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Solar Technology and Implementations in Malaysia: A Review

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ABSTRACT

Over the years, the depleting non-renewable and increasing price of fossil fuels has encouraged growing interest in renewable energy (RE) sources. This paper presents the growth of solar or photovoltaic (PV) energy technology, implementations and its prospect particularly in Malaysia. The tropical weather of Malaysia with sunshine throughout the year increases the potential of the PV generation. PV systems can either be stand-alone or grid-connected systems. Besides that, PV systems can also be integrated with battery storage for backup purpose or export the excess electricity back to the grid. Although the PV technology has high potential to become the major source of electricity in the future, the investment of this technology is still high for which it remains as the major concern in the choice of PV energy generation option in Malaysia. In addition, the government has come out with renewable energy policy to support the generation of PV energy which has significantly increase the growth of PV deployment and PV industry in Malaysia.

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INTRODUCTION

Over the past decades, the world has been over-relying on non-renewable energy sources i.e. fossils fuel, coal, gas and petroleum oil as the main energy sources for power generations (Wei Yee Teoh, *et al*., 2012). A non-renewable energy resource is non-reproduceable energy and it ceased to exist along the time. Non-renewable energy is mainly produced by the burning of fossils fuels such as coal and petroleum oil (School., S., 2012). The burning process of the fossils fuels releases huge amount of carbon dioxides gas. A study conducted by the U.S. Energy Information Administration (EIA), found that each gallon of gasoline and diesel fuels will emits 19.64 pound or 8.909 kg and 23.28 pound or 10.151kg of Carbon dioxides (CO2) gases to the atmosphere (EIA., U.S.E.I.A., 2012). The high utilization of fossils fuels leads to increasing amount of the carbon dioxide and greenhouse gases emissions, resulting in world climate change and global warming issue. Fossil fuels such as gas, coal and petroleum oil currently the major supply of electricity in the world. As an example in Malaysia, the electricity is supplied by Tenaga National Berhad (TNB) in peninsular, Sabah Electric Supply Berhad (SESB) in Sabah and Sarawak Electric Supply Corporation Berhad (SESCO) as well as Independent Power Producer such as Malakoff, YTL and others which is powered by fossil fuels and hydroelectricity. The available capacity in Malaysia as of 31st December 2010 is 23.27 GW powered by steam and hydroelectric (National Energy Balance 2010). This capacity is expected to increase to 12000 TWh in 2050 with the addition of the renewable energy. Energy sources can be classified into three main types which includes chemical energy, nuclear energy and thermo-mechanical energy (Dresselhaus, M.S. and I.L. Thomas, 2013). The chemical energy relies on oxidization of some reduced substance i.e. hydrocarbon usually measured in electron volt (eV) while the nuclear energy is produced by the nuclear reaction either splitting the heavy nuclei (fission) or nuclear fusion of the light nuclei. The energy produced by the nuclear reaction is within the range of 10^6 electron volts (MeV). The thermo-mechanical energy can be in forms of wind, water or geological sources of steam or hot water usually energy produced in mili-electron volt (meV). Each of the energy sources has its own characteristics, disadvantages and advantages. Any process that used the fossil fuels creates pollution or contaminant. Energy released from the nuclear reaction releases huge amount of radioactive reaction while a hydroelectric plant

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requires the large dams and water sources. The fossils fuel such Petroleum Oil, gas and coal has its own lifetime and is expected to deplete in the next 50 years.

Thus in order to sustain the need of energy there are high growing interest on alternative energy system. A renewable energy sources is the natural energy resources that are free and constantly available from earth. Renewable energy source such as Solar, Solar Photovoltaic (Solar PV), Fuel Cells, Biomass, Biogas and small Hydro are consider the future prospect of energy. The Malaysia government through the Ministry of Energy, Green Technology and Water (KeTHHA), Energy Commission of Malaysia (STM) and Sustainable Energy Development Authority Malaysia (SEDA) in its announcement of 8^{th} Malaysia Plan, has taken initiative to encourage the utilization of renewable energy in Malaysia (Accessed on January 14 2013). The goals of the 8th Malaysia plan include a safe, cost-effective, secure energy supply which means promoting renewables, cogeneration, diversification, efficiency and using auditing, financial and fiscal incentives, technology development, and labeling (STM, S.T.M., 2013). Based on this the Malaysia government has taken the initiatives to promote the use of PV energy by introducing several projects, such as the Malaysia Building Integrated Photovoltaic (MBIPV), Suria 1000 and Feed-in Tariff. Through MBIPV and Suria 1000 projects, users who install PV are paid according to the amount of electricity which is supply back to the grid based on the tariff set by the government. Based on these factors Solar PV is gaining its popularity and consider as a worth renewable energy sources to be explore in Malaysia.

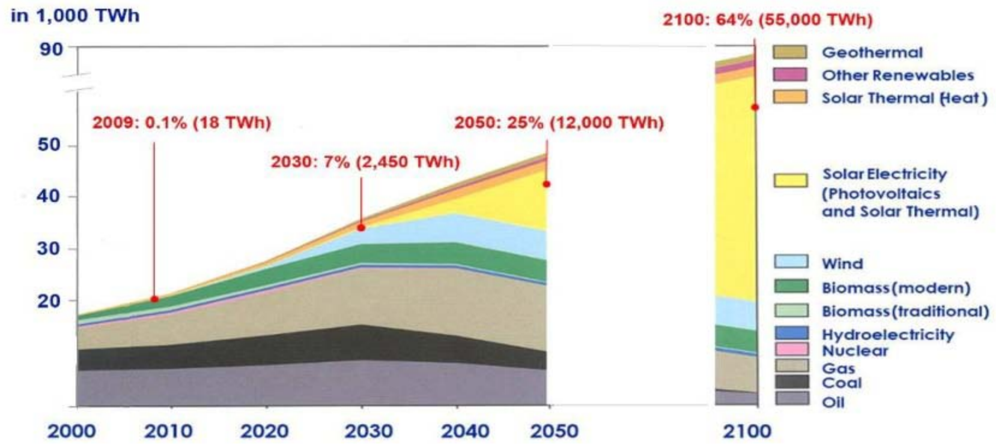


Fig. 1: Global energy outlook
Sources: Pusat Tenaga Malaysia (PTM) (Janssen, R., 2013)

Solar Pv:

Renewable energy is a naturally occurring energy sources that are free and constantly available. The sources of renewable energy can be from the sun, heat, wind or from other sources of energy within the earth. Renewable energy derives its electricity or heat from solar, wind, ocean, hydropower, biomass, geo-thermal resources, bio fuels and hydrogen (Ab Kadir, M.Z.A., *et al*., 2010). Solar energy and solar power generation have been identified by the scientist as the most important renewable energy sources for future sustainable energy supply. Scientists have predicted that the solar energy will consume more than 50% and 80% of the total renewable energy generated in the next 50 years (EPIA, E.P.I.A., 2012). Solar energy can be defined as the energy that is produced from the heat and incoming energy radiated from the sun. Solar energy can be categorized into two types i.e. Solar Thermal and Solar Photovoltaic. Solar thermal can be produced from Water Heating, Cooling and Ventilation Water Treatment, Process Heat, Cooking. Solar thermal is a non-produce able energy, thus it is classified as a non-renewable energy sources. The amount of energy produced by the solar thermal are mainly depends on the heat emitted from the other process. The greater the heat and temperature of the solar thermal, the higher the amount of energy produced.

