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Determinants of Renewable Energy Growth in Nigeria

Dissertation in Energy Systems and Policy
Master of Science in Energy for Sustainability

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ENERGIA PARA A SUSTENTABILIDADE
ENERGY FOR SUSTAINABILITY • EFS

Wojolomi Michael Ogbe

Determinants of Renewable Energy Growth in Nigeria

Master Dissertation in Energy for Sustainability, developed in the specialization branch of Energy Systems and Policy, presented to the Faculty of Science and Technology of the University of Coimbra, as part of the requirements for the award of the Master Degree.

Supervisor: Professor Patrícia Pereira da Silva

Co-Supervisor: Professor Pedro André Cerqueira

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"The time will come when diligent research over long periods will bring to light things which now lie hidden. A single lifetime, even though entirely devoted to the sky, would not be enough for the investigation of so vast a subject… and so, this knowledge will be unfolded only through long successive ages. There will come a time when our descendants will be amazed that we did not know things that are so plain to them… many discoveries are reserved for ages still to come, when memory of us will have been effaced. Our universe is a sorry little affair, unless it has something for every age to investigate…Nature does not reveal her mysteries once and for all."

Lucius Annaeus Seneca
In Natural Questions, Book 7 (c 1st century)

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Abstract

Renewable energy plays an important role in meeting the needs of a country; the development and proper use of renewable energy should be given high priority, especially with the current environmental issues plaguing the world today.

Given the importance of renewable energy in the discussion of a reliable and sustainable energy future, it is imperative to understand its main determinants and to draw result implications for energy policy.

This study analyses these determinants for sub-Saharan Africa, with a special focus on Nigeria. Using panel data techniques namely the Fixed Effects (FE) estimator for a period covering 1990-2011, the results suggest that increases in fossil fuel prices (oil price) and economic development (per capita GDP) aid renewables development while population growth impedes it.

Furthermore, the study investigates the potentials and current status of renewable energy in Nigeria. The investigation shows that Nigeria is blessed with great potential for developing renewable energy such as wind, biomass, solar and hydro power, dispersed in all regions of the country; however, these potentials haven’t been fully tapped into, even though many of them are plentifully available, and have good economic potential.

Finally, current policies and legislations regarding renewable energy in Nigeria are discussed, with recommendations and suggestions given, with regards to the formulation of appropriate policies towards renewable energy deployment.

Keywords: Renewable Energy, Fixed Effects, Nigeria, Sub-Saharan Africa.

Resumo

As energias renováveis assumem um papel importante para colmatar as necessidades de um país. O desenvolvimento e a adequada utilização das energias renováveis deverá ser uma prioridade, em especial tendo em conta as questões ambientais que atormentam o mundo dos dias de hoje.

Dada a importância das energias renováveis na discussão de um futuro energético sustentável e confiável, é imperativo compreender os seus determinantes principais e perceber as implicações dos resultado obtidos para as políticas energéticas.

O presente estudo analisa os diferentes determinantes para a África Subsariana, com um foco especial na Nigéria. Os resultados obtidos, utilizando técnicas de dados em painel, nomeadamente o estimador de Efeitos Fixos (EF), para o período 1990-2011, sugerem que o aumento dos preços dos combustíveis fósseis (preço do petróleo) e o desenvolvimento económico (PIB per capita) auxiliam o desenvolvimento de energias renováveis, enquanto o crescimento populacional tem o efeito contrário.

Relativamente às potencialidades e ao estado atual das energias renováveis na Nigéria, a investigação mostra que este país tem um grande potencial para desenvolver energias renováveis como a eólica, a de biomassa, a solar e a hidroelétrica, distribuídas por todas as regiões do país; contudo, estes potenciais não foram completamente aproveitados, embora muitos deles se encontrem abundantemente disponíveis e apresentem um bom potencial económico.

Finalmente, discute-se as políticas e legislações vigentes relativamente às energias renováveis na Nigéria, sugerem-se recomendações e sugestões no que diz respeito à conceção de políticas adequadas para o desenvolvimento das energias renováveis.

Palavras-chave: Energias Renováveis, Efeitos Fixos, Nigéria, África Subsariana

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List of Abbreviations and Acronyms

Abbreviations and Acronyms	Meaning
BTOE	Billion Tonnes of Oil Equivalent
BTU	British Thermal Unit
CF	Cubic Feet
CO_2	Carbon Dioxide
ECN	Energy Commission of Nigeria
EPSRA	Electricity Power Sector Reform Act
EU	European Union
FE	Fixed Effects
FEVD	Fixed Effects Variance Decomposition
FGN	Federal Government of Nigeria
FMP	Federal Ministry of Power
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GHI	Global Horizontal Irradiation
GWH	Gigawatt Hour
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
KGOE	Kilograms of Oil Equivalent
KW	Kilowatt
KWH	Kilowatt Hour
LHP	Large Hydropower
LNG	Liquefied Natural Gas
MW	Megawatts
MYTO	Multi-Year Tariff Order
NEMP	National Energy Master Plan
NEP	National Energy Policy
NESI	Nigeria Electricity Supply Industry
NERC	Nigerian Electricity Regulatory Commission
OECD	Organization For Economic Co-Operation And Development

OPEC	Organisation of the Petroleum Exporting Countries
PCSE	Panel Corrected Standard Errors
PHCN	Power Holding Corporation of Nigeria
PV	Photovoltaic
RE	Renewable Energy
REA	Rural Electricity Agency
REMP	Renewable Energy Master Plan
RETF	Renewable Electricity Trust Fund
RPS	Renewable Portfolio Standard
SSA	Sub-Saharan Africa
TCF	Trillion Cubic Feet
TCM	Trillion Cubic Metres
TWH	Terawatt Hour
WB	World Bank
WDI	World Development Indicators

Chapter One: Introduction

Renewable energy plays an important role in meeting the needs of a country in terms of sustainable development. The development and proper use of renewable energy should be given high priority, especially with the current environmental issues of climate change and global warming being in the forefront among the most critical energy related issues in the world today. The increased attention on renewable energy sources can be attributed to a number of factors beyond climate change. The recent concerns over the volatility of oil prices and the dependency on foreign energy sources are all contributing factors to the current interest in renewable energy sources (Apergis & Payne , 2010). Bolstered by this increasing importance, deployment of renewable energy sources has experienced a remarkable global growth profile in recent times (Aguirre & Ibikunle, 2014). The development of renewable energy sector will not only help to avoid the harmful environmental effects of the current energy consumption which mainly relies on fossil fuel energy sources and cause pollutant emissions and climate change, but also promote sustainable development objectives and reduce the dependency on foreign energy imports (Kaygusuz , 2007).

Given this important role of renewable energy in the discussion of a reliable and sustainable energy future, as can be drawn from the above discussions, it is important to understand its main determinants and to draw result implications for energy policy. Foremost, the increased concern over the issues related to energy security, climate change, and global warming suggests that there will be a greater reliance on the demand of renewable energy in the near future (Omri & Khuong, 2014). The level of deployment of renewable energy differs from country to country. These variations can be attributed to different factors. Marques et al. (2010) highlight some important determining factors in the deployment of renewable sources to include political, socioeconomic and country- specific factors.

Africa as a continent is blessed with abundant energy sources, but imbalance between electricity generation and demand still remains an issue in Sub-Saharan Africa (SSA) countries. The development of the renewable energy sector in Nigeria in particular has the potential of limiting harmful emissions brought about from the current reliance on fossil fuel sources for energy production, providing sufficient electricity for its teeming population and also promoting sustainable development objectives. This highlights the importance of a better understanding of the determinants of renewable energy use and growth in the country.

A number of studies have been carried out showing the renewable energy potential of Nigeria, but there is a dearth of in-depth empirical studies carried out to analyse the drivers of renewable energy in the country. This thesis intends to bridge that gap.

The primary aim of this Master's thesis thus, is to perform an empirical analysis to determine the factors that affect the growth of Renewable Energy in Nigeria. The specific research question being:

"What are the determining factors which aid or hinder the growth of Renewable Energy in Nigeria?"

Secondary objectives include:

- To perform a review of the potentials of Renewable Energy in Nigeria and Sub-Saharan Africa.
- To examine the current status of Renewable Energy deployment in Nigeria and Sub-Saharan Africa.
- To review the current policies regarding Renewable Energy growth in Nigeria.
- Outline recommendations for Nigeria in terms of improving the share of Renewable Energy.

This document is organized through six chapters and the remainder of this thesis is structured as follows:

Chapter two develops a literature review on previous studies that deal with renewable energy growth and its determinants. It draws on the work of other authors and their analyses of various factors which determine the growth of renewable energy in various regions or countries around the world.

Chapter three embodies the specificities of Energy development in SSA and specifically in Nigeria. The analysis includes a general overview of Nigeria and taking a look at the current electricity situation and its energy sources and utilisation. Furthermore, the renewable energy potential and present deployment are examined.

Current renewable energy related policies in place in the country are discussed in chapter four. Further policy options which Nigeria could adopt to boost renewable energy deployment are also discussed.

Chapter five provides the overall methodology with the discussion of the result and findings of the research. The Fixed Effects (FE) estimator is used in the analysis in this study. The contribution of renewable energy to the electricity mix in TWh/year is used to measure renewable energy. The results show the importance of per capita GDP, oil price and population growth on renewable energy deployment. Recommendations are proposed based on the findings of the research.

Chapter six concludes and summarizes the key findings of the research with the limitations of the study further outlined. Future work is also suggested.

Chapter Two: Determinants of Renewable Energy Growth: Theoretical Background

The increased attention on renewable energy sources can be attributed to a number of factors. The recent concerns over the volatility of oil prices, the dependency on foreign energy sources, and the environmental consequences of carbon emissions are all contributing factors to the current interest in renewable energy sources (Apergis & Payne , 2010). This chapter seeks to perform a review of the underlying influences as regards the factors which drive renewable energy growth.

As is mentioned by Marques et al., (2010) and Aguirre and Ibikunle (2014), the important factors which drive or determine renewable energy deployment can be split into political, socio-economic and country specific factors. Environmental factors are also taken into account.

2.1. Political Factors

Several studies, such as those carried out by Carley (2009) and Marques and Fuinhas (2012), point out political motivations as the most relevant aspect to the promotion of Renewable Energy. Political factors which influence Renewable Energy growth include public policies, institutional variables and energy security.

2.1.1. Public policies

Renewable Energy technologies are relatively expensive and cannot compete with traditional energy technologies without supporting policies (Aguirre & Ibikunle, 2014). Several studies (Marques & Fuinhas, 2012; Maria & Bernauer, 2014; Stadelmann & Castro, 2014; Kilinc-Ata, 2016) point out how public policies are one of the major motivating factors of renewable energy growth. Some of the most common public policy measures to encourage renewables include subsidies, quota policies, direct investment, research and development, feed-in tariffs, and green certificates. They could be influenced by both domestic and international factors such as characteristics of domestic political institutions or by what other countries or group of countries do (e.g. the European Union) (Maria & Bernauer, 2014). Policy design features tend to vary in structure, size, application, eligibility, and administration (Wiser et al., 2007). Despite these variations, public policies are aimed at increasing the capacity or percentage of renewable energy.

Carley (2009) performs a study aiming to explore the effectiveness of state energy programs with an empirical investigation of the linkage between state renewable portfolio standard (RPS) policy implementation and the percentage of renewable energy electricity generation across the United States using a fixed effects vector decomposition, with state-level data from 1998 to 2006. Results indicate that RPS implementation is not a significant predictor of the percentage of renewable energy generation out of the total generation mix, yet for each additional year that a state has an RPS policy, they are found to increase the total amount of renewable energy generation.

Marques and Fuinhas (2012) in their study, carry out an analysis to determine how public policies affect renewables deployment. They use panel data techniques for a time span of 1990-2007 on a sample of 23 European countries. Their findings suggest that public policy measures contribute, as a whole or disaggregated, to wider use of renewables. Specifically, policies of incentives/subsidies (including feed-in tariffs) and policy processes prove to be significant drivers of improved Renewable Energy use. They further ascertain that the deployment of renewables in most countries has been based upon direct interventions from governments, which are taking the risk of investments in green energy by the private players, either by guaranteeing the selling price of the energy or through public guidance.

Kilinc-Ata (2016) carries out a study to addresses what renewable policy instruments are effective ways to increase capacity of renewable energy sources. The study, similar to Marques and Fuinhas (2012) employs a 1990–2008 panel dataset to conduct an econometric analysis of policy instruments, namely, feed-in tariffs, quotas, tenders and tax incentives, in promoting renewable energy deployment. However, they increase the scope of the studies of Carley (2009) and Marques and Fuinhas (2012) to include 27 EU countries and 50 US states. They come to the same conclusion as Marques and Fuinhas (2012) suggesting that renewable energy policy instruments play a significant role in encouraging renewable energy sources, but their effectiveness differs by the type of renewable energy policy instruments. Findings further reveal that feed-in tariffs, tenders and tax incentives are effective mechanisms for stimulating deployment capacity of renewable energy sources for electricity, while the other commonly used policy instrument – quota – is not.

Lucas et al. (2015) perform similar analysis on the long-term developments in Africa's energy system using the results of a recent multi-model scenario study. Their results show that without climate policy, Africa's share in global energy-related CO_2 emissions is projected to increase to 3–23% by 2100. Emissions become significant on a global scale only after 2050.

2.1.2. Institutional variables

Institutions frame the manner in which political actors operate, and both directly and indirectly shape the structure of policy outcomes. The capacity of political organizations, the ideological underpinnings of political actors, and inter-party competition all affect the likelihood of environmental policy adoption and the degree to which outcomes conform to the policy objectives (Carley, 2009).

The adoption of the Kyoto-Protocol in 1997 was one of the earlier global measures put in place to tackle the environmental problems plaguing the world. The goal of the Kyoto-Protocol was to commit countries into reducing GHG emissions and to increase the share of electricity produced from renewables (Pablo, 2005). Such commitments to reduce emissions and increase share of renewables is one of the driving factors for the growth of renewables in countries. Countries that have ratified this agreement are expected to have a greater commitment to renewables deployment (Popp et al,, 2011).

Furthermore, global or regional institutions like the United Nations, European Union or the African Union set targets regarding emissions reduction and renewables deployment. Countries that are members of such institutions are thus incentivised to increase their shares of renewable energy.

Using new data on adoptions and changes in feed-in tariff and green certificate schemes in 26 advanced industrialized countries (which include 19 EU countries) over 20 years (1990–2010), Maria & Bernauer (2014) examine both domestic driving forces as well as international determinants of the underlying dynamics in policy-making as it relates to countries' efforts to increase their electricity supply from renewables. Using binary timeseries-cross-section analysis, their findings suggest that three factors play a particularly important role in pushing countries towards market-based support systems. One of those factors is EU membership, suggesting that EU membership and EU renewable policy efforts are likely to have facilitated peer-group effects in terms of horizontal policy diffusion for renewables. Stadelmann and Castro (2014) substantiate this result by further suggesting that membership within the EU seem to facilitate policy adoption on renewables.

Atalay et al. (2016) using largely qualitative analysis, seek to understand the reasons for the adoption of renewable energy technologies in oil-rich Gulf countries based on the hypothesis that the adoption of renewable energy technologies is the result of horizontal policy transfers from other countries, both within the region and from outside the region; endogenous developments within the countries themselves; or that it is a consequence of the implementation of international regimes, such as the United Nations Framework Convention on Climate Change. They argue that the recent adoption of renewable energy technologies in the Gulf and its striking variation can be explained by theories of policy transfer and endogenous policy development regarding political leadership. However unlike the results of Stadelmann & Castro (2014) and Maria & Bernauer (2014), they find that there is no support for the hypothesis of a strong direct influence of the international climate regime. Furthermore, they argue that policy transfer hypothesis and political leadership stand as coexisting influences on renewable energy adoption, rather than competing ones.

2.1.3. Energy Security

Energy security is the combination of available natural resources for energy consumption and national security. Domestic Renewable Energy deployment contributes to the improvement of energy security indicators related to geographic diversification and energy dependence. If Renewable Energy sources are deployed at a national level, they reduce energy dependence and the vulnerability entailed by the concentration of energy sources and origins (Escribano Francés et al., 2013).

Literature supports the hypothesis that energy security advances renewables deployment (Gan et al., 2007; Chien and Hu, 2008). Chien and Hu (2008) suggest that the import substitution of traditional energy by locally produced renewables has direct and indirect effects on increasing an economy's trade balance and the country's energy security. The higher the reliance of a country on energy imports, the higher the level of renewables deployment required in order to improve that country's energy security (Aguirre & Ibikunle, 2014). As Brahim (2014) further points out, harnessing and utilizing renewable energy is a viable tool for addressing energy security. Energy security dependency is a critical issue for both developed and emerging economies.

Narbel (2013) performs a study to investigate the partial correlations between the share of new renewable electricity in a country and income, energy security and climate change mitigation. New renewables in his paper, refers to the electricity generating technologies that have not yet reached grid-parity (e.g. wind, solar).He uses least squares analysis to perform his study on 107 middle and high income economies from around the world for the years 2007, 2008 and 2009. His findings show that rich countries relying on coal imports to generate their power are also those with the highest shares of electric power from new renewables. The results suggest that income and the political objectives of energy security are the likely macro elements promoting the wider use of renewable electricity generating technologies which have not reached grid parity.

