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Assessment of Solar Energy Potential and Radiation Impact in the Federal Capital Territory and Nasarawa State, Nigeria

***[1]Tor, T., [1]Nyam, G.G., [1,2]Samson, D.O., [1]Asake, J., & [1]Iortim, D.M.**
[1]Department of Physics, Faculty of Science, University of Abuja, Nigeria
[2]Department of Physics, Faculty of Health Sciences, Universiti Kebangsaan Malaysia, Bangi, Malaysia
***Corresponding author email**: ignatiustor33@gmail.com

Abstract
This study assesses the solar energy potential and radiation impact in the Federal Capital Territory (FCT) and Nasarawa State (NS), Nigeria, over ten years. Two main analyses were carried out: electricity generation potential and descriptive statistical analysis. It was observed that the solar radiation for FCT ranges from 11.4 MJm^{-2} day^{-1} to 22.0 MJm^{-2} day^{-1}, with an average value of 17.6 MJm^{-2} day^{-1}, and a total annual solar radiation of 211.7 MJm^{-2} day^{-1}. In contrast, NS ranges from 11.8 MJm^{-2} day^{-1} to 22.2 MJm^{-2} day^{-1}, with an average value of 17.5 MJm^{-2} day^{-1}, and a total annual solar radiation of 209.6 MJm^{-2} day^{-1}. During the off-rainy season, both regions demonstrated high reliability for solar power generation, with FCT showing a reliability of 0.62 and NS a reliability of 0.56. The performance of photovoltaic systems was also evaluated using a 550 W PV panel with FCT having a value of 6.206 x 107 MWh annually, while NS can produce 2.27 x 108 MWh. The observed clearness index (K_t) ranges between 0.414 – 0.665 and 0.432 – 0.662 for both FCT and NS. Moreover, the skewness values for FCT and NS are -0.379 and -0.220, respectively, suggesting that the distribution's tail is slightly shifted towards the left for both FCT and NS. The kurtosis results for both regions exhibit values of approximately FCT (1.322) and NS (1.168), indicating that the distributions are platykurtic. These results suggest that both regions have substantial potential for solar energy generation.

Keywords: Solar Energy Potential, Radiation Impact, Clearness Index, FCT, Nasarawa

Introduction
The rising global energy demand, driven by population growth and economic expansion, has intensified the search for sustainable energy solutions. Among renewable energy sources, solar energy stands out due to its abundance, environmental friendliness, and long-term economic viability. Its potential to replace fossil fuels while reducing greenhouse gas emissions has made it a central pillar of global sustainability and climate mitigation strategies.
Globally, solar energy deployment has expanded significantly due to falling technology costs, innovation in photovoltaic (PV) systems, and supportive government policies. Countries across varying climatic zones are increasingly investing in solar infrastructure to diversify their energy mix and ensure energy security. For instance, the Middle East and North Africa (MENA) region receives some of the highest global solar radiation ranging from 5.5 $kWhm^{-2}day^{-1}$ to 7.5 $kWhm^{-2}day^{-1}$ driving massive investments in solar farms (Alami & Khaled, 2021). In the United States, states like California and Nevada are projected to generate nearly 40% of their electricity from solar by 2035 (U.S. Department of Energy, 2022). Similarly, China leads the world in installed solar capacity, with projects such as the Tengger Desert Solar Park contributing over 1.5 GW to the national grid (Li et al., 2021).
In Nigeria, solar energy represents a critical opportunity to address the country's longstanding electricity access challenges. Situated within the equatorial belt, Nigeria receives substantial solar radiation, ranging from 4.0 $kWhm^{-2}day^{-1}$ to 7.0 $kWhm^{-2}day^{-1}$ across its regions (Shaaban & Petinrin, 2014). The Federal Capital Territory (FCT) and Nasarawa State (NS) are particularly promising, recording average daily solar radiation values of 5.5 $kWhm^{-2}day^{-1}$ and 5.7 $kWh/m^2/day$, respectively (Okonkwo et al., 2020). Despite this, around 43% of Nigeria's population, about 85 million people lack access to electricity (World Bank, 2021), with the national grid often unreliable and overburdened.

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To promote renewable energy adoption, Nigeria has implemented a series of policies and initiatives. The Nigerian Renewable Energy and Energy Efficiency Policy (NREEEP), introduced in 2015, set a goal for renewables to constitute 20% of electricity generation by 2030, with solar contributing 6,830 MW (Akinyele et al., 2021). The Renewable Energy Master Plan (REMP) aims to increase renewable electricity supply to 23% by 2025 (International Energy Agency, 2020). Further legislative progress was achieved with the 2025 amendment to the Nigerian Electricity Act, which introduced incentives such as zero-import duties for solar equipment and expedited approval processes (Nigerian Electricity Regulatory Commission, 2025). Financial instruments like the Nigerian Solar Investment Fund and green bond programs have also been established to support project financing (Brivana Solar, 2025). Notably, the Solar Nigeria Program 2.0, launched in 2025, aims to deliver solar power to 5 million homes by 2027 with ₦500 billion in funding (Sun King, 2023).

Despite this momentum, challenges persist including high upfront costs, inadequate funding structures, limited technical expertise, and low public awareness (Adaramola & Paul, 2017; Patriot NG, 2025). This study, therefore, aims to evaluate and compare the solar energy potential of FCT and NS by analyzing radiation levels, photovoltaic efficiency, and projected energy yield. The results are expected to inform energy policy, investment planning, and sustainable development strategies in Nigeria's renewable energy sector.

