Harnessing Solar Energy in Ewekoro, Ogun State: Opportunities and Economic Impact

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Abstract- ***This study investigates the solar energy potential of Ewekoro, a rapidly industrializing region in Ogun State, Nigeria, with a view toward assessing its viability for sustainable power generation and its broader economic implications. Utilizing high-resolution ERA5 satellite data from 2014 to 2023, Essential solar radiation metrics, encompassing shortwave radiation in both all-sky and clear-sky scenarios (ssrd, ssrc, ssrdc) and thermal radiation (str, strd, strdc), were examined to assess the feasibility of photovoltaic (PV) energy harvesting. Research indicates that Ewekoro receives an average of 1.64 MJ/m²/day of all-sky solar radiation (ssrd) and 2.36 MJ/m²/day under clear-sky circumstances (ssrdc), confirming its appropriateness for solar systems. The results revealed consistently favorable solar radiation values, with average daily shortwave radiation exceeding 1.5 MJ/m²—surpassing the minimum threshold required for basic PV system viability. Time-series analyses, boxplots, and histograms affirmed the stability and reliability of solar energy availability in the region, even under varying sky conditions. Further, the study explores the economic prospects of deploying decentralized solar power in Ewekoro, particularly in reducing dependence on fossil fuels, stimulating job creation, and powering industrial and rural communities. The local cement and mining industries stand to benefit immensely from the integration of solar technologies, enhancing productivity and cost-efficiency while minimizing environmental impact. Additionally, stable clear-sky radiation profiles and thermal moderation patterns indicate favorable conditions for long-term solar infrastructure with minimal performance degradation. By aligning with Sustainable Development Goals (SDG 7 and SDG 13), this research supports policy recommendations that promote investment in solar energy infrastructure, public-private partnerships, and energy access equity in underserved areas. The findings serve as a strategic roadmap for energy diversification and economic transformation in Ogun State and beyond.***

Indexed Terms- ***Ewekoro, Solar Energy, Photovoltaic Systems, Sustainable Development, Solar Irradiance***

I. INTRODUCTION

Access to dependable, cost-effective, and sustainable energy is fundamental to economic advancement, human development, and environmental sustainability. The energy sector in Nigeria is marked by chronic shortages, infrastructural inadequacies, and a heavy dependence on fossil fuels, especially diesel and natural gas. The World Bank (2023) reports that more than 85 million Nigerians, around 43% of the population, do not have access to grid electricity, with a substantial number residing in rural and semi-urban regions. Ogun State, notwithstanding its industrial significance, is not immune to this reality. Ewekoro, a significant local government area, accommodates energy-intensive activities including cement production and agro-processing enterprises, although it endures an inconsistent power supply. This highlights a significant disparity between energy demand and supply that necessitates resolution through sustainable alternatives. Despite the importance it holds, just a small amount of solar energy emitted by the sun is captured by the Earth. The majority of energy dissipates into space. The examination of solar radiation is hence essential in every research pertaining to energy balance in any region (Boyo & Adeyemi, 2011). Solar energy constitutes one of the most plentiful renewable resources in Nigeria, exhibiting irradiation levels

between 4.0 and 6.5 kWh/m²/day across different regions (Ajayi et al., 2022; IRENA, 2023). The southwestern region of the country, encompassing Ewekoro, receives in excess of 3000 hours of sunlight per year, indicating substantial potential for the implementation of solar photovoltaic (PV) systems. Nonetheless, despite its promise, the adoption of solar energy is constrained by obstacles like substantial initial expenses, insufficient regulatory structures, and a lack of knowledge (Oyedepo et al., 2021; GIZ, 2022). The issues are exacerbated by the absence of localized feasibility studies that offer data-driven insights for particular areas.

This research fills the gap by examining a decade of ERA5 satellite data pertaining to Ewekoro to assess the region's solar potential. It examines the technological feasibility and economic consequences of utilizing solar energy. The results are anticipated to guide local government policies, stimulate investor interest, and advance the overarching objective of attaining Sustainable Development Goal 7 (SDG 7), which promotes universal access to clean and affordable energy by 2030 (UNDP, 2023). The report offers a thorough evaluation of the potential of solar energy to serve as a transformative catalyst for energy security and economic advancement in Ewekoro.

