Potential of Solar Energy in Kota Kinabalu, Sabah: An Estimate Using a Photovoltaic System Model

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Abstract. Solar energy is becoming popular as an alternative renewable energy to conventional energy source, particularly in the tropics, where duration and intensity of solar radiation are longer. This study is to assess the potential of solar energy generated from solar for Kota Kinabalu, a rapidly developing city in the State of Sabah, Malaysia. A year data of solar radiation was obtained using pyranometer, which was located at Universiti Malaysia Sabah (6.0367° N, 116.1186° E). It was concluded that the annual average solar radiation received in Kota Kinabalu was 182 W/m². In estimating the potential energy generated from solar for Kota Kinabalu city area, a photovoltaic (PV) system model was used. The results showed that, Kota Kinabalu is estimated to produce 29,794 kWh/m² of electricity from the solar radiation received in a year. This is equivalent to 0.014 MW of electricity produced just by using one solar panel. Considering the power demand in Sabah by 2020 is 1,331 MW, this model showed that the solar energy can contribute around 4% of energy for power demand, with 1 MW capacity of the PV system. 1 MW of PV system installation will require about 0.0018% from total area of the city. This assessment could suggest that, exploration for solar power energy as an alternative source of renewable energy in the city can be optimised and designed to attain significant higher percentage of contribution to the energy demand in the state.

1. Introduction

Energy use nowadays has become a very critical concern in the last decades because of rapid increase in energy demand. The increased concerns for environmental impacts of conventional fossil fuels most importantly those related to global warming have been the major aspect driving the transformation towards green energy. This generation of power most favorably from renewable energy resources those is abounding and free [1]. Governments and industries from all around the world are progressively looking for ways to reduce the greenhouse emissions from their actions. One major way is to focus on the application and installation of sustainable renewable energy systems [2]. Among all the renewable energy resources, solar power attracted more attentions as one of the greatest promising option since it has many benefits compare to other resources such as wind and hydro energy. Solar energy is naturally free available and clean energy source which derived from the sun that can be harnessed directly to generate electricity [3]. No emission of pollutant, low maintenance and high reliability, with life span expectation of 20 until 30 years made solar power a favorable source of energy to be utilized in the future time [4].

Malaysia introduced new fuel mixed strategy from Four to Five-Fuel Diversification Strategy in year 2002 [5]. Since then renewable energy (RE) is considered as the 5th fuel for the new alternative
source Malaysia plans to attain 985 MW contribution of renewable energy in the energy mix in year 2015 [5]. At the present, renewable energy provides less than 1% to the energy mix in Malaysia. By 2020, the aim is for renewable energy to comprise 11% of overall electricity generation in the country. This aim can help to prepare to achieve much long ambitious target to 25% of total usage of renewable energy by year 2050 [6].

Malaysia as an equatorial country has an approximate of 4,000–5,000 Wh/m$^2$ of daily average solar radiation and a yearly average of 1,643 kWh/m$^2$ of the radiation received [7]. Considering that Malaysia gets on average 4–8 hour of free sunshine every day, the potential for solar power generation is very huge and estimated at four times the world fossil fuel resources [8]. Between 1998 and 2002, six pilot grid-connected PV systems were installed with power system capacity vary from 2.8 kWp to 3.8 kWp [9]. By the end of 2005 there were almost 470 kWp of grid-connected PV systems installed in Peninsular Malaysia which one of the most significant is the 362 kWp system at Technology Park Malaysia (TPM). The PV installation at TPM showed Malaysian ability to handle and manage large scale of PV installations [9].

