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Energy distribution and economic analysis of a residential house with the net-energy metering scheme in Malaysia

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ABSTRACT

Malaysia demonstrates its commitment to alleviating the negative climate and energy issues through various initiatives. One of the latest initiatives is the amendment of the net-energy metering (NEM) scheme that takes effect from 2019. This paper presents the distribution of energy to the residential house that has a grid-connected solar photovoltaic (PV) system installed. The study quantifies the percentage of energy consumed from the PV system and the grid as well as the percentage of PV generated energy that is exported to the grid. On average, 38% of generated energy was used for self-consumption that contributed to 28% of the total consumption. Economic evaluation over a 25-year lifecycle of the PV system is also conducted shows that the simple payback period for NEM 2019 and NEM 2016 is 8 years and 20 years, respectively. The latest version of NEM shows a superior advantage compared to the previous one which may attract more investments in PV generation.

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1. INTRODUCTION

Economic growth, urbanization and increase in population are some of the factors that relate to the increase in energy demand. Population growth and urbanization affects energy usage pattern significantly where the rising demand for housing, food, public utilities, land use, and transportation in urban areas. Increase the energy consumption [1], [2]. Energy is a key driver of economic activities such as production and transportation sectors along with capital, and labor where the higher the gross domestic product (GDP) per capita, the more the energy demand [3], [4]. The reliance on carbon-based resources for energy generation is no longer a favorable one due to adverse effects on the environment and climate. However, it is still dominating the market to fulfil the global energy demand. Thus, generating energy from renewable sources remains highly relevant, to be implemented and explored [5], [6].

According to the World Energy Issues Monitor 2020, in the era of industrial transitions, the energy-related issues that mostly being paid attention by the world leaders are the internet of things (IoT) blockchain, the US policy, big data and artificial intelligence, commodity price, and economic growth [7]. The Government initiatives are crucial in addressing the energy issues such as energy security, environmental concerns, and climate change. The world leaders pledged their respective countries' commitments through the Intended Nationally Determined Contributions (INDCs) in addressing the climate change during the Paris Agreement [8]. China pledged to cut emissions per unit of GDP by 60-65% of 2005 levels by 2030 while the

US committed to achieve 26-28% domestic reduction in greenhouse gases by 2025 compared to 2005. Malaysia, a country that is in the phase of rapid development intends to reduce its greenhouse gas (GHG) emissions intensity of GDP by 45% by 2030 relative to the emissions intensity of GDP in 2005 [9]. Overall, there are 193 countries submitted the climate pledges that lead to the respective countries' energy policy to achieve the commitments. Emerging economies that depend on coal, such as China and India, have begun to address consumption by adjusting the fuel's price, capping its consumption, reducing plans for new coal-fired power plants and supporting renewables [10].

Malaysia is one of the countries that extensively promote energy generation from renewable and sustainable resources [11]–[14]. In mitigating the issues of energy security, energy efficiency and environmental impacts to meet the energy demand as well as promoting the low carbon future, the Government of Malaysia has developed several key policies and incentives to achieve the objectives [15], [16]. In the Eighth Malaysia Plan (2001-2005), renewable energy (RE) was introduced in the country's energy mix for the first time in the Fifth-Fuel Policy. It is a fuel diversification policy where RE was added with a target to contribute 5% of the energy mix after oil, gas, hydro and coal. However, this policy ended up reaching only 0.3% of the target by the year 2005 [17]. The same target was set in the Ninth Malaysia Plan (2006-2010), but once again, it failed to achieve the goal with only 8.3% of the target [18]. Kardooni *et al.* [18] identified the barriers leading to the failure of this 10-year renewable energy policy are the lack of knowledge and agreement as well as technology, economic, political and social barriers. The country has to address a serious challenge on how to upsurge the contribution of the renewables in the energy mix as well as promoting public participation in achieving the goals [19].

