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ORIGINAL ARTICLE

Performance Assessment of Monocrystalline and Polycrystalline Solar Panel Types Used in Owerri, South-Eastern Nigeria

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KEYWORDS

monocrystalline,
polycrystalline,
silicon,
solar-panel.

ABSTRACT

A performance evaluation of monocrystalline and polycrystalline silicon solar panels was carried out in Owerri. They were installed and tested outdoors for a period of 28 days during both the rainy and dry seasons. Each panel was connected to a 12 V, 15 A charge controller and a 40 Ω load. Measurements including open-circuit voltage (V_{OC}), short-circuit current (I_{SC}), load voltage (V_L), and load current (I_L) were taken using a digital multimeter. The maximum power output (P_M) and power delivered to the load (P_L) were computed from these readings. The findings revealed that the monocrystalline panel exhibited higher V_{OC} during the early morning and late afternoon hours, while the polycrystalline panel's V_{OC} increased steadily with rising solar irradiance across both seasons. The monocrystalline panel consistently generated more current than the polycrystalline counterpart. Both panels showed peak performance between 10 a.m. and 3 p.m. during the rainy season, with the polycrystalline panel achieving a V_{OC} of 17.70 V, I_{SC} of 5.50 A, and P_M of 96.80 W, and the monocrystalline panel recording a V_{OC} of 17.94 V, I_{SC} of 5.50 A, and P_M of 94.24 W. However, during the dusty harmattan season, when sunlight levels were reduced, both panels experienced decreased performance. The monocrystalline panel reached a maximum power of 52.06 W, while the polycrystalline panel produced 50.95 W. Cloudy and rainy weather further impacted performance by causing significant drops in both voltage and current. The polycrystalline panel maintained a relatively stable voltage range of 16.06 to 17.98 V, whereas the voltage of the monocrystalline panel fluctuated between 15.01 and 17.99 V. The study concluded that although polycrystalline panels are more commonly used and generally more affordable, users may not be fully aware that they can also deliver slightly higher power output than monocrystalline panels under certain conditions.

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1 Introduction

As Nigeria faces escalating energy demands and persistent unreliability in grid electricity supply, solar photovoltaic (PV) technology has emerged as a viable and sustainable alternative for power generation. Situated in the South-Eastern region of the country at a latitude and longitude of approximately 5.48° N and 7.02° E respectively [1], Owerri is well-positioned to harness solar energy due to its abundant and consistent solar irradiance throughout the year. This makes the region particularly suitable for the deployment of PV systems.

Solar energy is utilized in homes in two ways, one: using it to supply heat to warm up spaces through solar collector, and two, using it to generate electricity through Photovoltaic (PV) cells. While solar energy for water heating is widely used and relatively inexpensive, photovoltaic (PV) technology is more costly and is primarily applied in scientific processes. In addition to being cost-effective, energy generated by solar cells

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is environmentally friendly, safe, and produces no gas emissions or noise [2].

A solar cell, or photovoltaic (PV) cell, is a device that converts light into electrical current through the photoelectric effect. Crystalline solar cells are classified into two types: monocrystalline and polycrystalline. This technology originates from the discovery of Alexandre-Edmond Becquerel, who found that certain materials emit electrons when exposed to light, thereby generating electrical current [3].

Charles Fritts created the first solar cell in the 1880s. While his selenium-based prototype converted less than 1% of the incoming light into electricity, its significance was acknowledged by both Ernst Werner von Siemens and James Clerk Maxwell [4]. In the 1940s, Russell Ohl's research laid the foundation for the development of the silicon solar cell, which was later advanced by Gerald Pearson, Calvin Fuller, and Daryl Chapin in 1954. These early solar cells were priced at 286 USD per watt and achieved efficiencies of 4.5 – 6% [5].

Solar energy, which powers these cells, is a renewable resource, providing a dependable energy source. Renewable energy systems, as a whole, offer a significant opportunity for reliable power generation. Despite the established effectiveness of solar thermal energy, it remains underused in many developed and developing countries due to factors like insufficient education and human reluctance to adopt new technologies.