Materials and Methods

Solar Irradiation Data (SID)

Nigeria's annual average solar radiation ranges from 12.6 $MJm^{-2}day^{-1}$ (3.5 $kWhm^{-2}day^{-1}$) in coastal areas to 25.2 $MJm^{-2}day^{-1}$ (7.0 $kWhm^{-2}day^{-2}$) in the extreme north, with the highest potential in northern regions (Chanchangi et al., 2023). The North Central region receives between 4.5 $kWhm^{-2}day^{-1}$ to 6.5 $kWhm^{-2}day^{-1}$, peaking at 6.0 $kWhm^{-2}day^{-1}$ from February to April (Adavuruku, et al., 2022). With proper investments, Nigeria's solar capacity could reach 600 GW, supporting sustainable energy development (Olatomiwa et al., 2023). The solar data used for this study were collected from the Nigerian Meteorological Agency (NIMET) and covered a period of ten years (2014 – 2023). The data shows the monthly average daily solar radiation, maximum, and minimum temperatures. The solar radiation dataset is the key parameter for the determination of solar PV output at all times and locations. Several solar radiation data sources exist across the globe, but none of them is perfect. The most common types of solar radiation data sources include ground measurements and satellite-based measurements or calculations.

Clearness Index (CI)

The CI analysis suggests that atmospheric conditions, such as dust and cloud cover, play a crucial role in determining the amount of solar radiation that reaches the surface. It is the fraction of the solar radiation that is transmitted through the atmosphere to strike the surface of the Earth. It is a dimensionless number between 0 and 1, defined as the surface radiation divided by the extraterrestrial radiation, as shown in equation (1) (Soneye, 2020).

$$K_t = \frac{H}{H_o} \qquad (1)$$

Where, K_t denotes the atmospheric clearness index, H is the global solar radiation collected from NiMET, and H_o indicates the extraterrestrial radiation.

Solar Energy Reliability (SER)

SER is the percentage time in days in a given period or season in which available daily global radiation reaches or exceeds the reference threshold radiation value. The reliability (Φ_R) will be quantified as given in equation (2) (Irekeola et al., 2020).

$$\Phi_R = \frac{n100}{N} \qquad (2)$$

Where, n and N are the total number of days/months in which daily global radiation reaches or exceeds the reference threshold value and the total number of days/months in the month/season, respectively. The threshold values used were 14.08 $MJm^{-2}day^{-1}$ (3.91 $kWhm^{-2}day^{-1}$) and 14.08 $MJm^{-2}day^{-1}$ (3.89 $kWhm^{-2}day^{-1}$) for FCT and NS.

Solar panel estimate of electricity generation

The solar panel chosen for the estimation of electricity generation in this research work is a monocrystalline silicon type solar panel with the following specifications: nominal power: 1 kW, peak power: 550 W, PV efficiency: 18%, and panel area: 2.17 m^2.

Solar electricity potential (SEP)

SEP is the amount of electricity that can be generated from solar energy at a specific region or location. The solar energy potential is calculated using equation (3) (Irekeola et al., 2020):

β = A x Ꞇ x H x ⌡ (3)

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Where, β, A, ƆƆ, H, and ⌡ represent the energy output, area of the photovoltaic panel, solar panel yield (%), annual average solar radiation on tilted panel, and performance ratio, respectively.

Method of data analysis

The solar data for this study is collected from the Nigerian Meteorological Agency (NIMET) and it covered a period of ten years (2014 – 2023). The data shows the monthly average daily solar radiation, maximum and minimum temperatures of the two case study areas. The normality test for the data collected is subjected to using skewness (Z_1) and kurtosis (Z_2) (DeCarlo, 2019).

$$\text{Skewness } Z_1 = \frac{\sum_{i=0}^{n}(x-\mu)^3}{n.\delta^3} \tag{4}$$

$$\text{Kurtosis } Z_2 = \frac{\sum_{i=0}^{n}(x-\mu)^4}{n\delta^4} \tag{5}$$

Where, x indicates the data value, µ represents the mean value, δ denotes the standard deviation, and n is the total frequency.

Results and Discussion

Results

The data collected from NIMET for the solar radiation (SR) of the two study locations includes the daily SR incident in the areas and the temperature of the two locations. The data are presented graphically in Figures 1 and 2. Figure 1 (a) highlights the yearly solar radiation incidents in FCT while Figures 1(b) and 1(c) indicate the average solar radiation (ASR) and total solar radiation (TSR) in FCT. From the three graphs, it was observed that the radiation incident in the twelve months of the year has a bell shape, i.e., during the rainy months, the ASR is far lower than during the dry seasons. However, the radiation incident had the same pattern over the ten (10) years of the study.

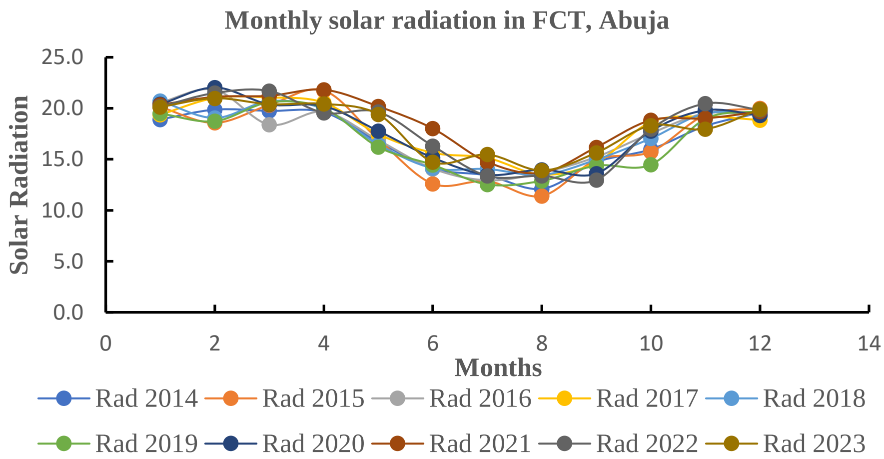

Figure 1 (a). Solar radiation incidents in FCT.