2.2. Socioeconomic Factors

Socioeconomic factors of Renewable Energy deployment include CO_2 emissions, prices of conventional energy sources, country income, energy need and the contribution of traditional energy sources to electricity generation.

2.2.2 Prices (oil, natural gas and coal)

The prices of alternate sources of energy, in this case fossil fuels, play an important role in determining the use of renewable energy. The price of renewable energy is still relatively high as compared to traditional sources. However, the prices of traditional energy sources fail to reflect the real costs of their use, when compared to the ones of renewable energy considering the environmental costs are not taken into account. But as Abas et al. (2015) point out, new global investments in oil and gas sector increased from 2004 to 2011 but started declining again after 2012 and the recent plunge in oil prices has discouraged investment in oil and gas exploration which could potentially have an effect of increased development of renewables.

Bird et al. (2005) in their study on market factors driving wind power development in the United States suggest that the increasing cost-competitiveness of wind generated electricity attributable to high natural gas prices is now an important driver for new wind installations. Van Ruijven & Van Vuuren (2009) examine the interaction of renewables and hydrocarbon prices in high and low GHG emission mitigation scenarios. Their results follow up on Bird et al. (2005) by opining that with high hydrocarbon prices, there is an improved position of renewable energy sources.

However, Sadorsky (2009a) contradicts this by suggesting that oil price increases have a smaller although negative impact on renewable energy consumption; a view shared by Omri & Khuong (2014) who examine the determinants of renewable energy consumption for a global panel consisting of 64 countries over the period 1990-2011 by using a dynamic system-GMM panel model.

The result of Van Ruijven & Van Vuuren (2009) is further corroborated by Reboredo (2015), who says that high oil prices encourage development of the renewable energy sector since the economic viability of renewable energy projects is enhanced, whereas low oil prices have the opposite effect. He further highlights that oil price dynamics impact on the performance of renewable energy companies by making the substitution of exhaustible energy resources with sustainable energy resources more or less profitable.

Soon & Ahmad (2015) perform a meta-analysis on the willingness-to-pay for renewable energy use. A meta-analysis is essentially a study of studies. They base their study on 30 previous studies. Their results show that more and more households are increasingly willing to pay for renewable energy use. They obtain a summary willingness-to-pay estimate of USD7.16. On average, households are willing to pay an increase of this amount per month over the price of energy they are currently paying for, to shift to Renewable Energy use. The type of renewable energy use however does not seem to be important in determining willingness-to-pay, nor does the temporal mode of payment.

2.2.3 Income and Economic Growth

The wealth of a country, usually measured by the gross domestic product (GDP) or the GDP per capita, plays a significant role in determining the deployment of renewables. A higher level of income means a higher potential or more resources to foster renewable energy growth. Larger income allows countries to handle the costs of developing Renewable Energy technologies and guaranteeing higher support for the costs of public policies in promoting and regulating renewables. The relationship between economic growth and renewables deployment has been tested by a number of studies (Sadorsky, 2009a; Sadorsky, 2009b; Apergis and Payne, 2010; Menegaki, 2011; Ohler & Fetters, 2014) and there is somewhat of a consensus as to the how they affect each other.

Sadorsky (2009a) presents and estimates an empirical model of renewable energy consumption for the G7 countries using panel cointegration and annual data from 1980-2005. His results show that in the long term, an increase in real GDP per capita is found to be a major driver behind per capita renewable energy consumption. Similarly, Sadorsky (2009b) shows that increases in real per capita income affect significantly and positively per capita renewable energy consumption, meaning that higher economic growth would require more renewable energy as a share of the total energy consumption. He further suggests that across time, renewable energy consumption per capita in emerging economies is expected to grow faster than real per capita income as economic development takes place.

Chang et al. (2009) improves on the study of Sadorsky (2009 a & b) by using a panel threshold regression (PTR) model to investigate the influence that energy prices have on renewable energy development under different economic growth rate regimes for the OECD member-countries over the period from 1997 to 2006. The results suggest that countries with high rates of economic growth can respond to energy price impacts by changing their use of renewable energy. On the other hand, countries with low rates of economic growth tend to be unresponsive to energy price changes in their renewable energy use. This shows that the contribution of renewable energy is price inelastic in low-growth countries. A high-economic growth environment thus provides a buffer against energy price impacts and is beneficial to renewable energy development.

Apergis & Payne (2010) like Sadorsky (2009 a & b), also examine the relationship between renewable energy consumption and economic growth for a panel of twenty OECD countries over the period 1985–2005 within a multivariate framework. Using a panel cointegration and error correction model, the results indicate bidirectional causality between renewable energy consumption and economic growth in both the short- and long-run.

Menegaki (2011) performs a similar empirical study on the causal relationship between economic growth and renewable energy for 27 European countries in a multivariate panel framework over the period 1997–2007 using a random effect model and including final energy consumption, greenhouse gas emissions and employment as additional independent variables in the model. The results however, are contrary to Apergis & Payne (2010). They do not confirm causality between renewable energy consumption and GDP, although panel causality tests unfold short-run relationships between renewable energy and greenhouse gas emissions and employment. The estimated cointegration factor refrains from unity, indicating only a weak, if any, relationship between economic growth and renewable energy consumption in Europe, suggesting evidence of the neutrality hypothesis, which can partly be explained by the uneven and insufficient exploitation of renewable energy sources across Europe.

Ohler & Fetters (2014) corroborate the results of Apergis & Payne (2010) by showing the presence of a bidirectional relationship between aggregate renewable electricity generation and GDP, highlighting that changes in GDP impact renewable energy. They analyse the impact of GDP growth on individual renewable sources and find out that GDP growth exhibits a positive impact on biomass and waste energy, but a negative impact on hydroelectricity. Solar shows a unidirectional relationship from GDP to solar energy. These results are similar to those obtained by Salim & Rafiq (2012)who analyse the determinants of renewable energy consumption in a panel of six major emerging economies, namely Brazil, China, India, Indonesia, Philippines and Turkey that are proactively accelerating the adoption of renewable energy. They use Fully modified ordinary least square (FMOLS), Dynamic ordinary least square (DOLS), and Granger causality methods for a period covering 1980-2006.

On another note, Wesseh Jr & Lin (2016) use an estimated Translog production model to provide insights on the effectiveness of renewable energy for Africa. The study utilizes country-level panel data for 34 African countries over the period 1980–2011. Their analysis shows that renewable energy is a higher driver of growth than the conventional fossil fuels over the sample period. This finding is reflective of the fact that renewable sources like wind, hydro and solar account for a greater share of power generation in most African countries.

2.2.4 Energy Need

Energy consumption is traditionally used as a development indicator. It is also used to reveal the energy needs of a country. Larger consumption needs, exert strong pressure on the level of energy use. The energy consumption could be satisfied by traditional energy sources, by renewables, and by using a combination of traditional and renewables (Marques et al., 2010).

Population and population growth are further indicators of the energy needs of a country. The projections of the International Energy Agency indicated that energy demand is expected to increase considerably in the coming years as the result of population growth and economic development driven primarily by Asian and African countries (IEA, 2015). 57% of Africa's population had no access to electricity in 2010. This implies that there is a need to provide modern energy to the present generation and make plans to cater for the future ones (Ackah & Kizys, 2015).

Carley (2009) suggests that States with larger growth rates will likely build more power capacity to satisfy growing state demand for electricity with renewable energy deployment being a viable option for satisfying this rising demand.

However, Aguirre & Ibikunle (2014) imply that energy use is negatively related to renewable energy participation, stating that under high pressure to ensure the energy supply, countries with increasing energy requirements are inclined to pursue more fossil fuel solutions and other cheap alternatives instead of renewables to cover electricity demand. This view is shared by Pfeiffer & Mulder (2013) who suggest that growth of electricity consumption appear to delay renewable energy diffusion.

These assertions highlight the importance of the energy needs of a country as a factor in determining renewables deployment, be it positively or negatively.

2.2.5 Contribution of traditional Sources to Electricity Generation

Another important determinant in the deployment of renewables is the contribution of traditional energy sources to electricity generation. Countries which have considerably large amounts of non-renewables tend not to focus on environmental issues abatement, and therefore, less renewables participation. As Elliott (2000) points out, the development of the renewable energy industries often occur with changes to generally accepted paradigms that are in place for conventional energy, highlighting that renewable energy technologies are trying to establish themselves in an institutional, market and industrial context based on the existing types of energy technology. To highlight this fact, Sovacool (2009) performs a study, aimed to understand the reason for the slow growth of renewables deployment in the United States considering the enormous benefits they bring. His study draws from textual analysis, interviews of energy experts, field observation, as well as advances in the historiography and sociology of technology. His results suggest that utility operators reject renewable resources because they are trained to think only in terms of big, conventional power plants.

Marques et al. (2010) and Marques and Fuinhas (2012) ascertain that in determining the factors which drive renewables deployment, the contribution of traditional energy sources can be used as an approximation to the competition between these energy technologies and renewables, as well as the influence traditional energy sources have on policies and the economy, also known as lobby. Elliot (2000) suggests something similar by stating that there are strong forces which defend the technological and institutional status quo, some of which have become manifest in strident denials from some fossil fuel interests that Climate Change is a significant problem. Marques et al. (2010) further highlight that the lobbying of traditional energy industries is noted in the capital markets, in the military industry, and, in general, in political decision-making of governments which results in a potential barrier to Renewable Energy development.

Maria & Bernauer (2014) suggest that the characteristics of the existing energy supply system – fossil fuel based - play an important role in driving countries towards market-based support systems for renewables. However, their finding is that a higher share of fossil fuels in the national energy supply intensity of the economy does not stand in the way of policies for supporting renewables. To the contrary, they increase the likelihood of a country adopting such policies. Pfeiffer and Mulder (2013) have a differing view, suggesting that high fossil fuel production appear to delay Renewable Energy diffusion.

2.2.6 Technological innovation

In their study on assessing the impact of technological change on investment in renewable energy, carried out with data across 26 OECD countries from 1991 to 2004, Popp et al. (2011) use the PATSTAT database to obtain a comprehensive list of patents for investment in wind, solar photovoltaic, geothermal, and electricity from biomass and waste. They find that technological advances do lead to greater investment, but the effect is small. Investments in other carbon-free energy sources such as nuclear power, serve as substitutes for renewable energy i.e. less investments in renewables. Kumar and Agarwala (2016) further point out that renewable energy technology diffusion rate is higher due to technological improvements resulting in cost reductions and government policies supportive of renewable energy development and utilization.

2.3. Country Specific Factors

Individual country specificities factor in as determinants of Renewable Energy deployment. They include Renewable Energy potential, continuous commitment to renewables and market regulation/structure.

2.3.1 Renewable energy potential

The natural endowment with renewable energy resources, such as solar irradiation, waterfalls or strong winds plays a key role in renewables deployment. These resources need to be present in sufficient quantity and quality to make Renewable energy investments competitive (Bird, et al., 2005). In their studies, Carley (2009) and Aguirre and Ibikunle (2014) both show that solar, biomass and wind potential are statistically significant in explaining renewables growth suggesting that countries that have greater renewable energy potential are expected to deploy more of these technologies. Stadelmann and Castro (2014) suggest that governments are more likely to support Renewable Energy technologies if their countries have sufficient natural resources to make them work in the first place. They perform a study on the determinants of the adoption of renewable energy support policies utilizing a discrete-time events history model with a logit link on a dataset of grid-based electricity policy adoption in 112 developing and emerging countries from 1998 to 2009. Their analysis estimates a significant positive relationship between wind resources and target adoption, solar resources and financial incentives, and biomass and hydro resources and tariff adoption.

The energy available depends on the location, quality and variation of earth energy flows. Land constraints can limit Renewable Energy access: complex geography, alternative land use, or environmental sensitivity. Geographical constraints may be more limiting than generally thought. Areas unsuitable for solar and wind energy include the deep sea, icecaps, high mountains and forests (Moriarty & Honnery, 2016).

2.3.2 Continuous Commitment to Renewables

The continued commitment of Renewable Energy implies large amounts of investments in developing renewable energy technologies and infrastructures. These investments allow for the generation of more energy from renewable sources, attenuating fixed costs. Lower average costs make profitability possible without subsidies. Thus, once an investment in renewables is made, a long term commitment with Renewable Energy is expected (Marques et al., 2010). Aguirre and Ibikunle (2014) show that countries that have considerable investments in renewables are more likely to keep increasing their use in the future with the case being the opposite for countries with comparatively lower levels of renewables investment portfolios.

2.3.3 Market Regulation

As Siddiqui et al. (2016) point out, the structure of an energy market has significant effects on the deployment of renewables.

Chassot et al. (2014) empirically demonstrate that venture capital investors exhibit policy risk aversion, in that they tend to avoid renewable energy investment opportunities if regulatory exposure is perceived to be high. They show that the aversion to policy risk is more pronounced among investors who hold strong individualistic worldviews and thus prefer "free markets" over government intervention. These views are different to that of Pfeiffer and Mulder (2013) who study the diffusion of non-hydro renewable energy (NHRE) technologies for electricity generation across 108 developing countries between 1980 and 2010 using two-stage estimation methods to identify the determinants behind the choice of whether or not to adopt NHRE as well as about the amount of electricity to produce from renewable energy sources. They discover that NHRE diffusion accelerates with the implementation of economic and regulatory instruments.

Nesta et al. (2014) found a significant effect of energy market liberalisation on innovation in Renewable Energy technologies implying that, given the characteristics of the energy market, in which the core competences of the incumbent are generally tied to fossil fuel plants whereas the production of Renewable Energy is mainly decentralised in small-sized units, the entry of non-utility generators made possible by market liberalisation increases the incentives for renewables. Similarly, Nicolli and Vona (2016) in their paper investigating the effect of market regulation and renewable energy policies on innovation activity in different renewable energy technologies, find that compared to privatisation and unbundling, reducing entry barriers is a more significant driver of renewable energy innovation, but that its effect varies across technologies and is stronger in technologies characterised by potential entry of small, independent power producers.

2.4 Environmental factor

Climate change is one of the most important environmental issues facing the world today. It is associated with the emission of greenhouse gases such as CO_2, chlorofluorocarbons, methane and ozone which are very harmful to the environment. Of the main greenhouse gases emitted into the atmosphere, CO_2 has the highest share and as such, the reduction of CO_2 emissions is a foremost objective for achieving sustainability (Rüstemoglu & Andrés , 2016).

The literature is rife with discussions on the impacts of CO_2 and its role in fostering the development of Renewable Energy. Sardosky (2009a) suggests that increases in carbon dioxide emissions, is a major driver to increased deployment of renewable energy. Marques et al. (2010) using panel data techniques to analyse drivers promoting renewables in 24 European countries for a period of 1990-2006 also highlight that CO_2 emissions are significant indicators of renewable deployment. However, they go on to suggest that carbon dioxide emission has a negative relationship with Renewable Energy deployment which means that it did not promote the development of Renewable Energy, which is a surprising result.

Aguirre and Ibikunle (2014) carry out a study to determine the determinants of country-level renewables participation in a sample of 38 countries which include countries from the EU, OECD and the 5 BRICS. The study covers a time span of 20 years from 1990-2010 employing the Fixed Error Variance Decomposition (FEVD) and Panel Corrected Standard Errors (PCSE) techniques. Similar to Sardosky (2009a) their findings suggest that CO_2 emission levels are significant indicators of renewables participation. Rafiq et al. (2014) using a multivariate vector error correction model (VECM) to examine the dynamic relationships among output, carbon emission and renewable energy generation of India and China during the period 1972 to 2011 show that in both countries, there is statistically significant unidirectional short-run causality from carbon emission to renewable energy generation. In the long run, bidirectional causality is found between carbon emission and renewable energy generation. This suggests that renewable technologies are being used to reduce the detrimental impacts of growing emissions.

Omri & Khuong (2014) further illustrate the importance of CO_2 as a major determinant of renewable energy consumption in countries highlighting that a high level of CO_2 emissions gives rise to the demand for environmental protection and encourages the development and use of alternative renewable energies which are carbon emission free. On the contrary, the decrease in the CO_2 emissions could lead to lower demand for renewable energy.

Global warming issues have put CO_2 emissions into the energy policy spot light. Any serious attempt to deal with global warming is going to have to reduce dependence on fossil fuels. Consequently, increases in carbon dioxide emissions, coupled with increased concern over global warming, are likely to lead to increased consumption of renewable energy (Sadorsky, 2009a).

2.5 Summary

From the above review, it is evident that the drivers of renewable energy are not uniform across countries or estimation method. These drivers range from CO_2 emissions, Renewable Energy potentials, energy prices, contribution of traditional energy sources to electricity mix, population, income, etc.

The literature identifies that these important factors which determine renewables deployment can be grouped into political, socioeconomic and country- specific factors. The political factors include policies such as quotas, feed-in tariffs or investment in research, development and demonstration, amongst others. The socioeconomic factors include income, energy consumption and CO_2 emissions. And the third category, which includes renewable energy potential, is identified as consisting of country-specific drivers.

