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Comparative Cost Analysis between Solar PV Energy and Diesel Generator as a Power Supply

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ABSTRACT

The phenomenon of rapid expansion of global systems of communication (GSM) is observed in several nations around the globe. The expansion of some regions, particularly in developing nations like Port Harcourt, has encountered several obstacles, with one prominent being the inadequate provision of public electricity. The energy cost of the diesel generating set and the PV system in terms of initial capital cost, future replacement, and maintenance cost for the first fifteen years were estimated. This study evaluates the comparative cost analysis of the use of solar energy from solar PV as the source of power against the Diesel generator being used at Airtel Switch Port-Harcourt. Cost analysis was conducted for short-term (5 years), mid-term (15 years), and long-term (25 years). It was found that solar PV was 84.4%, 89.9%, and 87.7% more cost-effective for a 5-year, 15-year and 25-year period respectively. Therefore, considering the cost analysis for short, mid, and long-term operations, excluding inflationary trends, cost of maintenance of diesel generators, oil change, and any other equipment change, Solar PV was found to be more cost-effective as the source of power supply at Airtel Switch Base, Port Harcourt: Solar PV, Short-term, mid-term, long-term, cost-effectiveness. The analysis indicated that, in terms of cost and environmental friendliness, the PV system was the better option to be selected as an alternative and sustainable to the grid supply energy for power generation. Renewable sources have a lower power generation cost than diesel power generation. The adoption of renewable energy as a power source for GSM stations in Nigeria is therefore strongly advocated to make the industry globally competitive.

Keywords: Cost analysis, Diesel generator, Global systems of communication (GSM), Renewable energy, Solar PV

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1. INTRODUCTION

Every contemporary civilization places a high value on energy since it is the cornerstone of society's social and economic development [Blaće et. *al*, 2012]. Electricity is the most common and most utilised form of energy globally. Telecommunication, like every other industry in contemporary civilization, depends entirely on electricity to function. Due to this complete reliance on power for operation, the telecommunications network must constantly contend with rising national grid demand for electricity. According to Blaće et *al.*, (2012), the telecommunications industry generally uses 4% of the world's power. Nigeria's inconsistent power supply and the complete lack of power in the majority of rural areas have forced telecom service providers to turn to alternative power sources such as power-generating equipment that run on fossil fuels like diesel and gasoline (Okedere et *al.*, 2021). The Nigerian telecommunications industry is now one of the ten fastest-growing telecommunications sectors worldwide and the fastest-expanding market in Africa. According to recent reports,

the Nigerian telecommunications industry managed over 135 million active users as of the end of 2014, and between 2003 and 2015, the base of Nigerian telecom subscribers grew dramatically (Abdulmula et *al*., 2022). Due to this, the service provider's average energy requirements to supply telecom services have also gone up. This usually increases the cost of operation which in turn results in higher tariffs, call and data rates. The competition among the current network providers has prompted studies on how to enhance the tariff so that it is reasonable for the burgeoning user base. This initiative has prompted telecommunications providers in Nigeria to begin exploring methods to reduce their ongoing operating costs and other costs. Hence, endeavours to conserve energy and reduce greenhouse gas emissions (GHG) are considered to be a secure approach towards implementing environmentally friendly operations in the telecommunications industry (Ojo et al., 2015).

To tackle the prevalent trend, it is imperative to develop tactics and investigate other forms of energy that provide improved cost-effectiveness, such as solar power. Multiple research projects have been carried out to investigate the practicality of using solar energy as a cost-effective alternative to conventional power sources. Kumar and Biswas (2017) offered a complete analysis of the techno-economic optimization of a standalone photovoltaic (PV) and/or pumped hydro storage (PHS)/battery system particularly intended for extremely low-demand scenarios. The research primarily explored the viability of deploying solar photovoltaic (PV) technology in combination with pumped hydro storage (PHS) and battery bank storage systems for rated loads not higher than 30 KW. The focus of their efforts was concentrated on maximising the efficiency of systems, lowering costs, and the actual deployment of energy storage. Each of the parts of the Renewable Energy Systems (RES) was simulated and correctly scaled. Each RES was subsequently optimised from a techno-economic standpoint, employing the levelized cost of energy (COE) as the aim function, with a target of 100%. To optimise the efficiency of solar photovoltaic (PV) systems, this study applied three meta-heuristic optimization techniques: Firefly Algorithm (FA), Grey Wolf Optimization (GWO), and Genetic Algorithm (GA). These algorithms were applied to maximise the size and storage capacity of the solar PV systems. The findings of the study suggested that the usage of a small-scale battery bank in conjunction with pumped hydro storage (PHS) resulted in a considerable reduction in the capacity of the upper reservoir, while concurrently creating a limited quantity of surplus energy.