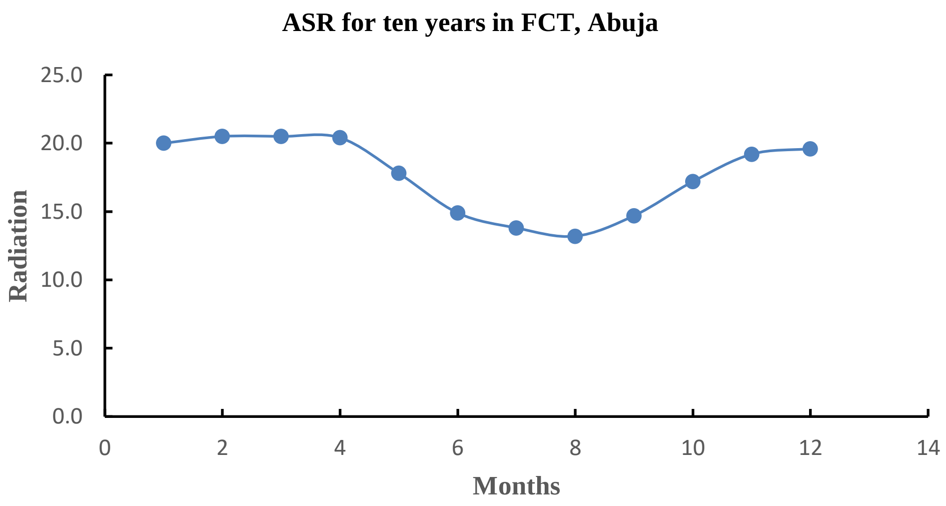

Figure 1(b). ASR over FCT, Abuja.

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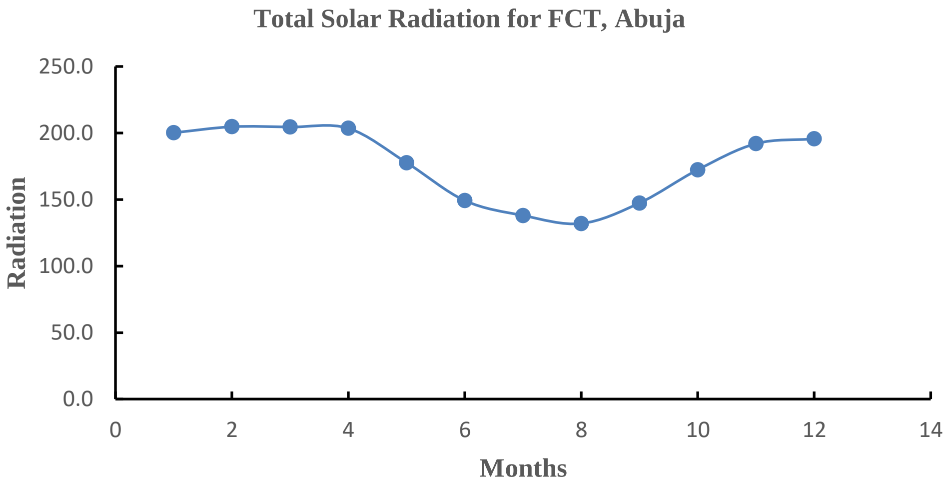

Figure 1(c). Total solar radiation over FCT, Abuja.

Figure 1 (a-c) illustrates that FCT, Abuja experiences a maximum solar radiation of 21.8 MJm^{-2} day^{-1}, a minimum of 11.4 MJm^{-2} day^{-1}, and an average value of 17.65 MJm^{-2} day^{-1}. The total solar radiation received annually for the ten years amounts to 2117.3 $MJm^{-2}day^{-1}$, with an average of 211.73 MJm^{-2} day^{-1} yearly. Notably, during the dry season, the solar radiation peaks, with the highest recorded value being 21.8 MJm^{-2} day^{-1}. However, the solar radiation data collected in 2014 and 2019 indicate unusually low values. The yearly average solar radiation dropped to 16.9 MJm^{-2} day^{-1}, marking the lowest average on record for FCT, Abuja. This period coincided with a minimum recorded temperature of 21.9°C, which could indicate a seasonal or atmospheric anomaly affecting both temperature and solar radiation levels.

