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Original Research Article

The impact of petrol subsidy removal on the adoption of solar power in Nigeria

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Abstract

For decades, the Nigerian government has subsidized the price of petrol, making it one of the lowest in the world. Historically, the country has relied significantly on petrol subsidies to make energy more affordable to its inhabitants. This policy, however, has imposed a significant budgetary burden, fostered smuggling and corruption, and discouraged investment in renewable energy sources. Additionally, it cuts down on the resources that governments may devote to achieving other development goals as well as sustainable development goals. With a growing global emphasis on renewable energy sources and the need to reduce carbon emissions, Nigeria faces the challenge of transitioning from its traditional reliance on fossil fuels to more sustainable alternatives. To determine the impact of petrol subsidy removal on the adoption of solar power in Nigeria, we present a cost analysis comparing the acquisition and operation of a 2.5 kVA solar PV system to that of a petrol generator of the same capacity. The cost analysis shows that the solar PV system is a more cost-effective and sustainable option for power generation than petrol generators, especially in the long term. The paper emphasised the need of harnessing Nigeria's tremendous solar potential and reducing carbon emissions through solar power adoption. The study also shed light on the potential benefits and challenges of promoting solar energy as a viable alternative to traditional electricity supply in Nigeria.

Key Words: *Subsidy, petrol, solar, carbon emission.*

1.0 Introduction

Energy subsidies are government interventions that serve to maintain prices below market rates in general [1], [2]. Energy subsidies' main objectives are to promote rural and industrial development [3], [4], support domestic producers in their competition with foreign rivals [5], and increase the security of the energy supply [6], [7]. Nigeria's fuel subsidy was about $5 billion in 2021 (Figure 1) [8]. This level of energy subsidies places financial strain on governments [9], lowers energy prices and encourages excessive consumption [10], [11], raises carbon emissions [12], and reduces the competitiveness of investing in renewable energy technologies [13]. For decades, Nigeria has relied significantly on petrol subsidies to reduce the cost of energy for its citizens, which resulted in huge financial burdens and inefficiencies. However, the development of renewable energy sources like solar power has been hampered by this subsidy-driven strategy.

Subsidies for fossil fuels have a significant negative impact on the environment because they encourage people to switch from renewable sources of energy, resources, and labour to fossil fuels, slowing down the transition to a low-carbon economy. There is growing interest in gradually eliminating subsidies for fossil fuels to decrease energy use and energy-related greenhouse gas emissions. It is a prevalent belief in policy discussions that fossil fuel subsidies promote energy waste and that eliminating them would reduce energy-related carbon dioxide (CO_2) emissions. However, it is still unclear whether this is the case and how much pollution will be reduced as a result of cutting back on fossil fuel subsidies. [12].

Long-term power sector analyses have focused on the potential of renewable electricity technologies to lower GHG (greenhouse gas) emissions and improve the security of the energy supply [14]– [18]. The majority of renewable energy technologies are still in the development stage, and their high production costs remain a significant impediment to their widespread market adoption [19], [20]. Despite the country's maximum sunlight exposure and potential for solar photovoltaic (PV), solar energy provides just a small portion of power output in Nigeria. Nigeria is located in the solar belt, which increases its solar potential; yet the prospects for harvesting renewable energies remain limited and impractical when compared to conventional electricity [21].

