A REVIEW OF THE CHALLENGES AND OPPORTUNITIES IN ENERGY GENERATION, TRANSMISSION AND DISTRIBUTION IN NIGERIA

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Abstract: *Nigeria's power supply is epileptic despite significant Government investment and spending over decades in this critical sector of the nation's economy. The lack of state-of-the-art infrastructure to support the nations ever-increasing population growth rate continues to hinder any meaningful impact regarding the social and economic benefit of the energy infrastructure investment in Nigeria. Over half of Nigeria's population still lack grid connect since post-independence. This study aims at identifying specific challenges and opportunities for power generation, transmission, and distribution in Nigeria. The methodology of the study involved an in-depth and critical review of relevant literature to identify the challenges in energy generation, transmission, and distribution in Nigeria. Findings from the literature revealed the opportunities and prospects of using off-grid technology like renewable energy system as an alternative energy source. Secondary data obtained was used for analysis to identifying prospects that would boost economic development, reduce widespread poverty, and channel of large numbers of unemployed youth into productive activities. Findings from study identified high costs of investment, shortage of indigenous expertise, the effect of added technical, commercial and collection loss, the slow pace of policy implementation, lack of support, as well as sabotage as significant constraints to an efficient power supply regime in Nigeria. The study concludes that the prolonged epileptic power supply system remains a single factor that hinders economic development of the nation and its attendant socio-political impact on the teeming populace. The study recommends the adoption of medium off-grid energy generation and supply system using renewable energy sources as a sustainable solution to the myriad of challenges in the power sector.*

Keywords: *Energy Generation, Off Grid, Nigeria, Renewable Energy*

1. INTRODUCTION

Nigeria has the largest economy in Sub-Saharan Africa with Gross Domestic Product of $405Billion with over 180 million people, with almost 50 percent of the population having limited or no access to the national grid. As a result, many commercial businesses are powered by expensive and unreliable alternatives [1]. A wide gap exists between the nations' production capacity and demand for electricity. This is even with the weak, unstable and unreliable electricity supply for both households and companies [3]. Nigeria's electricity grid is powered mainly by large hydropower and exhausting hydrocarbon. Fossil-based electricity generation contributes not only to increase in carbon footprints but also exposes the country to changes in the price of petroleum products and political instability from the oil-producing region of the country. However, the country is blessed with abundant Renewable Energy that has not been fully exploited [4].

Therefore, reliable access to electricity remains a challenge in many regions of Nigeria and achieving rapid electricity access for the nations' large geographic regions need alternative electrification pathways apart from the need for grid connection. The use of sophisticated planning tools to control techno-economic electrification pathways is imperative [5]. Therefore, the need for medium off-grid energy generation and supply system using renewable energy sources is proposed as a real solution to the current electric power instability. Repositioning Nigeria's energy sector will create a multiplier effect in the nations' socio-economic activities by rejuvenating the all dead, near dear, and sick industries that have suffered incalculable production setbacks. For example, the cost of production of industrial goods in Nigeria is higher than the imported substitute products as a result of power outages and the attendant high costs of dependence on generators and other artificial power supply systems. Bridging the power supply and distribution gap in Nigeria will give rise to an exponential increase in the productive sectors of the economy by introducing efficiency, value addition and reducing the overall cost of doing business, and improving overall living standards.
Nigeria as of today, cannot meet its energy demands with more than 60% of its population relying on off-grid-generators powered by petroleum products. This has created an opportunity for deregulation of the energy sector and developing renewable energy as a means of ensuring energy security while reducing the demands for fossil fuels [8]

This radical change would be a critical factor in bridging the gap in power generation. The ideals of collaborative working and integrated project delivery approach must be promoted to derive benefits from off-grid solution in Nigeria. The increasing pressure from both international agencies, civil rights organisations and the people of most developing countries to improve energy infrastructure provisions seems to distract the governments in seeking sustainable energy pathways [9]

2. LITERATURE REVIEW

Historically wind, biomass, hydro and solar were the first forms of energy that humans exploited, and till date are reference points to future development in the energy subsector. Hydropower in the 1900's played an essential role in the mass-energy infrastructure development. During the 20th century, states owned monopolies of generation, transmission, and distribution and relied on coal, oil, nuclear and natural gas mainly for power [10].
Afterward in 1970's the skyrocketing price of oil and gas spurred the experimental reforms and restructured for greater competition in renewable energy. Then the mid-2000's further enabled this innovation because of the volatility of oil and gas, therefore, encouraging developed countries to invest in Renewable Energy.

