Utilization of renewable energy for improved power generation in Nigeria

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Abstract. The current condition of electrical power supply in Nigeria poses serious risks to the wellbeing of its citizenry, economic progress and overall growth of the nation. The low-level diversification of electricity production in the country has led to the necessity of deploying sustainable energy resources, particularly renewables into its generation mix so as to meet Nigeria’s ever-increasing power demand. The most significant renewable sources in the country - hydro, wind, biomass and solar, all have high potential for power generation in Nigeria. This study highlights the present state of electrical power in Nigeria and suggests strategies to improve the situation, mainly by harnessing renewable energy resources within the country and then integrating their power output into the nation’s electricity grid.

Keywords: Low-level diversification, generation mix, sustainable energy resources, power generation, electricity grid.

1. Introduction

Energy is essentially considered to be an imperative element which contributes immensely to the advancement, modernization, industrial expansion and economic development of every country [1, 2]. As a consequence, there is an increase in how much energy is needed and required for use all over the world, tandemly with population, particularly in Africa [3, 4]. It is known fact that the production of energy worldwide (inclusive of electrical power) is still to an exceedingly high extent, reliant on the firing of hydrocarbon fuels like coal and natural gas which has been a main source [5-8]. These hydrocarbon fuels being non-renewable in nature however allow greenhouse and other gases to be directly released to the environment, hence causing serious pollution for the environment which can lead to health challenges. Furthermore, the irregular rising and falling fossil fuel prices happening on a consistent basis has negative consequences on energy profile and security [9]. These factors have led to the questioning of fossil fuel generation of electricity and have instigated the exploration and development of other fuel sources that are sustainable and environmentally benign [10].

Resources which are renewable in nature and their associated technologies have already been highlighted as part of the options for the sustainable generation of energy globally in the 21st century. By the virtue of nature, the renewable resources are always available, and can be replenished within reasonable periods [11]. Solar, wind, biomass and hydropower are included
among energy resources which are renewable. These named resources have already been effectively exploited in some countries [4, 12-15]. Expectations abound that renewable resources altogether will be known as the hugest power source in the near future, and that by the year 2040 will attain about 35% of the total global energy production [9].

Nigeria happens to be a country categorized as ‘developing,’ and is the most densely populated in the African continent while being the seventh most populous nation on the earth, with a population estimated at over 200 million, which increases yearly at the steady rate of 2.61% [16]. This African nation is known to be one among the main consumers of hydrocarbon fuels in the world and then, one of the two nations within sub-Saharan Africa having the highest demand for energy [5]. In the nation Nigeria, energy resources that are both conventional (non-renewable) and non-conventional (renewable) are available in excess amounts. This is considered to be an advantage, but despite this, generation of electrical energy within the nation has remained at an abysmally low level and as a result, failed to match up with the energy demand of the populace [17].

Based on the generation of electrical energy per capita in Africa, supply of electricity in urban and rural locations within Nigeria have remained poor and lowly ranked [18, 19]. Hence, the acceptance of non-conventional energy sources and also, the buildout of their associated technologies is of high priority in ensuring a sustainable open pathway to electrical power and energy security. The country essentially needs to enhance its energy generation mix with renewables. While this will enhance the buildout of Nigeria’s energy sector, it will also boost accessibility to electrical power in the nation.