The involvement from the pilot grid-connected projects indicated that such PV applications in Malaysia are indeed reliable and could produce 1.3 times more electricity when compared with similar installations in Germany. The most important is the energy yields are rather stable from month to month since Malaysia is enjoying the tropical weather throughout the whole year. The utilization of solar energy through PV has a huge potential providing several advantages such as BIPV (building-integrated photovoltaic). BIPV system does not need extra land and it generates electricity at the point of use thus reducing electricity transmission losses [10]. Taking into account that only the lower PV capacity value of 1 kWp for every 10 m$^2$ of available building roof surfaces in these areas the technical potential is around 11,000 MWp which could supply more than 12,000 GWh of solar-generated electricity. This is equivalent to 20% of the national energy demand [10].

1.1. Advantages of solar energy

Solar energy is clearly environmentally advantageous compared to any other energy source. It does not consume natural resources, does not cause CO$_2$ or other gaseous emission into the air or produces liquid or solid waste products. Relating to sustainable energy development, the main direct or indirectly derived advantages of solar energy are the following [11–14]:

- no emissions of greenhouse
- reclamation of degraded land
- scaling down of transmission lines from electricity grids
- improvement of quality of water resources
- increase of regional energy independence
- diversification and security of energy supply
- acceleration of rural electrification in developing countries

1.2. Photovoltaic (PV) systems

The process of photovoltaic consist a solar cell converts energy in the photons from the sunlight into electricity by means of the photoelectric phenomenon found in certain types of semiconductor materials such as silicon and selenium [15]. The efficiency of solar cells depends on temperature, solar radiation, spectral characteristics of sunlight and so on. Currently, the efficiency of photovoltaic cells is about 12–19% at the most promising conditions. Table 1 presents PV technology goals that have been accomplished between 2000 and 2005 [15]. Solar cell research continues to improve the efficiency of solar cells with targets aimed towards the present accepted limit of 25-30% [16]. The efficiency of another renewable energy such as biomass is much, much lower – perhaps less than 1%. Table 2 shows the cost comparison of energy sources in 2015 [17]. It shows that solar energy is still considered as one of the most expensive among all the renewable energy costs. But the cost of the PV modules is decreased and expected to be keep decreasing in the future [18]. The basic PV module is interconnected and enclosed panel of PV cells has no moving parts and it can last more than 30 years.
The best way to ensure and extend the life and effectiveness of the PV system and any other energy source system is by having it installed and maintained properly [19]. Energy Return on Investment (EROI) is used to compare the quantity of energy supplied to the quantity of energy used in supply process. The higher the ratio the less energy is consumed in producing the energy. Energy balance is the amount of time needed to pay back the energy consumed. The lower the payback time, the sooner the machine starts producing energy that is renewable. Energy Return on Investment = Quantity of energy supplied / Quantity of energy used in supply process [20].

| Parameters                  | 1995 | 2000 | 2005 |
|-----------------------------|------|------|------|
| PV modules efficiency (%)   | 7-17 | 8-18 | 10-20|
| PV modules cost ($/Wp)      | 7-15 | 5-12 | 2-8  |
| System life (years)         | 10-20| >20  | >25  |

Table 1. PV technology goals been accomplished

| Power Plant Type     | Cost ($/kW-hr) |
|----------------------|----------------|
| Coal                 | $0.10-0.14     |
| Natural Gas          | $0.07-0.13     |
| Nuclear              | $0.10          |
| Wind                 | $0.08-0.20     |
| Solar PV             | $0.13          |
| Solar Thermal        | $0.24          |
| Geothermal           | $0.05          |
| Biomass              | $0.10          |
| Hydro                | $0.08          |

Table 2. Cost comparison of energy sources 2015

PV systems mainly categorized into 2 main groups which are stand-alone and grid connected systems [21, 22]. Figure 1 shows the components of the PV systems. In summary, a PV solar system consists of three parts which are PV modules or solar arrays, balance of system and electrical load [23]. Large-scale application of this technology is mainly hindered by the high cost of PV panels.

