International Journal of Renewable Energy Resources 4 (2014) 28-34

EVALUATION OF SOLAR PHOTOVOLTAIC LEVELIZED COST OF ENERGY FOR PV GRID PARITY ANALYSIS IN MALAYSIA

Cheiw Yun Lau[1], *Chin Kim Gan*[1], *Pi Hua Tan*[1,2]
[1]Faculty of Electrical Engineering, Universiti Teknikal Malaysia Melaka (UTeM),
76100 Durian Tunggal, Melaka.
[1,2]Sharp-Roxy Sales & Service Company (M) Sdn. Bhd.
40400 Shah Alam, Malaysia.
Email: laucheiwyun@yahoo.com, ckgan@utem.edu.my, tanph@my.sharp-world.com

ABSTRACT
The Malaysian Government, under the Renewable Energy Act 2011 and the introduction of Feed-in Tariff (FiT) scheme has identified solar Photovoltaic (PV) system as one of the promising renewable resources that could generate 'green' electricity for the consumers in Malaysia. This is to reduce the dependency on fossil fuels and more importantly, to tackle the climate change challenge. In this regard, achieving grid parity is the main priority for the policy makers. When the cost of PV system generation is equal to or lower than the cost of conventional fossil fuel generation; grid parity is achieved. This paper presents the detailed PV grid parity analysis for a 4kW residential grid-connected PV system based on the calculation of the Levelized Cost of Electricity (LCOE). The research is carried out based on the three key parameters that drive grid parity, namely: the PV system price, electricity tariff, and discount rate. The FiT degradation rate of solar PV system has been taken into consideration. The finding suggests that the LCOE for a 4.0 kWp system in Malaysia is RM 0.9170/kWh in 2014. This means it may take up to 16 years for Malaysia to achieve PV grid parity. In contrast, with 1% yearly degradation rate of LCOE, results suggest that Malaysia will achieve grid parity in 2029. In addition, various analyses on the sensitivity of the key drivers to grid parity in Malaysia is carried out.

Key words: Photovoltaic generation cost, conventional electricity prices, grid parity, Levelized Cost of Electricity, Feed-in Tariff

1. INTRODUCTION

In these recent years, the use of non-renewable energy sources has brought a negative impact to the environment. Due to the high demand and long dependence of the world's energy consumption on fossil fuels, the non-renewable energy resources are gradually depleting over time. Therefore, solar Photovoltaic (PV) has emerged as an alternative energy resource. However, the PV has often been contemplated to be one of the most costly means for generating electricity, especially when compared with the much cheaper conventional fossil fuel power plant (U.K.W. Schwabe et al. 2010). Therefore, the Malaysian government has encouraged the installation of PV system by introducing the Feed-in Tariff (FiT) scheme in 2011 (A. Tam, 2013). Driven by the promise of PV installation, PV electricity generation cost is expected to decrease over the years. Hence, the degradation of PV generation price and increased electricity, the tariff will help to drive towards what is often called grid parity (G. Masson et al. 2013). Grid parity, in many countries across the world, is referred as the intersection where the price of electricity for the end consumer equals to the PV electricity generation cost. Many consumers in Malaysia have installed the PV system as an investment tool to take advantage of the FiT scheme. In light of this, the year when Malaysia will reach the PV grid parity is their great concern. However, electricity tariff is expected to be increased for the coming years. Hence, it will meet a break-even point when the PV system Levelized Cost of Electricity (LCOE) equals to or lower than the electricity tariff.

This paper presents a detailed analysis of grid parity based on the calculation of LCOE for the residential sector in Malaysia. In addition, the sensitivity of the key drivers, i.e., the projection of PV system LCOE compared to the forecasted conventional electricity tariff in Malaysia, is evaluated. The results suggest that Malaysia will achieve grid parity in 2029. As a result, Malaysia is expected to witness a significant growth in the PV market in the years to come.

2. METHODOLOGY

This section deals with the methodology for the calculation of the LCOE with some main assumptions of the relevant retailers of the PV modules, inverters, inflation rate, and prices of the conventional electricity.

A. Calculation of LCOE

The PV system LCOE is defined as the cost of generation PV electricity, which is associated with the PV system over its lifespan.
The LCOE can be calculated using:

$$\mathrm{LCOE} = \frac{CAPEX + O\&M}{E} \times \alpha \quad (1)$$

Where $CAPEX$ is the capital expenditures (RM), $O\&M$ is operation and maintenance cost (RM), E is annual electricity production (kWh/year) and α is capital recovery factor.

