THE POTENTIAL OF SOLAR ENERGY FOR DOMESTIC AND COMMERCIAL BUILDINGS

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May 2019

This dissertation is submitted to
Universiti Sains Malaysia
As partial fulfilment of the requirement to graduate with honors degree in
BACHELOR OF ENGINEERING (MECHANICAL ENGINEERING)

School of Mechanical Engineering
Engineering Campus
Universiti Sains Malaysia

Declaration

This work has not previously been accepted in substance for any degree and has not been concurrently submitted in candidature for any degree.

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Acknowledgement

I would first like to express my deepest and most sincere gratitude to my beloved supervisor, Mr. Abdul Yamin Saad for his precious guidance, unconditional encouragement and generous support throughout this project. I am also grateful for the helps and supports from my beloved friends and lecturers. They are very much appreciated.

CHEE KAR WEI

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Abstrak

Dalam thesis ini, analisis daya maju kewangan untuk ‘solar photovoltaic (PV) sistem’ yang bersambung dengan grid untuk bangunan domestik dan komersial telah dibentangkan. Daya maju kewangan merupakan salah satu faktor utama yang memikat hati pengguna sama ada untuk memasang solar PV sistem untuk premis mereka selain daripada mengurangkan jejak karbon. Pelbagai usaha telah dilakukan oleh kerajaan Malaysia untuk manarik minat pengguna termasuklah skim ‘Net Energy Metering (NEM)’ yang baru-baru ini disemak semula. Sekarang, skim NEM berasaskan harga jualan and belian elektrik yang sama dengan mengikut tarif yang diwartakan. Selain itu, daya maju kewangan akan disiasat melalui ‘payback period’ dan ‘return on investment (ROI)’. ‘Payback period’ dan ROI akan dibanding berdasarkan skim ‘Feed in Tariff (FiT)’ dan skim ‘revised Net Energy Metering (NEM)’. ‘Payback period’ solar PV sistem mengikut pengunaan elektrik rendah, sederhana dan tinggi telah dibentangkan dalam keputusan Part I. Pengunaan elektrik rendah dan sederhana untuk Tarif B dengan bil elektrik sebulan RM2500 dan RM5000 mempunyai ‘payback period’ 8.7 tahun untuk skim FiT dan NEM. ‘Payback period’ dan ROI solar PV sistem untuk bangunan komersial untuk Tarif B mempunyai ‘payback period’ terpendek iaitu 8.2 tahun bagi skim FiT dan NEM manakala ROI ialah 155.03 % untuk skim FiT dan 203.65 % untuk skim NEM. Akhir sekali, strategi dan rancangan yang telah dicadangkan ialah ‘Renewable Portfolio Standard (RPS)’, “Solar Carve Out’, ‘Virtual Net Energy Metering (VNEM)’ dan ‘solar referral program’. Oleh itu, solar PV sistem bagi FiT dan NEM yang disemak semula merupakan skim yang berdaya maju untuk bangunan komersial bagi tarif B yang mempunyai penggunaan elektrik rendah dan sederhana dengan bil elektrik sebulan RM2500 dan RM5000.

Abstract

In this thesis, financial viability of grid-connected solar photovoltaic (PV) system for domestic and commercial buildings which was investigated through the payback period and return on investment (ROI) is presented. The payback period and ROI were determined and compared based on Feed in Tariff (FiT) scheme and revised Net Energy Metering (NEM) scheme. In Part I of the results, it was found that consumers under Tariff B with monthly electric bill of RM2500 and RM5000 had the shortest payback period at 8.7 years for both schemes. In Part II of results, monthly electric bills of the buildings under the same locations as Part I were obtained and used for analysis. The payback period of commercial building (average bill of RM5003.43) under Tariff B – Low Voltage Commercial Tariff had the shortest payback period at 8.2 years for both schemes which tally with the results from Part I. The ROI of solar PV system installed for this commercial building were 155.03 % (FiT scheme) and 203.65 % (revised NEM scheme). Thus, solar PV system under FiT scheme and revised NEM scheme would be a financially viable option for commercial buildings with monthly electric bill of RM2500 and RM5000 under Tariff B. Lastly, the strategies and plans proposed to support the growth of solar industry in Malaysia were Renewable Portfolio Standard (RPS), Solar Carve Out, Virtual Net Energy Metering (VNEM) and solar energy referral program.

Chapter 1 Introduction

1.1 Research Background

Apart from the fact that solar electricity generation represents a cleaner power source compared to electricity from fossil fuels, with no issues of climate change and global warming, no risks of spike in electricity price, and no threats to our public health [1], solar photovoltaic (PV) system also offers consumers and businesses the ability to reduce costs of electricity bill and increase profitability as a means of generating long term income.

Nowadays, with the cost of producing solar power that is declining rapidly and efficiency of solar panel that is increasing steadily, it is a sign that the world may be on the verge of a dramatic change in how we power our buildings. The price drop is likely to spur a shift towards renewable power sources like solar energy and away from fossil fuels like natural gas and coal in the future. By the end of 2016, the levelised cost of energy of solar, for the first time, is lower than coal in terms of $ cent/ kWh (Figure 1.1). Not only that, it is shown that the price of solar panel per watt has dropped from $101.05 to as low as $0.37 in late 2017 (Figure 1.2).

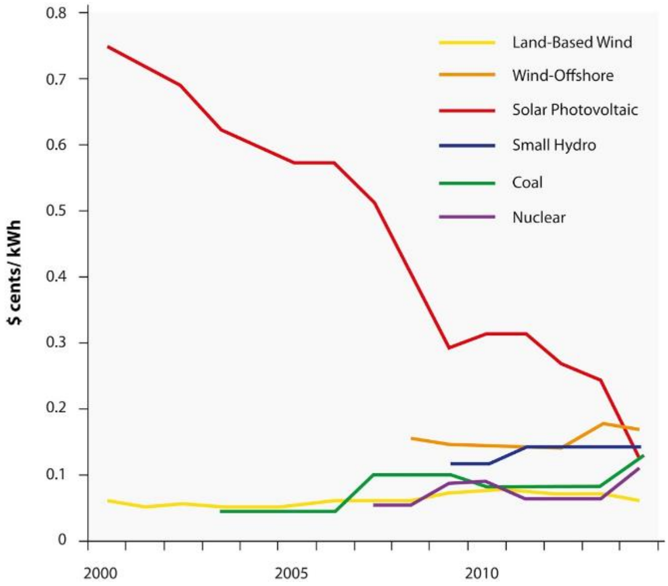


Figure 1.1 Levelised Cost of Energy (World Average) by energy type [2]

