COMPARATIVE STUDY OF THE PERFORMANCES OF SILICON MONOCRYSTALLINE AND POLYCRYSTALLINE PV SOLAR PANELS IN KADUNA METROPOLIS

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Abstract

The monocrystalline and polycrystalline silicon solar cells are the most commonly used Photovoltaic (PV) Solar technology that are deployed in both commercial and domestic applications in Nigeria. These devices are rapidly gaining acceptance. However, due to some few differences, which includes pricing and performance, there are certain uncertainties over the most appropriate choice of the two technologies. In order to throw more light and create better understanding of these devices, this study investigated the performances of the two technologies in Kaduna Metropolis. Two panels, rated 80W each of the monocrystalline and polycrystalline technologies were exposed to similar environmental conditions while the panels' output variables were measured together with the environmental indices. The data were analyzed and the results obtained indicated that while the solar irradiance varies irregularly across the days of the month and over months of the year, the ambient temperature was more uniform. These are the most dependent variables on the performance of PV solar cells. From the measured outputs it was found that the open circuit voltage of the monocrystalline was generally higher than that of polycrystalline, throughout the year. However, the short circuit currents of the two panels were nearly equal for the first seven months of the year, but the was slight increment for the monocrystalline during the last five months. These led to higher power and energy yield by the monocrystalline over the polycrystalline panels. This led to estimated energy generation of the total energy generation by PV1 and PV2 as 68.95 and 84.34 kWh respectively. At a cost respective cost of N16,500.00 and N18,500.00, it gives us a measure for the comparison of the two panels. The cost per unit energy generated was calculated at N199.42/kWh and N182/kWh respectively. Thus, while the

monocrystalline solar panels costs are slightly higher, but their energy generation is better and thus compensate, on the long run, giving better value of investment.

Keywords: *Performances, Silicon, Monocrystalline, Polycrystalline, PV Solar.*

INTRODUCTION

Energy is a critical factor to national development, as it is established that the development of any nation has a direct bearing to its energy. Worldwide, nearly 1.3 billion and 2.6 billion people lack access to electricity and clean cooking facilities, respectively (IEA, 2012). Renewable energy is an accepted energy of the future, due to its unlimited supply and environmental friendliness. Photovoltaic solar system is a viable energy of the future. From being a laboratory curiosity, these devices have been used for decades, as power supply for space craft, terrestrial (Green, 1998) and now to remote locations such as weather stations, navigational systems for aircraft and ships (Mazer, 1997). PV solar cells have been identified as the ultimate solution to the current energy challenges as well as the most ideal energy of the future (Sulaiman, 2015). The current efficiency is about 26% for crystal silicon and 22% for thin films (Fraunhofer, 2017). Thus, to make PV solar viable and price competitive, efforts have been geared towards increasing efficiency and reducing costs.. Over the last 10 years, efficiencies rose from around 18% and 10% to around 26% for crystal silicon and thin film solar modules respectively. (https://news.energysage.com/solar-panel-efficiency-cost-over-time/ Retrieved 19/01/2018). Similarly, the cost of production has crashed, with the average cost of solar cells fell from $76.67/watt in 1977 to just $0.74/watt in 2013, while it is shown that the average price of a solar module at $0.49/watt by July 2016, and the average price of a solar cell at $0.26/watt (http://pvinsights.com/). Also, according to Decker (2015), electricity generated by photovoltaic systems is 15 times less carbon-intensive than electricity generated by a natural gas plant (450g CO_2e/kWh), and at least 30 times less carbon-intensive than electricity generated by a coal plant, with cited energy payback times (EPBT) of solar PV systems between one and two years (Deker 2015). Wu et al (2017) have investigated the Efficiency Rating of Various PV Technologies under Different Indoor Lighting Conditions using the real-time one-sweep (RTOS) method for I-V measurement and showed that the indoor/outdoor ratios show different trends depending on the PV device type, which could highlight the specific type of PV that harvests better under indoor lighting and is preferable to indoor applications. It is therefore important to understand and establish how these

environmental variables affect the performance of various PV solar panels installed in and around Kaduna.

In this study we investigated the performances of both monocrystalline and polycrystalline silicon PV solar panels under the available environmental variables in Kaduna metropolis, with the aim of determining a comparative assessment of the performance of each device. This may give designers and installers a general guide on deployment of such panels at optimal approaches. The results of this study would greatly help researchers, policy makers, designers, installers as well as users in the selection and deployment of an optimum PV solar systems at a cost-effective rate. In addition, it would add to body of knowledge in this specialized area of photovoltaics to future investigations.