The decade leading up to the end of the last millennium saw systematic unbundling and privatization of power utility companies in Sub-Saharan Africa.
The main reason is that charges for electricity supply costs in village grids are too high for available subsidies; the economies of scale for renewable energy supply technologies favour national grids [13]. Although Photovoltaic, as an alternative for renewable energy, has significant potential in Nigeria to provide the needed sustainable energy needs. However, among many of the significant barriers faced in its penetration effective implementation is awareness and information gap. In contributing to easing such gaps as they vary across locations [14].

Nigeria consumes more proportionate energy per capital on residential housing than its peer countries (77.90%) as shown in figure 1. Some developing countries like Bangladesh and Indonesia use more than triple their energy than Nigeria does on industrial generation. While some G8 countries like South Africa and Brazil require only a little over a third of their energy per capital for residential consumption.

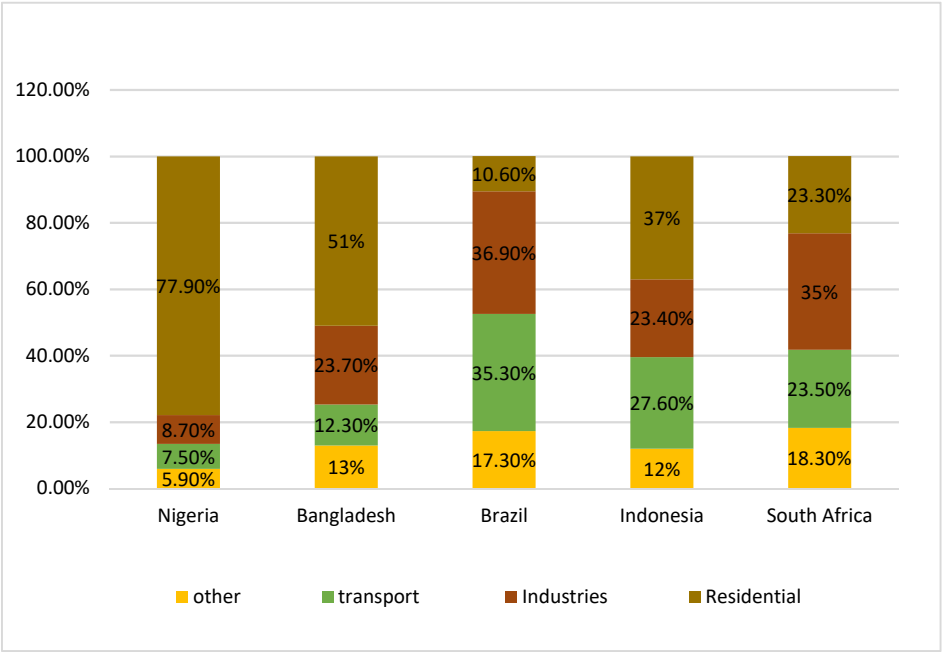


Fig.1.Total Electricity Consumption by Economic and consumption per capital for Nigeria and peer countries, 2012 (Source: IEA)

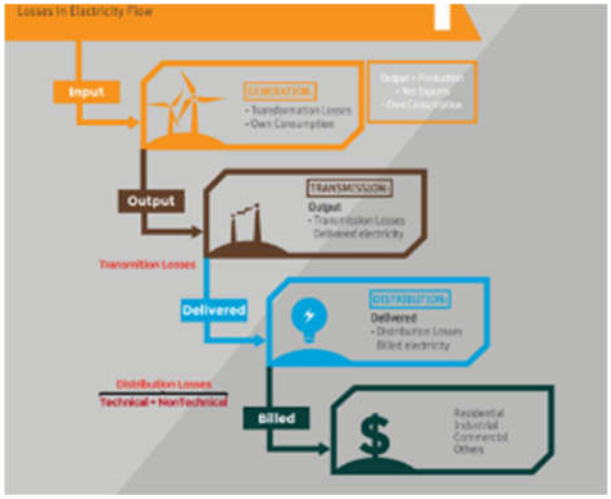
2.1. Review of Nigeria's Power

Nigeria has the largest population of all African nations, with significant population clusters scattered throughout the country's urban centres: Lagos 13.123 Million; Kano 3.587 million; Ibadan 3.16 million; ABUJA (capital) 2.44 million; Port Harcourt 2.343 million; Benin City 1.496 million [2]. These figures explain the impact of urban migration that has impacted so significantly on the power sector. Nigeria's power infrastructure has undergone significant reforms in recent years resulting apparently to the privatisation of the entire electricity value chain covering generation to distribution.