Domestic take-up of these panels differs dramatically from country to country, with Germany having reached a level of 50% of domestic homes with solar thermal, against the UK with around 2%. Nigeria is obviously negligible due to slow technological advancement [6]. Owerri's geographical and climatic profile is characterized by favorable solar conditions, with average monthly solar irradiance ranging from 4.54 to 5.49 kWh/m²/day across different seasons [7]. Solar panels mounted at a fixed tilt angle of 6° facing due south tend to yield maximum annual energy output [8]. While seasonal tilt adjustments can offer incremental gains in efficiency, such modifications are often impractical, especially in small- to medium-scale installations.

This study investigates the comparative performance of monocrystalline and polycrystalline PV modules under the specific climatic conditions of Owerri. The goal is to provide data-driven insights to inform the optimal selection of solar technologies for both residential and commercial applications. The analysis confirms that both monocrystalline and polycrystalline PV technologies are well-suited for use in Owerri. It revealed that polycrystalline silicon solar panels are more commonly adopted across various installations, primarily due to their lower initial cost and wider market availability.

Interestingly, many users selected polycrystalline panels without full awareness of their performance characteristics – particularly the fact that, under certain conditions such as higher temperatures or diffuse sunlight, polycrystalline modules can deliver comparable or even slightly higher short-term power outputs than monocrystalline panels. However, this choice is often economically motivated rather than technically informed, highlighting a gap in user education regarding the trade-offs between cost, efficiency, and long-term energy yield.

In the context of rising electricity tariffs and widespread power instability, selecting the appropriate PV system can significantly reduce dependence on fossil fuels and enhance local energy security. As such, solar energy not only offers environmental benefits but also presents a strategic solution for achieving reliable and cost-effective electricity in southeastern Nigeria.

2 Methodology

The methodology employed in this study involved the outdoor evaluation of monocrystalline and polycrystalline silicon photovoltaic (PV) modules, aimed at measuring key electrical parameters – namely, open-circuit voltage (V_{OC}), load voltage (V_L), short-circuit current (I_{SC}), and load current (I_L) in order to assess and compare the performance characteristics of both panel types.

The solar panels used for the experiment were procured from the open market and possessed the following manufacturer-specified ratings:

Table 1: Specification of monocrystalline and polycrystalline solar panels

Specification	Monocrystalline Si	Polycrystalline Si
Manufacturer	Flames	Flames
Peak power (P_{max}) (W)	100	100
Maximum power voltage (V_{max}) (V)	17.5	17.5
Maximum power current (I_{max}) (A)	5.72	5.72
Open-circuit voltage (V_{OC}) (V)	22.05	22.05
Short-circuit current (I_{SC}) (A)	6.40	6.40

The outdoor performance evaluation was carried out at Egbeada, Owerri, located at a geographic coordinate of 5°29'0" N latitude and 7°2'0" E longitude. The site experiences seasonal solar irradiance levels ranging between 4.54 and 5.49 kWh/m²/day. The operational temperature range for the photovoltaic modules used in the study spans from -40 ℃ to 85 ℃. The monocrystalline silicon panel has a rated efficiency of 20.0%, while the polycrystalline silicon panel exhibits an efficiency of 18.2%.

Both PV modules were mounted adjacently on a rooftop with direct sun exposure, using a ladder for installation. Each panel was individually connected to a 12 V, 15 A charge controller, which in turn was linked to a 13 A switch to control the measurement modes. A DT9205A digital multimeter was used to measure key electrical parameters: open-circuit voltage (V_{OC}), load voltage (V_L), short-circuit current (I_{SC}), and load current (I_L). Data collection was performed hourly between 07:00 and 18:00 local time each day. For accurate parameter isolation, the switch was toggled OFF to record V_{OC} and I_{SC} and turned ON to measure V_L and I_L.