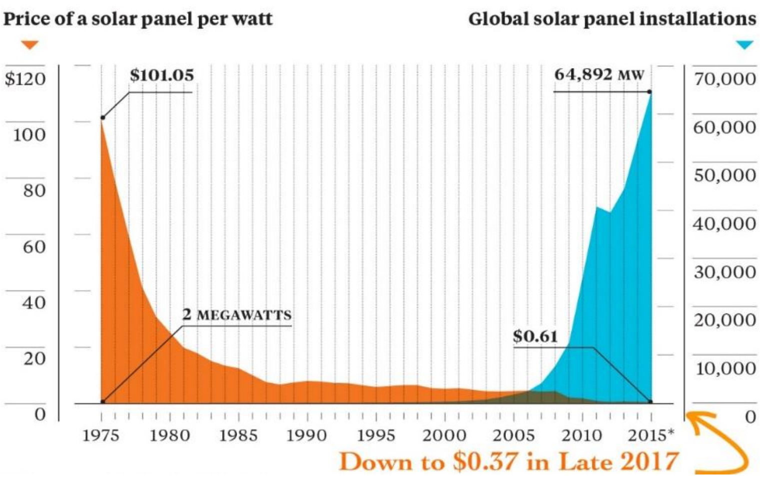


Figure 1.2 Price trend of solar panel [3]

Next, solar energy as a viable option for consumers and businesses is closely related to the payback period or return of investment (ROI) under the policies of Feed in Tariff (FiT) scheme and Net Energy Metering (NEM) scheme in Malaysia. The financial viability under different solar policies plays very important role in governing the interest of consumers to install solar PV system in either domestic buildings or commercial buildings.

To encourage the growth of solar energy sector in domestic, commercial, and even industrial consumers, the first introduced policy was Feed in Tariff (FiT) scheme in 2011 where grid-connected solar photovoltaic (PV) generators will be paid in cash for the amount of extra electricity they have generated [4]. However, the application of FiT scheme was closed for registration in the year 2016.

To solve the problem above, Net Energy Metering (NEM) scheme was introduced in Nov 2016 where energy produced from solar PV system installed will be consumed first, and any excess to be exported and sold to the Distribution Licensees (DLs) i.e. TNB /SESB at the prevailing Displaced Cost prescribed by the Energy Commission [5]. Sadly, as of October 2018, the total amount of NEM quota taken up is disappointingly low at only 17 MW (megawatt) or 3 %, out of the 500 MW [6]. The reasons for this low uptake are caused by the extremely low rate at which consumer can sell the energy produced by the solar PV system at 31 sen per kWh compared to purchase electricity at about 50 sen per kWh and even worse the excess electricity sold to DLs will be paid in credit rather than cash.

Again, to solve the low uptake of NEM quota, Minister of Energy, Science, Environment, and Climate Change, Yeo Bee Yin announced that starting 1st of Jan 2019, there will be no difference in sale and purchase prices for electricity under a revised NEM scheme. This means that the excess electricity generated from solar PV system will be exported back to the grid on a ‘one-on-one’ offset basis.

Moreover, Minister of Energy, Science, Environment, and Climate Change, Yeo Bee Yin also announced the new purchase mode of solar PV system which is solar leasing, other than with cash and loans in order to make solar PV system more affordable for the customers. Through solar leasing, consumers negotiate directly with solar contractor the upfront cost of solar PV system and pay monthly instalments over an agreed period [7].

With the revised NEM scheme announced, the viability of solar PV system will definitely catch the attention of consumers. Therefore, the current study will focus mainly on grid-connected solar PV system without battery storage by comparing the financial viability of solar PV system in both the domestic and commercial buildings based on available electricity consumption profile. By doing so, there will be a guidance to solar power system for consumers before they invest in a photovoltaic system in the future. Furthermore, the current study will also evaluate the different solar energy policies available such as Feed in Tariff (FiT) scheme, revised Net Energy Metering (NEM) scheme, Solar Leasing Concept and etc. in order to come out with more possible strategies and plans to further promote the growth of solar energy industry.

1.2 Problem Statement

It is well aware that solar photovoltaic (PV) system is a cleaner alternative to generate electricity than the fossil fuels. Nevertheless, installation of solar PV system in Malaysia is considerably low which can be reflected from the low quota uptake of Net Energy Metering (NEM) scheme. The reason being is consumers are still sceptical on the financial viability of installing solar PV system.

Firstly, there are limited studies that focus on the economic analysis of solar PV system for commercial buildings. Even though there are studies that focus on economic analysis of solar PV system for domestic buildings, the studies are based on Feed in Tariff (FiT) scheme and the past NEM scheme. With the recently introduced revised NEM scheme, it is essential to investigate the economic analysis of solar PV system again. Thus, this paper will be able to serve as a guideline for consumers in making decision on whether to install solar PV system in their properties or not.

Next, solar companies often make promises of short payback period for the installation cost of solar PV system. However, consumers do not realize that these promises of the short payback period do not include the hidden cost such as operation and maintenance cost. Thus, this paper aims to provide a realistic payback period of installing solar PV system, with hidden cost included and serve as a guideline for the consumers.

Therefore, the main objective of the present paper is to entirely evaluate the financial viability of solar PV system for domestic and commercial buildings under different solar policies available in Malaysia. Other than that, possible strategies and plans which are beneficial to the Distribution Licensees (DLs) and the consumers will be proposed. This hopefully will further convince the consumers to install solar PV system in their properties to help reduce carbon footprint caused by generating electricity through burning of fossil fuels.

1.3 Objectives

Two objectives that must be achieved in this study are:

- To evaluate financial viability of the grid-connected solar PV system through payback period and return of investment (ROI) for domestic and commercial buildings in Malaysia.
- To propose strategies and plans for supporting the growth of solar energy industry in Malaysia.

1.4 Scope of Study

This study will provide a comparison between financial viability of grid-connected solar PV system without battery storage in domestic and commercial buildings which are under different types Distribution Licensees (DLs) i.e. TNB electricity tariff as follows:

- Tariff A – Domestic Tariff
- Tariff B – Low Voltage Commercial Tariff
- Tariff C1 – Medium Voltage General Commercial Tariff

This study will also consider the different types of policies available in Malaysia such as Feed in Tariff (FiT) scheme and revised Net-Energy Metering (NEM) scheme into the analyzation of the financial viability. Eventually, this study will come out with different suggestions on the solar policies and strategies that are beneficial to both consumers and Distribution Licensees (DLs).

