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Feasibility Studies and Optimization Analysis of Wind-Solar Hybrid Energy System in Manasa Community of Aliero Kebbi State, Nigeria

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ABSTRACT

Electricity plays a major role in the development of every community.The demand for electricity in remote areas is a major obstacle to their development. Electricity grid extension to rural communities has been identified as a major challenge for the governments across the globe. However, to overcome these challenges, the off-grid renewable energy generation technology is considered as the best option. This paper investigates the feasibility of providing an off-grid hybrid energy system in remote village of Manasa community of Aliero local government of Kebbi State, Nigeria. The proposed hybrid energy system integrates different combination of solar PV modules, wind turbine, battery backups and converter, to meet the required electric demand. HOMER pro software was used to model and optimized the hybrid energy system. Thousands of simulations were carried out to achieve optimal autonomous system configuration for the hybrid energy system. The assessment criteria comprise of the Net Present Cost (NPC), Cost of Energy (COE), emitted and the Renewable Fraction (RF) and amount of CO_2 emission. The result obtained from the studies shows that Wind-PV hybrid energy system is considered to be the most optimized hybrid energy system. The result from the simulation analysis shows that the system can meet the electricity demand of 26kW/day primary demand load with 20 kW peak load. The Net Present Cost (NPC) of the optimized system is $67, 80978 and Cost of Energy (COE) of 0.07407 KW/$ with 100% renewable energy and 0 kg/yr of CO_2 emission respectively when compared to other combination which have higher NPC, COE and CO_2 emissions.

KEYWORDS: HOMER, Renewable Energy, Hybrid energy wind turbine, solar PV

1.INTRODUCTION

Energy resources are among the most important assets of any nation. It is a well-known fact that the high rate of industrial growth and development of any nation is a function of the amount of energy available and the extent to which that energy is utilized. Nigeria has the largest economy in Africa and the highest population growth rate. The inefficiency of the

Nigerian energy industry to meet the energy demands of the nation is due to its high dependency on oil and gas as the main source of revenue. Despite being the largest economy in Africa, only 48 percent of Nigerians have access to electricity while 52 percent live in total darkness [1].

Rural electrification improves the quality of life of rural dwellers having limited or non-access to electricity through decentralized electricity coverage. Since the price of oil is unstable and fluctuating day by day and grid expansion is not also a cost-effective solution, integrating renewable energy sources thus become an important alternative for rural electrification. Sufficient energy supply is indispensable for sustainable economic development of any nation. A country will not grow beyond the subsistence level without an appreciable access to energy [2]. An estimated two billion people around the world mostly in small villages in developing countries currently lack grid-based electricity services according to the United Nations Environment Program (UNEP) [3]. Thus, in view of this, renewable energy is considered as an alternative source of energy to replace the use of fossil fuel which can be the main sources of heat and electrical energy.

Renewable energy sources are highly abundant and accessible irrespective of the location (remote or otherwise). Remote location in this regard may not necessarily be limited to a location far away from the national grid, but it includes any site where it is not economical or feasible to extend grid network due to bad terrain and poor topography which mostly characterize rural villages and isolated desert places in Nigeria and other developing countries. Hence, small off-grid standalone renewable energy systems represent an important option for narrowing the electricity gap in rural parts of the developing world where progress in grid extension remains slower than population growth [4]. Even if there is an unlimited supply of fossil fuels, using renewable energy is better for the environment, because it is clean with little or no pollutants.

In 2017, the total available grid power of Nigeria was only 5074 MW for a population of over 190 million people with a peak demand of about 17,700 MW and the national electricity access rate was only 58% with a significant contrast between urban areas (78%) and rural areas (39%), also the grid extension in rural zones is most often impossible due to rugged terrains, thick jungles, geographical remoteness, high cost of supply, low consumptions, low household incomes, inadequate road infrastructures, and dispersed settlement of consumers were most people in rural areas rely on alternative sources, mostly diesel generators, for electricity supply [5].The worldwide use of Renewable Energy Technologies (RETs) to meet energy demands has been increasing over the years. These technologies have demonstrated their capability to contribute substantially to global climate protection by reducing the greenhouse gas emission, as well as offering low operation and maintenance cost, while meeting the rapid energy demand growth [6].

1.2 SOLAR PV

Solar photovoltaic (PV) is a system which is designed to convert the energy of the sun into electrical energy. It is composed of one or more solar panels combined with an inverter and other electrical and mechanical hardware that use energy from the sun to generate electricity. PV system can vary greatly in size from small rooftop or potable systems to massive utility scale generation [7]. The efficiency of the solar PV System is shown in equation 1

$$\text{Efficiency, } \eta_{PV} = \frac{P_{pv}}{A_{pv} \cdot G_{T\,STC}} \times 100 \qquad (1)$$

Where

η_{PV} = Efficiency of PV module under test condition

P_{PV} = the rated power output of the PV module (kW)

A_{PV} = the area of PV module (m^2)

G_T STC = the radiation (kw/m^2)

The size and number of PV module is determined using equation

$$M_T = \frac{P_{pv}}{\eta_D \times S_p \times P_m} \qquad (2)$$

Where

P_L = the total load power of the location.

S_P = the peak sun shine hour of the location.

P_m = the module power rating.

η_D = the design efficiency which is the product of ηi (inverter efficiency), ηb (battery efficiency) and ηw (wiring efficiency).

1.3 Wind Turbine

The principle behind this energy conversion system is that, wind moving with certain velocity produces rotatory motion in the blade rotor. The movement of the rotor is due to the air foil section of the blade, the more efficient air foil section is, the more is the rotatory motion and consequently, more is the output of the turbine, wind turbine turns wind energy into electricity using aerodynamic force from the rotor blades, which work like an airplane wing or helicopter rotor blade [8].

Horizontal axis wind turbine (HAWT) and Vertical axis wind turbine (VAWT) are built with the aim of generating electricity from wind. Both of the turbines consist of some basic components: a base or foundation, tower, generator, gearbox, rotor, control system and transformer. In horizontal axis wind turbine, the rotation axis is parallel to the ground. HAWT rotors and generators are at the top of the tower and must be pointed into the wind because it accepts wind only in one direction therefore yaw mechanism is needed to rotate the turbine in wind direction [9].

The power available in the wind can be calculated using the following equation:

$$P = \frac{1}{2} \rho A V^3 \quad (3)$$

Where

P = power

ρ = air density

A = swept area

V = velocity of the wind.

The power coefficientof the wind turbine for any given load demand can be determine using equation 4.

$$Cp = \frac{P}{0.5 \rho A V^3} \quad (4)$$

2. HYBRID ENERGY SYSTEM

Hybrid Power System (HPS) is a combination of different renewable resources such as wind, solar, biomass, hydrogen fuel, hydro, with fossil fuel powered diesel generator to provide electric power. It is commonly installed in remote areas isolated from the utility grid normally wind & solar energy are separately used to generate power [2].