Solar Photovoltaic cell on the other hands is a device that converts energy from sunlight into electric current using the photoelectric process. Solar PV cells are made up of layers of semi-conduction materials. Solar PV is easy to install and requires less maintenance as well as free from any kind of pollution and emission of carbon dioxides gases. Solar PV usually arranged in arrays and can easily fit on top of the residential or the building rooftops. Solar PV cells usually last more than 25 years. As illustrated in Figure 2, electrical energy is produced when the light from the sun flows through the layer of material of semiconductor within the photovoltaic cell, causing the electron to move to the proton layer and the thus movement of electron will produce voltage differential and when connected to load will caused the current to flows through the cells (Trust, E.S., 2012). The amount of electricity produced depends on the incoming energy radiated from the sun. The stronger the sunshine, the greater electricity produced (Wikipedia, 2012). The incoming energy radiated from the sun is expected to be at 171PW (Petawatts) where 50% of the total energy is absorbed by the land and the surface of the earth (SEDA., S.E.D.M, 2013). The Solar PV power usually measured in kWp (kilo-watts-peak) which is the rate of the maximum peak power that the cells can generate. The performance of the Solar PV are mainly depends on the climatic condition, the panel efficiency and the location as well as the position of the panel. The conversion efficiency of the Solar PV is small usually less than 40% with panel efficiency of 80%.The electrical energy converted from the photoelectric cell usually is in DC voltage. The DC voltage from the photoelectric cell can be used to turn on the light-bulb and at the same time can be used to charge the DC battery. The excess DC energy from the PV cell can be inverted to AC volt. and supplied back to the grid. The amount of the energy harnessed from the renewable energy sources can be sold to the government at the tariff set by the Sustainable Energy Development Authority Malaysia (SEDA) (Hitam, D.S.b., 2013).

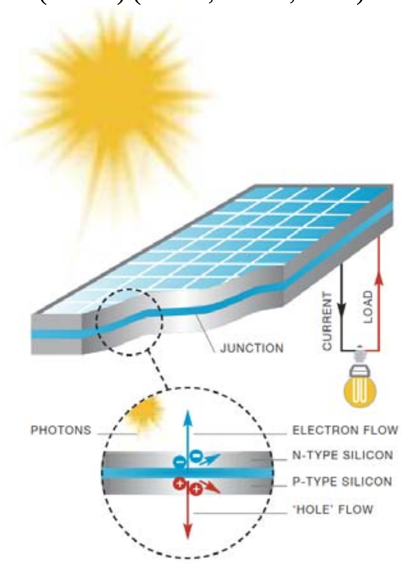


Fig. 2: Diagram of a Solar PV

The tropical climate in Malaysia with sunshine throughout the year will increase the potential of solar energy generation. Solar energy generated in Malaysia is expected to be four times the world fossil fuel resources (Ayu Wazira Azhari, *et al*., 2013). The average solar irradiation (annual) in Malaysia ranges from 4.21kWh/m^2 to 5.56$kWh/m^2$with the highest and lowest solar irradiation expected to be in August at 6.8$kWh/m^2$and November 0.61kWh/m^2 (Sung, C.T.B., 2013). Electricity produced by the Solar PV is mainly affected by the atmosphere, the clouds, ozone and the surface of the earth. The application of the Solar PV system mostly is for the household and domestic building. In Malaysia, total installed capacity of the Solar PV capacity was 3 MW includes the building of 0.44 MW integrated PV (BIPV) 2004. *(Report IEA-PVPS T1-14:2005).*

Pv System Overview:

Building Integrated Photovoltaic (BIPV) is a system that uses a Photovoltaic Material i.e. Cell or PV Panel mounted on the roof, skylights and facades of the building to generate electricity. Building Integrated Photovoltaic (BIPV) is not limited to electricity production alone but will be an integral part of the building to perform a specific function i.e. roof, window shading device and decoration facades (Integrated Photovoltaic). The main advantages of the BIPV system are the reduction in the system cost and improvement of the building interior appearances. By simultaneously serving both as a building decoration facades and power generator, BIPV system will help to reduce material and electricity costs by reducing the energy usage from fossil fuels and emission of the greenhouse gases. Building Integrated Photovoltaic (BIPV) system can be classified into two categories i.e. Grid connected and a stand-alone PV system. Stand-alone PV system is a system that requires a battery to operate and is commonly used in household electricity consumption, telecommunication and remote areas. A grid connected PV system is a PV system that is connected to the utility grid.

Stand-Alone PV system:

Solar PV can either be a Grid connected or a Stand-Alone system. Stand-Alone PV system is an independent PV system that may requires other alternatives energy sources i.e. Diesel Generator, Wind Turbine, DC Battery to generate electricity (Wikipedia, 2013). The stand-alone PV system is commonly used in household, rural and remote areas where the system was unable to connect to the grid. Stand-Alone PV system operates in such way that during day time, the incoming energy radiated from the sun is used to charge PV panel and produce electricity. Electricity produced by the Solar PV panels will be supplied to the users and residential house in rural areas. The excess energy from the Solar PV can be used to charge the DC battery and supply back to the grid during night time. The performance of the Stand-alone PV system depends very much on the climatic conditions and the size of the PV panel. In Malaysia, Solar PV system generation is expected to be 30% more than any similar system worldwide. Malaysia is having an advantage in harvesting the solar energy as it is located in the Equatorial region where the solar PV system can benefits the tropical weather as it will give abundant sunshine throughout the year. When considering the Stand-alone PV system, parameter such as load pattern, the position and location of the panel and the size as well as the climatic condition is needed to be considered. Wrong selection of the load and connection of the Solar PV system may result in lower system efficiency, generate harmonic distortion and may cause the mismatch between the load and inverter size.

