Evolution in Electrical and Electronic Engineering Vol. 3 No. 1 (2022) 364-376

EEEE

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/eeee
e-ISSN : 2756-8458

Development of Mobile Application for a Sizing and Cost Analysis of Grid-Connected Photovoltaic System

Nurul Izzati Ahmad[1], Ahmad Fateh Mohamad Nor [1,2]*

[1]Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Johor, MALAYSIA

[2] Green and Sustainable Energy (GSEnergy), Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Johor, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/eeee.2022.03.01.041
Received 04 February 2022; Accepted 08 April 2022; Available online 30 June 2022

Abstract: Usually, power is generated using fossil fuels and heat, which pollute the atmosphere by emitting CO2 (CO2). When fossil fuels are burned, carbon dioxide and other greenhouse gases are released into the atmosphere, causing global warming and climate change. Photovoltaic (PV) systems provide solar energy that is independent of the sun or the surroundings. However, due to Malaysia's tropical environments, where heavy rains and dry days occur annually due to the tropical rainy season, this sort of PV system has several issues. An ON-grid solar system linked to the grid ensures that electricity is always delivered to the user's infrastructure. Solar energy systems also need a high initial investment. Using a mobile application may help alleviate this difficulty. A mobile application for sizing and cost analysis of grid-connected PV systems is being developed to help users estimate the size and cost of a grid-connected PV system. This software may help consumers since it is available on Google Play or Appstore. This mobile application can calculate total load consumption, photovoltaic size, total energy production, tariff calculations, cost, and payback period. These mobile applications must be compared to computing methodologies to measure their efficacy and durability. So, computational method methodology is developed for grid-connected PV system size and cost analysis. According to the results of this mobile app, the monthly load usage is 615.42 kWh, the cost is RM 6460, and the total monthly bill after PV installation is 187.48. The monthly savings after installing PV system is RM 52.51. The app's final result displays a total payback period of 10.3 years. This implies that by comparing the findings of the mobile app and the computational approach, the mobile app can appropriately compute load consumption, PV sizing, tariff calculation, pricing, and total payback time.

Keywords: Mobile Application, Photovoltaic System, Cost Analysis

**Corresponding author: afateh@uthm.edu.my*

1. Introduction

l Renewable energy is the way to generate energy from unlimited natural sources such as air, wind and water. These resources are available without a short time and time to renew the energy. In a few years ago, renewable energy became one of the most suitable source to replace existing sources [1]. Therefore, this matter urges a country to develop a more sustainable energy system to cater for growth. The use of renewable energy sources is a viable alternative [2]. Renewable energy sources in Malaysia include wind, solar, biomass and tidal wave [3]-[4]. However, this energy is not fully utilized. Other than hydropower and wind energy, photovoltaic (PV) is the most important source of clean, renewable energy, with the biggest potential for solving the world's energy problems [5]. PV generates electricity from sunlight and converts it to electrical energy due to its low cost and high efficiency. In addition, the weather in Malaysia is suitable for the use of PV system because there is more sunlight than rain.

There are two options for photovoltaic system which is by using stand-alone PV system or combination of PV system with the grid known as grid-connected PV system [6]. Malaysian government has been always supporting the installation of grid-connected PV system by introducing the Net Energy Metering (NEM) back in 1st January 2019 [6]. Starting 2021, the NEM has been improved from the existing net billing to true net energy metering [7]. This is to help for the return of investment of solar PV under NEM. PV panels, batteries, inverters, and load are all things to consider when sizing. By sizing the design of the PV system, it may help to set up configuration easily. To prevent misuse, it must be measured in great detail.

A Mobile Application is described as "software designed specifically for use on portable, wireless computing devices, such as Mobiles and tablets, rather than desktop or laptop computers" [8]. Mobile Applications can make it easier for users to size a grid- connected PV system compared to using a laptop because they only need to download it on the service operating system store. In this project, Graphical User Interface (GUI) will be provided by using Mobile to sizing and cost analysis a grid-connected PV system and it will consider all specification in term of PV system, costing, load and return on investment. So, user can calculate the size by using Mobile Applications.

Until now, electricity is created using fossil fuels and heat, which damage the climate by producing CO2 (CO2). Burning fossil fuels releases carbon dioxide and other greenhouse gases into the atmosphere, trapping heat and contributing to global warming and climate change [9]. While energy may come from a number of sources, most of the energy utilised to meet the rising demand for power still comes from fossil fuels. The steady supply of fossil fuels is running exhausted. Renewable energy sources like solar energy are gaining popularity as they improve electrical energy output. The photovoltaic (PV) system is one of the solar energy sources that may be employed, although there are several issues with it. Malaysia has a tropical climate with considerable rainfall and dry days every year due to the local tropical wet season.

