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Impact Analysis of Renewable Energy based Generation in West Africa – A case study of Nigeria

Analiza produkcji opartej na odnawialnych źródłach energii w Afryce Zachodniej – studium przypadku Nigerii

Temitope M. Adeyemi-Kayode*, Sanjay Misra*, **,
Robertas Damaševičius***

**Covenant University, Canaanland, Nigeria*
***Atilim University, Ankara, Turkey*
E-mail: sanjay.misra@atilim.edu.tr
****Kaunas University of Technology, Kaunas, Lithuania*
E-mail: robertas.damasevicius@ktu.lt

Abstract
The limited supply of fossil fuels, constant rise in the demand of energy and the importance of reducing greenhouse emissions has brought about the adoption of renewable energy sources for generation of electrical power. In this paper, the impact of renewable energy generation in Nigeria is explored. A review of renewable deposits in Nigeria with a focus on Solar, Biomass, Hydropower, Pumped Storage Hydro and Ocean energy is detailed. The impact of renewable energy-based generation is assessed from three different dimensions: Economic Impact, Social Impact and Environmental Impact. In accessing economic impact; the conditions are employment and job creation, gross domestic product (GDP) growth and increase in local research and development. To analyze the social impact; renewable energy education, renewable energy businesses, ministries and institutes, renewable energy projects and investments as well as specific solar and wind projects across Nigeria were considered. Also, environmental issues were discussed. Similarly, policy imperatives for renewable energy generation in Nigeria was provided. This paper would be useful in accessing the successes Nigeria has experienced so far in the area of sustainable development and the next steps to achieving universal energy for all in Nigeria in 2030.

Key words: solar energy, biomass, hydropower, ocean energy, sustainability, thermal energy, economic impact, social impact, environmental impact, renewable energy, West Africa, Nigeria

Streszczenie
Ograniczona podaż paliw kopalnych, stały wzrost zapotrzebowania na energię oraz konieczność ograniczenia emisji gazów cieplarnianych pociągnęły za sobą konieczność stosowania odnawialnych źródeł energii do wytwarzania energii elektrycznej. W artykule zbadano wpływ wytwarzania energii odnawialnej w Nigerii. Szczegółowy przegląd zasobów energii odnawialnej w Nigerii, ze szczególnym uwzględnieniem energii słonecznej, biomasy, energii wodnej i elektrowni szczytowo-pompowych i energii oceanicznej. Produkcja energii ze źródeł odnawialnych została przeanalizowana w trzech różnych wymiarach: wpływ na gospodarkę, wpływ na społeczeństwo i wpływ na środowisko. W aspekcie wpływu na gospodarkę wzięto pod uwagę: zatrudnienie i tworzenie miejsc pracy, wzrost produktu krajowego brutto (PKB) oraz wzrost lokalnych badań i rozwój. Analiza wpływu społecznego objęła: edukację w zakresie energii odnawialnej, przedsiębiorstwa, ministerstwa i instytuty zajmujące się energią odnawialną, projekty i inwestycje w zakresie energii odnawialnej, a także konkretne projekty dotyczące energii słonecznej i wiatrowej w całej Nigerii. Omówiono również kwestie środowiskowe. W podobny sposób przedstawiono imperatywy polityczne dotyczące wytwarzania energii odnawialnej w Nigerii.

Ten artykuł wskazuje na istotny dla Nigerii cel zrównoważonego rozwoju, jakim jest odnawialna energia dla wszystkich. Celem jest osiągnięcie w tym kraju powszechnej odnawialnej energii dla wszystkich w 2030 r.

Słowa kluczowe: energia słoneczna, biomasa, energia wody, energia oceanu, zrównoważoność, energia cieplna, ekonomia, społeczeństwo, środowisko, energia odnawialna, Afryka Zachodnia, Nigeria

1. Introduction

Energy is the cornerstone and essential ingredient of any strategic plan in any nation that focuses at achieving sustainable development in all facets of life and its open access is a means to facilitate any developmental initiative (Xue et al., 2020). Nigeria is undoubtedly an energy resource rich country, yet the Nigeria's energy industry is perhaps inefficient in meeting the energy needs of her citizenry (Dioha, Emodi, Mathew, & Dioha, 2018; Osueke & Ezugwu, 2011) (John, Ucheaga, Olowo, Badejo, & Atayero, 2017). This is because Nigeria's energy supply is heavily dependent on fossil fuel and this sector for about two decades or more has experienced weighty bombardments and these have led services whose operations are dependent on the energy supplied from this sector to experience frequent or total shutdown. Sequel to this, communities that would have been connected to the power grid are left unconnected due to inadequate power generated; hence increasing the country's energy poverty profile. Furthermore, less than 7,000 MW of electricity is being generated from the available sources for about 196 million people in 2018 (Thomas et al., 2019) (Indicators, 2020). This of course, has weakened the zeal to achieve industrialization and consequently economic growth has outlined in vision 2020 (Akin, 2008). Nevertheless, full utilization of available energy sources will facilitate sustainable development and improve the general wellbeing of people especially in the rural areas. It is true that access to energy is expedient to successful national development such as those for health, education, rural development and agriculture and assist in improving a better living condition (E. Okewu, 2017).

