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FEASIBILITY ANALYSIS OF 1MW SOLAR POWER PLANT IN KADUNA POLYTECHNIC MAIN CAMPUS USING RET SCREEN SOFTWARE

***[1]Pindiga I. Y., [2]Muhammad S. U., [3]Mohammed M. A. and [4]Zarmai M. T.**

[1]Department of Electrical/Electronic Engineering. University of Applied Science and Engineering Technology Gambia, Kanifing. Banjul, Gambia.
[2]Department of Mechanical Engineering, Kaduna Polytechnic, P.M.B 2021 Kaduna, Nigeria.
[3]Department of Mechanical Engineering, University of Abuja, Nigeria.
[4]Department of Physics. Kaduna State University, Kaduna, Nigeria.

*Corresponding authors' email: ismailayusufpindiga@gmail.com

ABSTRACT

High electricity consumption and the resulting costs are significant challenges for managing public tertiary institutions in Nigeria. As a result, the utility companies frequently disconnect many institutions from the grid to force them to settle their debts .Facilities such as laboratories, libraries, and hostels have constant power demands. Electricity needs are met through power supplied by the Kaduna Electric distribution company, with institutions paying according to tariffs set by regulators and agreed upon by the utility. The proposed solution aims to lower electricity costs at Kaduna Polytechnic's main campus wshile reducing the carbon footprint, making the campus more sustainable. The analysis focuses on electricity generation, reducing greenhouse gas emissions, and financial aspects, using RET Screen simulation software. Weather data from NASA's database was export to analyses the performance of the photovoltaic system, 1MW solar power plant is recommended for installation at the campus. The results show that using RET Screen software, benchmark analysis, carbon emission reduction, and financial impacts can be effectively evaluated. The study reveals that the energy production cost is reduced to $0.12/kWh, with a greenhouse gas emission reduction of 639.2t CO2. Additionally, the system would export 1.5672 MWh of electricity to the national grid, generating an annual revenue of NGN 154,173,000 for the institution, with a simple payback period of 11.8 year. The aim of this study is to encourage public institutions to explore solar power as an independent energy source, addressing energy shortages and contributing to the development of sustainable energy infrastructure in Nigeria's higher education institutions.

Keywords: Feasibility Studies, Electricity Generation, Export Revenue, Energy Cost and RET Screen Software

INTRODUCTION

As the number of campus buildings has increased in together with the growth of staff and students, this has led to increased energy consumption and greenhouse gas emissions, primarily from fossil fuels. (Hamida et al., 2021). Adopting solar PV electricity generation in Kaduna Polytechnic can not only meet its electricity requirements but also reduce its environmental footprint and contribute to a greener energy future. To combat this, many researchers have highlighted renewable energy sources like solar and wind power as efficient ways to reduce greenhouse gas emissions. A clean energy simulation tool called RET Screen is used to optimize and evaluate the proposed 1MW solar photovoltaic (PV) system to determine the feasibility of renewable energy solutions. (Fasina, 2023).This analysis considers several factors, including project finances, fuel savings, energy production, capacity factors, and reducing greenhouse gas emissions. Institutional buildings must drastically cut their greenhouse gas emissions, particularly in energy use, as they are responsible for almost 33% of global emissions. (Rafique et al., 2018) The endeavor to lower greenhouse gas emissions from buildings is consistent with more general climate change regulations. (Luqman et al., 2023) With its abundant solar energy potential ranging from 3.5 kWh/m²/day to 7.0 kWh/m²/day, Nigeria presents a prime opportunity to harness solar power. (Schultz & Carvalho, 2022) However, solar energy systems, dependent on weather conditions, are considered non-dispatchable, meaning humans cannot directly control their output. (Shah et al., 2018) Numerous studies support the use of solar PV for off-grid electrification due to its modular design, low weight, and easy installation. The Nigerian government's recent removal of subsidies on petroleum products is expected to raise the cost of grid electricity in Nigerian tertiary institutions, making solar power a more attractive alternative (Ahmed & Gidado, 2008) There is also potential for donor support through developing a solar PV roadmap, which could guide Nigerian institutions in adopting solar energy. Such a roadmap would involve conducting comprehensive feasibility studies, covering financial risks, technical aspects, sensitivity analysis, and the environmental impact of installing solar PV systems, such as the one proposed at Kaduna Polytechnic.

