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Simulation Of A Solar –Hydropower Hybrid Energy System In A Rural Community In Rivers State

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ABSTRACT
The study aims to investigate the use of Homer Micro Grid Software in optimizing and analyzing the enhancement on electrification of a community in Port Harcourt, Nigeria. The project aims to provide a reliable and sustainable solution to the electricity needs of communities which have been under served by traditional electricity grid networks, using Choba in Port Harcourt as a case study. By using the HOMER Pro Micro Grid software, the project will assess the feasibility of implementing renewable energy sources, such as solar and hydro power, for the electrification of the community. The software will also be used to perform a cost-benefit analysis of the proposed solutions, taking into consideration various factors, such as the availability of renewable resources, cost of energy generation, and the demand for electricity in the community. The project will gather data on the current electricity needs and usage patterns of the community, as well as the availability of renewable energy resources in the area. This data will then be fed into the HOMER Micro Grid software to determine the optimal mix of renewable energy sources for the electrification of the community. In 2022, 5883 hours of electricity was supplied by Port Harcourt electricity distribution company (PHEDC). The findings also showed that the hybrid solution to hydro-PV renewable generation system is feasible which has a net present, cost of energy and initial cost of $8,254,346.73, $0.0189/kWh and $7,993,554.49 respectively, for the system to operate it requires hydro, solar PV and a converter with a total capacity of 2,000 kW, 3,704 kW and 900 kW. The result of the project will be useful for policy makers, researchers, and practitioners in the field of rural electrification, electrical and renewable energy.
Keywords: electricity grid networks, hydro-PV renewable generation, rural electrification

INTRODUCTION

The use of renewable energy sources, such as solar, wind and hydropower, to increase electricity in some areas in Nigeria is a topic of significant importance due to the country's growing population and the need to provide reliable and affordable energy to all areas of the country. One of the main challenges in renewable energy projects in these areas of Nigeria, including funding programs, technical assistance, and public-private partnerships. It is important to state that modern cities were once small communities, and therefore, communal development for national development cannot be overemphasized. Sub-Saharan Africa accounts for over 600 million people of the population of people living without electricity, which can be attributed to the poor development progress, both in technological development and human development, of the sub-Saharan Africa nations (Diemuodeke et al., 2021). In Nigeria, access to modern energy service in the smaller developing communities is worse as only 40% of Nigeria's population have access to stable electricity(Badejo et al., 2020). In addition to the economic and environmental benefits of renewable energy, increasing electricity supply in rural areas of Nigeria using renewable energy sources could also have significant social benefits, including improving access to education, healthcare, and other essential services.

Choba is a neighbourhood in Port Harcourt, Rivers State, Nigeria (Figure 2). It is located 16 km to the northwest of the Port Harcourt central business district, on the eastern bank of the New Calabar River. Choba was originally an Ikwerre village on the outer fringes of Port Harcourt, governed by a paramount king. As Port Harcourt has expanded Choba has been assimilated into the greater city conurbation.

Port Harcourt Electricity Distribution Network

Port Harcourt region currently controls six transmission substations: Ahaoda, Port Harcourt Mains, Port Harcourt Town, Yenegoa, Rumuosi, and Elelenwo (Figure 1.3). Rumuosi transmission station receives its energy from Port Harcourt mains sub transmission station and Omoku gas turbine at 132 kV. The electricity generated at the Omoku Power Station is first transmitted through high voltage transmission lines, which are part of the Nigerian Transmission System, to various substations. The Omoku plant is equipped with six units of 25MW GE Nuovo Pignone heavy duty gas turbines, making a total of 150MW installed capacity. The plant generates power and transmits to the national grid via its on-Site 132 kV switching facility through Rumuosi Transmission substation.

Rumuosi transmission station is equipped with two transformers rated at 40 MVA, 132/33 kV (T1) and 60 MVA, 132/33 kV (T2), as well as four load feeders: UPTH, NTA, Rukpokwu and New Airport Road, each of which has a maximum load capacity of 15.6 MW, 13.4 MW, 10.8 MW and 0.1 MW respectively. The UPTH lines serve the Uniport, and Choba injection substations as well as UPTH substation. Choba injection substations feed Aluu, Choba, and Rumuekini feeders, which in turn feed various parts of these communities.

Problem Statement

Nigeria is a country with a large and rapidly growing population and access to reliable electricity is essential for social and economic development. However many rural areas of the country have limited or no access to electricity, and the current electricity supply is often unreliable and subject to frequent outages. Taking Choba as the community in consideration, from the electricity distribution data it is evident that stable electricity is not a commodity the community can boast of. Electricity can facilitate economic development by supporting businesses, industries and agriculture. Choba as a community has over 3,000 inhabitants and there are businesses, schools, hospitals and investments that require stable electricity for carrying out their functions efficiently. There are several renewable energy technologies that could be used to increase electricity supply in different parts of Nigeria, including solar photovoltaic panels, wind turbines, and small scale hydro-electric power plants. There is a need to beam our searchlights on renewable energy and its potential for solving problems in the electricity sector. In Nigeria as a country, these problems have a negative impact on economic growth, education and overall quality of life. To improve electricity supply in Nigeria, it will be necessary to address the challenges and implement strategies that increase generation capacity, improve infrastructure and address governance and corruption issues. This could involve investing in new power plants, investing on renewable energy, upgrading and maintaining infrastructure and implementing policies and regulations to improve the overall electricity sector.

Aims and Objectives

The aims and objectives of this experimental research project in improving the electricity supply in Choba community in Nigeria by exploiting hybrid solar and hydropower sources of energy are as follows:

i. To identify the current state of electricity access and usage in the community in consideration including the availability and reliability of electricity, sources of electricity and amount of megawatts distributed per day in the year 2022.
ii. To assess the potential for improving electricity access and usage in Choba community and neighbouring settlements, including the feasibility and sustainability of hydropower energy sources and solar energy.
iii. To identify the economic impacts of improving electricity access and usage in the community, including the potential benefits to consumers.

iv. To determine the long-term sustainability and cost effectiveness of using solar and hydropower energy sources in Choba community.

v. To improve efficiency by optimizing energy infrastructure, evaluate electricity distribution audits and simulate implementation of renewable energy technologies using HOMER (Hybrid Optimization of Multiple Energy Resources) Pro Microgrid analysis software.

Load Demand Analysis

Load demand for Choba was analyzed using HOMER software, here's how the load demand was analyzed using HOMER software.

Data Input: The first step is to input data on the energy demand and supply. This data includes the hourly load profile of Choba, the cost and availability of different energy sources, and environmental and environmental constraints. The energy sources considered was solar and hydropower. The environmental constraints include the monthly averages of the daily irradiance for Choba, this data was attained using the HOMER software from the national solar radiation database and the monthly river flow data. Economic constraints refer to the costs associated with energy production and consumption, including the initial capital costs of the various components, their operating costs, and replacement cost. Economic constraints can impact the feasibility of energy projects and influence the choice of energy sources.

Load Profile Analysis: HOMER analyzed the load profile to understand the energy consumption patterns and peak loads. This information is essential in determining the size and number of energy sources required to meet the energy demand.

Energy Supply Analysis: HOMER then analyzed the different energy sources, the solar and hydropower. The software evaluates the economic and environmental feasibility of each energy source, taking into account factors such as costs, availability, and environmental impact.