Outdoor performance evaluation focused on the following electrical parameters: open-circuit voltage (V_{OC}), load voltage (V_L), short-circuit current (I_{SC}), and load current (I_L). The maximum power was calculated by multiplying V_{OC} and I_{SC}, according to Equation 1a,

$$P_M = V_{oc} \times I_{sc} \qquad 1a$$

The load power was also calculated by multiplying the load voltage and the load current, as shown in Equation 1b,

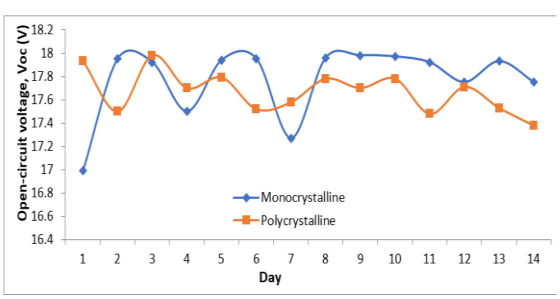
$$P_L = V_L \times I_L \qquad 1b$$

3 Results and Discussions

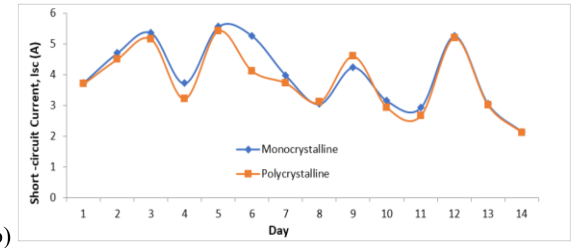
The following outcomes as shown in Table 2, were recorded for each day during the outdoor testing of the solar panels for the rainy season.

Table 2: Experimental results of open-circuit voltage (V_{OC}), short-circuit current (I_{SC}) and maximum power output of monocrystalline and polycrystalline Si solar panels for the fourteen days of the rainy season.

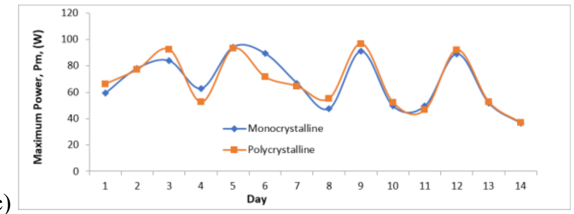
Monocrystalline Si				Polycrystalline Si		
Day	V_{OC} (V)	I_{SC} (A)	P_M (W)	V_{OC} (V)	I_{SC} (A)	P_M (W)
1	16.99	3.73	59.31	17.93	3.70	66.34
2	17.95	4.70	78.16	17.50	4.50	77.18
3	17.92	5.36	83.78	17.98	5.16	92.36
4	17.50	3.72	62.87	17.70	3.32	56.37
5	17.94	5.56	94.24	17.79	5.42	93.06
6	17.95	5.26	89.31	17.52	4.12	71.56
7	17.27	3.98	66.78	17.58	3.73	64.57
8	17.96	3.05	47.48	17.78	3.11	55.30
9	17.99	5.51	91.03	17.70	5.50	96.80
10	17.97	3.15	49.46	17.78	2.94	52.27
11	17.92	2.93	49.69	17.48	2.67	46.67
12	17.75	5.25	89.09	17.71	5.20	92.09
13	17.93	3.05	51.73	17.57	3.01	52.61
14	17.75	2.15	36.51	17.38	2.13	37.02



(a)



(b)



(c)

Figure 1: A plot of a.) V_{OC} max versus number of days b.) I_{SC} max versus number of days c.) P_M max versus number of days

3.1 Comparison of the Maximum Open-Circuit Voltage (V_{OC}), Maximum Short- Circuit Current (I_{SC}) and Maximum Power Output (P_M) for the Fourteen Days for both the Monocrystalline Si and Polycrystalline Si Solar Panels

Figure 1 illustrates the open-circuit voltage (V_{OC}), short-circuit current (I_{SC}), and the maximum power output (P_M) recorded over a 14-day outdoor testing period for both monocrystalline and polycrystalline silicon (Si) photovoltaic panels.

