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# Integrating Renewable Energy into Nigeria's Energy Mix: Implications for Nigeria's Energy Security

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**DECLARATION**

I, Oluwatoni Onyeka Obideyi, declare that this thesis is a result of my research investigations and findings. Sources of information other than my own have been acknowledged and a reference list appended. This work has not been previously submitted to any other university for award of any type of academic degree.

Signature……

Date…….

*Dedicated to my mother- Florence Ngozi Bolarinwa of blessed memory. Thank you for the positive mentality and strength you instilled in me. You are indeed missed*

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**List of Abbreviations**

| | |
|---|---|
| APERC | Asia Pacific Energy Research Centre |
| DISCOs | Distribution Companies |
| ECN | Energy Commission of Nigeria |
| ECOWAS | Economic Community of West African States |
| ECREEE | ECOWAS Centre for Renewable Energy and Energy Efficiency |
| EPSRA | Electric Power Sector Reform Act |
| GATT | General Agreement for Tariff and Trade |
| ICEED | International Centre for Energy, Environment and Development |
| IEA | International Energy Agency |
| IEDN | Independent Electricity Distribution Network |
| IKEDC | Ikeja Electricity Distribution Company |
| IMF | International Monetary Fund |
| IRENA | International Renewable Energy Agency |
| GDP | Gross Domestic Product |
| GENCOs | Generating Companies |
| GW | Gigawatt |
| LHP | Large Hydropower |
| MW | Megawatt |
| NACC | National Alliance for Clean Cookstoves |
| NAEE | Nigeria Alternative Energy Expo |
| NBET | Nigerian Bulk Electricity Trading |
| NCC | Nigerian Coal Corporation |
| NEAP | National Energy Efficiency Action Plans |
| NEMP | National Energy Master Plan |

| | |
|---|---|
| NEPA | Nigerian Electric Power Authority |
| NERC | Nigerian Electricity Regulatory Commission |
| NGC | Nigerian Gas Company |
| NLNG | Nigerian Liquefied Natural Gas |
| NNPC | Nigerian National Petroleum Corporation |
| NPC | National Population Commission |
| NRC | Nigerian Railway Corporation |
| NREAP | National Renewable Energy Action Plan |
| NREEEP | National Renewable Energy and Energy Efficiency Policy |
| OECD | Organization for Economic Cooperation and Development |
| OPEC | Organization for Petroleum Exporting Countries |
| PHCN | Power Holding Company of Nigeria |
| REA | Rural Electrification Agency |
| REEEP | Renewable Energy and Energy Efficiency Project |
| REMP | Renewable Energy Master Plan |
| RETs | Renewable Energy Technologies |
| SERC | Sokoto Energy Research Centre |
| SHP | Small Hydropower |
| TCN | Transmission Company of Nigeria |
| UNDP | United Nations Development Programme |
| UNFCCC | United Nations Framework Convention on Climate Change |

**ABRSTRACT**

With increased awareness in the importance of energy to economic and social development, the need to attain energy security has increasingly become a paramount factor in the energy agenda of countries. To expand their energy options and reduce dependence on fossil fuel resource countries are exploiting and including renewable energy into their energy mix. This is especially pertinent for countries that are heavily dependent on fossil fuels and have poor energy access like Nigeria. Despite its huge resources, its energy sector is grossly underdeveloped, thereby creating an energy security gap. As such, this study examines the share of renewable energy in its current mix and analyses the possible effect of renewables on Nigeria's energy security if fully exploited.

The study uses qualitative methods to assess the state of energy security, the renewable energy potential and integration level as well as its effect the energy security of the Nigeria. An energy security assessment framework was developed to tailor the peculiarities of the Nigerian energy system and this serves as a guide for this study. Existing literature focus on analyzing the state of energy security in Nigeria with focus on how all source of energy can by utilized, however, this study gives an updated status of energy security, renewable energy integration in Nigeria and most importantly projects the possible impacts renewable energy integration can have on its energy security.

The study reveals that the Nigerian government is conscious of the challenge of energy security faced by the nation and there are attempts made by the government and private individuals and institution to increase the share of renewable energy in the energy mix. This is met by several challenges identified by this study, hence renewable energy integration has been too slow. The study argues that the government lacks implementation of renewable energy policies and need to include more renewable energy incentives. It also suggests the need to increase renewable energy incentives and ensure rapid completion of renewable energy projects in the nation**.**

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# CHAPTER 1- INTRODUCTION

## 1.1 Introduction

Energy security is a growing concern in many countries of the world both developing and developed countries. Energy security, in general, implies adequate, reliable and affordable energy for all (Ölz & Kirchner, 2007). Globally, energy policies and strategies of energy systems in many countries are increasingly directed towards achieving a higher level of energy security. This is in response to the need to continually ensure energy supply in the face of increasing energy demand, rapid depletion and need to decrease the "risk of disruptions and volatility of energy supply and price" associated with conventional sources (International Renewable Energy Agency (IRENA), 2015 p.1). In addition, this invariably led to increased awareness of the unsustainable nature of an energy system highly reliant on conventional sources of energy; thus, countries are expanding their energy mix by diversifying the sources of energy to include local renewable sources of energy (ibid). The share of renewable energy in global energy mix has therefore increased over the years, thereby boosting the relevance of renewables to energy security (Ölz & Kirchner, 2007).

A nation cannot be considered as developed if it lacks a balanced, reliable and sufficient energy mix because energy is crucial for basic human needs to be met. This is emphasized in United Nations Sustainable Development Goal on energy which calls for clean, affordable and sustainable energy for all. However, many nations in Africa are developing nations due to lack of reliable and sufficient energy. According to the International Energy Agency (IEA, 2014a), Africa accounts for a mere 4% of World Energy consumption yet it accounts for 13% of the World population. However, there has been 45% increase in energy use and rapid economic growth in Sub-Saharan Africa from 2000 to 2012 (ibid). There is a mismatch in energy demand and supply in many Sub-Saharan African countries because increased use and demand for energy is met by inadequate supply as indicated in low access to electricity, high reliance on biomass, high energy prices and use of expensive alternative sources such as generators. Therefore, energy demand outweighs energy supply in most countries in sub-Saharan Africa. Furthermore, lack of adequate energy can be one of the reasons why Sub-Saharan Africa accounts for a high percentage 43% of the World poor (World Bank, 2011).

Nigeria is one of the Sub-Saharan African nations with extreme mismatch in energy supply and demand. Nigeria is the most populous country in Africa, the 8$^{th}$ most populous country in the World with rapid population growth. Though, Nigeria is the biggest oil

producing country in Africa and the 4th leading exporter of liquid natural gas in the world as at 2012, yet its grid electricity mix relies mainly on thermal plants (Emodi & Boo, 2015). Currently, the nation's primary energy supply excluding electricity, consists of biomass and waste (80.9%), oil (5.7%), natural gas (9.4%) and hydro (0.4%) (GIZ, 2015; SE4ALL, 2016). Nigeria is a nation with energy resources that are not fully tapped, it faces the problem of inadequate infrastructure, vandalism and oil theft (IEA, 2014b; Olaoye et al., 2016). According to International Energy Agency (IEA) report of 2015, Nigeria is one of the countries with the least energy access; it has an utterly weak electricity sector which was ranked 187 of 189 countries by the World Bank in terms of access.

With all the challenges listed above, the nation continually faces the challenge of energy security. Nevertheless, with the growing population, increase in energy demand and high fluctuations in global oil price, energy security will continue to decline and the nation will continue to remain a developing nation if more reliable energy sources are not incorporated into its current energy mix (IEA, 2014b; Oyedepo, 2012a). This has led the government and other international organizations to introduce certain renewable energy projects such as solar electrification, biofuel production and wind power projects in the country. The aim of this paper is to understand what implications integrating renewable energy into the current energy mix will have on the energy security of the nation.

**1.2 Significance of Study**

Nigeria is a nation blessed with abundant energy resources such as oil, coal, gas and lignite; with high amount of renewable energy resources such as solar, wind, hydroelectricity and biomass. As at 2006, Nigeria was estimated to have the tenth largest reserve of crude oil which contributes to 25% of its GDP and is the second highest contributor after crop production (Oyedepo, 2012b). Seventy percent (70%) of Nigeria's federal revenue is derived from energy (mostly oil and gas) (Sambo, 2009). It is pertinent to note that several development and security projects depend largely on this revenue (ibid). Despite these abundant resources stated above, the nation's energy sector is ridden by crisis.

Nigeria has been known to always experience the problem of inadequate power (electricity) generation. Between 1960-1979, hydro and thermal power plants were developed. Yet, there was no significant investment in developing infrastructures to increase power production capacity nor proper maintenance of the established plants till 1999 when the incumbent government launched a power sector reform (Sambo, 2008; Uzoma, Nnaji, &

Nnaji, 2012). Electricity generation increased by just 10% between 1985 and 2000, this is incomparably low as other countries like Vietnam and Malaysia increased generation by 342% and 243% respectively within the same period; it therefore not surprising that only about 40% of the Nigerian population have access to electricity as demand outweighs supply (Adenikinju, 2008; Oyedepo, 2012b). According to Oyedepo (2012a), about 70% of the rural population in Nigeria rely highly on the use of fuel wood due to lack of access to electricity and petroleum produce. Hence it is clear that lack of access and generation major challenges faced by the energy sector in Nigeria.

The Nigerian energy sector highly relies on fossil fuels for secondary energy such as transportation, residential (kerosene for cooking and lightning, diesel and petrol to power household generators), to generate electricity for commercial and industrial enterprise and generation of utility-scale electricity (Edomah, 2016). Crude oil has been the most explored while natural gas production has witnessed the most rapid growth in recent years in Nigeria (ibid). Nigeria has commercially produced crude oil since 1958 and it constitutes a major source of income for the nation through export. Though, crude oil generation has steadily increased over the year, Nigeria experienced decline between 2005 and 2009 due to vandalism and disruptions caused by militants in the Niger Delta region. In addition, the nation also faces the challenge of environmental damage, gas flaring and oil theft caused by vandalism in fossil fuels production (Emodi & Boo, 2015). It is however pertinent to note that fossil fuels are exhaustible energy resources and they operate based on reserves which can be exhausted as well and there has been increasing use of fossil fuels through gas fired power plant for electricity generation (Edomah, 2016). This implies that high reliance on fossil fuels is not a viable for the country in medium-term and long-term; hence, the need to integrate renewable energy sources is inevitable.

The Nigerian government has also recognized the need for integrating renewable energy sources by establishing certain renewable energy projects as stated earlier. However, there lack of studies that have report on the progress of these projects in relation to ensuring energy security in the nation. Thus, the significance of this study is to establish what the Nigerian government perceives to be energy security, what impact integrating these on-going renewable energy projects has had so far on Nigeria's energy security and also the impact if fully integrated.

## 1.3 Objectives

The objectives of this study are to ascertain what energy security implies to the Nigerian government, investigate how Nigeria arrived at the current energy mix, discuss the available renewable energy options and current renewable energy projects as well as their implications for energy security in Nigeria. In fulfilling the stated objectives, the following research questions will be discussed:

- How has Nigeria's energy mix evolved to its current state?
- What does energy security mean to the Nigerian government?
- What are the available renewable energy sources in Nigeria?
- What implications will renewables have on the national energy security if integrated into the current energy mix?

## 1.4 Organization of Thesis

This thesis is organized as follows: Chapter 2 gives an overview of differing views of energy security as a concept, and then develops the indicators for energy security assessment framework adopted for this study. Chapter 3 presents the methods of research used to conduct this study and why the methods were chosen. Chapter 4 presents the findings in form of an assessment of the Nigerian energy system in terms of its current energy mix and the state of energy security. Chapter 5 discusses the findings in relation to other relevant energy systems in the world and chapter 6 concludes with implications of renewable energy integration on energy security in Nigeria and recommendations.

## CHAPTER 2- ANALYTICAL FRAMEWORK

### 2.1 Introduction

The importance of the energy security of a nation to its economic growth and development cannot be overemphasized; as over the years the growth in population and changed consumption pattern has ultimately led to increased demand for energy. Energy is necessary for "enhanced human welfare, sustainable development and proper functioning of the economy" (Khatib, 2000 p.1). Hence, energy security has become an integral part of political and economic agendas for countries all over the world both in terms of national policy and foreign policy. Cherp & Jewell (2013) states that any framework that is being adopted for the purpose of assessing energy security must first have a clear conceptual clarification of the definition of energy security for the purpose of the study. What then is energy security? What are the indicators used for determining the state of energy security in a nation? This section intends to answer both questions (as the concept of energy security has numerous varying definitions) by tracing the most profound historical moments that contribute to the most recent development in the concept of energy security.

### 2.1 Conceptualizing Energy Security

Energy security as a concept received the foremost attention in 1973 due to the reduction in the supply of oil by Organization of Petroleum Exporting Countries (OPEC) countries; this led to increase in oil price which inevitably resulted in economic crisis in oil importing countries, thereby bringing to bare the existing vulnerability in the energy system (Dyer & Trombetta, 2013). This period was dominated by fossil fuel, energy security was then narrowly defined as a curtailed reliance on the consumption and import of oil especially in large-scale oil importing countries and the Organization of Economic and Cooperation Development (OECD) (Khatib, 2000). Within the next two decades there was the struggle to restore the growth pace witnessed during the 1950s-1960s but this was difficult to achieve; thus leading to an objection to government regulation and intervention in the energy market (Chester, 2010).

Consequently, this led to substantial adjustments and restructuring in the oil and other energy markets such as: decrease in government intervention in other sectors of the energy markets which included gas, electricity and telecommunications; increase in competition through disintegration of monopolies which ultimately led to increase in suppliers; more flexible and transparent pricing system; and establishment of new trading systems encouraged by International Monetary Fund (IMF), General Agreement on Tariff and Trade

(GATT), etc. (Chester, 2010 p.2; Khatib 2000). It is pertinent to note that the stabilization during this period led to a reduction of interest in energy security by the academic body (Cherp & Jewell, 2014).

In the 2000s, there was a need for resuscitation as there were new challenges that threatened the energy security especially in other energy markets. Also, increase in energy demand due to rapid increase in world population especially in Asia led to new threats to energy security such as regional shortages, natural disasters (such as hurricane Katrina which caused an interruption in the flow of electricity, oil and gas in the United States), possible sustainability of the existing energy system, climate change and environmental issues, disruption of gas supplies piracy and terrorist attacks, decrease in reserves due to conflict or war e.t.c (Dyer & Trombetta, 2013; Khatib, 2000; Yergin, 2006).

Energy security has thus evolved from the narrow definition of reductions in oil consumption and import to encircling an extensive scope of issues and an approach that tends towards human security (Sovacool & Brown, 2010). It is now closely intertwined with modern energy policy problems such as ensuring impartial access to energy and combating the threats brought about by climate change (Goldthau, 2011). Due to the aforementioned, energy security literature is one that is growing rapidly in the academic world with various definitions and various angles from which it can be analyzed; therefore, making the concept referred to as vague, blurred, elusive, etc. (Chester 2010; Löschel et al., 2010; Lucas et al. 2016; Winzer 2012). Analyzing some of these definition is important to have a better understanding of the concept and to have an overview of how it is utilized in this thesis.

Energy security can be analyzed at four major levels; global, regionally, nationally and individually (consumer). According to Khatib (2010), energy security on the global level can be defined as securing sufficient energy resources and prospects that would meet the lifelong needs of energy in the world; at the regional level energy security would imply ensuring continual growth of strategic reserves at the regional level and encourage partnerships through regional cooperation. He explains further that at the national level energy security would mean making available all forms of energy sources required for energy consumption and ensuring security of supply while at the individual/consumer level it will imply meeting the energy needs/ demands of the individual by providing adequate supply. Though energy security can be analyzed at various levels, these levels are not completely independent; they are inter-related and can be interdependent. A good example is that for consumer needs to be met there has to be security of supply at the national level and sometimes that global level.

Energy security can be defined as the security of supply; Winzer (2010) is of the view that energy security if streamlined to mean energy supply continuity, it would then be a concept that can be accurately measured and also there would be no room for overlapping with other issues like sustainability, climate change, economic efficiency e.t.c. Security of supply (uninterrupted energy supply) is a major component of achieving energy security, it is critical for appropriate operations for an economy (Correljé & van der Linde, 2006). Deficiency in energy supply caused by imbalance in 'demand and supply or partial or complete disruption of entry supplies' can endanger security of supply (Scheepers et al., 2007 p. 19). Some of these scholars however note that security of supply must include sufficiency of supply and it must be affordable, accessible and stable (Intharak et al., 2007; Jegen 2009; Bielecki 2002). Mitchell C. and Watson J. (cited in Mitchell et al. 2013) are of the view that energy supply is an important aspect to energy security but it is not a synonymous relationship as noted by Winzer (2010); it should also include ensuring a balance in energy supply and demand, ensuring access to affordable energy and putting environmental factors into consideration in the pursuit of energy security.

Energy security can also be defined in terms of security of demand but this applies more to energy exporting countries as this constitutes the bulk of the government revenues (Johansson 2013; Yergin, 2006). For these countries, security of demand may hold the same importance as security of supply as the economy and national budget are majorly dependent on the revenues; a good example is Saudi Arabia 87% of its revenues, 42% of its GDP and 90% of its revenues from export comes from its petroleum sector (CIA, 2017; Johansson 2013). Hence it is important to ensure that there is continuous demand for their energy products to avoid instability of income; however, Johansson (2013) further states the possible existence of conflict in interest between the energy producers/ exports and the consumers who prefer low energy price but still want adequate supply to meet their demand while the latter makes more earning from high price but still needs to ensure security of demand.

In relation to energy supply security, there is the diversification dimension of energy security. Jegen (2009) confirms that diversification is interwoven with security of supply. Diversification of energy mix with focus on energy supply sources, resources and technologies is an important aspect of energy security; it helps to avoid problems that can threaten the security of energy supplies as it expects for all options for energy sources to be kept open (Bielecki 2002; Lucas et al., 2016; Stirling cited in Sovacool, 2011). According to Yergin (2006 p.70), diversification has been a crucial component in achieving energy

security but 'diversification is not enough'; there are other components such as terrorism, supply-chain vulnerabilities, global energy trade and integration of major new economies into the world market. Nevertheless, he further notes the importance of diversification of supply as this reduces the effect of interruption in supply from one energy source due to the availability of other alternative sources. Diversification in energy security should also include diversification of energy technologies, geographical dispersal of energy facilities, diversification in energy control and production, diversification of ownership of energy companies, etc. (Sovacool & Mukherjee, 2011 p. 6).