This study will not cover the detailed design such as individual components of the grid-connected solar PV system without battery storage in domestic and commercial buildings. This study will also not cover the off grid solar PV system and solar PV system with battery storage.

Chapter 2 Literature Review

2.1 Solar Photovoltaic (PV) System

2.1.1 Operational Theory of Solar Photovoltaic (PV) System

A basic solar photovoltaic (PV) system consists of solar panels to receive solar radiations from the sun and generate electricity from that for energy usage of electrical appliances shown in Figure 2.1. The main components involved in a solar PV system are solar panel, solar charge regulator, battery and inverter. The solar panels first collect solar radiations from sun and actively convert them into electricity. They are normally installed on the roof or on the ground. The regular sizes of solar panel are shown in Figure 2.2. Next, solar charge regular is used to charge the battery and protect the battery from excessive charging. Battery is normally installed in order to store excess energy produced during the day and use the excess energy at night or days with bad weather. Lastly, the inverter is used to change direct current (DC) produced from solar panels to alternating current (AC) which is the usual form of electricity to power up electrical appliances [8].

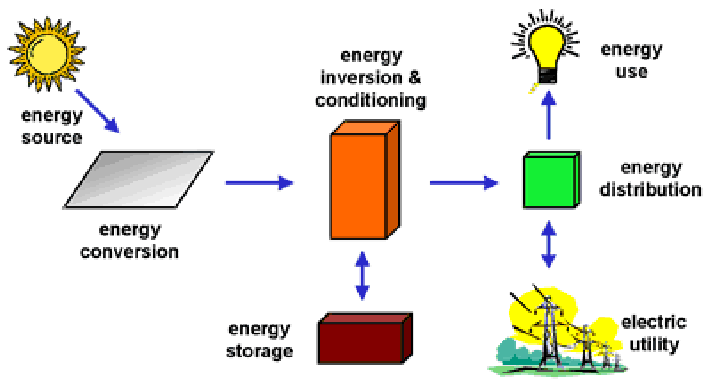


Figure 2.1 Major photovoltaic system components [9]

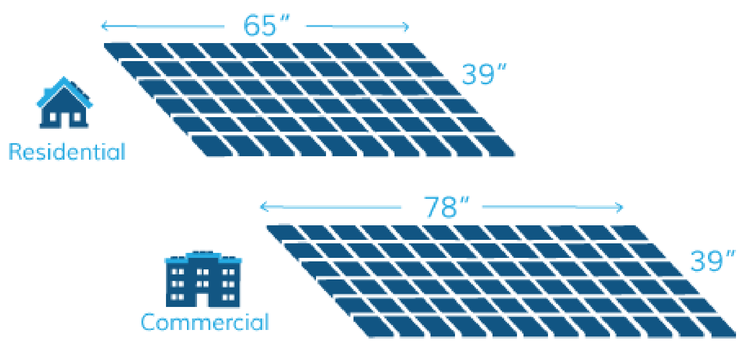


Figure 2.2 Residential vs. commercial solar panel size comparison [10]

2.1.2 Off-Grid vs. Grid-Connected Solar Photovoltaic (PV) System

For an off-grid solar PV system, the extra electricity generated is not allowed to be exported to the utility grid as it is purely for self-consumption only. In general, battery storage is required for off-grid solar PV system to make sure that electricity is available all the time, even when the sun is not available. Other than that, it is also important to design the system with 0 % power shortage as there will be no electricity from utility grid to support the system [11]. Next, an off-grid solar PV system is especially useful in rural and remote area where utility grid is not available. The advantage of this system is that the system owner does not need to pay electric bill anymore once the system is running. However, the downside of this system is that off-grid solar PV system is more expensive than grid-connected solar PV system due to maintenance and replacement of battery after 7 – 10 years [12].

As for a grid-connected solar PV system, the direct current (DC) generated by solar panels is converted into alternating current (AC) by inverter, which can be used by home electrical appliances and if any excess electricity is generated, can be fed into utility grid. Grid-connected solar PV system is cheaper and more effective than off-grid solar PV system because it does not have extra components like solar charge regulator and battery as the utility grid is already acting as a virtual battery bank [12] [13]. However, the downside of this system is that whenever there is no sunlight and utility grid is down, there would be no electricity available [13].

2.1.3 Large Scale Solar (LSS) Photovoltaic Plant in Malaysia

Large Scale Solar (LSS) scheme was introduced in the year 2016 where Energy Commission of Malaysia organized a tender process for the installation of large scale solar PV plant. This tender process involved participation of many interested parties which will submit bids and if success, will responsible for the construction and operation of the PV plant. The electricity generated from the grid-connected PV plant will be sold to Tenaga Nasional Berhad (TNB) and Sabah Electricity Sdn Bhd (SESB) under solar power purchase agreement (SPPA).

- 1st LSS tender round – roughly capacity of 450 MW was installed [14].
- 2nd LSS tender round – roughly capacity of 563 MW was installed [15].
- 3rd LSS tender round – expected capacity of 563 MW will be installed [16].

2.1.4 Costs of Grid-Connected Solar Photovoltaic (PV) System

The cost of solar PV system is one of the governing factors that homeowners consider before they install the system. The final cost of a solar PV system is contributed by solar panels, inverters, racking systems, balance-of-system hardware, labor, contractor profits, contractor overhead, permits, customer acquisition costs and etc. [17]. In Malaysia, it costs around RM10000 – RM15000 for each system capacity of 1 kWp. Therefore, a typical 5 kWp solar PV system will cost at least RM50000 which is not quite affordable except for rich homeowners [18].

2.1.5 Operational & Maintenance Costs of Solar Photovoltaic (PV) System

Maintenance of solar PV system is very important in order to maintain the optimal energy output throughout the average lifespan of 25 - 30 years of solar panels [19]. Solar PV system requires regular examination from time to time in order to prevent potential issues that will affect the system's performance such as loose racking, exposed wire and etc. [20]. It also requires panel cleaning every year to clear the dirt on the solar panel surface caused by leaves, dust and debris. Therefore, it is important to integrate maintenance and operational costs into the economic analysis of solar PV system which is roughly estimated at 1 – 1.5% of the acquisition cost of solar PV system, annually [21].