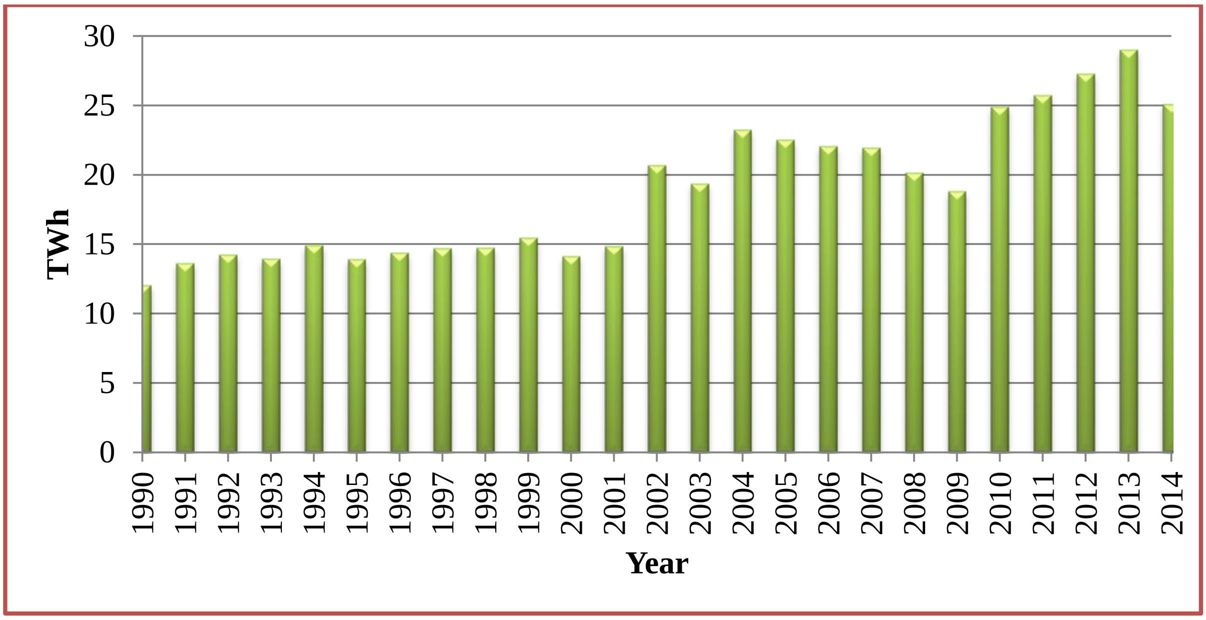
Chapter Three: Energy and Sustainability in Nigeria and Sub-Saharan Africa

This chapter discusses specificities of Nigeria and SSA regarding energy – both conventional and renewable. Section 3.1 is an overview of Nigeria in terms of demographics, area and electricity generation and consumption. Section 3.2 deals with conventional energy reserves and their utilisation. Section 3.3 talks about renewable energy potential and current utilisation in the country; this includes solar, hydro, biomass and wind power. Finally, section 3.4 gives an overview of the energy situation in the SSA region.

3.1 Overview of Nigeria

Nigeria has a population of over 170 million people, making it the most populous country in Africa. The population is projected to grow from 178,516,904 (as of 2014) to 183,523,432 by 2015, 273,120,384 by 2030, and 440,355,062 by 2050 (Emodi & Boo, 2015). It is an SSA country bordered by Cameroon to the east, Chad to the North-east, Niger to the North, Benin to the West and the Atlantic Ocean to the South. Nigeria lies within latitude 4.321N and 141N and Longitude 2.721E and 14.641E, with a land area of about 924,000km^2.

Figure 1: Annual Electricity Generation (WB, 2016)



The country's electrification rate is relatively low: 50% of the population has access to electricity and in rural areas that percentage drops to only 23% (IEA, 2012). Per capita consumption of electricity is approximately 125kWh which is utterly derisory for a country of its size. In comparison, South Africa, Brazil and China have per capita electricity consumption of 4500kWh, 1934kWh and 1379kWh respectively (FGN, 2009). In 2014, total electricity generation amounted to 25.08 TWh. Figure 1 shows the progression of electricity generation through the years.

The administration of President Umar Yar'Adua had set for the Country the Vision 20:2020, which simply is the target of being one of the world's 20 best economies by the year 2020. In order to achieve this Vision, an efficient electricity sector is a prerequisite, as there can be no industrial development without electricity. This led to the witnessing of a number of reforms in the Nigerian electricity sector.

In 2001, the National Electric Power Policy (NEPP) was introduced to kick-off a power sector reform and this lead to several other reforms in the past years. The NEPP in 2001 created the roadmap for Nigeria's Power Sector Privatization, but due to government bureaucracy; the policy was not signed into law until 2005. This signed document was the Electric Power Sector Reform (EPSR) Act in 2005 which was expected to level the playing ground for potential investors and improve the wellbeing of its citizens.

The first step in the process was to restructure the Nigerian Electric Power Authority (NEPA) to form the Power Holding Company of Nigeria (PHCN) founded in 2007, which existed until September 2013. PHCN acted as the state-owned agency responsible for generating, transmitting and distributing electricity for the entire country while the Federal Government sought to sell off much of the state-owned stake in the electricity services industry, retaining the transmission grid as a public entity. As a first step the government-owned generating companies (GENCOs) were put up for sale. Distribution was unbundled into 11 successor distribution companies while the government retained control of the transmission and system operations under the Transmission Company of Nigeria (TCN).

As a second step, the FGN founded a regulator - the National Electricity Regulator Commission (NERC), and a bulk trader - Nigerian Bulk Electricity Trading PLC (NBET), whereby the latter shall only exist until a time when the electricity market is fully privatised, after which the power purchase agreements it has signed will be passed on to the distribution companies (DISCOs). It also established the Operator of the Nigerian Electricity Market (ONEM) which acts as wholesale market and settlement operator. It therefore manages the metering system among generation, transmission and distribution companies. The Nigerian Bulk Electricity Trading Plc (NBET) manages buying the electricity from the GENCOs and selling it to the DISCOs in the interim.

The third step relates to the sale of 10 government-owned independent power projects, called National Integrated Power Projects (NIPPs). In 2004, the Nigerian government set up a special purpose vehicle to build and own these assets using private sector best practices, in order to address Nigeria's persistent power shortage. Eight of these power plants were initially designed as open-cycle gas turbine power plants while the remaining two were designed as combined-cycle gas turbine power plants[1].

These three steps cover the unbundling of PHCN and are classified as the phase prior to the transitional electricity market (pre-TEM) being set up. TEM is a phase where participants in the market are obliged to commence full trading by contracts while all the institutional and normative structures that define a competitive and efficient electricity market will be institutionalized. The Pre-Transition phase was accompanied by interim rules with the objective "*to establish a framework to govern trading arrangements during the interim period when power purchase agreements (PPAs) between the privatised generation companies and NBET and vesting contracts between NBET and the privatised PHCN successor distribution companies has not yet become effective*" (NERC, 2013). In order to proceed into the Transitional stage, criteria referred to as Conditions Precedent, which are defined in the Market Rules for Transitional and Medium Stages of the Nigeria Electricity Supply Industry (NESI) have to be satisfied (NERC, 2013). ONEM as market operator sets the financing required for the three arms of the market on the basis of the Multi-Year Tariff Order (MYTO). The objectives of the rules are to establish a framework to govern trading arrangements during the interim period when power purchase agreements (PPAs) between the privatised generation companies and NBET and vesting contracts between NBET and the privatised PHCN successor distribution companies has not yet become effective. In January 2015 the NERC determined that "the level of completion of all Conditions Precedent is sufficient to justify the evolution of the NESI by the commencement of the Transitional Stage

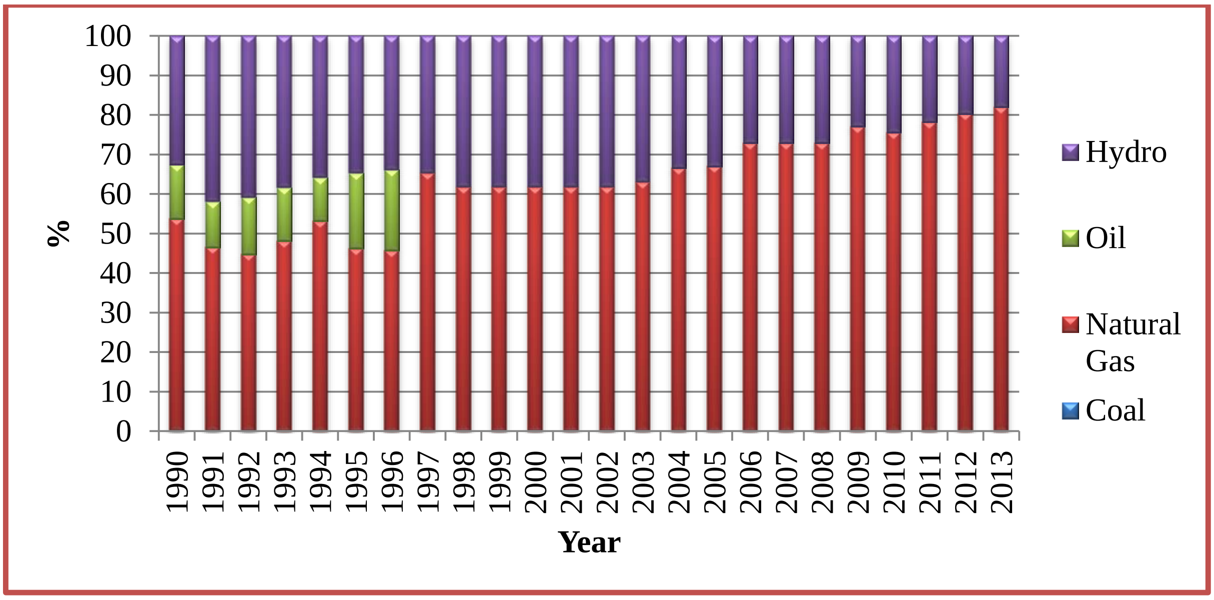
[1] Seven of the open-cycle plants have the capacity to be expanded to combined cycle gas turbine configuration.

Electricity Market (TEM)". Consequently the TEM commenced with effect from 1st of February 2015.

With its fast growing population, energy need per person, poor technology and fast growing urbanisation, Nigeria has been one of the countries with fast growing modern energy needs in the world over the last two decades. Nigeria is a major producer of primary energy but greater percentage of her secondary energy is supplied by imports, mainly due to inadequate technology to transform the country's primary energy from its raw state into usable form (Oseni, 2012).

Electricity, which was first generated for public use in Nigeria in 1896, is heavily dependent on fossil fuel sources. Although it has been generated for over a century, electricity demand in Nigeria is at present far more than the supply (Aliyu et al., 2015). In places where there is access to electricity, consumers suffer from frequent power outages which last for several hours. In 2009, the Community Research and Development Centre (2009) carried out a study and found out that 99% of their respondents do not get electricity supply for up to 24 hours. The power currently generated in Nigeria is inadequate and unstable, forcing a large portion of industry, businesses and households to rely on diesel and petrol generators as a primary or back-up source of electricity, which can be expensive and a source of noise and air pollution. The major factor responsible for the interruption of electric power in Nigeria is load shedding as a result of inadequate generation.

Figure 2: Electricity generation by fuel type (%) (WB, 2016)



Most of the nation's infrastructure in the power sector was built in the 1960s, 1970s and 1980s. Due to a lack of maintenance and expansion of the facilities, the country has suffered significantly from the impact of epileptic and limited availability of electricity supply. In spite of the abundant energy resources in the country and the huge Government investments in the sector over the last 10 years, electricity supply remains a serious challenge to Nigeria's development (Oyedepo, 2014). The dire electricity supply hinders the country's socio-economic and technological development and it unfavourably affects quality of life.

Electricity generation in Nigeria over the past half-century has varied within a combination of oil-fired, gas-fired, coal-fired and hydroelectric power generation systems. Currently, electricity generation is mainly based on gas-fired and hydroelectric systems with gas-fired generation making up about 80% of the mix (

Figure ***2***). This is centred on the fact that the primary fuel sources (coal, oil, water, gas) for these power stations are readily available in the country.

As earlier mentioned, the net electricity generation per capita in Nigeria is among the lowest in the world. The demand is far higher than the electricity generation resulting to regular power outages, load shedding and over reliance on individually owned generators. The government of Nigeria planned to increase the generation to about 20,000 MW by 2020. In order to achieve this target and attract local and foreign investors, the government of Nigeria recently embarked on privatizing the power holding company of Nigeria (Mas'ud, et al., 2015).

The total licenced on-grid generation capacity in Nigeria was 19,407 MW in 2014. Of this figure, 13,308 MW installed capacity is attributable to the main power plant fleet, the remainder has not yet been built or is under development. Despite all efforts, the available generating capacity was just above 6,100 MW in 2011. Out of this, 1270 MW was from hydro and the remaining 4830 MW was from fossil fuels. The highest peak generated ever in Nigeria was 5,074.7 MW on February 2nd, 2016 (FMP, 2016) and transmission losses are between 8 and 10% (NESP, 2014).

3.2 Energy reserves and utilization in Nigeria

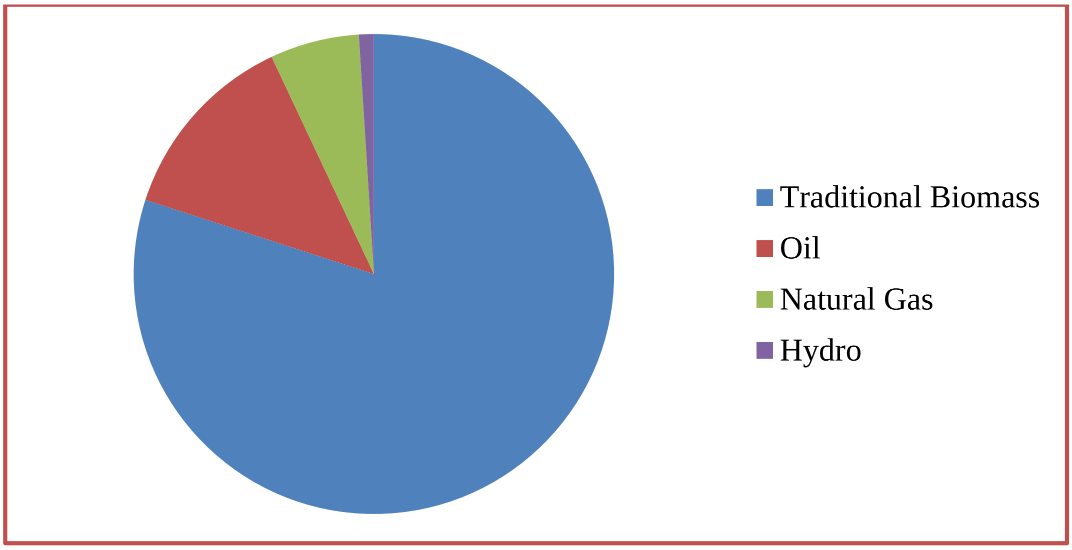
There are abundant energy resources in the country such as coal, crude oil, natural gas etc. It has the ninth largest natural gas reserves in the world and the largest oil reserves in the Africa. It became the world's fourth leading exporter of liquefied natural gas (LNG) in 2012. The proven reserve of crude oil is over 36 billion barrels and 187.44 trillion cubic feet (Tcf) for natural gas. Coal reserves stand at 2.175 billion tonnes, but production has long since ceased as the government has concentrated on the oil and gas resources (Emodi & Boo, 2015).

Table 1: Energy reserves in Nigeria (Emodi & Boo, 2015)**.**

Resource type	**Reserves**		**Production**	**Domestic utilization (natural units)**
	Natural units	Energy units (Btoe)		
Natural gas	187 TCF	4.19	6 billion CF/day	3.4 billion CF/day
Crude oil	36 billion barrels	5.03	2.5 billion barrels/day	450,000 barrels/day
Tar sands	31 billion barrels	4.31	Insignificant	Insignificant
Coal & lignite	2.175 billion tonnes	1.52	–	–

However, Nigeria oil production has been hindered by insecurity and supply interruption, whereas the natural gas sector is limited by the lack of infrastructure to monetize the gas that is presently burned off. Nigeria is also a member of the Organisation of the Petroleum Exporting Countries (OPEC), which it joined in 1971 after over 10 years of oil production that began in the late 1950s (Mas'ud et al., 2015; EIA, 2015). This abundance of fossil fuel sources explains its current dependence on fossil fuels for energy production (80% of electricity generation from fossil fuel sources). Nigeria's oil and natural gas resources are the mainstay of the country's economy. The country's oil and natural gas industry typically accounts for 75% of government revenue and 95% of total export revenue (EIA, 2015).