2.1WIND-SOLAR HYBRID ENERGY SYSTEM

This is combination of wind energy and solar energy, used to generate power from each other. Hybrid system is having advantage than system those which are totally depend on single source of energy. Researchers have very tough task to maximize the total energy output from the system with lower cost & reliability. Generally, wind-solar hybrid power system consists of wind turbines, photovoltaic array, controller and storage battery. Wind turbine is used to convert wind energy into mechanical energy and then into electric energy [10].

Wind-solar hybrid energy systems have great potential to provide higher quality and more reliable power to customers than a system based on a single source. The renewable energy sources can complement each other. Hybrid renewable energy sources are recognized mainly for remote area power applications and are nowadays cost-effective, where extension of grid supply is expensive. It has been observed that wind and solar energy has always been a popular renewable energy resource and widely accepted because of its availability virtually in all areas and regions all over the world [11]. Figure 1 shows the hybrid energy system.

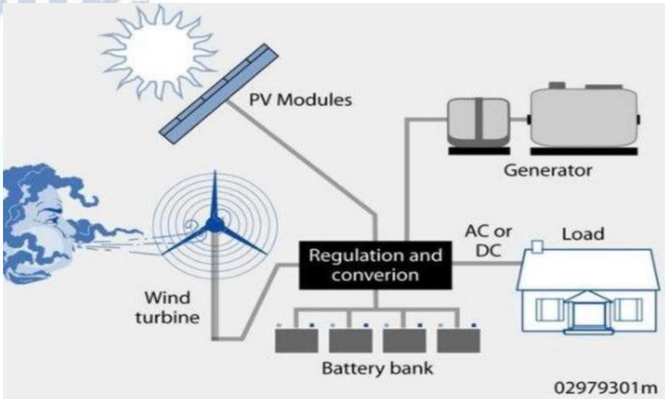

Figure 1: Hybrid energy system [12]

Oladigbolu et al., [13] conducted a feasibility and comparative study of different Hybrid energy system (HESs) to supply electricity to a typical Nigeria rural community. They concluded that the PV/hydro/wind/DG hybrid configuration was the best HES in supplying electricity to the selected rural site as it had the best environmental prospects as well as having an acceptable techno-economic outcome.The techno-economic evaluation of different HESs including a stand-alone DG system was investigated and their analysis reveals that PV configuration had the least COE of \$/0.3569kWh at a renewable and surplus energy fraction of 15.3% and 2.6% respectively.

Celik, [14] developed a novel optimization technique for techno-economic analysis for autonomous small scale photovoltaic wind hybrid energy system. An optimum combination of the hybrid photovoltaic wind energy system could provide higher system performance than either of the single system. It was shown that the magnitude of the battery storage capacity has important influence on the system performance of a single PV and wind system.

Rahul [15] concluded that the best among three hybrid systems for supplying electrical requirements, the most economical is the PV - diesel -battery hybrid system, which has a total net present cost of US\$271,637 and a cost of energy of US\$0.23/kWh. The action plan is formed on the basis of cost-effective modeling that is minimization of energy production cost in a near future. The amount of CO_2 Emissions Reduction is calculated to be 242 tonnes of CO_2/yr and US$3140/yr earned from the Carbon Credit.

3.0 METHODOLOGY

3.1 STUDY AREA

The selected study area is Manasa community in Aliero local government area of Kebbi state, Nigeria (Figure 2). The longitude and latitude of the location is 12.3562⁰N and 4.4388⁰E respectively. The area around the village is flat plain terrain, (Figure 3) with sufficient renewable sources to fulfil the energy demand of the village

Figure 2: Study Area

Figure 3: The outlook of Manasa community

3.2 REQUIREMENTS OF WIND-SOLAR HYBRID POWER SYSTEM

3.2.1 LOAD DEMAND

It is necessary part of system to design & analyze. To find out the exact load demand it is very complicated and difficult to decide. Load variation for different seasons is not predictable, so system have to design for nearer or more than load demand to full fill requirements.

3.2.2 SYSTEM CONFIGURATION

By studying all data like solar radiation, wind speed and load demand proper selection of equipment's have to be made for the system configuration. But the sizing of system will be according to the environmental conditions. Producing power from wind-solar depends upon the location which is to be selected [16].

The system configuration comprises of the wind turbine, solar PV arrays, batteries, System Converter and a diesel generator. The wind turbine and diesel generator are connected to A.C bus while the battery is connected to the D.C bus. The storage batteries will be charged from the excess electricity generated from wind and solar energy resource when the power output from these two resources is enough to supply the load demand. However, when the power produce from the wind turbine and solar PV are not enough for the load demand as a result of low wind speed or solar radiation, the charge batteries work to compensate for the energy short fall. The system configuration is shown in Figure 4.

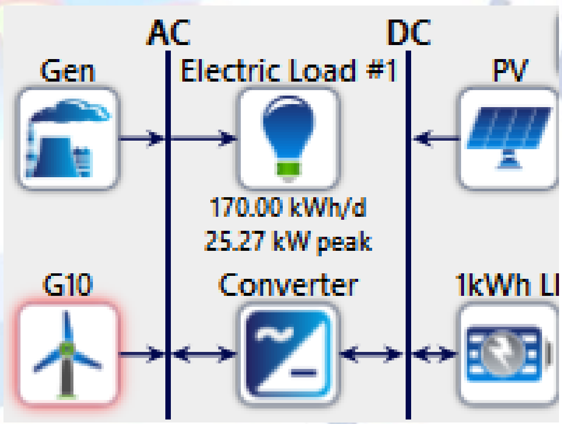

Figure 4: HOMER Schematic diagram for the System Configuration

3.3 RESOURCE ASSESSMENT

3.1 SOLAR ENERGY RESOURCE

The study area is blessed with abundant solar radiation. Solar energy radiation is almost available throughout the year at the study location. The data for the solar radiation is obtained from database of the National Aeronautics and Space Administration (NASA) through HOMER and presented in Figure 6, from the figure it can be observed that solar radiations are higher in the Months of March –June while the Months of July-August and December to January is characterized by low solar radiation. The annual average solar radiation ranges from 5.25 kWh/m²/day which is the lowest in the Month of December to 6.76 kWh/m²/day in the Month of April. While the clearness index ranges from minimum value of 0.54 to maximum value of 0.641 in April.

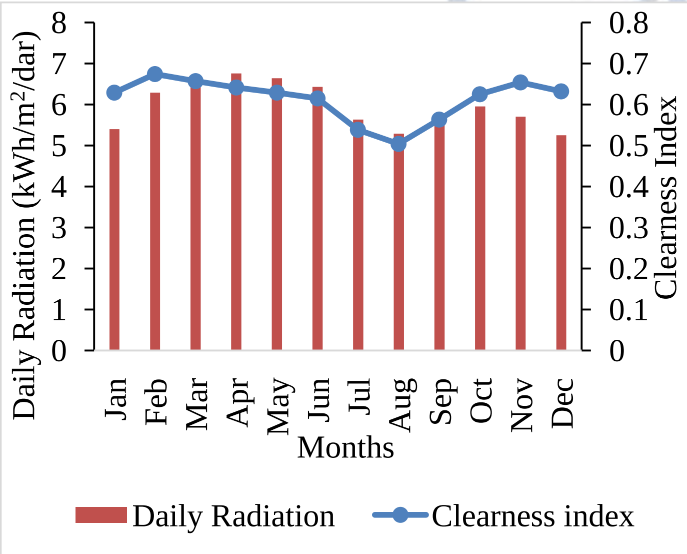

Figure 6: The monthly solar radiation through the year in Manasa community.