II. METHODOLOGY

This research utilizes a data-driven methodology to assess the solar energy potential of Ewekoro in Ogun State, Nigeria, employing satellite-derived climate reanalysis data. The ERA5 dataset from the European Centre for Medium-Range Weather Forecasts (ECMWF) was employed (Hersbach et al., 2020). ERA5 delivers hourly assessments of atmospheric, terrestrial, and oceanic climate variables at a spatial resolution of roughly 0.25° x 0.25°, ensuring dependable and uniform coverage over extended durations (Hersbach et al., 2020). The data included in this analysis encompasses the years 2014 to 2023, comprising over 1,200 entries pertinent to the study location. The key parameters examined comprise:

- Shortwave radiation: ssrc (surface solar radiation under clear skies), ssrd (downward surface solar radiation), and ssrdc (downward clear-sky radiation).
- Longwave radiation: str, strd, and strdc, denoting surface thermal radiation and its downward components.
- Surface albedo indices: alnid and alnip, which quantify the fraction of solar energy reflected by the surface.

These criteria were chosen for their significant relevance in evaluating the viability of photovoltaic (PV) systems. Shortwave radiation dictates the quantity of solar energy available for conversion, but longwave radiation and albedo influence temperature regulation and system efficiency (Urraca et al., 2018; Bhaduri et al., 2021).

Data cleansing and analysis were performed utilizing Panoply and Matlab software. Descriptive statistics, histograms, boxplots, and time-series plots were employed to evaluate radiation variability, mean magnitudes, and frequency distributions. Special emphasis was placed on contrasting clear-sky (ssrdc) and all-sky (ssrd) circumstances to ascertain the degree of cloud attenuation—a vital element in actual photovoltaic performance (Shaaban et al., 2020).

The geospatial alignment with the coordinates of Ewekoro (about 6.93°N, 3.23°E) guaranteed localized precision. This methodological technique facilitates the extraction of dependable findings regarding the temporal stability and spatial significance of solar energy potential in Ewekoro. Moreover, it establishes a replicable framework for analogous feasibility studies in other semi-urban villages in Nigeria, so contributing to the national dialogue on decentralized clean energy implementation.

III. FINDINGS AND ANALYSIS

The examination of ERA5-derived solar radiation data for Ewekoro over a decade indicates very advantageous conditions for solar energy implementation. Three essential shortwave solar radiation metrics (ssrd, ssrdc, and ssrc) offer a comprehensive overview of solar energy availability. The average values for ssrd, ssrdc, and ssrc are

roughly 1.64 MJ/m², 2.36 MJ/m², and 1.98 MJ/m² each day, respectively. The results above the minimum threshold of 1.5 MJ/m²/day for basic photovoltaic system viability, as corroborated by other renewable energy feasibility studies, especially in poor nations with tropical climates (Shaaban et al., 2020; Jacobson et al., 2022). Figure 1, a comparison time-series figure, illustrates that `ssrdc` consistently exhibits greater magnitudes than `ssrd`, emphasizing the impact of cloud attenuation.

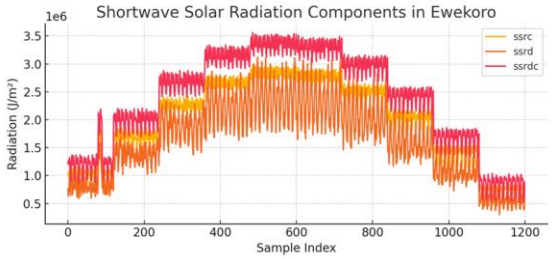

Figure 1: Time-series plot of shortwave radiation components (ssrc, ssrd, and ssrdc).

Figure 2 presents the histogram depicting the frequency distribution of ssrd values over time, demonstrating constant clustering within the range of 1.4–2.2 MJ/m². This stability bolsters the argument for enduring solar installations.

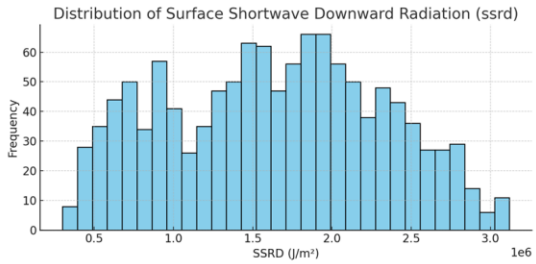

Figure 2: Histogram of surface shortwave downward radiation (ssrd).

Figure 3, a box plot comparison, further substantiates this finding by illustrating the median and interquartile ranges of each radiation component. Significantly, ssrdc routinely demonstrates elevated medians, corroborating Ewekoro's dependable clear-sky potential.