The capital recovery factor is expressed as:

$$\alpha = (1 + r)^T \quad (2)$$

Where, r is discount rate/interest rate (%) and T is economic lifetime of the PV system (year).
While capital expenditure can be defined as:

$$\text{CAPEX} = \text{Project Size} \times \text{Module Cost} \quad (3)$$

B. TNB Tariff

The data collection of the conventional electricity tariff from Suruhanjaya Tenaga (ST) was carried out to determine the annual average increment rate of the electricity prices in Malaysia as shown in Figure 1.

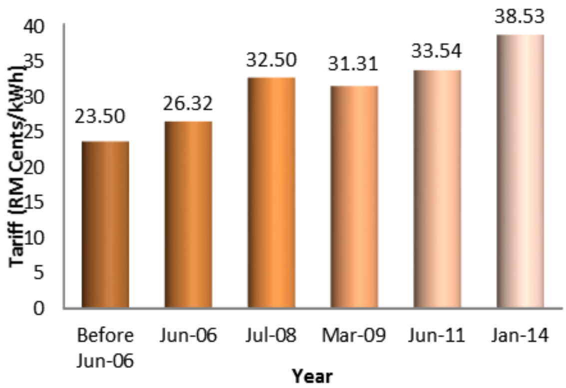

Figure 1 The average electricity tariff (cents/kWh) in Peninsular Malaysia (Suruhanjaya Tenaga, 2013).

Figure 2 shows the process flow of the PV grid parity analysis. It starts with the average TNB tariff data collection, and followed by the PV system prices collection. Depending on the availability of the existing data, the calculation of LCOE was carried out based on certain assumptions, such as system cost, inflation rate, and degradation rate. It is important to highlight that, the discount rate, FiT rate, and detailed system cost are amongst the essential parameters to be considered in the PV LCOE calculation.

Subsequently, the grid parity analysis was performed. Then, the results of the grid parity analysis were used to calculate the payback period for the PV system investors. Projects with long payback period would mean a higher risk of investment for the investor.

The key parameters that drive the grid parity are the electricity tariffs, PV system cost, and inflation rate. After carrying out the cost analysis, Malaysia might achieve grid parity by 2029. When grid parity is reached, the LCOE of solar PV will be equal to or lower than the TNB tariff. At this time, the FiT scheme will be removed and no longer be needed. A payback period is defined as the expected number of years required to recover the initial investment cost. The payback period is expected to be longer due to an increase in PV system LCOE. In consequence of an increase in LCOE, a higher electricity tariff would be resulted and thus, grid parity will be delayed. Therefore, a PV system investor will face financial risk of having longer payback period. Therefore, in order to secure a good investment; one must take into consideration of most of the significant factors. A short payback period is ideal for a PV investor to make profit out of the investment made.

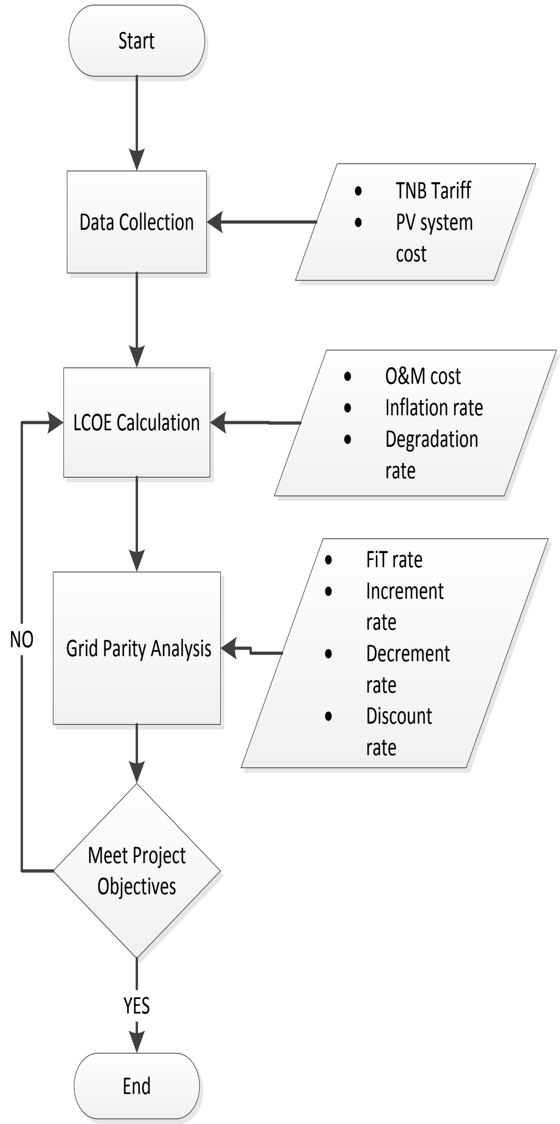

Figure 2 Flowchart of the methodology.