Figure 3: Total primary energy consumption in Nigeria in 2012 (EIA, 2015)



The U.S. Energy Information Administration estimates that in 2012 total primary energy consumption in Nigeria was about 4.5 quadrillion British thermal unit (Btu). Of this amount, traditional biomass and waste (typically consisting of wood, charcoal, manure, and crop residues) accounted for 80% (Figure 3). This high share represents the use of biomass to meet off-grid heating and cooking needs, mainly in rural areas.

3.3 Status of renewable energy in Nigeria

The potential of renewable energy sources in Nigeria is enormous taking into account the geographical location of the country. These sources have the potential of providing solutions to the long-lasting energy problems being faced in the country. However, these sources haven't been fully tapped into, with the exception of hydro sources.

Since Nigeria is blessed with these abundant renewable energy resources such as hydroelectric, solar, wind, tidal, and biomass, there is a need to harness these resources and chart a new energy future for Nigeria. In this regard, the government has a responsibility to make renewable energy technologies available and affordable to all (Oyedepo, 2014).

Table 2: Renewable Energy potential of Nigeria (NESP, 2014)

Resource	Potential	Current Utilisation and further remarks
Large Hydropower	11,250 MW	1,900 MW exploited
Small Hydropower[2]	3,500 MW	64.2 MW exploited
Solar	4.0 kWh/m2/day – 6.5 kWh/m²/day	15 MW dispersed solar PV installations. (estimated)
Wind	2–4m/s @ 10m height mainland	Electronic wind information system (WIS) available;
Biomass (non-fossil organic matter)	Municipal waste	18.5 million tonnes produced in 2005 and now estimated at 0.5kg/capita/day
	Fuel wood	43.4 million tonnes/yr. fuel wood consumption
	Animal waste	245 million assorted animals in 2001
	Agricultural residues	91.4 million tonnes/yr. produced
	Energy crops	28.2 million hectares of arable land; 8.5% cultivated

An analysis of the potentials and the current utilization of each renewable energy source is carried out below.

3.3.1 Solar Energy

Solar energy is the most promising renewable energy source because of its apparent limitless potential. The sun radiates energy at the rate of about 3.8×10^{23} kW/s. Most of this energy is transmitted radially as electromagnetic radiation, reaching the boundary of Earth's atmosphere at about 1.5kW/m^2. After traversing the atmosphere, a square metre of Earth's surface can receive as much as 1 kW of solar power or about 0.5 kW on average during daylight hours. This huge energy resource is available for about 26% of the day (Emodi & Boo, 2015).

Due to its location close to the equator, Nigeria lies within a high sunshine belt and within the country, solar radiation is fairly well distributed. The annual average of total solar radiation varies from about 12.6MJ/m^2/day (3.5kWh/m^2/day) in the coastal latitudes to about

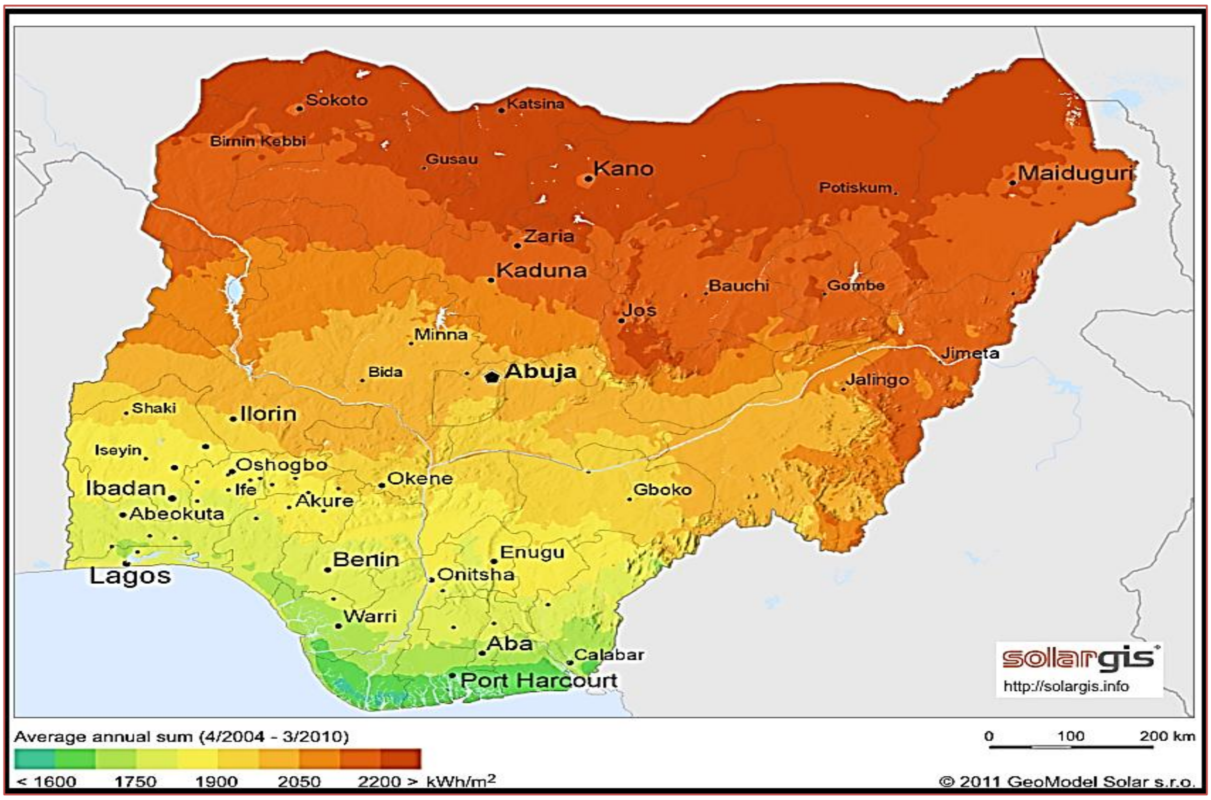
[2] The Nigerian Ministry of Power classifies the hydropower plants that have a generating capacity of less than 10 MW as small and medium hydro (FMP, 2016)

$25.2MJ/m^2$/day ($7.0kWh/m^2$/day) in the far north. Assuming an arithmetic average of $18.9MJ/m^2$/day ($5.3kWh/m^2$/day), Nigeria therefore has an estimated 17.439TJ/day of solar energy falling on its $924,000km^2$ land area. Annually, the above average solar intensity is $6898.5MJ/m^2$/year or $1934.5kWh/m^2$/year. This gives an impression that implementing solar energy strategy is a great opportunity for Nigeria to get renewable energy at low cost as well as minimize dependence from fossil fuels (Oyedepo, 2014).

As the average sunshine per day is 6.5h, the annual solar energy available is about 27 times that of the country's total fossil fuel resource, and it is over 115,000 times the electrical power generated. This implies that about 3.7% of the land area in Nigeria could collect an amount of solar energy equivalent to the conventional energy reserves within the country (Shaaban & Petinrin, 2014).

Considering the large number of the populace that do not have access to electricity in the country, solar power could be a good option to alleviate this problem. In view of the fact that most of the places without electricity are in the rural areas, solar energy could potentially provide affordable and ample energy to these communities seeing that they might be located too far from the nearest grid connection point.

Figure 4: Solar irradiation levels in Nigeria (SolarGIS, 2016)



As can be seen from Figure 4 above, the best potential for large-scale solar power plants lies in the northern part of the country. Long-term annual average Global Horizontal Irradiation (GHI) values in the northern states ranges from 2,000 to 2,200 kWh/m².

The current capacity of solar electricity in Nigeria is estimated at about 15MW, which is quite small considering the enormous potentials. Ohunakin et al. (2014) in their work on solar energy developments in Nigeria, highlight that the installed solar power capacity in Germany alone (a country located in a temperate region), is seven times more than the highest peak total electricity generated from all sources in Nigeria, being 4517.6MW as at December 2012[3].

Some of the major issues that need to be addressed to improve the participation of solar sources in the Nigerian energy mix are the market competiveness of solar power as it is at present 20 times higher in cost than the conventional fuels which are readily available. Before the potential of solar energy can be tapped in Nigeria, both government and private sectors have to play some major roles in ensuring that there are working policies and guidelines in that respect (Aliyu et al., 2015).

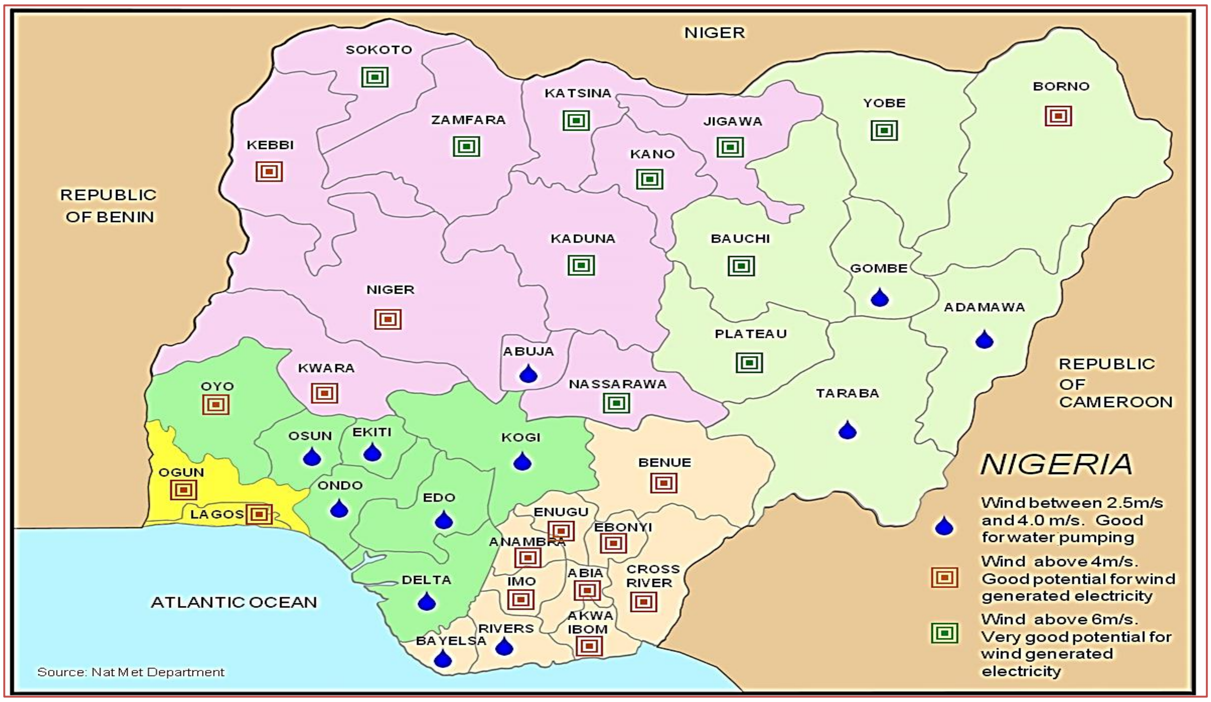
3.3.2 Wind Energy

Wind energy generation has gained worldwide recognition and it is one of the fastest growing renewable energy market in the world. The global cumulative installed capacity of wind power has increased steadily from 6100 MW in 1996 to 158,505 MW in 2009, and was expected to be over 238 GW by the end of 2014, a target that will aid the reduction of GHG emissions (Emodi & Boo, 2015).

In Nigeria, wind measurements at 10m height show that some sites have wind speeds between 1.0 and 5.1m/s. These wind speeds can be classified into four regimes: >4.0 m/s, 3.1–4.0 m/s, 2.1–3.0 m/s, and 1.0–2.0 m/s. Therefore, Nigeria is located within a moderate wind regime. The wind speed in southern Nigeria is relatively low, except for coastal regions and offshore, where the high wind speeds indicate great potential for exploiting wind energy (Vincent & Yusuf, 2014).

[3] 5,074.7 MW as at February 2nd, 2016 (FMP, 2016)

Figure 5: Wind energy locations in Nigeria (Emodi & Boo, 2015)**.**



According to Shaaban and Petinrin (2014), assuming a medium generation capacity of 5MWh/km^2 with a 30% capacity factor and using only 1% of the effective wind area of the selected states in their study, Nigeria has the potential to generate about 50,046MWh/yr of electricity. This is about two times the current annual generation from all sources.

At present, the share of wind energy in the national energy consumption has remained low with no commercial wind power plants connected to the national grid, only a little number of stand-alone wind power plants were installed in the early 1960s in 5 northern states mainly to power water pumps and a 5kW wind electricity conversion system for village electrification installed in Sokoto State (Oyedepo, 2014). However, there are two large wind farm projects ongoing at present, with capacities of 10 MW and 100 MW in the northern part of the country.

3.3.3 Hydro Power

Hydro electricity generation in the country is largely dominated by large hydropower (LHP) with little or no contribution from small hydropower despite the country’s significant potentials.

Nigeria has considerable hydro potential sources exemplified by her large rivers, small rivers and streams and the various river basins being developed. Nigerian rivers are distributed all over the country with potential sites for hydro power schemes which can serve the urban, rural and isolated communities (Oyedepo, 2014). Small hydropower potential sites exist in virtually all parts of Nigeria with an estimated total capacity of 3,500 MW; large hydro has been said to have potential of 11,250 MW.

Figure 6: Nigerian Waterways (LCA, 2016)***.***

Hydropower has been a mainstay in the Nigerian electricity generation mix. It currently accounts for about 20% of electricity generation in the country. The current hydropower capacity installed is 2.2 GW, although some of that requires maintenance and is not being used for generation. A World Bank reference scenario following FGN plans and feedback from stakeholders suggests hydropower utilisation could be increased to 7.2 GW by 2035. (WB, 2013).

Table 3: Ongoing Hydropower development (FMP, 2016)

No.	**Power Station**	**MW**	**Zone**
1	Zungeru project - Niger State	700	North Central
2	Mambilla Project - Taraba State	3,050	North East
3	Gurara II Project - Niger State	360	North Central
4	Gurara I Project - Niger State	30	North Central
5	Itisi Project - Kaduna State	40	North West
6	Kashimbilla Project - Taraba State	40	North East

There are currently a number of ongoing large-scale hydropower projects in various regions in the country. Table 3 above shows these various ongoing projects and their capacity. Upon completion, these projects aim to add a sizeable amount to the generation capacity of the country. This is part of the government's effort to tap into the huge potentials that hydropower offers the country and allay the current deficiency in electricity supply plaguing the country.

A successful execution of the planned LHP projects and proper maintenance of the already commissioned LHP projects will lead to LHP providing more than double the amount of the present available generation capacity in the country. This clearly indicates the role LHP can play in alleviating the present electricity crisis in the country (Aliyu et al., 2015).

3.3.4 Biomass Energy

Biomass energy refers to energy that is developed from organic materials like scrap lumber, forest debris, crops, manure, and some types of waste residue. Biomass is an indirect form of solar energy because it arises from the process of photosynthesis. Biomass resources found in Nigeria include wood, shrubs, forage grasses, waste from animals, forestry, agriculture, industry, and municipal areas (Emodi & Boo, 2015).

Nigeria has abundant biomass resources for full-scale exploitation. About 80 million cubic metres (43.4×10^9 kg) of fuel wood is consumed annually in Nigeria for cooking and other domestic purposes. Crop residues and waste produce estimates of 6.1 million tons of dry biomass with energy content approximate to 5.3×10^{11} MJ. Nigeria's forest land is about 9,041,000 ha, which is 9.9% of its total landmass. Meanwhile, 1985 estimates suggested that animals and poultry produced 227,500 tons of waste with energy content of 2.2×10^9 MJ when converted to biogas. Estimates show that this is of the order of 5.36×10^9 m^3 which has an energy content amounting to 2.93×10^9 kWh (Oyedepo, 2014).

From the perspective of available land and wide range of biomass resources, Nigeria has significant potential to produce biofuels and even become an international supplier. Bioenergy feedstock is not only abundant in Nigeria, it is also widely distributed (NESP, 2014).

The World Bank in its "Low Carbon Report", while firmly advocating the use of solar PV, also suggests *"other sources of power include using municipal waste to generate methane to generate power, combusting other biomass to make power, and small-scale hydropower. (...) These technologies are promising and advantageous with suitable local conditions, and are well worth pursuing."* (WB, 2013, p. 91).The suggestion is that by 2015 biomass-to-power could deliver as much as 1,643 GWh/year, with the figure rising to 13,140 GWh/year by 2035 (NESP, 2014).

However, there is little or no mention of any plan at the moment by the government to delve into constructing large biomass power plants, taking advantage of the huge biomass potentials of the country. This is surprising considering the huge advantages they offer. An increased use of the available biomass resources for energy production could potentially improve the energy situation in the country.