The methodology adopted in this research was by placing the different PV panels on a clear space, free from shading on the North-South axis. The solar irradiance meter was placed very close to the panels to ensure equal radiation falls on it as on the panels, while the ambient temperature, wind speed and relative humidity were measured by the various sensors also placed nearby. Digital multimeters and clamp meters were connected to measure the electrical parameters of the panels. The Prova PV Aanalyzer was used to measure certain parameters (Voc, Isc) of each panel on an interval of 60 minutes from a timer set to a reference time. The environmental variables such solar irradiance, temperature, wind speed, humidity and time were all recorded against these investigations. Based on the measurements, the performances of the devices were determined, and the varying ambient variables are studied for any impact on the results. For logistics, the study area was limited to the Renewable Energy and Technology Unit (RETU) at the Main Campus of Kaduna Polytechnic, in Tudun Wada Kaduna, Nigeria.

RESULTS AND DISCUSSION

The data set consisted of measured values of solar irradiance, Io, ambient temperature, Ta, relative humidity, R.H., open circuit voltages and short circuit currents of both solar panels. Since the performance of a solar panel depends, amongst other variables, on the solar irradiance and ambient temperature, the values of these parameters were plotted for the 12 months, so that their variation over the months can be studied. Some of these plots are presented in Fig. 1 to Fig. 9. From the figures, it is obvious that the solar irradiance and ambient temperature were high during the days for all the months, except some days where low values were observed. This could be attributed to the dependence of

both quantities on the radiation of the sun. this was the trend observed on all the data of every month. The presented months fully buttress this position.

The significance of these parameters is that each of them directly affects solar cell performance. While irradiance increase the yield through higher short circuit current and open circuit voltages, thus and efficiency, the temperature slightly increases short circuit current but with more impacting fall in the open circuit voltage. It is observed from the graphs that the solar irradiance varies sharply and apparently, irregularly. This, is understandably due to the erratic variation of the solar radiation arriving the earth. Factors such as solar storms and clouds conditions sharply affect the amount of radiation received. However, when compared to the solar panels' outputs, the open circuit voltage and short circuit currents, these were more stable. Their variations were not as sharply. Most especially, the Voc was more stable compared to the short circuit current. This is believed to be due to the fact that the Isc is more readily sensitive to Io compared to Voc. The graphs worthy of consideration and investigation is that of open circuit voltage and short circuit currents dependence on solar irradiance. These three quantities have been plotted on same graph each in order to understand their possible relationship. It is observed, from these results that both open circuit voltage and short circuit current follow the irradiance. It is obviously clear from the graphs of the is that the open circuit voltage of the PV2 is generally higher than that of PV1. That is the Voc2 is about 2 volts above that of Voc1. This implies that the monocrystalline solar cells have displayed higher values of open circuit voltage. Similar observation was made with the short circuit current, Isc. The implication of these two observations is that the monocrystalline panels have higher efficiency than the polycrystalline.

