# DETERMINANTS OF RENEWABLE ENERGY CONSUMPTION IN AFRICA

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## ABSTRACT

Increasing global demand for energy security and sustainable development has necessitated the need for a paradigm shift from fossil fuel energy sources to renewable energy sources in Africa. A sizeable number of African countries have set targets for the share of their electricity generation from renewable energy sources between 2020 and 2030. However, there is a dearth of information on the current pattern of renewable energy consumption as well as its key drivers in Africa. This study was therefore designed to investigate the determinants of renewable energy consumption in Africa, with a view to understanding the current pattern and its potential determinants.

The study employed panel data analysis involving five most populous and biggest economies in each of the five regions of Africa namely; Nigeria (West), Egypt (North), Ethiopia (East), DR Congo (Central) and South Africa (Southern) with annual data from 1990 – 2015 using $RE_{it} = \beta_0 + EI_{it}\beta_1 + OR_{it}\beta_2 + CR_{it}\beta_3 + NGR_{it}\beta_4 + CI_{it}\beta_5 + \varepsilon_{it}$. Carbon intensity (kilogram per kilogram of oil equivalent energy use), oil rents (percentage of GDP), gas rents (percentage of GDP), coal rents (percentage of GDP) and energy intensity (mega joules per unit of GDP) were considered as potential drivers of renewable energy consumption. Empirical analysis involved the estimation of both fixed effects and random effects models, while the Hausman test was employed for selecting the appropriate panel model and was significant at $p \leq 0.05$ with R-squared of 0.2311.

The renewable energy consumption in the five countries combined represents 60.2% of total African consumption. The variances across countries are ZERO for the null hypothesis and there is no evidence of any significant differences across the countries which mean that there is no panel effect. The key drivers of consumption were found to be carbon intensity, oil rents, coal rents, natural gas rents and energy intensity. The variables were all stationary at levels, they were integrated of I(0). The random effect model could not be accepted indicating that the appropriate model that fits the data was the fixed effect model. From the result, the F-Statistics test value of 94.15 implies that the determinants jointly account for the variation in renewable energy consumption in the selected African countries. The adjusted R-squared value of 0.6227 implies a good fitness of the model and that all the explanatory variables can explain for about 62.3% variation in renewable energy consumption. Energy intensity is inversely related with renewable energy consumption. Oil rent, Coal rent and Carbon intensity yields a significant and negative relationship with renewable energy consumption. However, natural gas rent revealed a positive and a significant relationship with renewable energy use in Africa.

These countries should charge higher tax rate for fossil fuels and thereby subsidize the development and use of renewable energies as a result of carbon intensity which was found to be a key determinant of renewable energy consumption in Africa . Similarly, for oil and coal rents, African countries need to diversify fossil fuels price risk and support the funding of renewable energy development.



**Keywords:** Renewable energy Consumption, Energy Intensity, Carbon Intensity, Panel data model


**Word count:** 462

## CERTIFICATION

This is to certify that this research work was carried out by **OLANREWAJU BUSAYO TEMITOPE** and that it has been read and approved as meeting part of the requirement for the award of Masters of Philosophy Degree in the Center for Petroleum, energy economics and law, University of Ibadan, Oyo State.

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# DEDICATION

This research study is ultimately dedicated to my Awesome Heavenly Father, my backup, my Best friend, my everything, my ever present Help in time of need without whom this M.phil. Programme would have been futile.