![Figure 1. The components of a PV system](image)

2. Study Area
Kota Kinabalu city is the capital of the state of Sabah in Malaysia. This state experiences a typical equatorial humid climate with high humidity, heavy rainfall usually in the afternoon, and the temperatures are uniformly high and extremely invariable throughout the year. The climate is generally hot and sunny all year round. Kota Kinabalu is also under the influence of monsoons which are the northeast monsoon (NEM) from November to March, southwest monsoon (SWM) from May to September and inter-monsoon (April and October) [24]. Kota Kinabalu is the most populous city in Sabah state with 462,963 totals of population with area size of 351 km² [25].
2.1. History of electricity supply performance in Sabah

Malaysia is divided into West and East Malaysia by the South China Sea as shown in Figure 2. By the geographical partition, the electric power supply is distributed by three independent grids which are West Malaysia Grid serving all the states in West Malaysia, Sarawak Grid serving Sarawak state in east Malaysia and Sabah Grid serving Sabah state in east Malaysia [26]. Since Sabah Grid is not interconnected to the other power systems, electricity is supplied from all the power plants within Sabah state. The existing Sabah Grid consists of the East Coast grid and West Coast grid, as shown in Figure 3.

![Figure 2. Map of Malaysia with Sabah as one of the 13 states [27]](image)

![Figure 3. Sabah grid consisting West Coast grid, East Coast grid and East-West grid inter-connection [28]](image)

2.2. Peak demand for electricity

Peak demand for electricity in Sabah from 2014-2023 is expected to grow at a rate of 5.13% per annum. Historically, peak demand growth from 2007-2013 was at an annual average of 6.78%. Table 3 shows the long term load forecast of electricity generation and peak demand for Sabah until the year of 2020. It is shown that by 2020 the electricity peak demand is forecasted to be 1,331 MW [29].

| Year | Generation (GWh) | Peak Demand (MW) |
|------|------------------|------------------|
| 2010 | 4,726            | 773              |
| 2011 | 4,940            | 830              |
| 2012 | 5,147            | 828              |
| 2013 | 5,506            | 874              |
| 2014 | 5,831            | 917              |
| 2015 | 6,253            | 983              |
| 2016 | 6,687            | 1,050            |
| 2017 | 7,132            | 1,119            |
2.3. Electricity generation mix
Sabah is relying heavily on gas-based electricity generation. It is apparent in terms of generation mix as shown in Figure 4. For the generation mix recorded in 2013, gas based generation had the highest share of 67%, followed by marine fuel oil (MFO) and diesel at 21%, hydro at 8% and biomass at 4% [29]. From here it can be seen that renewable energy resources contributed at 12% which combined from both biomass and hydro energy resources. Currently, there is no utility-scale solar PV or large solar power energy that contributing in electricity generation in Sabah.

![Figure 4. Electricity Generation Mix in 2013 (GWh)](image)

With the rapid increasing of development and as well the annual population in Kota Kinabalu, Sabah, the power demand in this city certainly will also increase. The question is the current power supply would be enough to fulfill this power demand and until when. Clearly fossil fuels are finite and it's only a matter of when they run out. By 2050, one-third of the world's energy will need to come from renewable energy resources such as solar, wind, hydro and other. This paper focuses on studying the potential of solar energy as another renewable energy power source to produce and contribute providing electricity in this area. Therefore, this research was purposely to estimate the solar energy that can be produced in this city.

3. Methodology
There are two phases of methodology in this study. The first is to analyse a year climatic data of solar radiation received in Kota Kinabalu, Sabah and the second is to estimate the solar energy potential by using a PV system model. Statistical analysis of the PV system is presented next to show and compared the accuracy of the PV system model used with study that had been done before.

3.1. Solar radiation data analysis
Solar radiation data are available for many locations on an hourly basis. For that reason many simulation studies of solar energy systems have generally used these hourly values to predict long-term annual performance. However, solar radiation can displays broad difference during an hour. The analyses presented by Vijayakumar et al. [30] confirmed that the variations in solar radiation within an hour cannot be considered insignificant when conducting performance analyses of solar energy systems. Therefore, a short-term data (for every 10 minutes) is considered to carry out this study.

