



ACCELERATING RURAL ELECTRICITY TRANSFORMATION THROUGH GRID CONNECTED MICROGRID AND ISLANDED MICROGRID GENERATION IN NIGERIA

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ABSTRACT

Africa has the largest population of people in the world without access to electricity, an estimate of about 600 million people lacking access and expected to reach 700 million by 2030. Over two-thirds of Nigeria's population, currently, have no access to quality electricity supply and most of the rural areas are not connected to the National grid. This is similar in other Sub-Saharan Africa countries, where the average electricity grid access rate is 20%. For Nigeria, where fossil fuel is the major source of commercial energy, finding an alternative source from, renewables are important for advancing sustainable development. This paper explores the benefits and challenges that exist because of the current energy policy in Nigeria and why the grid-connected microgrid and islanded microgrid application is the best bet in solving Nigeria's energy crisis. Global power source arrangements are accessible and efficient. Arrangements which are particular to Africa's vitality challenges are additionally rising. These arrangements will enable Africa to jump to accomplish least cost, earth well disposed vitality division advancement, which at last adds to feasible improvement objectives.

Keywords: Rural electricity, Microgrids, Islanded, Renewable Energy, Nigeria

Introduction

The epileptic state of the Nigerian electricity supply system is quite threatening and as such has a direct socio-economic effect on the entire population and the GDP of the Nation. Due to the growing population rate, the current electricity generation scheme and its transmission is a mismatch between the public and industrial demand. Lately, the Nigerian government and some energy experts have considered deploying renewable energy sources (solar, biomass and wind) as a valuable option in mitigating the current electricity generation and supply issues. However, a more in-depth investigation about the advantages of Off and Microgrid technology is equally required to help draw the attention of the government and energy experts on the relevance of these technologies in helping transmit electricity to rural areas and suburban centres ([1]-[3]).

Among the African countries, Nigeria government is known to have shown little commitment to shifting towards a cleaner energy system comprising solar, biomass, wind and hydro, due to their abundant availability. But little efforts have been made in implementing or pursuing this goal on clean energy because of the abundant fossil fuel reserves, and the existing fossil-based energy companies. A lot of vested interests in established business models and the cost of moving towards renewable energy may suggest a reluctance to this change in electricity supply and the present grid system adopted over the years (4).

Nigeria has solar energy approximately seventeen billion MJ/day is incident on the entire surface and biomass amounting to 47.97 million tonnes yearly. Sweet potato, jatropha, molasses, animal waste, and cassava are examples of biomass resources which could assist in the production of energy in Nigeria, but little attention has been paid to these sources. In Countries like the USA, Brazil, India, China, these resources are used in the production of biogas, biodiesel, organic fertilizers and briquettes, the Nigerian macroeconomic indicators before re-basing is as shown in Table 1 below ([1]-[3]).

Table 1: Nigeria macroeconomic indicators before and after re-basing

Year	1980*	1985	1995	2005	2010	2011	2012	2013	2014 ³	2015 ³	2016 ³
GDP, current prices	60.6	26.0	36.9	112.2	369.1	414.1	461.0	515.0	581.9	579.8	661.4

US \$ Billion											
GDP nominal growth, (1%)	-	-57.1	17.4	142.0	15.32	13.87	11.68				
Real GDP growth (%)					7.8	4.9	4.3	5.4	6.2	5.6	6.5
GDP per capita, current prices, US\$**	885	331	356	824	2,396	2,612	2,835	3,082	3,416	3,677	

Source: [5] and [6]

Nigeria's Gross Domestic Product (GDP) was revised in 2017 with electrification rates shown in Table 2. GDP is typically measured by reference to the shape of the economy in a "base" year. Statisticians sample businesses in different industries to see how fast they are growing. The weight they give to each sector depends on its importance to the economy in the base year. Naturally, these figures become less and less accurate over time. Nigeria's old GDP data relied on an outdated snapshot of its economy in 1990. The new figures (which have 2010 as the base year) give due weight to fast-growing industries such as mobile telecoms and film-making that have sprung up since then. Moreover, Nigeria's statisticians have improved the gathering of data. For instance, the old GDP figures were based solely on estimates of output. The new ones are now being reconciled with separate surveys of spending and income.

Table 2: Electrification rates in Nigeria and Sub-Saharan Africa

Region	Sub-Saharan Africa	Nigeria
Population without electricity	621 million	93 million

Overall electrification rate (%)	32	45
Urban electrification rate (%)	59	55
Rural electrification rate (%)	16	35

Source: [7]

The need for the attainment of clean energy led to the replacement of Millennium Development Goals by the Sustainable Development Goals in the year 2015 by the world leaders. The electrical power current obtainable for national use comes from hydro-plant and natural gas and from the total production as shown in figure 1&2, less than 48% of the overall households get energy and 45% do not have access to electricity. As at January 2018, Nigeria Generates less than 4.5GWh of Electricity annually. Therefore, they rely on diesel and kerosene to provide most of their energy needs during grid downtime. Most of the Population now rely on standby generators or industrial plants to supplement their electricity supply or cater for all their energy requirements (Doya, 2015).

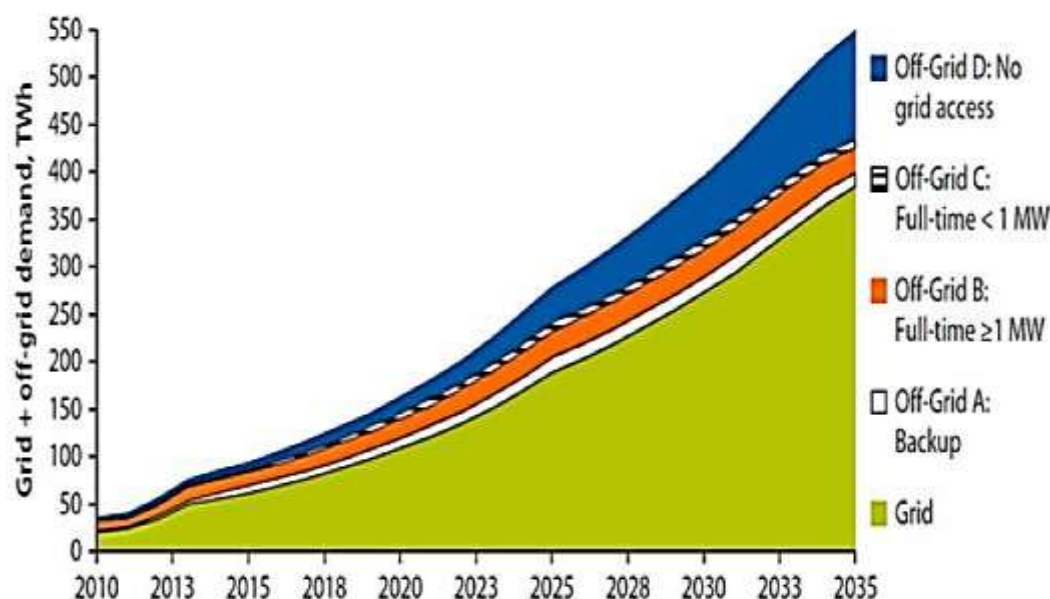


Figure 1: Projected grid and off-grid electricity demand in TWh

Source: Calculations based on FMP and Power Holding Company of Nigeria data and UN 2010 rural/urban population data (for off-grid D projections) listed in the chapter 3 references.