In their study, Abdulmula et al. (2022) evaluated the technical and cost-effectiveness of several renewable energy sources to create an ecologically sustainable off-grid communications tower in Malaysia, as an alternative to diesel generators. A comparative review was conducted on diesel generators, solar power, wind energy, and pico-hydro energy to assess their suitability for the stated aim. The Hybrid Optimisation Simulator for Energy (HOMER) simulation was employed to simulate hybrid power systems and identify which is the most cost-effective solution. The optimisation research reveals that among the most advantageous setups for providing power to off-grid telecommunication towers in Malaysia, considering both net present cost (NPC) and cost of energy, are the 2 kW pico-hydropower system in conjunction with a battery. Subsequently, the hybrid high-efficiency fixed photovoltaic (PV) system with battery exhibits a comparatively reduced cost of energy (COE). The costs of NPC and COE were determined to be 17.45%, 16.45%, 15.9%, and 15.5% lower than the costs of diesel generators and batteries, respectively. According to the study, the high-efficiency solar fixed PV panels system has a return on investment of 10 years when compared to the battery-powered diesel-powered generator, based on the annual earnings.

2. MATERIALS AND METHODS

This work considered how to use sun power, wind power, and small water power because each one can do different things. The study looked into parts that need replacing, the cost of work done by people, moving goods costs and these things every year as seen with Airtel in Port Harcourt, River State. Within the context of a base subsystem controller (BSC), there exist three distinct sorts of subsystem sides: the upside, the backbone side, and the normal side. The installation of a base station involves the selection of one of three subsystem sides: upside, rear bone, or normal.

2.1. Material Selection

2.1.1 Solar Panel

A solar panel refers to a collection of photo-voltaic cells that are arranged and affixed within a structural framework to facilitate installation. Solar panels harness the radiant energy emitted by the sun to produce

electrical energy in the form of direct current. The photovoltaic (PV) junction box is affixed to the rear side of the solar panel and serves as its output interface. The functionality of a solar panel relies on the principles of the photovoltaic effect.

The photovoltaic effect, which has a striking resemblance to the photoelectric effect, is a physical phenomenon that gives rise to the generation of an electric potential difference (voltage) within a material upon exposure to light. The selection of panel size is based on the total power that is required to be generated. In the case of Airtel Switch Base Port Harcourt, the power required to be generated as discussed in 3.2 is set at 500KW. Therefore, 380W solar panels were assumed to best suit this purpose. Consequently, the number of panels required to produce the required power output of 500KW can be determined by Equation (1).

$$\textbf{\textit{number of solar pv panels}} = \frac{\textbf{\textit{power Required to be Generated}}}{\textbf{\textit{Solar PV panel Power rating}}} = \frac{\textbf{500KW}}{\textbf{380}} \quad \textbf{(1)}$$

$$\textbf{Number of Solar PV panels} = \textbf{1315.8} = \textbf{1316}$$

2.2 Batteries

A battery is a collection of cells used in storing DC voltage. Batteries use the chemical potential of their composite material to store energy. From the assessment of equipment at Airtel Switch Port Harcourt, it is observed that there are already preinstalled batteries totalling 364 of three different ratings: 6V150AH, 6V200AH and 12V150AH which are being used in conjunction with inverters and UPS as backup power supply sources. Therefore, these batteries which are already grouped in racks for supply of power to individual systems, equipment and appliances will be sufficient to power these appliances and equipment at Airtel Switch Yard.

2.3 Inverter

An inverter is a device which converts direct current into alternating current form of electricity. Airtel Switch yard Port Harcourt has an installed inverter capacity of two 6 KVA, one 12 KV and a 40 KVA UPS. These installed systems are responsible for providing an alternative power supply during generator downtime. Thus, these systems can be repurposed to provide continuous power supply for all equipment, and appliances at the Switch Yard.

3. RESULTS AND DISCUSSION

3.1 Cost Implications of using Diesel at Airtel Switch Base Port Harcourt

Diesel consumption data was obtained from Airtel Switch Yard Port Harcourt for two years, 2020 and 2021. This data is presented in Figures 1, 2 and 3.