The open-circuit voltage exhibited day-to-day variation across both panel types. However, the monocrystalline Si panel maintained relatively stable voltage levels from Day 8 to Day 12, whereas the polycrystalline Si panel showed more fluctuations during the same period. From Day 8 to Day 14, the monocrystalline panel consistently demonstrated slightly higher V_{OC} values than its polycrystalline counterpart.

In terms of short-circuit current, both PV modules followed a similar trend throughout the 14 days, although the monocrystalline panel consistently produced higher I_{SC} values compared to the polycrystalline panel.

The maximum power output of both panels also exhibited comparable trends throughout the testing period. Notably, on Day 9, the polycrystalline Si panel produced the highest peak power output, surpassing that of the monocrystalline panel. Overall variations in maximum power output were attributed primarily to fluctuations in open-circuit voltage over the test period.

Based on the results obtained from the 14-day outdoor performance evaluation, the following conclusions were drawn:

i. **Open-Circuit Voltage (V_{OC}):** The monocrystalline Si panel exhibited higher V_{OC} values during early morning and late afternoon hours. In contrast, the polycrystalline Si panel achieved its peak V_{OC} around midday, with relatively stable values between 10:00 and 15:00 on most days. The monocrystalline panel's

V_{OC} was generally more variable compared to the polycrystalline panel.

ii. **Short-Circuit Current (I_{SC}):** The monocrystalline Si panel consistently produced higher short-circuit current than the polycrystalline panel. The I_{SC} for both panels increased progressively in the morning and was primarily influenced by the intensity of solar irradiance. Reduced I_{SC} values were recorded under cloudy conditions for both panel types.

iii. **Maximum Power Output (P_M):** The power output was closely linked to the magnitude of the short-circuit current. Variability in the monocrystalline panel's V_{OC} led to fluctuations in its power output. The polycrystalline panel achieved a higher peak power output during the test period, particularly on the 9th day, due to a higher V_{OC} at that specific time while the monocrystalline panel experienced a drop in voltage.

The following results as shown in Table 3 were obtained for each day during the outdoor testing of the solar panels for the dry season:

Table 3: Experimental results of maximum open-circuit voltage (V_{OC}), maximum short-circuit current (I_{SC}) and maximum power output of monocrystalline and polycrystalline Si solar panels for the fourteen days of dry season.

Monocrystalline Si				Polycrystalline Si		
Day	V_{OC} (V)	I_{SC} (A)	P_M (W)	V_{OC} (V)	I_{SC} (A)	P_M (W)
1	17.78	2.35	41.64	17.74	2.30	39.38
2	17.35	2.34	40.41	17.78	2.25	38.90
3	17.32	2.38	41.06	17.22	2.31	39.71
4	17.70	2.77	44.93	17.72	2.65	45.76
5	17.74	2.71	47.67	17.30	2.60	44.56
6	17.71	2.33	38.23	17.39	2.05	34.95
7	17.77	3.05	52.06	17.24	3.04	50.95
8	17.65	1.63	27.26	17.16	1.72	29.45
9	17.95	2.61	42.75	17.10	2.59	44.29
10	17.72	2.70	45.09	17.37	2.62	45.38
11	17.78	2.81	48.33	17.52	2.69	47.13
12	17.37	2.78	47.32	17.33	2.76	47.83
13	17.95	1.08	29.16	17.37	1.64	28.21
14	17.95	2.32	37.89	17.23	2.18	35.97

3.2 Comparison of the Open-Circuit Voltage (V_{OC}), Short-Circuit Current (I_{SC}) and Maximum Power Output (P_M) for the Fourteen Days for both the Monocrystalline Si and Polycrystalline Si Solar Panels.

