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Hybrid renewable energy system for 5G mobile telecommunication applications in Akure, Southwestern Nigeria.

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Abstract: Hybrid renewable green energy (solar and wind) configuration is mostly used in a specific situation where the power grid source is not efficient or costly. The ultimate rates associated with power grid source can be minimized through proper equipment sizing and load matching. This research aims to adopt precisely the efficient use of optimization of hybrid green energy system needed for powering base transceiver stations (BTS) for 5G mobile network applications in Akure, Nigeria. A dynamic simulation and optimization were carried out using Hybrid Optimization for Multiple Electric Renewable (HOMER 3.6 pro version) software to properly assess the appropriate level of the net present cost, operating cost per year and the energy cost/kWh. It was found precisely that hybrid renewable energy can be reasonably achieved in the study location. Renewable Hybrid-1 energy system is the optimized configuration in which photovoltaic, wind and conventional energy source| (diesel generator) typically contributed 60%, 30% and 10% of the total energy. These considerably percentages are equivalent to 5696 kWh/yr, 28976 kWh/yr and 9054 kWh/yr respectively. The renewable energy generated from all the hybrid sources can sufficiently satisfy the needed amount by the BTS with a total amount of 65700 kWhr/yr. The effective operation and maintenance cost, net present cost, and total cost of energy per kilowatt were typically₦3.06 million, ₦101 million and ₦118.80 kW/hr respectively. The overall result will produce economically the needed cost effectiveness power system that can positively enhance 5G operation and minimize the level greenhouse gas emissions within the study location. Hybrid-2 was undoubtedly found to be the possible configuration with lowest emission of CO_2, but it is economically not cost effective.

Keywords—Optimization, Hybrid Renewable Energy Systems (HOMER), Cost Effectiveness, Base transceiver station

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1.0 INTRODUCTION

Energy crises are exceptionally affecting some developing countries like Nigeria; therefore, there is a need for urgent national degree of research and development in the country. This will enable us to develop a system that can provide electrical energy from renewable energy at industrial, domestic, and commercial level. Wind, solar and biomass are good alternative energy sources which are the environmental friendly and abundant in nature, installation of this green energy sources require a huge capital cost for it to be installed.

In the past few decades, productions of energy were the order of the day because the burden has been seen on all the present sources of energy. Electrical energy is the backbone for the advancement of every nation. However, there is a need to replace the conventional energy resources so as to have efficient energy supply (Abraiz and Muhammad, 2012). Green energy resources are persistent, they naturally renew themselves and they are the environmental friendly. Non-renewable energy resources like petrol, coal and gas gradually decrease with time (Fesli and Bayir, 2009). However, the utilization of hybrid arrangement is the best option to improve the productivity of the system because the wind and solar energy resources are function of weather and timing, and that the scheme uses green energy most of the time (Jahdi, 2012). The availability of these natural resources (wind and sun) still remains uncertain, therefore, the system should be interconnected with the conventional means of energy generation (grid and diesel generator) so as to serve as backup when the green sources are unavailable to supply an efficient energy. This will make the system efficient, cost effective as well as dependable. Research and development is nevertheless required in the aspect of control management and design of this system to implement these technologies on domestic level (Ferreira *et al.*, 2003). At the moment, there are approximately four million macro base transceiver stations (BTS) installed worldwide, and each of the BTSs uses an average of 25 MWh of electrical energy per year (Lorincz and Bule, 2013, Balogun *et al*., 2017). The estimated values increases tremendously from year 2013 onward at a rate of 25% every year parallel to the increasing traffic demands, particularly in developing countries (Hassan *et al.,* 2011). The BTS are the primary energies needing part of the