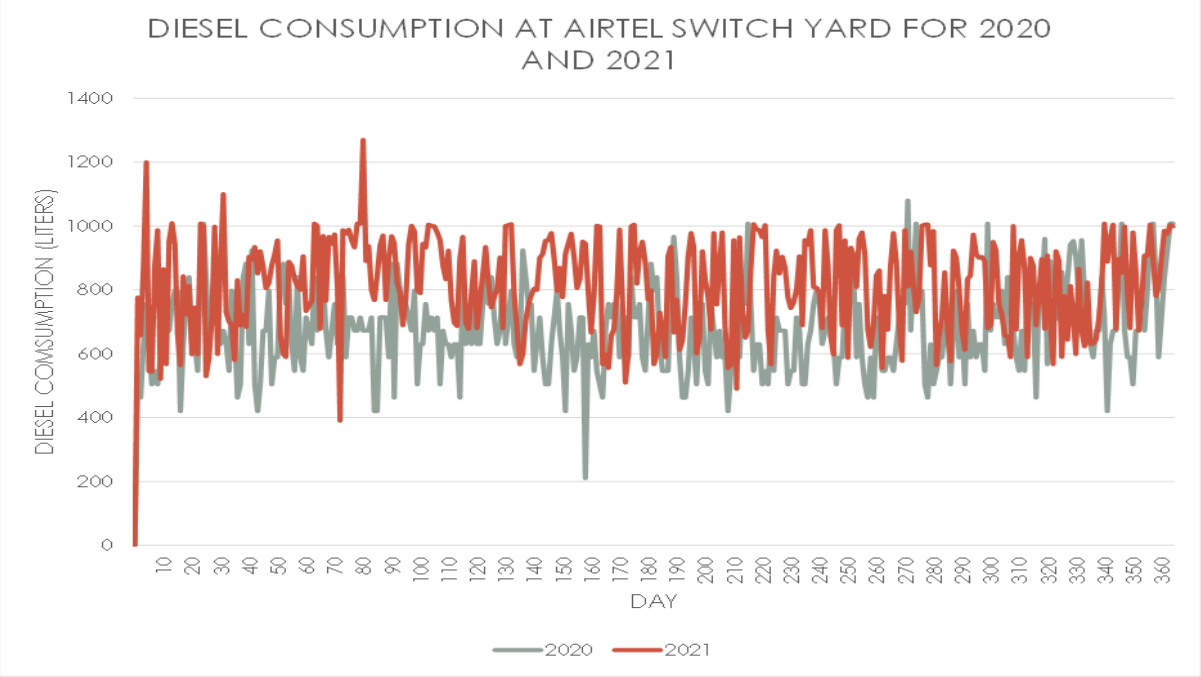

Fig. 1 Diesel Consumption for 2020 and 2021

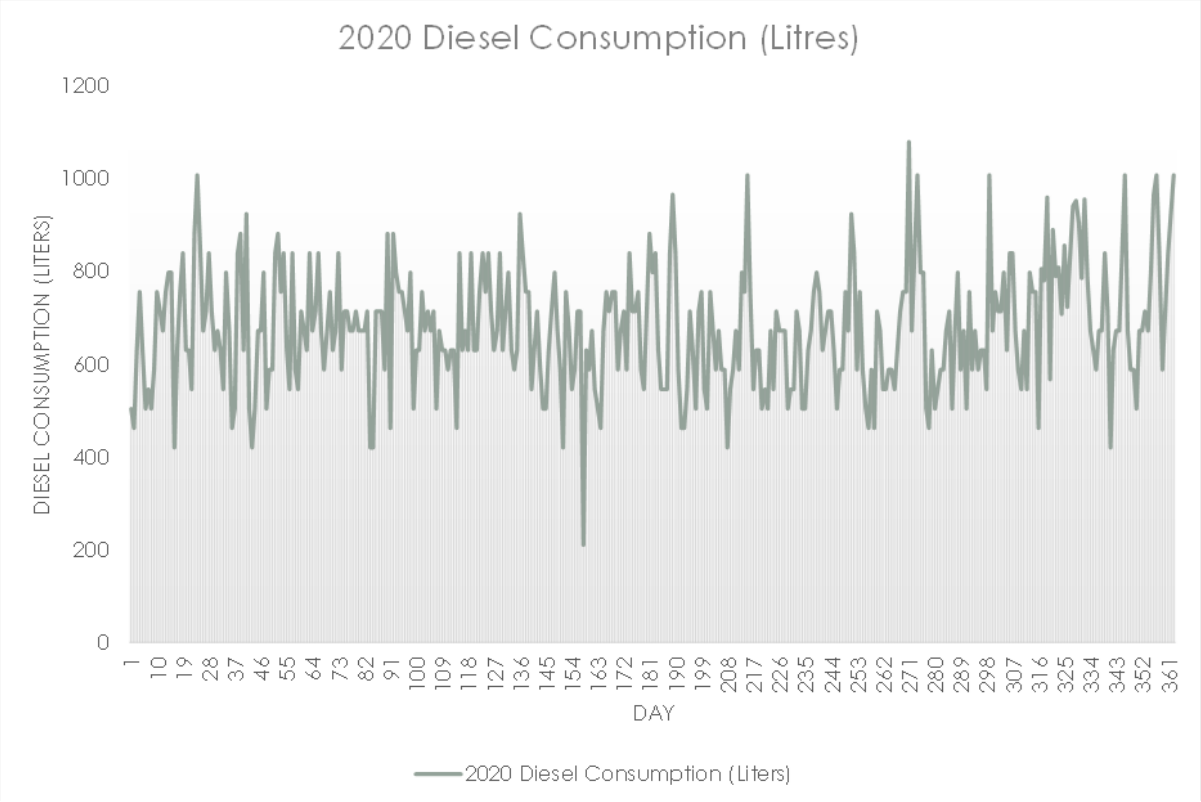

Fig. 2 Diesel Consumption for 2020

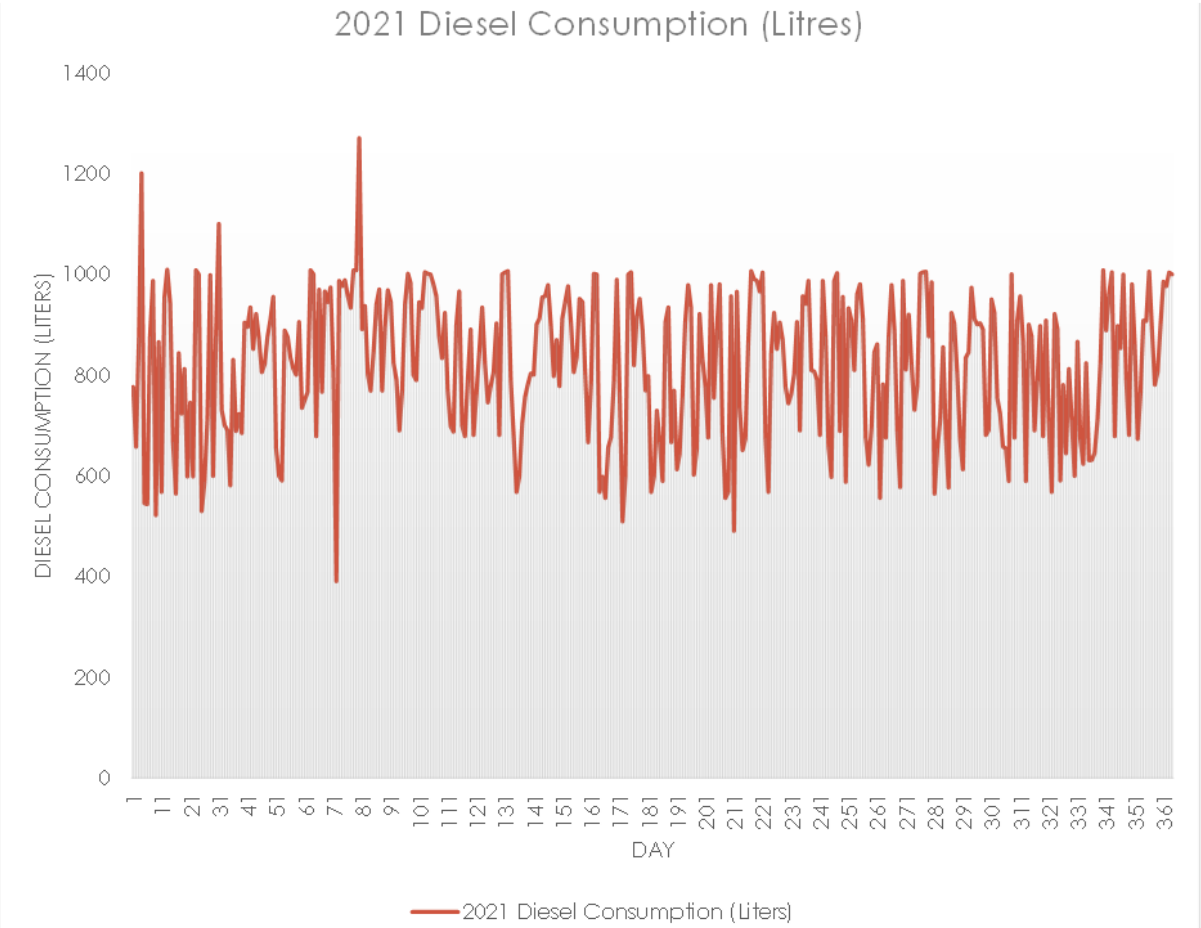

Fig. 3 Diesel Consumption for 2021

Table -1 Total Cost Incurred on Diesel for 2020 and 2021

Year	Total Diesel Consumed (L)	Toal Cost Incurred NGN (Naira)
2020	247561	247561 × 500 =123,780,500
2021	280918	280918 × 500= 140,459,00

From the data presented in Table 1, the diesel consumption for the two years 2020 and 2021 is computed to be 247561 Liters and 280918L respectively. Thus, taking the cost of diesel to be 500 Naira per litre, the total cost incurred for the two years is computed to be ₦123780500 and ₦14045900 respectively

3.2 Cost Implications of Installing Solar Energy at Airtel Switch Base Port Harcourt

A 380W solar PV panel is selected which goes for 75,000 Naira as of 02/06/2022. Given that the total number of solar panels required to supply 500KW of electric power is calculated to be therefore, the cost of purchase of solar panels can be computed to be:

75000 x 1316 = ₦198,700,000

Taking the cost of mounting a frame for one panel to be NGN800 according to Adejuyigbe et *al.* (2013), factoring in inflation, the cost of mounting frame for a one panel can therefore be set at 1200. The cost of installation of the Panel is therefore given as:

1200x1316= ₦1,578,200

Estimating cost of Wiring at ₦2,500,000 Therefore, the overall cost of installation of solar PV panels at Airtel Switch Base is given as ₦98,700,000 + ₦1,578,200 + ₦2,500,000 = ₦102,779, 000.