Figure 2 presents the variation of open-circuit voltage (V_{OC}), short-circuit current (I_{SC}), and peak power output (P_M) over time, recorded across a 14-day period during the dry season for both monocrystalline and polycrystalline silicon photovoltaic panels.

The open-circuit voltage exhibited day-to-day fluctuations for both panel types. However, the monocrystalline Si panel consistently displayed higher V_{OC} values than the polycrystalline panel from Day 5 through Day 14.

The short-circuit current patterns were similar for both panels over the entire testing period, with the monocrystalline panel maintaining a consistently higher I_{SC} than the polycrystalline panel.

Both panels followed a comparable trend in maximum power output. The monocrystalline panel achieved its peak power output on Day 7, outperforming the polycrystalline panel. Variations in maximum power observed between Days 4 and 14 were largely attributed to fluctuations in open-circuit voltage.

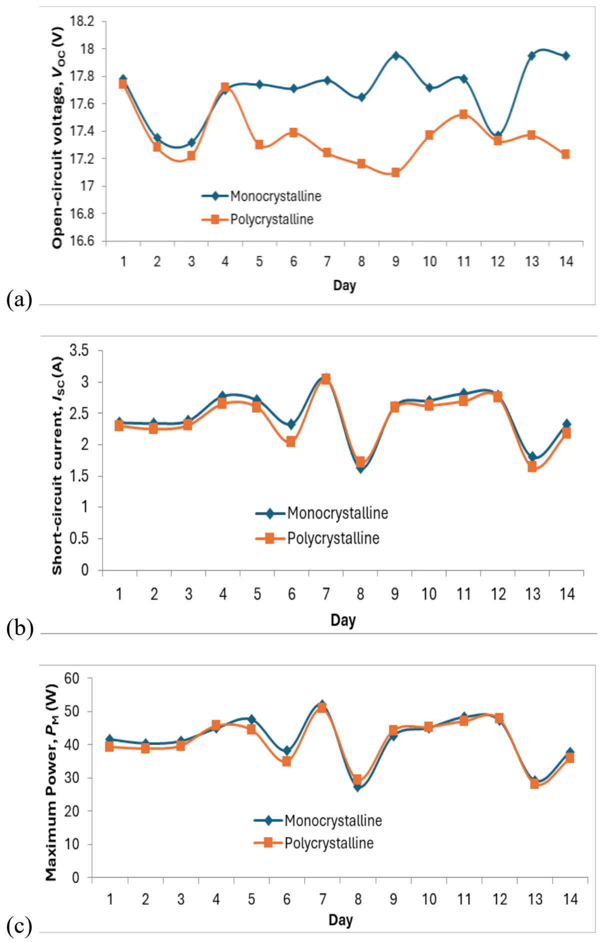


Figure 2: Plots of a.) V_{OC} max versus number of days b.) I_{SC} max versus number of days c.) P_M max versus number of days.

Conclusions from the 14-Day Dry Season Outdoor Evaluation:

i. **Open-Circuit Voltage (V_{OC}):** The monocrystalline panel recorded higher V_{OC} values in the early morning and late afternoon hours, whereas the polycrystalline panel showed higher and more stable V_{OC} around midday, particularly between 10:00 and 15:00. The V_{OC} of the monocrystalline panel demonstrated greater variability compared to that of the polycrystalline panel.

ii. **Short-Circuit Current (I_{SC}):** The monocrystalline panel consistently generated higher short-circuit current than the polycrystalline panel. I_{SC} increased progressively during the morning hours and was directly influenced by solar irradiance levels. However, due to reduced sunlight during the harmattan season, both panels exhibited lower I_{SC} values.

iii. **Maximum Power Output (P_M):** The maximum power output was directly correlated with the magnitude of short-circuit current. Reduced I_{SC} values, caused by diminished solar intensity during the harmattan period, led to lower power output from both panels during the test period.