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mobile telecommunication networks, due to diesel generator predominantly used throughout the operational period of the BTS these leads to increase in the amount of greenhouse gas (GHG) emission and high operating and maintenance cost (Murthy and Kavitha, 2012). Additionally, reduction of quality of service (QoS) can be experienced when there is over burden of micro cells due to the increment in power demand by BTS (Zhang *et al.,* 2015). In line with this objective, a call to save about 2.5 billion litres of diesel by the year 2012 was initiated by Telecommunication companies. This will assist to reduce CO_2 emission to a greater extent (Vincenzo and Sara, 2011, Balogun *et al.,* 2017). In addition, Airtel Telecommunication Company in Nigeria has started upgrading 250 BTS from diesel generator to a more environmental friendly green-renewable energy site to reduce the epileptic power supply and GHG emission to the concerned environments (Ani and Nzeako, 2008).

The recent call for migration from 4G to 5G mobile applications reflect another view to this study. Fifth generation telecommunication networks are aimed at achieving the requirements for mobile communications by supporting the inevitable increase in mobile data consumption. The features of fifth generation networks is not limited to capacity, data rate and latency enhancement, It is equally about maximum flexibility, to deliver a broad variety of services across a range of environments using disparate technologies in a highly efficient, robust and cost effective way (Brydon, 2014). Attaining the levels of flexibility, agility and cost effectiveness needed by future mobile networks will depend on novel architectural approaches especially in the adoption of green renewable energy systems (Brydon, 2014).

In this work, simulation and optimization were carried out using optimization tool-HOMER to assess the net present cost, operating cost per year and the energy cost/kWh for 5G mobile telecommunication applications in Akure, South western Nigeria.

The other sections of the paper are structured as follows: section two provides information on the site and data acquisition, as well as the methodology adopted. Part three is for results and discussion while section four gives the conclusive remarks.

2.0 Description of the Site and Data Acquisition

Figure 1 describes the studied location- Akure (7° N, 5° E), the capital city of Ondo State, Southwestern, Nigeria with population of about 484,798 based on 2006 population census. It also has a tropical climate which has a significant rainfall in most months, with an average annual temperature of 26.7 °C. Agriculture (including fishing) constitutes the main occupation of the people of the state.

Based on this study, the power consumption in BTS over some selected locations are investigated. The BTS locations are: Oke-Ijebu, Shagari Estate, Ijoka, Ondo Road, Owo Express Road and Alagbaka. The characteristics of each of the locations are presented in Table 1. The BTS in the chosen sites comprises of different types namely: backbone, micro and macro base stations. Macro cell type of BTS is used to cover a wider range compare to the micro base station which covers a shorter distance and it consume lesser power while backbone BTS have heavier equipment and it controls the macro and the micro BTS. The macro cell types of BTS are majorly found in all the locations of the studied sites. Table 2 presents different types of BTS based on the amount of the electrical power utilized. The values presented in Table 2 shows that the backbone BTS will utilize about 21.6 kW power to cater for heavier equipment and controls the macro and the micro BTS.

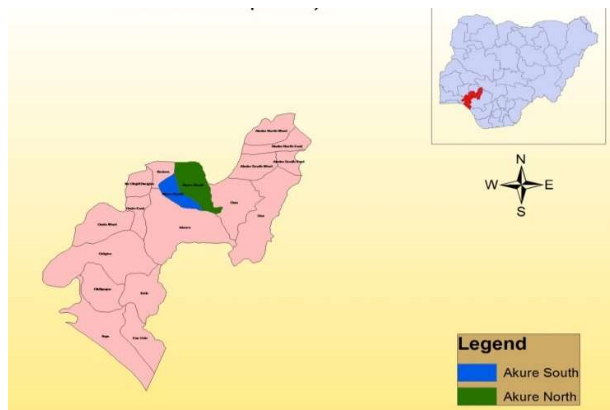

Figure 1: The map of study location (Akure, Nigeria).