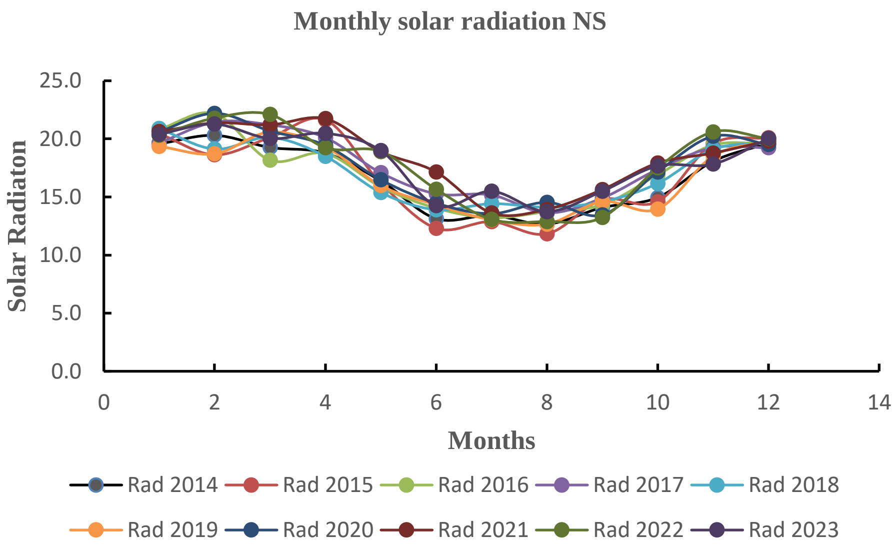

Figure 2 (a). Solar radiation over NS

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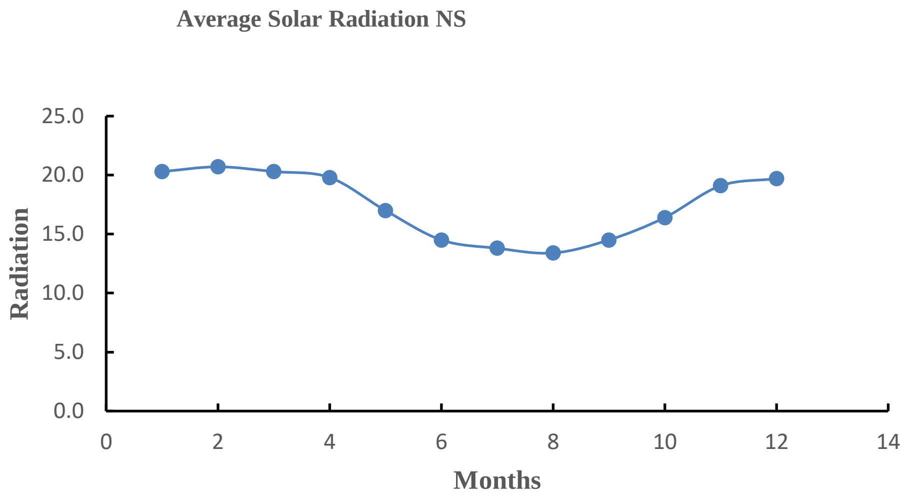

Figure 2 (b) Average solar radiation over NS.

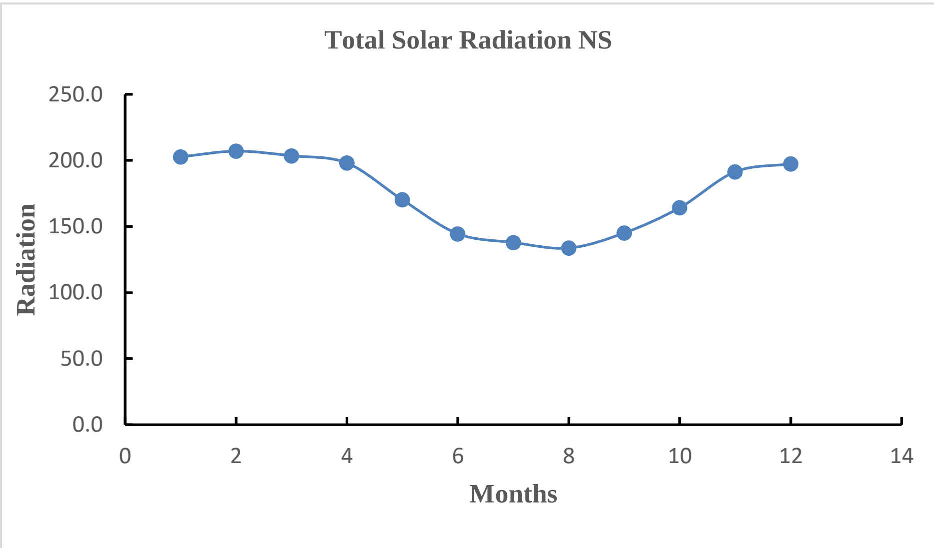

Figure 2 (c). Total solar radiation for NS.

Figure 2 (a-c) provides insights into the solar radiation characteristics of NS. The data reveals that the state experiences a maximum solar radiation of 22.2 MJm^{-2} day^{-1}, a minimum of 11.8 MJm^{-2} day^{-1}, and an average value of 17.46 MJm^{-2} day^{-1}. The total annual solar radiation recorded for the state in ten years is 2095.5 MJm^{-2} day^{-1}. During the dry season, NS achieves its peak solar radiation level, with the highest recorded value being 22.2 MJm^{-2} day^{-1}. Furthermore, the data indicate that solar radiation is more stable during the dry season compared to the rainy season, where fluctuations in radiation are more pronounced. This stability in the dry season may be attributed to clearer atmospheric conditions, reduced cloud cover, and minimal precipitation, which allow for consistent solar energy reception.

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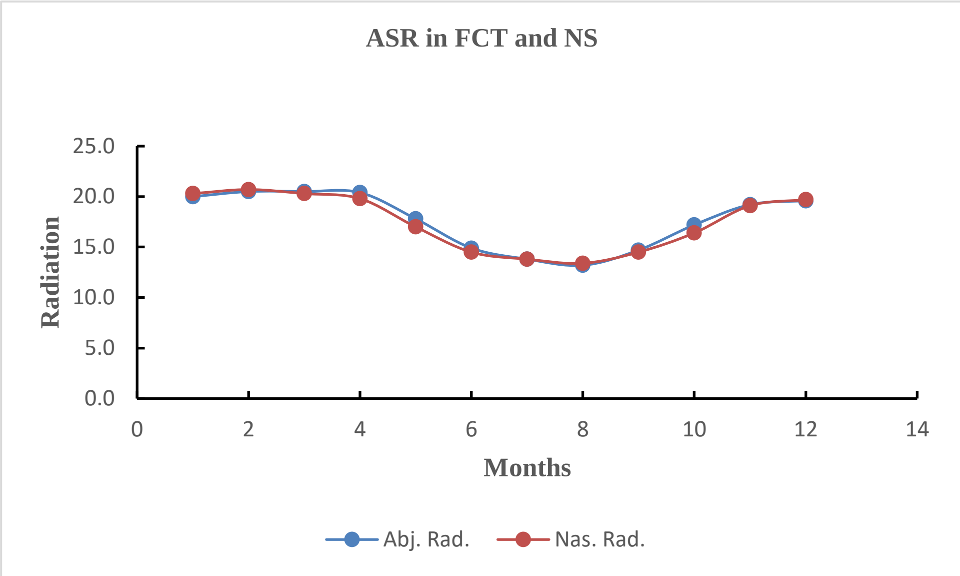

Figure 3: Comparison of ASR for FCT and NS.