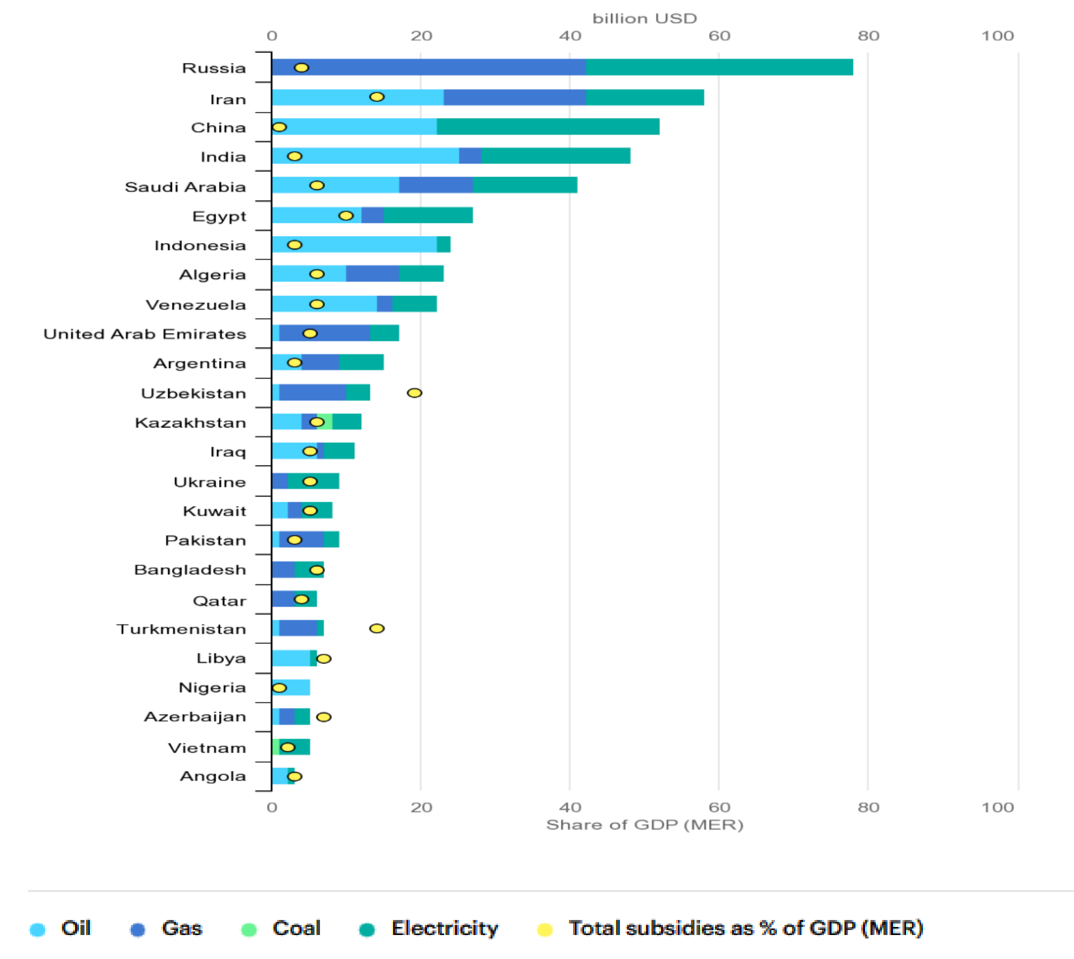

Figure 1: Value of fossil-fuel subsidies by fuel in the top 25 countries, 2021[8].

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2.0 Nigeria's petrol subsidy regime

According to Bakare [22], to subsidize is to sell a product at a lower cost of manufacture. Thus, in the Nigerian context, petrol subsidy involves selling premium motor spirit (PMS) below the cost of imports. The federal government, believing that the cost of production and transportation would be too high for the poor Nigerian masses to bear alone due to the rise in the price of fuel during the military era, decided to pay a portion of the total fuel cost to make the product available and affordable. This military intention of a petrol subsidy functioned from March 31, 1973, until 1986, when Gen. Ibrahim Babangida, the previous Head of State of Nigeria, raised the fuel pump price of petroleum from 20k to 39.5k, a 97.5% rise. According to sources, the situation worsened with the advent of democracy when, on June 1st, 2000, Chief Olusegun Obasanjo raised the pump price of fuel from 20 to 30 naira (a 50% rise) [23].

Since 2012, the issue of petrol subsidy removal or retaining the subsidy regime has been a significant topic of public debate. The fuel subsidy, which was initially intended to last six months, was introduced as a temporary measure in 1988 by the federal government of Nigeria as part of its Structural Adjustment Program (SAP), as a stop-gap measure while refineries were being rebuilt and to stabilize the price of petroleum products. The federal government has claimed that the fuel subsidy policy has prevented them from addressing issues with our nation's infrastructure, including roads, power, agriculture, fixing the refineries, etc. These unintended consequences and malpractices include the smuggling of petroleum products out of the country. The price of petrol subsidies has kept rising dramatically. This is due in part to the rising price of fuel, which forced the government to spend more money to maintain low domestic prices, as well as the pressures brought on by Nigeria's growing population, which led to higher fuel consumption. Taken together, these factors have made the cost of the fuel subsidy unsustainable. By 2011, the subsidy accounted for 30% of government spending in Nigeria, which was equivalent to 4% of the Gross domestic product (GDP) and 118% of the capital budget. The report of the Farouk Lawan-led House of Representatives Ad-hoc committee on the management of fuel subsidy discovered that over 232 billion naira in the form of subsidy was paid to marketers for PMS in 2011 yet the PMS was not supplied, and this subsidy has become a scheme for mismanagement of revenues. He discovered that subsidy computation is in two segments - (landing and distribution cost), the Landing Cost constitutes (total cost = 153.64 naira)**:-** Products, Insurance, and Freight: 141.40 naira; Lightering Expenses (SVH): 4.03 naira; Traders Margin: 1.19 naira; Storage Charges: 2.60 naira; Nigeria Ports Authority (NPA) charge: 0.62 kobo Jetty Depot throughout charge: 0.80 kobo; and, Distribution Cost includes (total cost = 15.49 naira):- Retailer's Margin: 4.60 naira; Transporters' Margin: 2.99 naira; Dealers' Margin: 1.75 naira; Marine Transport Average (MTA): 0.15 kobo; Budgeting Fund: 5.85 naira; Administrative Charges: 0.15 kobo [24].

