Journal of Sustainable Energy & Environment
12 (2021) 87-95

Renewable energy and green technology adoption: A viable option for efficient energy supply in Nigeria - Barriers and Government Policies

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Abstract: The risk of global warming and emissions of greenhouse gases associated with energy production from fossil fuels have necessitated the need to embrace renewable energy resources. Nigeria is Africa's largest crude oil producer and has tended to rely heavily on its fossil fuel for electricity generation over the years. In a bid to reduce over reliance on fossil fuel for electricity generation, the Federal Government initiated some projects aimed at harnessing the abundant renewable energy resources in the country. This paper reviews the current development on renewable energy sources and green technology adoption in Nigeria. Systematic review through hybrid approach was adopted. Out of the four renewable energy sources (wind, solar, hydro, biomass) that studies have shown as having great potential in the country, only two (hydro and solar) have been developed and commercialized for public use. Among the 36 states in Nigeria, Lagos, Delta and Sokoto are leading in renewable energy development and diffusion, based on reported number of projects sited in them. Some of the barriers to renewable energy and green technology adoption in the country include: high installation costs, substandard green technology products in the market, inadequate green skills and inconsistent government policy. The renewable energy and energy efficiency policy document of the country is robust, with detailed strategies on how to develop each renewable energy. However, there is a gap between the renewable energy policy document of Federal Government and actual implementation. The development and implementation of many renewable energy projects in the country are inconsistent with the provisions of National Energy Policy, which has led to sub-optimal performance or in some cases total abandonment of these projects.

Keywords: Renewable energy, green technology, adoption, nigeria.

1. Introduction

Energy is the foundation of modern day economy. Virtually everything done by humans today is dependent upon one form of energy or the other. This is critical to achieving almost all Millennium Development Goals (MDGs) [1], which can trigger economic activities and thus a prerequisite for human capital development [2]. Burgeoning population growth in the last five decades, with the attendant demands resulting from urbanization and industrialization has made the need for sustainable energy generation and distribution very important. In Nigeria, the energy sector is bedeviled with missed opportunities and wastage, due to lack of maintenance, poor regulation, and entrenched corruption. Transmission of electricity is a major challenge in Nigeria. The centralized grid system relies on large scale generation, and considerable amounts of energy are lost during transmission [3]. Epileptic electricity supply to homes and industries due to inadequate power generation and transmission, limited access to national grid, and high dependent on petrol and diesel powered generators are persistent problems for nearly every Nigerian. The country is blessed with vast oil and gas reserves, abundant sunlight all year round, and significant hydropower potential. Despite all these resources, energy crisis still persist in Nigeria. The major source of electricity in Nigeria is the natural gas and hydro, with the former accounting for 70% and latter 30% [4]. The 23 power grids connected to generating plants in Nigeria have installed capacity of 10, 396 MW, while about 6,056 MW is available. Out of the 6,056 MW available, 4,996 MW (82.5%) is from thermal base (gas generating plants) while the rest 1,060 MW is hydro [5]. With a human population over 200 million [6], it is obvious that energy per capita of Nigeria is very low compared to what is obtained in most developing and developed nations. The average power consumption in Nigeria is estimated at 143 kWh/year per capita. The grid electricity supply in Nigeria lagged behind that of similar emerging economies. The major reason that explains this low per capita power consumption, is that more than 50% of electrical energy consumed in the country is estimated to be currently off-grid by petrol and diesel powered generators of all sizes and shapes [7]. Due to insufficient and erratic supply of grid electricity, most homes and business owners rely heavily on diesel and petrol powered generators for their electricity supply. According to estimates from the National Electricity Regulatory Commission (NERC), Nigerians spend up to ₦769.4 billion (USD 89.5 million) annually in fueling generators. Of this amount, N540.9 billion (USD 69.2 million) was spent on diesel while N255.5 billion (USD 32.7 million) was spent on petrol [8]. In 2011, about 60 million petrol/diesel powered generating sets were used for electricity generation in Nigeria [9]. The over reliance on fossil fuels in the energy supply mix, experts have warned has debilitating effect on the environment and human health. Coming to terms with these realities and rethinking how we can live, work, and prosper in a rapidly evolving global order, where all daily activities are tied to energy use in one form or the other, intensifies the need for a shift from over dependence on gas powered turbines and use of petrol/diesel powered generators for electricity generation in Nigeria, to adoption of more environmentally friendly and reliable renewables - wind, solar, hydro and biomass. The current electricity generation and

consumption patterns in Nigeria is environmentally unsustainable. During the United Nations Rio+20 Conference on Sustainable Development, Heads of States around the world acknowledged that change from unsustainable to sustainable patterns of production and consumption is sine-qua-non for sustainable development. They emphasized that 'green economy' in the context of sustainable development is one of the major tools available for attaining sustainable development. The energy sector accounts for over 70% of carbon dioxide and other greenhouse gas emissions (GHG) globally [10]. Ensuring reliable, sufficient, and environmentally responsible supplies and distribution of energy is a major challenge for nations [11]. According to Cecily Davis, construction partner and Co-Head Fieldfisher's Africa Group "*it is unfortunate that a number of African countries particularly in North and West Africa, have become so reliant on oil and gas that they find themselves in a bind when it comes to investing in renewable energy projects"*.

