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Optimal sizing and techno-economic analysis of a hybrid solar PV/wind/diesel generator system

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Abstract. Hybrid power systems that combine wind and solar PV technology have been widely employed for power generation, particularly for electrification in remote and islanding locations, because they are more cost-effective and reliable than traditional power systems. This article intends to develop an environmentally friendly and cost-effective hybrid power system for selected critical loads in the Avuto community of Ghana. Following the acquisition of site data, a hybrid solar PV, wind, diesel generator, and converter analysis was conducted using HOMER software to establish the appropriate sizing of system components based on technical and economic parameters such as load served, annual electricity production, net present cost (NPC), emission, Operating cost, Fuel consumption and energy cost (COE). Based on the optimization computational results, it can be stated that the combination of system components, including solar photovoltaic, wind turbine, and diesel generator, is a good fit for the application region and might be used for rural and island electrification in the future. The suggested energy system has an LCOE of 0.39 US$/kWh for the 1.08 US$/litre diesel fuel cost and a 3.33-year payback period, with 58.8 kW for PV, 7 units for 3 kW wind turbines, 10 kW for diesel generator, and 6.99 kW for the converter. In terms of emission reduction, the proposed case presented a 55% emission reduction from the base case scenario.

1. Introduction

In most developing countries such as Ghana, access to electricity for rural communities is challenging despite the pledge to ensure the United Nations sustainable development goal 7 (Access to reliable, clean and affordable energy to all). These rural communities are either isolated from the grid due to their geographical location or grid extension such areas are economically impossible. According to a study conducted by [1], the population of people without access to electricity are over one billion in the World. To address the rising need for electricity, some countries aim to extend the main grid to those places where power is scarce, while others rely on diesel generators to provide basic electrification when it is required. The former method, as previously stated, is difficult to implement because the grid extension to such areas is economically not feasible.

According to a World Bank study on rural electrification programs, each km of grid extension in challenging terrains like islands and forests might cost up to $22,000 [2]. On the other hand, several challenges remain for the later power supply solution, such as rising costs, fuel logistics and storage, and noise and carbon emissions in environmental pollution [3]. The cost of electricity generation might be more than three times the cost of the national electricity bill.

Biogas, Solar PV and Wind energy technologies have seen decades of researches leading to their technological development in recent times. For these reasons RETs can be applied with high potential and reasonable expenditure to develop this alternative energy system. However, there are still certain obstacles to overcome. Due to the unavailability of renewable energy resources, which are subject to weather conditions, it is difficult to adjust output power to satisfy load demand [3].

Electrification in some developing countries is based on diesel generator, which has some limitations, whilst using exclusively renewable sources for power generation is also challenged with several issues, including the intermittent nature renewable sources and their associated high cost of investment. The current trends for microgrids for isolated rural communities have emerged over the past few years to be an alternative and clean source of energy supply. As a result, hybrid renewable energy [4,5]. HRES plays an essential role in power supply due to its capability to improve reliability, cost efficiency, and environmental friendliness [6]. Renewable energy systems have numerous merits when hybridized to meet reliability of power supply throughout the day. When one renewable energy technology (RET) is unable to generate due some weather conditions, another RET can generate to supply the energy demand. For instance, when solar energy is not available during cloudy days, wind turbines or tidal energy can be used to supply the energy demand. The advantages of mixing different renewables for greater benefits are well explained by [7,8].

Similarly, for wind generation, the most important consideration is the location of the site, which receives a consistent amount of wind. This system is almost self-sufficient in non-conventional energy and decreases long-term energy prices, with a diesel generator hybridized with wind to be utilized as a backup in instances such as large loads or low renewable power availability [9,10].

A viable HRES study is developed in this study to find an optimal size of the Solar PV/Wind/Diesel generator system for improving the current electricity system on Avuto.

Small businesses linked to tourism services, such as souvenir shops, hotels and resorts and the fish market have recently had the potential to flourish as a result of the growth of tourists. Furthermore, the presence of tourists has drawn investment for the development of city infrastructure, buildings, hotels, and other amenities, thus raising the level of living in the local community. This development calls for effective and efficient telecommunication services to improve service delivery in this community. The objective of this study is to assess the techno-economic viability of introducing a hybrid renewable energy system to power a telecommunication base station and a tourism and community clinic in Avuto using HOMER software.