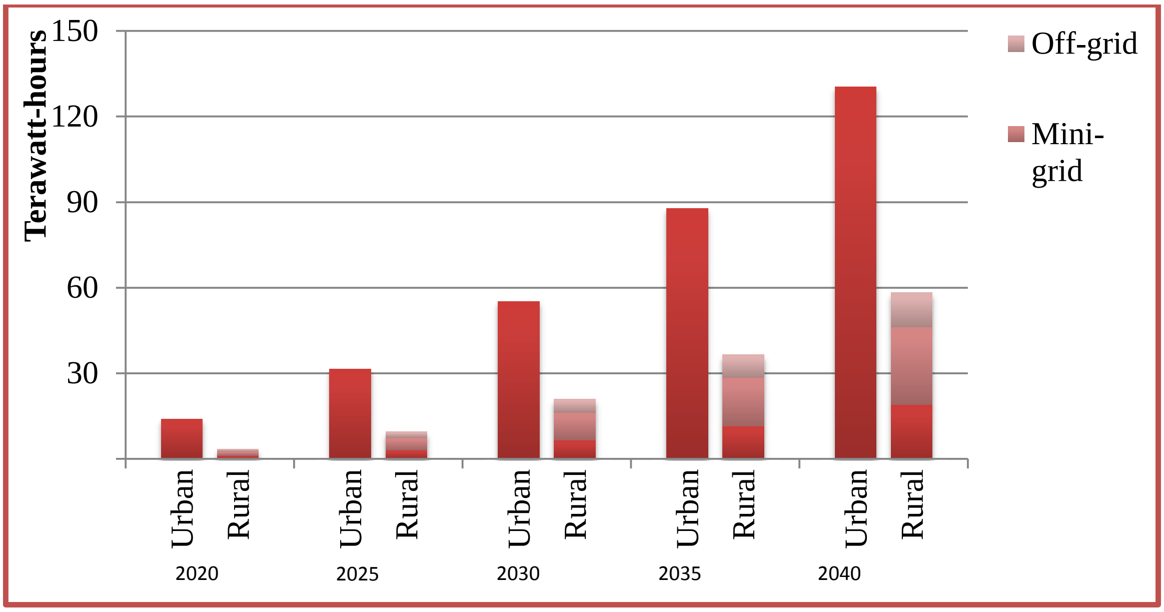
3.4 Energy in Sub Saharan Africa

The population of SSA in 2013 was around 940 million people, with growth being rapid, having increased by 270 million people from 2000 to its 2013 figure, and it is expected to reach one billion well before 2020. This huge increase magnifies many existing challenges, such as the quest to achieve modern energy access. Population growth has been split relatively evenly between urban and rural areas, in contrast to the strong global trend to urbanisation. Only 37% of the SSA population lives in urban areas – one of the lowest shares of any world region – which has important implications for the approach to solving the energy challenges. (IEA, 2014).

Access to electricity is dire in SSA - there are more people living without access to electricity in SSA than any other world region – more than 620 million people, and nearly half of the global total. It is also the only region in the world where the number of people living without electricity is increasing, as rapid population growth is outpacing the many positive efforts to provide access. As Adams et al. (2016) point out, the energy consumption of the average African in the early 2000s was less than what an average Brit used in England more than a hundred years ago. Overall, the electricity access rate for SSA has improved from 23% in 2000 to 32% in 2012 with the electrification levels ranging from 3% in Burundi to 100% in Mauritius — the only country in SSA that has achieved 100% electrification (Prasad, 2011). In comparison, more than 99% of the total population of North Africa has access to electricity. Nearly 80% of those lacking access to electricity across SSA are in rural Areas. For those that do have electricity access in SSA, average residential electricity consumption per capita is 317 kWh per year (225 kWh excluding South Africa) (IEA, 2014). Eberhard et al. (2011) note that installed capacity will need to grow by more than 10 percent annually just to meet Africa's suppressed demand, keep pace with projected economic growth, and provide additional capacity to support efforts to expand electrification.

Grid-based power generation capacity has increased from around 68 GW in 2000 to 90 GW in 2012, with South Africa alone accounting for about half of the total. Coal-fired generation capacity is 45%, followed by hydropower (22%), oil-fired (17%), gas-fired (14%), nuclear (2%) and other renewables (less than 1%). Until recently, countries developed their power systems largely independently of one another, focusing on domestic resources and markets, but there has been progress towards regional co-operation to permit concentrated resources, such as large hydropower, to serve larger markets (IEA, 2014).

Figure 7: Projected electricity demand from the sub-Saharan African population gaining access to electricity, 2020-40 (AfDB et al., 2016).



In addition to capacity linked to the main grid, there has been increasing emphasis on developing mini-grids and off-grid systems. To further supplement their power supply, many individuals and businesses have access to small diesel or gasoline-fuelled generators.

3.4.1 Energy Reserves and Utilisation

Sub-Saharan Africa is rich in resources, holding around 7% of world conventional oil resources and 6% of world gas resources. As of 2013, remaining recoverable oil resources in SSA are estimated at over 200 billion barrels of which around 70% are located offshore. SSA as a whole has around 65 billion barrels of proven oil reserves, equivalent to around 5% of the world total. Three-quarters of these oil reserves are held in two countries (Nigeria and Angola), with the next largest (South Sudan and Uganda) accounting collectively for only 9% of the total (IEA, 2014).

Sub-Saharan Africa is estimated to have 31 tcm of remaining recoverable conventional natural gas resources. Proven gas reserves have increased by 80% since 2000 and now stand at 9 tcm which is 5% of the global total. Until recently much of this gas was flared; an estimated total of 1 tcm of gas has been flared to date. Over the past five years, flared volumes have dropped from around 35 bcm per year to 28 bcm. As a replacement for flaring, increased volumes of available gas have been delivered to markets (mainly as liquefied natural gas exports from Equatorial Guinea since 2007) or re-injected to sustain oil production (mainly in Congo) (IEA, 2014).

Sub-Saharan Africa includes three of the ten-largest uranium resource-holders in the world (Namibia, Niger and South Africa). Namibia provides 8.2% of global production, Niger 7.7%, Malawi 1.2% and South Africa 1.1%. South Africa is the only country with existing nuclear power generation capacity, and has stated its intention of expanding it. Some other countries have stated their interest in introducing nuclear power into their domestic mix (e.g. Kenya and Namibia).

In resource-rich countries, energy export revenues are an important source of government income but the sector is not necessarily a large employer, nor does it constitute a large share of the economy overall (IEA, 2014).

Energy demand in SSA has been on the rise since 2000, increasing by half – reaching 570 Mtoe in 2012 – but still accounts for only 4% of the world total with bioenergy being dominant, accounting for more than 60% of total energy use. This is largely driven by the traditional use of biomass for cooking. South Africa and Namibia are the only countries in mainland SSA where bioenergy does not dominate the energy mix.

3.4.2 Status of Renewable Energy

Renewable energy technologies (mainly hydropower) make up a large share of total power supply in Africa and there is potential for this to expand as a wider range of technologies is deployed. Many countries are actively developing or considering developing their renewable energy resource potential. A recent survey carried out in Climatescope 2015 report on SSA (MIF et al., 2015) shows that South Africa has the highest investment in RE of about USD$16bn, followed by Kenya and Ethiopia. Suberu et al. (2013) highlight that modern Renewable Energy exploitation and development in SSA is lagging behind many any other regions in the world due to a number of reasons which include:

- Limited capital investment
- Lack of technological knowledge on RE development
- Constricted power generation planning

- Deficient electricity supply resulting from frequent power systems failure and unreliable equipment
- Low rate of electrification in the region
- High cost of electricity generation
- High transmission losses

Table 4: Renewable energy potential across Africa [Adapted* from (AfDB, 2012)*].

Region	Wind (TWh/yr)	Solar (TWh/yr)	Biomass (EJ/yr)	Geothermal (TWh/yr)	Hydro (TWh/yr)
East	**2,000-3,000**	**30,000**	**20-74**	**1-16**	**578**
Central			**49-86**		
South	**16**	**25,000-30,000**	**3-101**		**26**
West	**0-7**	**50,000**	**2-96**		**105**
Total SSA	**2,000-3000**	**105,000-110,000**	**74-357**	**1-16**	**1,844**

Hydropower

Hydropower has long been an important part of many African power systems and is the most used renewable energy source (excluding bioenergy). Eberhard et al. (2011) report that over 900 TWh (approximately 220 GW installed capacity) of economically viable hydropower potential in Africa remains unexploited, located primarily in the Democratic Republic of Congo, Ethiopia, Cameroon, Angola, Madagascar, Gabon, Mozambique, and Nigeria. Similarly, the Intergovernmental Panel on Climate Change (IPCC) estimates the technical hydropower potential at 1174 TWh per year (or 283 GW of installed capacity) – 8% of the global technical potential. This amount of electricity is more than three-times the current electricity consumption in SSA. Less than 10% of the technical potential has so far been tapped (Bazilian, et al., 2012; IEA, 2014).

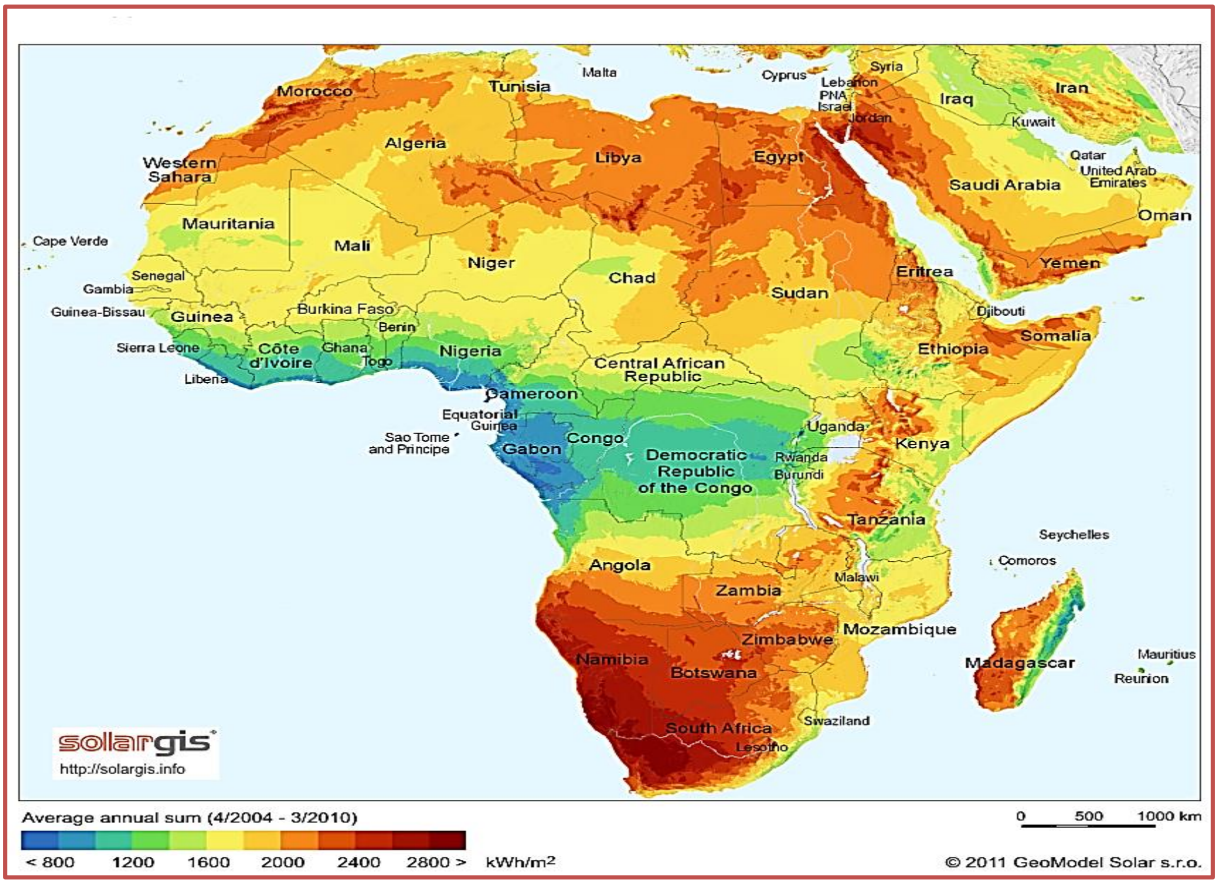
The large hydropower potential in DR Congo has long been a focus of policy makers, both in terms of the Inga III project (4.8 GW) that is planned and the several phases of the long discussed Grand Inga project (around 44 GW) which, if constructed, could transform the

African power supply picture. Currently, 20 GW of hydropower capacity is installed in SSA, with several countries, including Mozambique, DR Congo, Uganda and Kenya, relying on it for a significant share of power generation. Many large projects are planned e.g. further developments at the Inga site in DR Congo and Mphanda Nkuwa in Mozambique (IEA, 2014).

Solar power

Solar technologies have played a limited role in the power sector in Africa, but are gaining attention in many countries. As Suberu et al. (2013) note, solar energy consumption is currently limited to lighting and the operation of simple appliances in both rural and urban areas of SSA. Solar-powered water heaters, solar-powered cookers, building integrated photovoltaics and the application of solar photovoltaic distributed electric power generation are limited to just a few countries in SSA. They are more common in countries such as South Africa and Mauritius where there is an increasing tendency to embrace emerging Renewable Energy technologies in line with the accelerated global pace of Renewable Energy consumption.

Figure 8: Solar irradiation levels for Africa (SolarGIS, 2016)



Africa is particularly rich in solar energy potential, with most of the continent enjoying an average of more than 320 days per year of bright sunlight and experiencing irradiance levels of almost 2000 kWh per square metre (kWh/m^2) annually. Solar energy is gaining a foothold in SSA where installed capacity increased from 40 MW in 2010 (mainly small-scale PV) to around 280 MW in 2013 (including some large PV and concentrating solar power plants). There are several grid-connected projects under construction, including the 155 MW Nzema plant in Ghana and 150 MW of projects in South Africa. In addition, other countries are considering projects on the scale of 100 MW or more, including Mozambique, Sudan, Nigeria and Ethiopia (IEA, 2014).

Wind power

Wind power deployment in SSA to date has been very limited when compared to hydropower, even though the levelised cost of electricity from onshore wind technologies has declined significantly in recent years. SSA's wind potential is estimated at around 1300 GW (IEA, 2014). The IEA report further outlines that high quality wind resources are confined to a few areas, mainly the Horn of Africa, eastern Kenya, parts of West and Central Africa bordering the Sahara and parts of Southern Africa. Eight African countries are among the developing world's most endowed with wind energy potential (Mukasa et al., 2015). Somalia has the highest onshore potential of any country, followed by Sudan, Libya, Mauritania, Egypt, Madagascar and Kenya. The offshore wind energy potential is best off the coast of Madagascar, Mozambique, Tanzania, Angola and South Africa (IEA, 2014).

Despite this great potential supply of wind energy, installed capacity of wind-based electricity in Africa, estimated at 1.1 GW in 2011, does not exceed 0.5% of global capacity; with only 190 MW of the 1.1 GW having been installed in SSA (IEA, 2014; (Mukasa et al., 2015).

Geothermal

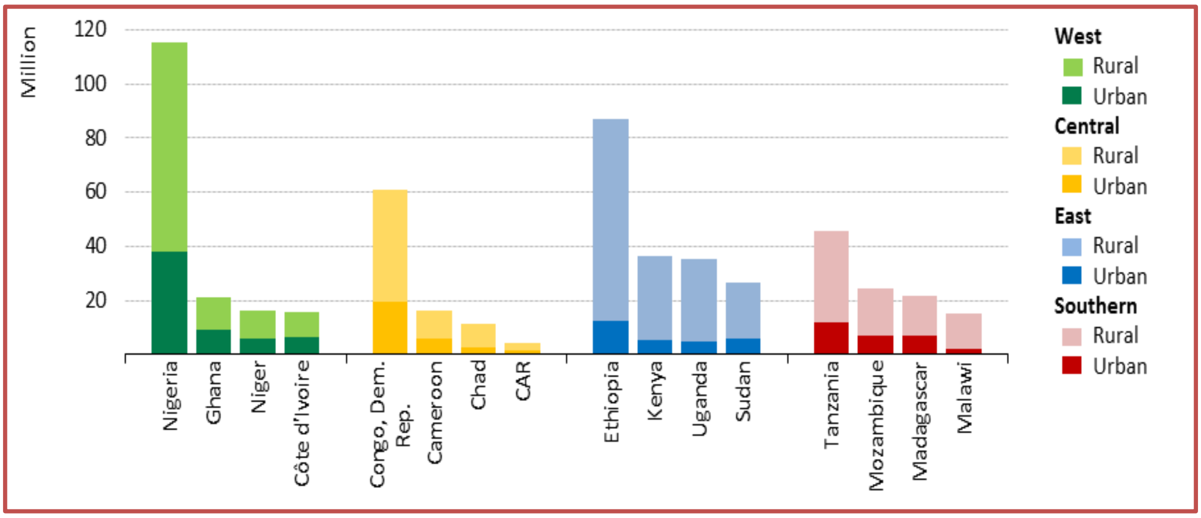
Geothermal technologies make up a small fraction of Africa's power supply, but can be an attractive option because adequate resources exist. These resources are concentrated in the East African Rift Valley, which is considered one of the most exciting prospects in the world for geothermal development, with total potential estimated at between 10 GW and 15 GW – more than East Africa's total existing power generation capacity, a large share of which is concentrated in Ethiopia and Kenya. Kenya has around 250 MW of installed geothermal capacity and a further 280 MW is under development. More than 40 wells a year are currently being drilled in Kenya, and the target is to develop more than 5000 MW by 2030 which is about half of the estimated potential (IEA, 2014; Suberu et al., 2013). Ethiopia is also actively developing its geothermal resources that aims to add 1GW of capacity over the next decade. A number of other countries are exploring their geothermal potential, but projects are challenging and typically have long-lead times. Zambia has a number of sites planned, while Tanzania is carrying out exploration (and has potential of around 650 MW), and Eritrea, Djibouti, Rwanda and Uganda have also carried out geothermal exploration (IEA, 2014).

