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LAPORAN PROJEK SARJANA MUDA

PV GRID PARITY ANALYSIS FOR RESIDENTIAL SECTOR IN MALAYSIA

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Bachelor of Electrical Engineering (Industrial Power)

June 2014

"I hereby declare that I have read through this report entitle "*PV Grid Parity Analysis for Residential Sector in Malaysia"* and found that it has comply the partial fulfilment for awarding the degree of *Bachelor of Electrical Engineering (Industrial Power)*"

Signature : ....

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Date : ....

PV GRID PARITY ANALYSIS FOR RESIDENTIAL SECTOR IN MALAYSIA

LAU CHEIW YUN

A report submitted in partial fulfilment of the requirements for the degree of Bachelor of Electrical Engineering (Industrial Power)

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2014

I declare that this report entitle "*PV Grid Parity Analysis for Residential Sector in Malaysia"* is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ……..……………………………

Name : ……………………………………

Date : ……………………………………

To my beloved mother and father

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Last but not least, my deepest gratitude to all my family members especially my parents for their constant support and tolerant throughout these years. Thank you.

Below is the published work as a result of my Final Year Project.

[1] C. Y. Lau, C. K. Gan, and P. H. Tan, "PV Grid Parity Analysis for Residential Sector in Malaysia," in *Power and energy conversion symposium (PECS) 2014*, 2014, pp. 111–117.

ABSTRACT

Solar Photovoltaic (PV) system has been identified as one of the promising renewable resources that could generate 'green' electricity for the consumers in Malaysia. The Malaysia Renewable Energy Act 2011 and the Feed-in Tariff (FiT) that have been introduced in 2011 have aimed to facilitate the increasing use of renewable energy in Malaysian energy mix. 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 project presents the detailed PV grid parity analysis for a 4 kW residential grid-connected PV system based on the calculation of the Levelized Cost of Electricity (LCOE). The research is carried out based on three key parameters that drive grid parity, namely: the PV system price, electricity tariff, and discount rate. The degradation FiT rate of solar PV system also taken into consideration. By using an annual energy yield of 1450 kWh/kWp, 21 years of system lifetime, 7.5% discount rate, 3.0% inflation rate, and 0.90% operation and maintenance (O&M) cost, the LCOE is calculated for a 4 kWp system to be RM 0.9170/kWh in 2014. With this, it may take up to 16 years for Malaysia to achieve PV grid parity. In contrast, with an assumption of 1.0%/year degradation rate of LCOE, results suggest that Malaysia will achieve grid parity in 2026. Various scenarios gave different number of years to reach grid parity in Malaysia. For both 8% and 10% degradation rate of FiT, the incomes after the grid parity is reached will be reduced for about RM 2,010.00 and RM 2,486.73 for year 2026 and 2029 respectively.

ABSTRAK

Sistem solar fotovoltaik (PV) telah dikenal pasti sebagai salah satu sumber yang boleh diperbaharui dapat menjana tenaga elektrik 'hijau' bagi pengguna di Malaysia. Apabila *The Malaysia Renewable Energy Act* dan *Feed-in Tariff* (FiT) telah diperkenalkan pada tahun 2011 dengan memudahkan pertambahan pengguna sumber yang boleh diperbaharui antara campuran tenaga di Malaysia. Tujuan tersebut untuk mengurangkan pergantungan terhadap bahan api fosil dan yang pentingnya dapat menangani masalah perubahan iklim. Dalam hal ini, pencapaian pariti grid adalah keutamaan bagi pembuat dasar. Apabila kos penjanaan PV sama atau kurang daripada tarif elektrik konventional; maka pariti grid tercapai. Projek ini telah menunjukkan analisis pariti grid PV bagi 4 kW kapasiti bagi kediaman perumahan dengan pengiraan kos levelized elektrik (LCOE). Penyelidikan ini dijalankan dengan berdasarkan tiga factor utama bagi mencapai pariti grid iaitu harga sistem PV, tarif elektrik dan kadar faedah. Selain itu, degradasi bagi kadar FiT bagi sistem solar PV juga dipertimbangkan. Dengan menggunakan hasil tenaga tahunan 1450 kWh/kWp, 21 tahun umur sistem, 7.5% kadar diskaun, 3.0% kadar inflasi dan 0.90% kos operasi dan penyelenggaraan (O&M); LCOE dapat dikirakan bagi sistem 4 kWp adalah sebanyak RM 0.9170/kWh pada tahun 2014. Dengan ini, pariti grid dapat dicapai dalam tahun yang ke-16 di Malaysia. Manakala, bagi 1.0% kadar degradasi tahunan LCOE menyebabkan pencapaian pariti grid pada tahun 2026. Senario yang berbeza membawa kesan yang berbeza bagi pencapaian pariti grid. Bagi kedua-dua 8% dan 10% kadar degradasi FiT, pendapatan selepas pariti grid mencapai akan berkurang sebanyak RM 2,010.00 dan RM 2,486.73 bagi tahun 2026 dan 2029 masing-masing.

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LIST OFABBREVIATIONS

AEO	-	Annual energy outlook
BOS	-	Balance of system
CAPEX	-	Capital expenditures
CO_2	-	Carbon dioxide
C-Si	-	Crystalline Silicon
DC	-	Direct current
DLs	-	Distribution Licensees
E	-	Annual electricity production
EIA	-	Energy Information Administration
FIAHs	-	Feed-in Approval Holders
FiT	-	Feed-in Tariff
FKE	-	Faculty Electrical Engineering
HIT	-	Hetero-junction with intrinsic thin layer
JNNSM	-	Jawaharlal Nehru National Solar Mission
KWh	-	Kilo-Watt hour
KWp	-	kilo-watt peak
LCOE	-	Levelized cost of electricity
LMP	-	Locational marginal prices

MYR	-	Malaysian ringgit rates
NDRC	-	National development and reform commission
O&M	-	Operation and maintenance cost
PV	-	Photovoltaic
RE	-	Renewable Energy
RM	-	Ringgit Malaysia
SDE	-	Simulation Renewable Energy
SEDA	-	Sustainable Energy Development Authority
SESB	-	Sabah Electricity Sdn Bhd
SESCO	-	Sarawak Electricity Supply Corp
SMA	-	System advisor Model
SRECs	-	Solar renewable energy credits
ST	-	Suruhanjaya Tenaga
TF	-	Thin film
TNB	-	Tenaga National Berhad
UTeM	-	Universiti Teknikal Malaysia Melaka

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CHAPTER 1

INTRODUCTION

1.1 Research Background and Motivation

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 [1]. Therefore, the Malaysian government has encouraged the installation of PV system by introducing the incentives such as Feed-in Tariff (FiT) scheme began as early as 2004, and in 2011 [2]. 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 the annual increment of electricity tariff will help to drive towards what is often called grid parity [3]. Grid parity, in many countries across the world, is referred as the intersection or breakeven point 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 advantages of the FiT scheme. In light of this, the year when Malaysia will reach the solar PV grid parity is their great concern. This is due to the grid parity will bring many revenue on financial segment for investors. Investors should know the effect when grid parity reached either earlier or later to avoid the financial risk such as income losses. However, electricity tariff is expected to be increased in the future year which will fasten the year to reach grid parity. Electricity tariff will meet a breakeven point when the PV system Levelized Cost of Electricity (LCOE) equals to or lower than the electricity tariff.

This project is a case study which presents a detailed analysis of grid parity based on the calculation of LCOE for the residential sector in Malaysia. In addition, the sensitivity of key drivers toward grid parity, i.e., the projection of PV system LCOE compared to the forecasted conventional electricity tariff in Malaysia, is evaluated. As the result, Malaysia is expected to witness a significant growth in the PV market in the years to come.

1.2 Problem statement

In Malaysia, the government has encouraged people to increase the installation of PV systems among the residential and consequently introduced FiT scheme. The combustion of fossil fuels such as natural gas, oil and coal produce the carbon dioxide which can be lead to acid rain and global warming. Therefore, generation of PV system has beneficial to the environment which could be reduce the Green House Gas including carbon dioxide (CO_2) emissions are relatively clear [4]. By installing PV plant system, customers will become like an investor since install the PV system such an investment which could be earn the payback money from the generating power to the grid. Due to these various incentives will made grid-connected solar photovoltaic power systems to be a great financial investments for many consumers.

Payback period becomes a key investment decision indicator among the investors in global. It can affect the generation of PV system, system performance and PV system energy cost. However, all of these parameters have not been analysed in Malaysia since banker and other parties are still not familiar with the beneficial of PV installation. In addition, grid parity is important to be analysed due to economic crisis in a country such as inflation or the rise of the electricity price on grid utility. Other than that, policy in a country and tariff degeneration could also affect the grid parity. Indeed, the generation of photovoltaic systems to reach grid parity was become one of the most popular discussed topics in the world of renewable energy [1]. Thus, it is the most significant to have accurate information of local electricity costs pricing schemes and usage. Therefore, a thorough understanding and make clear on what is the exact coming for the future after grid parity is reached. All the factors should indicate and the financial risk can be avoided after predicted the year of grid parity.

1.3 Objectives

The main objectives of this project are as following:

- To investigate the key parameters that drive grid parity in Malaysia and their respective sensitivity.
- To estimate the breakeven year to reach grid parity in Malaysia under various scenarios.

1.4 Scope

This project covers the historical and projection of electricity tariff and solar PV generation cost in Peninsular Malaysia. The subsidies are included for the electricity prices utility (TNB stated tariff). The estimation of the breakeven point of the year is to achieve project bankability and grid parity in Malaysia.

This project is expected to determine the key parameters that drive grid parity in Malaysia. There are few key drivers which will affect the period of year to reach grid parity such as conventional electricity tariff, inflation rate, discount rate and LCOE. For financial section, the discount rate of the value of cost of PV installation will decreases in a range year by year which can bring a big effect on grid parity. Besides that, technical performances will affect the yield of the power generation of PV system. The performance of solar will strongly influences the period of reaching grid parity in a country. Government policy plays an important role in driving the grid parity in Malaysia. Feed-in tariff (FiT) and incentives are designed to encourage more installation of PV systems of the consumers in Malaysia. By analysing the different increment rate of electricity tariff in Malaysia and PV generation cost (LCOE) in different scenarios and conditions, it will give different ranges of the estimation of the year to reach of grid parity in Malaysia. The comparison of cumulative incomes was carried out by different year of grid parity reached.

CHAPTER 2

LITERATURE REVIEW

2.1 Solar Energy

According to Sustainable Energy Development Authority (SEDA) [5], renewable energy (RE) is defined as any form of primary energy from recurring and non-depleting indigenous resources. In the first column of the Schedule of the RE Act 2011 [5] explained that renewable resources means the recurring and non-eliminate domestic resources or technology. Renewable energy is any energy source that naturally replenished such as sunlight, biomass, wind and hydro. These energy sources are environmentally friendly because it does not causing any pollution to the ecology whereas it can still help to reduce pollution such as carbon dioxide emission by solar energy. Non-renewable energy is simply the other way around, is the energy resource which is non-replenished such as fossil fuel, oil, natural gas and coal. These energy resources are harmful and hazard to the ecology. Recently, solar was chosen for one of the best renewable energy resources since there is a rapid growth demand in the world and cause the depletion of fossil fuel and coal for energy generation. Therefore, it pushes many studies towards the renewable energy especially solar energy.

Sun is a renewable source that can be harvested to generate electricity. The solar energy is an abundant and free resource of energy and it can help to improve the environment since it does not contribute to climate change. Today, the push of renewable energy sources is driven by a renewed concern for the environment. Solar energy is the example of an environmentally friendly energy since it is free from sun. The most wonderful point is the solar energy will not run out until the sun was goes out.

Solar energy has been divided into two categories which are solar photovoltaic and thermal solar. Solar photovoltaic usually referred to as PV. The word photovoltaic comes from “photo”, meaning light, while the “voltaic”, means to generate electricity power. Therefore, solar PV process is generates power electricity directly from sunlight. Solar PV offer customers the ability to produce electricity in a quiet, clean, secure and reliable way. Therefore, PV system is very encouraged by government because there is no release of pollutant, low maintenance, very long lifespan and high reliability to be used in future.

There are four different types of PV Solar systems were installed in the area of Faculty Electrical Engineering (FKE) in Universiti Teknikal Malaysia Melaka (UTeM) which are poly crystalline silicon (C-Si), mono crystalline silicon, thin film and heterojunction with intrinsic thin layer (HIT). The Figure 2.1 shows the various type of PV panel.

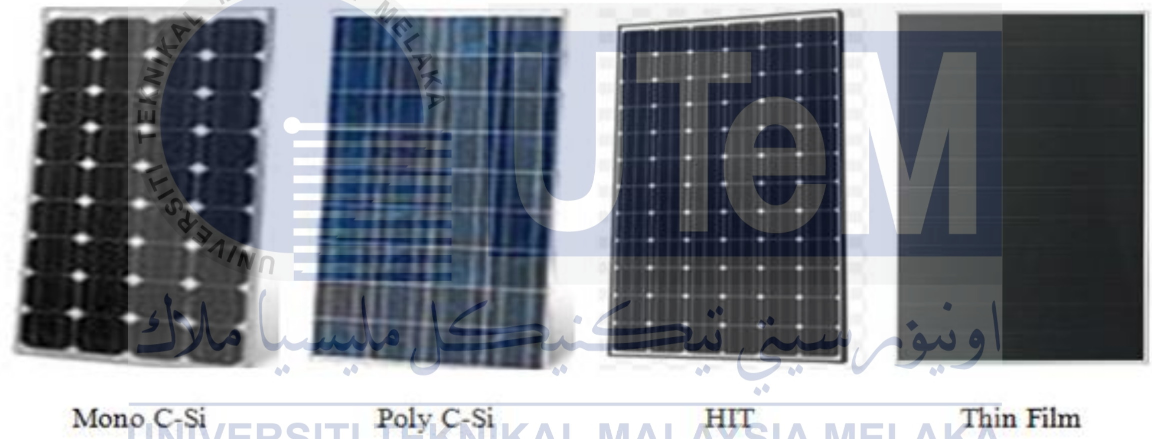

Figure 2.1: Various types of PV panels installed in FKE UTeM.

Malaysia is located at the equatorial region with an average solar radiation of 400-600MJ/m^2 per month [6]. However, due to the expensive of photovoltaic (PV) modules and solar electricity tariff rate which make solar energy is still at the initial stage in Malaysia. Malaysian government is keen to make solar energy as one of the important sources of energy in country to improve the production of power generation and reduce the used for gas and fossil fuel. Therefore, the Feed-in-Tariff (FiT) was designed for renewable energy to enable users to sell excess power to the power grid which could be encouraged more installation of PV panels in the country.

The installation of PV panels is still expensive in Malaysia compared with the electricity offered by utility companies in Malaysia such as, Tenaga Nasional Berhad (TNB) at Peninsular Malaysia, Sabah Electricity Sdn Bhd (SESB) and Sarawak Electricity Supply Corp (SESCO) since the PV modules are expensive of its manufactures cost [6]. This is the main reason why there are still less people install PV panels.