The absence of electricity supplied by engine-based diesel generators continues to plague rural areas where communications masts are built. The use of hybrid energy (PV/Wind/Generators) to power telecommunication towers can ensure energy continuity and ensure the telecommunication network in Avuto. Many researchers have conducted studies into the feasibility of supporting the energy demand of telecommunication base stations in remote areas in the world. This section presents studies that have been conducted in this special area.

In a comparative analysis study, [11] evaluated the economic and technical performance of standalone solar PV and diesel generator system to supply the power requirement of a telecommunication system in Malaysia. The authors used the HOMER software to design and compare the two systems. The technical and economic parameters used to evaluate these two systems were the life cycle cost, ability to meet the load requirement of the telecommunication system 24 hours each day. The results of the research highlighted the reduction in the net present cost of the proposed HRES to the conventional diesel generator power system from RM 610.639 to RM 421,244. Many similar studies, including [12–1]]relied on Homer to perform technical and economic analysis.

The authors in [18] conducted a study that assessed the financial and technical viability of different renewable energy technologies for telecommunications in India. Twenty-one locations in India were selected for this study. The study adopted LCOE for nine different hybrid renewable power configurations. The proposed configurations were technically evaluated using power supply availability for different hours (1hr, 2hrs, 4hrs, 8hrs, 12hr and 16hrs). The study revealed that among the nine configurations that were simulated, grid connected solar PV power system had the lowest LCOE for 1hr unavailability of power supply whiles another configuration with grid connected Wind, solar PV, Diesel generator and battery recorded low LCOE with 4hrs power unavailability.

Salisu et al. (2019) investigated a hybrid power system [19]. In this energy management system, different renewable energy systems were integrated to reduce the overall cost of hybrid power system. The An optimization method with multiple objective function aimed at minimizing cost, was adopted to select the best combination of riots' that will meet the load demand of the system. In addition, the study also reviewed other studies and their optimization models applied to similar RET configurations.

Again, [20] demonstrated with an FM transmitter station, the viability of a hybrid renewable energy system consisting of solar PVs and diesel generator system. The objective was to achieve a 100% reliability and reduction in cost of electricity. In Tunisia, [21] used a modelled a solar PV and wind hybrid system for Tunisia. The mathematical algorithm considered energy production, energy conversion efficiency, sustainability and resource maps of potential renewable sites. The algorithm used resources data to predict the hybrid renewable energy technology of the area.

Essalaimeh et al. (2013) used the weather resources of Jordan to evaluate the performance of a hybrid renewable energy system [22]. The experiment used variable load resistors to model different load conditions to measure their electrical energy productions. The HRES consisted of a solar PV and Wind technology. A simple payback period was estimated using mathematical modelling to assess the economic viability of the proposed hybrid system.

Kabalci et al. (2013) designed a renewable energy power plant using wind and solar PV system [23]. The authors adopted perturb and observed algorithm with a PI controller to control the proposed solar PV and wind energy system. Furthermore, in [24] a solar PV and wind energy design were applied to a mobile base station in a developing country to investigate the feasibility of the proposed standalone microgrid. The study was conducted in three different communities in DR Congo. HOMER computational software was used to design, simulate and optimize the solar PV and Wind energy system. Technical, economic and environmental impact assessment were conducted to rank the proposed system.

Using the HOMER computational software, Li et al. (2013) performed a technical and economic assessment of a standalone microgrid system using Solar PV, Wind and battery storage [25]. The proposed microgrid was designed and analysed using the results from the HOMER software. The simulation results of the study were 5-kW solar PV, 0ne 2.5kW wind turbine, 6.94 kWh unit batteries and a 5-kW converter for the configuration.

El Badawe et al. (2012) conducted a comparative analysis of a renewable energy system and a non-renewable energy system in Canada [26]. The authors adopted a telecommunication station as a case study energy consumer for the proposed comparative study. HOMER computational software was used to design, optimize and simulate the proposed configurations. The energy configuration that incorporated diesel generator was cost effective and reduced the running time of the diesel generator. This reduced the overall emission and fuel consumption of the base station under study.

The authors in [27] proposed an integrated hybrid RE power system that integrates an energy management system. The objective of the paper was to make the energy system efficient and again reduce the cost of energy. The system's effectiveness was tested using PSCAD platform.