2. Electrical power and renewable energy in Nigeria

2.1. Overview of Nigeria

Nigeria is a nation situated in Africa’s western region, boarded by Cameroun, Niger, and The Republic of Benin, towards the East, North, and West respectively and then, the Gulf of Guinea towards the South. Nigeria is positioned between latitudes 5° and 15° to the North of the equator and the longitudes 5° and 15° to the East of the Greenwich Meridian. Nigeria’s land and water area combined is approximated to be 924,000 km². The country is split into thirty-six administrative states; Abuja being the Federal Capital Territory (FCT). As shown in Figure 1, the Nigerian states are classified into six geopolitical regions.
2.2. Status of electricity in Nigeria
The availability of electricity in this present century has become a non-negotiable necessity for the sustenance of economic activities; electricity is also highly required for any form of social development. Hence, it functions as a bedrock for the new age society [21, 22]. It is worrisome that more than a billion out of the total world population still lack access to electricity, and a good number of the African nations, without the exception of Nigeria, is yet to provide sustainable electricity for its entire citizens. Studies show that in Africa, Nigeria has the worst electricity consumption per capita, a fall back behind its most of its West-African counterparts [23, 24]. Various researchers have examined the electricity insufficiency in Nigeria; their estimates have shown that about 15 million family houses in the nation Nigeria do not have any means to national electricity, and those that have access to the grid electricity usually suffer from inconsistent power supply [17]. Only 40% of the country’s populace has got access to electricity supply, mainly due to the nearness to the grid of that proportion [19]. This largely explains the poor rating of Nigeria as one of the countries with low developing index.
Currently, there are only six power generation stations in Nigeria for commercial electricity generation. Strong emphasis has been severally made that the ever-increasing power demand of the country as projected in Figure 2 far outweighs the generation capacity of these power stations which operate on fossil fuel [25]. Also, there exists a big difference between the installed power capacity and total delivered power in the country. As at year 2017, the nation’s overall installed power capacity was 14,380 MW, while the capacity delivered to consumers till date fluctuates between 4500 MW and 5000 MW. This shows that just 2850 MW has been the increase in the country’s generating capacity which was 1250 MW twenty years ago [26]. However, towards the end of 2018, the nation’s Minister of Power, Raji Fashola claimed that the electricity capacity deliverable for consumption is now increased to 7000 MW [27, 28]. Notwithstanding, the deliverable power capacity in the country is obviously low, and is as a result of the unsound state and insufficiency of these power generating systems which all stem from poor maintenance routine, very low investment into the energy sector, and fluctuating fuel prices for power plants [19, 29]. Hence the need to meet up with the increasing energy demand is therefore one of the prominent issues affecting the development of the country, as it is glaring that the inclusion of renewable sources into its generation mix is necessary for sustainability.

Interestingly, the Nigerian government has continued to postpone the large incorporation of renewable sources into the national grid largely because the government and also, a certain percentage of the citizenry are of the opinion that fossil fuels are generally cheaper, unfortunately they do not consider its severe negative impacts [30]. Olatomiwa and his colleagues [31] posited that power generating plants or sources of 140 GW, in contrast to its present capacity (between 5000 and 7000 MW), is needed to meet up with the country’s energy demand.
In the quest to improve the country’s power sector and its various services, the sector was reformed and restructured. Some agencies were established by the Federal Government of Nigeria as one of the means to relinquish its rule over the sector. The agencies and their responsibilities include: the Nigerian Electricity Regulatory Commission (NERC), assigned with the responsibility of promoting efficiency and improving access to electricity; the Transmission Company of Nigeria (TCN), established to be in control of the process of transmitting electricity to distribution companies; the Rural Electrification Agency (REA), meant to be responsible for the provision of electricity to communities in rural areas, and then the Electric Power Sector Reform Act, which made available the underlying process for privatization of the power sector [32]. This reorganization brought about some independent power projects with the aim to supplement the existing power infrastructures in the country [33]. Eventually, in November 2013, the government fully privatized the power sector with the exclusion its transmission component [22, 26]. Following this, the company responsible for governing the use and distribution of electricity in the country was split into different companies known as Local Electric Distribution Companies. Currently, there are 11 top electricity distribution companies in Nigeria covering its different regions and states as listed in [34, 35]. Even with this restructure, the poor electricity situation in the country has not seen any improvement.
Several challenges in the supply of electricity are the reasons small fractions of the country have electricity connection. Meanwhile, electricity supply to some of these fractions are not stable, as they constantly experience power outage and maybe just 5 hours of electricity supply in two days as a result of unreliable connection and poor state of some distribution lines as shown in Figure 3[36]. Thus, electricity supply in the country has so far been getting worse and declining day after day. This has prompted many Nigerians to purchase and depend on private diesel and petrol generators for homes, businesses, facilities, and other areas where reliable electricity supply is always needed.