The nation has a "30:30:30 electricity vision, and in the pursuance of this, the government-owned electricity utility company -National Electric Power Authority, was unbundled into 16 distribution companies (DisCos) and seven generation companies (GenCos) owned and managed privately, as well as one Transmission Company (TCN) owned by the Federal Government of Nigeria (FGN) [3].

Considering the increasing population proportion of urban centres compared to rural areas, electricity development in Nigeria is supposed to strengthen the national economy, being the engine that drives industrialization in a nation's economy, as access to electricity has significant benefits and potentials.

It has been estimated that developing countries like Nigeria will need 1000MW for every million of her population to meet the demands [7]. Presently this energy power by on grid generation which includes 23 grid connected plants with a total installed capacity of 10396MW (available 6,056MW) with thermal based generation an installed capacity of 8457.6MW (available capacity 4996MW). (How do you mean?). However, by carrying out reforms, Nigeria targets 40000MW generation by the Year 2020. This is somewhat of an uphill task given the nation's widespread poverty and some unemployed youths.



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Source: Figure 1: Aggregated technical, commercial, and collection loss

2.1.1. Generation

Primary energy efficiency in the power sector can be improved mainly by a shift in the energy mix and by carrying out positive technologically-based reforms targeted at efficiency in the electricity generation technologies [16].
There is significant under-utilized generation capacity on the Nigerian network. TCN and NERC list operational generation capacity at 7,604 MW; a theoretically, this could be as high as 13,699 MW if fully refurbished [17]. Nonetheless, seasonal changes can give rise to limited hydropower because of limited capacity during the dry or rainy seasons, thus, influencing availability as a result of weather on the Grids.

2.1.2. Transmission

Transmission is often significantly constrained and currently capped around 4,800 - 5,600 MW. The capacity varies with location and amount of generation available. The all-time high for peak power is 5,075 MW, evacuated on 2nd February 2016) [17]. Funding in the sector is also a significant barrier to the development of transmission, gas and generation capacity. None of the participants in the energy reform process is receiving full and reliable payments at present, and as a result, new players are cautious.

2.1.3. Distribution and Marketing

The poor electricity grid distribution network resulting from inadequate and weak coverage is responsible for the constant power failure in Nigeria. This, in turn, leads to the congestion of transformers and feeder pillars [18]. Also, the secondary distribution lines coupled with the inadequate and ineffective billing systems characterized by destructive and often unpatriotic practices by some personnel of the electricity companies contribute to aggregate technical, commercial and collection loss. These have quantitative effects on the business environment, including regulations, crime, corruption, and access to finance and total factor productivity (TFP) in Sub-Saharan Africa. [19]. It can be first explained as a technical loss for energy not delivered, energy lost in the grid network and energy injected at the distribution station [20].

While commercial energy not billed, energy is stolen, and billing failures contribute to 'Energy Consumed- Energy Billed.'

Finally, collections Energy not paid for the monetary value of Energy Billed – Payment Received. Figure 1 below shows the energy aggregated regarding technical, commercial and collection loss in the system. Figure 2 below illustrates the process of loss.

3. METHODOLOGY

The mode of study involved a critical review and exposition of relevant literature and a systemic utilization of secondary data that supports study research problem and research objectives. Data analysis focused on techniques that address the issues of power generation, transmission, and distribution.

Further analysis was conducted on the prospects of utilizing 'off-grid' renewable energy system with an assessment of its viability to guide policymakers.

4. CHALLENGE OF POWER GENERATION

One of the many problems of Nigeria is 'energy impoverishment amidst surplus' [21]. Given the vast amounts of sources of energy for electricity which include hydroelectricity, solar, wind, and biomass energy, crude oil, natural gas and coal deposits; Nigeria suffers unprecedented energy scarcity despite the abundance of these reserves for several decades.