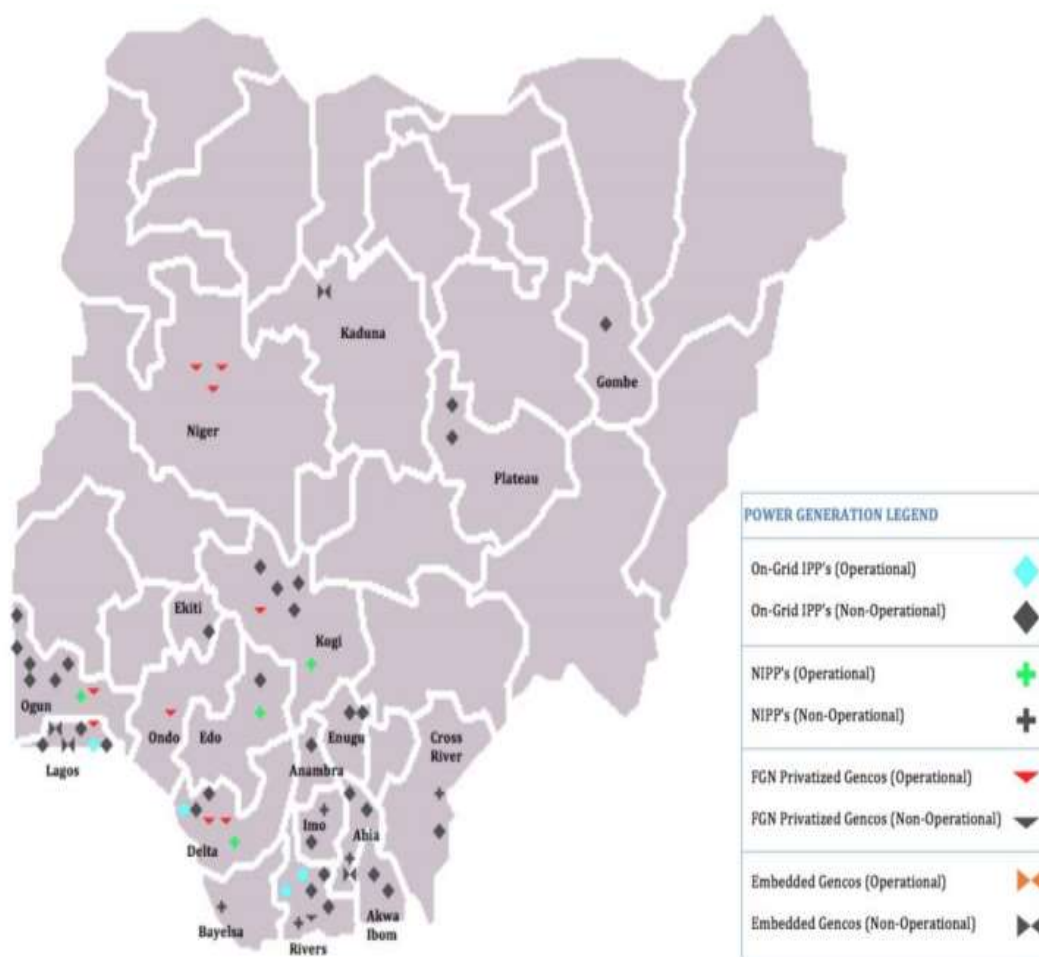


Figure 2: Power Generation Sites in Nigeria
Source: [8]

Renewable Energy sources like small-scale stand-alone Solar PV systems are being used in countries like South Africa, Kenya, Egypt, Morocco, Algeria, etc, for mini-grid service in rural communities especially for other community services, such as lighting the streets, mobile-phone charging stations, telecom towers, solar kiosks, and pumping water for domestic and agricultural purposes. Until recently, energy services have historically been using diesel fuel, renewable energy sources like solar, wind, Hydro, Biomass systems, offer a cost-effective alternative as seen in figure 3. Mini-grid based rural

electrification has been implemented in many African countries, and diesel based mini-grids are being upgraded with PV-diesel hybrid systems produced.

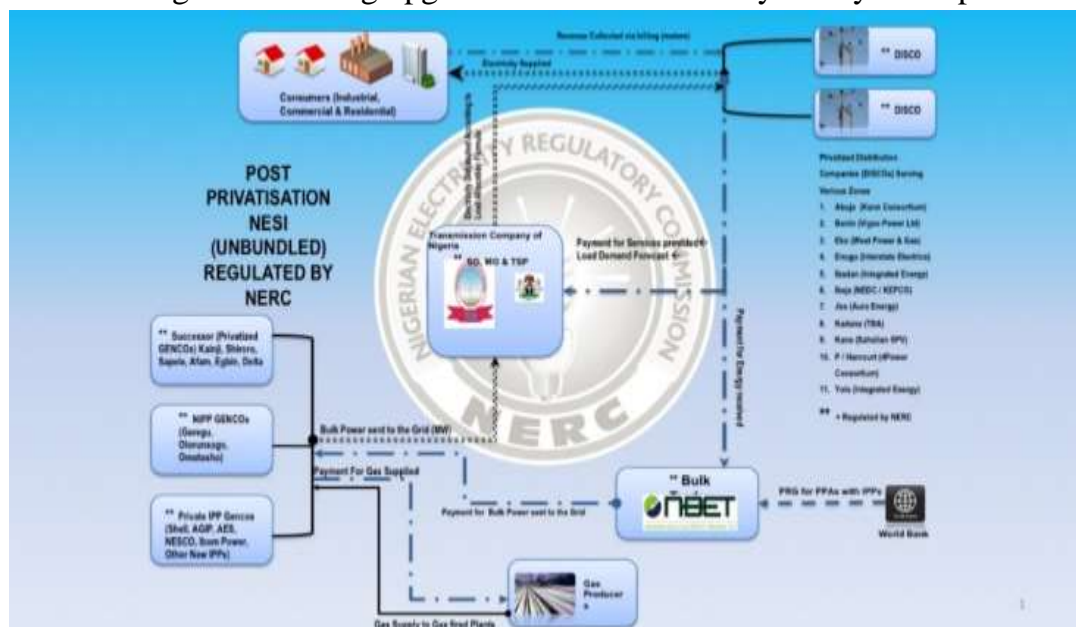


Figure 3: Structure of the Nigerian Electricity Supply Industry

Source: (9)

