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Optimization of Photovoltaic-Wind Hybrid System for Electrifying University of Ilorin E-Library

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ABSTRACT

The current paper presents the simulation of a PV-Generator-Wind hybrid power system to electrify University of Ilorin E-Library using HOMER (Hybrid Optimization of Multiple Energy Resources) software. Different performance analysis such as optimization and sensitivity is carried out by the software. Environmental and economic analysis is used to discuss the sustainability of the hybrid power system. Results from the analysis revealed that the hybrid system consisting of an 8.33 kW photovoltaic (PV) panel, 6.5 kW diesel generator, 6 kW wind turbine, a 6 kW converter and 10 batteries is the optimal system in terms of Net Present Cost (NPC), Cost of Energy (COE), Initial Cost and Operating cost. The system has NPC, COE, Initial Cost and Operating cost of US\$58,404, US\$0.358/kWh, US\$44,876 and US\$1,046 respectively which is better than a diesel system which has a Net Present Cost of US\$ 80,256 and a Cost of Energy of 0.492 US\$/kWh. Results show that the hybrid system emits 2,104.35kg/yr of carbon dioxide (CO₂), 5.19kg/yr of carbon monoxide (CO) and 4.23kg/yr of sulphur dioxide (SO₂) while the diesel system emits 20,115.90kg/yr of CO₂, 49.65kg/yr of CO and 40.40kg/yr of SO₂. The emission of the hybrid system is an order of ten lower compared to diesel system indicating a lower greenhouse effect. Sensitivity analysis on diesel price and wind speed shows that with increasing diesel price, the NPC and COE the hybrid system increases whereas with increasing wind speed, NPC and COE decreases. These results serve as a reference point for the design and installation of hybrid system for the building.

1. INTRODUCTION

Nigeria is a developing nation that has gone decades without stable electricity supply which has been identified as a contributor to the poor economic performance of the country (Momoh, Anuga, & Obidi, 2018). This is a result of poor generation and distribution which are also major barriers to the country's economic growth (Uzorh & Innocent, 2019). It was also reported by Lekana & Ikiemi, (2021) that energy consumption is one of the factors that is found to improve human development. Various economic policies have been put in place to improve electricity generation in Nigeria but to no avail. According to the International Energy Agency IEA, (2019), the number of people without access to electricity peaked at 610 million in 2013 and has gradually decreased to roughly 595 million in 2018. However, compared to other parts of the world, Sub-Saharan Africa's electrification rate of 45 percent in 2018 is still quite low. In Nigeria, about 50.6 million Nigerians lacked access to electricity (World Energy & Outlook, 2019). For Nigeria to become one of the leading economies in the world, the problem of generating and distributing sufficient amounts of electricity must be addressed. With the increased demand for electricity, escalating oil prices increased electricity tariffs as well as heightened climate change concerns, renewable energy resources have been proposed to be a good alternative to fossil fuel-based electricity generation worldwide (Islam, Hasanuzzaman, Rahim, Nahar, & Hosenuzzaman, 2014). For this study, solar and wind renewable energy were considered.

The sun radiates energy at a rate of about 3.8×10^{23} kW per second, and Nigeria receives up to 5.08×10^{23} kW of energy per day from the sun. Assuming solar energy appliances with as little as 5% efficiency are used to cover only 1% of the country's surface area, solar energy can provide 2.54×10^6 MWh of electrical energy. This quantity of energy equates to 4.66 million barrels of oil every day (Ajao, Oladosu, & Popoola, 2011). Nigeria with average wind speed ratings between 2.5 and 4.5 m/s is a viable wind resource zone. Wind energy is utilised with the help of wind turbines which consist of blades to harness the wind energy. These turbines generate large amounts of useful energy without constituting any environmental hazards. A combination of the two resources forming a PV-wind hybrid, therefore, offers a very interesting possibility for electricity generation. Research studies by Ibrahim, (2020); Salisu, Mustafa, Olatomiwa, & Mohammed, (2019); Salam, Aziz, Alwaeli, & Kazem, (2013) and Okonkwo, Okwose, & Abbasoglu, (2017) have shown the workability of this system. For this work, the HOMER (Hybrid optimization of multiple energy resources) software was employed. HOMER is a micropower optimization software developed by Mistaya Engineering, Canada developed for the National Renewable Energy Laboratory (NREL) USA, it simplifies the task of evaluating designs of both off-grid and grid-connected power systems for a variety of applications. In designing power systems, decisions about the configuration of the system are made. HOMER's optimization and sensitivity analysis algorithms make it easy to evaluate the many possible system configurations. HOMER simulates the operation of a system by making energy balance calculations and displaying a list of configurations, sorted by the net present cost that is used for comparison. Thus, this study aimed to analyse the cost benefits of a Photovoltaic (PV)-wind hybrid system over a fossil fuel (diesel) system for electrification of the E-Library at the University of Ilorin using HOMER software.

1.1 STUDY AREA

The E-Library is shown in Figure 1 and its located on the main campus of the University of Ilorin, Kwara state. Ilorin, the capital of Kwara state is located between latitudes $8^{\circ} 25'N$ and $8^{\circ} 32'N$ and longitudes $4^{\circ} 30' E$ and $41^{\circ}E$.



Figure 1: The study area

1.2 Review of Early Works.

Ajao et al., (2011) used HOMER software for optimization to find the best cost-benefit of hybrid -solar power generation relative to use cost in Nigeria and a comparison was also made with utility supply. The proposed system used (0.05 – 0.4 kW) PV panel with (0.4 kW DC) FD series wind turbine, (0.1 – 1.5 kW) converter, and (200 Ah / 12 V, bank size: 1-8 batteries, vision 6 FM200D) battery. The results obtained from the optimization gave the initial capital cost as 3,455 US\$ while operating cost is 69 US\$/year. The total net present cost (NPC) is US\$4,251 and the cost of energy (COE) is 1.74 US\$/kWh. The authors found that the hybrid system has a pay-back period of about thirty-three years. Salisu et al., (2019) applied HOMER software to examine the techno-economic and environmental analysis of solar PV and wind hybrid systems on a