RET Screen software, a tool developed by the Canadian government, is instrumental in conducting techno-economic and environmental studies on energy systems, making it ideal for such feasibility analyses. (Odoi-Yorke et al., 2023) Solar energy is increasingly viewed as a viable and promising alternative to conventional energy sources, especially in Nigerian tertiary institutions with limited access to reliable electricity. This study investigates the performance of the proposed 1 MW PV system at Kaduna Polytechnic using the RET Screen software. Implementing this system would address energy shortages and reduce carbon dioxide emissions at the institution, with the potential for other Nigerian tertiary institutions to benefit from a similar approach. Several studies (Owolabi et al., 2019) including one conducted at the Turkish Naval Academy of the National Defense University, have shown the advantages of solar PV systems. This study demonstrated a 93% reduction in greenhouse gas emissions and a savings of 721.1 tons of crude oil. (Asante et al., 2024) The results of these studies give stakeholders, decision-makers, and educational institutions in

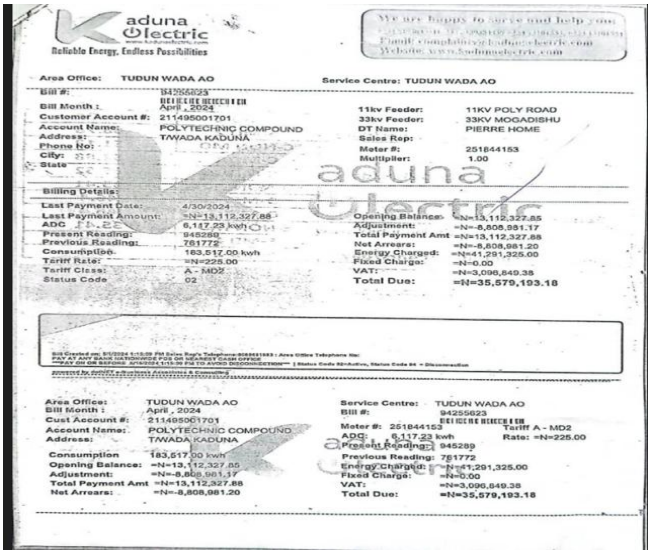
Nigeria important direction for comprehending the advantages and economic viability of solar photovoltaic systems. In the end, our findings enable a more robust and sustainable energy future for these institutions by helping to shape policies and promoting additional investments in renewable energy within the education sector.

The literature review seeks to give a thorough description of available research on solar photovoltaic (PV) power generation in educational institutions. Several studies have studied the application of solar PV systems in Nigerian universities. However, research is still restricted. Study(Odoi-Yorke et al., 2023) evaluated domestic solar water heating (SWH) systems in India using the RET Screen software to determine their technical, economic, and environmental performance. The results showed that the SWH project could cut greenhouse gas (GHG) emissions by 739 tons of CO_2 over a 25-year period, which is the system's anticipated lifespan. Furthermore study (Luqman et al., 2023) discovered that a solar PV system could generate up to 1,550.98 MWh of energy annually with an annual solar radiation of 5.74 kWh/m²/day; the highest energy production was recorded in March, at 146.89 MWh. The project was considered economically viable, with a net present value (NPV) of $681,164 and a positive internal rate of return (IRR) of 11.9%. Additionally, the system could reduce GHG emissions by 670.9 tons of CO_2, equivalent to the carbon absorption of 61.7 hectares of forest. In addition (Tozzi & Jo, 2017) evaluated a 1 MW solar PV system at the UMP campus in Malaysia, using the PV Geographical Information System (PVGIS) and PV Watt software for simulations. According to this study, the system could produce 1,390 MWh of electricity while lowering greenhouse gas emissions by 818.71 tons of CO_2. Both software programs' energy predictions agreed, and the system supplied 5% of the campus's overall energy needs. Moreover, study (Yeboah & Tseh, 2023) examined the integration of a solar-powered car park and found that it reduced electricity costs and carbon dioxide (CO_2) emissions by 18%. Compared to an overall output of 336.6 tons of CO_2, the solar parking lot's monthly energy generation of 147,116 kWh reduced 63.6 tons. Along with increasing energy reliability, this integration had a major positive impact on the environment. In addition, the study (Owolabi et al., 2019) Yobe state was found to have the highest capacity factor of 21.7% and the highest annual solar radiation of 5.96 kWh/m²/day, making it the most suitable location for solar PV projects in Nigeria. Yobe's proposed solar PV system could export 11,385 MWh to the grid, with a payback period of 13.6 years and a reduction in GHG emissions of 5,452.5 tons of CO2, which is equivalent to the carbon sequestration of 501.5 hectares of forest.