3.3 Short-Term Cost

3.3.1 Short-Term Cost of Using Diesel

Considering a short-term duration of 5 years, the cost-effectiveness of using solar as opposed to diesel at Airtel Switch Yard Port Harcourt can be computed by using the average volume of diesel consumed in two years as the Diesel for two years as a benchmark and setting a benchmark price of NGN500/L for diesel. Therefore,

$$\boldsymbol{V_{AD} = \frac{247561+280918}{2} = 264239.5L} \quad \textbf{(2)}$$

Therefore, for a short-term period of 5 years, the cost of running the Airtel Switch yard on a diesel generator, excluding other cost implications such as servicing and oil change, the cost incurred is calculated to be:

$$\boldsymbol{V_{AD} * n * P = 264239.5 * 5 * 500 = \text{NGN } 660{,}598{,}750} \quad \textbf{(3)}$$

Where;

V_{AD}= $Average\ Volume\ of\ diesel\ consumed$

$n = number\ of\ years$

$P = benchmark\ cost\ per\ liter\ of\ diese$?

3.3.2 Short-Term Cost of Using Solar PV System

From Section 2.3, the cost of installation of solar PV was computed to be. However, since no new installation of panels would be required within a short-term period of 5 years, the short-term cost of using solar PV as a source of power at Airtel Switch can be said to be the same as the cost of installation. Therefore, comparing the short-term cost of solar PV which stands at and that of diesel which stands at a total savings could be made through the implementation of solar PV at Airtel Switch Base. This accounts for:

$$\frac{\boldsymbol{NGN557,819,750}}{\boldsymbol{NGN660,598,750}} * \boldsymbol{100 = 84.44\%}$$

Thus, it can be inferred that excluding all other costs incurred such as maintenance of the generator, oil change, and rewiring, the use of solar PV as opposed to diesel generators at Airtel Switch Base Port Harcourt is found to be 84.4% more cost-effective, allowing for a total savings of NGN557,819,750.

3.4 Mid-Term Cost

For a mid-term range of 15 years, the cost-effectiveness of solar PV as opposed to diesel generators can be computed by substituting n=15 into Equation 3.17. Therefore, the mid-term cost of operating on Diesel can be calculated as:

$$V\text{ad} \times n \times P \quad (4)$$

264239.5 × 15 × 500 = *NGN*1,981,796,250

In terms of solar PV, assuming the solar PV panels are overhauled every 6 years according to Ebrahim et *al*. (2021), the mid-term cost of using solar PV can be calculated as:

(*Cost of installation of Panel* + *estimated cost of wiring*) × 2(98,700,000 + 2,500,000) × 2 = *NGN*202,400,000

Thus, in the mid-term, the cost-effectiveness of deploying solar PV as opposed to diesel can be calculated as:

***GN*1,981,796,250 − *NGN*202,400,000 = *NGN*1,779,396,250**

Thus, solar PV is 89.8% more cost-effective than diesel for a mid-term period of 15 years.

$$\frac{NGN1,779,396,250}{NGN1,981,796,250} * 100 = 89.8\%$$

3.5 Long-Term Cost

Considering a long-term operation of 25 years, the cost-effectiveness of solar PV as opposed to diesel generators can be computed by substituting n=25 into Equation 2

Therefore, the long-term cost of operating on Diesel can.be calculated as:

$$V_{AD} \times n \times P \quad (5)$$

264239.5 × 25 × 500 = *NGN*3,302,993,75

For solar PV, assuming the solar PV panels are overhauled every 6 years according to Ebrahim et *al***.** (2021), the long-term cost of using solar PV can be calculated as

(*Cost of installation of Panel* + *estimated cost of wiring*) × 4(98,700,000 + 2,500,000) × 4 = *NGN*404,800,000

Thus, the long-term operating cost-effectiveness of deploying solar PV as opposed to diesel can be calculated as:

***NGN*3,302,993,750 − *NGN*404,800,000 = *NGN*2,898,193,750**

$$\frac{NGN2,898,193,750}{NGN3,302,993,750} * 100 = 87.7\%$$

Thus, it is 87.7% more cost-effective in operating on solar PV than diesel for a long-term period of 25 years.