village in Northern Nigeria. From the results and sensitivity analysis, the optimal configuration was found to have an NPC of \$1.01 and COE of \$0.110/kWh, with an operating cost of \$4723. The system was found to be environmentally friendly with a renewable fraction of 98.3% and Green House Gas emission of 2889.36 kg/year. Thirunavukkarasu & Sawle, (2020) applied HOMER software to optimise a hybrid system consisting of Solar photovoltaic, diesel engine generator, and battery for the generations of electrical power. The result showed that the PV/Diesel/converter combination provided optimal results with 0% unmet load at the minimum electricity cost that was reduced from \$ 0.672 to \$0.319/Kwh. Okonkwo et al., (2017) in their work examined the potential of a stand-alone hybrid system comprising of solar PV and wind turbine to meet the electrical need of a hotel building in Jordan using HOMER optimisation software. The economic potential of the system was compared with that of the on-grid system of PV-wind turbine system. Results from the stand-alone system showed a net present cost of \$147,485 over its 25 years life span, a savings-investment ratio (SIR) of 1.924 and a payback period of 11 years. Other researchers have used HOMER optimisation software to investigate the technical feasibility and economic viability of PV/wind turbine systems are Okedu & Uhunmwangho, (2014), Salam et al., (2013), Sobhan, Ahmad, Rahimi, Ullah, & Arif, (2016), Hoque, Bhuiyan, Ahmed, Farooque, & Aditya, (2012) Al-Karaghoul & Kazmerski, (2010), Nema & Nema, (2010), and Rawat & Chandel, (2013).

2. METHODOLOGY

The research involved the simulation and optimization of a PV-wind hybrid micro-grid system for electrification. Hybrid Optimisation of multiple energy resources (HOMER) software was used for simulation, optimization and sensitivity analyses. HOMER calculated a ranked optimization in increasing order of Net Present Cost (NPC) of feasible design configurations.

A. Model Load Inputs

An energy audit was conducted to calculate the energy demands of the E-Library. The energy demands of the E-library are as follows: 41 lighting bulbs (25 W each), 50 computer systems (193 W each), and 20 air conditioning systems (1200 W each). The total power need is 34,675 W.

B. Load Profile

The load profile for the E-Library was built by considering the times of peak activity of the entire load with HOMER calculating the peak load as 5.38kW. A small baseload of 0.25kW occurs from 12 a.m until 7 a.m while the majority of the load (34.055kW) occurs during the day from 8 a.m to 7 p.m. The load profile is shown below in Figure 2.

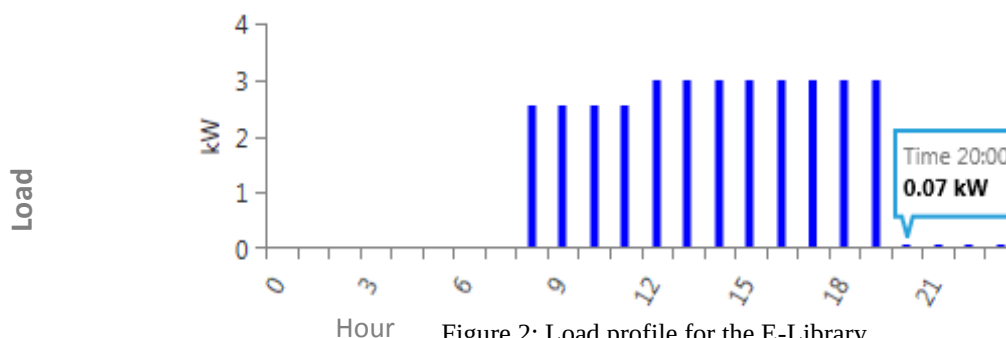


Figure 2: Load profile for the E-Library.

C. Collection of Renewable resources data

The performance of this hybrid system depends on available solar and wind resources.

(i) Solar Resource Data

Figure 3 shows the solar resource data profile for Ilorin over a year as obtained from the NASA Surface meteorology and Solar Energy site. The approximate location of the site used is 8° 29.1' N and 4° 35.9' E.

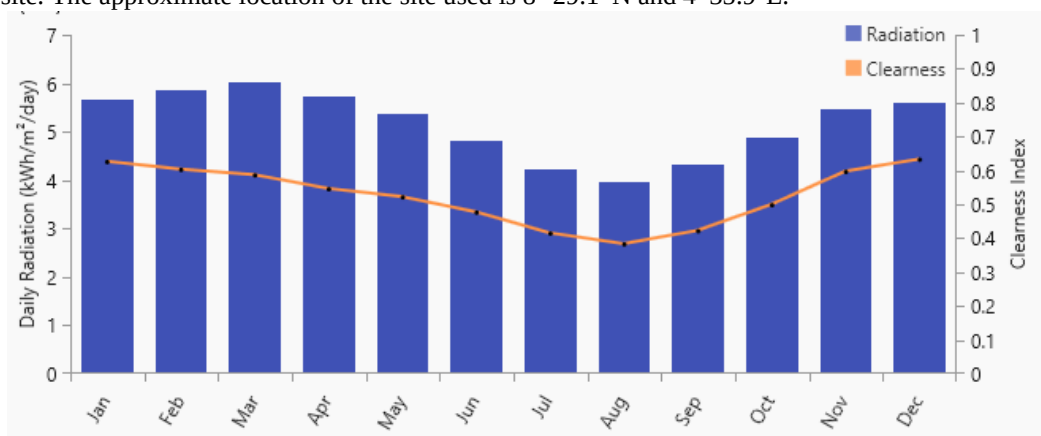


Figure 3: Solar radiation profile for University of Ilorin

(ii) Wind Resource Data

Figure 4 shows the wind resource profile for one year for Ilorin as obtained from NASA Surface meteorology and Solar Energy website. The annual average wind speed is 2.81 m/s measured from an anemometer height of 50m above ground level.

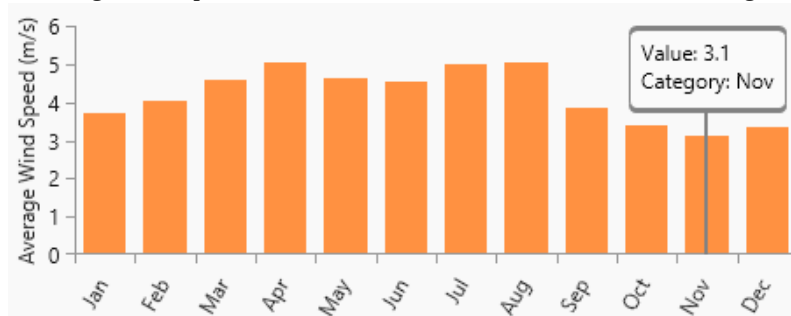


Figure 4: Wind resource profile for University of Ilorin

D. System Analysis

Homer performs three basic calculations; simulation, optimization and sensitivity analysis. These three calculations are performed in this study. For simulation, it decides whether the system is feasible or not. It determines the life-cycle cost of the system, which is the total cost of installing and operating the system over its lifetime. The Net Present Cost (NPC) is used by HOMER to reflect the system's life-cycle cost minus the present value of all revenues earned over the project's lifetime. The total NPC condenses all the costs and revenues that occur within the project lifetime in today's dollars, with future cash flows discounted back to the present using the discount rate. In the optimizing process, HOMER simulates every possible system configuration and searches for the best system that satisfies technical and economic constraints at the lowest life cycle cost (NPC). In the sensitivity analysis, HOMER performs multiple optimizations for a range of inputs to investigate the effects of uncertainties or changes in the model's inputs. For the study, a sensitivity analysis is carried out on different prices of diesel due to its fluctuating prices as well as changes in annual average wind speed.