Learning from the experience, Malaysia formulated a more comprehensive National Renewable Energy Policy and Action Plan 2009, which then gazetted the Renewable Energy Act 2011 and Sustainable Energy Development Authority Act 2011. Many initiatives and incentives were introduced to achieve the national RE policy target of 20% capacity mix by 2025 [14], [20]. The Feed-in Tariff scheme was made active in 2011 where the RE producers will be paid at premium tariff rate for each unit of electricity fed to the grid for a long period-usually 15 to 20 years [21]. The tariff rate varies according to the source of energy (biogas, biomass including municipal solid waste, small hydropower, and solar photovoltaic. The government imposed a quota for the FiT which was announced as 630 MW at the beginning, but later revised to 505 MW. The new application for the FiT scheme was closed when the quota was fully taken in 2014 [22]. In 2016, the net energy metering (NEM) was introduced for solar PV electricity system to the domestic, commercial and industrial premises. As illustrates in Figure 1, the concept of NEM is that the energy produced from the installed solar PV system will be consumed first, and any excess will be exported to the electric utility provider [23]. The allowable capacity for domestic customer is 12 kWp for single phase system and 72 kWp for three-phase system, while for industrial and commercial customer is 1 MWp. NEM considers the net energy generated and for the NEM 2016, the customer will be paid based on the displaced cost per kWh unit. However, NEM 2016 received poor response from electricity customers in Malaysia due to unattractive financial return [24].

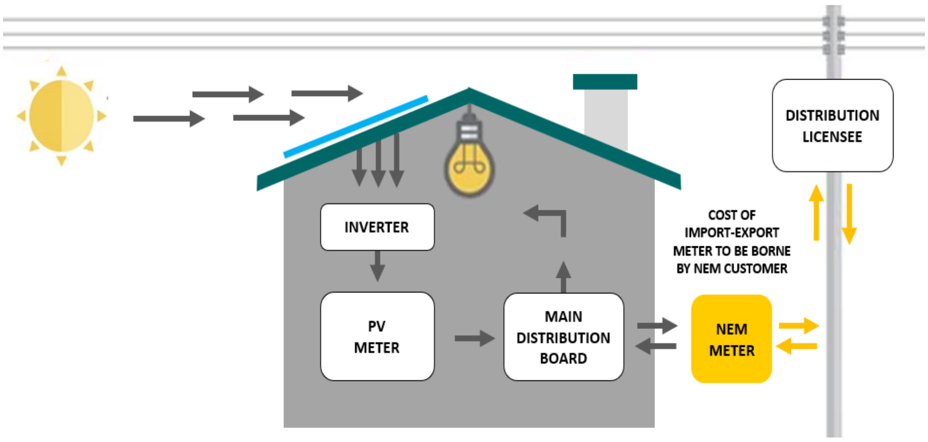

Figure 1. The concept of solar PV system with NEM connection [18]

To attract investors and to improve return on investment of solar PV in Malaysia, the changes of the NEM concept from net billing to true net energy metering effective was introduced from the beginning of

2019. The NEM 2019 adopts the true net energy metering concept and this allows excess solar PV generated energy to be exported back to the grid on a one-on-one offset basis. This means that every 1 kWh exported to the grid will be offset against 1 kWh consumed from the grid, instead of at the displaced cost per kWh previously [25]. Another sectors, i.e., agriculture is also added to the list of allowable customers. The rest remain the same as NEM 2016 scheme. Figure 2 depicts the allocated quota for solar PV electricity system in Malaysia from 2016 until October 2020. According to the figure, a significant increase in the utilization of the NEM scheme can be seen in the year 2020, which is more than a year after NEM 2019 was introduced. The new concept of as implemented in NEM 2019 is seen to serve its purpose to increase the PV electricity capacity, thanks to its better economic advantage. However, up to October 2020, only 259 MWac PV capacity is installed, a bit more than half of the 500 MWac that is targeted to be achieved by end of 2020 [26].

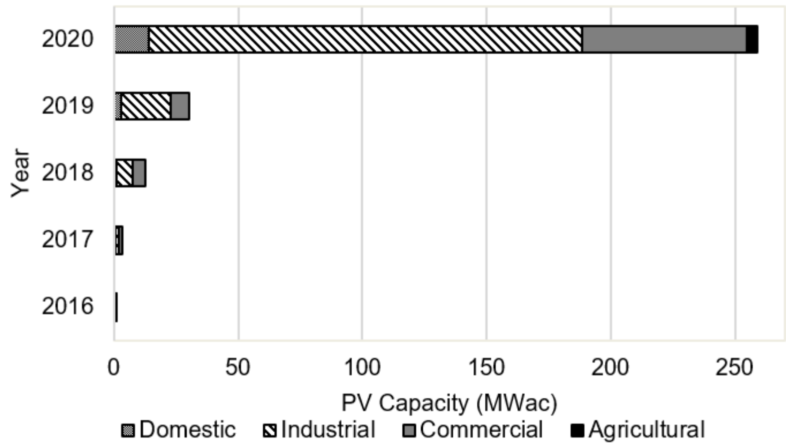

Figure 2. Allocated quota under the Malaysia's NEM from 2016 until October 2020 [20]

