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# The Economic Assessment of Small PV Rooftop Residential Installations in Malaysia Under Net Energy Metering Scheme

[1]Ramlan Zailani, [2]Halim Ghafar

[1] College of Engineering, School of Mechanical Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia, [2]Mechanical Engineering Centre of Study, Universiti Teknologi MARA Pulau Pinang, 13500 Permatang Pauh, Pulau Pinang, Malaysia.

Email: ramlanza@uitm.edu.my

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**Abstract**

Under the Net Energy Metering (NEM) 2.0 Scheme which was introduced by the Sustainable Energy Development Authority (SEDA) of Malaysia in January 2019 consumers could benefit more from installing solar PV on the rooftops of their homes which allow the excess of the generated energy to be exported to the grid on a one-on-one offset basis, instead of at the Displaced Cost as previously implemented under the NEM 1.0. The period of the return on investment (ROI) of the PV installations would depend on both, the energy consumption patterns and the PV system configurations, in addition to the external factors such as weather fluctuation, roof orientations and inclination angles. Generally, a significant saving could be achieved from the solar PV installation in individual homes with high energy consumption and with a big capacity of solar PV systems installations. This study evaluated the economic benefits of small PV rooftop systems in homes that consume less than 600 kWh monthly with PV installation of less than 4 $kW_p$. The period of ROI was evaluated based on the electricity consumption pattern, the electricity tariff billing structure, and the actual generation from a selected PV installation. The ROI payback period of 6.5 to 8.0 years could be realized with the correct sizing of the PV systems. This information could inspire small homeowners to install a rooftop PV system under the currently available NEM 3.0, first to reduce their electricity bills and to contribute to the Nation's inspiration of the Net Carbon Zero target by 2050.

**Keywords*:*** Residential Rooftops PV, Net Energy Metering, Return-On-Investment.

## Introduction

The Feed-in-Tariff (FiT) Scheme was introduced under the Renewable Energy Act 2011 to accelerate investment in renewable energy projects in Malaysia. A very competitive tariff was offered for solar PV installations including to individual homeowners, where they could sell the energy generated from the solar PV systems to the electricity grid at a relatively high tariff during the day and buy the energy at a much lower rate during the night. Theoretically, every homeowner could install solar PV panels on their rooftops and become an energy exporter. However, the FiT quota allocated for individual homes was too small and was fully subscribed within a few hours after each launching session. The fund for the FiT Scheme was provided by the Renewable Energy Fund, collected as a 1.6% surcharge on the overall amount of monthly electricity bills, from installations with energy consumption of more than 300 kWh. Due to partly, the insufficient fund available to cater more solar PV installations under the FiT Scheme, the Net Energy Metering (NEM) Scheme was launched for the new PV installations in November 2016 with a quota allocation of 500 MW up to the year 2020. The concept of NEM is that the energy produced from the solar PV installations will be consumed first, and any excess will be exported to the grid at a prevailing displaced cost. The period of the return on investment (ROI), the point where the overall savings from the generated energy finally matched the cost of installing the solar PV systems, under NEM Scheme would be significantly longer than those under FiT Scheme. As a result, there were much lower applications for solar installations under the NEM Scheme including those from individual homeowners than expected. By the end of 2018, only 2.37 MW individual home applications were approved by SEDA. The NEM 2.0 was introduced on the 1st of January 2019, as an effort by SEDA to encourage more NEM uptakes, with the true net energy metering concept where it allows excess solar PV generated energy to be exported back to the power grid on a “one-on-one” offset basis, which meant that every kilowatt-hour exported was offset against a kilowatt-hour of electricity imported from the grid. Under NEM 2.0, consumers could benefit a lot more from installing solar PV on home rooftops which will significantly decrease the ROI period and only future savings will continue for many years ahead. As the result, the applications for NEM 2.0 surged and the 500 MW quota under the NEM 2.0 was fully subscribed by the 31$^{st}$ December 2020, as shown in Figure 1 (SEDA, 2021).