2.2 Feed-in Tariff (FiT)

2.2.1 FiT in Malaysia

The Cabinet had approved a policy in Malaysia on 2nd April 2010 which is improving the application of native renewable energy resources to contribute towards sustainable socio-economic development and national electricity supply security [5]. According to SEDA [7], FiT was introduced in Malaysia as early as 2004 and 2011, the years of effort finally success in the passing of two laws related to sustainable energy. This result is the dawn of a new era for Malaysia in a move toward mitigating climate change and achieving energy autonomy.

Malaysia's FiT system obliges Distribution Licensees (DLs) to buy from feed-in Approval Holders (FIAHs) the electricity produced from RE and sets the FiT rate. The DLs will pay for RE supplied to the electricity utility for a specific time [8]. The FiT mechanism would ensure that RE becomes a viable and sound long-term investment for consumers by guaranteeing access to the grid and setting a reasonable price per unit of RE in Malaysia.

Advances of RE technology and deployment of RE will increase with FiT performance in Malaysia [9]. This situation helps in encouraging consumers to install the PV system. FiT is a program or tool that allows electricity that is produced from replenishment RE resources to be sold to grid utilities (e.g. TNB) at a fixed reasonable price for specific period. It can provide a secure and favourable environment which will make economic institutions to be comfortable in providing loan with longer period (>15 years) [5].

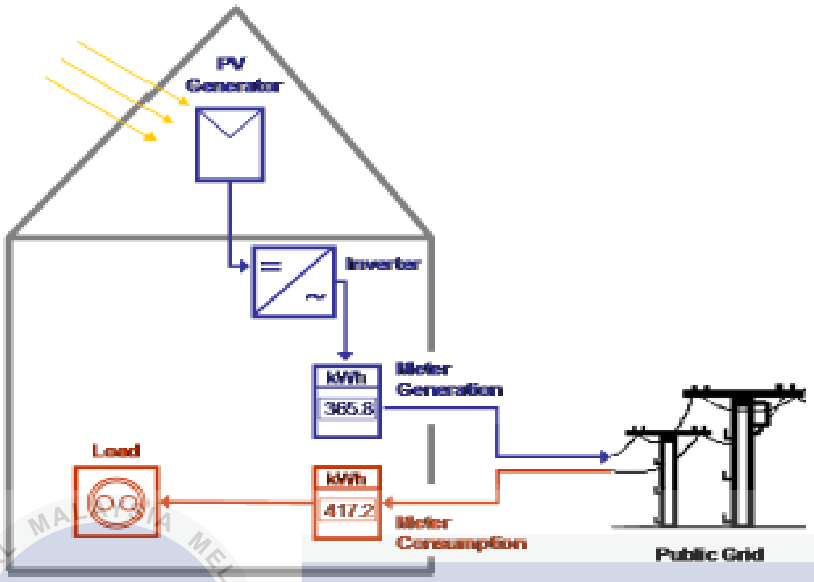

Figure 2.2: Basic concept of the FiT for household (Source: SEDA [5]).

FiT is high enough to produce favourable profit to act as an incentive which can provide business with secure investment environment. Indeed, to achieve grid parity, FiT is adequate “degression” to promote cost reduction [5]. FiT degression will make effect on the earning income which will become a risk for those solar PV investor.

2.2.2 FiT in German

German FiT for the generation of electricity from RE is under the Act of Granting Priority to Renewable Energy Sources which also referred to Renewable Energy Act ("Erneuerbare Energien-Gesetz", EEG) [10]. The EEG represented a refinement, replacement and update of German renewable energy policy. Feed-in Tariff (FiT) is defined as an aim to improve the market growth of RE technologies, especially for the electricity generation [11]. Mentona M [11] and Ito Y [12] and mentioned that Germany is recognized as a success story regarding the use of FiT to produce more RE in the country.

Since 1979, the German FiT law has been in developed, and it was introduced first real in 1990, which also known as the Electricity Feed-In-Law [11]. Germany has started the FiT system in 2000 with passage of EEG, which amended law will be enacted in 2012 [12]. In order to increase the use of RE sources, increases of taxes and other charges to electricity bills will be the result. By reducing the tariff rate annually (kWh) for plants modify for connectivity to the grid encourage innovation and cost cutting.

The 2011 report noted that the proximity of the PV FiT rates to parity with retail electricity rates raised important questions about future of both the PV market and the structure of FiT policies in the future [10]. Therefore, the annual reduction of tariff rates in German had driven on innovation and encouraged very fast development in the renewable energy sector which brings German to a success country in the world.

2.2.3 FiT in United States (US)

The preferred policy in many regions of the world especially in United States which help support investors to rapidly increase installation of renewable energy installations projects and markets is FiT [13]. The policy that is currently growing in popularity throughout the United States is also the FiT [14]. Experience around the world suggest that FiT policies could be effectively used to meet a number of U.S. policy goals, including economic development, job creation, and reaching the RE targets. There are three FiT payment calculation methodologies which includes according to the actual levelized cost of RE generation, based on utility's prevented cost, and offered as a fixed price incentive. FiT act as government incentives encouraging solar investments continue to drive the global solar market, and these programs are drying up in the U.S. [13]. This move towards FiT is a dramatic policy trend shift for many and some utilities are still fighting the concept. Barber [13] studied most FiT proposals in U.S. have specifically targeted PVs which lead the greatest rooftop PV marketing potential for module companies.

Virginia focus on FiT as a policy mechanism used to encourage deployment of RE technologies [15]. FiT is used to a limited extent around the U.S., but they are more common internationally. According to U.S. Energy Information Administration (EIA) explained that FiT mechanism usually guarantees that consumers who own a FiT eligible RE facility, such as a roof-top solar PV system, will receive a present value of price from their utility for all of the electricity they generate and provide to the grid [15]. In general, FiT rates that lead to considerable RE financing investment are set above the selling electricity prices.

2.3 Worldwide Review on Grid Parity

2.3.1 Grid Parity in the Netherlands

The effect when period of grid parity is attained for consumers in the Netherlands in 2011has been discussed in [16]. Sark V [16] states that a new scheme which is FiT originated by Simulation Renewable Energy (SDE) brings a big capacity growth within this two years: 2009 and 2010. There are three organizations take part to collect and find out the relevant values of inverters, PV modules and other Balance of System (BOS) components, which assist the market and consumers. This journal [16] provided an overview of inverters, PV modules, other system components including consultancy and installation cost, and technical performance test results.

In addition, [16] presented three different sizes of PV systems, technical solar PV performance and cost calculations. The PV system Levelized Cost of Electricity (LCOE) was calculated for a 2.5 kWp system to be 0.173 €/kWh. However, there is a higher retail electricity price of 0.23 €/kWh in the Netherlands. Grid parity had attained in the Netherlands in April 2012 which has presented in paper [16].

After the data collection for three different PV modules size, it shows that bigger modules (capacity) have cheaper prices which expressed in terms of €/W_p. Then, the information of inverters also been analysed and it is found expensive in Dutch market. Paper [16] shows that large size of inverters are clearly more efficient which approaching 98% compared the small size, show ~93%.

Figure 2.3 clearly shows the average price per Wp was 0.48 €/$W_{p.}$ The prices of inverters were gradually increased in Dutch Market. There is more expensive for small size inverters compared with large size of inverters. Due to the increase price of inverter, solar PV system price will also increase. Therefore, there are less people able to install solar PV system in residential segment.

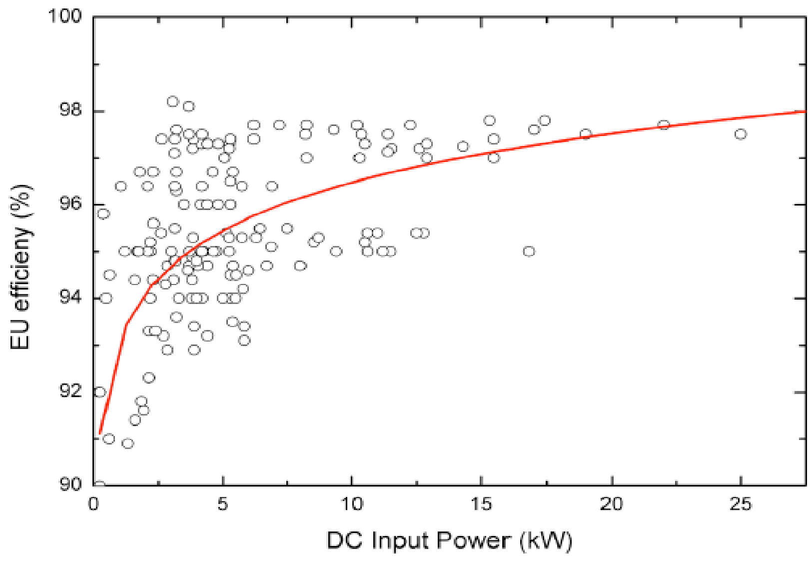

Figure 2.3: European inverter efficiency versus power at April 2012 [16].

The LCOE was investigated for four system sizes based on three different ranges of the interest rate soft loan (3%), mortgage type (6%), and commercial rate (8%) in paper [16]. Paper [16] shows the prices of PV generation for 3% and 6% are equal or lower than the current price of purchased grid electricity utilities in the Netherlands, therefore, the grid parity has been reached for mortgage type loans and soft loan for consumers. Pudjianto D [4] had discovered the penetration of PV system in Netherlands is still small. It means that after grid parity reached in the Netherlands, consumers/owners who installed large capacity (50 kW_p) PV systems, a cheaper tariff will be pay for about 0.10 €/kWh to utilities compared with 1 €/W_p which put PV in a very attractive investment.

2.3.2 Grid parity in Italy

Researches in [17], [18] and [19] have discussed the grid parity of solar energy in Italy. Pavan AM [17] [19] had discovered the LCOE at three different locations for Italy which are Palermo in Southern Italy; Rome in Central Italy; and Trieste in Northern Italy. It shows that Italy has become the largest PV market worldwide compared to Germany. Pavan AM researched that the grid parity was attained for residential consumer in Central and Southern of Italy in paper [19]. While, for his further investigation in next year, it shows that grid parity had achieved for certain commercial and industrial PV market in Italy [17] over one year. Thus, this growth is undoubtedly associated with the introduction of the FiT in 2005. Report [4] also stated that the application of FiT schemes in 2008 had led to a boom in PV installations in Italy. However, the incentives accorded through FiT programs, in the form of encourage paid for each kWh of electricity produced by PV plants, have been continuously decrease over the years [19]. By calculating the LCOE for industrial and commercial PV market and comparing with the optimal and mean yields of energy, it shows grid parity is already a reality for the consumer in Italy and it is no incentives or any subsidies considered [17]. He only studied the grid parity among commercial and industrial sector but not for residential segment.

Indeed, in [18], Mazzanti G studied the payback period trend of PV plant in Italy after grid parity. It stated that many papers were emphasized the pros and cons of RE resources with the main viewpoint of environmental friendly and it will not wipe out. However, from an economic point of view, [18] mentioned that there are three major incentive systems used in the world:

1) The investment subsidies
2) Feed-in Tariff (FiT)
3) Solar renewable energy credits (SRECs)

In Europe, PV energy is apprehensive; therefore the most common incentive system is the FiT. When the grid parity is attained; incentives are no longer needed since the selling price on the market is equal or higher than the long-term cost of installing PV system [18]. In [18], a consequence rise of the PV energy market in Italy has lead a progressive reduction of the production costs of PV energy and the payback time of PV plants. The grid parity in Italy was expected to be reached within 2013 since the cost of energy produced with large PV plants [18]. The main goal in paper [18] is to estimate the payback time trend in Italy if it is replaced by the solar PV grid parity. After analysed the 1^{st}, 2^{nd}, 3^{rd} and 4^{th} *Conto Energia* (CEs), they show a further reduction of the cost rates of PV plants. The simulations done by Mazzanti G [18] show a constant decline in payback period of solar PV system over the years, which is much cheaper even in the presence of current incentive rates. Therefore, he mentioned that the grid parity is virtually an affirmation for the future. In conclusion, economic factor can drive the period toward grid parity since it will slowdown in the PV market in Italy.

The grid parity has been attained in Italy [20] due to some main causes:

- Cost-competitive PV system installation prices, which lead a reduction of PV LCOE of 18.2% annually from 2009 to 2013.
- High irradiation levels in comparison to those in most of other Europe countries.
- Relatively expensive variable grid electricity utility costs.
- The discount rate used in the LCOE calculation, which is not a barrier for PV installation.

In addition, paper [20] had reported the LCOE in Italy is already lower than the lowest variable conventional grid electricity tariff, therefore, it make the more convenient for Italy is self-consumption. As shown in report [4], the application of FiT schemes in 2008 had led to a boom in PV installations in Italy. Grid parity had reached in Italy which brings down the bill of electricity due to PV self-consumption. It means that, this situation may attracted more installation of solar PV system for Italian. However, grid parity haven reached in Malaysia which may not encourage self-consumption for consumers.

2.3.3 Grid parity in New Jersey

Next, U.K.W. Schwabe [1] have study the utility-interconnected PV systems reaching grid parity in New Jersey. Paper [1] mentioned that for the renewable generation especially PV is beginning to become quite competitive in its own right, government subsidies such as solar renewable energy credit (SREC) program, national and state tax credits and rebates as well as various other incentives have already made grid interconnected PV power systems a great financial investments in many customer applications. This paper [1] provides an analysis of the cost of PV compared with locational marginal prices (LMP) utilities experience on PJM (the world's largest utility interconnection) in New Jersey.

This paper [1] has analysed the electric prices in New Jersey higher than they have ever been and thus design an achievable goal for PV system. EIA has provides Annual Energy Outlook (AEO) reports on future energy demand, supply and costs for worldwide. For New Jersey, the electric prices was projected with a growth rates of, on average, a little less than 1% per year for the maximum and about 0.3% for the minimum scenario [1]. Figure 2.4 illustrates average electricity prices projected by EIA in New Jersey which shows gradually increased for three different annual increment rates.

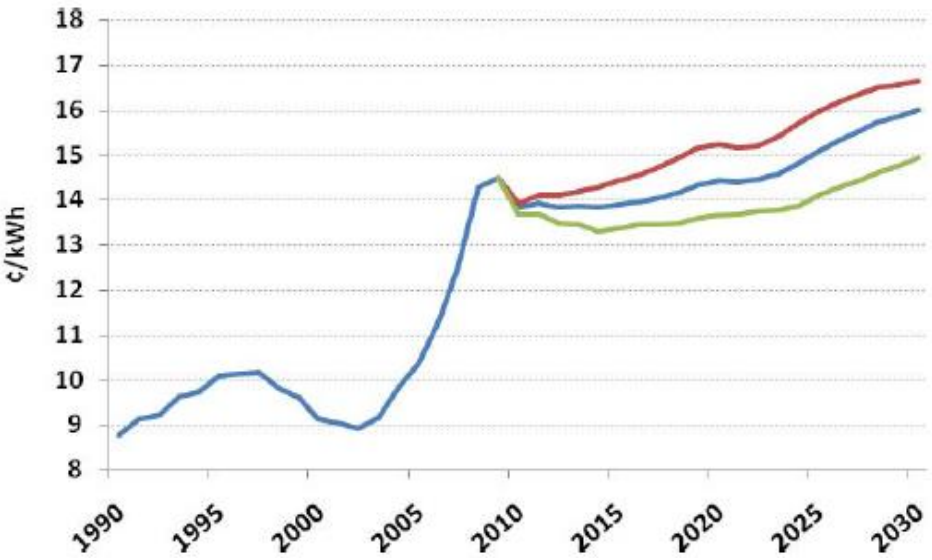

Figure 2.4: Average electricity prices estimated by EIA in New Jersey [1].

