



GLOBAL JOURNAL OF ADVANCED RESEARCH
(Scholarly Peer Review Publishing System)

DIVERSIFICATION OF ENERGY RESOURCES AND ENERGY SECURITY IN NIGERIA

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ABSTRACT

It is an unacceptable contradiction that Nigeria is rich in numerous energy resources and occupies an enviable place in the global energy market but perennially confronted with severe energy poverty and energy insecurity. It is significantly blessed with fossil, wind, sunlight, water and other renewable energy resource alternatives. However, these enormous and varied potentials in the economy largely remain undiversified and hence, unexploited over the years. This situation is as a result of the overdependence and dominance of petroleum sector in the economy. This scenario is a fundamental problem that endangers the sustainable development efforts of the nation. This study making use of document analysis method identifies lacuna in the nation's energy sector that needs to be filled. Accordingly, strategies towards promoting the use of clean energy sources are recommended for a sustainably diversified energy sector of the country.

General Terms: Energy resources and energy security, Nigeria

Keywords: Diversification, Renewable Energy, Sustainability

1. INTRODUCTION

Energy is an essential component of a contemporary economy given the urgent function it performs as a critical factor of production used in the creation of products, when optimally blended with required capital and labour. On the other hand, it is also regarded as a significant cause of global warming as result of greenhouse gas emissions (Anna, 2020). Nigeria's energy sector is fundamental to its prospective realization of socio-economic growth and development objective. However, this is in jagged disparity with the profuse energy resources obtainable, which could be exploited to meet the ever increasing energy demand and requirement of the country.

Unarguably, the dismal performance of the energy sector has remained a critical constraint for meaningful economic growth and transformation over a long period of time. This scenario has impacted negatively on the development of the economy. It is an unacceptable contradiction given that; Nigeria is rich in numerous energy resources and occupies an enviable place in not only in Africa but also in the global energy market. The country is significantly blessed with fossil, wind, sunlight, water and other renewable energy resource alternatives. However, these enormous and varied potentials in the economy largely remain undiversified and hence, unexploited over the years.

Achieving energy security through a sustainable electricity mix – the balance of sources of electricity in the supply – is becoming increasingly important as countries try to shift away from fossil fuels towards low-carbon sources of electricity (renewable energy including hydropower, solar and wind). This interest is anchored on the observation that the global economy is geometrically growing ahead of the pace with which the earth replenishes itself. World population explosion and excessive energy demands especially in the emerging economies like Nigeria pose great challenge to economic growth and the environment. The quest for energy options that are affordable and environmentally friendly to mitigate demand-supply imbalances would generally guarantee energy security.

There is the argument that most developing countries contribute significantly to gaseous emissions into the atmosphere as a result of the concentration on the use of less clean production technologies. Nigeria, as one of the developing nations is struggling to achieve a certain level of development and economic growth. In this part of world, the quest to achieve high level of GDP often leads to considerable level of energy consumption especially (fossil fuel) which not only discourages the development of other non conventional energy resources but significantly increases gas emissions. In addition to the above, oil spillage and natural resources usage tend to increase the level of environmental degradation. Hence, the economic growth process in Nigeria is undesirably pollution intensive (Akpan & Akpan, 2012).

According to the IEA, for there to be adequate access to energy, as envisaged globally, this would require a commitment and an increase in the investment of \$41 billion between 2010 -2015 and \$36 billion annually up to 2030, and for sub-Saharan Africa, \$14 Billion cumulative investments, is required up to 2030 to provide adequate access to modern cooking fuels. In stressing the importance of adequate energy access to economic development and the achievement of the UN Millennium Development Goals 2000, the IEA recommended a viable legal, institutional and financial framework, together with target setting by national governments, while favouring the need for the inclusion of the right to energy as one of its Millennium Development Goals. Nigeria is in sub-Saharan Africa, and its citizens are not only economically poor but energy poor, hence a more radical approach in the nature of Domestic Supply Obligation, is needed to achieve energy security (Dike, 2017).

No doubt that over-dependence on oil and hydro-electricity has arguably slowed down the development of alternative energy resources relevant for sustainable economic development. This remains a paradox given the diversity of abundant energy sources in the country. Nigeria is blessed with abundant primary energy resources. The current official estimates of energy resources in Nigeria show that crude oil reserves are currently estimated at 36 billion barrels. Current daily production of about 2.7 million barrels per day makes Nigeria the largest producer and exporter of crude oil in Africa and among the top ten producers of in the world (Iwayemi, 2012).

These natural endowments include reserves of crude oil and natural gas, coal, tar sands and renewable energy resources. However, the economy over the years has been not able to exploit these options for its development needs (Energy Commission of Nigeria, 2003). This has been described in many energy literatures as one of the major causes of the current energy crisis and insecurity truncating socio-economic prosperity of the nation.

This situation is as a result of the overdependence and dominance of petroleum sector in the economy. The petroleum sector alone contributes over 95% of Nigeria's export earnings, about 83% of her total revenue; and 12% of her gross domestic products (GDP) (Panshak, Irfan & Hüseyin, 2019). This indicates that any change in the purchase and consumption of oil by its international customers will not only affect the revenue generation but cause a monumental distortions and insecurity of the entire nation. This assertion is evidenced by the recent global financial meltdown of 2007/2008 as well the last economic recession of 2015/16.

The world economy is earnestly searching for clean energy alternatives to address issues of global warming and environmental degradation. It is however, pathetic that Nigeria still utilizes significant traditional energy source- biomass for most of its residential and other domestic use. The rural population, making up of over 60% of the country's populace depends on the non-conventional energy resources. This results to depletion of energy resources and deforestation creating crises (Okoye & Achakpa, 2007).