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# CHAPTER ONE

## 1.1 Introduction

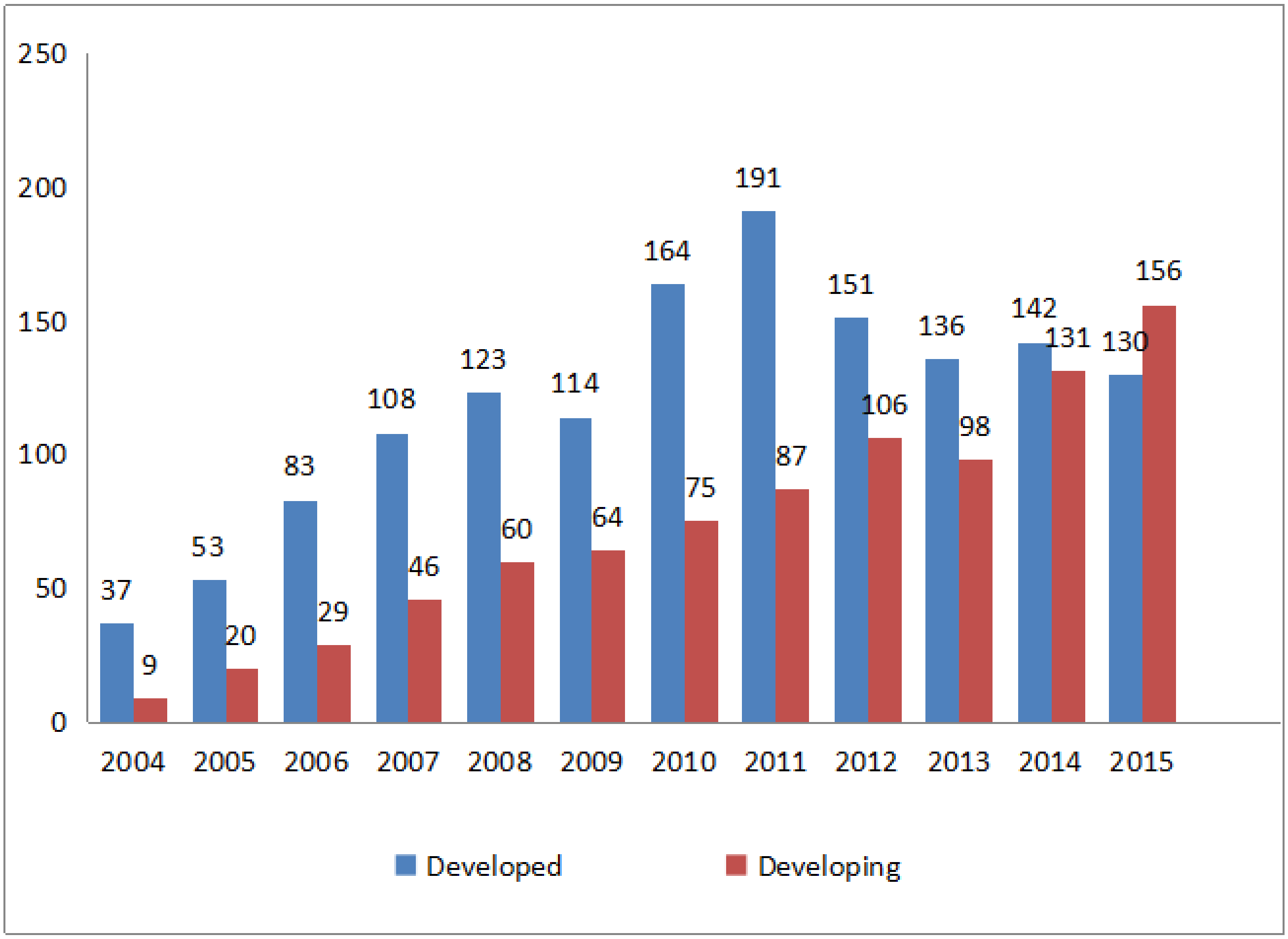
Renewable Energy can also be referred to as the unconventional energy which is the energy that are naturally replenished. This type of energy is said to be sustainable. It is a form of energy that meets the present generation's demand without compromising the future generation in meeting theirs. The use of global renewable energy sources like wind, biomass, solar, geothermal, biofuel and hydropower to generate electricity has developed extensively in 2010 at 19 per cent from 14 per cent in 2002 (AfDB, 2010). The improved alertness of the effect of climate change has resulted to growth in the use of renewable energy with the incentive programs by governments, targeted at improving the progress of the consumption of green energy are protocols such as Montreal and Kyoto Protocols (Olanrewaju, Olubusoye, Adenikinju and Akintande, 2019). The high discharge of emissions into the atmosphere from Nitrous oxide ($N_20$), methane ($CH_4$) and carbon dioxide ($CO_2$) that has caused climate change and resulted into global warming has made a lot of developing nations to delve into the utilization of green energy as alternatives to the conventional energy sources. Many countries globally have seen renewable energy as indispensable factor for economic development, sustainable development, energy security, environmental protection and also as a means to alleviating greenhouse gas emissions. (Gan et al., 2007; Carley, 2009; Johnstone et al., 2010; Marques and Fuinhas, 2012).