From Figure 6 it is observed that the solar irradiance is found to be higher March, April and May while it was found to be low in the months of January, August and December.

3.3.2 WIND ENERGY RESOURCE

The geographical location of the study area placed it at an advantage of high wind speed especially during the winter seasons. The wind data for the study area was obtained through the HOMER software by given the location. The hub height of an average wind turbine is between 20 m to 50 m height, for this study the wind data was extrapolated to 30 m height using equation 5.

$$V_{(Z)} = V_r = V_r \left(\frac{Z}{Z_r}\right)^{\alpha} \qquad (5)$$

Where

V(Z) is the speed of the extrapolated height.

Vr is the wind speed at the reference height.

Z is the extrapolated height

Zr is the reference height and

α is the ground roughness coefficient which is given a value at 0.31

Figure 7 shows the average wind speed of the study location, it can be observed from the figure that the highest average wind speed is 9.35 m/s and 9.13 in May and April, the figure shows further that the wind speed in the study location is adequate for the operation of the wind turbine.

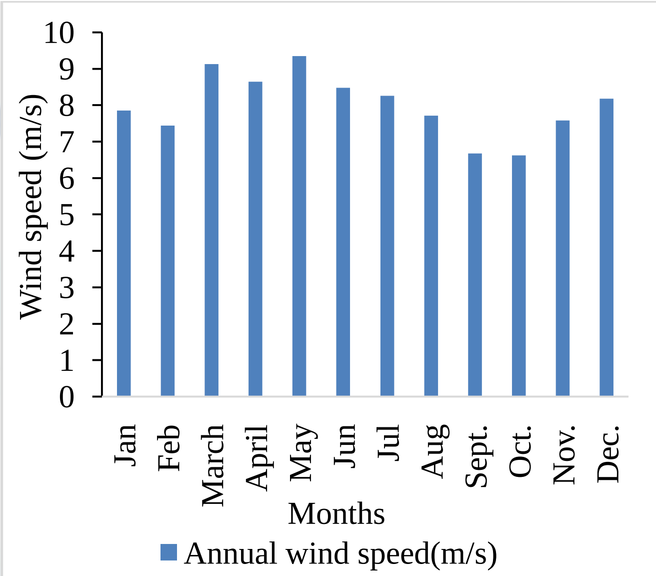

Figure 7: The annual wind speed of Manasa community

3.4 ELECTRICITY LOAD ASSESSMENT

The load demand of the selected community is sensitively estimated by on-site field assessment. The seasonal demand has been estimated according to the area with consideration of utilization time and power of the different appliances for the individual house hold. The community has 150 hots. The residential loads include two (2) bulbs for each hot in which one is inside and one as a security bulb outside the hot and six (6) bulbs for mosque including inner and security light and nine (9) bulbs for the classes. The primary load demand of the community is 170kW/day with a peak load of 25.27kW. Detailed load profile of the community is shown in Table 1.

Table 1: Total Load of the Community

S/N	Appliances	No. in use	wattage	Summer		Winter	
				hrs/day	Wh/day	hrs/day	Wh/day
1	Fans	2	90	3	270	3	270
2	Bulbs	315	20	7	140	7	140
Total load for 1 hot					**410**		**410**
Total load for 150 hot					**61,500**		**61,500**

3.5 ASSESSMENT OF COMPONENT

For techno-economic analysis, and designing of the system needs technical details and cost of different components used in the system modeling.

3.5.1 SOLAR PV MODULES

The photovoltaic system also known as solar PV system which is a power system designed to supply usable solar power by means of photovoltaics. It consists of an arrangement of several components including solar panels to absorb and converts sun light in to electricity. It also has a solar trading system to improve its overall performance. The specification of the Solar PV is presented in Table 2

Table 2: Solar PV specifications

Model	Generic flat plate PV
Abbreviation	PV
Panel plate	Flat plate
Rated capacity	1kW
Manufacturer	Generic
Efficiency	20%
Life time	25yrs
Capacity	10kW
Capital cost	$9000
Replacement cost	$8500
Operation and maintenance	$100

3.5.2 WIND TURBINE

The wind power system is the use of wind to provide mechanical power through wind turbines and turn the mechanical energy obtained in to electricity. A generic 10kW horizontal axis wind turbine was considered for the analysis. The availability of high wind speed at the study area determines the amount of power that could be generated by the wind turbine. The specification of the wind turbine is presented in Table 3, while the power curve of the wind turbine is presented in Figure 8

Table 3: Wind Turbine Specifications

Model	Generic 20kW
Abbreviation	G10
Rated capacity	10kW
Manufacturer	Generic
Efficiency	59.3 %
Life time	20 yrs.
Capital cost	$14000
Replacement cost	$13500
Operation and maintenance	$500

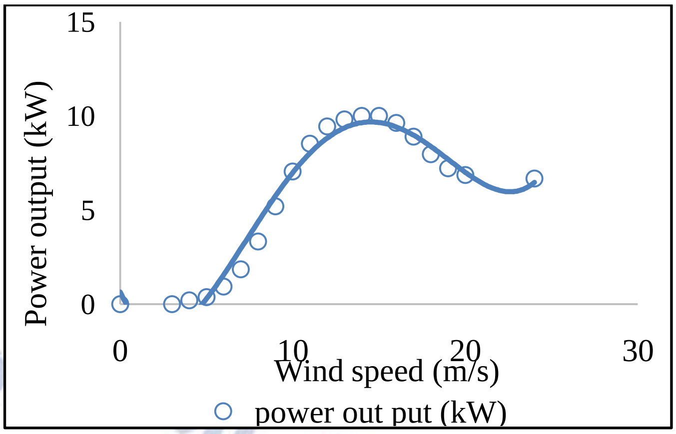

Figure 8: Power curve of the wind turbine (HOMER)

3.5.3 THE BATTERY

The battery system is an energy storage system device which can store energy whenever the supply exceeds the load demand and then provide energy whenever on-site generation is insufficient. In off grid renewable energy application, a deep circle battery is often used. In this study Generic 1kW Li-lon battery was used. The estimation of the size and the number of the batteries required is significant in designing wind-solar PV hybrid energy system. The capacity of the battery was obtained from HOMER using equation 6.

$$B_C = \frac{(AHL-SD)}{D_{max}} \quad (6)$$

AHL = the daily ampere load.