It is important to state that, energy security can vary from country to country. Yergin (2006) states that energy security for countries that are developed would naturally mean ensuring adequate supply is available at reasonable prices while for developing countries it would mean ensuring that fluctuations in global energy price has little or not effect on their balance of payment; for energy-exporting countries like Nigeria, Russia, Norway etc.; it would mean sustaining security of demand as energy export tends to account for a bulk share of government revenues. He further reiterates that, a country's view of energy security is what defines its long term energy policies as these countries have different varying interpretations of the concept.

A good example is the United States congress definition of energy security as "a future where abundant, reliable, and affordable energy is produced with little impact on the environment and no dependence on the goodwill of hostile nations" (US Congress in Sovacool, 2011 p. 5). This informs United States focus on alternative renewable energy/ sources with less reliance on imported oil. However, in Brazil, there has been times where energy security implies energy independence with politicians encouraging increase in import of fossil fuel and reducing the use of alternative renewable energy sources (Winzer, 2012). Also, analyzing energy security in terms of energy independence implies strengthening energy security by striving for decrease in reliance on import; this is a major goal championed by the United States (Månsson et al., 2014)

Other forms of analyzing energy security that will not be discussed fully in this thesis are energy efficiency, energy poverty and energy storage. In terms of energy efficiency, it can help enhance energy security as it promotes productive use of existing energy resources and decreases 'investment in energy infrastructure' (Trudea N. and Taylor G. cited in Sovacool 2011). Energy security in relation to household focuses on energy poverty; it involves access

to energy and affordability which has been mentioned in various definitions. Pachauri S. in Solvacool (2011) defines energy security as "access to secure, stable, and reliable supplies of modern energy available at affordable prices in amounts adequate to meet demands for energy services in full so as to ensure human health and wellbeing" (p.191). Lastly energy storage in relation to energy security can include "sufficient space production capacity, strategic reserves, backup supplies of equipment, adequate storage capacity along the supply chain, and the stockpiling of critical parts of electric power production and distribution" (Yergin, 2006 p. 8).

It is worthy of note that the concept of energy security has developed into a concept that pays increasing attention to global warming and environmental pollution. According Jegen (2009), to define energy security is to include reduction of pressures on the environment and producing energy that is environmentally friendly. Therefore, energy security can be said to include 5s which includes: supply which implies having energy resources including renewable and alternative energy sources available; sufficiency- implies having adequate supply and service from these sources; survivability- will remain resistant and durable when faced with vandalism or disruption; surety- accessible to all; and sustainability- implies ensuring limited waste and environmental preservation (Kleber, 2009).

According to Valentine (2011), though energy security as a concept has evolved from having sufficient access to traditional flammable sources of energy like wood and coal to ensuring access to modern alternative renewable energy sources, it is still based on three main pillars: affordability, resilience and availability. In terms of affordability, energy security implies the ability for a nation to maintain reasonable prices regardless of the increase in the cost or major global price fluctuations of fossil fuel as seen in the last decade; resilience implies that energy security can be achieved not only by safeguarding the current energy reserves but also fortifying the current energy mix against any disruptions; and availability implies that energy security is only possible if sufficient energy is available and accessible to all by increase the sources of energy in the current energy mix (Sovacool, 2011; Valentine, 2011).

Jegen (2009) defines energy security as having available energy resources in sufficient supply through diversification at affordable prices (fair for most people), publicly accessible to all citizens and having a clear difference between long-term and short term security needs. This definition is applicable to this study, energy security in Nigeria will

mean that there is available energy in adequate supply through diverse sources in its energy mix but ensuring that it is affordable and accessible to all Nigerians with the aim of clearly differentiating between Nigeria's long-term and short-term goals. For this study, energy security definition is complemented with some points from Shrestha & Kumar (2008) definition of energy security which includes available clean, sufficient and affordable diverse energy that supports economic growth and poverty alleviation. Hence analyzing energy security in Nigeria would look into how clear, affordable and accessible energy can improve economic growth and reduce poverty.

**2.2 Measuring Energy Security**

Measuring energy security can be quite complex as there is no particular set of indicators that can encompass all the various definitions of energy security and its value cannot be quantified by putting a price on it (Cherp & Jewell, 2013; Lucas et al. 2016). It is important to note that there have been various quantitative and qualitative measures of energy security, quantitative indicators measure the performance of energy security covering issues like cost of energy, energy intensity, ratios etc. while qualitative indicators focus on aspects that would be tough to quantify such as governance and geopolitics. But for the purpose of this chapter, it is important to state some of the most common indicators which sometimes overlap and as seen in several literatures on energy security indicators.

The Asia Pacific Energy Research Centre (APERC) in its 2007 report, adopted 4 "As" that serve as indicators and important components of energy security; they include Availability, Affordability, Accessibility and Acceptability. Availability implies measuring the available energy resources in the region, its cost and how it can be tapped to its full potential but with focus on fossil fuels and nuclear energy; accessibility focused on examining how accessible the energy resources are in the region and how supply can be secured while affordability meant measuring how profitable energy investments in the region will be in terms of oil prices and cost of infrastructure; lastly acceptability is concerned with the environmental issues in the energy system with emphasis on its main energy sources for the next century: coal, nuclear and unconventional fuels (Intharak et al., 2007). These indicators can be measured as both qualitative and quantitative.

Martchamadol & Kumar (2012) in the analysis of various literature on energy security indicators, categorizes the indicators using four dimension: institution, social, environment and economy; these measures are used to evaluate energy security in terms of sustainable

development. Under the economic dimension, the most common across the literature was "diversity of supply of fuel types and suppliers" as the first and "level of energy import" as the second (p. 4). The institutional dimension focused on political instability, rule of law, regulatory, level of corruption, regulatory quality as indicators etc. while the social dimension uses equity, education, health and safety as indicators. Lastly, the environmental dimension has climate change as the most common indicator followed by air quality, water quality, etc.

Also Kruyt et al. (2009) focuses on distinguishing between simple and aggregated indicators for measuring energy security. These simple indicators include resource estimates (available energy sources), reserve to production ratio, import dependency, diversity of energy sources and suppliers, political instability, energy price, mean variance portfolio, share of zero carbon fuels, market liquidity and energy demand indicators. While aggregated indicators include Shannon Index, the Energy Security Index of the IEA, Supply-demand Index and Oil Vulnerability Index. Månsson et al. (2014) distinguishes between simple and complex indicators. The simple indicators include: primary energy supply (average production cost, cost fluctuations and available energy sources), upstream market and import dependency (risk vulnerabilities in diversity, financial portfolio and supply routes), vulnerability and resilience of infrastructure, macro-economic effects of price fluctuations and value of lost load (cost of power interruption). While the complex indicators include reserve to production ratios, domestic energy intensity and diversity of suppliers.

It is important to define some of the quantitative indexes. One of them is the Shannon Diversity Index; it exposes the extent of "knowledge of types/ events of long term energy insecurity" (Keels cited in Sovacool 2011). Stirling (1998) further subordinates the diversity index into three properties: variety, balance and disparity. Variety refers to the number of classifications into which the quantity (e.g primary energy in Mtoe) can be shared as the more the categories the greater the diversity. While balance refers to how varied the market share is across classification as this determines diversity and disparity refers to the degree of difference in the classification. Another popular index is Supply/Demand Index (S/D index) as adopted by Scheepers et al. (2007) involves analyzing the energy security of supply in the medium and long term and ensuring that it includes the "final energy demand, energy conversion and transport and the primary energy supply" (p. 21). It is imperative to note that a certain weight is usually allocated to quantitative indicators and an aggregation is done to have a composite energy security index.

The Oil Vulnerability Index is also an important quantitative measure of energy security as oil accounts for 35% of global energy demand (IEA 2006 in Gupta 2008). This index focuses on 7 indicators: three supply risk indicators and four market risk indicators; the supply risk indicators include ratio of domestic oil reserves to oil consumption, oil supply vulnerability and market liquidity while the market risk indicators include ratio of value of oil imports to GDP, ratio of oil consumption to total primary energy demand, ration of oil consumption to GDP and GDP per capita.

One important set of indicators that would be quite useful for this study are the themes of energy security as elaborated by (Ang et al., 2015). These themes include energy availability (deals with diversification, supply security, import dependency and geopolitical factors), energy infrastructure, energy prices (affordability), societal effects (energy access/poverty), environmental sustainability, energy efficiency (modern technologies and energy intensity) and governance (energy policies). These themes were adopted from various definitions of energy security and it is pertinent to note that though these themes have varied in the history of the definition of energy security, energy availability has always been a priority for energy security and environmental sustainability rose to the highest in the last two decades. (Sovacool & Brown, 2010) also list similar criteria for developing energy security indicators: availability, affordability, energy and economic efficiency and environmental sustainability. Indicators for availability include import dependency and extent of dependence on fuel products, indicators for affordability include retail electricity and available fossil fuel price, indicators for efficiency include energy intensity and per capita electricity use and the indicators for sustainability include $SO^2$ and $CO^2$ emissions.

Energy security is difficult to encompass into one definition, so is it even more difficult to try to come up with the standard indicators that can be universally accepted to measure energy security. Axon et al. (2013) acknowledges the complex nature of conceptualizing energy security and its indicators; but states that a set of indicators must be adopted and they must be tailored according to the accepted definition and unique energy environment to which it will be applied. In the process of doing this, one must be diligent in order not to be tempted to include sets of indicators that have readily available data and yet adds no reliable contribution when applied to the accepted understanding of energy security within the context it is being applied to (ibid).

In light of the foregoing, Cherp & Jewell 2013 state that any framework that is being

adopted for the purpose of measuring energy security must include 5 stages. The first as stated earlier is a clear conceptual clarification of the definition of energy security for the purpose of the study; second involves an outline of the vital energy systems which involves "resources, materials, infrastructure, technologies, markets and other elements connected to each other stronger than they are connected to the world" and they are crucial "for the functioning and stability of the society" (Dyer & Trombetta, 2013 p. 151). The next stage is establishing the possible vulnerabilities of the mentioned vital energy systems; at the fourth stage will include reviewing and identifying indicators for these vulnerabilities. The final stage of measuring will be illustrating the indicators to reveal the state of energy security. These stages will be adopted for analyzing the state of energy security in Nigeria

Nonetheless "there is no one ideal indicator" for energy security as the conceptualization varies and it profoundly relies on unique energy context which is being measured (Kruyt et al., 2009 p.1).

**2.3 Renewable Energy and Energy Security**

Renewable energies are energy sources whose supply is replenished naturally almost as quickly as they are utilized (Ellabban, Abu-rub, & Blaabjerg, 2014). They are sourced from the sun either directly in form of thermal, photo-chemical and photo-electric energy or indirectly in form of wind, hydropower and photosynthetic energy stored in biomass (ibid). These sources of energy are inexhaustible but the supplies can be exhausted if used faster than they can be replenished (Oyedepo,2012). Renewable energies however do not include energy derived from fossil fuels or waste derived from inorganic sources (ibid). Renewable energy technologies are used to convert renewable energy into forms of energy such as heat, electricity and fuels that can be utilized (Ellabban, Abu-rub, & Blaabjerg, 2014)

With global energy demand on the increase, constant improvement in modern energy technologies and increased awareness on the need to mitigate climate change, various countries are looking to increase energy supply and reduce interruption in supply through diversification of their energy mix to include alternative clean renewable energy sources. Between 2012-2015 "over 100 Gigawatt (GW) of new renewable capacity has been added each year, accounting for more than half of net capacity additions in the global power sector" (IRENA, 2015 p. 1). Also, over 144 countries have set renewable energy goals with some enthusiastic targets. China's renewable energy goal is to have renewable energy account for 20% of its primary energy supply by 2030. Denmark has a more aggressive projection of

having renewable energy account for all of its energy. Renewable energy is of great significance to energy security because as renewable sources increase in the general energy mix so does its importance to energy security (Ibid).

Fossil fuels contributes about 85% of the global energy production and it has contributed to industrial growth but it is finite and costly; hence, it is inevitably unsustainable (Mathews, 2014). Also the price of fossil fuels has become so unstable and this has an inordinate effect on the poor people and they bear the brunt of it since they are heavily dependent on liquefied petroleum gas and kerosene. Furthermore, fossil fuel has a ripple effect of government's inadequacies to fund healthcare, provide clean water and education, and other basic essentials for development. This is practically due to the increase in government's subsidies on fossil fuels (Flavin & Aeck, 2010). Renewable energy matched with continuous technology improvements and decrease in cost had provided several renewable energy alternatives that are tailored to allow poor people have access to modern energy utilities (ibid). Renewable energy through increment of the primary energy supply can help cutback the reliance on fossil fuels especially oil (Kinn U. in Althusmann & Ruppel, 2016)

Renewable energy will enhance sustainable energy supply thereby "reducing global poverty" (Kinn U. in Althusmann & Ruppel, 2016 p. 13). About 2 billion people in the world lack access to modern energy supply. This implies that they lack the favorable circumstances that will enable them eradicate poverty on their own (ibid). In addition, renewable energy can improve livelihood by providing jobs. In Europe there has been over 550,000 jobs created through renewable energy with a turnover of about 33.4 billion Euros in 2009 (Hinrichs-Rahlwes, 2013).

Furthermore, Lucas et al. (2016) presents five advantages of renewable energy. Firstly, unlike conventional energy facilities, renewable advantage is that unlike conventional renewable energies when decentralized have lower chances of insecurity in terms of "physical failure and sabotage (primary energy risk)" (p.2). Secondly, renewables (with the exclusion of hydropower) are fairly not as dangerous as conventional energies if an accident occurs. Thirdly, renewables are "'zero marginal cost' technologies that do not need 'fuels' to generate power, hence they are not influenced by fossils fuel price fluctuations in the international energy markets. Fourthly, renewables can serve a stabilizer of the fossil fuels price fluctuations as they are uncorrelated. Finally, "renewables could reduce energy vulnerability through the diversification of the energy mix regarding both technologies and

energy sources" (p. 2). Therefore, in terms of sustainability, risks identified with renewables are minimal compared to conventional energy sources (ibid)

Despite all the advantages stated above, renewables have their shortcomings as well. Ölz & Kirchner (2007) affirms by analyzing how the output variability of the respective renewables can hinder stable and reliable supply. Hydropower can experience seasonal variability in seasons that are dry or have little rainfall especially in areas that lack adequate reservoir capacity thereby making it difficult to have "predictable power supply". Solar photovoltaics can also have low output variability due to seasonal variation, regular variation from daylight to nightfall and temporary variation from fluctuating cloud cover. In terms of wind energy, there can be low output variability if there is inadequate wind speed or too much wind (turbines are stopped to reduce the chances of getting damaged) and it can also be seasonal.

Lehr (2009) also concurs by pointing out the affordability issues of renewable energy, (GEF in Flavin & Aeck, 2010) analyses the affordability of renewable as well, stating that "upfront cost of equipment and installation and maintenance cost are not affordable to many rural residents without long-term financing options" (p. 17). In light of the foregoing, it is pertinent to note that renewable energy will not eradicate all issues that hamper energy security, it can improve it but new issues will definitely come up as long as there is a continuous advancement in the energy sector. Therefore, there is need for continuous review so as to come up with strategies to tackle these new issues (Johansson, 2013).

Renewable energy gains more momentum due to the awareness to reduce environmental pollution partly caused by major reliance on fossil fuel as a major source of energy, the increase in demand for world energy due to increase in population growth and decrease in the cost of renewable energy technologies (Francés et al., 2013). Renewable energy has become an important energy policy to achieve energy security in many nations of the world, hence this paper will assess if renewable energy will help to improve energy security in Nigeria.

## 2.4 Energy Security Assessment Framework

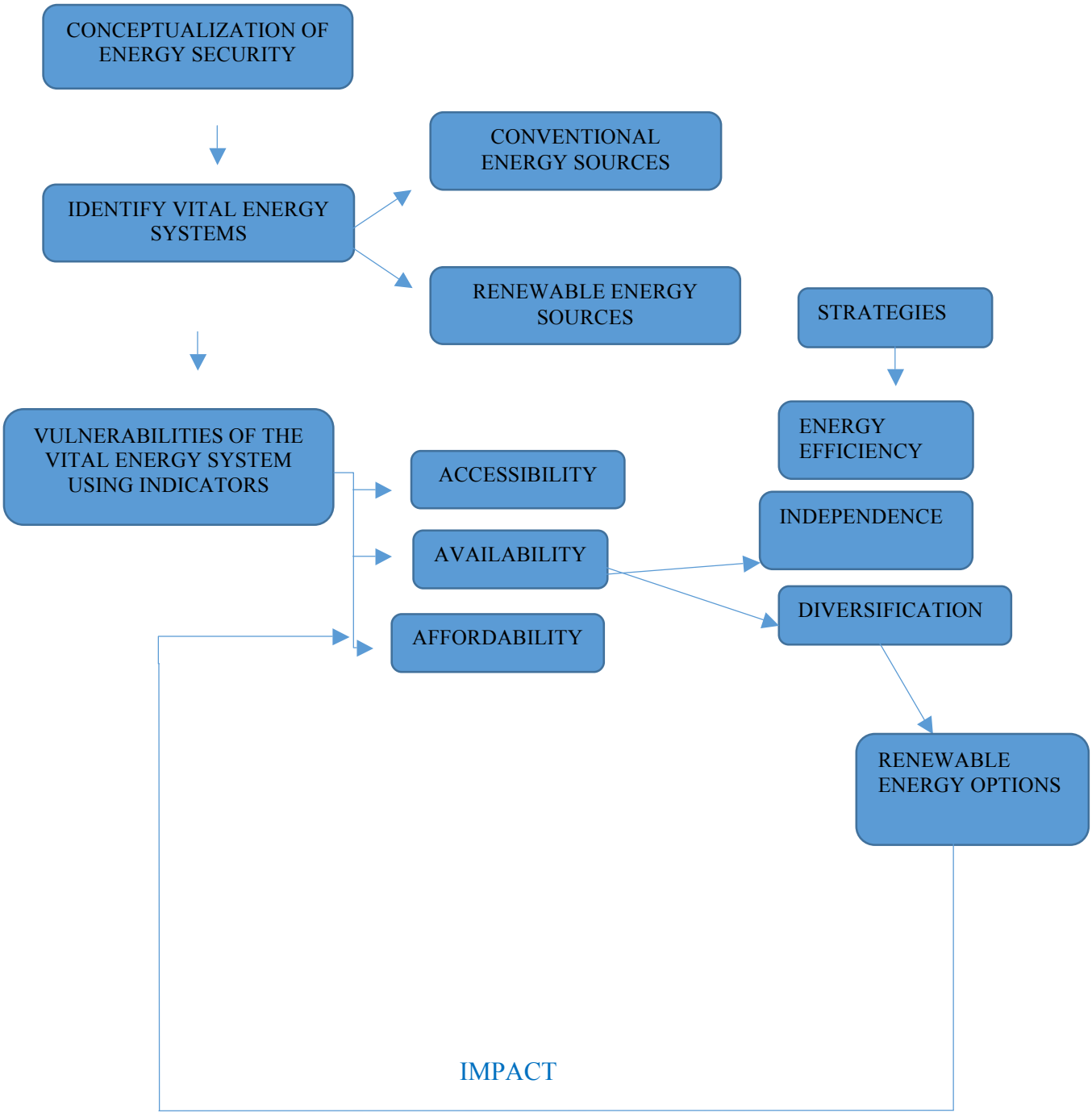


Fig. 2.4.1 Based on the assessment of energy security by Cherp & Jewell (2013), this diagrammatic framework was developed to include indicators coined from Jegen (2009) and Shrestha & Kumar (2008) definition of energy security as stated earlier. This was tailored to the peculiarities of the Nigeria energy system.