3.6 Discussion

The findings of this study are presented in a tabular format. Furthermore, the system's life cycle costs were considered. Technical and economic factors were examined by simulation using Life Cycle Impact Assessment (LCIA) software. Additionally, we thought about how much it costs to keep up the systems throughout their lifetime. The pictures down here show the big changes in cost between the diesel generator and the solar panel (PV) system. Picture 4 shows a big difference in pollution from the DG machine next to what comes out of solar panels. Diesel engine makes lots of warmth that is not good for nature. Figure 5 shows a picture that compares how Diesel Generators and Solar Photovoltaic (PV) systems affect the environment differently. The chart makes it clear that diesel generators release much more bad stuff into the air than Solar PV systems do. Looking at the chart, we can notice that the diesel generator is causing much damage to nature because it releases a lot of carbon. This pollution is very bad for people's health and also makes the ozone layer thinner. In contrast, solar photovoltaic (PV) systems demonstrate no adverse effects on the environment. Figure 6 illustrates the expenditure associated with the acquisition of a Diesel Generator and Solar Photovoltaic (PV) system. When considering the financial aspect, the total expenditure involved in the installation of a solar power system is significantly more in comparison to acquiring a DG Set with an equivalent kilovolt-ampere (kVA) capacity. Figure 7 depicts the deterioration that occurs in the vicinity of the Diesel Generator and Solar Photovoltaic (PV) system. The longevity of a Solar PV system surpasses that of a DG Set when regular maintenance is conducted. Figure 8 illustrates the maintenance cost of both devices. According to the provided chart, it can be observed that both the diesel generator set and PV system exhibit a maintenance cost of $0 during the initial month. Both the DG sets and PV system exhibit consistent growth from the second month to the fourth month. However, in May and November, the DG sets experienced a large increase, while the PV system maintained a steady rate. This phenomenon is visually shown in the graph. In comparison to the diesel generator set, the PV system has a higher starting cost. When both systems are consistently utilized, the diesel generator incurs higher operational expenses compared to the PV system. This is seen in Figure 9.