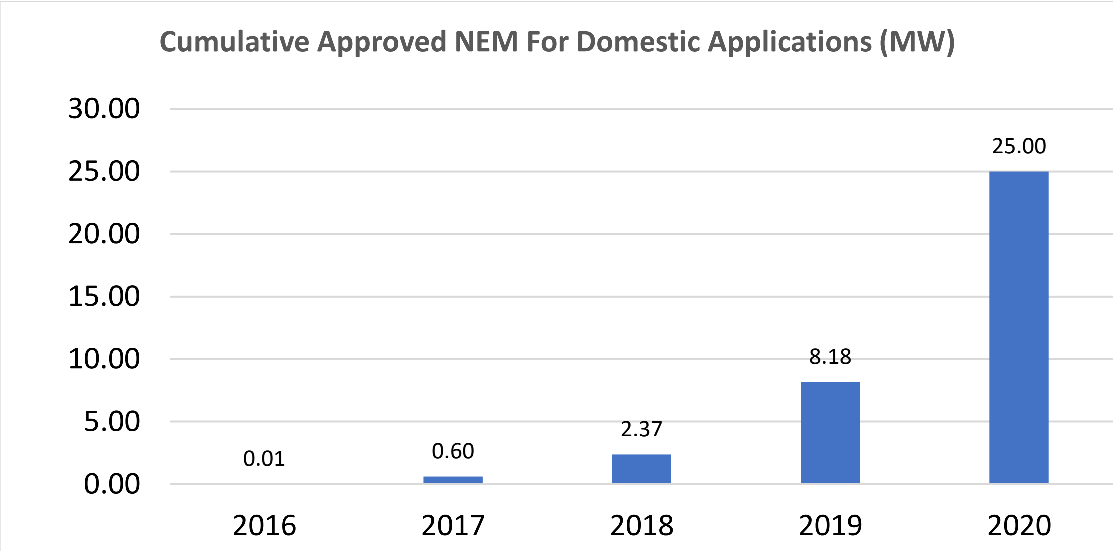


Figure 1. The cumulative NEM approved for domestic installation:
NEM 1.0 (2016-2018) and NEM 2.0 (2019-2020). (SEDA, 2021)

The Net Energy Metering 3.0 (NEM 3.0) was introduced in January 2021 to provide more opportunities for electricity users including individual homeowners to install solar PV systems on their premises to reduce their electricity bills. The NEM *Rakyat* 3.0 for residential or domestic account holders allocate 100 MW is available from 1$^{st}$ February 2021 to 31$^{st}$ December 2023. The concept of NEM 2.0 was adopted by NEM 3.0, but the capacity of each installation for NEM *Rakyat* 3.0 is capped at 4 $kW_{ac}$ and 10 $kW_{ac}$ for single-phase and three-phase configurations respectively, and the NEM tariff is only offered for 10-years, after which consumers could only consume the energy from their solar installation without the opportunity for exporting the excess energy to the grid.

The solar PV system's generation is highly affected by both, the technical parameters and the system configurations. The economic evaluation of rooftop PV systems should be considered in a case-by-case scenario and cannot be generalized due to the factors such as the availability of solar radiation, energy load profile of the buildings, roof utilization factors and PV system design mechanics (Dehwah et al., 2020). The daily weather conditions, the clearness and cleanliness of the solar panel, and the panels' orientations to the Sun's path are also important parameters. The roof inclination angles and roof orientations are essential parameters in the performance evaluation of a rooftop solar PV system which could significantly affect the solar output generation and these parameters vary for every house. The installation of rooftop PV differs in terms of both installation tilted angle and module parameters. Roof inclination refers to the tilt angle, while roof orientation refers to the azimuth angle, as shown in Figure 2, (Anon, 2022).