However, studies (Asante et al., 2024) evaluated the potential of the University of Environment and Sustainable Development's (UESD) rooftop solar photovoltaic system. After estimating rooftop surface areas using Google Earth software, the study concluded that the solar PV system could supply the institution's electrical demands and produce extra electricity that could be sold to the grid. This strategy assists schools' transition to a more sustainable energy system while lowering operating expenses. In Nigeria, particularly at Kaduna Polytechnic, electricity consumption and costs are significant challenges for the management of educational institutions. For instance, the average electricity consumption at the main campus in 2024 was over 183,517 kWh monthly, costing approximately NGN 41,291,325. High power demand during peak hours (10 am–4 pm) often leads to power fluctuations, disrupting academic activities. The installation of a 1MW solar power plant at Kaduna Polytechnic's main campus has been proposed to address this. This solar plant would supplement the campus's electricity supply and ensure a stable power supply during daylight hours, helping to reduce energy consumption and costs. This case study demonstrates how solar energy can provide a practical solution to the electricity challenges faced by public tertiary institutions in Nigeria, using Kaduna Polytechnic as an example.

MATERIALS AND METHODS

The study utilizes RET Screen software to model the energy performance, conduct financial analysis, and assess greenhouse gas (GHG) reduction for the proposed 1MW solar power plant. Developed by the Canada Excellence Research Chairs (CERC), the RET Screen is a powerful tool designed to help investors evaluate the feasibility of clean energy projects globally. Using data from multiple sources, its extensive databases provide more precise computations for metrics such as simple payback period, cumulative cash flows, and net present value (NPV) (Owolabi et al., 2019)The software, widely adopted by researchers and academics, is


Kaduna Electric
Reliable Energy, Endless Possibilities
Area Office: TUDUN WADA AO
Service Centre: TUDUN WADA AO
Bill Month : April , 2024
Customer Account #: 211495001701
Account Name: POLYTECHNIC COMPOUND
Address: TWADA KADUNA
Tariff Class: A - MD2
Status Code 02
11kv Feeder: 11KV POLY ROAD
33kv Feeder: 33KV MOGADISHU
DT Name: PIERRE HOME
Meter #: 251844153
Multiplier: 1.00
Last Payment Date: 4/30/2024
Last Payment Amount: =N=13,112,327.85
ADC 6,117.23 kwh
Present Reading: 945289
Previous Reading: 781772
Consumption 183,517.00 kwh
Tariff Rate: =N=225.00
Opening Balance: =N=13,112,327.85
Adjustment: =N=-8,808,981.20
Total Payment Amt =N=13,112,327.85
Net Arrears: =N=-8,808,981.20
Energy Charged: =N=41,291,325.00
Fixed Charge: =N=0.00
VAT: =N=3,096,849.38
Total Due: =N=35,579,193.18
Figure 1: The Monthly Cost Consumption Bill of Kaduna Polytechnic Main Campus

Essential for performing energy and cost-benefit analyses of renewable energy systems. Additionally, it is freely available and user-friendly.(Asad et al., 2022) RET Screen calculates system costs based on various
inputs, including capital expenditures, operating and maintenance costs, component replacement costs, and energy consumption.(Rafique et al., 2018)
Kaduna Polytechnic, founded in 1958, has grown to include a staff of 3,000 academic and non-academic personnel, and a student body of 37,000. The institution operates across four campuses, housing 62 departments. Its electricity supply is primarily sourced from the Kaduna Electricity Distribution Company (Kaduna Electric), with a contracted power demand of 5,396.6 kVA delivered through 11 kV substations. This bulk electricity is then distributed to the various buildings on the campus.