Daud et al. (2012) designed and analysed a hybrid energy system to provide electricity for a small family in Palestine [28]. The RE resource availability and load requirement was used to model the viability of the proposed system. The authors developed a computer model to reduce the life-cycle cost and CO2 emissions of the proposed HRES for the family in Palestine. The authors discovered that employing hybrid systems to provide electricity to a residence in this community is effective. For the isolated rural-urban community in Ghana, [29] used Homer software to compare wind/hydrogen fuel cell storage systems with wind/battery energy storage systems. The authors compared the NPC, LCOE, and autonomy days of the two storage systems.

A summary of literature suggests that hybrid renewable energy systems present a better option of providing electricity for remote and island communities at a lower cost and less environmental distraction as compared to grid extension or diesel generator alone. Unfortunately, few literatures have simulated and tested this hybrid renewable energy system to evaluate the potential advantages it presents in terms of cost of energy, ability to meet load demand, reduced investment cost and reliability for the selected location. The objective of this study is to conduct a technical and economic evaluation of a hybrid solar PV, Wind and diesel generator system for the selected community in Volta region of Ghana in terms of cost, availability and ability to meet the community's energy demand. This study has not been conducted before in the selected community and it presents an opportunity for stakeholders in the renewable energy sector and government to overcome the challenge of providing energy for remote and Island Communities at a lower cost but reliable.

2. Materials and Methods

This section seeks to explains to the methodology adopted to achieve the objectives of the study. This section presents the method for energy audit undertaken to determine the load profile of the study area. These sections explain the renewable energy resources, load profile, cost inputs, technical and economic parameters used to model and design the proposed system. In summary it describes how the HOMER computational tool was used to size and design the proposed hybrid system and the existing case. Figure 1 shows the methodology to achieve the objective of this study.

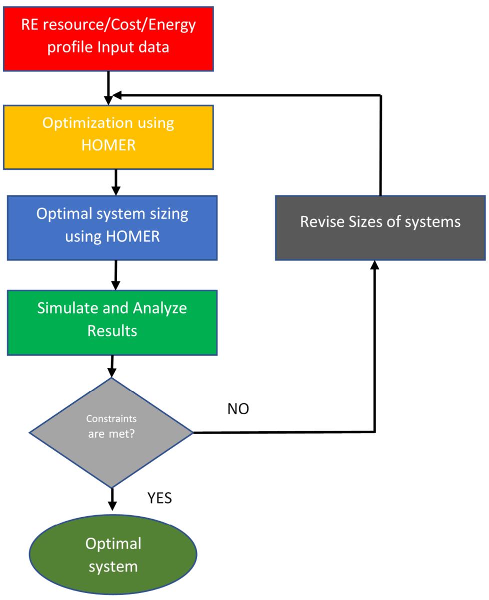


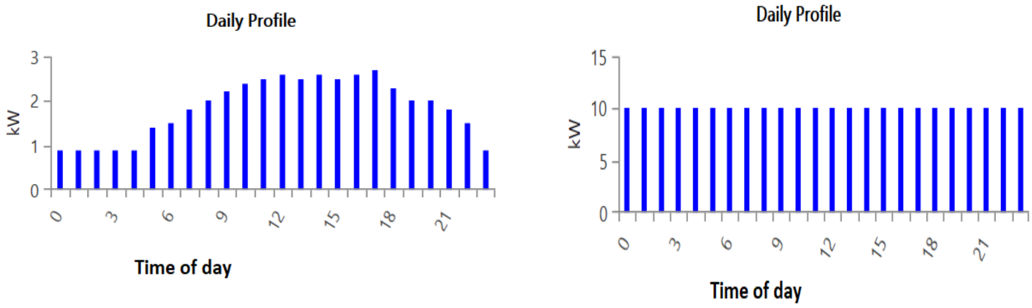
Figure 1. Methodology

2.1. HOMER computational software

HOMER computational software is adopted for the design, simulation, optimization and analysis of off-grid and grid-connected power system solutions for stand-alone, remote and distributed generations, both technically and financially. It allows the exploration of a wide range of technological solutions in order to account for energy resource availability and other factors. There are two optimization methods used by HOMER Pro. The grid search optimization technique replicates all of the Search Space's conceivable system configurations. The second and latest optimization method used by HOMER Pro is the propriety derivative-free method, which find the most cost-effective hybrid system whiles meeting the energy demand of the load. HOMER Pro will then show a list of configurations in order lowest net present cost (also known as life-cycle cost) for evaluation of the system design possibilities.