Iwayemi (2012) observes that the current and protracted energy crisis illustrates the most visible dimension of Nigeria's recent energy conundrum. Despite the availability of oil and gas, hydro and coal resources, generates 5,000 MW remains elusive whereas South Africa generating capacity is 40,000 MW. This is an unacceptable phenomenon. A careful investigation of the power

generation capacity required to carry place Nigeria on sustainable growth requires the generation of electricity in the range of: 35,000 – 40,000MW from 2020 (Idris, Lamin., Ladan, & Yusuf, 2012)

Based on the forgoing, there exists a lacuna in the mix of the nation's energy sector that needs to be filled. It is evidently clear that the present energy crisis in the largest economy in Africa-Nigeria poses several questions in her search for stable energy necessary for the achievement of sustainable development. The study submits that if Nigeria gets it right in terms of well diversified energy mix, Sub Saharan Africa would certainly be on the trajectory of sustainable growth and development. The contribution is essentially on the urgency of the subject matter as well as adding to the growing literature in this area. Making use of content analytical procedure, the study seeks to provide answers to the major questions including why is there energy insecurity in the face of numerous power sources in Nigeria. What are the policy alternatives to achieve sustainable energy mix? In line with the questions, the main objective of this research focuses on identifying sustainable energy sources and providing practical solutions to Nigeria's energy insecurity focusing on non conventional/renewable energy. It is hoped that the gap between demand for and supply of energy resources shall be equated if the policy recommendations emanating from the study are implemented. Policy makers and energy practitioners from the developing countries with similar challenges would certainly benefit from the outcomes of this research based on the remedies advanced to addressing Nigeria's energy challenges.

The study outline is as follows: Section two covers the review of related literature. Section three contains the theoretical underpinning. Section four identifies sources, problems and prospects of clean energy adoption in Nigeria. Section five articulates policy considerations and conclusion.

2 REVIEW OF RELATED LITERATURE

Over the last few years, energy security and sustainable economic development have driven and taken attention of energy practitioners and policy makers the world over. This is fundamentally so because of the understanding that a stable energy supply and availability at affordable price is sine qua-non to economic growth. Energy is believed to be one of the indispensable factors for socio-economic development (Brew-Hammond, 2010; Bada, 2011). Buttressing this fact, Okoro and Chikuni (2007) assert that a nation with unstable power supply risks keeps losing potential investors and development.

Energy has a number of different forms, all of which measure the ability of an object or system to do work on another object or system. Energy or power could be generated through potential (static) or kinetic (dynamic) sources. Oyedepo (2012) puts that energy is an essential ingredient for socio-economic development and economic growth. The objective of the energy system is to make available energy services. Energy services are the desired and useful products, processes or indeed services that result from the use of energy, such as for lighting, provision of air-conditioned indoor climate, refrigerated storage, transportation, appropriate temperatures for cooking, industrial processes such as conversion of raw materials to final products, etc (Oyedepo, 2012). According to Ajayi (2009), energy is fundamentally associated with sustainable development at the local, national, and regional levels. At the local level, contemporary energy is required to advance the on the whole quality of life (especially, that of the poor) by enhancing industrious activities and enterprise, which will produce increased incomes. At national and regional levels, adequate modern energy leads to stable economic development, promotion of trade, and enhancement of participation in global markets, in addition, the supplementary profits of enhanced social and economic linkages.

Non conventional energy resources refer to all renewable energy alternatives available to a particular nation or region. They include such sources such as sunlight, wind small hydro, biomass etc. They are clean natural endowments capable of replenishing themselves. Thus, they do not suffer any extinction dangers. This is the much reason why non conventional energy is most sought after in this age of global warming and energy insecurity.

Energy diversification refers to a nation using multiple sources of energy to run its economy and public services, eliminating dependence on any one source of energy (Uribe 2014). Diversification could be in the form of renewable and/or non-renewable energy sources. Renewable energy is indeed a major focus in energy diversification because the probable of insufficiency related with non-renewable source, which in itself potentially creates internal safety threats through economic insecurity.

Uribe (2014) observes that energy diversification became an important foreign policy strategy for nations to be able to avoid the trap of falling under the monopoly or oligopoly of a single or few foreign entities that had control over natural energy resource. Owing to this tactical stance, agreement is changing toward investment in domestic production of renewable energy sources. In essence, diversification helps to guarantee the economy remains productive and viable even in the event of adversity or conflict with other nations. Similarly, energy security has been the focus of various scholastic discourses and various scholars, writers, energy enthusiasts and commentators have attempted to define or describe the concept. Energy security in an ordinary parlance refers to the uninterrupted availability of energy sources at an affordable price. Energy security has both long and short-term aspects. Long-term energy security is principally connected to timely investments to provide energy in line with economic developments and ecological needs. Contrary, short-term energy security focuses on the capacity of the energy system to counter promptly any sudden changes in the supply-demand equilibrium.

As far back as 4000–3500 BC, human energy demands were met only by renewable energy sources: sun, biomass (wood, leaves, and twigs), water and wind power. With the advent of the Industrial Revolution, the use of energy in the form of fossil energy began increasing as more and more industries were established. In the past century, it became evident that the utilization of non-renewable sources of power had caused more environmental harm than any other human action. Electrical energy derived from fossil fuels especially; coal and crude oil has resulted to soaring concentrations of destructive gases in the atmosphere. This has in turn led to problems such as ozone depletion and global warming. In the developing countries like Nigeria, it has significantly contributed to the abandoning of the development of other natural free endowment of the nation.

