

Overview of the Solar Hybrid Power System (Case Study: Rivers State University, Port Harcourt, Rivers State)

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ABSTRACT: This Study considered the overview of the solar hybrid power system (Case Study: Rivers State University). The generator station of Rivers State University uses a 1.27 MW Diesel Generator for distribution to halls of residence, Security outposts, Staff quarters and Essential duties station. Solar Hybridization of the Generator station will reduce load sharing, Reliability due to high cost of diesel, incorporation of Illoabuchi sawdust biomass and low carbon emission in the university. The analysis of solar hybridization is carried out using utilizability method, and techno-Economical methods for the evaluation of the usable solar radiation present in the university and the economic significance associated with solar hybridization respectively. A Software is also used for analysis i.e. HOMER PRO 3.11.2 having more advance features than previous versions used. A comparative analysis of various solar hybrid configurations were brought to light in one case study. In second case study, Techno-Economic analysis of the solar+biomassgenerator+diesel generator and its significance in the university. A recommendation is given regarding the best method to be used for the future designing of solar hybrid power system in the university generator station.

KEYWORDS: Hybrid renewable energy systems, Utilizability, economic viability, Biomass, solar energy, wind energy, optimisation.

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I. INTRODUCTION

A Solar hybrid power system is a comprehensive energy setup that integrates solar photovoltaic (PV) panels, battery storage units, and an auxiliary power source or grid connection. When working together, these components form an integrated system capable of generating, storing, and supplying electricity. Under normal operating conditions, the system uses solar energy to generate electricity, stores excess power in batteries, and supplies any shortfall through the grid ensuring consistent energy availability. During periods of low solar output or grid outages, the battery system compensates for the deficit, maintaining a steady power supply. This coordinated operation reduces dependence on fossil fuels, optimizes the use of renewable resources, and lowers operational costs. Additionally, by balancing energy supply and demand, the system contributes to grid stability. Over time, it supports environmental goals by minimizing carbon emissions and enabling a more sustainable energy model.

The study area is the Rivers State University campus located south-south Nigeria, Port Harcourt city in Rivers State. Figure 1.1 shows the study area and its topographical directions; $4^{\circ} 47' 21''$ north, $6^{\circ} 59' 55''$ east. Port Harcourt is a district that is limited in the west by the Atlantic ocean, by this there is an adequate measure of wind asset because of the ocean breeze from the Atlantic ocean. The region also has a sufficient amount of solar resource because Nigeria is located within the equator, which results in a higher solar radiation level. Its geographical coordinates are latitude 4.801540699999999 north and longitude 6.9782191 east. [1].

The existing power supply is primarily sourced from the national grid via the Port Harcourt Electricity Distribution Company (PHEDC), supplemented by diesel generators due to erratic grid performance. Load

demand peaks in the mornings and evenings, driven by halls of residence, security outpost, staff quarters and essential duties consumption.

Rivers state university possesses significant renewable energy potential, particularly solar energy, due to its location within Nigeria's tropical belt. Solar irradiance in the region ranges from 3.486 to 4.820 kwh/m²/day, making it viable for photovoltaic deployment. There are also untapped opportunities in biomass energy, given the nearby Illoabuchi wood market. Wind energy potential is relatively low to negligible.

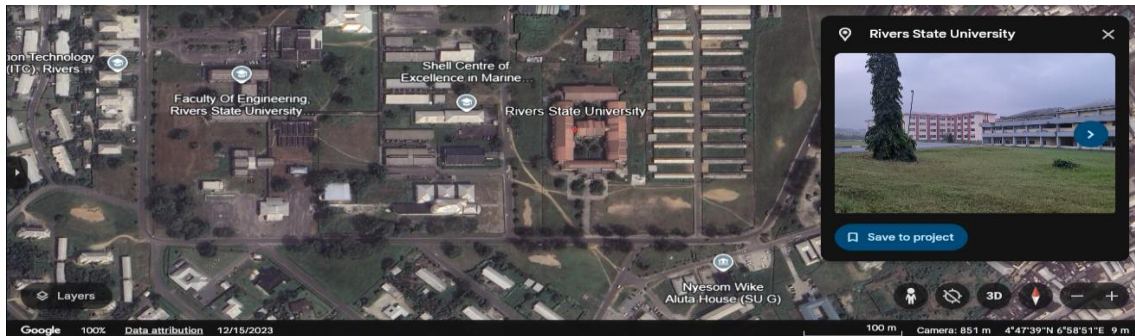


Figure 1.1 Rivers State University [6]