2.2. Electric load

The energy consumption profile of the study area is shown in Figures 2 (a) and (b). Figure 2 (a) represents the total primary load of the study which consist of the tourism office and the Community Hospital. Figure 2 (b) shows the telecommunication load on the 48V DC bus. The Telecommunication load remains constant because such services require a constant and uninterruptible power supply.



(a) (b)

Figure 2. (a) load profile of Hospital and tourism centre (b) Telecommunication base station

2.3. Geographical location of Avuto

Avuto is a community in the Volta region of Ghana, the capital of Batanes, Avuto is about 69 mi or (110 km) North-East of Accra, the country's capital. Farming and fishing are the two main economic activities in this area. As indicated in Figure 3 (a) and (b), the community's location provides exceptional prospects for tourism.

(a) (b)

Figure 3. (a) location of Avuto (b) Location of Avuto on map

Table 1. Geographical location of the study area

Site	Longitude	Latitude	Altitude
Avuto	5.967543	0.711054	696m

2.4. Solar Resource of the study area

The solar radiation and clearness index of Avuto is shown in Figure 4. Avuto has average solar radiation of 5.52kWh/m^2/day with high radiations in February, March and January in order of highest radiation (6.09 kWh/m^2/day, 5.94kWh/m^2/day and 5.78kWh/m^2/day respectively).

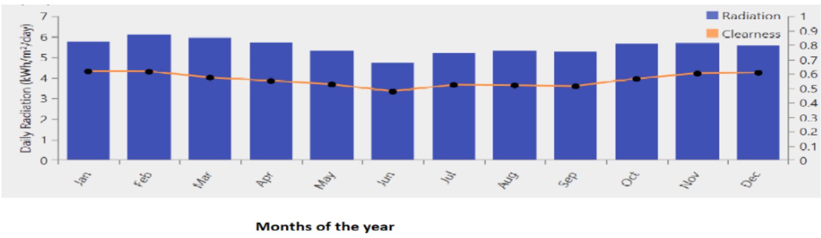


Figure 4. Solar radiation and Clearness index of Avuto

2.5. Wind resource of Avuto

The wind input data from the study area is presented in Figure 5. The wind resources were extracted from the National Aeronautics and Space Administration (NASA) weather satellite for Avuto. The average wind speed is 4.79 m/s with the highest winds recorded in July, August and September with a wind speed of 5.86 m/s, 5.93 m/s, and 5.46 m/s respectively. Other wind resource parameters considered for the analysis of the wind resources are presented in Table 2.

Table 2. Wind resource parameters

Parameter	Value
Anemometer Height (m)	30
Surface roughness	0.014
Weibull shape factor (k)	2

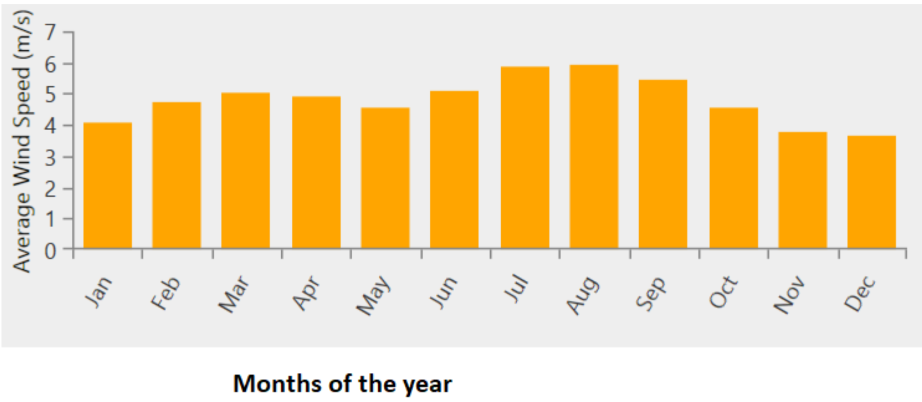


Figure 5. Wind speeds of Avuto

The proposed Solar PV/Wind/Diesel generator is designed in Homer software, simulated and optimized in Homer software. The design configuration is shown in figure 6. The proposed design incorporates two renewable energy technology into the existing diesel generator power system. The dispatch method for the proposed system is to have solar PV and wind serve the energy demand of the load and the diesel generator is used as a standby supply in cases where the former is not able to meet the load demand. The diesel generator provides power when the two renewable technology are not able to meet the load demand of the study area. This is to reduce diesel fuel usage and thereby reduce emissions.