The PV panel will only produce power up to its rated capacity under Standard Test Conditions (STC). STC needs 1000 W/m2 sun light and a temperature of 25°C. The PV system will not generate the solar power mentioned in its rating due to weather, sun hours, and Malaysia's average temperature of 30°C. A grid-connected PV system includes PV panels, PV arrays, batteries, and the requirement to assess the system with a grid-connected [10]. The array capacity of grid-connected PV systems is typically determined by the accessible site. Inverter, battery, and load sizing So, all of these size processes need multiple computations.

However, the costs of PV panels, inverters, installation, and maintenance make solar systems highly costly. As a consequence, mobile apps were created to aid clients in size and cost analysis of grid-connected PV systems simply by inputting data into mobile applications. This application also has various advantages over laptops, such as portability. In addition, sizing a grid-connected PV system is complex [11]. These mobile applications may be used to size PV systems for residential usage that are grid-connected. All information will be supplied in terms of PV system, cost, load, and ROI. So, for the users' convenience, Mobile Applications must be downloaded from the service operating system store.

The main objectives of this project are: to perform the sizing and cost analysis of grid-connected photovoltaic system using computational method, to develop a mobile application that can be used to sizing and cost analysis a grid connected photovoltaic system. Next, to evaluate the developed mobile application by comparing the results with the computational

With regard to the stated objectives, the scopes of the project are limited to as below:

1. The project is focus for single- storey terrace house in Jalan Taman Impian, Taman Manis, Parit Raja, Batu Pahat, Johor.
2. Visual Studio code is used to develop Mobile Applications and android studio as a platform to convert the application from window to mobile phone. All specifications will be provided in terms of actual monthly bill, total bill after install PV, total monthly saving, cost estimation of PV system and total payback period.
3. PV panel, inverter, installation and maintenance should be calculate to get the overall cost for the installation. PV panel will produce power according to its rating under the Standard Test Condition (STC) which requires solar radiation of 1000 Watts per square meter and temperature of 25 degree Celsius.

2. Materials and Methods

L This section will explain each step that will be used to calculate the load consumption until Return On Investment (ROI) for the overall PV system. All the information related to the sizing of a grid connected PV system really needs to be understood to ensure there is no mistake during the installation of PV system.

2.1 Load Consumption

The first step to do is calculate the total load consumption for a single-storey terrace house in Taman Impian, Parit Raja, Batu Pahat, Johor. This step is important to know how much energy is used in a month and how many monthly electricity bills have to be paid to Tenaga Nasional Berhad (TNB). Then, these prices will be compared before and after the installation of a grid-connected PV system.

The electrical load is different for each house depend to the consumer's load. The more electrical load used in the house, the higher total energy consumption. Equation 1 can be used to calculate the total energy consumption [9].

$$\sum EAC = \sum E(QXPRXt) \qquad \textit{Eq 1}$$

Where,

E = Total Energy Consumption (Wh/day)

Q = Quantity of the Electrical Load

PR = Power Rating of the Electrical Load (Watt)

t = Operating Time of Electrical Load (hour/day)

After the total energy consumption has been calculated, the monthly energy consumption can be calculated by using Equation 2 [9].

$$Mec = \sum EAC \times 30 \text{ days} \qquad \textit{Eq 2}$$

Where,

Mec = Monthly Energy Consumption (kWh)

$\sum EAC$ = Total Energy Consumption (Wh/day)

The mobile application design is done in the load analysis tab. Figure 1 shows the tab window.

Figure 1: Load Analysis Tab

2.1 Photovoltaic Sizing

Before proceeding to use Grid-Connected PV, the important thing that should be considered is size of the house and the rooftop area to determine how many panels can be installed on the rooftop area. In this study, the load consumption that has been calculated is below 1kWh. to use 1kWp of the PV. The space required for every 1kWp is 6.0m2. The PV panel used in this project is 300-watt poly- crystalline solar module and it is approximate to 2m2. So, only 4 solar panel will be used for 1kWp of PV which is 4 x 2 meter is equal to 8m2. Space is one of the factor that can affect the costing of the grid- connected PV system installation. The less rooftop space for solar panel can limit the size of the rooftop solar array and the smaller array will less the cost of installation [9].