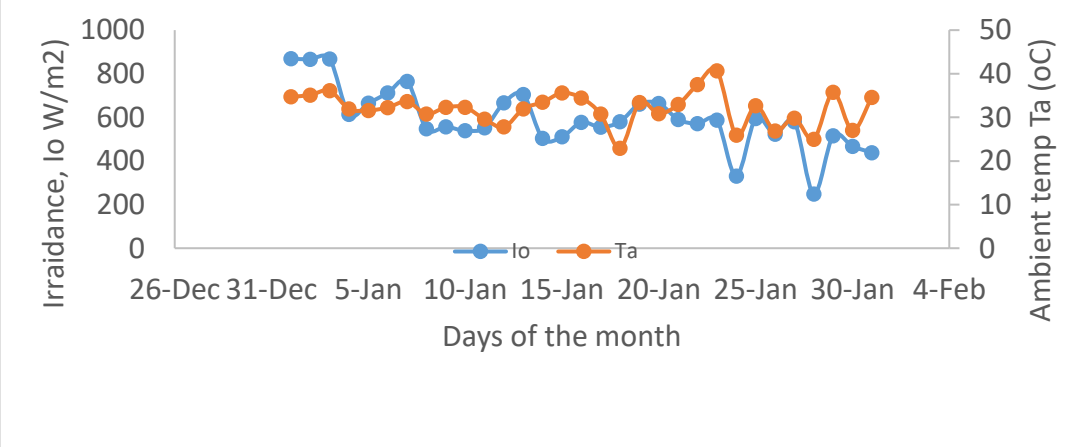

Fig. 1. Solar irradiance and ambient temperature for the month of January

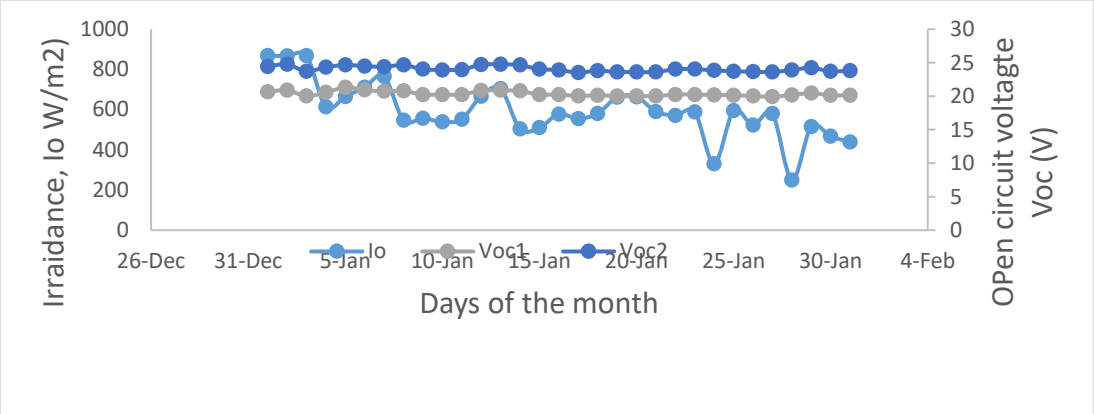

Fig. 2. Solar irradiance and open circuit voltages of the two panels for the month of January

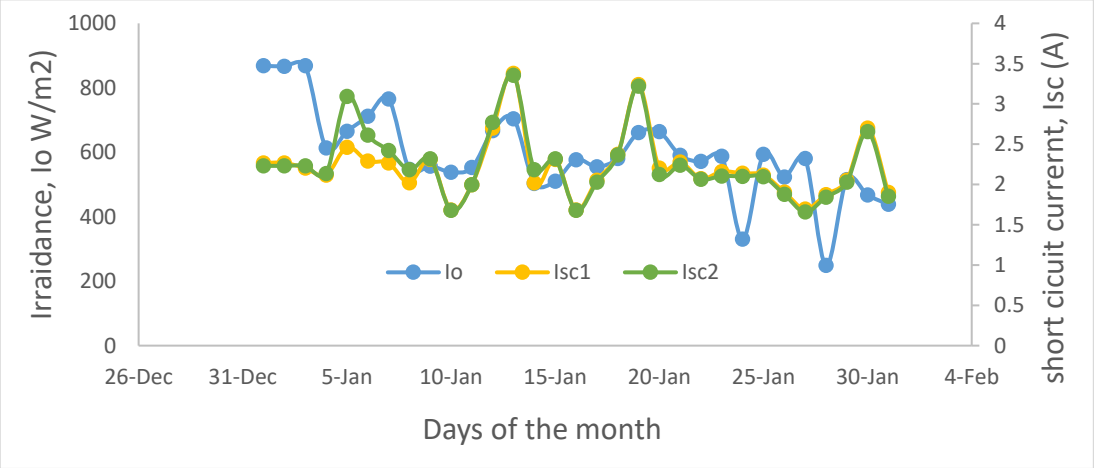

Fig.3 Solar irradiance and short circuit currents of the two panels for the month of January

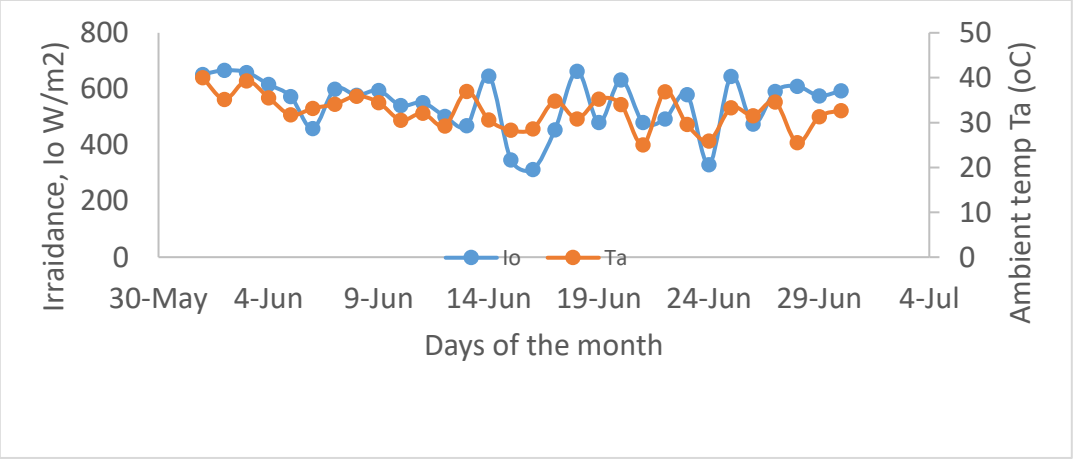

Fig.4 Solar irradiance and ambient temperature of the two panels for the month of June