II. REVIEW OF PAST WORKS

Nigeria's Power Sector Challenges

Renewable energy sources are capable of offering an economical and sustainable energy systems. The hybrid micro-grid system is also gaining more attention, based on its capability to secure the link of feeding the load with electric power in different operating conditions, and its optimum utilization for available resources within the community. The need in improving the performance of the power grid yields an attention to hybrid micro-grid power systems, which comprise of numerous types of power sources. These systems have good technical and economical features. The hybrid micro-grid power generation system is considered the most effective solution to overcome the problem of power shortage and to meet the Load demand. In addition, micro-grids give more significant advantages like the best supply-and-demand matching and optimized usage of green power sources. [1]

Biomass Energy Potential in Nigeria

Illoabuchi wood market, Mile 2, Port Harcourt is a viable place for biomass generation, This area is a local market for Carpenters, Wood planners, Tuners, Plank Cutters, Metal Work Fabricators. Based on large daily availability of sawdust and the backup required renewable energy in the Rivers State University, Port Harcourt. [2] proposed 7.5MW capacity bio power plant which is determined by the current and future electricity needs. Thus installing a biomass plant in the university will not only solve the electricity supply problem of the university but will also adequately address the problem of environmental degradation in and within the market.

Hybrid Renewable Energy Systems

[3] In their work various hybrid systems were being analysed and compared. It was noted the PV-disel systems were more economically viable as well as high reliability and reduced carbon emissions.

MATERIALS

The Load profile data from proposed Hybrid Renewable Energy System (HRES) network shall be collected from Rivers State University Generator station as shown in Figure 1.5. Saw dust samples from Illoabuchi wood market. Geographic and topographic information from satellite imagery and ground surveys with Historical weather patterns from earth.nullschool.net databases, Economic indicators from Central Bank of Nigeria, Equipment specifications from manufacturer datasheets, and Meteorological data (solar irradiance, wind speed, temperature) from the NASA metrological database as shown in figure 1.2 and 1.3 .

METHODS

Utilizability method and Techno-economic analysis technique will be used in the analysis and verification of the proposed Hybrid Renewable Energy System (HRES) for Rivers State University Generator station. Primary data were collected which serves as the input source to the activity of the proposed HRES network, which are also analysed on Hybrid Optimization Model for Electric Renewables (HOMER x64 3.11.2) environment. The

existing input data are used on the analysis of proposed HRES Network in order to obtain predicted results. The method also considered the application of utilizability method where applicable to estimate the usable solar radiation in the region and to improve the solar generation.

II. DESIGN CALCULATION USING RESOURCE ASSESMENT

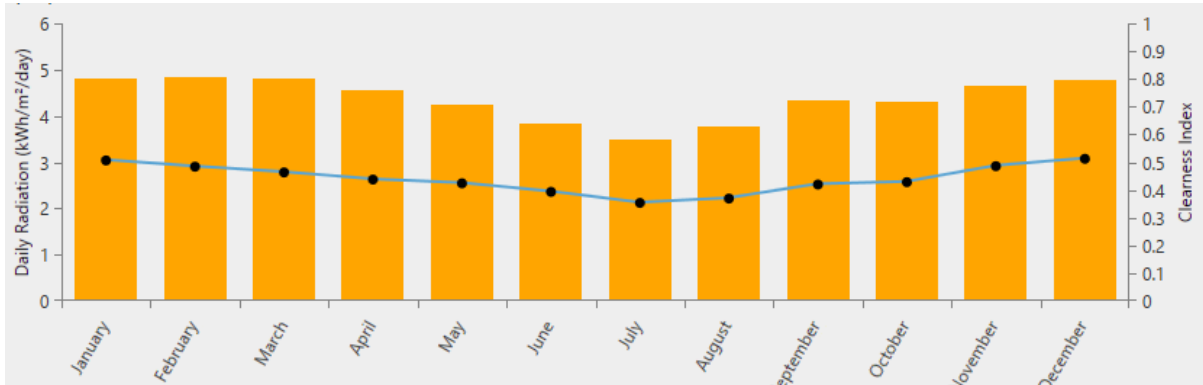


Figure 1.2 Rivers State University Solar resources. [6]

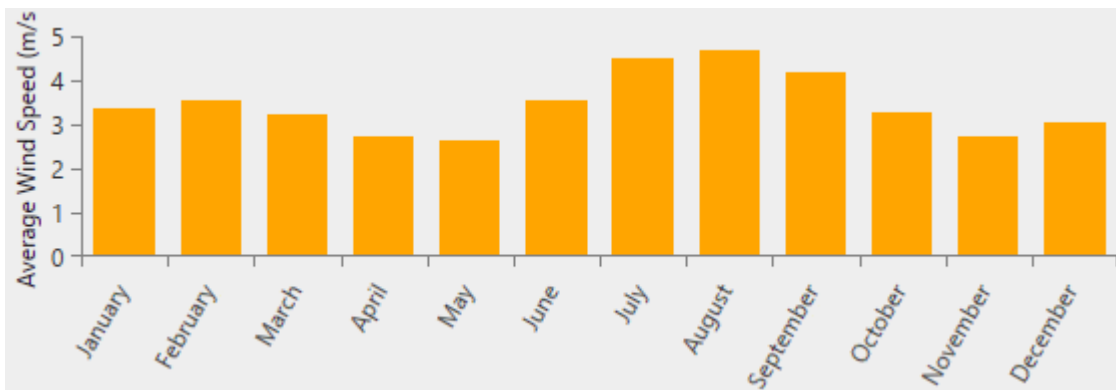


Figure 1.3 Monthly average wind speed (m/s) [6]