For the purpose of this study the concept of energy security will focus on the security of energy supply through diversification of the sources of supply by integrating other sources of renewable energy rather than the current over reliance on biomass as an alternative source of energy. Energy security will be assessed based on the indicators identified as peculiar to the Nigerian energy system, these indicators also have various meanings; it is therefore necessary to specify how they will be used in this study.

To ensure consistent availability, there has to be relative independence and diversification of energy fuels and services (Sovacool, 2011). This implies running an energy system that aims to reduce reliance on imported fuels, provide adequate and uninterrupted supply of energy. Also, diversification refers to both source and spatial diversification. Source diversification implies integrating various sources of energy into the energy mix while spatial diversification is to ensure dispersion of location for energy facilities (ibid).

Accessibility can be defined as having a high level of access to electricity and energy services, this correlates with higher levels of energy consumption and lower rates of energy poverty; while lower levels of access and minimal choice correlates with low levels of energy consumption, high reliance on biomass and lack of efficient equipment (Solvacool, 2011)

Affordability is having equitable prices that are not only relative to income but also stable and most importantly not volatile. Hence affordability is what is affordable, stable and equitable (Solvacool, 2011).

## CHAPTER 3- RESEARCH METHODOLOGY

The research methodology adopted in a study plays an essential role in ensuring that the right data is collected from the most appropriate sources using the most suitable form of data collection. In this study, certain approaches were adopted to fulfill the research objectives and answer the research questions as stated in chapter 1. This chapter illustrates the different approaches adopted in the research process of this study and the rationale behind them. Hence it examines four main angles in the methodology for this study: Firstly, it involves describing the approach adopted for this study which is the qualitative approach. Secondly, it focuses on sampling as an approach used for determining the selection process of respondents. Thirdly, it will explore the data collection methods adopted for the study and finally it aims to explain the limitations of the study

### 3.1 Qualitative Research Approach

The main aim of a research is not only to collect data but to seek answers to certain questions through a methodical approach. A qualitative research approach aims to provide answers to questions by studying individuals, groups or organizations in relation to the social setting which they are part of; it studies interactions within these social setting in terms of roles and structures (Berg & Lune, 2012). In this study, the main focus is on government parastatals and agencies who form an integral part of the decision making process that leads to energy policies in Nigeria. The aim is to understand the factors and views that influence the energy policies adopted in terms of integrating renewable energy into the current energy mix. Hence it was important to get the views of individuals in various energy agencies/ parastatals in Nigeria. The focus was therefore on words not numbers and the qualitative research makes emphasis on words (Bryman, 2008).

### 3.2 Sampling

The essence of sampling is to establish the sample population from which data will be collected in relation to the research questions. This study adopted adopted non-probability sampling methods- purposive and snowball sampling. Purposive sampling is one mostly used in the field or for exploratory research where representation of the entire population is not an important factor but rather to discover every probable context of an exact target population that are difficult to reach (Neuman, 2014). It involves purposive selection of the sample unit in relevance to the goal of the research and certain agencies were identified as relevant to answer the research questions and fulfill the goals of this research. Thus the sample

population relevant in the Nigeria energy sector include a representative from : Renewable Energy Programme under the Ministry of Environment, Energy commission of Nigeria, International Centre for Energy, Environment and Development (ICEED), Nigeria Electricity Regulatory Commission (NERC), Ministry for Environment, Ministry for Power, Nigeria Energy Support Programme under the Federal Ministry of Budget and Planning, Transmission Commission of Nigeria, Nigerian National Petroleum Corporation (NNPC), Distribution Company (DISCOs), Nigerian Liquefied Natural Gas (NLNG) and any bank in Nigeria.

Another form of sampling that was adopted in this study was snowball sampling. According to Bryman (2012), snowball sampling involves certain respondents who are relevant to the study and using them as a point of contact to other relevant organization. Given the short time frame for this study, snowball sampling was an important approach as it helped to ensure quick response from some of the agencies rather than going through a formal application process for data collection; this can take about a month or more. Snowballing was applied in this study to get the necessary contacts that can provide the essential policy documents and correspondence that helped in getting a better understanding of the energy system in Nigeria.

### 3.3 Data Collection and Analysis

The essence of data collection in a qualitative research is to explore who, what and where of a certain phenomenon that is being studied (Sandelowski, 2000). In this study, the 'who' represents the Nigerian government, energy agencies and stakeholders in the energy industry while the 'what' is the issue of renewable energy in relation to energy security and the 'where' in this study is Nigeria. This formed a foundation for the focus areas and it also determined the strategies for data collect, as it made the researcher ensure that these three parameters needed to be explored. Also Leedy & Ormrod (2012) emphasizes on the need to have a data collection plan which should not only answer the above questions but include the method of data collection that will be used and how the data will be analyzed.

The method of data collection includes primary and secondary data. The first point of primary data collection was through the Nigerian Alternative Energy Expo 2016 which is one of the largest renewable energy and power expo in Nigeria. The theme of the expo was 'Embracing Renewable Energy to tackle Nigeria's economic challenges'. The expo provided some insight into the renewable energy sector in Nigeria through various presentations and

discussions at the event, it was a good platform to start the data collection process and get the necessary contacts for possible interviews. The expo was however supposed to have prominent federal ministers in the energy sector but unfortunately none of them were present. To however get a better understanding of the rationale behind certain policies in the energy sector and the current state of the sector, it was important to get some views of representatives in the various government agencies that make up the sector. Also at the conference, I discovered the need to get the perception of private renewable energy businesses in the industry; they were the major drivers of the expo.

The perceptions needed for the study was derived through in-depth semi-structured interviews. According to Berg & Lune (2012) the essence of conducting an interview is to have a meaningful conversation with the aim of collecting more information on a particular area of interest and a semi-structured approach gives room to explore spontaneous areas introduced by the respondents and allowing for a certain level of comparison. A semi-structured interview was appropriate for this study but an interview guide served as a reminder of the necessary points to be discussed, certain questions were tailored for specific representatives who had more knowledge of a particular aspect of the energy sector than others and some respondents introduced some new issues which the researcher wasn't aware of prior to the interview.

The interview started after the conference with a respondent from the ICEED sending an introductory mail to some of his contacts in the respective agencies. Referrals were gotten during some of the interviewees and this helped to fasten the interview process during the short visit to Nigeria. The interviews took place in both Abuja and Lagos (Nigeria) from 23rd October, 2016 to 9th November 2016. The major stakeholders and the ministries in the energy sector have their headquarters in Abuja. A total of 13 people were interviewed: 8 of them were from the government parastatals, 2 private individuals, 1 from an NGO, 1 representative of private renewable energy business and 1 representative from the bank. 10 interviews were conducted in Abuja and 3 in Lagos and all interviews were conducted face-to-face with the shortest being for 30mins and the longest for an hour.

Audio-recording during interviews is an integral part of a qualitative study as it allows the interviewer to be highly attentive and probe further if certain areas of interest raised are unclear, it also ensure that the interviewer has an accurate account of the interview and give room to repetitively explore the responses (Berg & Lune, 2012). Before conducting an audio-

recording of an interview, informed consent is required; all interviewees were verbally asked for consent to be recorded, however only 11 interviewees were recorded as 2 people did not give consent to be recorded. During the interviews, there was minimal note taking in a research log so as to note some specific points especially figures that needed to be clarified and to ensure that all questions were answered.

In terms of secondary data collection, I had gotten some documents online before embarking on my field trip but there were some vital documents that were not available online and so many Nigerian sites had not been updated for a very long time. Thus, during the course of my interview I was able to request for updated documents like the Renewable Energy Master Plan (REMP), National Renewable Energy Action Plan (NREAP), National Energy Efficiency Action Plans (NEAP), National Renewable Energy and Energy Efficiency Policy (NREEEP) and some other hard copy publications from the respondents in the various ministries. I also got some other relevant publications that helped in my secondary data collection.

Upon my return from the field, all interviews were transcribed verbatim. Transcription is a beneficial exercise to a researcher as it allows gives room for re-examination of answers given by interviewees and it also brings the researcher closer to the data (Bryman, 2008). Transcription was a time-consuming task due to the length of some interviews, but it was a rewarding experience as some important points were drawn out. After transcription, coding was done to ensure better analysis; it entails classification of similar opinions under a certain tag (ibid). In this study, colour coding and thematic classifications were done with different colours representing a certain theme. Green represented responses that related to the vital energy systems that make up the Nigerian system, lemon represented comments on the vulnerabilities of the system, red represented responses related renewable energy potentials in Nigeria, yellow was for the importance of renewable energy integration and blue for challenges facing renewable energy integration in Nigeria.

### 3.4 Reliability and Validity

Reliability and validity are major factors that determine the quality of a research; these two are mainly used for quantitative research as they focus on measurements (numbers) rather than words. However, as measurement is not the main focus of a qualitative study, these concepts have been adapted to qualitative research with slight changes as quality is an integral aspect of social research (Bryman, 2008). Hence, according to Mason (1996),

validity in qualitative research is ensuring your study is actually exploring what you say you are; it also implies a clear understanding of the conceptual/theoretical framework of a study and how methods utilized in the study illuminate your understanding of the framework. A good example in this study is in terms of data collection, validity will imply demonstrating that all forms of data collection adopted for this research actually attempts to answer the research questions (Mason, 2002).

According to Guba and Lincloln (1994) reliability will imply the trustworthiness of a study; to review the trustworthiness of a research is to ensure the reliability of the research (Seale, 1999). Trustworthiness of a study measures the extent to which a research plan and its objectives are achieved and the key to reliability in qualitative research is to ensure consistency and dependability while triangulation (using multiple methods of data collection) helps to induce consistency and dependability (Merriam, 1995). It is important to note that triangulation is an important factor in ensuring validity and reliability. In this study, reliability was ensured by giving a clear description of the data collection procedures and concepts used in this study and how they are used. This implies that if this study is repeated, the same results are likely to be gotten thereby ensuring consistency and dependability. This study used different methods of data collection- primary and secondary from different kinds of sources- individuals, online sources, books, government policy documents, etc. and this strengthened the validity and reliability of the research.

### 3.5 Limitations of the Study

The initial plan before embarking on the journey to Nigeria for data collection was to discover what practical plans the government has in Nigeria in terms of integrating renewable energy through the NAEE conference. According to the expo program, the Minister of Power, Works and Housing, the Director of Energy Commission, the National Coordinator of Renewable Energy Program were to speak at the expo. Unfortunately, none of these people were present at the event, it was practically impossible to see them afterwards. It was only possible to get perceptions of some people in these parastatals who had a faint idea of what the government practical plans are. Thus the first limitation of this study is the fact that primary data on concrete plans/projects that the government is currently working on could not be gotten, I had to rely on secondary data such as policy documents and publications.

The primary data collection process was done in October/November 2016 for a period of one month, it couldn't be longer as school was still in session. Also one month is too short

a period for proper data collection process in Nigeria due to the bureaucracy and sometimes cumbersome process that exist in some of the organizations. There was the challenge of limited financial resources. For these reasons, a limited number of interviews were conducted within the timeframe and budget.

## CHAPTER 4- FINDINGS

In this section, I present the results in relation to the research questions stated in chapter 1. The section is divided into four: the first section will focus on how the Nigeria's energy mix has evolved to its current state making reference to the vital energy systems that make up the energy mix. The second section presents the available renewable energy sources and potentials in Nigeria. The third section focuses on the energy security situation in Nigeria with reference to the vulnerabilities of the vital energy systems and governments policies towards energy security. Lastly, the implication of renewable energy on the vulnerabilities of the energy system and the energy security of the nation will be presented.

### 4.1. Conceptualizing Energy Security in Nigeria: The Nigerian Energy Resource Mix

According to interviewee 6, the Nigerian energy sector can be seen as an infant that has refused to grow over the years and this stifles industrialization, innovation and development. Over the years, the sector has been ridden with untapped energy resources, inadequate infrastructure development and energy consumption supported by import thereby resulting in inevitable energy supply crisis (Ajayi & Ajanaku, 2009). The Nigerian energy resource mix comprises of oil, natural gas, biomass, coal and renewable energy (Diji, 2013). These resources form a vital part of the energy systems, hence findings would be presented in this section using each resource as a sub-heading with reference to its availability, consumption and infrastructural development over the years. Nonetheless, it is necessary to include the electricity sector as a sub-heading as it is an integral part of the energy system.
A brief recap of the Nigerian energy resources is illustrated in table 4.1

#### 4.1.1 Crude Oil

Oil plays a crucial role in the Nigerian economy, it is practically the most important non-renewable energy resource in the country as it accounts for 79% of government revenue and 71% of export earnings (SE4ALL, 2016). Nigeria is the largest oil producing country in Africa and it also has the 6th largest reserve of crude oil in the world. Oil was discovered by Shell D'Archy Company (sole concessionaire) in 1956 after about 50 years of exploration in a town called oloibiri located in the Niger Delta area of Nigeria; production began in 1958 and with a production rate of 5100bpd, Nigeria joined the league of oil producing countries (Odularu, 2008; Abubakar, 2015). According the NNPC (2016), after 1960, exploration rights was granted to other foreign companies both in offshore and onshore areas bordering the Niger Delta region and by 1965, Shell discovered the Exploration Asset (EA) field in

shallow water southeast of Warri (Odularu, 2008 p. 6).

**Table 4.1: A Recap of the Nigerian Energy Resources**

| Resources | | | Reserves | | Production | Domestic Utilization |
|---|---|---|---|---|---|---|
| | | | Natural Units | Energy Units (Btoe) | | |
| 1 | Crude oil | | 37.2 billion barrels (2013) | | 2.19 million barrels per day (2013) | 445,000 barrels/day allocation: 22% utilization of refineries |
| 2 | Natural Gas | | 182.3 trillion SCF (2013) | | 2.929 Tscf (2015) | 82% utilized 18% flared |
| 3 | Coal and Lignite | | 2.7 billion tonnes | 1.92 | 0 | Negligible |
| 4 | Tar Sands | | 31 billion barrels of oil equivalent | 4.22 | 0 | 0.224 million tonnes |
| 5 | Large Hydropower (LHP) | | 11,250MW | 1.11 (over 38 years) | 1938MW (167.4 million MWh/day) | 167.4 million MWh/day |
| 6 | Small Hydropower (SHP) | | 3500MW | 0.25 (over 38 years) | 30MW (2.6 million MWh/day) | 2.6 million MWh/day |
| 7 | Solar Radiation | | 3.5 - 7.0 kWh/$m^2$/day | 15.0 (38 years and 0.1 percent of Nigerian land) | excess of 20MWp of solar PV | excess of 20MWp of solar PV |
| 8 | Wind | | (2-4) m/s at 10m height | - | - | - |
| 9 | Biomass | Fuel wood | 11 million hectares of forest | - | 0.11 million tonnes/ day | 0.120 million tonnes/ day |
| | | Municipal Waste | 30 million tonnes/ year | - | 18.5 million tonnes in 2005 estimated at 0.5kg/capita/day in 2014 | N/A |
| | | Animal waste | 245 million assorted animals in 2001 | - | 0.78 million tonnes/ day in 2001 | N/A |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | Energy Crops and Agric Residue | 72 million hectares of Agric Land and all waste land | - | 28.2 million hectares of arable land | 8.5% of arable land cultivated |
| 10 | Nuclear Element | | not yet quantified | | | |

Source: Renewable Energy Master Plan (REMP, 2014), National Energy Master Plan (NEMP) 2012, (Diji, 2013), NNPC (2013)

The termination of the Biafra war and world oil price boost led to an increase in production and exploration of oil in Nigeria from the 1970s (NNPC 2016). The level of production rose to 2mbpd and Nigeria got immediate profitable earnings from its exploration, production and exportation of oil (Edomah, 2016). She became a member of the OPEC in 1971 and established the NNPC in 1977, NNPC is a government owned entity and a major actor in the downstream and upstream sector (Abubakar, 2015). The Nigerian oil attracted various buyers due to its high quality- it is light sweet crude and very low in sulphur. Notwithstanding, in the 1980s, Nigeria experienced a decline in production due to the economic downturn but this was rectified in 2004 as she bounced back to 2.5 million barrels per day. As of 2013, Nigeria has over 159 oil fields and 1,481 oil wells with daily estimated production of 2.5 million barrels per day (Diji, 2013). It is estimated by SE4ALL (2016) that if the current production rate is maintained, Nigeria is left with about 42 years of extraction.

In relation to production, Nigeria has four existing oil refineries managed by the NNPC. Though Nigeria has the second largest refinery in sub-Saharan Africa with a total capacity of 445,000 barrels per day or equivalent of 22.2million metric tons per annum that can meet the local demand; it performs at a sub-optimal run rate between 65% and 70% operational capacity, hence making it only possible to supply just 20% of the local demand leaving about 80% to be served by import substitution (IEA 2014). It is important to state that these refineries were constructed between 1965 and 1989, no actions were taken to construct new refineries till 2002 when license was granted for 18 new private refineries; however only 13 were granted approval to commence construction and only one has come on stream with a capacity of 1000 barrels per day (Diji, 2013). Also in 2015, it was reported by Sonny (2015) that President Muhammad Buhari granted licenses to 65 Nigerian companies to construct modular refineries but there is however no reliable update on the status of these licenses.

As at 2005 oil accounts for 57% of the secondary energy mix in Nigeria; hence

domestic demand has continually risen due to heavy reliance on crude oil for electricity generation (mainly fuel generators), transportation and residential use by the increasing population (Oyedepo, 2012; Edomah, 2016). In addition to the problem of import dependency, there is distribution challenge experienced in the downstream sector; the distribution network from the refineries to the oil depots is connected with 5001 km of pipelines. The sector is ridden with poor maintenance and operating conditions, pipeline vandalization, under-funding e.t.c which led to reforms that encouraged de-regulation of the downstream sub-sector in 2003 (Odularu, 2008).