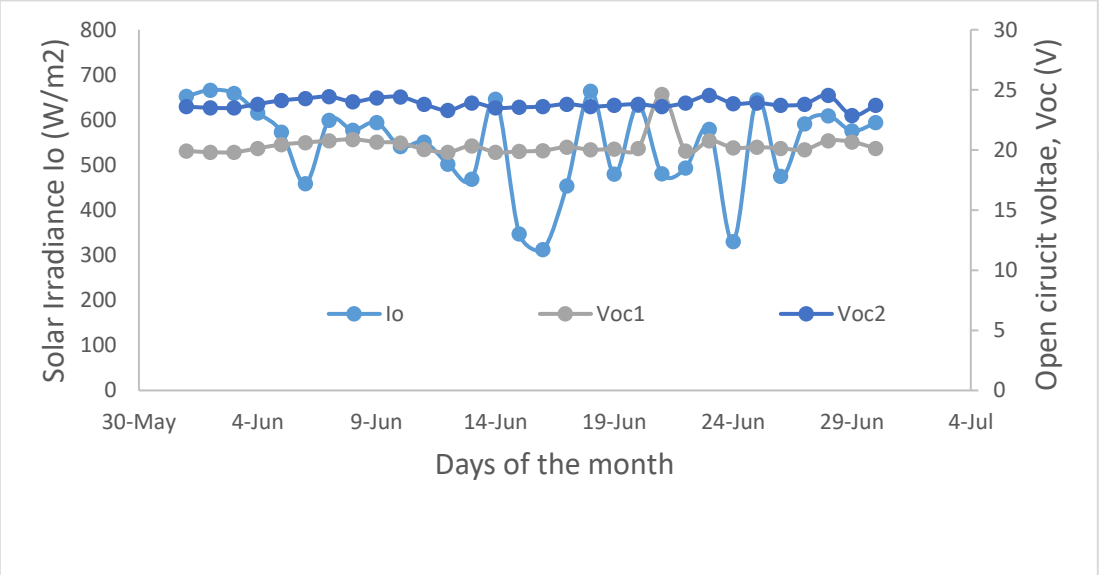

Fig.5. Solar irradiance and open circuit voltages of the two panels for the month of June