Sadly, despite the enormous opportunity in the clean energy and rapid transformation of the renewable energy technology in the world, in rural areas and remote areas, less than 1.1% of the entire population has access to electricity. More than ever before, the Nigerian government must shift from mere policymaking or postulation to developing renewable energy options that could help in solving the issue of electricity supply shortages, especially in the rural areas. The objective of this paper is to explore the challenges that arise from current energy policy in Nigeria and why the Off and Microgrid application through renewable energy sources may be the best bet for solving Nigeria's rural electrification agenda [9, 10].

Implementable Renewable Energy Sources Available in Nigeria

Renewable energy is a form of energy derived from sunlight both indirectly or directly through variance heating of the earth's surface, leading to air movement. Renewable energy is gaining popularity and there are four distinct areas where they can deploy such as air and water cooling or heating, electricity

generation as shown in figure 4, 5 and 6, rural electrification needs and motor fuels.

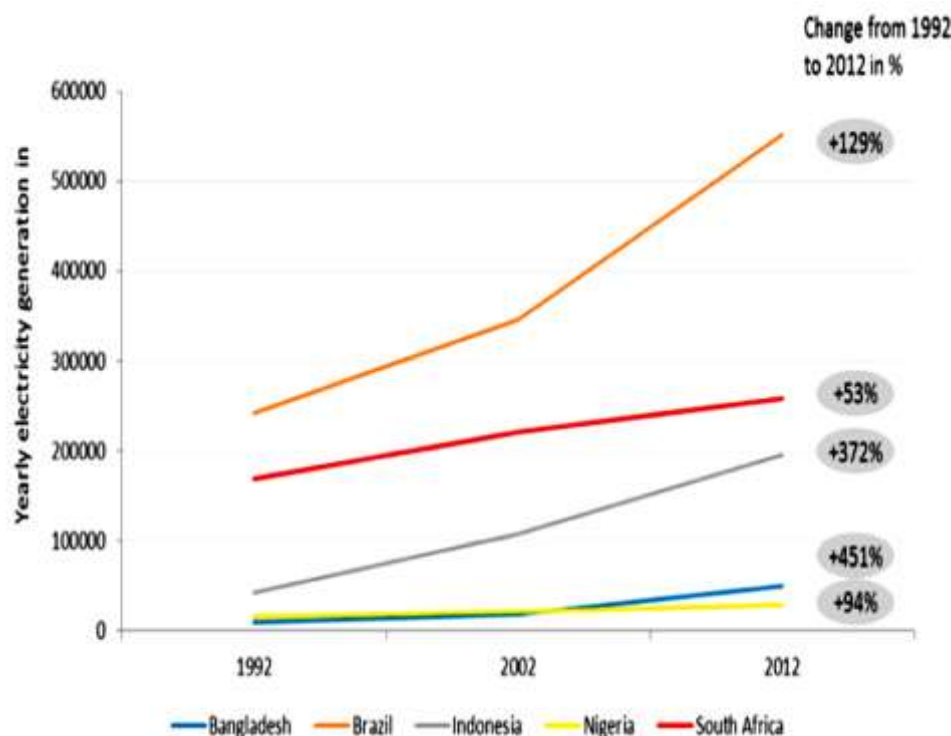


Figure 4: Electricity Generation (GWh) in Nigeria and Peer Countries Since 1992

Source: [7]

Wind Power

Wind Energy is the kinetic energy extracted from the Wind through wind turbines and could be used to drive electrical generators or to directly power pumps and other machinery. From current literature, the potential for wind in Africa exceeds demand by orders of magnitude. Although the wind energy is not evenly distributed in enormous capacity in Nigeria as shown in figure 5. However, some of the regions of the Northern part of Nigeria and the Atlantic still shows the potential of harnessing and utilising wind resources. Most of the lands or areas in Northern part of Nigeria are rural and have abundant space for use in wind resources but little or nothing was done about it [11].

According to the [12], at the end of 2013, the total installed wind resource capacity in Africa was about 1.5 GW. Also, in 2014, about 1 GW of new capacity was equally installed, bringing the total to about 2.5 GW. Given the

remarkable growth rate in South Africa, Morocco, Nigeria has shown little or no interest in Wind energy resource. In East Africa, there is an estimated growth, with given the 300 MW Turkana project under construction.

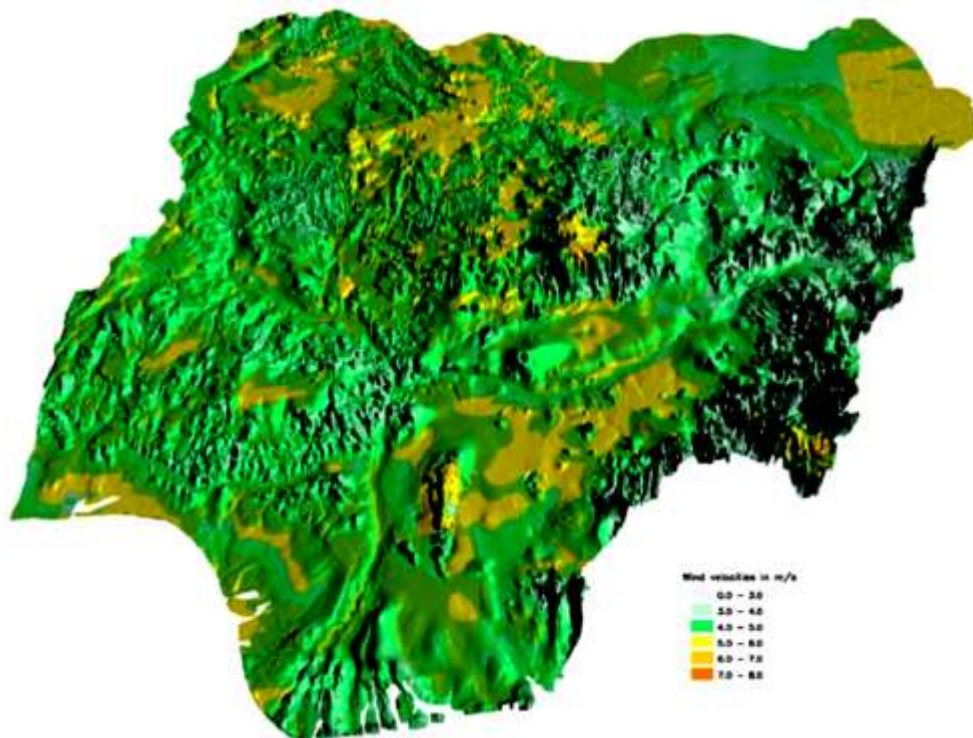


Figure 5: 3D Wind Map of Nigeria 80 M above the Ground
Source: [13]