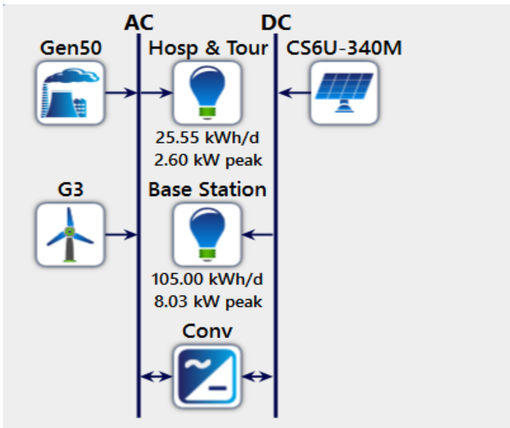


Figure 6. Homer design proposed system

2.6. *Solar PV Module*

The solar PV module with the technical and economic inputs used in this study are presented in Tables 3 and 4. The data used for the cost and technical specifications were adopted from the database of the HOMER software. These costs and technical input s from HOMER software reflect the average cost and characteristics of the solar PV used in this study.

Table 3. Cost input variables

Item	Cost
Initial cost ($/kW)	300.00
replacement cost ($/kW)	300.00
O & M cost ($/kW/year)	4.50

Table 4. Technical specifications of solar PV

Item	Specifications
Solar PV capacity (kW)	0.34
Operating temperature (^{0}C)	45
Efficiency (%)	17.49
Lifespan (Years)	25
Electrical Bus	DC

2.7. *Wind turbine*

The wind turbine with its associated cost and technical input variables are presented in Tables 5 and 6 below. Again, the data used for the selection of the wind turbine were collected from the HOMER software component library. These variables and their values are averagely similar to the market available wind turbines. The wind turbine used for the analysis is a low cost, a low-speed vertical axis wind turbine that is a commercially available off-the-shelve product.

Table 5. Cost input variables

Item	Cost
Initial cost ($/qty)	1885.42
Cost of replacement ($/qty)	1885.42
O & M cost ($/qty/year)	180.00

Table 6. Technical specifications of Wind turbine

Item	Specifications
Rated power (kW)	3
Cut-in-speed (m/s)	2
Rated speed (m/s)	15
Cut-out-speed (m/s)	20
Hub height (m)	30
Lifespan (Years)	20
Electrical Bus	AC

2.8. *Project economic input variables*

The economic input needed to analyze the proposed system economically are presented in Table 7. The economic input variable was adopted from the central bank of Ghana website. The project life of most renewable energy projects is 25 years [29–31]. Therefore a 25-year project lifespan was adopted to analyze the proposed system.

2.9. *Parameters for assessment*

The technical parameters adopted to assess this proposed system are Annual energy production (AEP), annual fuel consumption (AFC), total load served (LS) and Annual emission. These parameters were used because similar studies such as [29,32] just to mention a few used these parameters to technically assess a hybrid renewable energy system.
To calculate the annual energy production of the hybrid power system, equation (1) is used;

$$AEP = E_{PV} + E_{Wind} + E_{DG} \tag{1}$$

Where E_{PV} is annual electricity produced by the PV plant
E_{Wind} is the annual electricity produced by the wind farm
E_{DG} is the annual electricity produced by the Diesel generator

To estimate the total load served, the condition below must be fulfilled;
Annual electricity produced must greater or equal to the total load profile as shown in equation (2)

$$AEP \geq E_{Hosp\&Tour} + E_{Base} \tag{2}$$

$E_{Hosp\&Tour}$ is the annual energy consumed by the hospital and tourism centre
E_{Base} is the annual energy consumed by the base station.
The annual total emission is estimated using equation (3);

$$Em_{GHG} = Em_{CO_2} + Em_{H_2C} + Em_{PM} + Em_{SO_2} + Em_{N_2O} \tag{3}$$

Em_{GHG} is the GHG emissions
Em_{CO_2} is CO_2 emissions
Em_{H_2C} is H_2C emissions
Em_{PM} is Emission from particulate matter
Em_{SO_2} is SO_2 emissions
Em_{N_2O} is N_2O emissions