The latest revision of NEM scheme in Malaysia seems promising in increasing the renewable energy generation in the country. However, there is no literature found to be analyzing the energy distribution fraction for the energy use, energy import and energy export of the net-energy metering system using the real data. This real data is important in accurately projects the future financial of the system using the life-cycle cost analysis. This paper presents the initiatives by the Malaysian government to address the energy issues, which is the new Net Energy Metering scheme that gazetted to start in 2019 (NEM 2019). The analyses are conducted based on a case study of a domestic customer with a grid-connected solar photovoltaic (PV) system. A financial comparison between NEM 2016 and NEM 2019 is also presented.

2. METHOD

2.1. Grid connected solar PV energy generation system

The case study for the solar PV with NEM focuses on the domestic customer, which is a double storey terrace house located in Bandar Seri Putra, Bangi, Malaysia as shown in Figure 3. The coordinate for the location is 2°53′9.2″N 101°46′47.48″E, about 40 km to the capital of Malaysia. Malaysia generally experiences the hot and humid climate that is tied by South-west Monsoon (May to September and the North-Eastern Monsoon (November to April) with high rate of annual rainfall [27].

The studied domestic customer installs a 4.24 kWp solar PV system with a 5-kW grid-connected inverter. The schematic of the system is shown in Figure 4. The direct current (DC) generated by the PV array is inverted to alternating current (AC) by the inverter before the main distribution board. The inverter used in this system has the capability to log the important energy (PV generation, import and export from/to grid, and consumption) and send the data for cloud storage. The energy generated is set for consumption first and the excess will be export to the grid. Whenever the energy from the PV system is not sufficient for consumption, the energy will be imported from the grid. The import and export electricity will flow through the NEM meter, which the amount will be calculated according to the tariff for monthly electricity bill.

2.2. Net energy metering billing calculation

For domestic customers, the electricity price is charged according to Tariff A as tabulated in Table 1 [28]. However, the calculation procedure for the monthly bills is different for the respective NEM version.

The important parameter in the billing calculation is the total monthly energy consumption ($E_{consume}$), total monthly energy generation by the PV system (E_{PV}), the displaced cost (*DC*) and the electricity tariff. The total energy consumption is the energy consumed by the customer from both sources, i.e., the PV generation system and the electricity grid. *DC* refers to the average cost of generating and supplying one kilowatt hour of electricity from resources other than renewable resources (i.e. fossil fuels) through the supply line up to the point of inter-connection with the RE installation [29]. It is set at 31 cent/kWh for domestic customers. The monthly electricity bill under NEM 2016 is calculated using the following formula:

$$Monthly\ bill\ =\ (E_{consume}\ \times\ Tariff\ A) - (E_{PV}\ \times\ DC) \quad (1)$$

The monthly bill calculation for NEM 2019 is simpler compared to NEM 2016. NEM 2019 considers the net energy import (E_{import}) and export (E_{export}) from/to the grid at one-to-one basis according to the tariff. The monthly electricity bills of the domestic customer under NEM 2016 are calculated using (2).

$$Monthly\ bill\ =\ (Eimport - Eexport)\ \times\ Tariff\ A \quad (2)$$

Figure 3. Aerial view of the residential house with grid-connected PV system that is considered in this study

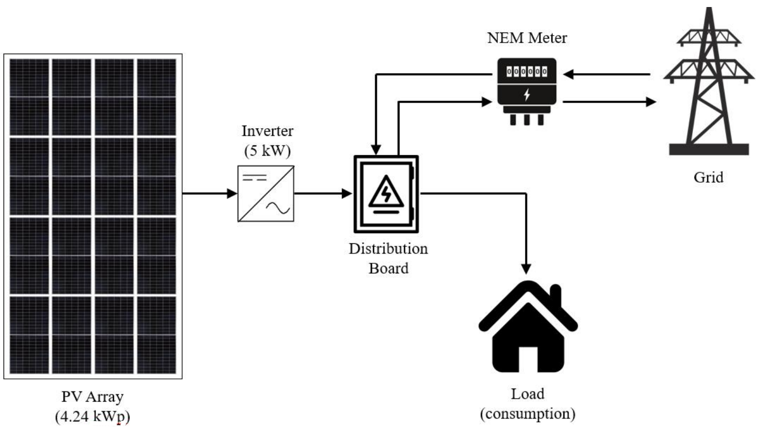

Figure 4. Schematic diagram of the grid-connected PV energy generation system for domestic customer

