Solar power for energy sustainability and environmental friendliness of Curtin University Sarawak

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Abstract. The demand on electrical energy is rapidly increasing. Everything around us requires electrical energy either during its production or usage stage. Sustainability has become the main concern nowadays as the availability of fossil fuels is limited. As renewable energy is the path-way to energy sustainability and environmental friendly environment, this paper proposes a solar power system for Curtin University Sarawak to reduce its electricity consumption and greenhouse gas emissions. The proposed 208 kW solar system saves an energy consumption of more than 380,000 kWh per year, and a CO2 offset by 285 Tons per year

1. Introduction

Virtually every single product around us has gone through these stages as illustrated in figure 1: extraction, production, distribution, consumption and disposal [1, 2]. Each of these stages necessitates the use of electrical energy. With the ever-increasing rate of material productions, electrical energy demand is rising swiftly.

Figure 1. Product Life Cycle.
Extraction is a process when natural resources are harvested to be used as raw material. With the increased in extraction process, natural resources will soon be used up. During the past three decades, about 33 per cent of the planet resources have been consumed [3, 4]. In production stage, electrical energy is primarily used to convert extracted raw materials into products. Some production involves chemicals, which is harmful to health and the environment. Once products have been produced, they are distributed to stores for consumption. The rate of consumption is rising and the products consumed are not being used efficiently. Studies [1-5] have shown that most products are only being used for six months before being disposed. The end of the products life cycle is the disposal stage. The per capita garbage generation is around 0.45 to 0.60 kg and this figure will reach a level of 1.20 to 1.50 kg in the next decade [1, 6, 7]. Garbage is being disposed in a landfill or being burned before being disposed in the landfill. This process pollutes the environment as many products are produced through chemical process. Burning these products emits harmful toxics such as dioxin into the environment. Hence the disposal is not environmental friendly and involves energy consumption also. If the product life cycle continues like this without adequate social and economic concerns, then human safety, energy resources availability and environmental friendliness will become horrendous. The proven way for energy sustainability and environmental friendly atmosphere is introducing renewable energy sources at all sectors and reducing the dependency on depleting fossil fuels [8-13]. Renewable energy such as solar power is an alternative way to conventional approach of generating electricity [14-17]. Using renewable energy to generate electricity is a step towards a cleaner future.

Malaysia plans to achieve 985 MW or 5.5% share of renewable energy in the energy mix by 2015. By 2020, the target is for renewable energy to comprise 11% or 2,080 MW of overall electricity generation in the country. However, as to-date, renewable energy has yet to be considered a major source of electricity generation as it contributes less than 1% to the energy mix in Malaysia [18-20]. In order to support the Government’s vision, Curtin University, Sarawak Malaysia (Curtin Sarawak) [21], the first and largest offshore campus of Curtin University in Perth, Western Australia and the first foreign university to be established in East Malaysia in partnership with the Sarawak State Government has exposed intense interest in presenting renewable energy systems. As sustenance to Curtin’s concern, this paper intends a 208 kW solar power plant.

2. Solar Insolation

Curtin Sarawak is situated in Miri. Miri is a coastal city in northeastern Sarawak, Malaysia, located near the border of Brunei, on the island of Borneo. The geographic coordinates of Miri, Malaysia are [22]:

Latitude: 4°24′53″ N
Longitude: 114°00′32″ E
Elevation above sea level: 8 m

For the Curtin campus, the average peak sun hours for a twelve month period is calculated and presented in table 1. The peak sun hours are the number of hours in a day where the solar irradiation is 1000 W/m2. For Curtin, it varies from a minimum of 4.16 to a maximum of 5.55 hours during a year. Also the monthly insolation on unit area at an angle of 21° is calculated as shown in the table 1.

| Month   | Peak Sun Hours Per Day (Hours) | Days/Month | Monthly Insolation kWh/m² |
|---------|-------------------------------|------------|---------------------------|
| January | 4.98                          | 31         | 262.82                    |
| February| 4.56                          | 28         | 232.70                    |
| March   | 4.97                          | 31         | 241.06                    |
| April   | 5.55                          | 30         | 208.09                    |
| May     | 5.39                          | 31         | 192.12                    |
June  | 4.73  | 30  | 175.80  
July | 5.43  | 31  | 189.08  
August | 5.44  | 31  | 210.16  
September | 5.21  | 30  | 226.99  
October | 5.50  | 31  | 252.06  
November | 4.45  | 30  | 250.69  
December | 4.16  | 31  | 261.35  
Total | 2702.91  

Sun path diagrams help in knowing how the sun will impact a selected site and building throughout the year. Stereographic sun path diagrams can be used to read the solar azimuth and altitude for a given location. Sun-path diagrams map the path of the sun across the sky. They show the position of the sun relative to the site, both by time of day and time of year. The Sun-path diagram for a twelve month period for Miri has been determined and presented as in figure 2.

