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Evaluation of Renewable Solar Energy Resources in Ekowe, Bayelsa State, Nigeria

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Abstract **Original Research Article**

This report presents an in-depth analysis of the solar energy resources available in Ekowe, Bayelsa State, Nigeria, with a specific focus on the renewable energy needs of the Federal Polytechnic Ekowe. Located in a region with approximately 4.6 kWh/m² of average daily solar radiation and around 6.6 hours of daily sunlight, Ekowe demonstrates strong potential for solar power as a sustainable energy solution. Data for this analysis was gathered from July 2023 to June 2024 using a solar-powered weather station, which provided real-time measurements of solar radiation, temperature, and other climatic factors. The primary goal of this project was to assess the feasibility of implementing solar energy infrastructure to alleviate reliance on diesel-powered generators, reduce carbon emissions, and promote energy independence in the community. Findings reveal several challenges, including limited infrastructure, high initial costs of solar system components, and low awareness among residents about the advantages and practicalities of solar energy. By addressing these barriers, Ekowe can improve local energy access, reduce environmental impact, and create opportunities for economic development through renewable energy. This report aims to guide decision-makers in implementing solar energy systems that align with sustainable development goals, offering a replicable model for similar communities in Nigeria.

Keywords: Renewable Energy in Agriculture, Rice Production Sustainability Solar Irrigation Systems, Biomass Energy from Rice Husk Chhattisgarh Agriculture, Energy Efficiency in Farming.

1. INTRODUCTION

1.1 Background

As the world moves from fossil fuels towards renewable energy resources, solar energy is an important component of this transition. Solar energy offers lots of benefits and also a workable answer to the problem of access to electricity and the national grid, which is a problem faced by Ekowe and many rural communities in Nigeria. Situated in the Southern Ijaw Local Government Area of Bayelsa State at coordinates 4.6740° N, 6.2067° E, the Ekowe community is home to the Federal Polytechnic Ekowe and the community benefits from ideal climate conditions for the production of solar energy. Solar hybrid mini grids can significantly boost the growth of rural communities by empowering local entrepreneurs, helping them start new businesses, and generating more income. This leads to increased economic opportunities and financial stability in these areas (Babalola et al., 2022).

Figure 1: Installed Ambient Weather

1.2 Purpose of the Report

This report provides an overview of the findings from the Institution-Based Research (IBR) project titled "Evaluation of

Renewable Solar Energy Resources in Ekowe," which was funded by TetFund. The research will take place at Federal Polytechnic Ekowe, where real-time solar energy measurements will be collected from July 1, 2023, to June 30, 2024. A solar-powered data collection rig equipped with a Wi-Fi Connected Intelligent Weather Station will be used to transmit data at a frequency of 915MHz from the outdoor sensor arrangement to the indoor display console and MS Excel is then used to compile and save the collected data.

2. PROBLEM STATEMENT

In developing countries such as Nigeria, rural areas like Ekowe hold vast sources of solar energy. The factors limiting the use of solar energy in this region are complex and multilevel in nature. These include a lack of infrastructures that need to be in place for any successful actualisation of solar energy systems (Agbo et al, 2021). While many households and businesses are constrained by the high initial costs of acquisition and installation of these solar technologies, aside from that, the non-availability of real-time data on solar incidents in Ekowe, coupled with general unawareness among people there about the potential and feasibility of solar energy, the situation gets even worse. These are challenges that must be tackled if the maximum capability of solar energy is to be tapped in this region and further improve life for its residents.

Figure 2: Weather Station

3. AIM AND OBJECTIVES

3.1 Aim

The aim of this research was to evaluate the renewable solar energy resources available in Ekowe.

3.2 Objectives

The report also tends to accomplish the following:

1. Quantify solar radiation levels by measuring daily, weekly, and monthly average solar radiation (kWh/m²) in Ekowe from July 2023 to June 2024.
2. Set a benchmark by comparing Ekowe's solar radiation with regional and national averages to assess its solar energy potential.
3. Obtain a thorough dataset detailing monthly and seasonal variations in solar radiation, with a target accuracy of ±5%.
4. Calculate potential energy cost savings for the Federal Polytechnic Ekowe by replacing diesel generators with solar power, and project carbon emissions reduction.
5. Launch an outreach initiative to educate over 200 local residents, students, and businesses on the advantages and basic operations of solar energy.

4. METHOD

4.1 Methodology

The data collection instrument, an Ambient Weather Station (Model WS-2902A), was calibrated to ensure accurate readings of solar radiation, temperature, humidity, barometric pressure, and other environmental factors. Initial calibration was performed against known standards in a controlled environment, using a secondary, high precision pyranometer to verify the station's accuracy. Calibration checks were performed quarterly with adjustments made to account for any drift observed in the measurements. Routine maintenance and recalibrations carried out also accounted for seasonal variations and potential environmental impacts on sensor accuracy, such as dust accumulation or extreme weather.

Figure 3: Display Console

4.2 Data Capture Frequency

Data collection occurred on a real-time basis with automatic logging at one-minute intervals. This high-frequency data capture allowed for a detailed analysis of diurnal variations in solar radiation. Data was averaged over each day, providing daily summaries, with weekly and monthly averages calculated for trend analysis. The continuous recording provided a robust dataset, ensuring that any transient changes in solar radiation, such as those caused by cloud cover, were adequately captured.

4.3 Statistical Tools for Data Analysis

The captured solar radiation data was processed using Microsoft Excel and statistical software for comprehensive analysis. The statistical tools included:

- **Descriptive Statistics:** Calculation of mean, median, and standard deviation of daily solar radiation values to provide insights into the average solar energy available in the region.
- **Trend Analysis:** Time series analysis was employed to evaluate seasonal patterns and variability in solar radiation data over the study period.
- **Comparative Analysis:** Solar radiation data for Ekowe was compared with regional benchmarks, allowing for an assessment of solar resource availability relative to similar geographic areas.

These analytical methods were selected to ensure clarity in identifying trends and variability, supporting a high-confidence assessment of solar energy potential in Ekowe.

4.4 Data Collection

Solar radiation data was gathered from the installed ambient weather station WS – 2902A to assess the average daily solar radiation levels in Federal Polytechnic Ekowe from 1st of July 2023 to 30th of June 2024 and the collected data can be seen in Appendix A.

4.5 Data Analysis

4.5.1 Seasonal Variations in Solar Radiation

The analysis of solar radiation data collected from July 2023 to June 2024 in **appendix A** reveals notable seasonal fluctuations, which are critical for assessing the feasibility of solar energy in Ekowe. During the dry season **(November – March)**, solar radiation levels were consistently high, with daily averages ranging between 5.0 and 6.5 kWh/m². November through March saw the highest radiation values, reaching a peak of 6.5 kWh/m² in November. This period also had relatively stable weather conditions characterized by lower cloud cover and minimal precipitation, leading to consistent sunlight exposure. The abundance of solar radiation during these months indicates an optimal period for maximizing solar energy output, making it an ideal season for solar energy reliance and storage.

The rainy season **(April – October)** showed considerable decreases in solar radiation, with daily averages dropping to 2.8–4.5 kWh/m², particularly in June and July. Increased cloud cover, coupled with frequent rainfall, contributed to these lower values and reducing the amount of sunlight reaching the weather station's sensors. Solar energy systems would likely face reduced efficiency during this period, necessitating alternative energy storage or hybrid systems to ensure a reliable power supply.

In the transitional months of April and October, radiation values fluctuated as conditions shifted between dry and rainy season patterns. These months experienced moderate solar radiation levels (around 4.3 – 4.7 kWh/m²) with occasional spikes during clearer days.

4.5.2 Implications for Solar Energy Feasibility

The significant reduction in solar radiation during the rainy season emphasizes the need for energy storage solutions to shield against low-radiation periods. Battery storage systems or hybrid energy setups would be necessary to maintain continuous power supply, especially for critical applications.