The Utilization of wind resources in Nigeria for off-grid applications in the rural areas, and particularly for water pumping in the agricultural sector, is highly necessary. This has become a widespread phenomenon in Africa and particularly in Southern Africa, where over 300 000 units of wind farms are fully in operation. The Wind energy technology is simple, cost-effective, and robust, with low maintenance requirements over the years. [13], carried out a cost comparison between wind and diesel pumping in Sudan and discovered that using wind is 30% less expensive than diesel [11].

Hydroelectric Energy

This is a kind of energy that rests on the raised water gravitational potential that was lifted from the oceans by sunlight. All reservoirs are very expensive to construct during excavation and for them to be made useful. In most cases,

hydroelectric energy is sometimes not reflected as renewable energy. However, energy experts, have discovered that small hydro turbines are suitable for connection to existing grids or for the provision of electricity in rural areas. Leveraging on their smaller sizes, any dams associated with these plants will have a significantly smaller environmental impact.



Figure 6: Location of Major Dams in Nigeria

Source: [13]

In Africa, there is already a total capacity of 525 MW from hydro plants with individual capacities of less than 10 MW, from this figure, 209 MW is in Eastern Africa alone [12]. No doubt, mini- and micro-hydro turbines offer cost-effective solutions to distributed power generation requirements in the rural areas, particularly when the supply is at the village or household capacity. Using such installations, water may be diverted from a rudimentary dam to power a small water turbine within a rural area. Where this technology is available, the implementation of small hydro plants is a cost-effective off-grid solution for rural areas. The capacity factor is high and generation costs can be relatively low, with an average levelized cost of energy (LCOE) of about USD 0.05/kWh. It has been estimated that the weighted average installation costs for small-scale

hydro in Africa are USD 3 800/kW (12). This is a very good opportunity and platform for the government to transform rural areas.

Bioenergy and biomass resources in Nigeria

Biomass is a prospective source of substantial renewable energy since it is extensively available in all parts of the country. It could be tapped by the government to generate electricity. Biomass Energy could come from plants as a direct or indirect reaction from the sun, through a process called photosynthesis and chemosynthesis. One of the major problems in the rural areas is the source of energy for cooking or heating purposes. Hence, burning of trees for cooking and to create warmth for the family is the predominant of this form of energy. This activity releases a substantial amount of CO₂ gases into the atmosphere and contributing to the major problem (climate change) facing our planet.

Recent forms of biomass energy involve the production of methane and alcohol for automobile fuel and fuel electric power plants. Biomass can be converted into electric power through several methods. The most common is direct combustion of biomass material, such as agricultural waste or woody materials. Other options include gasification, pyrolysis, and anaerobic digestion. Gasification produces a synthesis gas with usable energy content by heating the biomass with less oxygen than needed for complete combustion. Pyrolysis yields bio-oil by rapidly heating the biomass in the absence of oxygen. Anaerobic digestion produces a renewable natural gas when organic matter is decomposed by bacteria in the absence of oxygen (Nigerian Electricity Supply Industry [15]).

According to the [12], the total supply potential of crop biomass residue in Africa is estimated to be at around 4.2 EJ in 2030. The West Africa region of which Nigeria is a major part of has 40% of this resource. Again, it was estimated that the total supply potential of wood residues (including both logging and processing residue) and wastes and animal residues are estimated at around 1.1 EJ and 1.5 EJ per year, respectively. In most of the rural areas, wood biomass is used for cooking through combustion or wood burning process. The wastes from animals only serve as manure, unlike in India, China and other developed and developing countries where they are used for generating electricity and heating homes or another domestic purpose.

Biogas is one of the classifications of biofuel, it is a mixture of methane, CO₂ and apart from the production of electricity, and it is used during camping and as gas for cooking. The Epe Integrated Solid Waste management Project found in Lagos, Biofuel Production Complex at Ilimeso and gas-to-energy project at Olushosun landfill are some of the examples of bioenergy projects found in Nigeria. Some of the potential biofuel resources that could be used to generate biofuels include; Food crops (e.g. cassava and fruits), agricultural residues, Forest resources, animal waste (cow dungs, other faeces), municipal solid waste, etc.

Table 3: Renewable Energy Potentials

Resource	Potential	Current utilization and further remarks
Large hydropower	11,250 MW	1,900 MW exploited
Small hydropower	3,500 MW	64.2 MW exploited
Solar	4.0 kWh/m ² /day - 6.5 kWh/m ² /day	15 MW dispersed solar PV installations (Estimated)
Wind	2-4m/s @ 10 m height mainland	Electronic wind information system (WIS) available
Biomass (Non-fossil organic matter)	Municipal waste	18.5 million tonnes produced in 2005 and now estimated at 0.5 kg/capita/day
	Fuel wood	43.4 million tonnes/yr. fuel wood consumption
	Animal waste	245 million assorted animals in 2001
	Agricultural residues	91.4 million tonnes/yr. produced
	Energy crops	28.2 million hectares of arable land; 8.5% cultivated

Source: [16]

Gave an estimate of the energy content of crop biomass potentially available for conversion into liquid biofuel by 2030, is put at about 4.8 EJ/yr. 3.6 EJ. It is also estimated that this potential corresponds to crop for ethanol production. Again, it was observed that 65% of ethanol potential in Africa, is found in Southern Africa, while 20% is in East Africa, followed by Central Africa [12]. Another important feedstock which comes from Oil palm, the fruits which

comprise of biodiesel, is produced widely in plantations in West and Central Africa and particularly in Nigeria, Ghana and Benin. The 41% of biodiesel potential is found in Southern Africa and 22% each in Central and Eastern Africa, while West Africa accounts for 15% of the potential. No doubt there is enormous potential for biodiesel production in Nigeria. There is the case of Okomu Oil and Presco Oil both located around rural communities in Nigeria that run most of their plant with biofuel [12].