Furthermore, during the administration of President Goodluck Ebele Jonathan, the Subsidy Reinvestment Programme (SURE-P) was established to use the funds made available by the partial withdrawal of subsidies to improve a lot of Nigerians as a whole. The purpose of the committee's formation was to supervise and guarantee the prompt and efficient execution of projects that would be paid for with federal savings from the elimination of subsidies. SURE-P is primarily intended to lessen the effects of eliminating fuel subsidies and to hasten economic growth by funding urgently needed infrastructure. According to them, savings from the removal of subsidies under SURE-P are to be spent in important economic areas including power, health, the Niger Delta, youth, etc. Sure-P estimates that 41% of interventions are handled by the federal government, 54% by state and local governments, and 5% by ecology [25]. Due to the inefficiencies and corruption that plagued Nigeria's petrol subsidy regime, the Federal Government confirmed the total removal of the subsidy on petrol on May 29, 2023, resulting in a significant increase in energy costs in the country and further undermining Nigerians' ability to access affordable power. According to some petroleum marketers, the price of petrol at the pump might triple or even quadruple as a result of this removal. In comparison to the initial average price of N196 per litre, many gas stations are currently dispensing the product at more than N600 per litre. With the global push for sustainability, now may be is the greatest time for the country to explore and transition to a clean energy source such as solar energy.

3.0 Nigeria power supply scenario

Nigeria is facing significant issues in terms of electricity generation and supply. Continuous fluctuations, frequent power outages, and system instability characterize the national grid supply [26]. According to Oseni [27], a typical Nigerian home has access to an average of five hours of electricity supply daily from the national grid. According to Ajayi and Ajayi [28], self-generation using conventional biomass and fossil fuels has been encouraged because the Nigerian national grid has not been able to provide enough energy to meet the nation's demand. The demand and supply gap is fast expanding since the supply is extremely insufficient and inadequate to meet the population's rising demand. Nigeria has a population of approximately over 225 million people [29] and a total installed capacity of 14380 MW from 27 generation stations nationwide, of which approximately 7527.5 MW is available and between 3800 and 4700 MW is delivered to consumers [30]. Lack of investment, gas pipeline vandalism, system losses, a poor maintenance culture, and limited power evacuation all contribute to the low percentage of delivery capacity [30]. To address the problem, Nigeria’s government took some serious steps to combat the country’s problems, including partial liberalisation of the power sector. It created a new national regulatory authority, the Nigerian Electricity Regulatory Commission (NERC), and unbundled or separated the electricity sector into separate components, notably state-owned grid operators with contracted-out management. It also divided the distribution network into regional distribution companies (DISCOs) and established six fully privatized independent generating companies (GENCOs). In addition to partial market liberalisation, the government undertook to significantly increase the country's on-grid electricity capacity from an insignificant 12,667MW in 2018 to 22,958MW by 2023. Recognizing the difficulties, the Nigerian government developed a Power Sector Recovery Programme. Renewable energy is expected to grow from 13% of total power generation in 2015 to 23% by 2025, accounting for 10% of total energy consumption. Another goal has been to raise electrification rates from 42% in 2005 to 60% in 2015, and 75% by 2025. The strategy calls for growing small hydropower capacity from 600MW in 2015 to 2,000MW by 2025. There is also a proposal to create 500MW of solar PV and 40MW of wind power, as well as to increase biomass-based power plant generating capacity from 50MW in 2015 to 400MW by 2025. [31].

It is noteworthy to observe that despite numerous attempts, the Federal Government has not been successful in resolving the energy situation. Citizens in the country are still forced to generate their energy using fossil fuels because the country's electricity supply is insufficient and unstable. These have detrimental effects on the environment and health.

4.0 Overview of the residential energy situation in Nigeria

The Nigerian household sector's energy consumption is made up of demand from both rural and urban areas. An increase in per capita GDP, improved lifestyle, and population growth have all contributed to an increase in the energy demand of Nigeria's residential sector throughout the years.