The low interest rates shorten the payback period for PV system owners due to fast PV system pay off and lower total investment cost. Hence, if grid parity reaches earlier, it will bring great financial benefits for those residents with solar PV installation.

Table 1shows the FiT rate for the electricity energy from the solar PV application in Malaysia. Different PV installation capacity is given different tariff under the FiT scheme. In this project, a 4 kW_p PV system with a FiT rate of RM 1.0411/kWh was considered. Besides, bonus FiT of RM0.2201/kWh for installation in building structures has been added. Thus, the total FiT rate in this study is RM 1.2612/kWh.

Table 1 FiT rates for solar PVfrom seda (SEDA, 2014).

Description of Qualifying Renewable Energy Installation	**FiT Rates (RM/kWh)**	
(a) Basic FiT rates having installed capacity of:	**2013**	**2014**
(i) up to and including 4kW	1.1316	1.0411
(ii) above 4kW and up to and including 24kW	1.1040	1.0157
(iii) above 24kW and up to and including 72kW	0.9440	0.7552
(iv) above 72kW and up to and including 1MW	0.9120	0.7296
(v) above 1MW and up to and including 10MW	0.7600	0.6080
(vi) above 10MW and up to and including 30MW	0.6800	0.5440
(b) Bonus FiT rates having the following criteria (one or more):	**2013**	**2014**
(i) use as installation in buildings or building structures	+0.2392	+0.2201
(ii) use as building materials	+0.2300	+0.2116
(iii) use of locally manufactured or assembled solar PV modules	+0.0300	+0.0300
(iv) use of locally manufactured or assembled solar inverters	+0.0100	+0.0100

3. Results and Discussion

This section is divided into a few subsections, which discuss the details of grid parity analysis with some assumptions applied.

A. *PV system cost*

The key parameter to drive the grid parity is the PV system prices, which makes changes to the LCOE (J. Hernández-Moro, 2013). The improvements in the system lifetime, annual energy yield (kWh/kW_p), inflation rate, CAPEX, and operation and management (O&M) cost would lower the LCOE. There are indications that the PV module lifetime could go longer than the estimated 25 years (C. Breyer et al. 2008), which would further improve the LCOE. A better performance, lower inflation rate, and longer lifetime of the PV system will lower the CAPEX and O&M cost, hence improve the LCOE.

It is important to note that each country has different PV systems' CAPEX, O&M and LCOE. Figure 3 shows the positioning matrix of LCOE for selected countries. (David Pérez et al. 2014). It can be observed that Germany, Italy and Mexico (Ramchandra and Ingo, 2009) have achieved grid parity and hence with the regulatory support the PV is best positioned for self-consumption (Filippo Spertino et al. 2014). In addition, the study conducted at National University of Singapore in 2010 suggests that the LCOE of residential PV system in Singapore is S$0.276 /kWh (RM0.706/kWh) (Tilak et al. 2011).

In Malaysia, it is difficult to experience degradation in the system cost due to the average increase of inflation rate, which lead the higher CAPEX and O&M costs. The number of investors to venture into the PV generation may decrease due to the degradation of the PV generation prices. Subsequently, the government's mission to reduce carbon dioxide emission may be hindered.

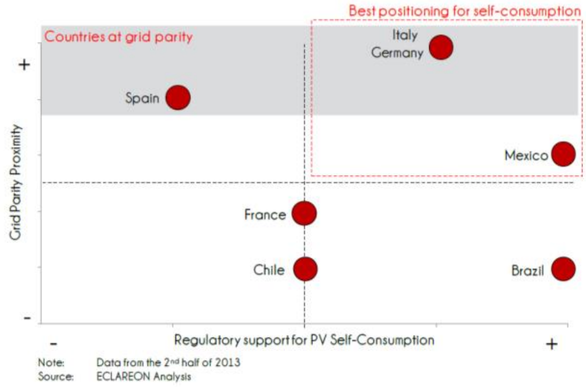

Figure 3 Positioning matrix of the countries analysed (Penwell, 2014).