Table 4: Renewable Energy Potentials

Crop	Production ('000 t)	Component	Weight available in million tons	Total energy available (PJ)
Rice	3,368.24	Straw	7.86	125.92
		Husk	1.19	23.00
Maize	7,676.85	Straw	10.75	211.35
		Cob	2.10	34.19
		Husk	0.92	14.32
Cassava	42,533.17	Stalks	17.01	297.68
		Peelings	76.56	812.30
Groundnut	3,799.25	Shells	1.81	28.35
		Straw	4.37	76.83
Soybean	365.06	Straw	0.91	11.27
		Pods	0.37	4.58
Sugar cane	481.51	Bagasse	0.11	1.99
		Tops/leaves	0.14	2.21
Cotton	602.44	Stalk	2.25	41.87
Millet	5,170.45	Straw	7.24	89.63
Sorghum	7,140.96	Straw	7.14	88.39
Cowpea	3,368.24	Shell	4.89	95.06
Total			145.62	1,958.94

Source: [17]

The major challenges that arise from the use of Bioenergy are the collection and transportation of residues which tend to constitute a significant part of the overall costs. This is equally an advantage to rural areas, since it is cost-effective

to convert feedstocks into fuels or final energy forms as close as possible, and the rural areas constitute the major source of the feedstocks generated. Again, the case of waste and residues that may have negative environmental impacts in Urban areas could be channelled to rural or remote areas that are sparsely populated and where the land mass is available. There is no gainsaying the fact that bioenergy technologies provide a cost-effective solution for the treatment of municipal wastes, and in addition to energy provision [12].

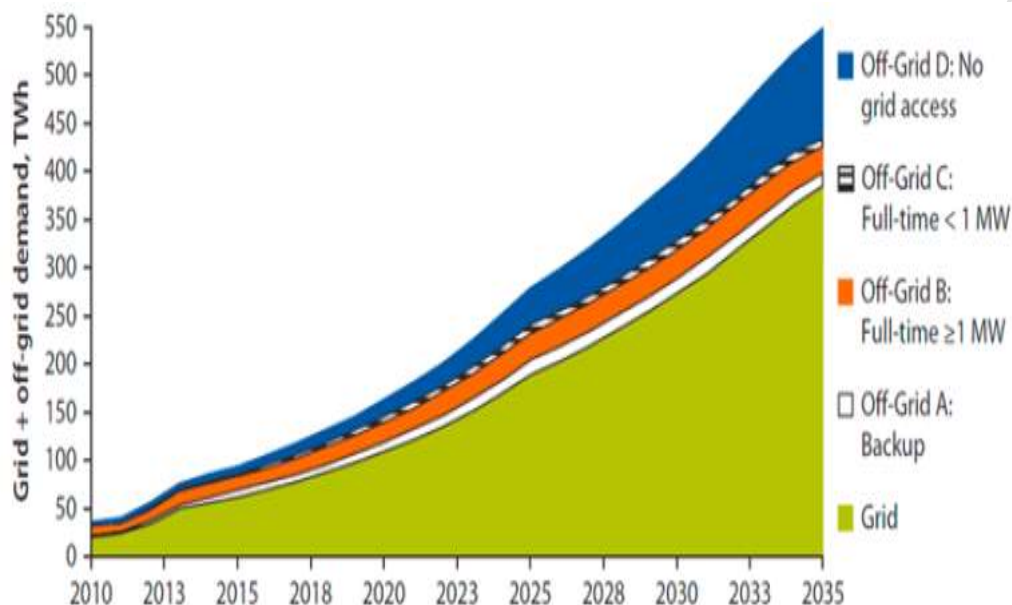


Figure 7: Projected grid and off-grid electricity demand in TWH

Sources: Source: Calculations based on FMP and Power Holding Company of Nigeria data and UN 2010 rural/urban population data (for off-grid D projections)

Solar Resource and Solar Energy

The electricity from solar energy technologies could come from the thermal system (Concentrated Solar Power) or Photovoltaic (PV). The solar thermal technologies could be applied in heating of houses, drying of crops while photovoltaic are useful in remote areas to drive rural television, streetlight, radio, refrigerator, pumping of water, powering cameras for security etc. It could also assist in supplying water to remote areas for agricultural purposes. The total solar radiation incident on the Nigeria surface is stated to be around 12.6MJ/m days in coastal zones but it is affected by the change in climate.

Overall, the Nigeria solar power generation potential exceeds future demand by orders of magnitude. In evaluating the fast-paced reduction in costs for PV module worldwide, with a cut by 75% between 2009 to 2015, the levelized costs of electricity (LCOE) of best practices for African utility-scale projects in the continent has also rapidly fallen. According to IRENA's Costing Alliance Database [12], LCOE for solar PV utility projects in Africa, between 2013 and 2014 ranged between USD 0.13 and USD 0.26 per kilowatt-hour (/kWh). The lowest cost for utility-scale PV in South Africa is below USD 0.075 per kWh, which is among the most competitive PV projects worldwide. This gap between the best practice and cost range in Africa portends further cost reduction potential [18,19].

In Nigeria Rural areas, small-scale PV systems could be installed and used with or without connection to a power grid to accelerate the slow-paced rural electrification project. In most of the African Countries like South Africa, Morocco, Kenya, Egypt, off-grid PV markets have experienced dynamic development. With the small-scale distributed solar PV systems, power can be supplied to houses and buildings in the rural areas for essential services such as lighting and charging electric appliances. In the countries mentioned above, they are already providing alternatives in rural settings to electricity from distribution lines connected to national transmission lines [20].

Over the years, extending a national or regional grid to remote rural areas or villages has often been an expensive solution in the rural electrification project. Solar PV technology has proven to be highly economical or cost-effective in reducing fuel costs in existing mini-grids. Despite where a connection to the existing National grid network is available, where an uninterrupted supply is needed, like in health-care or maternity facilities, solar PV systems with battery storage can be an economic solution.

Most importantly, the social welfare, economic prosperity, and environmental conservation would be boosted because of the application of solar energy technologies in Nigerian rural areas. To ensure these desirable results are obtained, the lack of infrastructure and practical skills needed for the extensive production of solar energy would have to be noted by energy and policymakers in Nigeria. The installation of solar energy in Nigeria is also affected by a number of factors such as; Climate change, Cost of generation, Government

policy, theft and vandalization, Population, the low level of research and development in Solar Energy [20].

