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Feasibility Assessment of an Off-Grid Solar PV System with Battery Storage for an Academic Building: A Techno-Economic and Environmental Approach

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Abstract
The rising cost of grid electricity and the instability of the national power network in Nigeria have made it necessary to find sustainable energy alternatives in academic institutions. This study evaluates the feasibility of integrating an Off-Grid solar photovoltaic (PV) power system with battery storage into a departmental building by conducting technical, economic, and environmental analyses using RETScreen Expert. The study provides a replicable framework for evaluating the feasibility of a solar PV system considering realistic electricity usage patterns and cost dynamics in Nigerian institutions. The analysis compared Grid electricity (Base case) with a photovoltaic PV solar (Proposed Case). RETScreen retrieved climate data such as daily solar radiation, cooling and heating degree-days, air temperature, and precipitation from ground-based weather stations and NASA satellites, which were used for analyses. Battery capacity and inverter size were calculated and selected to match the load; solar panel area was determined from the solar PV system. The capital and operating costs were used by the software to evaluate the annual cost savings, while financial parameters, including fuel cost escalation rate, inflation rate, discount rate and project life, were used by the software to assess Payback Period, Net Present Value (NPV) and Internal Rate of Return (IRR). Results from the analyses showed that the solar PV system is able to deliver 98.8% of the building's load throughout the year and achieve a positive Net Present Value (NPV) over a 20-year project life with annual GHGs reduction of 7.3 tCO_2, which is 100% in reduction in GHG emissions. These results provide a data-driven framework for the department to optimise energy efficiency and reduce greenhouse gas emissions. Transitioning to solar energy can significantly mitigate the financial burden of rising electricity tariffs.

Keywords: *Feasibility study, Greenhouse Gas Emission, Renewable energy, Solar photovoltaic (PV).*

1.0 Introduction

The concentration of anthropogenic greenhouse gases (GHGs) such carbon dioxide (CO_2), Methane (CH_4), and Nitrous oxide (N_2O) has increased the greenhouse effect, with CO_2 constituting majorly, thus warming the Earth's surface and is expected to continue for years to come. According to the International Energy Agency (IEA), global CO_2 emissions reached a record high of 36.8 billion tons in 2022 (IEA, 2023). The Intergovernmental Panel on Climate Change (IPCC) has stated that in order to limit the global average temperature increase to 1.5 °C by 2100, carbon neutrality must be achieved at the global level by 2050 (Allen et al., 2018). According to Churkina et al. (2020), growth of the global population and urbanization has increased the demand for more infrastructure including commercial buildings, institutional buildings and associated infrastructure, thus increasing the production of conventional building materials, which is a major cause of global emissions. Renewable energy is a major player in meeting Africa's demand with its vast renewable resource yet solar energy remains underutilized despite the continent having the highest solar radiation potential globally(International Energy Agency, 2019). Razzaq et al. (2023) Studies showed that transitioning to renewable energy systems through retrofitting academic buildings and conversion of these buildings to net zero energy buildings by installing alternate power supply like solar and also using tools like REVIT or RETScreen for analysis and modelling can reduce energy consumption and also lower CO_2 emissions, with payback periods as short as 2.3 years, this is key indication of the economic viability of the project while also supporting the attainment of SDG 7 and SDG 13.

In Nigeria, there is a constraint of chronic grid instability, as the national transmission network experienced 564 system collapses between 2000 and 2021 (Jimoh and Raji, 2023). The crisis was further clarified in March 2026 by the Minister of Power, Adebayo Adelabu who identified gas supply shortage as the major cause of the country's electricity crisis. As reported by Anthony-Uko (2026) in the Leadership Newspaper, the Minister noted that 'the main issue we have today is the gas supply shortage to the power plants, 75% of our power plants are using gas. While 25% use water. If there is no gas supply, there is nothing the generating

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companies can do. This heavy reliance on a single fuel source, amplified by a N3.3 trillion debt to gas suppliers, emphasizes the need for renewable energy solutions in academic facilities.