In addition, the Levelized Cost of Electricity (LCOE), Net Present Cost (NPC), and Operating Cost are used in this study to assess the proposed system's economic viability. Again, these parameters have been used by researchers to economically evaluate hybrid renewable energy systems [29,30,33,34]. The LCOE is estimated in this study using equation (4);

$$LCOE = \frac{TLCC}{TLC_{ey}} \quad (4)$$

$$TLCC = \sum_{t=1}^{n} \frac{I_t + O\&M_t}{(1+r)^t} \quad (5)$$

$$TLC_{ey} = \sum_{t=1}^{n} \frac{E_t}{(1+r)^t} \quad (6)$$

Where;
I_t is the investment cost in the time t;
$O\&M$ is the operations and maintenance cost in time t;
E_t is the energy generated in time t;
r is the discount rate
n is the Project life of the hybrid system.

The annual operating cost of the system is estimated using equation (7);

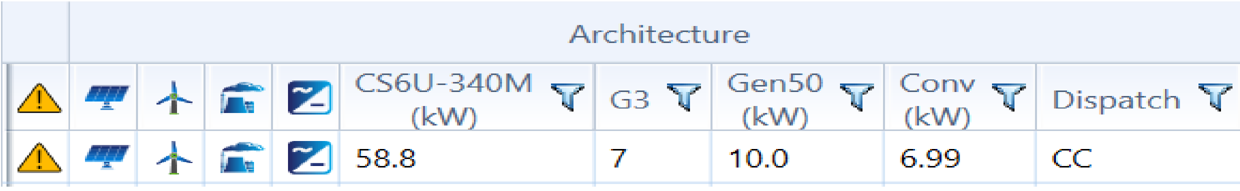
$$C_{oper,tot} = C_{ann,tot} - C_{ann,cap} \quad (7)$$

Where;
$C_{oper,tot}$ is annual Operating cost
$C_{ann,tot}$ is the annualized total cost ($/yr)
$C_{ann,cap}$ is the annual capital cost ($/yr)

2.10. Sensitivity analysis
In addition to the design and optimization of the proposed hybrid system, a sensitivity analysis was performed to assess the behaviour of the proposed system when the scaled annual average energy consumption per day is increased by 10% and 20%.

3. Results and Interpretations
This section presents the results of the simulation performed with the HOMER computational software. These results are presented in Tables, graphs and figures for interpretation. The section presents optimized results of proposed design, technical results, economic results, emission results and sensitivity results of the proposed design. The relevance of the results from the HOMER to the objective of the study are interpreted in this section.

3.1. Optimized results of the proposed design
The optimal sizing results of the proposed Solar PV/Wind/Diesel generator system is presented in Figure 7 from the Homer software. The optimal size of the proposed system consists of a 58.8kW of Solar PV, 7 wind turbines with each having a capacity of 3kW, a 6.99 kW converter and a 10-kW diesel generator.



Architecture								
				CS6U-340M (kW)	G3	Gen50 (kW)	Conv (kW)	Dispatch
				58.8	7	10.0	6.99	CC

Figure 7. Optimal sizing of the proposed system.

3.2. Technical results of the proposed design

The parameters adopted to evaluate the technical viability of the proposed system with the results from the HOMER simulation of the proposed system using Homer software are presented in Table 7. The table shows results for AEP, AFC, LS and Emissions. In addition, the table compares the proposed case with the base case based on the technical parameters adopted in the study. The breakdown of electricity production by the solar PV/wind/Diesel generator system is presented in Figure 8. The figure shows the monthly electricity production by the proposed case.

Table 7. Technical results

Cases	Fuel Consumption (L)	AEP (kWh/yr)	Emission (Kg/yr)	Load served (kWh/yr)
Base Case	16,455	49,685	43,716	47,648
Proposed case	7,423	154,549	19,722	47,648