There are 4 steps to calculate the average daily energy production. The equation can be referred in Equation 3-9 [9].

Step 1:

$$P_{arr\text{-}g} = Pmp \times Pguaranteed \times nm \qquad \textit{Eq 3}$$

Where,

Parr-g = Minimum Guaranteed Power Output of the Array

Pmp = Maximum DC Power Rating

C_g = Manufacturer Power Guaranteed

n_m = Number of Module in Array

Step 2 PVcon = Parr-g × [(Avetemp-STC) × Ctemp] *Eq 4*

Where, $P_{ar\text{-}T}$ = Parr-g – PVcon *Eq 5*

PVcon = PV Consideration

P_{arr-T} = Temperature-Corrected Array Power Output
Avetemp = Array Average Operating Temperature Standard
STC = Test Conditions
Ctemp = Temperature Coefficient for Power

Step 3:

$P_{arr-net}$ = $P_{arr-T} - [P_{arr-T} \times \text{wiring losses}]$ *Eq 6*

Where,

$P_{arr-net}$ = Net Array Power Output
P_{arr-T} = Temperature-Corrected Array Power Output3%
Wiring losses = or 0.03

Step 4:

Inv. PoutAC = $P_{arr-net} \times \text{Inveff} \times \text{InvMPPT}$ *Eq 7*

Where,

Inv. PoutAC = Inverter Maximum AC Power Output
Inveff = Inverter Power Conversion Efficiency
InvMPPT = Inverter MPPT Efficiency

Average daily energy production

Poutave= Inv. PoutAC × Aveinsolation *Eq 8*

Where,

Poutave= Average Daily Energy Production

Inv. PoutAC = Inverter Maximum AC Power Output Aveinsolation = Average Daily Insolation (PSH)

Monthly energy production

MEP = Poutave × 30 days *Eq 9*

Where,

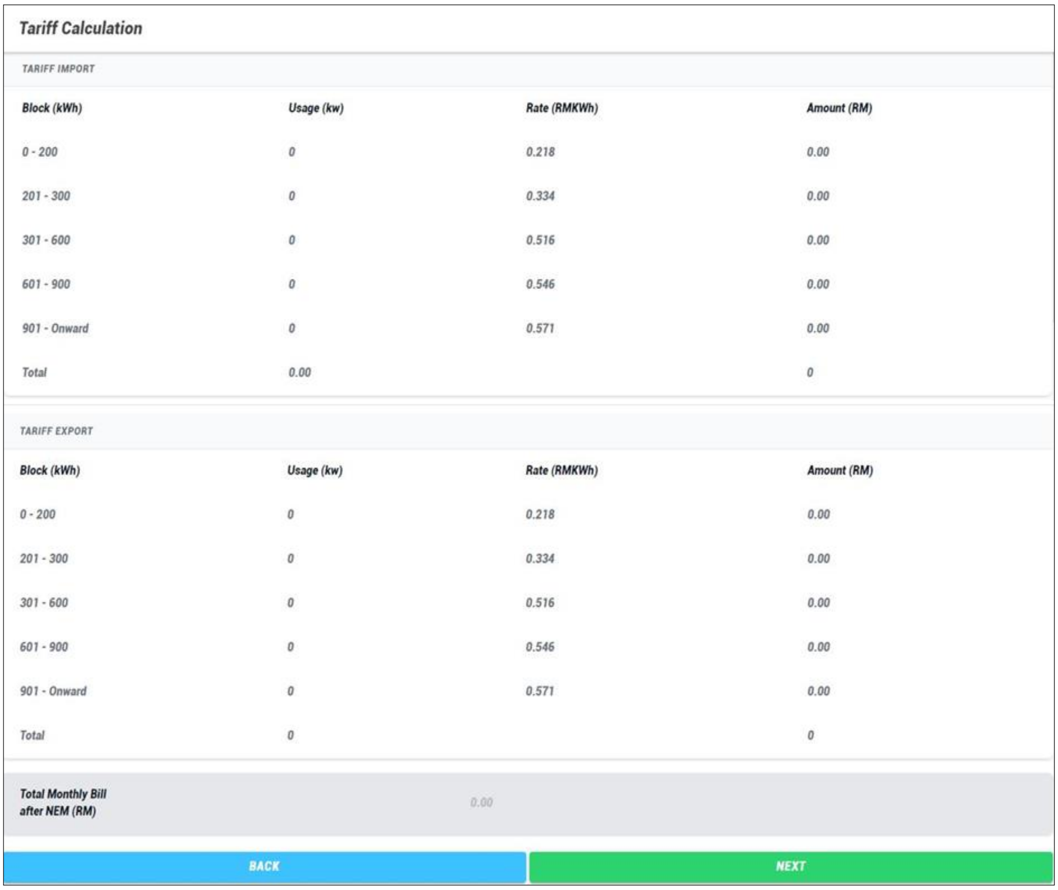
MEP = Monthly Energy Production
Poutave = Average Daily Energy Production