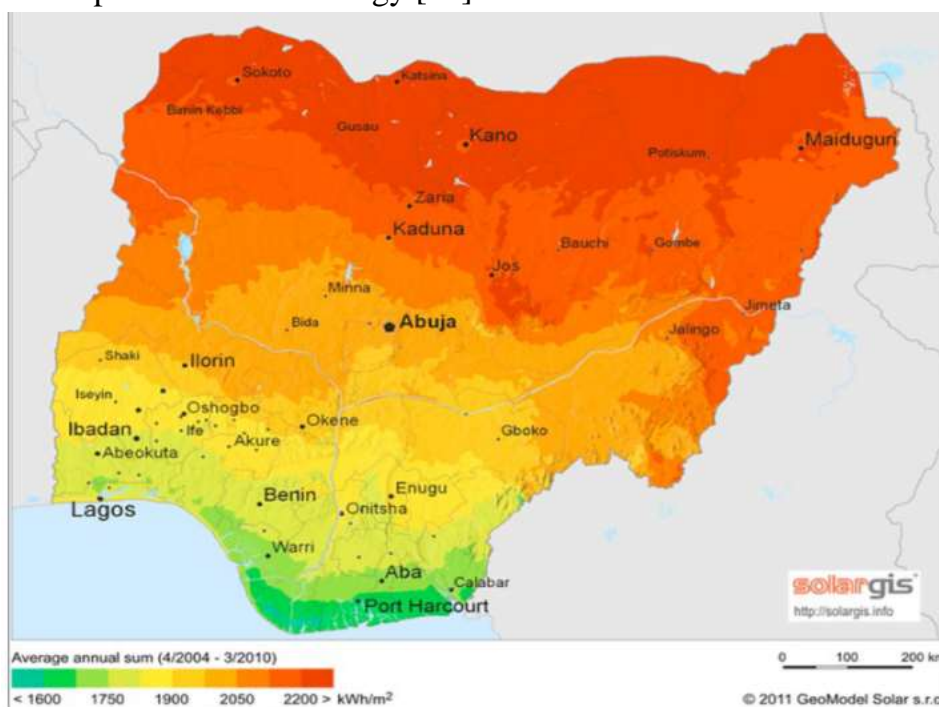


Figure 8: Solar radiation level (GHI)

Sources: [20]

Table 5: Summary of Renewable Electricity Targets

S/N	Resource ⁵⁵	2012 [MW]	Short Term (2015) [MW]	Medium Term (2020) [MW]	Long Term (2030) [MW]
1	Hydro (LHP)	1,938.00	2,121.00	4,549.00	4,626.96
2	Hydro (SHP)	60.18	140.00	1,607.22	8,173.81
3	Solar	15.00	117.00	1,343.17	6,830.97
4	Biomass	-	55.00	631.41	3,211.14
5	Wind	10.00	50.00	57.40	291.92
All renewable plus LHP		[1,985.18] 2,023.18	[2,438.00] 2,483.00]	8,188.20	23,134.80
All energy resources [on grid power plus 12,500MW of self generated power]		21,200**	24,380**	45,490**	115,674**

% of renewable incl. LHP	[23%]	10%	18%	20%
% renewable energy excl. LHP	0.80%	1.30%	8%	16%

Sources: [20]

Table 5: Summary of Renewable Electricity targets

State of Residence	Have Electricity	No Electricity	Missing	Number of hh surveyed
North Central	48.7	51.2	0.1	5,942
FCT-Abuja	77.7	22.0	0.3	361
Benue	22.1	77.9	0.0	1,365
Kogi	62.9	37.1	0.0	876
Kwara	90.6	9.1	0.3	617
Nasarawa	33.2	66.5	0.3	550
Niger	51.7	48.2	0.1	1,504
Plateau	36.3	63.7	0.0	669
North East	29.3	70.4	0.3	5,115
Adamawa	37.6	62.2	0.2	726
Bauchi	29.3	70.3	0.4	932
Borno	33.0	66.5	0.5	1,560
Gombe	48.1	51.8	0.1	464
Taraba	10.9	88.8	0.3	634
Yobe	18.1	81.7	0.2	799
North West	42.2	57.7	0.1	9,992
Jigawa	26.0	74.0	0.0	1,152
Kaduna	53.5	46.2	0.3	1,915
Kano	52.1	47.9	0.0	2,606
Katsina	31.3	68.5	0.2	1,257
Kebbi	44.4	55.6	0.0	1,069
Sokoto	38.9	60.9	0.2	898
Zamfara	29.1	70.6	0.3	1,096
South East	66.4	33.6	0.0	4,687
Abia	81.7	18.3	0.0	644
Anambra	88.1	11.8	0.1	1,050
Ebonyi	39.2	60.7	0.1	978
Enugu	55.4	44.6	0.0	920
Imo	69.9	30.1	0.0	1,096
South South	68.3	31.3	0.4	5,239
Akwaihom	68.0	31.8	0.2	892
Ravelsa	52.5	47.3	0.2	322
CrossRiver	57.4	41.4	1.2	848
Delta	78.3	21.6	0.1	946
Edo	82.4	17.5	0.1	702
Rivers	65.1	34.5	0.4	1,529

South West	81.1	18.8	0.1	7,546
Ekiti	92.7	7.3	0.0	376
Lagos	99.3	0.5	0.2	2,240
Ogun	72.0	27.9	0.1	1,355
Ondo	66.3	33.7	0.0	920
Osun	89.4	10.6	0.0	853
Oyo	66.6	33.3	0.1	1,802
Total	55.6	44.2	0.2	38,522

Source: [21]

Microgrid Technologies Option for Rural Electrification in Nigeria

A microgrid is a collection of interconnected loads and DEES within an obviously defined boundary which performs as a solitary manageable unit with respect to the grid. Electricity access forms the bedrock of two crucial issues in Nigeria as far the growth and development of the country are concerned. The Country has suffered from the unreliable power supply over the past four decades and with the population growing annually by 2.6% these challenges if not tackled, portends danger to the economy of the nation. Off-grid solutions, including mini-grids and stand-alone solutions, are necessary to complement centralised grid-extension efforts.

Off-grid solutions, which can be deployed rapidly and customised to local needs, offer the only option for electrification in areas where grid extension is technically or financially unviable [18].

Estimates suggest that nearly 60% of the additional generation required to achieve universal access to electricity in Africa will need to come from off-grid solutions [7]. With recent, rapid cost-reductions, renewable energy technologies now represent the most cost-effective option to expand electricity access in most rural areas. Off-grid renewables have gained significant progress in Africa, where more than 28.5 million people benefit from access to electricity through solar lighting projects [Light Africa, 2010].

The need for ensuring a steady or reliable and sustainable electricity supply for all Nigerians in both the rural and urban areas and facilitating or extending the socio-economic growth of the Nation has created a lot of challenges and opportunities in the past two decades. The Nigeria government in a bid to address these issues of the epileptic power supply will have to explore and exploit her vast energy resources which are clean and renewable and how to transform them into electricity supply.