Nigeria's Energy Master Plan of Nigeria was created to provide a roadmap for implementing the nation's renewable energy policies and targets. It envisaged a 13% targeted share of renewables in electricity generation by 2015, 23% by 2025 and 36% by 2030 [8]. In 2010, renewable energy accounted for 19.4% of electricity production in Nigeria. The government in 2011 introduced the Renewable Energy Feed-in Tariff system with the aim of increasing domestic production of energy from scattered renewable energy sources. By late 2014, the policy document was once reviewed mandating electricity distribution companies to receive at least 50% of their total electricity buy from renewables. Unfortunately, most of these reforms remain on paper and are hardly implemented as a result of changing policies, including a coalition of opposing interests' groups, such as stand-alone generator suppliers, diesel dealers, the staff of electricity agencies. Even contractors to the electric utility companies may prove difficult. Besides, self-generated electricity contributes 389 million tons of carbon dioxide (CO2) emission. This ranks Nigeria in the top 20 on the global CO2 emission index. [22]

Active monitoring and supervision of the power sector have been shrouded in secrecy through the over-centralization of administration in the sector [21]. Electricity governance in Nigeria, despite several reforms, continue to wallow in endemic corruption.

Some key findings on energy challenges of developing countries are as follows: firstly, there is a lack of quantitative data on actual electricity generation, distribution and consumption. Opportunities in the sector are primarily driven

by unfulfilled basic needs, whereas corruption and weak electricity grid networks are the main barriers. Workable business models should be replicable [23]. Evidence shows penetrating renewables is no more dependent on technology or economics than on developing markets that are flexible and provides smarter energy alternatives.
More than 70% of Nigeria's rural population use wood fuel for cooking. According to [24] the deforestation rate in Nigeria is reportedly about the highest (55.7%) in the world.

4.1. Opportunities in the Energy Sector

Recent evidence has shown that Renewable Energy- Solar and Wind energy, in particular, are now the cheapest source of energy [25] unless you need to store it. Previous Renewable energy had limited application because of the problem of intermittent supply as shown in figure 2 below.

There has been an increasing pursuit of energy security, technological advances, the falling costs of renewables, and the movement to exploit renewable energy sources for electrification. In Nigeria, the rural electrification strategy targets 75 % coverage by 2020. However, while the demand for off-grid solar PV is expanding, the capacity of the grid connect system is still more quickly integrated and continues to account for most of the solar PV installed.

In Nigeria, Lumos Global has invested USD 90 million in off-grid solar energy to expand its operations. Also, Arnergy's Pay-As-You-Go (PAYG) services have been operating solar mini-grids across off-grid villages that power over 600 homes. PAYG model is used to enable smaller scale production of energy for powering water pumps, ago processing mills, clean cooking and lighting [16].

Almost all the major manufacturing firms in Nigeria produce electricity through diesel-powered plants with implications for the cost of production and greenhouse gas emissions. Meanwhile, eco-innovative manufacturing firms have the potentials to decouple economic growth from excessive use and environmental pressure [26]. The most commonly used economic competitive signal between renewable energy and traditional forms of electricity is the levelized cost of electricity. Despite the positive outlook for renewable energy, the global fall in oil prices presents a challenge for renewable energy in the short-term [10].

Unfortunately, in Nigeria, the oil and gas sector is the crucial economic market driver of prices of goods and commodities. These product prices are continued to rise irrespective of the international volatility of the market. As such, the price of Premium Motor Spirit, PMS has never dropped even when the international price drops.

Table 1. Nigeria Energy Potential Source: [35]

Resources	**Potential**	**Remarks**
Large Hydropower	11250mw	1900MW exploited
Small hydropower	3500MW	64.2MW exploited
Solar	4.0-6.5KWh/m2/day	15MW dispersed solar PV installations
Wind	2-4 m/s @10m height mainland	Electronic wind information system (WIS)available; a 10MW wind farm in Katsina in gross
Biomass (non-fossil organic matter	Municipal waste	
Fuelwood	18.5 million tonnes produced in 2005 and now estimated at 0.5kg/capita/day	
43.3 million tonnes/yr. fuelwood consumptions		
	Animal waste	245 million assorted animals in 2001

