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Design of Hybrid Solar-Wind Power System for a Coaster Area in Lagos State, South Western Nigeria

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Abstract: **Akodo community in Ibeju Lekki local government area of Lagos State is a rural area without access to grid electricity. Extension of the grid to the community is difficult and uneconomical; hence a hybrid energy system stands as a solution for electrification in Akodo.**

In this project, the HOMER (Hybrid Optimization Model for Electric Renewables) software was used to simulate a Solar and Wind hybrid system. In terms of energy delivery, the design was adequate for the 89kW load of the community. The important variables in the simulation are the level of availability of resources and the slope of the PV modules. The slope of the modules at 12^o and 15^o gave different levelised costs of energy (LCOE) of N27.521/kWh for the 12^o PV slope and N28.846/kWh for the 15^o PV slope. The PV slope at 12^o is more desirable and more economical than that at 15^o. The hybrid system is proposed for a project lifetime of 25 years.

Keywords: **Hybrid Power, Optimisation, Solar Energy, Wind Energy.**

1. INTRODUCTION

Stable and constant electricity is one of the driving forces of the developed countries but the situation in developing countries such as Nigeria is different. In Nigeria, people are struggling to receive enough power even for their basic needs. It is evident that the country has a problem in the power sector, which operates below its estimated capacity i.e. power supply is not covering the energy demand of the populace. Since power sector is working below its estimated capacity therefore, power outage is frequent. Due to this great challenge, privately own generators are being used to compensate for lack of stable and constant power supply.

According to the EIA 2004 Annual report, Nigeria's energy consumptions are from the three (3) different types of energy: Oil (58 percents), natural gas (34 percents) and hydroelectricity (8 percent). Nigeria is the world's 8th largest exporter of crude oil. However, corruption and ill-management skills are militating against the progress of oil production, distribution and exportation. Despite the huge availability of crude oil in the country yet, more than the half of the populace are living in poverty. Furthermore, the powers that are generated from these oil and natural gas cannot cater for the demand of the masses.

However, energy from the sun and the wind are inexhaustible, renewable and environmental friendly. In order to avoid colossal pollution created by non-renewable energy from gas, oil, coal and so on, it is important to adopt renewable energy methods of generating electricity. Though, initial cost of implementation of renewable energy is higher but less maintenance is required and it serves as a sustainable energy of the future.

Renewable energy has been designed for small scale in the residential environment for low-power household appliances but not yet used to supply large communities.

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One source of energy, such as solar source or wind source, may not be sufficient because solar panels and wind turbines depend on climate and weather conditions. Therefore, neither solar nor wind is sufficient alone. In the summer time, when sun beam are strong enough, wind velocity is relatively small. In winter time, when sunny days are relatively shorter, wind velocity is high on the contrast. In that case, it is necessary to complement solar energy and wind energy with each other in order to sustain continuity of energy production in the solar-wind hybrid synchronous inverter. Converter are used to correct voltage magnitude and phase (in case of solar energy) and also used to isolate mechanical and electrical frequencies (in case of wind energy).

1.1 Aim and Objective:

In this work, our aim is to design hybrid solar and wind power for Akodo community, a coastal area in Lagos State, Nigeria.

In the remote rural areas, where the grid extension is difficult and not economical , hybrid energy systems stands as a simple solution for rural electrification project. Such system incorporates a combination of one or several renewable energy sources including solar photovoltaic, wind energy, micro-hydro and conventional generators if need be for any power backup.

2. HISTORY OF HYBRID POWER GENERATION

Research on hybrid power systems ―combining renewable and fossil derived electricity generators started 25 years ago, but few have written papers about cost savings derived when compared with stand–alone systems. The first papers describing renewable energy hybrid systems appeared in the mid-eighties, but literature on hybrid systems did not blossom until the early 1990s. Initially, this expansion in hybrid literature was driven by the need to increase grid stability and reliability as large quantities of wind power were being added to small autonomous grids. There are some papers that optimize hybrid system and a few noteworthy papers are mentioned here. Schmid examined the economic feasibility of converting stationary diesel plants in rural Brazil into Diesel/Battery/Photovoltaic (PV) plants and found that conversions were economically favourable for smaller (<50 kW) diesel-based systems . Park modelled the cost savings of converting a ferry's propulsion from diesel into PV/Battery/Diesel. Chedid created software that predicted the operational cost of a hypothetical autonomous PV/Wind/Diesel system. He concluded that the inclusion of renewable energy into a diesel power plant would significantly reduce the operational cost of the plant.

Nehrir used a Matlab model to examine the performance of a Wind/PV system and concluded that the use of an electric hot-water heater as a dump load made the renewable-only system more economically feasible. Ashok used a Quasi-Newtonian method to find the system that provided the lowest cost electricity to a rural Indian village. He finds that a PV/Wind/Diesel/Micro hydro system would provide 24 hour coverage at the cost of only US$0.14/kWh. Nfah examined pico-hydro/biogas/PV systems for use in rural Cameroon and reasoned that the inclusion of biogas would decrease the generation cost of hybrid systems. Ruther converted a diesel-only mini-grid into a hybrid system in rural Brazil. He then used diesel consumption data to show that similar PV/diesel systems with no battery storage can reduce diesel fuel consumption in Northern Brazilian plant. Ruther dismissed the inclusion of battery banks into a hybrid because the losses introduced by the batteries increases diesel fuel consumption. Ruther admits one limitation to the PV/Diesel system that a solar array's total energy contribution to a hybrid system without energy storage cannot be above roughly 10 percent because of PV's tendency to destabilize a grid. Phuangpornpitak examined the economic benefit (or lack thereof) of 105 solar/wind/diesel hybrid systems installed in Thailand between 1990 and 2004.

Phuangpornpitak supplied a mix of experimental data and HOMER model data to provide information on the technical and financial operation of the systems. This was the only paper found that described the financial cost of actual systems and even stated that some systems were more costly than the baseline diesel only system due to over design. Nayar et al. built, installed, and tested a PV/diesel/battery/grid Uninterruptible Power Supply (UPS) in two locations in India. He reported roughly 24 hours of data on the system performance including plots of the battery bank's voltage, inverter power output, utility voltage, and system frequency, but omitted any information on system cost. He concluded that he successfully created a system that would improve power reliability and power factor to the load. While these four papers do use and report limited experimental data on the cost of a hybrid system, they do not discuss system design and optimization. In Nigeria, fossil fuel generators are mostly used for power generation for off-grid locations or to serve

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critical needs. There are distinct disadvantages of fossil fuel generators, such as high operation and maintenance costs, high emission of Green house gases (GHG) and other pollutants, and so on. Very little attempt has been made to generate power for remote areas with renewable resources such as in solar panels and wind turbines. These renewable energy generators are expensive to install. In this project, I model a hybrid system comprising the Solar and wind energies.