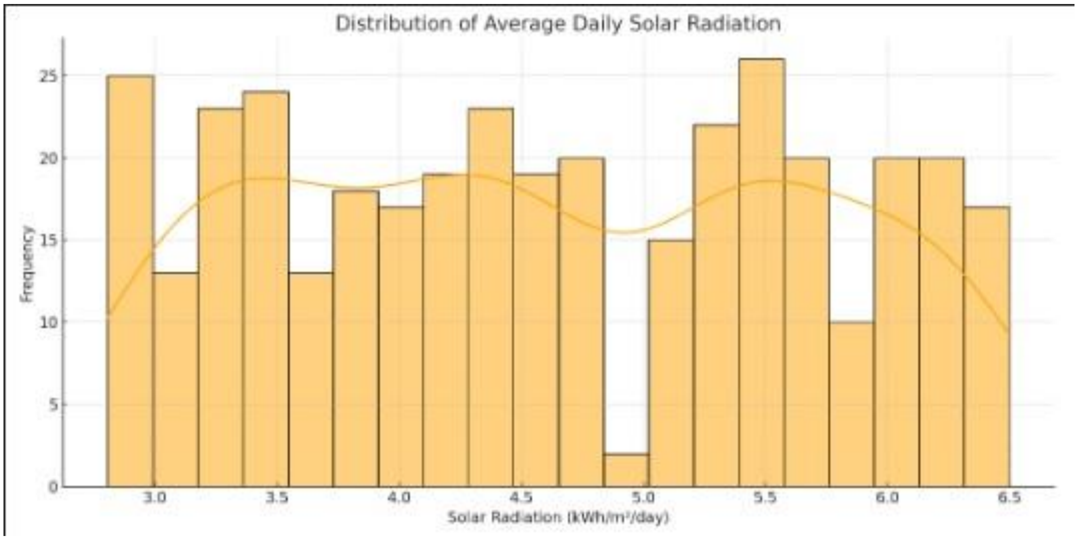
The peak radiation in the dry season indicates that solar panel systems can be sized to harness excess energy during high-radiation months, potentially offsetting the reduced production in the rainy season. Optimizing panel orientation and angle adjustments to capture maximum sunlight during low-radiation periods can further improve system performance.

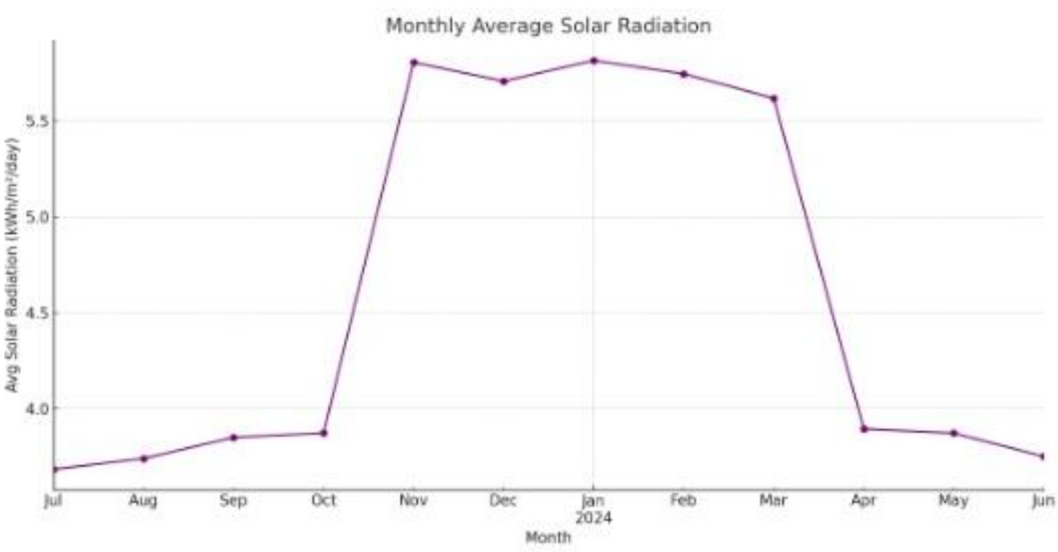
This seasonal analysis provides a clearer understanding of the feasibility and operational challenges of solar energy systems in Ekowe, guiding practical measures to ensure consistent energy availability year-round.

Statistical tools are employed to carefully examine the data that has been collected on solar radiation and this analysis involves using various statistical methods to gain insights into the patterns, trends, and variations in the solar radiation data, which can help in understanding the behaviour of solar radiation over time and across different locations.

5. FINDINGS

5.1 Solar Radiation Assessment





The analysis of the Solar Radiation column in **appendix A** reveals that solar radiation values vary significantly and clustering around certain levels with a relatively even spread from lower to higher values. This indicates a range of sunlight exposure which could relate to varying levels of cloud coverage or seasonal sunlight patterns. The monthly averages show slight seasonal shifts, with months like July and August tending towards lower solar radiation due to increased cloud cover or rainy conditions, while November to March displays higher values suggesting clearer skies.

High solar radiation days (top 5%) occur predominantly from November to March. These days show high UV indexes, clear skies, and typically lower humidity. Low solar radiation days (bottom 5%) mostly fall in July to August aligning with rainy or dull conditions, with increased precipitation and relatively high humidity levels. Solar radiation and UV index appear to generally follow similar trends as they are both are influenced by sunlight intensity. Peaks represent sunny days with clear skies, while dips may align with cloudy or rainy days.

The data collected showed that Ekowe received a mean daily solar radiation of approximately **4.6 kWh/m^2** and an average solar hour per day of **6.6 hours**. The data displayed in the line chart showed that Polytechnic's solar radiation intensity increased from 3.8 to 5.2 **kWh/m^2** in November 2023 and sustained the intensity till April 2024 with the maximum value at **6.5 kWh/m^2**. The average daily solar radiation data fluctuated from 2.8 to 6.5 **kWh/m^2** in the one-year period. (Chineke & Okoro, 2010) used The Sayighr "Universal formula" to estimate the global solar radiation in the Niger Delta region of Nigeria with levels ranging from 1.99kWh to 6.75kWh.

Also, according to Global Solar Atlas and RVO.nl, Nigeria has an annual solar energy potential of about 1,500 to 2,200 hours of sunshine but the Polytechnic received a total of about 2,400 hours of sunshine during the period. These support the feasibility of solar energy systems integration into the power mix for the institution and rural electrification projects in Ekowe.

These insights can help in energy planning, agricultural timing, or further weather pattern analysis.

5.2 Infrastructure Evaluation

The current solar energy infrastructure has limited availability of panels and installation services, along with a lack of community-based renewable energy programs or initiatives (Mirzania et al., 2019).

5.3 Barriers to Adoption

These fall under three broad area barriers that will be discussed:

Economic Barriers: These include high upfront costs associated with purchasing and installing solar systems. The high initial investment that marks the front line regarding solar technologies is indeed a potential barrier to the adoption of sustainable energy solutions at either an individual or community-wide level (Ellabban & Alassi, 2019).

Technical Barriers: These have something to do with the lack of technical know-how and skills on the part of local technicians in installing and maintaining solar systems. Without adequate training in understanding the technology, any effort at effectively implementing and maintaining the solar infrastructure is doomed to fail (Brooks & Urmee, 2014).

Awareness Barriers: There would be discrete levels of awareness and understanding regarding the benefits derived and working/operation principles of solar technologies among its community users. Ironically, a lack of information and education about the possible advantages of solar may result in insufficient access and utilization by a community.

5.4 Cost-Benefit Analysis of Solar Energy Adoption

5.4.1 Installation Costs and Initial Investment

Estimating the cost for a **100kW solar-inverter system** in Nigeria involves several components, including solar panels, inverters, charge controller, mounting structures, batteries, installation, and other logistics. The breakdown of the estimated costs in Nigerian Naira (NGN) based on current market trends is given below:

I. **Solar Panels**

$$Cost/kW\ for\ high\ quality\ solar\ panels = N200{,}000.00$$

$$\Rightarrow \quad For\ 100\ kW, the\ Total\ cost = N20{,}000{,}000.00$$

II. **Inverter System**

High quality, grid-tied or hybrid inverters are required for efficient power conversion.

$$Cost\ for\ 100kW - rated\ inverter\ system = N10{,}000{,}000.00$$

III. **Mounting Structures and Accessories**

This includes mounting racks, wiring, circuit breakers, and other electrical and mechanical components.

$$Cost\ for\ mounting\ structures\ \&\ accessories = \ N3{,}000{,}000.00$$

IV. **Batteries:**

For energy storage to maintain power during nighttime or low sunlight, lithium-ion or deep-cycle batteries are preferred.

$$Battery\ cost\ for\ 100kW\ capacity\ depending\ on\ backup\ hours = N20{,}000{,}000.00$$

V. **Installation and Labour**

This includes design, engineering, and labour costs for setting up the system.

$$Installation\ \&\ labour\ cost = N4{,}000{,}000.00$$

$$\Rightarrow \boldsymbol{Total\ Estimated\ Cost} = NGN53{,}000{,}000.00$$

This cost range provides a robust 100 kW solar system capable of supplying consistent power and includes options for energy storage.

5.4.2 Carbon Emission Reduction from Solar Energy Adoption in Ekowe

5.4.2.1 Current Carbon Emissions from Diesel Generators

To calculate the carbon emission reduction from replacing a 100kW diesel generator with a solar energy system in Ekowe, we need to estimate:

1. **Diesel Consumption of the Generator**: The fuel consumption for a 100kW diesel generator is characteristically around 20 – 27 litres per hour at full load.
2. **Carbon Emissions per Litre of Diesel**: Each litre of diesel burned emits approximately 2.68 kg of CO_2.
3. **Annual Operating Hours**: Assumed daily hours of generator usage to find total annual emissions.