Table 1. Domestic tariff

Tariff A - Domestic Tariff	Unit Price (cent/kWh)
For the first 200 kWh (1-200 kWh) per month	21.80
For the next 100 kWh (201-300 kWh) per month	33.40
For the next 300 kWh (301-600 kWh) per month	51.60
For the next 300 kWh (601-900 kWh) per month	54.60
For the next kWh (901 kWh onwards) per month	57.10

2.3. Economic assessment

Economic evaluations to compare the grid-connected PV system with NEM2016 and NEM2019 schemes are conducted by considering the economic parameters as tabulated in Table 2. The lifetime of the system is considered as 25 years. The capital cost for the complete system is estimated as RM 5,000 per kWp according to the current market value, which includes the PV modules, inverter, wiring, and supporting structure. The inverter needs to be replaced every 10 years with its initial cost is assumed as RM 5,000. The operation and maintenance (O&M) cost for a solar PV system is very minimum, hence it is estimated as 1% of the initial cost annually. The inflation rate for Malaysia for the last 10 years was in the range of between 0.11% and 3.8% [30]. In this analysis, the 10-year (2009-2019) average inflation rate of 2.02% is used throughout the life of the system. According to the electricity price trend, the tariff rate is predicted to rise by 5% annually for the energy block above 300 kWh while for the usage of 300 kWh and below, the tariff is constant. The billing calculation also include the 6% service tax, which is chargeable for the consumption of above 600 kWh [31]. There is an additional surcharge at 1.6% of the monthly electricity price by the government called the Renewable Energy Fund. The fund is collected for the renewable energy related programs such as research grants and community projects that open for government and private institutions to apply. All the energy quantities (PV generation, consumption, import, and export) are assumed based on the energy distribution for the year 2019. According to Sangwongwanich et al., for hot humid climate, due to degradation of the PV modules, the energy generation will reduce by 1% annually [32]. This degradation factor is considered in this study.

Table 2. Economic evaluation parameters

Item	Rate
Complete 4.24 kWp PV system	RM 21,100.00
Inverter replacement cost	RM 5,000.00 (year 0)
Inflation rate	2.02%
Operation and maintenance cost	1% of the initial cost
Annual electricity price increment	5% for the energy blocks above 300 kWh
Assumed annual PV for the first year	5294 kWh
Annual PV generation degradation	1% of the previous year
Assumed total annual consumption	7784 kWh
Assumed PV energy self-consumption	38% of the PV generation
Assumed PV energy export to grid	62% of the PV generation
Assumed electricity imported from grid	74% of the consumption
Service tax	6% for the energy blocks above 600 kWh
Renewable energy fund surcharge	1.6% of the monthly price

3. RESULT AND DISCUSSION

3.1. Energy distribution

The energy generated by the PV system was recorded by the built-in data logger in the inverter. Figure 5 shows the monthly energy generation for the year 2019. Due to the needs of approval from the authority, the PV system was only connected to the distribution board starting from June 2019. The PV generated energy from January to May 2019 was not used and dumped by the system since no energy storage device installed. According to the figure, the monthly energy generated by the PV system is in the range of 350 kWh to 550 kWh, with the cumulative energy for the year is 5579 kWh. The highest energy generated by the system is in May 2019, i.e., 553 kWh. It can be noted that the system generated lower energy during the North-Eastern Monsoon (January to April and November to December). This monsoon season carries high rainfall that peaks in December and January. Thus, the energy generation for these two months was the lowest as expected.

The PV generated energy is ready to be used starting from June 2019, which was utilized for own domestic consumption and the excess was exported to the grid. As the energy was not stored, the consumption and export of energy from PV source was only active during daytime whenever the system generated energy. On average, 38% of the generated energy was used for own consumption from June to December 2019.

Figure 6 depicts the sources of electricity that was consumed by the studied domestic user. The electricity from the grid was mainly supplied by the grid with 74% from June to December 2019. According to the user interview, the air-conditioning system for the house was in use mostly at night to provide conducive environment to sleep. Thus, the electricity supply from the grid was needed at that time since no generation from PV at night. It is most likely the reason for the grid supply was higher during the nighttime. Figure 7 summarizes the total energy distribution for the grid-connected PV system for June to December 2019.