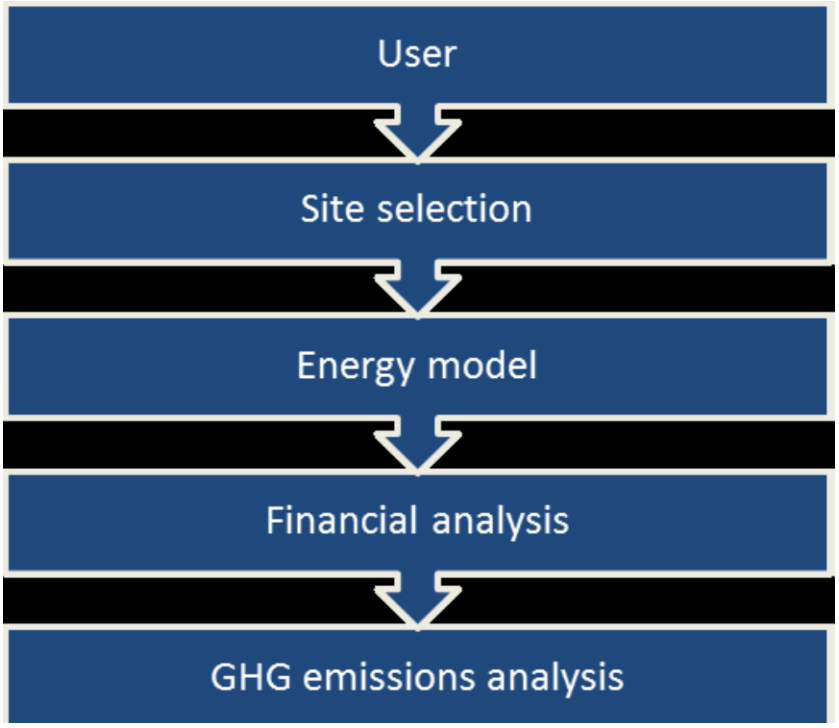


Figure 2: Schematic Diagram of Energy Optimization

However, Kaduna Polytechnic faces a significant challenge with its high electricity costs, which regularly exceed NGN 41.572 million per month at the main campus in Tudun Wada. The average monthly electricity bill for the main campus, as depicted in Figure 1, reflects this heavy financial burden, with the institution currently paying an average rate of NGN 225 per kWh. This rate corresponds to the Band A tariff for institutions and businesses, equivalent to approximately USD 0.15 per kWh.

	Unit	Climate data location	Facility location
Name		Nigeria - Kaduna	Nigeria - Kaduna State - Kaduna
Latitude	°N	10.5	10.5
Longitude	°E	7.4	7.4
Climate zone		1A - Very hot - Humid	1A - Very hot - Humid
Elevation	m	598	610

Figure 3: Show the study Area

The proposed solar power plant has a capacity of 1MW, which may replace the electricity deficiency in Kaduna Polytechnic's main campus. Rescreen software version 9.10 is used in the study for feasibility analysis including, technical viability of the proposed solar energy plant, economic and environmental viability (Expert, 2024) RET screen software selected the proposed project location, includes the location's latitude and longitude, altitude and relevant climate data (Jo et al., 2017) All these are incorporated in the software database the type of facility to be used for the analysis, the facility capacity and the technology involved (Islam et al., 2023). Furthermore, the technical viability for the proposed energy production can be predicted using the software. For the emission Analysis based on the information provided, the software calculates the expected greenhouse gas emission for the proposed solar project. The software allows users to choose multiple levels of input for calculations, with the selection typically depending on the available data and the project's stage of development. The results presented in this paper are categorized into three sections: Technical, Emission, and financial analysis. The technical analysis shows the amount of power delivered to the grid in kilowatt-hours (kWh). The emission analysis estimates the net annual greenhouse gas emissions, specifically carbon dioxide, for each site. Meanwhile, the financial analysis provides insights into the payback period and the time it takes to recover the initial investment through equity.