Most houses and buildings in the country own at least a dedicated generator set to ensure reliable and smooth running of operations and comfort life, as a result, Nigeria is reportedly the highest importer of generators. In some vicinities, certain individuals have humorously referred to these generators as their main source of electrical energy while the one from the grid is referred to as ‘stand-by’. The survey carried out by [22] reveals that the cost of operations and maintenance of these generating sets are expensive as billions of Naira are being wasted annually in comparison with grid tariff. The amount lost yearly is figured to be slightly below 800 billion Naira [26]. Besides, the emissions from these fossil fuels power sources pose negative threats in the form of smog (including fine particulate), environmental pollution, climatic change, and damage to the atmosphere.

The economy of the country also suffers from the epileptic power supply. This says a lot about the refusal and unwillingness of several foreign trade investors, companies and industries to establish and set up firms in the country. With this, the Nigerian power sector can be thought of to be the main hinderance to economic and social development in the nation. As at 2018, Nigeria claimed the 145th place among 190 countries according to the World Bank’s ranking in the ease of getting stable electricity for business operations [37]. This is primarily because the availability
and supply of reliable electricity is one of the basic needs of running and promoting business to gain high productivity. The intermittent nature of power supply has also heavily affected the country’s manufacturing sector, leaving many of its manufacturing firms uncompetitive and unproductive as a result of huge amount regularly spent on diesel for private power generation [23]. In fact, a sizeable number of these companies have exited the country.

Obviously, the production and supply of electricity through sustainable means, like most developed nations, is the solution to the power crisis [38]. Various countries across the world are known to have successfully adopted and diversified into sustainable power sources but Nigeria had seemed not to have these as major priorities. To achieve sustainable solution, it was advised that Nigeria needs to diversify into renewable energy sources, stating that close to 60 GW of electrical power obtainable from these sustainable sources would enhance industrialization within the country to a very large extent [39].

However, the Energy Commission of Nigeria projected that a higher capacity of about 300 GW would be needed in year 2030 to revive the country’s power sector and economy [26].

Overall, efforts to put an end to the several challenges confronting the nation’s power industry have not been so much significant. Moreover, the environmental effects and economic impacts of the continued use of conventional power sources in the country stimulate the drive to adopt and develop renewable energy.

2.3. Renewable energy potentials in Nigeria

There are prominent renewable energy sources with promising potentials within Nigeria. A minute percentage of these energy sources have been harnessed to produce electricity within the country but there are plenty of opportunities for them to be exploited for satisfactory electric power production.

2.3.1. Hydropower. “Hydropower is created through the conversion of potential energy of water into electrical power through turbines and generator” [32]. Hydropower, is one of the largest renewable energy sources across the world, and provides close to one-fifth of the global electrical power and above four-fifths of the electricity generated from renewables worldwide [29].

Considering the current level of diversification of power supply in Nigeria, hydropower holds the largest share (20 per cent) of renewable energy sources [40]. The operation of the thermal-hydro plants with fossil fuels for power generation is one of the reasons that hydropower is not receiving sufficient attention in Nigeria.

Till date, Shiroro dam, Jebba dam and Kainji dam are three major dams notable for huge power generation in the country with each capacity ranging from 500 MW to 800 MW [38, 41, 42]. However, it was noted that, apart from these three dams mentioned, Nigeria has many other dams in different sizes and scales which could be designed, constructed and developed for hydropower purposes, given its huge availability of water resources [43]. According to [3] and [29], Nigeria has the potential to generate above 18 GW from its hydro resources, however, the country only has only harnesses just 20% of it for the generation of electricity.

All these reports show that the hydropower potential in Nigeria has not been well utilized, adequately harnessed and developed for power generation.
2.3.2. Wind energy

Wind energy requires the use of wind turbine or wind mills [44, 45]. Wind blows both day and night, it is however dependent on the geographical location of a place and/or season of the year. It is rather intermittent in nature, varying in degree and consistency. Presently, the level of wind utilization in Nigeria is very low, due to the fact that wind energy has been majorly harnessed for the purpose of irrigation.