The most accurate measurements of solar radiation are obtained by a pyranometer or pyrometer plant at a location for a number of years, usually more than a decade in order to measure the direct radiation every few minutes. However, the volume of data generated by this process makes it impractical to supply the full data set for each location for PV system design. Instead, the data collected can be presented in some other formats. The most conceptually straight forward method of reducing and arranging the data set is to average the data over the measuring period. This form of data is called average daily, monthly or yearly radiation data. The average solar radiation data, particularly...
for each month of the year is also extensively used in rough prediction on the total of PV panels required [31]. In this study, annual average solar radiation is used to estimate the amount of PV panels using a PV system model.

3.2. The photovoltaic (PV) system model

This PV system model is basically a calculation to find the solar energy output of a PV system. The global formula to estimate the electricity generated in output of PV system is [32];

$$E = A \times r \times H \times PR$$

Where;
- $E$ is the energy output (kWh)
- $A$ is the total solar panel area ($m^2$)
- $r$ is the solar panel yield (%) 
- $H$ is the annual average irradiation on tilted panels (shadings not included) (kWh/m$^2$)
- $PR$ is the performance ratio, coefficient for losses

Table 4 shows more detailed how to estimate the solar energy produced by using this formula. Below are the characteristics of the solar panel that been used in this PV system model.

One solar panel area $= 1.6 \, m^2$

Electrical power $= 250$ Watt peak (Wp)

The yield of the solar panel ($r$) is given by the ratio: electrical power (in kWp) of one solar panel divided by the area of one solar panel. Total power of the PV system can be calculated by multiply the electrical power of one solar panel to the total of solar panels used. $H$ is the annual average of solar irradiation that received in Kota Kinabalu, Sabah, as analyzed in the first phase of this study methods. PR is the performance ratio of the whole PV system. This is the coefficient for losses (default value = 0.75). These losses are depending on the site of the system, technology used, and sizing of the system. As shown in the table, the losses are include inverter losses, temperature losses, DC (direct current) and AC (alternating current) cable losses, shadings, weak irradiation and dust.

### Table 4. PV system model

| a = One solar panel area (m$^2$) | 1.6 |
| b = Total solar panel used |
| A = Total solar panel area (m$^2$) |
| d = Electrical power of one solar panel (Wp) | 250 |
| r = Solar panel yield (%) | 15.63 |
| Total power of the system (kWp) |
| H = Annual average irradiation on tilted panels (shadings not included) (kWh/m$^2$) |
| Losses details (depend of site, technology, and sizing of the system) |
| - Inverter losses (6% to 15 %) | 8% |
| - Temperature losses (5% to 15%) | 8% |
| - DC cables losses (1 to 3 %) | 2% |
| - AC cables losses (1 to 3 %) | 2% |
| - Shadings 0 % to 40% (depends of site) | 3% |
| - Losses weak irradiation (3% to 7%) | 3% |
| - Losses due to dust, snow etc. (2%) | 2% |
| - Other losses | 0% |
| PR = Performance ratio, coefficient for losses (range between 0.9 and 0.5, default value = 0.75) | 0.75 |
| E = Energy Output (kWh) |
3.3. Statistical analysis of the photovoltaic system model