Recently, Malaysia's currency has dropped over the year and this has led to the increase of inflation rate and the PV system prices. Therefore, it has caused the PV system prices to rise and has led to the ascent of LCOE prices (Ouyang and Lin, 2014). However, the PV system prices can be decreased due to low market demands. Therefore, two forecast assumptions were made, which are degradation of LCOE with 1%/year rate, and increment rate of 1.0%/year for inflation rate of the PV system prices.

B. Electricity Prices

The current electricity tariff escalation for residential consumers has been averaged at 7.0%/year from year 2006 to 2014 in Malaysia (S.Tenaga, 2013). The high demand of electricity supply, which is generated mainly by petroleum, coal, and natural gases, has led to the escalation of electricity prices in Malaysia.

Therefore, the forecasted TNB tariff for the coming 21 years; that is in average increment rate of 7.0% from year 2014 is shown in Figure 4.

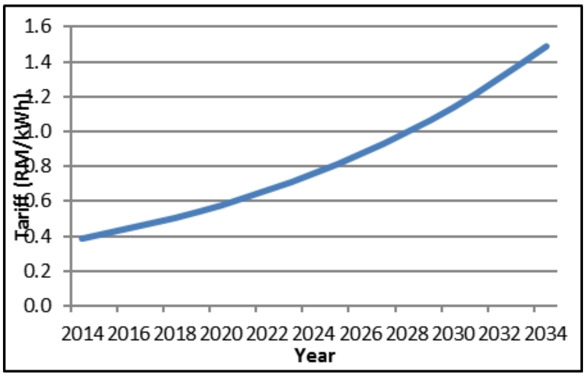

Figure 4 Forecasted average electricity tariff (cents/kWh) in Peninsular Malaysia.

C. Levelized cost of electricity (LCOE)

As for the 4.0 kW_p systems with the associated system prices, the LCOE is calculated.

Based on the following assumptions:

- PV module degradation rate of 0.70%/year;
- Inflation rate of 3.0%;
- Bank Interest rate of 7.5%;
- Loan duration of 10 years;
- FiT tariff rate of RM 1.23.

The LCOE analysis suggests that the PV LCOE for the beginning of the year is RM 0.9170/kWh, which is greater than the conventional TNB tariff of RM 0.3853/kWh. Due to the increase of inflation rate over the year (Peter, 2014), there may be an assumption of increment rate of 1.0%/year of inflation rate, followed by the increase of CAPEX and O&M cost as the LCOE shows a steady increase curve, which is illustrated in Figure 5. In contrast, if there is a degradation of LCOE with 1%/year rate, a decline curve is shown, as in Figure 6.

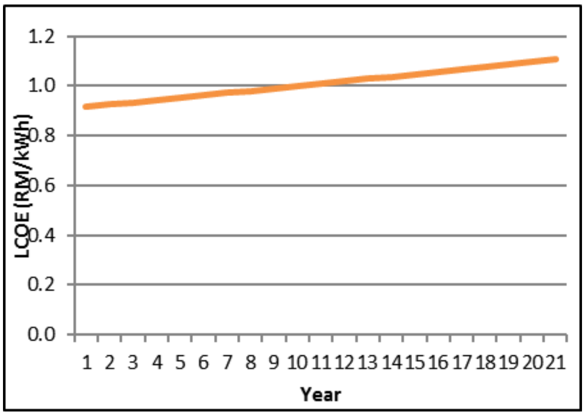

Figure 5 Forecast of LCOE with 1.0%/year increment of inflation rate.

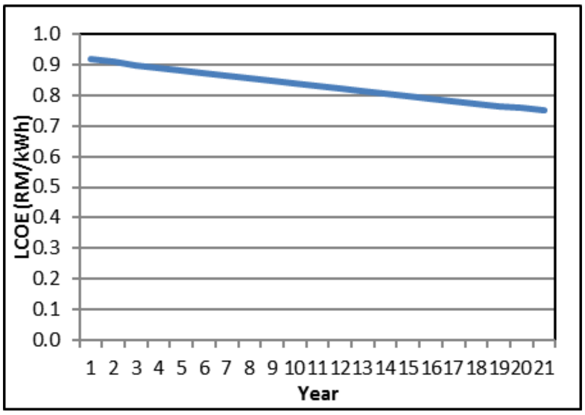

Figure 6 Forecast of LCOE with 1.0%/year degradation rate.