In [46], an estimation of the prospects of wind energy in Maiduguri and Pokiskum (North-Eastern Nigeria) was reported. In the same vein, [13] presents an evaluation of the wind resources carried out in Nigeria, and appraised the size of land suitable for the harnessing of wind power as shown in Figure 4. Their results revealed that the two locations are suitable for the generation of wind power. An investigation on the wind power potential available in Kano (North-Western Nigeria), where there is usually high amount of wind blowing was discussed in details elsewhere [47]. They made a conclusion that at a height of 10 metres, the average monthly wind power density of Kano is in the highest class, and hence suitable for applications related to wind power electricity generation. Typically, the Northern region of Nigeria has been identified as a premium site for the implementation of initiatives targeted towards the harnessing of wind to generate electricity. The Jos highlands in Plateau State and a number of North-Western parts within the country have also been identified as sites appropriate for production of wind power connectable to the national grid. This was also suggested by [29].

Up until now, Nigeria has not made any attempts to deploy wind energy for electricity generation. Many researchers believe that the prospects are enough to justify a major effort to integrate wind power into the electricity grid [48, 49]. The northern region of Nigeria has been generally suggested as an excellent site for the implementation of initiatives towards harnessing wind for electric power generation.
2.3.3. **Biomass.** Biomass energy refers to the type of energy derived from food crops and their wastes, agricultural by-products and farm residues; municipal solid wastes; and other organic materials for power production. Although they are available in very voluminous quantities in Nigeria, biomass is yet to be developed for the production of electricity via bioelectric power generation.

A reported literature [50], gave an explanation on the way pyrolysis -- an efficient thermo-chemical process for energy applications-- can be used to produce bio-fuel, and how generation of 500 MW of electrical power can be achieved, making use of oil palm residues in Nigeria.

Another study [14] suggested that Jatropha biodiesel-fired plant might serve as a very good replacement for natural gas which is usually made use of in industrial gas turbines, and also for electric power production in Nigeria, with the consideration that it can bring down yearly by 76 per cent, greenhouse gas emissions arising from individually-generated electricity.
2.3.4. Solar energy. This is the most important renewable energy resource because majority of other renewable resources (like wind, hydro, biomass) are directly or indirectly dependent on it. Clearly, Nigeria has optimal conditions for producing electricity from solar energy, seeing that it has plenty of sunshine all through the year. The efforts in harvesting and putting to use solar energy within the country is largely monitored by the Energy Commission of Nigeria (ECN) which is as well aided by the National Agency for Science and Engineering Infrastructure (NASENI), through these listed institutes of research: National Centre for Energy Research and Development (NCERD), Sokoto Energy Research Centre (SERC), and NASENI Solar Energy Ltd. SERC has had a few research achievements, utilizing solar energy for solar drying and heating, and also for pumping of water [51]. There is therefore a requirement to deliberately look into the prospects of solar energy technologies in catering for Nigeria’s up-shooting demand for electricity.

The development of solar energy technologies tends to offer a huge amount of social and economic benefits to the country through various applications such as Photovoltaics (PV) and Concentrated Solar Power (CSP) technologies for electricity. Generally, it is well established that solar power improves equity by bringing down electricity costs in cities and towns that have no access to grid electricity [52]. Hence solar energy has been considered as the best and most effective solution to energy poverty in developing countries like Nigeria [4].

Asides from power generation, the development and utilization of solar power technologies will result into creation of jobs in diverse sectors, thus creating a boost in the economy of the nation.

Geographically, Nigeria is situated close to the equatorial region and hence lies in the high sunshine belt which therefore increases its solar energy potential for the generation electrical power [12, 29].

Numerous studies aimed at assessing the potential of solar energy within Nigeria have been embarked upon. It was reported that the aggregate of solar radiation incident on the land surface area of Nigeria is 12.6 MJ/m\(^2\)day in the coastal regions and 25.2 MJ/m\(^2\)day in the Northern part. A total of 17,459 billion MJ of solar energy was reported to be received on Nigeria’s total land surface every day [18]. In a different study by [53], the daily mean solar insolation in the coastal or southern region was estimated as 3.5 kWh/m\(^2\)day and that of the northern region was estimated to be 7.0 kWh/m\(^2\) day. Concisely, the quantity of sunshine hours across the country on a daily basis spans from 7 to 9 hours on the average.