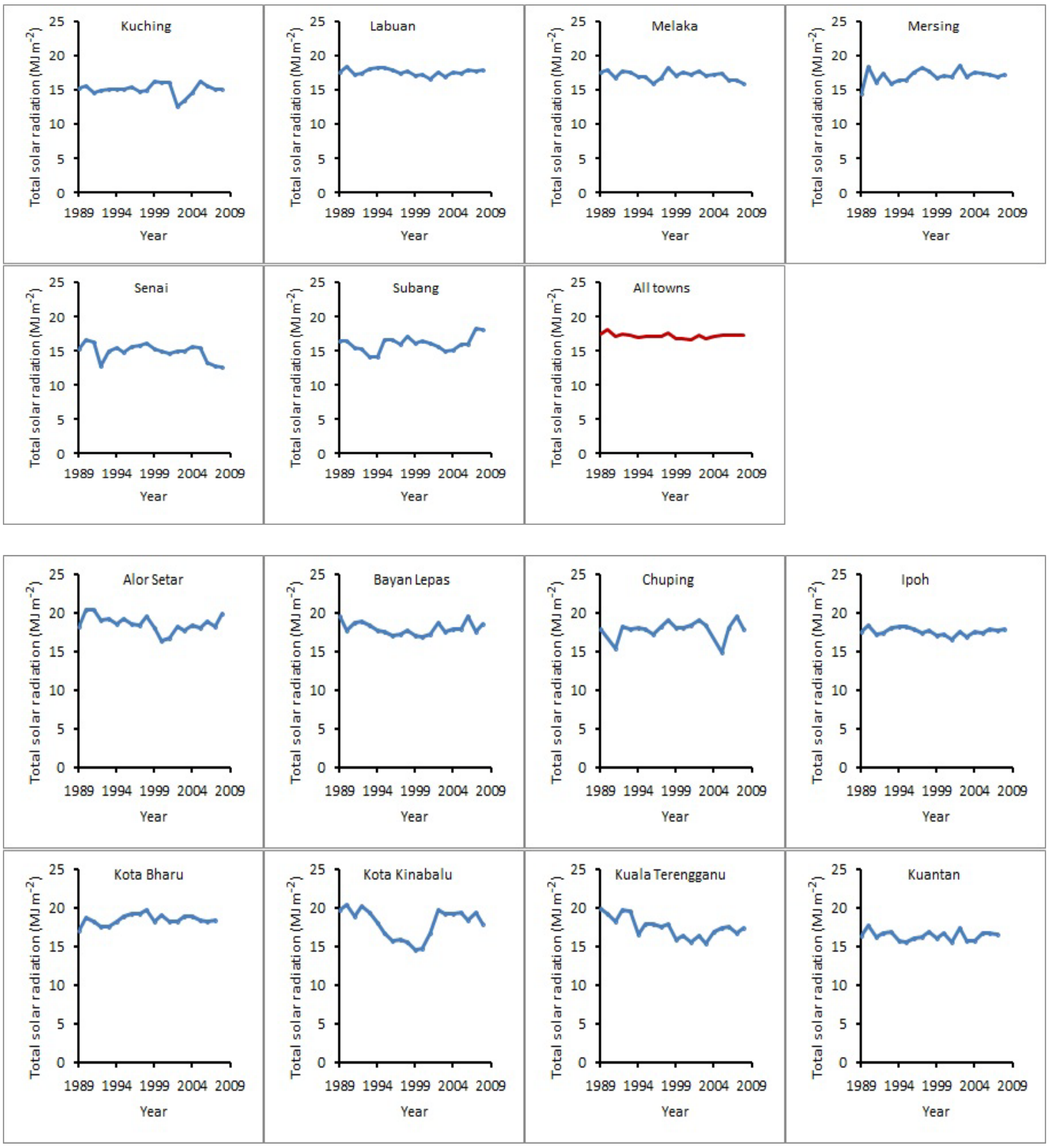


Fig. 3: Average daily solar radiation (MJ per sq. m) for some towns in Malaysia from 1989-2008 (Ir. Hadri Haris, N.P.L.)

Grid Connected PV System:

Grid Connected PV system is the Solar PV system that is connected to the utility grid. The installation of a Grid Connected PV system offers high financial incentives in terms of rebates programs, tax exemption and production incentives. In Grid Connected Solar PV system, users will be paid up to RM1.2 for each kWh of electrical energy supplied to the grid. This has made a Grid connected Solar PV the popular choices compared to other types of alternatives energy sources. The Grid Connected PV system operates in such way that during daytime the energy generated from the Solar PV will be used to supply the AC loads and the excess DC energy from the Solar PV will be sold back to the grid at a fixed tariff set by the government. In cases when peak demand occurred and the Solar PV are unable to provide the electrical energy required, the energy will be imported from the grid. A grid connected PV system can be installed in residential area, schools and the industrial area. Figure 4 shows an illustration of a Grid connected Solar PV system consists of the PV modules, Inverter, Electricity Meter and Power grid. An inverter is used to convert the DC energy from the Solar PV to the AC power to supply the AC load. The main advantages of the Grid Connected PV system are the secure supply of electrical energy and high return of investment (ROI) rate as well as the opportunity to utilize PV technology without the need of land use. There are several factors such as climatic condition, location, cost orientation and return of investment that need to be considered before implementing the PV system.

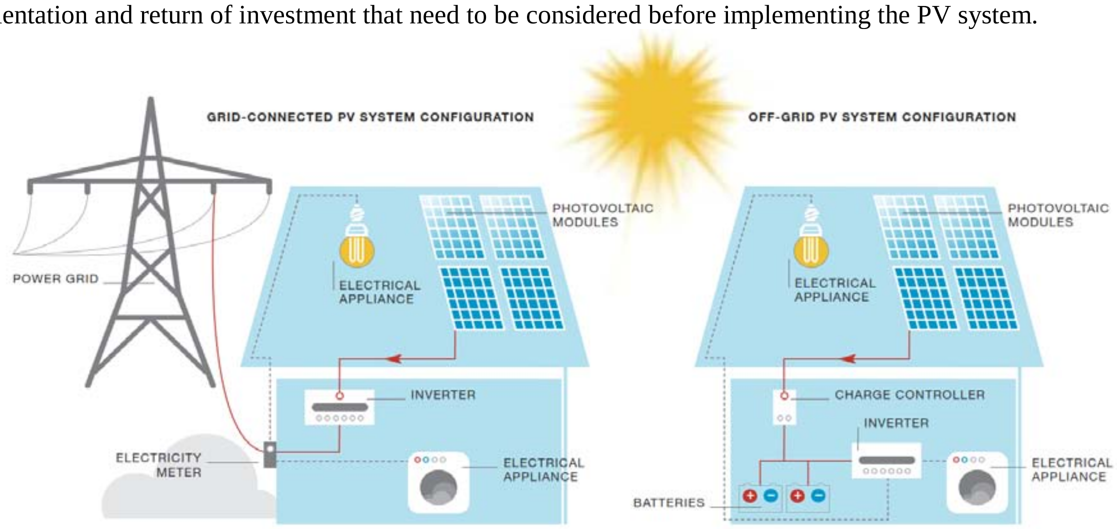


Fig. 4: Grid Connected and Stand Alone Solar PV system (Trust, E.S., 2012)