2.1 Tariff Calculation

To calculate the monthly energy production, the value of average daily energy production will multiple by 30 days. Once kWh is produced, the next step is to multiply with the rates given by Tenaga Nasional Berhad. To ensure that the calculation is accurate, the calculation will compare with NEM calculator provided by SEDA [7**].**

Figure 2 shows the tab of the grid-connected photovoltaic system and Figure 3 depicts Tariff Bill Calculation Tab.

Figure 2: Grid-connected Photovoltaic System Tab



Tariff Calculation

TARIFF IMPORT

Block (kWh)	Usage (kw)	Rate (RMKWh)	Amount (RM)
0 - 200	0	0.218	0.00
201 - 300	0	0.334	0.00
301 - 600	0	0.516	0.00
601 - 900	0	0.546	0.00
901 - Onward	0	0.571	0.00
Total	0.00		0

TARIFF EXPORT

Block (kWh)	Usage (kw)	Rate (RMKWh)	Amount (RM)
0 - 200	0	0.218	0.00
201 - 300	0	0.334	0.00
301 - 600	0	0.516	0.00
601 - 900	0	0.546	0.00
901 - Onward	0	0.571	0.00
Total	0		0

Total Monthly Bill after NEM (RM) 0.00

BACK NEXT

Figure 3: Tariff Bill Calculation Tab

2.1 Costing

The next calculation is about the costing of the overall system including PV panel price, inverter, installation and maintenance price. As a user, cost is an important part because the requirements of the PV system are dependent on the user's budget. The calculation can be calculated by using the Equation 10-15 [9].

PV Panel Price

Total PV Panel Price = Cost Per Panel × Total Needed Panel *Eq 10*

Inverter Price

Total Inverter Price = Inv. $Pout_{DC}$ *Eq 11*

Where,

Inv. $Pout_{DC}$ = Inverter Maximum DC Power

Installation Price

Total Labour Price = Labour Rate *Eq 12*

Total Wiring Price= % /100 ×∑ (PV panel + inverter + labour) price *Eq 13*

Where,

The percentage is set by 30% from the total price of panel, inverter and labour in this project.

Maintenance Price

Total Maintenance Price = Annual Cleaning + Annual Inspection *Eq 14*

Where,

Total Costing Price

$$\text{Total} = \sum (\text{PV panel} + \text{Inverter} + \text{Labour} + \text{Installation} + \text{Maintenance})\ \text{price} \qquad \textit{Eq 15}$$

The costing tab is represented in Figure 4 This page displays the cost calculation for the installation of a PV system. This tab requires the user to enter the panel cost, quantity of panels, and size of inverters. Users should consider the cost of labour and wire while installing. It also covers the maintenance of grid-connected PV systems, which must be considered.