S_D = the number of days of autonomy or storage days.

Dmax = the battery maximum depth of discharge.

The battery specification is presented below in Table 4.

Table 4: The Battery Specifications

Battery	Value
Battery name	Generic 1kW Li-lon
Through put	3000kWh
Nominal voltage	6v
Nominal capacity	1kWh
Nominal capacity	167Ah
Round trip efficiency	90%
Maximum charge current	167A
Maximum discharge current	500A
Life time	15 yrs.
Capital cost	$600
Replacement cost	$550
Operation and maintenance	$10

3.6 THE CONVERTER

The converter used in the present study is called the converter system. The inverter is a device for converting DC (direct current) to AC (alternating current) these involves DC-DC converter (charge controller), DC-AC converter (inverter). The specific size of the inverter for a certain load demand was obtained by HOMER using equation 7.

$$\text{INVR} = \frac{P_{Lmax}}{\eta_i} + 25\% \qquad (7)$$

$P_{L}max$ = the maximum load of the location

η_i = the efficiency of the inverter.

The 25% over size will increase the reliability and life time of the inverter and the specifications of the converter is presented in Table 5

Table 5: Converter specifications

Model	System converter (generic)
Abbreviation	Converter
Efficiency	90%
Peak efficiency	95%
Rated capacity	100%
Life time	20 yrs.
Capacity	1kW
Capital cost	$254
Replacement cost	$254
Operation and maintenance	$0

3.7 Diesel Generator

The diesel generator is an auto size gen set which is a combination of a diesel engine with an electric generator to generate electrical energy using diesel as its fuel. It operates as a continuous source of electricity. The diesel generator emits some pollutant to the immediate environment which is in little composition and has little or less harmful to the environment and the populace, the emissions include CO, unburnt Hydro carbon, fuel Sulphur to particulate matter and nitrogen oxide. The emissions composition is presented in Table 6.

Table 6: The Generator Specifications

Properties	Value
Name	Auto size gen set
Initial capital	$350
Replacement cost	$350
Operation and maintenance	$0.030
Fuel price	$ 0.40
Fuel curve intercept	1.17L/hr
Fuel curve slope	0.251L/hr/kW

The fuel used in the generator also has its certain properties which include the low heating value, the density, the carbon content and the Sulphur content which are presented in the Table, This generator automatically sizes itself to meet the load demand. The capacity of the generator will be the smallest that will produce no capacity shortage in all the sensitivity cases and future years and it adjust its fuel curve to match its size.

3.8 Modelling Software

HOMER-pro software (Hybrid Optimization of Multiple Energy Resources) was use for this study. The software was developed by the National Renewable Energy Laboratory (NREL) which can give assistance in the tasks to configure, simulate, evaluate and optimize several choices of designs of various systems for distribution of electricity generation and consumption units. HOMER is capable of computing the optimal cost and required size of each type of energy source. Net Present Cost NPC was computed for various combinations to derive most optimized solution. The proposed hybrid energy system (HES) consists of five key components which include a solar PV system, wind turbine, batteries, diesel generator and a converter.

4.0 RESULTS AND DISCUSSION.

4.1 SIMULATION RESULTS

In this section the simulation results were discussed. Based on the Meteorological data and load consumption of the target community, thousands of renewable energy combinations were simulated to achieve optimal system configurations. HOMER estimates their technical feasibilities and scales them in terms of net present cost, (NPC) cost of energy (COE), renewable energy fractions and amount of CO_2emitted. Homer executes a timely simulation for both the feasible and infeasible system configuration base on the values presented at the initial stage. For the feasible system its categorized through technical and economic variables which include Operating cost, NPC, COE, renewable fraction etc. HOMER helps to evaluate the feasibility and sustainability of each design in the system configuration based on its technical, economic and environmental assessment criteria. The input data are analyzed, characterized, and tabulated systematically so as to determine the most economic hybrid system.

4.2 OPTIMIZATION RESULTS

The categorized optimization result from the simulation results were performed by Homer based on the annual real interest rate of 10% and a projected life time of 25 years. Homer simulates thousands of combinations and categorized the best five combinations that are economically feasible, cost effective, and environmentally friendly. The categorized form of the optimization results is shown in Table 7. The five cases considered feasible by the HOMER based on the techno-economic and environmental parameters as component combination changes and these cases are presented as follows: are as follows; Case 1: PV/WT/battery system, Case 2: PV/battery model, Case 3: PV/WT/DG/battery system, Case 4: PV/DG/battery system and Case 5: WT/DG/battery system.

Table 7: Categorized Optimization Results

Hybrid Energy combination	PV (kW)	WT (G10)	Gen (kW)	Battery	NPC ($)	COE ($)	Operating cost ($/yr)	Initial capital cost (%)	Ren. Fract. (%)	Total fuel ($)	O&M Cost ($)	Mean output (kW)
PV/WT/Batt.	33.00	01.00	-	143	67,810	0.0741	1,152	50,280	100	-	250	2.29
PV/Batt.	50.60	00.00	-	185	78,668	0.0861	1,111	61,767	100	-	-	3.29
PV/WT/DG/Batt	27.10	01.00	28.00	158	81,121	0.0859	1,667	55,756	89.8	1,946	250	2.40
WT/DG/Batt.	00.00	02.00	28.00	103	89,183	0.0944	3,527	35,507	60.6	7,193	500	2.53
PV/DG/Batt.	38.9	00.00	28,00	176	90,317	0.0957	1,924	61,041	83.4	3,112	-	3.47

4.2.1 CASE 1: PV/WT/BATTERY SYSTEM

Based on the simulation results PV/WT/battery system is considered to be the most feasible of all the system with less cost compare to other systems. It has NPC and COE of $ 67,810 and $0.0741, with 100% renewable energy penetration. The results show that the detail annual production and consumption of the electrical energy by the system is 88.023kWh/yr and 60,160kWh/yr respectively.

The Monthly electrical production of PV/wind/battery system for the whole year is presented in Figure 9. From the Figure it can be observed that the PV output has the highest production of electricity across the whole year followed by the WT output. From the Figure the Monthly electrical production of PV/wind/battery system shows that the electrical production fluctuates between the PV output and the WT power output. The PV output has it peak production in February and March and the lowest production in the months of August, while for the wind turbine output it has a peak production in the month of May and the lowest production in the month of October through the year.