E. Description of the Hybrid System

The proposed system consists of a PV array (CS6X-325), diesel generator (Gen), an inverter (BDI 1P), wind turbine (XL6) and a battery (IND27-2V). The Direct Current (DC) power from the PV arrays is converted to Alternating Current (AC) by the inverter and is fed into the AC bus. The AC power generated from the wind turbine is fed directly into the AC bus. Excess power produced is stored in the battery bank and is utilised by the fuel cell in case of a lack of generated power by the PV or wind turbine. A schematic diagram of the proposed system is shown in Figure 5.

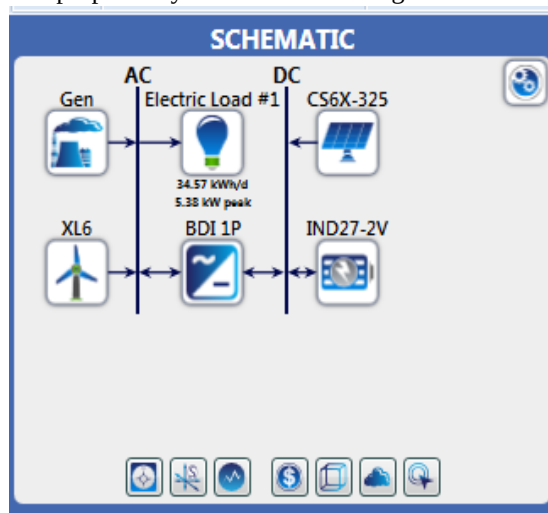


Figure 5: Diagram of the hybrid system

2.1 Description of the proposed system

The system components are: PV panel, Wind Turbine, Diesel generator, Inverter, Battery

2.1.1 PV Panel

The PV panel is a combination of PV modules that produce DC directly proportional to the incident solar radiation on it, ignoring the temperature and voltage to which it is exposed. The suggested PV panels to be used in the system simulation is the Canadian Solar DYMOND CS6X-325 which is rated at 6.5kW (at 1000 W/m² and 25°C) and 12V and has an estimated capital cost of US\$10,000 with shipping cost. It is having a lifespan of 25 years. A de-rating factor of 80% was applied to the electric production from each panel. This factor reduces the PV production by 20% to approximate the varying effects of temperature and dust on the panels. PV panel sizes of up to 10kW were considered.

2.1.2 Wind turbine

The wind turbine consists of blades that continually rotate due to the action of wind impinging on it. The generator at each turbine converts the mechanical energy of the blades into electrical energy. The wind turbine considered for this system is the BERGEY EXCEL 6 wind turbine which has an estimated capital cost of US\$19,500. A single wind turbine was considered for the simulation. It has a lifetime of 20 years and a hub height of 30m. The wind turbine data is shown in Figure 6.

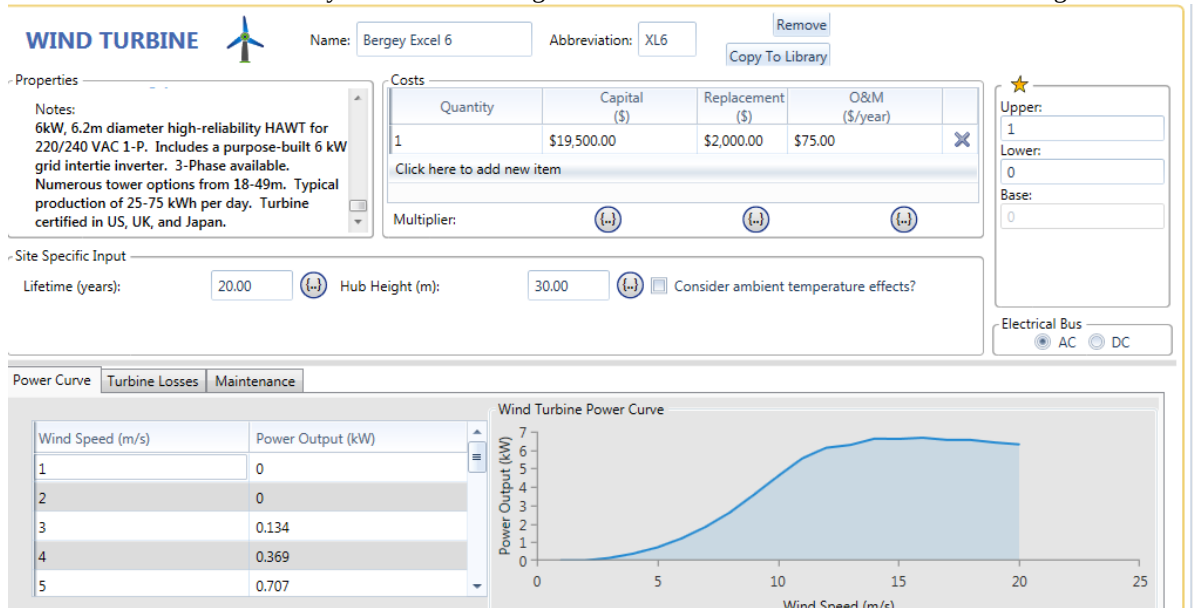


Figure 6: Wind turbine data.

2.1.3 Diesel generator

The diesel generator supplements the power produced by the PV array and the wind turbine. In case there is a capacity shortage from PV array, wind turbine, or battery (due to state of charge), the generator supplies the electricity. The generator used is a 6.5kW/8.0kVA diesel generator with a capital cost of US\$1,500. Figure 7 shows the generator data.