Biomass

Estimates indicate that between 80% and 90% of the people in SSA depend on biomass fuels, and fuelwood accounts for more than 75% of the household energy balance (Jumbe et al., 2009). Varieties of biomass residues from agriculture, municipal solid waste and forest biomass can be found in sustainable quantities in SSA. Biomass for electricity generation has not been widely exploited in most regions in Africa, except South Africa and Mauritius, both of which use sugar cane in combustion power plants. Biomass consumption in Africa has traditionally been dominated by direct burning of bio residues for heat energy production, especially for cooking and heating purposes (Suberu et al., 2013).

Biogas, which is mainly obtained from varieties of biodegradable waste raw materials, is another promising clean source of energy for cooking and small power generation in rural districts. Although biogas is mainly used for cooking in developing countries, in developed nations it is used for both cooking and power generation. Some ongoing Renewable Energy programmes in the SSA region are strenuously advocating for biogas consumption for cooking.

Figure 9: African population relying on solid biomass for cooking, 2012 (AfDB et al., 2016)



Different countries in SSA have attempted testing various bioelectricity conversion technologies, such as combustion, gasification and pyrolysis, although these are on a very small scale and at an experimental stage (Suberu et al., 2013). The total methane production potential from the feedstocks available to households, communities and at a commercial scale in SSA (excluding Sudan and South Sudan) is estimated to be 26.1 billion m^3, equivalent to 270 TWh of heat energy. Crop waste normally burned makes up the greatest portion of this potential (36%), and also presents the greatest potential on a per capita basis. Benin is estimated to have the highest per capita energy production potential of 732 kWh/pp/yr with particularly high potentials for using crop waste normally burned and crop primary equivalent waste (CPEW) as biogas feedstocks. Ghana has the highest energy production potential from CPEW of 375 kWh/pp/yr (Rupf et al., 2016).

3.5 Summary

This chapter talked about the present energy situation in Nigeria and SSA. Nigeria is a country with a very large and growing population. Electricity generation is grossly inadequate with Nigeria having a very low per capita electricity consumption and a large number of the population without access to electricity.

The country and the region are blessed with an abundance of energy resources such as natural gas, crude oil and coal. These resources make up the crux of economic income and their abundance explain the country's current dependence on them for electricity generation.

Furthermore, Nigeria is blessed with great potential for developing renewable energy such as wind, biomass, solar and hydro power, dispersed in all regions, which makes this country an attractive place for renewable energy investors. However, these potentials haven't been greatly tapped into with the exception of hydro power, even though many of them are plentifully available, and have good economic potential. Only hydropower at the moment has a substantial share in the national energy mix.

The major problems facing the energy sector in SSA are low consumption, unreliable power supply, power shortages, high electricity cost, and unequal access. To increase access to electricity, the performance of the sector has to improve in the areas of governance reform, capital injection including higher private sector participation, and increasing regional power trade.

Chapter Four: Government Policies and legislation on Renewable Energy

As is evident from the literature and from the current status of Renewable Energy in Nigeria, the application of renewable sources for the generation of electric power in the country has been relatively slow. It is necessary to put in place measures to boost the growth of renewable sources in the country. These measures could come in the form of policies, legislations, regulations and licensing (Aliyu et al., 2015).

This chapter presents such policies and legislations. Section 4.1 talks about current legislation and policies already in place in Nigeria. Policies in place in various parts of the world which Nigeria could implement to augment its current policies to boost renewables deployment are further highlighted in section 4.2.

4.1 Nigerian Legislation on Renewable Energy

The Energy Commission of Nigeria (ECN) was set up by the government in 1997 to conduct strategic planning on energy issues and was mandated to introduce new energy resources and ensure efficient utilization of energy resources. This was one of the first steps by the government aimed at taking action regarding energy related issues in the country.

Here, some of the policies and legislations currently in place in the country with regard to renewable energy under the auspices of the ECN are discussed.

4.1.1 National Energy Policy (2003)

The ECN in 2003 established the National Energy Policy (NEP) that addresses issues related to the challenges faced in the energy sector. This document was designed to stand as the first overall framework for the development of the sector and its effective contribution to the country's economy. Before this, there was no established policy regarding energy related issues in Nigeria. The NEP sets out government policy on the production, supply, and consumption of energy, reflecting the perspectives of its overall needs and options (Emodi & Boo, 2015). The main goal of the policy was to create energy security through a robust mix of energy sources by diversifying the energy supply and energy carriers based on the principle of "an energy economy in which modern renewable energy increases its share of energy consumed and provides affordable access to energy throughout Nigeria, thus contributing to sustainable development and environmental conservation" (ECN, 2003).

The key objectives of the NEP are:

- To ensure the development of the nation's energy resources, with a diversified energy resources option, for the achievement of national energy security and an efficient delivery system with an optional energy resource mix.
- To accelerate the process of acquisition and diffusion of technology and managerial expertise in the energy sector and indigenous participation in energy sector industries, for stability and self-reliance.
- To guarantee an efficient and cost effective consumption pattern of energy resources.
- To promote increased investments and development of the energy sector industries with substantial private sector participation.
- To ensure a Comprehensive, integrated and well informed energy sector plan and programmes for effective development.
- To foster international co-operation in energy trade and projects development in both the African region and the world at large.
- To guarantee adequate, reliable and sustainable supply of energy at appropriate costs and in an environmentally friendly manner, to the various sectors of the economy, for national development.
- To guarantee increased contribution of energy productive activities to national income.
- To successfully use the nation's abundant energy resource to promote international cooperation.

Renewable Energy is one of the energy types articulated in the policy. Prior to 2003, there was no consideration whatsoever for the inclusion of renewable energy sources such as solar and wind in the national energy mix. The 2003 Energy Policy document, for the first time, included elements of renewable energy planning, though in a superficial manner (Oyedepo, 2014). This is important because for a renewable energy plan to be totally effective, it must be steeped in an equally effective national energy policy.

The NEP outlines the key elements for the development and application of renewable energy:

- To promote a decentralised energy supply, especially in rural areas, based on renewable energy resources.
- To develop, promote, and harness the renewable energy resources of the country and to incorporate all viable options into the national energy mix.
- To promote efficient methods for the use of biomass energy resources.
- To keep abreast of international developments in renewable energy technologies and applications.

Although some parts of the policy may require an update and new developments in the sector are covered in subsequent policy papers or acts, the policy still remains in force as the guiding principle for the direction of sector reforms (PTFP, 2013).

In 2006, the government of Nigeria established the National Energy Master Plan (NEMP) whose objective was to provide a framework for the implementation of the NEP. In the NEMP, for every economic sector, there are detailed programmes and timeline for every strategy in order to ensure effective implementation.

In the NEMP, the major issues hindering the development of Renewable Energy in Nigeria were identified. These include unidentified demand and lack of legal framework to attract international investors into the sector. The policy provides the aims to address these constraints by adopting the following strategies (ECN, 2014):

- Huge investment in research and development.
- Empowering local business capabilities.

- Creating industries for the production of raw materials for Renewable Energy facilities and spare parts.
- Educating local and urban dwellers on the prospects of Renewable Energy as a form of heating and electricity supply.
- Intensifying the current economic reforms.
- Establishing standards for Renewable Energy systems.
- Creating a Renewable Energy fund.
- Establishing a Renewable Energy agency as a regulatory body for renewable energy.

4.1.2 Power sector reforms and regulations

As mentioned earlier, the government of Nigeria undertook power sector reforms in the early part of the last decade. The enactment of the Electricity Power Sector Reform Act (EPSRA) of 2005 by the Federal Government marked the end of vertically integrated electric utility in Nigeria. The Act stipulates the unbundling and privatization of electricity sector thereby allowing IPPs to generate and sell to the national grid. The general aims of the reforms in Nigeria like deregulated electricity industries in other countries across the globe are to improve efficiency, to create a more competitive energy-producing industry, to attract new investors and also to divest the state of over-regulated, and often heavily indebted, electricity undertaking, providing welcome cash for the government that can be spent on social services (Aliyu et al., 2015).

With the enactment of EPSRA, private individuals are also allowed to own and operate off-grid power generators with a capacity of less than 1 MW without acquiring electricity license from the electricity regulator NERC and regardless of the fuel type (Aliyu et al., 2015). This law empowers individual or group of individuals to invest in stand-alone or off-grid power generating systems (Ohunakin et al., 2014).The significance of this is that this exemption to holding a license favours energy generation from renewable because electricity generation sources used by private individuals with a capacity of less than 1 MW are usually from renewable sources.

The legislation also made way for the establishment of the Rural Electricity Agency (REA) whose major objectives are to extend the national grid, facilitate independent off-grid systems, generate renewable energy power and coordinate renewable electricity activities among the state and federal agencies (Ohunakin et al., 2014). REA is also responsible for administration of the Rural Electrification Fund (REF), which provides autonomous funding opportunity through the Renewable Electricity Trust Fund (RETF) (Aliyu et al., 2015).

4.1.3 Renewable Energy Master Plan (2005)

In an effort to translate the Renewable Energy component of the NEP into an actionable plan, in 2005 the ECN developed the Renewable Energy Master Plan (REMP) to complement the NEP, which reiterated the government’s pledge to support the development, demonstration, and implementation of Renewable Energy resources for both small and large applications. To create the appropriate enabling environment for the promotion of Renewable Energy, the REMP identified the need for appropriate financial and legal instruments, technology development, awareness raising, capacity building and education as the strategic areas to be paid attention and further sets specific goals for each of those areas (Emodi & Boo, 2015).

However, due to new policy guidelines, developments that took place both locally and internationally, and with the document being voluminous and needing to be concise and precise, a second draft edition was created and concentrated on concisely bringing out the renewable energy programmes of biomass, solar energy, hydropower, wind, emerging technologies and framework programmes (ECN, 2012).

The specific objectives of the Renewable Energy Master Plan are to:

- Enhance national energy security;
- Expand access to energy especially in the rural areas;
- Stimulate employment, economic empowerment and growth and reduce poverty;
- Increase the scope and quality of rural services, including, schools, health services, water supply, information, entertainment and stemming the migration to urban areas;
- Reduce environmental degradation and health risks, particularly to vulnerable groups such as women and children;

- Improve learning, capacity-building, research and development on various renewable energy technologies in the country.

To achieve its aims, the REMP set a map to increase the share of Renewable Energy in the national energy supply mix through three development stages: short term (2013-2015), medium term (2016-2020) and long term (2021-2030) (ECN, 2012). The target set for the three development stages is shown in Table 5 below.

Table 5: Target for renewable energy contribution to electricity generation in Nigeria (ECN, 2012).

Renewable energy sources	Short term (MW)	Medium term (MW)	Long term (MW)
Large hydropower	4000	9000	11,250
Small hydropower	100	760	3500
Solar photovoltaic	300	4000	30,005
Solar thermal	300	2136	18,127
Biomass	5	30	100
Wind	23	40	50
All renewable sources	4628	15,966	63,032
All energy sources	47,490	88,698	315,158
% of Renewable sources	10%	18%	20%

The REMP is therefore a roadmap for implementing government's commitment to create the necessary enabling environment for sustainable energy supply for national development with active participation of the private sector. It is divided in to programmes with targets, timelines and activities. Incentives to promote the attainment of the programmes as well as generally grow the renewable energy market are also provided (NESP, 2014).

4.1.4 Renewable Electricity Policy Guidelines (2006)

The Renewable Electricity Policy Guidelines (REPG) is the federal government's overarching policy on all electricity derived from renewable energy sources. The REPG sets out the federal government's vision, policies and objectives for promoting renewable energy in the power sector.

The document issued by the Federal Ministry of Power and Steel stipulated that the federal government would expand the market for renewable electricity to at least five per cent of total electricity generation and a minimum of 5 TWh of electric power production by 2016.

In the document, renewable energy is clearly regarded as means to extend electricity services to those not yet connected to supply sources (e.g. new settlements in urban areas) and to run electrification campaigns in rural areas. These aspects make a clear distinction between it and other energy generation technologies – with the exception of diesel based generation. As a final goal, renewable energy shall in the mid-term be integrated into the energy mix of the national grid. The policy recognises the advantages renewable energy can bring to the system such as adding additional generation systems to the constrained system, enhancing the stability mitigating local disruptions in supply and reduction of emission (NESP, 2014).

The document gives a very brief overview on the electricity sector situation, recaps the role and situation of renewable energy against the background of other policies and the legal framework, reviews the existing and preceding policies including their targets, formulates Renewable Energy policy objectives, and sets the following policy goals along with respective strategies:

1. Expansion of the market for renewable electricity to at least five percent of total electricity generating capacity and a minimum of 5 TWh of electric power production.
2. Establishment of stable and long-term favourable pricing mechanisms and ensuring of unhindered access to the grid with guaranteed purchase and transmission of all electricity produced by renewable electricity producers and obliging the grid operators upgrade the system accordingly.

3. Construction of independent renewable electricity systems in areas not covered by the electricity grid.

4. Development of innovative, cost-effective and practical measures to accelerate access to electricity services in rural areas through renewable sources.

5. Setting up of a Renewable Electricity Trust Fund to be governed by the Rural Electrification Fund.

6. Creation of a multi-stakeholder partnership for the delivery of renewable electricity to meet national development goals.

7. Broadening international cooperation in expanding the role of renewable electricity for meeting national development goals and contributing to global efforts in addressing climate change.

Further to these goals, the document looks at the energy reserves and renewable energy potentials, the global capacities and technologies together with their costs trends.

4.1.5 Multi-Year Tariff Order (2008)

The Multi-Year Tariff Order (MYTO), which is set to cover a total of 15 years going forward and is reviewed biannually, sets a feed-in bandwidth in order to ensure there are clear rules in the interim market[4] (NESP, 2014).

The Nigerian Electricity Regulatory Commission (NERC) developed the Multi-Year Tariff Order 1 (MYTO1) in 2008 under the authority of the Electric Power Sector Reform Act. The MYTO 1 regulated prices paid to licensed electricity generation companies for providing electricity for distribution and retailing companies from the 1st of July 2008 to the 30th of June 2013. This was also a policy that provided fiscal and financial incentives for electricity companies who exploited multiple Renewable Energy resources for power generation. The policy also provided options for feed-in tariffs and premiums for small electricity providers, as well as consumers who were able to generate electricity for sale to the utility companies.

[4] The interim market is the phase prior to the transitional electricity market (pre-TEM) being set up (see section 3.1).

However, this policy was suspended in 2012 after a progress review by the federal government (Emodi & Boo, 2015).

The NERC released the Multi-Year Tariff Order 2 (MYTO 2), which has similar features to MYTO 1 but includes some improvements, and will be effective from 1st June 2012 to 31st May 2017. The retail tariff in MYTO 2 will be reviewed bi-annually and changes may be made for all electricity generated at wholesale contract prices, adjusted for the Nigerian inflation rate, US$ exchange rate, daily generation capacity and the likes.

The review of all inputs to the tariff calculation is expected to begin by 2016 as the basis of a new Multi-Year Tariff Order designed to kick-start the next five years starting from 1st June 2017. The MYTO 2 contains a 15-year tariff pathway for electricity generated from Renewable Energy, with bi-annual minor reviews and major reviews every five years. The MYTO 2 tariffs are negotiable if a generator can prove to the NERC that their costs for electricity generation from renewables are not in-line with the assumptions of the MYTO 2 (Emodi & Boo, 2015).

The MYTO 2 policy document states that: "*In Nigeria, the true cost of electricity production is not reflected in the consumer tariff. MYTO 2 is intended to be cost reflective and provide financial incentives for urgently-needed increased investments in the industry. These investments, in turn, lead to a significant and continuous improvement in the quantity of energy and quality of service enjoyed by the consumer (...). NERC has determined that the price of electricity to be paid to generators will be at the level required by an efficient new entrant to cover its life cycle costs (including its short-run fuel and operating costs and its long run return on capital invested) (...). It is pertinent to note that feed-in tariffs have been developed for investors wishing to invest in generation capacity that utilises other sources of energy including solar, wind, biomass and small hydro."* (NERC, 2012, pp. 11, 16).

4.1.6 National Renewable Energy and Energy Efficiency Policy (NREEEP), 2014

The National Renewable Energy and Energy Efficiency Policy (NREEEP) was formulated by the Federal Ministry of Power in 2014. It outlines the global thrust of the policies and measures for the promotion of renewable energy and energy efficiency. NREEEP seeks to bring to the attention of policymakers the economic, political and social potential of renewable energy. The document also stipulates that existing policies lack a coherent and all-encompassing framework that drives the sector and therefore calls for an integrated renewable energy and energy efficiency policy which will serve as a useful vehicle that limits conflicts in the future and promotes development and deployment of renewable energy technologies in Nigeria. It can be regarded as an umbrella document consolidating the various other aforementioned policies and strategies in one document (NESP, 2014).