A solar feasibility study is the systematic assessment of the technical, financial, and environmental aspects of a proposed solar power system whether it can satisfy the required load under local climatic conditions. RETScreen Expert provides an integrated platform for conducting these analyses, it integrates the technical, economic and environmental analyses all in one place. Studies by Mansouri Kouhestani et al. (2019) showed that Lethbridge estimated rooftop PV potential is nearly 38% of its 2016 electricity consumption, and about 96% of this potential is economically feasible in a technical and economic study. It was concluded that the utilisation of a PV system on a university campus in Indonesia is technically feasible after assessing the study location and system configuration, electric load profile of the campus, solar resource and radiation, and sizing the storage batteries, PV module and inverter. However, the analysis was not feasible economically (Kristiawan et al., 2018). Owolabi et al. (2019) used RETScreen to evaluate a 6 MW grid-connected PV plant across locations in the north-eastern region, while Akinsipe et al. (2021) examined an off-grid residential PV system in Jos. These studies confirm that feasibility outcomes are sensitive to project scale, solar resource, load, and financial assumptions.

Academic buildings in Nigeria face a distinctive energy problem because unreliable grid supply is frequently supplemented by petrol or diesel generators, thereby increasing operating costs, and emissions. Diyokea et al. (2021) implemented a 2-axis tracking PV system to supply the load of the faculty of Engineering at Enugu State University of Science and Technology (ESUT), their findings indicated that a 60 kW installation can supply the entire load of the mechanical and electrical departments, achieve a 22% capacity factor and a total annual output of 115 MWh. Although the study established the feasibility of PV for a Nigerian university building, its configuration, scale, and operating assumptions differ from those of smaller departmental facilities. Just like the regional assessment of Owolabi et al. (2019) which evaluated a utility-scale grid-connected plant using representative climatic and financial parameters rather than a room-level institutional demand profile. Therefore, the relevant gap is not the absence of Nigerian RETScreen studies, but the limited evidence on compact off-grid PV-battery systems that combine a room-by-room appliance inventory, historical daily electricity demand, seasonal load-coverage estimates, and current Nigerian cost conditions for an academic departmental building.

Institutional buildings, especially academic facilities, experience fluctuating loads influenced by operational schedules, seasonal activities, grid instability, and diesel generator dependence, while financial conditions are affected by inflation, fuel price increases, the discount rate, and exchange rate fluctuations. In response, the Agricultural and Biosystems Engineering (ABE) departmental building is examined as a critical case study for addressing these energy challenges through a comparative analysis using RETScreen Expert, by evaluating a proposed off-grid battery connected solar PV power system integration against the existing grid base Case Its novelty lies in integrating five building-specific elements within one RETScreen framework: a room-by-room inventory of connected appliances; historical daily demand alongside peak connected load; explicit sizing of PV, battery storage, and inverter capacity for autonomous operation; monthly assessment of the fraction of load supplied; and lifecycle financial and operational-emissions analysis based on Nigerian cost conditions. This combination distinguishes the framework from earlier Nigerian utility-scale, residential, and grid-connected university assessments and makes it transferable to similar departmental buildings where detailed smart-meter data are unavailable.

Accordingly, the aim of this study was to assess the technical, economic, and environmental feasibility of an off-grid solar PV system with battery storage for the ABE departmental building. The specific objectives were to: (1) To calculate the solar Panel PV area (m^2) and determine the required inverter and battery capacity for the Solar PV system (2) To estimate the annual emission reductions from the building relative to the base case and project lifespan and financial viability (using these financial parameters: NPV, IRR, payback period, and annual cost savings) given a certain project. The remainder of the paper is organised as follows: Section 2 describes material and model methods used. Section 3 presents and discusses the technical, economic, and environmental results while, section 4 summarises the main findings, limitations, and implications for similar Nigerian academic buildings.