The sector's energy mix includes traditional solid biomass (wood and charcoal), electricity, kerosene, petrol, and liquefied petroleum gas (LPG) [32]. Households use energy to provide various services such as cooking, lighting, heating, and running appliances such as refrigerators, fans, air conditioners, televisions (TVs), and so on [33]. Electricity access in rural areas remains limited, with just approximately 41% of households electrified. Access to clean cooking utensils that use cleaner and more environmentally friendly energy sources for cooking is even more limited. Modern cooking fuels are only available to roughly 3.5% of rural homes. Few households use transition fuels like kerosene for cooking, but the vast majority use traditional biomass. However, access to electricity in urban areas has improved significantly over the years, with 86% of urban households being electrified, whereas just 8.5% have access to modern cooking fuels. The energy requirements for cooking in the Nigerian residential sector are variable. Cooking fuels include wood, charcoal, kerosene, LPG, and, to a lesser extent, electricity [34]. Fuelwood is the most often used cooking fuel in Nigeria, particularly in rural regions. In rural areas, it is mainly harvested from the forests surrounding settlements, however in urban areas, it is obtained from local vendors for a relatively low price when compared to alternative cooking fuels such as kerosene and LPG [33]. In Nigeria, the significant reliance on fuelwood for cooking has led to the destruction of numerous natural habitats and the depletion of numerous forests [35]. Figure 2 shows the share of rural and urban households for different energy sources for cooking [34].

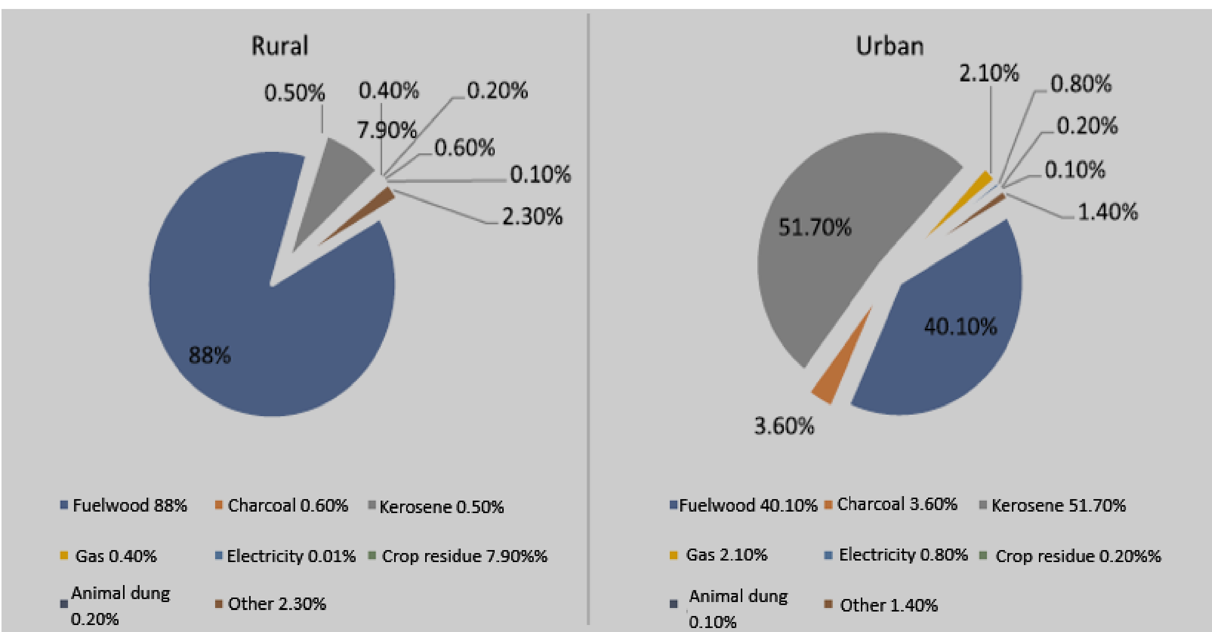

Figure 2: Share of rural and urban households for different energy sources for cooking [36].

It can be seen that the usage of contemporary cooking fuels such as electricity and LPG is quite limited and is mostly found in metropolitan houses. This can be linked to many Nigerian households' low-income levels, which inhibits their capacity to ascend the energy ladder [37]. However, other minute elements, like accessibility and cultural standards, have an impact on the choice of cooking fuels [32]. There have recently been a lot of attempts and political discussions to supply modern cooking equipment to all Nigerian households by 2030. Many actors (government and civil society) have keyed into this, but it remains to be seen how much of their good intentions will be realized in the near future [36].