Thus, this paper presents a systematic literature review of renewable energy resources and green technology adoption in Nigeria. The aim of the review is to examine level of investment/ development on renewable energy resources, and green technology adoption in Nigeria. Additionally, some of the barriers to renewable energy development and green technology adoption in Nigeria and government policies as reported in existing literature are highlighted. The paper is structured as follows: Section 2 explains the literature review methodology that has been adopted. Section 3 reviews the concept of green technology. Section 4 examines the government investment on renewable energy and adoption of green technology in Nigeria. Section 5 is an overview of barriers to renewable energy and green technology adoption and existing government policies. The paper ends in Section 6 with conclusions on the gains Nigeria will derive from transiting to renewable energy and green technology.

2. Method

This paper reviews the current development on renewable energy and green technology adoption in Nigeria. It presents a succinct review of policy options by Federal Government of Nigeria on renewable energy and energy efficiency. The paper takes a hybrid approach which combines literature review with original analysis of data from secondary sources. Such hybrid approach is gaining prominence in several environmental studies [12]. The secondary data source used in producing the map on adoption/diffusion of renewable energy (Fig. 2) was obtained from [13]

3. Concept of green technology

3.1 Technology

Before delving into the concept of green technology, it is necessary to know what 'technology' means. Technology refers to collection of skills, techniques, processes and methods used in the production of goods or services or in achieving some set objectives [14]. It is a system created by 'humans which uses knowledge and organization to produce objects and techniques for the attainment of specific goals" [15]. Li- Hua [16] opined that "technology represents the combination of human understanding of natural laws and phenomena accumulated since ancient times to produce things that fulfill our needs and desires or that perform certain functions".

3.2 Green Technology

There exists no commonly universally agreed definition of green technology. However, one important point that dominates whatever definition being given to green technology is "environmental sustainability". Green technology can be defined as technology that has the ability or potential to significantly enhance environmental performance relative to other technology. This definition has its premise from the "environmentally sound technology", a term adopted under the United Nations Conference on Environment and Development Agenda 21 [17]. Agenda 21 of the UN states that environmentally sound technologies are geared towards protecting the environment with less pollution, sustainable use of resources, recycle more wastes and products and handle the residue from the wastes in a more acceptable manner than the technologies for which they were substituted [18]. It is a type of technology that is considered environmentally friendly as a result of processes involved in its production or supply chain. It could also be referred as clean energy production that involves the use of alternative fuels and technologies that have less harmful effect to the environment than fossil fuels [19]. Long [20] noted that green technology concentrates on sustainable innovation that takes into consideration short- term and long-term environmental effects. Green technology is not only used to promote reduction in greenhouse gas emission and sustainability, but also proffer answers to climate change [21]. Green technology involves development and application of products, equipment and systems that conserve resources and minimize negative environmental impact of human actives [14]. According to the authors, green technology satisfies the following criteria:

i) It minimizes environmental degradation
ii) Zero or low greenhouse gas (GHG) emissions
iii) Conserves energy use and natural resources
iv) Promotes the use of renewable resources

Green technology encompasses a broad range of production and consumption technologies that minimize damage to the environment and improve the condition of ecosystems [22].

In terms of pollution arising from energy generation and consumption, green technology involves both process and product technologies that generate little or no waste and increase energy efficiency. Green technology does not only refer to individual technologies but also systems. The systems include: procedures, know-how, equipment, goods and services, as well as managerial and organization procedures [22]. Combining the aforementioned view points, green technology is any innovation, production process or procedure that promotes energy efficiency and environmental sustainability. It has four pillars – environment, social, economic and energy as shown in Fig. 1.

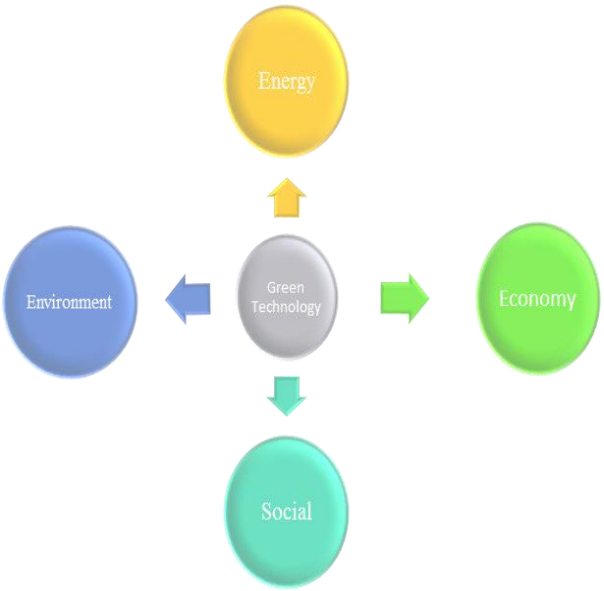

Figure 1. Four pillars of renewable energy and green technology adoption in Nigeria.