Energy Policies In Malaysia:

Although the renewable energy has become significantly important as potential energy source in the future, many industry and energy sector are still depending on non-renewable energy source. In Malaysia, the energy demands to supply more than 27 million population, industrial sector, transportation, and residential area with electricity is high. Thus there is a need to search for alternative energy sources as a backup plan for future. The development of renewable energy in Malaysia begins with introduction of the 8th Malaysia plan (2001-2005) in 2001. The 8th Malaysia plan has been initiated with initial purpose to encourage the research and the development of the renewable energy through the Ministry of Energy, Green Technology and Water (KeTHHA), "Suruhanjaya Tenaga Malaysia (STM)" and Sustainable Energy Development Authority Malaysia (SEDA). Ministry of Energy, Green Technology and Water (KeTHHA) has outlined three main objectives as the guidelines for the Research and Development of the new energy (Ministry of Energy. G.T.a.W., 2012). The objectives include securing supply of energy where the diversification of fuel sources needed, second to promote the efficient utilization of energy and to avoid the non-productive energy consumption, as well as to minimize the negative impact of the energy production i.e. contaminants, pollution and global warming (Accessed on January 14 2013). Government also had taken initiative to encourage the utilizations of renewable energy such as Solar Photovoltaic, Biomass, Biogas and small Hydropower through the "Sustainable Energy Development Authority Malaysia (SEDA)". The objective of SEDA was to enhance the utilization of renewable energy resource to contribute toward national electricity supply security and sustainable socioeconomic development (SEDA, S.E.D.M., 2013).

The development of renewable energy in Malaysia continues with the introduction of 9th Malaysia plan (2006-2010). The 9th Malaysia plan emphasis is placed onto the energy efficiency and nation energy challenge in line with the sustainable development agenda (Oh, T.H. *et al*., 2010). In 9th Malaysia plans, government has introduced more than ten policies act related to energy development to encourage the research and development of the renewable energy. These include National Depletion Policy 1980, Four Fuel Diversification Policy 1981, Electricity supply act 1990, Gas supply act 1993, Fifth Fuel Policy 2000, Energy Commission Act 2001, National Biofuel Policy 2006 and National Green Technology Policy (Malaysia, G.o., 2006; Muhammad-Sukki, F., *et al*., 2011; Muhammad-Sukki, F., *et al*., 2012; Chua, S.C. and T.H. Oh, 2011). National Depletion Policy and Four Fuel Diversification Policy has been implemented with the initial purpose to ensure the cost effective, secure and continuous supply of energy as well balanced utilization of national resource i.e. Oil, Gas, Hydro and Coal. The Four Fuel policy had been revised from time to time to ensure the continuity of supply and the avoid the over-dependent on a single energy sources (Oh, T.H., *et al*., 2010). In 1999, the Five-Fuel Diversification Strategy has been introduced. The Five-fuel diversification strategy is a revised version of the Four Fuel Policy (1980) with the initial to enhance the capacity of energy supply mix through the generation of renewable energy.

Five-fuel diversification goals is the ensure 5% contribution from renewable energy of the country electricity demand in 2005. In an approach to realize the goals, the Small Renewable Energy Power Program (SREP) is formed in May 2001. SREP main purpose is to support the government policy to enhance the utilization and development of renewable energy as the major fuel resource in Malaysia. SREP main focus is to support the implementation of a Grid connected Renewable energy on a small power station.

In addition, many projects such as Malaysia Energy Efficiency Improvement Programed (MIEEIP) and Centre for Education and Training on the Renewable Energy and energy efficiency (CETREE) and Demand Side Management (DSM) was also introduced by the government through KeTHHA to encourage the utilizations of the Renewable Energy and Energy Efficiency in Malaysia (Homer, H.O.M.f.E.R., 2006).

Feed In Tariff:

Feed-In Tariff is a scheme that will be paid to the user who generates renewable energy and supplied back to the grid. In other words, Feed-In Tariff is a return of investment of the renewable energy. Feed-In Tariff is proven to be the most effective mechanism and cost-effective way to encourage the generation of the renewable energy in Malaysia (Hashim, H. and W.S. Ho, 2011). Malaysia's Feed-In Tariff has outlined the rules for the Distribution Licensees (DL) to buy from Feed-In Approval Holders (FIAHs) the electricity produced from renewable energy sources and set the FiT tariff. The electricity supplied to the grid for a specific duration will be paid by the Distribution Licensees (DL) (Hitam, D.S.b., 2013). By guaranteeing the access to the grid and setting a favorable price per unit of renewable energy, the FiT mechanism would ensure that renewable energy becomes viable and long-term investment for entrepreneurs and industry.

In July 2010, the government led by the chief technical advisor Ministry of Energy, Ir. Ahmad Hadri Haris has announced the proposed Feed-In Tariff for the Solar Photovoltaic (Solar PV), Biomass, Biogas and Mini-Hydro (Haris. I.H., 2010). The proposed FiT tariff for 2011 is introduced to improvise the previous tariff. It is expected that with the new FiT tariff, the RE scenario in Malaysia will change drastically. Table 1 illustrated the new improvised tariff for renewable energy generation in 2011. As summarized in Table 1, the rate of amount electricity generated from Solar PV ranges from RM1.25 to RM1.75, Biomass ranges from RM0.24 to RM0.35, Biogas ranges from RM0.28 to RM0.35, Mini Hydro RM0.23 to RM0.24, Geothermal ranges from RM0.28 to RM0.46, Solid waste and sewage gas ranges from RM0.3 to RM0.46 ad Wind ranges from RM0.23 to RM0.35. The FiT rate for Solar PV is 50% higher than other renewable energy sources. The tariff factor has made Solar PV generation method more popular and higher investment value compared to others. Subsequently with the introduction of the Feed-In Tariff, the government has also introduced the displaced cost. The displaced cost can be defined as the average cost of generating and supplying electricity through the utility supply line and up to the point of interconnection with the renewable energy systems. The Solar PV system has the highest displaced cost at RM0.3504/kWh followed by Biomass, Biogas and Mini Hydro at a constant rate of RM0.2214/kWh. The displaced cost is estimated to increase by 0.5% every year (Haris, I.A.H., 2008).