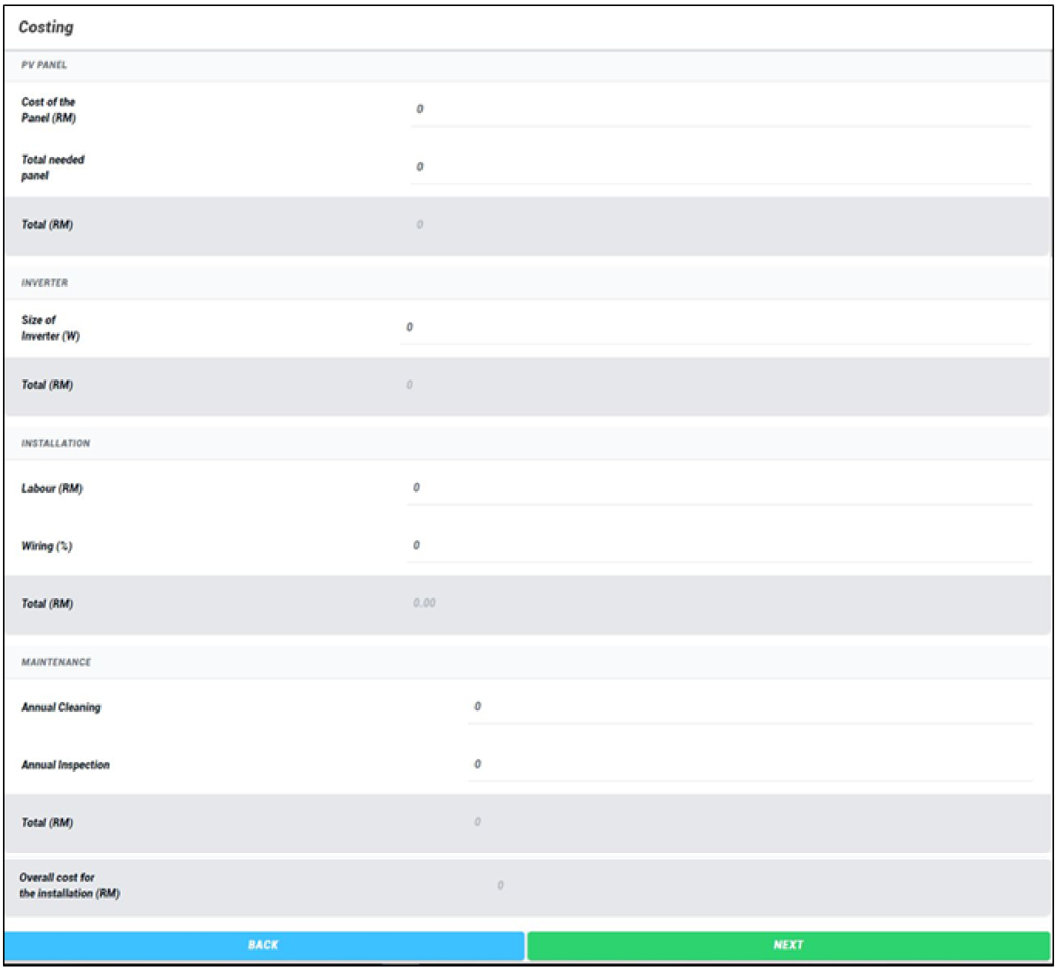


Figure 4: Costing tab

2.5 Total Payback Period

The Return on Investment (ROI) refers to the effective returns generated by investment during the life of the solar system [10]. The greater the monthly savings on electricity costs from solar, the faster original investment will be returned and the higher ROI. Usually, the residential consumer should expect the payback in 5 to 7 years. Solar panel cost is one of the factors that need to be considered in return on investment of solar panels. Solar system consists of a PV panel, inverter and other equipment.

The lower the cost of the solar system, the shorter the payback period. Equation 16 shows the formula that can be used to calculate total payback period [9]. Peak-Sun Hours are also an important factor in determining return of investment. ROI will be shorter when the sun hour is better. This is because the production of solar energy is higher [11].

$$\text{Total Payback Period (Year)} = \frac{\mathit{Total\ Costing\ Price\ (RM)}}{\frac{\mathit{Total\ Monthly\ Saving\ (RM)}}{\mathit{12\ Month}}} \qquad \mathit{Eq\ 16}$$

On the last tab, it is also an auto generate tab. This tab contains the results of all calculations from the first to the fifth tabs. This tab may display the data or the actual monthly bill, total bill after installation and the total monthly saving. Other than that, the tab also displays the data for the total payback period. Figure 5 shows the tab of the total payback period tab.

Figure 5: Total payback period tab

2.6 Location of Observation

This project is focusing on the single-storey terrace house at Taman Impian, Parit Raja, Batu Pahat, Johor. After making a few observations, this house is suitable because it has a strong roof without leaks or damage and has a spacious roof or ground yard to accommodate all the solar equipment. Figure 2 above shows the location of the house.

(a) (b)

Figure 6: Location of the Single-Storey House

3. Results and Discussion

The sizing steps in Section 2 are for the terrace house's grid-connected PV system. This mobile application will size appropriately with any value other than the one shown. It depends on the user, electricity demand, PV panel, inverter, and labour. Any error might cause extra energy production and raise installation costs. Table 1 presents the statistics from the single-storey terrace home.