Energy poverty is the lack of access to modern energy services. These services are defined as household access to electricity and clean cooking facilities (e.g. fuels and stoves that do not cause air pollution in houses). A review of papers reveals that there are billions of people living without electricity worldwide (Moss & Bazilian, 2018; Raworth, 2012; Smalley, 2005; Zahnd et al., 2018). The vast majority of people in this category reside in Sub-Sahara Africa (SSA) and South Asia. It is said that an overwhelming estimation of 2.7 billion people rely on traditional biomass for cooking, while 1.4 billion people are not connected to the energy grid (Karekezi, McDade, Boardman, & Kimani, 2012). Energy poverty is one of the prevailing problems in Sub-Saharan Africa.

Access to energy is a prerequisite for human development. Energy is needed for individual survival, it is important for the provision of social services such as education and health and a critical input into all economic sectors from household production or farming, to industry. Historically, many researchers and development organizations agree that the wealth and development status of a nation and its inhabitants is closely correlated to the type and extent of access to energy. The more access to usable energy and the more efficient energy converting technologies are available, the better the conditions for development of individuals, households, communities, the society and its economy (Day, Walker, & Simcock, 2016; Sørensen, 2012). Thus, improving access to energy is a continuous challenge for governments and development organizations(Energy Poverty, 2016).

The total estimated grid generation in SSA is about 90 gigawatts (GW), South Africa alone generates half of this, leaving the remaining half to the rest of SSA (Power People Planet, 2015). South Korea produces more electricity and her population is only 5 percent of SSA. The gulf in generation is alarming. Nigeria's electricity generation is about one-quarter of the electricity produced in Vietnam, for a population that is twice the size of Vietnam. Even within Africa, an average South African consumes nine times more energy than a Nigerian. It is important to note that Nigeria's population is three times the size of South Africa's population (Dai, 2015).

With the exception of South Africa, the average energy consumption in SSA is 162 kWh per capita per year. The global world's average is 7000 kWh (Power People Planet, 2015). An average Tanzanian will take around eight years to consume as much electricity as an American consumes in a month (Power People Planet, 2015). Even oil exporting super powers like Nigeria is not left out of this dismal trend, 93 million Nigerians do not have access to electricity (Power People Planet, 2015). Although Angola has five times the average income level of Bangladesh, Bangladesh has far higher access to electricity in the ratio 55:35 percent (Power People Planet, 2015).

It is estimated that if Africa continues to move at the current trends, universal electricity access for all in Africa would be until the year 2080. Some of the contributing factors to Africa's poorly developed energy systems include waste of resources, high dependence on centralized energy systems that favors the rich and bypasses the poor, corruption, energy-sector bureaucracy amongst others. Despite all these challenges, Africa's poorest people pay one of the highest energy tariffs in the world. The Africa's panel for Progress estimates that about 138 million households in Africa comprises of people who spend US $10 billion yearly on energy related products like candles, charcoal, kerosene and firewood and live on less than US $2.50 per day (Power People Planet, 2015). Comparing energy costs between African countries and the United States, the average cost of electricity in the US is US $0.12 per kWh and is US $0.15 in the UK, whereas in Africa around US $10 per kWh is spent only on lighting (Power People Planet, 2015). Some of the solutions brought forward to combat the Energy Poverty situation experienced in Sub-Saharan Africa include:

- Leapfrogging centralized generation for distributed generation (Levin & Thomas, 2016; Mandelli & Mereu, 2013; Murenzi & Ustun, 2015; Sebitosi & Okou, 2010; Szabó, Bódis, Huld, & Moner-Girona, 2013);
- Decentralize the burdened national grid network as a way of ensuring the sustainable delivery of power to consumer (Ambode targets 3000 MW 24-hr power generation for Lagos, 2017);
- Optimally utilize available energy resources which is central to all aspects of the life of any nation (Sambo, 2008);
- To do an extensive investigation of the technical and economic benefits of new integrated renewable systems, especially for communities yet to be connected to the grid.

In this paper, an investigation of the impact of the factors responsible for facilitating renewable energy-based generation in Nigeria would be conducted. An attempt to providing tangible solutions to sustainability issues and energy access in the region would be conducted. Section 2 provides a breakdown of renewable deposits in Nigeria with a focus on Solar Power, Biomass and Ocean Energy would be discussed. Section 3 details the Economic Impact of Renewable Energy in Nigeria, focuses on the Social Impact of Renewable Energy Generation in Nigeria with considerations to Renewable Energy Education in Nigeria, Business, Ministries, Institutes and Investments in Nigeria; and the Environmental Impact of renewable energy generation. Section 4 details policy imperatives for renewable energy generation in Nigeria and Section 5 concludes the paper.