Due to the problems associated with the use of fossil fuels, unconventional sources of energy have become imperative and relevant in today's world. These sources can never be exhausted and are thus called renewable or non-conventional sources of energy. They cause less emission and are available locally capable of maintaining energy security. Their use can significantly reduce chemical, radioactive, and thermal pollution and could as well enlarge energy mix and scope in most countries. They are viable sources of dirt free and unlimited energy. Most of the renewable sources of energy are fairly non-polluting and considered clean. Note that renewable electricity here is the sum of hydropower, wind, solar, geothermal, modern biomass and wave and tidal power. Nigeria, Africa's most populous country, is severely challenged with chronic inadequacy of energy generation, transmission, and distribution capacity because virtually all electricity generated is from oil and hydro sources. Despite being one of the leading oil producers in the world and with varied energy sources, 70% of her over 160 million people live below the poverty line. Energy sector deficiencies have kept over 40% of the population living without electricity, while those with access experienced unfortunate quality and worth of service. A substantial part of the country is unconnected to the grid (Iwayemi, 2012).

Dreyer and Stang (2013) note that definitions of energy security ranges from narrow issues of physical supply disruption to broader ones involving the economic, environmental, and political consequences of changes to energy markets. It means to the common man, having near constant supply of electricity whether through gas fired turbines, steam turbines, nuclear fission, solar panels or such other means without recourse to self generation, such as the use of petrol or diesel generators. It can also be defined as the uninterrupted availability of energy sources at an affordable price (Uribe 2014).

But energy security considerations must also be equated against competitiveness and ecological concerns; principally those connected to climate change. The energy challenges that engulfed Nigeria in last two decades approximately, has been massive and has chiefly contributed to the prolonged energy poverty paralyzing manufacturing and profit-making activities over the years. The economy forgoes 126 billion naira (US\$ 984.38 million) annually on power outages (Council for Renewable Energy of Nigeria, 2010). Apart from the huge income loss, it has also resulted in health hazards due to the exposure to carbon emissions caused by constant use of domestic generators in diverse households and commercial enterprises, unemployment, and high cost of living leading to a worsening of living circumstances (Oyedepo, 2012).

The current situation in Nigeria is paradoxical because, regardless of Nigeria's enormous oil and gas sector, scores of communities do not have access to electrical energy which is a secondary form of energy powered by petroleum with which Nigeria is richly gifted. Apart from electricity, even petroleum products like gasoline, diesel, kerosene and other petroleum products had in the past, been quite often, in short supply (Iwayemi, 2012). For a long time, in Nigeria, the lack of access to efficient energy resources has had adverse effect on production. Agriculture hardly developed beyond the small holder survival stage, as farmers could not increase production without energy, while harvests had been mostly lost due to lack of storage. Artisans, small scale enterprises and larger productive enterprises are in danger owing to lack of reachable energy. The overall result is the loss of jobs and the impoverishment of many. On average, as noted by Ngilari (2009:2) "*citizens in most regions receive only 6 hours supply of electricity daily at best*". There are many rural settlements in the country that are until now even having no access to any electrical power. They still rely on some other mechanical sources of energy like fuelwood. Others, who can afford to, acquire privately owned generators which are barely cost-effective. The lack of infrastructural development makes the energy security problem in Nigeria amongst the worst in the world.

The Manufacturer Association of Nigeria (MAN) argued that about 60 million citizens now possess power generating sets for their energy producing harmful toxics not ecologically pleasant. The same numbers of people spend a staggering N1.56 trillion (\$13.35million) to fuel their generators annually. The state of affairs is such that the country is contending with the provision of this basic social infrastructure. A large part of the population does not have any access to electricity while those that have it cannot rely on the very poor supply from the Power Holding Company of Nigeria, which for a very long time was an integrated government owned utility company and run as a monopoly.

The policy of the Federal Government had been to subsidize the pricing of locally consumed petroleum resources, together with electrical energy. In order to make the petroleum downstream sector more efficient and in an attempt to stem petroleum product utilization as a policy focal point, the government has reduced and removed subsidies on a variety of energy resources in Nigeria. The various policy options have always engendered price increases of the products (Famuyide., Anamayi & Usman, 2011).

There is no pessimism that costly and erratic power remains a major challenge to all sectors of the economy in Nigeria: the industrial, commercial, and domestic sectors especially. As a result of this crucial dilemma, industrial enterprises have been coerced to install their own electricity generation and transmission equipment, thereby adding up significantly to their operating and investment outlay. Threats to energy security include the political instability of several energy producing countries, the manipulation of energy supplies, the competition over energy sources, attacks on supply infrastructure, as well as accidents, natural disasters, rising terrorism, and dominant countries reliance to the foreign oil supply. Other threats to energy production and supply include: Political (Niger Delta problem), vandalization of power towers, huge transmission losses, power evacuation problems, illegal electricity connections either to the national grid or the existing residential/industrial electricity outfit. The trends of climate change have led to a continual loss of water. Since the power output of hydro plants is dependent upon the flow of the river, with less water, there is less potential energy to harness (Obodata, 2009)

2.1: Brief Overview of the Objective of Energy Policy in Nigeria

Attaining energy security for sustainable economic prosperity largely depends on the extent of diversification of energy resources in an economy. Nigeria's energy mix and the potentials of the conventional sources of electricity generation and fuel supply have been proven, but have remained largely untapped. Cheap energy supply is the major determinant of industrialization and overall economic growth. Hence, diversification of the energy sector to renewable sources especially to those areas and regions that have comparative cost advantage over others.