Moreover, the projections on PV systems were predicted to be cut by one percent annually. After the forecasted on PV cost and the electricity prices, U.K.W. Schwabe [1] expects that grid parity will be reached by 2012 to 2014 in New Jersey for the average new system (PV generation electricity). Figure 2.5 shows the analysis for New Jersey PV electricity cost forecast and electricity prices projection. When there is a higher increment rate of electricity prices with degradation of PV cost, breakeven will reach earlier. Due to dramatically growth of PV system in the worldwide market, it can be estimated for a low degradation rate which is the same for the market in Malaysia.

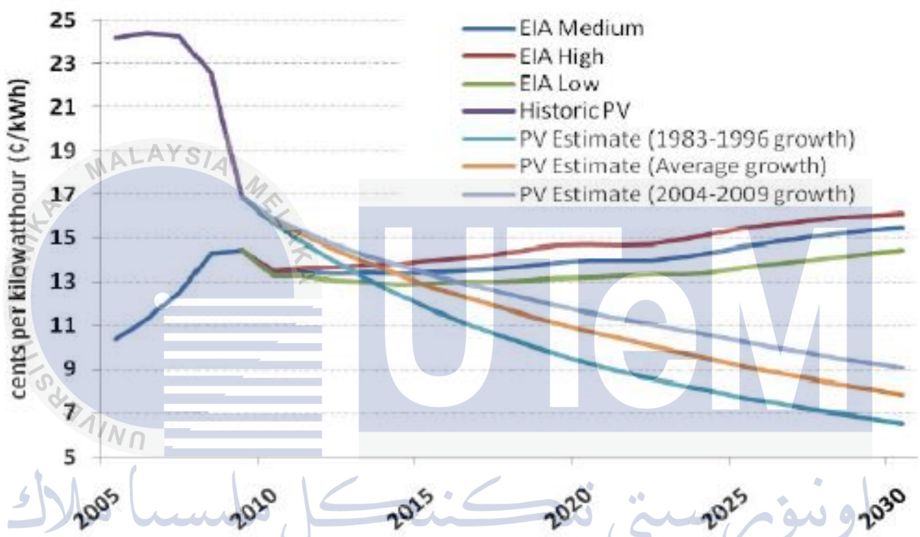

Figure 2.5: Forecast electricity cost and PV system cost in New Jersey [1].

2.3.4 Grid parity in United States (U.S)

Paper [21] discussed the key drives and sensitivities for the grid parity for residential PV in the U.S. In this journal [21], S Ong and et al. have evaluated few of the key parameters which drives of PV breakeven cost which are four major drives:

(i) Electricity prices and rates
(ii) Technical performance
(iii) Policies
(iv) Financing parameters

The break-even cost of residential PV systems had projected will be occur within 2015 [21]. By establishing a base scenario for 2015, S Ong [21] included an escalation of 0.5% for real electricity price annually compared with the forecast shown in EIA is 0.4% annually. The analysis was done by not including the local incentives for the top 1000 utilities in the U.S.

Therefore, it can be concluded that the electricity prices would be the largest key drive of the break-even point (grid parity) [21]. The other factors generally followed by finance parameters, policy issues, and technical performances. S Ong [21] stated that the large variation of the electricity prices will varies the break-even cost for residential PV customers in U.S. As a result, the scenarios evaluated in [21] represented a market entry point for solar PV system which with an overall concluded that breakeven point is the attractive financing tools and combination of good solar access to consider a PV system.

2.3.5 Grid parity in India

It has been reported [22] that the Indian solar market has seen dramatically growth with the installed solar PV capacity increase from under 20MW to more than 1000MW within 2010 and 2011. According to the Jawaharlal Nehru National Solar Mission (JNNSM) [22], the Solar PV tariffs were discovered which applicable for industrial and commercial power consumers in some states in India. JNNSM [22] has estimated at the earlier end of 2017-2019, the grid parity could happen. The grid parity is defined as the point occurs with two parameters – the rate of decrease in solar power prices and the rate of increase in conventional power prices. They had estimate the conventional electricity cost increase at the rate of 4% annually while the solar PV power cost decrease at the rate of 5-67% annually [22].

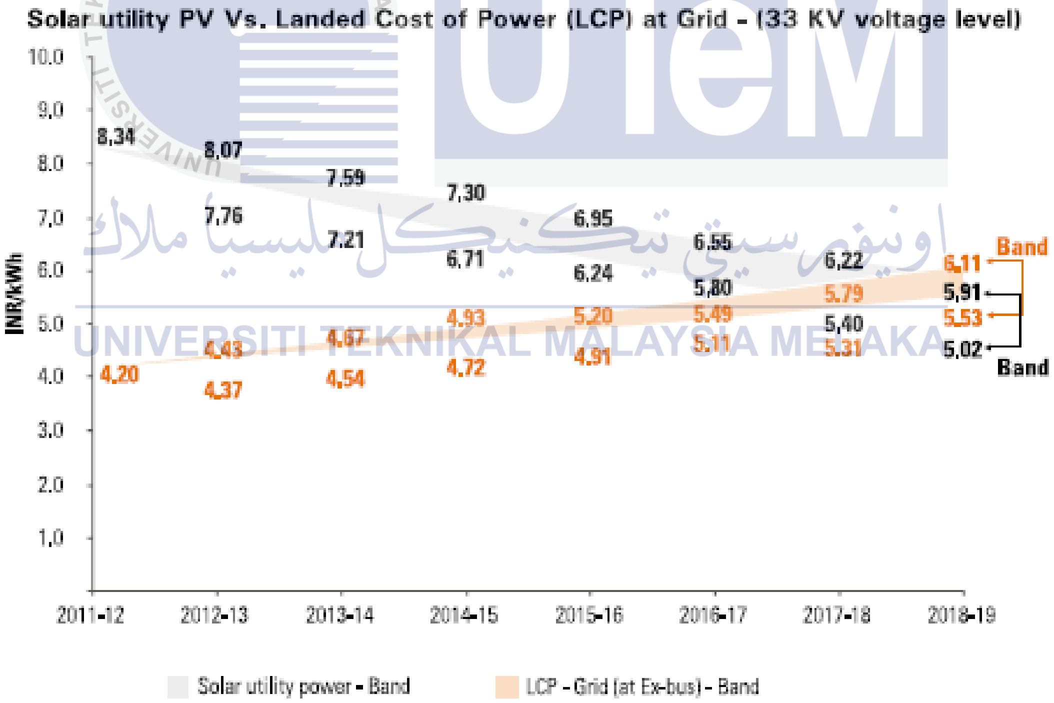

Figure 2.6: Solar utility PV and landed cost of power at grid, Source: KPMG's solar grid parity model [22].

The improvement on the attractiveness of PV system installation among the residential consumers which can reduce the monthly electricity bill and increase the tariffs by installing the PV solar system [22]. The government in India can used a method to encourage the solar PV installation for consumers which is made a sharp reduction in solar PV module prices. In globally, the solar industry has seen a drastic reduction in the selling price of solar modules during 2011.

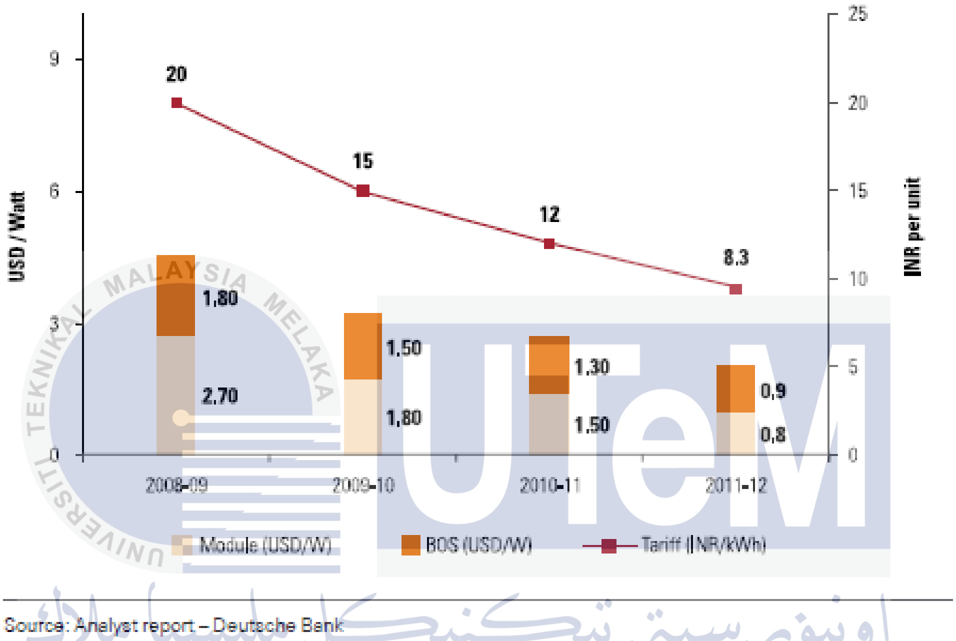

Figure 2.7: Cost declined trends [22].

India would like to make the rooftop market as an attractive segment for the future since the solar power can be effectively help to meet the long-term security and climate change considerations [22]. By increasing the feed-in tariff and reducing the tariff of PV system cost, it can promote the period of grid parity.

2.3.6 Grid parity in China

A report in [23] shows that the global additive solar PV capacity installation has risen of 100% indicated during 2009-2011 is likely to grow even further in China and will reach grid parity within the next few years.

According to the news article from China Daily [24], there was a boost of the local solar energy market in Xi An, China. "By 2018, grid parity will be met in China, two years ahead of the United States," Gay predicted [24]. The report [23] stated that the LCOE for solar PV will continue declined due to the reduction cost of capital and increasing capacity factor.

Jessica S [25] mentioned that a Chinese study was proposing solar power could reach grid parity by 2015 since China's influential National Development and Reform Commission (NDRC) has introduced a standard FiT scheme of 1 yuan/kWh. This rate is higher than other suggested tariff in tenders of many developers.

China government's wishing to make the country not only the largest PV manufacturing base, but also the biggest solar energy application market [24].

2.4 Summary and discussion

Based on the previous work done by other country, all had shown that grid parity is very important to PV penetration in the future. In Europe, there is the largest installation of PV system in the world which has applied the Feed-in Tariff program. However, in Malaysia, the use of PV system is still in the infant stage and the FiT scheme was just carried out since few years ago. Therefore, many consumers in Malaysia are not familiar with the benefits of using solar PV system.

According to [16] to [24], the grid parity analysis were carried out most in the country of Europe and US. There have discussed that grid parity is mostly influenced by the electricity prices in the country. There are few key parameters which drive the breakeven point in the country and they have various sensitivities.

Figure 2.8 shows the grid parity positioning matrix for seven different countries: Brazil, Chile, France, Germany, Italy, Mexico, and Spain. This is the latest issue released by Eclareon to analyse the grid parity proximity with regulatory support for PV self-consumption [26]. In this magazine article, it shows that most European countries have reached grid parity especially Italy and Germany in commercial sector. It helps the savings on the electricity bill by PV self-consumption when the grid electricity was replaced by PV.

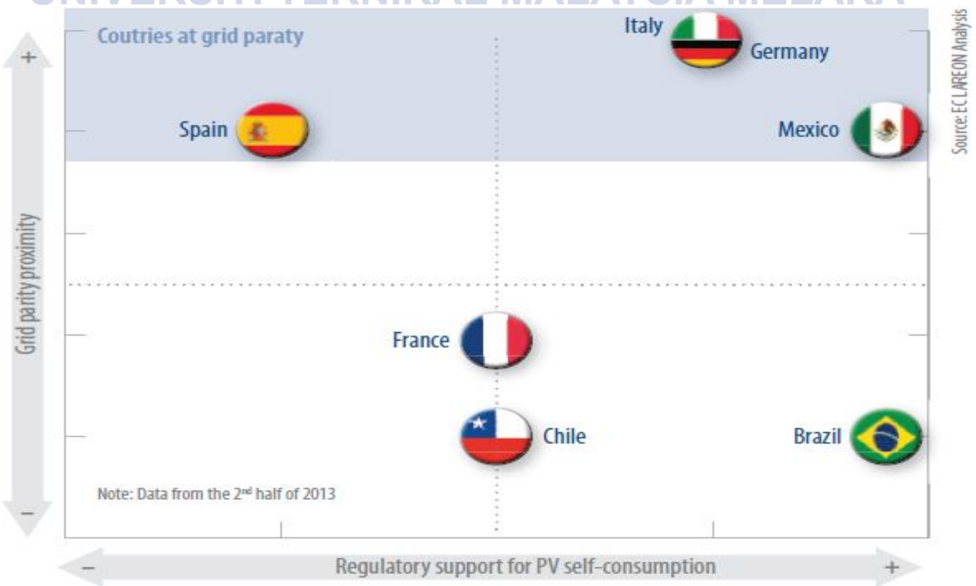

Figure 2.8: Grid parity positioning matrix [26].

Nevertheless, Malaysia has not reached the grid parity but grid parity is inevitable in this country. Therefore, government strongly encourage the increase of installation of solar PV system due to the benefit of PV generation technologies to the country. Generally, the degression of the selling prices of solar PV systems will reach the grid parity when the point intersects with the increased of electricity tariff. However, consumers in Malaysia are still not familiar with the advantages of solar PV systems thus there are not many research in the information of the solar PV instead the grid parity in Malaysia.

Many investors have installed solar PV system to take advantages of FiT scheme but they take exception of the year to achieve grid parity. When grid parity is achieved, it helps bring down or maintain the electricity tariff in country which is significant for residential consumers. Therefore, this case study is to analyse the key drivers and their sensitivities to attain grid parity in the coming years.

CHAPTER 3

METHODOLOGY

This chapter discusses the methods used to accomplish this project. Generally, project methodology involves steps of procedures and method that is performed from the beginning until the final stage of the project. Hence, a proper method and analysis tool are important to assist the purpose and scope of this project. Thus, a process of methodology flowchart which shown in Figure 3.1 is aid to show the steps of the project run from the beginning till the end of the project.

Figure 3.1 shows the process flow of the PV grid parity analysis. It starts with the average historical TNB tariff data collection, and followed by the PV system prices collection. Depending on the availability of existing data, the calculations of LCOE are carried out based on certain assumptions, such as operation and maintenance (O&M) cost, inflation rate, and degradation rate. In addition, 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 is analysed. Then, results of the grid parity analysis are used to calculate the payback period for the PV system investors. Those projects that have long payback period would have higher risk in financial such as large income losses in their investment.