Existing literature is replete with technology adoption and diffusion studies too numerous to mention. However, the most consistent conclusion in technology adoption literature is that the adoption pathway follows a sigmoid (S-shaped). Adoption and diffusion of technology are two interrelated concepts describing the decision to use or not to use and the spread of a given technology among a given people or economic units over a given period of time. Adoption is a behavioural choice made at a given time and space, whereas diffusion is the pattern of adoption over time [23]. Rogers [24] highlighted five characteristics of innovations that have impact on the speed of adoption. These characteristics include: compatibility, relative advantage, observability, complexity and divisibility. Another two characteristics that affect adoption rate: variations in the cost of adoption and group action requirements of the technology were added by Supe [25]. Group action requirements of the technology refer to relevant characteristics and roles played by the technology. The traditional adoption/ diffusion curve identifies five categories of participants: i) innovators who tend to be experimentalists and interested in technology itself; ii) early adopters who may be technically inclined and are keen on using technology to solve their problems; iii) early majority who are realists; iv) late majority who less comfortable with technology and skeptical and v) laggards who may not adopt technology and are critical of its use.

4. Renewable energy resources in Nigeria

4.1 Policy Targets on Renewable Energy

Evidence from existing literature on renewable energy adoption and deployment suggests that given the intricacies of renewable energy, policy is a game changer. Thus, the National Renewable Energy and Energy Efficiency Policy (NREEEP) approved by the Federal Executive Council in 2015 set a timeline and targets for the development of various renewable energy sources in Nigeria. This is presented in Table 1.

Table 1. Timeline/Target.

Activity/Item	**Timeline/Quantity**		
	Short-Term (2015)	**Medium-Term (2020)**	**Long-Term (2030)**
Large Hydropower (MW)	2,121	4,549	4,627
Small Hydropower (MW)	140	1,607	8,174
Total (MW)	2,261	6,156	12,801
Biomass Electricity(MW)	5.0	57	292
Biofuel (ML/day)* - Bio ethanol (E10) - Biodiesel (B20	 5.3 2.0	 9.7 3.4	 24.2 11.7
*Based on 7% Growth rate Supply Projections of PMS and AGO			
Solar (All PV and Solar Thermal Systems inclusive)	117	1,343	6,831
Wind Electricity (MW)	55	631	3,211
Windmill Water Pumping Systems (No)	20	100	200

Source: NREEEP [63] Federal Government of Nigeria

4.2 Hydropower

The adoption of renewables have a relatively short history in Nigeria, especially in the public view. However, this perception may not be true as renewable energy from hydropower has actually been at the centre of Nigeria's grid electricity production since the 1960s. Until very recently, the Kanji and Jebba Dams (1300MW) accounted for about half of Nigeria's power sources [26]. However, the situation changed when the country started building gas powered stations for electricity generation, whose role continues to be constrained by poor management, corruption and unstable gas supplies. Out of the 23 operational power plants in Nigeria, as at 2015, only 3 are hydro plants, the rest are gas plants. The last hydropower plant in Nigeria was built 38 years ago. However, as climate change debate continues and the need for nations to reduce their carbon emissions increases, the Federal Government of Nigeria, through its agencies have started diversifying to renewables in meeting the energy need of the people. One of such initiatives is the setting up of new large scale hydropower plants in parts of the country identified as having hydro potentials for electricity generation. Some of the ongoing large scale hydropower projects by the Federal Ministry of Power are presented in Table 2. Relatedly, the Federal Ministry of Water Resources (FMWR) in conjunction with the Federal Ministry of Power have integrated small hydropower schemes into dam projects across the country in order to boost electricity supply. The FMWR has identified and conducted studies on some of the completed and on-going dam projects for hydropower. The dams include; Gurara, Oyan, Ikere Gorge, Bakolori, Dadin Kowa, Tiga, Kiri, Jibiya, Challawa Gorge, Owena, Doma, Waya, Mgowo, Zobe, Kampe, Kashimbilla, Ogwashiku, Zungeru and Mambilla [8].

Table 2. Existing large scale hydro power plants in Nigeria.