Table 1: The estimated load consumption

No	Electrical Load	Quantity (Q)	Power Rating (Watt)	Total Connected Load (Watt)	Operating Time (Hour/Day)	Energy Consumption (E, Watthour/Day)
1	Ceiling Fan	3	75	225	11	2475
2	Compact Fluorescent Light	13	18	234	8	1872
3	Air-Conditioner (1 Hp)	2	746	1492	5	7460
4	Television (32 Inch)	1	60	60	4	240
5	Printer	1	30	30	0.5	15
6	Water Heater	1	3600	3600	0.5	1800
7	Electric Kettle	1	1800	1800	0.3	540
8	Refrigerator	1	200	200	24	4800
9	Rice Cooker	1	400	400	0.5	200
10	Washing Machine	1	500	500	1	500
11	Mobile Charger	4	7	28	1	28
12	Laptop Charge	4	73	292	2	584

Table 2 displays the chosen PV panel for a single-storey terrace home. They were taken from the datasheet. In this case, four panels are plenty for a 1kWp PV system on a terrace home. All the calculation in section 2 has been made by the mobile application. So the GUI and manual computation provide the same result in Figure 7.

Table 2: Grid-connected PV System

Description	Step	Result
PV Panel Rated DC Power Output		300W
Manufacturer Power Guarantee		0.90
Number of Panel in Array	**1**	4
Array Guarantee Power Output		**1080 Watt**
Array Avg. Operating Temperature		55°
Temperature Coefficient for Power		0.0050
Standard Test Condition Temperature		25°
Temperature-Corrected Array Power Output	**2**	**918.00 Watt**
Array Wiring and Mismatch Losses		0.03
Net Array Power Output	**3**	**890.46 Watt**
Inverter Maximum Dc Power Rating		1200 Watt
Inverter Power Conversion Efficiency		0.90
Inverter MPPT Efficiency		1.00
Inverter Maximum AC Power Output	**4**	**801.41 Watt**
Average Daily Insolation (PSH)		**4**
Average Daily Energy Production		**3205.64 Wh/days**

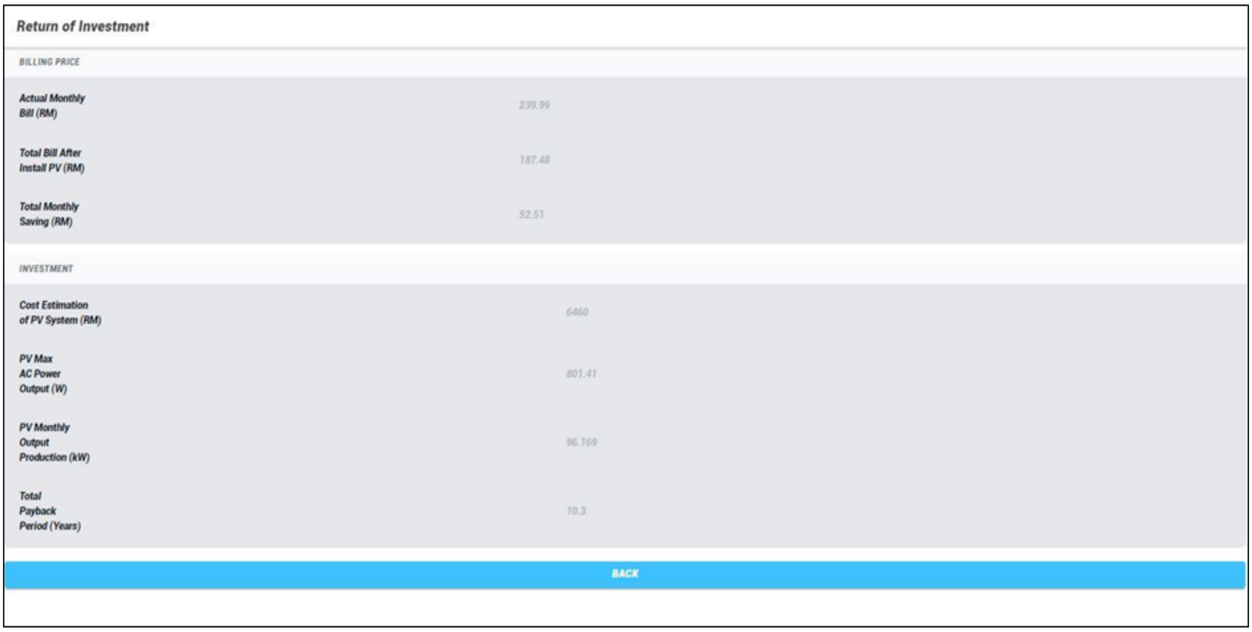


Figure 7: The return on investment tab

Table 3 illustrates the results of the return-on-investment calculations performed manually and using a mobile application. In this case, the total payback period comes out to be around 10.25 years, the same as the computational method. On the other hand, mobile application comes up with a value of 10.30, which is just different in terms of decimal points. This is evidence that mobile application can be used in this PV systems.

