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STUDY ON FEED-IN-TARIFF (FiT) FOR BIPV SYSTEM; A MALAYSIA SCENARIO

S. Thanakodi[a*], N.S.M.Nazar[a], N.A.Othman[b], H.D.M.Hidzir[a], S.S.H.Shah[a]

[a]Department of Electrical & Electronic Engineering, Faculty of Engineering, Universiti Pertahanan Nasional Malaysia
[b]Institute of High Voltage and High Current, Faculty of Electrical Engineering, Universiti Teknologi Malaysia, 81310, UTM Johor Bahru, Johor

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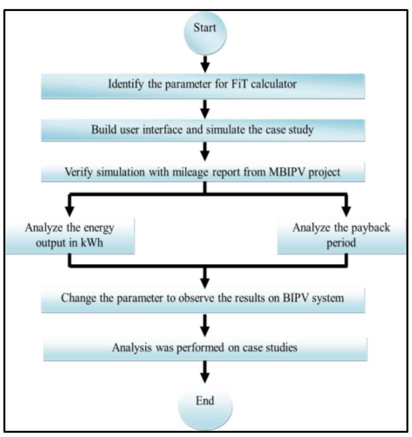
*Corresponding author
suresh@upnm.edu.my

Graphical abstract



Abstract

Feed-In Tariff (FiT) was introduced in Malaysia in 2004 and has been undergone many stages to make its implementation in Malaysia successful. The first Building Integrated Photovoltaic (BIPV) introduced in Malaysia is Suria 1000 under the supervision of Pusat Tenaga Malaysia (PTM). The aim of this paper was to study the FiT and BIPV implementation in Malaysia. It is observed that Malaysian did not invest in BIPV due to its expensive investment. The FiT Calculator was developed to prove the benefits of FiT in BIPV by practically calculating the investment and profit in the long run which was after 21 years of implementation. FiT Calculator was developed using Microsoft Visual Basic 2010 and variable parameter such as the solar irradiation, types of solar panel and inverter were studied to obtain the estimation of power output, the annual income, net income and the payback period of BIPV. Results of all case studies were verified with MBIPV mileage report and the built FiT Calculator has shown up to 96.89% accuracy against the case study done.

Keywords: Feed-in tariff, building integrated photovoltaic (BIPV) system, kWp, microsoft visual basic 2010.

1.0 INTRODUCTION

Feed-In Tariff (FiT) is a scheme where the owner of Renewable Energy Technology (RET) are paid for any amount of power generated in kilowatt-hour (kWh) under the contract that typically lasted for 20 years[1]. Feed-In-Tariff was introduced in 1991 and put on hold for a while and then the scheme was improved in 2000 after German successfully implemented it in their country. Since then, the scheme has become an alternative method for modern and developing country to encourage civilian and residents to rely more on safe and usable green energy technology under the 'Renewable Energies Law' [2]. Taking the initiatives to increase the usage of RET in Malaysia; the government expand the first draft of Renewable Energy Act on 15th December 2010 wherein the FiTscheme was proposed. In April 2011, the Malaysian House of Representative (Dewan Rakyat) passed the RE Bill which leads to FiT policy and passed the Sustainable Energy Development Authority (SEDA) Bills which henceforth approved by the Malaysian Senate [3].

Building Integrated Photovoltaics (BIPV) is designed to harness the energy from sunlight and convert it to electrical energy without the depletion of any resource or causing an environmental effect. There are three main forms of commonly BIPV which are flat roof, facade and pitched roof or solar shingles. These forms are all integrated or attached to a building. However, solar panels that usually placed in the large open area and detached from the building are not considered as BIPV. The history of BIPV system in Malaysia was started by launching the Malaysia Building Integrated Photovoltaic (MBIPV) project starting from July 2005 by Government of Malaysia (GoM) under the 9th Malaysia Plan with the aim to develop an appropriate, proactive and integrated plans and policies to exploit solar PV energy in Malaysia [4].

Malaysia has been relying on non-renewable energy for electricity generation purposes. According to U.S. Energy Information Administration website, it is recorded that Malaysia has been using natural gas for 36%, coal for 17%, petroleum and other liquid for 40%, biomass and waste material for 4% and hydro for 3%. From the statistic, it is observable that Malaysia has been using gas and petroleum at a high percentage. This is a major cause for carbon emission. According to indexmundi.com, Malaysia's carbon emissions were increased by 52.75% from 1999 to 2009. Therefore, to overcome this problem, Malaysian government introduced Feed-In-Tariff to encourage RET users to reduce carbon emissions. It is also recorded that Malaysian has a very low percentage of awareness about RET and FiT [5].