In 2003, the Federal Government Nigeria signed the National Energy Policy (NEP) to articulate the sustainable harnessing and utilization of all viable energy resources. The policy is based on private sector development of the energy sector. The key contents in the national policy position toward diversification and adoption of non conventional energy in Nigeria (ECN, 2003) are as follows:

- i. Harnessing hydropower potential available in country for electricity generation, also paying attention to the development of the mini and micro hydropower schemes.
- ii. Tapping of the hydropower resources in an environmentally sustainable manner and encouraging private sectors and indigenous participation in hydropower development.
- iii. Encouraging the use of alternative energy sources to fuelwood by developing an appropriate technology to use wood chips rather than the direct use of wood.
- iv. Aggressive use and integration of solar energy into the nation's energy will be done, by developing the nation's capability in the utilization of solar energy as well as monitoring worldwide development of solar energy technology. To enable the use of solar energy as complementary energy resources in the rural and urban areas.
- v. Developing wind energy resources and integrating them with other energy resources to form a balanced energy mix. It will as well involve taking necessary measures to ensure that wind energy is harnessed at a sustainable cost to both suppliers and consumers in the rural developing local capability in wind energy technology and applying it in areas where it is technically and economically feasible.
- vi. Harnessing non-fuelwood biomass energy resources and integrating them with other energy resources. Also promoting efficient methods in the use of biomass energy resources.
- vii. Keeping abreast of international developments in RE technologies and applications

3. THEORETICAL FRAMEWORK

Aside the famous U-Shaped Environmental Kuznets Curve (EKC) theory which states that a rise in GDP may lead to a rise in environmental quality degradation but as economic growth increased up to a certain threshold level, environmental quality degradation starts to decline; the study also leans on the insights of comparative cost advantage and the balanced growth theories in the quest to achieve diversified and secure energy mix for sustainable development for Nigeria. The EKC concept was forwarded in the early 1990s by Grossman and Krueger (1991). The notion that growth is essential in order for environmental quality to be maintained or improved is an essential part of the sustainable development argument promulgated by the World Commission on Environment and Development (1987) in *Our Common Future* (Butlin, 1989). The view that greater economic activity inevitably hurts the environment is based on static assumptions about technology, tastes, and environmental investments (Omojolaibi, 2010). The implication of the EKC suggests that the quality of the environment decays at the initial stage of growth because of the massive usage of conventional energy sources such as fossils and eventually improves at the later stage when economic development is achieved.

In achieving secure energy mix, the insight of comparative advantage, which suggests that a country/region ought to focus on production goods and service that have a margin of superiority in cost. Ricardo (1817) argued that region/countries have different factor endowments of labour, land and capital inputs. Countries/regions ought to concentrate in and production of those goods which can be produced massively with the factors of production which they are mainly gifted. Accordingly, if each region of the country specializes in production of energy resources where they have an advantage, then total electricity productivity and economic benefits can be improved (under certain assumptions). Through this, energy security could be achieved in the country. In line with this, given the various potentials of respective regions in Nigeria, states like Kano, Jigawa, Imo and other states especially in the north should

significantly exploit solar energy in other reduce the dependence on the national grid. Building capacity in wind energy in Sokoto, Katsina, Borno; and other similar states that have considerable wind speed will help adding to the energy supply capacity of the nation. Small Hydro Power has high prospects in states such Benue and Zamfara. Plateau state has high prospect for small hydro power as demonstrated by NESCO in Kurra falls and needs to be maintained and expanded for optimal output.

The foregoing theoretical position corroborates the balanced growth theory of Nurkse (1907–1959). The theory proposes that the government of any developing nation needs to raise enormous investments in a number of industries simultaneously. Using this analogy, balanced development of various natural energy resources is capable of making Nigeria a well diversified and sustainable nation in terms power and overall development. The development of unconventional fuels from locally available energy resources should therefore be vigorously pursued.

4. APPRECIATING THE DISTRIBUTION OF ENERGY RESOURCES IN NIGERIA

It is well documented that Nigeria is richly blessed with abundant energy resources as clearly illustrated in Table 1. The country's major foreign exchange earner; Crude oil reserves stands at 36.22 billion barrels, primarily from the Niger-Delta axis. At the same time, the status of tar sands reserves stands at 31 billion barrels of oil equivalent, principally in a narrow belt, 120 km wide in parts of Ijebu-Ode in Ogun State and western areas of Edo State. The North-Central, North East and South Eastern States jointly contribute about 2.7 billion tonnes of coal and lignite. In terms of natural gas, Niger Delta region accounts for about 187 trillion standard cubic feet. Recent discoveries reveals that Nigeria has substantial oil and gas around the the Chad Basin, the Upper Benue Troughs in the North Eastern part of the country as well as in the Bida Basin and the Sokoto Basin (Sambo, 2014)

The hydropower potential of the country stands at about 11,250 MW and small hydropower potential of 3,500 MW. Hydropower capacities transcend 30 MW in Nigeria; therefore, they are referred to as large. Based on year on year average, mean daily solar radiation intensities of between 3.5 kWh/m²/day and 7.0 kWh/m²/day exist within the country. This is obtainable as one travels from the southern to the far northern regions of the country. Annual average on-shore wind resource of between 2m/s and 4m/s, at 10 metres height, is also found within the country. In 2005, software that shows wind speeds at any position and heights of between 10m and 100m within Nigeria was produced by Lahmeyer Consultants of Germany for the Federal Ministry of Science and Technology. This is a powerful wind energy database that will enable designers and developers to use the data to design wind energy systems for all parts of the country.