Hybrid system components and specifications

The design, analysis and simulation of this system was done using HOMER (Hybrid Optimization Module for Electric Renewable) software. HOMER software is a microgrid analysis tool that uses mathematical models to analyze and optimize the design of microgrid systems, including renewable energy systems such as solar and hydropower. The tool allows users to analyze a wide range of microgrid configurations and evaluate the performance, cost, and sustainability of different design options (Muh et al. 2019). Some of the key uses of HOMER Pro include:

I. System Design: HOMER Pro can be used to design and optimize microgrid systems, taking into account factors such as energy demand, available resources, and equipment specifications (Muh et al. 2019)

II. Financial Analysis: HOMER Pro can perform a detailed financial analysis of microgrid systems, including cost of energy, payback period, and internal rate of return, to help users make informed decisions about their microgrid investments (Shafiullah et al. 2016).

III. Energy Simulation: HOMER Pro can simulate the performance of microgrid systems over time, taking into account factors such as energy demand patterns, energy resource availability, and equipment performance (Izadyar et al., 2016).

IV. Sensitivity Analysis: HOMER Pro can perform sensitivity analysis to evaluate how changes in input parameters, such as energy prices and equipment performance, impact the performance and economics of microgrid systems (Shafiullah et al. 2016).

V. Equipment Selection: HOMER Pro can be used to select the most appropriate equipment for microgrid systems, taking into account factors such as performance, cost, and compatibility with other components in the system (Muh et al. 2019).

In this paper, two power system components are employed to feed a load. These components create what is called "the hybrid power system", which is constructed of hydroelectric power station, photovoltaic solar panel and a convertor for DC-AC conversion as represented in the Fig 3.2

Solar Photovoltaic (PV) module

Photovoltaic module PV is mainly employed in solar systems in order to handle with sun radiation effectively such that the incident sun light is converted to electricity due to the semiconductor materials employed in order to follow and achieve the observable fact (phenomena) that exposed in physics (Hussain et al 2018). The employed PV panel used for this study is specified by 0.35 kW (LONGi LR6-72HV-350M) for lifetime of 25 year. Solar panel model was estimated to cost $250/kW and an operating and maintenance cost of $10/year. Below is the manufacturer's specifications.

Name	LONGi LR6-72HV-350M
Abbreviation	LONGi
Panel Type	Flat plate
Rated Capacity (kW)	0.35
Temperature LCOEfficient	-0.41
Operating Temperature (C)	45
Efficiency	18.1
Manufacturer	LONGi Solar
Notes	72 Mono-crystalline cells

Table 3.1 Manufacturer's specification for Solar PV module

Hydroelectric power station

The hydro turbine is considered the primary system component that the proposed load depends majorly on the amount of the power produced by the Hydro turbine. The hydro power station is constructed in HOMER based "run off river" methodology that is the technique that does not need to absorb the turbine in the river. The available head used was assumed to be 10 m considering the characteristics of the geographical area of the river. The nominal power of the turbine (Hyd2MW) used for this study is 2,000 kW and is estimated to have a cost of $7,000,000 and an operating cost of $450,000/year. In general, the nominal power of hydro turbine can be calculated by the following equation.

$$P = \frac{wQH\eta}{1000}\ (MW) \tag{3.1}$$

Q is the design flow rate in m^3/s, H is the available head, w is the weight density of water in N/m^3 , η is the overall efficiency. Below is the manufacturer's specification of the proposed hydro turbine.

Grid

In, HOMER, Grid-connection refers to the connection of a decentralized energy system to the larger electrical grid. When a system is connected, it can both import electricity from the grid when necessary and export surplus electricity back to the grid when available. The software takes into account the available electrical grid resources and specifications, as well as the characteristics of the energy system components and their interactions with the grid. The software then calculates the energy production and consumption of the system, taking into account the cost of grid electricity and the economic benefits of selling surplus electricity back to the grid. For Choba the grid power price is (N38.81) $0.086/kWh and the grid sellback price is N30.80 /$0.067/kWh which is 80% of the grid power price.

Note N460= 1$ dollar (currency conversion rate)

Converter

The proposed system example converts DC voltage produced by the PV panel to AC in order to provide the proposed load with sufficient AC power based on the principle of (DC – AC) inverter. The converter size is specified in HOMER software by 900 KW in order to satisfy the size of the primary load input for a life time of (10 years). The cost of the converter used is $75.00/kW.

Site Evaluation and Energy Resource Assessment

The New Calabar River is located on the eastern hand of the Niger Delta River System. It lies between longitudes 4 ° 301 and 5 ° 001 N and latitudes 6 ° 301 and 7 ° 001 E. It took its rise from Elele- Alimini where it's acidic, fresh and non-tidal. At Aluu, it's joined by a smaller tributary swash which took its rise at Isiokpo. It's a black water type and empties into some creeks and lagoon skirting the Atlantic Ocean. At Aluu, the sampling area for this study, the river is fresh and tidal, whereas at a little stretch downstream (Choba and Ogbogoro), it's brackish. The study area is submersed by tidal waters during floodtides. The climate is tropical with dry season during November to March and wet season during April to October. The foliage is thick rain, swamp timber with gentle leaning geomorphology. The tidal nature of the river is reflective of well mixed, unsteady floodtide and ebbtide overflows. The New Calabar river receptacle gests an periodic downfall of 254 mm (P.U. Uzukwu, 2014). Some of the activities that take place on the New Calabar River includes; Dredging activities, fishing, swimming and transportation. The river is quite vital for travelers to Isiokpo community.

Measurement of the physical characteristics of the river

Selected physical characteristics of the river were measured just after the bridge on the east west road.

1 Width: The width of the river was measured from bank to bank on boat using strava app. Strava is a smartphone app that depends on GPS for recording activities, it can track how the distance your phone moves from one place to another in water.

2 Depth: The depth of river was measured using a portable fish finder (MeterMall) shown in Figure 3.8, the unit can be used in the river, the lake or the sea. The system uses sonar to locate and define structure, bottom contour and composition, as well depth directly below the transducer. The transducer sends a sound wave signal determines distance by measuring the transmission time between the transducer to the detected object then uses the reflected signal to interpret location size and composition of an object.

The depth was measured horizontally across the river a 10 m intervals with the depth finder.

3 River flow velocity: Since the velocity both across the flow and vertically through it is not constant, it is necessary to measure the water velocity at a number of points to obtain a main value. The velocity can be measured by a floating object, which is located in the center of stream flow. The time (t) in seconds elapsed to traverse a certain length (L) in meter is recorded. The surface speed (m/s) is given as (Nasir, 2014)

$$V_{rs} = \left(\frac{L}{t}\right)\ (m/s) \tag{3.2}$$

To estimate the average flow speed V_r, the above value must be multiplied by a correction factor, that may vary between (0.6) and (0.85), depending on the water course depth and their bottom and river bank roughness (0.75 is a well-accepted value) (Nasir, 2014).

$$V_r = V_{RS} \times 0.75\ (m/s) \tag{3.3}$$

4 Discharge of the river**:** The discharge of the river was computed as the product of the average cross-sectional area and the river flow velocity (Nasir, 2014).

$$Q = A * v\ \left(\frac{m^3}{s}\right) \tag{3.4}$$

Where Q is the discharge of the river in m^3/s and A is the cross-sectional area of the river. The mean annual flow (MAF) which is the average discharge of a river or stream or other watercourse over a period of one year is 327.86 m^3s^{-1}.