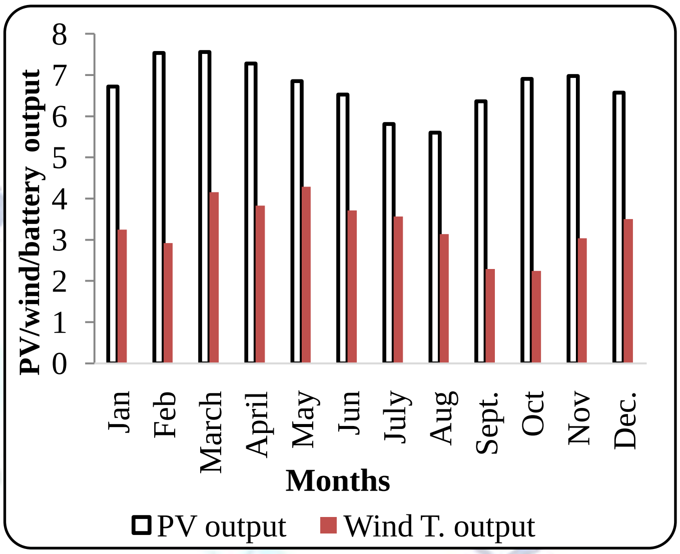

Figure 9: Monthly electrical production of PV/wind/Battery system

The Excess electricity for case 1 is presented in Figure10, this excess electricity (EE) is the total amount of unconsumed electricity that occurred during the year of performance. From the figure it can be seen that the excess electricity is produce at it's peak in the Month of May while the lowest excess electricity is produced in the Months of January throughout the year. The plot shows that which shows that the excess electricity produced is much more in the month of May.

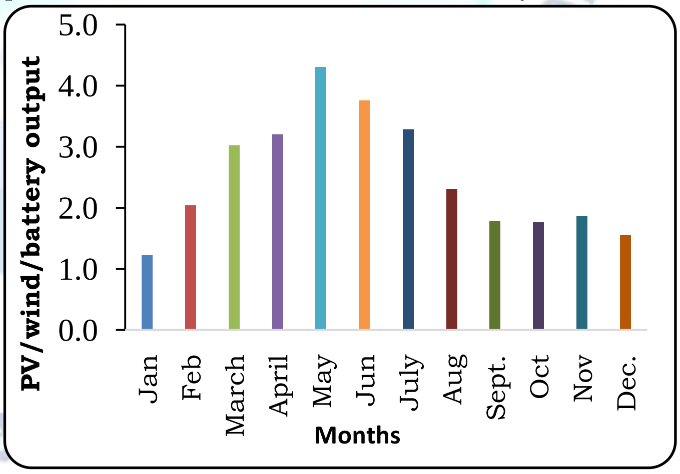

Figure 10: The Excess Electricity production of PV/wind/Battery system in a year

4.2.2 CASE 2: PV/BATTERY SYSTEM

The second most optimized and feasible combination for the hybrid system is the PV battery system. Based on the simulation results PV/ battery system is considered to be the second best system it has NPC and COE of $78,668 and$0.0861, with 100% renewable energy penetration. The results show that the detail annual production and consumption of the electrical energy by the system in total is 90,328kWh/yr and 60,033kWh/yr respectively.

The Monthly electrical production of the PV battery system for the whole year is presented in Figure 11. The result shows that PV output is the only component that has the highest production of electricity across the whole year. The monthly electricity production in this case shows that electrcity is produced much higher in the month of March and have a lowest production in the month of August across the year.

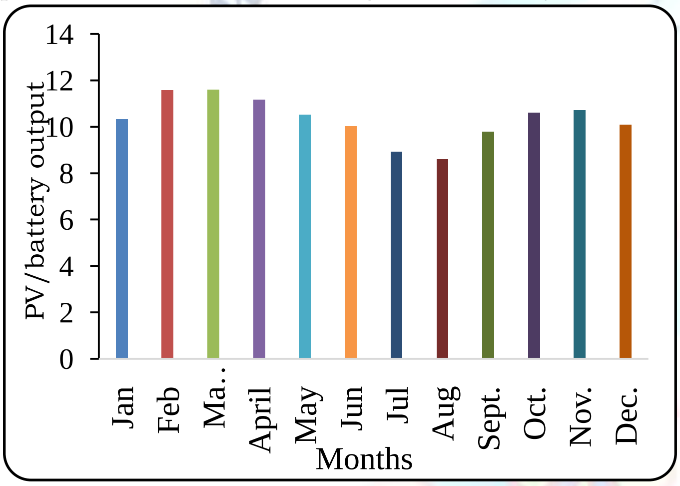

Figure 11: Monthly electrical production of PV/Battery system.

The excess electricity for case 2 is presented in Figure 12 which shows that the excess electricity produced as observed is much higher in the months of May and Jun. with low excess electricity in the month of Jan. and Dec., across the whole year as presented in Figure 12.

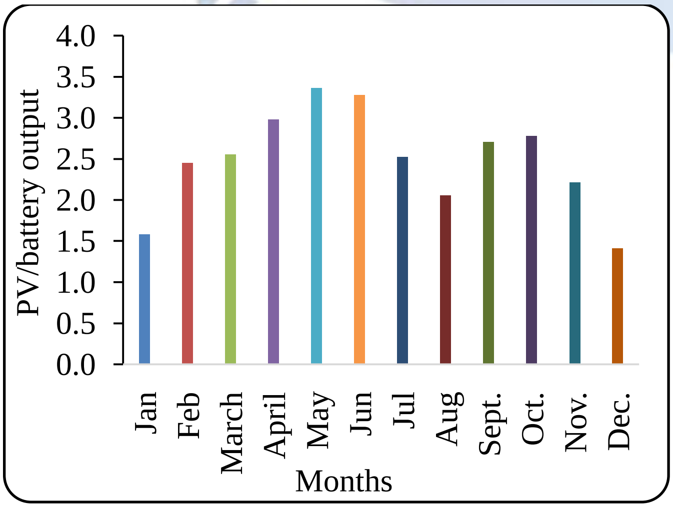

Figure 12: Excess Electricity of PV/Battery system

4.2.3 CASE 3: PV/WT/DG/BATTERY MODEL

The System in case 3 is the PV/WT/DG/Battery system and it is the third most feasible and optimized system from the simulation result. The system has NPC and COE of $81,121, and $0.0859. In this case, the details of the annual production and consumption of the electrical energy by the system in total is 83.931kWh/yr and 62,050kWh/yr respectively. The result presented in Figure 13 shows that the PV output produces the highest electric output followed by the wind turbine, then the DG. As observed in Figure 13, the monthly electrical production. For the PV output, the electricity produced is found to be higher in the months of February, March and April while the lower electrical production was found to be in the month of July and August across the year. As for the wind turbine output, the higher electrical production was found to be in the months of March, and May with a lower production in the months of September and October, while for the Diesel generator the electrical production is higher in the month of January and December with a lower production in the months of April and June and has no production in the months of May and July across the year as presented in Figure 13.