Statistical analysis of the PV system model can be referred to a study by Lim et al. [33]. Based on the measurement data on the solar radiation at Kota Kinabalu, Sabah, the annual energy output of 1 kWp of PV panel is 1,600 kWh. The study showed that when Kota Kinabalu receiving 1,600 kWh of solar radiation, 1 kWp capacity of PV system will produce 1,600 kWh of energy. The performance of those PV panels systems is estimated with 100% efficiency of solar cell yield with no energy is considered lost during the photoelectric occurred for every area of 1 m\(^2\) of the solar cell. There is also no energy assumed to be lost in the whole sized of PV system (0% losses in inverter, temperature, DC&AC cables, etc.). A study by Borhanazad et al. [34] not only calculated the average solar radiation but also the peak solar hours (PSH). PSH is used to indicate solar irradiation in a specific location when the sun is shining at its maximum value for a certain number of hours. Since the peak solar radiation is 1 kW/m\(^2\), the number of peak sun hours is numerically equal to the daily solar radiation in kWh/m\(^2\). For example, the daily output of solar array can be estimated to be 535.3 Wh, if 100 Wp solar array is installed in Sabah with an average solar radiation of 5.35 kWh/m\(^2\)/d. The PV system model that been used in this study is more specific and detailed where some loss is considered occurring in the system.

4. Results and Discussion

The results and discussion of this study are presented in two parts, which the first is the output of analyzed data of solar radiation received in Kota Kinabalu, and the second is the solar energy potential produced estimated by using the PV system model.

4.1. Solar radiation in Kota Kinabalu, Sabah

A year climatic data of solar radiation was obtained from pyranometer that located at Universiti Malaysia Sabah. Figure 5 shows the monthly average solar radiation received at Kota Kinabalu in 2014. Among the highest solar radiation received was during in February, March and the peak time during in April with 201.77, 221.26 and 224.25 W/m\(^2\) respectively. November received slightly lower among the higher readings with 193.78 W/m\(^2\). January and December was received the less solar radiation with 151.77 and 156.81 W/m\(^2\) respectively. May until October received almost the same amount of solar radiation with 176.51, 171.63, 164.84, 173.10, 177.47 and 168.35 W/m\(^2\) respectively. Overall, the annual average of solar radiation received in Kota Kinabalu was 182 W/m\(^2\).

Despite of rainy season (NorthEast monsoon) in the South East Asia during month November until March they still have tendency increase of solar radiation compare to other months. This is caused by the difference of rainfall regime in this region. The northwest coast of Sabah (including Kota Kinabalu) experiences a rainfall regime of which two maxima and two minima that can be distinctly identified. The primary maximum occurs in October and the secondary one in June. As shown in Figure 5, month October and June are among the months with low amount of solar radiation. The primary minimum occurs in February and the secondary one in August. While the difference in the rainfall amounts received during the two months corresponding to the two maxima is small, the amount received during the month of the primary minimum is substantially less than that received during the month of the secondary minimum. Therefore, month February has tendency higher solar
radiation since it received less rain compare month August as the secondary minimum. It can be deduced here that month November until March has higher average of solar radiation because in northwest coast of Sabah they received less rainfall compare with the other months. In some areas, the difference of rainfall is as much as four times.

4.2. Solar energy potential

Before using the photovoltaic (PV) system model, all the solar radiation data retrieved from the pyranometer in W/m² unit has to be converted into kWh/m² unit. Figure 6 shows the daily and monthly average solar radiation after the conversion. The annual average solar radiation received in Kota Kinabalu was 1,590 kWh/m². This means that Kota Kinabalu receiving around 4.4 kWh/m² daily average of solar radiation. This high amount of solar radiation is obviously giving solar energy a huge potential to be harnessed to produce electricity. Higher solar radiation will produce more electricity through the PV system practically, but technically it will still depend on its system performance and the impact of environmental on it.

![Figure 6. Solar radiation received (kWh/m²)](image)

In this PV system model, only one solar panel was used to estimate the energy produced. One solar panel will size a 0.25 kWp of total capacity for the PV system. The losses details are shown as in the model and these are only an estimated value of percentage of the energy that been lost in the system. These values always can change depending on the site of PV location, technology used and total sizing of the system. The result of the PV system model shows that, with an annual average solar radiation of 1,590 kWh/m², 0.25 kWp capacity of PV system will produce around 29,794 kWh/m² of electricity in a year. This is equivalent to 0.014 MW of electricity produced just by using one solar panel.