2.2 Solar Strategies, Plans and Policies in Malaysia

2.2.1 Feed in Tariff (FiT) Scheme

In the 10th Malaysian Plan, new renewable energy (RE) regulations that include Feed in Tariff (FiT) was introduced to accelerate the RE prodution. Under FiT, investors are able to sell the RE generated to national grid and this includes solar energy. Next, FiT has a regression rate of 8 % annually for new registrants. As for the registered investors, the tariff rate on that particular year will be fixed for 21 years. The regression rate is there to balance out current investment and cheaper RE technologies in the future. However, FiT is only beneficial to the rich homeowners only as preparing RM50000 for 3600 kWh electricity production yearly is not affordable by the low and middle income homeowners [22]. Furthermore, annual regression with decreasing FiT rate every year is causing the payback period to deteriorate for new registrants over the year.

As a result, investors will eventually lose interest in the FiT mechanism [22]. The estimated payback period and investment yield from FiT calculated by PEKAT Teknologi based on rate of RM0.911/ kWh, in the year 2015 are shown in Table 2.1 below.

Table 2.1 Feed in Tariff (FiT) income [23]

Area	Capacity Installed	Initial Investment	Average Monthly Receipts From TNB	Payback Period	Expected Total Net Income (For 21 years)	Investment Yield
Klang Valley and Johor	8kWp	RM56,000.00	RM789.50	6 Years 3 months	RM159,922.33	16.90%
	10kWp	RM70,000.00	RM986.90		RM199,902.92	
	12kWp	RM84,000.00	RM1184.30		RM239,883.50	
Seremban, Melaka and Ipoh	8kWp	RM56,000.00	RM850.30	5 Years 9 months	RM174,485.59	18.00%
	10kWp	RM70,000.00	RM1062.80		RM218,106.99	
	12kWp	RM84,000.00	RM1275.40		RM261,728.39	
Kelantan, Penang, Kedah and Perlis	8kWp	RM56,000.00	RM911.00	5 Years 4 months	RM189,048.85	19.00%
	10kWp	RM70,000.00	RM1138.75		RM236,311.06	
	12kWp	RM84,000.00	RM1366.50		RM283,573.27	

2.2.2 Net Energy Metering (NEM) Scheme

Net Energy Metering (NEM) scheme was introduced in Nov 2016 where energy produced from solar PV system installed will be consumed first, and any excess to be exported and sold to the Distribution Licensees (DLs) i.e. TNB /SESB at the prevailing Displaced Cost prescribed by the Energy Commission [5]. Under Net Energy Metering (NEM) scheme, the payback period for domestic building with low electricity consumption is 9.334 years (yearly profit = RM2678.40). The low electricity consumption is assumed with TNB bill of RM250 per month which is around 633.33 kWh of electricity usage. Next, the payback period for domestic building with medium electricity consumption is 5.339 years under the same NEM scheme (yearly profit = 4682.23). The medium electricity consumption is assumed to be RM500 per month which is around 1083.84 kWh of electricity usage. For the two cases, solar irradiation value is considered at 6 hours and the monthly electric bills are assumed to be the same throughout the period. The two cases are also based on grid connected solar system of 4 kWp which is assumed to be around RM25000 and able to generate 8760 kWh of electricity yearly. Thus, it is clear that under the same 4kWp solar PV system, consumers with higher monthly electricity usage have a more viable system [24].

2.2.3 Revised Net Energy Metering (NEM) Scheme

Net Energy Metering (NEM) scheme had been improved in Jan 2019 where the ‘sell back’ price of solar energy or the prevailing displaced cost of RM0.31/ kWh was abolished. Beginning Jan 2019, the billing calculation would be based on ‘one-on-one’ where the sale and purchase prices of electricity are the same according to the gazetted tariff [25]. Other than that, revised NEM scheme is pretty much the same with the past NEM scheme.

2.2.4 Supply Agreement for Renewable Energy (SARE) Programme

Supply Agreement for Renewable Energy (SARE) is a Tenaga Nasional Berhad (TNB) platform for behind-the-meter business models such as solar leasing and solar power purchase agreements (SPPA). The purpose of SARE programme is to make participation in NEM scheme more affordable to the customers. Under SARE programme, it allows consumer (as the lessee), the investor/ owner (i.e. company which owns and leases the solar PV system to consumer) and the utility (i.e. TNB or SESB) to agree on the arrangement in which the leasing fee may be paid to investor/ owner via electricity bills [26]. Under SPPA, the Feed-in Approval Holders/ customers are paid for the solar energy generated (RM/ kWh) over an agreed tenure (i.e. 21 years) by electricity distribution licensees (i.e. TNB or SESB). Under solar leasing, customers can lease-to-own or lease just for energy procurement. Lease-to-own customers can negotiate the upfront down payment with solar PV lessors and the contract is designed to suit a willing buyer/ seller mode [7].

2.3 Electricity Usage Profile in Malaysia

2.3.1 Electricity Usage Profile of Domestic Consumers

The daily electricity usage of domestic buildings depend mainly on the usage of basic electrical appliances by the domestic consumers according to their lifestyle. Some of basic electrical appliances include lamp, washing machine, refrigerator, iron, television, air conditioner, microwave, laptop/ desktop, rice cooker, fan, vacuum cleaner, hair dryer, water heater, toaster, blender and VCD/ DVD player. From Figure 2.3 below, it clearly shows that the peak hour electricity consumption is between 7.00 am to 9.00 am and from 7.00 pm to 10.00 pm. This makes sense as for most domestic residents, 7.00 am to 9.00 am is the time where they are preparing for work and 7.00 pm to 10.00 pm is the time where they are resting at home after work. That is why the electricity usage is high at these periods. As for the period in between, the electricity usage is low because the houses are mostly vacant.