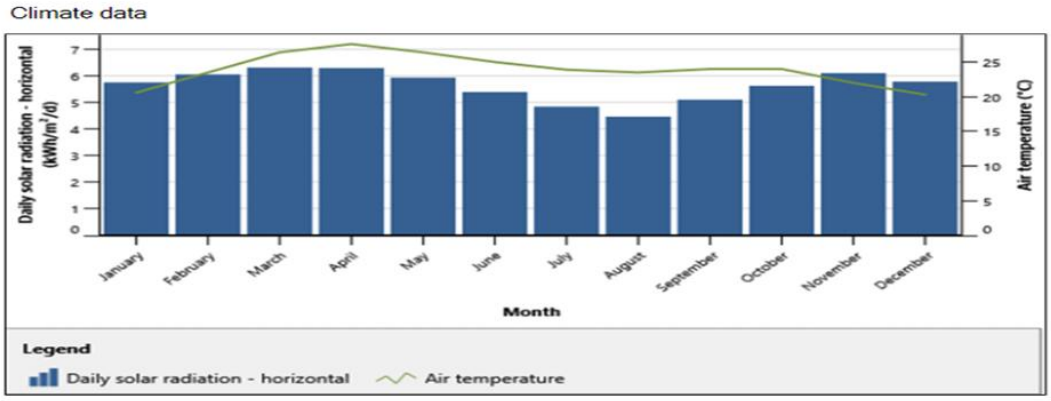
Technical Viability Analysis for the Proposed 1MW Solar Power Plant

Based on the technical analysis, the net electricity exported to the grid is 1,542 MWh, generating an annual revenue of NGN 154,176,000. For the proposed solar power plant, climate data was sourced from the RET Screen expert database to carry out the feasibility study calculations. The RET Screen software incorporates climate and geographical data for nearly every city worldwide, as reported by NASA, allowing for precise modeling (Younis et al., 2019). The results are presented in Table 4. Table 4. RET screen weather data for the location.

RESULTS AND DISCUSSION

The study uses RET screen software vision 9.1.07 expert to analyses the proposed energy generated, energy export to the grid, energy cost savings and carbon dioxide reduction. The climate data provided by NASA played a crucial role in the feasibility analysis of the proposed solar power plant project at Kaduna Polytechnic. (Fasina, 2023).

The technical, financial, and economic aspects of the 1MW solar power plant are evaluated in this study. The climate data used for the analysis was chosen to reflect the conditions that would best support the plant's potential. The average annual solar radiation for Kaduna is approximately 5.64 kWh/m²/day. The climate variables taken into consideration in the energy modelling include air temperature, relative humidity, precipitation, daily solar radiation, atmospheric pressure, wind speed, and earth temperature. By benchmarking the energy costs of the proposed 1MW solar power plant, the institution was able to compare the production cost of $0.10 per kWh (based on the current exchange rate) with the current electricity tariff of $0.15 per kWh charged by the Kaduna Electricity Distribution Company (Kaduna Electric) for Band A customers. However, when comparing the current tariff of $0.15 per kWh in Naira amounts to NGN225 per kWh, while the proposed benchmark is $ 0.12 per kWh (NGN150), with a difference of NGN75.00.



Heating design temperature	17.5	
Cooling design temperature	32.8	
Earth temperature amplitude	14.1	

Month	Air temperature	Relative humidity	Precipitation	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
	°C	%	mm	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January	20.6	39.1%	0.31	5.76	94.4	4.8	20.3	0	329
February	23.5	32.3%	0.84	6.06	94.4	4.5	23.6	0	378
March	26.4	36.0%	6.82	6.32	94.2	3.7	27.0	0	508
April	27.6	54.6%	59.10	6.30	94.2	3.2	28.7	0	528
May	26.4	71.5%	131.75	5.94	94.3	2.9	27.3	0	508
June	25.0	79.5%	196.20	5.40	94.5	2.8	25.5	0	450
July	23.9	83.2%	279.00	4.85	94.5	2.7	24.3	0	431
August	23.5	85.7%	316.82	4.47	94.5	2.4	23.7	0	419
September	24.0	83.9%	258.60	5.11	94.5	2.1	24.0	0	420
October	24.0	74.5%	94.86	5.63	94.4	2.2	23.8	0	434
November	22.0	54.8%	2.40	6.11	94.4	3.5	21.3	0	360
December	20.3	46.0%	0.31	5.79	94.5	4.5	19.8	0	319
Annua	23.9	61.9%	1,347.0	5.64	94.4	3.3	24.1	0	5,084