5 Cross-sectional area: The cross-sectional area was obtained by using the River cross section creator and calculator from GeographyFieldwork.com. GeographyFieldwork.com was a website that provided resources and information on conducting geography fieldwork, particularly for students and teachers. The website offered a variety of resources such as guidance on selecting research topics, designing research methods, collecting and analyzing data, and presenting findings. The website also included case studies and examples of past fieldwork projects. The average cross-sectional area is 862.82 m^2.

Water Resources

In HOMER, water resource data is critical input for modelling hydropower systems. The software uses water resource data to calculate the available energy from a water source. The design flow data is the available discharge of the river, which is used to calculate the available energy from the water source.

$$Q_{av} = MMF - Q_{mfr}\ \left(\frac{m^3}{s}\right) \tag{3.5}$$

Q_{av} is the available

discharge of the river or the stream flow, the monthly minimum, represented by the Tessmann method (EFM7), which is based on the division of the year in 12 monthly periods. According to Tessman, the minimum monthly e-flows $Q_{mfr}(t)$ were assigned as a ratio of Mean Monthly Flow (MMF) to MAF, following three categories (Kuriqi et al., 2020),

$$If\ MMF < 0.4MAF, then\ Q_{mfr}(t) = MMF \qquad (3.6a)$$

$$If\ MMF > 0.4MAF, and\ 0.4MMF < 0.4MAF, then\ Q_{mfr}(t) = 0.4MAF \qquad (3.6b)$$

$$If\ 0.4MMF > 0.4MAF, then Q_{mfr}(t) = 0.4MMF \qquad (3.6c)$$

Financial Analysis

Every system or project being carried out must have an economic feasibility plan for the system to be worth investing on. One of the most important values to consider in the course of this project is the Grid power price at 0.086$/kWh while the grid sellback price is 0.067$/kWh. In this study, the total net present value (NPV), cost of energy (LCOE) and renewable fraction (RF) have been considered as performance metrics to evaluate the feasibility of the hybrid power systems.

1. Net present value (NPV): The total NPV of a system is the present value of the revenue returns minus the present value of all the costs that it incurs over its lifetime. Costs include capital costs, replacement costs, operational and maintenance costs, fuel costs, and emissions penalties (Shafiullah & Carter, 2016). The NPV is evaluated using

$$NPV(\$) = \sum_{t=1}^{n} (CF_t + SV) - (I_t + M_t + F_t) \qquad (3.7)$$

   I is the investment expenditure, $M$is the operations and maintenance expenditures, F is the fuel expenditure, CF is the cash flow, SV is the total salvage value n is the expected lifetime and t is the year.

2. Renewable Fraction: The RF is that portion of the system's total energy production originating from renewable power sources. HOMER calculates the RF by dividing the total annual renewable power production by the total energy production. The higher the RF is, the better the hybrid model output is [22]. RF is represented by equation:

$$f_{ren} = \frac{E_{ren}}{E_{tot}} \qquad (3.8)$$

3. Levelized cost of Energy (LCOE): LCOE is the average cost per kWh of electricity. To calculate the LCOE, HOMER divides the annualised cost of producing electricity by the total useful electric energy production (Shafiullah et al. 2016). LCOE can be calculated using following equation:

$$LCOE = \frac{\sum_{t=1}^{n} \frac{(I_t + M_t + F_t)}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}} \qquad (3.9)$$

   where r is the discount rate. The lower the NPV and LCOE are, the better is the hybrid model output (Shafiullah et al. 2016).

Economic constraints used in this study include project lifespan of 25 years, a discount rate of 12.5% and an inflation rate of 15.75%. The effect of inflation rate and discount rate on the energy output and cost was investigated by varying their values.

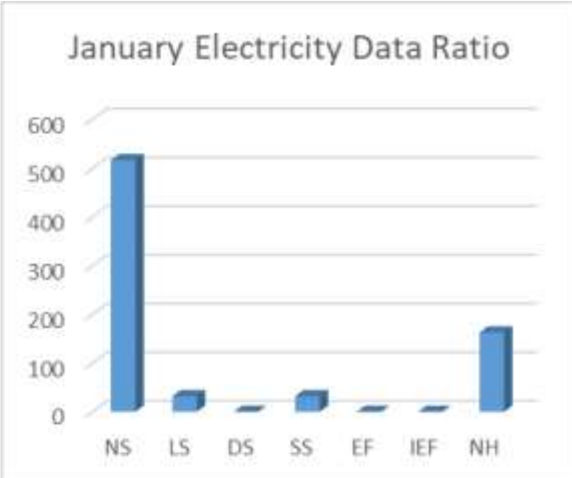
RESULTS AND DISCUSSIONS

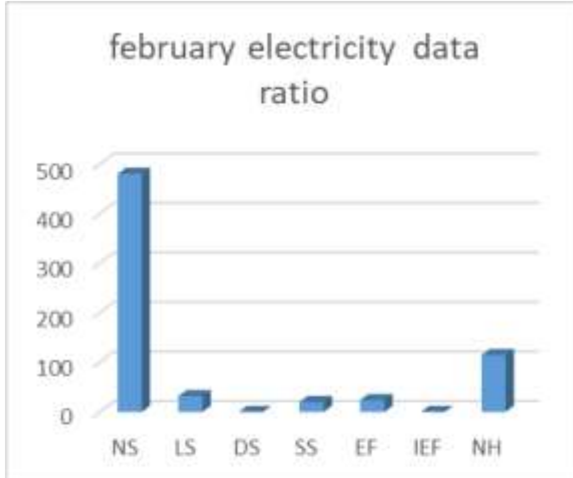
Current State of Electricity Consumption in Choba

The energy consumption for the year 2022 was obtained therefore obtained from the distribution station. Microsoft excel was used to record and compute the obtained data on the electricity consumption. The total amount of power consumed per day in Megawatts, the total number of hours where there was No Supply(NS), Low Supply(LS), Disconnected Power, Service Shutdown(SS) and Earth Faults(EF) where all computed. Choba is classified under the band D distribution network, in this band the cosumers are expected to be supplied power for a minimum period of 8 hours per day. The experiment was conducted with the electricity distribution data, a chart of the electricity supply for each month is shown below. It is observed that NS (Number of hours of no supply) has the greatest value at 5883 hrs/yr in Choba community for the year 2022 compared to that of NH (Number of hours of supply) which is only 1890 hrs/yr Choba community for the year 2022. As a community in Band D which the expected supply period is ment to be 8-12 hours of electricity per day, the actual supply period is 5.178 hrs/day which means there has been more outages than normal, this is as a result of inadequate gas supply, poor maintenance, and other operational issues in the power stations across Nigeria.

Table 4.1 The total supply hours per month for the year 2022.