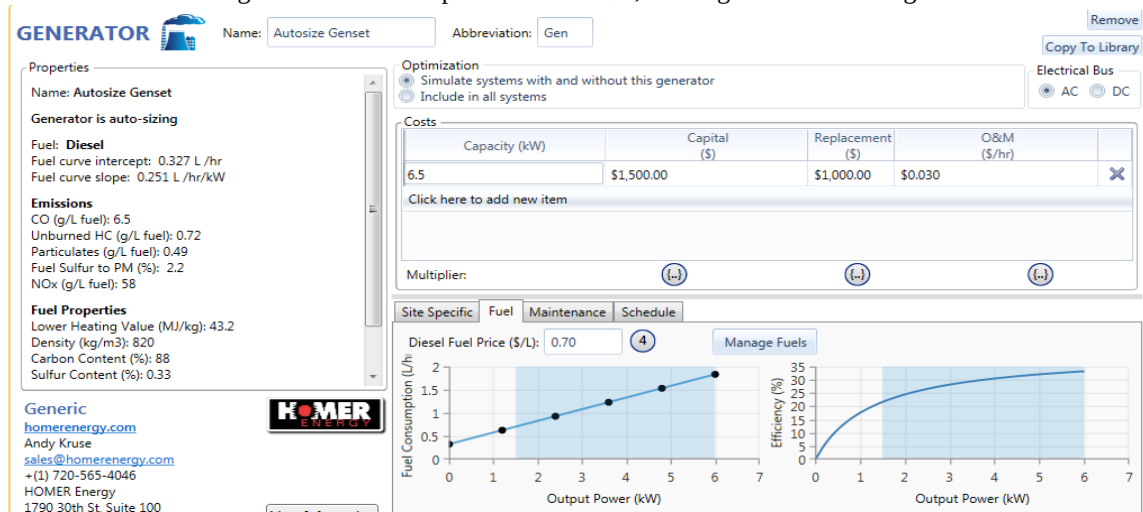


Figure 7: Diesel generator data

For the simulation, the price of diesel is set to US\$0.7/L. The generator was not allowed to operate at less than 30% capacity. HOMER determines the amount of time the generator is used in a year and calculates the total operating costs from this value. The costs used for this study are very conservative and maybe much higher in reality. Only one generator is allowed per system and that generator has to be large enough to meet the peak load. HOMER considers two different types of control strategies. Under the load-following (LF) strategy, the generator provides only the power necessary to meet the load at the time. With the cycle-charging (CC) strategy, once the generator is operating, it uses as much power as possible to charge the batteries in addition to meeting the load. A cycle-charging strategy was employed because it prevents overcharging of the batteries and prolongs the battery and generator lifespan. A hundred percent (100%) reliability is assumed for the system. Thus, the annual capacity shortage value was set to zero implying that the system meets 100% of the electric load and supplies power at all times.

2.1.4 Inverter (Converter)

An inverter is a circuit that converts DC power to AC. The inverter considered here is the LeonicsS219CPH 5kW 48Vd converter which has an estimated price of US\$600 and its lifetime is up to 10 years. Inverters of various sizes (6kW and 8kW) were considered in the analysis. The inverter and rectifier efficiencies were assumed to be 96% and 94% respectively.

2.1.5 Battery

When power from the PV array and wind turbines is unavailable, the battery fills the void with stored extra energy. HOMER employs the Kinetic Battery Model, which depicts batteries as a "two tank" system. The first tank provides immediately available capacity, whilst the second tank can only be discharged at a limited rate over the battery's lifespan; HOMER presume that the properties remain constant and are not changed by external influences such as temperature. The chosen battery is the Trojan IND27-2V battery which is a flooded/wet lead-acid battery that is rechargeable and cheap. The battery price is estimated to be US\$757. Its float life is considered to be 20 years. Up to 20 batteries were considered. Figure 8 shows the battery data.

Figure 8: Battery data

2.2 Sensitivity Analysis

Sensitivity analysis is carried out on the price of diesel and wind speed. The price of diesel is set to 0.7US\$/L but consideration was made for an increase in this price and therefore prices of 0.8US\$/L, 0.9US\$/L, and 1.0US\$/L were considered. In the case of wind speed, various wind speeds of 3m/s, 4m/s, and 5m/s were also considered.

3. RESULTS AND DISCUSSION

3.1 Optimization results

HOMER optimization results indicate that the ideal hybrid system which is capable of producing the lowest Cost of Energy (COE) at a diesel price of 0.7US\$/L and at annual average wind speed of 2.8m/s is the one comprising of an 8.33kW PV panel, 1 wind turbine, a 6kW diesel generator, 6kW converter and 10 batteries. The COE is US\$0.358 with the system having a Net Present Cost (NPC) of US\$58,404. The initial cost and capital cost of the system are US\$44,876 and US\$1,046 respectively. Figure 9 below the optimization results.

Optimization Cases: Left Double Click on a particular system to see its detailed Simulation Results.																	☒ Categorized	☐ Overall			
Architecture									Cost				System	Gen					CS6X-32		
					CS6X-325 (kW)	XL6	Gen (kW)	IND27-2V	BD1 1P (kW)	Dispatch	COE (\$)	NPC (\$)	Operating cost (\$)	Initial capital (\$)	Ren Frac (%)	Hours	Production (kWh)	Fuel (L)	O&M Cost (\$)	Fuel Cost (\$)	Capital Cost (\$)
					5.84		6.00	7	6.00	CC	\$0.248	\$40,486	\$1,641	\$19,268	56	1,147	5,577	1,776	32	1,243	8,984
							6.00	1	6.00	CC	\$0.337	\$54,940	\$3,806	\$5,742	0.0	4,380	12,701	4,622	121	3,235	
					8.33	1	6.00	10	6.00	CC	\$0.358	\$58,404	\$1,046	\$44,876	81	614	2,382	799	17	559	12,821
						1	6.00	1	6.00	CC	\$0.447	\$72,987	\$3,693	\$25,242	8.8	4,379	11,515	4,323	121	3,026	
					9.38		6.00		6.00	CC	\$0.476	\$77,682	\$4,508	\$19,408	7.5	6,832	11,675	5,165	189	3,616	14,423
							6.00			CC	\$0.492	\$80,256	\$6,101	\$1,385	0.0	8,760	19,014	7,639	243	5,347	

Figure 9: Optimization results

3.2 Simulation Results

The simulation results of the optimum system give the contribution of each component of the system. Figure 10 shows the graph of the monthly average electricity production and the contribution of each component. The results showed that the production of the PV panel, diesel generator and wind turbine are 12,732kWh/yr., (75.84%), 2,382kWh/yr. (14.19%) and

1,674kWh/yr. (9.97%). The total consumption of AC load is estimated to be 12,620kWh/yr. while that of DC load is zero since the load modelled is strictly AC load. Excess electricity of 16.7% is obtained from this system, but this can be offset by assuming a capacity shortage of 1-5%. This implies that the power system should meet a certain percentage of the annual load plus the operating reserve. This excess electricity can be stored in the form of hydrogen gas which could also be used to generate electricity.