With respect to lighting, Nigerian households depend on electricity, kerosene, dry cell battery, candle, grass, etc., but at the national level, electricity and kerosene constitute the main sources of lighting for the vast majority of households [34]. Electrical appliances such as refrigerators and air conditioners are mainly in urban households [32]. The majority of domestic appliances in Nigeria are quite old and inefficient. Some of them are imported from Western countries after their usable life has expired. This shows that there is a lot of room for energy savings in the sector [36] by Implementing policies and incentives to encourage the use of energy-efficient appliances because the old, imported appliances are less energy-efficient due to their age.

5.0 Nigeria solar energy outlook

Nigeria has significant solar energy potential that is largely untapped. Nigeria's location in the tropical region exposes it to excessive sun radiation. Nigeria has an average of 6.25 hours of sunlight per day, ranging from 9.0 hours in the far Northern boundary to about 3.5 hours in the coastal areas, implying that Nigeria receives about 12.6 MJ/m^2/day at the Southern coastal latitudes and about 25.2 MJ/m^2/day in the far Northern part of the country, giving the mathematical average as 18.9 MJ/m^2/day [38]–[41]. This translates to an equivalent of 229.1667 W/m^2 in power terms. Global Solar Atlas (GSA) [42] provided the details of direct normal irradiation across Nigeria, with an average of about 724 kWh/m^2 in the far Southern part and 1653 Wh/m^2 in the far Northern region. This translates into a PV power potential of 1248 kWh/kWp in the South and 1756 kWh/kWp in the North, and this information is further illustrated in Figure 3. With a total land area of 923,786 km^2, Nigeria typically receives an impact of solar radiation of about 1500 × 109 MWh annually, with an annual average of 19 MJ m^{-2}day^{-1} [41].

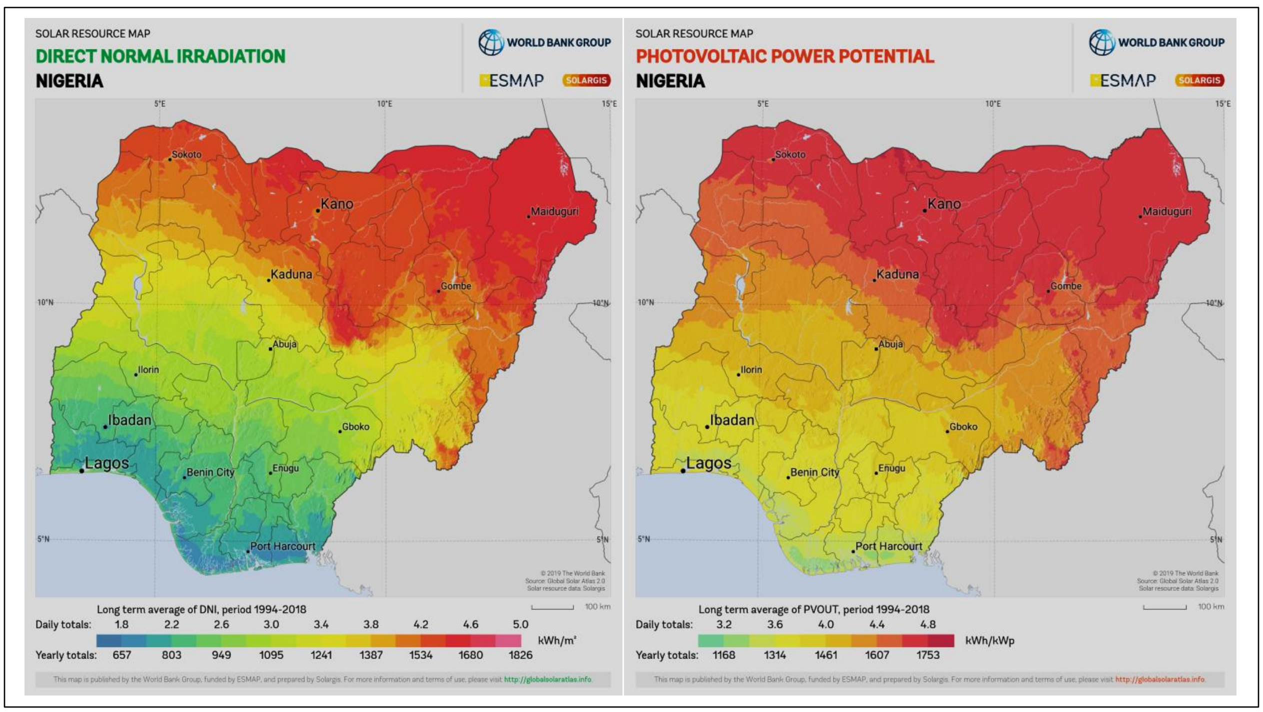

Figure 3: Direct normal irradiation and PV power potential [42].