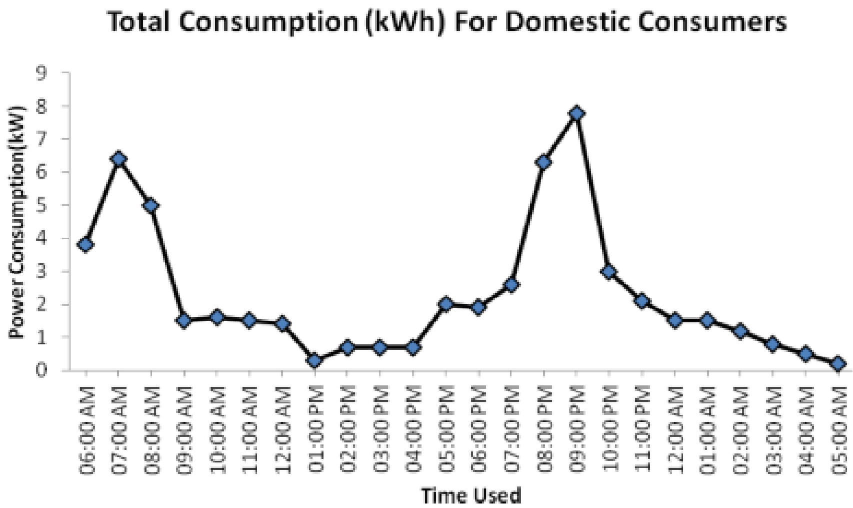


Figure 2.3 Electricity usage profile of domestic consumers [27]

2.3.2 Electricity Usage Profile of Commercial Consumers

For commercial buildings, some of the common electrical appliances that could be found include lamp, printer, fax machine, television, photocopy machine, laptop/ desktop, rice cooker, fan and vacuum cleaner. However, there are some critical electrical appliances for commercial consumers that consume huge amount of electricity which include refrigerator/ freezer, compressor, air conditioner, drill machine and saw machine. From Figure 2.4 below, it shows that the peak electricity usage is from 10.00 am to 6.00 pm which is the period where most commercial buildings are operating their businesses.

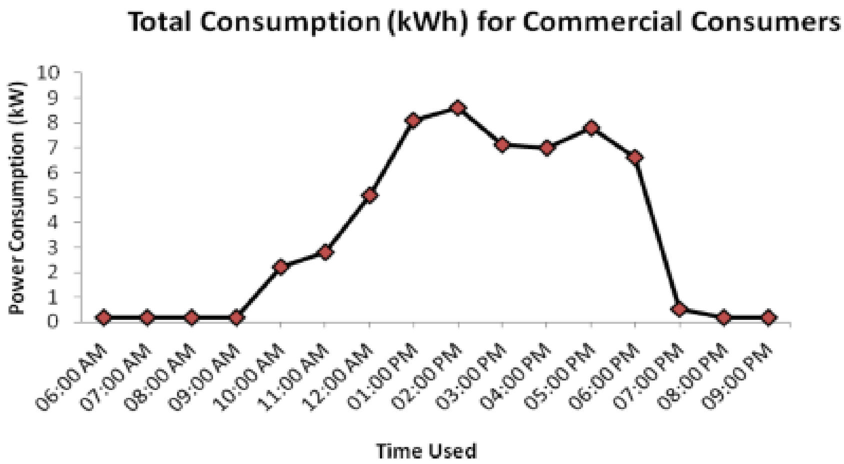


Figure 2.4 Electricity usage profile of commercial consumers [27]

2.3.3 Daily Solar Energy Generation

The amount of daily solar electricity generated, expressed in units of kW, mainly depends on the solar irradiation value of a specific location. Most locations in Malaysia share the same curve pattern for daily solar electricity generation, but with different maximum power. Based on Figure 2.5 below, it is clear that solar electricity generated in Kampung Kedah, Parit Buntar is only available for the period of 7 am to 8 pm. Compared to the daily electricity usage of either domestic or commercial consumers in Figure 2.3 and Figure 2.4 (refer Chapter 2.3.1 and Chapter 2.3.2), the solar electricity generated can be either for own usage or 'sell back' to the national grid. For the period of 8 pm to 7 am where solar electricity is not available, the domestic or commercial consumers can purchase the electricity from national grid. This phenomena of actually 'sell back' and purchase electricity via national grid makes the national grid a virtual battery bank, provided that the sale and purchase rate is based on 'one-on-one' basis.

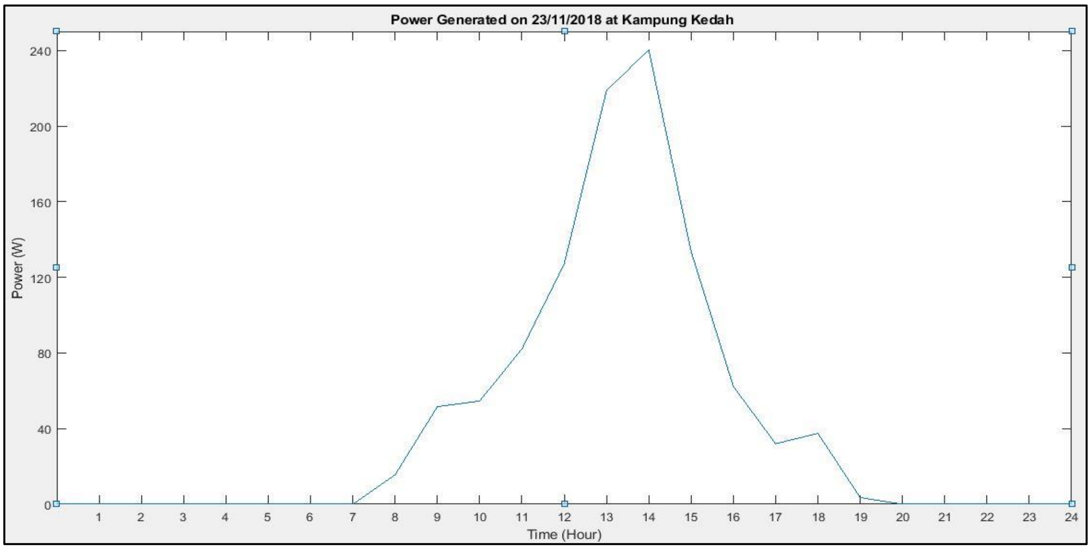


Figure 2.5 Daily solar electricity generation in Kampung Kedah [28]

2.3.4 Capacity of Solar Energy in Malaysia

Although there are also potentials in biomass, wind offshore, mini hydro, and etc., solar PV has been identified as the energy source with the highest potential in satisfying the energy needs of Malaysia [29]. Statistic also shows that contribution of solar energy in Malaysia's electricity generation is increasing steadily and as of the year 2018, solar energy has a capacity of 438 Megawatts in electricity generation (shown in Figure 2.6 below). It is also expected the solar energy in Malaysia's electricity generation continue to grow even in the future which is shown in Figure 2.7 below. With the strategic geographical location, Malaysia benefits from a large quantity of solar insolation per year, ranging from $1400 \text{ to } 1900 \text{ kWh/m}^2\text{/year}$ [30], it would be a waste for not to fully utilise solar PV energy.