3.1 Flowchart of Methodology

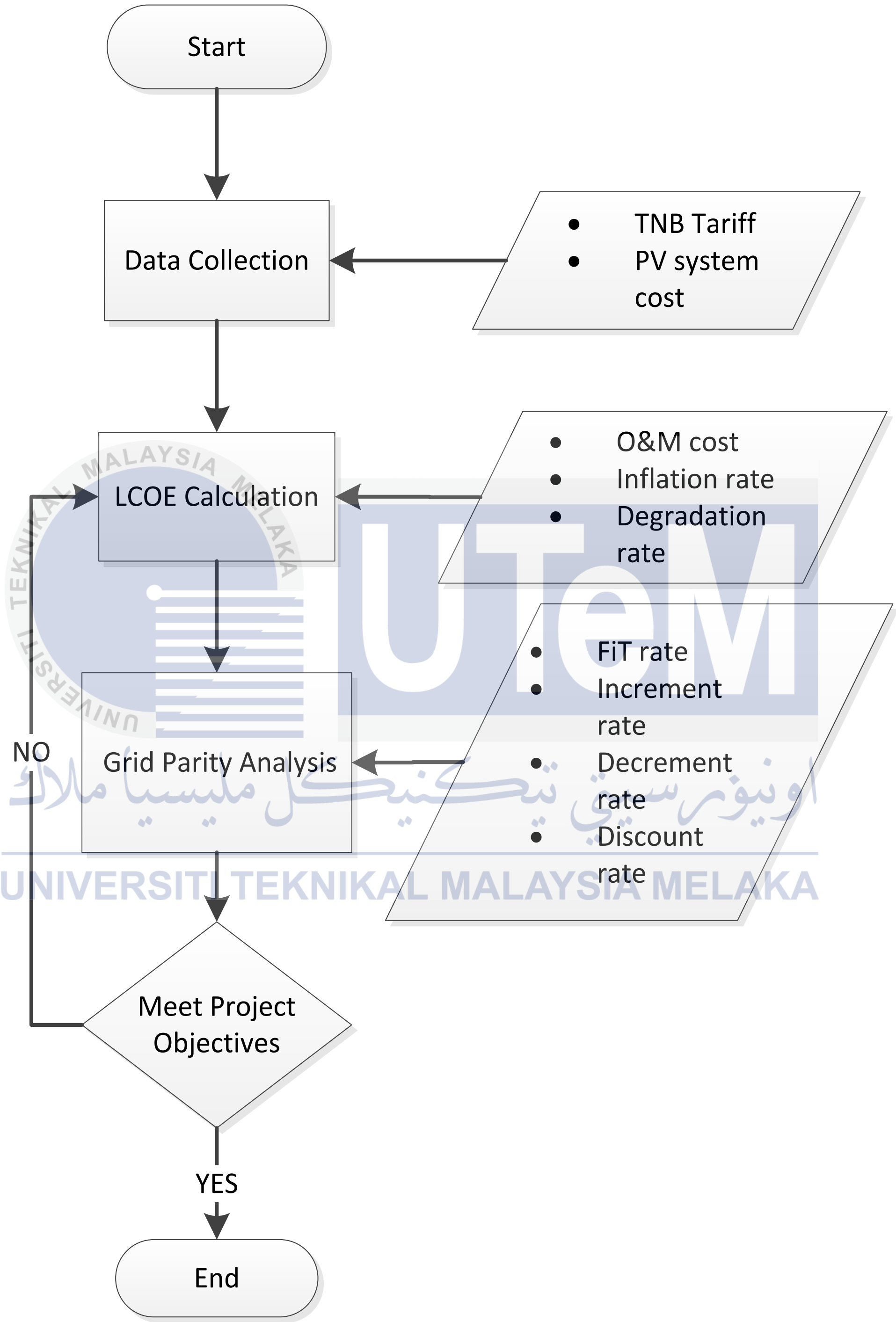

Figure 3.1: Flow chart of methodology.

3.2 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. LCOE is important to indicate the PV generation cost over the year which is used to compare with the conventional electricity tariff.

The LCOE is calculated by using:

$$\text{LCOE} = \frac{CAPEX + O\&M}{E} \times \alpha \tag{3.1}$$

Where,

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

The capital recovery factor is expressed as:

$$\alpha = (1 + r)^T \tag{3.2}$$

Where,

- r is discount rate/ interest rate (%) and
- T is economic lifetime of the PV system (year).

Capital expenditure is calculated by:

$$\text{CAPEX} = \text{Project Size} \times \text{Module Cost} \tag{3.3}$$

3.3 TNB electricity tariff

The data collection of the conventional electricity tariff from Suruhanjaya Tenaga (ST) was carried out to get the annual average increment rate of electricity tariff in Malaysia.

In Malaysia, the average tariff rate of electricity has increased over the years due to the interest rate and inflation in the country. This parameter is essential for the data analysis steps due to the rate of escalation on electricity prices would drive the reach of grid parity in the country. When the electricity prices increase in a slow rate, this will delay the reach for the grid parity, while if electricity prices boost drastically, it will improve and push the grid parity attained earlier. The speed for the reaching of grid parity is very attracting the consumers who have the set value of the installation of PV system. Table 3.1 shows the historical average electricity prices in Peninsular Malaysia.

According to the historical average electricity tariff in Malaysia, the forecasted annual average increment rate is around 6.5%/year to 9.5%/year. Figure 3.2 illustrates the flows of electricity tariff in Peninsular Malaysia from year 2004 to 2014. It clearly shows that the electricity tariff was increased over the year; from RM 0.2350/kWh in 2004 increased to RM 0.3853/kWh in 2014. Therefore, there are two forecasted increment rates of electricity tariff were chosen for this project which are 7.0%/year and 8.0%/year.

Table 3.1: The average electricity prices in Peninsular Malaysia [27].

Year	2004	2006	2008	2009	2011	2014
Electricity Tariff (RM Cents/kWh)	23.50	26.32	32.50	31.31	33.54	38.53

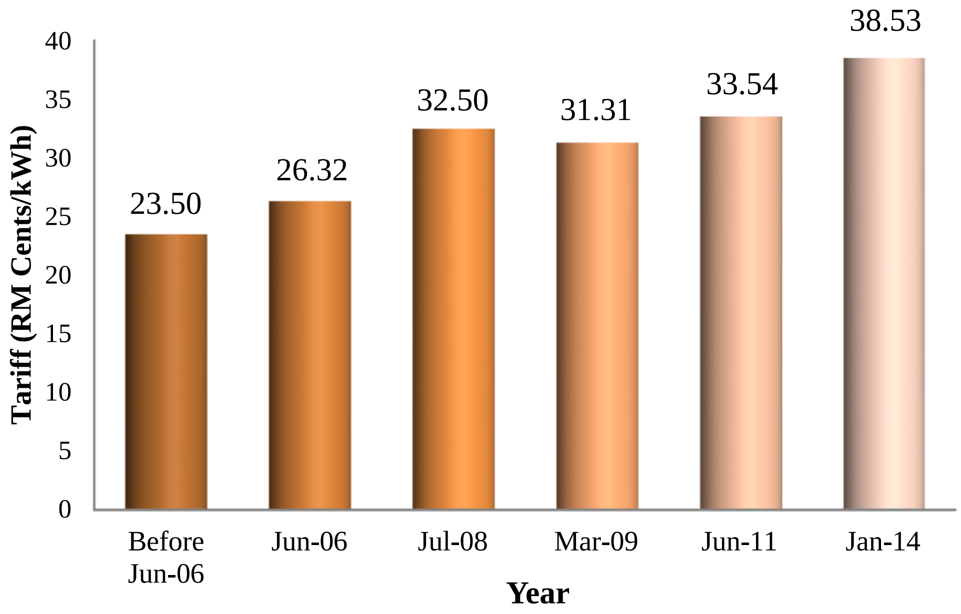

Figure 3.2: Historical average electricity tariff (RM cents/kWh) in Peninsular Malaysia.

3.4 Feed-in Tariff Rates in Malaysia

Besides the LCOE and electricity tariff, FiT is also be considered for grid parity analysis. There are two different degradation rates of FiT were accounted in this analysis which are 8% and 10%. At 1 Jan 2014, the degression rate of FiT was 8% which is shown in Table 3.2. Meanwhile, 15 March 2014, the degression rate of FiT was increased to 10% for some specific installation of capacity which shown in Table 3.3.

Both of the degradation rates of FiT can affect the grid parity analysis. The different of both ranges will bring the effect on the FIAH Holders. According to the Table 3.2 with 8% degression rate of FiT, a 4 kWp PV system with a FiT rate of RM 1.0411/kWh was considered. Besides, a bonus FiT of RM 0.2201/kWh for installation in building structures has been added. Thus, the total FiT rate with 8% degradation is RM 1.2612/kWh. In contrast, after 15 March 2014, FiT rate for the same size of capacity of 4 kWp is RM 1.0184/kWh with a bonus of RM 0.2153/kWh of the installation in building. Therefore, the total FiT rate with 10% degression rate is RM 1.2337/kWh. Therefore, it will be a loss of RM 0.0275/kWh with a same capacity size of solar PV installation when the FiT degradation from 8% to 10%.

Table 3.2: FiT rates of 8% degradation rate for solar PV from SEDA [7].

Description of Qualifying Renewable Energy Installation	**FiT Rates (RM/kWh)**	
(a) Basic FiT rates having installed capacity of:	**2013**	**1 Jan 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

Table 3.2 shows the degression of FiT rate of 8% from RM 1.1316/kWh in 2013 to RM 1.0411/kWh on 1 January 2014. The bonus FiT rates also experienced the degression rate of 8% from RM 0.2392/kWh to RM 0.2201/kWh. This results the FiT rate for the 4kW PV system on the rooftop of a building is reduced from RM 1.3708/kWh to RM 1.2612/kWh.

However, the degression rate is increased by 2% on 15 March 2014 which is 10% degression compared with the FiT rate in 2013. Table 3.3 shows the solar PV FiT rate after 15 March 2014 which is published by SEDA official portal. The degressions only happen for the capacity up to 4kW and 12kW. Subsequently, the bonus FiT rates for all criteria are experienced 10% of degression rate.

Table 3.3: FiT rates for 10% degradation rate for solar PV from SEDA [7].

Description of Qualifying Renewable Energy Installation	**FiT Rates (RM/kWh)**
(a) Basic FiT rates having installed capacity of:	**15 Mar 2014**
(i) up to and including 4kW	1.0184
(ii) above 4kW and up to and including 12kW	0.9936
(b) Bonus FiT rates having the following criteria (one or more):	**2014**
(i) use as installation in buildings or building structures	+0.2153
(ii) use as building materials	+0.2070
(iii) use of locally manufactured or assembled solar PV modules	+0.0500
(iv) use of locally manufactured or assembled solar inverters	+0.0500

CHAPTER 4

RESULTS AND DISCUSSION

4.1 PV system cost

The key parameter to drive the grid parity is the PV system prices, which makes changes to the LCOE. The improvements in the system lifetime, annual energy yield (kWh/kWp), inflation rate, CAPEX, and operation and management (O&M) cost can raise the LCOE. There are indications that the PV module lifetime could go longer than the estimated 25 years [28], which would further improve the LCOE. A better performance, lower inflation rate with a longer lifetime of the PV system will lower the CAPEX and O&M cost, hence improve the LCOE.

In Malaysia, it is difficult to experience degradation in the system cost due to the average increase of inflation rate and currency, which lead the higher CAPEX and O&M costs. The number of investors to install the PV system will become lesser due to the degradation of the PV generation prices. Subsequently, the government's mission to reduce carbon dioxide emission will be unsuccessful, and this will bring the downstream of economy in the country.

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 in future and has led to the ascent of LCOE prices. However, the PV system prices can be decreased due to low market demands. Therefore, two forecast assumptions made, which are degradation of LCOE with 1%/year rate, and increment rate of 0.1%/year for inflation rate of the PV system prices.

4.2 Electricity tariff

The current electricity tariff escalation for residential consumers has been averaged around 7.0%/year to 8.0%/year from year 2006 to 2014 in Malaysia [29]. The high demand of electricity supply, which is generated by petroleum, coal, fossil fuels, and natural gases, has led to escalate the electricity tariff in Malaysia.

Therefore, there are two forecasted increment rates will be considered for TNB electricity tariff for the coming 21 years. Figure 4.1 shows the forecasted electricity tariff for two increment rates. Electricity tariff is the main parameter which drives the period to reach the grid parity. As the increment rate of electricity tariff higher, the grid parity will reached earlier. In contrary, grid parity can be achieved slower at a longer period when there is a low value of increment rate.

In this case, 7% increment rate of electricity tariff will have a lower tariff after 21 years compared with 8% increment rate of electricity tariff. In 2034, a total of RM 1.4910/kWh tariff will be attained for 7% increment rate; RM 1.7959/kWh tariff for 8% increment rate.

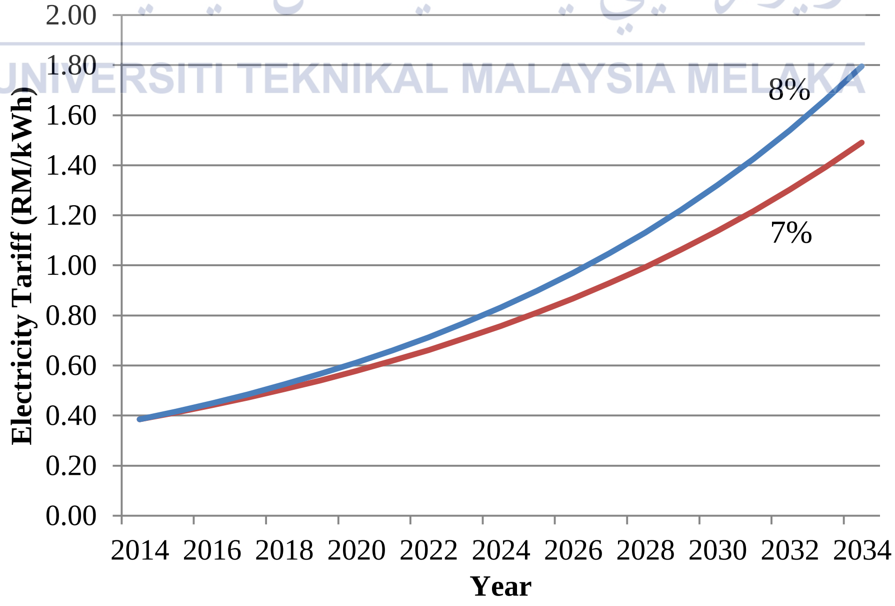

Figure 4.1: Forecasted average electricity tariff (RM/kWh) with two different increment rates.

4.3 Levelized cost of electricity (LCOE)

As for the 4 kWp solar PV system with associated prices, the LCOE is calculated based on few parameters. Table 4.1 shows the assumptions made for few parameters which included in the calculation of LCOE for year 1. The LCOE was calculated using Equation 3.1. Meanwhile, Table 4.2 is the lifetime cost assumptions of CAPEX and maintenance cost calculated using equation 3.3.

Table 4.1: Parameters assumptions for calculation of LCOE.

Assumptions	**Value**
Project size @DC	4 kW
Cost	RM 9.99/W
FiT rate	RM 1.23
Annual energy yield	1450 Wh/Wp
Discount rate	7.5%
Inflation rate	3.0%
Production years	21 years
Degradation	0.70%
Operation cost	0.90%
Year 1 Levelized Cost of Energy (LCOE)	**RM 0.9170**

Table 4.2: Lifetime cost assumptions.