Table 1: Proposed FiT in Malaysia

Renewable Energy	Duration (year)	Tariff RM/kWh (USD/kWh)[1]	Annual digressions	Displaced electricity cost RM/kWh (USD/kWh)[2]
Wind	21	0.23-0.35 (0.07-0.110)	1%	0.22 (0.07)
Solar PV	21	1.25-1.75 (0.39-0.54)	6%	0.35 (0.11)
Solid waste and sewage gas	21	0.3-0.46 (0.09-0.14)	1.50%	0.22 (0.07)
Biomass	16	0.24-0.35 (0.07-0.11)	0.20%	0.22 (0.07)
Biogas	16	0.28-0.35(0.09-0.11)	0.20%	0.22 (0.07)
Geothermal	21	0.28-0.46(0.09-0.14)	1%	0.22 (0.07)
Mini-hydro	21	(0.23-0.24)(~0.07)	0%	0.22 (0.07)

Sources: Feed In Tariff Outlook in Malaysia by SC Chua, Tick Hui Oh and Wei Wei Goh Multimedia University (MMU) Malaysia[32].

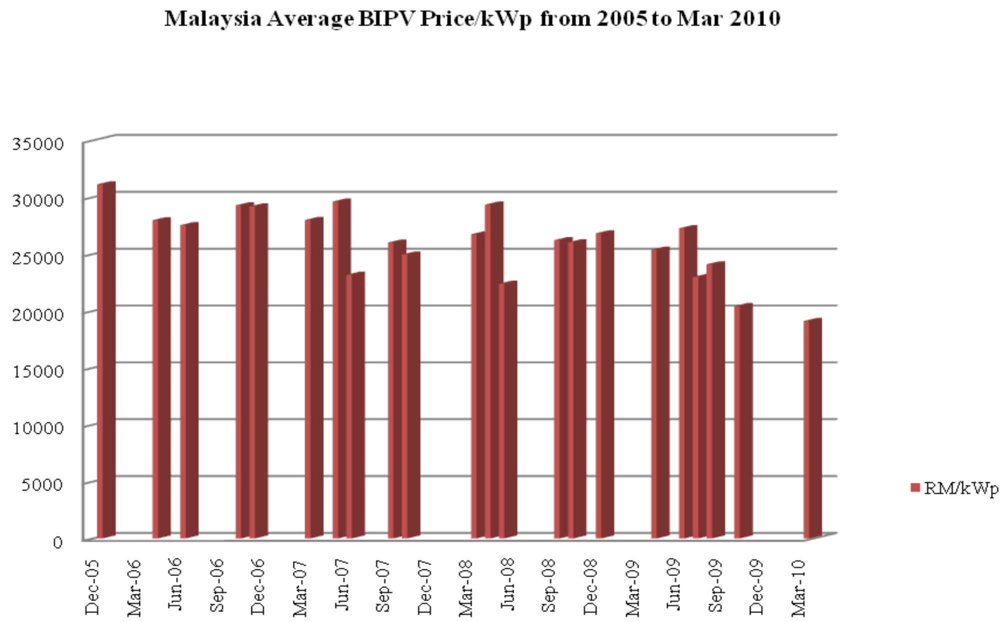
Solar Pv Projects In Malaysia:

Malaysian Building Integrated Photovoltaic (MBIPV):

Although the Solar PV has the potential to become the major sources of electricity in future, the cost for the Solar PV that is extremely high for mass production and will pose major concerns considering the renewable energy options (Ong, H.C. *et al*., 2011). Current market of a PV System rated at RM28/Wp (US$ 8.40) (Alia Farhana Binti Jamaluddin, U.P.M., 2009). The initial cost of the PV system that is extremely high that would make Malaysian entrepreneurs to think twice before placing any investment on the PV manufacturing. Most of the PV module and inverters was imported from the foreign country i.e. European, Japanese and China. The government has taken an initiative to reduce the cost of the Solar PV System by introducing the Malaysia Building Integrated Photovoltaic (MBIPV) in 2005 in association with Global Environment Facility disbursed through United Nations Development Programmed (UNDP/GEF) and various private sectors (MBIPV, M.B.I.P., 2011). The overall project cost of the MBIPV project is rated at USD 24,959,160.00. MBIPV system is a system that integrates the panels into the building design to provide electricity for the building uses. MBIPV system is connected to TNB utility grid to offer network and shaving the peak demands of the grid during the peak daylight hours. The system is able to provide up to 50% of the energy used in the building and operate in such a way that during daytime, the system will transfer the excess energy generated to the grid and during night time the system will import the energy back from the grid to use to cool the panels (Oh, T.H., *et al*., 2010).

The primary objective of the Malaysia Building Integrated Photovoltaic (MBIPV) is to reduce the long term cost of the BIPV system within the Malaysian market which will lead to the sustainable developments of BIPV technology in an approach to reduce the emission of the Greenhouse Gases from the electricity sector (MBIPV, M.B.I.P., 2011). The project is expected to be able to reduce approximately 65,100 tons of CO_2 emissions from the country power sector (Roster, S., 2010). The project objective can be achieved by developing and implementing strong financing mechanism, solid intuitional, policy framework, extensive education and awareness campaign, introduction of standards and guidelines, enhancing and promote the local industry to local manufacturing. In addition, the MBIPV project will also stimulate the other projects i.e. Demand Side Management and Energy Efficiency related to sustainable energy programs. The implementation of MBIPV project will lead to cost reduction of 20% per year and total 330% of cost reduction by 2010. As illustrated in Figure, after the implementation of MBIPV in Dec 2005, the average BIPV price has dropped from RM31k/kWp in Dec 2005 to RM19.1k/kWp in March 2010 which about 40% reduction. Currently, MBIPV system has been widely used in residential area, school and industrial area either off-grid or on grid connection.