2.0 Materials and Methods

The study utilises RETScreen Expert software to perform a techno-economic and environmental analysis. The methodology procedure involves comparing a base case (existing grid) against a proposed case (solar PV system). This follows a four-step approach: site description/ climate data, Energy modelling, and financial/environmental modelling. Figure 1 below is a methodological flowchart of the off-grid PV-battery assessment

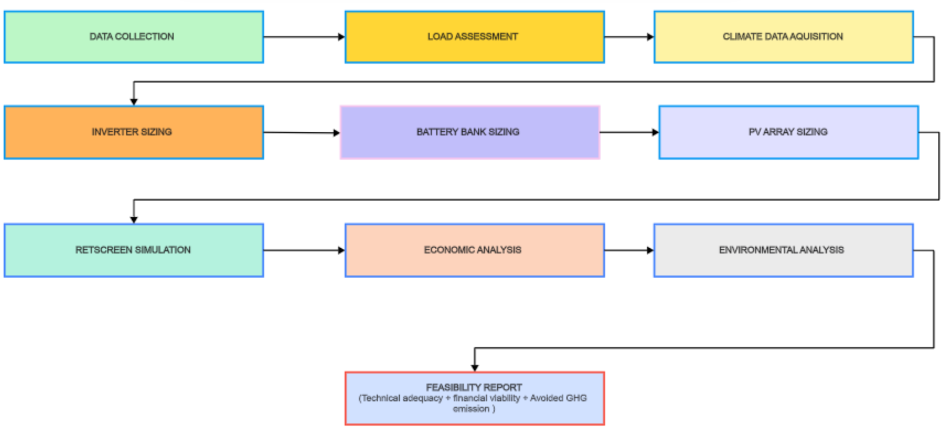

Figure 1: Methodological flowchart for the techno-economic and environmental feasibility assessment of the proposed off-grid solar PV–battery system.

2.1 Site Description and Climate Data

The analysis was carried out in the Department of Agricultural and Biosystems Engineering, University of Ilorin. whose geographical coordinates are Latitude 8.5ºN and Longitude 8.5ºE. The building consists of 21 rooms that include offices, a toilet and a boardroom with a total area of 662.14m². The proposed facility type, as specified in RETScreen, is power | storage | off-grid, and the technology type is a Photovoltaic system mounted on the roof of the building. Climate data in RETScreen obtained from NASA Prediction of Worldwide Energy Resources (POWER) Data obtained includes: air temperature, relative humidity, precipitation, daily solar radiation, Atmospheric pressure, wind speed, earth temperature, heating degree days, and cooling degree days. Table 1 shows the environmental data pulled from NASA by RETScreen

Table 1: Environmental Data from NASA by RETScreen

Month	Air Temperature	Relative Humidity (%)	Precipitation (mm)	Daily Solar-Radiation - horizon horizontal	Atmospheric pressure	Wind speed	Earth Temperature	Heating degree-days 18ºC	Cooling degree-days 10ºC
January	24.4	56.9	7.44	5.67	97.2	2.5	24.5	0	446
February	26.3	58.2	15.4	5.84	97.2	2.8	27.2	0	456
March	27	68.3	51.77	6.02	97.1	3.2	27.9	0	527
April	26.7	77.5	106.8	5.71	97.1	3.5	27.4	0	501
May	25.9	82.6	153.45	5.37	97.2	3.1	26.3	0	493
June	24.9	85.4	189	4.82	97.4	3	25.2	0	447
July	23.9	86.8	214.52	4.21	97.4	3.4	24.2	0	431
August	23.7	87.4	210.18	3.95	97.4	3.4	23.9	0	425
September	24.2	87.1	246	4.33	97.4	2.6	24.4	0	426
October	24.8	84.8	148.49	4.89	97.3	2.1	24.9	0	459
November	24.8	74.1	19.2	5.47	97.2	2	24.6	0	444
December	24	62.8	9.61	5.58	97.3	2.2	23.7	0	434
Annual	**25**	**76.1**	**1371.86**	**5.15**	**97.3**	**2.8**	**25.3**	**0**	**5489**

2.2. Energy Modeling

The energy modelling on RETScreen follow four steps, these steps take data about the base and proposed case which will be used in the technical analysis of the study. Figure 1 shows the steps taken by RETScreen.

