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Comparative study of net energy metering and feed-in tariff for the 496 kWp UiTM segamat solar photovoltaic system

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ABSTRACT

The energy and natural resources ministry (KeTSA) of Malaysia has introduced the net energy metering (NEM) 3.0, which provides an opportunity for consumers to install solar photovoltaic (PV) systems to reduce electricity bills. The NEM 3.0 introduces three new initiatives that offer 500 MW quota from 2021 till 2023. NEM has been implemented since 2016, replacing the feed-in tariff (FiT) strategy by promoting the users to utilize the generated energy in the first place before selling any surplus to the utility. As in the FiT strategy, users can only sell the generated energy at a fixed rate without utilizing it. This paper presents the comparative study between NEM and FiT for 496 kWp solar photovoltaic system in UiTM Segamat, Johor in the perspective of economy and energy practice based on the simulation result of MATLAB/Simulink software.

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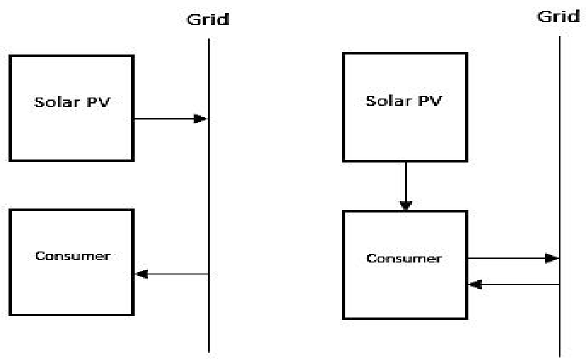
1. INTRODUCTION

The traditional resources of energy, for example, fossil fuels, are diminishing promptly due to the surge in energy consumption. The international energy agency (IEA) states that world energy consumption has increased drastically by approximately two times from 1975 to 2015 [1]. The burning of fossil fuel gives rise to the emission of CO_2 that damage the environment. The British petroleum Co. (BP) published in their world energy statistical review in 2019 that energy consumption is responsible for 2% of CO_2 emission, which is the quickest rise in the last seven years. In the context of Malaysia, CO_2 emission rises approximately 3.6% from 2017 to 2018, which is 241.6 million tons to 250.3 million tons. Moreover, the Asia Pacific region is the highest contributor to CO_2 emission that is 49.4% in total, approximately 16744.1 million tons [2].

Renewable energy (RE) can be the most suitable alternative for the prospective energy demand and preserve nature. Initiatives have been taken by many countries, including Malaysia, striving to reduce fossil fuel-based energy dependency. RE has an excellent prospect in Malaysia because of its geographical location. The utilization of solar energy is the most suitable RE in the context of Malaysia.

The solar photovoltaic demand has been increasing rapidly as the price of photovoltaic is falling, and the significance of sustainable energy development has been brought to light continuously [3], [4]. In Malaysia, solar energy is leading with a 43% market share, and other RE sources have also impact such as biomass 26%, hydropower 26%, and biogas with the least contribution of 5% market share. The standard monthly solar radiation in Malaysia is 400 to 600 MJ/m^2. Therefore, the prospect of a large-scale solar power plant is promising from Malaysia's perspective [5].

The renewable energy act (RE Act) was gazetted in 2011 by the Malaysian government along with the sustainable energy development authority act (SEDA Act), which catalyst the generation of energy from sustainable resources [6], [7]. The feed-in tariff (FiT) was introduced before the development of net energy metering (NEM) in 2016 [5]. The FiT strategy turned out to be a non-sustainable project due to the high cost of funding the scheme [8]. The difference between the two projects can be seen in Figure 1.