The economy of Africa has been increasing with a remarkable speed. Regardless of the global recession brought about by the financial disaster in 2008, Africa has become the fastest growing continent in the world with 5% growth on the average for over a decade (African Development Bank Group, 2014). Africa is endowed with a lot of natural resources especially renewable energy resources depending on the geographical area. North, south and eastern Africa has abundant of wind resources, geothermal energy can be found along the Great Rift Valley. Hydropower and biomass are more in the forested, wet areas of south and central regions of Africa while solar energy sources are found everywhere in Africa. (IRENA, 2015). Research has been carried out that renewable energy sources like power from the sun (which can be referred to as solar thermal and photovoltaic), biofuel, wind energy, hydropower have all contributed immensely to the sustainable development of both socioeconomic and environmental development of many countries that tap them. With respect to the reduction of climate change effects which both developing economies and developed economies have committed themselves to in the Kyoto protocol, renewable energy has been beneficial in both local and international levels.

On the other hand, evenly spread worldwide involvement in renewable energy consumption is still very inadequate. Globally, the total power output for power generation accounts to about 40.9 per cent of coal which is still the major source of energy for the generation of power (EIA 2015). 15% of global population with no access to electricity is in Sub-Sahara Africa out of about 1.4 billion people in the world. Is it ever reasonable and possible for there to be no electricity supply in United State or United Kingdom for just one hour? It will definitely become a tragedy because many businesses will shut down and it will greatly affect the whole country.

The developing countries invested a lot of money in renewable energy in 2015 even higher than the developed countries for the very first time (UNEP, 2015). In 2015, $156 billion was expended on renewables by developing countries which accounted for 19 per cent rise on what was expended in 2014 which is more than what the developed countries invested in their renewables combined (REN21, 2016). Total worldwide investment in renewable energy in 2015 was $285.9 billion and additional 147 gigawatts to the renewable power capacity worldwide was included which was the most ever built in a year (Olanrewaju, Olubusoye, Adenikinju and Akintande, 2019).

The figure below, Figure 1.1 showed that in 2015, the total investment in green energy by the developing economies of $156 billion surpassed that of developed economies investment of $130 billion (UNEP, 2016).




**Source: UNEP, 2016**

**Figure 1.1: Global Green Energy Investment In Both Developing Economies and Developed Economies between 2004 to 2015 in $BN**

## 1.2 Statement of the Problem

The environmental challenges of carbon dioxide emissions, issues concerning the instability of crude oil value and also the dependence on imported energy sources are all factors that necessitated the growing clamor of elements that regulate the use of renewable energy sources. In the 1990s, a barrel of crude oil was between US$18 and US$23 and increased to US$40 in 2004 and eventually skyrocketed to US$60. In 2007, during the summer period, the price of a barrel of crude oil increased to US$70 and again skyrocketed to about US$147 in July 2008 (AFDB, 2009). With about 38 net oil-importing countries in Africa, oil prices was lower in the 1970s than in 1980s in actual terms that is, after price increases has been attuned and this increase affected those oil-importing countries negatively (AfDB, 2009). This inconsistency in the prices of oil definitely has an adverse effect on government's budget, consumers and various enterprises mostly in Africa. This makes the terms of trade and also balance of payments of these countries that are refered to as oil importing to depreciate and with this, there is high probability for their economic growth to decrease.

According to OPEC (2018), the crude oil price was US$55 in 2017and eventually rose in 2018 to US$70. Inspite of the plentiful natural resources in Africa and the increase in the prices of crude oil, there is still insecurity as regards energy. The regional economic integration in Africa is solely based on the effectiveness of these nations to sell their goods in the global market though at prices that are economical and this also implies that they must not use that to compromise the domestic needs of their citizenry. Therefore, energy security is a vital factor for economic integration and this can only happen by securing the supply and demand of energy in the continent. (Economic Commission for Africa, 2012).