3. METHODOLOGY

3.1 Site Survey of Akodo Community:

Akodo community is located in Ibeju Lekki local government of Lagos state of Nigeria, around latitude 06° 25[1] north latitude and 03° 24[1] east longitudes. Communities in its environs include Imagbon, Idotu , Eleko and Bogije. It is a water front area and has beaches, including the popular Eleko beach around it. The residents of the communities are mainly fishermen, farmers and traders. The community has no access to grid-supplied electricity and relies on few individual portable diesel-generators for electricity. There is a potential for electricity generation from solar and wind sources based on daily solar irradiation between 63.813 and 74.127 kWh/m^2 / day. The annual average wind speed is 4.504m/s.

In this study, a hybrid power system of solar PV and wind is proposed power the community's load demand of 88.9kw. In this study, HOMER (Hybrid Optimization Model for Electric Renewables) software is used for system simulation and cost analysis. For the simulation, input information includes electrical load demand, solar and wind resource availability, technical specification of different components, costs, type of load dispatch strategy etc

3.2 Energy Resources:

For any energy system design, energy resources selection is vital. Renewable energy is sometimes called infinitive energy, because it relies on energy that is in infinite supply and there is no fuel cost for renewable energy system. Renewable energy is also considered as green or clean energy, because it does not produce toxins or pollutants that are harmful to the environment. In the location of my study, wind and solar energy are being considered based on their abundance. There is no water-body for a hydro-electricity generation project, or natural gas reserves for gas-to-electricity installations.

3.3 Solar Energy Resource Availability in Akodo Community:

Solar energy is received from the sun's rays that reach the earth being converted to energy through different processes. Solar can be converted to electricity via Photovoltaic cells or panels. Solar irradiance, a measure of incoming solar radiation of Akodo is very good for the purpose of electricity generation. The monthly average global radiation data obtained from Nigeria Meteorological Agency (NIMET) is about 8.084kwh/m 2/day. The clearness index is a measure of the clearness of the atmosphere with an average value of 0.813 for Ibeju Lekki local government of Lagos state. Table 1 shows the clearness index and daily radiation for the local government; it also shows the monthly averaged values of clearness index and daily radiation.

Table3.1: Solar resource values for Akodo community (REF: NIMET).

Month	Clearness Index	Daily Radiation (kWh/m^2/Day)
January	7.0	65.346
February	6.9	68.258
March	7.0	72.552
April	7.1	74.127
May	7.1	72.268
June	7.4	73.658
July	3.0	30.062
August	7.2	73.931
September	7.1	73.328
October	7.1	70.860
November	7.0	65.977
December	7.1	63.813
Annual Average	0.813	8.084

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3.4 Wind Energy Resource Availability in Akodo:

Lagos State is situated along the coastal line at the southern part of Nigeria, and so is the local government being studied. It is very close to the Eleko beach of the Atlantic Ocean. The areas near the coastal line have wind speed high enough to produce electricity commercially due to lack of obstruction on the ocean and the strong south/south-western monsoon wind come from the Atlantic Ocean traveling a long distance over the Niger Delta area of Nigeria. This wind blows over Nigeria from March to September with a monthly average speed of 3 m/s to 9 m/s at different heights. According to the studies of Nigerian Meteorological Agency (NIMET), wind speed is high in Nigeria during the Monsoon period (7 months, March–September). In rest of the months (October –February) wind speed remains either calm or too low. The peak wind speed occurs during the months of July to September. The wind speed data in Ibeju Lekki local government is recorded at 2m height. Table 2 shows the monthly average wind speed around the year in Lagos.

Table 3.2: Wind speed at 2m height in Ibeju Lekki local govt. of Lagos.

Month	Wind Speed (m/s)
January	4.0
February	3.9
March	3.5
April	4.5
May	4.3
June	3.9
July	6.0
August	6.9
September	6.0
October	3.6
November	3.9
December	3.5
Annual Average	4.504

Wind energy is the kinetic energy of the moving air mass. The power, P, in watts, possessed by wind blowing with a speed of V, in meter per second (m/s), is directly proportional to the area swept by rotor and to the cube of the wind speed, and is given by,

$$P = 1/2\ \rho.A.V^3 \ldots\ldots\ldots 1$$

Where, A is the area perpendicular to the direction of flow (m^2)

ρ is density of air, kg/m^3, is approximately 1.2 kg/m^3 . Only a part of the total available power calculated by equation (1) can be extracted and is given by,

$$P = 1/2\ \rho.A.V.^3 C_P$$

Cp is the power coefficient; it is the ratio of power extracted by a wind turbine to power available in wind at that location. A theoretical maximum of 59.3% of available power can be extracted. Practically a typical maximum of 40% is achievable. The hour of peak wind speed is simply the time of day tends to be windiest on an average throughout the year. In this study, 15 hours are used as the hour of peak wind speed.

3.5 Design of Hybrid Energy System for Akodo:

A hybrid power system for the studied community is designed where wind and solar power generation have been combined together. Solar-Wind has been chosen due to its operating reliability and low cost, quick start and small size. It has good thermal and electrical efficiency. Moreover, it has low fuel consumption and good load support. The figure below shows the connection of the solar-wind hybrid power system with its accessories.