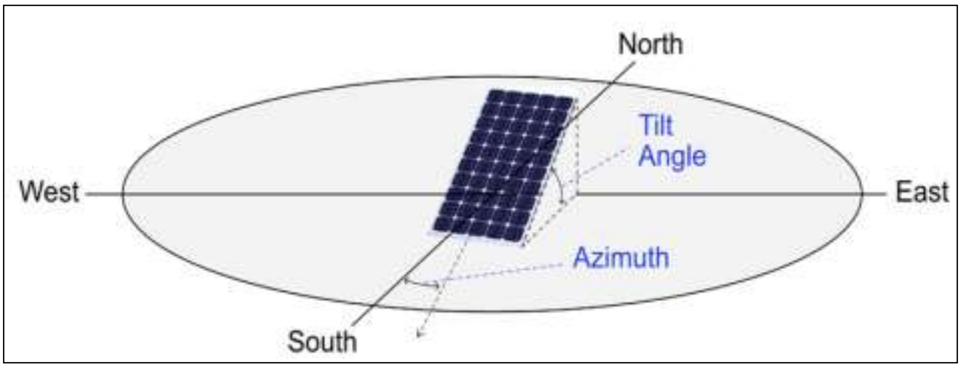


*Figure 2*. Roof orientation determines the tilt and azimuth angle.

However, these parameters are fixed for the existing rooftops and other parameters should be evaluated to achieve the best size and configuration of the installed systems. The losses due to deviation of the azimuth and tilt angle of the roof are taken into account when sizing the PV installation system since the losses could be as high as 20% depending on the deviation angles (Barbon et al., 2022). Considering the actual spatial layout of the PV panels is a vital aspect of maximizing ROI for solar installations, given the limited and often irregularly shaped rooftop space available (Zhong et al., 2022).

The correct choice of the installed capacity of the solar PV system is essential to achieve the best economical gain from the system. The shortest ROI period could be achieved with the right parameters setting and the system capacity that the consumers need to install. Proper strategies and suitable approaches need to be considered to extract the best from the system e.g., the optimum system power capacity equitable with the power consumption of various types of households, and the suitable position of solar panels to be installed. The calculation of the ideal power generation should consider the latest energy tariff billing structure provided by the utility provider in Peninsular Malaysia, which is the *Tenaga Nasional Berhad* (TNB). It is crucial to find a way to benefit the customer to achieve the quickest return-on-investment period to achieve the best savings for the consumers to comply with the NEM 3.0 guidelines where there will be no roll-over of credits to be allowed after ten years of the solar PV installation.

Most of the available studies on solar PV installations in Malaysia focus on the technological advancement for commercial or large-scale PV system. (Husain, 2021). Residential rooftop PV installations require an economic feasibility analysis to determine if it is worthy of investment. Currently, the general perception is that the economic benefits from solar installations would be lesser for individual homes with small PV capacity and less savings could be achieved for small homes with low energy consumption, compared to those which consumed more energy. This study provides a financial analysis for a small rooftop PV system under NEM 2.0 and the recently launched NEM3.0 on the profitability of such projects and clarifies the limitation of a system implemented under these schemes. This study evaluated the profitability of the installation of a small solar PV in residential homes which consumed less than 600 kWh monthly with PV installation of less than 4 $kW_p$. This work aims at closing this gap by evaluating the financial benefit of small PV systems on the rooftops of residential homes. The evaluation involved the assessment of the TNB electricity billing structure, the income-outcome ratio of a small solar PV installation and the cost of the system's installation based on the current market value.

**Materials and Method**

For residential electricity users, the energy consumption is charged in the tariff blocks based on the monthly electricity usage. Table 1. Shows the *Tenaga Nasional Berhad* (TNB) Billing Block System for the domestic tariff. The monthly bill for the first 300 kWh and 600 kWh energy consumption are RM77.00 and RM232.80 respectively and were used as the base reference in the assessment. Additionally, the bill will also include a Renewable Energy (RE) Fund surcharge and a service tax if the monthly consumption exceeds certain amounts. RE Fund is a 1.6% surcharge imposed only on usage blocks of above 300 kWh and the service tax is a 6% government tax imposed only on usage blocks of above 600 kWh within a month's bill. The monthly bill for the first 300 kWh and 600 kWh energy consumption are RM77.00 and RM232.80 respectively and were used as the base reference in the assessment.