Name	**Year**	**Installed available capacity (MW)**	**Actual generation capacity (MW) as of May 2015**	**Status**
Jebba	1986	427	255	Operational
Kainji	1968	180	181	Operational
Shiroro	1989	480	50	Operational
Ongoing Large hydropower projects by Federal Ministry of Power				
Name	**Location**	**Installed capacity (MW)**	**Status**	
Zungeru project	Niger State	700	Ongoing	
Mambila project	Taraba State	3,050	Ongoing	
Gurara II project	Niger State	360	Ongoing	
Gurara I project	Niger State	30	Ongoing	
Itisi Project	Kaduna State	40	Ongoing	
Kashimbilla project	Taraba State	40	Ongoing	

Source: Nigerian Energy Support Programme GIZ -EU, GIZ [27]

4.3 Solar

Among the renewable energy sources in Nigeria, solar seems to have gained prominence in terms of investment and adoption. Nigeria is endowed with huge solar potential by virtue of her location around the equator, within a high sunshine belt where solar radiation is fairly distributed [28]. The annual daily average of total solar radiation in Nigeria varies from about 12.6MJ/m^2/day (3.5kWh/m^2/day) in the southern coastal regions to about 25.2MJ/m^2/day (7.0kWh/m2/day) in the far north [29]. Solar resources are highest in the northern Nigeria, because it is an arid region with high temperature and low rain fall. The southern Nigeria has less potential for solar energy as it is often cloudy and has longer rainy season [27]. The production of solar

energy system is heavily dependent on the amount of incoming solar energy, referred to as solar irradiation or more generally as solar resource. The high potential of solar resource in the country makes it an attractive pathway for renewable energy supply and reduction in carbon emissions [30]. Nigeria is endowed with huge solar resource, however, there is no existing large scale commercial solar project [8]. In order to explore and develop the existing solar potential in Nigeria, the Nigerian Electricity Regulatory Commission (NERC), granted licenses to some companies in 2014 to generate electricity in commercial quantity through solar energy. The list of the companies are presented in Table 3.

Table 3. NERC license for electricity generation through solar.

License Name	(MW)	Type	State	Geo-political Zone
Rook Solar Investment	50	Solar	Osun	South-West
Quaint Global Nigeria	50	Solar	Kaduna	North-West
Nigeria Solar Capital	100	Solar	Bauchi	North-East
Anjeed Kafanchan Solar Limited	10	Solar	Kaduna	North-West
Lloyd and Baxter LP	50	Solar	Abuja	North-Central
KVK Power Pvt Limited	50	Solar	Sokoto	North-West
Pan African Solar	54	Solar	Katsina	North-West

Source: Nigerian Energy Support Programme GIZ -EU, GIZ [27]

4.4 Solar Photo voltaic (PV)

The early stages of green technology adoption in Nigeria, started with solar powered boreholes since the mid-1990s. Boreholes especially in rural areas rely on generators which are expensive to maintain. For example, the Niger Delta Wetlands Centre (NDWC) has been experimenting with solar-powered water boreholes since the 90s. Due to the cloudy nature of the region, people thought that solar powered boreholes may not work. However, NDWC has been able to demonstrate model water boreholes around several key principles and provide direct evidence to disentangle the "too cloudy hypothesis" [26]. Over 50% of Nigeria's population lack access to grid electricity [31] and it is even erratic [65]. In order to fill this deficit in electricity supply, there is an ongoing transition within the energy sector in Nigeria [14]. The current transition from heavy reliant on fossil fuels for electricity generation to adoption of renewables (solar, wind, bio-gas) has open a new chapter in Nigeria's energy history. Some of the factors that triggered the shift include: (i) Nigeria's energy system which depends heavily on fossil fuels has functioned limitedly over the years, triggering the demand for alternative sources of energy and (ii) the central government has not been the major driver of the shift towards adoption of renewable energy, rather state governments, private corporations and community initiatives [13]. One of the arguments for failure of the energy sector in Nigeria, is centralization of generation and transmission. The sub-nationals (state governments) have not been given opportunity to fully participate in the generation and transmission of electricity in Nigeria. However, the current transition within the energy sector in Nigeria, affords private organizations, Local Governments, State Governments and individuals the opportunity to actively participate. In their study in Kano, one of the mega cities in Nigeria, Barau et al. [32], reported that over 50% of respondents that have adopted solar PV were resident in unplanned neighbourhoods of the city. The implication of this according to the authors is that areas of the city that are planned have relatively stable grid electricity supply compared to those that are unplanned. Similarly, majority of adopters in the study area, changed their high energy consuming appliances to more efficient ones after their installation of solar PV. In another seminal study, [13], examined the conditions for adoption and development of renewables and green technology in Nigeria. In this study, adoption/diffusion of solar, biogas, wind and biofuel among the 36 states in Nigeria was examined. The authors applied method of qualitative comparative analysis (QCA) to analyze three different cases of adoption/diffusion of renewable energy in Nigeria. Thus, the states were categorized as: i) pioneer states in renewable energy development, (ii) semi-laggard states and (iii) laggards. A state is considered a pioneer when it has a threshold of installed capacity of 1000kw or more. It is considered a semi-laggard when it has a threshold of installed capacity between 1000 kW and 100 kW. Finally, a state is a laggard when it has a threshold of 99 kW–5 kW of installed capacity. The threshold used for this study according to the authors was the share of installed capacity rather than energy per capita due to lack of verifiable data on annual electrical use of the state in KW hours. Their findings revealed that there is a variation in renewable energy adoption/diffusion in Nigerian states on the basis of type of technology and installed capacity in KW per state. Based on their findings, (Figure 2) Lagos, Sokoto and Delta are pioneers (early adopters); Enugu, Oyo and Bauchi are semi-laggard States (late majority) while Nasarawa, Niger, Edo, Ogun, Jigawa, Bayelsa, Katsina and Benue are laggard states.