Fuel wood, which meets the largest share of the energy needs of the rural communities in the country, is available within about 11 million hectares of land in the country, and about 0.11 million tonnes is consumed daily. It should be noted that about 70% of the nation's population reside in the rural areas. In addition to fuelwood, the rural communities also utilize animal waste and agric residues produced from about 300 million assorted animals in 2009 and 72 million hectares of agricultural land, respectively.

In addition to the above energy endowments in Nigeria, the country is also gifted with substantial deposits of uranium ore particularly in the North Eastern States and some parts of Cross River State. This resource is a radioactive component/element whose fission in a nuclear reactor generates incredibly high pressure and temperature steam for expansion in a Rankine Cycle turbine for power production.

The climatic condition of the country places the country on a better position to harness solar energy resource. Solar energy can be openly changed into direct current (DC) electricity via photovoltaic process, in solar cells, for use in D.C loads. The direct current (DC) may then be inverted to alternating current (AC) for use in A.C. loads. Solar energy can also be changed initially into heat energy, by means of a solar thermal collector, from where vapour can be raised at high temperature and pressure; expanded in a turbine in a Rankine cycle, and the mechanical power produced is used to drive an electric generator.

Irrespective of the strength fossils reserves, at the present rate of exploitation, it has been estimated that, these renewable in the next four decades face extinction risk and depletion. Energy demand in Nigeria mounts great pressure on the existing supply capacity of the available energy sources. Relating this to various scenarios at different growth rate as shown in Table 1, energy supply capacity need to be augmented to support the ever increasing demand at present and in the near future. The below table shows Nigeria's energy resource types, reserves and capacity utilization:

Table 1: Energy Resources in Nigeria

S/No.	Type of Energy Resource	Reserves(Natural Units)	Production capacity (natural units)	Capacity Utilization (natural units)
1.	Light Crude Oil	36.22 billion barrels	2.5 million barrels/day	450,000 barrels/day
2.	Natural Gas	187 trillion SCF	6 Billion SCF/day	3.4 billion SCF/day

3.	Coal and lignite	2.734 billion tonnes	insignificant	insignificant	
4.	Tar Sands	31 billion barrels of oil equivalent	-	-	
5.	Large Hydropower	11,250 MW	1,938 MW (167.4 million MWh/day)	167.4 Million MWh/day	
6.	Small Hydropower	3,500 MW	30 MW (2.6 million MWh/day)	2.6 million MWh/day	
7.	Solar Radiation	3.5 - 7.0 kWh/m ² /day (485.1 million MWh/day using 0.1% Nigeria land area)	Excess of 240 kWp of solar PV or 0.01 million MWh/day	Excess of 0.01 million MWph/day of solar PV	
8.	Wind	(2-4) m/s at 10m height	-	-	
9.	Biomass	Fuelwood	11 million hectares of forest and woodland	0.110 million tonnes/day	0.120 million tonnes/day
		Animal waste	245 million assorted in 2001	0.781 million tonnes of waste/day in 2001	NaN*
		Energy Drops and Agric Residue	72 million hectares of Agric. Land and all waste lands	Excess of 0.256 million tonnes of assorted crops residues/ day in 1996	NaN*
10.	Nuclear Element	Not yet quantified	-	-	

Sources: Nigerian National Petroleum Corporation (NNPC) 2007
Renewable Energy Masterplan (REMP) 2005
Ministry of Mines and Steel Development (2008)
Sambo (2014); NaN* = Not available Now

Table 2: Total projected energy demand (mtoe)

Scenario	2000	2010	2015	2020	2025	2030
REFERENCE 7%	32.01	51.40	79.36	118.14	169.18	245.19
HIGH GROWTH (10%)	32.01	56.18	94.18	190.73	259.19	414.52
OPTIMISTIC (11.5%)	32.01	56.18	108.57	245.97	331.32	553.26
OPTIMISTIC (13%)	32.01	72.81	148.97	312.61	429.11	715.70

Source: Energy Commission of Nigeria (2006): National Energy Policy, Federal Republic of Nigeria, Abuja.

Non conventional or Renewable energy has an important role to play in meeting the future energy needs in both rural and urban areas. Nigeria is blessed with a large amount of renewable natural resources which, when fully developed and utilized, will lead to poverty reduction and sustainable development. Renewable energy resources and technologies are a key component of sustainable development for the following primary reasons:

- i. Non conventional energy resources generally cause less environmental degradation than other energy sources. The implementation of renewable energy technologies will help to address the environmental concerns that emerged due to greenhouse gas emissions
- ii. If used carefully and systematically, non conventional energy resources can provide a reliable and sustainable supply of energy almost indefinitely that energy security can be achieved.
- iii. Non conventional energy are applicable to system decentralization and local solution that is somewhat independent of the national network, thus enhancing the flexibility of the system and providing economic benefits to small isolated communities.
- iv. There are great opportunities in non conventional energy resources in sustainable development, given large market size in Nigeria. The barriers and constraints to the diversification of renewable energy should be overcome.
- v. Energy security can easily be achieved because renewable energies have security of supply, and are not determined or negotiated on the international market.
- vi. Non conventional energies are significantly and fairly well distributed all over the country, even though wide spatial and temporal variations occur. Thus, all states/regions of the country have reasonable access to one or more forms of renewable energy supply.
- vii. Most communities in Nigeria lack access to modern energy, thus, the implementation of renewable clean technologies will integrate the rural communities into national grid. This presents a special opportunity to construct power plants close to these areas.

4.1: Harnessing Renewable Energy Resources for Energy Security in Nigeria

Energy self-sufficiency and long-term energy security are key promoters of sustainable development. No sector can optimally exploit its full potential in the face of erratic and interrupted power supply. Thus, energy diversification to clean energy alternatives will not only create stability in energy sector but will be the cornerstone in economic transformation and development. Diversification to achieve a wider energy supply mix will ensure greater energy security for the nation. The domestic demand for petroleum products is growing rapidly. The development of alternative fuels from locally accessible energy resources should therefore be enthusiastically pursued.