Table 1

*Tenaga Nasional Berhad Billing System for the Domestic Tariff. (TNB, 2022)*

| **Electric Energy consumption (kWh)** | **Cost per kWh (RM)*** |
|---|---|
| First 200 kWh (1-200 kWh) per month | 0.218 |
| Second – Next 100 kWh (201-300 kWh) per month | 0.334 |
| Third – Next 300 kWh (301-600 kWh) per month | 0.516 |
| Fourth – Next 300 kWh (601-900 kWh) per month | 0.546 |
| Next kWh (901 kWh onwards) per month | 0.571 |

*RM1.00 RM = USD 0.2357 (as on 25$^{th}$ January 2023).

The monthly bill for the first 300 kWh and 600 kWh energy consumption are RM77.00 and RM232.80 respectively and were used as the base reference in the assessment. The actual solar PV system generation data, energy consumption pattern and electricity bills for 24 consecutive months of an installation were thoroughly analyzed to establish the consumption trend, energy saving and the projected period of the return on investment of the installation.

The energy data were extracted from the inverter data logger, the TNB smart meter and the monthly electricity bills. The reference installation is a 3.12 $kW_p$ with eight PV panels on a single-storey terrace house as summarized in Table 2.

Table 2
Reference Installation details

| | |
|---|---|
| Type of Property. | Single-story terrace. |
| Location. | Shah Alam City area.<br>~ (3.08 N, 101.53 E) |
| Panels orientation and tilt angles. | 4 panels facing 300˚ N.<br>4 panels facing 210˚ N.<br>Tilt angle: 15˚ |
| Total max generation capacity.<br>Inverter capacity. | 3.12 $kW_p$<br>4 $kW_{ac}$ |
| Capacity and number of panels. | 390 W x 8 (Monocrystalline Si). |
| PV panels cost. | RM750.00 x 8 |
| Total installation Cost. | RM12,500.00 |

Several scenarios of energy consumption and PV system capacity were simulated based on the reference installation for the economical comparison of the corresponding PV systems. The reference installation was used in the analysis, to eliminate the effect of the variation of weather, roof slope angle and orientations, and energy consumption patterns. The results obtained from the analysis using PVSyst 7.2 software show that for Shah Alam City Section 1 (3.0696 N, 101.5038 E) the optimum tilt angle of 10˚ and azimuth angle of 0˚ are proposed for the PV panel installations (Mansur, 2021).
The solar generation index ($S_i$) is defined as

*$S_i$ = The daily solar energy generation (kWh) / System's theoretical maximum capacity (kW)*

The saving gain is calculated based on the monthly financial gain achieved from the solar installation.

*Saving (%) = (Actual monthly bill with solar/ Calculated bill without solar installation) x 100%*

The period of return on investment (ROI) is a financial ratio used to calculate the benefit an investor will receive concerning their investment cost and is most measured as net income divided by the original capital cost of the investment. A simple payback period (SPP) is defined as the time required to repay the up-front cost of the investment. This method is simple because the time value of money is not considered (Dehwah et al., 2020).

***SPP (years) = (Cost of Investment of solar system/Annual net income from solar system)***.

The daily solar energy generation from the PV system is highly dependent on the solar radiation received by the PV panels, hence the daily weather conditions. Figure 3a shows a typical output from the inverter on a mix of the sunny and cloudy day which show that the power generation output could vary from above 90% to less than 10% of the system's maximum capacity within a short time, due to the appearance and disappearance of the shadow cast by clouds passing by the panels throughout the day. However, the corresponding energy generation and hence the solar earnings are distributed normally as shown in Figure 3b, with the daily highest generation attained between 11.00 a.m - 3.00 p.m. One of the highest daily energy generations of 16.00 kWh was recorded with a generation index $S_i$ = 5.33

on a sunny day, while one of the lowest generations of only 2.40 kWh with $S_i$ = 0.80 was recorded due to continuous rain throughout the day.