Table 3: Result of Computational Method for Return on Investment Compared with Mobile Application

No	Analysis	Computational Method	Mobile Application Result
1	Actual Monthly Bill	RM239.99	RM239.99
2	Total Bill After Install PV	RM 187.48	RM 187.48
3	Total Monthly Saving	RM52.51	RM52.51
4	Cost Estimation Of PV System	RM 6460	RM 6460
5	Total Payback Period	10.25 years	10.3years

4. Conclusion

In conclusion, the collection of data for the whole project and sizing a grid-connected PV has been presented in this report. This project includes load analysis, PV sizing, tariff bill, costing for installing grid connected PV system and total payback period for single-storey terrace house in Taman Impian, Parit Raja, Batu Pahat, Johor. The entire payback period is dependent on the total monthly savings and the total cost of the PV installation, as indicated in the figures in the table above. This sizing method will help the consumer to get a lower price with the better system at the house.

Acknowledgement

The authors would like to thank the Green and Sustainable Energy (GSEnergy) Focus Group, Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia for its support.

References

[1] M. S. N. Samsudin, M. M. Rahman, and M. A. Wahid, “Akademia Baru Power Generation Sources in Malaysia: Status and Prospects for Sustainable Development,” 2016.

[2] N. Sagar, A. Tiwari, S. Kumar, L. Kumar, M. Belwal, and S. Kumar, “Identifying and using Viable Alternative Energy Resources (WIND Energy),” in Proceedings - 2019 Women Institute of Technology Conference on Electrical and Computer Engineering, WITCON ECE 2019, Nov. 2019, pp. 40–44, doi: 10.1109/WITCONECE48374.2019.9092940.

[3] A. Y. Azman, A. A. Rahman, N. A. Bakar, F. Hanaffi, and A. Khamis, “Study of renewable energy potential in Malaysia,” in 2011 IEEE 1st Conference on Clean Energy and Technology, CET 2011, 2011, pp. 170–176, doi: 10.1109/CET.2011.6041458.

[4] V. Nandhini, K. Bharathi, S. Giri, S. Sowvav, and A. Suyampulingam, “Energy management and smart control of home appliances,” J. Phys. Conf. Ser., vol. 1706, no. 1, 2020, doi: 10.1088/1742-6596/1706/1/012087.

[5] M. Kumar, “Social, Economic, and Environmental Impacts of Renewable Energy Resources,” in Wind Solar Hybrid Renewable Energy System [Working Title], IntechOpen, 2020.

[6] sustainable energy authority malaysia, “NEM 3.0 – Renewable Energy Malaysia.” http://www.seda.gov.my/reportal/nem/ (accessed Jun. 13, 2021).

[7] kettha, “Understanding Your Net Energy Metering Bill | Solar System Malaysia.” https://www.solarsystemmalaysia.com/nem/understanding-your-net-energy-metering-bill/ (accessed Jun. 10, 2021).

[8] H. M. Salman, W. F. Wan Ahmad, and S. Sulaiman, “Usability Evaluation of the Smartphone User Interface in Supporting Elderly Users from Experts’ Perspective,” IEEE Access, vol. 6, pp. 22578–22591, Apr. 2018, doi: 10.1109/ACCESS.2018.2827358.

[9] L. Abdallah and T. El-Shennawy, “Reducing Carbon Dioxide Emissions from Electricity Sector Using Smart Electric Grid Applications,” J. Eng., vol. 2013, 2013, doi: 10.1155/2013/845051.

[10] J. Sreedevi, N. Ashwin, and M. Naini Raju, “A study on grid connected PV system,” 2016 Natl. Power Syst. Conf. NPSC 2016, pp. 0–5, 2017, doi: 10.1109/NPSC.2016.7858870.

[11] Y. Ru, J. Kleissl, and S. Martinez, “Storage Size Determination for Grid-Connected Photovoltaic Systems,” 2012.