D. Grid parity analysis

Grid parity analysis emphasizes on the breakeven point of the LCOE and the TNB tariff within 21 productive years of solar PV system with 4 kW_p size capacity. The breakeven point will occur after 16 years from now, as shown in Figure 7. Figure 7 depicts the grid parity dynamic that will be achieved in 2029 for residential market in Malaysia. Nevertheless, grid parity can be achieved earlier by possessing very good solar condition, low PV system prices, and high TNB electricity tariff.

Figure 8 shows that the grid parity will be achieved earlier with the decline of LCOE. The assumption of 1%/year degradation rate will shorten the period for reaching grid parity in the 13^{th} year, which is better compared to the increase in the PV system prices. Therefore, degradation rate of PV LCOE will affect the consumers who installed the PV system with lower system prices.

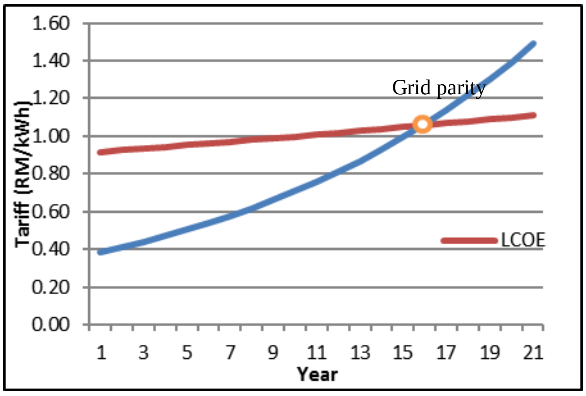

Figure 7 Grid parity analyses in Malaysia – residential segment with an increment rate of 1.0%/year of inflation rate.

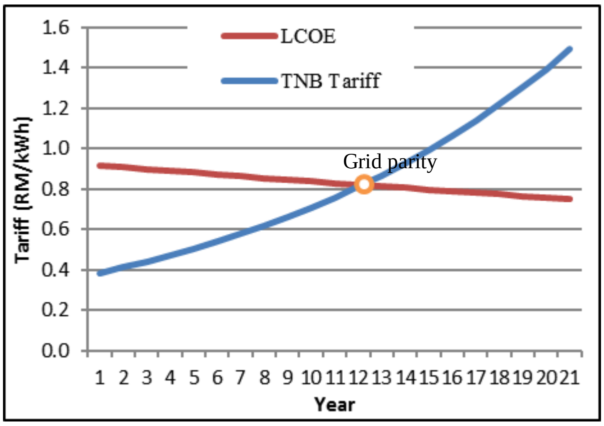

Figure 8 Grid parity analysis in Malaysia-residential segment with degradation rate of 1.0%/year.

By considering the FiT degradation rate of 8%/year and 10%/year, respectively, the results indicate a very low tariff after 16 years from the installation. Figure 9 shows the relationship between the parameters, i.e. FiT, LCOE, TNB tariff, and Feed-in Approval Holders (FIAH) tariff. This graph consists of two ranges for the degradation rate of FiT, which is only slightly different for the FIAH tariff. When the grid parity reaches a specific year, the LCOE and the FIAH tariff will be equal with the TNB electricity tariff. A 2% gap is shown between 8% and 10% FiT degradation rates, which only affects slightly on the income losses. A clear outcome of the grid parity analysis in Malaysia states that when the PV system LCOE is lower or equal to the conventional electricity tariff, the PV system LCOE will equal to the TNB electricity tariff. When grid parity has been achieved, the FiT scheme will no longer be needed because the FiT will be similar to the TNB electricity tariff. All results indicate that the year to reach grid parity will be boosted with higher electricity tariff and lower inflation rate.

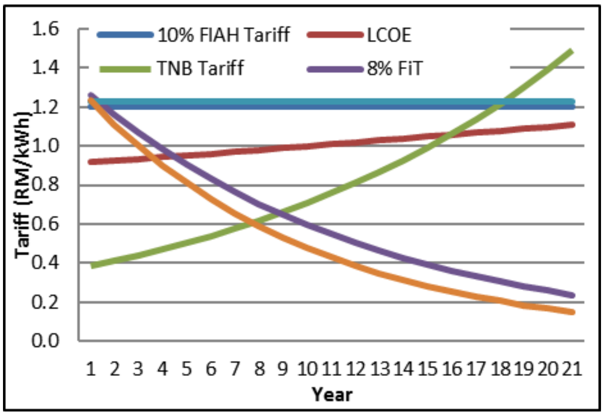

Figure 9 Relationship of combination parameters.