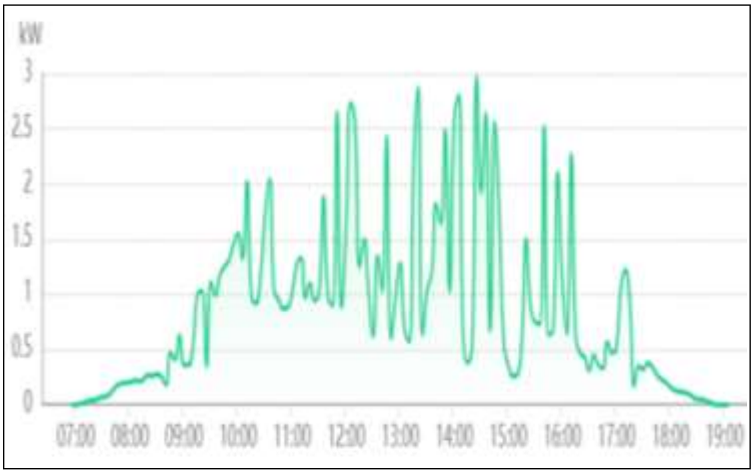


Figure 4. Typical Daily Solar PV Generation Profiles.

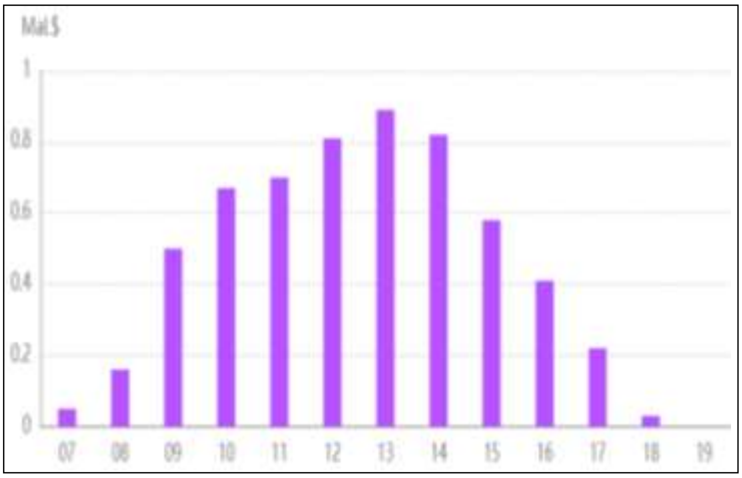


Figure 4. The Daily Earning from the Solar PV System.

The solar generation indices for 24 consecutive months are shown in Figure 5. For the two-year cycle 2021-2022, the generation index in the first year was almost repeated in the second year, which indicates that the solar generation could be predicted from the weather pattern in the previous year. The indices are higher in February-April and August-October with the highest monthly generation index $S_i$ = 4.01 recorded in February 2021. The generation indices were only between 2.88 – 2.97 from November to January which is normally the rainy season in Peninsular Malaysia.