Table 1: The study location within Akure south and north local government

Studied Location	Network Provider	Coordinate of Studied Location in degree (°)
Oke Ijebu	MTN	7.264746N, 5.204355E
Shagari Estate	MTN	7.286098N, 5.201068E
Ijoka	GLO	7.236135N, 5.225486E
Ondo Road	MTN	7.251807N, 5.148010E
Owo Express Road	GLO	7.278099N, 5.209665E
Alagbaka.	GLO	7.246199N, 5.226214E

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Table 2: The power consumption based on different categories of BTS

S/N	Types of base stations	Total load on generator (kW)
1	Backbone	21.60
2	Macro	7.50
3	Micro	4.50

Figure 2 shows the hourly load consumption in the BTS for a period of 24 hrs. During the period between 08:00 and 19:00 hours of the day, the power consumption is 7.3 kW because the security light will be put OFF. However, additional 0.2 kW will be added to the load unit in the night hours especially when the security light is put ON. Also the total amount of load that can be on the diesel generator in addition to the night period is about 7.5 kW. This is regarded as the total power utilized in the BTS.

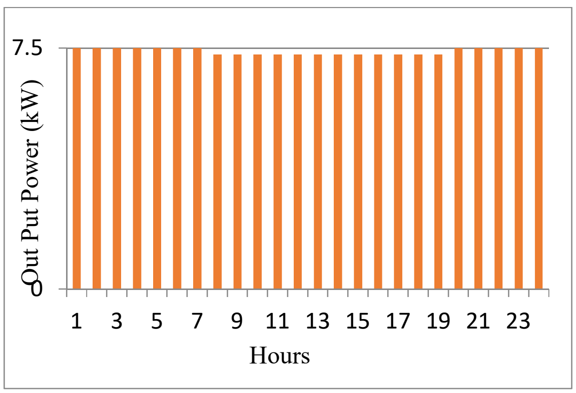

Figure 2: Daily profile of load utilization at the BTS

2.1 Data sets

For this empirical study, 22 years (1983-2005) solar irradiation and wind speed satellite reanalysis data obtained from National Aeronautics and Space Administration (NASA) were used appropriately to typically model the prevailing wind and alternative energy subsystem for different telecommunication base stations in the study location. The global positioning system (GPS) in HOMER was typically used to map out the precise coordinate within the base stations of the research sites. Table 3 presents the monthly average solar irradiance and wind speed reanalysis data obtained for the chosen site.

For the specific purpose of sufficient clarity and correctness, a high-resolution, ground-based tropospheric data acquisition network (TRODAN) data available from independent stations located in Akure, Nigeria, were equally used for the empirical validation of this work. The specific instrument is located at a Latitude of 7.29575° (N), and Longitude: 5.14811° (E) with elevation angle of 20 m above the seal level (ASL). Akure, in the South Western province of Nigeria has very good potential in solar resources, the average solar radiation is precisely between 5.6 – 5.8 kWh/m^2/d, delivering the highest solar radiation in the month of February. The wind speed in study location is poor which utilize the average resource between 2.5 m/s to 3.2 m/s, month of March typically having the highest wind speed. According to NREL the wind speed fall under class 1 (lowest) wind speed.

Table 3: Monthly average solar irradiance and wind speed data for the study location

Months of the Year.	Average Wind Speed (m/s).	Monthly Average Irradiance (kW/m^2/d)
January	2.980	5.670
February	3.110	5.770
March	3.230	5.630
April	3.060	5.350
May	2.590	5.030
June	2.630	4.560
July	2.740	3.980
August	2.810	3.780
September	2.650	4.090
October	2.350	4.650
November	2.690	5.260
December	2.660	5.500
Average	2.790	4.940

2.2 System Model

Figure 3 shows how the system is typically designed in such a way that the Photo voltaic, fuel cell and the battery are connected to the local DC bus while the independent generator and the modern wind turbine are properly connected to the local AC bus. The converter is precisely an intermediary between the AC and DC bus. The battery in this system precisely serves as potential source of considerable power when the scheme is down and is equally a typical load in the continuous process of charging.