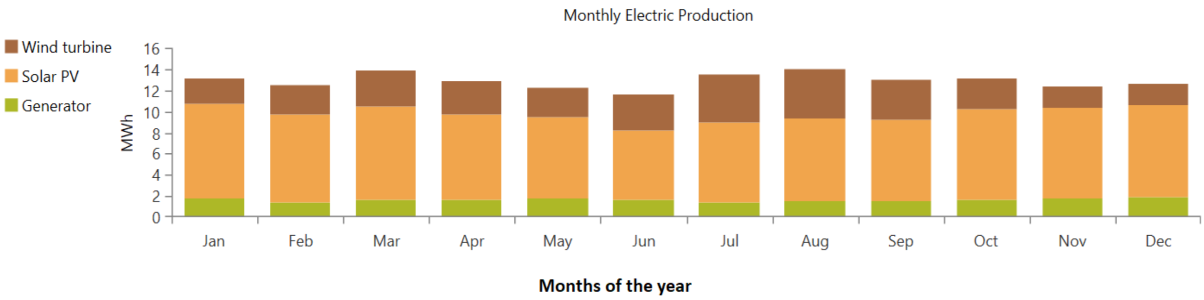
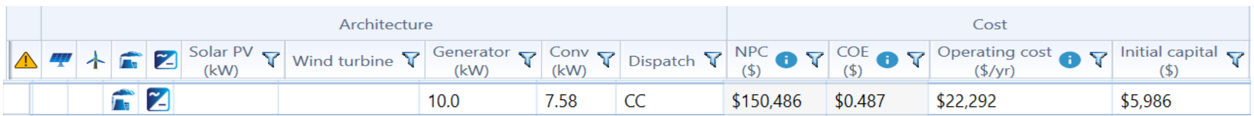


Figure 8. Detailed monthly production of the proposed system

3.3. Economic results of the proposed system

The results of the simulated proposed system are presented in Figure 9. The results show the costs obtained for the economic parameters adopted for the evaluation of the proposed system. The results also compare the proposed case with the base case concerning the economic parameters (NPC, LCOE and operating cost) used to evaluate them (See Table 8).



Architecture									Cost			
					Solar PV (kW)	Wind turbine	Generator (kW)	Conv (kW)	Dispatch	NPC ($)	COE ($)	Operating cost ($/yr)	Initial capital ($)
							10.0	7.58	CC	$150,486	$0.487	$22,292	$5,986

Figure 9. Economic parameters

The table shows a lower LCOE for the proposed case as compared to the base case (Diesel generator alone). In general, the LCOE, NPC and Operating cost of the proposed case is lower than the base by 21%, 21% and 43% respectively.

Table 8. Economic comparison of cases

Cases	LCOE($/kWh)	NPC ($)	Operating Cost ($)
Base Case	0.49	150,486.00	22,292.00
Proposed case	0.39	118,788.00	12,658.00

3.4. *Emission results of base case and Proposed case*

Figure 10 shows the graph of total emissions of the base case and proposed case. The graphs also show the constituent of GHG emission of both base case and proposed case. These figures represent the emissions in kilogram per year.

Figure10. (a) Proposed case emissions (b) Base case emissions

3.5. *Results for sensitivity analysis*

The results of sensitivity analysis performed on the proposed hybrid system using increasing scaled average energy demand are presented in Table 9 and 10. The sensitivity analysis evaluated the technical and economic impact of scaled annual daily energy demand.

Table 9. Technical results for sensitivity analysis

Scaled average load (kWh/day)	Fuel Consumption (L)	AEP (kWh/yr)	Emission (Kg/yr)	Load served (kWh/yr)
25.5 kWh/day	7,423	154,549	19,722	47,648
10%	7,580	152,761	19,844	48,557
20%	7,577	159,211	19,834	49,490
30%	7,635	163,186	19,988	163,186

Table 10. Economic results for sensitivity analysis

Scaled average load (kWh/day)	LCOE($/kWh)	NPC ($)	Operating Cost ($)
25.5 kWh/day	0.385	118,788.00	12,658.00
10%	0.381	119,807.00	12,872.00
20%	0.377	120,875.00	12,861.00
30%	0.373	122,040.00	12,938.00

4. Discussion

To meet the electricity demand of the load presented in this study whiles minimizing the LCOE, NPC and operating cost of the proposed system, an optimal size of solar PV, wind and converter was estimated Homer software. The optimal sizes estimated were 58.8 kW solar PV, 7 wind turbines (3kW each) and a 6.99 kW converter.