5.4.2.2 Calculations

I. **Estimate of Diesel Consumption**

$$\Rightarrow Average\ amount\ of\ diesel\ burnt\ per\ hour\ for\ 100kW\ generator\ =\ 23.5\ litres$$

Assuming the generator operates **8 hours per day**:

$$Daily\ diesel\ consumption = 8\ hours\ x\ 23.5\frac{litres}{day} = 188\ litres/day$$

II. **Estimate of Annual Diesel Consumption**

$$Annual\ diesel\ consumption = 188\frac{litres}{day}\ x\ 365\frac{days}{year} = 68{,}620\ litres/year$$

III. Calculation of Annual CO_2 Emissions

Utilising 2.68 kg of CO_2 per litre of diesel, we have:

$$Annual\ CO_2\ emissions = 68{,}620\frac{litres}{year} x\ 2.68\frac{kg}{litre} = 183{,}902\ kg\ CO_2/year$$

IV. Carbon Reduction from Solar Energy Adoption

By replacing the 100kW diesel generator with a solar system that operates without fossil fuel, **183.9 kg** or **183.9 metric tonnes of CO_2 emissions would be eliminated annually**. This shift not only reduces carbon emissions but also leads to cost savings on fuel and mitigates environmental pollutants like NO_x and particulate matter. This reduction contributes to improved air quality and health benefits by reducing diesel exhaust exposure and also alleviates the environmental impact of burnt fossil fuels.

5.4.3 Cost – Benefit Analysis

To compare the costs and benefits of a **100kW diesel generator** and a **100kW solar-inverter system** over time, we need to examine both initial and ongoing costs (fuel and maintenance for the generator, and maintenance and potential battery replacement for the solar system).

5.4.3.1 Cost-Benefit Analysis Components

- ✓ **Initial Setup Costs**
- ✓ **Operating and Maintenance Costs**
- ✓ **Fuel Costs for Diesel Generator**
- ✓ **Carbon Emission Costs (optional, if considering environmental impact)**
- ✓ **Return on Investment (ROI) and Payback Period**

The following assumptions were made in other to perform the analysis:

- **Generator Usage**: 8 hours/day, 365 days/year.
- **Fuel Cost**: Diesel price of NGN 1,200 per litre.
- **Diesel Consumption**: 23.5 litres/hour (for 100 kW generator).
- **Solar System Lifespan**: 25 years, with battery replacement every 3 – 4years if applicable.
- **Maintenance**: Diesel generator maintenance annually; minimal for solar.

I. **Initial Setup Costs**

$$100\ kW\ Diesel\ Generator\ costs\ approximately\ NGN\ 25{,}000{,}000.00$$

$$100\ kW\ Solar\ System = NGN\ 53{,}000{,}000.00$$

II. **Operating and Maintenance Costs**

$$Diesel\ Generator\ Maintenance\ costs\ around\ NGN\ 2{,}000{,}000.00\ -\ 5{,}000{,}000.00\ per\ year.$$

$$Solar\ System\ Maintenance\ costs\ around\ NGN\ 200{,}000.00\ -\ 500{,}000.00\ per\ year\ for\ cleaning\ and\ inspections.$$

III. **Fuel Costs (Diesel Generator)**

$$Daily\ diesel\ cost = 188\frac{litres}{day}x\ 1{,}200/litre = NGN\ 225{,}600.00/day$$

$$Annual\ Fuel\ Cost = \frac{225{,}600}{day}\ x\ 365\ days = NGN\ 82{,}344{,}000.00/year$$

5.4.3.2 Total Cost Over 10 Years

The **10-year total costs** plan for each system is calculated below:

Diesel Generator (10 Years):

$$Initial\ Setup\ Cost = NGN\ 25{,}000{,}000.00$$

$$Fuel\ Cost = NGN\ 82{,}344{,}000.00\ per\ year$$

$$10\ years\ fuel\ cost = NGN\ 823{,}440{,}000.00$$

$$Maintenance\ Cost\ Average = NGN\ 3{,}500{,}000.00\ per\ year$$

$$10\ years\ maintenance = NGN\ 35{,}000{,}000.00$$

$$\boldsymbol{Total\ Cost\ (10\ Years)} = 25{,}000{,}000 + 823{,}000{,}000 + 35{,}000{,}000 = \boldsymbol{NGN\ 883{,}000{,}000.00}$$

Solar System (10 Years):

$$Initial\ Setup\ Cost = \ NGN\ 53{,}000{,}000.00$$

$$Battery\ Replacement\ (Every\ 3-4\ years) = NGN\ 60{,}000{,}000\ (included\ thrice\ in\ the\ 10-year\ period)$$

$$Maintenance\ Cost = NGN\ 500{,}000.00\ per\ year$$

$$10\ years\ maintenance = \ NGN\ 5{,}000{,}000.00$$

$$\boldsymbol{Total\ Cost}\ (10\ Years)(including\ battery\ replacement) = 53{,}000{,}000 + 60{,}000{,}000 + 5{,}000{,}000 = \boldsymbol{NGN\ 118{,}000{,}000.00}$$

Cost Comparison Summary (10 Years)

$$Diesel\ Generator = NGN\ 883{,}000{,}000.00$$

$$Solar\ System = NGN\ 118{,}000{,}000.00$$

5.4.3.3 Carbon and Environmental Benefits

Migrating form diesel generator to solar would reduce approximately **183,902 kg of CO_2 emissions per year** thereby adding significant environmental value and aligning with sustainability goals.

Although the initial costs of installing the solar-inverter system is considerably higher than that of the diesel generator plant, the over 10 years analysis has shown that the solar system is dramatically less expensive, with a savings of over half a billion naira (more than NGN 500,000,000.00).

5.5 Case Studies Demonstrating Solar Energy's Impact on Emissions

The **Nigeria Rural Electrification Agency (REA) Projects** implemented solar mini grids in rural communities, similar to Ekowe, have demonstrated significant reductions in diesel consumption and CO_2 emissions. For example, a 100kW mini grid serving 300 households eliminated approximately 50 metric tons of CO_2 per year by replacing diesel generators. Also**,** the Solar Urja through Localization for Sustainability (SoULS) project in **India** provided rural villages with solar microgrids, reducing dependency on kerosene lamps and diesel generators. A study showed that emissions fell by 20 – 25 metric tons annually per village by adopting solar.

5.6 Scaling Impact on Ekowe and Similar Regions

By expanding solar adoption to additional institutions and community facilities, Ekowe could witness regional emission reductions totalling hundreds of metric tons annually. This would support national climate goals by aligning with Nigeria's commitment to the Paris Agreement and the Sustainable Development Goals (SDGs), specifically SDG 7 (affordable and clean energy) and SDG 13 (climate action).

5.7 Broader Implications for Rural Communities in Nigeria and West Africa

The findings from Ekowe's solar energy assessment highlight practical applications that could benefit other rural communities in Nigeria and West Africa facing similar energy challenges. Many rural areas across this region lack consistent access to electricity due to limited infrastructure, high fuel costs, and dependency on fossil fuels like diesel. Implementing solar energy offers a sustainable alternative with broad potential impacts such as:

- ✓ **Improving Energy Access and Economic Empowerment**: By transitioning to solar power, communities can reduce reliance on diesel generators, which are expensive and emit harmful pollutants. Solar energy provides a cleaner, more affordable source especially given the region's high solar irradiance. Also, with more reliable electricity, local businesses can operate proficiently and explore new opportunities, particularly those in agriculture, food processing, and small manufacturing. This economic empowerment aligns with rural development goals and fosters resilience by promoting locally generated energy sources.

- ✓ **Scaling Renewable Energy Infrastructure**: The data collected from Ekowe serves as a baseline for solar radiation levels and energy storage needs, offering a replicable model for developing solar microgrids across similar rural locations. By creating regional benchmarks, stakeholders can scale solar installations with greater accuracy, optimizing resource allocation and design. Insights from Ekowe can guide policies encouraging renewable energy incentives, subsidies, and technical training, which are essential for promoting solar adoption in off-grid communities. Policymakers can use Ekowe's example to justify rural electrification programs that prioritize renewables, integrating solar solutions with regional energy goals.
- ✓ **Climate Action and Health Benefits:** For communities with limited alternatives to fossil fuels, switching to solar power has significant climate benefits. Scaling similar solar initiatives across rural West Africa could contribute to carbon emission reductions on a larger scale, supporting national and international climate commitments, such as the Paris Agreement. Reducing diesel generator use decreases air pollution, lowering respiratory health risks for rural populations. The health benefits of cleaner air, combined with a reliable power supply for medical facilities, contribute to improved healthcare access and quality in these underserved regions.
- ✓ **Strengthening Rural-Urban Synergies**: Reliable access to electricity in rural areas can reduce the economic divide between rural and urban regions, decreasing migration pressures. Solar energy can support economic stability and increase opportunities in rural communities, providing the infrastructure for education, commerce, and healthcare. Ekowe's solar initiative can serve as a case study for collaboration among West African nations. By sharing expertise and resources, countries in the region can accelerate renewable energy adoption, fostering cross-border partnerships that strengthen collective energy security.