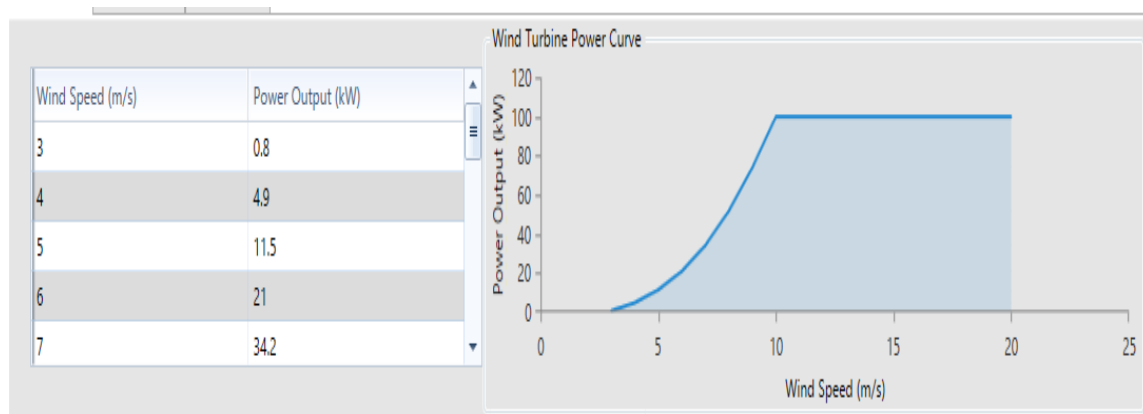


Figure 1.4 Selected wind turbine power curve [6]

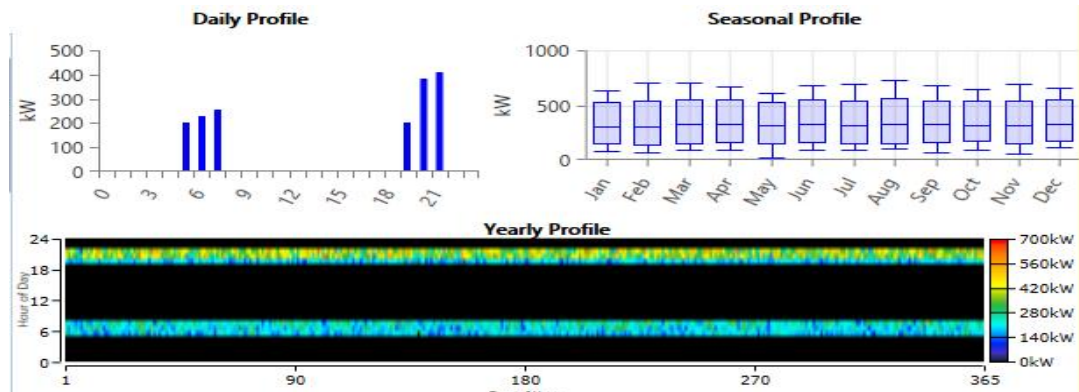


Figure 1.5: Daily, seasonal and yearly design load profile [6]

UTILIZABILITY METHOD

Utilizability, Φ , is defined as the fraction of insolation incident on a collector’s surface that is above a given threshold or critical value. The utilizability method is based on the concept that only radiation that is above a critical or threshold intensity is useful.

The utilizability method is a design technique used for the calculation of the long-term thermal collector performance for certain types of systems. Initially suggested by Whillier (1953), the method, referred to as the Φ -curve method, is based on the solar radiation statistic, and the necessary calculations have to be done at hourly intervals about solar noon each month. [4]

Table 1.1: Value of global solar radiation for Port Harcourt [5]

Month	H(MJ/m ²)	H _o (MJ/m ²)	S(h)	S _o (h)	S/S _o	H/H _o
January	12.9	34.56	3.83	11.75	0.33	0.38
February	14.47	36.44	4.22	11.85	0.36	0.40
March	14.85	38.06	4.09	11.97	0.34	0.39
April	14.80	38.63	4.07	12.11	0.34	0.38
May	14.62	38.17	4.03	12.23	0.33	0.38
June	13.10	37.71	3.37	12.28	0.27	0.35
July	12.36	37.90	2.96	12.26	0.24	0.33
August	11.21	38.56	2.35	12.16	0.19	0.29
September	13.08	38.44	3.16	12.03	0.26	0.34
October	15.79	37.10	4.75	11.89	0.40	0.43
November	14.44	35.10	4.43	11.77	0.38	0.41
December	15.45	34.02	5.18	11.72	0.44	0.45

From the above table 1.1, H = Global solar radiation, H_o = Daily extraterrestrial radiation, H/H_o = Clearness index S = Maximum sunshine duration or day length S_o = Daily sunshine duration S/S_o = Measure of cloud cover. Hence taking values for the month of April.