2. Renewable Energy Potentials in Nigeria

In this section, the Renewable Energy Potentials in Nigeria are explored and discussed. The Renewable energy deposits discussed are Solar, Biomass, Hydropower and Pumped Storage Hydro (PSH), and Ocean Energy.

i. Solar

Based on Nigeria's location on the Sunshine belt, her Solar energy potentials are enormous. Figure 1 shows the Nigeria solar radiation map. The solar intensity in Nigeria ranges per region between 3.5 kW/m/day - 7.0 kW/m/day. By covering just 1% of the Nigeria's land area with solar modules, it would be possible to generate 1850×10^3 GWh of solar electricity per year. This value is more than 100 times the current energy consumption in Nigeria (Charles, 2014). For the entire landmass of Nigeria, the average solar energy over a year would be 6,372,613 PJ/year (approximately 1770 thousand TWh/year)(Olayinka S. Ohunakin, 2014); that is about 120 thousand times the total electrical energy generated by the PHCN in 2012. Geographically, the annual average solar radiation is about 12.6MJ/m^2-day and 25.2MJ/m^2-day in the costal and northern region respectively (Akuru, Onukwube, Okoro, & Obe, 2017). According to Nigerian Bulk Electricity Trading company (NBET), as at the 10th of November 2015, there was around 8 PPAs who had indicated their interests in developing Solar power projects (Isoken G. Idemudia, 2016).

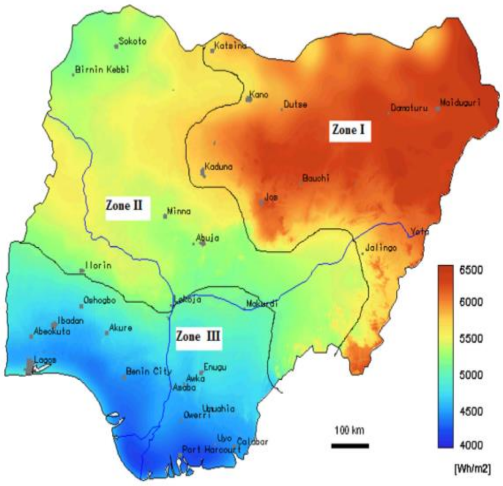

Figure 1. Nigeria's Solar Radiation Map (Olayinka S. Ohunakin, 2014)

ii. Biomass

Bio-based renewable energy fuels otherwise known as Combustible renewables and wastes exists in 3 states solids, liquids and gases.

Solid biofuels consist of wood, wood waste, twig, leaves, chips, materials generated from the wood and paper industry, nut shells, rice husk, fibrous wastes; these materials are directly burned or converted in to low quality gas in a small low technology anaerobic tank digester.

Nigeria produces about 227,500 tons of fresh animal waste daily (Charles, 2014). By estimation, 1 kg of fresh animal wastes produces 0.03 m^3 of biogas. This means that Nigeria can produce 6.8 million m^3 of biogas daily from animal waste only.

Nigeria's land area distribution includes (get values of land distribution): Forests and Woodlands- 16 %, Permanent Pasture – 42 %, Arable land – 33 %, Permanent crops – 3 %, Others – 6 %
Assuming that the High heating value (HHV) of wood less the latent heat of vaporization of produced water is 18 MJ/kg. If only 10 percent of the arable land (3,020,000 ha) is used for energy production, 574 PJ of energy or 12.8 Mtoe (million tonnes oil equivalent) would be produced.

iii. Hydropower and Pumped Storage Hydro (PSH)

In Nigeria, Hydropower is the most exploited renewable power generation option. This exploitation started as far back as 1968 when 8 units where commissioned with a total generation capacity of 760 MW. Combining river Kaduna (Shiroro), Benue (Makurdi) and Cross River (Ikom) indicated that total capacity of about 4,650 MW is available and also the Mambilla plateau is estimated to be 2,330 MW. Small hydropower sources have also been underdeveloped in Nigeria. There are over 278 SHP sites that have not been developed in Nigeria, totaling in 734.3 MW potential capacity; only 3 MW of these has been exploited. In June 2016, the minister of Power, Works and Housing, Babatunde Fashola, inaugurated a committee tasked with the responsibility of identifying and developing plans for the exploitation of SHP in rural communities in Nigeria. 8 locations have been decided upon to constitute the first leg of the pilot study, the locations are Tiga, Challawa dams in Kano-State, Omi-Kampe in Kogi State, Jibiya, Zone dams in Katsina, Bakalori in Zamfara state, Doma in Nassarawa State and Ikere Gorge in Oyo-State (*Federal Government Energize Rural Communities with Small Hydros*, 2016).
Pumped storage hydro plant is established machinery for energy storage. It stores potential energy from water that is raised against gravity. The first of its kind was constructed in the early 20th century in Schaffhausen, Switzerland. This system was started in 1909 and is still working up till now. As years go by, pumped storage hydro system becomes more attractive and recently it was heavily employed for supplying peak energy (Torres, 2011).
Nowadays, PSH is the most widely used method of mini hydroelectric power systems and is becoming domineering because of its cost effectiveness. I t does not require building a base load plant to cushion the effect of peak demand; instead the peak load demand is taking care of by increasing the peak hydro power production via pumping the already used water from the underground reservoir into the overhead reservoir using the excess electricity during the off-peak period. This can be achieved by swiftly configuring the generator to work as a motor for pumping up water during the trough periods (Jayesh, Arun, Patil, & Shailendra, 2013). It stores energy in the form of water in an upper reservoir during low electricity demand and during the high electricity demand; the stored water is released through the penstock to the power house via the turbine where electrical power is generated in the same way as conventional hydro power plants(Association, 2016).
According to the water flow and capacities that can be generated in Nigeria, PSH can be categorized into:

- Mini hydro – ≥ 100 kW ≤ 2 MW
- micro hydro – ≥5 kW ≤ 100 kW
- Pico hydro – < 5 kW

The aforementioned types of PSH can also be a run-of-river type. This means that there is no water storage for electricity generation. Moreover, the water for electricity generation is sidetracked from a river via a barrier. The run-of-river type of electricity generation is more profitable for a Pico hydro power generation because it reduces the investment cost per KW of electricity (Chiyembekezo, Cuthbert, & Torbjorn, 2012). PSH is a good prospect for a better electricity future to rural communities across Nigeria and for replacing every other unhealthy means of energy generation for the purpose of lighting, warming, cooling, powering radios, TVs and machinery, and providing other livelihood opportunities. The heart of a PSH is the turbine, which drives an alternator for electricity generation**.** Table 1 provides the potential Small Hydro sites in Nigeria.

Table 1. Small Hydro Potential in surveyed states in Nigeria (Manohar & Adeyanju, 2009)

State (Pre 1980)	River Basin	Total Sites	Total Capacity
Sokoto	Sokoto-Rima	22	30.6
Katsina	Sokoto-Rima	11	8.0
Niger	Niger	30	117.6
Kaduna	Niger	19	59.2
Kwara	Niger	12	38.8
Kano	Hadeija-Jamaare	28	46.2
Borno	Chad	28	20.8
Bauchi	Upper Benue	20	42.6
Gongola	Upper Benue	38	162.7
Plateau	Lower Benue	32	110.4
Benue	Lower Benue	19	69.2
Rivers	Cross River	18	258.1
Total		277	734.2

iv. Ocean

Nigeria has an approximate value of 834km coastline that runs through seven states. These states are Ogun, Ondo, Akwa-Ibom, Bayelsa, Cross-rivers, Lagos, and Rivers bordering the Atlantic Ocean. The Bight of Bonny, Bight of Benin, Cross River Estuaries and Lagos lagoon are a few of the water bodies that holds the potential to operate an OBRE. Table 2 shows the wave characteristics of these locations. Different ocean forces such as the tides, salinity, current etc. can be used to generate electricity.

Table 2. Wave characteristics of different ocean bodies in Nigeria

Location	Highest mean wind speed (knots)	Highest mean wave height (m)
Bight of Bonny	7.5	1.24
Bight of Benin	7.6	1.4
Cross River Estuaries	5.6	0.9

3. Various Factors affecting Renewable Energy Generation

There are three important pillars of sustainable development – Economic, social and environmental, which majorly affect renewable energy generation. In the following sections we are providing them in details.

3.1. Economic Impact of Renewable Energy Generation in Nigeria

Some of the economic impacts of renewable energy generation are diversification of energy supply, increased urban, peri-urban and rural development opportunities, development of local industry and increased employment opportunities. It is expected that with the increase in energy generation via the inclusion of renewable energy generation; income distribution would be widespread and impact on tourism would be increased (Del Río & Burguillo, 2008) (E. Okewu, Misra S., Fernandez S.L., Maskeliunas R., & Damasevicius R,, 2018).

i. Gross Domestic Product (GDP) growth

Increased Energy generation would undoubtedly increase productivity and economic growth of a nation (John et al., 2017). Increased industry presence and output would facilitate the growth of GDP of the nation.

ii. Increase in Local Research and Development

One of the industries lacking in Nigeria is Research and Development, it is expected that with increase in RE generation, the need for companies focused on Research and Development would be on the increase. This would thereby lead to an increase in job creation and economic growth.

3.2. Social Impact of Renewable Energy Generation in Nigeria

In this section, the social impacts of renewable energy generation in Nigeria is discussed with a focus on Employment and job creation Renewable energy education, Renewable energy businesses, ministries, and institutes, renewable energy projects and investments as well as specific solar and wind projects across Nigeria.

i. Employment and Job Creation

Based on literature, renewable energy projects have a significant effect on employment and job creation. In Nigeria, several renewable energy companies have arisen in recent years and these have increased the demand for both skilled and un-skilled labor in RE development.

ii. Renewable Energy Education in Nigeria

The increase in Renewable Energy generation has increased the need to train local workers on specific trainings. Some of these may require informal education and others may require a more formal educational setup. In a bid to train the next generation of renewable energy specialists and engineers in Nigeria, a number of renewable energy type programs are being hosted in Nigerian Tertiary Institutions.

Data on engineering programs offered by Nigerian Tertiary Institutions (NTI) – Universities and Polytechnics relating to Renewable energy was analyzed. The analysis reveals the proliferation of these engineering programs in NTIs and other programs of interest that could be developed. The following programs are considered in this analysis Climate engineering, Control engineering, Electrical/Electronics, Electrical, Electronics, Electromechanical, Energy Engineering, Engineering Physics, Engineering Science, Information Technology (IT) Engineering, Information Engineering, Mechanical, Mechatronics, and Power Distribution Engineering.