5.8 Real World Applications

5.8.1 Implications for Solar Farm Sizing

The solar radiation data gathered from Ekowe, which indicates an average daily solar radiation of around 4.6 kWh/m², provides essential insights for determining optimal solar farm sizing. With this data**, panel capacity and layout and land use and efficiency can be performed.** Solar panels can be arranged to maximize sunlight exposure, particularly during the high radiation dry season period from November to March. To maintain consistent energy output, the system's capacity can be designed with a margin to account for the lower average radiation during the rainy season (April to October). Also, by analysing seasonal radiation data, planners can determine land area requirements to meet specific energy goals. For instance, achieving a consistent output of 1 MW may require around 2 hectares of land, assuming a 15 – 20% efficiency for solar panels. This land area could be adjusted upward to provide a buffer during low-radiation months.

5.8.2 Energy Yield Estimations

Given the average daily radiation data, estimations can be made for the total annual energy yield. For example, a 1 MW solar farm could yield approximately 1,600 – 1,800 MWh annually, with peak outputs occurring during the dry season. This information allows stakeholders to plan energy storage solutions to manage output fluctuations.

Similarly, estimating yield based on monthly and seasonal variations enables accurate financial forecasting. By understanding the lower yield during the rainy season, the need for supplemental energy sources or energy storage solutions can be quantified. This approach supports a balanced, economically viable energy system, and potentially reducing the initial and operational costs associated with excessive storage capacity.

5.8.3 Infrastructure and Grid Integration

The seasonal variation data aids in designing solar farms that align with energy demands and grid stability requirements. Integrating solar with existing grid infrastructure will require adjustments to ensure continuous power delivery, especially during low-radiation months. For areas like Ekowe with seasonal fluctuations, a hybrid energy model combining solar and backup systems (e.g., battery storage or a small generator) would optimize energy availability and reliability, minimizing downtime.

6. RECOMMENDATIONS

1. **Community Education and Skills Training**: To encourage solar energy adoption, Federal Polytechnic Ekowe should launch comprehensive education and outreach programs. These initiatives would inform community members about the environmental and financial benefits of solar energy, helping to build local support for renewable projects. TetFund, in collaboration with other stakeholders, can sponsor practical training sessions at the Polytechnic to equip local residents with skills in solar panel installation, maintenance, and energy system management. Training a team of community-based technicians would ensure long-term system maintenance and foster local expertise in solar technology.
2. **Financial Incentives and Subsidies**: Collaborate with government agencies, banks, and NGOs to introduce financial mechanisms that lower the cost of solar technology for residents and businesses. Potential solutions include low-interest loans, grants, tax incentives, and subsidies for solar panels and related equipment. Such support will make solar energy accessible to households and small businesses that currently rely on costly, polluting diesel generators. Establishing partnerships with microfinance institutions could further empower local entrepreneurs to invest in solar-powered small businesses.
3. **Enhanced Infrastructure for Solar Adoption**: To ensure successful solar energy implementation, TetFund and the Polytechnic should prioritize infrastructure improvements within Ekowe. This includes establishing specialized training centers for renewable energy technicians and building dedicated solar panel installation facilities. Additionally, creating incentives for local businesses to stock and service solar energy components will facilitate easy access to technology and maintenance. Infrastructure upgrades will support a self-sustaining ecosystem around solar energy and ensure consistent system performance.
4. **Pilot Solar Hybrid Systems for Energy Reliability**: Given the seasonal variations in solar radiation, introducing pilot solar hybrid systems with battery storage will ensure energy availability during the rainy season when solar output is lower. Such systems could serve as a model for rural electrification and help refine the Polytechnic's approach to sustainable energy

planning. A pilot project, potentially funded by TetFund or other renewable energy grants, can demonstrate the viability and cost-efficiency of solar power in Ekowe, attracting further investments in renewable infrastructure.

5. **Monitoring and Data Collection Expansion**: Expand the scope of the current solar data collection to include additional environmental variables and longer-term trend analysis. This enhanced dataset will inform future energy planning, helping to optimize solar panel configurations and predict maintenance needs. Regular reporting on solar energy performance in Ekowe could also provide valuable insights for stakeholders considering similar renewable energy projects in other rural areas.

7. CONCLUSION

The findings from this report underscore Ekowe's potential as a site for substantial solar energy investment, given its high solar irradiance levels and year-round sunlight. By leveraging solar energy, Ekowe can significantly reduce its dependence on diesel fuel, resulting in lower carbon emissions, decreased fuel costs, and enhanced energy reliability for Federal Polytechnic Ekowe and the surrounding community. The recommended actions, including community education, financial incentives, infrastructure upgrades, and the development of pilot solar systems, offer a roadmap to overcoming the current challenges of high initial costs and limited local expertise in solar technology. This proactive approach positions Ekowe not only to address its immediate energy needs but also to serve as a model for renewable energy adoption in rural Nigeria.

Implementing solar energy in Ekowe would align with Nigeria's commitment to the Paris Agreement and contribute to Sustainable Development Goals (SDGs) 7 (Affordable and Clean Energy) and 13 (Climate Action). Realizing these opportunities will depend on coordinated efforts between the Polytechnic, TetFund, government agencies, and the local community to secure funding, streamline technical training, and build a supportive infrastructure network. Ekowe's success in adopting solar energy could spark interest in renewable projects across the region, driving sustainable growth and creating pathways to energy independence for underserved communities.

REFERENCES

Agbo, E., Edet, C., Magu, T., Njok, A., Ekpo, C., & Louis, H. (2021). Solar energy: A panacea for the electricity generation crisis in Nigeria. Heliyon, 7. https://doi.org/10.1016/j.heliyon.2021.e07016.

Babalola, S., Daramola, M., & Iwarere, S. (2022). Socio-economic impacts of energy access through off-grid systems in rural communities: a case study of southwest Nigeria. Philosophical transactions. Series A, Mathematical, physical, and engineering sciences, 380. https://doi.org/10.1098/rsta.2021.0140.

Brooks, C., & Urmee, T. (2014). Importance of individual capacity building for successful solar program implementation: A case study in the Philippines. Renewable Energy, 71, 176-184. https://doi.org/10.1016/J.RENENE.2014.05.016.

Chineke, T., & Okoro, U. (2010). Application of Sayigh "Universal Formula" for global solar radiation estimation in the Niger Delta region of Nigeria. Renewable Energy, 35, 734-739. https://doi.org/10.1016/J.RENENE.2009.08.010.

Ellabban, O., & Alassi, A. (2019). Integrated Economic Adoption Model for residential grid-connected photovoltaic systems: An Australian case study. Energy Reports. https://doi.org/10.1016/J.EGYR.2019.02.004.

Mirzania, P., Ford, A., Andrews, D., Ofori, G., & Maidment, G. (2019). The impact of policy changes: The opportunities of Community Renewable Energy projects in the UK and the barriers they face. Energy Policy. https://doi.org/10.1016/J.ENPOL.2019.02.066.

DAY	AVERAGE SOLAR RADIATION (kWh/m²/day)	AVG. UV INDEX PER DAY	AVERAGE DAILY BAROMETRIC PRESSURE (mmHg)	AVERAGE WIND SPEED (km/hr)	DAILY PRECIPITATION (mm)	MAX. DAILY OUTDOOR TEMPERATURE (ºC)	MIN DAILY OUTDOOR TEMPERATURE (ºC)	AVG DAILY OUTDOOR TEMPERATURE (ºC)	AVERAGE RELATIVE HUMIDITY (%)
7/1/2023	2.8	3	760.0	15.13	14.8	35.8	22.6	32.5	86.3
7/2/2023	4.2	1	764.0	10.88	5.1	35.8	22.6	32.5	91.2
7/3/2023	3.6	7	763.3	8.32	16.3	34.4	22.6	25.3	85.9
7/4/2023	4.2	4	761.6	15.46	9.8	36.4	22.4	27.4	81.7
7/5/2023	4.7	6	749.6	13.93	12.3	35.5	23.0	24.0	90.3
7/6/2023	4.1	6	766.3	14.55	8.9	35.1	22.9	22.7	79.9
7/7/2023	3.6	5	765.7	11.02	11.4	35.3	22.4	26.4	89.4
7/8/2023	3.3	5	765.2	14.66	7.9	36.4	24.7	26.2	90.7
7/9/2023	3.5	4	758.0	12.54	6.8	35.0	23.5	26.3	82.6
7/10/2023	4.0	6	766.5	14.84	12.7	35.3	22.5	25.6	83.5
7/11/2023	2.9	3	760.7	9.09	7.9	34.2	23.5	25.6	93.4
7/12/2023	4.4	7	752.4	9.65	9.7	35.4	22.8	25.6	87.9
7/13/2023	3.4	2	764.9	10.33	8.4	35.0	24.2	26.9	90.6
7/14/2023	3.7	6	760.5	10.06	14.9	36.7	23.4	30.3	82.4
7/15/2023	4.5	6	754.7	13.45	9.5	35.9	22.4	31.8	87.4
7/16/2023	2.8	5	763.6	15.34	16.6	36.7	23.8	34.7	81.1
7/17/2023	3.3	4	751.0	8.05	15.9	34.2	24.7	32.5	81.7
7/18/2023	3.4	1	762.9	8.43	16.0	37.0	22.4	32.6	86.5
7/19/2023	3.3	2	759.9	14.94	4.8	36.6	22.0	34.3	87.7
7/20/2023	4.3	5	748.9	14.50	13.7	34.3	23.2	31.4	86.0
7/21/2023	4.3	4	757.9	14.38	10.2	36.0	23.0	31.7	85.5
7/22/2023	3.1	6	759.7	10.96	8.4	35.0	23.4	23.2	84.6
7/23/2023	4.5	6	756.3	13.06	12.6	36.7	23.5	30.5	86.6
7/24/2023	3.5	3	761.4	15.99	2.5	34.2	24.1	29.1	90.4