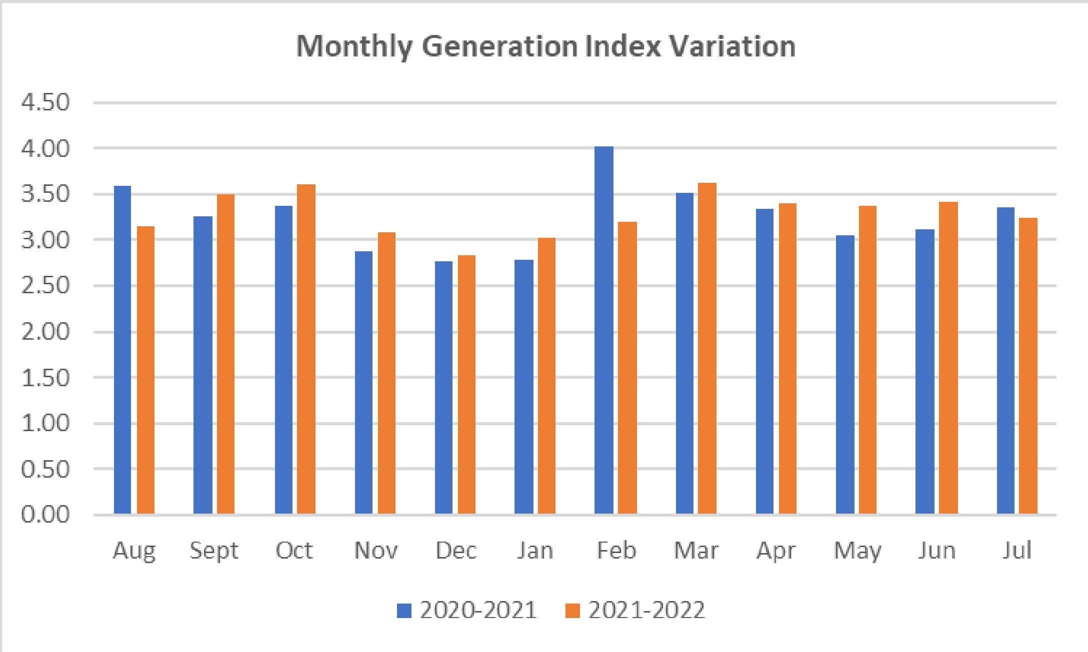


Figure 5. The variation of the Monthly Solar Generation Index, $S_i$

The average annual solar generation is 3.25 which is slightly lower than the average index for Shah Alam City, $S_i$=3.39 obtained from the simulation using PVSyst 7.2 Software, adopting the best tilt angle (Mansur, 2021). The annual solar generation in the second year (2021-2022) was 3601 kWh which is slightly higher compared to that 3557 kWh generated in the first year (2020-2021) which indicates that the efficiency degradation of the solar PV panels was small and would not significantly affect the calculation of the ROI payback period.

The monthly saving gained depend on both, solar energy generation and energy consumption. Figure 6 shows that higher energy saving is correlated to higher solar generation and lower energy consumption. Energy savings of above 80% were achieved in February 2021 (81.0%) and March 2022 (80.6%). The lowest energy saving of 66.3 % was recorded in May 2021 which corresponds to the highest monthly energy import recorded (410 kWh).

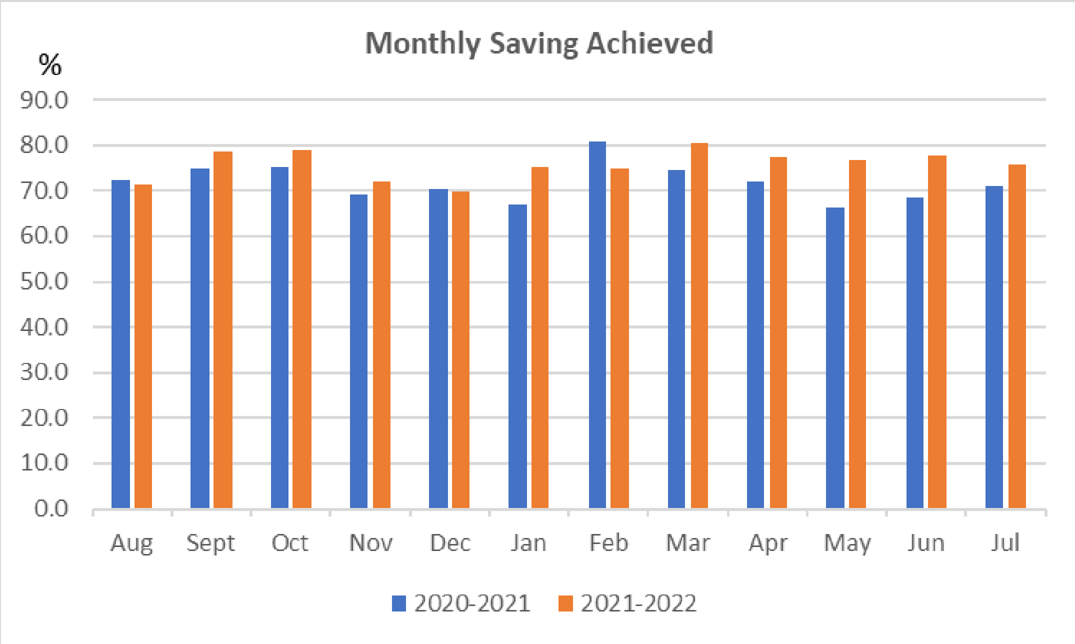


Figure 6. The variation of monthly savings attained from solar PV Installation.