Figure 3 provides a comparative analysis of solar radiation incidence between the FCT, Abuja, and NS. The data reveals distinct differences in solar radiation patterns between the two areas during the rainy season. Notably, the solar radiation values in the two regions are not identical, with variations observed due to differing atmospheric and environmental conditions. As the rainy season concludes, solar radiation levels in both areas decline to their lowest point. However, starting from November, solar radiation begins to increase steadily, peaking in February every year. This trend highlights the seasonal nature of solar radiation, with lower values during the wet months and higher values during the dry season. During the dry season, the incident solar radiation for both FCT and NS exhibits a near-zero slope, indicating a stable and consistent level of solar energy reception. Over the study period, however, the average solar radiation for FCT is slightly higher than that of NS by approximately 1%. This difference underscores the greater solar energy potential of FCT, likely due to factors such as geographical location, atmospheric clarity, and reduced cloud cover compared to Nasarawa State.

Evaluation of CI

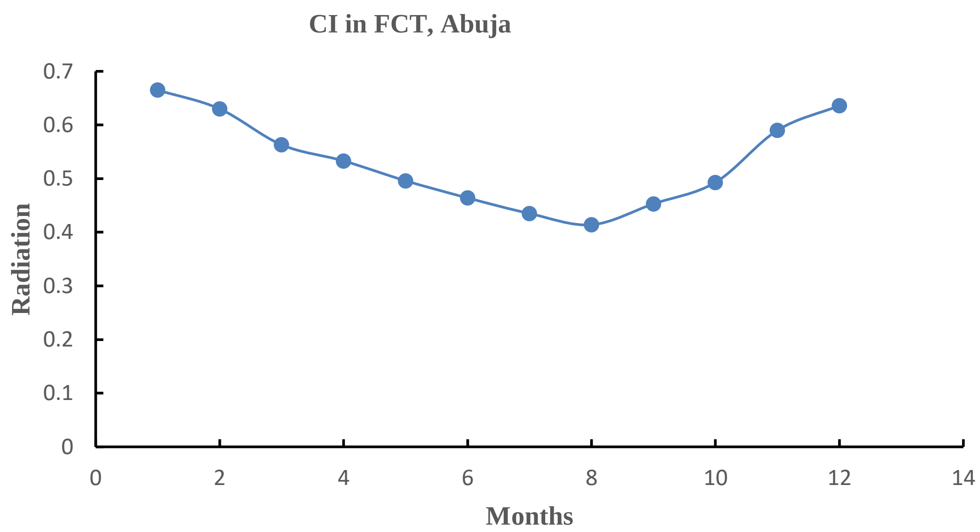

Figure 4 (a): CI over FCT, Abuja.

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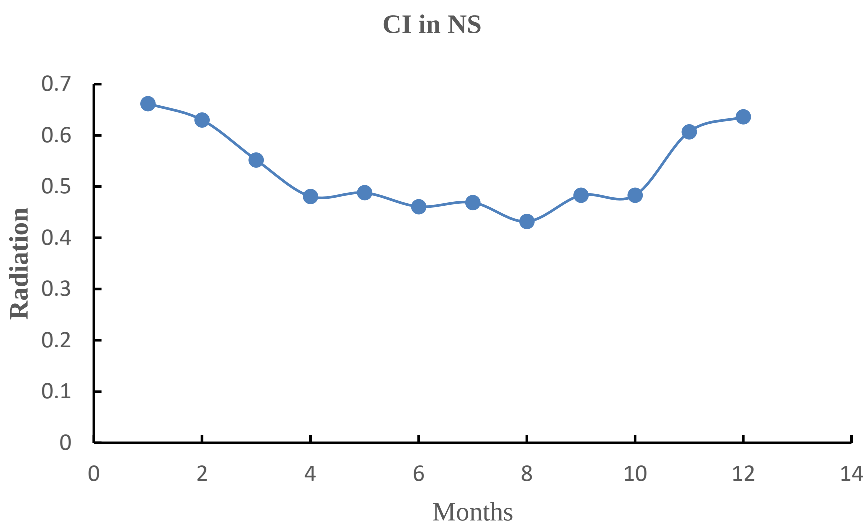

Figure 4 (b): CI over NS.

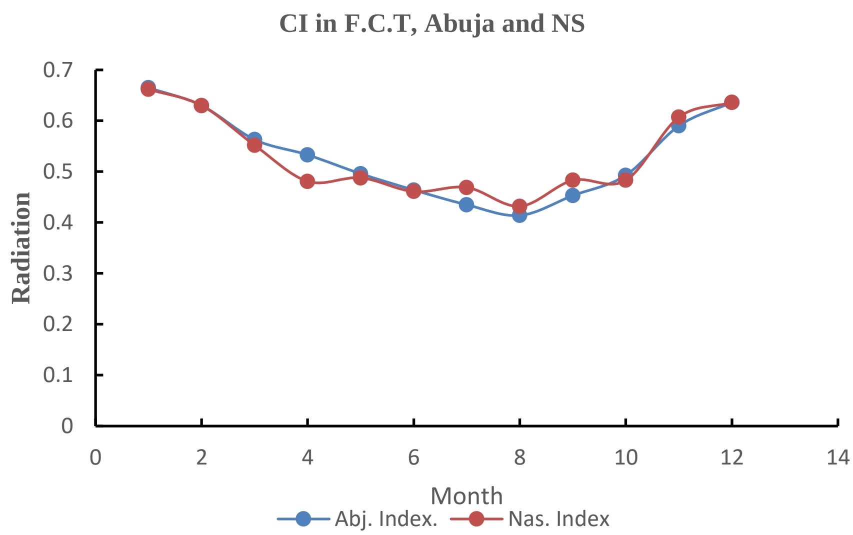

Figure 4 (c): CI over FCT and NS.