7/25/2023	3.8	6	757.4	12.29	10.8	35.1	22.1	35.4	87.9
7/26/2023	4.6	2	757.4	14.57	3.9	36.8	22.9	27.3	84.4
7/27/2023	2.8	4	760.3	13.79	6.2	34.4	22.9	26.8	87.9
7/28/2023	3.3	6	751.4	10.13	5.1	36.4	23.3	28.8	87.6
7/29/2023	3.2	4	753.1	15.49	11.9	34.4	24.6	26.6	85.1
7/30/2023	3.8	6	766.8	14.94	8.9	35.3	22.5	26.0	88.8
7/31/2023	3.4	2	755.0	13.09	5.9	35.4	24.6	32.3	84.1
8/1/2023	3.9	5	752.5	7.16	5.4	30.9	20.7	27.1	79.8
8/2/2023	2.9	5	761.7	6.45	5.6	30.9	21.8	28.8	79.2
8/3/2023	3.1	1	761.2	4.04	2.0	30.3	20.8	27.8	91.9
8/4/2023	4.6	6	756.0	9.04	1.9	31.0	20.0	26.6	74.8
8/5/2023	3.5	5	754.2	6.06	0.9	31.3	20.5	26.7	82.3
8/6/2023	3.9	3	758.2	7.05	3.1	31.6	23.3	27.0	82.7
8/7/2023	3.1	4	751.8	6.89	5.9	30.8	20.3	26.7	81.5
8/8/2023	3.7	2	757.3	6.36	1.9	31.6	21.2	27.6	75.9
8/9/2023	4.7	3	755.9	10.47	5.5	30.4	22.3	27.6	86.9
8/10/2023	4.3	2	759.7	9.36	2.3	31.1	20.5	26.8	83.3
8/11/2023	4.3	6	760.5	7.23	5.0	30.1	22.7	27.0	85.2
8/12/2023	4.0	5	760.1	8.41	2.3	30.5	20.5	28.7	88.5
8/13/2023	3.4	3	748.0	8.17	5.6	30.2	22.2	27.4	77.3
8/14/2023	3.9	3	762.9	4.38	0.9	30.9	22.6	28.0	85.0
8/15/2023	3.3	7	765.6	8.71	2.7	30.1	22.0	27.3	92.5
8/16/2023	2.8	1	762.6	11.45	1.4	31.1	20.0	28.8	75.4
8/17/2023	3.9	3	758.0	11.14	1.1	31.5	20.7	27.4	84.5
8/18/2023	2.9	4	749.2	7.06	2.5	31.5	20.6	26.1	86.7
8/19/2023	2.9	2	762.3	10.69	4.7	31.9	21.3	27.7	76.9
8/20/2023	4.0	4	758.0	7.68	2.0	30.8	20.6	28.0	92.0
8/21/2023	4.8	3	754.1	10.97	2.6	31.9	22.1	27.2	85.9
8/22/2023	4.8	4	762.3	4.23	3.1	31.7	23.2	28.5	77.7

8/23/2023	3.0	1	752.2	4.88	4.9	31.6	23.2	28.7	69.4
8/24/2023	4.4	6	758.7	4.56	4.9	31.8	20.6	28.3	81.0
8/25/2023	3.0	2	762.8	7.79	2.4	30.4	20.6	28.1	70.5
8/26/2023	4.2	4	754.3	6.06	4.8	31.7	23.4	28.3	88.8
8/27/2023	3.9	2	758.4	8.51	1.1	30.2	22.9	28.7	84.8
8/28/2023	3.0	2	760.8	6.90	4.7	30.3	23.1	28.0	80.8
8/29/2023	4.1	3	755.9	10.62	1.7	31.8	23.5	27.8	83.2
8/30/2023	4.7	6	766.3	8.24	2.4	30.3	21.5	28.0	91.5
8/31/2023	3.1	7	758.8	9.85	1.9	30.7	22.5	26.4	83.8
9/1/2023	4.0	5	759.7	7.35	2.6	31.3	21.5	28.6	82.2
9/2/2023	4.8	3	765.5	9.58	2.7	29.1	19.3	26.7	87.3
9/3/2023	2.9	3	763.1	6.66	3.5	30.4	21.7	27.3	90.3
9/4/2023	4.7	6	757.9	9.13	9.7	31.1	22.6	28.1	86.0
9/5/2023	4.7	2	752.0	10.00	4.6	30.3	21.1	28.9	84.7
9/6/2023	4.7	5	763.1	6.21	3.3	33.6	19.0	28.0	84.3
9/7/2023	3.0	3	762.5	6.17	3.1	29.2	22.4	27.3	84.5
9/8/2023	4.5	2	766.0	6.96	9.5	30.1	23.1	27.8	88.3
9/9/2023	3.2	2	763.4	9.40	11.5	32.7	21.4	27.4	81.2
9/10/2023	4.5	4	762.5	5.37	3.4	34.0	22.8	28.0	87.6
9/11/2023	4.4	4	762.5	7.40	14.2	31.5	19.2	27.1	84.0
9/12/2023	3.4	7	765.6	6.44	15.9	32.6	21.8	26.5	84.2
9/13/2023	4.3	3	755.1	7.01	2.2	29.8	19.0	28.5	86.8
9/14/2023	3.0	6	762.0	8.06	16.9	31.4	21.8	28.3	77.4
9/15/2023	2.9	2	761.9	8.76	4.0	30.8	23.4	26.1	86.1
9/16/2023	3.8	2	753.8	7.47	6.9	32.8	20.8	28.1	87.8
9/17/2023	3.2	1	755.6	6.11	14.0	32.8	22.0	27.5	85.1
9/18/2023	3.6	5	763.7	7.89	8.5	31.1	22.1	28.8	86.9
9/19/2023	4.4	7	759.7	9.32	7.8	33.8	23.4	27.3	86.1
9/20/2023	3.3	6	755.7	9.72	4.4	33.8	19.2	26.1	87.8

9/21/2023	3.2	4	752.4	7.03	2.6	30.0	23.0	28.4	88.0
9/22/2023	3.2	3	754.3	6.49	15.4	33.3	20.5	28.1	85.4
9/23/2023	3.6	1	752.8	8.16	6.4	29.1	19.5	27.4	84.8
9/24/2023	3.2	3	750.8	5.31	9.5	33.6	21.2	27.3	86.3
9/25/2023	4.5	6	759.7	9.10	11.4	32.5	23.5	28.6	80.2
9/26/2023	4.3	6	760.7	9.27	0.0	29.3	23.1	26.9	88.7
9/27/2023	4.2	6	764.5	5.70	18.4	29.9	19.2	28.3	87.9
9/28/2023	3.6	7	752.6	8.81	16.6	32.4	20.4	26.6	88.2
9/29/2023	4.1	2	763.2	7.17	0.0	30.5	21.2	28.7	88.4
9/30/2023	4.4	3	749.7	7.84	5.9	29.1	23.5	28.2	81.3
10/1/2023	4.3	5	761.3	10.38	12.7	35.5	23.9	30.4	85.6
10/2/2023	3.0	7	753.6	9.52	11.5	33.2	23.0	28.9	80.0
10/3/2023	4.5	4	749.7	9.11	5.2	32.2	22.5	27.6	81.3
10/4/2023	3.0	7	749.6	7.40	4.8	34.9	22.8	30.3	76.9
10/5/2023	3.6	5	750.6	10.85	9.7	35.3	22.4	28.7	84.4
10/6/2023	4.6	5	749.2	8.46	13.2	35.6	21.9	28.3	86.8
10/7/2023	4.0	3	753.8	9.78	11.2	34.4	21.6	31.2	80.1
10/8/2023	4.3	5	748.9	8.68	13.1	35.5	24.8	29.0	75.1
10/9/2023	3.0	3	750.7	9.42	7.3	32.7	23.0	32.0	88.1
10/10/2023	4.7	3	752.9	10.04	15.1	34.9	23.9	28.4	79.8
10/11/2023	3.8	5	759.3	9.77	12.1	32.1	21.2	29.1	75.5
10/12/2023	4.3	7	750.0	7.05	9.8	33.6	21.7	31.3	84.7
10/13/2023	3.3	7	765.2	7.27	12.5	35.5	21.2	31.7	81.8
10/14/2023	4.5	2	759.9	8.78	9.1	34.4	22.6	27.5	79.3
10/15/2023	4.2	6	754.5	8.54	8.3	33.7	24.9	29.0	75.7
10/16/2023	3.5	2	749.0	9.62	10.8	34.6	22.2	28.1	85.2
10/17/2023	4.8	1	763.2	7.23	8.4	33.3	24.5	28.8	80.7
10/18/2023	4.0	7	750.8	7.64	12.3	32.8	22.2	30.7	82.4
10/19/2023	3.8	7	758.0	10.15	13.4	32.3	22.1	27.9	79.1