To do this, modern renewable technologies and microgrids or off-grids would have important roles to play. Inexhaustible innovations advance more comprehensive financial and social improvement than non-renewable energy source based choices since they are reasonable for little scale arrangements both in the provincial and urban focuses that can run autonomously from the National matrix [12].

Benefits of Smart/ Microgrid

As a result of combining Smart/ Micro- Grid with the liberalisation of PHCN will permit the customers to use RESs and to explore the possibilities to overcome the challenges in electricity by the proprietors of the PCHN successor companies. The Smart/ Micro- Grid will cause improvement in main value areas, for example, economics, safety, efficiency, security, and reliability. A more reliable power for the government services will be a benefit to the society since there will be a reduction in environmental cost such as carbon emission [23].

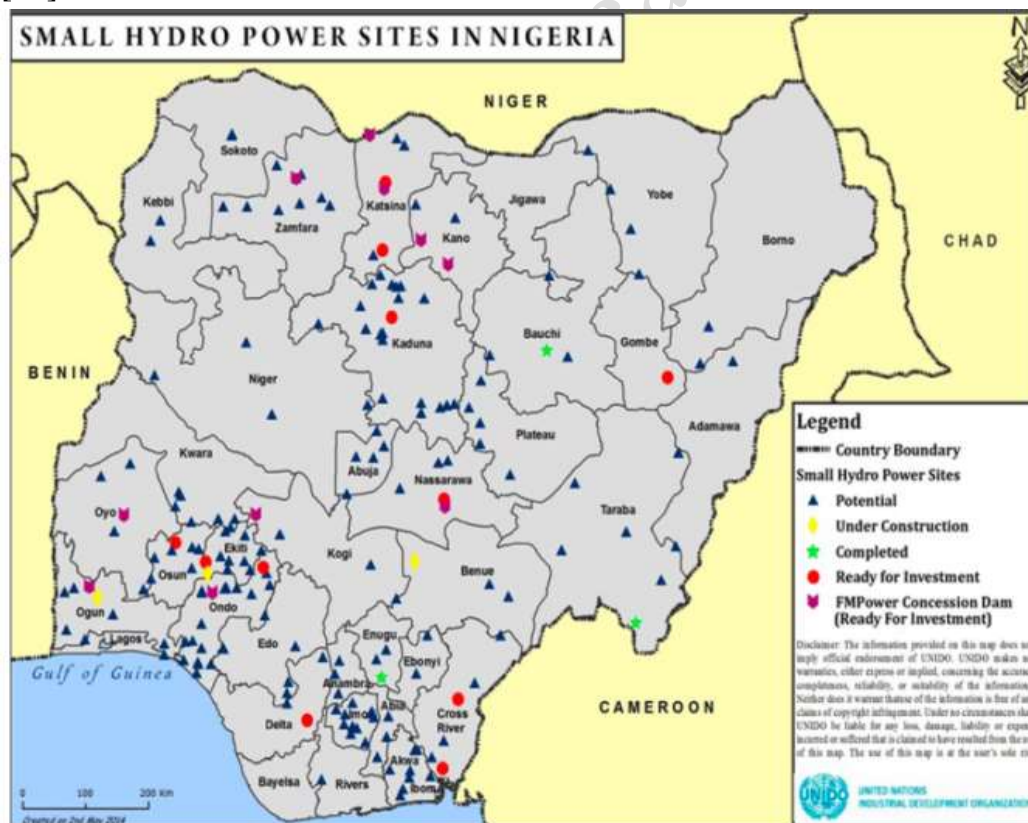


Figure 9: Small Hydro Power sites in Nigeria Source: UNIDO (2013)

The issues of theft will also reduce since criminals will not have hidden places, job opportunities will be created, and growth in the economy will be noticed.

Challenges of the Smart/ Micro- Grid in Nigeria.

In spite of the Smart/ Microgrid having numerous benefits, there are still many challenges numerous countries are still facing when it comes adopting these inventive technologies for delivering the electricity infrastructures for the next generation. These challenges include; the instability of sustainable power sources must be considered. Eventually, factors, for example, wind speed and overcast cover are wild, and quick changes in climate can make power creation vacillate [19]. First and foremost, it is difficult to persuade the majority of not well-off people to SM-G since they favour the lowest upfront investment such as generators powered by electricity and diesel. There is need of adopting this technology in rural areas since the cost of running it is low but involves high initial investment [19].

Secondly, many people are lacking awareness and reluctant when it comes to allowing fresh technologies since many peoples are not aware of the merits of renewable energy or SM-G technologies. A good number of people do not know even how electricity is produced and transmitted to places they are staying. In order to solve this matter, seminars and conferences should be organized by the academic institutions to help in promoting SG-M technologies in the country [19].

Thirdly, insecurity in the region has brought fear to investors. This is because most people living in Nigeria are not in a position of installing the aforementioned sources of energy to partly or fully power their houses, thus no business will thrive in an environment lacking security. The level of security in Nigeria is driving away foreign investors in the country.

The fourth challenge is the cost, especially at the household level. In advanced countries, generation of electricity from RESs and SM-G installation cost needs to be subsidized. Allocation of funds needed to carry out research related to originals and demonstrations in SM- G project before taking off.

Trained manpower and technical capacity is another challenge affecting SM-G since it is a new technology requiring new software tools, new skills and knowledge, new modelling and simulation techniques and to achieve this, relevant training is required to guarantee the availability of an appropriate

workforce to enhance afterwards production grid in Nigeria. There must be a concrete step put in place before the adoption of new technology because currently, an absence of power plant components and insufficient sizes to uphold the numerous units of the standing energy zone is faced by the national grid [24].

Another challenge facing the development of Smart and Microgrid technology in Nigeria is a problem in research and development amongst Nigerian scholars and government institution. There is the need for extensive research works by experts from industries and university academics. Researchers from various areas such as science, IT and engineering disciplines need to come together and carry out research concerning these problems affecting SM-G technologies

Policies and programs developed by Nigerian Government

Policies developed by Nigeria to assist them to attain a protected entrance to renewable energy which will be combined with the projected smart grid into the Nigerian grid. The government policy on production, supply, and consumption was set out by the National Energy Policy. This policy aimed at creating energy supply by diversifying the supply of energy and energy carries such that modern renewable energy increases its share of energy consumed and provides affordable energy in the whole of Nigeria. Main elements for application and development of RE are outlined in the national policy as;

- To grow and stimulate the countries renewable energy resources found.
- To stimulate decentralized energy supply more so in remote areas.
- To stimulate appropriate method for the use of biomass energy resources.
- To depress the use wood as fuel.