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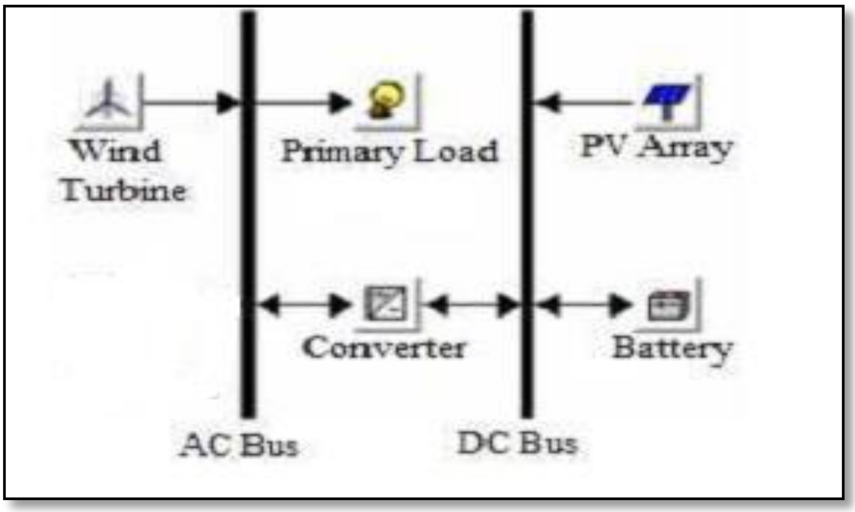

Fig 3.1: Solar-Wind Hybrid Power System

3.6 Load Profile:

The load profile is the basis for designing the projected hybrid system by using simulation software. Generally the load profile is the determination of electrical load distribution in any area which is generally measured in of 150 users daily or monthly basis. In this study, a hypothetical model area in Akodo community is considered which is comprised. In the community, there are four Shops, two Salons, two Poultries, three Churches, two Mosques one Primary School and one Secondary School. The electricity consumption in the households of the rural areas is comparatively lower than those of urban areas. A rural household generally uses electrical energy for lighting, cooling and entertaining. Each Akodo household is considered to consume about 3W made up of energy efficient lamps (compact fluorescent bulb, 15W each), 2 ceiling fans (80W each) and 1 television (100W). The daily average hours of use the light and TV are 6-7hrs, fan 16-17hrs . The primary load or energy consumption pattern usually varies daily and monthly of the year. The tables below show the load and energy demand for an Akodo household.

Table 3.3 Load Input 1

HOURLY LOAD [W]	00h	01h	02h	03h	04h	05h	06h	07h	08h	09h	10h	11h	12h	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Energy	[Wh]
Fan	100	100	100	100	100	100	100	100	100							100	100	100	100	100	100	100	100	100	1800	
Radio						80	80	80	80							80	80	80	80	80	80	80	80			
Kitchen light					40	40	40	40												40	40	40	40		320	
Bathroom					40	40	40	40												40	40	40	40		320	
Bedroom light						40	40	40												40	40	40	40		280	
sit. Rm light					40	40	40	40											40	40	40	40	40		360	
Television																120	120	120	120	120	120	120	120			
TOTAL [W]	100	100	100	100	220	340	340	340	180	0	0	0	0	0	0	300	300	300	340	460	460	460	460	100	5000	[Wh]
Number of users	150																									
TOTAL USERS [kW]	15	15	15	15	33	51	51	51	27	0	0	0	0	0	0	45	45	45	51	69	69	69	69	15	750	[kWh]
Demand factor	0.8																									

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Table 3.4: Load Input 2

HOURLY LOAD [kW]	00h	01h	02h	03h	04h	05h	06h	07h	08h	09h	10h	11h	12h	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h
TOTAL DEMAND	12	12	12	12	26.4	40.8	40.8	40.8	21.6	0	0	0	0	0	0	36	36	36	40.8	55.2	55.2	55.2	55.2	12
Shops									20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	
Salon									15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7			
Poultry	8	8	8	8	8	8	8	8												8	8	8	8	8
Church						2	2	2												2	2	2	2	2
Mosque						2	2													2	2	2		

3.7 Homer Input Summary:

This is a HOMER file for Akodo community in Lagos State, using solar and wind hybrid electricity.

AC Load: Akodo Load

Data source: Synthetic

Daily noise: 5%

Hourly noise: 5%

Scaled annual average: 895 kWh/d

Scaled peak load: 88.9 Kw

Load factor: 0.419

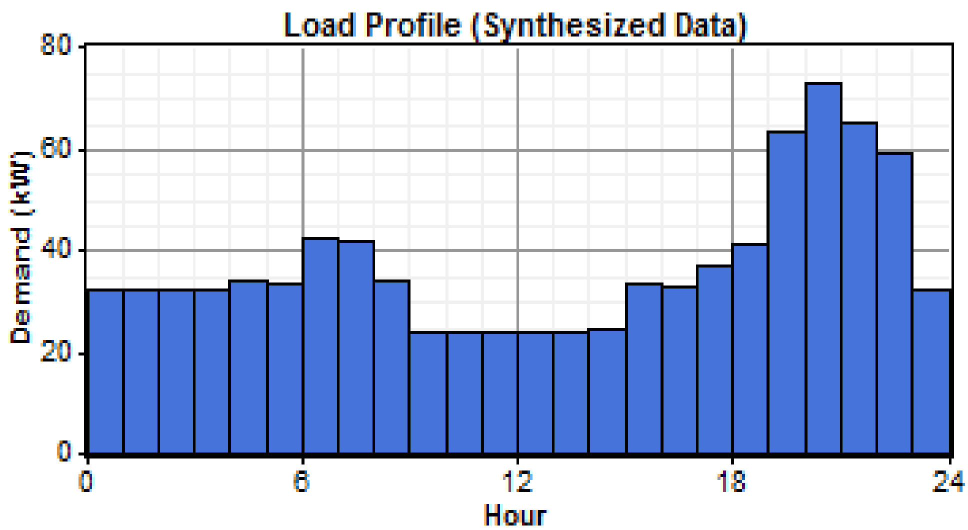

Table 3.5 PV sizes and costs

Size (kW)	Capital ($)	Replacement ($)	O&M ($/yr)
0.080	22,000	22,000	500
0.140	35,000	35,000	500

Sizes to consider: 50, 100, 150, 200, 205, 220, 240, 260, 300 kW

Lifetime: 18 yr

Derating factor: 80%

Tracking system: No Tracking

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Slope: 15, 12 deg
Azimuth: 0 deg
Ground reflectance: 20%
Solar Resource
Latitude: 6 degrees 25 minutes North
Longitude: 3 degrees 24 minutes East
Time zone: GMT +0:00
Data source: Synthetic