(a) (b)

Figure 1. Basic block diagram for solar PV: (a) FiT connection to the grid and (b) NEM connection to the grid

FiT is a scheme that allows consumers to generate their electricity and sell it to the utility [9]. FiT covers small hydroelectric, biomass, biogas, and solar photovoltaic and fixed tariff rate for a specific duration of time by the contract with the TNB [5]. On the other hand, NEM is a scheme that lets the consumers use the generated energy while exporting any surplus to the utility. NEM only covers the solar photovoltaic and is still in development for other RE. The meter used for NEM is different from the standard meter, which uses the bidirectional meter, and readings are taken remotely. The determination of the bill for the FiT scheme is the amount of energy consumed by the user as the generated energy from PV is exported to the grid at the fixed selling rate. Unlike FiT, the power generated from the solar PV using the NEM scheme will first be consumed by the user, and the excess energy will be exported to the grid at displaced cost prices. Thus, the energy consumed by the user from the grid will reduce with the monthly electricity bill.

In January 2019, the NEM concept was changed, which improved the return of investment (ROI) of solar PV [10]. The concept switched to the true net energy metering from existing net billing. The true net energy metering allows the excess generated energy from the solar PV to be sold to the utility on a head-to-head balance basis, which means every 1 kWh that is exported to the grid will be offset against 1 kWh consumed from the grid. The previous concept using displaced cost is at 31 sen/kWh compared to the purchase at tariffs, which is over 50 sen/kWh, making the previous concept inefficient [11].

After the success of the new NEM's concept, including the 500 MW allocated quota, has been completely registered and implemented, the KeTSA of Malaysia established the NEM 3.0. A 500 MW quota is offered by the NEM 3.0 from 2021 to 2023 and maintains the previous NEM concept, which was head-to-head balance for ten years, and then converted into the self-consumption (SelCo) scheme. Three initiatives are introduced in the NEM 3.0: NOVA for commercial and industrial construction, NEM GoMEn program for the buildings of government, and for domestic users NEM Rakyat [5].

Many researchers used various techniques to design, present, simulate, and demonstrate either for the NEM scheme and FiT scheme comparison or highlight one of the schemes. For example, the 4.0 kWp solar PV system design for the residential house under NEM scheme and the analysis of NEM for a residential house in terms of technical and economical designs, and simulated using PVsyst and Meteonorm software [12], [13]. Moreover, this manuscript is inspired by [14] presented by Rodney H.G. Tan, where the findings are modelled using MATLAB/Simulink software for the comparison of FiT scheme and NEM scheme for UCSI University North Wing Campus with 100 kW solar photovoltaic system. Based on the results obtained, the ROI for the FiT is shorter, and the total profit after ROI is higher than the NEM scheme.

In addition, the study of feasibility for rooftop solar PV system implementing net metering in Abu Dhabi is demonstrated using HOMER software [15]. Another study was conducted on technical constraints of integrating NEM from Malaysia's perspective using DigSILENT powerfactory software, which focuses on the technical setbacks due to the NEM scheme [11]. Although FiT and NEM are different mechanisms that result in different costs and energy outcomes, both schemes help to reduce the consumption of energy along with the monthly utility bill and help to reduce the carbon footprints by implementing renewable energy generation.

2. METHOD

A MATLAB/Simulink model was developed to determine the FiT and NEM scheme outcome and illustrated in Figure 2 [14]. The purpose is to investigate the energy, cost difference, savings, and return of investment between both schemes. The solar PV system in Segamat consist of 6 main blocks and each block made up from a specific subsystem which consist of required mathematical equations.