Due to the discovery of oil and the commencement of oil production in Nigeria, sectors like the agricultural sector (which was the mainstay of the economy prior to oil discovery) and resources like coal, natural gas were either totally abandoned or under-utilized; there was a major shift in focus to oil. Nigeria became a "mono-economy" with high reliance on revenues from the export of oil than ever before; oil replaced agriculture as the mainstay of the economy (Watts, 2004)

It is important to state that, the Nigerian oil sector faces certain challenges (in addition to sub-optimal refinery) which hampers its development such as militant unrest, vandalism and oil theft. Oil theft according to IEA (2014 p. 121) is estimated at 150kb/d, it also contributes to oil spill and causes an estimated revenue loss of about $5 billion every year; oil spill is a major environmental concern in the Niger Delta region and it is one of the major reasons for unrest in the region (Borok et al, 2013).

### 4.1.2 Gas

The discovery of gas in Nigeria is associated with oil exploration and production which started in 1958, the associated gas was flared and not utilized. The Petroleum Act of 1969 was a legal instrument established to manage the activities of the petroleum industry; under drilling and production, it obligated production companies to submit a feasibility study for gas utilization within 5 years after production commencement date (Nelson, 2015). The petroleum act was ineffective and this led to an amendment decree in 1978 which approved the use of associated gas (produced jointly with crude oil) without royalty payments (Nelson, 2015; Emodi, 2016).

However, gas was still flared and this led to the Associated Gas re-injection Act of 1984 was put in place to disallow companies from flaring gas without special permission from Minister of Petroleum Resources (Nelson, 2015). The reinfection act also failed as the government couldn't provide its share of its cost for building gas re-injection facilities and

there was lack of infrastructure for gas utilization (ibid). Therefore, the penalty for gas flaring was reduced to a low fine of 2 kobo per 1000 standard cubit feet (scf) in 1984 but later increased to N10 per 1000 scf by 1998 (Chaytor & Gray, 2003). Eboh (2017) reports that the penalty was increased to $3.5 per 1000 scf in 2008 but companies have refused to implement this and they still pay the old fine of N10. Despite this, gas flaring has reduced from as high as 75% in the past to 13% as at 2012.

Nevertheless, the first attempt to commercialize natural gas in Nigeria was by Shell-BP in the 1960s, it was supplied for thermal electricity generation and to some industries in Aba (Abdulkareem & Odigure, 2009). In 1978, the Sapele gas supply system and the gas department was commissioned and charged with the responsibility of managing the gas system (ibid). However, to have a structured improvement in gas production, the NNPC merged the gas department with its gas division and established the Nigerian Gas Company (NGC) as a subsidiary in 1988 (Abdulkareem & Odigure, 2009; Emodi, 2016). The NGC was charged with the responsibility of gathering natural gas from flow stations owned by oil production companies, heating the gas and transmitting it for the purpose of thermal power generation, industrial heating, feedstock, etc., in Nigeria and ECOWAS sub-region (Abdulkareem & Odigure, 2009). Currently the NGC is responsible for transmission, distribution and marketing of natural gas. NGC owns approximately 1,100km of various diameters of pipelines for transmission (Diji, 2013).

Gas production in Nigeria increased substantially from 310 million cubic metres in the 1960s to about 36,036.6 million cubic metres in 1998 due to the encouragement of gas utilization projects driven by the government (Ojide et al., 2012). These led to the establishment of the NLNG in 1989 which steered the installation of an LNG plant to encourage higher production of natural gas (Edomah, Foulds, & Jones, 2016). The NLNG is responsible for liquefaction and export of Liquefied natural gas from the country and they currently have 6 trains facility with the capacity of 22 million tones per annum to do this (Diji, 2013). The substantial export of liquefied natural gas commenced in 1999 and in 2012, Nigeria was declared the fourth world leading exporter. With the largest gas reserve in Africa as seen in table 1, the government has focused on increased utilization of gas for electricity generation. Also 80% of the gas utilized for domestically for power generation, while the rest is shared between the industry and household though the latter is very negligible (ECN, 2014).

### 4.1.3 Coal

Coal was found in Enugu and it's the oldest form of commercial fuel in Nigeria (Edomah, Foulds, & Jones, 2016). Coal mining started in1906 and by 1916, production output was 24,500 tons (ECN, 2003). This era witnessed increase in the share of coal as a primary energy source in electricity generation, railway transportation and other industrial purposes. The peak in production was in 1958/59 with an output of 905,000 tons but coal contributed about 70% to the commercial energy consumption (Edomah, Foulds, & Jones, 2016; ECN, 2003). Coal production decreased continuously and was neglected after the discovery of oil in 1956, it decreased to about 52,700 tonnes by 1983 and to a poor production output of 14,390 tons by 2000 (ECN, 2003; Nasiru, 2012; Onakoya et al.,2013). According to ECN (2003), coal contributed a miserly 0.02% to the commercial energy consumption.

It is pertinent to state that, there were other challenges that led to the neglect of coal production. One main challenge was the Nigerian civil war, most of the coal mine were abandoned during the war and afterwards in 1970-1971 (reconstruction years); there was no tangible production (Odesola, Samuel & Olugasa, 2013). Also the Nigerian Railway Corporation (NRC) was the main consumer of coal but the train engines were changed from coal burning to diesel powered (ibid). In addition to this, there was a transition from coal power generating equipment to diesel and gas by the Electricity Corporation (ibid). Nwaobi (2008) also noted the challenge of inadequate electricity supply, lack of local technical knowhow for proper maintenance, poorly motivated mines, etc.

In light go the following, Odesola et al. (2013) explains the demise of the coal industry in Nigeria. They point out that after the loss of the NRC, the Nigerian Coal Corporation (NCC) commenced the exportation of coal to Italy and the United Kingdom. However, the Obasanjo administration approved the operation of private companies in the coal mine as joint ventures with the NCC before the ultimate goal of selling off the NCC asset to the private investors. The goal involved keeping 40% of the asset and selling off 40% to private investors and 20% to the Nigerian public. But by 2002, the mines owned by NCC stopped working and the government announced a plan to rejuvenate the coal industry by creating a technical advisory committee to come up with strategies.

### 4.1.4 Biomass (Fuel Wood and Biofuel)

Biomass consists of all living matter, they are organic compounds in which solar energy is in retained in form of chemical bonds. This can be converted to generate three main

products heat / electrical energy, fuel (biofuel) and feedstock for chemical (Saxena, Adhikari & Goyal, 2009). Biofuel can be in liquid form used as transport fuel (biofuel) or solid form which includes wood burning for domestic or industrial purposes or gas (biogas) produced from methane, hydrogen, monoxide, etc. from microbes (Serrano-Lotina & Daza, 2013; Aliyu, Dada, & Adam, 2015). Biomass energy in Nigeria can be derived from four major sources as shown in table 4.1, they can be in form of forage crops, charcoal, grasses, shrubs, wood residues, etc. (Agbro & Ogie, 2012). Nigeria has high potentials in biomass as she has diverse biomass resources that can be converted for energy purposes; she is known for large production of energy crops like cassava, sesame, soybean, etc. (Mas'ud et al., 2015). Abila (2010) mentions that with this high level of production, Nigeria has the potential to be a leading exporter of biofuel.

The most prevalent source of biomass energy in Nigeria is fuel wood, it is used by over 70% of the rural population. Oyedepo (2012b) states that, 80 million $m^3$ (43.4 x $10^9$ kg) of fuel wood is utilized for cooking, heating and other domestic purposes. He explains further that the energy content in the fuel wood utilized is 6.0 x $10^9$ MJ and only about 5 to 12% is gainfully used. Also Nigeria consumes over 50 million tonnes of fuel wood annually, the average daily consumption of dry wood per person is about 0.5 - 1 kg; this alarming rate surpasses the renewal rate afforestation programs (Oyedepo, 2012a; Diji, 2013).

All interviewees from the government parastatals and 3 others agree with the foregoing, interviewee 6 however points out the unsustainable usage of wood inevitably leading to deforestation. Sambo (2009) expressed that afforestation rate is about 50,000 hectares per year while deforestation caused by not only fuel wood utilization is at a rate of 350,000 hectares per year. Over the years there has been increase in demand for fuel wood in Nigeria, the demand is speculated to increase from 39 million tonnes in 2000 to 90 million ton by 2030, especially with the constant growth in population (ibid). Interviewee 2 from a government parastatal asserts that demand will continue to increase as biomass is the cheapest form of energy for domestic purposes in the rural areas.

Nevertheless, other forms of biomass like plant biomass can be converted to fuel for small scale industries and if fermented by anaerobic bacteria, it can produce cheap biogas (Olaoye et al., 2016). Biogas energy can be sourced from agricultural residue, municipal waste and industrial waste (Agbro & Ogie, 2012). Akinbami et al., (2001) reports that Nigeria produces about 227,500 tons of fresh animal waste daily and 1kg of fresh animal waste can produce about 0.03 $m^3$, this implies that Nigeria has the potential to produce about 6.8 million $m^3$ biogas daily from its animal waste. With the nation's aggregate production of

285.1 million tones, she has the potential to produce over 3 billion cubic meters of biogas yearly (Diji, 2013).

### 4.1.5 Electricity Sector

Electricity is a fundamental prerequisite for a decent standard of living, efficient industrialization and economic development; a country cannot develop nor sustain its development without providing minimal access to electricity to majority of its population (Oyedepo, 2012; Aliyu et al.,2013). The electricity sector in Nigeria is one bedeviled with incessant power outages caused by inadequate functioning generation and transmission infrastructure (IEA, 2014). Nigeria's electricity consumption per capita is around 100 KWh per annum, this is reported to be one of the lowest in the world (Ogunleye et al., 2016). According to the NREEP (2015), only 40% of about 180 million has access to electricity. Interviewee 3 who is a representative of the power sector is of the opinion that 40% access is quite questionable due to fact that more than half of the population is rural. An overview of the electricity sector with reference to major developments is imperative.

Electricity generation and supply in Nigeria can be traced to 1886 when two generating sets with a capacity of 60MH were installed in the colony of Lagos (Obadote, 2009; Sambo et al., 2012). The first regulatory authority was the Electricity Corporation of Nigeria which was established in 1952 and the Nigerian Dam Authority in 1962 by an act of parliament, both entities were merged by the Federal Government to form the Nigerian Electricity Power Authority (NEPA) in 1972 (Sambo et al., 2012; Okoro, 2014). However, NEPA was replaced by the Power Holding Company of Nigeria (PHCN) after a restructuring and unbundling of the latter in 2005 by the Electric Power Sector Reform Act (EPSRA); this was to encourage private companies to participate in the electricity sector (ADB 2009). The EPSRA act also established the Nigerian Bulk Electricity Trading (NBET), National Electricity Regulatory Commission (NERC) and the Rural Electrification Agency (REA) as key institutions in the sector (ibid).

In 2010, the Federal Government of Nigeria launched the power sector roadmap which covered key solutions to mitigate the obstacles to private sector investment. Areas covered includes: the sale of generating and distribution companies to the private sector; strengthening the technical and managerial capacity of the Transmission Commission of Nigeria; and strengthening the Nigerian Electricity Regulatory Commission. This further led to the PHCN being dismantled and the birthing of 18 companies – 1 transmission company (TCN), 6 power generating companies (GENCOs) and 11 distribution companies (DISCOs)

(Onochie, Egware, & Eyakwanor, 2015). The privatization process was finalized in 2013 and the Federal Government retained ownership of the TCN and adopted NERC as its regulatory body (ADB, 2009). The transmission process was however managed on behalf of the government by Manitoba Hydro International (MHI) from 2012 to 2016, but due to irreconcilable differences it was returned to the Federal Government (Ogunleye, 2016).

Despite the restructuring of the sector, its development has been very slow. One major challenge affecting the development of Nigeria electricity sector is generation. All generating plants are quite old with inefficient operable capacity, there has been no additional plant to the grid since 1990 (Iwayemi, 2008). According to Oseni (2011), the major electricity generation sources in Nigeria are fossil fuels. Over the last 45 years, electricity generation in Nigeria "has varied from gas-fired, oil-fired, hydroelectric power station to coal-fired with hydroelectric power system and gas-fired system taking precedence" (Sambo et al., 2012 p.3). Nigeria has 14 power generating plants supplying electricity to the national grid, they consist of 11 thermal (gas/steam) and 3 hydro plants (ibid). Gas based power plant accounts for 84% of the installed capacity generation while hydro accounts for 16% (SE4ALL, 2016). It is also important to note, all forms of generation above 1MW require the issuance of license by NERC and a Power Purchase Agreement (PPA).

According to ECN (2014), the installed grid generation capacity as at 2012 was 9,955.4 MW but the average available capacity of 5,516.38 MW and estimated generation was about 3700 MW. Most recently, Babatunde Fashola (the current Minister for Power) mentioned that Nigeria has the installed capacity to generate 12,000 MW (Premium Times, 2016). In spite of the generating capacity of 12,000, the available operable capacity is far lower as the grid constantly suffers partial or complete collapse; as of june 2017, there has been a total of 213 in the last 9 years with 12 total collapses and 2 partial collapses in 2017 alone (Sunday, 2017). The nation's peak electricity generation for 2016 was 5300MW in February, electricity generation fluctuates averagely between 2500MW and 4500MW. As at march 2017, the electricity generation was 4303 MW as against the country's peak demand forecast of 19100 MW (Okere, 2017). Interviewee 8 comments "it is embarrassing for Nigeria to be generating around 4000 MW with a population of about 180 million, the nation should be looking at generating 100,000 MW; Nigeria is so backward in terms of electricity generation".

Electricity transmission is also a major challenge in the Nigeria electricity sector. All generating stations, distribution stations and substations are interlinked by a transmission network, the national grid (Ohajianya et al., 2014). According to Ikeme and Ebohon (2005),

"power transmission in Nigeria is through overloaded low and substandard power grid lines and about 200 injection substations". SE4ALL (2016) reports that the lines comprise of 5,523.8 km of 330 kV and 6801.49 km of 132 kV and the Transmission System Providers of Nigeria is responsible for transmission across the grid. The domination of 132 kV lines on the transmission lines is a major challenge as they have low transmission capacity; this can cause the plants to generate below the installed capacity and lead to loss of power (Ikeme & Ebohon, 2005). In addition, the transmission lines do not cover all the whole country and it has low capacity to transmit about 5500 MW which is much less than the generation capacity (ECN, 2013). Obadote (2008) comments on the grid structure, he stated that the vulnerable and unstable structure of the grid makes it prone to sabotage. Interviewee 4 also expressed his thoughts, "there are many transmission substations that have gone obsolete; they went bad and have not been repaired".

Another challenge faced by the Nigerian electricity sector is electricity distribution. According to Edomah (2016), the current distribution network in Nigeria is dilapidated. The network is divided into 11 regional grids, 60% was sold to private investors and government retained 40%; it is managed by distribution companies (Discos) (Awosope, 2014). The discos face the challenge of faulty transformers or overloaded transformers that require constant load shedding (ibid). They also experience power loss, there was 46% energy loss in the distribution network in 2014-12% was due to technical faults, 8% due to commercial loss (inaccurate billing) and 28% due to collection loss (billed but not paid for) (NESISTATS, 2015).

In relation to the electricity sector in Nigeria, individuals are allowed to install and run an off-grid power generator, however with a capacity below 1MW; all forms of generation above this must obtain a generation license from NERC. In 2012, NERC signed two regulations- the Independent Electricity Distribution Network (IEDN) and Embedded Generation. The IEDN allows for communities, local and state government to invest in electricity distribution networks in areas with little or no access to the grid, bad distribution network or poorly serviced areas. While embedded generation allows communities, investors, local and state government to generate and distribute electricity solely for their consumption, utilizing the facilities of electricity distribution companies or independent electricity distribution networks that already exist.

### 4.2 Renewable Energy Potentials in Nigeria

Most interviewees were of the view that Nigeria has abundant, untapped renewable

energy resources. Interviewee 1, 5 and 6 assert that the potential for renewable energy in Nigeria is quite enormous and the main potential sources are wind, solar and hydro. Interviewee 5 reiterates that, renewable energy potential in Nigeria is so large and if well utilized the nation doesn't need grid electricity. Also, interviewee 6 affirms the abundance of renewable energy sources and the required landmass to utilize the potentials. Nigeria has adequate renewable energy potentials to meet its present and future energy needs, yet hydropower is the only renewable source of energy currently connected to the grid (Charles, 2014). It is therefore necessary to examine other renewable energy sources excluding biomass and their various potentials in Nigeria.

### 4.2.1 Hydropower

Though hydropower is the main renewable energy source utilized in Nigeria's electricity supply mix, it only accounts for 30% of the nation's electricity supply and it is not being harnessed to its full potential (Sambo, 2005; Aliyu, Dada & Adam, 2015). Hydropower plants can be classified by its generating capacity; according to the ministry of power, small, medium and large scale hydropower plants are classified as having a generating capacity lower than 30 MW, more than 30 MW and more than 100 MW respectively (GIZ, 2015). LHP plants depend on the availability of large rivers while small hydro depend on small rivers, waterfall, streams or storage dams (Aliyu, Dada & Adam 2015). Nigeria is blessed with large rivers, small rivers and streams and energy; about two-third of the nation lies in the watershed of the Niger River which is Africa's third longest river and fifth largest in terms of discharge (Zarma, 2006 & Charles, 2014).

According to Olaoye et al. (2016), hydropower potential in Nigeria can generate 6,396,390 MW with its 11W/$m^2$ potential and the availability of water on 63% of her land space. If 1% of this potential is harnessed using small, medium or large power plants, it is possible to generate 64,000 MW of hydropower in Nigeria (ibid). However, the current exploitable potential for large hydropower is in excess of 14,750 MW including the developed 1930 MW from Kainji, Jebba and Shiroro dams while for small hydropower estimated potential is 3500 MW; current SHP installed capacity is 30MW (Oyedepo, 2012). Though the developed capacity only account for 19% of total exploitable potential which is capable of producing about 36,000 GWh of electricity annually (Ikuponisi, 2004; Aliyu et al., 2013). Sambo (2005) emphasizes that SHP can provide electricity as an off grid solution to enhance electrical projects in rural areas.