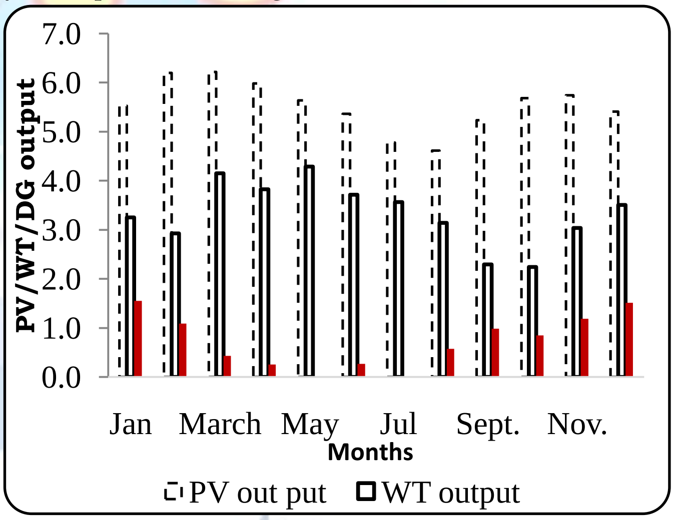

Figure 13: the Monthly electrical production of PV/WT/DG/Battery system

The excess electricity produced for this case is presented in Figure 14. The highest excess electricity is produced in the month of May, June and July while lower excess electricity production is observed to be in the months of January, February, October and December across the whole year.

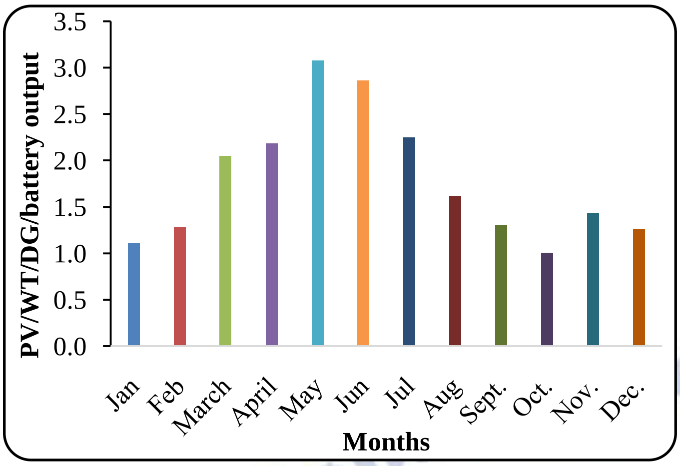

Figure 14: Excess Electricity of PV/wind/DG/ Batterysystem

4.2.4 CASE 4: WT/DG/BATTERY SYSTEM

The fourth most feasible system is case 4 which is the WT/DG/Battery. It has NPC and COE of $89,183, and $0.0944 respectively with an operating cost of $3,527 per year.The annual production and consumption of the electrical energy by the system is 82,835kWh/yr and 62,050kWh/yr.

Figure 15 presents the monthly electrical production for the WT/DG/battery system. From the figure, it can be observed that DG output produces more electricity than the WT output. The DG output has more electrical production in the month of March, April, May and June with a lower production in the month of September and October. On the other hand, the WT output have higher electrical production in the month of January, February March, August, September, November and December with less electrical production in the months of April,, May, June, July and October access the whole year. This higher production of the WT is attributed to the seasonal changes where that particular period is winter.

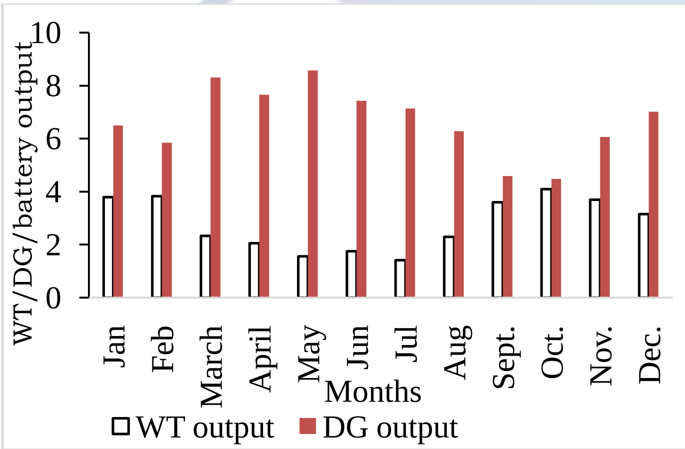

Figure 15: The Monthly electrical production of WT/DG/Battery system

As presented in the Figure 16 the excess electricity produced for the WT/DG battery system is higher in the monthly of May and June while the little excess electricity produced is observed in the month of January, February, September, October, November and December

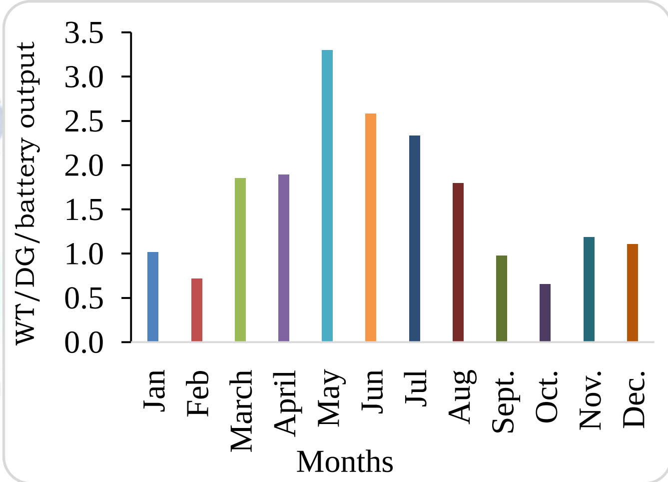

Figure 16: Excess Electricity of WT/DG/Battery

4.2.5 CASE 5: PV/DG/battery MODEL

The system in this case is the fifth most feasible and optimized system from the simulation result. This system comprises of the solar PV, and Diesel generator. The system has NPC, and COE of $90,317, and $0.0957 respectively, with a mean output of 3.47kW and 83.4% renewable energy fraction. The annual production and consumption of the electrical energy by the system is 79721kWh/yr and 62,050kWh/yr respectively.

From Figure 17, it is observed that the electrical production of the PV/DG/battery system in the case of PV output is observed to be higher in the months of March, April and Nov and found to be lower in the months of July and August while for the case of DG it is observed to be higher in the months of Jan and Dec. and lower in the months of April, Jun and July across the whole year

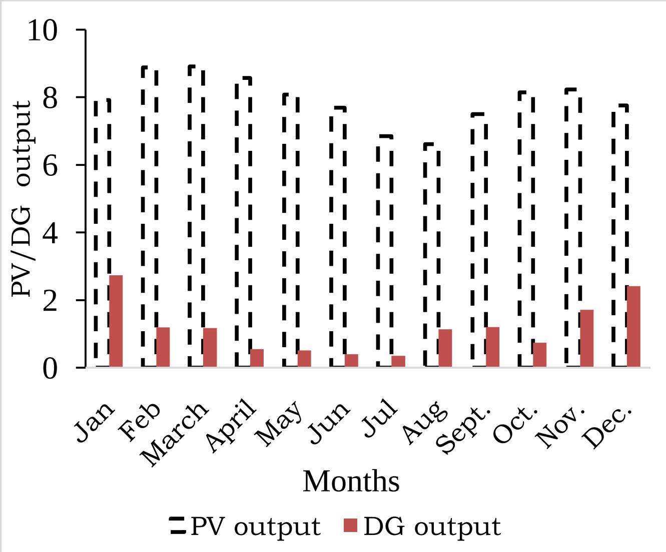

Figure 17: The monthly electrical production of PV/DG/Battery system.