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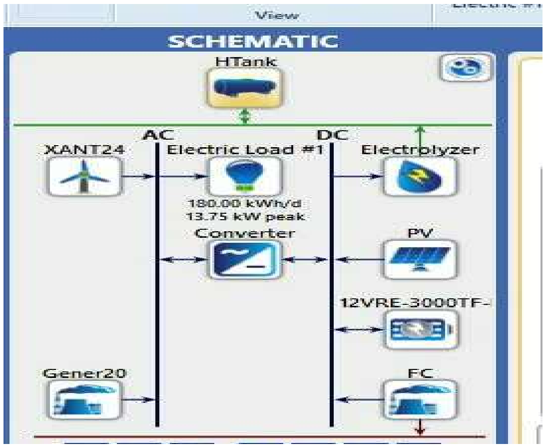

Figure 3: Systematic diagram of how hybrid energy is been configured

2.3 Optimization Process

Optimization process is achieved using HOMER to determine the optimized hybrid system that satisfies user specific constraint with lowest total net present cost (TNPC). The TNPC is estimated as:

$$TNPC(C_i) = N_i\left(CptlC_i + (RplC_i \times M_i)\right) + \frac{OMC_i}{CFR} \quad (1)$$

where C_i is the overall system annualized cost, N_i is total number of component, C_c capital cost of the component R_c, replacement cost of component, M_i single payment present worth of a component, OMC_i operation and maintenance cost of a component and *CRF* is the capital recovery factor

The overall system annualized cost is computed using:

$$C_i = C_{PV} + C_{WT} + C_{FC} + C_{DG} + C_{CONV} + C_{BAT} \quad (2)$$

where C_{PV} is the cost of photo voltaic cells, C_{WT} Is the cost of wind turbine, C_{FC} is the cost of fuel cell, C_{DG} is the cost of a diesel generator, C_{CONV} is cost of converter and C_{BAT} is the cost of a battery.

where

$$CFR = \frac{ir(1+ir)^R}{(1+ir)^R - 1} \quad (3)$$

where *CFR* capital recovery factor, *R* project life time and *ir* the annual interest rate for project.

2.4 Power Generated From Renewables

2.4.1 Wind Turbine

Wind turbines work by converting the rotational kinetic energy into electrical energy. According to Jin *et al,* (2014) energy generated by wind turbine can be expressed as

$$P = \frac{1}{2}.\rho.A.V^3 \quad (4)$$

where P is the energy generated by photo voltaic, cells ρ is the density of air (1.22 kg/m^2), *A* is the swept area by the turbine and *V* is the wind speed at hub height (m/s).

2.4.2 Photo Voltaic (PV)

Mathematical model for Solar Photovoltaic Generator using the available solar radiation require the hourly energy output of the PV generator (E_{PVG}) and can be calculated using:

$$E_{PVG} = Y_{PV}\, F_{PV}\left(\frac{G_T}{G_{T,STC}}\right) \quad (5)$$

where E_{PVG} is the energy generated by the wind turbine, Y_{PV} is the rated capacity of the PV array (kW) to be modelled, F_{PV} is the PV de-rating factor (96%), G_T is the solar radiation incident on the PV array (kW/m^2) from solar data and $G_{T,STC}$ is the incident radiation at standard test condition (1 kW/m^2).

2.5 Battery Sizing

To calculate the battery size required to provide for n days of back-up in the event where there was no sun and no enough power generation from wind turbine, the battery bank would need to be rated as follows (Faruk *et al*, 2012).

$$E_t = P_t \times T \quad (6)$$

where E_t is total energy required in the telecommunication base station (kWh), P_t is total power consumption (W) and *T* is the operating time of the equipment is 24h

$$B_{AHR} = \left(\frac{E_t \times n}{V_s \times \eta}\right) \quad (7)$$

where B_{AHR} is ampere of battery storage (Ah), N is the number of autonomy, V_S is the operating voltage of the battery (V), η is efficiency of the battery = 0.8 and E is total energy that will be obtained from equation (7)

$$N_{BTR} = \frac{B_{AHR}}{I_b} \quad (8)$$

where B_{AHR} is ampere of battery storage hours (Ah), N_{BTR} is the total number of battery to be used I_b is the current rating of the battery.