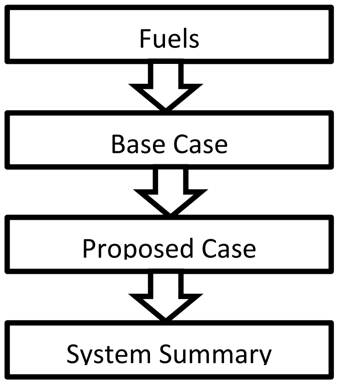

Figure 1: RETScreen Energy Analysis Flow Chart

2.2.1 Base Case Specification and Load Analysis

Energy modelling involves providing information on the type, unit, and rate of fuel and electricity used by our base case and proposed case, which the software uses to convert physical energy flows into financial metrics. The selected fuel type is Diesel, and the rate is specified at N907.50/L. Base case capacity is evaluated using the total load connected method, where we assumed that the department operates at maximum capacity, meaning all 21 offices were fully occupied and all equipment was operated simultaneously. By analysing the retrofitted dataset and aggregating the maximum power ratings of all individual appliances across the offices, the peak load of the department was determined to be 22.35 kW Table 2 shows the energy consumed at peak period in the building. The annual maintenance cost is set to 0 because it is internalised in the per-kWh cost of electricity. The daily electricity load required by the base case is 20.6 kWh based on historical data of the department. Same value was specified as daily electricity load of the proposed case.

Table 2**:** Estimated Peak Energy Consumption of Each Office

S/N	Room Number	Fridge (Wh)	AC (Wh)	Desktop (Wh)	Fan (Wh)	Laptop (Wh)	Bulb (Wh)	Phone (Wh)	Total Room Power (Kw)
1	1	0	0	0	0	0	26	0	0.026
2	2	115	1200	250	80	65	40	15	1.765
3	3	0	800	250	80	65	26	15	1.236
4	4	0	2400	0	80	65	45	15	2.605
5	5	0	800	65	80	65	26	15	1.051
6	6	0	800	65	80	65	26	15	1.051
7	7	0	800	0	80	65	26	15	0.986
8	8	0	800	0	80	65	26	15	0.986
9	9	0	800	195	80	260	26	60	1.421
10	10	0	800	0	80	65	26	15	0.986
11	11	0	0	0	0	0	0	0	0
12	12	0	1200	0	80	65	40	15	1.4
13	13	0	1200	0	80	65	40	15	1.4
14	14	0	1200	0	80	65	40	15	1.4
15	15	0	800	0	80	65	26	15	0.986
16	16	0	800	0	80	65	26	15	0.986
17	17	0	800	65	80	65	26	15	1.051
18	18	0	800	65	80	65	26	15	1.051
19	19	0	800	0	80	65	26	15	0.986
20	20	0	800	0	80	65	26	15	0.986
21	21	0	0	0	0	0	0	0	0
GRAND TOTAL									**22.359**

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2.2.2 Proposed Case Specification

We specified that the proposed case system contain a battery storage system to provide energy security during low solar irradiation and an inverter which serves as a bridge between DC and AC load. Capacity, efficiency losses and initial cost of the inverter were specified; in addition to this, the battery days of autonomy, efficiency, depth of charge, and initial cost were also specified.

2.2.3 Battery and Inverter Specification

Battery capacity is the amount of energy that can be stored to be used by the load during low or no solar generation. According to Institute of Electrical and Electronics Engineers [IEEE] (2008), battery capacity can be determined using Equations 2.1 and 2.2. Meanwhile, the days of autonomy (consecutive days without any solar energy input) were evaluated using Equation 2.3 to be 1 day, with a recommended depth of discharge of 80%.

$$\text{Battery Capacity (Ah)}, C_{bat} = \frac{E_{load} \times N_{autonomy}}{DOD \times V_{battery}} \quad (2.1)$$

$$\text{Battery Capacity (kWh)} = \text{Battery capacity (Ah)} \times \text{Battery Voltage} \quad (2.2)$$