10/20/2023	3.7	5	756.5	7.26	6.6	33.2	22.3	29.5	83.1
10/21/2023	3.8	2	766.0	8.80	9.6	33.2	23.7	31.5	74.9
10/22/2023	3.1	3	749.8	10.18	12.2	32.0	24.3	28.0	77.5
10/23/2023	3.8	3	764.2	10.37	7.6	33.7	22.7	28.1	80.5
10/24/2023	3.3	4	759.3	7.11	13.2	34.6	22.0	31.6	81.4
10/25/2023	4.2	3	766.1	7.41	13.5	33.7	22.8	27.5	87.1
10/26/2023	3.8	5	754.4	9.14	7.6	35.7	21.9	29.2	85.4
10/27/2023	4.6	6	764.0	10.30	5.2	33.3	21.7	31.3	81.8
10/28/2023	4.4	3	754.0	9.56	13.6	34.8	22.2	28.6	78.9
10/29/2023	3.3	5	752.5	7.41	15.1	33.0	21.3	29.6	82.6
10/30/2023	3.8	2	759.5	10.91	8.6	32.8	22.2	27.7	80.0
10/31/2023	3.0	5	748.6	10.85	14.9	34.3	23.5	29.6	81.2
11/1/2023	5.2	6	763.0	6.11	1.9	31.8	21.3	25.9	82.6
11/2/2023	5.8	10	748.2	5.48	1.9	30.5	22.0	25.7	80.2
11/3/2023	6.5	10	751.7	6.95	0.3	33.1	22.2	25.9	84.3
11/4/2023	5.8	7	760.4	7.87	0.3	30.7	20.1	25.7	82.9
11/5/2023	6.0	9	752.5	6.86	0.8	30.9	20.0	25.5	85.3
11/6/2023	5.1	8	758.0	9.98	1.3	31.8	22.4	25.9	87.6
11/7/2023	6.4	8	754.5	9.41	1.5	33.3	24.2	25.6	84.3
11/8/2023	5.6	10	755.7	9.96	1.9	31.3	20.7	25.5	81.8
11/9/2023	5.5	6	763.6	8.63	1.9	32.1	24.5	25.9	86.5
11/10/2023	6.2	9	753.1	8.01	1.4	30.7	23.5	25.9	85.4
11/11/2023	5.4	9	766.3	5.68	1.8	33.9	20.3	25.8	84.2
11/12/2023	6.4	7	764.3	9.92	1.0	33.0	23.5	25.6	86.8
11/13/2023	6.4	9	759.1	9.53	0.7	33.7	21.3	25.6	85.4
11/14/2023	5.7	7	756.8	5.48	1.0	30.6	20.1	26.0	81.8
11/15/2023	5.7	8	754.0	5.58	0.2	31.6	23.2	25.6	84.6
11/16/2023	5.4	5	764.3	8.34	1.6	32.6	23.8	25.7	81.3
11/17/2023	6.0	8	765.3	9.62	1.6	33.2	23.6	25.9	82.5

11/18/2023	5.4	7	757.4	7.33	0.3	33.2	19.8	25.8	86.0
11/19/2023	6.4	7	750.1	6.16	0.9	32.9	23.2	26.0	83.9
11/20/2023	6.4	10	751.3	9.60	1.0	34.1	22.6	25.5	87.9
11/21/2023	5.6	11	765.0	5.88	0.0	30.1	21.9	25.7	83.1
11/22/2023	5.5	10	750.6	7.74	0.3	30.3	21.2	25.5	89.3
11/23/2023	5.4	10	749.0	8.47	1.1	33.1	20.7	25.7	88.5
11/24/2023	5.6	5	753.2	5.96	0.0	32.3	22.8	26.0	86.3
11/25/2023	6.0	7	754.9	5.33	0.2	33.1	22.4	25.8	80.4
11/26/2023	5.3	5	751.0	8.70	0.7	34.1	20.7	25.9	85.8
11/27/2023	6.4	9	755.9	6.36	1.0	34.1	21.8	25.7	83.6
11/28/2023	5.3	10	758.5	7.28	0.4	30.5	23.6	25.9	82.4
11/29/2023	5.3	7	753.2	5.61	0.9	31.2	22.0	26.0	82.1
11/30/2023	6.5	8	759.5	6.63	0.4	31.0	21.0	25.7	80.7
12/1/2023	5.4	7	756.7	7.54	4.8	35.2	20.6	27.5	62.3
12/2/2023	5.5	10	764.5	9.52	2.7	39.0	24.2	29.6	71.1
12/3/2023	6.0	10	765.4	9.05	5.5	38.9	24.1	28.0	69.6
12/4/2023	6.1	8	757.3	9.92	2.4	36.3	24.2	30.2	69.5
12/5/2023	6.3	5	750.8	7.45	4.4	35.4	20.4	27.4	72.8
12/6/2023	5.0	7	754.5	8.98	5.0	37.7	21.8	27.3	70.9
12/7/2023	6.0	7	752.7	8.81	5.0	35.3	24.3	27.4	72.5
12/8/2023	6.4	7	764.3	7.65	5.9	35.7	22.8	30.3	66.2
12/9/2023	5.5	6	750.1	7.44	5.7	37.2	20.7	30.4	68.7
12/10/2023	5.1	8	756.2	6.97	2.2	34.8	23.8	29.0	64.8
12/11/2023	5.4	8	762.8	8.61	1.4	35.1	20.0	31.0	73.1
12/12/2023	6.2	5	759.6	7.92	5.8	35.6	21.1	28.3	69.4
12/13/2023	6.2	10	760.9	8.08	2.5	34.3	23.8	30.9	68.4
12/14/2023	5.3	7	765.2	6.18	4.3	34.8	20.8	30.2	67.8
12/15/2023	6.4	7	761.1	8.56	2.4	36.7	22.7	28.3	67.3
12/16/2023	6.1	8	752.6	9.33	2.5	38.8	20.3	27.9	70.5

12/17/2023	5.1	11	755.2	6.65	3.9	38.8	24.3	31.8	72.6
12/18/2023	5.4	9	756.6	9.45	0.8	34.0	23.6	30.4	72.3
12/19/2023	5.8	6	766.9	8.77	5.6	37.4	20.4	27.4	68.4
12/20/2023	5.6	7	759.2	6.53	5.6	36.6	20.5	30.3	70.9
12/21/2023	6.5	6	755.0	6.68	0.0	37.4	22.5	31.4	71.6
12/22/2023	5.4	7	752.0	6.74	0.7	39.2	23.2	28.2	67.6
12/23/2023	5.1	10	756.1	9.58	0.0	35.9	20.3	31.6	64.6
12/24/2023	5.2	10	762.2	6.47	0.0	38.6	23.8	27.9	64.9
12/25/2023	5.0	10	756.3	7.73	0.2	38.0	22.8	31.1	68.4
12/26/2023	5.0	7	757.2	9.60	0.9	38.4	22.6	31.4	66.5
12/27/2023	6.2	7	758.5	7.14	8.0	35.0	24.1	27.3	67.2
12/28/2023	6.0	6	748.6	8.53	1.2	38.4	23.6	29.9	68.2
12/29/2023	6.2	5	755.9	6.88	2.3	38.8	22.4	29.4	70.0
12/30/2023	5.3	11	751.8	9.52	0.4	35.4	23.7	27.5	70.2
12/31/2023	5.9	7	760.7	6.14	1.3	39.0	19.9	31.3	74.5
1/1/2024	5.1	5	752.0	9.52	0.9	40.0	22.0	31.0	63.2
1/2/2024	6.2	11	761.2	9.40	1.4	40.1	21.4	29.1	71.6
1/3/2024	5.8	7	748.1	7.11	2.0	37.0	21.1	29.9	67.0
1/4/2024	6.0	11	749.6	7.35	0.4	39.5	23.0	30.5	60.4
1/5/2024	6.2	6	764.2	5.46	1.3	36.4	19.6	31.1	59.3
1/6/2024	5.4	10	765.2	8.87	3.0	36.0	21.9	29.6	67.4
1/7/2024	6.0	6	763.9	8.40	7.3	39.4	19.7	30.5	68.1
1/8/2024	5.3	5	761.2	8.01	3.0	37.6	24.0	30.3	66.1
1/9/2024	5.9	6	765.5	9.87	0.9	40.5	21.5	31.5	64.9
1/10/2024	5.7	8	751.2	9.45	4.6	38.8	19.5	31.9	60.9
1/11/2024	6.3	8	751.3	8.56	5.0	39.2	22.5	32.2	66.2
1/12/2024	6.0	6	765.9	5.22	1.3	36.7	19.7	32.9	61.5
1/13/2024	6.4	10	760.5	8.51	2.0	39.0	24.0	32.6	65.2
1/14/2024	5.5	11	765.7	7.51	3.8	36.9	24.0	31.8	63.3