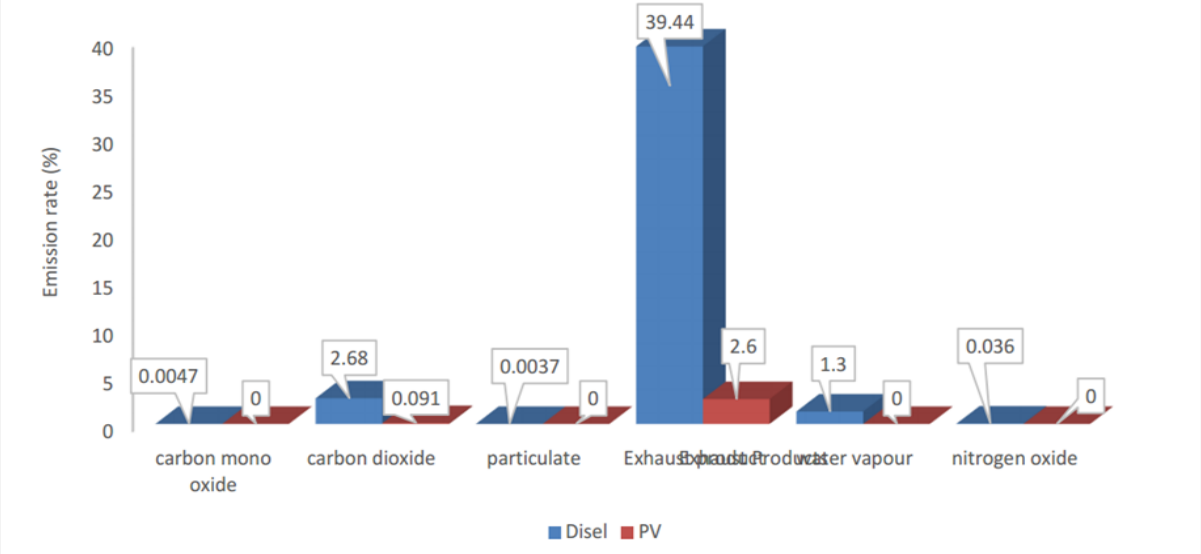

Fig. 4 Output results for diesel generator and solar PV emissions

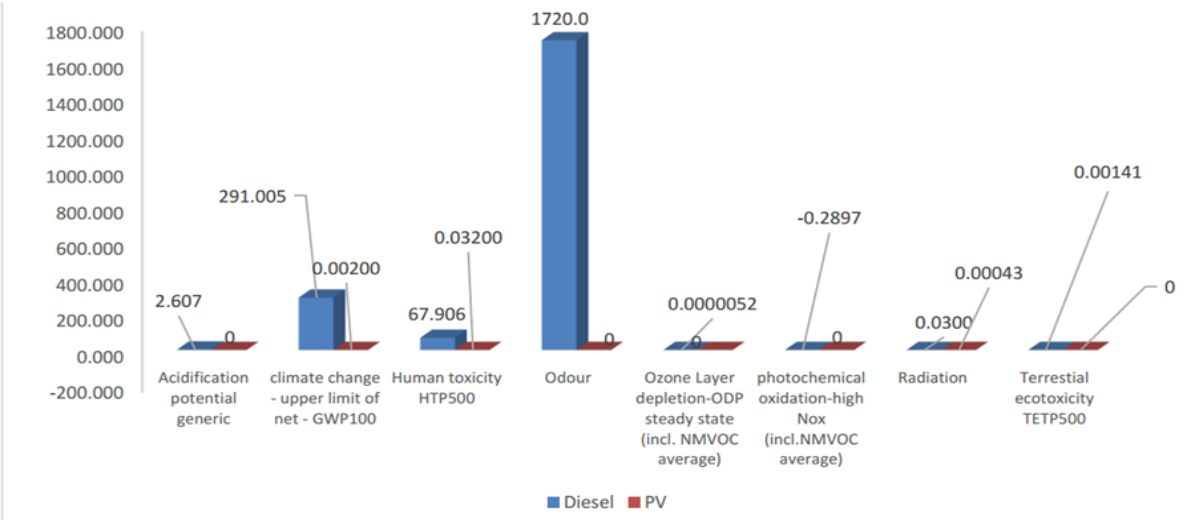

Fig. 5 Impact of the Diesel Generator and Solar PV on the Environment (kg/hr)

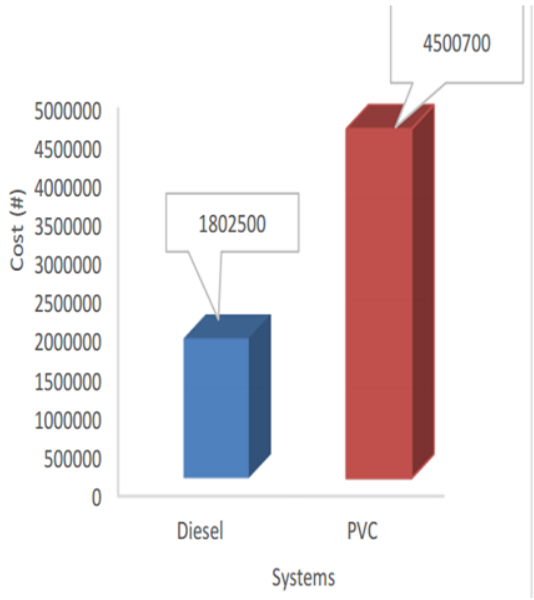

Fig. 6 Purchase cost comparison (Naira)

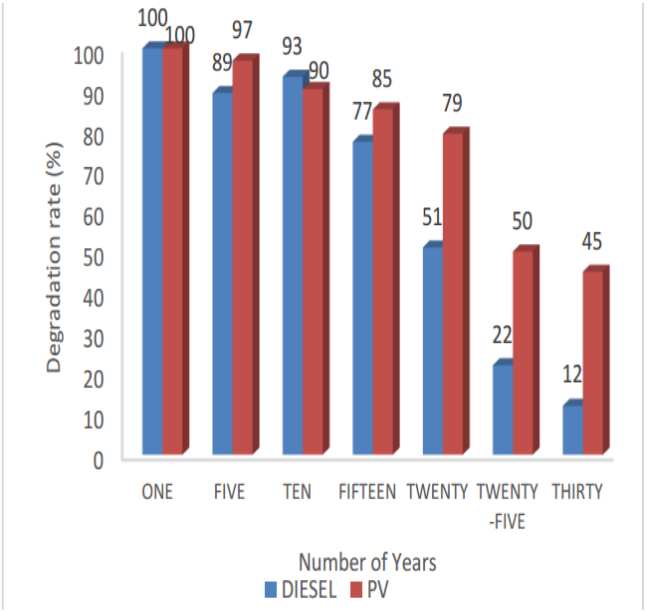

Fig. 7 Degradation Downstream (years)