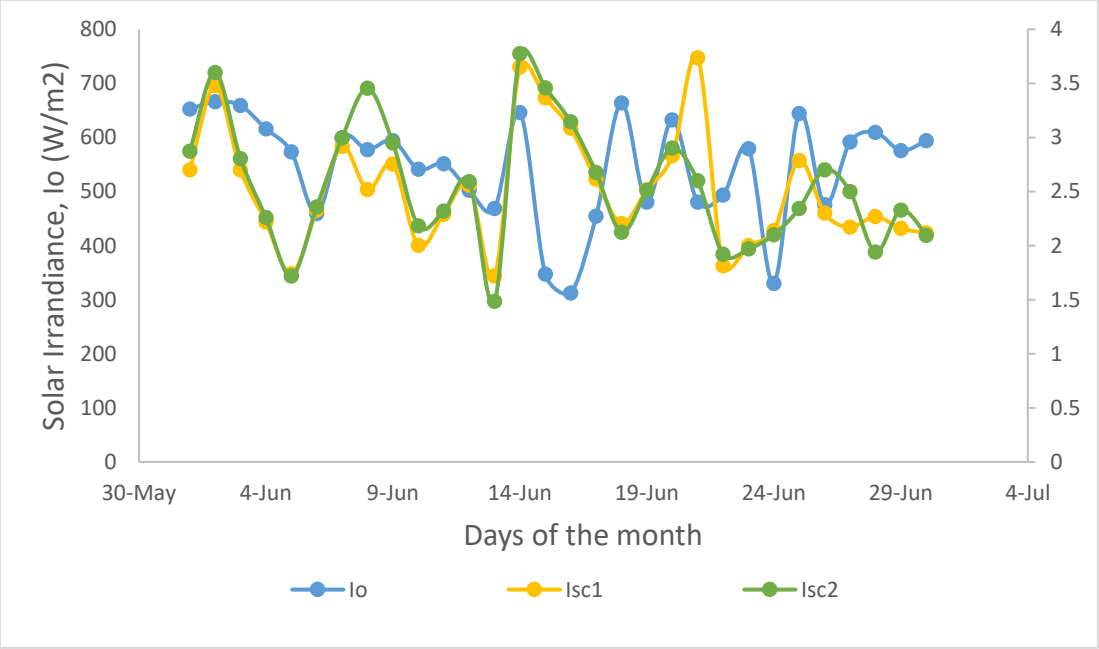

Fig.6 Solar irradiance and short circuit currents of the two panels for the month of June

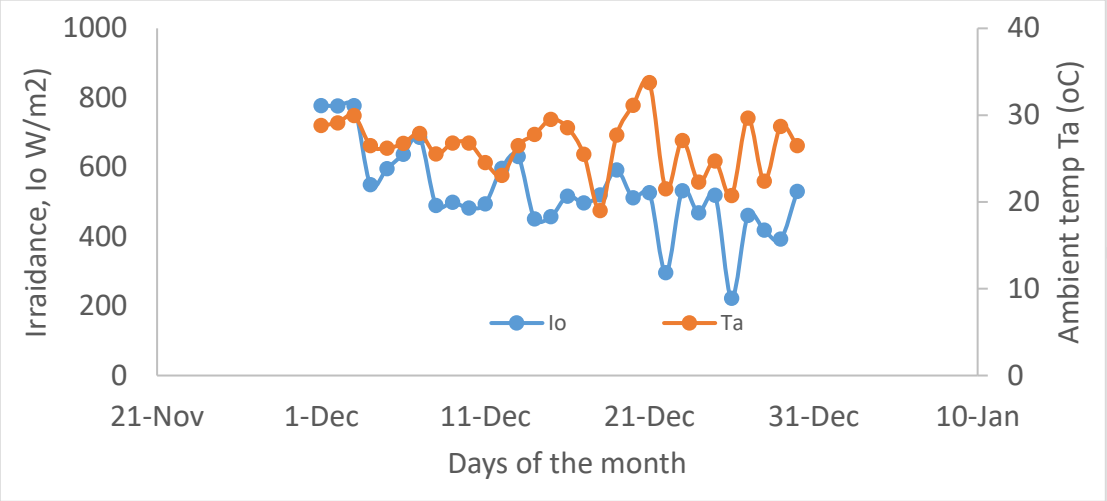

Fig.7 Solar irradiance and ambient temperature of the two panels for the month of December