Cost	**RM**
CAPEX	30,960.00
Maintenance cost	10,622.61
Total lifetime cost	**50,582.61**

The LCOE for the first year is RM 0.9170, which is greater than the electricity tariff with RM 0.3853. Due to the rise of inflation rate over the year, assumption of this annual increment rate is 0.1%/year. As the increase of inflation rate, CAPEX and O&M

cost subsequently increase. This situation leads an ascent for the value of LCOE. Figure 4.2 illustrates a steady increase curve for LCOE. In contrast, it may have a degradation of LCOE due to the degression of energy generation and the reduction of performance of solar PV system. Therefore, a decline curve is formed which is shown in Figure 4.3. A decline curve for LCOE will faster the reach of grid parity while ascent curve will further the period to attain grid parity in Malaysia.

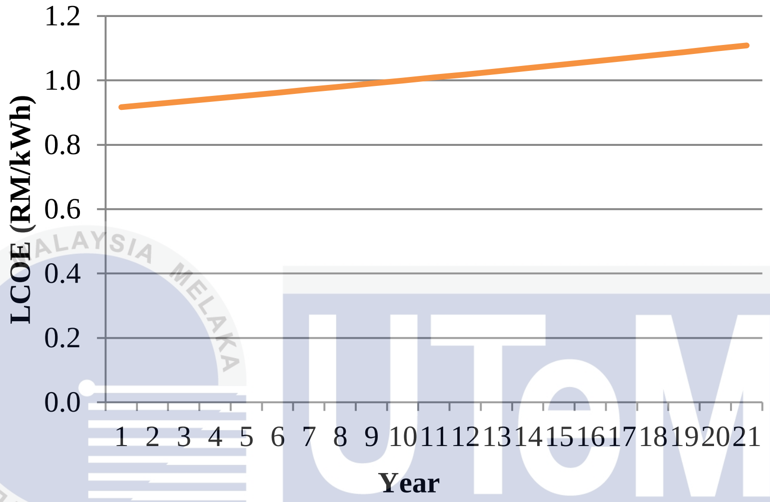

Figure 4.2: Forecast of LCOE with 0.1%/year increment rate of inflation rate.

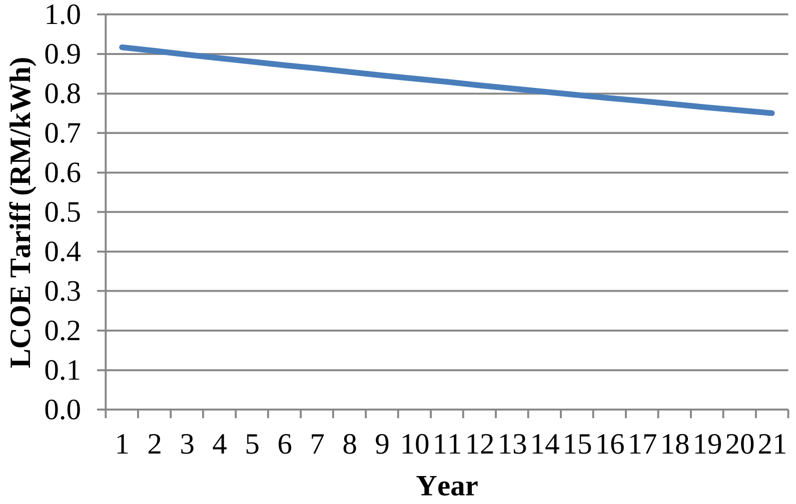

Figure 4.3: Forecast of LCOE with 1.0%/year degradation rate.

4.4 Grid parity analysis

Grid parity analysis emphasizes on the breakeven point of the LCOE and TNB electricity tariff within 21 productive years of solar PV system with 4 kWp size capacity. After the analysis with the data collection of electricity tariff and the calculation of LCOE, the breakeven point will occur after 16 years from current year, as shown in Figure 4.4. Figure 4.4 depicts the grid parity dynamic for both 7.0%/ and 8.0% annual increment rate of electricity tariff that will be achieved in 2029 and 2027 respectively.

Grid parity reached earlier with a high annual increment rate (8%) of electricity tariff compared low increment rate (7%). It shows that electricity tariff can bring high effect on grid parity. Nevertheless, grid parity can be achieved earlier by possessing very good solar condition, low PV system prices and high electricity tariff.

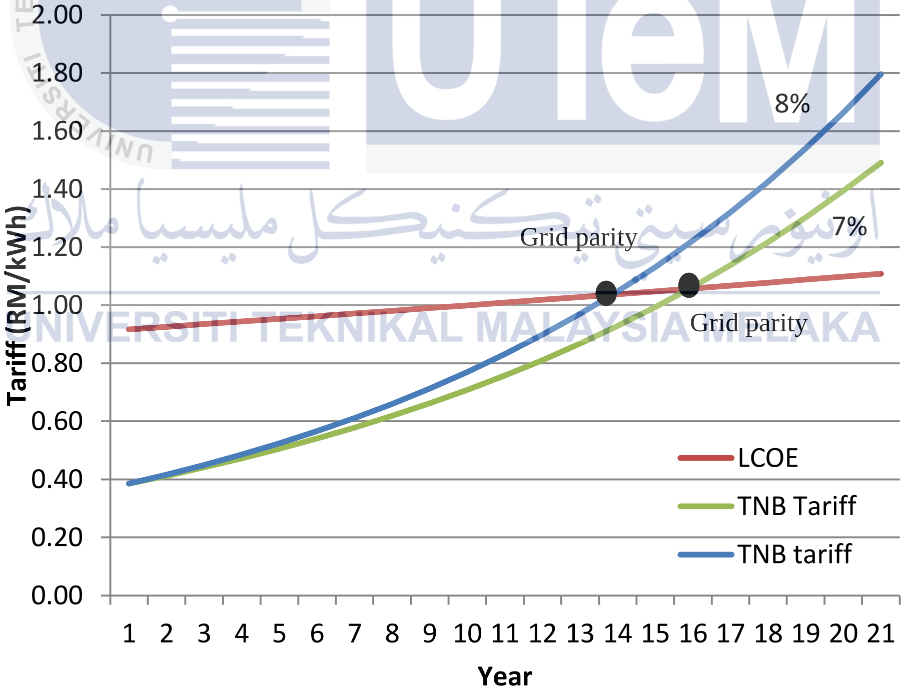

Figure 4.4: Grid parity analysis in Malaysia-residential sector with 0.1%/year increment rate of inflation rate.

In other case, grid parity will reach earlier in the 2026 with the degradation of 1.0%/year. Figure 4.5 shows the grid parity will be achieved earlier in the coming 13th year with 7.0% annual increment rate of electricity tariff. However, grid parity will reach in two year earlier with 8.0% annual increment rate of electricity tariff. When there is a degradation rate for solar PV LCOE, it will shorten the period to reach grid parity. Therefore, solar PV system prices and electricity tariff are the key parameters to drive grid parity in Malaysia since both bring effect on the period to attain grid parity.

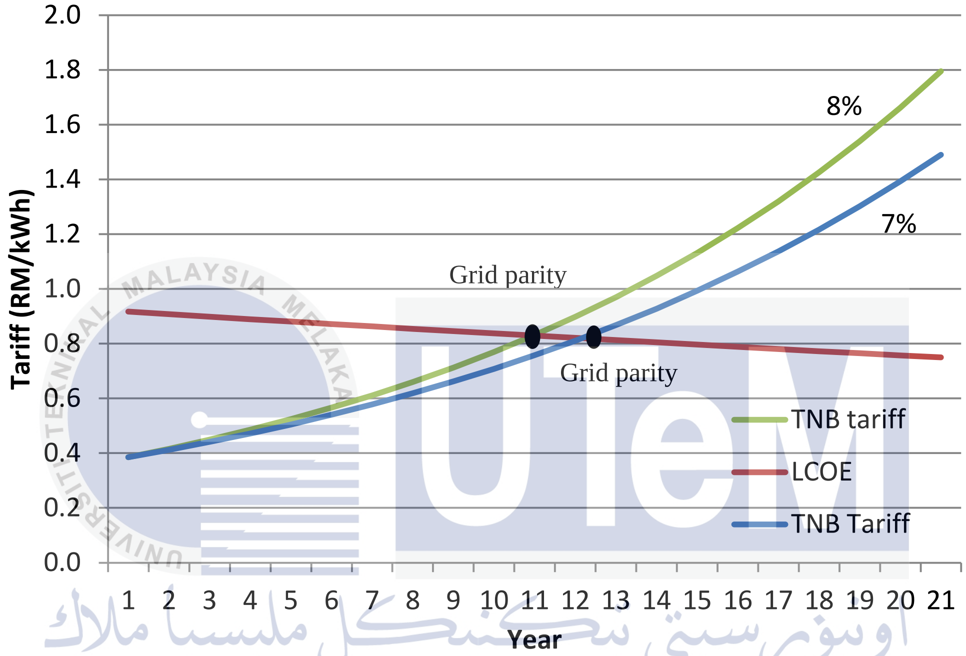

Figure 4.5: Grid parity analysis in Malaysia-residential segment with degradation rate of 1.0%/year.

By considering the FiT degradation rate of 8%/year and 10%/year which are introduced by SEDA in 2014, the results indicated a very low tariff after grid parity occurred. Next, 7.0% increment rate of electricity tariff was chosen for the following analysis. Figure 4.6 shows the relationship between the parameters, i.e. FiT, LCOE, electricity tariff and Feed-in Approval Holders (FIAH) tariff. FiT is a mechanism oblige energy utilities to buy renewable energy from producers at a fixed premium price for a specific duration. The Distribution Licensee (DL) will pay the FIAH a premium tariff for clean energy that is generated. Therefore, this allows owners to sell their clean energy to the DL for a fixed number of years. The incentive provides a fixed payment which referred as FIAH Tariff from the electricity supplier (TNB) for every kilowatt hour (kWh) of electricity generated. This study consists two ranges for the degradation rate of FiT which are 8% and 10% on 1st January 2014 and 15th March 2014 respectively. These two different rates lead two different premium FIAH tariff. When the grid parity is reached, both PV LCOE and FIAH tariffs will be equal with the TNB electricity tariff. Even though there is only a small different between 8% and 10% FiT degradation rates, however, it can bring a large different in the cumulative incomes [30] .

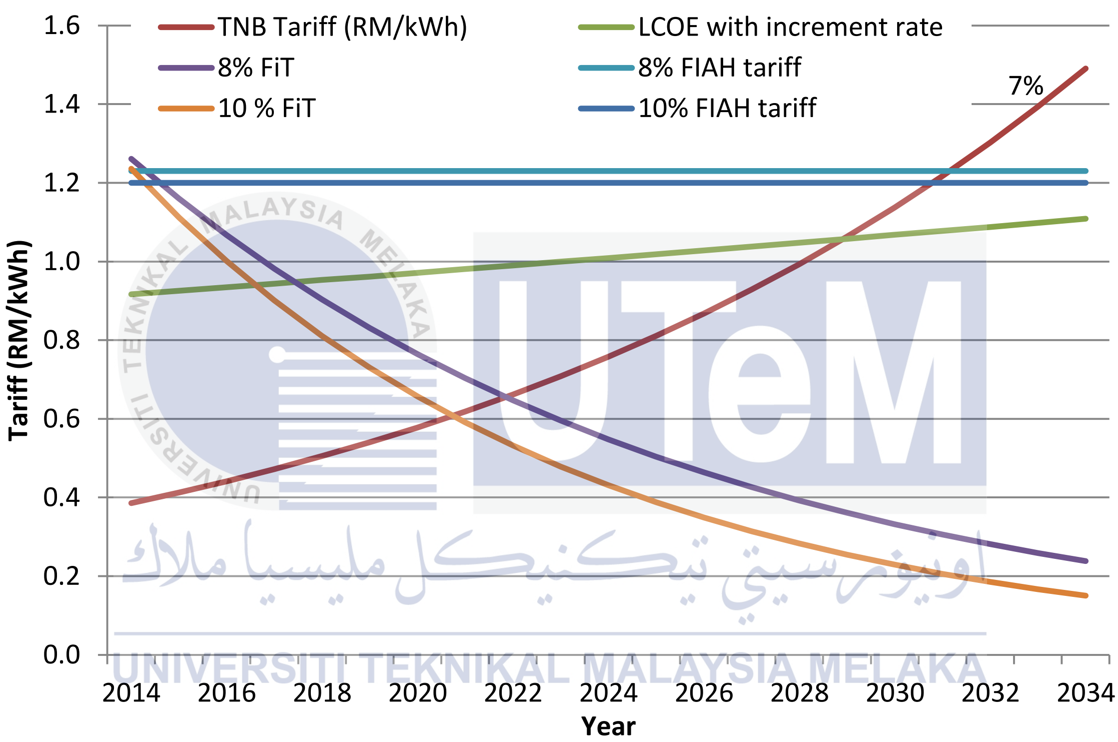

Figure 4.6: Relationship of combination parameters with 7% increment rate of electricity tariff [30].

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; grid parity is occurred. Subsequently, PV system LCOE of the following year will be same with the TNB electricity tariff. According to government policy, the FiT scheme will no longer be needed when grid parity has been achieved, because FIAH tariff will be similar to the electricity tariff. All results indicate that the year to reach grid parity will be boosted with a high electricity tariff and a low inflation rate.

When the grid parity is achieved later, investors can avoid income losses since the payback period of loan is usually short and can pay off before the grid parity is reached. Payback period is proportional with PV LCOE; it may bring economic risk to the investors. Therefore, grid parity is significant to indicate those investors about the financial risk and the payback period for PV installation in the residential sector.

Figure 4.7 plots the combinations of LCOE and other parameters after grid parity, which is equal to the TNB electricity tariff. For further analysis, several assumptions have been accounted with LCOE. The variations of solar PV electricity energy yield are significant for the calculation of LCOE. PV system cost will increase due to inflation rate, which leads the LCOE increases and the year to attain grid parity will be delayed as well.