We analyzed 48 NTIs reported to offer engineering programs. We further analyzed the data to reveal only Nigerian Universities with the above listed Renewable Energy type programs. Out the 48 NTIs, 47 reported to having a minimum of one (1) renewable energy type program and a maximum of five (5) renewable energy type program. The results also show an average of 2.586 engineering programs per university. A total of 150 renewable energy programs in the 48 NTIs under observation. Appendix 1 shows Universities in Nigeria and the number of renewable engineering type programs they offer.

iii. Businesses, Ministries, Institutes and Investments

The emergence of Renewable energy generation has led to an increase in Renewable Energy pilot projects, businesses and investments across Nigeria. Table 3 provides a lists of renewable energy ministries and institutes in Nigeria; Table 4 shows a list of renewable projects and investments across Nigeria and Table 5 provides a list of specific wind and solar projects across Nigeria.

3.3. Environmental Impact of Renewable Energy Generation in Nigeria

Some of the environmental issues with renewable energy are air pollution, water pollution, damage to biodiversity (wildlife and plant life), damage to hab-

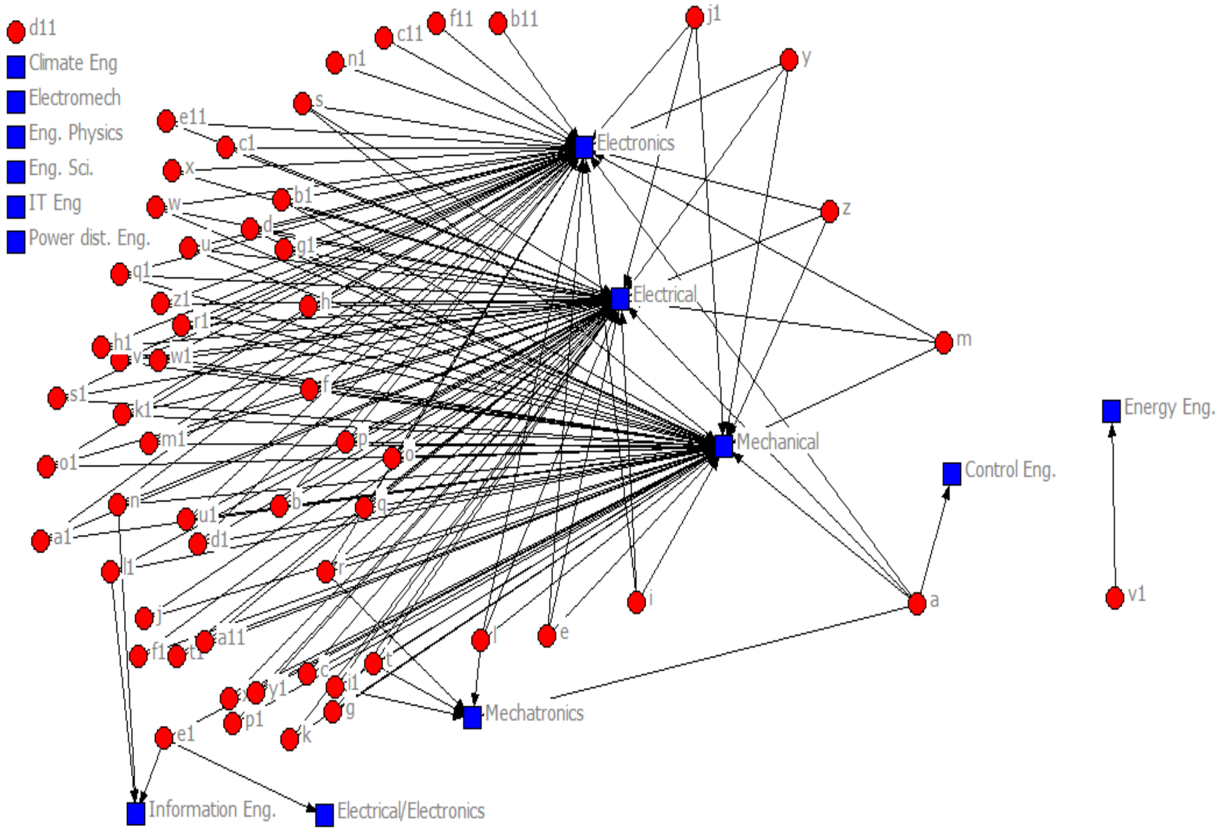

Figure 2. Network of Tertiary Institutions in Nigeria and Renewable Energy Related Projects

