0.020	0.040	0.080	0.120	0.160	0.240
7	0.040	0.080	0.160	0.240	0.320	0.480
8	0.085	0.170	0.340	0.510	0.680	1.020
9	0.160	0.320	0.640	0.960	1.280	1.920
10	0.300	0.600	1.200	1.800	2.400	3.600
11	0.420	0.840	1.680	2.520	3.360	5.040
12	0.485	0.970	1.940	2.910	3.880	5.820
13	0.510	1.020	2.040	3.060	4.080	6.120
14	0.485	0.970	1.940	2.910	3.880	5.820
15	0.420	0.840	1.680	2.520	3.360	5.040
16	0.300	0.600	1.200	1.800	2.400	3.600
17	0.160	0.320	0.640	0.960	1.280	1.920
18	0.085	0.170	0.340	0.510	0.680	1.020
19	0.040	0.080	0.160	0.240	0.320	0.480
20	0.020	0.040	0.080	0.120	0.160	0.240
21	0.005	0.010	0.020	0.030	0.040	0.060
22	0.000	0.000	0.000	0.000	0.000	0.000
23	0.000	0.000	0.000	0.000	0.000	0.000
Total	**3.540**	**7.080**	**14.160**	**21.240**	**28.320**	**42.480**

3.2 Annualized cost

Two basic economic concepts will be used in this research to value the cost saving for 25 years period. The two concepts are net present cost (NPC) and annualized cost. NPC is the present value of all the costs the system incurs over its lifetime, minus the present value of all the revenue it earns over its lifetime [17]. While, annualized cost of the component is the cost that, if it were to occur equally in

every year of the project lifetime, would give the same net present cost as the actual cash flow sequence associated with that component [18]. The formulas of both economic concepts are shown below:

$$NPC = \left(\sum_{t=1}^{N} \frac{R_t}{(1+i)^t} \right) \qquad (1)$$

$$Annual\ worth = present\ value \times \frac{i(1+i)^N}{(1+i)^N - 1} \qquad (2)$$

Where;
R_t – net cash flow
i – real discount rate
N – number of years
t – time cash flow

This paper uses real discount rate, i of 6%, and assumes that every year it will produce the same value. While, the project lifetime, N, is set for 25 years. Therefore, the simplified formula is written as:

$$NPC = \left(\sum_{t=1}^{25} \frac{R_t}{(1.06)^t} \right) \qquad (3)$$

$$Annual\ worth = present\ value \times \frac{0.06(1+0.06)^{25}}{(1+0.06)^{25} - 1} \qquad (4)$$

Table 3. Capital and Maintenance Cost for Different Size of PV Panels

PV Panel Size (kW$_p$)	Initial Capital (RM)	Maintenance Cost (RM)
2	13,900	150
4	26,000	200
6	35,000	250
8	42,000	300

3.3. Electricity tariff

The electricity tariff used in this paper is based on TNB Tariff A - domestic tariff on residential consumer. The electricity bill is calculated monthly by multiplying the total consumption in a month with Tariff A. Then, it is assumed that monthly electricity bill is the same for every month, then the annual electricity bill is calculated as follows;

$$\left(\sum_{d=1}^{30} \sum_{h=1}^{24} P_{d,h}^{consump} \right) \times Price^{tariff} \times 12 \qquad (5)$$

Since the electricity bill is calculated for 25 years, the present cost is considered. Assume that the discounted value is 6% every year. The total electricity bill for 25 years can be formulated as follows;

$$\sum_{n=1}^{25} \left(\sum_{d=1}^{30} \sum_{h=1}^{24} P_{d,h}^{consump} \times Price^{tariff} \times 12 \right) \times \frac{1}{1.06^{n-1}} \qquad (6)$$

Therefore, the annualized cost of can be formulated as follows;

$$Cost_{existing}^{annualized} = \sum_{n=1}^{25} \left[\left(\sum_{d=1}^{30} \sum_{h=1}^{24} P_{d,h}^{consump} \right) \times Price^{tariff} \times 12 \right] \times \frac{1}{1.06^{n-1}} \times 78.227 \times 10^{-3} \qquad (7)$$

4. RESULTS AND ANALYSIS

The results for large, medium and small customers for different PV size is given in figure 3, 4 and 5 respectively. From figure 3, for large customers, the higher the PV size, the lower the annualized electricity cost. The cost is maximum if the large customer didn't install solar PV system and reduces as the size of solar PV system increases. In this study, large customer consumes 900kWh a month. They are paying the high electricity tariff at 21.8 cents/kWh (for 1-200 kWh), 33.4 cents/kWh (for 201-300 kWh), 51.6 cents/kWh (for 301-600 kWh) and 54.6 cents/kWh (for 601-900 kWh). With solar PV system, the customer can generate its own energy and reduce the amount of energy bought from the utility (TNB). With this, the customer can avoid paying the high electricity tariff. The bigger the PV size, more energy can be generated resulting in lower electricity bill and hence lower annualized cost.