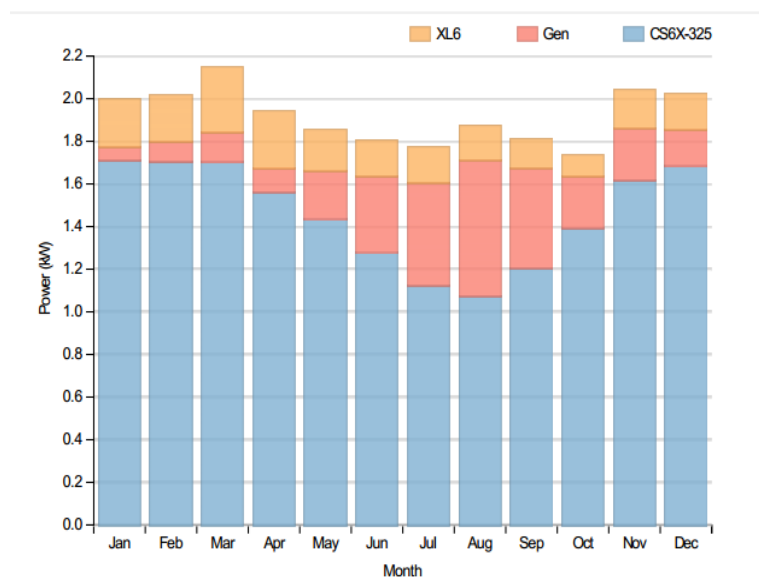


Figure 10: Monthly average electric production

The renewable fraction of the system which is the contribution by renewable sources of energy to the overall system is 81.1 with renewable penetration being 26,631.

3.2.1 Cost summary

The cost summary is shown in Figure 11. It shows that the Wind turbine has the highest NPC while the converter has the lowest NPC. Table 1 shows the breakdown of total Net Present Cost by components and various costs.

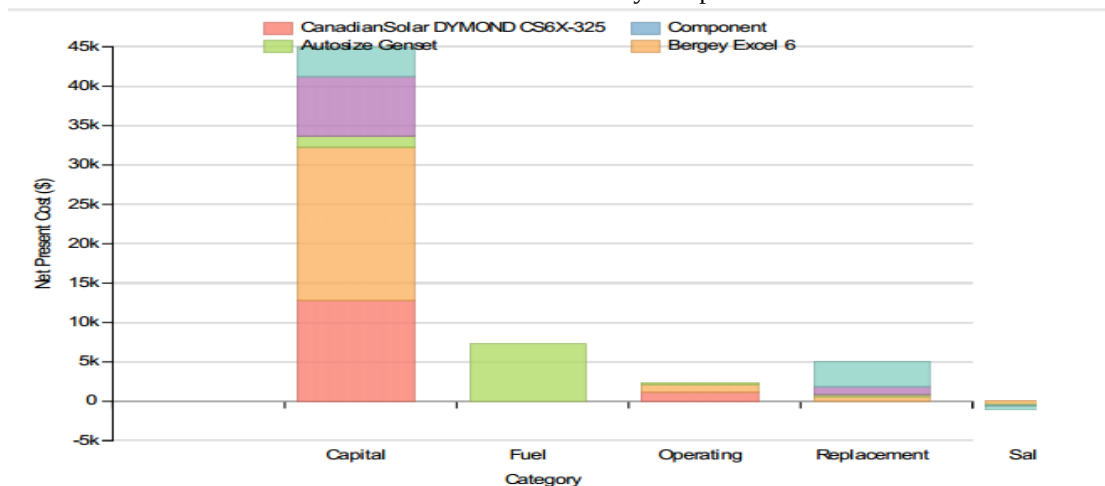


Figure 11: Cost summary of PV-wind hybrid system

Table 1: Cost breakdown for each system component

Component	Capital	Replacement	O&M	Fuel	Salvage	Total
Canadian Solar DYMOND CS6X-325	12,821	0	1,160	0	0	13,981
Bergey Excel 6	19,500	638	970	0	-359	20,748
Auto-size Diesel Gen-set	1,385	228	220	7,231	-216	8,848
HOMER Cycle Charging	0	0	0	0	0	0
Trojan IND27-2V	7,571	948	0	0	-41	8,478
Leonics S219CPH 5KW 48Vdc	3,600	3,180	0	0	-431	6,349
System	44,876	4,995	2,350	7,231	-1,048	58,404

3.3 Cash flow
The
Nominal
cash flow
analysis is
shown in
Figure 12.
It shows

that the proposed hybrid system has Leonics converter and diesel generator replacement cost at the 10th year, Trojan battery and diesel generator replacement cost at the 14th year, a Leonics converter, Wind turbine and diesel generator replacement cost at the 20th year.

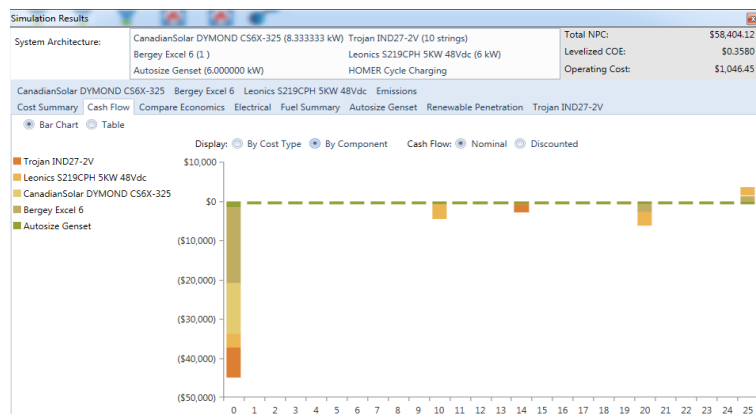


Figure.12: Nominal cash flow analysis

Figure 13 shows the PV output for an entire year. It has a maximum output of 8.17kW with a level cost of 0.085US\$/kWh and it operates for 4,346hrs/yr. with a PV penetration of 101%.