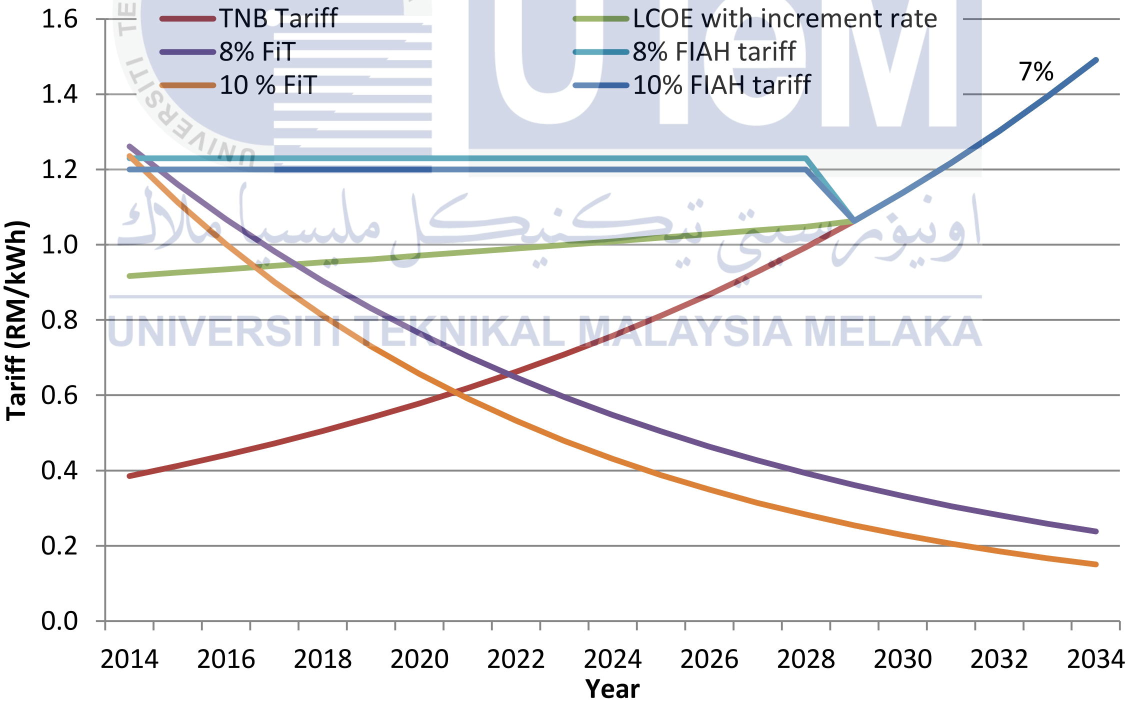

Figure 4.7: Relationship of parameters and tariff after grid parity with the 7% increment rate of electricity tariff [30].

The grid parity will be reached in 2029 when it is a small increment of inflation rate. After grid parity is reached, there is a sudden drop in both FIAH tariff from RM 1.23/kWh and RM 1.20/kWh to RM 1.0631/kWh, which is equal to electricity tariff. Afterwards, the FIAH tariffs will follow the increment of electricity tariff for the following years. This situation may cause losses of RM 0.1669/kWh and RM 0.1369/kWh for 8% and 10% FIAH tariff respectively.

There are very low FiT tariffs for both 8% and 10% which are clearly shown in Figure 4.7. This means that the FiT will has further degradation rate over the years. For those investors who had installed PV system within 1st January 2014 will experience 8% degradation rate on FiT, therefore they will get a fixed FIAH tariff of RM 1.23/kWh. Consequently, those investors who had installed PV system on or after 15th March 2014, they will get a fixed premium FIAH tariff of RM 1.20/kWh since there is a 10% FiT degradation rate. Therefore, the earlier the installation of PV system, the higher the FIAH tariff will be offered.

Consequently, Figure 4.8 illustrates the relationships between all parameters with a degradation of PV system LCOE. It shows that the grid parity would reach earlier compared to Figure 4.6. If the grid parity reaches slower, both FIAH tariffs will be equivalent with TNB electricity tariff with a tiny drop. Therefore, it can be concluded that the grid parity achieved slower, the larger the profit.

Fast grid parity attainment will bring effect for those investors with high amount of FIAH tariff as they may face large reduction of incomes. The difference of cumulative incomes for both degradation rates of PV LCOE will be discussed in subsection 4.5. Meanwhile, if the year to reach grid parity is further, investors can earn more profit before the tariff drop.

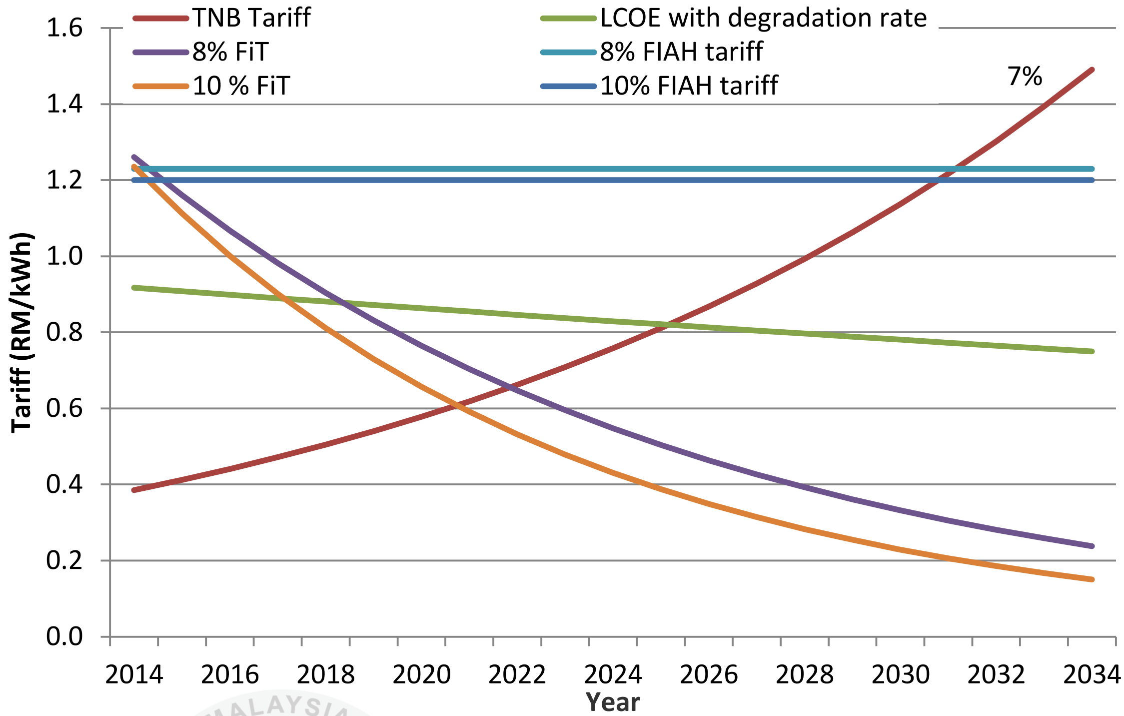

Figure 4.8: Grid parity analysis with the combination of parameters with 7% increment rate of electricity tariff.

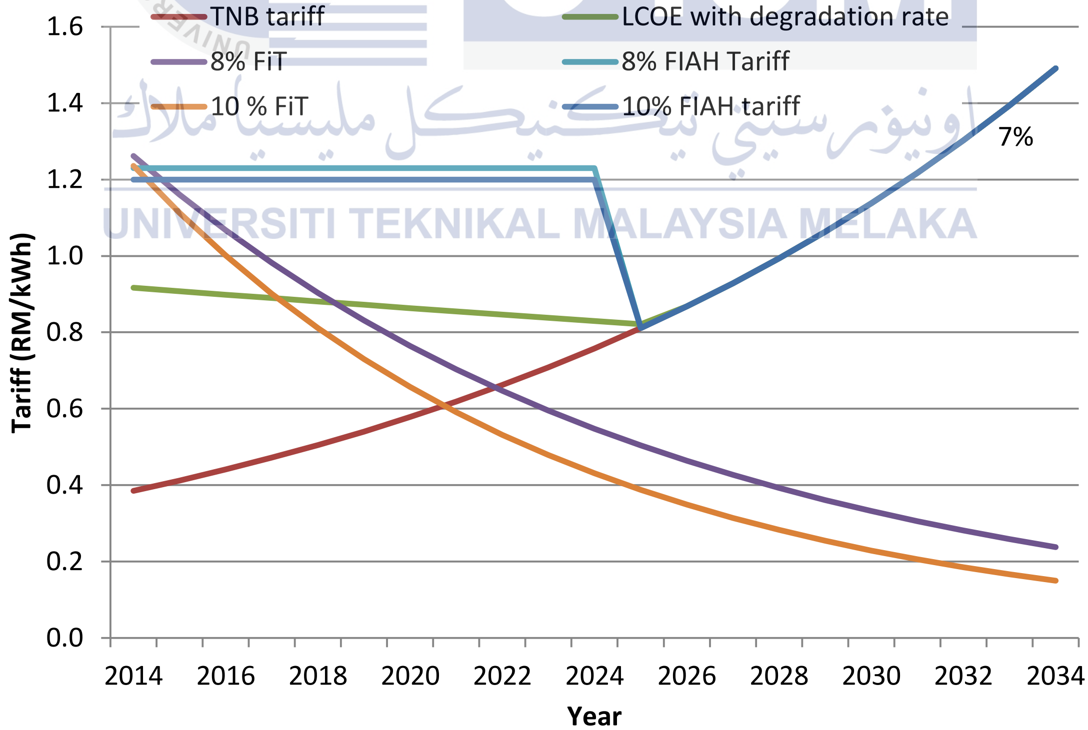

Figure 4.9: Relationship of parameters and tariff after grid parity with 7% increment rate of tariff.

Figure 4.9 exhibits the grid parity that reaches earlier in 2026 with 1.0%/year degradation rate on PV system LCOE. When the grid parity is attained earlier in year 2026, both FIAH tariff will have a sudden drop and equivalent to the conventional electricity tariff. When PV system LCOE is lower or equal to the electricity tariff, the offer from FIAH tariff and LCOE will become equal to the TNB electricity tariff. FIAH tariff with 8% FiT degradation rate will face a sudden drop from RM 1.23/kWh to RM 0.8678/kWh at the breakeven point in 2026. In this case, investors may experience a drop on FIAH tariff of a total RM 0.3622/kWh. Meanwhile, the FIAH with 10% FiT degradation rate shows a drop from RM 1.20/kWh to RM 0.8687/kWh. The investors will have a loss about RM 0.3322/kWh.

Figure 4.10 shows the combination of parameters with the 8% annual increment rate of electricity tariff. It indicates that the grid parity will reach in the coming 14 years. When grid parity reached in 2027, the LCOE will equal to the electricity tariff as shown in the Figure 4.11. Both ranges of FIAH tariffs will drop and equivalent to the TNB electricity tariff as mentioned in the Power Purchase Agreement (PPA). It means that those investors will have a tiny loss of profit when grid parity reached in 2027.

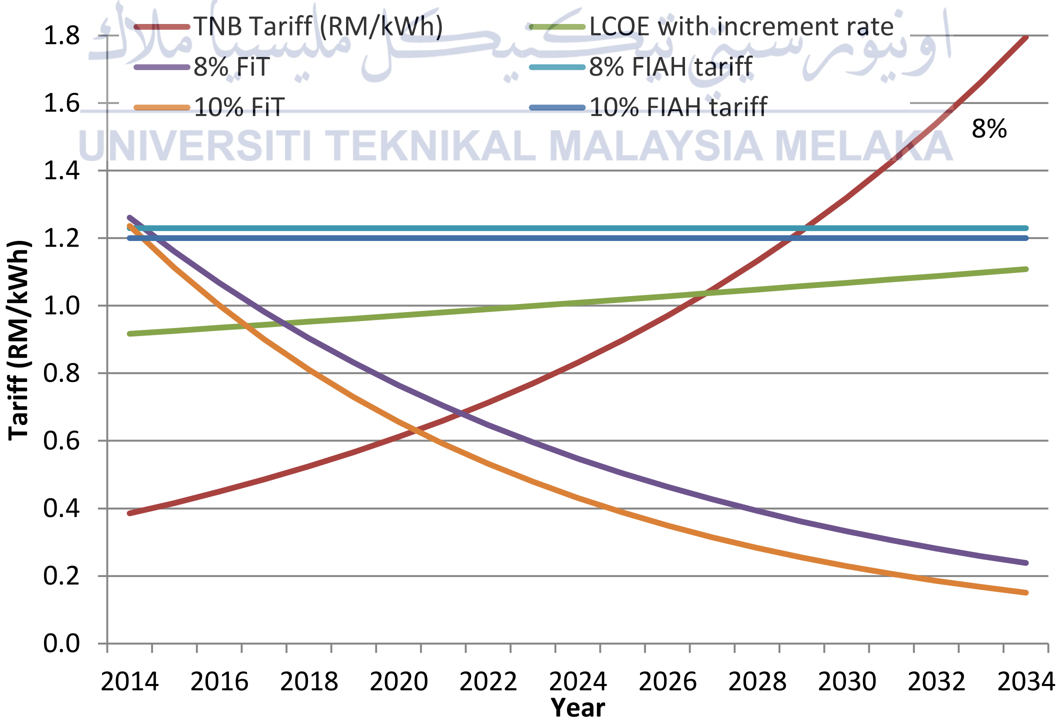

Figure 4.10: Relationship of parameters with 8% increment rate of electricity tariff.

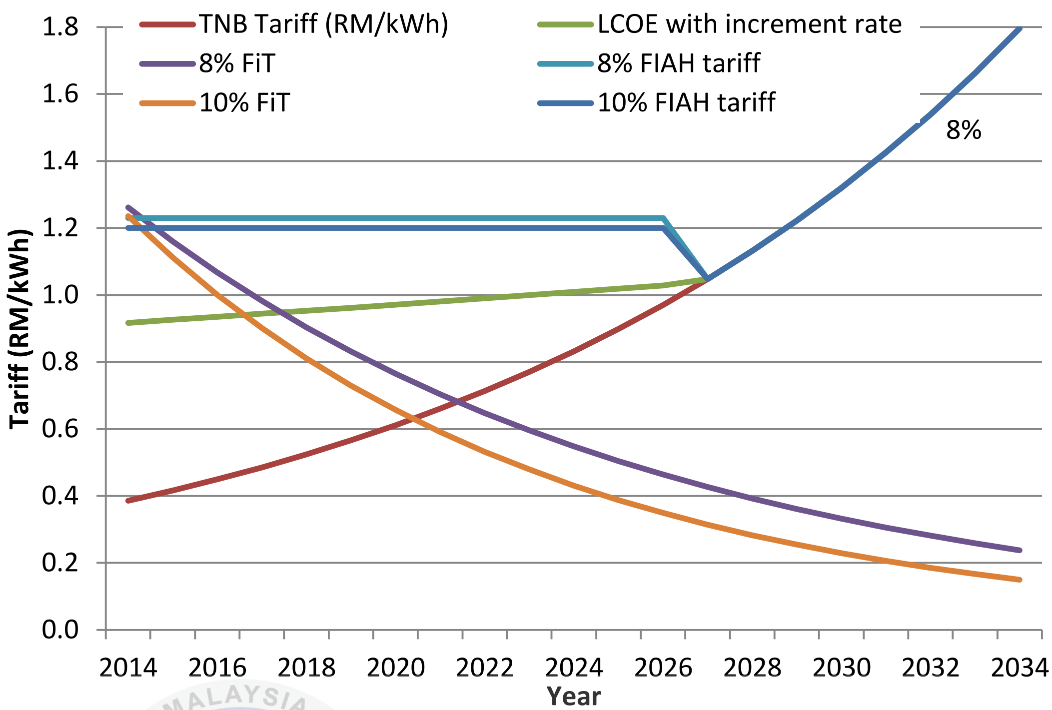

Figure 4.11: Parameters after grid parity with 8% increment rate of electricity tariff.