Figure 4: Climate Data

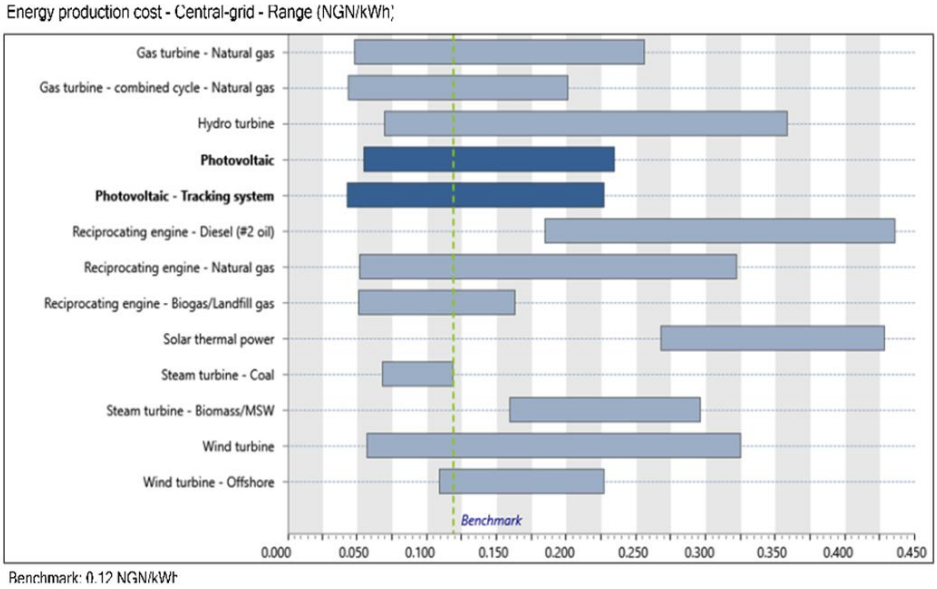


Figure 5: Benchmark on Cost of Production for the Proposed Photovoltaic

The electricity cost from this Power plant is about NGN150.00 per kWh, much less than the current electricity tariff from Kaduna Electric Band A of the country's power generation options. The proposed photovoltaic power plant at Kaduna Polytechnic's main campus proves to be financially viable in terms of power production costs, making it a promising candidate for further economic evaluation. Financial viability, in this case, refers to the plant's ability to generate enough revenue to cover operational costs, meet debt obligations, and, if applicable, support growth while maintaining service quality.(Samu et al., 2019) For the Polytechnic's decision-makers, the techno-economic analysis of the solar PV facility is also examined in this study. Key elements such as project lifetime, greenhouse gas (GHG) emission credits, inflation rate, energy

Financial viability

Financial parameters

General		
Inflation rate	%	2%
Discount rate	%	9%
Reinvestment rate	%	9%
Project life	yr	20
Finance		
Debt ratio	%	70%
Debt	NGN	1,120,000
Equity	NGN	480,000
Debt interest rate	%	7%
Debt term	yr	15
Debt payments	NGN/yr	122,970

Annual savings and revenue

Electricity export revenue		
Electricity exported to grid	MWh	1,542
Electricity export rate	NGN/kWh	0.10
Electricity export revenue	NGN	154,176
Electricity export escalation rate	%	2%

Figure 6: The Financial Viability of the Proposed Solar Power Project

Cost escalation, and energy prices are considered when using RET Screen software to evaluate the 1MW PV power plant's financial viability. In Figure 6, these financial characteristics are described in full. Before conducting the financial analysis, it's essential to establish appropriate assumptions regarding inflation, discount rates, reinvestment rates, and project lifespan, as these assumptions directly influence the financial viability process. The project is project to be twenty-five-year lifetimes with electricity export revenue of NGN154, 175.000 Per annum and the electricity export rate of $0.10 per kWh which is less cheap than the current tariff of Kaduna Electric of $0.15 per kWh for the institution.