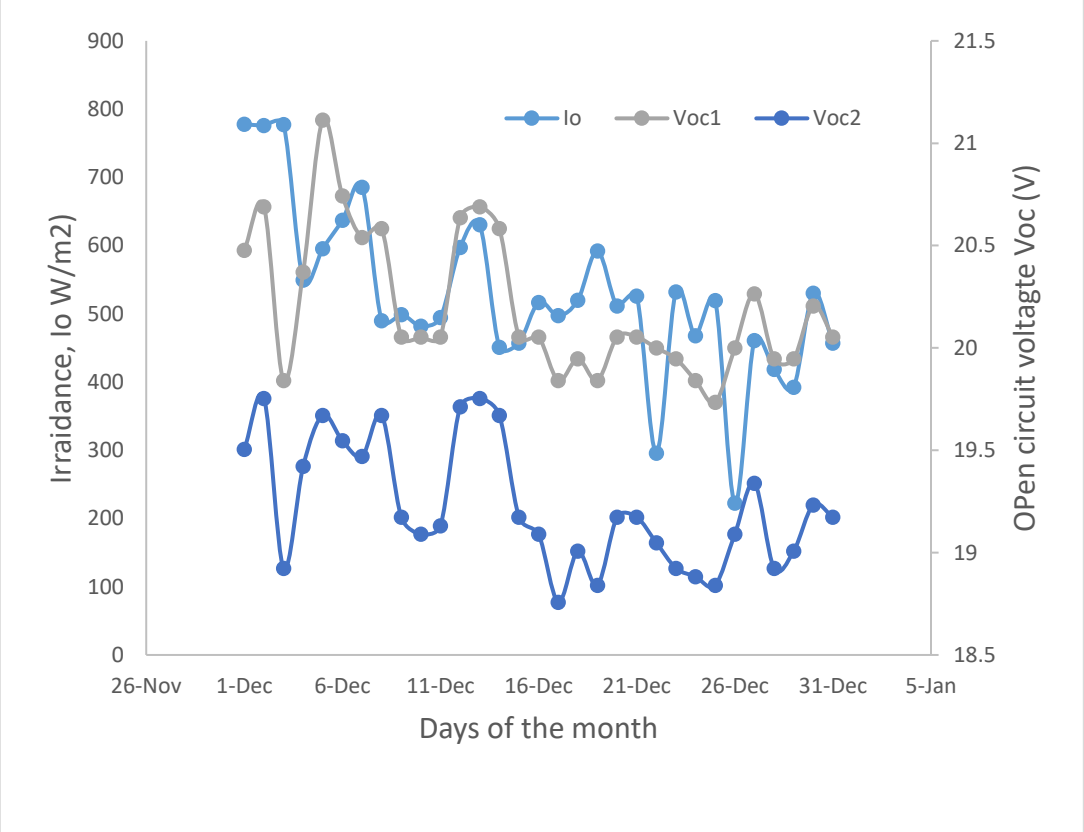

Fig.8. Solar irradiance and open circuit voltages of the two panels for the month December

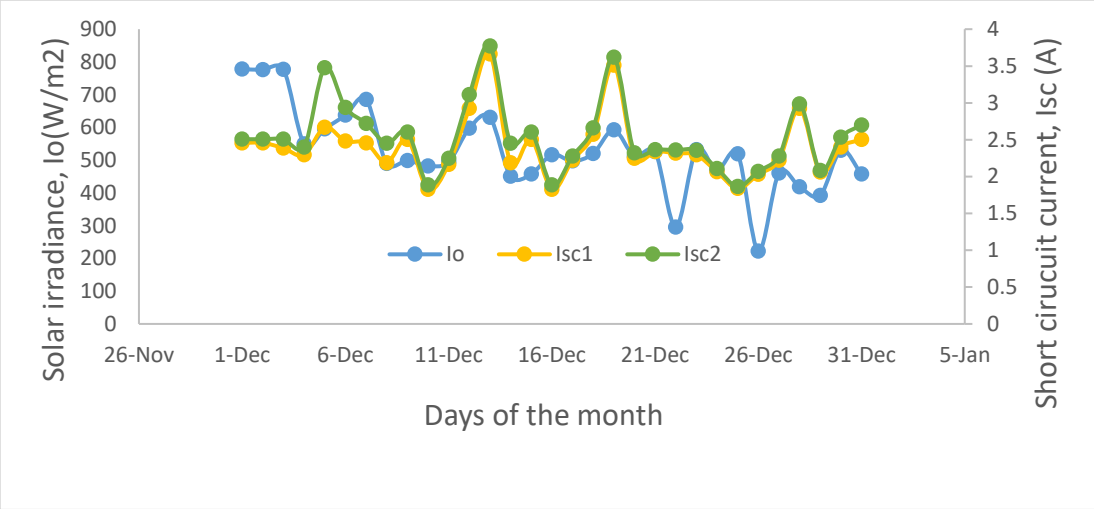

Fig.9 Solar irradiance and short circuit currents of the two panels for the month of December

Average Values

In order to study the performance and behaviors of the environmental variables and the subsequent performance indices of the two solar panels over the months of the year, the average values of all the variables were computed and studied. The results were plotted and presented in Figs. 10 to 13 and Table 1. Here is observed that the solar irradiance varies much more widely over the years. Highest radiation were observed between March and May and September, while lowest values were obtained between June and August. On the other hand, the ambient temperature was more stable over the months with little variations over the months. When the solar panels output were studied, it was found that the Voc and Isc were nearly stable over the months. These results, as indicated in Figs. 11 and 12, confirms the earlier assertion that the indices of panel 2 is better than that of panel 1. While the Voc2 was higher than Voc1 across all the months, the Isc1 and Isc2 were very close from January to July, however, Isc2 showed remarkedly higher values for the rest of the year. This implies that the performance of the monocrystalline panel is better than that of the polycrystalline over the whole year, the improvement is more pronounced during the August to December months.

The comparative performance of the two panels is more pronounced from the results presented in Table 1 where the average and cumulative values of the panels performance are given. Here, the total power and energy generated by

the two panels were computed and compared with the cost of the two devices. Here it is seen that the total energy generation by PV1 and PV2 are 68.95 and 84.34 kWh respectively. At a cost of N16,500.00 and N18,500.00 respectively, it gives us a measure for the comparison of the two panels. This is the cost per unit energy generated. The calculated values were N199.42/kWh and N182/kWh respectively. This is the index that can be used to determine a very important value of solar cells. That is the payback time.