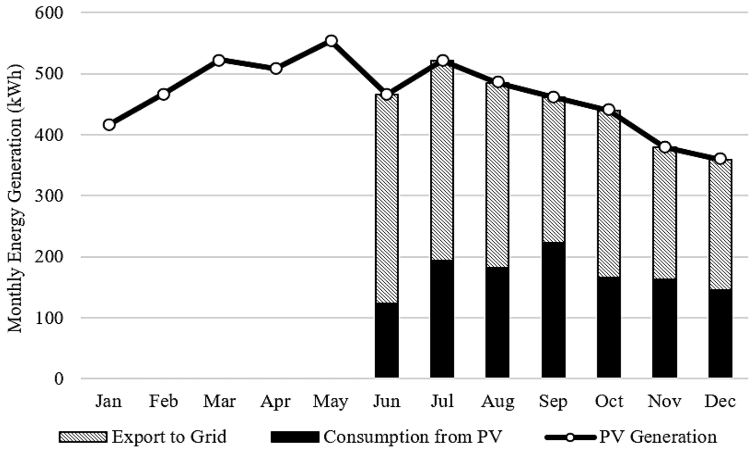

Figure 5. PV system energy generation and its distribution

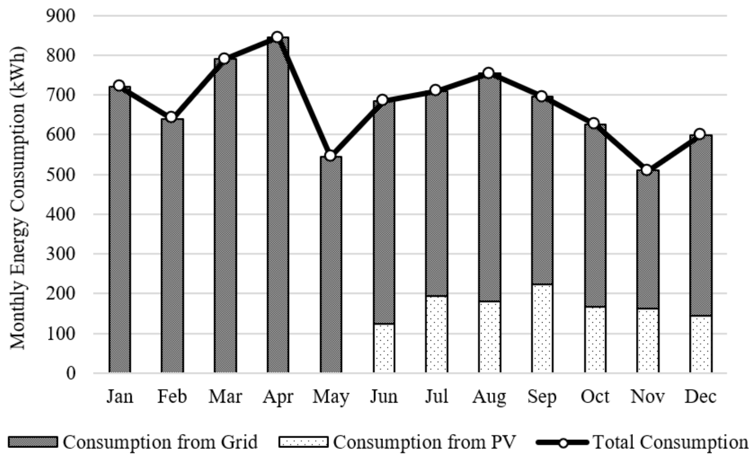

Figure 6. Energy consumption by the studied domestic user

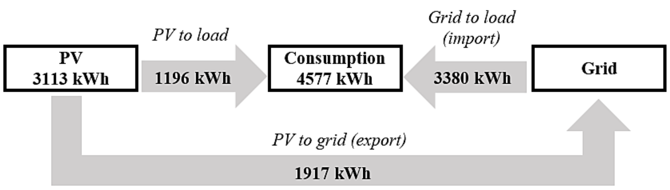

Figure 7. Total energy distribution from June to December 2019

3.2. Economic evaluation

Comparison of monthly electricity bill for the studied domestic customer without the consumption from the PV system, and with the grid-connected PV system using NEM 2016 as well as NEM 2019 are compared in Figure 8. Figure 9 shows the cumulative energy cost savings through the 25-year analysis period. Comparing to the capital cost of RM 21,100, the grid-connected PV system with the NEM 2019 scheme will achieve the simple payback period in the eighth year. On the other hand, the system applying the NEM 2016 scheme only able to achieve the payback in the year 20. From the other perspective, considering the annual present value and other costs, the value of the system with NEM 2019 becomes positive on the eighth year and stays positive even there will be inverter replacement cost as shown in Figure 10. However, with NEM 2016, the positive value of the system is never achieved. At the end of the lifecycle of the system, the cumulative savings are RM 69,392.40 and RM 23,218.40 for the NEM 2019 and NEM 2016 schemes, respectively. This projection clearly indicates that the NEM 2019 scheme demonstrates a better economic advantage compared to NEM 2016.