According to UN (2017), with the rising Africa population annually to about 1.3 billion in 2017, there is still a wide gap in knowledge about the determinants of green energy use most especially, with the global environmental challenges such as the depletion of the ozone layer and climate change which have been traced to the used of various energy particularly the conventional energy which are fossil fuels (oil, gas and coal) and has become a big issue in Africa.Though, fossil fuels are very essential because it has proved to be a simple and easy source of energy and this has been known to have powered the industrialization of many developed nations but the issues has recently been revealed with continuous use of these forms of energy are many such as political, economic, health and of course environmental challenges.

## 1.3 Research questions

1. What the pattern of the consumption of renewable energy in Africa?
2. What are the factors that determine renewable energy consumption in Africa?
3. What is the consequence of those determining factors on Renewable energy consumption in Africa as a whole?
4. Are the countries homogeneous or heterogeneous as regards their renewable energy activities?

## 1.4 Objectives of the Study

The key aim of the study is to examine the elements that determine Renewable Energy use in the most heavily populated and largest nation in each of the five (5) regions of Africa. These countries are; Democratic Republic of Congo (Central), Ethiopia (East), South Africa (Southern), Nigeria (West) and also Egypt (North).

The specific objectives of this research are to:

1. Identify the pattern of the consumption of renewable energy in Africa;
2. Identify the factors that determine renewable energy consumption in Africa;
3. Quantitatively measure the consequence of those determining factors on Renewable energy consumption in Africa as a whole; and
4. To investigate the homogeneity or heterogeneity of each economy as regards their renewable energy activities.

## 1.5 Justification of the Study

Africa population has been growing at an increasing rate and the zeal of expansion has significantly increased in different countries. This has resulted into sustainable development and transformation in this continent and in order to keep and sustain this growth and development, enormous investment in conventional fuels such as oil, gas and coal is not helping due to the huge emissions of carbon dioxide ($CO_2$) into the atmosphere which has caused global warming.

Therefore, knowing the factors that determine renewable energy use will help in the growth of the economy by creating new employment opportunities and enterprises in order to reduce and eliminate the consequences of climate change and most importantly availability and accessibility of electricity to the rural ones of Africa continent.

The knowledge of the elements that enhance the use of renewable energy offers diverse benefits from facilitating to diminish the bad environmental consequences of the conventional energy use to encourage sustainable development goals and alleviate the reliance on eternal energy imports (Payne, 2012). Conducting research in this aspect is very vital because there are only few studies that has been done in this area. Therefore, this research study examines the key factors of renewable energy use in Africa and also investigates the quantitative consequence or outcome of these determining factors on the use of renewable energy in Africa region as a result of improving on previous studies that have been done.

The results from this study will definitely be useful to researchers in different fields of research. This will also be beneficial to economists, students, several policy makers, various governments and various stakeholders to help them develop a suitable environment for renewable energy sources in Africa. This entails deliberate efforts to having the knowledge of  the determinants of renewable energy use and then discovering the appropriate policies to use, incentives and several stakeholder partnership at both the regional levels and national parastatals. This can also empower these nations to plan and strategize the appropriate methods to alleviate emissions in general and renewable energy to be precise.

Table 1.1 shows the carbon dioxide emissions from each source of energy measured in carbon dioxide equivalent per kilowatt-hour

**Table 1.1: Carbon dioxide Emissions per Energy Source**

| S/N | ENERGY | EMISSIONS( carbon dioxide equivalent per kilowatt-hour ($CO_2E$/kWh) |
|---|---|---|
| 1 | NATURAL GAS | Between 0.6 and 2 pounds |
| 2 | COAL | Between 1.4 and 3.6 pounds |
| 3 | OIL | 2.0 and 3.0 pounds |
| 4 | WIND | 0.02 to 0.04 pounds |
| 5 | SOLAR | 0.07 to 0.2 pounds |
| 6 | GEOTHERMAL | 0.1 to 0.2 pounds |
| 7 | HYDRO | 0.1 and 0.5 pounds |

**Source: Intergovernmental Panel on Climate Change (IPCC), 2011**

Table 1.1 above describes the carbon dioxide emissions per energy source which is measured per kilowatt-hour. This table illustrates both conventional energy sources(oil, gas and coal) and also the unconventional energy sources such as wind, solar, geothermal and hydro. Coal which is the largest carbon dioxide emitter, emits between 1.4 and 3.6 pounds followed by oil which emits between 2.0 and 3.0 pounds. Unlike the popular believe that the unconventional energy sources do not emit carbon dioxide at all, hydro is the largest emitter of carbon dioxide as measured per kilowatt hour and emits between 0.1 and 0.5 pounds followed by geothermal which is the energy from the ground , emits between 0.1 and 0.2 pounds. The lowest emitter of carbon dioxide is wind energy which emits between 0.02 and 0.04 pounds.