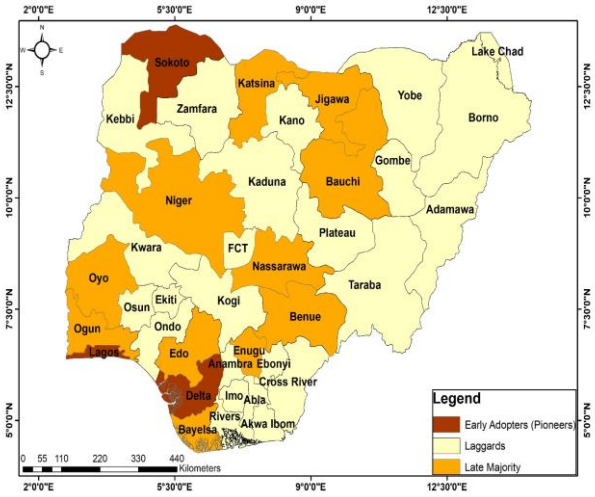

Figure 2. Adoption/development of renewable technology among the Sates in Nigeria. Data source: [13]

Federal Government of Nigeria has been providing incentives (such as tariff waivers, subsidies) to encourage investment in fossil energy sources. Switching these subsidies and tariff waivers to fund renewable energy development will accelerate the adoption of green technology especially solar PV [28]. Most households in Nigeria that use solar PV technology is for lighting during the night. The adoption solar PV in Nigeria has gained prominence over the last five years. For example, Baru et al. [31] in their study reported that 60% of solar energy adopters in Kano city, Nigeria installed their solar system between 2015 and 2016, which reveals that there is increase in adoption of solar PV by Kano residents. According to SEFAA [7] report, efficient lighting will be used by 40% of households in Nigeria by 2020 and 100% by 2030. Through the National Clean Cooking Scheme (NCCS) launched in 2012, the Federal Government of Nigeria approved the sum of 9 billion Naira (45,000,000 USD) in 2014 for the distribution of 750,000 energy efficient clean cook stoves to households, in a bid to discourage indiscriminate felling of trees and depletion of forest resources.

4.5 Energy Efficient Appliances

Adoption of energy efficient appliances (end-use energy efficiency) in Nigeria has improved over the years. A lot of energy is wasted in Nigeria because households, industries, private and public organizations use more energy than necessary, because they use old and inefficient electrical appliances, production process and inefficient habits of energy users ([32, 8]). The use of incandescent bulb in Nigeria by households has dropped over the last decade. In their study on three major cities in Nigeria – Lagos, Benin and Federal Capital Territory Abuja, Uyigue et al. [33] reported that about 65% of respondents sampled claimed that they use incandescent bulbs while the rest use LED bulbs. However, in another study conducted years later by Wahab [34] on use of energy efficient bulbs among households in Ile-Ife, Osun State, it was reported that 72.6% of respondents use LED bulbs (energy saving bulbs) for lighting. One major reason that aided the shift from use of incandescent bulbs to LED bulbs in Nigeria, is the sharp reduction in prices of LED bulbs over the last five years. For example, in 2008, the price of LED bulbs in Nigerian market ranged between ₦800 to ₦1000 (₦ is Naira Local currency) while incandescent bulbs ranged from ₦30 to ₦100 [33]. Today, the market price for LED bulbs range between ₦200 to ₦350 depending on the brand and wattage. The sizes of LED bulbs in the market are 5W, 10W, 15W, 20W and 25W. Adoption of LED bulbs by Nigerian households over the years has strongly been influenced by reduction in cost and improvement in level of environmental awareness. The use of incandescent bulbs is energy intensive, only about 5% of total energy in incandescent bulbs is converted to light energy, the rest (95%) is converted to heat energy [35]. There has been some laudable innovations in Nigeria over the couple of years in solar PV. Development of affordable and robust LED lighting attachments, better battery options and dramatic decline in the cost of solar-panel components. New products in the market today are compact, with battery and LED life span measured in years (some batteries have between 3-5 year lithium variations) [26].