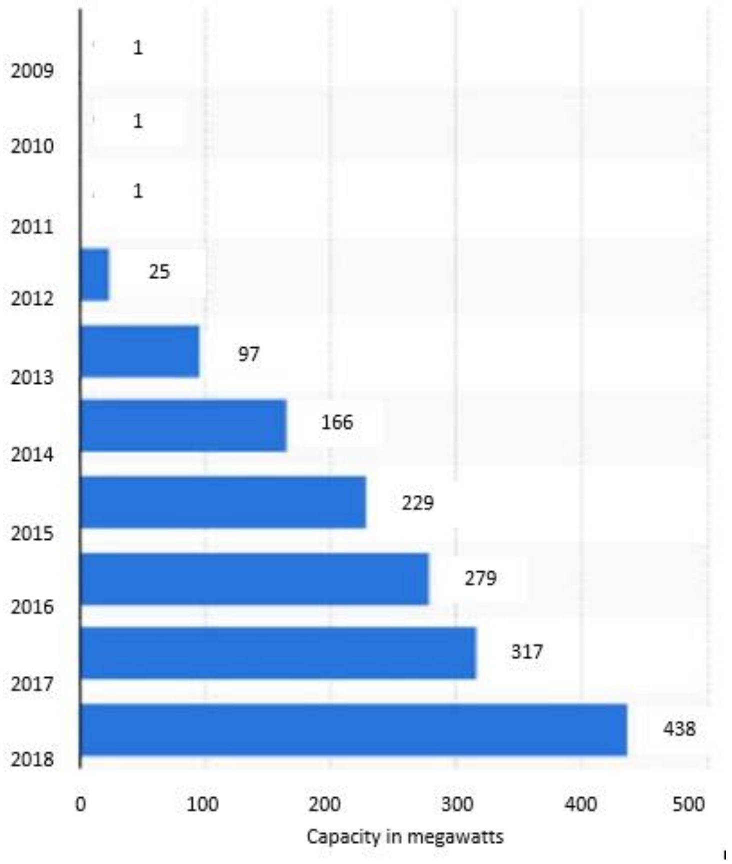


Figure 2.6 Solar energy capacity in electricity generation [31]

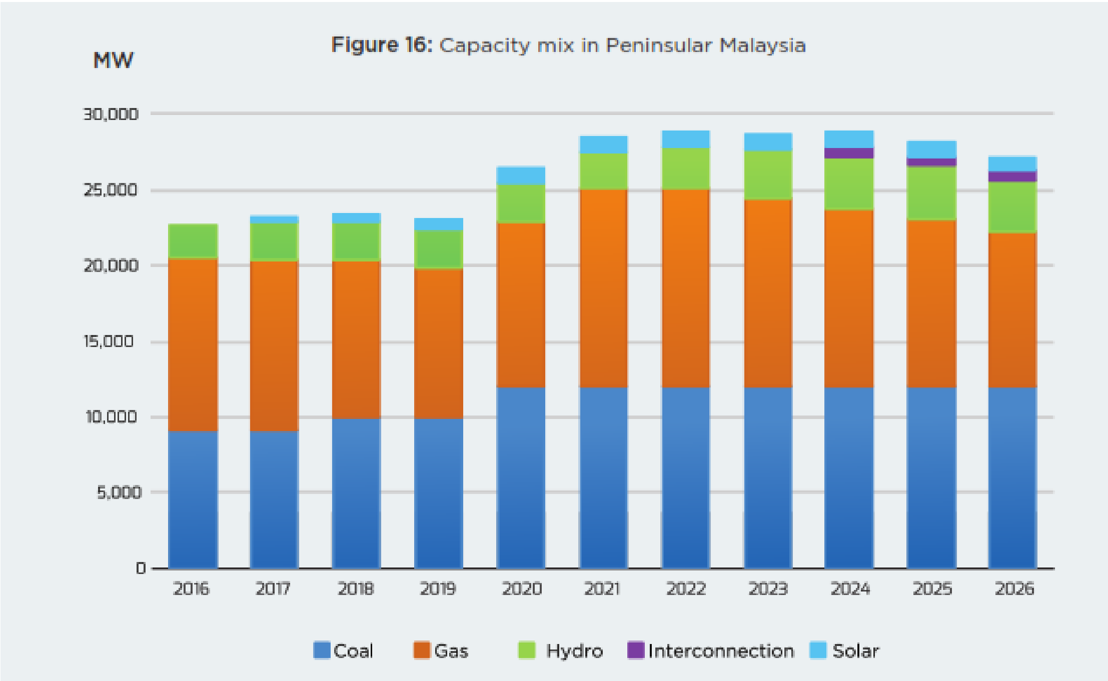


Figure 2.7 Capacity mix in Peninsular Malaysia [32]

2.3.5 Tenaga Nasional Berhad (TNB) Tariff Rates

The electricity pricings for different tariffs are revised from time to time. The payback period and return on investment (ROI) are directly affected by the revisions. The comparison of pricing revisions are shown based on the total monthly electric at a specific usage for Tariff A, B and C1. Three latest tariff rate revisions (June 2011, January 2014 and latest 25th May) obtained directly from Tenaga Nasional Berhad (TNB) website are compared.

2.3.5.1 Tariff A – Domestic Tariff

From Figure 2.8 below, it is clear that after the revision in Jan 2014, the pricing was raised for usage of 301 kWh to 1200 kWh (assuming highest usage) compared to revision in June 2011. As for the latest revision, it is remained at constant pricing as revision in Jan 2014. It is also found that starting at the usage of 901 kWh, the line is steeper which means the electricity pricing is more expensive.