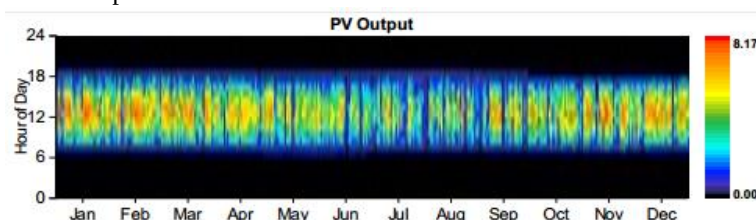


Figure.13: PV output for one year

Figure 14 shows the CDF curve of the PV panel. The curve shows that the output of the PV panel is at 8.1kW hundred percent of the time and the panel never operates below minimum load.

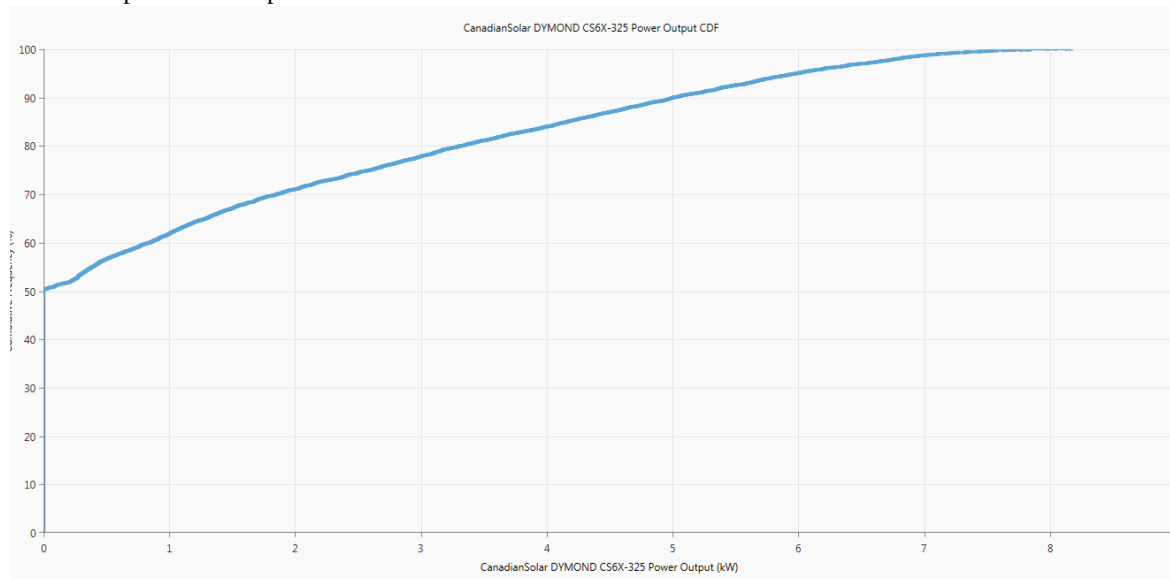


Figure 14: Cumulative distribution function (CDF) curve of PV panel

The wind turbine output for one year is shown in Figure 15. The wind turbine has a maximum output of 4.52kW with a wind penetration of 13.27% and operates for 5,551hrs/yr. with a level cost of 0.96US\$/kWh

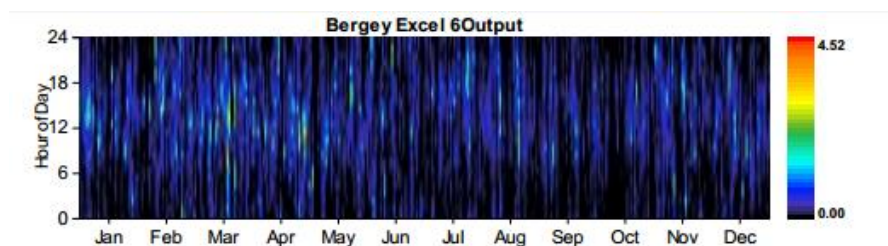


Figure 15: Wind turbine output for one year

Figure 16 shows the diesel generator output where the mean electrical output for the generator is 3.88kW with a minimum electrical output of 1.5kW. HOMER estimates the fuel consumption as 799.2L with 614hours of operation yearly.

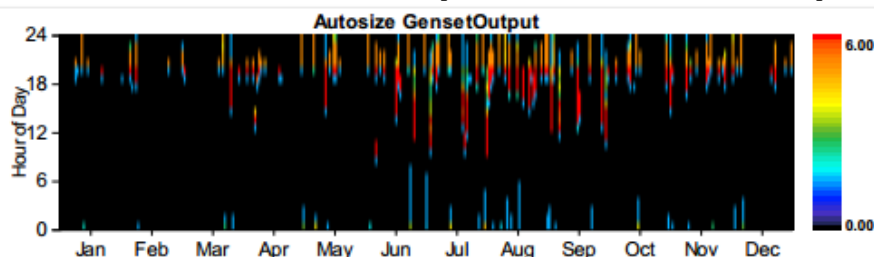


Figure.16: Diesel generator output.

HOMER estimates the Trojan battery to have an autonomy of 22 hours which indicates that in a situation where the system is down or malfunctions, the battery can provide adequate power to meet the load for 22 hours. With an expected life of 13.06 years and an annual throughput of 3,867.04, the battery represents a very reliable source for backup. Its state of charge is represented in Figure 17.

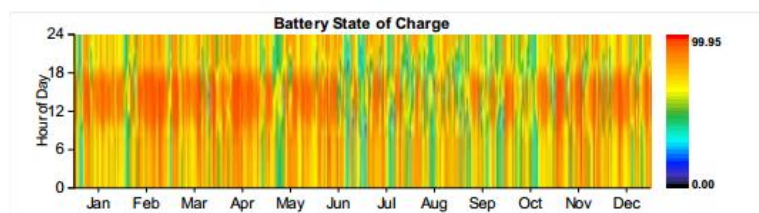


Figure 17: Battery state of charge

3.4 Effects of changes in diesel price and wind speed on COE and NPC

The sensitivity analysis carried out on diesel price and wind speed indicated that for a diesel fuel price of 0.8US\$/L, the cost of energy (COE) and Net Present cost (NPC) are 0.366US\$/kWh and US\$59,779 respectively. This represents a significant increase in the values obtained for a diesel price of 0.7US\$/L. For a diesel price of 0.9US\$/L, the COE and NPC are 0.378US\$/kWh and US\$61,726 with more batteries and a PV panel of higher rating needed. Wind speed influences the COE and NPC. For a fixed diesel price of 0.7US\$/L at a speed of 2.81m/s, the COE is 0.358US\$/kWh and NPC is US\$58,404; for an increased wind speed of 4m/s, the COE drops to 0.337US\$/kWh and NPC of US\$54,990. Figure 18 shows the surface plot for the variation of COE and NPC with varying values of wind speed and diesel price.