Table 3.5: Solar Resource Values

Month	Clearness Index	Average Radiation (kWh/m^2/day)
Jan	7.000	65.346
Feb	6.900	68.258
Mar	7.000	72.552
Apr	7.100	74.127
May	7.100	72.268
Jun	7.400	73.658
Jul	3.000	30.062
Aug	7.200	73.931
Sep	7.100	73.328
Oct	7.100	70.860
Nov	7.000	65.977
Dec	7.000	63.813

Scaled annual average: 8.08 kWh/m²/d

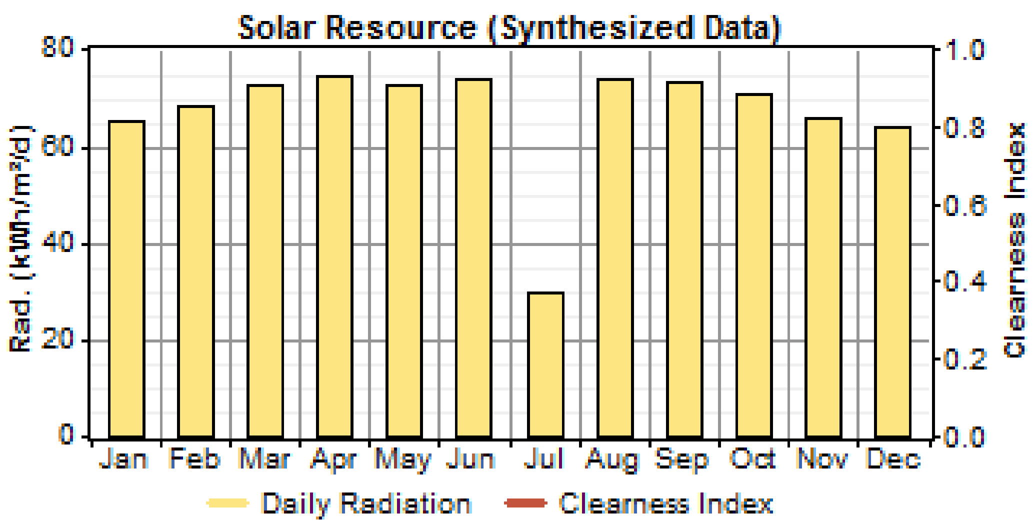

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Table 3.6 AC Wind Turbine: BWC Excel-S

Quantity	Capital ($)	Replacement ($)	O&M ($/yr)
1	5,940,990	5,940,990	1,500

Quantities to consider: 1, 2, 3, 4, 5, 6, 7, 9, 10
Lifetime: 15 yr
Hub height: 20 m

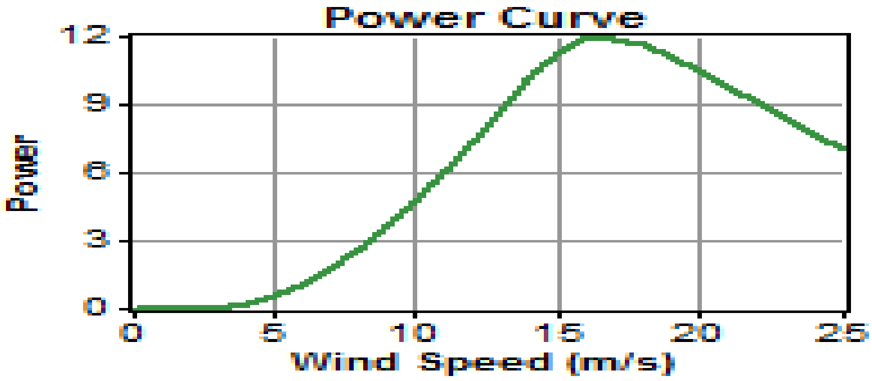
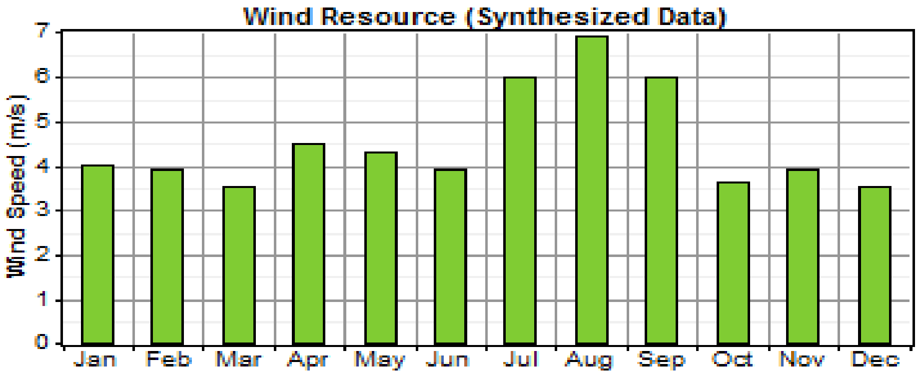


Table 3.7 Wind Resource Data source: Synthetic

Month	Wind Speed (m/s)
Jan	4.0
Feb	3.9
Mar	3.5
Apr	4.5
May	4.3
Jun	3.9
Jul	6.0
Aug	6.9
Sep	6.0
Oct	3.6
Nov	3.9
Dec	3.5



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Weibull k: 2.00

Autocorrelation factor: 0.850

Diurnal pattern strength: 0.250

Hour of peak wind speed: 15

Scaled annual average: 6 m/s

Anemometer height: 10 m

Altitude: 2 m

Wind shear profile: Logarithmic

Surface roughness length: 0.01 m

Table 3.8: Battery: Hoppecke 20 OPzS 2500

Quantity	Capital ($)	Replacement ($)	O&M ($/yr)
1	114,117	114,117	500.00

Quantities to consider: 10, 12, 15, 18, 20, 30, 35, 40
Voltage: 2 V
Nominal capacity: 2,500 Ah
Lifetime throughput: 8,523 kWh
Min battery life: 4 yr