Figure 4 illustrates the thermal radiation components in Ewekoro, offering significant insight into the atmospheric heat exchange dynamics pertinent to solar energy applications.

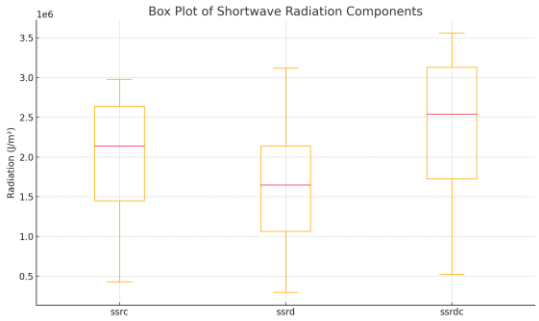

Figure 3: Box plot comparison of shortwave radiation components.

The graphic encompasses three parameters: str (net surface thermal radiation), strd (all-sky downward thermal radiation), and strdc (clear-sky downward thermal radiation). These variables elucidate the quantity of thermal energy emitted from the Earth's surface and the amount collected from the atmosphere under varying conditions.

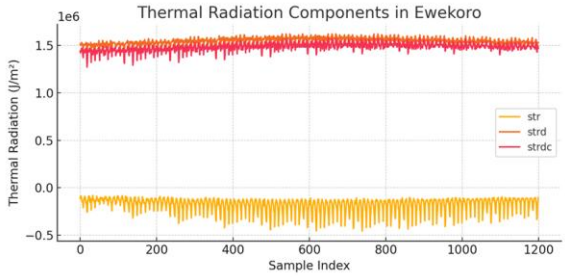

Figure 4: Graph of thermal radiation elements.

The str values in the plot are uniformly negative, signifying a net loss of thermal energy from the surface. This is common in the absence of direct sunshine, such as at night or under clear skies, when the ground emits heat back into the atmosphere. In Ewekoro, the str values fluctuate between around −450,000 J/m² and −80,000 J/m². The consistent heat loss indicates stable nighttime cooling conditions, advantageous for photovoltaic (PV) system performance, as lower ambient temperatures enhance PV conversion efficiency, particularly during early morning and evening hours. The strd values denote the longwave radiation emitted by the atmosphere, encompassing clouds, directed back toward the surface. In Ewekoro, these values approximate 1.54

MJ/m². This signifies that the atmosphere is transmitting a moderate quantity of heat energy to the earth, in accordance with the humid and semi-cloudy environment characteristic of southwestern Nigeria. An increased value in this context would indicate enhanced cloud cover or humidity, which diminishes surface cooling by functioning as a thermal barrier. Conversely, the strdc component, which measures downward thermal radiation in clear-sky conditions, averages marginally lower at 1.48 MJ/m². The minor discrepancy between strd and strdc indicates that cloud cover does not significantly modify the longwave radiation profile in Ewekoro. This consistency substantiates the hypothesis that the region endures very steady air conditions, advantageous for solar PV system development and performance modeling. Consequently, the thermal radiation graph for Ewekoro illustrates a stable and foreseeable pattern of heat exchange, characterized by uniform nocturnal cooling and moderate atmospheric insulation. These conditions augment the dependability and efficiency of solar PV systems by facilitating temperature control, reducing overheating during daylight hours, and optimizing energy output over time.

IV. PROSPECTS FOR SOLAR ENERGY IN EWEKORO

The data analysis confirms that Ewekoro has significant solar energy potential applicable to various uses, including household electrification and industrial-scale energy delivery. Clear-sky downward solar radiation (ssrdc) averages 2.36 MJ/m²/day, while all-sky circumstances (ssrd) average 1.64 MJ/m²/day, indicating a reliable solar input sufficient for photovoltaic (PV) generation (IRENA, 2023). These results exceed the baseline requirements for off-grid systems and demonstrate adequate capacity for storage-based hybrid solutions. The potential for implementing solar energy in Ewekoro is favorable in three primary areas: residential, commercial/industrial, and community electrification.