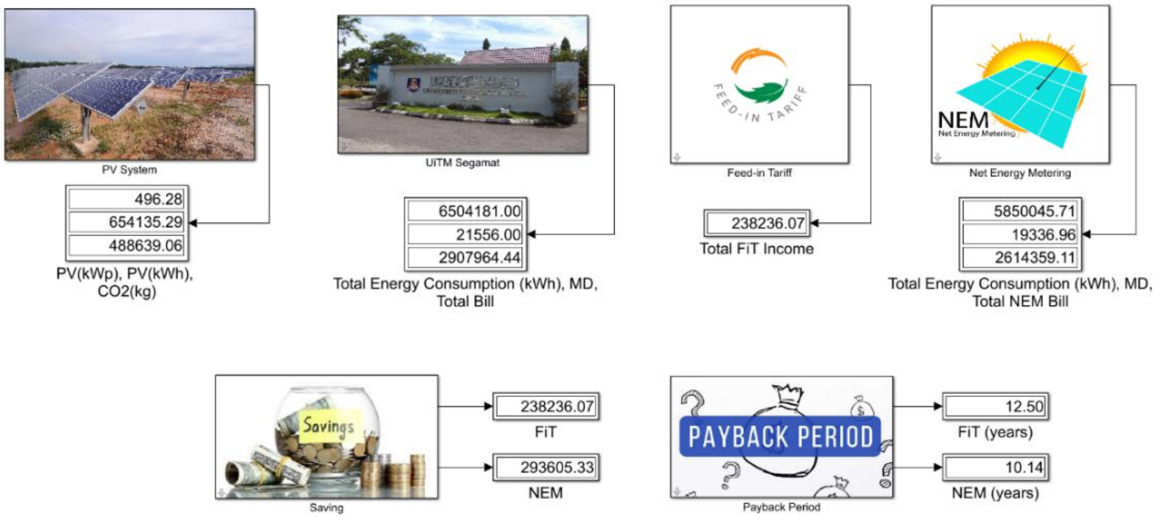


Figure 2. MATLAB/Simulink Simulation model of NEM and FiT for the solar PV in UiTM Segamat, Johor

2.1. 496 kWp PV system

The PV system for the UiTM Segamat simulates the power generation of the 491 kWp PV array. The single block will simulate the solar PV capacity from the solar irradiance and the specification of the solar panel and the inverter. The block also will simulate the generated power from the solar PV along with the CO_2 emission avoidance. For the UiTM Segamat, the solar PV model used is 496 kWp having the solar irradiance obtained from the meteorological software that is the Meteonorm 7.1. The construction of the 496 kW PV system model consists of 1140 parts of the 435W PV module. The PV module includes 20 strings in which each string is 8.7 kW, and each string contains 57 modules.

PV array is designed utilizing (1), which includes the parameters of the solar module.

$$PV_{array}(t) = \left(I_{mp} \times N_{string}\right) \times \left(V_{mp} \times N_{module}\right) \times G_t \tag{1}$$

Here, maximum power current is indicated as Imp and maximum power voltage indicated as Vmp, these parameters are taken from the datasheet of the solar module. The solar module generated power is indicated by PVarray, Nstring indicates the number of strings, Nmodule denotes the quantity of module attached to a string, and solar irradiance is indicated by G in kW/m2. Meteonorm 7.1 software is utilized to get solar irradiance. The output power from the modules can be determined using (2).

$$PV_{out}(t) = PV_{array}(t) \times \eta_{inv} \times PR \tag{2}$$

Here, the PV_{array} is multiplied by the efficiency of the inverter and the performance ratio (*PR*). The performance ratio is the coefficient for the losses and it is in the range between 0.5 to 0.9. The CO_2 emission reduction for the FiT and NEM scheme contributes equally since both schemes generate electricity using RE instead of combustion procedure. Therefore, the calculation of CO_2 emission reduction is set by (3).

$$C0_2 = PV_{kWh} \times Rate_{C0_2} \quad (3)$$

The CO_2 emission is calculated in kg by multiplying the PV generated energy PV_{kwh} with the CO_2 rate for each kWh. The UiTM Segamat releases an average of 0.747kg CO_2.