## 1.6 Scope of the Study

The study shall cover a period of twenty-five years for five African countries. This is between 1990 and 2015. The sampled Africa countries in the study are selected on regional basis which are West Africa, Southern Africa, North Africa, East Africa and Central Africa region.

One country was selected per region. The countries are Nigeria (West Africa) South Africa in Southern Africa and Egypt in the North, Ethiopia for East and Democratic of Congo for Central Africa. The choice of the period was guided by data availability considerations. The choice of the Countries was influenced by the fact that these countries are among the countries in Africa that represent about 75 percent of the world population by population size (UN, 2017). These countries also have highest GDP combined of 1.151trillion dollars out of 3.3 trillion for all the 54 African Countries in 2018 (UN, 2018) and represent 60.2% of the whole of Africa combined in renewable energy consumption and have great potential for harnessing renewable energy in Africa. The following renewable energy sources will be considered: Solar energy, geothermal, hydro, biomass and wind energy.

## 1.7 Plan of the Study

Following the introductory part in chapter one, the background to the study is discussed in chapter two. The relevant theoretical, empirical and methodological literature is reviewed in chapter three. The theoretical foundation on which the models are predicated is developed in chapter four. The methodology of estimation and the specification of the various equations are also presented in this chapter. This is followed by the estimation results and interpretation of results in chapter five. The study is rounded up with summary of findings, conclusion, limitations and policy recommendation in chapter six.

# CHAPTER TWO

# BACKGROUND OF STUDY

The chapter examines the background of the study, the definitions of each renewable energy source being considered in this research and also reviews the trend of renewable energy consumption, renewable energy electricity output, share of energy use in the selected African countries. Some of the energy policies and targets in Africa are also reviewed.