Therefore, to attain this height, there is need to aggressively pursue the harnessing of the nation's non conventional energy: solar, wind and small hydro energy. Diversifying the national energy base through non conventional or renewable power would be a desired progress as it will not only serve to partly cover existing gaps between demand and supply but also improve Nigeria's energy security. It is important to note that Nigeria is a party to the United Nation's Framework Convention on Climate Change (UNFCCC) and she has ratified the Kyoto Protocol which has to do with reducing Green House Gases (GHGs). Therefore, Nigeria is expected to formulate, implement, publish and regularly update national and where appropriate, regional agenda containing actions to lessen climate change by tackling anthropogenic emissions by source and removal all Green House Gases.

To achieve optimal energy mix that reduces CO₂ emissions and exposure to local air pollution, the county need to transition electricity away from fossil fuels towards low-carbon sources:

i. Wind Power

Today wind energy is one of the fastest developing renewable energy technologies in the world and mainly onshore. Wind is among the cheapest renewable sources per unit of electricity produced. Analysis indicates that a network of land-based 2.5MW wind turbines could supply over 40 times current worldwide electricity consumption. Wind energy generation market is continuously growing worldwide (Idris, et al 2012).

A non conventional alternative energy to supply power to homes and potentially communities not currently linked to national grid is wind energy. Windmills were used in Nigeria as early as the mid 1960s. However, with the fall in fossil prices in 1970s, wind power became less appealing alternative. Investment in windmills ceased and the infrastructure became mundane. The existing infrastructure is obsolete, but research into the feasibility of wind power in certain regions has suggested the physical potential for this type of power generation is high in some regions of Nigeria.

Total wind potential energy capacity 19,043 (MW) and potential generation of 50,046mwh/yr in Nigeria shows immense prospect when fully exploited. Specifically in regions with an adequate wind presence, the amount of potential power is dictated by the size of the windmill. Windmills vary in size with small windmills used to pump water or provide power for cooking and refrigeration. Medium windmills provide electricity for one or more homes. Large windmills or utility scale windmills are capable of providing power for entire communities. Often these larger windmills are connected to a mini-grid as to reduce the overall demand for conventional energy

Table 3: wind potential energy in Nigeria

Selected states	Area (km ²)	Windy Area (%)	Effective Wind Area (km ²)	1% Area (km ²)	Potential capacity (MW)*	Potential Generation (MWh/yr) **
Adamawa	37,957	45%	17,080	170	854	2244
Bauchi	48,197	50%	24,098	240	1204	3166
Borno	72,767	100%	72,767	727	3638	9561
Gombe	17,428	100%	17,428	174	871	2290
Jigawa	23,415	100%	23,415	234	1170	3076
Kaduna	44,217	60%	26,530	265	1326	3486
Kano	20,389	90%	18,350	183	917	2411
Katsina	23,822	100%	23,822	238	1191	3130
Kebbi	36,320	25%	9,080	90	454	1193
Plateau	26,539	90%	23,885	238	1194	3138
Sokoto	32,146	90%	28,931	289	1446	3801
Taraba	59,180	40%	23,672	236	1183	3110
Yobe	44,880	100%	44,880	448	2244	5897
Zamfara	33,667	80%	26,933	269	1346	3539
TOTAL	580,824	76%	380,871	3,808	19,043	50,046

Source: Nigeria Climate Assessment, LCD Power Sector, preliminary report (WBG /Lumina Decision Systems, 2011)

Comparing the potentials that Nigeria has in this sector is greater than the present installed capacity in UK, Brazil and Egypt in 2014. China remains the greatest in wind energy with about 114,763MW installed wind capacity. Probably, this explains the tremendous growth in China (See Table 4).

Table 4: Total Installed wind power and generation capacity of some selected counties in 2014

Country	Installed capacity (MW)
China	114,763
United Kingdom	12,440
Brazil	5,939
Turkey	3,763
Egypt	610
Rest of Africa and Middle East	129

Sources: Global Wind Energy Council, 2014 and Wind Energy Report (GWEC 2013)

Innovation in wind power technology will definitely prove cost effective in the long-term. Further, Nigeria would be able to lower some of the initial costs after the first installations by installing and maintaining the windmills in-house in the future. This will significantly help in achieving secure and stable energy supply.

ii. Solar Energy

Another cheap clean energy source capable putting Nigeria on the right path of attaining security in the energy sector is the solar energy. Photovoltaic cells made from silicon alloys can convert sunlight into other forms of energy, such as heat and electricity. Steam generators using thermal collectors to heat water sometimes convert even larger amounts of solar energy into electricity. Solar power can help mitigate capacity challenges on local power grids and reduce greenhouse gas emissions by decreasing the use of electricity from power plants that use fossil fuels.

Sambo (2005) states that there are many solar thermal systems especially solar water heaters and solar dryers in use in many parts of the country. Solar cookers, solar stills, solar chicken brooders and solar thermal refrigerators developed by research centres and confirmed to be of practical application. Solar photovoltaic applications have considerable current installation in the country and these include solar photovoltaic water pumping systems, solar powered vaccine refrigerators as well as telecommunication repeater stations that are powered by solar photovoltaics. Solar power plants that can supply electricity to entire villages and also others that can power on stand-alone basis should be widely promoted to assist such projects such as rural health centres television cinema centres and other recreational attractions. Investment in this worthwhile venture will definitely be a right step in right direction.

iii. Small Hydro Power

Small hydropower in Nigeria refers to small hydropower generation with a capacity of 1-10MW. Nigeria is blessed with large rivers along with some natural falls. Nigeria's rivers have the capacity to generate about 11,000 MW of electricity, of which 19% are currently being developed. Existing hydropower plants in the country need rehabilitation due to lack of adequate maintenance (Aliyu and Elegba, 1990; ECN, 2010). There is no standard definition which size of hydropower is small or large, but Table 1 shows classification of ranges of hydropower along with their capacity.