A 3–5 kW rooftop solar photovoltaic system, complemented by lithium-ion battery storage, may adequately fulfill the typical household energy requirement of 600–900 kWh per month in Ewekoro. Due to the region's consistent radiation levels and comparatively low nighttime temperatures (shown by stable strdc values), the efficiency of these systems may be sustained throughout the year with little performance declines (Chineke & Ezike, 2017; Owolabi et al., 2021). Additionally, municipal edifices, educational institutions, and healthcare facilities might utilize solar backup systems, which have been effectively implemented in comparable semi-urban areas through the pilot initiatives of the Rural Electrification Agency (REA, 2023). The industrial outlook is becoming persuasive. Ewekoro hosts one of Nigeria's largest cement factories and many medium-scale agro-processing companies that predominantly depend on diesel generators. The incorporation of solar microgrids, whether as a primary energy source or as a backup, can diminish energy expenses by as much as 60% and cut greenhouse gas emissions (Akuru et al., 2022). Moreover, solar energy can bolster energy security during national grid failures, which frequently occur in the region (Oyedepo et al., 2021).

Furthermore, the implementation of solar mini-grids in isolated or underprivileged areas inside Ewekoro LGA is both technically and economically viable. Mini-grids with capacities between 10 and 100 kW can supply energy to clusters of 50 to 150 houses, providing dependable power for lighting, water pumping, and small businesses (AllOn, 2022; Ogunleye & Adenikinju, 2021). The current road and grid infrastructure in Ogun State provide a basis for the efficient expansion of such systems. Ewekoro can function as a model center for Ogun State's solar energy adoption strategy, given these multifaceted potential. A collaborative initiative encompassing governmental incentives, commercial investments, and community engagement will be essential to realizing the comprehensive advantages of solar energy in the region.

V. ECONOMIC CONSEQUENCES

The economic advantages of using solar energy in Ewekoro are diverse, encompassing cost reductions, employment generation, productivity improvement, and macroeconomic stability. Primarily, solar energy provides a markedly reduced long-term cost of electricity in comparison to diesel generators, which presently prevail in Nigeria's off-grid power sector.

As reported by GIZ (2022), the Levelized Cost of energy (LCOE) for solar photovoltaic systems in Nigeria has decreased to between ₦25 and ₦30 per kilowatt-hour (kWh), but diesel-generated energy varies from ₦90 to ₦120 per kWh or higher, contingent upon fuel prices and generator efficiency. In Ewekoro's businesses, especially in cement manufacture and milling activities, this cost disparity results in annual savings amounting to millions of naira. In residential settings, implementing rooftop photovoltaic systems with little battery backup can significantly decrease dependence on the national grid or obviate the necessity for costly generators. A 5-kW solar household system, priced at approximately ₦3.5 million inclusive of batteries, recoups its investment within 3–5 years, particularly when financed or acquired through cooperative leasing schemes (BOI, 2023; REA, 2023). Furthermore, in rural regions with restricted or inconsistent grid connectivity, solar mini-grids provide not only energy but also enhanced living conditions, facilitating prolonged company operations, better healthcare, and sustained educational opportunities. The generation of employment is another vital economic benefit. The Nigerian Economic Summit Group (NESG, 2022) projects that extensive solar adoption may create more than 200,000 direct and indirect employment opportunities by 2030. These encompass positions in panel fabrication, installation, maintenance, project creation, and system evaluation. The Nigeria Energy Support Programme (NESP) has initiated vocational training initiatives, and Ewekoro could gain from local talent involvement if training centers and apprenticeship models are expanded (GIZ, 2023). In addition to direct economic indicators, solar energy enhances macroeconomic stability by diminishing Nigeria's reliance on imported fuels. More than 30% of the country's foreign cash is allocated to refined gasoline imports, thereby destabilizing the naira and exacerbating trade deficits (World Bank, 2023). By decentralizing electricity production via solar investments, localities such as Ewekoro enhance national energy sovereignty. Ultimately, solar adoption increases property value and draws investment. Areas with reliable electricity are more inclined to attract entrepreneurs, small industries, and service-oriented enterprises. As Ewekoro modernizes its energy infrastructure via solar integration, it emerges as a more appealing destination for both domestic and foreign investors seeking industrially viable areas with little operating risks.

VI. POLICY AND REGULATORY FRAMEWORK

A robust policy and regulatory framework is essential for the expansion of solar energy in Nigeria, especially in areas such as Ewekoro. The realization of solar potential depends on supportive policies, financial mechanisms, institutional backing, and community involvement. In recent years, the Nigerian government and its development partners have undertaken significant initiatives to cultivate a renewable energy ecosystem via legislative instruments and focused programs. The National Renewable Energy and Energy Efficiency Policy (NREEEP) serves as the strategic framework for incorporating renewable energy sources, such as solar, into Nigeria's energy portfolio at the national level. It delineates objectives for both off-grid and on-grid renewable energy production and advocates for the adoption of clean technologies via incentives such import duty exemptions and feed-in tariffs (FMPWH, 2022). Despite patchy implementation across regions, the policy establishes an essential framework for sub-national involvement.