I: Determination of Diffusion radiation and Beam radiation

$\delta = 9.41^\circ$ and the sunset hours, $h_{ss} = 89.2^\circ$
 $\alpha = 0.409 + 0.5016 \sin(h_{ss} - 60) = 0.409 + 0.5016 \sin(89.2 - 60) = 0.4441 \dots\dots(5)$
 $\beta = 0.6609 - 0.4767 \sin(h_{ss} - 60) = 0.6609 - 0.4767 \sin(89.2 - 60) = 0.4878 \dots\dots(6)$
 $h = 0$ (noon)

Correlation for Total radiation, r_n is expressed as;

$$r_n = \frac{\pi}{24} (\alpha + \beta \cos(h)) \frac{\cos(h) - \cos(h_{ss})}{\sin(h_{ss}) - (\frac{2\pi h_{ss}}{360}) \cos(h_{ss})} \dots\dots(7)$$

$$r_n = \frac{\pi}{24} (0.4441 + 0.4878 \cos(0)) \frac{\cos(0) - \cos(89.2)}{\sin(89.2) - (\frac{2\pi \times 89.2}{360}) \cos(89.2)} = 0.12286 \dots\dots(8)$$

Correlation for Diffusion radiation, $r_{d,n}$ is expressed as;

$$r_{d,n} = \frac{\pi}{24} \times \frac{\cos(h) - \cos(h_{ss})}{\sin(h_{ss}) - (\frac{2\pi h_{ss}}{360}) \cos(h_{ss})} \dots\dots(9)$$

$$r_{d,n} = \frac{\pi}{24} \times \frac{\cos(0) - \cos(89.3)}{\sin(89.3) - (\frac{2\pi \times 89.3}{360}) \cos(89.3)} = 0.13193 \dots\dots(10)$$

Beam Radiation

Recall that Latitude, $L = 4.63^\circ N$

$$R_b = \frac{\sin(L-\beta) \sin(\delta) + \cos(L-\beta) \cos(\delta) \cos(h)}{\sin(L) \sin(\delta) + \cos(L) \cos(\delta) \cos(h)} \dots\dots(11)$$

$$R_b = \frac{\sin(4.63-0.4878) \sin(9.41) + \cos(4.63-0.4878) \cos(9.41) \cos(0)}{\sin(4.63) \sin(9.41) + \cos(4.63) \cos(9.41) \cos(0)} = 0.99929 \dots\dots(12)$$

Daily Clearness

$$K_T = \frac{H}{H_0} = \frac{14.80}{38.63} = 0.38 \dots\dots(13)$$

II: Determination of Hourly Radiation Tilt factor (R)

PV arrays are not installed horizontally but at an angle to increase the amount of radiation intercepted and reduce reflection and cosine losses.

Monthly average critical radiation level ($\frac{HD}{H}$)

$$\frac{HD}{H} = 1 - 0.2832 K_T + 2.555 K_T^2 - 0.8444 K_T^3 \dots\dots(14)$$

$$\frac{HD}{H} = 1 - 0.2832 \times 0.38 + 2.555 \times 0.38^2 - 0.8444 \times 0.38^3 = 0.784 \dots\dots(15)$$

Hourly Radiation Tilt Factor

$$R = (1 - \frac{rdn HD}{rd H}) R_B + \frac{rd, n HD}{rn H} (1 + \frac{\cos(\beta)}{2}) + P_g (1 - \frac{\cos(\beta)}{2}) \dots\dots(16)$$

$$R = (1 - 0.13 \times 0.784) \times 2.982 + 0.13 \times 0.784 \times (1 + \frac{\cos(0.4878)}{2}) + 0.25 \times (1 - \frac{\cos(0.4878)}{2}) = 0.999 \dots\dots(17)$$

Ratio of daily Radiation to total radiation

$$\frac{HD}{H} = 1.311 - 3.022 K_T + 3.427 K_T^2 - 1.821 K_T^3 \dots\dots(18)$$

$$\frac{HD}{H} = 1.311 - 3.022 \times 0.38 + 3.427 \times 0.38^2 - 1.821 \times 0.38^3 = 0.558 \dots\dots(19)$$

III: Determination of Montly Radiation Tilt factor (\bar{R})