Table 3. Renewable Energy Ministries and Institutes in Nigeria

Author	State	Year	Ministry/Institute	Activities
(Osunmuyiwa & Kalfagianni, 2017)	Delta	2007	Two institutions on energy (Delta Green Economy Commission, Rural Development Agency)	Development of renewables and rural electrification
	Lagos	2009	Lagos Waste Management Authority (LAWMA)	First created in the 1970's, the ministry was created to handle to large amount of municipal waste generated in the state for energy generation
	Sokoto	2009	Ministry of Environment	Deployment of renewable technologies
	Lagos	2011	Ministry of Energy and Mineral Resources	Saddled with the responsibility of designing an energy master plan with renewable energy development at the core
ECN, 2017 ("Research Centres," 2007)	University of Nigeria, Nsukka, Enugu		National Centre for Energy Research and Development	Research in Solar and Renewable Energy
	Usmanu Danfodiyo University, Sokoto		Sokoto Energy Research Centre (SERC)	Research in Solar and Renewable Energy
	University of Lagos		National Centre for Energy Efficiency and Conservation (NCEEC)	Research in energy efficiency and conservation
	University of Ilorin		National Centre for Hydropower Research and Development (NCHRD)	Responsible for research in Hydropower
	Abubakar Tafawa Balewa University, Bauchi		National Centre for Petroleum Research and Development (NCPRD)	Responsible for research in petroleum oil and gas

Table 4. Renewable Energy Projects and Investments in Nigeria

Author	Project Name	Pilot Location	Collaborating Companies or ministries and Location	Scope
(Osunmuyiwa & Kalfagianni, 2017)	2014	Lagos	Total Energy Group and the Lagos State Government	A 1.5 million USD solar powered service station in Lagos
	2012	Lagos	Schneider, Siemens and Lagos State Government	Development of techno-institutional capacities in the deployment of Renewable Energies
	From 2005		KNX and ZAGO and the Sokoto State Government	Rural Electrification projects in Sokoto. Especially the deployment of Solar refrigerators to 90 rural villages in Northern Nigeria
	2012-2014	Lagos, Sokoto, Delta	United Nations Development Programme (UNDP) and Bank of Industry (BoI)	Invested US$4780 million on financing renewable energy projects in these states in order to facilitate the growth of micro, small and medium enterprises in the states
		Lagos	Ifelodun/Ojokoro Cooperative Multipurpose Agricultural Society	Initiate the deployment of a 18m3 pig dung biogas plant in Lagos
		Ibadan	International Institute for Tropical Agricultural (IITA)	Development of biofuel project
		Enugu	National Centre for Energy Research and Development	Several pilot scale solar water hearters and solar dryers, National Stove Eligibility laboratory funded by the Global alliances for Cook Stoves
	2009	Bauchi **	Bauchi State Government and Chinese equipment corporation	Deployment of Power generating plants for use in rural communities
		Bauchi **	Bauchi State Government and German company, Helior Energie	Generation of 20-30MW of energy through solar power

** states has no renewable energy agency, ministry or policy

Table 5. Specific Solar and Wind Power Project across Nigeria

Technology/System			Additional Information
Based on REN 21 (2015) (cumulative capacity at end of 2014)			
(Rainer Quitzow, 2016)	Mini-grid (solar)		6 units
	Mini-grid (solar)		4 kWp, 150 residents electrified
	Hybrid mini-grid		16 kWp, 12 Compact mini-grid
Based on IRENA (2015 e)			
Mini-grid	Mini-grid		6 units, 700 households electrified
Journal reports	Journal reports		
(Chiemeka Onyeka Okoye, 2015)	Solar Street Lights	Ado Ekiti (South-West)	
	Kwalkwalana village electrification	Sokoto (North)	7.2 kW_p
	Nangere water pumping scheme	Sokoto, North	1.5 kW_p
	Solar Rice Dryer	Adani, Enugu, South-East	2 tonne
	Iheakpu-Awka village electrification	Enugu, south-east	1.9 kW_p
	Solar Forage Dryer	Yauri, Kebbi North	1.5 tonne
	Solar Energy Plant	Katsina, North	20 MW_p
	Solar farm	Katsina, North	50 MW_p ; Synergent Group
	Solar power plant	Katsina, North	60 MW_p, (Nigeria-German Energy Partnership)

	Solar farm (Nigeria Solar Capital Project and Gigawatt solar)	Bauchi, North	100 MW_p (Nigeria Solar Capital Project and Gigawatt solar)
(Olayinka S. Ohunakin, 2014)	Solar based rural electrification	Oporoma, Ekawe	Bayelsa
	Solar based rural electrification	Ekowe, Egwuma, Okokolo, Ogbanlu, Ekwo, Enungba, Ojantele, Ikobi, Adija, Usha, Egwuma	Benue
	Solar Plant	Evwreni, Ughelli North LGA	Delta
	Solar based rural electrification	Ibuza	Delta
	Solar based rural electrification	Filin-dabo	FCT
	Development of a farm for bio fuel production	Abuja	FCT
	Solar pilot project	Malam Inna	Gombe
	Solar based rural electrification	Laya, Sakura, Sharhori, Tudun Wada, Dabau	Jigawa
	Solar based rural electrification	Kurmin sata, Chikun, Kasuwan Daji Igabi, Gubuci, Kudan, Makarfi, Hunkuyi, Panlandan by Railway, Sokoto Rd Zaria	Kaduna
	Solar based rural electrification	Kano – Kafur Rd Malumfashi, Galadima Sallau, Tunai Dudi, Shawai Rd, Malumfashi, Galadima Abu, BCGA-Dan Murubo Rd, Borin Dawa Muntari Abubakar Rd Malumfashi, Danbilagu Unguwar Makera, Malumfashi Danbilagu Unguwar Makera (II), Malumfashi, Birin Kogo, Faskari, Sirika B, Dutsi LGA, Galadima Abu, BCGA_Dan Murubo Rd, Malumfashi, Birin Kogo	Katsina
	Wind energy foe electric power generation	Kebbi, Yauri	Kebbi
	Solar based street lighting	Adeyemi Street Ogun Oloko, Mafoluku Oja	Lagos
	Solar based rural electrification	Old Muri and Environs, Palace way to Comprehensive Sec. Sch, Behind SSS office Jalingo, Tella village	Taraba
	1565 kWp Solar-powered borehole and street lighting	Malarin Gamma Village, Malam Madori LGA	Jigawa
	1820 kWp Rural solar electrification project	Gui, AMAC	FCT
	2.85 kWp solar based electrification	Centre for Mentally ill Destitute, Itumbuzo	Abia
	1.75 kWp solar based electricity and street lighting	Ini LGA Secretariat	Akwa Ibom
	7.5 centralized solar power plant	Oduduwa road, University of Ibadan	Oyo state
Journal reports	Journal reports		
Technology/system			Additional information