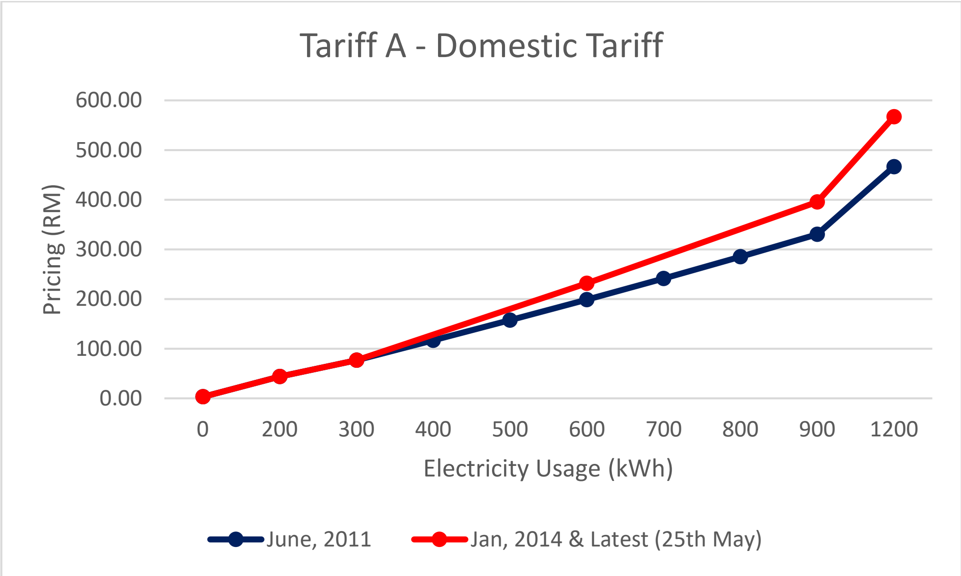


Figure 2.8 Tariff rates for Tariff A

2.3.5.2 Tariff B – Low Voltage Commercial Tariff

From Figure 2.9 below, it is found that after revision in Jan 2014, the electricity pricing was raised for usage 200 kWh to 16500 kWh (assuming highest usage) compared to revision in June 2011. However the pricing for latest revision is found to be the same as revision in Jan 2014.

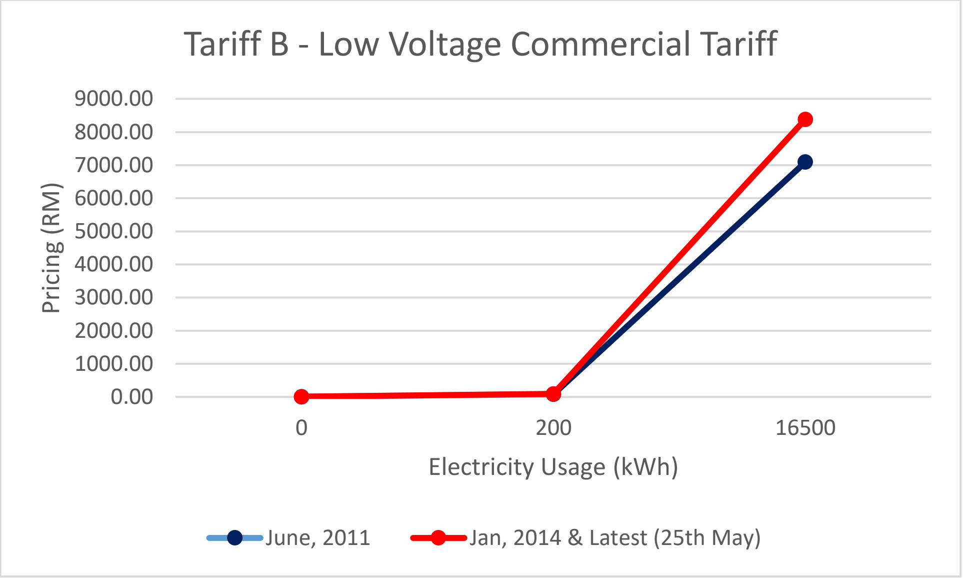


Figure 2.9 Tariff rates for Tariff B

2.3.5.3 Tariff C1 – Medium Voltage General Commercial Tariff

From Figure 2.10 below, it is found that the pricing which is constant up to 55000 kWh (assuming highest usage) was raised in the revision on Jan 2014 compared to revision on June 2011. However the pricing is found to be the same for the latest revision.