Northern Hemisphere Sunset hour on tilted PV

$$h'_{ss} = \min [h_{ss}, \cos^{-1}(-\tan(L-\beta) \tan(\delta))] \dots\dots(20)$$

$$h'_{ss} = \min [8.92, \cos^{-1}(-\tan(4.63-0.4878) \tan(9.41))] = 89.2^\circ \dots\dots(21)$$

$$R_b = \frac{\cos(L-\beta) \cos(\delta) \sin(h'_{ss}) + (\frac{\pi}{180}) h'_{ss} \sin(L-\beta) \sin(\delta)}{\cos(L) \cos(\delta) \sin(h_{ss}) + (\frac{\pi}{180}) h_{ss} - \sin(L) \sin(\delta)} \dots\dots(22)$$

$$R_b = \frac{\cos(4.63-0.4878) \cos(9.41) \sin(89.3) + (\frac{\pi}{180}) 89.3 \sin(4.63-0.4878) \sin(9.41)}{\cos(4.63) \cos(9.41) \sin(89.3) + (\frac{\pi}{180}) 89.3 - \sin(4.63) \sin(9.41)} = 2.982 \dots\dots(23)$$

$$\frac{HD}{H} = 1.311 + 3.022 K_T + 3.427 K_T^2 + 1.821 K_T^3 \dots\dots(24)$$

$$\frac{HD}{H} = 1.311 + 3.022 \times 0.38 + 3.427 \times 0.38^2 + 1.821 \times 0.38^3 = 0.558 \dots\dots(25)$$

Monthly Radiation Tilt Factor

$$\bar{R} = (1 - \frac{HD}{H}) R_H + \frac{HD}{H} (1 + \frac{\cos(\beta)}{2}) + P_g (1 - \frac{\cos(\beta)}{2}) \dots\dots(26)$$

$$\bar{R} = (1 - 0.558) \times 2.982 + 0.558 \times (1 + \frac{\cos(0.4878)}{2}) + 0.25 \times (1 - \frac{\cos(0.4878)}{2}) = 1.875 \dots\dots(27)$$

$$\frac{Rn}{\bar{R}} = \frac{0.999}{1.875} = 0.532 \dots\dots(28)$$

IV: Determination of Dimensionless Critical Radiation (X_c) and Monthly Utilizability Energy ($N H_t \Phi$)

The Dimensionless Critical Radiation Level is

$$X_c = \frac{It}{rn Rn H} \dots\dots(29)$$

Where It is

$$X_c = \frac{117 \times 3600}{0.122 \times 0.997 \times 17.56 \times 10^6} = 0.196 \dots\dots(30)$$

$$\Phi = \exp\{ [A + B (\frac{Rn}{R})] [X_c + C X_c] \} \dots\dots(31)$$

$$\Phi = \exp\{ [0.205 - 0.501 (0.532)] [0.196 + 0.1365 \times 0.196] \} = 0.99 \dots\dots(32)$$

The Monthly Utilizability Energy, Where N = No of DaysS

$$N H_t \Phi = NHR\Phi \dots\dots(33)$$

$$N H_t \Phi = 30 \times 17.56 \times 1.875 \times 0.99 = 977.3 \text{ MJ/m}^2 \dots\dots(34)$$

Hence the Monthly Utilizable Solar Energy in Rivers State University is 977.3 MJ/m², which is good for Power generation.

SOLAR RESOURCE

PV system DC power output:

$$P_{DC} = G_t \times A \times \eta_{STC} \times [1 - \gamma(T_c - T_{STC})] \dots\dots(35)$$

Where:

1. G_t : Irradiance on the panel (W/m²)
2. A : Panel area (m²)
3. η_{STC} : Module efficiency at standard test conditions
4. γ : Temperature coefficient (%/°C)
5. T_c : Cell temperature (°C)
6. T_{STC} : 25 (standard test condition)

PV module specs:

Panel area (A): 1.7 m² (e.g., ~280 W panel) $\eta_{st\ oh}$ (efficiency at STC): 20% → 0.20 γ (temp coeff): 0.4%/°C → 0.004

Cell temp (T_c): 49 °C

$T_{st} = 25$ °C

Temperature factor:

$$[1 - \gamma(T_c - T_{STC})] \dots\dots(36)$$

$1 - 0.004 \times (49 - 25) = 0.904$ Thus,

$PDC = 450 \times 1.7 \times 0.20 \times 0.904 = 138.3$ W, per panel under these peak conditions.