4.6 Wind

Wind power seems to be the least well-understood source of renewable energy in Nigeria. Until recently, Nigeria was thought of by both local and international policymakers as 'not a windy country' but this conclusion is based on a very limited dataset. The assertion that Nigeria is 'not a windy country' is mainly due to lack of accurate data to support or contradict it [26]. Studies have suggested that the northern part of Nigeria is endowed with more wind resources than the southern part ([36-38]. Oyedepo et al. [42] examined wind potential for three sites in South-Eastern Nigeria (Enugu, Owerri, and Onitsha) using wind data from the Nigerian Meteorological Agency (NIMET) captured at a height of 10 m. The annual mean speed for Enugu, Owerri and Onitsha were reported to be 5.4, 3.4 and 3.6 m/s, respectively, while the yearly wind speed carrying maximum energy for the site is given to be 6.5, 4.3 and 3.9 m/s. The development of wind and other renewable energy sources in Nigeria have not experienced much progress in recent years due to some inherent problems that have impeded growth of the industry. Nigeria has coastal line of about 853 km which has potential for the generation of electricity via the use of offshore wind turbines. However, technical investigation to evaluate the exact wind energy resources that abound in the shores of the country has not been carried out [39]. Wind energy has not really been utilized in Nigeria. Most of the studies conducted are either pilot in nature or mere use of time series data obtained from some agencies or organizations by researchers to model, predict or analyse wind potentials that abound in the country ([40-43]). Ayodele et al. [44] through a cross regional analysis of the six geo-political zones in Nigeria, examined the wind resources at 10 m height by employing the Weibull distribution functions. Findings from the study revealed that only Kano and Jos out of the fifteen sites considered produced the most excellent wind energy potentials that is cost effective and could be connected to grid systems. For example, Ajayi et al. [40] used the Weibull probability density with two-parameter function to analyze the electricity generation potential from wind in one of the states in northern Nigeria (Kano state). The results showed that the mean monthly wind speed ranged between 6.6 m/s -9.5 m/s. Ajayi et al. [40] increased the scope of the study by evaluating wind potential in ten sites located in southern Nigeria using 24 years data (1987 to 2010) obtained from the Nigerian Meteorological Agency (NIMET). The results obtained showed that the wind mean speed for Lagos was 2.9 m/s while for Oyo state it was 5.8m/s. Unlike solar energy which utilization for electricity generation by households is currently being commercialized, wind as an alternative renewable energy source is still at the exploratory stage in Nigeria.

4.7 Biomass

Biofuels are liquid or gaseous forms of fuels processed from biomass sources (agric crops, forest biomass, bio-waste) which can replace fossil fuels such as petrol and diesel used for operating various automotive and mechanical machines. According to the official gazette of the Nigerian bio-fuel policy and incentives,: "*Bio-fuels refer to fuel ethanol and bio-diesel and other fuels made from biomass and primarily used for automotive, thermal and power generation, according to quality specifications stipulated by the Standards Organisation of Nigeria (SON), Department of Petroleum Resources (DPR), and any other competent government agency"*. Biofuels are in the form of biogas, biodiesel and bioethanol [45]. Biofuels are increasingly making inroads into the energy sector, and the demand for them as alternatives to fossil fuels is increasing. The rising interest in biofuels in both developed and developing countries is linked to rising cost of petroleum products as well as concerns for environmental sustainability and reduction in carbon dioxide emissions associated with the use of fossil fuels [46]. Although Africa's biofuel production potential is huge, especially through agricultural co-production, its growth has been slow, owing largely to inefficiencies in the agricultural systems [23]. Large scale biofuels remains limited in Sub-Saharan Africa with only Malawi and Kenya and just recently Zimbabwe [47] and Mozambique showing some progress in biofuel production [48]. Global distribution of biofuels production capacity and potential is predicated on three factors: water availability, arable land for feedstock production and current level of food security [49]. Based on these criteria, Nigeria is one of the countries ranked as having very high potential of biofuels [46]. The overall impact of unstable supply of refined imported petroleum products, erratic grid electricity supply, and environmental degradation concerns prompted the introduction of biofuel policy by the Federal Government of Nigeria in 2007. The biofuel policy is meant to provide an alternative via agriculture and green technology in solving energy related and environmental problems in Nigeria. The biofuels development program in Nigeria is at the second phase, which involves the development of the local capacity for meeting targets at 10% ethanol in gasoline blends and 20 to 30% biodiesel [50]. The Nigerian Biofuel Policy gave an estimate of fuel ethanol requirement at 10% blending rate, to be about 1.3 billion litres per annum with projected increase to 2 billion litres by 2020. The market value of this estimate is about 391 million USD annually [51]. Ishola et al. [52] noted that the second phase of biofuels program in Nigeria seems to be struggling to fully takeoff. Although adoption and promotion of biofuels represent a giant step towards addressing the myriads of energy-related challenges confronting Nigeria, the promotion of these new fuels must be based on a clear analysis /assessment of the current fossil fuels demand in the country [53]. Since the