Where:
E_{load} = Daily energy demand
$N_{autonomy}$ = Days of Autonomy (consecutive days without any solar energy input)

$$\text{Days of Autonomy} = \frac{\text{Battery Capacity}}{\text{Avg daily consumption}} \quad (2.3)$$

An inverter of 25 kW was recommended to support peak load without draining battery voltage; its efficiency of 95% was recommended by RETScreen for the analysis

2.2.4 PV Sizing and Specification

The technical analysis of the study involves sizing of the photovoltaic majorly involving the determination of the PV array power capacity, number of panels and the area covered by the solar panel area which are used by RETScreen with other specification which were provided by RETScreen, as shown in Table 3 to evaluate the annual fraction of load delivered by the PV system.

Table 3: PV Sizing and Specification on RETScreen

Photovoltaic	
Type	Mono-Si
Power Capacity	6.1 kW
Number of Units	20
Efficiency	20%
Nominal Operating Cell Temperature	45 ºC
Temperature Coefficient	0.4 % /ºC
Solar collector area	30.5
Miscellaneous losses	5%

Capacity of the PV array is calculated using the PSH method, where the daily energy demand is divided by the PSH value and efficiency of the system. Meanwhile the system efficiency accounts for all the loses in the system including inverter efficiency, battery efficiency (Al Riza and Gilani, 2014). The formula to calculate PV array power capacity (P_{pv}) and system efficiency is shown in equation 2.4 and 2.5 below. The PSH value is gotten from previous studies on PSH of Ilorin (ADEDIJI et al., 2021).

$$PV\ array\ power\ capacity(P_{pv}) = \frac{P_{load}}{PSH\ x\ \eta_{system}} \quad (2.4)$$

Where:
P_{pv} = PV array power Capacity (P_{pv})
P_{load} = Daily energy demand (kWh/day)
PSH = peak sunlight Hours (kWh/m^2)
η_{system} = Efficiency of the system

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$$\eta_{system} = \eta_{inverter} \times \eta_{battery} \times \text{Loss factor}` \quad (2.5)$$

Where:
$\eta_{inverter}$= Efficiency of inverter
$\eta_{battery}$= Efficiency of battery

According to Messenger and Abtahi (2010) the number of photovoltaic module (panels) required for the PV system is calculated using Equation 2.6 as shown.

$$P_{pv}=N\times P_{panel} \quad (2.6)$$

Where:
N = Number of PV panels
P_{Pv} = Total PV array power capacity (W)
P_{panel} = Rated power of a single PV module(W)

The area required for the solar panel is a direct computation of the system's power capacity, standard solar irradiance and the efficiency of the modules. According to (Kishore, 2009), the solar panel area is calculated using Equation 2.7

$$\text{Solar Panel Area} = \frac{P}{G \times \eta} \quad (2.7)$$

Where:
A = area (m^2)
P = power (W)
G = solar irradiance (W/m^2)
η = panel efficiency

2.3 Financial and Environmental Modelling

Level 2 analysis on RETScreen was employed to achieve greater detail and accuracy. Financial indicators, including Net Present Value (NPV), Internal Rate of Return (IRR), payback period, and lifecycle savings, were used to ensure the financial viability of the project.

The project life was set at 20 years, which is the expected lifespan of the solar PV system. A discount rate of 27% was applied; this rate corresponds to the Monetary Policy Rate retained by the Central Bank of Nigeria in November 2025 and reflects the high financing costs and investment risks prevailing during the assessment period (Central Bank of Nigeria, 2025a). Additionally, an inflation rate of 15.15% was specified based on Nigeria's headline inflation rate for December 2025, as reported by the Central Bank of Nigeria (Central Bank of Nigeria [CBN], 2025b). The analysis also incorporated a fuel cost escalation rate of 5%, The value was not interpreted as a historically observed constant tariff-growth rate because electricity tariffs in Nigeria are revised periodically under the Multi-Year Tariff Order framework.