IV. ECONOMIC ASSESSMENT

Cost of Electricity for Diesel Generator

The cost of Electricity for Diesel Generators is given by:

$$COE = 0.42S^{-1}P + 0.071P + \frac{\beta CA_T}{8760\Psi S(1+i)} + \left(\frac{iCA_T}{8760\Psi S}\right) \times \left(\frac{(1+i)^n}{(1+i)^n - 1}\right) \dots\dots(36)$$

Where:

- P: Price per gallon of diesel
- β : Operation and maintenance cost
- CA_T : Acquisition cost
- n: Number of years
- i: Interest rate
- Ψ : Power factor
- S: Generator size

The Net Present Value (NPV) Method

This method is a discounted cash flow technique and explains the time value of money. The net method value

$$NPV = \left[\frac{CF_1}{(C1+r)^1} + \frac{CF_2}{(C1+r)^2} + \frac{CF_3}{(C1+r)^3} + \dots + \frac{CF_n}{(C1+r)^n} \right] - CF_0 \quad (37)$$

Where;

$CF_1, CF_2 \dots$ Future inflows occurring at the end of first year, second year... etc.

n: life of the project in years r: discount rate (cost of capital) : present cash out flow

Conditionality Constraints;

If: $NPV = 0$, it indicates that the present cash outflow and present values of future cash inflows are equal.

If: $NPV < 1$, it indicates that the present value of future cash inflows of less than the resent cash outflow. If:

$NPV > 1$, it indicates that the present value of the future cash inflow is more than the resent cash out flow.

V. RESULTS AND DISCUSSION

Fig 3.1 shows the schematic line diagram of the proposed Hybrid Renewable Energy System when modelled using HOMER PRO 3.11.3 version. The results revealed that a **solar PV+Bio genset+battery+diesel hybrid system** offers a viable solution for improving energy access in Rivers State University Generator unit with its schematics shown in figure 1.6, balancing reliability with affordability and solutions to the Greenhouse emissions in the region. The system significantly reduces dependence on diesel, lowers operational costs, improves voltage profiles, and can be tailored for replication in similar Nigerian universities. Fig 3.2 shows the Renewable penetration. From the simulation it showed that 48% of the total electric load is being met by renewables (I.e. PV and Biogenset). Renewable penetration explains the share of total energy production supplied by renewable sources in the system. During low solar output periods, either the Biomass generation tends to pick-up, similarly, the diesel generator may be dispatched with less than 10% runtime utilization, preserving fuel while maintaining supply continuity. The hybrid system was able to meet 100% of the load demand during **simulation**, ensuring uninterrupted supply and improved reliability. The study gave insights and reasons why wind power is not achievable due to lesser months with wind speeds greater or equal to 4.5m/s which is the cut in speed for wind electricity generation, as shown in figure 1.3 and 1.4.

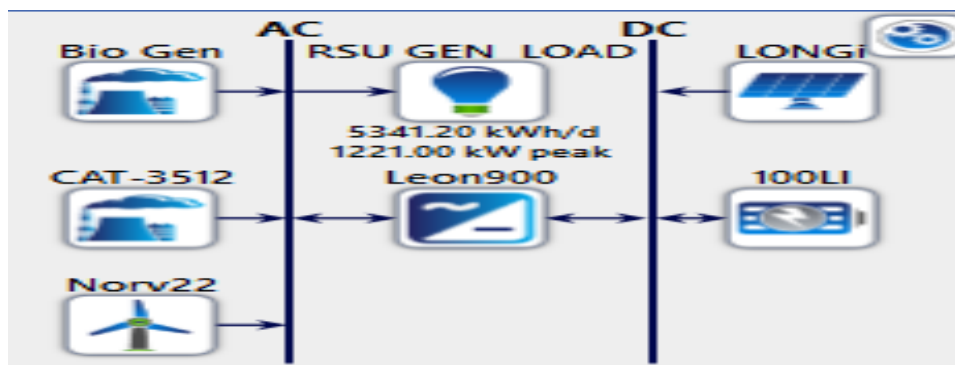


Figure 1.6 Schematic Line Diagram of Hybrid Renewable Energy System (HRES) Rivers State University Generator Station. [6]

Table 1.2: Technical and Economic Summary of Optimal Hybrid System

Component	Total Size/Rating	Lifetime	Remarks
LONGi LR4-72HV-350M Solar PV	350 kW	20 years	Energy source
Norvento nED 22 Wind Turbines	100 kW	25 years	Energy source
Li-ion Battery Storage	100 kWh	15 years	For reliability and autonomy
CAT-3512 Diesel Generator	1,135 kW	10 years	Backup during peak/low sun
Leonics GTP519S Inverter	900 kW	20 years	For DC-AC conversion
Biogas Genset	500kW	10 years	Energy source
NPC	-	-	Total lifecycle cost saving
LCOE	-	-	Levelized energy cost
Renewable Fraction	-	-	High renewable contribution

The simulation conducted using HOMER Pro yielded several hybrid system configurations optimized for the energy demands and resource availability in Rivers State University as shown in Table 1.2. Among these, the configuration that offered the optimal balance between reliability, cost, and renewable penetration was the **PV-Bio Genset-Battery-Diesel hybrid system** operating in standalone mode. Table 1.2 shows the Technical and economical summary of the optimal hybrid system.