2.0 TYPES OF SOLAR PANEL

There are three main types of solar panel available in the market namely Monocrystalline, Polycrystalline and Amorphous. The manufacturing of these three solar panels are different which contribute to different parameters and characteristics of each panel. Hence, BIPV users should choose the right solar panel to their system so that the correct results and outcome can be obtained.

Monocrystalline is manufactured by cutting a slice of pure crystalline silicon in a shape of octagonal. It is manufacturedto aligned in only one direction, so that when the sun shine on the mono solar cell at the correct angle, it will have the most efficiency which is up to 15 to 20%. This type of module also has a uniform blacker to absorb most of the light. Monocrystalline solar cells also have the longest lifespan among the other three solar panels; theoretically up to 25 years warranty. However, this type of solar cells is much expensive since it used a tremendous amount of silicon in the manufacturing process [6].

Polycrystalline (p-Si) is also known as Multicrystalline Silicon (mc-Si). Polycrystalline panels are made up from a piece of silicon, molded to form blocks and create a cell made up of several bits of pure crystal. Since the individual crystals are not necessarily perfectly aligned together and there are losses at the joints between crystals, polycrystalline can be considered as not efficient. However, this slight misalignment can be beneficial in some circumstances, because the cells work better from light at all angles, especially in low light. Typically, polycrystalline panels have efficiency around 14% [7].

Amorphous silicon (a-Si or a-Si:H) solar cells belong to the category of silicon thin-film, where one or several layers of photovoltaic material are deposited onto a substrate. The types of thin-film solar cells have a huge potential. These technologies are expected to grow rapidly in the coming years as they mature. In 2011, amorphous silicon solar cells represented about 3% of market used. The current challenge is that the amorphous silicon solar cell conversion efficiency is quite low compared to the international advanced level of about 10% [8].

The differences of PV solar module are summarized in Table 1.

Table 1 Differences of PV Module

Aspect	Monocrystalline	Polycrystalline	Amorphous
Cost	High	Moderate	Low
Efficiency	15%-18%	14%-11%	10%
Space Required	Least	Moderate	Most
Lifetime	25 years	25 years	10 years
Mass	Medium	Medium	Medium-light

3.0 METHODOLOGY

Figure 1 shows the flow chart of methodology for this paper. Investigation on how the Photovoltaic (PV) modules affect the BIPV system was studied. The effect of BIPV on FiT was studied using Microsoft Visual Basic 2010 by modeled a Feed-In Tariff calculator that was used to calculate the estimation of solar power output in kWh, net income and annual income; both in MYR and to estimate the payback period of actual BIPV project in Malaysia. There are three types of BPIV and three locations chosen for BPIV installation which is the first one is the 4.4 kWp BIPV project was installed at SMK (P) Sri Petaling , next is 9.9 kWp BPIV was installed at Damansara Utama Shoplots, and finally 11.88 kWp BPIV was installed at Putrajaya Perdana Berhad Headquarters.

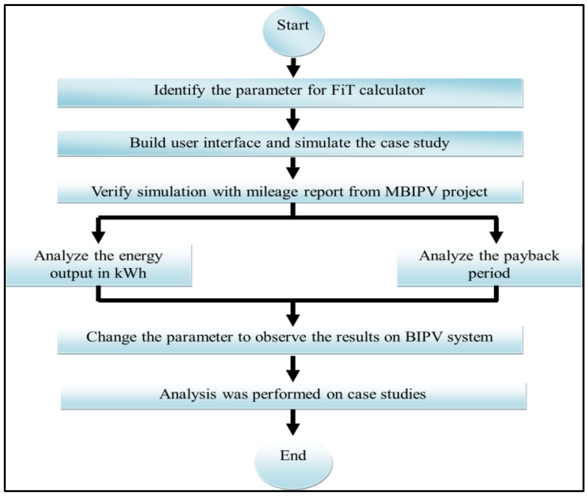


Figure 1 Flow chart of methodology

FiT calculator was developed to calculate the parameters used to estimate the power output, PPV (kWh) such as the solar irradiation (kW/m^2), angle of incidence of solar panel (°), area of solar panel (m^2), efficiency of solar panel (%) and the efficiency of solar inverter (%). In order to calculate the estimate power output the equation has shown in equation 1. Where, P_{pv} is the estimation of solar output (kWh), R is the solar radiation (W/m^2), η_p is the efficiency of solar panel, η_m is the efficiency of MPPT, A_p is the area covered (m^2) and ϕ is the inclination of solar panel. Thus, to estimate the payback period, users can simply divided the total investment of solar system with the annual income obtained from selling the generated energy.