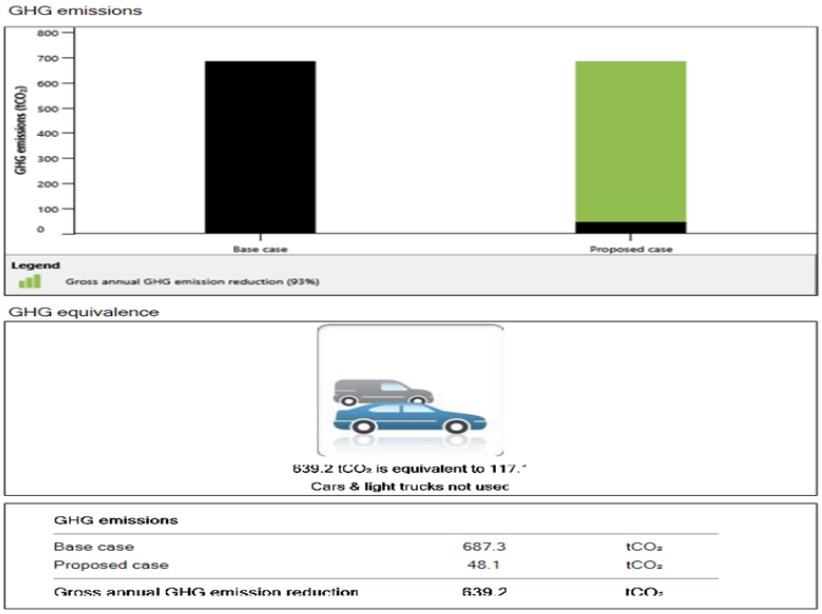
Green House Emission Analysis in the Proposed 1MW Solar Power Plan

This work considers the base case of carbon dioxide emission of 687.3 tCO2 and the proposed case of 48.2 tCO2, resulting in a carbon dioxide emissions reduction of 639.2 tCO2 by implementing the whole solar project. Implementing the entire solar project is expected to reduce 639.2 tons of CO2

emissions in a year, as shown in Figure 7 below. It is certainly going to be a vital contribution to mitigating global warming.

Economic Analysis of the Proposed Solar Power Project

Assessing a project's financial aspects to see if it is making enough money is known as financial analysis. Examining important financial papers including the cash flow statement, balance sheet, and income statement is usually part of this procedure. For this project, RET Screen, a well-known software used in renewable energy technologies, has been chosen to conduct the financial analysis(Rafique et al., 2018).



GHG emissions		
Base case	687.3	tCO_2
Proposed case	48.1	tCO_2
Gross annual GHG emission reduction	839.2	tCO_2

Figure 7: Greenhouse Emission Reduction for the Proposed Photovoltaic

This section presents the financial analysis of the proposed solar power model. A number of important economic factors have been considered, such as a simple payback period of 11.8 years, an energy production cost of NGN 0.119 per kWh, and a cost of NGN 26.1 per tonne of CO2 to reduce greenhouse gas emissions. Additionally, the analysis highlights an annual revenue saving of NGN 154,176,000 from electricity exported to the grid, as shown in Figure 8 below.