An average of 6, 372, 613 PJ year^{-1} (approximately 1770 × 103 TWh year^{-1}) of solar energy received in the entire land area is 120,000 times the total PHCN (Power Holding Company of Nigeria) electricity generating capacity of 2002, and this energy value was estimated at 115,000 times the electrical energy generated by PHCN and about 27 times the value of total fossil fuel resources in the country [43].

Solar energy is limitless and non-polluting, making it a viable prospective source for green electricity generation. Despite the vast amount of solar energy reaching the earth's surface, numerous underdeveloped countries, including Nigeria, are having difficulty utilizing the resource [44]. According to Mohammed et al. [45], several developed countries have seen electrical stability following solar investment. Investing in solar energy harvesting technologies has the potential to decrease or eliminate energy poverty in developing countries while also promoting the reduction of greenhouse gases (GHG).

6.0 Solar technology penetration challenges in Nigeria

Nigeria has a lot of solar potential. However, the amount of PV installation is meagre than other developing countries in the region (Figure 4). Countries with lower energy demand than Nigeria and a smaller population experience significant adoption rate of photovoltaic (PV) systems [44].

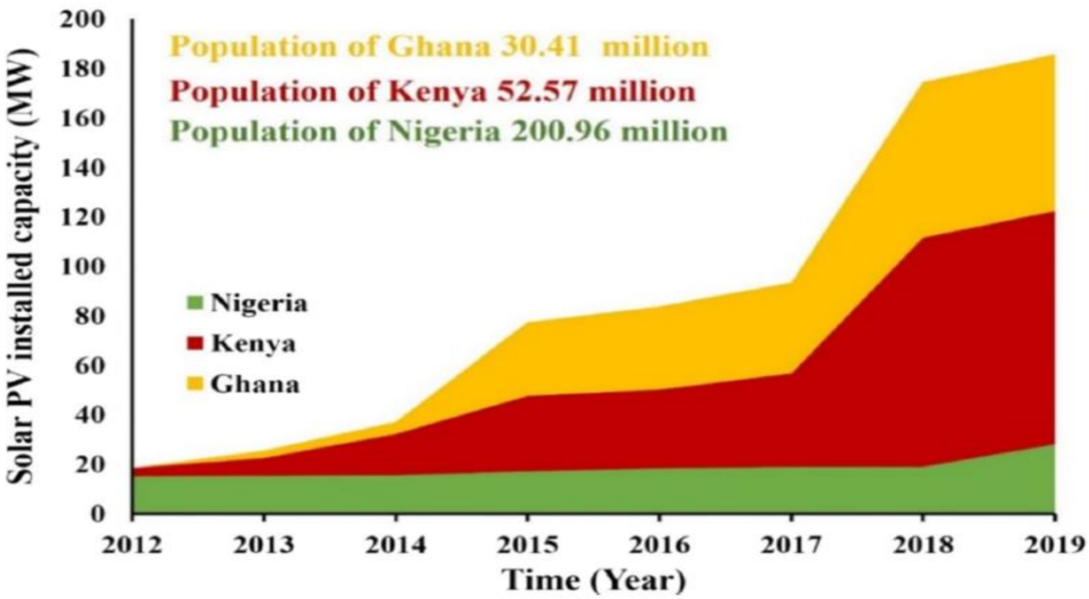

Figure 4: PV installed variation among three sub-Saharan countries [46].

The initial cost of installing solar photovoltaic technology is relatively high when compared to other energy harvesting methods such as diesel generators. However, the technology is significantly less expensive in the long run. Low-income earners will have affordability issues, as most people who do not have access to the national grid will be unable to acquire the equipment [47]. The vast majority of people are sceptical about using solar energy technology for energy generation due to inadequate information being disseminated about the great solar energy potential in the nation and a lack of awareness regarding the enormous benefits of solar PV [45], [48]–[50]. There is also little or no awareness of climate change and the repercussions of GHG emissions from the use of fossil fuels in energy generation [44].

With regard to including solar energy in the mix of national supplies, the Nigerian government has made policy implementation U-turns over time. However, the Nigeria Renewable Energy and Energy Efficiency Policy (NREEEP) is available [48] but has not yet been fully implemented because the government has not yet fully implemented some of the sub-policies such as incentives and any other palliative mechanisms to encourage and attract potential investors to the sector. NREEEP aims to contribute about 3% in 2020 to about 6% in 2030 of solar energy to the national supply mix [45], [47], [48]. There are high hopes that the recently signed Electricity Act 2023 by the federal government shall introduce tax incentives that are necessary to promote and facilitate the generation and consumption of energy from renewable energy sources.