Figure 4 illustrates the monthly variations of the clearness index (K_t) for both the FCT and NS. These variations provide valuable insights into the sky conditions and the processes of transmitting and scattering incoming solar radiation in the two locations. The clearness index (K_t) is a critical parameter that reflects the fraction of solar radiation transmitted through the atmosphere. Lower values of K_t indicate reduced global radiation, typically associated with cloudy skies and a higher proportion of diffuse radiation components. Conversely, higher K_t values correspond to elevated levels of global radiation, predominantly dominated by direct solar radiation. The data depicted in Figure 4 reveal a dip pattern in the clearness index during the dry season for both locations, suggesting an increase in diffuse solar radiation. This observation could be attributed to atmospheric conditions such as the presence of dust, haze, or other aerosols commonly observed during the dry season, which enhance scattering and reduce the direct component of solar radiation. For the FCT, the CI (K_t) ranges between 0.414 to 0.665, while for NS, the values span from 0.432 to 0.662. These differences underscore the slightly clearer atmospheric conditions in NS compared to Abuja, likely resulting in a higher proportion of direct solar radiation in NS.

Electricity Solar Power Potentials for FCT and NS

Solar energy can be converted into electricity for use via Photovoltaic panels. a 550W PV panel was used,

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as earlier stated in section 3.4, to simulate the collected data for the two study areas. As expected from Figure 5, the power output pattern is the same as the radiation pattern and also opposite to the clearness index.

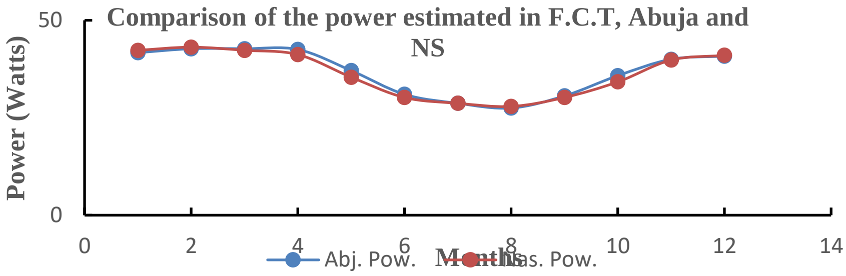

Figure 5. Comparison of the Power estimated in the FCT and NS.

The solar power estimates for the FCT and NS are provided in terms of minimum, maximum, and average power outputs. For FCT, the minimum power output is estimated at 27.5W, the maximum at 42.7W, and the average at 36.8W. In contrast, NS shows lower power estimates, with the minimum power output at 27.9W, the maximum at 43.1W, and the average at 36.4W. These estimates are based on the solar radiation values for the two regions and the performance of photovoltaic (PV) systems under typical conditions. For this simulation, the photovoltaic units considered have an area of 2.17 m². This area is crucial for determining the total potential power generation, as it directly relates to the efficiency and the energy captured from solar radiation over time. Next, we consider the total surface areas of the two regions. The FCT spans an area of 7315 km², while NS covers a much larger area of 27117 km². The size of these areas is important for calculating the total potential solar power generation, as the available land area influences the number of photovoltaic panels that can be installed. To estimate the potential power generation for both regions, we multiply the area of each region by the power output of a single photovoltaic unit (based on the given estimates). For Abuja, the total electricity that could be generated, based on the entire area of the region and the annual total solar radiation, is approximately 6.209 x 10^7 MWh (1.49 x 10^6 MW). Compared to Anthony (2023), he analyzed a standalone PV solar power plant for a typical 200-bungalow housing estate in Abuja, Nigeria, which was designed and simulated to study its technical and economic feasibility using PV system 7.3 software. The result shows that the horizontal irradiation reaching Abuja, through a 360 KWP PV system, supplied the energy to an estate with an energy demand of 1,480 kWh/day. The system produced a total of 571,288 kWh of electric energy per year with a performance ratio of 75.4 %. For NS, the estimated total electricity generation potential is 2.27 x 10^8 (5.55 x 106 MW. Comparing with Musa (2023), he used geospatial techniques to integrate ground-measured solar radiation data with temperature to assess solar energy potentials in Niger, Kogi and Nasarawa States of North central, Nigeria. The findings revealed that the amount of exploitable solar power in NS was 144.262 x 10^6 MWh. However, it is essential to note that using the entire land area for solar photovoltaic installations is not a practical or feasible approach. Numerous factors, such as urbanization, infrastructure, agricultural use, and environmental concerns, would limit the amount of land available for solar panel installations. As a result, it can be reasonably assumed that only a fraction of the land would be suitable for such purposes. Given these practical constraints, it is plausible to achieve at least half of the projected potential. Therefore, for FCT, this would translate to an achievable power generation potential of approximately 7.45 x 10^5 MW, and for NS, an achievable power potential of around 2.73 x 10^6 MW. This more realistic estimation considers land availability and other limitations in the deployment of solar energy systems.

Statistical Analysis

Statistical analyses were conducted in order to study the behavior pattern of the collected data. The nature and behavior of the data can reveal the potential and reliability of the collected data. The results of the descriptive statistics conducted on the collected solar radiation data are presented in Table 1.