The greenhouse gas emission reduction analysis for the proposed case is evaluated in the Emission page of the RETScreen software. The project location was specified as Nigeria, and the fuel type for the Base case electricity supply was set to Oil. The GHG emission factor of the base case, which is Nigeria's national grid emission factor, excluding transmission and distribution losses, was set at 0.44581 $kgCO_2/kWh$, with the transmission and distribution losses specified to 53.8%, according to(Adamu et al., 2022).

The software calculated and adjusted the GHG emission factor to 0.965 $kgCO_2/kWh$. The greenhouse gas emission of the base case is calculated using Equation 2.8

$$\text{GHG Emission} = \text{Annual energy consumption} \times \text{GHG emission factor} \quad (2.8)$$

3.0 Results and Discussion

The RETScreen analysis was done on the technical, economic and environmental performance of the ABE building. addressing the core objectives of this study, namely: technical viability (battery and inverter sizing), the economic feasibility (total cost of implementation and financial performance over the project lifespan), and the environmental impact through greenhouse gas emissions (GHG).

3.1 Technical Performance of the PV System

The building's energy demand was characterised by a peak load of 22.35 kW and a daily requirement of 20.6 kWh. Figure 2 detailed the load distribution across 21 offices, which served as the foundation for system sizing.

To size the system, Peak Sun Hour (PSH) method for Ilorin was used, the required PV capacity was determined to be 6.1 kW. This was met using 20 units of 300 W solar panels, covering an estimated area of 30.65 m² using the formulas in the methodology. A 25.75 kWh battery bank was specified to provide one day of autonomy. An inverter capacity of 25 kW was selected to handle the 22.35 kW peak load, surges and for

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reliability. RETScreen simulation indicated that the system delivers 98.8% of the annual load as shown in Table 4. Although this simplified calculation corresponds to an annual useful-energy potential of 7,519 kWh, RETScreen predicted 7,426.407 kWh/year delivered to the load because the simulation accounted for monthly solar-resource variation and component-level operating losses. This resulted in 98.8% annual load coverage and an unmet annual demand of 92.593 kWh. Minor deficits occurred only in July and August due to high rainfall and low solar radiation during those months.

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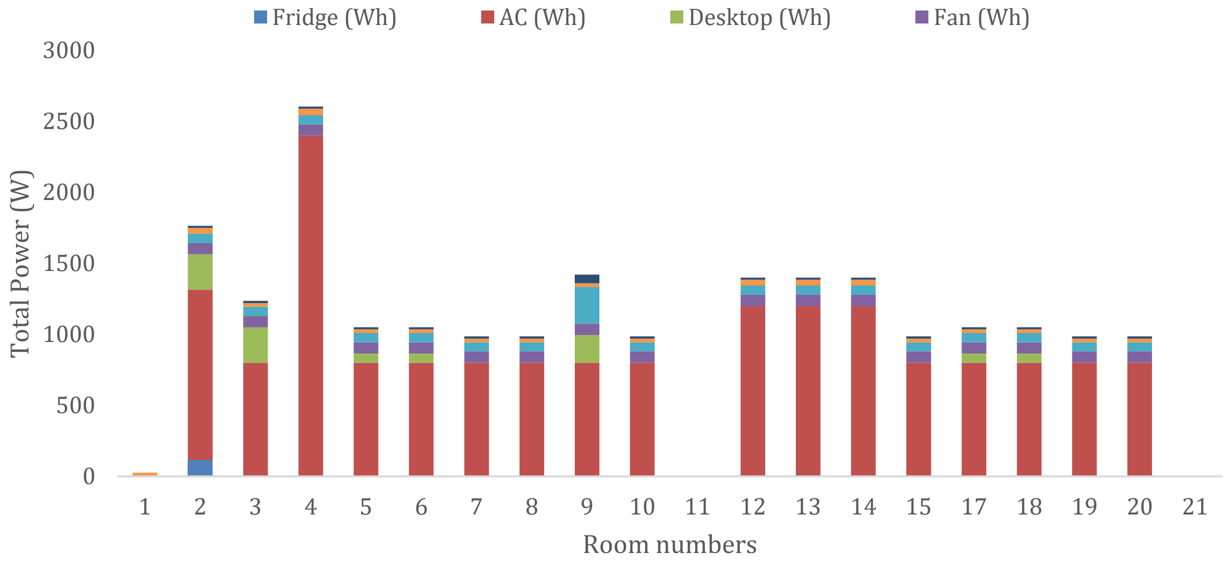