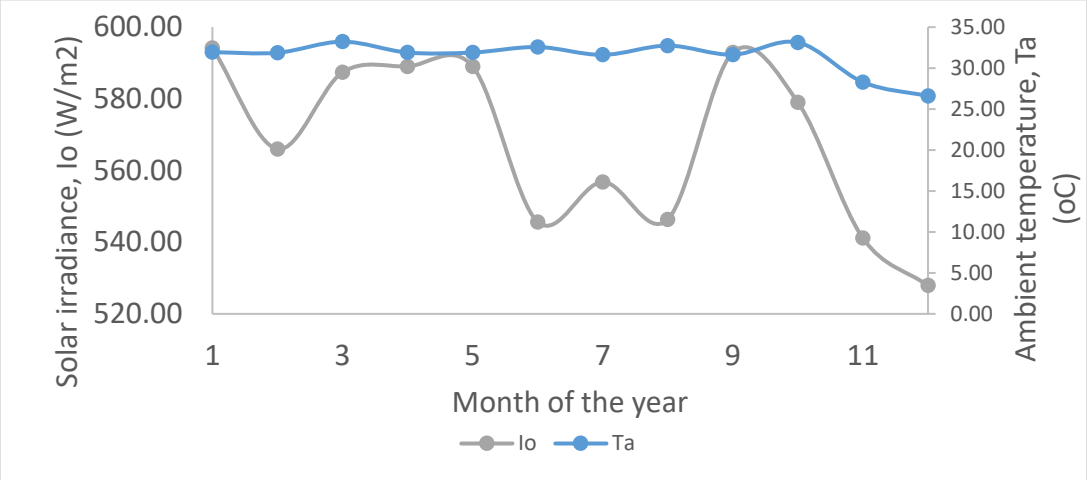

Fig.10 Average values of the Solar irradiance and ambient temperatures over the months

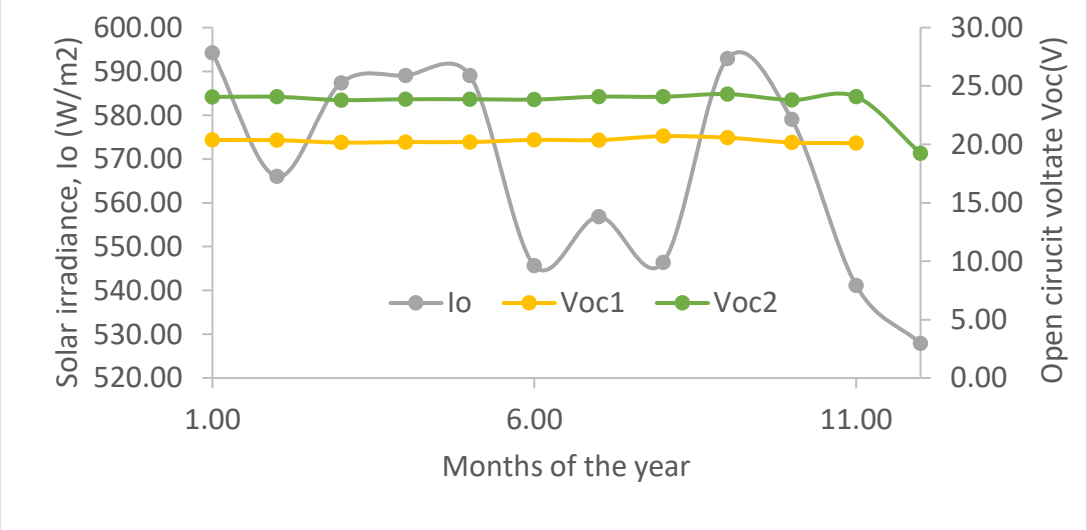

Fig.11. Average values of Solar irradiance and open circuit voltages of the panels for the year