Furthermore, an AEP of 154,549kWh, which is 68% less than the base case (Diesel generator alone). The other technical parameters compared with the base case showed a reduced emission by 55%, and a reduction in fuel consumption by 55% as shown in Table 7. The proposed system served the electrical load 100% with annual excess electricity of about 68%. The annual unmet and capacity shortage for a system that has a renewable energy fraction of 58.7% were 0.0112% and 0.0914%. These figures compared with Single RE technology such as Solar PV and Wind alone are insignificant. This study is supported by previous studies such [35] which suggest that a hybrid system overcomes the limitation of a single energy source in terms of electricity production and reliability.

Moreover, the proposed case presented in this study reduced the annual fuel consumption by the diesel generator by 55% from the fuel consumption of the base case. As suggested by Wesly et al. (2020), electricity from diesel generators alone is expensive due to the high cost of fuel to remote and isolated areas. The authors suggested a hybrid system with a diesel generator in the mix to ensures reliability and reduces fuel consumption.

The proposed case recorded a total yearly greenhouse gas of 19,722 kg as compared to 43,716 kg by the base case. A significant annual emission reduction of 55%. A study conducted by [37] showed results that suggest that with a renewable fraction exceeding 72%, a hybrid system can reduce more than 2000kg of CO_2 emission annually. In this study, a renewable energy fraction of 58.7 % is reducing CO_2 emission of 23,643 kg from the base case. The results of this proposed system exceeded the projections of the study conducted by [37].

Again, the proposed case showed superior performance in terms of economic feasibility as compared to the base case. The LCOE of the proposed case was 0.39 $/kWh as compared to 0.49 $/kWh for the base case. The NPC and Operating costs of the proposed case were 21% and 43% lower than the base case economic performance. A study conducted by [38] concluded that a hybrid energy system is more reliable and cheaper than a single energy system.

The proposed hybrid solar PV, Wind and Diesel generator produced emission of 19,722 kg/yr of GHG whiles the base case produced 43716 kg/yr of GHG. From the HOMER simulation, it be deduced that the proposed case reduced the annual emission from the base case by 55%. Emission reduction is a major objective for the adoption of renewable energy. For this reason, a 55% reduction of emission from the proposed case is a significant achievement. This reduction presents the proposed case as environmentally feasible hybrid power system to serve the load requirement of the community. The sensitivity results show that an increase in the daily energy demand of the hospital and tourism centre increases the electric production of the proposed hybrid system. The increase also causes an increase in annual energy consumption and proportional increase in the annual emissions. The intermittent nature of renewable energy system requires a proportional increase in the energy production from diesel generator system. Again, an increase in daily energy consumption causes an increase in the net present cost and operating cost of the system whiles the levelized cost of energy slightly decreases.

5. Conclusion

This study was aimed at assessing the technical and economic feasibility of a solar PV/Wind/Diesel generator to serve a selected electrical load of Avuto community in the Volta region of Ghana. The electrical load considered in this study were a community clinic, a tourism centre and a telecommunication base station sited in Avuto.

A solar and wind resource of the study area NASA weather database. The average solar and wind resources with the highest and lowest values are presented. A proposed hybrid renewable energy system was designed using Homer software. The design was optimized to meet the electrical load whiles reducing, LCOE, NPC, Operating cost, fuel consumption and emissions. Again, the existing energy system which was termed in this study as a base case was also designed and simulated. The results of the optimized proposed case based on the economic parameters (LCOE, NPC and Operating cost) used were 0.39 $/kWh, $118,788.00 and $12,658.00 respectively. The base case on the other hand produced LCOE, NPC and operating costs of 0.49 $/kWh, $150,486.00 and $22,292.00 respectively. The technical parameters used for the comparison of the proposed case and base case were also presented in the study. The proposed case had AFC, AEP, Emission and LS to be 7,423L, 154,549 kWh/year, 19,722 kg/year and 47,648 kWh/year. For the same technical parameters, the base case had 16,455 L, 49,685 kWh/year, 43,716 kg/year and 47,648 kWh/year. The proposed case proved superior to the base case in both technical and economic analysis of the two cases. The study can confidently conclude that the proposed solar PV/Wind/Diesel generator is technically and economically feasible for implementation in the study area.

The study recommends the following for further investigation;

The proposed case in this current study had an excess electricity generation of 105,841kWh/year and a study to size a suitable energy storage system to store the excess electricity is critical.

A sensitivity analysis should be performed on the fuel price, average solar radiation, wind speeds and load consumption to test the robustness of the proposed case.

An economic assessment of the CO_2 emission reduction concerning carbon reduction credit to present its economic benefits.

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