4.2. Renewable Off Grid Generation

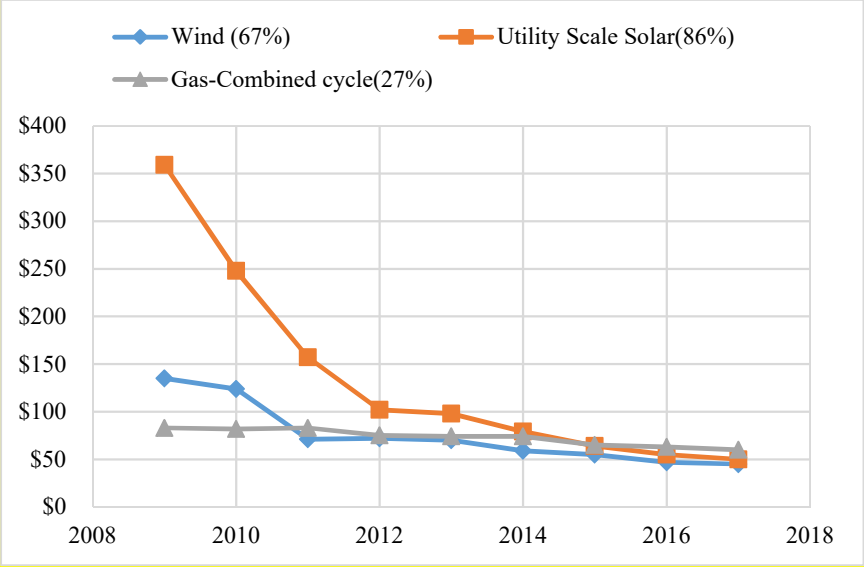
Renewable Energy is generally an expensive scheme. Despite its high cost, countries like Iceland, Paraguay, Norway and Costa Rica have almost wholly produced electricity from a renewable energy source [27]. Renewable Energy-based off-grid or decentralized electricity supply has traditionally considered a single technology-based limited supply to meet basic needs, without considering the constant energy needs of the rural consumer. A pragmatic solution to these shortcomings is the adoption of a hybrid approach which fundamentally combines renewable energy generators at an off-grid location. This is viewed as a more competitive alternative to grid extension system, and it is sustainable, techno-economically viable and environmental sound [28]. In an off-grid generation, solar PV is cost-effective in Nigeria. A Solar PV averages 20cents/kWh as opposed to USD 3cents/kWh and 60cents/kWh for Diesel and gasoline Generator [15]

Rough estimates suggest that the total market for self-generated power in Nigeria is between 14–20 GW. The total issued licenses that can be regarded as off-grid (self-generated power) adds up to about 1,700 MW. This leaves a massive gap of self-generated power that is mostly not accounted for [3]. Generally speaking, Off-grid solar electric power is a promising technology for remote regions in rural Africa where expansion of the electricity grids is prohibitively expensive.

Improving energy security in Nigeria through diversifying electricity generation could also mean improvement in economic growth [18].

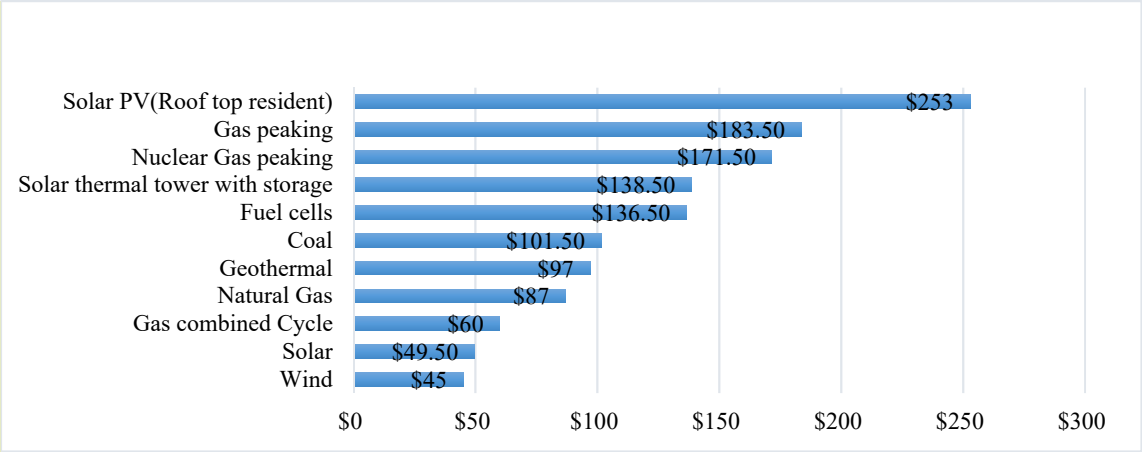
Renewable mini-grids is cost-effective, particularly for rural areas. However, the particular risk faced by these projects is the 'roll out' of rural renewable mini-grids. This condition hinders the involvement of private investors.