2.2. UiTM segamat

The UiTM block model calculates the total energy consumption shown in (4) and the total bill for the whole year by summing all the monthly bills. The monthly electricity usage or known as the monthly load profile for the year 2019, is obtained from the facility department of the UiTM Segamat. The average energy consumption for 2019 is about 542,015 kWh per month, with a maximum demand of 1,796 kW per month. The tariff code for the UiTM Segamat is indicated by C1 that represents the commercial tariff for medium voltage [16]. The C1 tariff rate is 0.365 RM/kWh, and the rate of maximum demand (*MD*) is 30.3 RM/kW.

$$Total\ Usage = (kWh \times 0.365) + (MD \times 30.30) \quad (4)$$

Incentive-based regulation (IBR) includes a mechanism called imbalance cost pass-through (ICPT) permits the grid to reflect changes in electricity tariff regarding generation-related costs every six months, and this mechanism is suitable to non-domestic consumers only like UiTM Segamat. In 2019, the surcharge of the ICPT from January to February was about 0.0135 RM/kWh and 0.255 RM/kWh for March to December. Since IBR's second regulatory period was 2019, which ICPT is under surcharge and not as a rebate [11], [17]. The ICPT surcharge is shown in (5) for January to February 2019, and the surcharge for March to December 2019 is shown in (6). ICPT supports total energy consumption disregarding charges for maximum demand.

$$ICPT_{Jan-Feb} = kWh \times 0.0135 \quad (5)$$

$$ICPT_{Mac-Dec} = kWh \times 0.0255 \quad (6)$$

UiTM Segamat includes the category of learning institutions where a 10% discount is provided since the electrical utility company Tenaga Nasional Berhad (TNB) initiated the rebate suitable for all private and government learning institutes. The scheme can be fully supported or partially by the government [18] and expressed in (7) and (8) as follows:

$$Total\ Charges = Usage + ICPT \quad (7)$$

$$Discount = 10\% \times Total\ Charges \quad (8)$$

moreover, government obtains the RE fund (KWTBB) through the consumed electricity by the customers, and this fund is not a type of taxation [19], [20]. The fund is collected to support the natural resources for the next generations and encourage electricity generation growth utilizing RE sources. Malaysia's sustainable energy development authority (SEDA) is benefited from this fund [7]. Besides, the fund is obtained via a surcharge of customer's electricity usage at a rate of 1.6%, and a 10% discount off the KWTBB is given to UiTM Segamat, which is shown in the following equations,

$$KWTBB = Usage \times 1.6\% \quad (9)$$

$$Discount_{KWTBB} = 10\% \times KWTBB \quad (10)$$

$$KWTBB_{after\_discount} = KWTBB - Discount_{KWTBB} \quad (11)$$

The aggregate monthly bill is achieved by calculating the aggregate charges, the discount of the learning institute, and KWTBB after discounted and expressed in (12). Moreover, service tax is omitted as the service tax is implemented on the category of the domestic tariff, and SST is implemented on the category of commercial tariff [21].

$$Total\ Bill = Total\ Charges - Discount + KWTBB_{after\_discount} \quad (12)$$

2.3. Feed-in Tariff

The rates for the Feed-in Tariff scheme have been reducing each year, particularly the solar PV rates beyond 72 kW equal to 1MW, wherein the UiTM Segamat is listed as shown in Figure 3. Thus, the 2019 FiT rates for beyond 72 kW equal to 1MW signifies that the UiTM Segamat is eligible with RM 0.3642 per kWh [22]. During the FiT scheme, UiTM Segamat has not utilized the PV system generated energy since all the generated energy is transferred and sold to the power grid at a rate designated by the government and TNB. In (13), the amount of FiT is calculated by the product of solar-generated energy to the selling price of generated energy under the FiT scheme. Besides, $FiT_{rate,}$ which is 0.22% less than the buying price of RM 0.365 per kWh.