$$P_{PV} = R\eta_P\eta_m A_P \cos\phi \quad (1)$$

Figure 2 shows a simple interface that consists of two buttons was built to welcome the user. The first button is a start button that allowed user to proceed to the calculator while the second button is the 'Exit' button of the system.

There are 15 choices of solar panel that can be picked up from the selection and specification tab by simply clicking on the "Display Solar Panel Specs" as can be seen in Figure 3. New form will pop out showing the basic specs of selected solar panel.

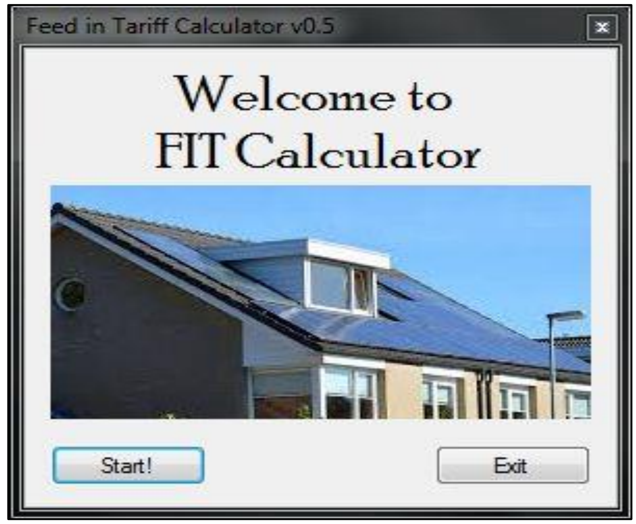


Figure 2 Welcome interface

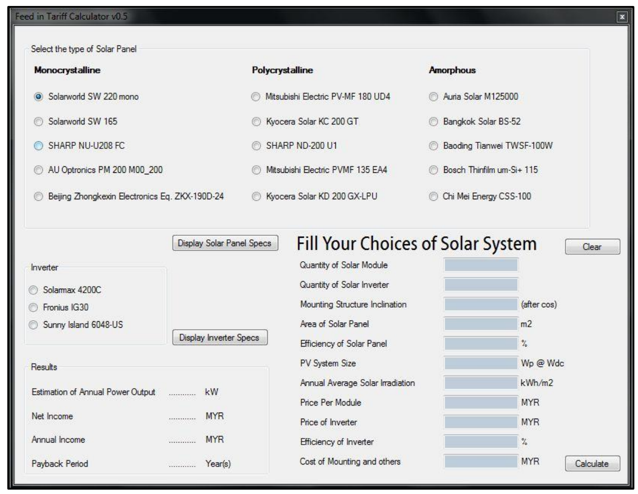


Figure 3 Empty user interfaces

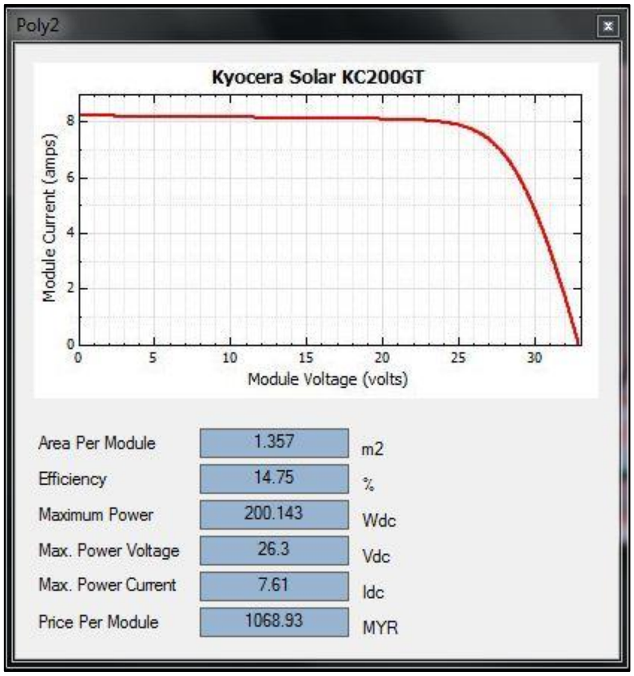


Figure 4 Polycrystalline Kyocera Solar KC200GT specifications

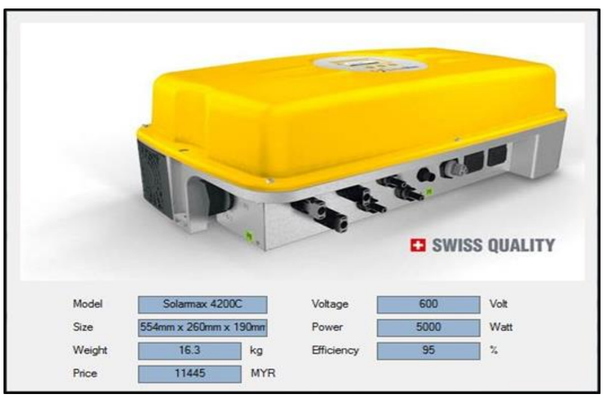


Figure 5 Solarmax 4200C Inverter specifications

Several basics of electrical aspect of solar panel needed for the calculator as well as the solar price in the market will be shown in the specification tab in Figure 4. By using this simple form of solar panel specification, users are able to differentiate between two or more solar panel and fill the form in the calculator. Figure 5 shows the Solarmax 4200C and the same concept was applied to the inverter specification. Users only have to choose any inverter, and click on 'Display Inverter Specs' in order to view the electrical and technical aspect.

FiT Calculator able to calculate the power output, net income, annual income and payback period if and only if, all the text box in the form are filled.

4.0 RESULTS AND DISCUSSION

From this point onward, Case Study 1, Case Study 2, and Case Study 3 will now be henceforth refer to SMK (P) Sri Petaling, DamansaraUtamaShoplots and Putrajaya Perdana Berhad, respectively. Results obtained were compared and dissected to analyze the effect of solar panel performances on Feed-In Tariff (FiT). The results of FiT Calculator simulation can be observed in Figure 6, 7 and 8. The summarized detail can be observed in Table 2.