By the way, when there is a degradation of LCOE meet with an annual increment rate of 8% of electricity tariff; grid parity is boosted. High increment rate of electricity tariff with degradation of LCOE, grid parity will reach earlier in 2024 which shows in Figure 4.12. After grid parity reached in 2024, both FIAH tariffs and LCOE will be equivalent to the electricity tariff which is RM 0.8318/kWh. Figure 4.13 shows the results of sudden drop of the high FIAH tariff when grid parity reached. The large sudden drop brings large income reduction for those investors with the high FIAH tariff rate.

When grid parity reached earlier in 2024, those investors who sell the electricity with a high FIAH tariff rate offered by TNB will experience large reduction of income. Subsequently, their revenue will be less when grid parity reached earlier. For example, investors with a FIAH tariff rate of RM 1.20/kWh will reduce to RM 0.8318/kWh which is the low conventional electricity tariff.

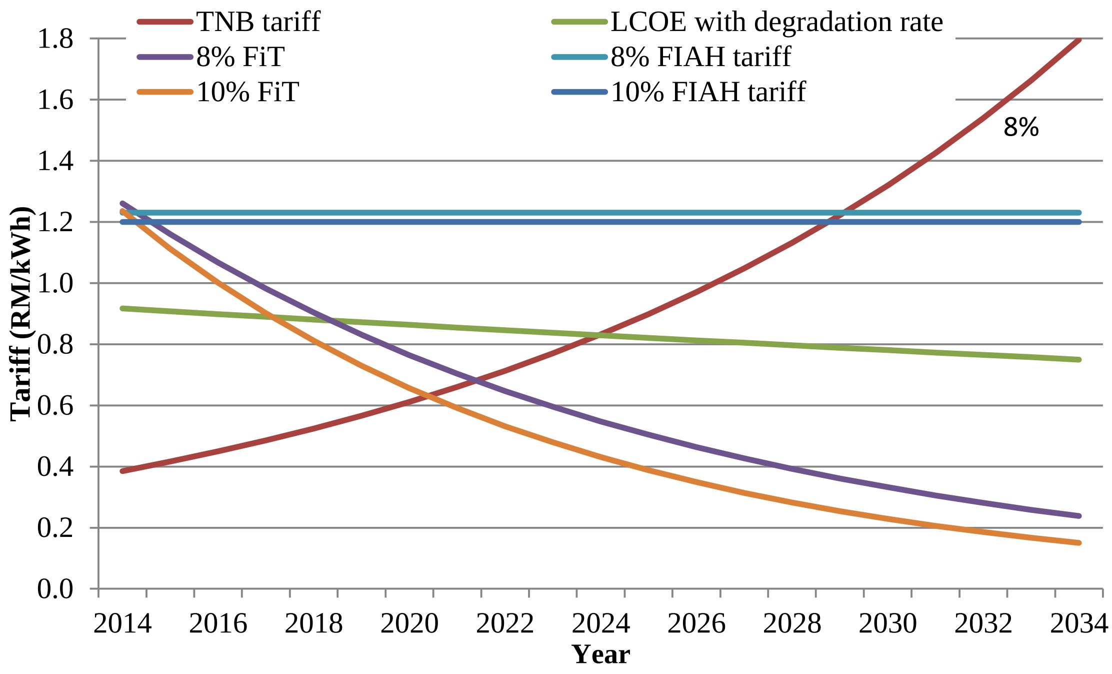

Figure 4.12: Combination parameters with 1% degradation of LCOE and 8% increment rate of electricity tariff.

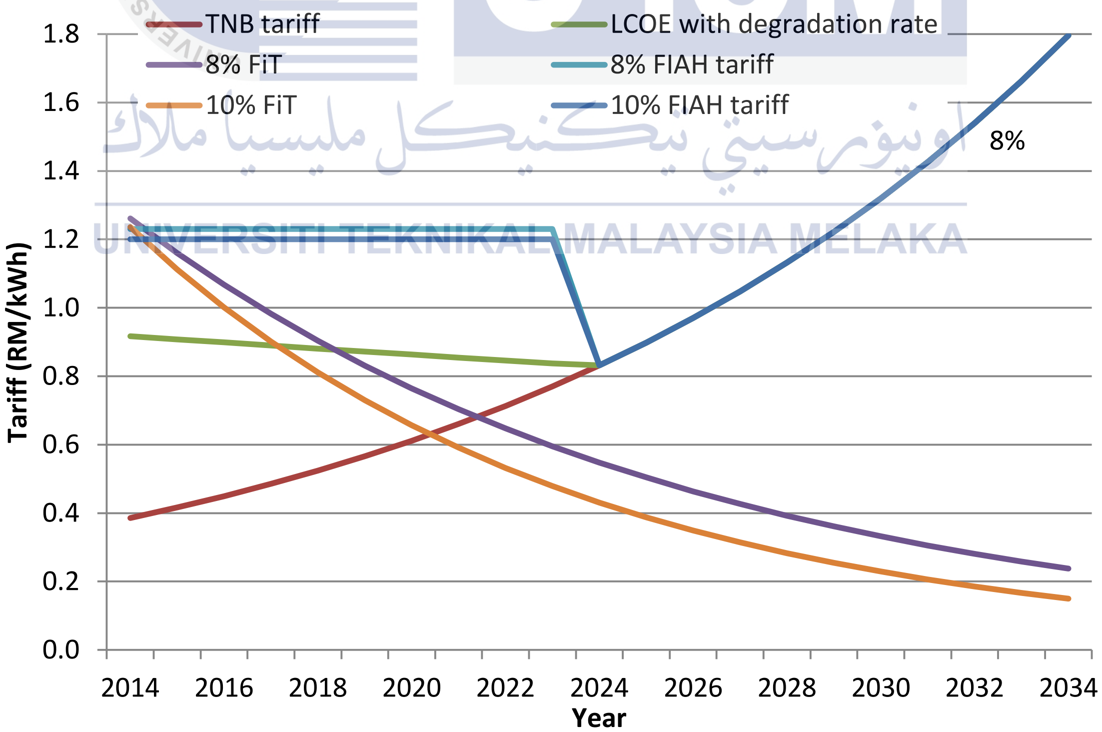

Figure 4.13: Parameters after grid parity with 1% degradation of LCOE and 8% increment rate of electricity tariff.

Table 4.3: The year of grid parity reached with different ranges of electricity tariff and variation of LCOE.

Annual increment rate of electricity tariff	Inflation rate/ (Degradation rate)	Year of grid parity reached	No. of year to reach grid parity
7.0%	0.1%/year	2029	16
7.0%	(1.0%/year)	2026	13
8.0%	0.1%/year	2027	14
8.0%	(1.0%/year)	2024	11

Table 4.3 shows the comparison of the two ranges of increment rate of electricity tariff with the variation of LCOE by inflation rate or degradation rate. The number of year to reach grid parity can be easily affected by both key drivers which are electricity tariff and solar PV generation cost (LCOE).

For those investors who have installed the solar PV system later, they will experience large income losses due to the sudden drop to a lower tariff from their higher fixed FiT rate when grid parity reached. 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. When the FIAH tariff drops to a lower electricity tariff after grid parity reached, investors will not get back the high tariff rate to pay off their initial investment cost in the specific payback period.

Therefore, grid parity will bring effect on the tariff rate since it will bring down a higher tariff which causes the income losses for investors.

4.5 Comparison of incomes

The analysis on maximum and minimum grid parity implied that they will cause different losses to the residential consumers. Base case income is the actual incomes that should gain by investors if there is no any change on the fixed FIAH tariffs. Indeed, when

FIAH tariff experienced a drop due to the attainment of grid parity, the basic incomes will be affected. Both Table 4.4 and 4.5 are the cumulative income when there is a 7% annual increment rate of electricity tariff. Table 4.4 shows the difference between cumulative incomes for both FiT degradation rate when grid parity reached earlier in 2026.

Table 4.5 shows the difference between cumulative incomes when grid parity reached in 2029. Both of the tables indicated the cumulative incomes before and after grid parity was attained with two ranges of FiT degradation rate with 7% annual increment rate of electricity tariff.

Table 4.4: Difference between cumulative incomes when grid parity in 2026 with 7% annual increment rate of TNB electricity tariff.

FiT degradation rate	**Base case income (RM)**	**Income when grid parity reached in 2026 (RM)**	**Income reduction (RM)**
8%/year	139,843.62	136,168.83	3,674.79
10%/year	136,432.80	134,158.83	2,273.97
Difference of income	3,410.82	2,010.00	1,400.82

Table 4.5: Difference between cumulative incomes when grid parity in 2029 with 7% annual increment rate of TNB electricity tariff.

FiT degradation rate	**Base case income (RM)**	**Income when grid parity reached in 2029 (RM)**	**Income profit (RM)**
8%/year	139,843.62	140,941.88	1,098.26
10%/year	136,432.80	138,455.15	2,022.35
Difference of income	3,410.82	2,486.73	924.09

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

However, in 15 March 2014 [8], the FiT degradation rate is increased to 10%/year, all the cumulative incomes will be affected. The reduction in base case income is RM 3410.82 in 10% degradation rate compared to the 8% FiT degradation rate. When grid parity is reached, the cumulative incomes for 10% degradation rate will be lesser compared to 8% FiT degradation rate. There is a reduction income for RM 2,010.00 and RM 2,486.73 in 2026 and 2029 respectively. The overall profit will reduce with a total of RM 924.09 when degradation rate increased from 8% to 10% in year 2029.

Table 4.6 and 4.7 shows the difference between cumulative incomes with 8% annual increment rate of electricity tariff. It shows that there is a little income profit when grid parity reached earlier in 2024 while there is a large income profit when grid parity reached in 2027. When there is a FiT degradation rate of 8%, the cumulative incomes is RM 141.113.04 and RM 146,433.68 after grid parity in 2024 and 2027 respectively. Table 4.7 illustrates a large income profit when grid parity reached in 2027 with an annual increment of 8% of electricity tariff. Those investors can gain avenue of about RM 6,590.06 and RM 7,830.86 for degradation rate of 8% and 10% respectively. This means that it will give large revenue when grid parity reached in 2027 compared with the cumulative incomes after grid parity in 2024.

Table 4.6: Difference between cumulative incomes when grid parity in 2024 with 8% annual increment rate of TNB electricity tariff.

FiT degradation rate	**Base case income (RM)**	**Income when grid parity reached in 2024 (RM)**	**Income profit (RM)**
8%/year	139,843.62	141,113.04	1,269.42
10%/year	136,432.80	139,426.47	2,993.67
Difference of income	3,410.82	1,686.57	1,724.25

Table 4.7: Difference between cumulative incomes when grid parity in 2027 with 8% annual increment rate of TNB electricity tariff.

FiT degradation rate	Base case income (RM)	Income when grid parity reached in 2027 (RM)	Income profit (RM)
8%/year	139,843.62	146,433.68	6,590.06
10%/year	136,432.80	144,263.66	7,830.86
Difference of income	3,410.82	2,170.02	1,240.80

Even if there is only about 2% difference in the FiT degradation rate; it can still cause large difference income profit for both grid parity years. Therefore, those investors who have already installed the PV system could avoid reduction of income compared to those who make the installation later. This is because when investors installed the PV system earlier, they will gain more profit to earn back the initial investment cost before the grid parity reached.

When consumers have installed the PV system earlier, it helps to avoid the reduction of incomes since the FIAH tariff will be based on the range of FiT rate on which year the PV system is installed. Thus, it will drop when the grid parity is attained. Subsequently, those investors who have installed the PV system earlier and get a higher tariff rate will get back their initial investment cost even before the breakeven point occurs, thus helps them to avoid income reduction. In contrast, those investors who have installed the PV system at a later year would experience a very low FIAH tariff since FiT will degrade; thus they could not get back their initial investment cost when breakeven occur hence financial risk cannot be avoided. 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. Hence, it will not be affected by the attainment of grid parity. Therefore, residential consumers can avoid loss of income and financial risks when grid parity is reached.

The number of years to reach grid parity can be easily affected by few parameters such as TNB electricity tariff, inflation rate and LCOE degradation rate.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Grid parity, which is defined as the breakeven point or intersection where the PV generation cost is equal to the conventional electricity tariff. These phenomena will bring a great repercussion to the residential consumers. Those 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 risk such as loss of income. 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 initial invested amount ahead of the grid parity year will also help reduce income losses that might face by investors. Through this, they can avoid the losses when the grid parity is attained.

For example, grid parity has been reached in other countries such as Thailand, Japan and Italy. After grid parity is attained, it helps the saving of the electricity bills by PV self-consumption. By mean of this, grid parity can help to bring down or maintain the conventional electricity tariff. Therefore, the year when grid parity reached is the great concern for residential consumers in Malaysia.

As for the residential consumers in Malaysia, PV electricity generation cost is expected to achieve the grid parity in 2029 with the increment of inflation rate; and in 2026 with a degradation rate of LCOE with 7% annual increment of electricity tariff. In contrast, grid parity will reach in 2027 with the increment of inflation rate; and in 2024 with degradation of LCOE with 8% annual increment of electricity tariff. Customers who are interested in the investment of solar PV system should consider the installation of 4kW capacity PV system in residential sector. This installation is very potential before 2015 since it can avoid financial sick such as reduce the 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 alternative source of energy in Malaysia. Solar PV is expanding widely over the world, it can help to reduce or maintain the electricity tariff in the country. When grid parity reached, solar PV will become a great market which helps to create job opportunity and lead to improve Malaysia's economic.

5.2 Recommendations

For those residential consumers who wish to gain revenue from solar PV system should consider few factors:

i. Low interest rate of bank loan
ii. Short payback period
iii. Low PV system installation price

Installation of PV system in residential sector should concern with the inflation rate and PV system generation cost which referred as Levelized Cost of Electricity (LCOE). All of these factors would affect their incomes when grid parity is reached.

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APPENDICES

APPENDIX A

[1] C. Y. Lau, C. K. Gan, and P. H. Tan, “PV Grid Parity Analysis for Residential Sector in Malaysia,” in *Power and energy conversion symposium (PECS) 2014*, 2014, pp. 111–117.

PV Grid Parity Analysis for Residential Sector in Malaysia

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Abstract— **The Solar Photovoltaic (PV) system has been identified as one of the promising renewable resources that could generate 'green' electricity for the consumers in Malaysia. The Malaysia Renewable Energy Act 2011 and the Feed-in Tariff (FiT) that have been introduced in 2011 have aimed to facilitate the increasing use of renewable energy in the Malaysian energy mix. 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 three key parameters that drive grid parity, namely: the PV system price, electricity tariff, and discount rate. The degradation FiT rate of solar PV system also taken into consideration. By using an annual energy yield of 1450 kWh/kWp, 21 years of system lifetime, 7.5% discount rate, 3.0% inflation rate, and 0.90% operation and maintenance (O&M) cost, the LCOE is calculated for a 4.0 kWp system to be RM 0.9170/kWh in 2014. With this, it may take up to 16 years for Malaysia to achieve PV grid parity. In contrast, with 1%/year degradation rate of LCOE, results suggest that Malaysia will achieve grid parity in 2029. For both 8% and 10% degradation rate of FiT, the incomes after the grid parity is reached will be losses about RM 2,010.00 and RM 2,486.73 for year 2026 and 2029 respectively.**

Index Terms—**Photovoltaic generation cost, conventional electricity prices, grid parity, Levelized Cost of Electricity, Feed-in Tariff**

I. 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 [1]. Therefore, the Malaysian government has encouraged the installation of PV system by introducing the Feed-in Tariff (FiT) scheme in 2011 [2]. 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 [3]. 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.