$$FiT = RE_{kWh} \times FiT_{rate} \tag{13}$$

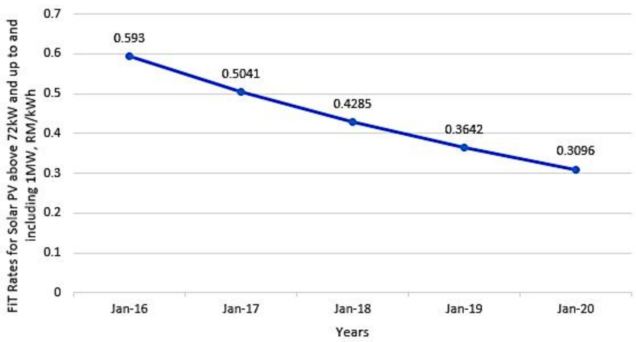


Figure 3. FiT rates for solar PV beyond 72 kW equal to 1MW

2.4. Net energy metering

Net energy metering (NEM) became operative with its new features on January 1, 2019. NEM applications based on solar PV have been increasing by 188%, 37.5951 MWac in 2019 from 13.0748MWac in 2018. The amount maximized in 2020 to 442.8327MWac, and the allocated quota has been wholly retained [23]. The new method permitted the extrasolar PV generated power to transfer back to the utility on a head-to-head balance basis that means each 1 kWh transferred to the utility will be balanced against 1 kWh utilized from the utility. The displaced cost will be replaced in this case that applied for the earlier NEM method [24]. The net power usage is indicated in (14), wherein the power usage by UiTM Segamat in kWh is deducted from the solar PV generated power.

$$Net_{kWh} = kWh - RE_{kWh} \tag{14}$$

As the total power consumption is reduced by the solar PV generated power, the maximum demand will be reduced. The shaved off maximum demand is shown in (15), and the computation of total usage is shown in (16), where NEM is applied.

$$MD_{shaved} = MD(T) - PV_{out}(T) \tag{15}$$

$$Total\ Usage = (Net_{kWh} \times 0.365) + (MD_{shaved} \times 30.30) \tag{16}$$

2.5. Savings

The saving will be computed for both schemes by the savings block. Saving for FiT is shown in (17), wherein FiT quantity in (13) will be similar to the FiT saving since the solar PV generated power will be transferred entirely and sold to the utility.

$$FiT_{saving} = Fit \tag{17}$$

While the saving for NEM is based on (18) by subtracting the total monthly bill without solar PV system to the total NEM charge for the month.

$$NEM_{saving} = Total\ Bill - Total\ Usage \tag{18}$$

2.6. Return of investment

The return of investment (ROI) is computed in (20) for both methods. The complete PV system speculation is approximately RM 2,977,698.24, wherein the solar PV installation cost is approximated per kW at RM 6,000. The UiTM Segamat network is around 496 kW. The annual savings in (19) is the total monthly savings for 2019. The monthly savings are attained from the savings computed in (17) for the FiT scheme and in (18) for the NEM scheme since the load profile used is based on monthly energy consumption.

$$Annual\,Savings = Monthly\,Savings \times 12 \tag{19}$$

$$ROI = Total\,Investment\,Cost/Annual\;\,Savings \tag{20}$$

2.7. Total profit after return of investment

The case study is 21 years, given by the FiT contract period in Malaysia [25]. Thus, to determine the profit saving after the return of an investment will be using (21), where $T_{contract}$ is the contract period, which is 21 years, and ROI is obtained from (20).

$$Total\,Profit\,after\,ROI = (T_{contract} - ROI) \times Annual\,Savings \tag{21}$$

3. RESULTS AND DISCUSSION

This study covers the campus, excluding a PV system and the campus including a PV system under two different schemes, which are FiT and NEM. The campus with a PV system requires solar irradiance data obtained from the Meteonorm 7.1 software to simulate the solar irradiance for a specific location. UiTM Segamat at Johor (2.488°N, 102.728°E) is located in the southern part of Peninsular Malaysia, and the annual solar irradiance is about 1614 kWh/m^2. In Figures 4 and 5, the monthly solar irradiance obtained from the Meteonorm 7.1 software highlights that the highest solar irradiance throughout the year is in March with 153 kWh/m^2, and the least is in December, which is 115 kWh/m^2. Hence, the highest energy generated in March is about 61,890 kW, and December is the least energy generated month, which is about 46,520 kW.