This configuration comprises the following key components:

- i. Solar PV Array:** Total installed capacity of approximately 36.8 kW, designed to harness the university’s average daily solar irradiance of 3.1–5.2 kWh/m²/day.

- ii. **Bio Genset:** Total installed capacity of approximately 500 kW, designed to harness the Illoabuchi woodmarket estimated biomass of 8,817 tonnes per month.
- iii. **Battery Storage System:** Lithium-ion batteries sized to ensure continuous supply during non-solar hours and periods of reduced irradiance. The battery bank capacity was optimized in the range of 100–150 kWh.
- iv. **Diesel Generator (DG):** A 1.27 MW installed generator included as a backup source to transition to the renewable system. Used to provide energy during prolonged cloudy periods or peak load surges.
- v. **Inverter System:** Bidirectional inverters with efficiencies between 95% and 98%, ensuring smooth conversion and control of power flows between DC and AC buses.
- vi. **Control Strategy:** HOMER Pro’s optimization favored a cycle charging strategy, where the generator runs at full capacity when on and charges the batteries simultaneously, reducing fuel consumption and operational costs.

This system was selected based on its ability to:

- i. Meet the university’s average daily energy demand of 5.3MWh/day.
- ii. Achieve a Net Present Cost (NPC) of approximately ₦10,209,460,000. Indicating economic viability.
- iii. Maintain a Levelized Cost of Energy (LCOE) of ₦302.88/kWh. A negative LCOE means revenue from energy
- iv. Export is factored in, thus this system makes/saves money per kWh.
- v. Operate with minimal diesel runtime of less than 10% of total generation, thereby reducing emissions and dependency on fossil fuels.

The HOMER Pro simulation also indicated that Diesel-only systems, Wind-Diesel systems, Biogenset-Diesel or PV–Diesel system combinations without battery support were either technically infeasible or economically suboptimal due to high emissions, LCOE, NPC, operating costs and load variability. Therefore, while Diesel generators were considered, its contribution was minimal compared to solar PV, WTGs and batteries.

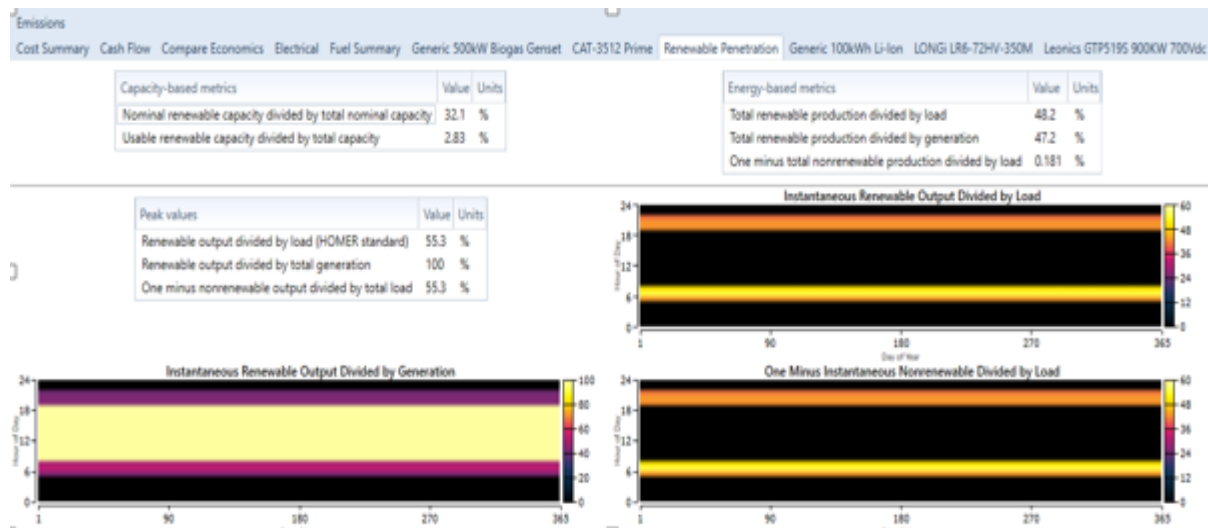


Figure 1.7 Renewable penetration [6]