Table 2: Malaysia Average BIPV Price/kWp from Dec 2005 to Mar 2010 (MBIPV, M.B.I.P. 2010)



In addition, the installed household MBIPV cell has the potential to save up to RM200 from total monthly electricity bill (the example is applicable only for monthly usage more than 400kWh). The example explained the potential saving of the monthly electricity bill with the PV system installed (MBIPV., M.B.I.P., 2010).

Example,
If the electricity usage per month is 1500kWh (without PV system installed),
The electricity bill will be at RM568.50 (current TNB tariff).
If the PV system rated at 5.25kWh generate 481.25kWh.
The total energy usage from TNB will be,
=1500kWh-481.25kWh
=1018.75kWh.
The new electricity bill with the PV system installed in the house is RM353.86 (current TNB tariff).
The monthly saving will be at RM214.64.

SURIA 1000 Projects:

Another Solar PV projects that is worth to mention in Malaysia is the Suria 1000 projects. Suria 1000 is a co-financed project of public (owner of the system), Suruhanjaya Tenaga (represent the government of Malaysia), and the PV industry (via the discount and the rebate of the PV system). The program was initiated in 2007 targeting the residential and commercial areas to establish the PV market and to provide direct opportunities to the public and industry in the renewable energy initiatives. The programmed basically offers the average household or businessman to generate and sell the solar energy to SESB and TNB with attractive returns. Suria 1000 projects offers up to 60% discount and rebate to encourage people to invest in the solar technologies. The Suria 1000 doesn't only promote the generation of solar energy through discount and rebate but also through the bidding of the Solar and MBIPV project in Malaysia as well (Mekhilef, S., *et al*., 2012). Starting from year 2007, the Suria 1000 project has been offered a limited number of grid connected solar system to the public through a bidding concept with the minimum capacity of 3kWp per application. The bidding of the project is organized by the administrated project team and promoted through local media. Successful bidders would then install a PV system as Building Integrated Photovoltaic (BIPV) supplied by the PV Service provider at their premises. The cost of the PV system is to be borne by the successful bidders at the bidding price and supplemented by the project (MBIPV, M.B.I.P., 2007). It forecasted that in future, the PV player will be able to offer the similar price of the PV system as in the most of the European country and Japan. Currently, the cost of 5kWp turn-key rooftops in Malaysia is about RM27000/kWp. Therefore, the estimated cost per 5kWp PV system is rated at RM135000 with approximately 6000kWh energy generated per annum. Recent call of bidding for the Suria 1000 projects is from 1st of July 2009 to 1st of December 2009 with the target BIPV capacity available for bidding at 340kWp and the maximum bidding incentives of 42% for the residential and commercial applications.

Latest PV project in Malaysia:

The tropical climate of Malaysia with sunshine throughout the year has increased the generation of Solar PV in Malaysia. In Malaysia, Solar PV panels is expected to absorb more than 30% of the total energy radiated from the Sun with the highest Solar irradiance measured in Sabah and East Malaysia. This had led to the development and implantation of Solar PV in Sabah and Sarawak. Recently, there has been a lot of ongoing research of the Solar PV in Malaysia especially in Sabah and Sarawak. The development of Solar PV in Sabah initiated with the installation of a 260kW Solar PV system in Kalabakan. The projects were initiated with the cost of USD2.6 million contract funded by Malaysia Ministry for Rural Development with the initial purpose to enhance and promote the generation of renewable energy in rural area in Malaysia. The Kalabakan project is a collaboration of TNB Research team and ERAMAZ property development which integrated the Solar PV with Diesel Generator and automated control to generate 260kW electricity for rural area in Kalabakan. The PV system for rural electrification in Malaysia was initiated by TNB in the late 1980 with the initial purpose to provide the electricity for house, island villages and remote areas in Sabah and Sarawak. The first implementation of Solar PV in Sabah and Sarawak is a Grid Connected Solar PV system. Grid connected Solar PV in Sabah connects the grid lines and rural area the State of Electricity Authority (PBEN), formerly known as Sabah Electricity Sdn. Bhd. (SESB), Sarawak Electricity Supply Corporation (SESCo) for Sarawak and TNB in Peninsular Malaysia. For rural and remote areas where the Solar PV system was unable to connect to the grid, the alternative energy sources i.e. Solar PV, Wind, Hybrid and Diesel Generator had been used to generate the electricity in Sabah and Sarawak.

Other PV Application in Malaysia:

a) Stand-Alone PV system in Malaysia:

In the announcement of the 8th and 9th Malaysia Plan from 1996 to 2005, the government has outlined an objective of approximately of 3MWp for rural electricity generation using a stand-alone PV system. The government has also encouraged the small solar devices generation and garden solar lights with the annual capacity of 1MWp. Furthermore, the idea of a solar street lights, road safety and telecommunications devices powered by a stand-alone PV system is fully accepted and considered by the local authorities and private enterprise. In recent developments of Stand-alone PV system in Malaysia, the School-Net Projects, island and rural electricity using Solar PV-Diesel Hybrid System and 24 hours electricity supply in school is launched. The 24 hours electricity supply in school project is expected to supply more than 200 schools in Malaysia with the approximation of 17kWp per school. The objective School-Net Project is to provide the PC and internets to all schools with PC and VSAT powered by the Hybrid of Solar PV-Diesel System. The project is expected to achieve its objective of 4kWp generation per school with the total generation of 1MWp in 2007. As of May 2010, the total of 9652 locations throughout Malaysia has been successfully installed with a School-Net system (MOE, M.o.E., 2009). In addition, 7 projects powered by the Solar PV-Diesel Hybrid Systems were launched by the government from May 2006 to December 2007. The projects objective is to supports the electricity generation in rural area and island. The project is expected to be able to generate up to 500kWp to supply the electricity for the Island and rural area in Sabah and Sarawak.