Figure 2: Energy consumed by each room at peak yielding 22.35 kW

Table 4: Fraction of load delivered by the PV to the building

Month	Daily Solar Radiation (Horizontal) kWh/m²/d	Daily Solar Radiation (Tilted) kWh/m²/d	Electricity Delivered (kWh)	Fraction of Load Delivered (%)
January	5.67	6.45	638.6	100%
February	5.84	6.25	576.8	100%
March	6.02	6.45	638.6	100%
April	5.71	5.31	618	100%
May	5.37	4.73	638.6	100%
June	4.82	4.18	618	100%
July	4.21	3.74	597.016	93.5%
August	3.95	3.66	587.591	92%
September	4.33	4.2	618	100%
October	4.89	5.06	638.6	100%
November	5.47	6.1	618	100%
December	5.58	6.47	638.6	100%
Annual	**5.15**	**5.17**	**7426.407**	**98.8%**

3.2 Economic Viability

The total initial cost of the photovoltaic (PV) system was calculated to be N4,530,000, which includes the cost of the photovoltaic panels, inverters, and battery components. According to the analysis in Figure 3, the system can generate annual savings of N1,691,775, primarily due to reductions in electricity consumption from the national grid and diesel consumption.

The Net Present Value (NPV), Internal Rate of Return (IRR), and payback period were used in further analysis of the economic feasibility of the project. The result indicates a positive Net Present Value (NPV), which shows that the project is economically operable over its 20-year life span. The 2.5-year equity payback period confirms that the system pays for itself within the first 15% of its 20-year operational life, providing 17 years of net financial gain for the university. indicating that the initial capital can be recovered within a short period.

The Internal Rate of Return of 44.1% exceeds the Discount rate of 27%, indicating the project is financially profitable and worth investing in. This align with findings in existing literature, for example

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Delapedra-Silva et al. (2022) emphasized that key financial indicators such as NPV, IRR, and Payback Period are important in evaluating renewable energy projects, compared to conventional investment where IRR values greater than 10–15% are considered attractive, the significantly higher IRR obtained in this study reflects strong profitability under Nigerian economic conditions. Similarly, the short payback period aligns with findings in solar PV feasibility studies, where systems with payback periods below 5–7 years are generally considered highly feasible. Studies by Naqvi et al. (2021) on a residential grid-tied PV system showed a PBP of 3 years, which is lower than our 2.5 years, and this is due to the small size of our system, thus requiring less initial cost. The cumulative cash flow of this project over its life span is indicated in Figure 3 below.

RETScreen - Financial Analysis **Subscriber:**

Financial parameters		
General		
Fuel cost escalation rate		5%
Inflation rate	%	15.15%
Discount rate	%	27%
Reinvestment rate	%	0%
Project life	yr	20
Finance		
Incentives and grants	NGN	0
Debt ratio	%	0%
Income tax analysis		☐

Annual savings and revenue		
GHG reduction savings		
Gross GHG reduction	tCO_2/yr	7
Gross GHG reduction - 20 yrs	tCO_2	145
GHG reduction savings	NGN	0
Other revenue (cost)		☐

Costs | Savings | Revenue			
Initial costs			
Incremental initial costs	100%	NGN	4,530,000
Total initial costs	**100%**	NGN	**4,530,000**
Yearly cash flows - Year 1			
Annual costs and debt payments			
O&M costs (savings)		NGN	0
Debt payments		NGN	0
Total annual costs		**NGN**	**0**
Annual savings and revenue			
Fuel cost - base case		NGN	1,691,775
GHG reduction savings		NGN	0
Total annual savings and revenue		**NGN**	**1,691,775**
Net yearly cash flow - Year 1		**NGN**	**1,691,775**