3.0 Results and Discussion

Table 4 shows the simulation result of the optimized hybrid configurations generated by HOMER. Traditionally based on the lowest total net present cost, reasonable cost of renewable energy and operating and maintenance cost as properly presented in Table 4 shows that hybrid configuration hybrid-1 (PV/Wind/Diesel Generator) can be found to be recommended for this area. That is, the PV/Wind/DG hybrid energy system type could be typically considered as the most appropriate (optimal) hybrid renewable energy solution option for powering any base station at the considered location. This preferred option is followed by;

Hybrid-2 (PV/Wind/ Fuel cell/DG hybrid energy system),

Hybrid-3 PV/DG hybrid energy system,

DG only, in that order.

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The simulation result in Table 4 also shows that solar system and modern wind turbine can be adopted precisely in the specific location of study. This can be achieved with PV cells of 39 kW and wind turbine of 95 kW to reasonably satisfy the renewable energy needed. It clearly shows that the fuel cell cannot be used due to the continuous non-availability of excess energy from PV and wind turbine to adequately supply to the electrolyser in other to efficiently generate hydrogen gas. The generator rated 20 kW represent part of the simulation result to serve as backup when the renewable sources and the battery bank are down, total net present cost (NPC) ₦101 million, possible cost of renewable energy per kWh is precisely ₦118.80 and operating and maintenance cost is ₦3.06 million while net present cost, cost of energy per kWh and operating and maintenance cost is ₦207 million, ₦354 and ₦12.4 million. The optimization result shows that 56 batteries will be used correctly in the BTS for the optimized configuration and 114 batteries will be typically used for the diesel generator configuration only.

The total Net Present Cost (NPC) increases with the considerable decrease of renewable energy components in the hybrid systems. This empirical observation unanimously agrees with the published work of Bagul *et al*., (1996), in which notable source renewable energy usually leads to active component oversizing, which increases the operating and the life cycle cost.

Table 4: Optimization result for hybrid configuration

	RENEWABLES/QUANTITIES			GENERATOR (kW/1)	BATTERY QUANTITY	CONVERTER (kW)	NPC (₦) in million	COE (₦/kW)	O&M (₦) in million
HYBRID-1	PV	Wind	X	20	56	11.00	101	118.80	3.06
	39 kW /39	95kW /1							
HYBRID-2	PV	Wind	Fuel cell	20	56	12.60	106	124.33	3.20
	39 kW /39	95kW /1	25kW						
HYBRID-3	PV	X	X	20	56	11.60	110	130.00	3.60
	39 kW /39								
DIESEL GENERATOR ONLY	X	X	X	20	114	11.70	207	354.00	12.24

Figures 4 and 5 presents the monthly average of the solar and wind output power over a considerable period of one year. The possible results show that renewable energy is routinely available in the month of January to April and October to December. Solar energy generation reduces in the typical month of May to August, during these months we have much rain fall which appreciably reduces the clearness index of the atmosphere while in the typical months of January, February, March and April, wind turbine contribute significantly to the green energy hybrid system and in the months of May to December wind turbine contribute less significant to the hybrid green energy system due to more of precipitation and the commencement of dry season.

Figure 6 shows the considerable variation in all potential sources of renewable energy combine with the independent generator. It can be seen precisely that the solar system generates excess energy (above 7.5 kW). The electrical energy supply by the independent generator is minimal which shows that the considerable length of specific usage have been modestly reduced. The independent generator usage also increases in the specific months where the renewable energy appreciably because, the time of charging the backup (battery) reduces.