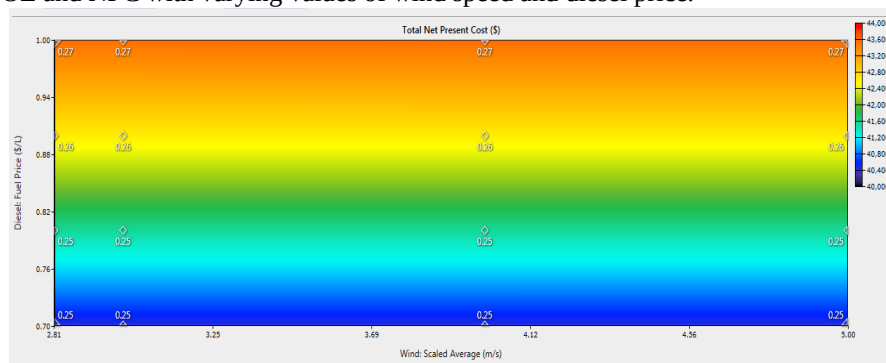


Figure 18: Surface Plot showing effects of diesel price and wind speed on NPC and COE

3.5 Comparison of the hybrid system to a stand-alone diesel system

HOMER also simulates a stand-alone diesel generator capable of providing the power to meet the load demand and from optimization results; the diesel system has an NPC of US\$80,256 and COE of US\$0.492kW/h which is significantly higher than that of the hybrid system. Thus, making the hybrid system more economical. Figure 19 shows the differences between these two systems.

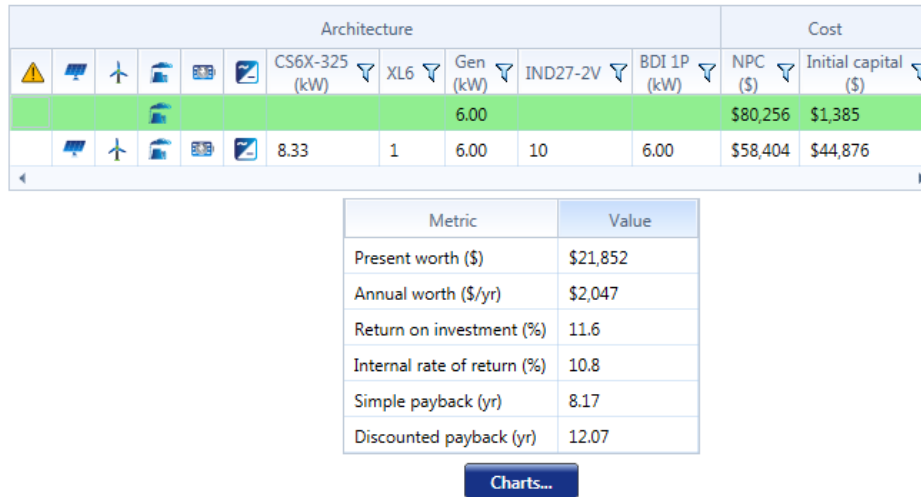


Figure 19: Comparison between hybrid system and Diesel system

The hybrid system has an annual worth of US\$2,047/yr. and present worth of US\$21,582 with a simple payback of 8 years indicating that the capital outlay for a stand-alone diesel system would be recouped within 8 years if the hybrid system is employed.

Figure 20 shows the nominal cumulative cash flow, the base system's (diesel system) line on the graph shows that the cost of the system increases progressively with time while that of the hybrid system remains on the same path showing that the system has a relatively fixed cost which depreciates with time.

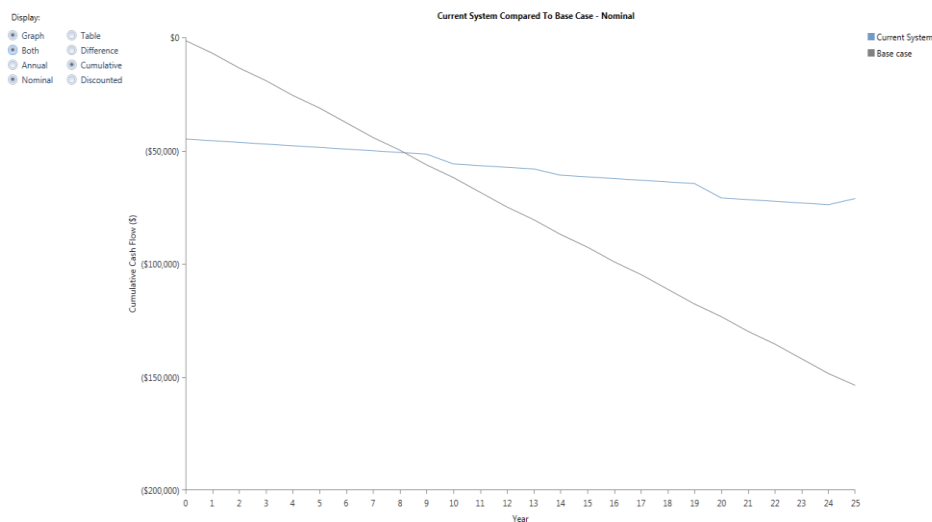


Figure 20: Nominal cumulative cash flow analysis of both systems

3.6 Greenhouse gas emission

HOMER estimates the emissions of greenhouse gases by the hybrid system and the diesel system. The result is shown in Tables 2 and 3 respectively. The amount of greenhouse gases emitted by the stand-alone diesel system is almost ten times that of the hybrid system. Thus, the hybrid system reduces emissions by as much as an order of ten.