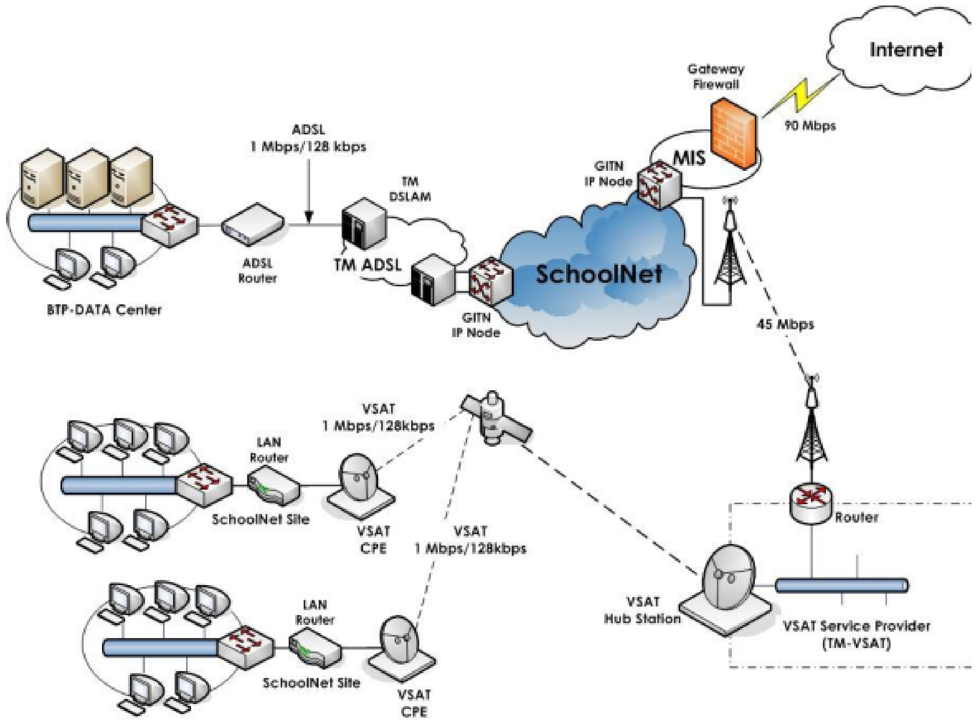


Fig. 5: Diagram of a School-Net System for VSAT-TM location.
Sources: School-Net Projects[41]

b) Grid Connected PV system in Malaysia:

The 1st ever grid connected system in Malaysia was installed in August 2008 on the rooftops of the College of Engineering, University Tenaga National (UNITEN). The installation is a part of the TNB Pilot Research Project owned by TNB Research Project (TNBR). The project was founded by the Malaysian Electricity Supply Industry Trust Account (MESITA) and Tenaga Nasional Berhad (TNB). The system is powered by a 42" Siemens 75Wp panels with the system capacity of 3.15kWp to supply electricity throughout the building. The objective of the installation of the PV system is to provide an introductory experience of grid connected system in Malaysia which is simple and operational with some technical issue. In the same year, two more grid connected PV systems were installed in Taman Solar, University Kebangsaan Malaysia, Bangi and BP petrol station in KESAS Highway. The systems are powered by the 72" BP Solar 80Wp and 106" BP Solar 75Wp PV panel with the system capacity of 5.76kWp and 8kWp respectively. In august 2000, the 1st Residential Grid Connected system was installed in at the residence of a TNB Senior Officer in Port Dickson. The system is powered by the 41" BP Solar 75Wp panels with the generation capacity of 3.15kWp. Subsequently, two more Grid connected PV systems were installed at the Solar PV Research and Monitoring Centre (Solar House) in Bangi and the residential house in Subang Jaya, Shah Alam. The systems are powered by 48" Solartech 75Wp and Kyocera 120Wp with the system capacity of 3.6kWp and 3.12kWp respectively. However, these BIPV systems were done on a retrofit and installed on top of the existing roof tiles. In addition, the installation residential PV system in Subang Jaya and Bangi has provided the practical experiences of the BIPV system to the homeowners and the project developers.

(i) (a)

(ii) (b)

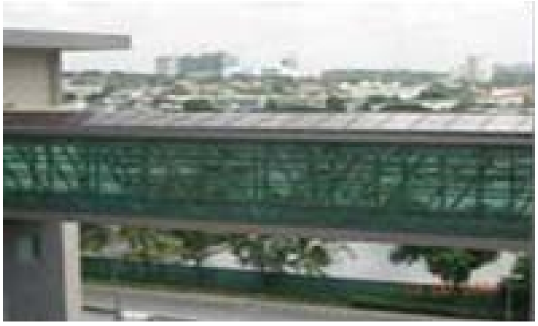
(iii) (c)

Fig. 6: (a) College of Engineering UNITEN, Bangi (b) Taman Solar, UKM Bangi (c) BP Petrol Station, KESAS Highway
Sources: PV system in Malaysia in 1999 (MBIPV, M.B.I.P., 2011)

Malaysia is taking the challenges of designing energy efficient building by taking initiatives to introduce energy savings in the construction and design of high rise buildings by improving the air flows as well as the use of Solar System in the lighting system and heating requirement (Amin, N., *et al*., 2009). In October 1999, the TNB Research Centre had installed a Grid connected PV system in a single-story house with the system capacity of 3.6kWp. Subsequently, the Prototype Solar House (PSH) was built in Kuala Lumpur as a part of the Industry Research and Grant Scheme (IGS) Project. The project was funded by the Ministry of Science, Technology and Innovation (MOSTI) with the initial objective to emphasize the multi-functional aspects of PV in buildings for urban residential of Malaysia (Safari, A. and S. Mekhilef, 2011). The Prototype Solar House (PSH) was built to demonstrate the technical and architectural integration of a PV system to a living house in Malaysia (Haw, L.C., 2011). Furthermore, in late 2005, a 5.25kWp BIPV system was installed on the rooftops of a bungalow in Semenyih. The PV system installed in Semenyih is powered by a 30” Sharp 175Wp panels and able to produce the power of 5.25kWp. The house is designed and built by the “Smart and Cool Home” technology through energy efficient approach. Since the house was built on energy efficient basis it helps to reduce the energy consumed from the grid and thus enhances the opportunity of the Solar PV generation in the house. Currently, there are almost 500kWp of Grid Connected PV systems installed in Peninsular Malaysia, with the highest capacity generated at Technology Park Malaysia (TPM) at 362kWp (MBIPV, M.B.I.P., 2011). The PV installation at Technology Park Malaysia (TPM) has demonstrated Malaysia’s capabilities in handling and managing a large PV system. Moreover, other BIPV system installation can also be found in local university, TNB Research Centre and School.