![Sun-path diagram for Miri, Sarawak.](image)

3. Proposed Solar Power Plant
A total solar power plant capacity of 208 kW for four buildings, which is equivalent to 52 kW per building, is being proposed to accommodate a minimum of 30% of the total electrical consumption of Curtin. The identified four buildings are Prinia 1, Prinia 2, Prinia 3 and Heron 1.

The assumptions made for the solar panel modules are presented in table 2.

| Assumption                                | Cost (RM)  |
|-------------------------------------------|------------|
| Cost per 250 W solar panel                | 1200       |
| Cost per 12 kW inverter                   | 10,000     |
| Maintenance cost per year                 | 4,000      |
| Additional cost and labour cost per kW    | 1,000      |
| Life Expectancy                           | 25         |

Technical Data:
Solar Module
   Nice Sun PV Co., Ltd.; Model: NCS-6BM250
   26 string x 8 modules
\[ \text{Voc} = 37.5 \text{ V} ; \quad \text{Vmp} = 30.1 \text{ Volts} \]
\[ \text{Isc} = 8.87 \text{ A} ; \quad \text{Imp} = 8.32 \text{ A} \]

**Inverter**

GOODWE Inverter GW12k-DT

5 units AC SPD 20kA

\[ \text{Pdcmax} : 12300 \text{ W} \quad \text{Pacmax} : 12000 \text{ W} \]

\[ \text{Vdcmx} : 1000 \text{ V} \quad \text{Idcmx} : 22/11 \text{ A} \]

\[ \text{Iacmx} : 19 \text{ A} \quad 2 \text{ MPPT} \]

Figure 3 shows the electrical interconnections of a 52 kW solar system of Prinia 1. The energy converted from solar to electricity per month by the 208 kW solar power plants has been determined and presented in table 3.

**Table 3.** Monthly Energy Generation (kWh).

| Month    | kWh   |
|----------|-------|
| January  | 32111 |
| February | 26557 |
| March    | 32047 |
| April    | 34632 |
| May      | 34755 |
| June     | 29515 |
| July     | 35013 |
| August   | 35077 |
| September| 32510 |
| October  | 35464 |
| November | 27768 |
Though Malaysia is a tropical country with four seasons, there is not wide variation in the monthly kWh generations. The annual kWh generation is 382273 kWh and the average daily kWh generation is found to be 1047 kWh. The daily kWh generation is not very high since the modules tilting angle follows the roof angle of the buildings as it is.

4. Curtin’s Energy Consumption

Curtin’s monthly energy consumption for year 2014 has been received [21] and adjusted by the energy generations of the proposed 208 kW solar power system. The net energy consumption payable to the external grid is found out and tabulated as in table 4. Figure 4 shows the energy consumption with and without the PV panels.

| Months   | Energy Consumption, kWh | Energy Generated, kWh | Net Energy Consumption Payable, kWh |
|----------|-------------------------|-----------------------|-------------------------------------|
| January  | 67549                   | 32111                 | 35438                               |
| February | 63610                   | 26557                 | 37053                               |
| March    | 76418                   | 32047                 | 44371                               |
| April    | 84539                   | 34632                 | 49907                               |
| May      | 87539                   | 34755                 | 52784                               |
| June     | 85553                   | 29515                 | 56038                               |
| July     | 75164                   | 35013                 | 40151                               |
| August   | 88505                   | 35077                 | 53428                               |
| September| 82790                   | 32510                 | 50280                               |
| October  | 83047                   | 35464                 | 47583                               |
| November | 87763                   | 27768                 | 59995                               |
| December | 63930                   | 26824                 | 37106                               |

Figure 4. Energy consumption with and without solar power.

Likewise the energy consumption bills for the twelve month period with and without the proposed solar system have been worked out and the saving in energy consumption due to the solar system if
implemented has also been brought out as in table 5. The comparison of electrical consumption charges with and without the proposed solar system is shown in figure 5.