According to Figure 18 the excess electricity of this case is observed and the PV/DG output is found to be higher in the months of May and Jun. and also observed to be lower in the months of Jan. and Dec. across the whole year.

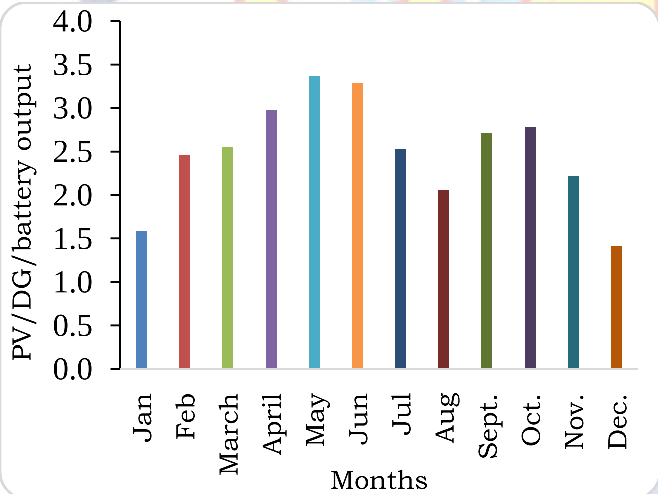

Figure 18: Excess Electricity of PV/DG/Battery System

4.3 SENSITIVITY ANALYSIS

Important variables that directly or indirectly affects the overall cost as well as the feasibility of the proposed systems are modeled using the sensitivity analysis. For the sesnsitivity analysis, the best optimal case is used. HOMER eliminates all the non-feasible combinations/configurations through the sensitivity analysis. It also considers feature development such as increase or decrease in load demand, resources, increase in wind speed, or diesel price using optimal system type graph (OST) and the line graph options. The sensitivity results for the optimized system is presented as follows: Figure 19 and 20 presents the sensitivity analsysis of the optimal system type for both the NPC and the cost of energy. From the Figure it can be seen that the the optimal system considered feasible by HOMER for the target location is the WT-PV-Battery system, It is the most feasible and optimized system among the other configurations. The total NPC and the COE of the optimal system type is agrees with results obtained from the optimization analysis.

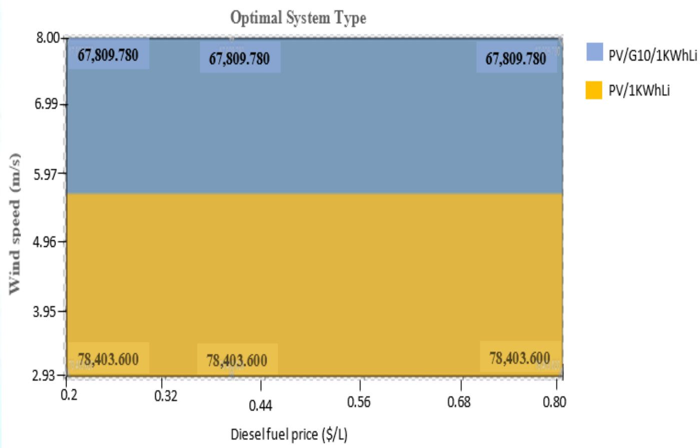

Figure 19: Sensitivity analysis of the WT-PV-Battery system (NPC)

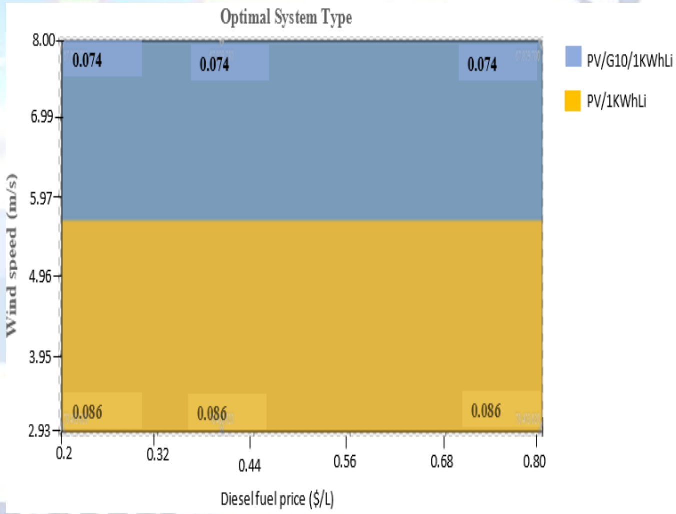

Figure 20: Sensitivity analysis of the WT-PV-Battery system (COE)

4.3.1 Effect Of The Variation Of Wind speed On The NPC And COE

The effect of the variation of the wind speed on the NPC and COE is presented in Figure 21, The NPC and the COE depends on the wind speed. Base on the obsavation made in Figure 21 the increase in wind speed affects the total NPC and COE of the systems. The increase in wind speed leds to decrease in the NPC and the COE, the NPC and the COE is high when the wind speed is between 2.93-3.0 m/s. the NPC and the COE began to decrease as the wind speed increases.

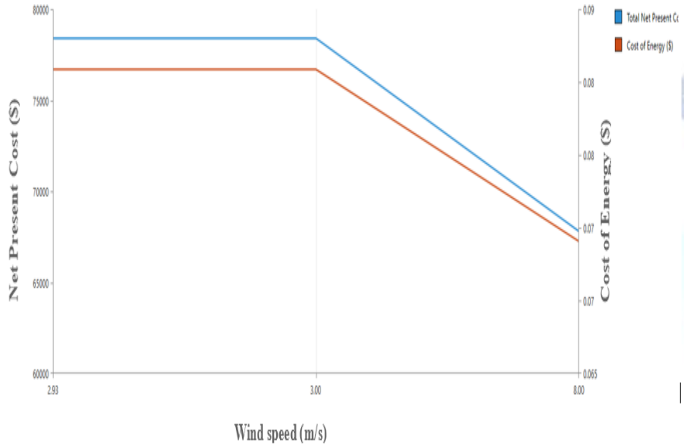

Figure 21: Effect of variation of wind speed on the net present cost and cost of energy

4.3.2 Effect Of The Variation Of Wind speed On The Npc And Excess Electricity

The effect of variation of wind speed on the NPC and Excess electricity of the system is presented in Figure 22. The figure shows the sensitivity results for the system design for varying wind speed. It can be observed from the figure that the wind speed has positive impact on the total NPC and the excess electricity of the system. As the wind speed increase excess electricity also increased, and the total net present cost decreases respectively.