To build a PV system with 1 MW capacity, this model will need 4,000 totals of solar panels. If one solar panel has the area of 1.6 m², then with 4,000 solar panels it would require 6,400 m² of area to install the PV system. Considering Kota Kinabalu area size is 351 km², 1 MW capacity of PV system installation will take only about 0.0018% from the total area of the city. The model showed that with 1 MW capacity of PV system, 55 MW of electricity can be produced in a year. Considering the power demand in Sabah by 2020 is 1,331 MW, 1 MW capacity of PV system can contribute around 4% to generate electricity for Sabah. Currently, there is still no large utility-scale solar PV plant or solar energy that contributing in electricity generation in Sabah. Other than the high cost of the PV system installation, the awareness and economics are among the two significant barriers in solar energy implementation in Sabah [35].

The challenge to become a green and resource efficient economy entirely independent of fossil fuels by 2050 has to be accepted one way or another. This model can help sizing the PV plant to make solar power as the main energy source in the future for Kota Kinabalu. Considering the power demand by 2020 is 1,331 MW, the model showed that the PV solar plant will need 100,000 totals of solar panels to generate 1,361 MW of electricity. This is equivalent to 25 MW capacity size of PV solar plant where it would take about 0.05% from Kota Kinabalu total area for the solar plant installation. This is one huge potential energy that can be harnessed within the city.
5. Conclusion
The study showed that Kota Kinabalu received an annual average of 182 W/m² solar radiations in a year which is equivalent to 1, 590 kWh/m². By using a photovoltaic (PV) system model, Kota Kinabalu is estimated to produce around 29,794 kWh/m² of electricity in a year. This is equivalent to 0.014 MW of electricity produced just by using one solar panel. Considering the power demand in Sabah by 2020 is 1,331 MW, 1 MW capacity of PV system can contribute about 4% to generate electricity for Sabah. 1 MW capacity of PV system installation will take only 0.0018% from the total area of the city. This assessment could suggest that, exploration for solar power energy as an alternative source of renewable energy within the city can be optimised and designed to achieve significant higher percentage of contribution to the energy demand in the state.

Recommendation
The results of this paper would recommend to a further feasibility study into implementation of solar energy in Kota Kinabalu, Sabah. This will cover the aspect of costing, project design, obtaining and implementation phases. All components selected must be assured to be mutually compatible and manufactured to provide a professionally engineered and integrated power system, thereby enhancing the photovoltaic system reliability, performance and longevity.