Month	Supply (hrs/mth)
January	163
February	115
March	118
April	174
May	119
June	117
July	206
August	194
September	182
October	172
November	159
December	171
Total	1890


January Electricity Data Ratio
600
500
400
300
200
100
0
NS
LS
DS
SS
EF
IEF
NH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200
100
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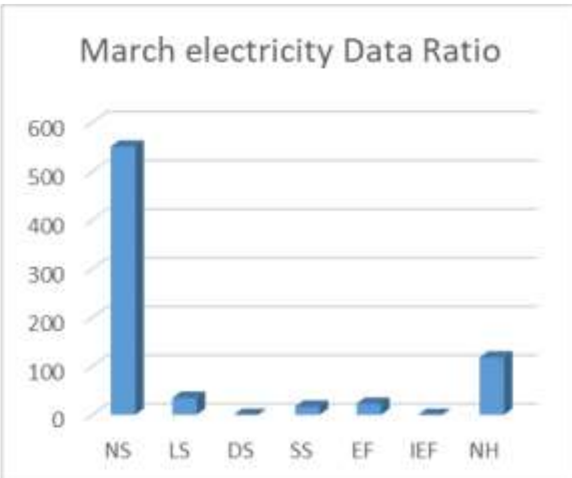
NS
LS
DS
SS
EF
IEF
NH


March electricity Data Ratio
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200
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NS
LS
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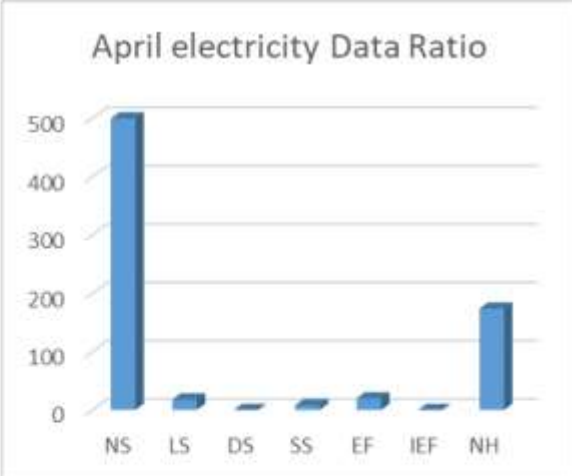
SS
EF
IEF
NH


April electricity Data Ratio
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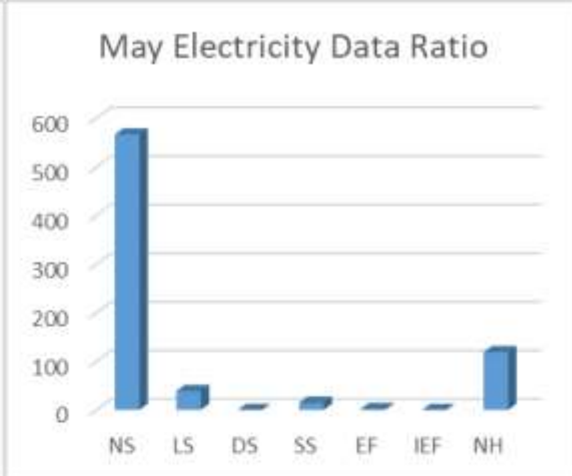
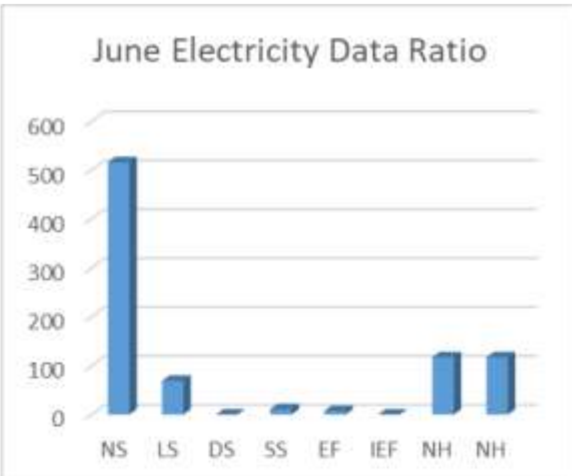
400
300
200
100
0
NS
LS
DS
SS
EF
IEF
NH


May Electricity Data Ratio
600
500
400
300
200
100
0
NS
LS
DS
SS
EF
IEF
NH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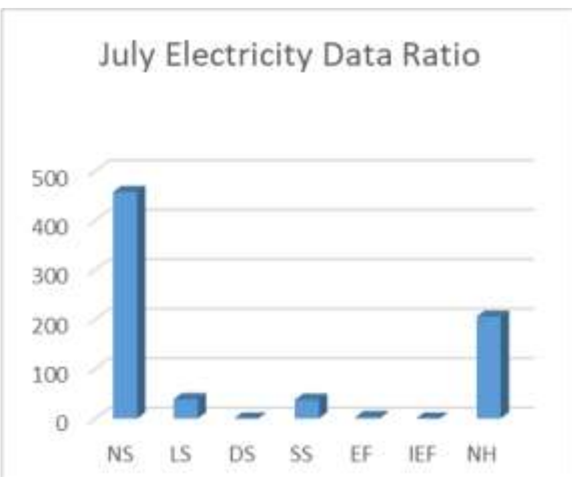
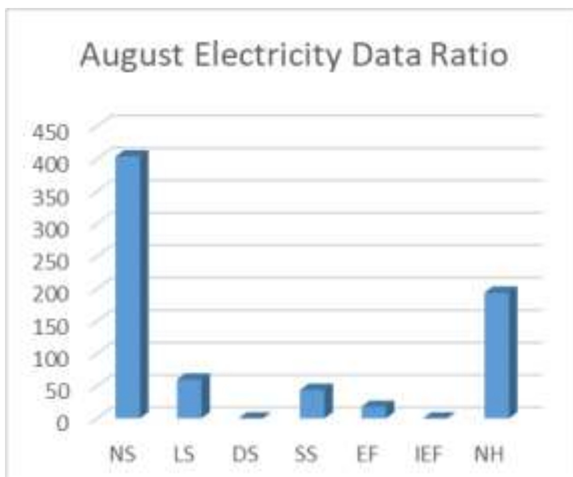
300
200
100
0
NS
LS
DS
SS
EF
IEF
NH
NH


July Electricity Data Ratio
500
400
300
200
100
0
NS
LS
DS
SS
EF
IEF
NH


August Electricity Data Ratio
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400
350
300
250
200
150
100
50
0
NS
LS
DS
SS
EF
IEF
NH