### 4.2.2 Solar

Solar energy is generated from sunlight either in form of electricity known as Solar Photovoltaic or in form of heat (utilized for cooking, heating or drying) known as thermal power. Solar energy is the major point of reference for the notion of renewable energy in Nigeria due to the visible abundance of sunlight (Ilenikhena & Ezemonye, 2010; Newsom, 2012). Nigeria is located in the equatorial region with direct sun rays and high temperature, hence the potential solar energy generation is high (Charles, 2014). According to Shaaban and Petinrin (2014), solar radiation in Nigeria can generate approximately 3.8 x $10^{23}$ kW, an equivalent of 1,082million ton of oil (Mtoe) worth of energy in a day; this is about 4000 times the crude oil production and 13,000 times the gas production per day as at 2009. Furthermore, to generate the same amount of solar energy which is equal to the country's conventional energy reserves, only about 3.7% of Nigeria's land area is needed (Ibid).

Shaaban and Petinrin (2014) notes that, though Nigeria has sufficient solar radiation to generate energy that can meet its local demand; there is high variation in solar radiation across the country with the North having a higher solar radiation than other parts of the country. Ohunakin et al. (2014) further points out that, variation in total solar radiation ranges from about 3.5 kWh/$m^2$/day in the coastal region to 7.0 kWh/$m^2$/day in the far north. Also Nigeria has average sunshine hours of about 6 hours per day with a variation of about 3.5 hours in the coastal region and 9.0 hours in the far Northern region (Sambo, 2009; Charles, 2014). Based on these, an average of about 1,770 TW/h of solar energy falls on the entire land area and this is about 120,000 times the total electricity generated in the country (Oyedepo, 2012 p. 2; Aliyu, Dada, & Adam, 2015). Interviewee 2 mentioned that if solar energy potential in Nigeria was developed, no house will be without light. As such, the availability of these enormous solar energy potential is for only about 26% of the day (Ikuponisi, 2004)

With an average solar radiation of 5.5kWh/$m^2$/day in Nigeria and the general productive level of commercial solar electric generators, Oyedepo (2012) speculates that if solar collectors or modules occupy only 1% of Nigeria's land area of 923,773 $km^2$, approximately 1850 x $10^3$GWh of solar electricity can be generated per year. He goes further to state that, the generated solar electricity can be used through off-grid solutions to provide power especially to the rural areas that are not connected to the national grid. This can be done through low and medium power applications such as vaccine refrigeration, rural clinic and school power supply, village electrification, etc Ibid (p. 7). Solar energy can also be used as a primary energy resource to facilitate other renewable energy sources like hydro, wind,

biomass, etc. In summary the solar energy potential in Nigeria is endless and it's not fully harnessed.

### 4.2.3 Wind

Energy can be derived from wind and converted into useful energy such as electricity using wind turbines (Agbetuyi et al., 2012). The potential for wind energy in Nigeria is quite modest when compared to its enormous potential of solar and massive potentials that exist in other 'windier' countries (Newsom, 2012). This can also be reflected in the literature on wind energy potential in Nigeria as majority of the studies are focused on certain cities or sites which are perceived to have high wind potential. However, in total Nigeria is reported to have an average wind speed at10 m heights with a variation from 3 m/s in the coastal areas mostly southern areas to 7 m/s in far north areas with less vegetation (Ajayi, 2007; Idris et al., 2013).

In addition to the foregoing, Ajayi (2010) mentions that due to the variation in topography and roughness of the country; it is possible to have high variation in wind within the same locality. However according to a study by the ECN reports, that the potential for wind energy generation can vary from 8MWh/year in Yola (North-East) to 51MWh/year in high mountain areas like Jos (North-Central) to 97MWh/year in Sokoto (North-West) (Iloeje, OC 2004). Also Shaaban and Pentirin (2014) speculate that wind potential can generate about 50,046 MWh/yr of electricity with a medium generation capacity of 5MWh/km$^2$, a 30% capacity factor and 1% of effective wind area in certain selected states. Due to the low wind speed in most of the Southern region of Nigeria, wind energy can effectively be generated and utilized through stand alone power generating systems using small scale wind turbines (Oluseyi O. Ajayi 2010). Energy generated can be used for water pumping, irrigation and small agricultural industries in these areas (Okoro, Chikuni, & Govender, 2007).

In summary, all interviewees believe that the renewable energy source with the most potential in Nigeria is solar.

## 4.3 Measuring Energy Security in Nigeria

Orazulike (2012) asserts that energy security in Nigeria has not been pursued with the sense of purpose, determination and consistency it deserves. He further mentions the first major attempt at energy security in Nigeria was the policy guidelines for energy presented in 1987; its objective was to have a good mix in the development of Nigeria's energy resources in an environmentally acceptable way as well as ensure national self-sufficiency and security. The energy policy was reviewed afterwards in 1993, 2003 and 2013 respectively. The final

review lays more emphasis on energy security stating the over-dependence on oil and the need to diversify energy supply mix through development of various energy resource options, focus on achieving adequate production levels and ensure efficient energy delivery system (ECN, 2013).

One of the interviewees who works at NERC defines the current state of energy security to the Nigerian government as "assuring today and tomorrows' supply with no particular source holding you to ransom" while a representative at the NNPC emphasized on the government's focus on stable supply economic development with less attention on energy access, he stated "energy security to the Nigerian government is ensuring availability of energy to provide sustainable power for economic activities, the priority is providing access to those that already have access and contribute to the GDP". This is about 30 years after the first policy on energy security yet Nigeria still has a long way to go in achieving energy security. Interview 2 expressed "energy security cannot be achieved with high reliance on one source of energy". Hence, this section will outline the vulnerabilities of the energy sector using the indicators adopted as shown in the assessment framework adopted.

### 4.3.1 Availability

As stated earlier, Nigeria has various available abundant energy resources which range from renewable energy to non-renewable energy sources; if properly managed can mitigate its current energy problems (Momodu, 2013). The nation operates a centralized energy system which focuses on fossil fuels and fuelwood as the major source of energy (Diji, 2013). Energy security focuses on not only the availability of resources but also the utilization of these resources to ensure sufficient and uninterrupted supply. However, Nigeria's energy resources are not properly utilized and managed to ensure sufficient supply of energy domestically. Iwayemi (2008) laments that the Nigerian energy industry lacks sufficient supply and is inefficient in meeting the needs of its citizens, stating how evident it is in the persistent shortage of supply of electricity and petroleum products. These oil products include gas, petrol, diesel and kerosene.

IEA (2014) reports that the total primary energy supply (excluding electricity trade and oil imports) for Nigeria in 2014 was 127,142 ktoe as against 69810 ktoe in 1990. The primary energy supply mix includes 85.5% biofuels and waste, 11.3% natural gas, 2.8% crude oil and 0.4% hydro respectively. A total of 8405 ktoe of oil products was imported and a total energy of 112,926 ktoe was exported. Energy export composed of 534 ktoe oil products, 20,179 ktoe natural gas and 112,926 ktoe crude oil. The largest source of primary

energy supply in Nigeria has been biofuels and waste with fuelwood being the major primary source of biofuel; fuelwood continually increases over the years (Emodi, 2016). This can be seen in Fig 4.1, as well as the trend in other energy source that constitutes Nigeria's primary energy supply between 1990 and 2012. There has been gradual increase in the supply of natural gas and gradual decrease in the supply of oil.

In terms of consumption, biofuel and waste is the highest fuel consumed and the residential sector has the highest consumption rate as seen in fig 4.2 and 4.3 respectively. The residential sector utilizes energy for cooking, heating, lighting and it depends highly on fuel wood. It is readily available; this is why it utilized by over 60% of the population (Uzoma, Nnaji, & Nnaji, 2012). According to interviewee 4, "the energy consumption mix is poor, it shows that we have not developed our energy sector because a large percent of the population still resorts to fuelwood". Interviewee 5 complements this by stating that "the energy consumption mix is highly imbalanced due to the availability of biomass resources". According to Akorede et. al (2017), as at 2011, per capita electric energy consumption in Nigeria for an average household of 5 was 149 kwh per annum. In addition, the transport sector depends on petrol and diesel, it consumes 74% of the local petroleum products supplied (Momodu, 2013). The industrial sector also utilizes electricity, diesel and gas to meet its energy needs and the agricultural sector consumes diesel and gas through propelling machines used for fertilizer production (ibid).

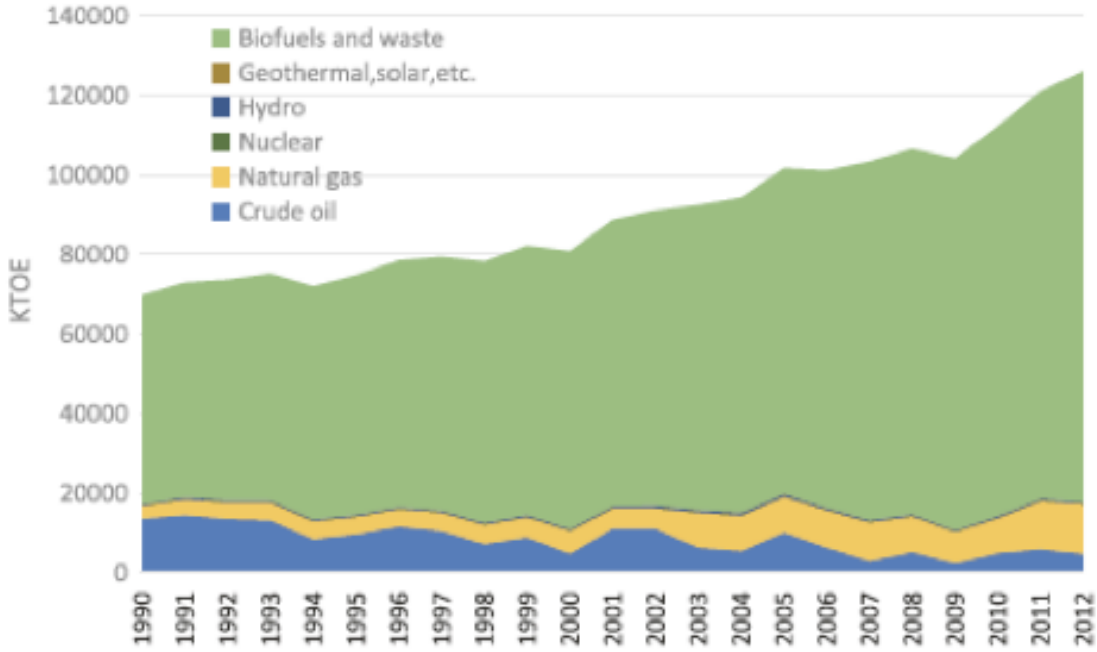


Fig 4.1 Nigeria's total primary energy supply (1990-2012). Source: IEA (2015), Emodi (2016)

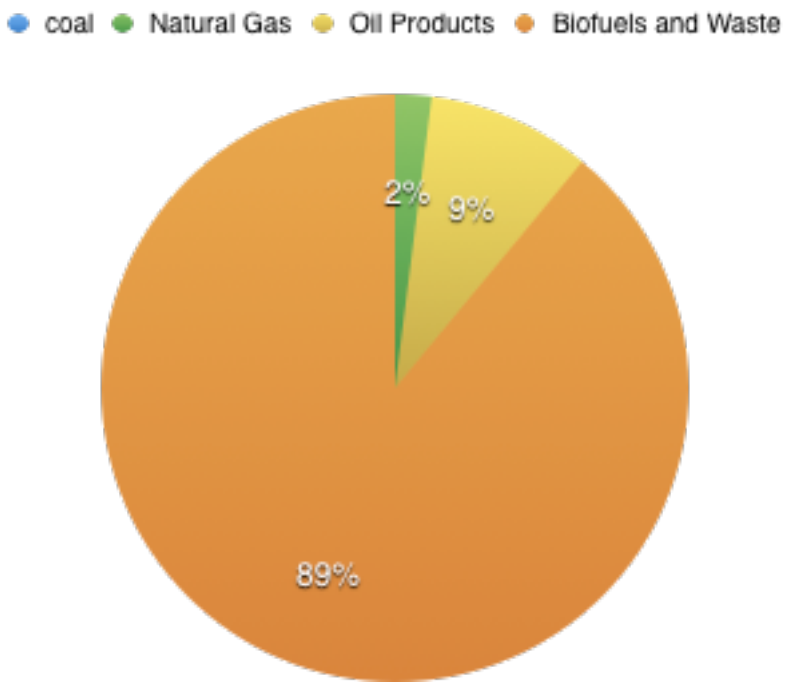


Fig 4.2 Primary Energy Consumption by Fuel (2012) Source IEA (2015), Emodi (2016)

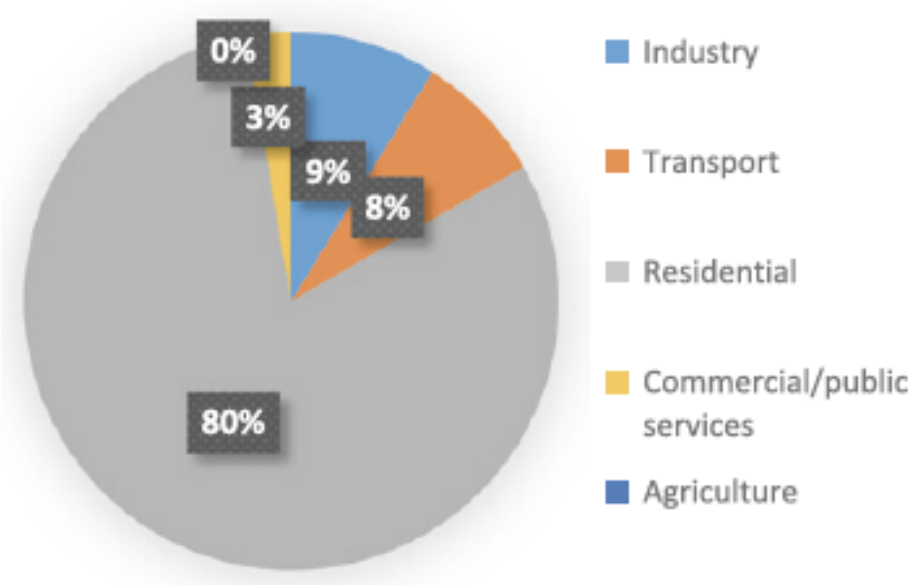


Fig 4.3 Total Primary Energy Consumption by Sector (2012) Source IEA (2015), Emodi (2016)

Energy supply in Nigeria is highly unreliable and insufficient, it is not only insufficient but it is also erratic and of low quality. There is a high level of mismatch between electricity demand and supply of energy in Nigeria. According to SE4ALL (2016), the estimated power demand which includes both surpassed and latent demand is 17,520 MW as

against the peak generation capability of 5300 MW and transmission capability of 5500 MW. Having a gas-dominated power generation system is one major challenge in the shortage of electricity supply as this is solely sourced from the restive Niger Delta region. Nigeria frequently experiences interruptions or inadequate supply of gas due to vandalization of the gas pipelines in the Niger Delta region (Iwayemi, 2008). The nation also experiences seasonal fluctuations in weather which leads to reduced water availability for thermal generation of electricity (Ajayi, 2010). The electricity demand is met by pervasive reliance on self-generated electricity through back up generators, this accounts for at least 80% of the installed capacity of the national grid (ECN, 2013).

### 4.3.2 Accessibility

About 98 million people lack access to grid electricity, the national electrification rate is 45% with 55% and 36% electrification rate in the urban and rural areas respectively (IEA 2016). Interviewee 4 comments on the national electrification rate, 'access to electricity might even be lower than figures given by the media as it might be technically lower….some areas are connected to the grid but haven't had electricity for a very long while, can we call this access?'. There is a large gap in access between regions, for example less than 10% of households located in the rural northern part of the country have access to the grid. Yet almost every household in an urban state like Lagos have access to electricity while about 60% of residents in Southern states have access to the national gird.

Momodu (2013) mentioned that, one major factor affecting access to energy services in Nigeria is the mediocre state of social infrastructure in the country. He further states infrastructural problems like bad road network, dispersed inaccessible locations, high cost of grid extension hinders the distribution and supply of petroleum products to rural areas. Another infrastructural problem is insufficient generation and poor distribution of electricity, this limits access to energy for domestic use and leads to high dependence on fuelwood. Interviewee 3 laments about energy access for domestic use "as a country we lack access to clean cooking fuels, even in the cities; it is usually a mixture of firewood and kerosene"

### 4.3.3 Affordability

It is important for the price of energy services to be economically reasonable for most people especially the poor in a country. However, affordability becomes a problem in a developing country like Nigeria where a large portion of the populace have low purchasing power with a relative poverty level of 69% (Momodu, 2013). Interviewee 8 states that "due to the income index and poverty level in Nigeria, the energy consumption mix we have is

inevitable as this is what is affordable to most people". Fuelwood is more affordable to the poor rather than other energy sources such as gas, kerosene and coal (ibid) as there is often no cost implication using fuel wood to meet their domestic energy needs.

In relation to the foregoing, the difference in cost of Liquefied Petroleum Gas (LPG) and kerosene makes the latter the most popular after fuelwood especially as it is quite available in certain urban areas and few rural areas; however, both LPG and kerosene are frequently scarce with constant increase in price, (Ibitoye, 2013). Bad road network in Nigeria makes the price of kerosene in rural areas to be 50% higher than in urban areas, generally the price of LPG and kerosene has risen by more than 1000% since 1991(Diji, 2013). Also due to import dependency, fluctuation in global prices affects local price of oil products as a result of the expenditure burden on imports (ibid). These make the prices less affordable especially for those in the rural areas, hence they result to the use of fuel wood which is cheaper (Momodu, 2013). With a high immigration level of more than 70% from the rural areas to urban areas in Nigeria, it implies that there are also the poor in urban or semi-urban areas who cannot afford modern energy options (Babanyara, & Saleh, 2010).

The minimum wage in Nigeria is N19,800 with pump price for petroleum and diesel being N145 and N195 per litre respectively while kerosene fluctuates at an average of N282 (Okafor, 2017). Interviewee 11 express the irregularities that cannot be ascertained in the minimum wage, "there are many people who receive wages and earn a living way lower than the set minimum wages". It is however important to state that in urban and semi-urban areas, people resort to a more expensive captive electricity generation using petrol/diesel generators. It is estimated that roughly 4000MW is generated and it costs about 30 cents to generate a KWh using these generators, yet grid electricity is estimated to cost an average of 4.3cents per KWh (Tallarpragada, 2009).

### 4.4 Assessing Energy Policies in Nigeria

This section will focus on the major energy policies that have shaped the Nigerian energy system. According to Ajayi and Ajayi (2013), the Nigerian energy policy was first documented in 2003, reviewed in 2013 and has served as a foundation for the development of several energy policy documents. They include Renewable Energy Master Plan, Nigeria Vision 20:2020, National Energy Master Plan, National Renewable Energy Action Plan and the National Renewable Energy and Efficiency Policy.