Name of site = UiTM Segamat
Latitude [°] = 2.489, Longitude [°] = 102.729, Altitude [m] = 26
Climatic zone = V, 1

Radiation model = Default (hour); Temperature model = Default (hour)
Diffuse radiation model = Default (hour) (Perez)
Tilt radiation model = Default (hour) (Perez)
Radiation: scenario B1, year 2019
Temperature: scenario B1, year 2019

Month	H_Gh	H_Dh	H_Bn	Ta
Jan	135	74	95	26.8
Feb	142	80	88	27.5
Mar	153	89	89	27.8
Apr	143	80	88	27.7
May	140	80	88	27.8
Jun	130	74	82	27.5
Jul	135	77	87	27.1
Aug	139	83	79	27.1
Sep	135	82	73	27.1
Oct	134	90	61	27.0
Nov	116	72	65	26.7
Dec	115	73	63	26.6
Year	1614	952	956	27.2

Legend:

H_Gh: Irradiation of global radiation horizontal
H_Dh: Irradiation of diffuse radiation horizontal
H_Bn: Irradiation of beam
Ta: Air temperature

Radiation in [kWh/m²]
Temperature in [°C]

Figure 4. Result for monthly solar irradiance obtained from Meteonorm 7.1 software

Figure 6 highlights the load profile without PV, with PV net power and PV generated power. The load profile without PV is obtained from UiTM Segamat monthly energy consumption, while the load profile with PV net power is obtained from (14). The PV generated power is obtained from (2). The generated power from PV can be seen steady throughout the year, with the average generated power is about 54,511 kW per month. The highest power generated is 61,890 kW in March, and the lowest is 46,520 kW in December.

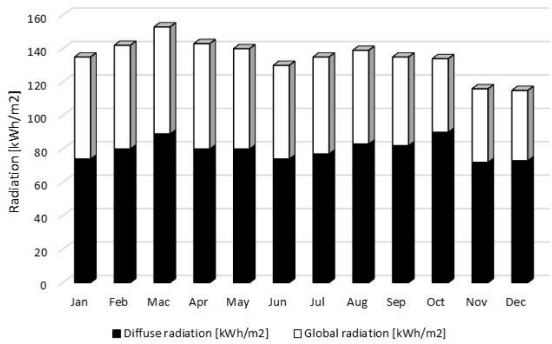


Figure 5. Bar graph of monthly solar irradiance obtained from Meteonorm 7.1 software

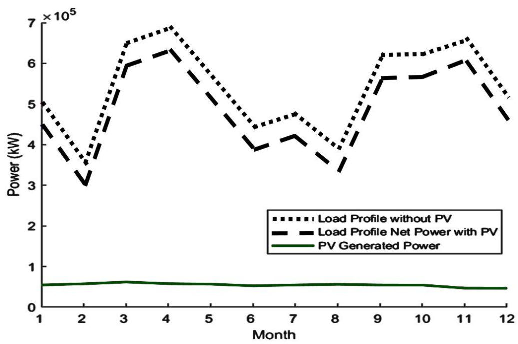


Figure 6. Load profile without PV, with PV net power and PV generated power

It can be observed from Figure 6 that the highest load profile is in April, with the campus consuming 691,400 kW power. By applying the NEM scheme, the campus consumes 633,500 kW power with a difference of 8.37% from the highest load profile without PV. The lowest load profile was in February, with the campus only consuming 362,500 kW power. By considering the NEM scheme, the campus only consumes 305,100 kW power, decreased by 15.83% from the lowest load profile without PV. The load profile pattern can be seen as repetitive and continuous as the load profile in February, and also starting from June until August, it is lower than the other months because of semester break having the lowest electricity usage.