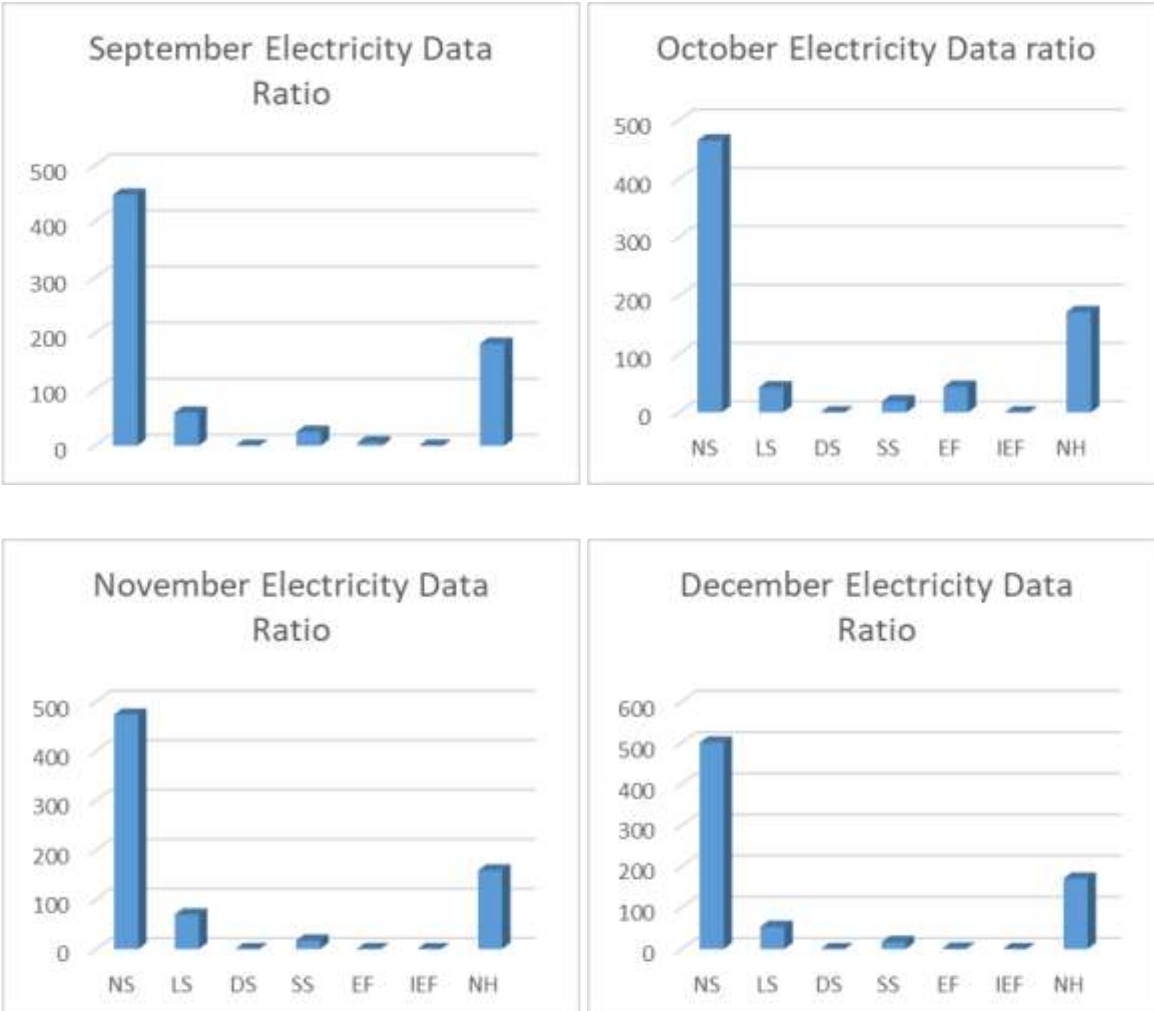


Fig 4.1 Electricity Supply for Choba in 2022

Energy Modelling

Solar resources

In this study, the monthly average temperature data over a period of 22 years (July 1938- June 2004) were obtained via HOMER. The average annual temperature is 25.33 ^{0}C, the monthly average temperature is shown in Figure 3.7. The mean monthly global horizontal Solar radiation data (22 years average) and clearness index of Choba were obtained from the NASA Surface Meteorology and Solar Energy website, using the exact location of the site: latitude and longitude (Muh et al 2019). The annual average irradiance is 4.21 kWh/m^2/day. Figure 3.4 and 3.5 shows the average air temperature over the year and monthly average solar global horizontal irradiance for Choba.

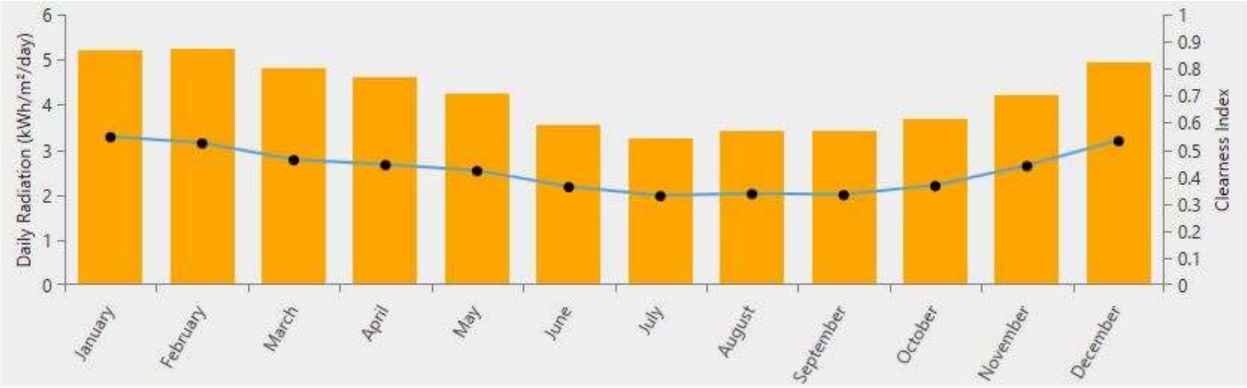


Fig 4.3 Monthly average Solar (GHI) Global Horizontal Irradiance for Choba community.

Hydrological Characteristics of the New Calabar River

Table 4.2 shows the mean monthly flow, the minimum flow rate and the available discharge of the river. The discharge has a peak value at 396.16 m^3/s in the month of September reason being that it's the rainy season during that period so the river flows more rapidly and the water level increases. While December has the lowest discharge being that it is the dry season and water levels have begun to drop and the river flows less rapidly.

Table 4.2 shows the mean monthly flow, the minimum flow rate and the available discharge of the river.

Month	MMF (m^3/s)	Q_{mfr} (m^3/s)	Q_{av} (m^3/s)
January	267.04	131.144	135.9
February	267.04	131.144	135.9
March	320.97	131.144	189.83
April	327.87	131.144	196.73
May	347.29	138.916	208.374
June	339.83	135.932	203.898
July	389.87	155.948	233.922
August	356.54	142.616	213.922
September	396.16	158.464	237.696
October	355.48	142.192	213.288
November	275.01	131.144	143.866
December	260.4	131.144	129.26

Table 4.2 The mean monthly flow, the minimum flow rate and the available discharge of the river.