3.3 Comparison of Results Obtained with Literature

Outdoor testing revealed significant variability in the open-circuit voltage (V_{OC}) of the monocrystalline silicon (Si) solar panel. This observation aligns with the findings of [9], who conducted an outdoor performance comparison between crystalline silicon and amorphous solar modules. The study reported that the V_{OC} of crystalline modules fluctuated more significantly than that of amorphous modules.

Additionally, both monocrystalline and polycrystalline panels exhibited similar short-circuit current (I_{SC}) characteristics. This result is consistent with the study by Abdelkader et al. [10], who performed a comparative performance analysis of monocrystalline and multi-crystalline silicon PV cells under semi-arid climatic conditions in Jordan. Their findings also indicated comparable current behavior across both technologies.

Furthermore, the polycrystalline Si panel demonstrated higher maximum power output (P_M) compared to the monocrystalline Si panel. This supports the findings of Kalu et al. [11], who conducted a simulation-based comparative study of three photovoltaic technologies – monocrystalline silicon, polycrystalline silicon, and thin-film PV. Their analysis showed that polycrystalline modules exhibited superior array efficiency relative to monocrystalline modules, with thin-film PV performing the lowest. Consequently, they recommended polycrystalline Si due to its relatively high array efficiency

4 Conclusion

A performance evaluation of two photovoltaic technologies - 100 W monocrystalline and 100 W polycrystalline silicon panels, both manufactured by Flames Company – was conducted in Owerri, located in the southeastern region of Nigeria. The assessment involved outdoor testing over a 14-day period during both the rainy and dry seasons to determine the more efficient panel under varying environmental conditions. Throughout the study, both panels exhibited similar voltage and current behavior. Performance comparison was primarily based on the maximum power output (P_M) of each panel. Observations indicated that key electrical parameters; open-circuit voltage (V_{OC}), load voltage (V_L), short-circuit current (I_{SC}), and load current (I_L) were directly influenced by solar irradiance. Increased solar insolation resulted in higher current generation, whereas reductions in sunlight such as those caused by cloud cover or pre-rain conditions led to decreased short-circuit current and reduced panel efficiency. During the harmattan period of the dry season, reduced sunlight due to dust in the atmosphere further diminished panel output. In contrast, during the rainy season, peak solar intensity was typically observed between 10:00 AM and 3:00 PM, though it varied across days. The highest maximum power recorded was 96.80 W for the polycrystalline panel and 94.24 W for the monocrystalline panel, both achieved during the rainy season. These values closely approach the manufacturer's rated capacity of 100 W. Lower power outputs were recorded during the dry season, attributed to the reduced I_{SC} under low insolation conditions.

5 Recommendation

The polycrystalline Si panel demonstrated more stable voltage output compared to the monocrystalline Si panel, which exhibited considerable voltage fluctuations. While the difference in current output between the two panel types was relatively minimal, the polycrystalline panel proved capable of delivering consistent performance under the prevailing environmental conditions. In addition to its performance benefits, the polycrystalline Si panel offers greater cost-effectiveness, as monocrystalline panels are generally more expensive.

To enhance the reliability of performance assessments, it is recommended that extended outdoor testing be conducted over a full calendar year. This would enable identification of the months with optimal solar energy yield and facilitate the development of a comprehensive performance database. Such data would be valuable for informing policy decisions and guiding individuals, government agencies, and corporate entities in selecting appropriate solar technologies. Future studies should also incorporate additional PV technologies such as amorphous silicon panels to broaden the comparative analysis. Furthermore, it is essential to include irradiance measurements in subsequent outdoor evaluations to better understand the relationship between solar radiation levels and photovoltaic performance.

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Credit author statement

E. Onuoha: Conceptualization, Investigation, Writing-Original draft preparation, **C. E. Orji:** Supervision, **K. B. Okeoma:** Supervision, **O. K. Echendu:** Resources, Methodology, Project Administration**, J. A. Ezihe:** Writing-

Reviewing and Editing, **J. C. Echewodo:** Project Administration

Declaration of Competing Interest

The authors disclose no personal or financial conflicts that might have affected the research.

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