#### 4.4.1 Nigeria Energy Policy

The main focus of the energy policy is to mitigate the nation's energy challenges

through reduced dependence on oil, diversification of its energy resources and active participation of the private sector (ECN, 2013). It contains 13 objectives, among which are:

- "To ensure the development of the nation's energy resources, with diversified energy resource option, for the achievement of national energy security and an efficient delivery system with an optimal resource energy mix."
- "To guarantee adequate, reliable and sustainable supply of energy at appropriate cost and in an environmentally friendly manner, to the various sectors of the economy."
- "To promote gender sensitivity and special attention to rural energy needs"
- "To ensure effective coordination of national energy planning, programs and policy implementation"

The document outlines policies and objectives in relation to specific energy resource as well as short, medium and long term strategies to achieve them. In terms of crude oil, the nation aims to substantially explore and produce crude oil with emphasis on internal self-sufficiency and increase in its reserve capacity. This will be achieved by increasing investment in all oil production activities, increasing the refining capacity to meet both local and international petroleum needs short-term while "ensuring geographical of oil refining and petroleum products distribution network" medium-term and continuous review for long-term. Also, the main gas policy is to escalate gas exploration and encourage sufficient transmission and distribution of gas across the geographical zones in the nation with its main objective being to increase the use of gas for domestic fuel and power generation. The immediate strategy was to ensure the utilization of associated gas thereby eradicating gas flaring by 2015 while the medium-term strategy is to enforce the appropriate urban and regional planning regulations as well as establish gas reserves all over the country.

Furthermore, the policy aims to revive the coal industry and boost the share of coal in the national energy mix to 30%, however it states the need to maintain reduced environmental pollution by aligning with acceptable global practices. The long-term strategy is eventual resumption of the use of coal in electricity generation while inclusion of clean coal technologies and enhanced incentives to encourage investment in coal exploration are the intermediate and immediate strategies respectively.

In the 2003 version of the Nigerian energy policy, the renewable and conventional energy sources were listed in the same section. On the other hand, the revised version introduced a renewable energy policy with the main aim of increasing the share of renewable energy in the current energy mix. In terms of hydropower, the policy focuses on full utilization of the country's hydropower potential for electricity generation with emphasis on

small, mini and micro hydropower stations to improve rural access. The immediate strategy to achieve this is by stimulating research and development of hydropower to encourage establishment of more hydropower stations while the medium strategy is to promote indigenous training institutions for skill acquisition in hydropower technology.

The nation commits to vigorously attempt to integrate solar energy into its current energy mix while considering cost effectiveness; it aims to utilize solar energy as the primary source of energy in rural and semi-urban locations especially those with high solar energy potential. Some of the short-term objectives include: "To develop the nation's capability and capacity in the utilization of solar energy; "to intensify human and institutional capacity building in solar energy technologies and applications; "to provide adequate incentives to suppliers of solar energy products and services". The intermediate strategy is to establish a framework for the promotion of the use of solar energy by taking advantage of funds from experienced international agencies and countries.

In terms of wind as a source of energy, the policy acknowledges the need for a wind energy development programme. Hence, it intends to commercially cultivate wind energy as an alternative energy resource while implementing measures to guarantee affordable and sustainable cost to both suppliers and consumers in rural areas. The strategies are quite similar to that of solar, the immediate strategy is to "encourage research and development in wind energy utilization", "develop skilled manpower for local production of components that make up wind power systems as well as training of local crafts men to ensure operation and maintenance of wind energy systems".

The updated energy policy document also has a separate section for biomass for electricity and heat generation called bioenergy policy. The major focus of the policy is to exploit non-fuelwood sources of energy while setting a "limit on the amount of biomass use for energy, to ensure that the overall demand can be accommodated alongside other demands for land such as food production or biodiversity conservation". It also intends to encourage biomass as an alternative source of energy mainly in rural areas. All these will be achieved by stimulating research and development in biomass energy and technology, inaugurating pilot projects and giving sufficient incentives to local entrepreneurs short-term and putting measures in place for efficient conversion for biomass energy medium-term.

In relation to the above, there are also sub-sectors for biofuel and fuelwood under the bioenergy policy. The policy recognizes the inefficient use of fuelwood in the country, hence the focal point for fuelwood is to "de-emphasize the use of wood as a fuel in the nation's energy mix and promote improved efficiency in the use of fuelwood". This is to be realized

by “ensuring the availability and effective distribution of alternative energy sources to fuelwood at all times”, develop efficient wood stoves and “ensuring the existence of effective forestry laws to stop willful felling of trees” short-term. The intermediate strategy is to expand the areas covered by forest reserves and create suitable pricing for other alternative fuel types to promote substitution from fuelwood.

On the other hand, the biofuel policy is an “attempt at integrating the agricultural sector with the downstream petroleum sector”. It aims to blend biofuels as a component of fossil-based fuels, advocate for investment in the biofuel industry and encourage gradual reduction of reliance on fossil fuels. This would be intermediately done by creating a research and development fund where biofuel companies will contribute 0.25 of their income for research in feedstock production, improved local and farming techniques, this hopes to promote collaboration between public and private sectors.

Lastly, the policy also introduced electricity policy which emphasizes on the inadequate supply of electricity in Nigeria. Some of the policies include: providing “steady and reliable electric power available at all times, at economized rates, for industrial, economic, and social activities of the country”; pursuing “measures to diversify energy sources for electricity generation, encouraging state and local governments to provide access to electricity in rural areas through off-gird solutions” and “ensuring a sustainable supply of gas for electricity generation”. The main objective is to make electricity available to 75% of the population by year 2020and 100% by 2030, ensure security of supply of electric power as well as a balanced electricity supply mix, however the main focus is to “provide electricity state capitals, local government headquarters and other major towns by the year 2020”. Some of the immediate strategies to achieve this includes rehabilitation of power plants, promoting the development and expansion of transmission and distribution networks while completing existing projects to ensure that national demand is met. The intermediate strategy is to promote and encourage indigenous production of basic engineering infrastructure.

### 4.4.2 Nigeria Vision 20:2020

This is a policy document that states the strategies for economic transformation and sustainable development in Nigeria between 2009 and 2020. It touches on various sectors that make up the Nigerian system but this focus will be on the vision 2020 goals for the energy sector. The vision statement for the energy sector is “by 2020, the energy sector will be the major engine of the nation’s sustainable social, economic and industrial growth, delivering affordable and constant energy supply efficiently to other sectors of the economy” (NPC

2009, p 12). Also, it takes into cognizance the interdependency of the various sub-sectors of the energy sector unlike its previous predecessors - Vision 2010, NEEDS 1 and 2; hence it merges plans of the sub-sectors aimed towards the main goal.

One of the strategies to achieve the vision statement is by diversifying the energy consumption mix using renewable energy sources such as wind, solar, hydro and biomass, the end goal is to improve security of energy supply. There are also goals directed specifically to the various energy sources. For conventional sources, some of the goals include to increase reserves for both oil and gas and realize 10% and 20% contribution of coal to the national power generation mix by 2015 and 2020 respectively. Some of the goals for renewable energy sources include: to attain 15% and 20% contribution of hydro to the nation's electricity mix by 2015 and 2020 respectively, attain 1% contribution of wind and solar respectively to the electricity generation mix by 2020, ensure replacement of 50% of firewood consumed with biomass energy technology by 2020 and utilize biomass resource to obtain power generation capacity of 1000MW.

The goal for the electricity sector is to increase installed generation and distribution capacity to 20,000MW by 2015 and 35,000MW by 2020, however the private sector will provide 80% of the generation capacity and own 100% of the distribution assets; likewise, the transmission capacity will be increased to 20,000MW in 2015 and 35,000MW by 2015. Electricity access will be increased to 60% by 2015 and 80% by 2020.

### 4.4.3 Renewable Energy Master Plan (REMP)

The REMP principally aims to improve the development of renewable energy and eliminate obstacles that hinder this goal. It amplifies the framework, targets and timelines of specific renewable energy sources which include solar energy, hydropower, biomass and wind. The current version was documented in 2012 following the review of the first version done in 2005. The main objective is to promote national energy security, improve energy access especially in rural areas and encourage research and development of renewable energy in Nigeria. The objectives are to be achieved short-term (2013-2015), medium term (2016-2020) and long-term (2021-2030) and the programmes include: National Biomass Energy Programme, National Solar Energy Programme, National Hydropower Programme, National Wind Energy Programme, Emerging Energy Programme and Framework Programme for Renewable Energy Promotion. A summary of the renewable energy targets can be seen in table 4.2.

The REMP contains a section which aims to ensure that the targets are reachable,

hence this section identifies activities that promotes its achievement. It contains sub activities which is generalized under 10 framework programmes, among these are: development of Financing Option Programme, incentives for Renewable Energy Development, public awareness/sensitization, local manufacturing and commercialization, regulatory and institutional frameworks and Standards Codes of practices and Specifications. It is important to note that incentives were regarded as an important aspect of renewable energy development, it was subdivided into fiscal and financial incentives; fiscal incentives include activities like subsidies, grants which relates to demand while financial includes activities like duty and levy waivers, tax relief that relates to the supply side. Some important fiscal incentives are reduction on import duty, payment of 50% profit tax as against the present 30% and minimum tax holiday of 10 years for upcoming companies active in renewable energy while financial incentives include reserving certain percentage of yearly loans for Renewable Energy Supply and Utilization Project at a maximum interest rate of 5%p.a. as well as 30% of initial cost for setting up a renewable energy utilization facility.

**Table 4.2: Summary of Renewable Energy Targets**

I. Renewable Electricity Supply Projection in MW (7% GDP Growth Rate)

| S/N | Resource | 2012 | Short-term(2015) | Medium Term (2020) | Long Term (2030) |
|---|---|---|---|---|---|
| 1. | Hydro (LHP) | 1938 | 2,121 | 4,549 | 4,626.96 |
| 2. | Hydro (SHP) | 60.18 | 140 | 1607.22 | 8,173.81 |
| 3. | Solar | 15.0 | 117 | 1343.17 | 6,830.97 |
| 4. | Biomass | - | 5.0 | 57.40 | 291.92 |
| 5. | Wind | 10.0 | 50 | 631.41 | 3211.14 |
| | All Renewables | 2023.18 | 2,483 | 8,188.20 | 23,134.80 |
| | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| | All Energy Resources(On-grid power plus 12,500MW of self-generated power) | 21200** | 24,380** | 45,490** | 115,674** |
| | % of Renewables | 23% | 10% | 18% | 20% |
| | % RE less LHP | 0.8% | 1.3% | 8% | 16% |

**Supply projections are based on the addition of on-grid power, and a base capacity of 12,500MW of self-generation (i.e. power generated for own use) including off-grid generation from year 2012 to 2030.

Source: NREEEP (2015), GIZ (2015)

II. Non-Electricity (Thermal)

| Activity/Item | Timeline/Quantity | | |
|---|---|---|---|
| | Short Term | Medium Term | Long Term |
| Total thermal Energy Production (GWh) | 193,709 | 202,128 | 248,809 |
| Renewable Energy Share (%) | 85 | 80* | 79* |
| Other non-renewable Share | 15 | 20 | 21 |

* Note that the decline over the years is due to the planned decrease in consumption of fuel wood

Source: REMP (2012)

III. Biomass Programme Targets*

| S/N | Item | Timeline/Quantity | | |
|---|---|---|---|---|
| | | Short Term | Medium Term | Long Term |
| 1 | Biomass Electricity (MW) | 5.0 | 57 | 292 |
| 2 | Biofuel (ML/day)*<br>Ethanol (E10)<br>Biodiesel (B20) | 5.3<br>2.0 | 9.7<br>3.4 | 24.2<br>11.7 |

Source: NREEEP (2015)

### 4.4.4 National Renewable Energy And Energy Efficiency Policy (NREEEP)

The NREEP delineates the policies that also promote renewable energy development but with an additional emphasis on the need to look into energy efficiency. The focus is not only on development of renewable energy source but creation of additional energy through efficient use of energy. It also stresses the need for a more detailed framework for renewable energy and with a specific focus on the electricity sector which previous policies lack. Hence it is an integration of renewable energy and energy efficiency to improve electricity supply in Nigeria. It is important to note that this policy is motivated by the unification of renewable energy and energy efficient policies in the ECOWAS region.

Some of its objectives include:

i. Set national targets for achievement in electricity from renewable energy and energy efficiency capacity addition by 2020 and beyond;
ii. Set out a framework for action to address Nigerians challenge of inclusive access to modern and clean energy services, improved energy security and climate objectives
iii. Recognize national significance of renewable electricity generation activities by providing for the development, operation and maintenance, and upgrading of new and existing renewable energy electricity generation activities

In summary the energy efficiency policy emphasizes on the need for alternative sources of energy, sufficient and reliable production levels and an effective distribution of all fuel types. One specific target to achieve this is by replacing at least 40% of all old and inefficient appliances with energy efficient appliances by 2020 and complete overhaul by 2030. The action plans for the achievement of this policy is however stated in National Renewable Energy Action Plan (NREAP) and National Energy Efficiency Action Plans (NEEAP). These are the most recent policy developments for renewable energy in Nigeria.

The NEEAP provides background data on energy efficiency in Nigeria, establishes framework for targets and plans of energy efficiency programme and recommends activities that will make the targets achievable, covering a timeline from 2015-2030. Some of the targets for 2020 includes efficient lighting available in 40% of households, achieve 10% biofuel blends, reduce distribution loss by about 15-20% and increase energy efficiency. While by 2030, almost all households will be using efficient lighting, reduction in firewood demand to stay below supply capacity and distribution loss reduced to less than 10%. The NREAP also provides background data for renewable energy development in Nigeria,

suggests targets that can be achieved and suggests measures for meeting these targets. These targets cover grid connected renewable energy, off-grid applications of renewable energy, renewable domestic cooking energy, solar water heaters, biofuel, etc.

### 4.5 Renewable Energy Integration in Nigeria - Journey So Far

Assessing the status of renewable energy integration in Nigeria can be quite difficult as there are no official reports on this, though there are unofficial knowledge of stand-alone renewable energy installations all over the country. There are many projects written in policy documents and under the renewable energy programme, yet their current status could not be ascertained in the course of this study due to the lack of comprehensive database. There is however evidently slow integration of renewable energy into the energy mix despite its abundance in the nation. Hence, this section presents the available data on the integration of the various sources of renewable energy available in Nigeria and the challenges of renewable energy integration in Nigeria.

#### 4.5.1 Solar Energy

Solar energy is the fastest growing renewable energy source in terms of consideration for integration into Nigeria's energy supply mix (Sambo & Bala, 2012). According to Ohunakin et al. (2015), all solar energy utilization in Nigeria are either stand alone mini-grid or off-grid light application as there are currently no off-grid hybrid or grid connected solar systems. These applications exist either in the form of solar thermal or solar PV, method of usage include solar lighting, solar cooker, solar refrigerators and solar-powered water pumps. Vincent-Akpu (2012) asserts that the Sokoto Energy Research Centre (SERC) and the National Centre for Energy Research and Development (NCERD) alongside the supervision of the ECN have conducted various pilot projects and research to improve the availability of power for domestic and industrial activities such as cooking, crop drying, chick brooding, incubation, etc.

Currently, most of the solar PV installations in Nigeria are from private individuals and investors. There are many houses and offices that have solar installations either as back up for grid power or as the sole source of power. All interviewees confirmed this assertion as they personally knew one or two people who use solar systems. Interviewee 4 explained, "two of my friends have migrated to solar, they are completely off the grid though they invested a lot of money." Interviewee 5 has a solar PV system in his house, he said "I only use solar in my house, the cost is economically viable for me rather than running a generator…I can get 3.5kw/hr per meter square and if I use very efficient equipments, I

cannot consume above 6kw/hr". However, there is no official report or database that gives the exact number of private solar installations.

The government is also involved in some partnership with private sectors to provide both on-grid and off-grid solar solutions. The Minister of Power confirms that license has been granted to 14 solar developers to include solar to the national grid and the Nigerian Bulk Electricity Trading (NBET) signed the first solar Power Purchase Agreement (PPA) with these developers to produce a total of 975MW of utility-scale solar. However, interview 3 mentioned that "the total signed PPA is about 1250MW that will be connected to the grid and completion is expected to be mid-2018 and interviewee 4 confirmed that "government approved tenders and contract for solar integration is 1250MW". Also A national Solar Home System Program (SHS) was recently introduced in alliance with the NDPHC and Azuri technologies (a private mobile pay-go systems specialist); the goal is to provide 20,000 homes with off-grid solar power systems within a period of 12 months (initial phase) (Ofikhenua, 2017). This solution is targeted towards rural areas that lack access to the grid, it aims to stimulate social and economic activities by ensuring affordability through a monthly repayment scheme; about 200 units were deployed at the pilot phase in Wuna, a rural village on the outskirts of Abuja (ibid).

Solar installations in Nigeria is however a mix of successes and failures. One good example of a successfully executed project is the Jigawa State solar project. It is a full-scale rural electrification program which commenced in 2011 and is funded by the Japanese government, United States Agency for International Development (USAID) and United States Department of energy; total funds invested is $450,000 (Okereke, 2017). The project provided a water pumping system, street lighting, a microenterprise center, light for 20homes, and portable pump for crops as well as power to healthcare centers, schools and religious centers (ibid, p.11). The project was implemented and is being maintained by Solar Electric Light Fund (SELF), an NGO located in Washington, DC (ibid). An example of a failed solar project is the Osinowo village of Bishop Kodji located in Lagos state, it was fully funded by the Lagos State Government at the cost of $83,000 (about N10,000,000) (Okereke, 2017). The system was a 300 watts PV panel which was to power the community building, primary school, a mosque, a church, fish driers and a water-pump, it was reported to have worked for only 3 months before it failed (ibid).

### 4.5.2 Wind Energy

The contribution of wind energy to the current energy mix is highly insignificant.

Wind energy technology has mostly been tried in the early 1960s in the Northern region of the country (kano, Sokoto, Katsina, Bauchi, Plateau) mainly for water pumping from open wells in secondary schools but they are no longer working (Emodi & Yusuf, 2014). However the nation currently has two existing wind electricity technology that are functioning, this includes 1kW Benin energy research centre Edo State, rehabilitated wind power pump at Kadawa village in Kano State, 5kWp capacity located at Sayya Gidan-Gada and 0.75kWp located at Danjawa village both in Sokoto State (Aliyu, Dada, & Adam, 2015).