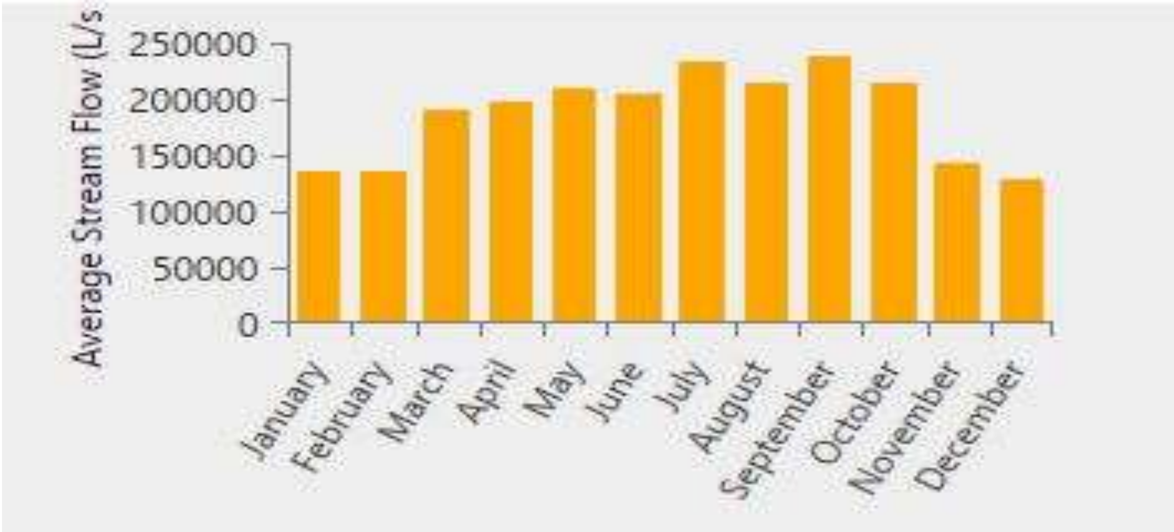
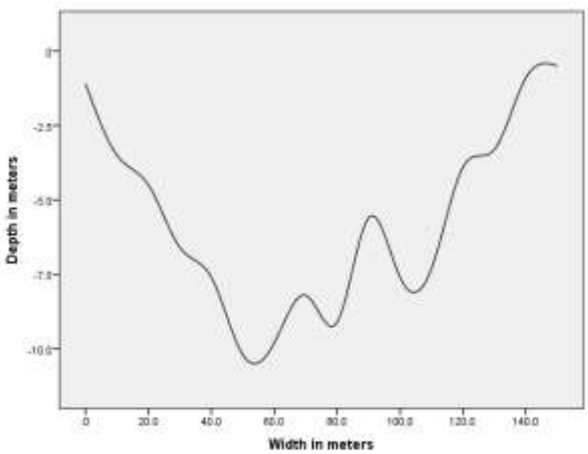
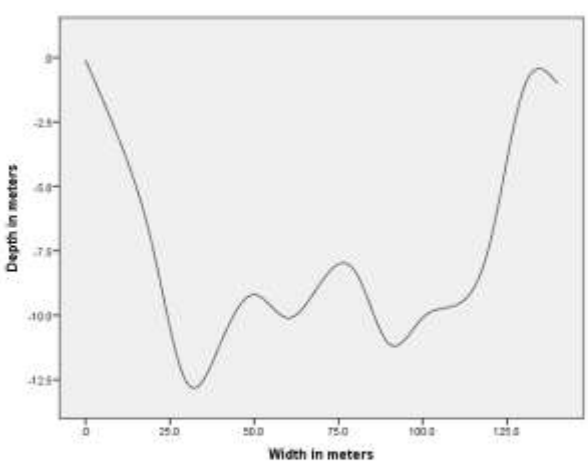


Fig 4.4 Average stream flow Data for different months in the year

The following (figures 4.6) are a representation of the topography at the base of the river. The river bed descent is steep due to activities such as dredging in the river that may have altered the normal flow channel of the river. This situation may have caused an increase in the cross-sectional area and altered the normal environmental flow of the river.





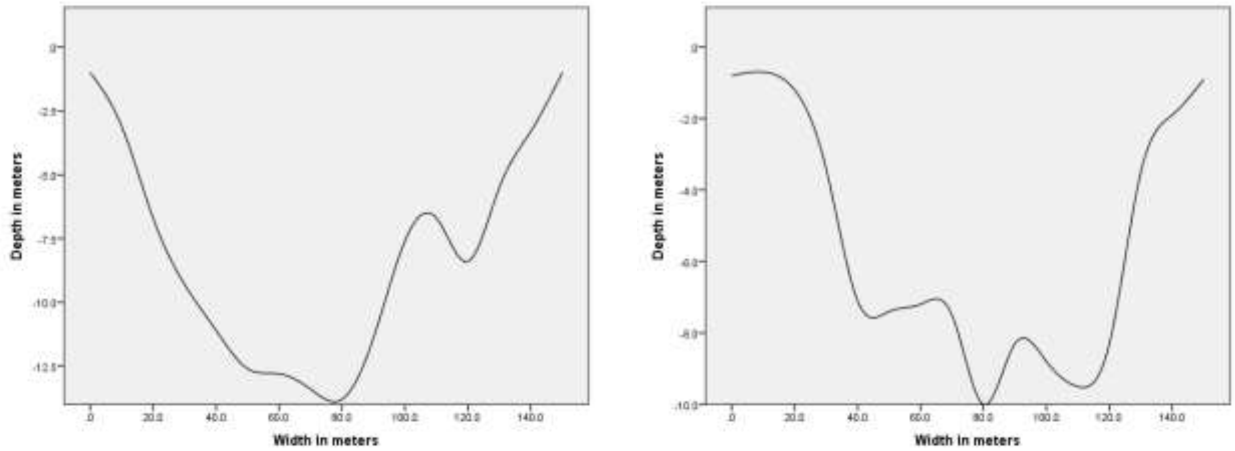


Fig 4.5 Width to depth profiles for New Calabar River

Energy Demand

The community load assessment gave an estimated daily load of 46,032.60 kWh/d with a peak loads being experienced between the time of 8 pm and 9 pm having loads of 2,310.32 kW, 2,275.76 kW respectively (Fig 4). At this time, almost all the residents will be back home and almost all the appliances will be running. In this study, weekend loads are assumed to be the same as for working days. The seasonal variations in the community load profile are indicated in Figure 4.1. There is a fairly constant trend throughout the year with November having the highest load average of 1992.80 kW and January having the lowest average of 1826.00 kW, the mean average is 1918.0 kW.