Costs | Savings | Revenue

Initial costs			
Initial cost	100%	NGN	1,600,000
Total initial costs	**100%**	**NGN**	**1,600,000**
Yearly cash flows - Year 1			
Annual costs and debt payments			
O&M costs (savings)		NGN	19,000
Debt payments - 15 yrs		NGN	122,970
Total annual costs		**NGN**	**141,970**
Annual savings and revenue			
Electricity export revenue		NGN	154,176
GHG reduction savings		NGN	0
CE production revenue		NGN	0
Total annual savings and revenue		**NGN**	**154,176**
Net yearly cash flow - Year 1		**NGN**	**12,206**

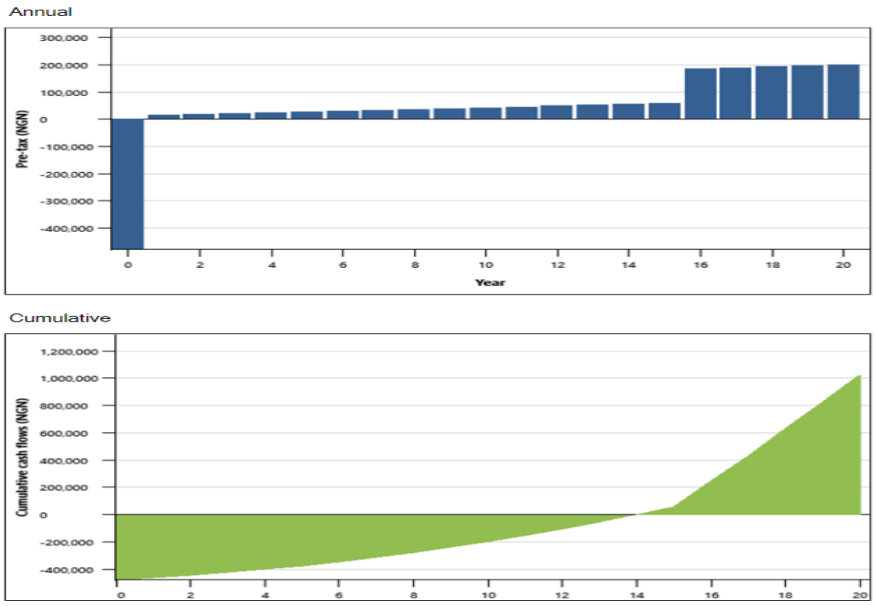
Financial viability

Pre-tax IRR - equity	%	8.6%
Pre-tax MIRR - equity	%	8.7%
Pre-tax IRR - assets	%	-0.4%
Pre-tax MIRR - assets	%	2.4%
Simple payback	yr	11.8
Equity payback	yr	14
Net Present Value (NPV)	NGN	-23,761
Annual life cycle savings	NGN/yr	-2,603
Benefit-Cost (B-C) ratio		0.95
Debt service coverage		1.1
GHG reduction cost	NGN/tCO_2	26.1
Energy production cost	NGN/kWh	0.119

Figure 8: The Economic Viability of the Proposed Solar Power Project

Annual Cash flow and Cumulative Cash Flow

The electricity exported to the grid amounts to 1,542 MWh, generating an annual revenue of NGN 158,178,000, with a corresponding greenhouse gas emission reduction of 639.2 tCO_2. Based on these figures and other relevant factors, both annual and cumulative cash flow analyses have been conducted, and the results are presented in Figure 9. A positive outcome signifies that the institution has generated more revenue than its expenditures. As shown in Figure 10, the institution consistently generated more cash than it spent, except for the first year of the project's implementation.



Figures: 9 and 10: The Annual and Cumulative Cash Flows Of the Proposed Solar Power

CONCLUSION

This study evaluated the techno-economic feasibility of a proposed 1MW grid-connected photovoltaic (PV) power plant at Kaduna Polytechnic, situated in the southern part of Kaduna State. By considering local climate conditions, initial economic factors, and other technical constraints, the study estimated key metrics such as annual energy production, electricity export revenue, greenhouse gas emission reductions, payback periods, and electricity costs. Based on the analysis, the following conclusions were drawn:

i. The energy benchmark analysis of the proposed solar power plant in Kaduna Polytechnic's main campus reduces from $0.15kWh to $0.12kWh (from NGN225.00 of Band A to NGN192.00), representing a 16.67% reduction
ii. Electricity exports to the grid of 1.542 MWh with Annual revenue of NGN154,176,000
iii. The greenhouse gas emission reduction of 639t Co_2 from the proposed solar plant.
iv. The simple payback period of 11.8 years.
v. And Proposed project lifetime of 25 years.

The above study shows significant reductions to the institution.

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