It is necessary to state that the first wind farm in Nigeria was awarded in 2010 with expected completion in 2012; it is a 10MW farm located in Katsina and it is worth 5.5billion Naira (Saddik & Alhassan 2012). According to Sunday (2016), the project activities has been slow since inception, only about 5 wind turbines of 37 expected units have been mounted; each turbine was installed at a height of 55m and has a generation capacity of about 275kW. However, the project is yet to be completed even after a second projected completion and commissioning was slated for 2014 and 2015 respectively (ibid). During the NAEE conference of 2016, a correspondent from Katsina stated that work has resumed at the site and it would be commissioned in 2017. As at July, 2017 there is still no update on the progress of the Katsina wind farm.

Some attempts are being made by the Sokoto Energy Research Centre (SERC) and the Abubakar Tafawa Balewa University to promote capacity development for wind energy technologies in Nigeria (Kuku, 2013).

### 4.5.3 Biomass (Biofuel and Fuelwood)

As stated earlier, biomass accounts for a high percentage in the Nigeria's energy mix. However, fuelwood is not used efficiently or in a renewable way, hence the focus in Nigeria is on improving efficiency in fuel wood usage and also attempting to integrate biofuel into the Nigeria's energy mix.

Interviewee 7 expressed "introducing biomass stoves can reduce fuel wood consumption by 50%-80%, 50% should be the minimum for household stove and 85% for institutional stoves". The government and some private local and international institutions have made some attempts to introduce biomass stoves. One prominent example by the government was in 2014, the FEC approved 9.2billion Naira for the purchase of clean cooking stoves and wonder-bags under a program called the National Clean Cooking Scheme managed by the Ministry of Environment, it was specifically targeted towards women in rural areas (Ayodele, 2014). The scheme was to deliver 20 million cooking stoves at the unit cost

of N464 over the period of 5 years and it was to be distributed for free all over the local governments in Nigeria (ibid). But controversies sprang up over this project, in 2015 the project was terminated by the Ministry. It was reported that, 5 billion had been released by the government and 1.3billion had been released to the German supplier who was given 3 months to supply 750,000 cooking stoves and 18,000 wonder-bags who only supplied 45,000 cooking stoves; also there has been no single beneficiary of the programme (Channelstv, 2015). This project as at January, 2017 was under probe and to be investigated to determine the status of the fund released for the project (Vanguard, 2017).

Another example of is the save80, a program which was expected to distribute12,500 stoves in the Guinea Savannah zone of Nigeria (Akorede et al., 2017). It was sponsored by Atmosfair Germany and implemented by Developmental Association for Renewable Energies (DARE) under the Efficient Fuel Wood Stoves for Nigeria (CDM 2711), the stoves consume 80% less fuelwood than the replaced traditional stoves and they were sold at reduced price (UNFCCC,2012). The United Nations Framework Convention on Climate Change (UNFCCC) in its monitoring report stated that as of 2016, 5370 stoves have been successfully deployed. Another example is ICEED in conjunction with various organizations to encourage local production and distribution of clean cooking stoves. ICEED led an initiative which was inaugurated in 2011under National Alliance for Clean Cookstoves (NACC), the main aim is to distribute 10million cooking stoves by 2020. It is a public-private partnership and it aims to achieve its main goal through various activities which include: building partnerships to improve recognition, have a clean cook stove conference, encourage the EU project in Katsina (distribution of 35,000 stoves between 2014 and 2018), encourage private sector participation, create awareness and reach out to at least 10 million households and institutions to adopt clean cook stoves. The EU project is currently being executed with no formal update other than a recently concluded capacity building programme on clean cookstoves testing and standards in June 2017 in conjunction with Ecowas Centre for Renewable Energy and Energy Efficiency (ECREEE). Hence this project can be considered as a work in progress with no formal report on how many stoves have been successfully deployed.

The main biofuel program in Nigeria is the NNPC Automotive Bio-fuels Programme, it is sub-divided into biofuels policy and industry programme. The biofuels policy aims to establish a legal framework that promotes a domestic biofuels industry that will bloom, it sets out to utilize sugarcane, cassava and palm oil as feedstock for the production of biofuels. It

also consists of two elements, namely ethanol which can be used as a blend with gasoline (PMS) for vehicles and biodiesel used as a blend with petroleum diesel for automotive purpose. Hence fuel ethanol (at E10) consists of 10% ethanol 90% Petroleum Motor Spirit (PMS) and biodiesel (B20) consists of 20% biodiesel and 80% petroleum diesel. The industry programme focuses on the practical activities like establishing domestic biofuels companies, feasibility studies and business plans etc. that would lead to implementation of the biofuels policy.

It is pertinent to note that the Biofuels Policy Incentives document was approved and gazetted by the Federal Government in 2007 but still hasn't been passed into law, interviewee 1 confirms this "the policy has not been passed into law, but in the meantime I think it's undergoing review". In 2007, the NNPC reported that it had gotten a grant of 70,000 Euros from Renewable Energy, Energy Efficiency Partnership (REEEP) from Germany to support detailed feasibility studies at certain locations. In 2011, NNPC reported that it solely has 7 biofuel projects (3 sugarcane to ethanol projects, 2 cassava to ethanol projects and 2 oil palm to biodiesel projects) which are being developed; it also had completed 5 feasibility studies which proved profitable, identified 7 potential private investors that qualified for MOUs for equity partnerships on the biofuels programme as well as received off-take from 2 local private biofuel producers with ongoing discussion for partnership (NNPC: Renewable Energy Division, 2011). However, interviewer 1 stated that as at 2016, 7 feasibility studies have now been completed with one more project being developed but the major hindrance is that "renewable energy is a policy driven project and the policy is not passed into law".

The latest development in relation to this policy as at the time of conducting this study was the sensitization workshop on biofuel development held in February, 2017. According to Edeh (2017), the executive secretary of the Petroleum Product Pricing Regulatory Agency (PPPRA) stated that the government is making concerted effort to ensure the development of alternative sources of energy to petroleum products; hence this should encourage a faster development of the political will to implement the policy. Notwithstanding, there has been some reported developments of biofuel on the state level. Ayandele (2016) reports an official launch of a 6,000hectare cassava farm to produce over 1.5million metric tonnes of ethanol and starch annually. Also, there is a report of a signed MoU between Biodiesel Nigeria Limited and Kogi State government to establish a mini-biofuel refinery in Lokoja with an initial capacity of 100,000liters per day (Ventures Africa, 2017).

### 4.5.4 Hydropower

As stated earlier, hydropower is the largest commercially exploited renewable energy source in Nigeria. The nation generates more from LHPs, though SHPs came into existence in Nigeria about 45 years before the first LHP in Kainji. Both forms of hydropower are not utilized to their full potential as only 14% of the available LHP potential is being utilized and SHP development has remained stuck at an infant stage since its inception as it only operates in three states (Ohunakin, Ojolo, & Ajayi, 2011).

The government nevertheless, is making attempts to construct both LHP and SHP plants. The biggest project for the LHP power plant is the 3050MW Mambilla project in Taraba state, the first contract was awarded in 2007 yet there was delay in take-off. The current government stated that the capacity of the project is 2600MW rather than 3050 declared in 2007 and as at 2016, it plans to commence the project soon; it was reported that the site was visited by about 40 Chinese engineers in preparation for take-off (Magaji, Sunday, & Mac-Leva, 2016). According to Akorede et. al (2017), the government also signed a contract worth $1.293billion for the construction of 700MW plant in Zungeru and constructions have started. There is also the 215MW dual fired power plant in Kaduna which was awarded in 2009, it was expected to be completed in 2012 but it was affected by inadequate budgetary allocation; hence the new set date was June, 2017(Punch 2016).

In addition to the foregoing, interviewee 3 commented on the addition of new small hydro projects to the grid, “we have ongoing small and medium hydro projects that might be coming up to the grid soon, it is located in Gurara about 30MW and Kashimbilla with a capacity of 40MW”. The Minister of Power in an interview with Daily Trust mentioned that the Kashimbilla project has been reviewed but has a challenge of financing as it was inherited from the previous government but he speculated that the completion should be latest by 2018. He also mentioned the addition of 240MW plant located in Afam to the grid, the turbines are currently in the county and hopes that by December it would be completed.

## 4.6 Challenges of Renewable Integration in Nigeria

### 4.6.1 High cost

One of the reasons for slow integration of renewable energy into the energy mix is its relatively high initial investment cost and long repayment period (Ohunakin et. al, 2014). All interviewees acknowledged the high cost of renewable energy technologies, interviewee 8 commented, “The cost of a kw/hr using renewable energy is higher than the conventional energy for now”. According to Newsom (2012), due to upfront cost individuals will rather go

for N300 kerosene lantern with constant fuel needs rather than solar lantern of N3,000 and purchase a diesel or petrol generator of N40,000 rather than a solar power unit of N200,000. He states further that not only is the cost of installation high, there is also the need to invest in additional protection due to several hazards like accidental damage, abuse, lightning, etc that are bound to happen in Nigeria.

### 4.6.2 Lack of indigenous components and technical know-how

According to interviewee 1, "though Nigeria has potentials, we lack indigenous technologies for renewable energy utilization and we do not participate in the value chain of these technologies; hence, makes it more expensive for us". Interviewee 10 explained "lack of local content has led to the importation of renewable energy technologies that either do not suit the Nigerian climate or the kind of appliances we use in this country". There is also lack of manpower with adequate technical expertise in renewable energy technologies. Interviewee 1 laments, "We don't have adequate experts that have full understanding of renewable energy technology and this seems to have greater negative impact on its acceptance"

### 4.6.3 Lack of standardization

As stated earlier, renewable energy technologies are mainly imported, especially from China with most of them having no trademark certificate or logo; yet there are no national standards for determining the right standards, specifications and quality of renewable energy technologies that should be allowed into the country (Ohunakin et. al, 2014). This is due to the lack of personnel with relevant training and knowledge required and it has led to the influx of low quality and inferior RETs. Interviewee 6 spoke about the problem of standardization, "non-standardization of the sector gives people the freedom any kind of renewable energy into the sector, the market is not regulated hence quality cannot be tested and customs officers in Nigeria have minimal knowledge of the codes manufacturers should adhere to". However, interviewee 8 commented that the problem of standardization cannot be completely eradicated

### 4.6.4 Change of Government

Change of government also slows down the integration of renewable energy as it sometimes leads to the abandonment of some already existing projects or planned projects that have not been implemented. This was mentioned by the Katsina representative at the NAEE conference, he lamented on how the Katsina wind farm project was started by Musa

Yar'Adua government in 2010 but was abandoned when Goodluck Ebele Jonathan took over; it was however resuscitated after 2015 when the Mohammadu Buhari led administration took over. Interviewee 2 gave an example of the problem in change of government, "the national policy on renewable energy and energy efficiency was to create a federal renewable energy agency in 2015 when Goodluck Ebele was the president; however, we haven't heard much about the Renewable energy program since the Buhari Administration came in".

### 4.6.5 Lack of Policy Implementation

Nigeria has many policies that are reviewed severally and not passed into law. As stated earlier the biofuel policy as well as the REMP are yet to be passed into law. Interviewee 7 lamented, "The policies are really slow to be passed into law, when passed into law it is hardly implemented; hence investors are not comfortable, they need to know their money is in safe hands".

### 4.6.6 Low level of awareness and bad reputation

There is low level of awareness of the socio-economic and environmental advantages of renewable energy in Nigeria due to the lack of adequate flow of information on its various applications and technologies (Oji et al., 2012). Interviewee 10 concurs by saying "people do not know how efficient renewable energy is and its benefits due to the lack of awareness". Renewable energy technologies also have a bad image especially to the common man in Nigeria, this is in correlation to the existence of many counterfeits in the market. Interviewee 14, a staff of a bank asserts, "Though I can afford to have renewable energy in my house as a back up, i won't do so because it doesn't work; i know a lot of friends who wasted their money on it". Hence the general perception for renewable energy technologies is that they are not matured yet and they only fit into certain niche markets (Emodi & Ebele, 2016).

Interviewee 7 explained, "Renewable energy needs a lot of advocacy to inform people about the benefits and correct previous wrong impressions about renewable energy"

### 4.6.7 Inadequate Incentives for Renewable Energy Development

According to Emodi (2016), the incentives on renewable energy are not adequate especially when compared to conventional sources of energy that have enjoyed incentives for so many years. Interviewee 2 compliments this by stating that, "the current policies do not have adequate incentives that will encourage private investors to go into renewable energy development in Nigeria". The existing incentives have additional challenges or are not implemented. Interviewee 1 gave an example of a challenge with the incentive of waiving

import duty for renewable energy technologies, “the process for securing a waiver is bureaucratic and people end up paying demurrage”

### 4.6.8 Project Implementation/Corruption

Nigeria has many renewable energy projects that have either been partially implemented with no formal status update or with no form of implementation. During the interviews, enquiries were made concerning projects like nail light solar electrification programme, energy efficient housing scheme, establishment of a renewable energy village, etc. and interviewees have either not heard about it or are not sure if the project was implemented. One specific instance is when interviewee 11 a representative at the Ministry of Environment was asked about the CDM project to distribute 150m bulbs, “I don’t think the project scaled through, I know there was an attempt”. Hence, the Nigerian government is poor in terms of starting and completing renewable energy projects.

Also, the problem of corruption in form of mismanagement of funds is a general problem in Nigeria and this is also a challenge for renewable energy. There are no proper checks and balances to ensure proper management of funds allocated to renewable energy projects, sometimes the status of the funds cannot be account for. A good example is the funds issued for the N9.2 billion clean cooking stoves project which cannot be ascertained.

### 4.6.9 Lack of adequate funds

The government is sometimes unable to provide the required funds for renewable energy projects and as a result they try to encourage both local and international investors. Inadequate funding is however a major factor responsible for slowing down renewable energy integration in Nigeria, it affects both the government and private individuals due to its high initial capital cost. The nation is constrained capital wise with several demands competing for the scarce available capital, hence renewable energy technology investors face challenge raising funds from the system. Also the consumers especially the poor lack sufficient fund and have difficulty in accessing loans. Interviewee 4 who is a representative from the bank commented on why accessing loan for renewable energy investments is difficult both for investors and consumers. He expressed “due to unreliable credit records, investments in Nigeria needs collateral; when you look at Renewable Energy Technologies (RETs), the technologies and land cannot be taken as collateral as the technologies are uncertain and the land still belongs to the government”. He concluded by saying the banks would rather reduce their risk by getting involved in projects that have a degree of equity higher than 30% and the involvement of an Export Credit Agency.

An example of inadequate funds and competition for available capital is the cuts in some 2017 budget allocations for power projects. This includes the Mambilla Project cut from N950m to N500m, the 215MW dual plant cut from N5 billion to N4 billion, the Zungeru power project cut from N1.3 billion to N1 billion and the Katsina wind farm cut from N904m to N804 (Mudashir, & Krishi, 2017)

## CHAPTER 5- DISCUSSIONS

### 5.1 Introduction

This chapter focuses on the discussion of the findings in this study and its implications in relation to the analytical/conceptual framework adopted for the purpose of this study. The discussion is mainly based on the five stages of energy security assessment framework as presented by Cherp & Jewell (2013) and explores the implications of renewable energy integration on energy security using indicators outlined by Jegen (2009).

### 5.2 Assessment of Energy Security in Nigeria

The first stage in the assessment of energy security is to have a tailored definition of energy security that applies to the energy system of Nigeria. The Nigerian energy system highly relies on fossil fuels and biomass in an unsustainable way, this implies that energy supply cannot be guaranteed as fossil fuel is finite and biomass is utilized unsustainably (Borok et al, 2013). The concept of energy security adopted in this study is ensuring security energy supply through diversification of energy sources and the monolithic energy system that exist in Nigeria cannot provide adequate and reliable supply of energy. Hence there is urgent need to address this challenge, this led to the increased awareness of the need to diversify and include renewable energy sources into the Nigerian energy mix.

The second stage is to identify the vital energy systems that are peculiar to the energy system. Currently in Nigeria, the vital energy sources include oil, gas, biomass (fuelwood and waste) and hydro. These resources are highly (in case oil and gas, and fuelwood) exploited. Other energy resources, with economic viable potential, but rarely exploited in the country include coal, wind energy and solar energy.

The discovery of oil in Nigeria is majorly responsible for the high reliance on fossil fuels. The existing infrastructures in Nigeria are three major large hydro dams, four oil refineries, 14 power generation grids which consists mainly of thermal plants, a national grid capacity of about 12,000MW, a transmission facility of about 5500MW which covers only about 40% of the country and 11 regional distribution grids. Though Nigeria possesses sufficient energy sources to improve its energy supply, it lacks the adequate infrastructure to exploit these resources to their full potential. These infrastructures are not only inadequate, they are also dilapidated and poorly maintained.

The third stage is to identify the vulnerabilities of the energy system. The Nigerian energy system is a very fragile system that currently cannot meet its growing energy demands (Sambo, 2009). One major challenge identified is the lack of newly improved energy

infrastructures and suboptimal performance of the existing structures; the substantial investments made in energy sector was in the 1970s after the oil shock (Tallapragada, 2009). No new infrastructure has been added to the energy system in 20 years, though there are plans and projects but implementation is at a very slow rate. Also poor maintenance is responsible for the suboptimal performance of existing structures.

Another main challenge is the dual dependency problem of Nigerian energy system. The Nigerian system does not only rely on imports of fossil fuel for domestic use, it also depends on export of fossil fuel as its mainstay for the economy. With the current drop in the price of oil, the foreign earning has drastically reduced, this has inevitably led to increase in cost of fossil fuels due to lack of funds to subsidize imports and a dwindling state of the economy. The full consequence of a central energy system can be evidently seen in Venezuela, a nation that highly relies on oil exports for 95% of its earnings and runs a central energy system that utilizes fossil fuels and hydropower. Despite having the world's largest oil reserve, the government has had to increase local price of gasoline by over 6000% and the economy is at the brink of collapsing (Khan, 2016). Another nation highly reliant on oil exports is Saudi Arabia and the nation plans to be completely independent of oil in 2030 (Zaremba, 2017). This serve as a reminder for the Nigerian government to tirelessly pursue alternative sources of energy and reduce reliance on fossil fuels.

The Nigerian government is clearly aware of the current challenges in the energy sector and has developed various policies with good intentions. Yet, these policies are hardly passed into law and they lack active implementation which inevitably leads to little or no achievement of set targets. Though policies are periodically renewed with improved targets and goals, the past problems that contributed to the previous policy targets not being achieved are never addressed. This implies that the Nigerian energy sector is in its current state partly due to the lack of the will of the government to address the challenges it faced in implementing previous policies and lack of tenacity to implement current policies.

The next stage is to match the vulnerabilities with indicators. The Nigerian energy system as described in the findings is plagued with insufficient supply of energy with a higher percentage of the population lacking access to energy supply and relying on fuelwood which is more affordable. Thus, the indicators adopted for this study to measure energy security were availability, affordability and accessibility.