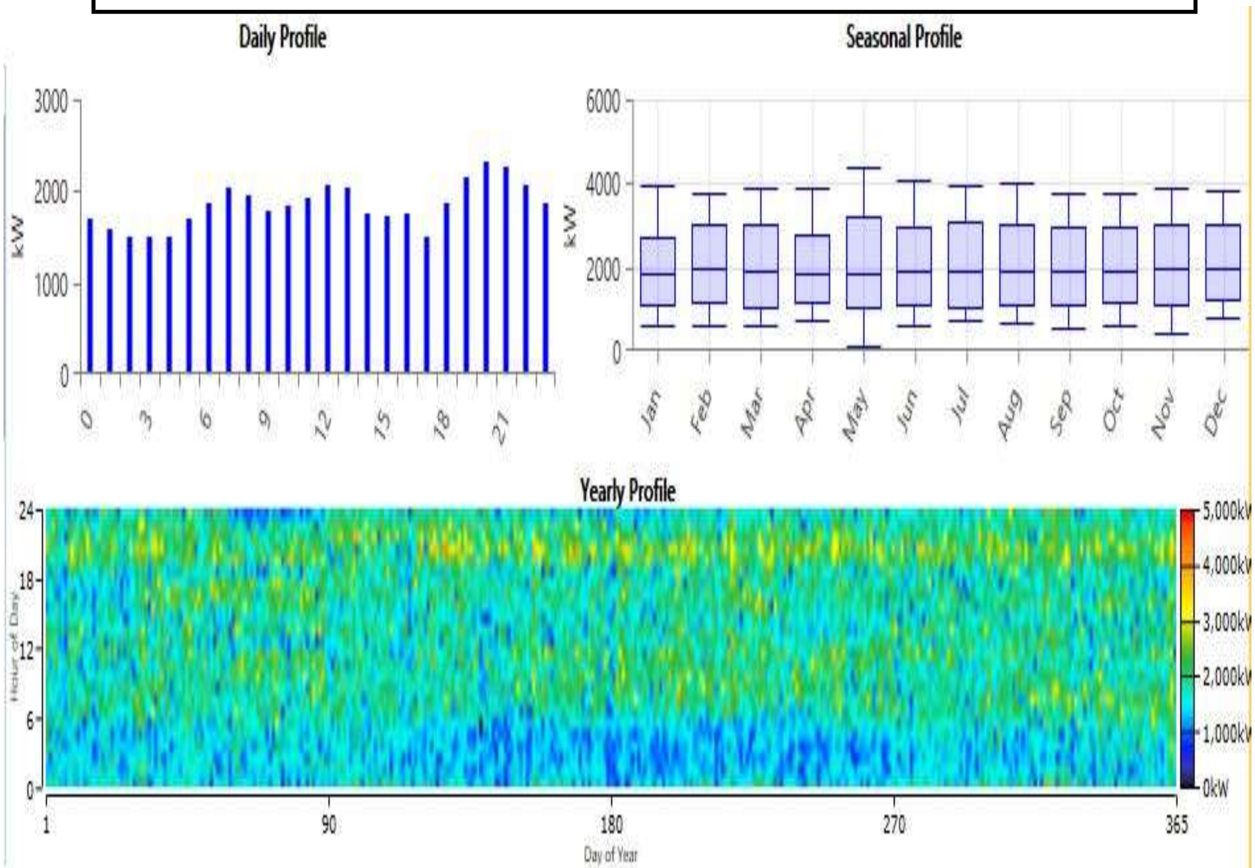


Fig 4.6 Daily, seasonal and yearly electricity load distribution profile

Analysis of the proposed System

Hybrid system consists of 3,704 kW of solar PV system, 2,000 kW hydro turbine, converters having a total capacity 900 kW and the system is connected to a grid having an estimated selling capacity of 999,999 kW.

Electricity production

Neglecting transmission losses the yearly electrical power output from this system is illustrated in figure, with February having the highest average power output at 3,243.82 kW this is because it February also experiences the highest daily radiation (5.240 kWh/m^2/day). The hydro turbine has a constant energy production contribution of 2,550 kW throughout the year because the available discharge for energy generation was always greater than the design flow rate (25,484.20 L/s).

Production	kWh/yr	%
LONGi LR6-72HV-350M	4,822,705	17.6
Hydro	22,338,000	81.6
Grid Purchases	214,961	0.785
Total	27,375,667	100

Consumption	kWh/yr	%
AC Primary Load	16,801,899	66.4
DC Primary Load	0	0
Grid Sales	8,513,961	33.6
Total	25,315,860	100

Quantity	kWh/yr	%
Excess Electricity	1,944,686	7.10
Unmet Electric Load	0	0
Capacity Shortage	0	0

Quantity	Value
Renewable Fraction	99.2
Max. Renew. Penetration	176

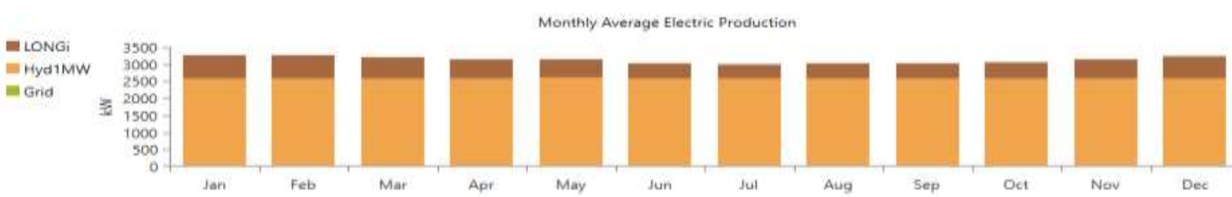


Fig 4.7 Monthly average production of Hybrid system

This hybrid renewable power system produces an annual electricity of 27,160,706 kWh/yr of which hydropower accounts for 81.6% (22,338,000 kWh/yr) and solar accounts for 17.6% (4,822,705kWh/yr). Primary AC load consumes 66.4% (16,801,899 kWh/yr) of the all the power generated by the system, the remaining power (8,513,961 kWh/yr) is sold to the grid. The system produces an excess electricity of 1,944,686 kWh/yr with no unmet load and capacity shortage. The amount of excess power produced by this system is high enough to sustain future demand increases (increase in the number of households, business expansions, increase household appliances and usage durations, as well as the connection of neighboring communities).

The LONGi LR6-72HV-350M (3,704 kW) PV array , has a mean output of 551 kW, maximum output 3,513 kW, capacity factor 14.9 %, the PV array produced a total of 4,822,705 kWh/yr, with 4,449 hours of operation per year, giving a levelized cost of $0.0129/kWh and a PV Penetration 28.7%.

Quantity	Value	Units
Rated Capacity	3,704	kW
Mean Output	551	kW
Mean Output	13,213	kWh/d
Capacity Factor	14.9	%
Total Production	4,822,705	kWh/yr

Quantity	Value	Units
Minimum Output	0	kW
Maximum Output	3,513	kW
PV Penetration	28.7	%
Hours of Operation	4,449	hrs/yr
Levelized Cost	0.0129	$/kWh

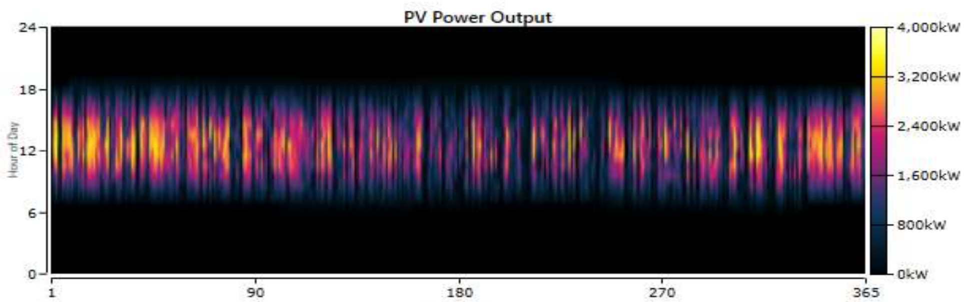


Fig 4.8 Solar PV Output Data

The amount of energy sold to the grid is 41,953,375 kWh with its peak sale month (4,316,044 kWh) in January, this is influenced by the load demand and the energy produced in the month.