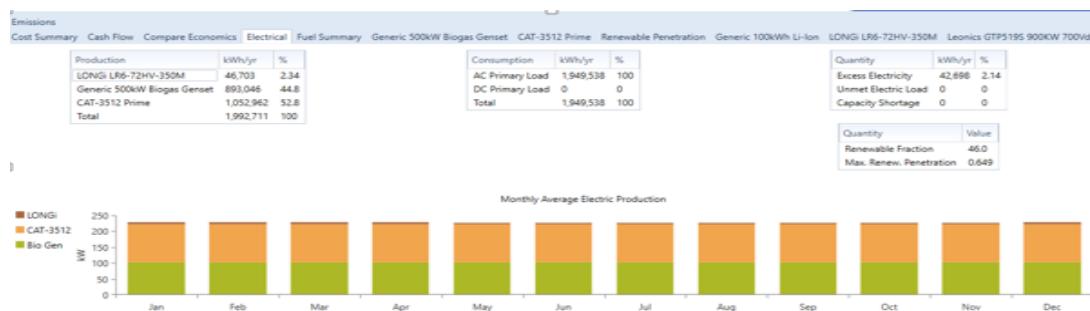


Figure 1.8 share of energy supplied from each energy source [6]

Table 1.4: Summary of cost comparison

System Type	LCOE (₹/kWh)	NPC (₹)	Renewable Fraction	Fuel (₹/year)	Cost	Remarks
PV+Biogaset+ Battery+Diesel	302.88	10.3 billion	46%	483 million		Optimal mix of cost and reliability
PV+Biogaset+ Wind+Diesel+ Battery	393.68	13.4 billion	47.1%	474.7 million		High operating cost and Low or no wind output
PV+Biogaset+ Battery	305.9	103 billion	100%	0		High operating cost
Diesel+Biogaset	291.72	9.83 billion	0%	484.1 million		Less autonomy, higher fuel use

Net Present Cost (NPC)

The NPC represents the total discounted cost of installing, operating, maintaining, and replacing system components over the project's lifetime (25 years in this study). For the optimal configuration (PV-Biogaset-Battery-Diesel), HOMER Pro calculated an NPC of approximately ₹10.3 billion, inclusive of capital expenditures, fuel costs and O&M costs.

This value reflects a long-term profit making and cost-saving potential compared to a diesel-only or grid only alternative, which typically incurs higher fuel or O&M costs over time.

Levelized Cost of Energy (LCOE)

The LCOE is the average cost per kilowatt-hour (kWh) of electricity generated over the system's lifetime. It allows for fair comparison between different energy options. For the selected hybrid system, the LCOE was estimated at ₹302.88/kWh, which is significantly lower than both current diesel generation costs and higher grid-supplied electricity under Band A/B tariffs though with far greater reliability.

Renewable Fraction

The Renewable Fraction, the share of total energy supplied from renewable sources was approximately **46%** in the optimal system. This renewable share indicates strong reliance on solar PV+Biogaset and minimal dependence on wind generation and grid, resulting in lower greenhouse gas emissions and reduced exposure to fuel price volatility as shown in Table 4.1.

Table 1.5: system sensitivity to fuel price fluctuations

Diesel Price (₹/L)	NPC (₹)	LCOE (₹/kWh)
1200	10.3 billion	302.88
1,400	10.5 billion	302.88
1,500	10.6 billion	302.88

To understand how variations in external factors could affect the economic and technical performance of the proposed hybrid renewable energy system, a sensitivity analysis was conducted using HOMER Pro. The Table 4.2 shows analysis which evaluated the impact of changes in key variables such as diesel fuel price, solar PV capital cost, discount rate, inflation rate and load demand on the system's Net Present Cost (NPC) and Levelized Cost of Energy (LCOE).

Table 1.6: Payback period for the hybrid system

Metric	Value
Initial investment	₹9.83 billion
Annual worth	₹845 million
Return on investment %	13.3
Simple payback (yr)	5.8
Discounted payback (yr)	6.1

Table 4.3 Shows analysis which includes a comparative assessment of the Payback Period, Return on investment and cost savings potential relative to conventional diesel-based or grid-based generation. These metrics were computed using HOMER Pro outputs and validated with economic models.

VI. CONCLUSION AND RECOMMENDATION

CONCLUSION

This study successfully demonstrates the overview of solar hybrid renewable energy systems for integration into Rivers State University Generator Unit for reliability and economic viability. Key findings include:

1. Technical Viability: The optimal hybrid system configuration Solar PV + Bio genset + Battery + Diesel Generator was successfully designed to meet the average daily electricity demand of approximately 5.3MWh/day in Rivers State University generator unit.

2. Economic Attractiveness: The hybrid system achieved a Levelized Cost of Energy (LCOE) of approximately ₦302.88/kWh net, which is significantly lower than the estimated ₦1,138/kWh for diesel-PV-wind generation or ₦393/kWh for diesel-PV-wind generation-Biogenset

3. Environmental Benefits: Significant environmental improvements include 866.6 tons/year Carbon dioxide CO₂ emissions reduction and 0.53 tons/year Carbon monoxide CO emissions reduction

RECOMMENDATION

Future research should focus on:

1. Solar PV, supported by battery storage and backed by diesel generation, should be prioritized as the core hybrid model due to its strong performance in terms of availability, cost-effectiveness, and scalability
2. Development of standardized frameworks for HRES deployment in Nigeria.

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