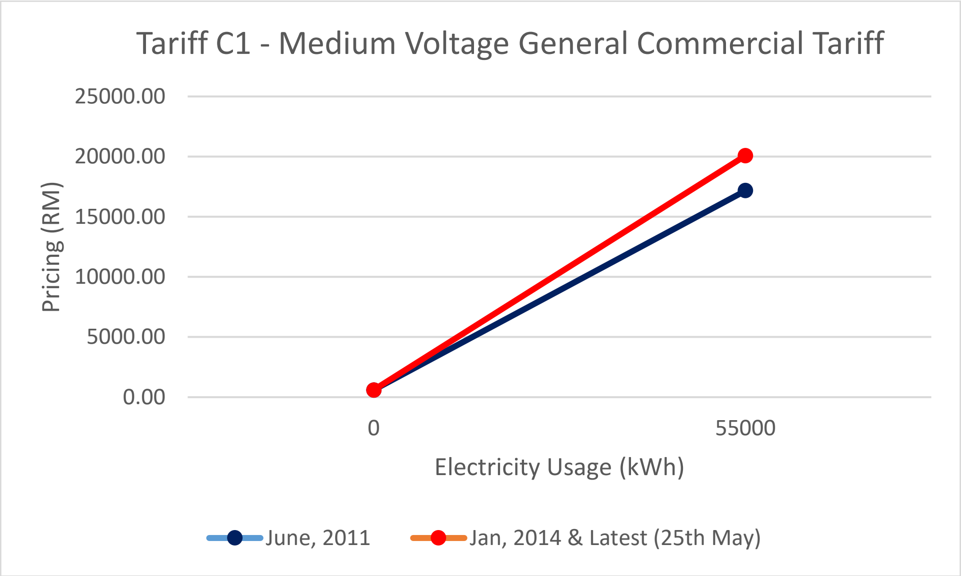


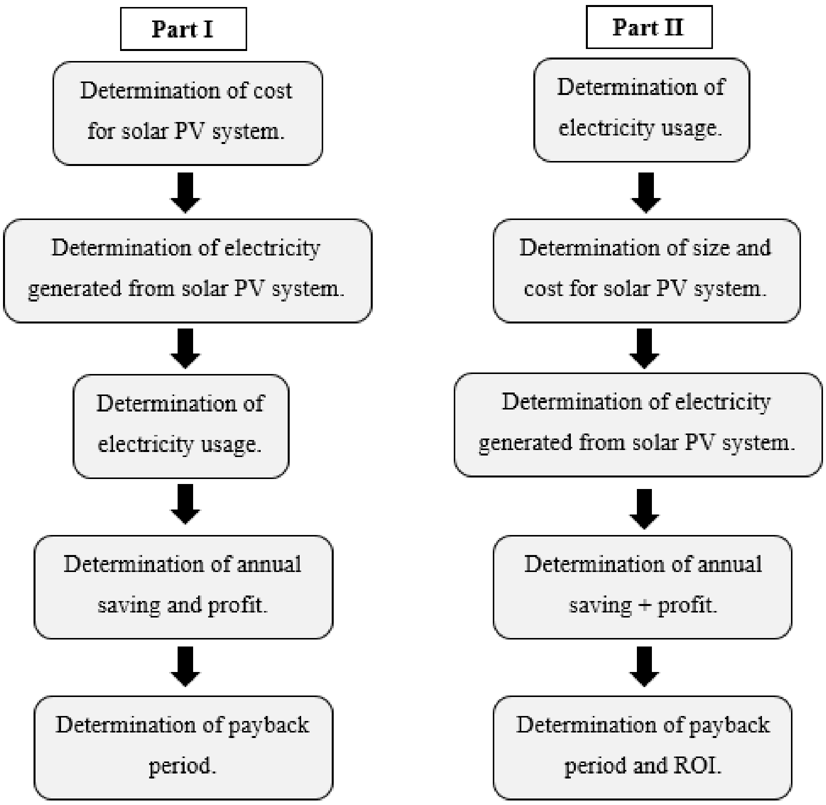
Figure 2.10 Tariff rates for Tariff C1

Chapter 3 Research Methodology

3.1 Overview

The solar payback period and return on investment (ROI) are the major factors that govern the interest of consumers to install solar PV system in their houses. Solar payback period is a calculation that estimates how long it will take for you to "break even" on your solar energy investment [33]. Return on investment (ROI) is a performance measure used to evaluate the returns of an investment or to compare efficiency between different investments. ROI measures the return of an investment relative to the cost of the investment [34].

In this study, the result is separated into three parts, which are Part I, Part II and Part III. Financial viability of a various sizes of solar photovoltaic (PV) systems through payback period under different monthly electric bill is shown in Part I. Payback periods and return on investment (ROI) of three buildings under different tariffs are shown in Part II. After that, comparison is done between Part I and Part II. The general steps taken to determine the payback period and ROI are as follows:



As for Part III, strategies and plans for supporting the growth of solar energy industry in Malaysia are proposed.

Payback periods of solar photovoltaic (PV) system for Feed in Tariff (FiT) scheme and revised Net Energy Metering (NEM) scheme are shown in Part I, at three different locations based on different sizes of system, monthly electric bills and DLs i.e. Tenaga Nasional Berhad (TNB) pricing & tariffs.

1. Tariff : A – Domestic Tariff
Location : Jinjang, Kuala Lumpur
Monthly electric bill : RM200, RM400, RM600

2. Tariff : B – Low Voltage Commercial Tariff
Location : Kampung Kedah, Parit Buntar
Monthly electric bill : RM2500. RM5000, RM7500

3. Tariff : C1 – Medium Voltage General Commercial Tariff
Location : Nibong Tebal, Pulau Pinang
Monthly electric bill : RM10,000, RM15,000, RM20,000

Payback period and return on investment (ROI) of solar photovoltaic (PV) system for Feed in Tariff (FiT) scheme and revised Net Energy Metering (NEM) scheme are shown in Part II, at three buildings of different locations under different DLs i.e. TNB pricing & tariffs which are shown as below:

1. Tariff : A – Domestic Tariff
Location : Jinjang, Kuala Lumpur
Building type : Single storey semi-detached

2. Tariff : B – Low Voltage Commercial Tariff
Location : Kampung Kedah, Perak
Building type : Fuel station

3. Tariff : C1 – Medium Voltage General Commercial Tariff
Location : Nibong Tebal, Pulau Pinang
Building type : Educational institution

3.2 Part I

3.2.1 Cost of Solar Photovoltaic (PV) System

In Malaysia, it costs around RM10,000 – RM15,000 for each system capacity of 1 kWp [18]. However, it is very difficult to propose an exact amount of money needed for a complete solar PV system. Therefore, the costs estimated for different sizes of solar PV systems with maintenance and operation costs included, are assumed as shown in Table 3.1 below.

For example, the total cost of a solar PV system, size 1.2 kWp, based on Table 3.1 is estimated at RM11,749.98 as shown in Table 3.2 below. For the rest of the study, the total costs of different sizes of solar PV systems are estimated according to Table 3.1.

Table 3.1 Costing of solar PV system

No	Item	Price	Remark
1	Components-Solar panel	RM1.00/ watt	300 watt solar panel (Alibaba price)
2	Components-Solar mounting system	RM0.55/ watt	Roof mounted solar mounting system. (Alibaba price)
3	Components-Inverter	RM1932/ kilowatt	RM8500 for a 4.4kW inverter. (Wholesale Solar price)
4	Components-Electric meter	RM1112/ unit	1 unit is needed for every solar PV system.
5	Free on board (FOB)	40 % of total component's price	Charges implied on buyer for shipping of goods.
6	Operation & Maintenance (25 years)	1.5 % of total component's price [35]	Average system lifespan is 25 years (Cost x 25).
7	Labour	RM1.50/ watt	-
8	Miscellaneous	5 % from total price	Includes application fee for different scheme, insurance, fee of study before application and etc.

**Assuming 1 USD = 4 MYR for the conversion of components' prices.*

Table 3.2 Total cost of 1 kWp solar PV system

No	Item	Price	Unit	Total
1	Components-Solar panel	RM1.00/ watt	1200 watt	RM1200.00
2	Components-Solar mounting system	RM0.55/ watt	1200 watt	RM660.00
3	Components-Inverter	RM1932/ kilowatt	1.2 kilowatt	RM2318.40
4	Components-Electric meter	RM1112/ unit	1 unit	RM1112.00
5	Free on board (FOB)	40 % of total component's price	-	RM2116.16
6	Operation & Maintenance	1.5 % of total component's price	-	RM1983.90
7	Labour	RM1.50/ watt	1200 watt	RM1800.00
8	Miscellaneous	5 % from total price	-	RM559.52
			Total	**RM11,749.98**