The average monthly energy consumption for 2020-2021 was 530.2 kWh, of which 370.4 kWh was imported from the grid. The average monthly output of solar generation was 296.4 kWh, of which 159.8 kWh was consumed and 136.6 kWh was exported to the grid. The average monthly saving was 71.8% and the ROI could be achieved within 7.4 years. Figure 7 shows the variation of annual savings and payback period with energy consumption. The savings would be lesser if more energy was consumed. However, the corresponding ROI could be achieved in a much shorter period. The shortest ROI of 6.8 years could be achieved if the energy consumption was 30% higher than the benchmark value (641.3 kWh) with an average monthly saving of 60.7%. On the other hand, the saving percentage would be higher if less energy was to be consumed but the ROI could only be achieved in a longer period. If the energy consumption was 20% lower than the benchmark value (456.1 kWh), the saving would be much higher at 81.4 %. However, the ROI would be achieved only after 8.1 years.

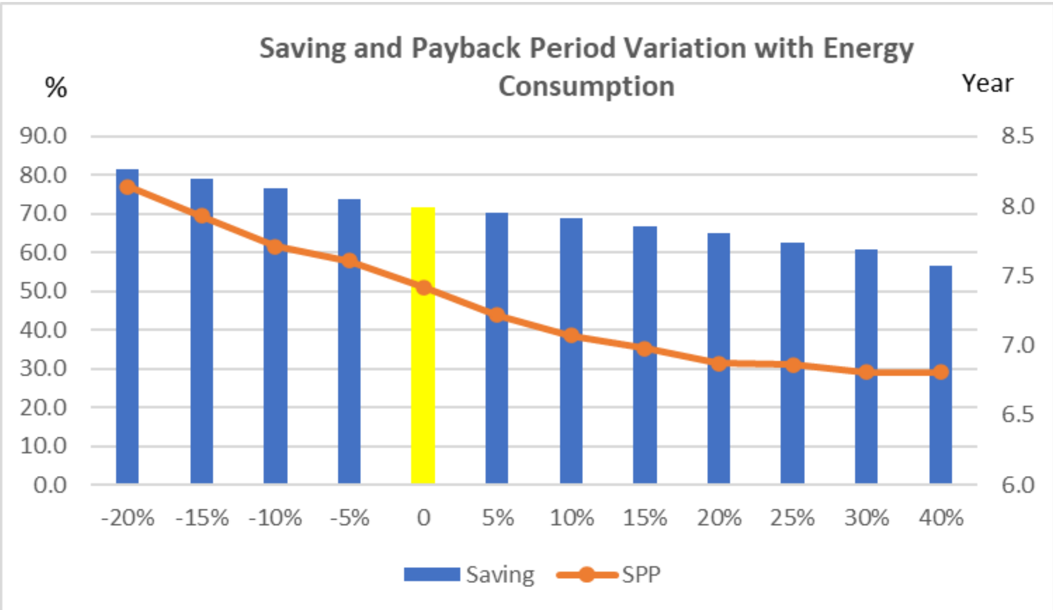


Figure 7. The variation of annual saving and payback period with the energy consumption.