itat, global warming etc. It should be noted that air pollution also affects economic growth of a nation (John, Ucheaga, Badejo, & Atayero, 2018) (E. Okewu, Misra S., Fernandez S.L., Ayeni F., Mbarika V., & Damasevicius R,, 2019).

Nigeria has seen many economic changes as well as an evolution in the power generation sector. The Nigerian power sector has also undergone privatization in 2013 with the generation and distribution companies being unbundled. The transmission company is still in control of the Federal Government.

i. Air Pollution

Some of the main air pollutants are Sulphur oxides, nitrogen oxides and suspended particulates. Globally speaking, Africa has not contributed a lot to global toxic gas emissions (John et al., 2018) due to low levels of industrialization. However, the major sources of air pollution in Nigeria include: Particles from desert zone of the Sahara; Biomass burning that produces huge amounts of black and organic carbon; The use of biofuels resulting in the increase of gaseous air toxins like NOx, CO, Volatile organic compounds (VOC), SO_2. This is also associated with combustions in vehicles, domestic power generators and industrial activities.

In Lagos, one of the most populous cities in the world, air pollution due to high population and vehicular activity is on the increase. Table 6 shows the ambient air pollution in traffic areas and non-traffic area in Nigeria in comparison with the Federal Environmental Protection Agency (FEPA) of Nigeria.

Table 6. Ambient air pollution in traffic and non-traffic zones in Nigeria

	Non-traffic urban zone	Traffic zone	FEPA standards
TSP μ/m^3	31.4 – 746.5	720 – 950	250
NOx (ppm)	81 – 81.5	34 – 131.6	40 – 60
SO_2 (ppm)	0.5 – 43	20 – 250	100
CO (ppm)	0.5 – 3.9	10 – 250	10

ii. Damage to biodiversity and habitat

Asides from the troublesome nature of large land use which comes with grave consequences. Clearing of biodiversity and wildlife life to the reduction in the natural floral or fauna of the land, extinction of rare species and erosion etc. Clearing biodiversity could increase the rate of loss of food, medicine, and other uses of biodiversity by indigenous people; Increase local temperature and the resultant health challenges with emerging diseases pathogens due to warming and Increase cumulative cost of social wellbeing and the antecedent challenges.

4. Policy Imperatives for Renewable Energy Generation in Nigeria

Prior to 2005, there was no defined renewable energy plan in Nigeria. In order to fully appreciate the growth of Renewable energy in Nigeria via policy formations and Government interventions, a review of Renewable Energy policies in Nigeria is detailed in Table 7. Accelerating the adoption of renewable energy requires deliberate action backed-up with policy that will enable quick and early decisions.

Policies and schemes that facilitate production of renewable energy products like production-based incentives, tax credit should be encouraged. Feed-in tariff, investments tax credit, value added tax (VAT) exemption, interest-free loan and loan guarantees.

5. Conclusion

Going by the reality that the solution to Nigeria's power challenge is not close in sight, the need to conserve and efficiently manage the available power becomes very imperative. Various energy sustainability and efficiency initiatives have been introduced which includes the introduction of CFLs and LEDs lightings, use of energy efficient electrical appliances, use of renewable energy and various Clean energy initiatives.

With the deregulation of the Nigerian Power sector, some of the possible investment opportunities available to members of the business community, industry captains and private investors are provision of renewable energy power generation infrastructure which includes; microgrid development, development of hybrid system, consortium formulation for Independent Power Producers (IPPs) generation and sales of power, sales and maintenance of metering infrastructure, capacity building of young workforce in the area of energy auditing, environmentalists, measurement and verification experts, policy experts etc.

Similarly, Modern energy should be considered as an indispensable necessity and a fundamental right, and should be provided on the basis of justice for the all. Energy should be made a high priority and likewise enshrined in the constitution.