The overall focus of the policy is on optimal utilisation of the nation's energy resources for sustainable development. The purpose of this policy on renewable energy is:

1. To set out a framework for action to address Nigerians' challenge of inclusive access to modern and clean energy resources, improved energy security and climate objectives.

2. To recognise the national significance of renewable electricity generation activities by providing for the development, operation and maintenance, and upgrading of new and existing renewable electricity generation activities.

3. To declare that the proportion of Nigeria's electricity generated from renewable energy sources shall increase to a level that meets or exceeds the ECOWAS regional policy targets for renewable electricity generation and energy efficiency for 2020 and beyond.

4. To recognise that poverty mitigation and environmental protection are hindered by the continued predominance and inefficient use of oil and natural gas in meeting our energy needs.

5. To take a step in the right direction and broaden the definition of energy security to include renewable energy as equally important indigenous sources of energy, in addition to oil and gas.

6. To incorporate provisions for renewable energy generation activities into government policy statements and plans, and recognise the importance of enabling framework conditions for private investment in renewable energy.

7. To set national targets for achievements in electricity from renewable energy capacity addition by 2020 and beyond.

8. To require the preparation of a national action plan for renewable energy and set a time frame within which implementation is required.

9. To recommend that the signatory parties to this policy should collaborate in preparation of the action plans and work together in achievement of the final mandatory targets.

10. To make it mandatory for the Ministry of Power to facilitate the development of an integrated resource plan (IRP) and ensure the continuous monitoring and review of the implementation and effectiveness of the action plans prescribed under the national policy statement.

11. To take steps away from the overheated rhetoric that Nigeria's future energy independence be secured by ever more gas and oil consumption.

12. To facilitate the establishment of a framework for sustainable financing of renewable energy projects and programmes in Nigeria.

4.2 Policy Options

As seen in the previous section, Nigeria currently has a number of legislations and policies regarding renewable energy. However, as highlighted in the previous chapters and as is evident from literature, the current state of renewable energy in the country is not at an acceptable level even with the current policies in place as already mentioned in the previous section. As a result, renewable energy growth can be boosted further by the implementation of other policies being implemented in other parts of the world.

There are a number of policy trends used by various countries or regions in the world to promote the development of renewable energy. These policies are often enacted to tackle a variety of barriers that hinder renewable energy growth. These barriers could include subsidies for conventional forms of energy, high initial capital costs of investment, imperfect capital markets, lack of skills or information, poor market acceptance, technology prejudice, or financing risks and uncertainties - most of which are present in Nigeria.

Policy measures currently being used around the world for promoting renewable energy which Nigeria could take advantage of include price setting and quantity-forcing policies, investment cost reduction policies, and public investments and market facilitation activities (Oyedepo, 2014).

4.2.1 Price setting and Quantity-forcing policies

Price-setting policies reduce cost and pricing-related barriers by establishing favourable pricing regimes for renewable energy relative to other sources of power generation. The quantity of investment obtained under such regimes is unspecified, but prices are known in advance. Quantity-forcing policies do the opposite; they mandate a certain percentage or absolute quantity of generation to be supplied from renewable energy, at unspecified prices. Often price setting or quantity-forcing policies occur in parallel with other policies, such as investment cost-reduction policies. The two main price-setting policies seen to date are the PURPA legislation in the United States and electricity feed-in laws in Europe. The quantity forcing policies include: Renewable Energy (Green) Certificates, Renewable Energy Portfolio Standards (RPS), Competitively-Bid Renewable-Resource Obligations and Mandatory Market Share (MMS) policy or Quotas (Rogers et al., 2008; Oyedepo, 2014).

In the European Union for example, the dominant instruments for promoting the generation of electricity from renewable energy sources have been feed-in tariffs and tradable green certificates. The main advantages of feed-in tariffs system are the long term certainty about receiving support (revenues are known and guaranteed in advance), which may significantly reduce investment risks, for the reason that it creates a basis for long term investment planning (Zamfir et al., 2016).

PURPA was enacted in 1978 in part to encourage electric power production by small power producers using renewable resources to reduce U.S. dependence on foreign oil. The policy required utilities to purchase power from small renewable generators and co-generators, known as qualifying facilities, through long-term (10-year) contracts at prices approximating the avoided costs of the utilities (Oyedepo, 2014).

Renewable Energy Portfolio Standards is considered to be the least-cost option for Renewable Energy promotion. It also brings down the early cost of a technology and thereby creates a competitive market for different Renewable Energy technologies. Thus, the price of electricity generated from Renewable Energy sources becomes lower. It is also a more sustainable and favourable policy to utilities, since the government's initiatives compensate them for extra costs by means of subsidies (Abdmouleh et al., 2015).

4.2.2 Cost-reduction policies

Cost-reduction policies are policies designed to provide incentives for voluntary investments in renewable energy by reducing the costs of such investments. These policies can be characterized as falling in five major categories. They include policies that: reduce capital costs up front (via subsidies and rebates); reduce capital costs after purchase (via tax relief); offset costs through a stream of payments based on power production (via production tax credits); provide concessionary loans and other financial assistance, and reduce capital and installation costs through economies of bulk procurement (Oyedepo, 2014).

Tax exemptions or reductions can encourage private individuals and companies to consider investing in RE projects as an attractive financial option. For example, in Germany and Sweden, investment in wind schemes can be offset against tax for individuals, while in Ireland, Netherlands and Spain companies receive tax relief if they invest in Renewable Energy projects. In another light, experience from different countries in the Asia-Pacific region showed that initially subsidies have been successful in promoting off-grid Renewable Energy technologies (Abdmouleh et al., 2015).

The high upfront investment cost of renewable energy technologies makes them unattractive choices for investors. Removing this barrier by reduction in the initial capital outlay by consumers for Renewable Energy systems goes a long way in promoting their usage.

4.2.3 Public investments and market facilitation activities

Public finance mechanisms have a twofold objective: to directly mobilize or leverage commercial investment into renewable energy projects, and to indirectly create scaled up and commercially sustainable markets for these technologies. Public finance policies are designed such that their direct short-term benefits do not create market distortions that indirectly hinder the growth of sustainable, long-term markets (Oyedepo, 2014).

This mechanism can be provided through grants, equity investments, government procurements, or loan guarantees and low-interest loans which are usually given by national or regional financial institutions with public subsidy support. Those incentives reduce the burden of the initial investment by decreasing equipment costs and addressing market barrier (Abdmouleh et al., 2015).

In general, the funds from public investment serve a variety of purposes, such as paying for the difference between the cost of renewables and traditional generating facilities, reducing the cost of loans for renewable facilities, providing energy efficiency services, funding public education on energy-related issues, providing low-income energy assistance, and supporting research and development (Oyedepo, 2014).

Market facilitation supports market institutions, participants, and rules to encourage renewable energy technology deployment. A variety of policies are used to build and maintain this market infrastructure, including policies for design standards, accelerated siting and permitting, equipment standards, and contractor education and licensing. Additionally, policies to induce renewable technology manufactures to site locally and direct sales of renewable systems to customers at concessionary rates facilitate market development (Mendonc et al., 2009).

4.3 Summary

As is already clearly evident, the development of renewables in Nigeria is still at its infancy. The above described legislations currently in place in Nigeria still do not have the desired market-oriented policies that can drive the increased renewable energy investors' participation in constructive development of the available renewable energy resources in the country.

A major problem confronting the renewable energy deployment in the country is the high upfront installation cost, which is beyond the reach of a large percentage of the Nigerian population. Incentives through effective policy making are absolutely necessary to strengthen the prospect for increased investment and development of renewable energy technologies (Aliyu et al., 2015).

Furthermore, renewable energy growth can be driven through incentive-oriented policies (as mentioned in section 4.2), such as feed-in tariffs as in many European Member countries, tax incentives, subsides and zero import duty on renewable energy equipment, access to affordable loan and investment in research and development in areas of renewable energy power generation systems and its integration into the electricity grid.

Chapter Five: Determining the factors behind Renewable Energy growth in Nigeria.

The main objective of this chapter is to carry out an analysis to determine the main determinants of renewable energy growth in Sub-Saharan Africa with a special focus on Nigeria, controlling for drivers already suggested by the literature (See Marques et al., 2010 and Aguirre & Ibikunle, 2014).

5.1 Data

The estimations use annual data for 17 Sub-Saharan countries[5] spanning 22 years from 1990 to 2011 which were derived from a number of sources which include the World Bank's World Development Indicators (WDI), the United Nations Framework Convention on Climate Change and British Petroleum. The dependent variable is the contribution of renewables to the electricity mix and following Marques et al., (2010) and Aguirre and Ibikunle (2014), the explanatory variables are some of the drivers of renewable energy based on the literature review in earlier chapters. They include: CO_2 emissions, fossil fuel prices, population growth, GDP per capita, energy use, electricity import and the ratification of the KYOTO protocol. Public policy variables such as green certificates, feed-in tariffs, direct investments etc., used by other similar studies in their analysis aren't used in this study due to a lack of data for the countries analysed. Table 6 presents a summary of the variables along with their descriptive statistics and data sources. Below is a brief description of each of these variables:

Contribution of renewables to the electricity mix

The contribution of renewables to the electricity mix is used as the dependent variable in the analysis and it is defined in TWh/year. Renewable energy capacity data is gotten from the WDI. Over the years, many SSA countries have generally had a large portion of their total electricity generated from renewables[6] due to the abundant presence of these resources, but in

[5] Nigeria, Benin, Congo Republic, Cameroon, Cote d'Ivoire, Ethiopia, Gabon, Ghana, Kenya, Mozambique, Namibia, Tanzania, Togo, Senegal, South Africa, Zambia and Zimbabwe

[6] Hydropower has been the main renewable energy source used.

Table 6: Variables definition and descriptive statistics

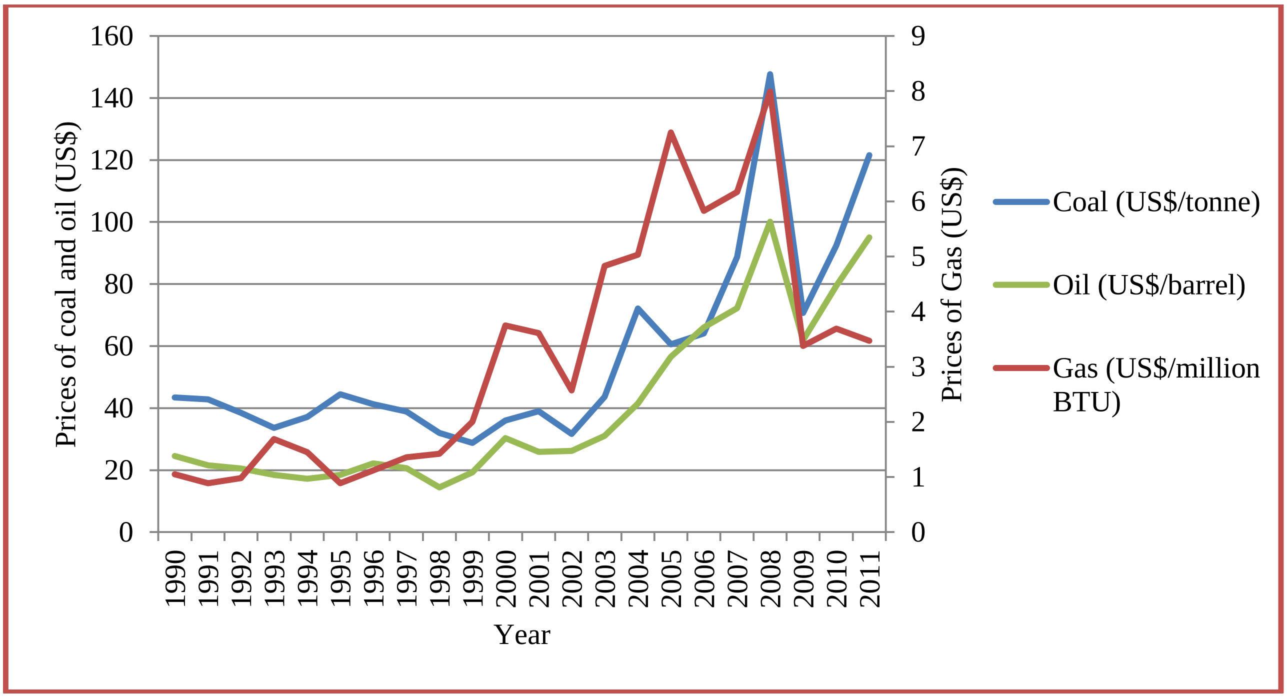
	Definition	Source	Observations	Mean	Median	Minimum	Maximum	Std. Dev.
Variable								
Ren	Contribution of Renewable Energy to electricity generation (TWh/year)	World Data Bank	374	2.84	1.71	0.00	16.78	3.2
CoalPr	Coal prices (US$ per tonne)	BP Statistical Review of World Energy	22	56.78	43.1	28.79	147.67	30.59
GasPr	Natural Gas prices (US$ per million Btu)	BP Statistical Review of World Energy	22	3.20	2.97	0.89	7.99	2.13
OilPr	Crude Oil prices (US$ per barrel)	BP Statistical Review of World Energy	22	40.15	26.04	14.39	100.06	26.50
PopGr	Population growth (%)	World Data Bank	374	2.63	2.64	0.64	3.98	0.53
CO2pc	CO_2 emissions (metric tons per capita)	World Data Bank	374	0.92	0.29	0.033	9.55	2.04
GDPpc	Gross domestic product per capita (constant 2005 US$)	World Data Bank	374	1353	579.75	113.70	8280	2055
Eneuse	Energy Use (GWh/capita)	World Data Bank	374	7.2×10^{-3}	4.87×10^{-3}	2.41×10^{-3}	3.46×10^{-2}	6.53×10^{-3}
EleImp	Contribution of Electricity Imports to Electricity Consumption (TWh/year)	World Data Bank	374	0.87	0.088	0.00	12.2	2.26
Kyoto	Ratification of the Kyoto Protocol (DUMMY)	UNFCCC	374	0.31	0.00	0.00	1.00	0.46

countries like South Africa, Benin and Senegal have only produced a few GWh from renewables over the years while countries like Zambia, Republic of Congo and Ethiopia have traditionally produced a higher amount.

Fossil fuel prices:

The model includes the prices of conventional energies, such as natural gas, oil and coal. The prices are collected from British Petroleum Statistical Review of World Energy. Traditionally, the price of energy generated from conventional energy sources is lower than the price of energy generated from Renewable Energy sources; higher prices of fossil based energy sources promote the switching from traditional sources to renewable sources. In the case of Nigeria being an exporter of fossil fuels, prices could have a different effect. Figure 10 below shows the evolution of fossil fuel prices over the study period. As the figure shows, the prices of coal, gas and oil didn't change much between 1990 and 2000 and after that, they steadily increased along the years until 2008 when there was a sharp dip in the prices.

Figure 10: Evolution of coal, gas and oil prices (BP, 2015)



Population:

Population growth has been rapid in SSA (averaging 2.7% annually during the study period) having increased by 270 million people since 2000 to around 940 million in 2013 and this growth has been split relatively evenly between urban and rural areas, in contrast to the strong global trend to urbanisation. Only 37% of the sub-Saharan population lives in urban areas – one of the lowest shares of any world region (IEA, 2014; WB, 2016).

Nigeria's population showed a substantial increase in the study period. It has increased from 95.6 million individuals in 1990 to 163.7 million individuals in 2011. This change corresponds to an 85.5% increase and Nigeria is the most populous country in Africa (WB, 2016). Urban population rate has also increased considerably during the study period. Between 1990 and 2011, it has increased from 29.6% to 46.9% (WB, 2016).

CO_2 emissions:

CO_2 emissions is an environmental explanatory variable and it is measured in metric tons per capita. The need to reduce carbon emissions and efforts to fight global warming encourages countries to turn to Renewable Energy sources, since they do not cause emissions into the atmosphere. Average CO_2 emissions per capita in SSA have remained relatively stable along the study period. Despite continued economic growth and increased energy use, CO_2 per capita has averaged between 0.8 and 0.9 metric tons per capita throughout the period (WB, 2016).

The carbon emissions in Nigeria have increased from 45,375 KT (in 1990) to 88,026 KT (in 2011) and this change corresponds to a 94% increase, however, per capita emissions haven't increased in the same proportion. Per capita emissions have averaged between 0.4 and 0.7 metric tons per capita. (WB, 2016). Transport, electricity and heat production are the main economic activities which affect Nigeria's CO_2 emissions with 40.8% and 36.2% respectively in 2011. The shares of all economic sectors in the country's carbon emissions is presented in Table 7 below.