The operation of three individual case studies is shown in Table 1. The three case studies are excluded PV system, PV system included for the implementation of FiT, and the implementation of NEM. Four different outputs are considered, which are power usage, maximum demand acquired from the received data of UiTM Segamat monthly power usage, solar PV generated power acquired from (2), and CO_2 emission avoidance acquired from (3). In 2019, the solar PV system generated 654,135.29 kWh of energy, and the NEM scheme given in (14) reduces energy consumption from 6,504,181 kWh to 5,850,045.71 kWh a year, which is about a 10% reduction of energy consumption.

Table 1. Energy consumptions, maximum demand, solar PV generated energy and CO_2 emission avoidance

	Without PV system	Feed-in Tariff (FiT)	Net energy metering (NEM)
Energy Consumption (kWh)	6,504,181	6,504,181	5,850,045.71
Maximum Demand (kW)	21,556	21,556	19,336.96
Solar PV Generated Energy (kWh)	0	654,135.29	654,135.29
CO_2 Emission Avoidance (kg)	0	488,639.06	488,639.06

Table 2 shows a yearly bill summary, annual income and savings, return of investment, and profit after return of investment for the three cases: without PV system, with PV system applying FiT and with PV system applying NEM. The yearly bill summary for without PV system and with PV system applying FiT is based on (12), and for the case with the PV system applying NEM is based on (16). The annual income and annual savings for the FiT scheme are gained from (13) and (17), respectively. The annual savings for the NEM scheme is based on (18), while there is no annual income for the NEM scheme since all the generated energy is consumed and no excess energy is exported to the grid. The return of investment (ROI) for both FiT and NEM cases are based on (20), and both total profits after ROI are based on (21).

The annual FiT scheme saving for 2019 is RM 238,536.07 with return of investment of 12.5 years and resulting in RM 2 million profit after the return of investment. For the NEM scheme, the annual saving is RM 293,605.33, which is 23% higher than the FiT scheme and provides 10.1 years return of investment with a total profit of RM 2.6 million that is 30% higher than the FiT scheme. This study highlights several interesting findings in which the NEM scheme is a very efficient scheme compared to the FiT scheme. The outcomes of this study are slightly different compared to the findings obtained in [12]. This is caused by the new NEM concept, which was introduced and applied in early 2019, and also the reason for decreased selling FiT rate in 2019.

Table 2. A yearly bill summary, annual income and savings, return of investment and profit after return of investment

	Without PV system	Feed-in Tariff (FiT)	Net energy metering (NEM)
Energy Consumption Charge (RM)	2,374,026.06	2,374,026.06	2,135,266.69
Maximum Demand Charge (RM)	653,146.80	653,146.80	585,909.75
2019 Annual Income (RM)	0	238,536.07	0
2019 Annual Total Bill (RM)	2,907,964.44	2,907,964.44	2,614,359.11
2019 Annual Savings (RM)	0	238,536.07	293,605.33
Return of Investment (Years)	0	12.5	10.1
Total Profit after ROI (RM)	0	2,027,556.60	2,600,043.16

4. CONCLUSION

The comparative studies of net energy metering (NEM) in contrast to the feed-in tariff (FiT) for the 496 kWp UiTM Segamat Solar Photovoltaic System have been carried out and presented in this paper. MATLAB/Simulink platform is utilized for both mechanisms of FiT and NEM along with the irradiance information that is acquired from the software Meteonorm 7.1. The new concept introduced in the NEM scheme provides a better cost efficiency with a shorter return of investment compared to the FiT scheme. This study shows that the annual electricity bill saving in 2019 for the NEM scheme is about 12.37% with 10.1 years for the return of investment, and for the FiT scheme is about 10.05% with 12.5 years for the return of investment. For this reason, the selling rate for the FiT scheme has been decreasing every year. Apart from that, both schemes result in monthly and annual bill reduction, and eventually, both schemes able to reduce about 539 tons of CO_2 emission per year.

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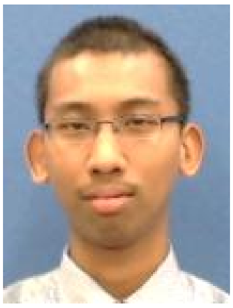

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