There should be an attitudinal change towards sustainable energy development by the government and willingness to make policies that will stand the test of time. Thus, governments have to consider it as one of their ultimate responsibilities. It is expected that with the increased attention by the government, employment and job creation, gross domestic product (GDP) growth, and local research and development would be on the increase. Also, with regards to renewable energy education, more specialized courses need to be adopted and included in the tertiary institution curriculum. Policy imperatives for achieving increased energy generation was also discussed.

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Table 7. Review of Energy Polices enacted in Nigeria

Author	Year of Policy formulation	Formulating body	Policy to take effect from	Policy Name	Policy Details
(Emodi & Boo, 2015) (Mas'ud et al., 2015)	2005	ECN		Renewable Energy Master Plan (REMP)	The REMP contains details of the Government's support for Renewable energy for all applications. The need for financial and legal instruments, technology development, raising awareness, capacity building and education as strategic areas to be developed.
(Emodi & Boo, 2015)	2008	NERC (Nigerian Electricity Regulation Commission)	1st July, 2008 to 30th June, 2013 (withdrawn in 2012)	Multi-Year Tariff Order 1 (MYTO 1)	Regulation of prices paid to licensed electricity generation companies. The policy also provided for fiscal and financial incentives for electricity companies who exploited multiple RE resources. Feed-in-tariffs and premiums for small electricity providers as well as consumers who are able to generate and sell to utility companies.
(Emodi & Boo, 2015)	2011	ECN & Federal Ministry of Environment		REMP	The REMP contained targets from 2015 to 2030 on renewable energy contributions to total energy consumption in Nigeria. It also contains some fiscal and market incentives to boost development and deployment of RE technology
(Emodi & Boo, 2015)			1st June 2012 to 31st May 2017	Multi-Year Tariff Order 2 (MYTO 2)	The retail tariff in MYTO 2 will be reviewed bi-annually, prices and rates would be adjusted based on Nigerian Inflation rate, US$ exchange rate etc. It also contains a 15-year tariff for electricity generated from RE. However, the prices are still negotiable assuming the generator can show to the NERC that the cost of generation is not in line with the assumptions
(Osunmuyiwa & Kalfagianni, 2017)		Lagos and Sokoto State Government	2013	Energy policy on Renewable Energy	In Lagos the framework revolved around ensuring that the 400MW of energy via renewables was achieved and 90% use of renewable by 2020

Appendix

Nigerian Tertiary Institutions and the number of Renewable Energy Type Programs they offer

5 programs	a
4 Programs	r, n
3 Programs	b, q, h1, f, h, I, m1, y, l, m, j1, o, p, e1, g1, s, t, u, v, w, l1, b1, z, a1, s1, q1, d1, o1, i1, u1, k1, z1, w1, r1
2 Programs	k, g, d, f1, j, c1, e, c, t1, x1, y1, p1, a11, e11, x
1 Program	n, v1, c11, b11, f11

Key

	University		University
a	Modibbo Adama University of Technology Yola (Federal University of Technology)	d1	Federal Polytechnic Nasarawa
b	University of Lagos	e1	Covenant University Ota
c	University of Ilorin	f1	Federal University of Technology Minna
d	Federal University of Technology Owerri	g1	Federal University of Agriculture Makurdi
e	Nnamdi Azikiwe University	h1	Federal University of Petroleum Resources Effurun
f	University of Maiduguri	i1	Bells University of Technology Otta
g	Rivers State University of Science & Technology	j1	Federal Polytechnic Mubi
h	Enugu State University of Science and Technology	k1	University of Agriculture Abeokuta
i	Obafemi Awolowo University	l1	Landmark University
j	Ahmadu Bello University	m1	University of Jos
k	Federal University of Technology Akure	n1	University of Calabar
l	Federal University Oye Ekiti Ekiti State	o1	Ekiti State University Ado Ekiti (University of Ado Ekiti)
m	University of Uyo	p1	Imo State University Owerri
n	Elizade University Ilara Mokin	q1	Cross River State University of Science & Technology Calabar
o	Akwa Ibom State University of Technology	r1	Federal Polytechnic Bauchi
p	University of Ibadan	s1	Adeleke University Ede
q	University of Nigeria	t1	Olabisi Onabanjo University (Ogun State University)
r	Afe Babalola University Ado Ekiti	u1	Osun State University
s	Madonna University Nigeria	v1	African University of Science & Technology Abuja
t	Bayero University Kano	w1	Nigerian Defence Academy Kaduna
u	Ladoke Akintola University of Technology	x1	Polytechnic Ibadan
v	Kaduna Polytechnic	y1	Federal Polytechnic Ilaro
w	Baze University Kuchigoro	z1	Gregory University Uturu
x	University of Benin	a11	Kano University of Science and Technology Wudil
y	Auchi Polytechnic	b11	Western Delta University
z	Yaba College of Technology	c11	Lead City University Ibadan
a1	Ambrose Alli University Ekpoma	d11	American University of Nigeria
b1	Igbinedion University Okada	e11	Oduduwa University Ipetumodu Osun State
c1	Nigerian Turkish Nile University Abuja	f11	Adekunle Ajasin University

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