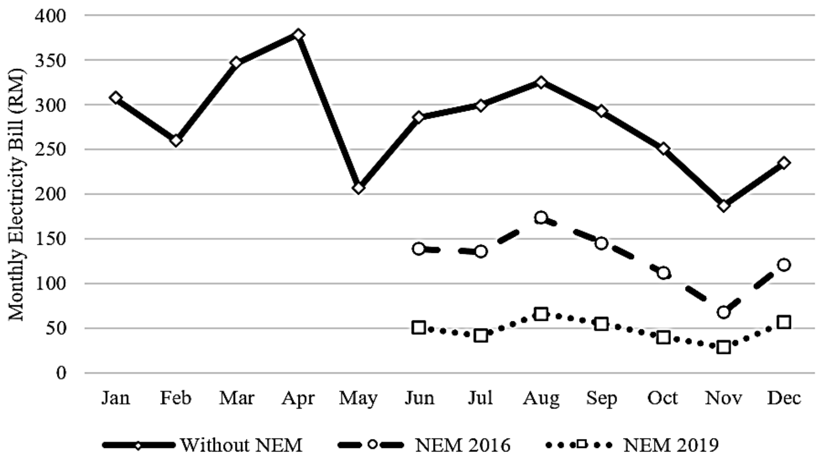

Figure 8. Electricity bill for the studied domestic customer without the consumption from the PV system, and with the grid-connected PV system using NEM 2016 and NEM 2019

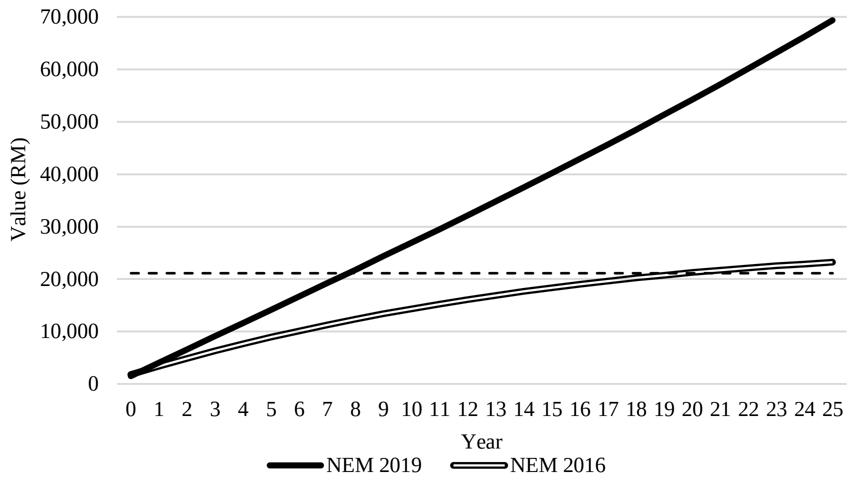

Figure 9. Cummulative energy cost savings through the analysis period

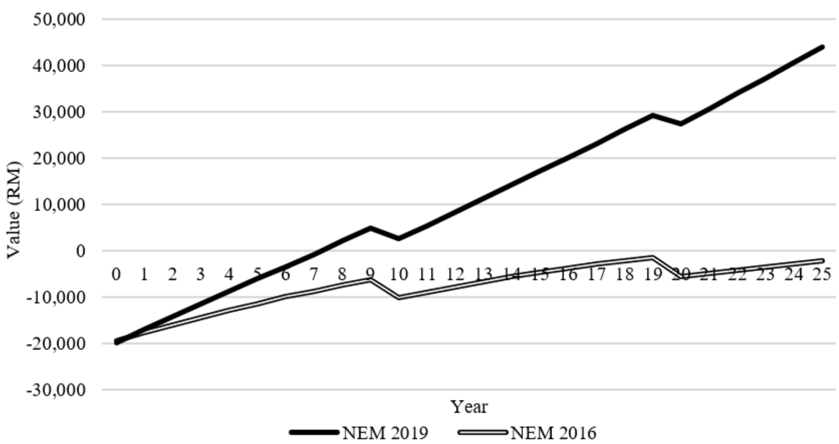

Figure 10. The annual present value of the system worth over the economic analysis period

4. CONCLUSION

The Government of Malaysia's commitment in reducing the carbon emission and enhancing energy generation from sustainable resources is shown with the introduction of acts, policies, regulations, and incentives on this matter. To ensure their effectiveness, these initiatives have been modified from time to time. One of the latest modifications is the enhanced net energy metering (NEM) scheme starting from the year 2019, replacing the 2016 version. Based on the case study on the domestic user, the application of NEM 2019 is much more financially attractive compared to the previous one. This would captivate more investments in solar PV energy generation, hence help the government to achieve the targeted goals. The findings presented in this paper could help to the investor to decide in investing in the renewable energy generation system, utilizing the net energy metering scheme.

In a bigger perspective, Malaysia could be an example of a developing country that consider the issue of sustainability in the development of the nation. The formulations of policies are made and updated according to the country's resources available at that time as well as learning from previous experience. Other countries that have similar background may adopt the same initiative in order to improve the utilization of renewable energy generation in the respective countries. The rapid grows of residential PV system would provide power to offset as much of the household load as possible.

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