Table 3.8: Converter

Size (kW)	Capital ($)	Replacement ($)	O&M ($/yr)
4.000	150,000	150,000	1,000

Sizes to consider: 30, 40, 50, 60, 70, 80, 90, 100 kW

Lifetime: 15 yr

Inverter efficiency: 90%

Inverter can parallel with AC generator: Yes

Rectifier relative capacity: 90%

Rectifier efficiency: 85%

Economics

Annual real interest rate: 6%

Project lifetime: 25 yr

Capacity shortage penalty: $ 0/kWh

System fixed capital cost: $ 0

System fixed O&M cost: $ 0/yr

Generator control

Check load following: No
Check cycle charging: Yes
Setpoint state of charge: 80%

Allow systems with multiple generators: Yes

Allow multiple generators to operate simultaneously: Yes

Allow systems with generator capacity less than peak load: Yes

Emissions

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Carbon dioxide penalty: $ 0/t

Carbon monoxide penalty: $ 0/t

Unburned hydrocarbons penalty: $ 0/t

Particulate matter penalty: $ 0/t

Sulfur dioxide penalty: $ 0/t

Nitrogen oxides penalty: $ 0/t

Constraints

Maximum annual capacity shortage: 3%

Minimum renewable fraction: 95%

Operating reserve as percentage of hourly load: 10%

Operating reserve as percentage of peak load: 0%

Operating reserve as percentage of solar power output: 10%

Operating reserve as percentage of wind power output: 15%

The HOMER simulates the operation of the hybrid system by making energy balance calculations for every hour of the 8760hours in a year.

The generated results from the load inputs are shown in the charts and the corresponding tables as given above. The components' specifications and costs of the PV, the Wind Turbine, the battery and the Converter are also included.

4. RESULTS AND DISCUSSION

For the hybrid system designed for the Akodo community, the PV panels, wind turbines, the batteries and the Converter systems were configured and simulated using HOMER software. The results generated from the software are shown in the Tables and the corresponding Charts given below.

4.1: SYSTEM REPORT – AKODO:

The System Report presented below is extracted from the HOMER software simulation. The sensitivity case is presented for the angle of slope of the PV panels 12^o.

Sensitivity case

PV Slope: 12 deg

Table 4.1: System architecture

PV Array	150 Kw
Wind turbine	2 BWC Excel-S
Battery	240 Hoppecke 20 OPzS 2500
Inverter	80 Kw
Rectifier	72 Kw

Table 4.2: Cost summary

Total net present cost	$ 112,276,448
Levelized cost of energy	$ 27.521/kWh
Operating cost	$ 2,933,637/yr

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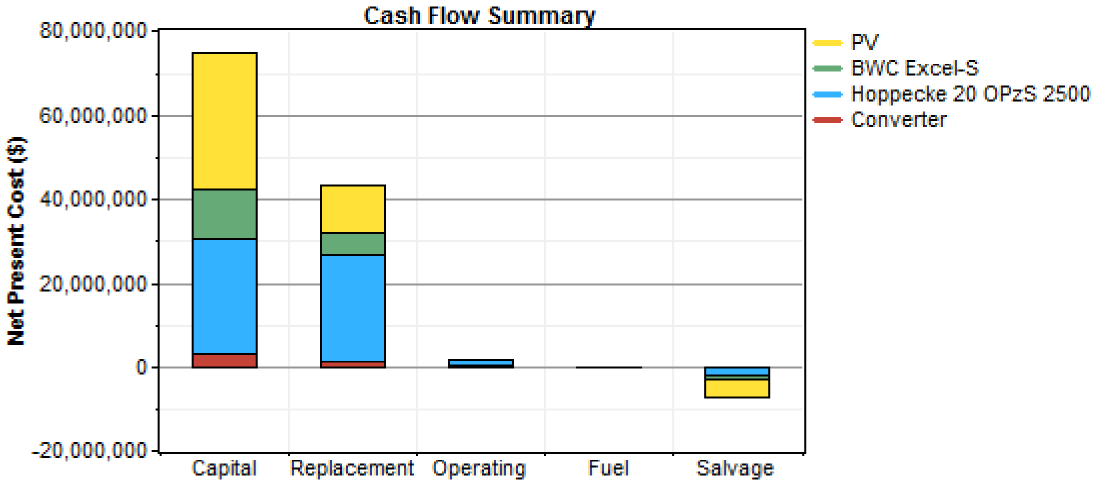

Table 4.3: Net Present Costs

Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
PV	32,504,664	11,387,818	6,392	0	-4,628,283	39,270,592
BWC Excel-S	11,881,980	4,957,939	38,350	0	-922,830	15,955,439
Hoppecke 20 OPzS 2500	27,388,080	25,531,760	1,534,004	0	-1,677,860	52,775,980
Converter	3,000,000	1,251,796	255,667	0	-232,999	4,274,466
System	74,774,720	43,129,312	1,834,413	0	-7,461,971	112,276,456

Table 4.4: Annualized Costs

Component	Capital ($/yr)	Replacement ($/yr)	O&M ($/yr)	Fuel ($/yr)	Salvage ($/yr)	Total ($/yr)
PV	2,542,733	890,832	500	0	-362,055	3,072,010
BWC Excel-S	929,488	387,843	3,000	0	-72,190	1,248,142
Hoppecke 20 OPzS 2500	2,142,480	1,997,266	120,000	0	-131,253	4,128,492
Converter	234,680	97,924	20,000	0	-18,227	334,377
System	5,849,381	3,373,865	143,500	0	-583,726	8,783,018

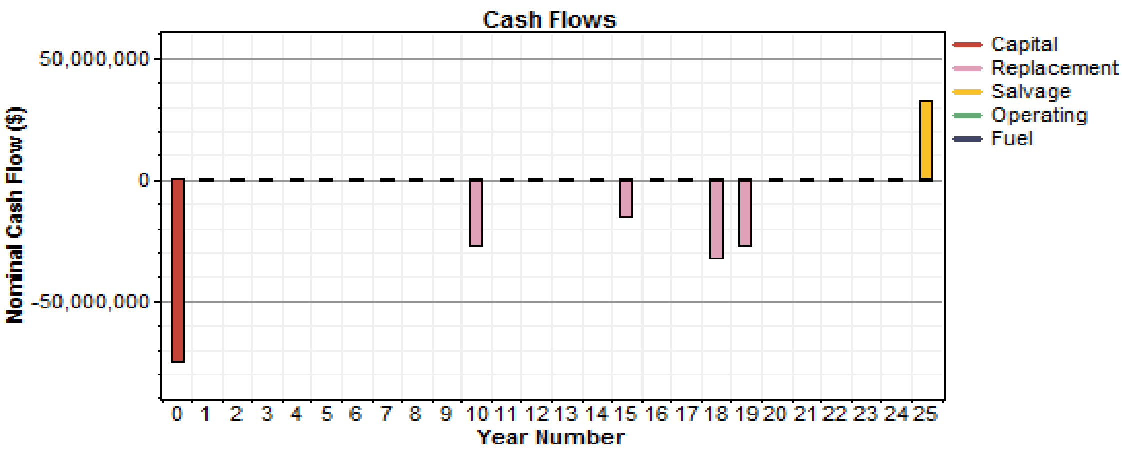

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Table 4.5: Electrical Production