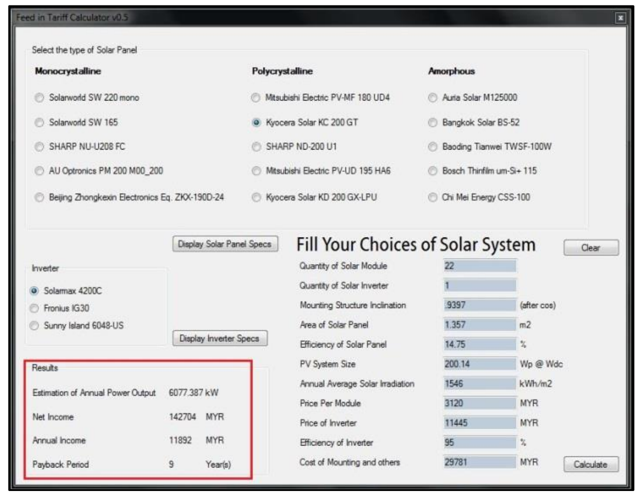


Figure 6 SMK (P) Sri PetalingFiT calculator simulations

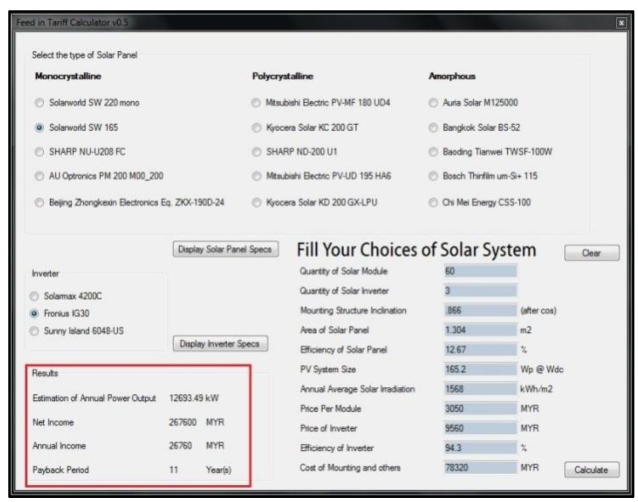


Figure 7 Damansara Utama Shoplots FiT calculator simulations

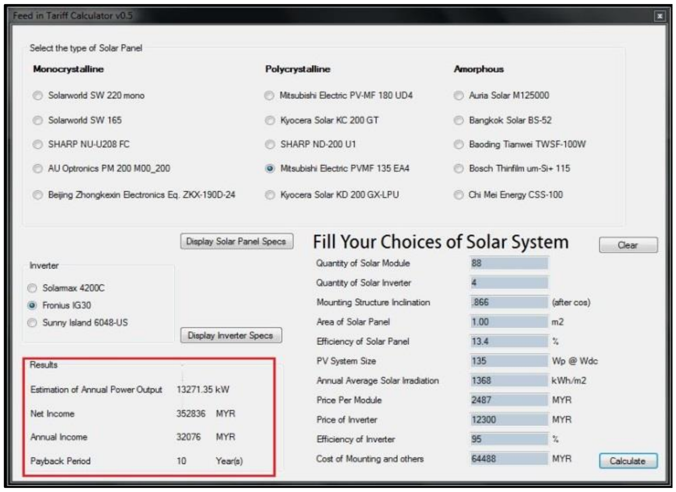


Figure 8 Putrajaya Perdana Berhad FiT calculator simulations

Table 2 Results of FiTCalclulator

Aspect	SMK (P) Sri Petaling	Damansara Utama Shoplots	Putrajaya Perdana Berhad
Area covered, m²	30	78	88
PV System Size, kW$_p$	4.4	9.9	11.88
Solar panel	Kyocera Solar KC 200 GT	Solarworld SW 165	Mitsubishi Electric PVMF 135 EA4
Investment, RM	109,866	290,000	351,627
Estimation of annual power output, kWh	6077.39	12,693.49	13,271.35
Annual income, RM	11,892	26,760	32,076
Net income, RM	142,704	267,600	352836
Payback Period, years	9	11	10

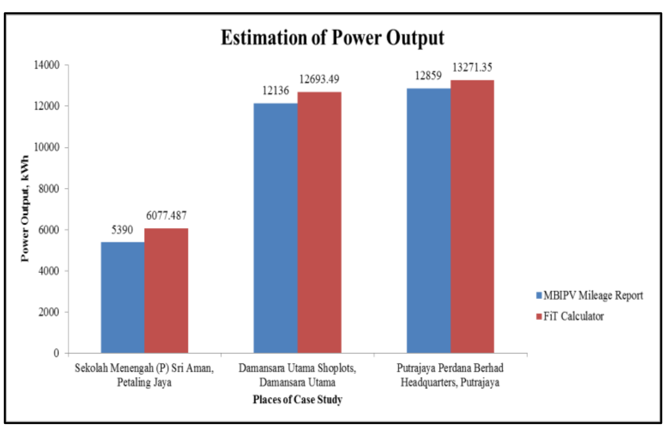


Figure 9 Comparison of solar output

Figure 9 indicates the estimation of power output from both calculation and the MBIPV Project mileage report. Note that the blue bar is the power estimation by MBIPV Project mileage report and the red bars is the power estimation obtained from the calculation. The accuracy of the calculator for SMK (P) Sri Petaling, Damansara Utama Shoplots and Putrajaya Perdana Heights were 88.68%, 95.6% and 96.89%, respectively.

The differences in margin were calculated for all three cases and for Case 1, the margin was 11.31%, for Case 2 it was 4.39% and finally for Case 3, the margin was at 3.1%. The differences of power output estimation between all three cases diminishes as the system size of the solar getting bigger. The error margin was due to the mileage report prepared by the MBIPV Project utilizes more on mathematical modeling and the calculator provided a calculation more on the practical approach.