[54] suggested that an electrical energy generation of \(1.85 \times 10^6\) GWh can be achieved from solar energy almost every year, if solar modules are installed to cover as small as 1 % of Nigeria’s land area. This is expected to result into a yield of more than a hundred times the current grid of electricity supply in the country. In the same vein, [18] proposed that just 3.7 % of the country’s landmass is sufficient for use as solar farms to produce solar power that will satisfy the nation’s electricity need.

An assessment of Nigeria’s solar energy potentials was also carried out by [19]. In the assessment, the cities of Lagos, Onitsha, and Kano were considered; the consideration was due to the dense population and enormous economic activity associated with the cities. The outcome of the assessment indicated that on a yearly basis, Kano city situated in the North-West geopolitical region possesses the highest mean daily global solar resource (6.08 kWh/m\(^2\)), while the solar
resources in Lagos (South-West) and Onitsha (South-East) are almost the same having values of 4.42 kWh/m² and 4.43 kWh/m² respectively.

Solar radiation is very well doled out across Nigeria. A review of the potentials of solar energy throughout the expanse of Nigeria was carried out and reported in [31]. The six geopolitical zones of the nation were all considered, and their conclusion was that every location has very tangible potential appropriate enough for diverse applications, solar power inclusive. The quantity of solar radiation differs from location to location, but it is usually higher in the Northern part of the country. The northern region, predominantly the North-East and North-West geopolitical regions are the most appropriate sites for large scale solar ranches. These locations have very high solar energy potentials for generating electrical power.

3. Conclusion

This study has indicated that the current situation of electrical power in Nigeria is exceedingly challenging. However, it also highlights steps which will result to the strategic improvement of the situation if taken. Nigeria with its surplus renewable energy resources has magnificent potential for power generation from these resources. The diverse large dams, rivers, and lakes furnish this country with high future prospects for hydroelectricity generation. The huge availability of biomass resources in all parts of the country can also be utilized for electric power production. Wind for power application is fairly available in the whole country. Finally, Nigeria’s geographical location, close to the equatorial region, allows the country to encounter a lot of sunshine which can be exploited for power generation.

The integration of power output from these renewable energy sources into the nation’s generation mix must be promptly considered by the government. This consideration should lead to tangible investments in renewable energy technologies, and all of these options should be explored at appropriate locations to attain optimum yield. Kano is one of such places highlighted to be suitable for the installation of both solar and wind power technologies. Considering the climate in Kano, several power technologies can be adopted. The fact that over half of the installed solar projects in Nigeria are in the northern part of the country implies that such location is promising for solar energy investment. While the pace for adopting these technologies should be accelerated, technologies such as concentrated solar power for electricity generation should also be considered, although this is not currently in place in Nigeria.

Renewable energy projects should be awarded to certified professionals, thus ensuring high quality project executions which will result into long lasting performance of installed technologies. Abandoned renewable energy projects should also be revisited. Utmost priority should be given to initiatives towards the development of the renewable energy sector in Nigeria. Government can promote this initiative by providing further incentives to individuals who generate power for their personal use from renewable energy sources. These private individuals can also be encouraged to sell excess energy generated to the grid; this will also in turn have very positive economic impact on the Nigerian society.

The authors recommend that the Nigerian government should therefore first develop strong and positive attitude towards the large implementation of renewable systems for power generation. In addition, the government should partner with some of the leading countries in the utilization of renewable sources, in order to learn from their expertise and also achieve such feat in quick time.
This should serve as a call up and challenge for the Federal Government of Nigeria to act promptly on the issue as most developed countries have gone pass this stage, and are now focusing on the electrochemical storage of renewable energy due to the intermittent nature of these resources. Functional policies that favour the sustainable utilization of renewable energy in Nigeria should be enacted. Time-framed goals targeted at making a sizeable proportion of the nation’s energy generation mix emerge from renewable resources should also be set and pursued.

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