Table 5: Categorization of Hydro-power

SCALE	CAPACITY RANGE
Large	>100mw
Medium	50 – 100mw
Inter medium	10 – 50mw
Small	1 - 10mw
Mini	0.5 – 1mw
Micro	<0.5 mw

Source: Adapted from Bada 2011.

Small hydro plants support decentralization and distribution network with low voltages, Short planning horizons and construction periods with the use of local available materials and skills which are readily available in Nigeria. This source of energy can provide continuous availability of power any time demanded, cost effective and is environmentally friendly. Small hydro has not received the needed attention as shown by the current installed capacity in Nigeria.

Table 6: Installed Capacity of Small Hydro Plant in Nigeria

S/N	River	State	installed capacity (MW)
1	Bagel (1)	Plateau	1.0
2	Bagel (2)	Plateau	2.0
3	Kurra	Plateau	8.0
4	Lere (1)	Plateau	4.0
5	Lere (2)	Plateau	4.0
6	Bakalori*	Zamfara	3.0
7	Oyam*	Ogun	9.0
	Total		31

Source: UNIDO/ECN (2003). *Under refurbishment

Total installed capacity of all sites in Nigeria is only 31. This is grossly inadequate given unharnessed potential of 743.2 in Table 5.

Table 6: Potential capacity of small hydro plant in Nigeria

STATE	RBDA	NO. of Sites	Potential Capacity (MW)
Sokoto	Sokoto Rima	22	30.6
Katsina	Katsina	11	80.0
Niger	Niger	30	117.6
Kaduna	Niger	19	59.2
Kwara	Niger	12	38.8
Kano	Hadeija-jama're	28	46.2
Borno	Chad	29	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
Cross River	Cross River	18	28.1
TOTAL		278	734.2

Source: adapted from (Manohar & Adeyanju, 2009)

There are great potentials that need to be harnessed in small hydro renewable energy source as seen in the above table 6. Untapped potential of 734.2 can augment the current energy insufficiency of the country

4.3: Challenges of Penetration of Renewable Energy (RE) Technologies in Nigeria

Following the above information on renewable energy potentials in the Nigerian nation, it is pathetic that the country is still groaning under severe energy poverty. The apparent applications, installations and level of utilization leave much to be desired of the needed quantum for consequential economic growth and overall prosperity. The principal hindrances that require urgent attention for the country generates thousands of megawatts from solar photovoltaics, small hydro and wind electricity conversion systems include:

i. Lack of Adequate Understanding and Consciousness of the worth of RE Technologies

Despite the campaigns by the Energy Commission of Nigeria (ECN) and the Energy Research Centres in educating the general public on the significance of RE technologies, much is left to be desired. Majority of the populace in the Nigerian economy is not conversant with the benefits RE technologies. The rural communities are the worst hit by this ignorance making the provision of the energy needs for socio-economic progress of the country worst off.

ii. Insufficient Financial and Fiscal inducements

Contrary to what is obtainable in Germany, Spain, China and India that have substantially adopted a diversity of financial and motivations/incentives that led to the growth their respective RE markets and industries, Nigeria's lacks these important factors to enhanced the development of the supply and demand components of the RE energy market and particularly for electrical elements.

iii. Dearth of Human Capital and Infrastructural Capacity

The technical know-how to build up, install and handle renewable energy is laughable in the country. This situation is further made worst by reliance of country on expertise from outside the country. The infrastructure for the construction and supply of components of renewable energy systems is critically inadequate or even unavailable in the country

iv. Inadequacy of RE Data for Plan implementation and Investment Decision

Though this factor is not peculiar to RE alone, the whole the nation lacks trustworthy RE resource record to aid in the plan, creation and monitoring of RE technologies in all the parts of the country. In addition, such records, which are indispensable in taking investment decisions and in particular for the electricity industry, is absent.

v. Intermittency of RE Resources

All RE based electricity generation systems produce intermittent or cyclic outputs. The challenge to this global problem is the development of energy storage and system management during periods of lack of resource and this adds to the complexity of the systems.

vi. High Start-Up Investment Outlays

In comparative terms, RE electricity systems are characterized by huge preliminary cost when compared to the investment cost of traditional systems (non-renewable). This can be attested by the significant attention at international scene in advanced countries where tremendous research and development efforts aimed at lowering initial cost of RE have started reducing the cost figure.

vii. Insufficient Policy and Organizational Structures

It is evident that virtually all the countries that have realized enormous successes in the large scale utilization of RE technologies achieved that by improving their RE policies into a handful of laws and regulations plus what is commonly known to as the feed-in-tariff which provides preference to electricity generated from renewable energy. At present in Nigeria, increasing and meeting global practice seems elusive. Disjointed duplication of functions by many Ministries, Departments and Agencies in executing RE projects is a problem to successful implementation and evaluation of success.