7.0 Harnessing renewable energy for decarbonization and sustainable development

Global warming and climate change have elevated to the forefront of public discourse. Burning fossil fuels, such as coal, oil, petrol, and natural gas, damages the environment by releasing a significant amount of greenhouse gases (GHGs), mainly carbon emissions (CE) [51]. The necessity to eliminate CE has recently grown more pressing. To address this issue, at the United Nations climate summit in Paris in December 2015, all nations agreed to work together to reduce global GHGs and slow climate change. States pledged in 2015 to keep global warming below 2°C and to achieve carbon neutrality by 2050 under the Paris Agreement [52].

Renewable energy is a feasible option for achieving carbon neutrality, as recent studies have shown that renewable energy consumption can reduce CE [51], [53], [54]. In addition, it emphasizes the significance of using renewable energy instead of fossil fuels and optimizing energy efficiency to achieve carbon neutrality by 2050. As a result, we must urgently implement a global energy transition to achieve Sustainable Development Goal 7 (SDG 7), which consists of three key objectives: making modern energy services affordable, reliable, and accessible; making renewable energy a more prominent part of energy systems; and accelerating the pace of global energy efficiency improvements [55]. The transition to low-carbon energy is critical, as fossil fuel-related CE accounts for two-thirds of global GHG emissions [56]. Technological improvements, particularly those linked to renewable energy, are essential to this energy transition. Due to the capital-intensive nature of renewable energy, financial development (FD) is required for its adoption [52].

The FD could improve environmental sustainability by lowering CE through technical advancement, research, and development (R&D) [57]. Furthermore, capital markets could aid renewable energy R&D by attracting foreign corporations capable of exporting these innovations to local firms [58]. Green technology, together with the use of renewable energy sources and FD, is essential for achieving sustainable development without harming the environment [59], [60]. Green technology is the use of technologies to create and consume energy to increase energy efficiency and reduce negative environmental effects. According to the International Energy Agency's 2021 study, if the world is to reach carbon neutrality by 2050, further oil, natural gas, and coal mining and development must halt by 2021. Green technologies are therefore crucial for the transition from conventional to renewable energy. They also help to bridge the rhetorical and real-world realities of net-zero CE [52].

The Nigerian transport sector is solely dependent on fossil fuels, which are a chief driver of global warming. Hence, there is a need to start now to prepare for a significant presence in the electric vehicle market. Changing the climate-unfriendly attitude towards transportation and investing in research and development to harness renewable energy potential can serve as effective means to achieve a decarbonised transport system [61].

8.0 Cost analysis of a Solar PV system as compared to petrol generator.

A cost analysis of acquiring and operating a 2.5 kVA solar PV system installed in a middle-income residential 2-bedroom apartment in Mando, Kaduna State for a year, compared to acquiring and operating a petrol generator of the same capacity, is presented.

- ***Solar PV System***

The cost requirement of the solar PV system is shown in Table 1.

Table 1: The bill of engineering measurement and evaluation for the 2.5 kVA solar PV system.

S/N	Requirement	Quantity	Rate (₦)	Amount (₦)
1	200Ah, 12V Deep cycle Battery	2	150,000	300,000
2	250W Solar PV panel	2	60,000	120,000
3	2.5 kVA, 24V Hybrid solar inverter	1	160,000	160,000
4	Battery rack	1	10,000	10,000
5	Solar panel rack	1	5,000	5,000
6	Cables and accessories		30,000	30,000
7	Installation		15,000	15,000
Total Cost				640,000

The cost of using solar system to power the case study at a load of 1500*W* for 5 hours/day in one year period is:

Cost of acquiring and installation = N640,000
Assume coat of maintenance (Annual) = N10,000
Total = N650,000

- ***Petrol Generator***

A 2.5 kVA, 220 V, 50 Hz, Elepaq petrol generator is selected. The petrol consumption rate is *1.23 litres per hour* for a load of 1500*W* [62]. Consequently, the cost of using the petrol generator to power the case study for 5 hours per day, at a 1500*W* load, over the course of one year, is as follows:

Cost of 2.5 kVA generator = N167,400
Cost of petrol = N620/litre
Petrol consumption per day (5 – hour period) = 1.23 x 5 = 6.15 *litres*
Cost of petrol per pay (5 – hour period) = 6.15 x 620 = N3,813
Assume cost of Annual maintenance = N30,000
Cost of using petrol generator considering one year period,
= 167,400 + (3,813 x 365*days*) + 30,000 = N1,589,145

Table 2 and Figure 5 present the costs of operating the two power systems for four years assuming all factors are constant over the four-year period.