Financial viability		
Pre-tax IRR - equity	%	44.1%
Pre-tax MIRR - equity	%	13.7%
Pre-tax IRR - assets	%	44.1%
Pre-tax MIRR - assets	%	13.7%
Simple payback	yr	2.7
Equity payback	yr	2.5
Net Present Value (NPV)	NGN	3,364,568

Yearly cash flows		
Year	**Pre-tax**	**Cumulative**
#	**NGN**	**NGN**
0	-4,530,000	-4,530,000
1	1,776,364	-2,753,636
2	1,865,182	-888,454
3	1,958,441	1,069,987
4	2,056,363	3,126,350
5	2,159,181	5,285,531
6	2,267,140	7,552,671
7	2,380,497	9,933,169
8	2,499,522	12,432,691
9	2,624,498	15,057,189
10	2,755,723	17,812,912
11	2,893,509	20,706,422
12	3,038,185	23,744,607
13	3,190,094	26,934,701
14	3,349,599	30,284,299
15	3,517,079	33,801,378
16	3,692,933	37,494,311
17	3,877,579	41,371,890
18	4,071,458	45,443,348
19	4,275,031	49,718,380
20	4,488,783	54,207,162

Figure 3: Financial Analysis result from RETScreen

3.3 Environmental Impact

According to the methodology, the greenhouse gas emissions were calculated by multiplying the annual energy consumption by the localised GHG emission factor. The total annual emission of the base case (grid electricity) was calculated to be 7.3 tons of CO_2, with transmission and distribution losses specified to be 53.8% as shown in Table 5 This high T&D loss highlight technical inefficiencies of the Nigerian National Grid, it amplifies the environmental damage of grid electricity because for every for every 1 kWh of electricity the ABE building consumes from the grid, the national power plants must actually generate approximately 2.16 kWh to account for what is lost when transmitting.

The result of the analysis also showed that the annual greenhouse gas reduction is approximately 7.3 tCO_2, which is a 100% reduction in greenhouse gas emissions relative to the base case. Over the 20-year lifespan of the project, the ABE building will prevent a total of 145 tCO_2 from entering the atmosphere. The significant reduction in greenhouse gases shows the environmental sustainability of the photovoltaic (PV) system. It highlights the potential of solar energy to reduce the impact of climate change on the environment, especially in countries like Nigeria, where grid electricity is carbon-intensive.

Table 5: Emission Factor, T&D losses and Gross Annual GHG Emission Reduction

Metric	Value
Base Case Emissions	7.3 tCO_2
Proposed Case Emissions	0 tCO_2
Annual Emission Reduction	7.3 tCO_2
Reduction Efficiency	100%
Emission Factor (excl. T&D losses)	0.446 $kgCO_2$/kWh

Emission Factor (incl. T&D losses)	0.965 $kgCO_2/kWh$
Transmission & Distribution Losses	53.8%

4.0 Conclusion

This study presents a comprehensive techno-economic and environmental feasibility assessment of an Off-Grid solar PV system for the Agricultural and Biosystems Engineering Department building at the University of Ilorin using RETScreen Expert software. The energy demand in the building was evaluated, revealing a moderate load profile that guided the system design. The results indicate that a modestly sized PV system, supported by battery storage and an appropriately rated inverter, can effectively meet 98.8% of the energy needs of the building ensuring reliability during periods of low solar irradiance. Overall, the system demonstrated strong technical performance, supplying nearly all of the annual energy demand, with only minor variations observed during seasons of reduced sunlight. Economically, the project proved to be highly feasible according to the financial parameters used to determine it viability, the project requires a reasonable initial investment and the short payback period highlights the ability of the system to recover costs quickly while providing long-term cost saving.

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