Component	Production (kWh/yr)	Fraction
PV array	354,756	90%
Wind turbines	39,121	10%
Total	393,877	100%

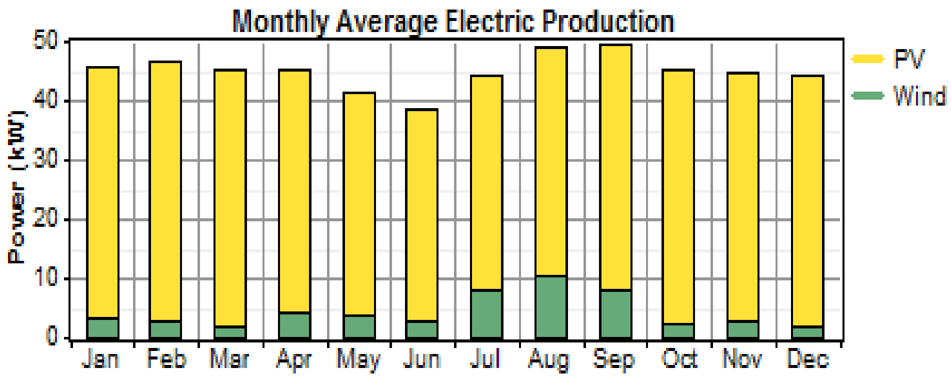

Table 4.6: Electrical Consumption

Load	Consumption (kWh/yr)	Fraction
AC primary load	319,136	100%
Total	319,136	100%

Table 4.7 PV Values

Quantity	Value	Units
Excess electricity	10,544	kWh/yr
Unmet load	7,539	kWh/yr
Capacity shortage	9,620	kWh/yr
Renewable fraction	1.000	

Quantity	Value	Units
Rated capacity	150	kW
Mean output	40.5	kW
Mean output	972	kWh/d
Capacity factor	27.0	%
Total production	354,756	kWh/yr

Quantity	Value	Units
Minimum output	0	kW
Maximum output	150	kW
PV penetration	109	%
Hours of operation	4,314	hr/yr
Levelized cost	8.66	$/kWh

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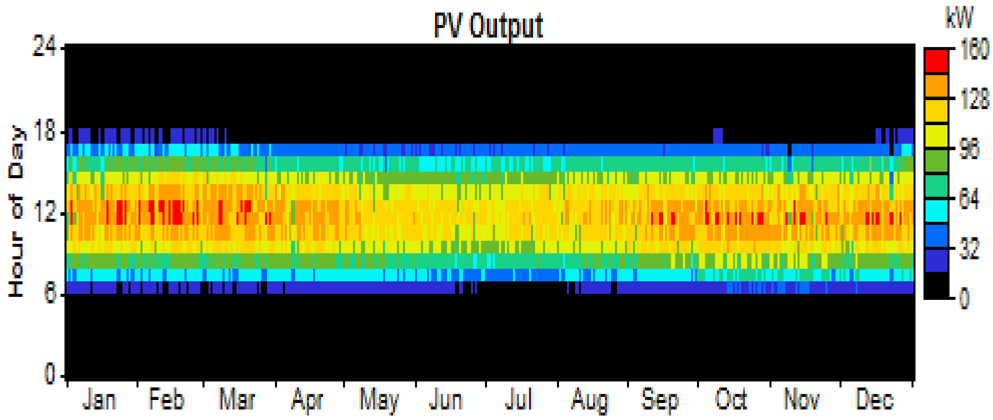

Table 4.8: AC Wind Turbine: BWC Excel-S

Variable	Value	Units
Total rated capacity	20.0	Kw
Mean output	4.47	Kw
Capacity factor	22.3	%
Total production	39,121	kWh/yr

Variable	Value	Units
Minimum output	0.00	kW
Maximum output	24.0	kW
Wind penetration	12.0	%
Hours of operation	8,289	hr/yr
Levelized cost	31.9	$/kWh

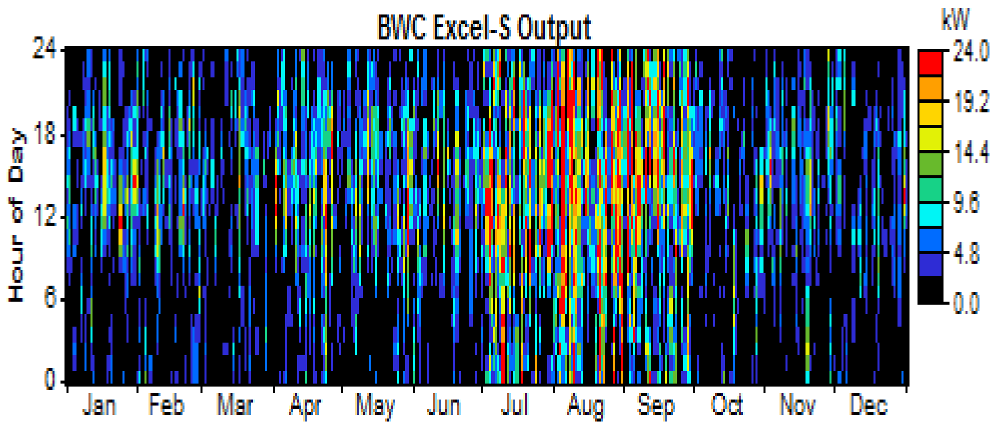

Table 4.9 Battery

Quantity	Value
String size	24
Strings in parallel	10
Batteries	240
Bus voltage (V)	48