When the grid parity is achieved later, investors can avoid losses since the payback period of loan is usually short. When LCOE increases, the payback period will also increase and this may bring economic risk to the investors. Therefore, grid parity is significant to indicate investors about the risk and payback period for PV installation in the residential sector.

Figure 10 plots the combinations of LCOE and FIAH tariff after reaching the grid parity, which is equal to the TNB tariff. For further analysis, several assumptions of parameters have been combined by applying all deviations of CAPEX with LCOE (Falko et al. 2013). The variations in PV electricity energy yield are significant for the LCOE. PV system cost will increase due to inflation, which will lead the LCOE to increase and the year to reach grid parity will be delayed as well.

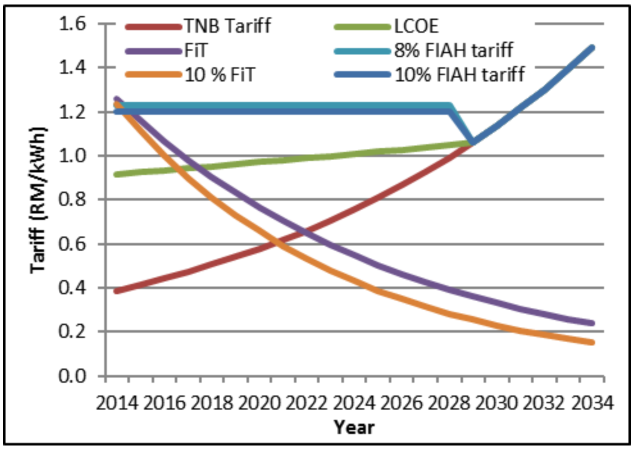

Figure 10 The tariff after grid parity with the combination of parameters.

The grid parity will be reached in year 2029 with a small increment of inflation rate; it brings a sudden drop to the FIAH tariff from RM 1.23/kWh to RM 1.0631/kWh, which is equal to TNB tariff. Afterwards, the FIAH tariff will follow the increment of the TNB tariff for the coming years. This scene may cause losses of about RM 0.1669/kWh.

Figure 11 illustrates the relationship between FIAH tariffs and the TNB tariff with a degradation of the PV system LCOE. It shows that the grid parity would reach earlier compared to Figure 9. If the grid parity reaches slower, both the FIAH tariffs for 8% and 10% would be equivalent to the TNB tariff with a tiny drop. It shows that the further the grid parity is achieved, the smaller the losses.

Fast grid parity attainment will bring effect for those investors with high amount of FIAH as they may face large losses. The difference of income losses for both degradation rates is discussed in the next section. Meanwhile, if the year to reach grid parity is further, investors can get more income before the tariff drop.

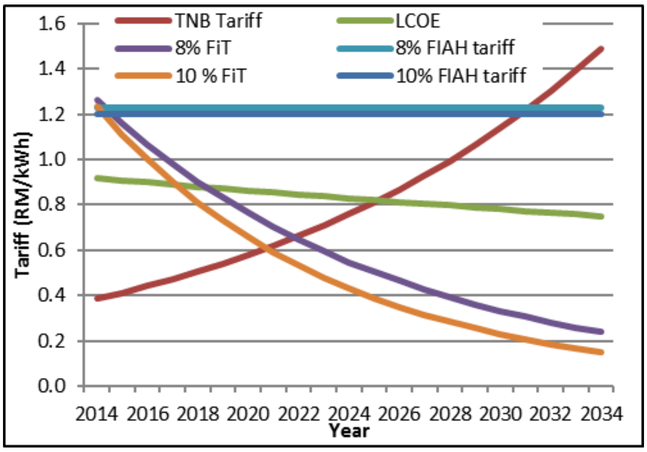

Figure 11 Grid parity analysis with the combination of parameters.