1/15/2024	5.5	5	752.0	6.16	1.4	37.4	20.8	31.6	70.7
1/16/2024	6.1	10	757.1	8.41	0.7	35.4	22.1	31.7	60.4
1/17/2024	6.2	9	766.8	9.79	1.6	35.9	21.2	31.0	67.0
1/18/2024	5.4	8	749.0	8.44	1.1	40.2	20.1	29.7	66.4
1/19/2024	5.7	6	762.3	5.04	2.4	35.8	19.9	29.0	63.1
1/20/2024	6.4	7	752.0	7.57	5.8	35.2	20.7	32.5	67.8
1/21/2024	5.9	5	765.9	6.00	5.1	37.2	22.5	31.8	64.5
1/22/2024	5.6	8	749.8	5.10	0.3	35.7	22.7	30.4	61.3
1/23/2024	5.2	7	763.2	7.34	5.2	38.8	19.6	29.4	66.4
1/24/2024	6.1	9	756.3	5.57	3.5	40.6	23.0	31.3	61.1
1/25/2024	5.1	8	759.2	8.39	2.3	40.0	19.3	31.2	69.8
1/26/2024	6.1	7	750.9	8.34	7.4	38.7	23.1	29.1	62.6
1/27/2024	5.4	6	749.0	6.60	6.3	35.1	24.0	32.2	62.0
1/28/2024	6.4	5	752.7	6.93	7.2	38.7	24.9	31.8	67.8
1/29/2024	5.1	5	754.3	9.46	4.3	39.0	20.5	30.5	62.0
1/30/2024	6.0	10	764.6	5.13	0.9	38.3	23.9	32.6	64.0
1/31/2024	6.5	9	760.0	6.24	3.4	36.8	21.2	29.1	69.3
2/1/2024	5.9	9	756.3	9.27	1.0	37.6	21.2	29.2	72.3
2/2/2024	5.5	7	762.4	7.20	0.5	39.6	23.8	30.0	74.2
2/3/2024	5.8	8	748.9	8.83	1.1	42.0	22.6	31.5	72.5
2/4/2024	5.6	7	755.2	7.33	1.8	34.2	21.5	30.8	71.0
2/5/2024	6.3	8	764.3	6.04	2.1	36.3	23.0	32.4	76.7
2/6/2024	5.0	7	766.5	7.19	1.8	38.4	24.4	29.5	69.6
2/7/2024	6.0	11	752.5	5.35	0.5	40.5	24.4	32.0	71.7
2/8/2024	5.3	8	754.4	5.96	0.8	40.9	23.0	32.6	73.9
2/9/2024	5.3	6	751.0	8.71	0.1	42.0	22.2	30.6	78.5
2/10/2024	6.2	8	753.9	5.94	1.3	36.0	22.4	29.5	70.5
2/11/2024	5.7	10	759.3	7.29	0.7	37.7	23.4	29.5	65.4
2/12/2024	5.3	7	762.7	8.31	0.2	34.3	24.3	29.4	75.7

2/13/2024	6.2	5	760.5	5.81	4.8	39.6	22.4	32.7	67.5
2/14/2024	5.4	7	763.8	8.30	0.7	34.8	24.7	30.9	71.7
2/15/2024	6.3	10	766.8	5.10	3.8	36.1	21.3	30.5	68.2
2/16/2024	5.7	10	749.7	8.03	2.5	37.4	24.4	33.0	72.0
2/17/2024	5.7	10	760.6	5.09	2.1	40.6	20.9	30.3	67.6
2/18/2024	6.1	8	756.5	5.75	4.6	35.2	24.1	30.8	72.4
2/19/2024	5.7	11	755.7	6.25	1.0	37.3	22.9	32.2	76.5
2/20/2024	5.3	7	754.0	9.08	0.8	39.6	22.7	32.9	73.2
2/21/2024	5.0	10	749.4	8.72	0.2	41.1	24.6	29.6	79.7
2/22/2024	5.7	7	756.5	5.64	3.1	40.1	21.2	29.2	71.6
2/23/2024	5.7	9	752.4	6.97	1.5	35.0	22.0	32.0	71.1
2/24/2024	5.8	8	752.6	7.23	0.8	42.1	22.7	32.5	82.5
2/25/2024	6.3	9	753.7	8.91	1.1	38.8	23.6	32.8	77.1
2/26/2024	6.5	11	766.2	9.37	3.4	37.0	21.8	30.8	70.0
2/27/2024	5.1	9	758.7	8.84	1.0	34.4	21.6	32.4	69.3
2/28/2024	6.1	10	760.0	9.05	2.2	34.2	22.9	31.7	71.0
2/29/2024	6.2	6	757.9	8.07	0.7	36.2	24.1	32.7	78.4
3/1/2024	6.3	5	752.8	6.42	1.4	38.1	23.2	29.3	75.0
3/2/2024	5.5	11	766.3	8.43	1.8	36.9	25.8	29.0	77.9
3/3/2024	5.5	7	763.8	6.53	1.9	35.1	22.1	29.0	75.3
3/4/2024	5.2	8	757.7	8.25	1.8	34.5	22.8	30.2	83.0
3/5/2024	5.3	5	750.9	10.40	3.0	34.4	23.4	28.9	78.3
3/6/2024	5.3	9	754.1	7.59	0.9	37.5	23.5	29.5	69.9
3/7/2024	5.3	7	757.9	10.36	0.6	37.4	23.6	28.8	74.1
3/8/2024	5.6	6	749.2	6.89	4.9	34.0	24.6	28.9	78.2
3/9/2024	6.1	6	754.7	7.40	1.3	38.9	25.2	31.3	76.8
3/10/2024	5.1	6	757.7	7.21	3.7	35.4	21.8	31.1	78.9
3/11/2024	5.3	9	764.0	7.45	1.8	36.6	24.7	31.0	81.9
3/12/2024	6.2	7	761.7	6.61	3.1	36.1	24.4	31.2	81.4

3/13/2024	5.2	7	755.8	8.16	0.8	35.6	25.7	31.3	80.1
3/14/2024	6.4	11	764.7	6.33	1.7	36.9	22.1	29.2	79.2
3/15/2024	5.8	8	765.2	6.99	4.9	36.3	24.1	31.3	70.6
3/16/2024	5.4	7	764.8	7.99	3.9	38.5	25.7	28.8	74.6
3/17/2024	5.6	10	759.1	6.90	1.1	33.9	25.4	31.1	76.1
3/18/2024	6.1	10	758.5	10.02	0.2	39.1	22.1	31.0	80.4
3/19/2024	5.4	9	756.9	9.00	2.0	36.0	24.8	29.5	73.8
3/20/2024	5.4	7	759.0	8.98	3.7	37.1	24.1	29.9	77.9
3/21/2024	5.3	6	763.1	6.21	4.2	38.6	22.0	28.5	78.1
3/22/2024	6.2	6	748.1	6.92	1.3	34.2	24.0	28.9	80.1
3/23/2024	5.1	8	748.4	9.56	1.1	34.7	26.0	29.6	79.0
3/24/2024	5.6	10	765.5	6.43	3.8	36.9	22.5	28.8	71.2
3/25/2024	5.7	7	760.5	6.04	0.3	37.5	25.7	28.1	75.6
3/26/2024	6.2	8	762.2	10.07	1.9	38.2	24.4	31.0	81.5
3/27/2024	5.5	9	748.2	10.07	4.4	34.2	23.0	30.9	78.4
3/28/2024	5.5	5	756.4	8.44	4.8	39.2	25.5	28.6	78.7
3/29/2024	5.7	9	760.6	10.15	2.5	38.1	23.5	29.7	82.6
3/30/2024	5.8	9	766.6	7.89	2.3	34.1	22.0	28.1	76.9
3/31/2024	5.4	5	764.2	6.08	1.7	37.5	23.0	29.6	76.7
4/1/2024	4.3	6	759.9	11.82	1.0	38.5	24.7	28.9	82.2
4/2/2024	4.5	1	764.6	11.58	6.4	37.3	24.0	29.6	78.9
4/3/2024	3.4	6	764.1	12.13	5.9	37.6	24.5	28.6	78.3
4/4/2024	4.3	7	750.9	8.47	4.9	33.7	24.0	31.5	80.8
4/5/2024	4.0	7	752.4	10.14	4.2	38.1	24.6	28.9	81.4
4/6/2024	4.5	2	759.5	7.38	3.7	38.1	24.8	28.5	83.9
4/7/2024	3.3	5	749.6	8.36	7.4	34.1	24.6	30.1	77.2
4/8/2024	3.4	3	757.8	13.39	7.7	35.9	24.8	30.3	80.1
4/9/2024	4.5	1	755.8	12.42	1.4	38.6	25.0	29.6	76.0
4/10/2024	3.4	3	765.6	12.39	6.9	34.0	24.1	30.8	72.2