Table 4.3 Energy purchased and sold from the grid for the entire year

MONTH	Energy Purchased (kWh)	Energy Sold (kWh)
January	11219.83	806933.65
February	14966.04	642985.87
March	10478.99	723681.56
April	10269.43	741687.85
May	29412.41	775704.84
June	22364.39	691151.93
July	21503.98	723976.69
August	21122.25	674736.63
September	18587.81	677636.013
October	12935.25	720102.88
November	21130.05	646638.04
December	20970.90	688724.86
TOTAL	214961.32	8513960.81

The converter with a capacity of 900 kW, a mean output of 315 kW, maximum output of 900 kW, a capacity factor of 35.0% with operational hours the same as the PV array at 4,449 hrs/yr. The energy output and energy input is 2,762,898 kWh/yr and 2,878,019 kWh/yr respectively, therefore has an energy loss of 115,121 kWh/yr.

The hydro turbine has a mean power output of 2,550 kW, a capacity factor 128%, a minimum and maximum output of 2,550 kW and 2,550 kW respectively this are the same because the available discharge is greater than the design flow rate all through the year, a hydro penetration of 133%, with an operational hour of 8,760 hrs/yr and a levelized cost of 0.0167 $/kWh.

Quantity	Value	Units
Nominal Capacity	2,000	kW
Mean output	2,550	kW
Capacity factor	128	%
Total Production	22,338,000	kWh/yr

Quantity	Value	Units
Minimum output	2,550	kW
Maximum output	2,550	kW
Hydro penetration	133	%
Hours of operation	8,760	hrs/yr
Levelized Cost	0.0117	$/kWh

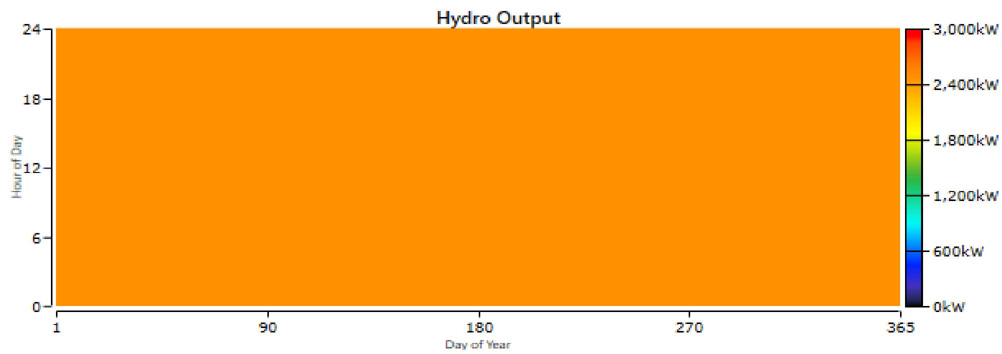


Fig 4.9 Hydro Turbine Output data

Economic Analysis

In the course of this project, a Solar (PV) Photo Voltaic, converter, Hydro turbine and Electricity grid are part of the parameters to take into consideration for this electrification project. Their individual cost implication is recorded in the Table 4.4

Table 4.4 Cost summary for Components of the System

Component	Capital cost	Replacement cost	Operating and Management cost	Salvage	TOTAL
Hydro turbine 2MW	$7,000,000.00	$0.00	$3,327,305.83	($679,345.46)	$9,647,960.37
Grid	$0.00	$0.00	($20,405,579.18)	$0.00	($20,405,579.18)
Leonics GTP519S 900KW 700Vdc	$67,500.00	$209,049.54	$0.00	($68,783.73)	$207,765.82
LONGi LR6-72HV-350M	$926,054.49	$0.00	$1,369,451.78	$0.00	$2,295,506.27
System	$7,993,554.49	$209,049.54	($15,708,821.58)	($748,129.19)	($8,254,346.73)

This system worth a total net present value of $8,254,346.73, the NPV is a positive value proving that the cash inflow is greater than the cash outflow. The levelized cost of energy of the system is $0.0189/kWh with maintenance and operational cost of $4,696,757.61 and payback period of 6.61 years. From the cost summary table 4.4 cost breakdown shows that well over 80% of the system's initial capital cost ($7,993,554.49) is consumed by the hydropower system. Also, if the system is designed for the load to use both AC and DC appliances, the cost of inverters will be avoided and this will reduce the system and energy cost.

Sensitivity Analysis

If the discount rate increases from 12.5% to 15%, the system's levelized energy cost drops from $0.0189 /kWh to $0.0171/kWh while the NPV drops from about $8,254,346.73 to $3,875,902.98. Thus, a high discount rate will make the system's energy cheaper for consumers but with a decrease in the profit made. More specifically, when the system design discount rate drops from 12.5% to 10%, the LCOE and NPV increases to $0.022/kWh and $15,053,203.74, therefore an increased discount rate is more desirable.

Whereas when the inflation rate is increased (15.75% to 20%) the COE reduces to $0.014/kWh and the NPV increases to $20,846,178.18, favouring both the consumer and the producers. But a decrease of the inflation rate to 10% saw a decrease in the COE and NPV to $0.00962/kWh and $211,651.42) respectively, therefore favouring just the consumers.

CONCLUSION

In Conclusion, the research project on hybrid solar and hydropower optimization of electricity for Choba community using HOMER micro grid software has demonstrated the effectiveness of combining renewable energy sources to meet the energy needs of a community. The HOMER micro grid software provided valuable insights into the design and optimization of the hybrid energy system, taking into account the unique characteristics of the local environment, energy demand, and cost constraints.

The results of the simulation showed that the hybrid system can significantly reduce the reliance on grid electricity and provide a reliable and cost-effective source of power for the community. Additionally, the study found that optimizing the system parameters, such as the size and location of the solar and hydropower systems, can further enhance the system's performance and economic viability.

The individual components had good production performances with the solar PV producing 17.6% and the Hydro turbine producing the remaining 81.6 % of electricity. This solution is feasible with a reduced initial capital and still meet the total load demand as well as eliminating the electricity demanded from the grid while compensated with the sale of excess electricity generated, the profit also reduced the operating cost of the entire system and the NPV.

The research project provides valuable insights into the potential benefits of combining renewable energy sources and optimizing their performance using advanced software tools. This approach can help to reduce greenhouse gas emissions, improve energy security and promote sustainable development in rural communities.

RECOMMENDATIONS

Based on the research project on Hybrid solar and Hydropower optimization of electricity for Choba community as a case study using HOMER software, here are some recommendations for further study:

i. Assess the environmental and social impacts of the hybrid system: While the project demonstrates the technical feasibility and economic viability of the Hybrid system, it is important to evaluate the potential environmental and social impacts of the system. This can include assessing the carbon footprint of the system, the impacts on local ecosystems, and the social acceptability of the system

ii. Conduct a comparative analysis with other systems: The research project has identified the optimal system parameters based on certain assumptions. However, it is essential to conduct a comparative analysis with other systems of power generation.

iii. Explore energy storage options: The Hybrid System studied in the research project relies on a combination of solar and Hydropower sources to provide electricity. However, energy storage is crucial to ensure a reliable and consistent power supply. Future studies can investigate storage options, pumped Hydro storage to improve the performance and efficiency of the system.

iv. Consider the role of policy and regulation: The adoption of hybrid energy can be influenced by policies and regulations that promote or inhibit their development. Future research can examine the impact of policy and regulation on the adoption of hybrid energy systems in rural communities, and identify ways to promote their development.

Overall, the research project on Hybrid solar and Hydropower Optimization of electricity for a community using HOMER software provides a valuable foundation for further research and development of renewable energy systems for rural communities.

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