Advances in Natural and Applied Sciences, 7(5) December 2013, Pages: 542-555

(i) (a)



(ii) (b)

(iii) (c)

Fig. 7: (a) University Teknologi Malaysia, Skudai (b) Monash University, Kuala Lumpur (c) Sek. Men.Keb San Min, TelukIntan.
Sources: PV system in Malaysia (MBIPV, M.B.I.P., 2011)

Pv Industry In Malaysia:

The Malaysia government in its announcement of GREEN Technology in July 2009 has outlined objective for the Renewable Energy generation capacity of 1GW and 1.25GW by 2015 and 2020. Energy Commission of Malaysia (STM) has estimated that 6500kWh can be generated by using 40% of nation roof tops (2.5 million houses) and 5% commercial building (Bhd, A.E.S. and L. Ann's, 2012). Solar PV manufacturers such as First Solar, Q-Cell, AUO and Sun Power unit and MEMC have spread their manufacturing wings to Malaysia. First Solar, an American manufacturer of PV modules has launched their Solar PV manufacturing plants in Kulim Hi-Tech Park Kedah in 2007. First Solar uses cadmium telluride (CdTe) semiconductor material to produce the Solar PV panel. First Solar is supported by 6 plants in Kulim with the generation capacity of 1.5GW. Sun Power and AU optronics started their PV panel production in 2011 with the capacity of generation of 5MW and the highest conversion efficiency of 22.5%. The plants have installed Solar PV panel in the rooftops and in the parking garage to help supports the generation of Solar PV. The innovative design of the plants is expected to produce excess of 10MW per year. Furthermore, Sun Power and AU Optronics have started the construction of their new manufacturing plants respectively. The plants are expected to be operational by 2013 with the generation capacity of up to 1400MWh supported by 28 production lines.

Recently, the Japanese electronics manufacturer, Panasonic (M) Sdn. Bhd. has announced the construction of a new PV manufacturing plant in Kedah. The plant is expected to be operational by the 4^{th} quarter of this year with the generation capacity of 300MW. The plant is expected to be supported by 1500 local employees and will focus on solar wafers, modules and cell production to produce Panasonic HIT voltaic module. Furthermore, the German giant manufacturer Bosch and Twincreek Technologies have also stated their intention to increase the production of PV panel in Malaysia (Engineur, D., 2012). Furthermore, the Malaysia Solar Resources and TS-SOL Lite have also begun their manufacturing plants in Malaysia. Malaysia Solar Resources first went into production in 2011. The plants which is located in Kuantan, Pahang produces Mono-crystalline and Polycrystalline PV panel with power ranges from 185Wp to 315Wp (Resource, M.S., 2012). TS-SOL Lite begin its operation in 2003 in Selangor. The plants produces PV panel for Solar PV generation and specialize in design and manufacture the integrated Solar PV system i.e. PV standalone, PV Hybrids and Grid connected PV systems (Malaysia, T.-S.L., 2012).

Solar Pv Prospect In Malaysia:

The development of renewable energy in Malaysia begins with the introduction of National Energy Policy (NEP79), National Depletion Policy (NDP80), Four Fuel Diversification Policy (4FDP81) and Fifth Fuel Policy 2000 (5FP2000). The objectives of the project are to ensure secure supply and full utilization as well as minimizing the negative impact to the environment for both Renewable and Non-Renewable energy. In the expense of availability and fossil fuels price, the National Energy Balance (NEB) has been introduced. The objective of the National Energy Balance is to ensure the secured supply of renewable energy using a systematic energy data and trends approach (Ministry of Energy, G.T.A.W. 2012). National Energy Balance (NEB) acquires and analyzes energy data from the Malaysia Energy Databases and Information System (MEDIS). MEDIS is the main database and information center for economic, demographic and other energy related data (Malaysia, G.T., 2012). In the expense of the high GDP and population raise, the GREEN Energy Tech has been introduced in Malaysia. Green Tech's main purpose is to enable the regional and worldwide publication by combining local and international energy data. The Green Tech in Malaysia started with the introduction of Malaysia Energy Centre (MEC) in 1997. MEC has played major part in energy policy research, guardian and repository of national energy database, promoter of the national RE and EE program, coordinator, lead manager in energy research and development as well as demonstration of Green Technology related projects. The development of Green Tech in Malaysia continues with the introduction of Green Tech Council, Green Vehicles, Green Township, Green procurement and eco-labeling, Green Job creation, Green Conferences and Green awareness program. Besides that, the Green Tech in Malaysia also offers benefit and incentives such as the net saving of USD1 and 1.5 billion for energy cost and infrastructure developments and reduction of non-renewable energy usage in Malaysia. Recently, several local universities in Malaysia has undergone the research and development of Renewable Energy related equipment including inverters, PV concentrators, Solar cell fabrication and characterization, hybrid systems and energy conversion tracking programs to enhanced the generation of renewable energy in Malaysia. This includes the ongoing research and development of Solar Cell by University Science Malaysia (USM), the development of 5kW grid connecter inverter and EV car, development of 3kW Grid Connected Inverter by University Malaya (UM) and the development of PV system and concentrator by University Technology Mara (UiTM) and TNB Research Sdn. Bhd. (Energy, D.A.F.R., 2010). The research of renewable energy was funded by the Ministry of Science, Technology and Innovation (MOSTI). Furthermore, the government had also taken an initiative to encourage the generation of renewable energy by enhancing the FiT rate and introducing Renewables Energy related project such as Small Renewable Energy Program (SREP), Malaysia Energy Efficiency Program (MIEEIP), Centre of Training and Education in Renewable Energy and Energy efficiency (CETREE), Biogen, MBIPV and Suria 1000 projects. MBIPV and SURIA 1000 project aim to reduce the initial cost of the Solar PV in Malaysia by offering a remunerative return of investment for Solar PV through the selling back of the energy to the grid at a tariff set by the government. However, due to high initial cost and electricity tariff for Solar PV, the solar energy was not included in the SREP.

Conclusion:

In a nutshell, the development of the future renewable energy sources is very important towards future's sustainable and efficient energy, as well as secured supply of energy sources. The renewable energy such as Solar PV is the most promising energy sources for the future. Solar extracts energy from the Sun which is free and produces less contaminant. Although the cost for the Solar PV i.e. Malaysian Building Integrated Photovoltaic (MBIPV) is expensive and generates less amount of energy as compared to other alternative sources i.e. Nuclear and Hydro but the government policy which supports the invention of the Solar PV by paying back the energy generated from Solar PV panel to the grid through a system called "Feed-In Tariff" makes solar a worthy renewable energy. It helps to reduce monthly electricity bill for a heavy consumers such as industrial and transportation. Besides, installation of Solar PV panel on the building or the residential house

Advances in Natural and Applied Sciences, 7(5) December 2013, Pages: 542-555

rooftops will also help to improve the exterior appearance of the building. Furthermore, the PV industry in Malaysia has grown significantly with many Solar PV manufacturers around the world expands and builds their new manufacturing plants in Malaysia. The government has outlined milestone that by the year 2020, 1.25GW capacity will be generated by Solar PV.

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