The final stage of the assessment is using these indicators to show and analyze the state of energy security in the nation. According to Solvacool (2011), availability will imply having relative independence and diversification of energy fuels. Nigeria is highly dependent

on export and import of fossil fuels with very low diversification in its energy supply mix. It is indeed an irony, a nation that exports petroleum products is unable to sufficiently meets its local demand; import substitution however contributes to scarcity as this is greatly affected both by the fluctuation and availability of dollar in the system, thereby decreasing availability. In terms of diversification, the central energy system allows for constant interruption of energy supply due to disruptions; though the nation has various resources, its focus is mainly on fossil fuel. The nation is running an energy system which currently cannot provide adequate and reliable supply, it lacks source diversification and has a low level of spatial diversification. All oil fields and gas plants are either located in the Niger Delta region or sourced from the region and all hydro plants are located in the Northern region. Hence disruptions like gas pipeline vandalization, low water level, technical failures inevitably lead to low energy supply.

In terms of electricity, there is supply-demand imbalance, this has led to self-generated energy using fossil fuel and fuelwood. It is important to state that running a fossil-fuel based energy system is highly unsustainable and it also contributes to major environmental problems. Unreliable supply and poor electricity production is a major cause of poor industrial development in Nigeria. Electricity generation in Nigeria at a peak of about 4300MW is far too low for its size of population, though it is reported that the nation has an installed capacity of 12,000 MW; this cannot be compared to some many other countries like the UAE with an installed capacity of 4740 MW for a population of 4 million or South Africa with a generation capacity of 44,000 MW to a population of 46 million (Adenikinju, 2008). There has also been slow growth in electricity generation over the years, Magida (2008) revealS that, as at 2000 Nigeria's generation had only grew by 10% while Indonesia had grown by 237% and Malaysia had grown by 243%. Electricity generation, transmission and distribution facilities are not only poorly managed, there is also poor communication between the transmission and distribution centers; this sometimes leads to a collapse in the national grid (Emodi, & Yusuf, 2014).

Sovacool (2011) also described accessibility as an indicator of energy security to mean having high level of access to both electricity and energy services. As established in the findings, the level of access to modern energy in Nigeria is quite worrisome especially in the rural Northern area of the country. Akorede et al. (2017) rightly establishes that, access to energy correlates with economic growth and poverty reduction, a higher level of access to modern energy will translate to a better rate of economic growth and creation of wealth inevitably leading to poverty reduction. Thus, low access to energy service is mainly

attributed to high rate of poverty in Nigeria especially in the Northern region. Low access level also correlates with high reliance on biomass and inefficient infrastructure as established earlier as well as low consumption level. As shown in the findings, the per capita electric energy consumption in Nigeria is too low and here is also a correlation between high energy consumption and high rate of economic growth (Akorede et al. 2017).

Affordability according to Sovacool (2011) is having stable prices that are not volatile, prices should be equitable in relation to income. Though there is a minimum wage, there are many people living below this wage and this makes it difficult to determine what equitable price is. The prices are however, highly volatile; prices of petroleum products are the most volatile as they fluctuate constantly. One major factor that causes this is import substitution as the population currently relies on petroleum products for cooking, generator-based electricity and for transportation. This is a major problem as the price of petroleum products fluctuates and this affects the cost of transportation as well as the cost of generating electricity. It is a ripple effect as the cost of transportation also affect the prices of petroleum products in terms of distribution and this has led to social tension in the country.

In summary, for a nation to attain a high level of energy security, it needs to ensure constant supply accompanied with high level of access and stable prices. On this note, Nigeria has a very low level of energy security, it not only has a low level of access; it also cannot provide reliable constant energy services to those who currently have access. Though its energy prices are low when compared to other countries in the world, the alarming rate of poverty and low minimum wage rate has to be put into consideration. Energy supply is constantly disrupted, all gas stations are located in the Niger Delta region which has been riddled with unrest and vandalization by locals.

### 5.3 Renewable Energy Potential Vs Integration

Adoption of renewable energy in Nigeria is far below the potentials that has been widely established. Despite the realization of the need to diversify energy sources and the identification of its renewable energy potentials, Nigeria has been too slow in integrating renewable energy sources into its energy mix. However, there has been some attempts through projects, but most of them have either failed or the completion period is continually postponed.

Hydropower potential in Nigeria is enormous yet its current LHP integration is about 14% of its potential while its SHP integration is 19% of its current potential. This is too low given the fact that 64,000 MW can be generated if only 1% of the current potential can be

harnessed. The government has focused more on the exploitation of gas for electricity since the discovery of oil than it has on hydropower. However, LHP projects take longer period to complete than SHP but the potential for SHP is only about 3500MW and this is currently too low to meet the current energy demands. The governments' current LHP projects if completed will add at least 3700 MW to the current generation capacity and the SHP and Medium Hydropower (MHP) projects if completed will add at least 70MW. This is these power pants are fully utilized without any challenges. These current projects are still meagre compared to the potential but if the government can complete these projects and strive to utilize its SHP potential soon, this will improve the current energy mix.

The solar potential is quite high and endless, indeed if the solar energy potential in Nigeria is fully harnessed, there will be no blackouts. Though solar integration has made some reasonable progress and awareness in Nigeria, the current opinion of Nigerians on solar energy is mixed. As established in the findings, some people are of the view that solar technology fails most of the time and it is a waste of money, while some feel it is the best option to power their houses in Nigeria; hence there are many standalone solar units owned in Nigeria but the exact MW generated from these cannot be currently ascertained. The government currently reports the domestic utilization of solar PV to be in excess of 20 MW, it is not clear in what capacity this is utilized as there are currently no off-grid hybrid or grid connected solar systems.

In relation to the above, the government's first solar PPA to develop at least 1050 MW which will be added to the grid is a good step in integrating solar to the energy mix. These projects are to be developed in the Northern part of Nigeria which has been established to have the highest potential for solar and if completed will encourage further development of solar even in areas with less potential. This is however a long term project; the government needs to get involved in more short-term projects that will be not only be implemented in due time but properly maintained. The government should also encourage more investments in off-grid solution as well, this is an immediate solution to the current challenge of poor energy access in Nigeria. Lessons needs to be learnt from the Jigawa solar project, this is indeed a ray of hope for more off-grid solutions to be considered.

Wind energy has less potential in Nigeria when compared to solar, this is one major reason why there are few projects to utilize this potential. Wind energy projects in Nigeria are very few with very low capacity as well, though there has been reports of attempts made to promote capacity development and awareness for wind by the government. There are no reports of private stand alone wind generating systems in Nigeria, this implies that there is

less investments and awareness of wind energy technology in Nigeria. Despite the potential of 50,046 MWh/yr of electricity, the highest MW of wind project in Nigeria is 10 MW and it is yet to be completed. Hence it is difficult to determine if Nigeria has this high potential and if the wind energy technologies of megawatt scale will function properly in Nigeria. Notwithstanding, more small scale wind turbines need to be exploited in Nigeria.

Biomass potential in Nigeria is high as well but biomass in form of fuelwood is utilized in a non-renewable and wasteful manner while biomass in form of biofuel is under utilized. Of the 80 million $m^3$ ($43.4 \times 10^9$ kg) of fuel wood utilized for household purpose, only about 5 to 12% is gainfully used (Diji, 2013). This implies that an estimate of 88% of the energy content of fuelwood is wasted in the process of utilization and if this energy is utilized it will not only reduce the rate of deforestation in Nigeria, it will also increase the availability of fuelwood for use. The need for efficiency in use of fuelwood has been discovered and this is what led to various clean cook stoves projects in Nigeria. The projects that are making some level of progress in Nigeria are either by private institutions in partnership with investors or in partnership with the government. There is currently no official record of progress made solely by the government in terms of clean cook stoves.

Biofuel in various forms have high potentials in Nigeria but they have rarely been exploited. For example, there are only a few biogas digesters and they are mostly owned by research centres and private individuals and most of them are reportedly no longer functioning, the biogas industry in Nigeria is currently undermined (Ani, 2014). Also, despite the solid waste potential stated in table 1 there is no current plan of any waste to energy plant in Nigeria by the government. The government has mainly focused on biofuel policy but its policy implementation has been too slow and as the policy is yet to be passed into law; it carries little or no weight. It is a cause for concern that this policy came into existence in 2007 and only feasibility studies have been done for 10 years now with no other major progress recorded.

All renewable energy sources are utilized way below their potentials, the current progress made though commendable is inadequate given the growing energy demand in Nigeria and the huge positive difference that utilizing these potentials can have on the current energy mix. It is pertinent to mention that, most of the progress made in the renewable energy sector is attributed to the private sector but lack of adequate incentives and public funds hinder the growth of the private sector investment in renewable energy.

### 5.4 Biomass: A Path to Improved Energy Security in Nigeria?

The paradox of biomass in Nigeria is that the nation has abundant biomass resources but this is seen as a traditional source of energy in a modern world, hence there needs to be a switch to modern energy sources. Nevertheless, its biomass resources can be a key to the improvement of energy security in the nation. Biomass is readily available, accessible and affordable for the mass, this implies that it also is capable of increasing energy independence, thereby making Nigeria sufficient in itself without high reliance on external energy markets. The problem is not however the over reliance on biomass but the current manner of utilization.

There is a clamour for the switch to modern energy sources in developing countries. Ironically, developed countries are strategically making efforts to include more biomass to improve energy security and meet domestic energy demands. A good leading example in biomass energy is Sweden, as of 2016 it makes 33% of its final energy consumption and currently contributes the highest to the current energy mix; bioenergy replaced oil as the leading source of energy in 2009 (World Energy Council, 2016). The nation has steadily over the years increased the share of energy from biomass and waste in its energy mix, in 2013 biomass accounted for 23% of the total supply as against 11% in 1983. The biomass utilized in Sweden consists majorly of fuel wood and less of agricultural waste and biofuels (Ericsson & Werner, 2016). Another example is Denmark, many of the nation's heat and power plant are increasingly fuelled by biomass. Also Germany, Austria and the Netherlands utilize biomass for electricity generation

It is pertinent to state that in Nigeria biomass and waste is currently used mainly for cooking and less for heating or electricity. While developed countries like Finland, Denmark and Sweden utilize biomass for heating mainly due to the climatic conditions which have cold seasons. Nigeria's climate does not necessarily need the amount of energy generated for heating in any of these countries, as the Nigerian weather is fairly warm. The use of biomass in Nigeria is mainly for cooking. Improving the utilization of biomass in Nigeria will therefore mean, providing efficient technology for the utilization of biomass for cooking. Also biomass can be used to generate electricity either directly or through a co-firing power generation system. This will inevitably reduce the reliance on fossil fuel for power generation

Biomass though seen as a traditional source of energy can be modified in a more efficient manner with less environmental pollution and efficient energy conversion technologies. Converted biomass energy can be used for heating, electricity and transportation. This can be a solution to the current reliance on fossil fuels, the modern

energy technologies in Nigeria readily depend on fossil fuels directly or through grid electricity which highly relies of fossil fuels as well. Biomass can substitute fossil fuels and contribute to energy security as it is domestically sourced and can be converted to use locally (World Energy Council, 2013). An investment in the research and development of biomass resources, an effective management and efficient utilization of this resource might can improve the nation's energy security, however the peculiarities of the Nigerian system has to be put into consideration.

### 5.5 Implications of Renewable Energy Integration for Nigeria's Energy Security

Renewable energy if integrated fully, can increase Nigeria's current energy supply by about 60,000MW or 60GW with no substantial increase in environmental pollution (Olaoye et al., 2016). However, due to the complexity of the grid and transmission challenge in Nigeria, it is advisable to stick to off-grid renewable energy technologies. Though renewable energy technologies face several challenges in the Nigeria system, it is still the fastest and efficient energy solution to the current Nigeria energy problems. This section will attempt to look into the effect of renewable energy integration on energy security in Nigeria using the indicators adopted.

#### 5.5.1 Availability

The high energy demand and the low energy supply that currently bedevils the energy system calls for the nation to increase energy supply. The finite nature and the environmental degradation cause by fossil fuel makes it necessary to integrate renewable energy to have other sources of supply. Having various sources of energy will not only increase sustainable energy supply, it will also reduce interruption in supply, thereby increasing reliability and spatial diversification. Due to the decentralized nature of off-grid solutions, it implies that vandalization or failure will have reduced effect on energy supply unlike the current conventional energies that are central and failure grossly leads to inadequate supply.

There is currently high tension on the grid which contributes to reduced availability of electricity supply, off-grid renewable energy solution will however cover for the shortfalls. Off-grid renewable energy will take less time to complete and it can be easily managed than the complex nature of the national grid. This will also reduce the current demand on electricity from the grid which implies less tension.

#### 5.5.2 Accessibility

There is no doubt that integrating renewable energy will increase energy access in

Nigeria as most of the existing renewable energy projects are targeted towards those that lack energy access or are currently experiencing energy poverty. Considering the fact that the majority of the people that lack access to energy are in the Northern region and renewable energy potential in higher in the North than any part of the country; thus if these potentials are fully utilized, it will unavoidable increase energy access in the region. Also off-grid renewable energy solutions will not be affected by poor road networks and other distribution challenges faced by fossil fuels. Renewable energy technologies have the capacity to increase the number of people with access to electricity and energy for household usage like cooking, this will reduce the reliance on fossil fuel and encourage access to efficient use of fuelwood. According to Akorede et al. (2017) access to modern electric energy can directly increase economic growth and reduce poverty through creation of wealth. Hence increased access through renewable energy sources can help reduce poverty in Nigeria.

### 5.5.3 Affordability

The affordability of renewable energy technologies has always been a challenge and contributes to its slow integration. It is necessary to state that the prices of renewable energy technologies have continually reducing over the years but a comparison of cost with conventional technologies is necessary. A good example illustrated by Oyedepo (2012) is a cost comparison between small-scale hydro power plants and diesel generators for rural electrification. He concluded that small hydro power plants are more cost effective than diesel generators especially in the long-run.

The upfront high cost of renewable energy technologies in Nigeria especially due to their lack of local content cannot be ignored. Its long-term benefit and energy efficiency level should be put into consideration, in the long run it is usually more affordable. This is because once installed, they do not need constant fuel to generate power; hence the zero marginal cost nature of renewables should be taken advantage of. It is also important to state that renewable energy cost to the end user is fairly stable as it is not subject to the fluctuations in the international energy markets like fossil fuels as noted by Lucas et al. (2016). An example given by Afikhenua (2017) is the national soar system which was launched in Nairobi since 2011 and it was successful as it cut weekly energy spending by as much as 50% and it has typically reduced the price they spend on kerosene. This suggests renewables are a better option for Nigeria because of the existent volatile prices of fossil fuel.

Affordability can also be relative, it is sometimes usually more affordable for the government to consider off-grid renewable energy projects in rural areas especially due to the

low energy consumption, and it is cheaper than extending the grid. Therefore, it will not be wise to spend a hue amount on conventional energy like grid electricity in rural areas as they utilize less energy than the urban areas. The Lagos State government realized this and the Osinowo off-grid project cost N10,000,000; the government opted for this option as the estimated cost of connecting the village to the grid was about N150,000,000.

## 6. CONCLUSION AND RECOMMENDATIONS

The purpose of this study was to investigate the current state of energy security, renewable integration in Nigeria and the implications of renewable energy integration on the country's energy security. This study maintains that energy security is a global phenomenon with growing importance, and it drives the energy policies of many countries both at the international and domestic level. Though, energy security has evolved since inception to incorporate current global issues, it still revolves around providing sufficient and uninterrupted energy for all. The analytical framework demonstrates the increased diversification of energy sources among nations to include renewable energy sources. Energy security is an important prerequisite for economic growth and development.

This study established in the findings that, Nigeria has abundant conventional and renewable energy resources but has a deteriorating state of energy security. The nation has mainly focused on exploitation of its conventional source of energy, mainly fossil fuels over the years and its' renewable energy potentials have been minimally exploited. Failure to diversify the sources of energy, increase demand for energy, lack of new energy infrastructures and lack of proper maintenance of existing infrastructures are major reason for lack of energy security as any form of disruption leads to very low supply of energy.

The findings and discussion of this research provides the updated energy policies of the Nigerian government with major reference to renewable energy and energy security. We find that, there has been very minimal practical steps taken by the government and most of these steps were taken by the current Mohammadu Buhari administration. The current government is making attempts than any other government; however, this can be attributed to the increased awareness of renewable energy at the global level.

This study recommends that the government needs to take more active and practical steps to improve renewable energy integration into its current energy mix by providing more incentives like cash rebate to encourage investments from individuals, the private sector and international organizations. The government should also provide adequate information on the benefits of renewable energy with the aim of increasing awareness especially among the rural populace and focus on immediate cheaper off-grid solutions. Most importantly, if the current renewable energy projects are fully executed, there will be improvements in the nation's state of energy security and this will improve economic growth and development; thereby leading to increased investment in the sector. However, to rapidly improve its energy security, the

government needs to focus more on immediate cost effective off-grid solutions for the rural populace while it speeds up its maintenance plans on the existing structures.

The study recommends a further study of renewable energy integration in Nigeria on a smaller scale. This study focuses on renewable energy integration at a larger scale, an investigation into the status of renewables in various states and local governments of Nigeria with a focus on the rural projects is hereby suggested. This will establish the current state of renewable energy targeted towards rural areas and the impact of low energy security especially on the rural populace as they bear the brunt of a weak energy system

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**Appendix 1: Interview Guide**

General Questions

- What is your opinion on the current energy mix in Nigeria?
- Nigeria's current energy mix consists of a high proportion of biomass and waste, with less hydro. Why do you think this is so?
- Do you think the energy resources we possess as a nation can help improve the current energy mix?
- It has been seen over the years that energy demand in Nigeria will continue to increase, what is being done by the Nigerian government to meet this energy demand?
- What do you think is responsible for low energy consumption in Nigeria?
- Do you think Nigeria possesses abundant renewable energy potentials? If yes, has it been fully harnessed? If no why?
- Do you think renewable energy as an alternative source of energy is economically viable for Nigeria?
- What do you think are the challenges hindering the progress of renewable energy in Nigeria?
- Do you think Nigeria has enough solar radiation to integrate or be fed into the national grid? (a bit specific for A representative of Energy Commission of Nigeria)

Specific for the department of renewable energy in ministry of environment

- What is the current status of the solar farm established in Kaduna in 2011?
- What is the status of the distribution of 150m bulbs under the clean development mechanism?
- What is the current status of the efficient housing scheme in conjunction with Aso savings?
- What are the challenges of establishing a renewable energy village in Nigeria

Specific for bank representative

Are there any forms of credit available for renewable energy businesses?

Why are the Nigerian banks not actively involved in renewable energy investment?


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