enactment of biofuel policy in Nigeria, about 24 projects are yet to be actualized due to policy summersault, and corruption. Also the biofuel industry in Nigeria depends largely on edible foodstuff, such as sugarcane, cassava and palm oil which puts pressure on local foodstuff demand in Nigeria [54]. Biofuel potential production estimate for cassava in Nigeria is about 15,500.0 ML (million litres), palm oil 18,742.5 ML and sugarcane 378.0 ML [46]. The Nigerian National Petroleum Corporation (NNPC) has been at the forefront of bio-fuel development in Nigeria. The renewable energy program (automotive bio-fuel program of NNPC) has attracted investment grants from foreign donors. For example, the German government through its Renewable Energy Efficiency Partnership (REEEP) donated 70,000 Euros (53,846 USD) as grant to NNPC for its automotive bio-fuel projects [55]. The aim of the partnership is to diversify from over reliance on fossil fuels and mitigate environmental pollution. The biofuel project is expected to generate income for government, create employment, green technology promotion, and reduction in greenhouse gas emissions [56]. Carbon-dioxide emissions associated with energy consumption in Nigeria has been rising, with sectoral emissions estimated to have risen from 6 million tonnes in 1971 to 51 million tonnes in 2007 [57].

5. Barriers to renewable energy and green technology adoption in Nigeria

Green technology or eco-innovations are environmentally friendly and less harmful than available alternatives. Most developed countries have developed their renewables and adopted green technologies extensively. However, developing nations lag in this area due to a number of barriers to the adoption and diffusion of such innovations [58]. Unlike other sectors of the Nigerian economy, the energy sector has its own challenges. Weak purchasing power due to low income affects the ability of most Nigerians to adopt green technology or innovations that will promote switching from high energy consumption appliances to more energy efficient ones. For example most homes are still using the incandescent bulbs which are cheap instead of LED bulbs that is efficient in terms of energy consumption. High initial costs including high installation costs and ineffective quality control have been identified as some of the barriers hindering solar technology in Africa and Nigeria in particular ([59, 29]). Absence of national standards and effective quality control are some of the institutional challenges to the adoption of renewable energy by households in Nigeria. Most of the solar products in the market are imported from China through the nation's porous border without trade mark certificates and certificate of analysis from manufacturing firms. The consequence is that the market is flooded with poor/substandard solar products [29]. There is low level of awareness among citizens and private sector on renewable energy and other related energy efficiency projects that could promote low carbon dioxide emissions and environmental sustainability. Policy summersault is another major barrier to renewable energy and green technology development in Nigeria. Implementation of the country's renewable energy policy has been inconsistent. For example, the past administration in Nigeria invested billions of Naira to purchase improved clean cooking stove for households in order to enhance energy efficiency from biomass use. The improved cooking stove project ended with the expiration of the last administration. According to Slav [60] "a lot of African governments jumped on the renewables bandwagon and made ambitious plans to make their countries entirely dependent on renewable energy. However, they overshot the deadlines and were forced to accept that it could not happen as fast as they thought, and this makes investors wary of funding wind, solar or hydropower projects in the continent". Lack of trained personnel and inadequate number of professionals in the field of renewable energy is another barrier impeding green technology development in Nigeria ([33, 8]). Adoption of some green technologies may likely impose new capital costs and increased running costs on their users. However, their adoption occurs because of the desire of adopters to reduce carbon emissions or pollution associated with energy use. On the other hand, reduction in pollution is linked with more efficient use of materials and energy inputs such that running costs are reduced alongside reduction in pollution [61].

6. Government policies on promoting renewable energy development in Nigeria

As the climate change debate on how to reduce carbon emissions from energy consumption rages on, national governments around the world are shifting from consumption of fossil fuels to renewables especially in Europe, North America and some Asian is not left out in this paradigm shift, the government through its agencies has put in place several initiatives at promoting renewable energy and green technology. A large part of these programmes is aimed at supporting research and development in the area of renewable energy solutions [62]. Existing literature on renewable energy adoption and deployment suggests that given the intricacies of renewable energy, policy is a game changer [63]. After series of stakeholders meetings, workshops and collation of various documents, the inter-ministerial committee set up by the Federal Government of Nigeria came up with the first ever national policy on Renewable Energy and Energy Efficiency in 2015. The policy document was developed in line with objectives of Millennium Development Goals, National Energy Policy, the National Economic and Development Strategy and Rural Electrification Strategy and Plan. Some of the policy statements are presented in Table 4.

Table 4. Polices and strategies on how to develop renewable energy resources in Nigeria.