Quantity	Value	Units
Carbon Dioxide	2,104.35	kg/yr
Carbon Monoxide	5.19	kg/yr
Unburned Hydrocarbons	0.58	kg/yr
Particulate Matter	0.39	kg/yr
Sulfur Dioxide	4.23	kg/yr
Nitrogen Oxides	46.35	kg/yr

Table 2: Hybrid system emissions

Quantity	Value	Units
Carbon Dioxide	20,115.90	kg/yr
Carbon Monoxide	49.65	kg/yr
Unburned Hydrocarbons	5.50	kg/yr
Particulate Matter	3.74	kg/yr
Sulfur Dioxide	40.40	kg/yr
Nitrogen Oxides	443.06	kg/yr

Table 3 Diesel system emissions

4. CONCLUSION

Using the HOMER microgrid software, the best PV-wind hybrid system combination for the E-library is one that consists of an 8.33kW PV panel, 1 wind turbine, a 6kW diesel generator, 10 batteries and a 6kW converter (inverter) with the hybrid system having a Net Present Cost (NPC), Cost of Energy (COE), Initial Cost and Operating cost of US\$58,404, US\$0.358kWh, US\$44,876 and US\$1,046 respectively with a project lifetime of 25 years. This system is found to adequately meet the energy requirements of the E-Library and these figures make the hybrid system a very cost-effective and viable option for electrification of the E-Library. The result from HOMER simulation indicates that changes in diesel price and wind speed have varying effects on the NPC and COE of the hybrid system. With increasing diesel price there is an increase in NPC and COE of the system while with increasing wind speeds the values of NPC and COE drop markedly. A comparison of the NPC and COE of the hybrid system with the stand-alone diesel system shows that the diesel system has a much higher NPC of US\$80,256 with higher operating costs as well as COE with the hybrid system having a simple payback of 8 years. This short payback period is ideal since money invested would be recouped at this time. HOMER results also show that the emission of greenhouse gases by the diesel system is almost ten times more than that of the hybrid system. The hybrid system reduces emissions by as much as 90% thus, making the hybrid system very environmentally friendly. The results obtained are fairly general and this model may be adequate for a household, institutional building, or small industry where a hybrid system or a system with one renewable energy source is willing to be adopted.

REFERENCES

- Ajao, K. R., Oladosu, O. A., & Popoola, O. T. (2011). Cost Benefit Analysis of Hybrid Wind Solar Power Generation by HOMER Power Optimisation Software. *Journal of Applied Science and Technology (JAST)*, 16(1), 52–57.
- Al-Karaghoul, A., & Kazmerski, L. L. (2010). Optimization and life-cycle cost of health clinic PV system for a rural area in southern Iraq using HOMER software. *Solar Energy*, 84(4), 710–714. <https://doi.org/10.1016/j.solener.2010.01.024>
- Hoque, M. M., Bhuiyan, I. K. A., Ahmed, R., Farooque, A. A., & Aditya, S. K. (2012). Design, Analysis and Performance Study of a Hybrid PVDiesel Wind System for a Village Gopal Nagar in Comilla. *Global Journal of Science Frontier Research Physics and Space Sciences*, 12(5), 0–5.
- Ibrahim, S. (2020). A Review of Solar-Wind Hybrid System for Power Generation in Nigeria. *African Scholar Journal of African Sustainable Development (JASD-2)*, 19(2), 95–110.
- IEA. (2019). World Energy Outlook 2019. In *World Energy Outlook Series*. Retrieved from <https://www.iea.org/reports/world-energy-outlook-2019> <https://www.iea.org/reports/world-energy-outlook-2019> <https://webstore.iea.org/download/summary/2467?fileName=Japanese-Summary-WEO2019.pdf>
- Islam, M. A., Hasanuzzaman, M., Rahim, N. A., Nahar, A., & Hosenuzzaman, M. (2014). Global renewable energy-based electricity generation and smart grid system for energy security. *Scientific World Journal*, 2014. <https://doi.org/10.1155/2014/197136>
- Lekana, H. C., & Ikemi, C. B. S. (2021). Effect of Energy Consumption on Human Development in the Countries of the Economic and Monetary Community of Central Africa (EMCCA). *Theoretical Economics Letters*, 11(03), 404–421. <https://doi.org/10.4236/tel.2021.113027>
- Momoh, Z., Anuga, J. A., & Obidi, A. J. (2018). Implications of Poor Electricity Supply on Nigeria's National Development. *Humanities and Social Sciences Letters*, 6(2), 31–40. <https://doi.org/10.18488/journal.73.2018.62.31.40>
- NASA <http://eosweb.larc.nasa.gov> Accessed online 04/02/20220
- Nema, P., & Nema, R. (2010). PV-solar / wind hybrid energy system for GSM/CDMA type mobile telephony base station. *International Journal of Energy and Environment*, (March 2015).

- Okedu, K. E., & Uhunmwangho, R. (2014). Optimization of renewable energy efficiency using HOMER. *International Journal of Renewable Energy Research*, 4(2), 421–427.
- Okonkwo, E. C., Okwose, C. F., & Abbasoglu, S. (2017). Techno-economic analysis of the potential utilization of a hybrid PV-wind turbine system for commercial buildings in Jordan. *International Journal of Renewable Energy Research*, 7(2), 908–914.
- Rawat, R., & Chandel, S. S. (2013). Simulation and optimization of solar photovoltaic-wind stand alone hybrid system in hilly terrain of India. *International Journal of Renewable Energy Research*, 3(3), 595–604. <https://doi.org/10.20508/ijrer.88774>
- Salam, M. A., Aziz, A., Alwaeli, A. H. A., & Kazem, H. A. (2013). Optimal sizing of photovoltaic systems using HOMER for Sohar, Oman. *International Journal of Renewable Energy Research*, 3(3), 470–475. <https://doi.org/10.20508/ijrer.84833>
- Salisu, S., Mustafa, M. W., Olatomiwa, L., & Mohammed, O. O. (2019). Assessment of technical and economic feasibility for a hybrid PV-wind-diesel-battery energy system in a remote community of north central Nigeria. *Alexandria Engineering Journal*, 58(4), 1103–1118. <https://doi.org/10.1016/j.aej.2019.09.013>
- Sobhan, S., Ahmad, T., Rahimi, J., Ullah, H., & Arif, S. (2016). American Journal of Engineering Research (AJER) HOMER Based Feasibility Study of Off-Grid Biogas Power Generation Model Using Poultry Litter for Rural Bangladesh. (1), 21–33.
- Thirunavukkarasu, M., & Sawle, Y. (2020). Design, analysis and optimal sizing of standalone PV/diesel/battery hybrid energy system using HOMER. *IOP Conference Series: Materials Science and Engineering*, 937(1). <https://doi.org/10.1088/1757-899X/937/1/012034>
- Uzorh, E. A. C., & Innocent, N. (2019). Solution to Power Generation Shortages Using Solar Energy The International Journal Of Engineering And Science (IJES) Solution to Power Generation Shortages Using Solar Energy. (January).
- World Energy, & Outlook. (2019). *Africa energy outlook*. <https://doi.org/10.1787/g2120ab250-en>