Low electrification levels and frequent blackouts in grid-connected areas pose a big challenge for the Government. It is generally held that without a robust private involvement, and the use of other electrification solutions other than grid extension, Nigeria will not achieve universal access to electricity [30].



Source: Fig.3. Selected historical cost of Energy [25]

In Nigeria, 90 percent of the economy is dependent on petroleum as a source of energy. Hence, the challenge of investment in Renewable Energy is essential for security and sustainability objectives, more so at this period that more jobs are created in Renewable Energy than in oil, gas, and coal combined. Hence Renewable Energy is a win-win-win approach that is good for the environment, business expansion and job creation. Therefore, public sector investment should focus on the next economy and not on old fossil fuel.



Source: Fig.4. Average Energy cost (leveled cost of energy per MW/h) 2017[25]

The table 3 below illustrates the average renewable energy price for IMW/H for various forms of energy that can be used to run an off-grid energy source. This is an estimated equivalent energy requirement for 330 households for an hour. From table 3 above the average levelized cost per MW/h is about $45 and $49.5 for wind and solar energy respectively. Using basic principles of cost management to estimate the unit cost multiplied by the number of hours for a month which was then converted to Naira at 360.
Subsequently, the cost per unit of the household was determined as shown below in Table 3. These figures focus on the generation cost mainly excluding the cost of distribution and connection. Similarly, it does not differentiate between stand alone, mini-grids and off the grid in the cost estimation.

Simplification of LCOE calculations [31]

$$LCOE = \frac{\text{Total Life Cycle Cost}}{\text{Total Lifetime Energy Production}}$$

$$\Sigma^{n}_{t=1} \frac{(I_t + M_t + F_t)}{(I+r)^t} \Big/ \Sigma^{n}_{t=1} \frac{E_t}{(I+r)^t}$$

I_t=investment expenditure in a year
M_t=operation and maintenance in a year
F_t= fuel expenditure in a year (must renewable energy sources have zero cost)
E=Electricity generated in a year
r= discount rate
n=life of the system

Afterward, the LCOE is converted to units suitable to explain monthly estimate for the general household as shown the table 3 below.

Table 3: Estimated cost of electricity according to Energy sources

Renewable Energy	Unit cost (MWh)	Cost per month $	(Naira)	Cost per household
(Naira)				
Wind energy	$45	$32,400	11,664,000	35,345
Solar utility Energy	$49.5	$35,640	12,83,0400	38,880
Large scale hydropower	$50	$36,000	12,960,000	39,272

However, these two viable options would be challenging to estimate because the average Nigerian household does not experience constant power supply. Nonetheless, the most competitive technology for electric power generation at the moment is large-scale hydropower and natural gas in a combined cycle turbine which is between $50 and $70 MWh [15].

It could be deduced that the figure above the average cost in Naira ranges from 35345 to 54,981 each month to power an average household. These figures explain the opportunities for solar and wind energy technology within Nigeria. However, given the challenges of distribution, and the diverse nature of an off-grid system, the investors are typically the direct benefactors of the project.

Wind and solar power systems provide energy at variable intervals and quantities. The limited supply creates a new challenge for planning the electricity grid, especially when in high demand.

This expectation requires more investment in innovation for grid monitoring, forecasting, and control technologies that will ensure improved efficiency of the Renewable Energy Mix [10].

5. CONCLUSION

The actual cost and benefit analyses of generating off -grid and on- grid energy have not been fully explored given the disparity between government and private generation, transmission and distribution in Nigeria.
The comparative cost analysis as suggested in table 3 showed possible options for achieving the sustainable development goals in the power sector. The identified operational bottleneck in exploring the alternatives is mainly the role of government in policy and implementation to enable private participation. Others include the challenge of being an import-dependent country for specific vital input resources of critical need and dependency, especially with regards to tools and skilled workforce, arising from apparent gaps in knowledge and technical know-how within the field of off-grid technology. Also, the effect of market forces (demand and supply dynamics) influencing the price of commodities also impacts negatively as it discourages the private sector investment in the Energy sector.

Other identified bottlenecks in the reform of Nigeria's energy sector include the high cost of capital, currency variation, and community conflicts. The above bottlenecks have therefore created a need for the consideration of alternative energy sources requiring wind and solar energy utility energy in bridging the gap created between power generation and actual demands of the country**.**

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