II. 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:

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

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:

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

Where r is discount rate/interest rate (%) and T is economic lifetime of the PV system (year).

While capital expenditure can be defined as:

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

B. TNB Tariff

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

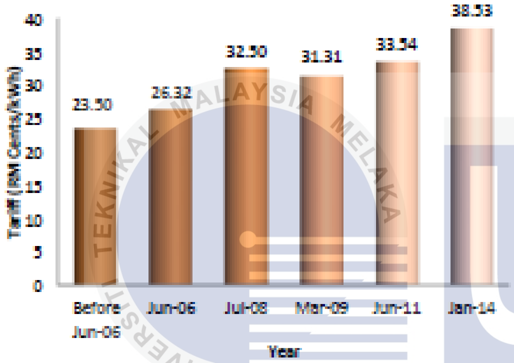

Fig. 1: The average electricity tariff (cents/kWh) in Peninsular Malaysia [4].

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 existing data, the calculation of LCOE was carried out based on certain assumptions, such as system cost, inflation rate, and degradation rate. In addition, 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 was analysed. Then, the results of the grid parity analysis were used to calculate the payback period for the PV system investors. Those projects that have long payback period would have higher risk of investment.

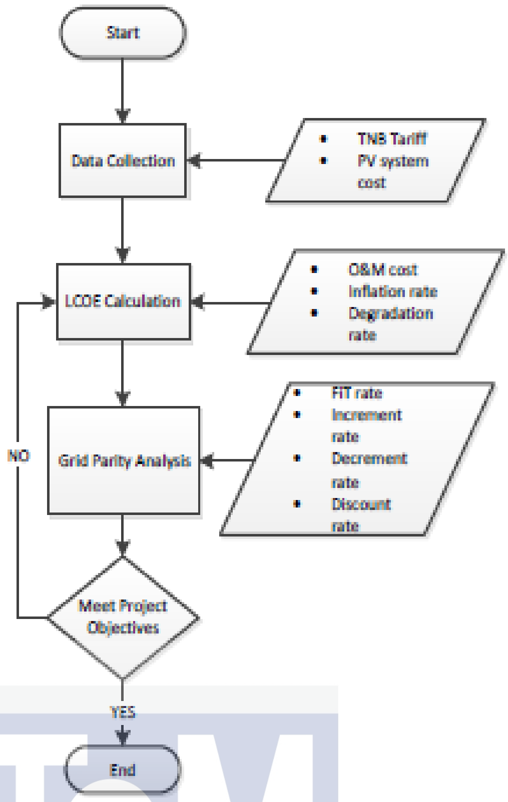

Fig. 2: Flowchart of the methodology.

The key parameters that drive the grid parity are the electricity tariffs, PV system cost, and inflation rate. After calculating the cost analysis, Malaysia might achieve grid parity by 2029. When grid parity occurs, the LCOE will switch to the same tariff with the TNB tariff and FiT will no longer be needed.

As for the investors who have installed the PV system in 2014 without any loan, the payback period is around 8-9 years. On the other hand, the payback period for investment with loan is around 9-13 years according to the grid parity analysis. 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 and a short payback period is ideal for a PV investor to make profit out of the investment made.

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 I FiT RATES FOR SOLAR PV FROM SEDA [5].

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

TABLE II shows the FiT rate for the electrical 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.

III. RESULTS & 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. The improvements in the system lifetime, annual energy yield (kWh/kW_p), inflation rate, CAPEX, and operation and management (O&M) cost can raise the LCOE. There are indications that the PV module lifetime could go longer than the estimated 25 years [6], 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.

In Malaysia, it is difficult to experience degradation in the system cost due to the average increase of inflation rate and currency, which lead the higher CAPEX and O&M costs. The amount of investors to install the PV system will become lesser due to the degradation of the PV generation prices. Subsequently, the government's mission to reduce carbon dioxide emission will be unsuccessful, and this will bring the downstream of economy in the country.

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 in future and has led to the ascent of LCOE prices. However, the PV system prices can be decreased due to low market demands. Therefore, two forecast assumptions made, which are degradation of LCOE with 1%/year rate, and increment rate of 0.1%/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 [7]. The high demand of electricity supply, which is generated by petroleum, coal, fossil fuels, and natural gases, has lead to escalate the electricity tariff 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 2.

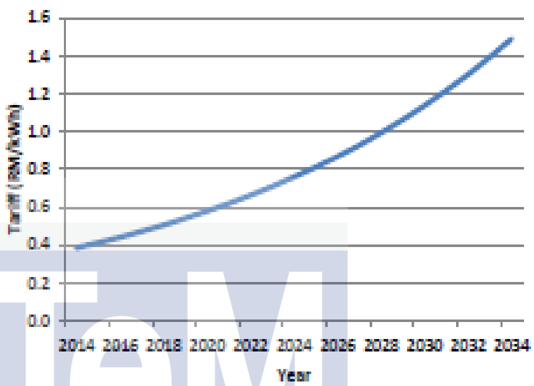

Fig 3: Forecasted average electricity tariff (cents/kWh) in Peninsular Malaysia.

C. Levelized cost of electricity (LCOE)

As for the 4.0 kW_p systems with associated prices, the LCOE is calculated with the escalation of inflation rate and the increase of system cost.

Some assumptions are made for a few parameters, which include the calculation of LCOE.

The assumptions made are:

- 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 for the beginning of the year is RM 0.9170, which is greater than the conventional TNB tariff of RM 0.3853. Due to the rise of inflation rate over the year, there may be an assumption of increment rate of 0.1%/year, followed by the increase of CAPEX and O&M cost as the LCOE shows a steady increase curve, which is illustrated in Figure 4. In contrast, if there is a degradation of LCOE with 1%/year rate, a decline curve is formed, as in Figure 5.

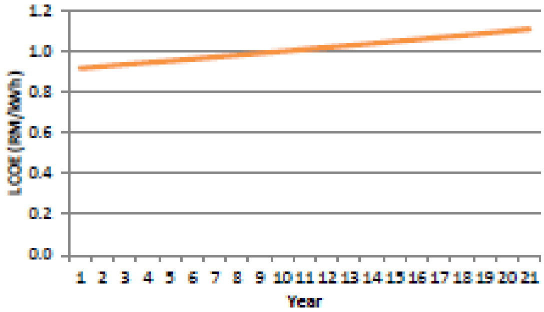

Fig. 4: Forecast of LCOE with 0.1%/year increment of inflation rate.

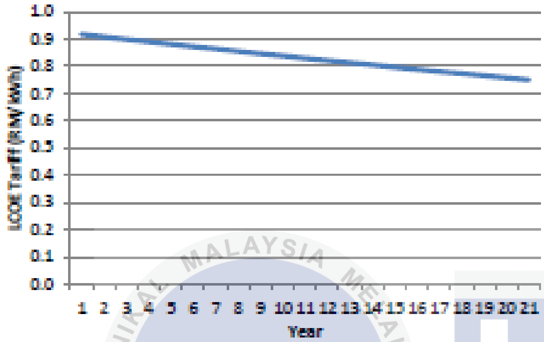

Fig. 5: Forecast of LCOE with 1.0%/year degradation rate.

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 6. Figure 6 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.

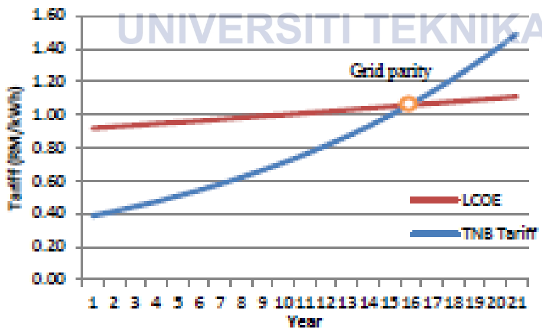

Fig.6: Grid parity analysis in Malaysia – residential segment with an increment rate of 0.1%/year of inflation rate.

Figure 7 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 13th year, which is better compared to the ascent in the PV system prices. Therefore, degradation rate affects the consumers which meet the year with low PV system prices.

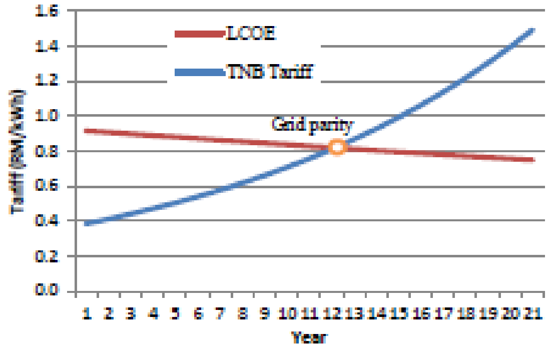

Fig.7: Grid parity analysis in Malaysia-residential segment with degradation rate of 1.0%/year.

By considering the FiT degradation rate of 8%/year and 10%/year, the results indicated a very low tariff after 16 years from the installation. Figure 8 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. 2% gap is shown between 8% and 10% FiT degradation rates, which only affects slightly on the income losses.

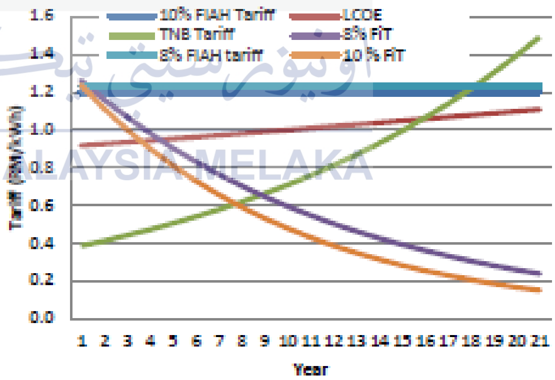

Fig.8: Relationship of combination parameters.

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.

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 9 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. 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.

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.

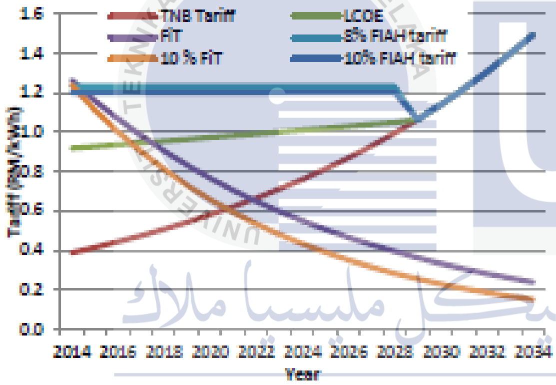

Fig 9: The tariff after grid parity with the combination of parameters.

Figure 10 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 8. If the grid parity reaches earlier, both the FIAH tariffs for 8% and 10% would be equivalent to the TNB tariff with a tiny drop. It shows that the earlier 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.

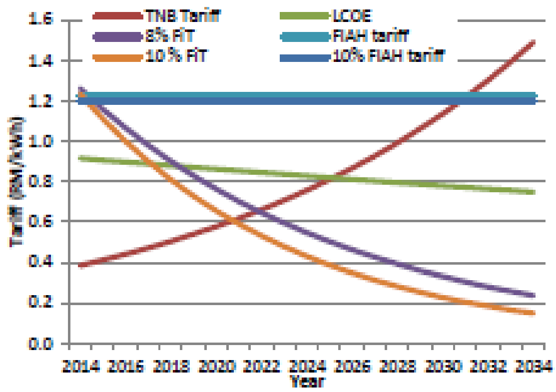

Fig. 10: Grid parity analysis with the combination of parameters.

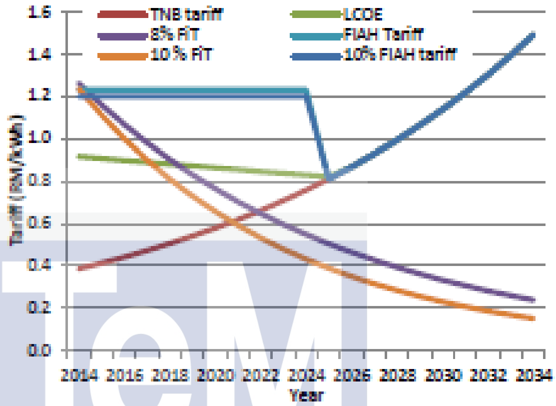

Fig. 11: The tariff after grid parity with the combination of parameters.

Figure 11 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. TABLE IIII shows the comparison between the cumulative income 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 consumers have installed the PV system earlier, it reduces the losses to avoid the FIAH tariff drop when the grid parity is attained. Those investors who have installed the PV system with a high tariff rate will get back their initial investment cost even before the breakeven point occurs, and thus helps them to reduce income losses.

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 IIV COMPARISON OF CUMULATIVE TARIFF BETWEEN 2026 AND 2029 WITH 8% AND 10% DEGRADATION RATE OF FIT.

FiT Degradation rate	Basic 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

IV. CONCLUSION

Grid parity, which is defined as the breakeven point where the utility electricity prices are equal to the PV generation cost, will bring about great repercussion to the residential consumers. 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 loss of income. 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. The installation is very potential 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

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APPENDIX B

Year	2013				2014				
Project Activities	**Sept.**	**Oct.**	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mac.**	**Apr.**	**May**
1. Finding out the project title and understand the title.									
2. Study and research for relevance information.									
3. Data collection on historical of generation PV system cost and electricity prices.									
4. Submission of progress report.									
5. Data collection on the PV technical performances (LCOE, energy yield).									
6. Data collection on the PV system cost and electricity prices (forecasted).									
7. Analysis the data.									
8. Report writing and presentation.									

APPENDIX C

FiT Rates for Solar PV (Individual) (21 years from FiT Commencement Date)

Description of Qualifying Renewable Energy Installation	FiT Rates (RM per kWh)
(a) Basic FiT rates having installed capacity of :	01-JAN-2014
(i) up to and including 4kW	1.0411
(ii) above 4kW and up to and including 24kW	1.0157
(iii) above 24kW and up to and including 72kW	0.7552
(iv) above 72kW and up to and including 1MW	0.7296
(v) above 1MW and up to and including 10MW	0.6080
(vi) above 10MW and up to and including 30MW	0.5440
(b) Bonus FiT rates having the following criteria (one or more) :	
(i) use as installation in buildings or building structures	+0.2201
(ii) use as building materials	+0.2116
(iii) use of locally manufactured or assembled solar PV modules	+0.0300
(iv) use of locally manufactured or assembled solar inverters	+0.0100

FiT Rates for Solar PV (Individual) (21 years from FiT Commencement Date)

Description of Qualifying Renewable Energy Installation	FiT Rates (RM per kWh)
(a) Basic FiT rates having installed capacity of :	15-MAR-2014
(i) up to and including 4kW	1.0184
(ii) above 4kW and up to and including 12kW	0.9936
(b) Bonus FiT rates having the following criteria (one or more) :	
(i) use as installation in buildings or building structures	+0.2153
(ii) use as building materials	+0.2070
(iii) use of locally manufactured or assembled solar PV modules	+0.0500
(iv) use of locally manufactured or assembled solar inverters	+0.0500