For a small PV system, the variation of the system configurations was limited and hence the period of ROI was calculated based on the current market installation cost and individual components. The variation in the system's capacity and hence the cost is mainly due to the difference in the number of PV panels in each configuration. The optimum size of the system that could contribute to the shortest period of ROI could be closely determined before the system installation.
Figure 8 shows the variation of the annual saving and the payback period with the PV system capacity. The annual saving of 71.8% (RM1685.00) and the ROI for the currently installed system could be achieved within 7.4 years. If one PV panel (390 W) was added to the existing configuration, the ROI could be achieved in 6.9 years. However, the additional panel (3.90 W) will increase the ROI slightly back to 7.1 years. Reducing one panel from the existing configuration would only marginally increase the ROI but a further reduction of one panel would significantly increase the ROI to 7.9 years.
For individual homes with energy consumption of less than 600 kWh, the energy bill reduction could be realized by installing a small capacity solar PV system of less than 4 $kW_p$, and the payback period of ROI between 6.9 to 8.0 years could be realized with the correct size of the PV systems capacity. This average period of ROI is slightly longer than the average of 6.0 to 7.0 years which could be attained from larger homes with bigger installed PV systems capacity (5 $kW_p$ – 12 $kW_p$), depending on the energy consumption (Nazli, 2022)

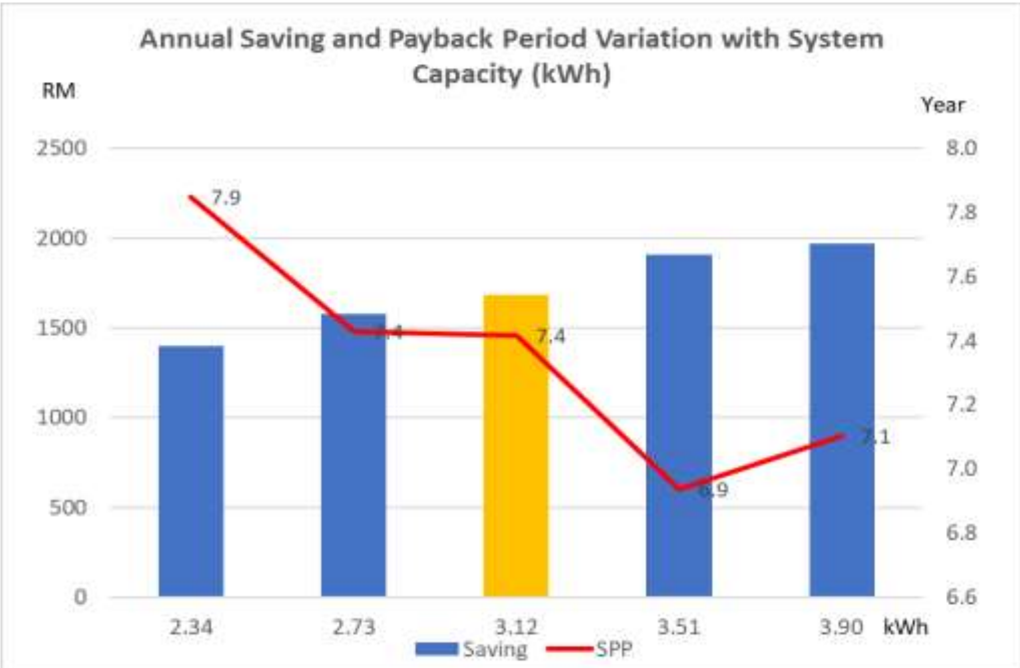


Figure 8. The variation of the annual saving and the payback period with the PV system capacity.

## Conclusion

The economic potential of a small-capacity solar PV system installed in a home with low energy consumption was analysed. The payback period of between 6.5 to 8.0 years could be realized with the correct size of the PV systems capacity. This analysis was based on the current TNB electricity bill tariff, which was implemented in 2017, and the current market installation cost. Shorter periods of ROI could be realized if the new revised tariff is to be implemented due to the increasing cost of fuels for electricity generation in recent years.

Given the recent rapid decrease in the global PV system pricing and predictions for continued reductions where the costs of a residential system using mono PERC modules are expected to fall 17% from 2020 to 2025 as highlighted by Sylvia( 2022), the period of ROI on solar PV installations could be significantly shorter than the current figures. This information could inspire small homeowners to install a rooftop PV system under the currently available NEM Rakyat 3.0, first to reduce their electricity bills and to contribute to Malaysia's inspiration of the Net Carbon Zero target by 2050.

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