The independent production of each system is presented in Figure 7. Photovoltaic production represents 60% with 56969 kWh/yr, wind turbine is expected to generate power of 30% with 28976 kWh/yr and finally, diesel generator production represents 10% with 9054 kWh/yr which shows that the emission rate of Co_2 will drastically reduce and make the atmosphere safer.

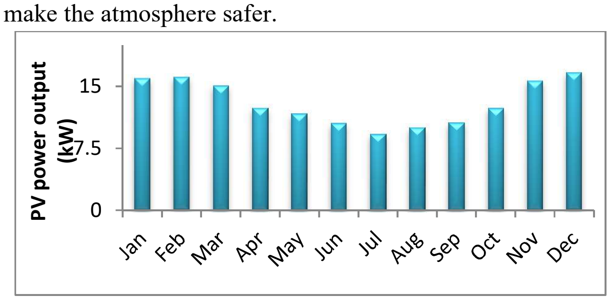

Figure 4: Monthly average of the output energy generated by photo voltaic (PV)

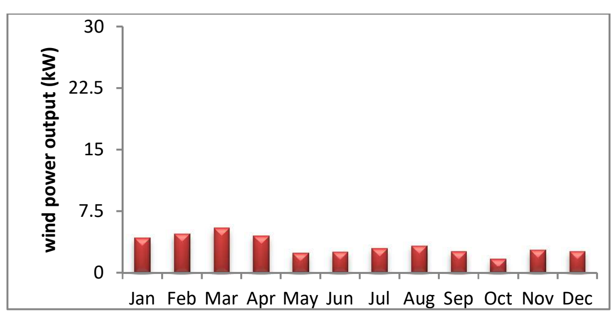

Figure 5: Monthly average of the output energy generated by wind turbine

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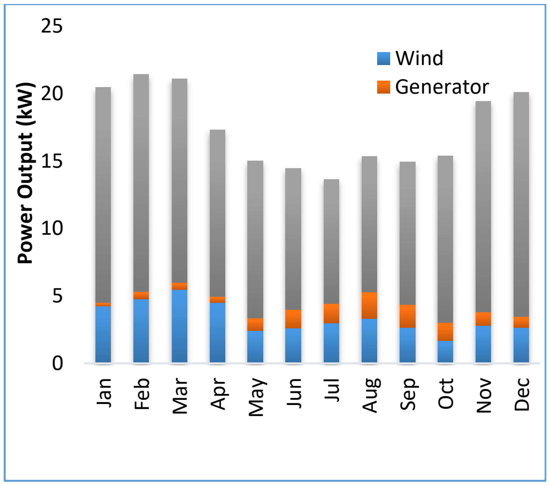

Figure 6: Trend in all independent sources of energy to the base stations

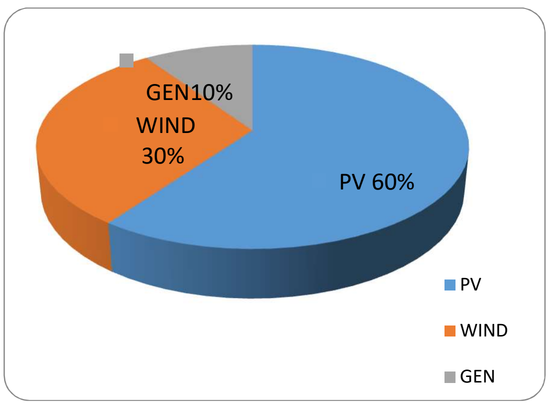

Figure 7: Contributions of hybrid energy source to the base stations.