	FCT, Abuja	NS
Mean, (μ)	17.650	17.460

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Median	18.500	18.050
Mode	20.500	14.500
Standard deviation (δ)	2.807	2.837
Skewness (Z_1)	-0.379	0.220
Kurtosis (Z_2)	1.322	1.168
Standard error	0.810	0.819
Range	10.600	10.300
Minimum Radiation	11.4	11.8
Maximum Radiation	22.00	22.200
Total Radiation	2113	2095

Table 1: Analysis of the FCT and NS

The standard errors for these datasets are 0.810 for FCT and 0.819 for NS. These values fall within an acceptable range, indicating that the data are reliable and provide a sound basis for analysis. In addition to the standard error, two important statistical variables considered in this analysis are skewness and kurtosis, as presented in Table 9. Skewness measures the asymmetry or "tilt" of the data distribution relative to a normal distribution curve, indicating the direction and degree of skew. Kurtosis, on the other hand, quantifies the "tailed Ness" or the sharpness of the peak and the thickness of the tails of the distribution compared to a normal distribution. These two measures help describe the shape of the distribution, which is crucial for understanding the underlying characteristics of solar radiation data for the two regions. For the solar radiation data, the skewness values for the FCT and NS are -0.379 and -0.220, respectively. A negative skewness value of -0.379 for Abuja indicates that the distribution's tail is slightly shifted towards the left, meaning that the data points in Abuja are more concentrated on the higher end of the scale, with fewer extremely low values. In the same way, a negative skewness of -0.220 for NS suggests that the distribution's tail also shifted to the left, indicating that NS data concentrated on the higher end of the scale, with fewer extremely low values. These skewness values align with Figure 4, which illustrates the distribution patterns of solar radiation in both locations. This distribution pattern implies that solar radiation in both regions is more reliable during the dry season when radiation levels are more consistent. On the other hand, during the rainy season (or early stages of the year), the solar radiation values tend to fluctuate more due to cloud cover and other atmospheric factors.

Regarding kurtosis, both regions exhibit values of approximately 1.322 for FCT and 1.168 for NS. These values indicate that the distributions are platykurtic, meaning that the data have flatter peaks and wider tails than a normal distribution. This suggests that the data from both regions deviate less sharply from the mean and exhibit a more uniform spread of values compared to a normal distribution. In other words, both FCT and NS solar radiation distributions have relatively less extreme outliers than would be expected in a normal distribution. These skewness and kurtosis values suggest that both regions may share similar underlying processes for generating solar radiation data. Despite the differences in the shape of the distribution (slightly left-skewed for FCT and NS), the general behavior of the solar radiation data in both locations follows similar trends, which could indicate comparable climatic and atmospheric conditions that influence solar energy generation in these regions.

Evaluation of Reliability

Reliability is the degree to which the result of a measurement or calculation can be depended on to be accurate. Therefore, the frequency of solar radiation in the study areas has been above the recommended threshold capable of generating electricity was estimated and the reliability calculated is shown in Table 2.

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YEAR	Abuja	Nasarawa
2014	83.333	75.000
2015	75.000	83.333
2016	83.333	83.333
2017	91.667	91.667
2018	91.667	91.667
2019	83.333	83.333
2020	75.000	83.333
2021	91.667	83.333
2022	75.000	75.000
2023	91.667	91.667
Average	84.167	84.164

Table 2: Reliability of electricity generation for the FCT and NS.

According to the data presented in Table 2, the FCT demonstrates equal reliability for generating electricity from solar resources compared to NS. This conclusion is drawn based on the observation that Abuja experiences a greater number of days where solar radiation exceeds the recommended threshold for efficient photovoltaic power generation. The threshold typically represents the minimum amount of solar radiation required for solar panels to operate effectively and efficiently. The higher number of days in Abuja with solar radiation surpassing this threshold suggests that, over the year, FCT enjoys more frequent and sustained periods of high solar radiation. This is an important factor in determining the feasibility and efficiency of solar energy production in a given location. In comparison, NS, with a larger land area, also experiences higher days with solar radiation exceeding the recommended threshold, thereby indicating a high consistency in the availability of solar energy. This variability in NS can result in predictable solar energy generation, equal in its reliability when compared to Abuja. Additionally, the average values of solar radiation and the clearness index (Kt), further corroborate these findings. The solar radiation and clearness index data for Abuja are consistent with the trends observed in Table 10, reinforcing the notion that Abuja receives more consistent and reliable solar radiation throughout the year. The clearness index is a key parameter that indicates the fraction of solar radiation that is transmitted as direct radiation (as opposed to diffuse radiation). A higher clearness index suggests clearer skies and more direct sunlight, which are favorable conditions for solar energy generation. Abuja's higher average clearness index indicates that it is more likely to experience clear skies and optimal solar radiation conditions, further supporting the conclusion that it is a more reliable location for solar energy generation compared to NS.

Conclusion

The study confirms that both FCT and NS possess significant solar energy potential, with FCT showing slightly more consistent and stable solar radiation levels. Although NS recorded marginally higher peak radiation values, FCT demonstrated greater reliability, making it a more viable location for sustained solar power generation. The seasonal variations observed in the data highlight the importance of understanding climatic conditions when designing solar energy systems. The CI analysis suggests that atmospheric conditions, such as dust and cloud cover, play a crucial role in determining the amount of solar radiation that reaches the surface. These conditions influence the efficiency of solar panels, particularly in the dry season when increased aerosol presence can scatter sunlight and reduce direct radiation levels. Statistical findings indicate that both regions exhibit a negatively skewed distribution, which implies that high radiation values are more common than extremely low values. Despite its smaller land area, FCT emerges as a slightly better location for solar energy projects due to its higher CI, more stable radiation levels, and greater reliability. However, NS's larger land area provides greater opportunities for large-scale solar power installations if infrastructural and environmental factors are adequately considered. These findings align with previous studies indicating that North Central Nigeria has the potential to generate significant solar energy, surpassing the current installed capacity of other energy sources in the region. If properly harnessed, solar power can serve as a major contributor to Nigeria’s electricity supply, reducing dependence on fossil fuels and improving energy security.

Recommendation

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To maximize solar energy potential in Abuja and Nasarawa, strategic investments should focus on large-scale photovoltaic projects in Abuja due to its higher solar reliability, and expansive solar farms in Nasarawa, leveraging its land availability. Hybrid systems with battery storage are essential to ensure energy reliability during low-radiation periods, while integrating other renewables like wind and hydro can enhance grid stability.

Further studies on atmospheric effects—particularly dust, haze, and cloud cover—are necessary to improve system efficiency, alongside research into anti-dust and self-cleaning panel technologies suited for the region. Land-use optimization strategies such as rooftop solar, floating installations, and agrivoltaics should be prioritized to balance energy generation with land conservation.