In the year 2005, a Renewable Energy Master Plan (REMP) was developed by the Energy Commission of Nigeria to reiterate governments pledge to development, demonstration and implementation of renewable energy for both large and small applications, the creation of enabling an environment for renewable energy promotion[25]..

In the year 2006, National policy and Guidelines were produced in order to expand renewable energy market by 5% of the overall electricity produced in

the year 2016. The various approaches that were employed in order to attain this were promising both native manufactures, gathering of renewable energy mechanisms and providing subsidies. In the same year, a draft National Energy Master Plan was developed by the Energy Commission which acknowledged the imminent dangers of the fossils driven economy and creating a justifiable energy supply mix.

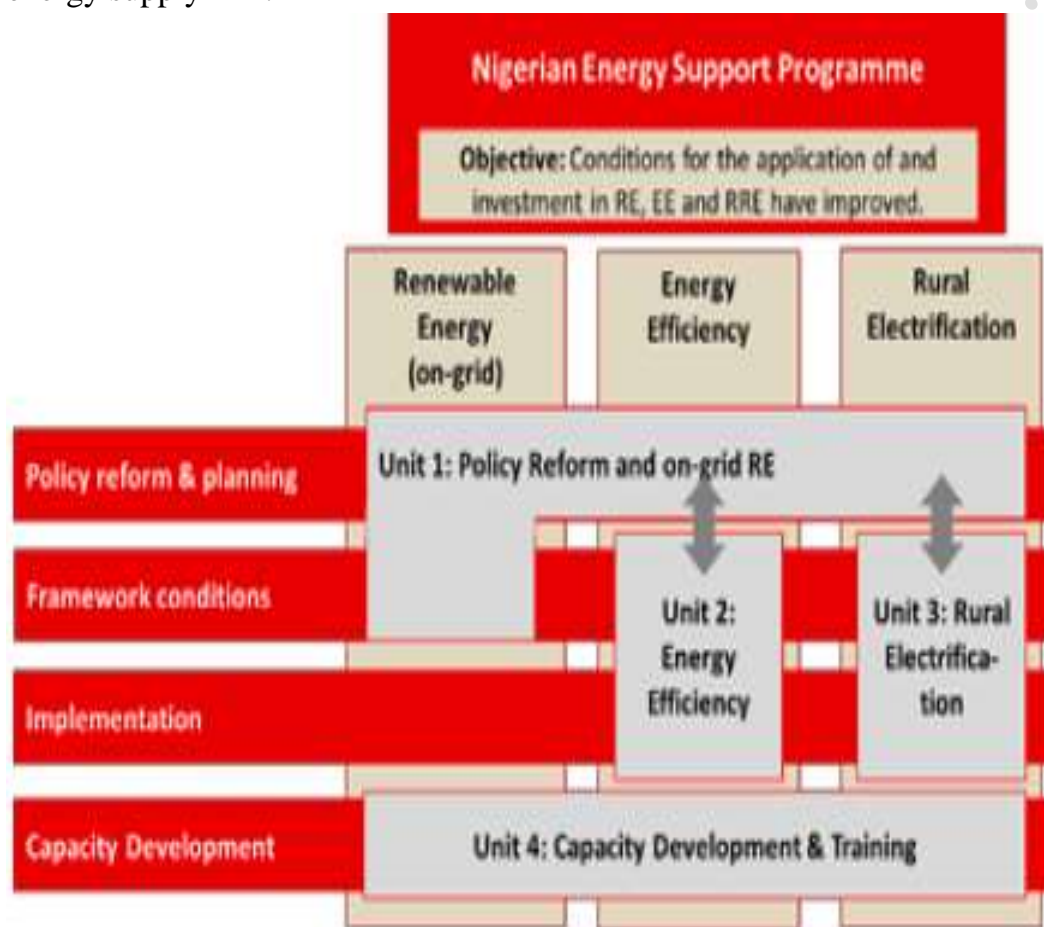


Figure 10: Nigerian Energy Support Programme (NESP)
Source: [7]

A National Gas Master Plan came with a move to decentralize electricity generation held privately. The plan also aimed at making use of nation large gas reserves, but utilization of Compressed Natural Gas was not mentioned in this plan (World Bank, 2014b).

Nigeria's nuclear potential was explored by the newly established commission known as Nigeria Atomic Energy Commission. The growing population and

high demand for electricity have led to an activation of a Nigerian Atomic Energy Commission and Nigerian nuclear programme and it is noted that countries such as Germany are abandoning nuclear energy gradually.

The Future Prospects of Nigeria Rural Electrification Agenda

The problem of electricity in Nigeria can be solved by putting Microgrid technologies into practice and ensuring policies and programs are developed to spur the creation of microgrids and for Nigeria to realize in part her vision 2020, they must put effort on energy supply mix thus enhancing greater energy security for Nigeria. By effectively exploiting its bottomless clean power assets, Nigeria can possibly impel itself towards a sustainable power source insurgency.

Power request in Nigeria is anticipated to triple by 2030, offering enormous potential for sustainable power source arrangement. The power division in Africa requires ventures of USD 70 billion every year by and large amongst now and 2030. This can be part into about USD 45 billion every year for age limit and USD 25 billion for transmission and appropriation. Renewables could represent 66% of the aggregate interests in age limit, or up to USD 32 billion every year. Understanding this open door will make noteworthy business action in Nigeria and Africa by and large.

In the power part, the offer of renewables could develop to half by 2030. This would bring about around 310 Mt CO₂ outflows decrease contrasted with the Benchmark situation in 2030. Hydropower and wind limit could achieve 100 GW limit each, trailed by a sun based limit of more than 90 GW[12][22].

Conclusion

Nigeria is scaling up its electricity supply to overcome supply shortages in the short term and meet the demand to fuel economic growth. In the longer term, the aim is also to ensure modern energy access to the entire population. In doing so, Nigeria's power sector needs to diversify the sources of power to enhance the security of supply. Nigeria has sufficient fossil resources but if it continues relying on them, it will not allow a transition to a low-carbon power supply system. Hydro resources are also large, but excessive reliance on it also raises a supply security concern, because climate change increases the risk of droughts[12].

Through this, Nigeria rural areas could see large economic growth in the agricultural sector, the creation of a thriving job market and, importantly, improved quality of life for millions of people. Significantly, this abundance of clean energy also suggests that, if harnessed efficiently, the continent could reduce its CO₂ emissions by 27% [12].

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