4.4: Prospects of Energy Security in Nigeria in 2050

In 2010 Nigeria's population was estimated at 158,259,000 and is projected to be between 254,000,000 (low variant) and 326,000,000 (high variant) in 2050. The most realistic, not by any means less shocking, estimate of Nigeria's population in 2050 is 289,000,000 (medium variant) (ECN, 2010; Sambo, 2012). The world will be an unusual place in 2050. Technology will rule virtually every aspect of life, and because there will be more people living on this planet, it will also be a very competitive place. Renewable energy will mostly power our way of life, good old oil (if Nigeria still has any left) will be on the decline, if not already out as the primary energy source.

Several actions needed to reduce these harmful gases are the same that would be needed to generate more electricity, create more jobs and reduce local environmental problems. The benefits of greenhouse gas emissions reductions become an added bonus. Nigeria's best opportunity to reduce these gases is from ending gas flaring and in addition adopting a 30 percent renewable portfolio standard. Latest available statistics show that gas flaring accounts for 31.4 percent of a total 54.9 percent of emissions from Nigeria's energy sector (Oisamoje, & Oisamoje, 2013). Making this currently flared gas available for electricity production will be the needed tonic for solving the current power crisis. Also, continuous investments in abundant sources of renewable energy, stipulated in the Renewable Energy Master Plan would assist in addressing energy security in 2050. The country should apply its oil wealth to develop a broader-based economy with better infrastructure and institutions, which will support long term productivity growth. By diversifying its energy sector in favour of wind, solar and small hydro, Nigeria can realize its potential by 2050.

5. RECOMMENDATIONS AND CONCLUSION

The provision of adequate, affordable, accessible and reliable energy is essential for a sustainable economic growth. Diversification of Nigeria's energy sector to have a fair mix of Renewable and Non-renewable energy alternatives will expand Nigeria's energy base and increase the energy security position of the country. For this reason, regions identified with comparative advantage in the natural endowment of small hydro, wind and solar energy potentials should be optimally harnessed. Prioritization in respect of energy distribution to industrial, commercial and residential should be efficiently determined. All relevant policies and institutional arrangements should be put in place to eliminate constraints to deployment of non conventional energy technologies in Nigeria. Public- Private Partnership in terms coordination, financial investment and long term goal of the economy needs to be appropriately ascertained. There should be more incentives for private sector investments in all renewable energy technologies in the country. The renewed political will of current administration towards renewable energy in the rural communities be expanded and sustained. Nigeria will be out of energy dilemma if the below recommendations are put in place:

i. Policy Coherence and Consistency

Stability, policy consistency and transparency in the political environment are critical to the success of achieving energy security through renewable energy options. Total institutional reform of the current policy on electricity generation and distribution

should be overhauled to create a fair way for the whole group of stakeholders in the emerging power sectors within and outside Nigeria.

ii. **Technical Concern**

The most dangerous challenge facing Nigeria's energy sector at present are technical issues. Inadequate maintenance of existing power plants has led to an insufficient electricity supply. There is a lack of standards, codes, and certification. The educational system of the country is too broad and the curriculums are not tailored to the need of the environment at large. Right technology toward promoting renewable energy, relevant personnel, spare parts for the new technologies and integrating non conventional power into our tertiary institutions should be pursued as national virtues.

iii. **Socio-Economic Concern**

A purposeful investment in non conventional technologies is needed. An important policy effort is the articulation of right economic incentives to support domestic investment of efficient and environmentally cleaner technologies. The capital stock should have a pre determined time frame to ensure efficiency improvement in renewable energy technology and the enhancement of the nation's power industries. Therefore, in order to make electricity available to consumer, it will require utilization of the renewable energy resources in the country.

iv. **Regional and Ecological Concern**

In achieving a balanced mixed of energy in the country that can guarantee stability in the energy sector, natural endowment of every region should be optimally exploited to boost the total energy to be generated and distributed in the country. In this vein, wind and solar energy could better be harnessed in the North West and east of this country. When articulating strategies for diversifying the energy sector, government should consider the cost-benefit of the technology in respect of regional characteristics before adoption.

v. **Marketability Concern**

Nigeria's long-term security ultimately requires intelligent public policy in support of a vibrant domestic market for renewable energy. Our dependence on fossils and hydro sources of energy has made Nigeria vulnerable to ethnic militants and religious fundamentalists spawned by despotic regimes and elites whom our government has in some cases covertly placed in power. Despite the fact that there are enormous market potentials for renewable energy technologies in Nigeria both locally and internationally, the federal government should as a matter of necessity should lead by example. It will be expedient if all ministries and parastatals at federal, state and local government sourced their energy needs from the non conventional sources (wind, solar or small hydro power). This to a large extent will promote renewable energy in Nigeria, create market and reduce demand on the national grid. This will definitely promote energy security in Nigeria.

vi. **Regulatory Concern**

In order to reduce overloading of the national grid and abuses, there should be a conscious selective distribution of power. Recreational areas need to be powered with non conventional energy while industrial areas with large hydro and other conventional energy sources at the initial level. Country sites should be powered with renewable energy sources to permit industrial locations fuelled with the conventional energy as obtainable in many developed nations. Sound climate change governance structure that will maximize synergy among the three key stakeholders, government, consumers and producers should be entrenched.

In line with the above, investment in non conventional/renewal energy is a viable opportunity not only for mitigating Green House emission however to countries like ours a tool of power diversification and for achieving energy security. The utilization of clean energy sources would certainly place Nigeria on the course to attaining energy security for the present and future generation. This has helped developed countries and would definitely assist Nigeria a well as its developing counterparts to take complete advantage of the of these abundant free gift of nature to advance her economic and ecological drive to becoming one of the most developed nation in the world in the nearest future.

ACKNOWLEDGMENTS

We sincerely appreciate all authors for their enormous contributions towards making this document a worthy addition to the body knowledge.

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