Table 2: Four-year costs for operating the power systems.

Year	Solar PV System (₦)	Petrol Generator (₦)
1st year	650,000	1,589,145
2nd year	660,000	3,010,890
3rd year	670,000	4,432,635
4th year	680,000	5,854,380

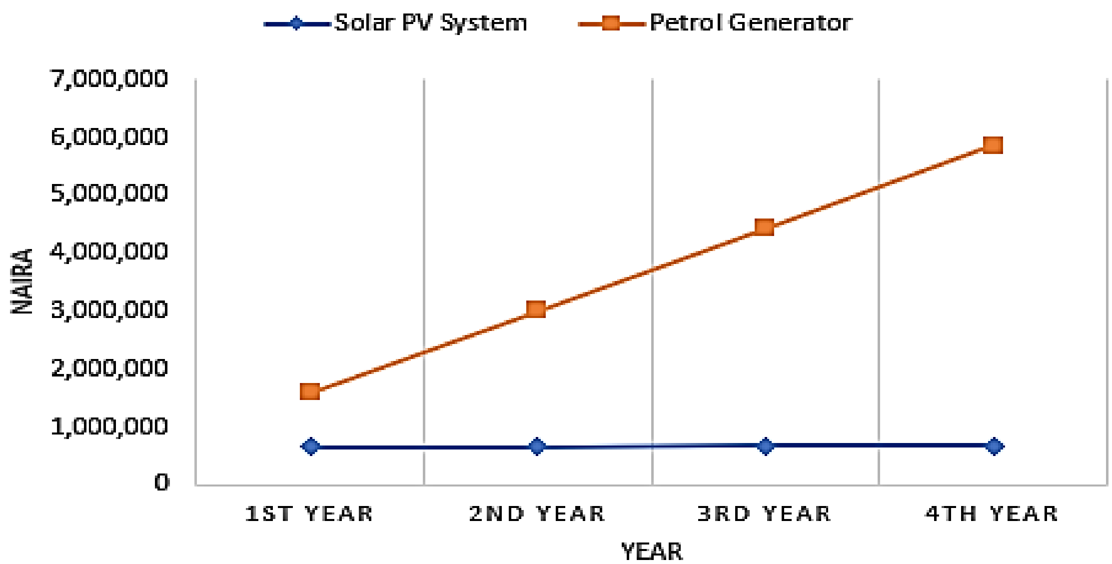

Figure 5: Four-year costs comparison of solar PV system and petrol generator.

9.0 Discussion

The cost analysis shows that the initial cost of acquiring a solar PV system is notably higher than that of a petrol generator. However, in the first year, the cost of acquiring and operating a solar PV system is lower (650,000 Naira) than that of a petrol generator (1,589,145 Naira). This significant difference indicates that the barrier to entry for solar power adoption is higher due to the upfront investment required. Over the four-year period, the cost of operating the solar PV system increases gradually, with increments of 10,000 Naira each year. In contrast, the cost of operating the petrol generator experiences a sharp increase each year, with the cost more than doubling from the first to the second year and increasing by substantial amounts in subsequent years. The relatively moderate increase in operating costs for the solar PV system contrasts sharply with the rapid growth in operating costs for the petrol generator. This trend underscores the long-term cost savings and stability associated with solar PV system compared to petrol generators, which are subject to volatile fuel prices and maintenance expenses.

It should be noted that these results are based on assuming constant prices over the four-year period under consideration. However, the maintenance cost for the solar-PV system is not likely to increase substantially over that period compared to petrol price which is usually volatile.

The results of the cost analysis comparing the acquisition and operation of a 2.5 kVA solar PV system versus a petrol generator of the same capacity reveal significant insights into the economic implications and potential impact of petrol subsidy removal on the adoption of solar power, particularly in regions like Mando, Kaduna State. Thus, more households would tend to adopt solar-PV power system because of the substantial savings compared to fossil fuel use.

10. Conclusion

The removal of petrol subsidies could exacerbate the financial burden of operating petrol generators, further amplifying the economic advantages of solar power. Without subsidies, the cost of fuel would likely increase, driving up the operational expenses of petrol generators and diminishing their cost competitiveness compared to solar PV systems. Consequently, the removal of petrol subsidies could incentivize individuals and households to transition to solar power as a more sustainable and cost-effective alternative. The long-term savings and stability offered by solar energy become even more compelling in a scenario where fossil fuel prices are subject to market fluctuations without government intervention. Thus, the impact of fuel subsidy removal would be to encourage more households to adopt solar-PV power systems, which can play a leading role in Nigeria's quest to achieving the United Nations' Sustainable Development Goals (SDGs) by 2030.

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