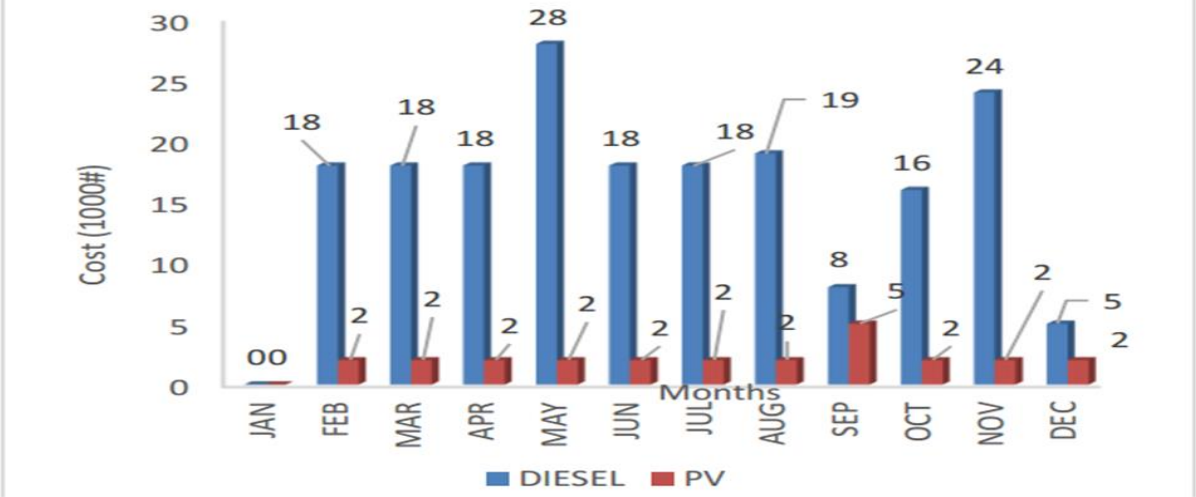

Fig. 8 Maintenance cost analysis (Naira/Month)

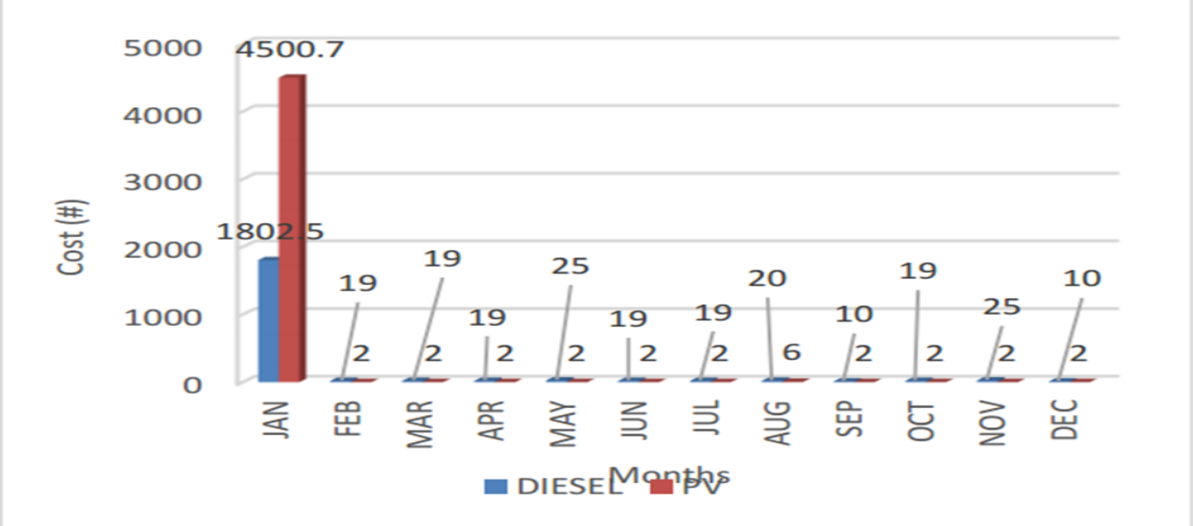

Fig. 9 Cost impact of diesel and PV system for a year

RECOMMENDATIONS

Hybrid power systems have the potential to serve as a financially viable solution for providing inexpensive and dependable electricity to remote areas that face challenges in implementing costly and complex grid expansion projects. The economic potential of these technologies is highly promising and warrants consideration for integration into the power generation capacity of emerging countries such as our own. The utilization of the HOMER (Hybrid Optimization Model for Electric Renewables) software in the present study facilitates the determination of appropriate hardware dimensions for hybrid energy systems, as well as the selection of optimal operational configurations for various system components, such as batteries and converters. The prioritization of research and development endeavours is crucial within the realm of renewable energy systems, as a means to address the inconsistent and unreliable power supply in Nigeria. It is recommended that governments at all levels make substantial investments in alternative energy sources to provide power to isolated, remote, and rural areas inside the country. The encouragement of community activities and assistance from multinational corporations and non-governmental organizations is essential in facilitating the deployment of renewable energy systems, therefore complementing the efforts made by the government in this domain.

CONCLUSION

Solar energy, derived from the Sun, is estimated to be 1000Trillion watts. This study was conducted to determine the cost-effectiveness of deploying solar PV compared to diesel-generating sets at the Airtel Switch Base, Port Harcourt, Nigeria. The study compared the performance of load forecasting, load assessment, and life cycle cost of diesel generators and solar photovoltaic systems. The findings of the study showed that solar PV was 84.4% more cost-effective for 5 years than diesel, with a total savings of 89.8% for 15 years and 87.7% for 25 years. The cost of power generation using diesel is the most substantial, followed by mini-hydro and windmill systems. Renewable sources of power have a lower cost of power generation compared to diesel power generation. The Photovoltaic (PV) power option has a significant advantage in terms of life-cycle cost (LCC) over 25 years. The study recommends embracing renewable energy as a viable power source for GSM stations in Port Harcourt.

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