References
[1] Mekhilef S, Saidur R and Safari A 2011 A review on solar energy use in industries Renewable and Sustainable Energy Reviews. 15 1777–1790
[2] Abdelaziz E A, Saidur R and Mekhilef S 2011 A review on energy saving strategies in industrial sector Renewable and Sustainable Energy Reviews. 15 150–168
[3] Saidur R 2010 A review on electrical motors energy use and energy savings Renewable and Sustainable Energy Reviews. 14 877–898
[4] Saidur R and Mekhilef S 2010 Energy use energy savings and emission analysis in the Malaysian rubber producing industries Applied Energy. 87 2746-2758
[5] Energy sector embracing climate change by Pusat Tenaga Malaysia, In: National conference on climate change preparedness towards policy changes 2007 Online: http://www.undp.org.my/uploads/a Energy sector PTM.pdf. May 2011
[6] Online: http://envdevmalaysia.wordpress.com/2011/03/26/renewable-energyneeds-a-push/. May 2011
[7] Overview of Policy Instruments for the Promotion of Renewable Energy and Energy Efficiency in Malaysia Background Report, Online: http://www.serdis.ait.ac.th/cogen/62/reports/countries/malaysia.pdf. May 2011
[8] Oh T H, Pang S Y and Chua S C 2010 Energy policy and alternative energy in Malaysia: issues and challenges for sustainable growth Renewable and Sustainable Energy Reviews. 14 1241-1252
[9] Online:http://www.renewableenergyworld.com/rea/news/article/2007/01/equatorial-sunshine-the-malaysia-bipv-programme-51560. May 2011
[10] Rosnazri A, Ismail D and Soib T 2012 A review on existing and future energy sources for electrical power generation in Malaysia Renewable and Sustainable Energy Reviews. 16 4047-4055
[11] Tsoutsos T, Frantzeksaki N and Gekas V 2005 Environmental impacts from the solar energy technologies Energy Policy. 33 289-296
[12] Karapanagiotis N 2000 Environmental impacts from the use of solar energy technologies THERMIE
[13] Wang Q and Qiu H-N 2009 Situation and outlook of solar energy utilization in Tibet, China Renewable Sustainable Energy Review. 13 2181-2186
[14] Saidur R, Islam M R, Rahim N A and Solangi K H 2010 A review on global wind energy policy *Renewable Sustainable Energy Review.* 14 1744-1762
[15] Fiorenza G, Sharma V K and Braccio G 2003 Techno-economic evaluation of a solar powered water desalination plant *Energy Conversion and Management.* 44 2217-2240
[16] Online: http://www.pveducation.org/pvcdrom/design/efficiency-and-cost
[17] US DOE Annual Energy Outlook 2014 Online: http://www.eia.gov/forecasts/aeo/pdf/electricity_generation.pdf
[18] IRENA 2015 Renewable Power Generation Costs in 2014
[19] Online: http://www.gosolarcalifornia.ca.gov/solar_basics/faqs.php
[20] Murphy D J and Hall C A S 2010 Year in review – EROI or energy return on (energy) invested. *Ann. N.Y. Acad. Sci.* 1185 102-118
[21] Libo W, Zhao Z M and Liu J Z 2007 A single-stage three-phase grid-connected photovoltaic system with modified MPPT method and reactive power compensation *IEEE Transactions on Energy Conversion.* 22 881-886
[22] Park J H, Ahn J Y, Cho B H and Yu G J 2006 Dual-module based maximum power point tracking control of photovoltaic systems *IEEE Transactions on Industrial Electronics.* 53 1036-1047
[23] Zeman M SOLAR CELLS Chapter 9 Photovoltaic systems *Delft University of Technology*
[24] Cooke F M 2003 Living at the Top End: Communities and Natural Resources Use in the Kudat/Banggi Region of Northern Sabah *WWF Malaysia, Kota Kinabalu*
[25] Online: https://en.wikipedia.org/wiki/Greater_Kota_Kinabalu. September 2015
[26] Interim Report on the Performance of the Electricity Supply in Malaysia for the First Half Year of 2009 2009 *Energy Commission*
[27] Online: http://en.wikipedia.org/wiki/Malaysia. September 2015
[28] Online: http://www.sesb.com.my/corporate_profile.cfm
[29] Sabah Electricity Supply Industry Outlook 2014 *Energy Commission*
[30] Vijayakumar G, Kummert M, Klein S A and Beckman W A 2005 Analysis of short-term solar radiation data *Solar Energy.* 79 495–504
[31] Online: http://www.pveducation.org/pvcdrom/properties-of-sunlight/analysis-of-solar-irradiance-data-sets. October 2015
[32] Online: http://photovoltaic-software.com/PV-solar-energy calculation.php. September 2015.
[33] Lim Y S, Lalchand G and Gladys M S L 2008 Economical, environmental and technical analysis of building integrated photovoltaic systems in Malaysia *Energy Policy.* 36 2130–2142
[34] Borhanazad H, Mekhilef S, Saidur R and Boroumandjazi G 2013 Potential application of renewable energy for rural electrification in Malaysia *Renewable Energy.* 59 210-219
[35] Sulaiman J, Azman A and Sabooiri B 2014 Development of solar energy in Sabah Malaysia: The case of Trudgill’s Perception *International Journal of Sustainable Energy and Environmental Research.* 3 90-99.