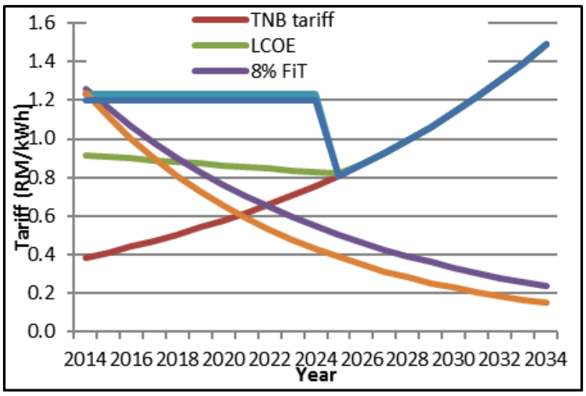

Figure 12 The tariff after grid parity with the combination of parameters.

Figure 12 exhibits the grid parity that reaches earlier with 1.0%/year degradation rate on the PV system LCOE. When the grid parity is attained earlier in year 2029, the FIAH tariff and the PV system LCOE will be equal to the TNB tariff. When LCOE meets the breakeven point with the TNB tariff, the offer from FIAH tariff will become equal to the TNB electricity prices through a sudden drop. FIAH tariff for 8% FiT degradation rate shows a sudden drop from RM 1.23/kWh to RM 0.8678/kWh at the breakeven point in year 2026, and the investors of this type of PV system will experience losses of RM 0.3622/kWh. In contrast, the FIAH tariff for 10% FiT degradation rate shows a drop from RM 1.20/kWh to RM 0.8678/kWh at the breakeven point in year 2026, and the investors of this type of PV system will lose RM 0.3322/kWh. For those investors who have installed the PV system later, they will have large income losses due to the lower tariff that is equivalent to the conventional electricity prices brought by grid parity. Due to the potential risk, investors may not be able to fulfil the bank requirements by following the provision of the payback period for term loan.

The grid parity will affect the PV system investment with lower tariff caused by the grid parity; the financial institution may not able to finance the PV project due to long term payback period. If the tariff after the grid parity is still high, the investors will not gain from the project financing fund. Hence, it can encourage more installation of PV systems among residential to moderate the greenhouse effects and carbon dioxide emission.

E. Comparison of income losses

The analysis on maximum and minimum grid parity implied that they will cause different losses to the residential consumers. Table2 shows the comparison between the cumulative incomes of 21 years for two different years of breakeven point that occur with two different degradation rates.

When FiT degradation rate is 8%/year, the fundamental income for the total energy of 113,694 kWh from 4 kW_p PV modules is RM 139,843.62 for 21 productive years without the occurrence of grid parity. However, when the grid parity is achieved earlier in 2026, a total of RM 3,674.79 is reduced in the income as compared to the basic income with the same amount of energy generated. When grid parity is reached later in year 2029, the cumulative income will become RM 140,941.88, which means there is a profit of RM 1,098.26.

When the FiT degradation rate increases at a rate of 2%/year, all the incomes will be effected. The loss in basic income is RM 3,410.82 compared to the 8%/year degradation rate. The income after the grid parity is reached will be lesser compared to 8%/year, which is RM 2,010.00 and RM 2,486.73 lesser for years 2026 and 2029 respectively.

Even if there is only about 2% difference in the FiT degradation rates; it can still cause large income losses. Therefore, the investors who have already installed the PV system could avoid income loss compared to those who make the installation later. When the consumers have installed the PV system earlier, it can avoid income reduction when the grid parity is attained. Those investors who have installed the PV system with a high FiT rate will get back their initial investment cost even before the breakeven point occurs, and thus helps them to increase incomes.

If the provision of the payback period from the bank is less than 10 years, all the initial investment would have been paid off earlier, and it will not be affected by the attainment of grid parity. Hence, residential consumers can avoid loss of income and financial risks when grid parity is reached.

Table 2 Comparison of cumulative tariff between 2026 and 2029 with 8% and 10% degradation rate of FiT.