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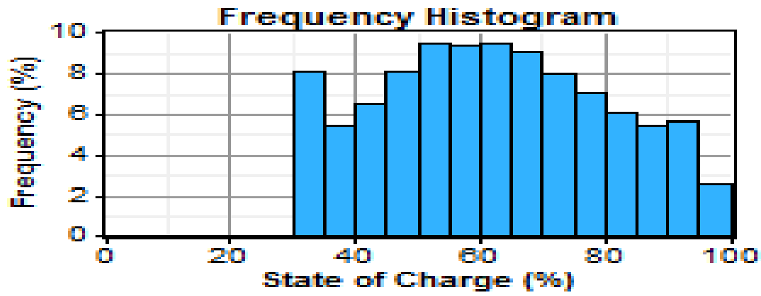
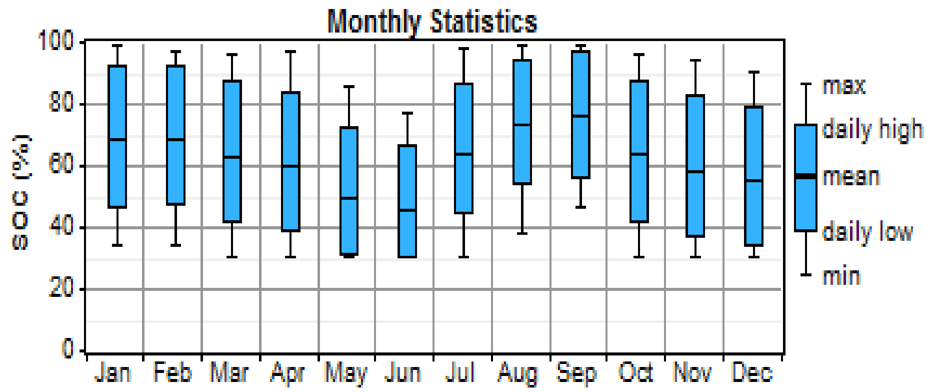
Quantity	Value	Units
Nominal capacity	1,200	kWh
Usable nominal capacity	840	kWh
Autonomy	22.5	Hr
Lifetime throughput	2,045,520	kWh
Battery wear cost	14.438	$/kWh
Average energy cost	0.000	$/kWh

Quantity	Value	Units
Energy in	2,40,759	kWh/yr
Energy out	2,07,682	kWh/yr
Storage depletion	572	kWh/yr
Losses	32,505	kWh/yr
Annual throughput	2,23,949	kWh/yr
Expected life	9.13	Yr





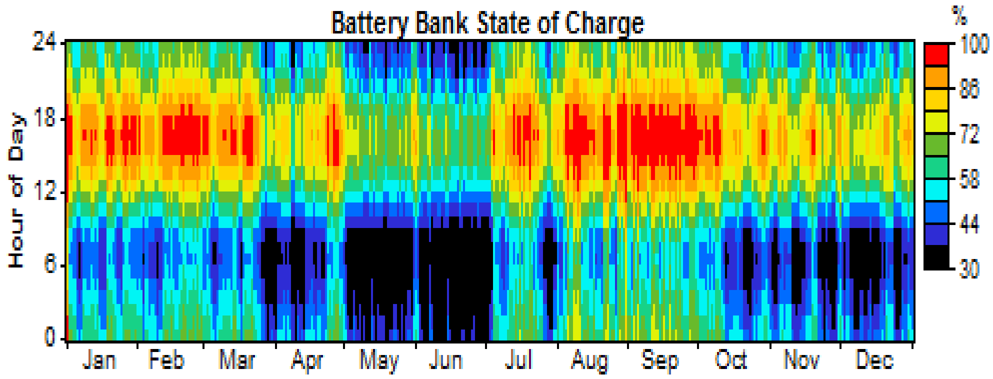


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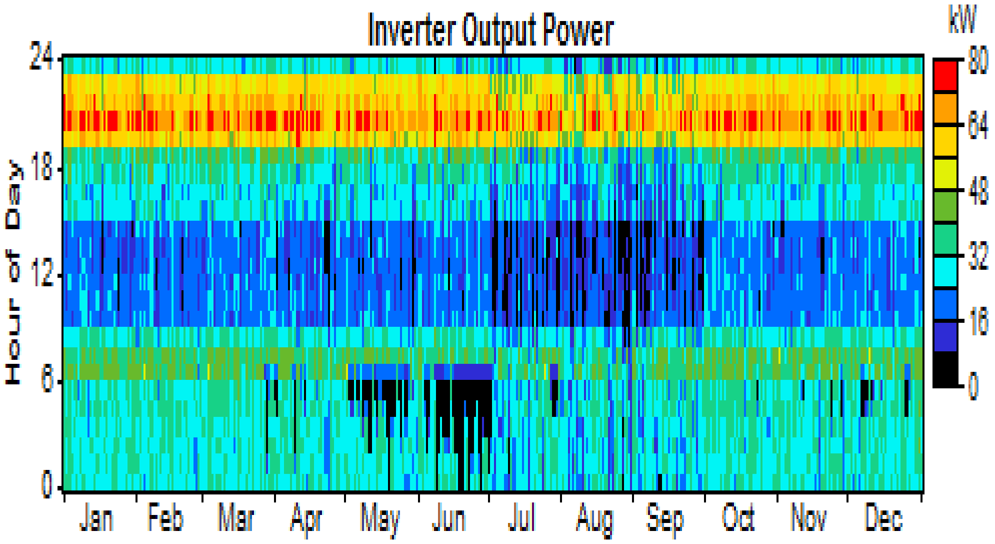
Table 4.10 Converter

Quantity	Inverter	Rectifier	Units
Capacity	80.0	72.0	kW
Mean output	32.0	0.0	kW
Minimum output	0.0	0.0	kW
Maximum output	80.0	2.7	kW
Capacity factor	40.0	0.0	%

Quantity	Inverter	Rectifier	Units
Hours of operation	8,589	22	hrs/yr
Energy in	3,11,162	26	kWh/yr
Energy out	2,80,046	22	kWh/yr
Losses	31,116	4	kWh/yr