Table 5. Energy Bill Comparison & Net Saving.

| Months   | Energy Bill Without Solar Energy, RM | Energy Bill With Solar Energy, RM | Net Saving in Energy Consumption Charges, RM |
|----------|--------------------------------------|----------------------------------|------------------------------------------|
| January  | 20470.70                             | 10837.39                         | 9633.31                                  |
| February | 19289.00                             | 11321.77                         | 7967.23                                  |
| March    | 23131.40                             | 13517.43                         | 9613.97                                  |
| April    | 25567.70                             | 15178.10                         | 10389.60                                 |
| May      | 26467.70                             | 16041.28                         | 10426.42                                 |
| June     | 25871.90                             | 17017.34                         | 8854.56                                  |
| July     | 22755.20                             | 12251.42                         | 10503.78                                 |
| August   | 26757.50                             | 16234.36                         | 10523.14                                 |
| September| 25043.00                             | 15289.88                         | 9753.12                                  |
| October  | 25120.10                             | 14480.90                         | 10639.20                                 |
| November | 26534.90                             | 18204.50                         | 8330.40                                  |
| December | 19385.00                             | 11337.90                         | 8047.10                                  |
| Total    | 286394.10                            | 171712.27                        | 114681.83                                |

Figure 5. Energy consumption charges with and without solar power.

5. Financial and Environmental Facets
The total installation cost involved in the proposed 208 kW solar project is worked out based on the assumptions presented in table 2 as:

\[
\text{Installation Cost} = \text{Cost of solar panels} + \text{Cost of Inverters} + \text{Additional cost and labor} \\
= \left[ \left( \frac{208 \times 1000}{250} \right) \times 1200 \right] + \left[ \frac{208}{12} \times 10000 \right] + [208 \times 1000]
\]

Table 6 shows the total cost of the proposed solar project in terms of installation cost and maintenance cost.

Table 6. Installation Cost.

|                     |                  |
|---------------------|------------------|
| Installation Cost   | 1,379,733        |
| Estimated Maintenance Costs | 100,000       |
| Total Cost          | 1,479,733        |
Assuming a life-time of 25 years, and the drop in PV panel performance of 0.8% per annum, the financial benefits out of the proposed project are determined and shown in table 7.

During the project’s life span, the avoided annual carbon dioxide emission is projected as shown in table 8 [23, 24]. The reduction in carbon emission at the beginning of the project is around 286000 kg per year and increases to a maximum of around 367000 kg at the end of its life span. If there is any emission credit facility available by the norms of the local government, then this project is eligible for such a privilege.

### Table 7. Financial Benefits over THE LIFE-Time.

| Year | Expected PV Performance (%) | Financial Benefits (RM) |
|------|-----------------------------|-------------------------|
| 1    | 100.0                       | 114681.84               |
| 2    | 99.2                        | 228446.23               |
| 3    | 98.4                        | 341293.16               |
| 4    | 97.6                        | 453222.63               |
| 5    | 96.8                        | 564234.65               |
| 6    | 96.0                        | 674329.22               |
| 7    | 95.2                        | 783506.33               |
| 8    | 94.4                        | 891765.99               |
| 9    | 93.6                        | 999108.19               |
| 10   | 92.8                        | 1105532.94              |
| 11   | 92.0                        | 1211040.23              |
| 12   | 91.2                        | 1315630.07              |
| 13   | 90.4                        | 1419302.45              |
| 14   | 89.6                        | 1522057.38              |
| 15   | 88.8                        | 1623894.85              |
| 16   | 88.0                        | 1724814.87              |
| 17   | 87.2                        | 1824817.44              |
| 18   | 86.4                        | 1923902.55              |
| 19   | 85.6                        | 2022070.20              |
| 20   | 84.8                        | 2119320.40              |
| 21   | 84.0                        | 2215653.15              |
| 22   | 83.2                        | 2311068.44              |
| 23   | 82.4                        | 2405566.28              |
| 24   | 81.6                        | 2499146.66              |
| 25   | 80.8                        | 2591809.58              |

### Table 8. Avoided Emission.

| Year | Carbon Emission Without PV (kg) | Carbon Emission With PV (kg) | Carbon Reduction (kg) |
|------|---------------------------------|-----------------------------|-----------------------|
| 1    | 708670                          | 422424                      | 286246                |
| 2    | 708670                          | 419044                      | 289625                |
| 3    | 708670                          | 415665                      | 293005                |
| 4    | 708670                          | 412286                      | 296384                |
6. Conclusions
The paper has addressed a renewable energy concept to reduce the fossil fuel energy conception of Curtin University, Sarawak, Malaysia. The energy generated by the 208 kW PV project varies from a minimum of 31% to a maximum of 47% of the monthly energy consumption of Curtin. Hence there is corresponding reduction in the energy bill payable to the grid connected electricity. Apart from the financial aspect, there is an added advantage of emission credit by avoiding the carbon emission throughout the project lifespan. The proposed 208 kW solar system saves an energy consumption of more than 380,000 kWh per year, and a CO2 offset by 285 Tons per year. The only concern is the budget for the investment of the proposed project. Curtin shall implement the project in four segments considering one building at a time.

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