Figure 4 shows the results for medium customers. The annualized electricity cost is reducing from No PV into 4 kWp PV size, slightly reduces for 6 kWp PV size but increases for 8 kWp PV size. These results show that bigger PV size (8 kWp) will not benefit PV owner as it consumes lower kWh energy than large customer. It will only result in high net generation that can only be carried over to next months for up to 24 months. If PV generation is higher than kWh consumption for every month, the net generation will not give any financial benefit.

From Figure 5, it can be seen that the small customers with no PV systems has the lowest annualized electricity cost. The cost increases as the PV size increases. In this case study, small customer only consumes 300 kWh a month and hence only being charged with low electricity tariff at 21.8 cents/kWh (for 1-200 kWh) and 33.4 cents/kWh (for 201-300 kWh). Any PV generation will not benefit small customers as they already paying low electricity bill. Having PV system will only increase the electricity cost due to high capital cost of PV system.
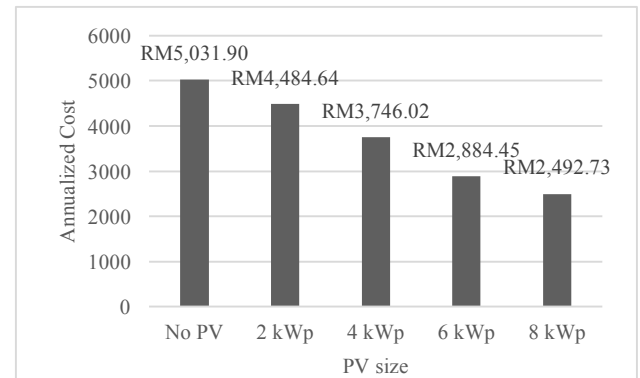

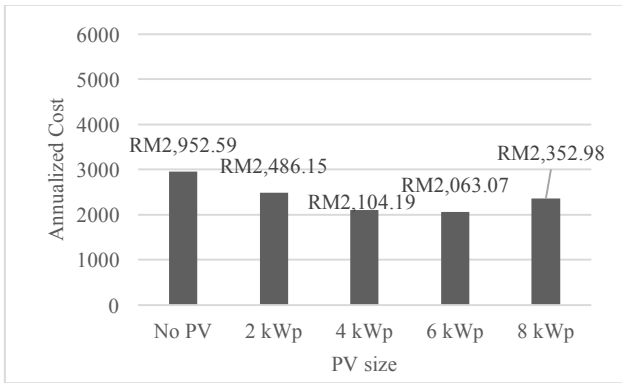Figure 3. Annualized cost for large customer for different PV sizes

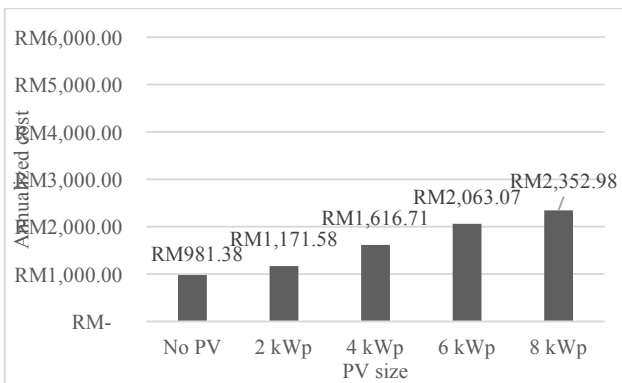Figure 4. Annualized cost for medium customer for different PV sizes

Figure 5. Annualized cost for small customer for different PV sizes

5. CONCLUSION

This paper compares the annualized electricity cost of different residential customers for different PV size system under net energy metering (NEM) scheme. The results show that high PV size does not guarantee reduction in annualized electricity cost especially for medium customers as the excess PV generation can only be accumulated for 24 months. Large kWh consumers may have benefited the most with lower annualized cost with larger PV system, while small customers do not benefited at all as the annualized cost for all sizes are higher than the system without PV.

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