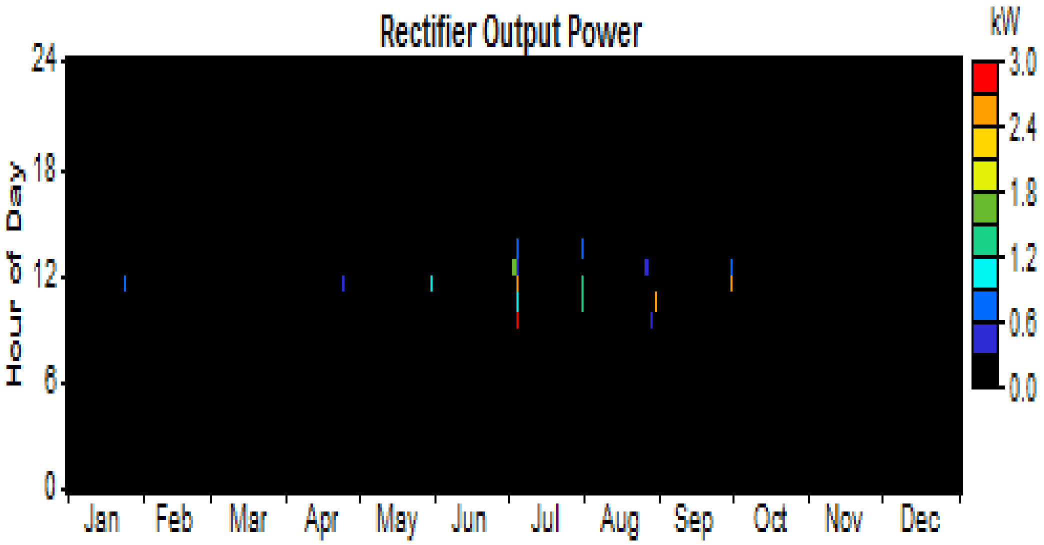


Table 4.11 Emissions

Pollutant	Emissions (kg/yr)
Carbon dioxide	0
Carbon monoxide	0
Unburned hydrocarbons	0
Particulate matter	0
Sulfur dioxide	0
Nitrogen oxides	0

4.2 Cost Summary:

This deals with the cash flows as either a present value or annualized cost, categorized by component or cost type. The three cost outputs, the total net present cost, levelized cost of energy, and the operating cost appear in the top right corner of the Simulation Results window.

4.2.1 Total Net Present Cost (NPC):

The total net present cost of a system is the present value of all the costs that it incurs over its lifetime, minus the present value of all the revenue that it earns over its lifetime. Costs include capital costs, replacement costs, O&M costs and emissions penalties (but there is no emission penalty) . Revenue is the salvage value. The NPC of this system is $112,276,448.

HOMER calculates the total net present cost using the following equation:

$$C_{NPC} = C_{ann,tot} / CRF(I, R_{proj})$$

where
:

$C_{ann,tot}$ = total annualized cost [$/yr]
CRF() = capital recovery factor
I = interest rate [%]
R_{proj} = project lifetime [yr]

The total net present cost is HOMER's main economic output. HOMER ranks all systems according to total net present cost. It could be seen from the chart and table that the PV has the highest cost ($32,504,664), followed by the battery ($27,388,080,) then the turbine ($11,881,980) and the converter ($3,000,000) has the least costs. The total cost of the system is $74,774,720.

No fuel was used so the cost fuel is zero. The gain from the HOMER is seen under salvage. The costs of replacement were not as high as the amount in which the components were purchased. The cost of operation and maintenance (O&M) were very low.

4.2.2 Levelized Cost Of Energy (COE):

HOMER defines the levelized cost of energy (COE) as the average cost per kWh of useful electrical energy produced by the system. The COE of the system at 12 degree was $27.521/kwh at 12 degree. To calculate the COE, HOMER divides the annualized cost of producing electricity (the total annualized cost minus the cost of serving the thermal load) by the total useful electric energy production. The equation for the COE is as follows:

$$COE = C_{ann,tot} - C_{boiler} E_{thermal} / E_{prim,AC} + E_{prim,DC} + E_{def} + E_{grid}$$

where
:

$C_{ann,tot}$ = total annualized cost of the system [$/yr]

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c_{boiler} = boiler marginal cost [$/kWh]
$E_{thermal}$ = total thermal load served [kWh/yr]
$E_{prim,AC}$ = AC primary load served [kWh/yr]
$E_{prim,DC}$ = DC primary load served [kWh/yr]
E_{def} = deferrable load served [kWh/yr]
$E_{grid,sales}$ = total grid sales [kWh/yr]

The second term in the numerator is the portion of the annualized cost that results from serving the thermal load. In systems that do not serve a thermal load ($E_{thermal}$=0) this term will equal zero. The grid sales will equal to zero.

The COE is a convenient metric with which to compare systems, but HOMER does not rank systems based on COE.

4.2.3 Cash Flow Outputs:

The Cash Flow tab of the simulation results window shows a graph of the system cash flow. Each bar in the graph represents either a total inflow or total outflow of cash for a single year. The first bar, for year zero, shows the capital cost of the system, which also appears in the optimization results. A negative value represents an outflow, or expenditure for fuel, equipment replacements, or operation and maintenance (O&M). A positive value represents an inflow, which may be income from electricity sales or the salvage value of equipment at the end of the project lifetime. The income we have from this system is about $50,000,000 in the 25th year. The outflow of capital is almost $75,000,000 in year 0 and Replacement is $33,000,000.

5. CONCLUSION

The hybrid power system simulation carried out on Akodo community shows that a 150kW array of solar panels and 20kW of wind turbines can be used to power the community, which has its peak load to be 89kW. Despite the intermittent nature of the two sources, the energy supplied using solar-wind hybrid power system could be reliable, as they complement each other and excess electricity is stored in the battery bank for use later. Though, there can be some factors like vandalization, theft case, flood and others which can cause the break- down of the system. The hybrid system can produce electrical energy to power appliances in the community, with solar panels producing 86% of the electrical energy while wind turbines produce 14%. The initial cost of implementing the solar-wind hybrid power system is estimated at $110,434,080*. The total lifespan of the project is proposed to be 25 years, while the salvage value of the entire system is estimated at $50,000,000*. In this study, it is shown that when the panels were sloped at 12^{o} they gave values for Net Present Cost and Levelised Cost of Energy which were lower than that of panels sloped at 15^{o}. Despite having high initial costs, renewable energy hybrid systems are long-term investments which are economically profitable, environmentally friendly and can cater for the electrical demand of remote communities lacking grid electricity.

*Although, the HOMER software uses the dollar sign, the actual amounts shown in the tables and charts are naira value

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