Table 5 and 6 also presents the empirical validation of the prevailing wind and solar data using ground base measurement data, the possible reason for this is not far-fetched, carefully considering the fact that the intelligent HOMER software is using appropriately satellite data which demonstrates a significant tendency to properly obtain a considerable value at some specific regions like a coastal area. Often considerable times there is necessary adjustment to carefully adjust some loss factors from the possible default, and with other losses of about 15 % cumulated from multiple losses such as module mismatch, formidable array and ohmic-losses and the insolation that is typically provided by its empirical data.

Table 5: Validation of average monthly wind speed for Akure, Nigeria

Month	Average wind speed at anemometer height of 10 m (m/s)		Wind speed at anemo meter height of 50 m (m/s)		
	2011	2012	NASA	(In-situ) wind monthly average power generated (kW).	(Satellite) Wind monthly average power generated (kW).
Jan	0.78	0.89	2.98	1.60	4.22
Feb	1.17	1.36	3.11	5.58	4.77
Mar	1.32	1.28	3.23	6.03	5.47
Apr	1.04	1.29	3.06	4.39	4.51
May	1.07	1.07	2.59	3.36	2.41
Jun	1.10	1.14	2.63	3.86	2.58
Jul	1.34	1.44	2.74	7.35	2.98
Aug	1.39	1.54	2.81	8.63	3.29
Sep	1.19	1.19	2.65	4.63	2.63
Oct	0.84	0.89	2.35	1.81	1.61
Nov	0.89	0.94	2.69	2.10	2.79
Dec	0.77	0.85	2.66	1.6	1.60
Average	1.08	1.16	2.70	4.23	3.32

Table 6: Validation of average monthly solar irradiations for Akure, Nigeria.

Month	Solar Irradiance (kWh/m^2/d) Average				
	2011	2012	NASA	(In-situ) PV monthly average power generated (kW).	Satellite monthly average power generated (kW).
Jan	3.64	2.93	5.67	10.24	15.85
Feb	3.88	3.31	5.77	11.23	16.18
Mar	3.91	4.12	5.63	12.53	14.82
Apr	4.37	4.41	5.35	13.69	13.29
May	4.13	4.04	5.03	12.7	11.65
Jun	3.84	3.94	4.56	12.16	10.50
Jul	3.30	3.03	3.98	9.87	9.96
Aug	2.76	2.47	3.78	8.16	9.61
Sep	3.19	2.66	4.09	9.13	10.75
Oct	3.22	3.21	4.65	10.03	12.86
Nov	3.74	4.09	5.26	12.21	15.65
Dec	3.37	4.14	5.50	11.72	16.65
Average	3.61	3.87	4.94	11.66	13.15

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Figures 8 and 9 show the net present cost (NPC) of the individual component and how the cash is spent and necessary money sufficiently realised from the system respectively. The combined net present cost (NPC) of a system has been adequately described as the present value of all the operational costs that it typically incurs over its operational lifetime, minus the present value of all the potential revenue that it typically earns over its operational lifetime. Operational costs include capital costs, replacement costs, active operation and maintenance costs, fuel costs, and the operational costs of buying power from the local grid. Potential revenues typically include salvage value and grid sales revenue. However, the functional analysis presented here typically considers neither the operational costs of buying power from the local grid nor grid sales revenue, since the specific focus of this empirical study is on BTS. Results from Figure 8 shows that wind turbine is most costly followed by the battery, photo voltaic and the net present cost of the converter, in that order; while Figure 9 shows how the NPC is being typically spent throughout the life cycle of the hybrid energy system. It also shows the 1st year include the most significant expenditure which represent the initial cost of the hybrid setup. There are possible replacement and proper maintenance in the 9th, 12th, 16th, 21th, 22nd and 24th year. However, in the 21th year, a capital maintenance was carried out and the 26th year shows the salvage revenue, that is, the considerable amount that the expired system is been sold off.