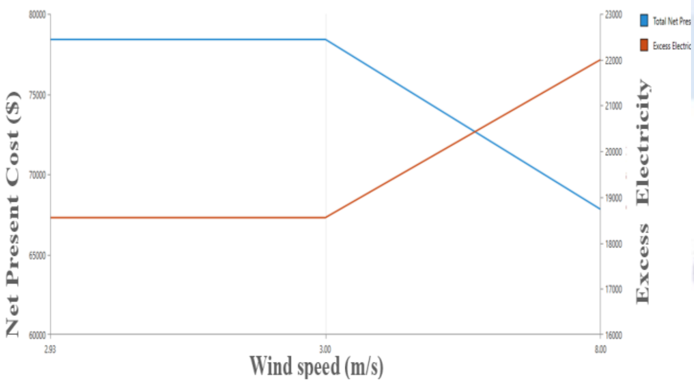

Figure 22: Effect of increase of wind speed on NPC cost and Excess Electricity

4.4 TECHNICAL ASSESSMENT

Table 8 shows the technical characteristics of each of the five different system cases configurations. The energy produced when the load requirement has been completely met was found to be much more in case 1 (PV/wind/battery) because it generates surplus electricity during the period at high solar irradiation as for case 5 (PV/DG/battery) it produces 10.90% extra power and the battery absorbs all the excess electricity produced. More so, case 2 (PV/battery) shows that without the inclusion of diesel generator the system will produce 24% excess electricity. The hybrid energy system in case 3, case 4 and case 5 had 0% capacity shortage and also 0% unmet electric load and this indicated that the system had a full up time without having any shortage of electricity and the system was able to completely take care of its electric load as required. For the two other cases which are case 1 and case 2 the percentage of their capacity shortage and unmet electric load is very small and this shows that they all have a tolerable and maintainable unfulfilled load with a little percentage of electricity shortage which is 5.09% and 5.08% respectively.

For the optimized system both PV/wind/battery (case 1) and PV/battery (case 2) have 100% renewable energy penetration (fraction) this is because there generated much more electricity as compared to other hybrid energy systems However, the PV/wind/battery, electricity generation of 22,001kWh/year and produces excess electricity of 25% while the PV/battery system have electricity generation of 21,831kWh/year and produces excess electricity of 24%.

Table 8: The electrical characteristics of the five cases

Cases	Excess electricity production (%)	Electricity generation (kWh/yr)	Renewable fraction (%)	Capacity shortage (%)	Unmet electric load (%)
PV/wind/batt.	25.00	22,001	100	5.09	3.05
PV/batt.	24.00	21,831	100	5.08	3.25
PV/wind/DG/batt.	18.70	15,657	89.8	0.00	0.00
Wind/DG/batt.	17.20	14,240	60.6	0.00	0.00
PV/DG/batt.	10.90	8,682	83.4	0.00	0.00

4.5 ECONOMIC ASSESSMENT

The economic parameters like NPC are used to analyse the best optimal result of the five different cases.

Case 5 presented the highest NPC out of the five different cases, while case 1 has the lowest NPC. The NPC of the system cases of case 1, case 2 and case 3 are found to be $67,809.78, $78,667.73 and $81,121.06 with levilised COE of $0.07407, $0.08611 and $0.08591 respectively. The initial cost was expensive because of the PV that makes the fraction of the capital in NPC to be the highest and cost of fuel consumed by the DG in the period when the battery system, PV and wind turbine are unable to fulfill the electricity demand and it was found to be the highest contributor. It was observed that the electricity generation by component was 100% done, with an excess electricity prodution of 25% compared to case 3, case 4, and case 5 which has the excess electricity production of 18.7%, 17.2% and 10.1% respectively. More so, it was also observed that the cash flow of the systems in case 1 and case 2 are increasing to the peak untill the end of the 25 years therefore, the wind solar hybrid energy system in case 1 which is the most optimized those not only function better than other cases but it also displays most economic feasibility of the system in Manasa community.

4.6 EMISSION ASSESSMENT

The consideration of the amount of green house gas and pollutant emission released is very vital when investigating the feasibility of a renewable and non renewable hybrid energy system because they also contributes to the global warming. In the present study the emissions are associated with the burning of diesel fuel and the annual consumption of the diesel wth its emissions are based on the density of the surlphur and carbon contents. The pollutant emissions of the five different cases configured are presented in Table 9 above. The emission total values given by the components such as CO_2, CO, UHC, PM, SO_2, NO_X are presented according to the system cases. Therfore base on the emissions assessment, the wind solar hybrid energy system in case 1 was found to be the most environmental friendly system in Manasa community.

Table 9: Pollutant emissions (kg/year) of the five different cases

HES Cases	CO_2	CO	UHC	PM	SO_2	NO_X
PV/wind/battery	0.00	0.00	0.00	0.00	0.00	0.00
PV/battery	0.00	0.00	0.00	0.00	0.00	0.00
PV/wind/DG/battery	5,094	32.1	1.40	0.195	12.5	30.2
Wind/DG/battery	18,830	119	5.18	0.719	46.1	111
PV/DG/battery	8,147	51.4	2.24	0.311	19.9	48.2

The results of the entire System configurationsrevealed that the PV output has the highest electrical production in the month of March and lowest production in the month of August the highest values of the PV output production is due to the weather condition where the sun radiation is very intense at that particular period, and in August when the rain is intense the PV output is low due to cloud cover,while the wind turbine is observed to have the highest electrical production in the month of May and the lowest electrical production is recorded in the month of October. This is because the WECS output cannot supply the electrical demand of the study area in a whole day without the support of other energy resources.

5 CONCLUSIONS

The inexhaustible energy available in nature can be harnesses and utilized to provide source of electricity that is sustainable than fossil fuels. Access to electricity is particularly important concern for people without access to the electricity grid. The economic feasibility of hybrid power systems integrating renewable energy to meet the load requirements of Manasa community in Aliero, Kebbi State of Nigeria has been successfully investigated using HOMER software. The feasibility studies and optimization analysis of wind-solar hybrid energy system in Manasa community of Kebbi State Nigeria was investigated, the result of the simulation shows that two pieces of Generic 10kW wind turbine with the total rated capacity of 20kW, Levelized cost of $0.07407, NPC to be $67,809.79 and for the system converter it has the capacity of 19.8Kw, and an operating cost of $1,151.97 with a fuel price of $0.40/L.

Rural electrification improves the quality of life of rural dwellers having limited or non-access to electricity through decentralized electricity coverage. Since the price of oil is unstable and fluctuating day by day and grid expansion is not also a cost-effective solution, integrating renewable energy sources thus become an important alternative for rural electrification. The world facing the problem of global scarcity of electricity and pollution can be easily overcome with renewable energies. Base on the research carried out, wind solar hybrid energy system is the most feasible among all the five different cases which shows that having wind-solar hybrid energy system operating in the rural communities would create low cost of electricity and improve the living standard of life of the dwellers of rural communities and also more interest in developing health care centers. In conclusion the government should reduce the dependency on natural grid by providing wind-solar hybrid energy systems for the rural communities.

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