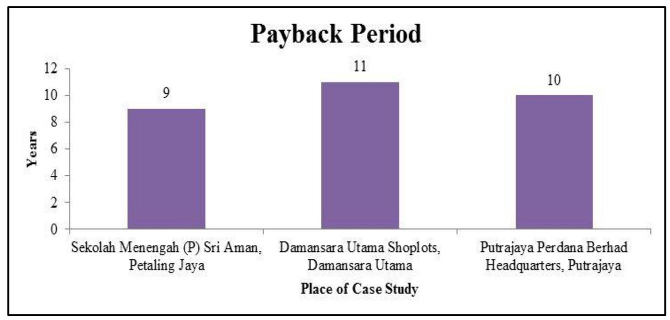


Figure 10 Comparison of payback period

In a BIPV installation, the cost for solar panel will take a huge percentage of the whole investment, nearly up to 62 to 63% of the whole investment. Choosing a solar panel that can offer the best performance with lowest price available able to offer a quicker payback period. Figure 10 indicates that a high power generation using solar system does not guarantee the payback period of the investment. Putrajaya Perdana Berhad has installed a higher BIPV system rounded up to 11.88 kWp but the payback period is faster than DamansaraUtamaShoplotspayback period which the solar system is at 9.9 kWp. Provided that Case 2 had chosen a different solar with the same electrical specification as Solarworld SW 165 but much cheaper, the payback period will be different entirely and it will be decreased.

Monocrystalline solar panel is much expensive than polycrystalline and amorphous solar due to its efficiency and its capability to generate more power with a smaller dimension of solar panel; that is why Case 2 choose to continue the BIPV implementation with monocrystalline solar panel instead of polycrystalline or amorphous solar panel.

Case study 2 was repeated with different type of solar panel particularly Auria Solar M125000 amorphous solar panel which is much cheaper than the previous solar panel. The only aspect that has been changed in the latter simulation is the solar panel. The inverter, cost of mounting, and miscellaneous cost of solar system remain the same. Summarized differences between two types of solar panel can be observed in Table 3.

Table 3 Differences of payback period

Aspect	Case 2	Case 2 (repeated)
Quantity of solar, unit	60	80
Price per module, RM	3050	1247
Solar size, W	165	125
Area, m	78	165
Power generated, kWh	12,693.81	12,817.89
Annual income, RM	26,760	27,000
Payback period, years	11	9.7

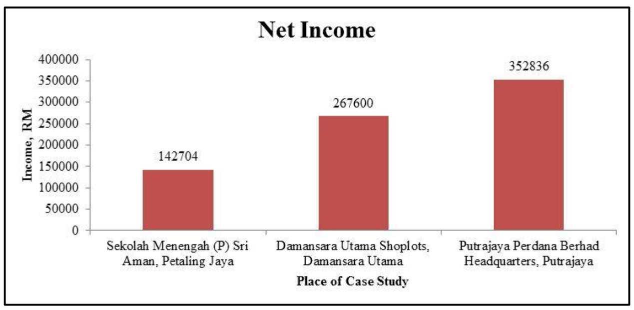


Figure 11 Net incomes after 21 years of FiT implementation

One of the major factors that affect Malaysians and renewable energy technology user alike was the profit obtained by selling energy produced to the utility. Based on the calculation using the developed calculator, it is estimated that SMK (P) Sri Petaling will obtained up to RM 142,704, DamansaraUtamaShoplots will obtained up to RM 267,600 and Putrajaya Perdana Berhad Headquarters will obtained RM 352,836 after 21 years of FiT implementation. It can be concluded that bigger solar system sizes ensure a higher net income for renewable energy user despite needing to invest in a large amount. The passive income requires only maintenance and good care. It is also can be concluded that bigger solar system size generates more income after the implementation reaches the end of payback period.

5.0 CONCLUSION

Implementation of Feed-In Tariff (FiT) in Malaysia has a great potential to our impeccable solar insolation as the location of Malaysia in the equator. The abundance of solar energy in Malaysia is a great platform for Malaysian to take part in the steps of saving the environment by reducing the carbon emission and also to obtain a steady passive income for the user. However, to acquire an accurate profit of the investment, the actual performance of BIPV must be determined correctly, either by consulting an expert or obtaining as much information about implementation of FiT for BIPV system. From the conducted research, Malaysian has lack of knowledge in FiT and therefore, is unwilling to indulge in the renewable energy program. This needs to be changed by spreading the words from mass media to the Malaysian from the government and private sector [8].

Selection of components for solar system plays an important role in FiT implementation. It is accepted that the development of FiT Calculator able to estimate the power output of solar system, the annual power output, net profit, and the payback period of the installed BIPV. Results obtained from the Feed-in Tariff Calculator were verified with the mileage report from MBIPV Project.

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