Table 7: Economic sector shares of CO_2 emissions in Nigeria (WB, 2016)

Economic activity	**Share in Nigeria's CO_2 emissions (1990) %**	**Share in Nigeria's CO_2 emissions (2011) %**
Transport	41.9	40.8
Manufacturing & construction	13.6	11.6
Electricity & heat production	29.4	36.2
Residential buildings & commercial & public services	15	3.9
Other sectors	0	7.5

GDP per capita:

The economies of the SSA countries have been steadily increasing. As the IEA (2014) reports, the sub-Saharan economy has more than doubled in size since 2000 to reach \$2.7 trillion in 2013; however, rapid population growth has meant that GDP per capita has increased more slowly (about 45%). Agriculture has been a large sector in many economies, accounting for around 20% of regional GDP (compared with a 6% share globally). Mining (energy and non-energy commodities) is also an important industry in several sub-Saharan economies and in resource-rich countries, energy export revenues are an important source of government revenue (IEA, 2014; AfDB et al., 2016). Even though increasing average incomes across much of SSA have helped to lift a large number of people out of absolute poverty, defined as living on less than \$1.25 per day, SSA accounts for 27 out of 36 low income countries and only one high income country (Equatorial Guinea)[7] (IEA, 2014).

In 2014, Nigeria was the 22nd largest economy in the world and largest in Africa (World Bank, 2014), with a real GDP of 194.8 billion US\$[8]. Between 1990 and 2014, Nigeria's real GDP has increased by 245% from 56.4 billion US\$ to 194.8 billion US\$, with an average

[7] While average income levels result in Equatorial Guinea being categorised as a high-income country, it suffers from many of the issues seen in low-income sub-Saharan countries.

[8] Data is taken from the WDI, with GDP measured in constant 2005 USD per capita.

growth of 7% in the last decade. Correspondingly, real GDP per capita has increased from 590 US$ to 1098 US$ in the same period (WB, 2016).

The economic structure of Nigeria has remarkably changed during the study period. The share of agriculture has declined from 31.5% to 20.2% and the share of industry has declined from 45.2% to 24.2% between 1990 and 2014 where the share of services has increased from 23.2% to 55.5% in the same period (WB, 2016).

Renewable Energy is expected to increase with higher levels of economic development, because, among other things, the latter implies more private and public financial resources, increasing environmental awareness and growing electricity demand (Del Río González, 2009; Popp et al., 2011).

Energy use:

Energy demand in SSA has increased by half since 2000 – reaching 570 Mtoe in 2012 – but still accounts for only 4% of the world total. While growth in sub-Saharan energy demand has outpaced that in the rest of the world, it has lagged behind economic expansion, as in many countries it was led by sectors with relatively low energy intensity such as tourism and agriculture (IEA, 2014). Energy use per capita is, on average, one-third of the world average. Across SSA, there are large differences in per-capita consumption between urban and rural areas, with those in cities tending to be wealthier, and often enjoying better access to energy than those in rural areas (IEA, 2014).

Nigeria's energy consumption per capita has increased from 695 kgoe in 1990 to 775 kgoe in 2011 (WB, 2016). As energy consumption increases, it is expected that renewable energy growth increases alongside. In this study, energy consumption is measured in GWh per capita.

Electricity Import

As already mentioned in previous chapters, the subject of energy security is an important driver of the growth of renewables and as such, the import of electricity from neighbouring countries is included in the study and it is measured as the contribution of electricity imports to total electricity consumption. As countries become more dependent on importing electricity to satisfy their local energy demands, it is expected that this will boost the local deployment of renewables.

Ratification of the Kyoto Protocol:

As already mentioned in previous chapters, the commitment to reduce climate change is a significant driver of the growth of renewables. The ratification of the KYOTO protocol is one of the key steps in achieving this. It is drawn up as a dummy variable in this paper; the Kyoto dummy is 1 for a year, for countries that have ratified the protocol and zero otherwise. Table 8 shows the year the countries in this study ratified the Kyoto protocol.

Table 8: Year of ratification of the Kyoto protocol

Country	Year
Benin	2002
Congo Republic	2007
Cameroon	2002
Cote d'Ivoire	2007
Ethiopia	2005
Gabon	2006
Ghana	2003
Kenya	2005
Mozambique	2005
Namibia	2003
Nigeria	2004
Tanzania	Not ratified
Togo	2004
Senegal	2001
South Africa	2002
Zambia	2006
Zimbabwe	2009

5.2 Analysis

To begin, the data sample was converted to a panel data format. Panel data contains more information, greater variability of data, less collinearity between the variables, higher number of degrees of freedom, and more efficiency in the estimates (Greene, 2003; Marques et al., 2010). CO_2 emissions, oil price, gas price, coal price, GDP per capita, energy use and the dependent variable are converted to their natural logarithm format.

Marques et al., (2010) and Aguirre and Ibikunle (2014) in their studies on renewable energy growth determinants, use an estimator called the Fixed Effects Variance Decomposition (FEVD) given the need to include both rarely changing/time invariant and time variant variables in their model. It is a three step procedure for the estimation of fixed effects models that, “provides the most reliable estimates under a wide variety of specifications common to real world data.” - It gives more efficient coefficient estimates than the standard Fixed Effects (FE) estimator (Plümper & Troeger, 2007). However, Greene (2010) points out that the FEVD estimator simply reproduces (identically) the linear fixed effects (dummy variable) estimator then substitutes an inappropriate covariance matrix for the correct one. The consistency result follows from the fact that OLS in the FE model is consistent. He further notes that the “efficiency” gains of the FEVD are illusory and the claim that the estimator provides an estimator for the coefficients on time invariant variables in a fixed effects model is also untrue.

As the model in this study only takes into account time-variant variables, the standard fixed effects (FE) estimator is employed in order to control for unobserved country heterogeneity, which will help time-variant variables coefficient bias. GroupWise heteroscedasticity tests are carried out. To account for robustness, the regression is run four times, excluding insignificant variables each time. Next, a model is estimated which includes Nigeria as a dummy variable to determine the differences between Nigeria and the rest of SSA.

The econometric model used in this analysis is given as:

$$Y_{ct} = \propto \, + \sum_{k=1}^{k} \beta_k X_{kct} \, + \, \varepsilon_{ct}$$

Where $\varepsilon_{ct} = \mu_c + \eta_{ct}$. X is a vector of k time-variant variables, μ_c represents the N - 1 country specific effects, η_{ct} are the independent and identically distributed error terms, Y = renewables growth, $\propto and \: \beta$ are regression coefficients of the variables, c represents each one of the countries, and t represents the year.

5.3 Results and Discussions

Tables 9 and 10 show the results of the models. Table 9 shows the results of the whole panel of countries used in the study. Table 10 shows the results of the model which includes Nigeria as a dummy variable.

Table 9: Results from panel analysis estimated with FE[9]

Variable	(1)	(2)	(3)	(4)
Cons	−2.036 (1.428)	−2.038 (1.406)	−2.029 (1.397)	−1.343 (0.881)
CoalPr	−0.140 (0.105)	−0.1401 (0.105)	−0.1404 (0.105)	−0.137 (0.105)
OilPr	0.203 * (0.111)	0.204 ** (0.103)	0.204 ** (0.103)	0.193 * (0.101)
GasPr	−0.047 (0.045)	−0.048 (0.045)	−0.048 (0.045)	−0.046 (0.045)
CO2pc	−0.028 (0.077)	−0.028 (0.077)	−0.028 (0.077)	−0.041 (0.074)
GDPpc	0.249 * (0.132)	0.249 * (0.131)	0.248 * (0.128)	0.244 * (0.129)
PopGr	−0.135 ** (0.058)	−0.135 ** (0.058)	−0.134 ** (0.056)	−0.133 ** (0.056)
Eneuse	−0.127 (0.201)	−0.127 (0.201)	−0.127 (0.201)	
EleImp	−0.00075 (0.012)	−0.00075 (0.012)		
Kyoto	0.00046 (0.064)			
R^2	0.97	0.97	0.97	0.97
S.E. of Regression	0.29	0.29	0.29	0.29

*Notes: The table reports the estimated coefficients and standard errors in brackets for determinants of renewables growth using Fixed Effects estimation method. All variables are as defined in Table 6. *, **, *** represent significance at 10%, 5% and 1% respectively*

For the whole panel data set, the statistically significant variables across all four regressions are oil price, GDP per capita and population growth. Of these significant variables, oil price

[9] This estimation was carried out using the GRETL software package

and GDP per capita have a positive impact on renewables growth at 10% significance level. The coefficients' magnitude of 0.2 and 0.25 from (1) implies that a 1% increase in the oil price and per capita GDP raises the renewable energy production level by 0.2% and 0.25% respectively. Population growth has a negative impact on the dependent variable at 5% level of significance; with the coefficient's magnitude of -0.13 implying that a one percentage point increase in the population growth rate reduces the renewable energy production level by 13%.

The results suggest that countries with increasing energy requirements are inclined to pursue more fossil fuel solutions and other cheap alternatives instead of renewables. This is borne out in the negative relationship between population growth and renewables deployment. This result is similar to the findings of Aguirre and Ibikunle (2014) and although not a surprising result, it is contrary to the findings of Marques et al. (2010) and Stadelmann and Castro (2014), where the relationship is positive. Stadelmann and Castro (2014) point out that population as measure for the overall size of the country is positively related with policy adoption for renewables. This disparity in results could be explained by the fact that all the countries used in this study are SSA countries and most of them are developing countries with an increasing population and increasing energy demands. Thus, as Aguirre and Ibikunle, (2014) point out, one might suggest that for countries with large population and whose growth is energy intensive, there is a greater emphasis on the use of fossil fuels and less inclination to increase renewables relative to energy requirements.

Larger income allows countries to handle the costs of developing Renewable Energy technologies; this is highlighted in the positive relationship between GDP per capita and renewables. This result is corroborated by Carley (2009) who mentions that states with greater wealth, other things equal, will have a higher percentage of Renewable Energy because they have the ability to invest more heavily in Renewable Energy deployment or other green energy opportunities. It further guarantees higher support for the costs of public policies in promoting and regulating Renewable Energy. Sardosky (2009a) also provides similar results, highlighting that higher income countries are also more likely to have access to or the development of new technologies that are important to the increased production and use of renewable energy.

Table 10: Results from panel analysis including Nigeria as a Dummy variable

	(1)	*(2)*	*(3)*	*(4)*
Variable	Coefficient *(Std. Error)*	*Coefficient (Std. Error)*	*Coefficient (Std. Error)*	*Coefficient (Std. Error)*
Const	−1.729 (2.357)	−2.013 (2.173)	−2.114** (1.052)	−2.082** (1.041)
CoalPr	−0.139 (0.11)	−0.14 (0.11)	−0.136 (0.109)	−0.136 (0.109)
GasPr	−0.046 (0.048)	−0.046 (0.048)	−0.044 (0.048)	−0.045 (0.047)
OilPr	0.207* (0.115)	0.213** (0.107)	0.199* (0.105)	0.199 (0.105)
CO2pc	−0.049 (0.083)	−0.049 (0.083)	−0.066 (0.079)	−0.066 (0.079)
GDPpc	0.349** (0.144)	0.35** (0.144)	0.343** (0.143)	0.336** (0.139)
PopGr	−0.133** (0.059)	−0.132** (0.059)	−0.129** (0.058)	−0.127** (0.057)
EleImp	−0.0034 (0.013)	−0.0032 (0.013)	−0.0029 (0.013)	
Eneuse	−0.153 (0.204)	−0.154 (0.203)		
Kyoto	0.0089 (0.065)			
Nig_l_CoalPr	0.126 (0.505)	0.121 (0.504)	0.177 (0.491)	0.176 (0.49)
Nig_l_GasPr	0.02 (0.252)	0.0156 (0.251)	−0.0012 (0.249)	−0.0001 (0.249)
Nig_l_OilPr	−0.471 (0.701)	−0.439 (0.685)	−0.419 (0.684)	−0.418 (0.683)
Nig_l_CO2pc	0.049 (0.535)	0.0936 (0.512)	0.31 (0.365)	0.311 (0.365)
Nig_l_GDPpc	−1.625 (3.754)	−0.631 (1.612)	−0.516 (1.598)	−0.507 (1.595)
Nig_PopGr	3.613 (8.494)	1.821 (5.895)	2.106 (5.864)	2.093 (5.856)
Nig_l_Eneuse1	3.47 (5.289)	2.958 (4.978)		
Nig_kyoto	0.2578 (0.91)			
R^2	0.97	0.97	0.97	0.97
S.E of Regression	0.3	0.3	0.3	0.3

*Notes: The table reports the estimated coefficients and standard errors in brackets for determinants of renewables growth using Fixed Effects estimation method. All variables are as defined in Table 6. *, **, *** represent significance at 10%, 5% and 1% respectively*

Oil price increases results in a shift to renewables. This is dissimilar to the results of Marques et al. (2010) and Omri and Khuong (2014) where they found a negative effect of oil prices on renewable. However, the analysis of Marques et al. (2010) ends in the year 2006 which means that the rising path of oil prices in the late 2000s is not included in their study. On the contrary, a number of studies highlight the positive impact of oil price increases on renewables (Van Ruijven & Van Vuuren, 2009; Reboredo, 2015). High oil prices encourage the deployment of renewable energy since the economic feasibility of renewable energy projects is enhanced.

The insignificance and negativity of the KYOTO and CO_2 emissions variable can be explained by the fact that the countries in the study are developing countries and are not placing too much emphasis on emissions reduction or climate change goals. These countries are currently focusing on satisfying energy demand borne out from an increase in economic development, urbanisation and population growth. Energy use although also not significant, carries a negative sign implying that increased consumption of energy leads to reductions in renewable energy use.

Table 10 shows the results which include Nigeria. Electricity import for Nigeria is omitted from the model because Nigeria is a zero importer of electricity. The insignificance of the Nigeria variables shows that the impact of the variables for Nigeria is not different to the rest of SSA. As oil price and GDP per capita have a positive impact on renewables, this can be understood by the fact that Nigeria is an oil exporting country. This leads to a kind of correlation between oil price and GDP. With increasing oil prices, there is increased revenue from oil exports and with Nigeria's economy heavily dependent on its oil exports, it forms a large part of its GDP. So just like the rest of SSA, this increased revenue translates to an increase in the growth of renewables.

Another explanation could be that as oil prices increase, Nigeria tries to take advantage of this revenue stream as already highlighted above, and shifts focus to an increased use of its already existing hydropower facilities to supply demand. With Nigeria's population constantly increasing during the study period, it could be argued that this population increase leads to increased energy demand and as such, energy stakeholders are forced to look to available fossil fuel sources to satisfy demand, hence explaining the negative relationship between population growth and renewables deployment.

In light of these results, policy makers and energy stakeholders have to be aware of the fact that income, represented by GDP per capita, and oil price are statistically significant and positive, highlighting the importance of these two variables in explaining renewable energy growth. One would suggest that government policies should include good monetary and fiscal policies, an economic setting free of corruption, and well-functioning labour markets. Furthermore, with the current declining of oil prices, the domestic environment should be made more conducive to foreign investment by reducing the cost of doing business and improving the quality of infrastructures to sustain economic growth which could nurture renewable energy technological innovations.

As increased energy demand is a consequence of population growth, which the results indicate has a negative impact on the growth of renewables, government should create new energy efficiency policies and try to implement them alongside existing ones to reduce energy demand.

Chapter Six: Conclusion

This research work aimed to find out the determinants of renewable energy growth in SSA, with a special focus on Nigeria. Secondary objectives included:

- Performing a review of the potentials of Renewable Energy in Nigeria.
- Examining the current status of Renewable Energy deployment in Nigeria.
- Reviewing the current policies regarding Renewable Energy growth in Nigeria; and
- Outlining recommendations for Nigeria in terms of improving the share of Renewable Energy.

Nigeria is blessed with great potential for developing renewable energy such as wind, biomass, solar and hydro power, dispersed in all regions, which makes this country an attractive place for renewable energy investors. However, these potentials haven't been fully tapped into, even though many of them are plentifully available, and have good economic potential with only hydropower at the moment having a substantial share in the national energy mix.

Policies and legislations regarding renewable energy are currently in place in Nigeria but they still do not have the desired market-oriented policies that can drive the increased renewable energy investors' participation in constructive development of the available renewable energy resources in the country.

Finally, the analysis carried out in the study used the standard Fixed Effects estimator. The results reveal that GDP per capita, oil price and population growth are significant determinants of renewable growth in both SSA as a whole, and in Nigeria in particular. Per capita GDP and oil price both have a positive impact on renewable energy growth while population growth affects renewable energy deployment negatively. As Nigeria is an oil exporting country with revenues from this export making up a large part of its GDP, coupled with the significance of per capita GDP, the results highlight the importance of a strong and growing economy on the growth of renewables. Focus should be placed by government and energy stakeholders on solidifying and sustaining economic growth which could nurture renewable energy technological innovations.

One main limitation on the development of this thesis was the unavailability of data for most of the SSA countries, resulting in the use of only 17 countries for the analysis in the study.

The development of this research project offers possibilities for future work. These include:

i. Extending the number of countries used in the study based on data availability
ii. Analysis of the impact of government policies on renewable energy growth.
iii. Investigating for the determinants of the growth of non-hydro renewable energy.

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