FiT Degradation rate	Base Case Income (RM)	Income when grid parity in 2026 (RM)	Income when grid parity in 2029 (RM)
8%/year	139,843.62	136,168.83	140,941.88
10%/year	136,432.80	134,158.83	138,455.15

4. CONCLUSION

Grid parity, which is defined as the breakeven point where the utility electricity prices are equal to the PV generation cost (Kenton, 2013), will bring about great repercussion to the residential consumers under the current FiT scheme. The investors who wish to install PV system should take action as soon as possible, or else they might encounter grid parity contingency because they might face financial problem such as reduction of income (Stefan and Michael, 2013). In order to minimize the risk, several things should be taken into account. For instance, investors can take bank loan with lower interest rate so that they need not pay a large sum of interest. Besides, achieving a shorter PV system payback period, i.e. getting back the invested amount ahead of the grid parity year will also reduce income losses faced by investors. Through this, they can avoid the losses when the grid parity is attained. As for the residential consumers in Malaysia, PV electricity generation is expected to achieve the grid parity in 2029 with the increment of inflation rate, and in 2026 with a degradation rate of LCOE. Customers who are interested in the PV system should consider the installation of 4kW capacity PV system in the residential area given its higher FiT rate and affordable investment required. Such installations are highly financial viable before 2015 since it can avoid financial risk, such as income losses before grid parity is reached. This will be a good investment project for investors. In a nutshell, if the grid parity is achieved sooner than expected, the PV system will become a very competitive alternate source of energy in Malaysia.

ACKNOWLEDGMENT

The authors would like to gratefully acknowledge the research funding provided by the Ministry of Education Malaysia under the research grant no. RAGS/2012/FKE/TK02/2 B00009.

REFERENCES

Breyer C., Gerlach A, J. Mueller, H. Behacker and Milnerbb A. 2008. Grid-parity analysis for EU and US regions and market segments-Dynamics of grid-parity and dependence on Solar irradiance, local electricity prices and PV progress ratio: 4492–4500.

David P., María Jesús B., Jules L. 2014. PV Grid Parity Monitor Commercial Sector 1st issue, Eclareon S.L.

Falko U., Lion Hirth, Gunnar L., Ottmar E., 2013. System LCOE: What Are The Costs of Variable, Renewables Energy 63: 61-75.

Filippo S., Paolo D.L. Valeria C. 2014. Which are the Constraints to the Photovoltaic Grid-Parity In The Main European Markets, Solar Energy 105: 390-400.

Hernández-Moro j, Martínez-Duart J. M. 2013. Analytical model for solar PV and CSP Electricity Costs: Present LCOE Values and Their Future Evolution, Renewable and Sustainable Energy Reviews 20: 119-132.

Kenton D. Swift. 2014. A Comparison of the Cost and Financial Returns for Solar Photovoltaic Systems Installed by Businesses in Different Locations across The United States, Renewable Energy 57: 137-143.

Masson G., Rekinger M., I. T. Theologitis, and Papoytsi, M. 2013. European Photovoltaic Industry Association (EPIA): Global market outlook for PV 2013-2017. http://www.epia.org/fileadmin/user_upload/Publications/GMO_2013_-_Final_PDF.pdf.

Peter Lund D. 2014. Energy Policy Planning Near Grid Parity Using a Price-Driven Technology Penetration Model, Technological Forecasting and Social Change.

PV Magazine, Penwell, UK March 2014.

Ramchandra B., Ingo S., 2009. Grid Parity Analysis of Solar Photovoltaic Systems in Germany Using Experience Curves, Solar Energy 83(9): 1634-1644.

Schwabe U. K. W., Jansson P. M., Member S., and Pricing A. L. M., 2010. Utility-Interconnected Photovoltaic Systems Reaching Grid Parity in New Jersey, Power and Energy Society General Meeting 1–5.

Stefan R., Michael Y., 2013. The prospects For Cost Competitive Solar PV Power, Energy Policy 55: 117-127.

Suruhanjaya T. (Energy Commission): Peninsular Malaysia electricity supply industry outlook 2013, 1st ed. Putrajaya, Malaysia 2013.

Sustainable Energy Development Authority (SEDA), Available online at: http://seda.gov.my/, March 2014.

Tam A. Parliament of Malaysia: Feed-in Tariff and Renewable Energy Fund 2013. Available online at: http://www.parlimen.gov.my/images/webuser/artikel/ro/amy/FiT%20and%20RE%20Fund.pdf.

Tenaga S. 2013. Review on Electricity Tariff in Peninsular Malaysia under the Incentive-based Regulation Mechanism (FY2014-FY2017) Kuala Lumpur.

Tilak K. Doshi, Neil S. D'Souza, Nguyen P., Linh and Teo Han G. 2011. The Economics of Solar PV in Singapore, Energy Study Institute.

Xiaoling O., Boqiang L. 2014. Levelized Cost of Electricity (LCOE) of Renewable Energies and Required Subsidies in China, Energy Policy 70: 64-73.