4/11/2024	3.5	5	766.4	11.44	7.3	36.5	25.8	30.6	74.6
4/12/2024	3.8	2	756.5	13.86	4.6	34.7	25.3	31.2	74.5
4/13/2024	3.4	5	761.7	12.96	3.9	35.3	25.3	29.7	78.9
4/14/2024	3.3	5	759.3	12.79	9.6	33.7	24.3	28.6	81.3
4/15/2024	4.0	7	760.5	9.37	7.8	38.4	25.3	31.4	78.0
4/16/2024	2.8	6	765.1	11.95	5.0	34.8	24.6	30.6	80.1
4/17/2024	3.1	7	762.6	11.90	9.2	35.5	24.5	30.4	72.8
4/18/2024	4.1	4	758.3	9.02	6.5	38.6	25.3	30.4	79.3
4/19/2024	4.2	6	753.5	11.67	5.1	34.0	24.2	30.7	82.6
4/20/2024	4.4	2	748.5	7.79	3.1	33.2	24.1	31.0	83.0
4/21/2024	3.7	7	759.9	10.25	4.5	37.7	24.5	31.4	73.9
4/22/2024	3.6	4	748.5	13.23	1.4	37.9	24.9	29.3	78.3
4/23/2024	4.2	6	748.2	10.41	2.4	34.4	25.1	30.5	78.5
4/24/2024	3.0	6	758.4	8.53	4.0	36.4	25.0	31.6	74.9
4/25/2024	4.2	5	764.6	10.17	1.1	34.2	25.2	31.6	75.9
4/26/2024	4.0	2	764.2	7.59	4.3	38.3	25.1	28.9	81.1
4/27/2024	4.7	4	758.3	8.20	5.2	33.1	25.1	30.1	81.0
4/28/2024	4.2	3	758.0	12.16	4.6	38.7	25.4	31.9	74.2
4/29/2024	4.3	6	766.5	8.33	2.5	36.0	24.4	29.5	80.4
4/30/2024	4.6	1	749.1	13.42	8.7	33.1	24.5	31.8	79.3
5/1/2024	3.5	5	765.0	12.89	8.0	34.8	21.4	27.6	78.9
5/2/2024	4.7	6	765.7	11.14	7.6	33.7	22.4	28.8	85.4
5/3/2024	4.5	4	764.9	9.09	12.8	34.6	21.4	27.1	82.2
5/4/2024	3.3	6	758.6	12.78	12.0	34.1	24.0	28.9	81.0
5/5/2024	4.2	5	763.0	14.49	6.5	34.3	23.8	27.3	83.0
5/6/2024	2.9	3	761.1	11.48	6.1	35.1	22.8	29.4	82.1
5/7/2024	3.8	2	754.5	12.87	12.0	35.7	22.1	29.9	79.3
5/8/2024	3.4	5	763.4	8.47	12.1	33.0	21.5	29.7	77.6
5/9/2024	3.6	6	751.4	11.93	11.8	33.0	21.9	30.7	78.1

5/10/2024	4.5	4	754.7	8.49	9.8	33.3	23.0	30.4	84.7
5/11/2024	4.3	1	764.2	9.91	9.8	34.9	22.6	30.8	81.4
5/12/2024	3.0	7	753.6	9.36	11.1	37.8	22.2	27.5	82.1
5/13/2024	4.0	5	760.2	7.96	8.4	38.0	21.8	27.2	78.6
5/14/2024	3.0	1	765.2	10.66	11.0	34.6	22.5	28.9	82.0
5/15/2024	4.5	6	756.7	9.78	3.6	37.6	23.4	30.2	80.7
5/16/2024	3.5	4	758.5	10.98	5.2	32.0	21.9	30.5	81.1
5/17/2024	3.4	3	753.8	9.85	7.3	33.5	21.1	30.3	78.3
5/18/2024	3.0	3	749.8	12.78	8.8	35.5	22.0	29.8	82.8
5/19/2024	4.7	3	756.2	10.85	11.9	36.6	21.9	27.2	79.5
5/20/2024	4.2	3	749.0	12.63	5.7	36.3	23.8	29.9	76.1
5/21/2024	4.8	4	753.0	14.81	12.9	33.0	23.1	27.8	78.1
5/22/2024	4.3	6	760.5	9.86	6.0	35.0	23.0	28.2	74.4
5/23/2024	3.3	4	756.0	14.97	6.6	32.5	22.2	27.8	79.2
5/24/2024	3.0	3	757.6	10.99	7.4	35.0	21.8	28.5	78.7
5/25/2024	4.8	2	753.9	10.32	6.1	33.7	21.2	27.6	82.4
5/26/2024	3.3	2	756.9	8.88	5.3	32.5	23.1	27.3	83.2
5/27/2024	3.0	6	756.9	11.97	5.7	33.0	23.3	27.3	83.8
5/28/2024	3.9	3	764.8	9.70	10.2	34.7	21.1	30.8	83.0
5/29/2024	4.8	4	766.3	12.19	3.0	37.2	23.9	29.3	82.2
5/30/2024	4.5	6	756.3	14.63	4.8	37.6	22.0	30.6	82.1
5/31/2024	4.5	4	762.8	11.57	2.5	33.7	22.6	27.2	87.9
6/1/2024	4.2	7	762.9	12.65	11.9	32.5	21.6	27.5	87.1
6/2/2024	4.7	5	755.9	13.41	16.6	34.4	21.4	27.1	80.4
6/3/2024	3.4	4	761.1	8.40	11.6	32.9	21.4	26.7	81.6
6/4/2024	3.4	4	754.3	9.71	16.2	31.4	23.6	27.7	80.0
6/5/2024	3.3	2	760.7	9.36	4.6	35.2	20.1	26.9	85.0
6/6/2024	3.5	1	754.8	8.91	5.9	34.1	22.7	27.8	78.1
6/7/2024	3.6	2	749.6	9.92	13.8	36.1	21.3	28.1	88.8

6/8/2024	2.8	5	764.1	9.11	11.6	31.6	21.1	26.6	84.6
6/9/2024	3.5	4	761.0	14.54	8.0	35.9	24.2	28.0	86.6
6/10/2024	3.2	3	759.5	10.37	7.3	35.3	23.4	27.0	89.3
6/11/2024	3.4	5	750.7	10.45	5.6	34.1	21.0	26.9	84.2
6/12/2024	4.4	3	748.5	12.80	5.3	30.0	21.8	27.6	82.6
6/13/2024	3.9	4	753.3	14.69	5.2	33.7	22.6	27.2	85.2
6/14/2024	3.5	1	764.0	12.50	9.0	34.5	23.0	28.1	79.2
6/15/2024	2.8	2	748.3	11.73	16.3	35.6	21.3	26.6	85.0
6/16/2024	4.6	6	764.8	12.96	14.9	32.5	22.3	27.6	87.3
6/17/2024	4.7	2	754.0	9.84	6.8	32.1	20.3	27.6	84.8
6/18/2024	3.7	2	753.3	7.97	10.5	34.2	22.2	26.8	81.6
6/19/2024	3.3	4	763.8	7.56	16.7	31.2	22.6	27.8	86.4
6/20/2024	4.1	4	757.9	9.16	11.9	35.9	21.8	28.5	92.5
6/21/2024	2.8	5	753.7	7.48	4.1	35.3	20.3	27.2	85.3
6/22/2024	3.4	6	750.6	12.98	16.9	30.4	20.5	28.0	84.7
6/23/2024	4.7	4	749.2	12.86	7.8	32.7	24.2	28.1	88.9
6/24/2024	2.9	2	758.0	14.37	5.6	35.5	23.5	26.6	83.0
6/25/2024	4.2	5	761.2	10.30	8.6	35.4	24.4	27.6	79.1
6/26/2024	4.4	6	755.0	7.80	15.7	32.5	20.7	27.8	80.4
6/27/2024	3.7	4	748.3	12.96	6.0	35.9	19.8	27.2	88.9
6/28/2024	4.0	6	757.8	13.14	10.0	30.3	22.9	28.0	87.0
6/29/2024	4.5	5	758.6	10.78	15.1	30.1	21.0	27.3	83.3
6/30/2024	3.9	6	752.5	11.11	10.3	35.2	22.2	28.2	83.5