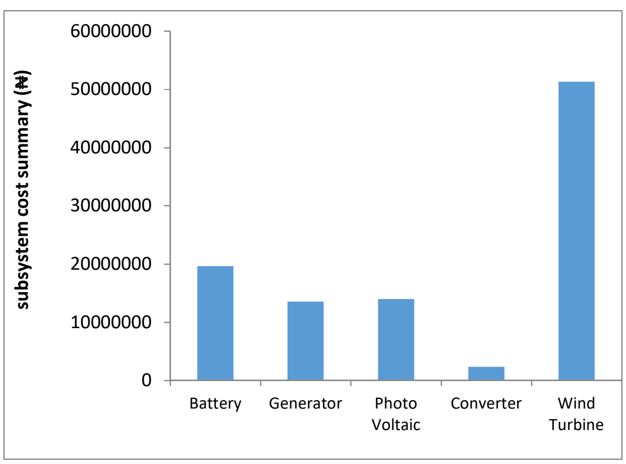

Figure 8: Estimated cost summary of individual components of the hybrid system.

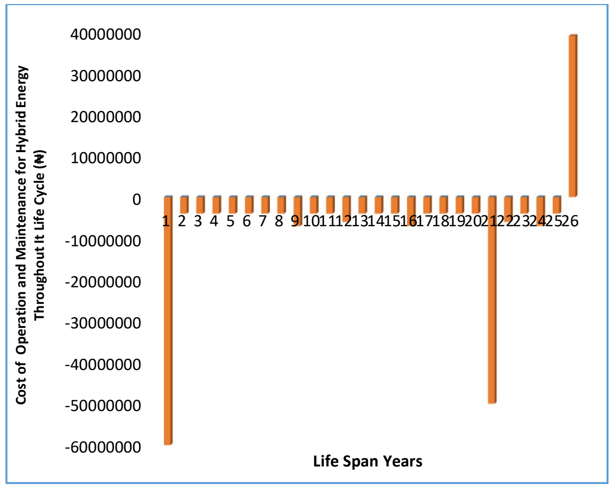

Figure 9: Estimated cash flow throughout the life cycle of the hybrid system

In Table 6 hybrid-2 has the lowest emission with the highest number of renewable energy component of PV/wind/fuel cell and DG follow by hybrid-1 that has lesser component of renewable with PV/wind and DG. The use of only DG shows the highest value of CO_2 emission which really justify the need and advantage of renewable energy source in other to make the atmosphere safer.

Table 6: Emission generated from individual hybrid system

Emission	HYBRID-1 kg/yr	HYBRID-2 kg/yr	HYBRID-3 kg/yr	Diesel generator and battery (kg/yr)
CO_2	13710.6	10968.48	54844.24	109684.8
CO	93	74.4	372	744
CH	23.75	19	95	186.4
Particulate matter	5.65	4.52	22.6	56.5
Total emission	13833	11066.4	55333.84	110670.5

CONCLUSSION

In this study hybrid system possessing various combinations of energy, sources were carefully analysed by properly utilizing HOMER software. The minimum cost of renewable energy (CoE) was found with solar-wind and diesel generator system (hybrid-1) at load of 180 kWh/d, with minimum cost of energy at ₦118/kW. The nets present cost (NPC) for the entire system is typically ₦101M. The most expensive configuration is typically modern diesel engine only with COE of ₦151/kW which clearly show that hybrid renewable is cheaper and Cost Effective for BTS in Akure. The energy generated by the

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renewable (PV and wind) and diesel generator were accurately determined and the results show that the PV efficiently generated more energy (60%) to the BTS which will typically serve as the primary source of power to the BTS of the studied location, followed by the wind turbine which generates only 30%. One of the ultimate objectives of the research is reasonably achieved by typically reducing the specific usage of the independent generator which progressively reduces the cost of operating and necessary maintenance normally spent by telecommunication companies and it reduces the pollutant emission (CO_2, CO, CH and the particulate matter) due to gradual reduction in hours or specific period which diesel generator is being used appropriately. This was achieved by optimal usage of the renewable energy before adequately considering the diesel generator.

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