Policies to drive hydropower development in Nigeria	**Key strategies**
i) The nation shall fully harness the hydropower potential available in the country for electricity generation	Providing basic engineering infrastructure for the domestic manufacturing of components of hydropower plants, equipment and accessories
ii) Particular attention shall be paid to the development of the mini and micro Hydropower schemes.	Encouraging the private sector, both indigenous and foreign, in the establishment and operation of mini and micro hydropower stations, under the Power Sector Reforms initiative
iii) The exploitation of the hydropower resources shall be done in an environmentally sustainable and socially acceptable manner	
iv) Private sector and indigenous participation in hydropower development shall be actively promoted	

Solar	
Key Policies to drive development of solar for electricity generation	**Strategies**
i) The nation shall promote the use of efficient solar energy conversion technologies, such as use of photo-voltaic, solar-thermal and concentrated solar panels for power generation.	Promoting Research and Development in solar energy technology Sourcing and providing adequate incentives to local entrepreneurs for the production of solar energy conversion systems
ii) The nation shall intensify efforts to increase the percentage of solar energy in the present energy mix	Training of skilled manpower for the maintenance of solar energy conversion systems.
iii) The nation shall compliment solar power development with energy efficiency programmes.	
Wind	
Key policies to drive development of wind energy source	**Strategies**
i) The nation shall commercially develop its wind energy resource and integrate this with other energy resources into a balanced energy and electricity mix	Encourage research and development in wind energy generation and utilization Training of skilled local craftsmen to ensure the operation and maintenance of wind energy systems
ii) The nation shall ensure the development of indigenous small scale wind generating devices and energy storage devices	Intensifying work in wind data acquisition and development of wind maps and implement a web-based wind prospecting tool to encourage the implementation of wind projects
iii) The nation shall take necessary measures to ensure that this form of energy is harnessed at sustainable costs to both suppliers and consumers in the rural areas	Providing appropriate incentives to producers, developers and consumers of wind power systems
Biomass	
Key policies to drive development of biomass energy source	**Strategies**
The nation shall effectively harness biomass resources and integrate them with other energy resources for electricity generation	Promoting Research and Development in biofuel technology
The nation shall promote the use of efficient biomass conversion technologies	Establishing pilot projects for the production of biomass energy conversion devices and systems Providing adequate incentives to local entrepreneurs for the production of biomass energy conversion systems

Source: NREEEP [63] Federal Government of Nigeria

Conclusion

Nigeria has abundant renewable energy resources that could promote reduction in carbon dioxide emissions arising from heavy reliance on fossil fuels. Currently, over 70% of grid electricity generated in the country is from gas powered stations. In the country's quest to increase share of renewables in her energy mix, green technology or innovation is needed for proper harnessing and efficient use of these renewable energy resources. The major feature of green technology is that it promotes or facilitates a reduction in greenhouse gas emissions relative to status quo. This reduction can be in energy generation process (wind, solar, biomass, hydro) or in consumption (e.g use of LED bulbs, energy efficient home appliances and so on) [61]. Similarly, development of renewable energy potentials in Nigeria will help in creating direct and indirect job for the teeming unemployed youths. It will also provide electricity access to majority of the Nigerian population living in rural areas, including more sustainable provision for household's cooking. This paper therefore, reviewed the various studies that have been carried out on renewable energy resources and green technology adoption in Nigeria. Based on this review, some barriers to renewable energy development and green technology adoption were highlighted as well as existing federal government policies. Out of the four renewable energy sources (wind, solar, hydro, biomass) that studies have shown as having great potential in Nigeria, only two (hydro and solar) have been developed and commercialized for public use. The large scale hydropower stations in the country have installed capacity of 4,120MW, but actual generation is only 486MW (11.8%), which shows that they are underutilized. Solar PV installations in Nigeria are growing. It is utilized in homes and some government buildings for pumping water, lighting, and operation of electrical appliances. The adoption of LED bulbs, solar powered appliances such as lamps, battery chargers, radio, and fan has gained prominence in Nigeria over the years. Deployment of renewable energy in Nigeria is still at infancy stage as shown by the review. Apart from hydropower that is connected to grid, other renewables have no grid connection yet (off grid). The rate of renewable energy adoption/diffusion in Nigeria is highest in Lagos, Sokoto and Delta States. These States have more renewable energy projects compared to others. Some of the barriers that have hindered renewable energy development and green technology adoption in Nigeria include: high initial installation costs, low purchasing power, substandard green technology products in the market, inadequate manpower with 'green skills' and policy inconsistency on the part of political office holders towards renewable energy development. The country's renewable energy and energy efficiency policy document drafted in 2015, contains detailed strategies to be adopted in developing renewable energy resources in the country, diversify the energy mix and provide practical and realistic access to electricity for all citizens. However, poor implementation of this robust policy document has slowed down the development of renewables and green technology adoption in Nigeria. Through a strong political will, government can unlock the renewal energy potentials in the country.

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