A pertinent endeavor is the “Solar Power Naija” program, established under the Economic Sustainability Plan. The initiative seeks to provide 5 million solar connections for Nigerian households utilizing diverse delivery options such as solar home systems (SHS), mini-grids, and rooftop systems (BOI, 2023). Communities such as Ewekoro are strategically positioned to capitalize on this program, particularly due to their energy shortfall and industrial importance. The Nigeria Energy Support Programme (NESP), a collaboration between the Federal Government and GIZ, has enhanced capacity-building, solar worker training, and technical standardization nationwide (GIZ, 2023). These frameworks aim to eliminate technical and financial impediments while guaranteeing the long-term viability of solar projects.

Ogun State has demonstrated its commitment to renewable energy by aligning with the National Energy Transition Plan (NETP) and collaborating

with the Renewable Energy Association of Nigeria (REAN). Nonetheless, additional efforts are required to convert state-level excitement into localized execution. Municipal councils, including Ewekoro, must implement supplementary rules to facilitate solar installations in public institutions, provide land for mini-grid development, and provide incentive frameworks for local cooperatives and SMEs. Moreover, consistency in policy and clarity in regulation are essential for instilling confidence in the private sector. Developers frequently encounter bureaucratic obstacles in obtaining licenses, accessing land, and securing tariff clearances. Optimizing these procedures via a centralized energy investment portal or municipal green energy office could enhance Ewekoro's appeal to solar developers. In summary, although national policies and donor-driven initiatives provide a solid framework, effective execution in Ewekoro will rely on local adaptation, political commitment, and community ownership. Policies should not merely be theoretical but must be realized via tangible activities, including pilot projects, public-private partnerships (PPPs), and robust monitoring and evaluation systems.

CONCLUSION

The results of this study confirm that Ewekoro, Ogun State, presents significant potential for sustainable solar energy production. Examination of ERA5 reanalysis data over a decade indicates that the region consistently receives sufficient solar energy, averaging 2.36 MJ/m²/day in clear-sky conditions and 1.64 MJ/m²/day in all-sky conditions. These values significantly surpass the globally recognized minimum threshold of 1.5 MJ/m²/day necessary for the effective implementation of photovoltaic (PV) systems, especially in off-grid or underprivileged regions (IRENA, 2023; Jacobson et al., 2022). The stability and reliability of solar resources in Ewekoro render it exceptionally appealing for residential, industrial, and commercial energy applications. The economic consequences of implementing solar energy in the region are significant. As the expense of solar power generation continues to decrease and diesel costs fluctuate, solar systems now offer a financially viable option for both residential and industrial applications. The payback periods of 3–5 years for residential photovoltaic systems, along with diminished operational expenses for industries, highlight the enduring financial feasibility of solar implementation (BOI, 2023; GIZ, 2022). The capacity for employment creation, particularly in installation, maintenance, and system design, provides further socioeconomic advantages, fostering rural development and youth empowerment.

Nigeria's renewable energy plan, encompassing initiatives like Solar Power Naija and the NREEEP framework, fosters a conducive atmosphere for the proliferation of solar energy. Successful implementation at the local government level, exemplified by Ewekoro, necessitates more intentional measures, including municipal regulations, investment incentives, and stakeholder collaboration. Public-private collaborations, community awareness initiatives, and technical training are crucial for reconciling policy with practice (REA, 2023; GIZ, 2023). The shift to solar energy in Ewekoro corresponds with worldwide objectives, notably the United Nations Sustainable Development Goal 7 (SDG 7), which aims for universal access to affordable, dependable, and sustainable energy by 2030. This shift can serve as a repeatable example for other regions in Nigeria and West Africa, beyond its local significance. The incorporation of localized climatic data, technological feasibility analyses, and economic impact evaluations, as evidenced in this study, ought to guide future planning and investment. Ewekoro is distinctly poised to emerge as a center for solar energy transformation in Ogun State. The region possesses significant solar potential, economic feasibility, and a dynamic regulatory environment, presenting both the necessity and the chance to spearhead Nigeria's energy transition. Actualizing this promise necessitates concerted efforts across several sectors, enduring political commitment, and, crucially, community engagement.

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