Supportive policy frameworks, including tax incentives and streamlined project approvals, will accelerate adoption. Public awareness and technical training programs will build local capacity, promote job creation, and drive sustainable development. These measures can position Abuja and Nasarawa as models for solar energy advancement in West Africa.

References

Adaramola, M. S., & Paul, S. S. (2017). Economic analysis and potential feed-in tariff of grid-connected PV systems in Nigeria. *Environmental Progress & Sustainable Energy*, *36*(1), 305–314. https://doi.org/10.1002/ep.12482

Adavuruku, B. M., Aghaegbunam, E. J., Chidozie, I. K., & Stephen, M. A. (2022). Geospatial analysis of solar energy potentials in Niger State, Nigeria. *American Journal of Modern Physics*, *11*(6), 85–94. https://doi.org/10.11648/j.ajmp.20221106.12

Ajayi, O. O., Olawale, A. S., & Nwankwo, U. C. (2021). Challenges and prospects of solar energy utilization in Nigeria: A policy perspective. *Journal of Sustainable Energy Research*, *16*(2), 115–132.

Akinyele, D. O., & Odewumi, S. O. (2021). Energy development in Nigeria: The role of solar power. *Renewable Energy Technology*, *28*(1), 45–58.

Alami, A., & Khaled, M. (2021). Solar energy development in the MENA region: Challenges and opportunities. *Renewable Energy Reports*, *18*(2), 156–172.

Brivana Solar. (2025). *Nigeria's solar energy policy evolution*. https://brivana.com.ng

Chanchangi, Y. N., Ghosh, A., Sundararajan, A., & Mallick, T. K. (2023). Assessment of solar radiation as a power generation source in Nigeria. *Journal of Renewable and Sustainable Energy*, *15*(1), 013102. https://doi.org/10.1063/5.0115090

DeCarlo, L. T. (2019). On the meaning and use of kurtosis and skewness: A historical review and look to the future. *International Journal of Statistics and Probability*, *8*(2), 15–30. https://doi.org/10.5539/ijsp.v8n2p15

Eke, J. (2020). Solar energy and its role in Nigeria's energy crisis. *Renewable Energy Journal*, *32*(3), 174–186.

International Energy Agency. (2020). *Renewable energy market analysis 2020*. https://www.iea.org/reports/renewable-energy-market-analysis

International Energy Agency. (2022). *World energy outlook 2022*. https://www.iea.org/reports/world-energy-outlook-2022

International Journal of Energy. (2020). Challenges in scaling solar energy in Nigeria. *IOP Conference Series: Earth and Environmental Science*, *83*(1), 012015. https://doi.org/10.1088/1755-1315/83/1/012015

Irekeola, B. J., Bori, I., Adedipe, O., & Babawuya, A. (2020). Analysis of solar energy potentials in Katsina and Sokoto States, Nigeria. In *Proceedings of the 33rd Conference of the Nigerian Society of Engineers (NSE)* (pp. 186–192). http://repository.futminna.edu.ng:8080/jspui/handle/123456789/1816

Li, X., Yang, Z., & Xu, W. (2021). China's solar energy expansion: Technological advancements and policy impacts. *Journal of Renewable Energy*, *14*(3), 210–228.

Nigerian Electricity Regulatory Commission. (2025). *Regulatory reforms for solar energy in Nigeria*. https://nerc.gov.ng/index.php/library/documents

Okonkwo, G. N., Adegbite, S. O., & Yusuf, M. T. (2020). Solar radiation assessment in selected Nigerian locations: A case for sustainable energy development. *Renewable Energy Journal*, *49*(1), 290–305.

Olatomiwa, L., Mekhilef, S., & Sanusi, K. O. (2023). Renewable energy integration for sustainable electricity supply in Nigeria: A review. *Renewable and Sustainable Energy Reviews*, *180*, 113980. https://doi.org/10.1016/j.rser.2023.113980

Patriot NG. (2025). *Solar power adoption in Nigeria: A lifeline for energy-deficient communities*. https://patriot.ng

Primeteknologies. (2025). *Solar energy revolution in Nigerian industries*. https://primeteknologies.com

Reuters. (2024, August 12). Nigeria-China economic pact boosts solar energy cooperation. *Reuters News*. https://www.reuters.com

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Shaaban, M., & Petinrin, J. O. (2014). Renewable energy potentials in Nigeria: Meeting rural energy needs. *Renewable and Sustainable Energy Reviews*, *29*, 72–84. https://doi.org/10.1016/j.rser.2013.08.078

Soneye, O. O. (2020). Evaluation of clearness index and cloudiness index using measured global solar radiation data: A case study for a tropical climatic region of Nigeria. *Atmósfera*, *34*(1), 25–39. https://doi.org/10.20937/ATM.52796

Sun King. (2023). *Solar energy adoption trends in Nigeria*. https://www.sunking.com

U.S. Department of Energy. (2022). *Solar energy growth in the United States: Current status and future projections*. Office of Energy Efficiency & Renewable Energy. https://www.energy.gov/eere

Udeh, C., Eze, S., & Umeora, O. (2023). An evaluation of solar radiation and energy potential in northern Nigeria. *Energy Reports*, *9*, 123–135. https://doi.org/10.1016/j.egyr.2023.01.012

Wang, L., Zhao, H., & Chen, Q. (2020). Comparative analysis of solar power policies in China, Australia, and the USA. *Journal of Energy Policy*, *52*(4), 321–339. https://doi.org/10.1016/j.enpol.2020.04.005

World Bank. (2021a). *Nigeria energy access scale-up: A comprehensive overview*. https://www.worldbank.org/en/country/nigeria

World Bank. (2021b). *Nigeria Electrification Project*. https://www.worldbank.org/en/news/feature/2021/03/04/nigeria-electrification-project

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