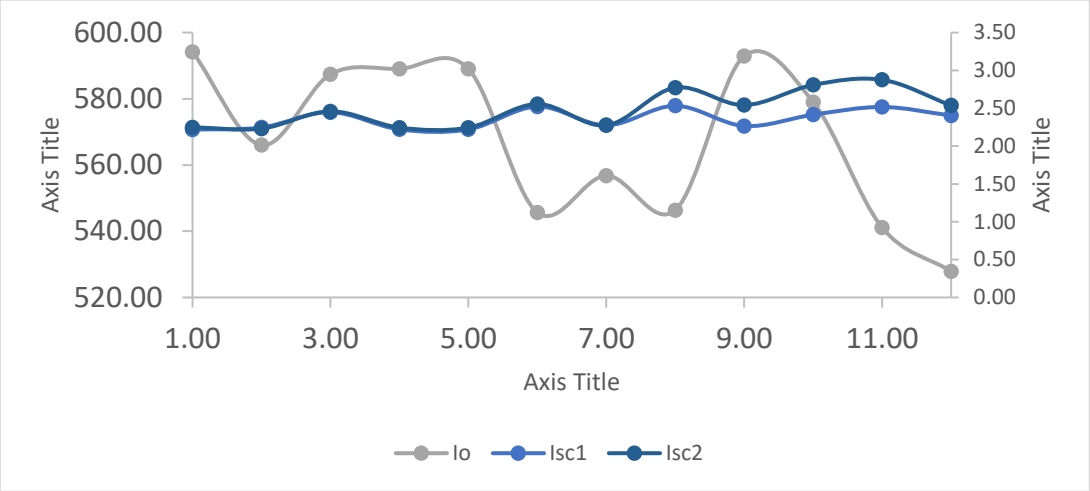

Fig.12. Average values of Solar irradiance and short circuit currents of the panels for the year

TABLE 1. SUMMARY OF RESULTS

MONTH	Weather variables			Panels' outputs			
				PV1 Polycrystalline		PV2 Monocrystalline	
	IOM	T (°C)	RH(%)	Voc1	Isc1	Voc2	Isc2
JAN 2019	594.20	31.94	18.78	20.37	2.22	24.07	2.25
FEB 2019	566.00	31.87	22.53	20.36	2.25	24.07	2.23
MAR 2019	587.39	33.22	19.10	20.15	2.45	23.79	2.46
APR 2019	589.03	31.90	18.75	20.20	2.22	23.87	2.24
MAY 2019	589.03	31.90	18.75	20.20	2.22	23.87	2.24
JUN 2019	545.64	32.57	27.67	20.38	2.52	23.84	2.56
JUL 2019	556.81	31.62	21.62	20.37	2.27	24.08	2.27
AUG 2019	546.36	32.74	27.35	20.70	2.53	24.08	2.77
SEP 2019	592.93	31.64	24.57	20.57	2.27	24.31	2.54
OCT 2019	579.00	33.13	19.52	20.16	2.41	23.80	2.81
NOV 2019	541.13	28.28	26.18	20.11	2.52	24.09	2.88
DEC 2019	527.89	26.59	18.85	20.20	2.40	19.23	2.54
AVERAGE/CUMMULATIVE	567.95	31.45	21.97	243.78	28.28	283.09	29.79
AVERAGE POWER/MONTH (KW/MONTH)				6.89		8.43	
AVERAGE ENERGY/MONTH (KWh)				68.95		84.34	
COST (N)				16,500.00		18,500.00	

COST/KWh	199.4217	182.79135
TOTAL POWER GENERATED	82.73924	101.20829
TOTAL ENERGY GENERATED	827.3924	1012.0829

Conclusion

The study has compared the performance of two solar PV panels one was polycrystalline and the other was monocrystalline type. Each was rated 80W but at different cost price. The monocrystalline panel cost slightly higher than the polycrystalline. Both panels were exposed to similar environmental conditions while their open circuit voltages and short circuit currents were recorded over a period of one year. The results obtained indicated that while the solar irradiance fluctuated over the days and months, the ambient temperature was more gentle in the fluctuation. Similarly, among the solar panel output parameters the short circuit current showed more fluctuation than the open circuit voltage, due to the stronger dependence of Isc on irradiance compared to Voc. On the overall, the monocrystalline panels showed higher values of Voc and Isc compared to the polycrystalline. This led to estimated energy generation of the total energy generation by PV1 and PV2 as 68.95 and 84.34 kWh respectively. At a cost respective cost of N16,500.00 and N18,500.00, it gives us a measure for the comparison of the two panels. This is the cost per unit energy generated. The calculated values were N199.42/kWh and N182/kWh respectively. Thus, while the monocrystalline solar panels costs are slightly higher, but their energy generation is better and thus compensate, on the long run, giving better value of investment.

Thus, as far as the Kaduna environment is concerned, the monocrystalline solar panels are more preferrable compared to the polycrystalline, despite the slightly higher price of purchase. It is recommended that for further research work in this area, an automated data acquisition system is used rather than the manual type for better accuracy, consistency and less errors in measurement.

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