## 2.1 Non-Renewable (Fossil Fuels) Energy Development in Africa

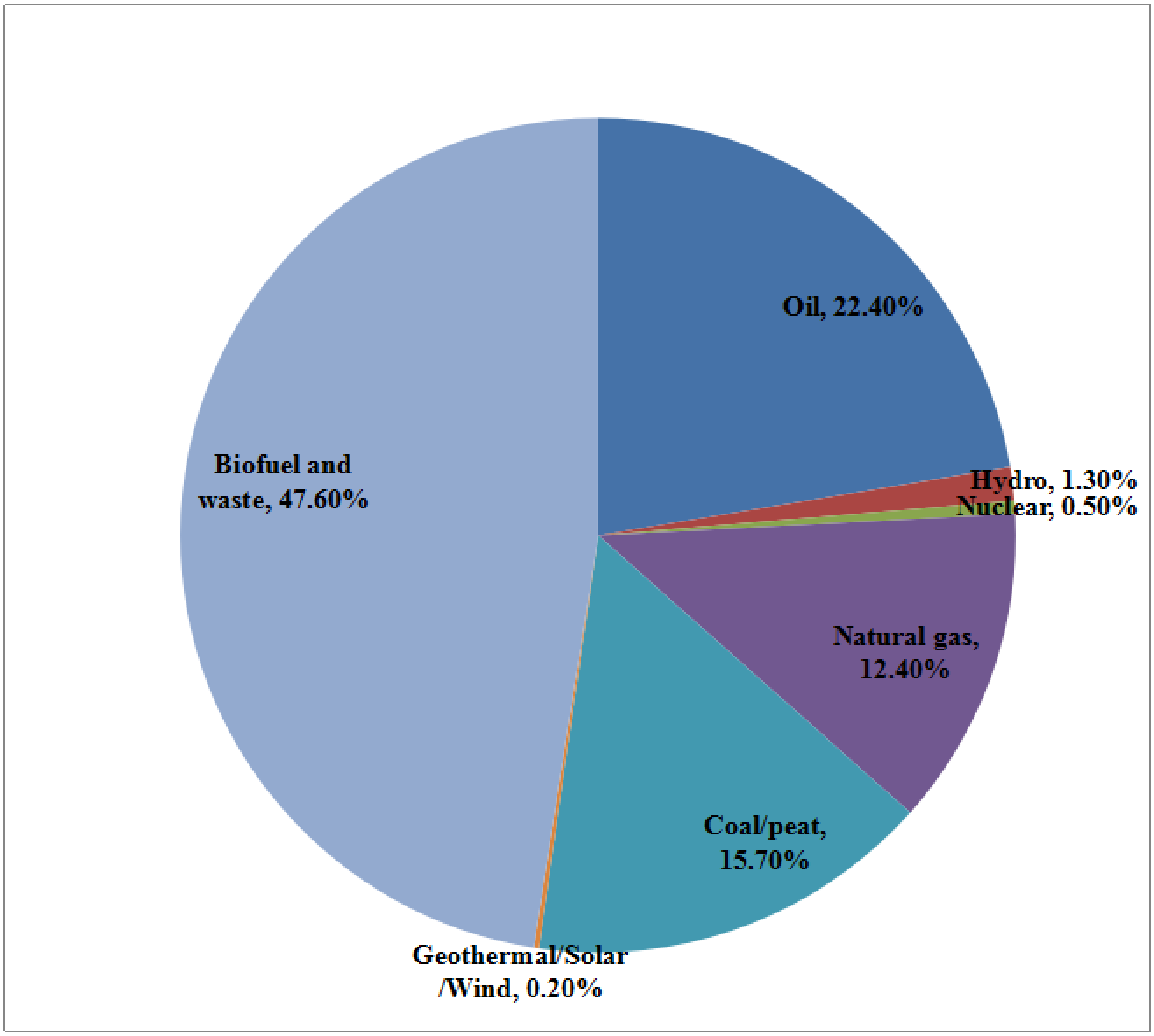
As regards the economies of African nations and its energy system, conventional energy sources are imperative sources of energy and they play important roles in Africa because Africa is widely endowed with these conventional energy. The oil and gas landscape of Africa as a whole is very dynamic in which there is possibility that more reserves will be discovered in the foreseeable future, particularly in the sub-Saharan region of Africa (AfDB, 2011).

Out of the total proven reserves of fossil fuels in the world, Africa has huge potentials of coal, natural gas and crude oil which accounts for about 4%, 8% and 9.5% respectively (BP, 2012).
About 50% of these energy resources is made up of the total primary energy supply and also one-third of energy use apart from generation of electricity in Africa (IEA, 2011a).With respect to the same source, fossil fuels contain over 80% of electricity generated throughout the continent. For most oil producing economies in Africa, these energy resources represent their major source of revenue which accounts for 50 to 80 per cent of government revenues (Zalik and Watts, 2006). For instance, exports of oil is made up of about 80% of government incomes in, Nigeria, Angola and Libya whereas natural gas exports consist of 60% of Federal government revenues in Algeria (CIA, 2011). These statistics propose that an enormous amount of fossil fuels produced in Africa countries is consumed somewhere else.

Estimations by British Petroleum (BP) and the African Development Bank indicates that proven oil reserves of even more than 122 billion barrels (BBLS) and potential oil reserves of almost 159 BBLS is less than the surface of the African continent. As regards natural gas, the Africa possesses about 560 trillion barrels of cubic feet (TCF) of proven reserves and potential reserves of around 319 TCF.

Amazingly and regardless of these enormous energy resources, Africa is still confronted with massive energy issues that comprises of low access to contemporary energy, inadequate energy amenities, low productivity and absence of technical and institutional capacity to use these vast resources. For instance, only about 31% of Sub-Saharan the population in Africa have access to electricity with about 14% and 60% electrification rates in the rural and urban zones, respectively (IEA, 2011a). In addition, conventional biomass dominates energy utilization in the Africa, accounting for about 50% of the entire energy supply in 2008 (IEA, 2011a).

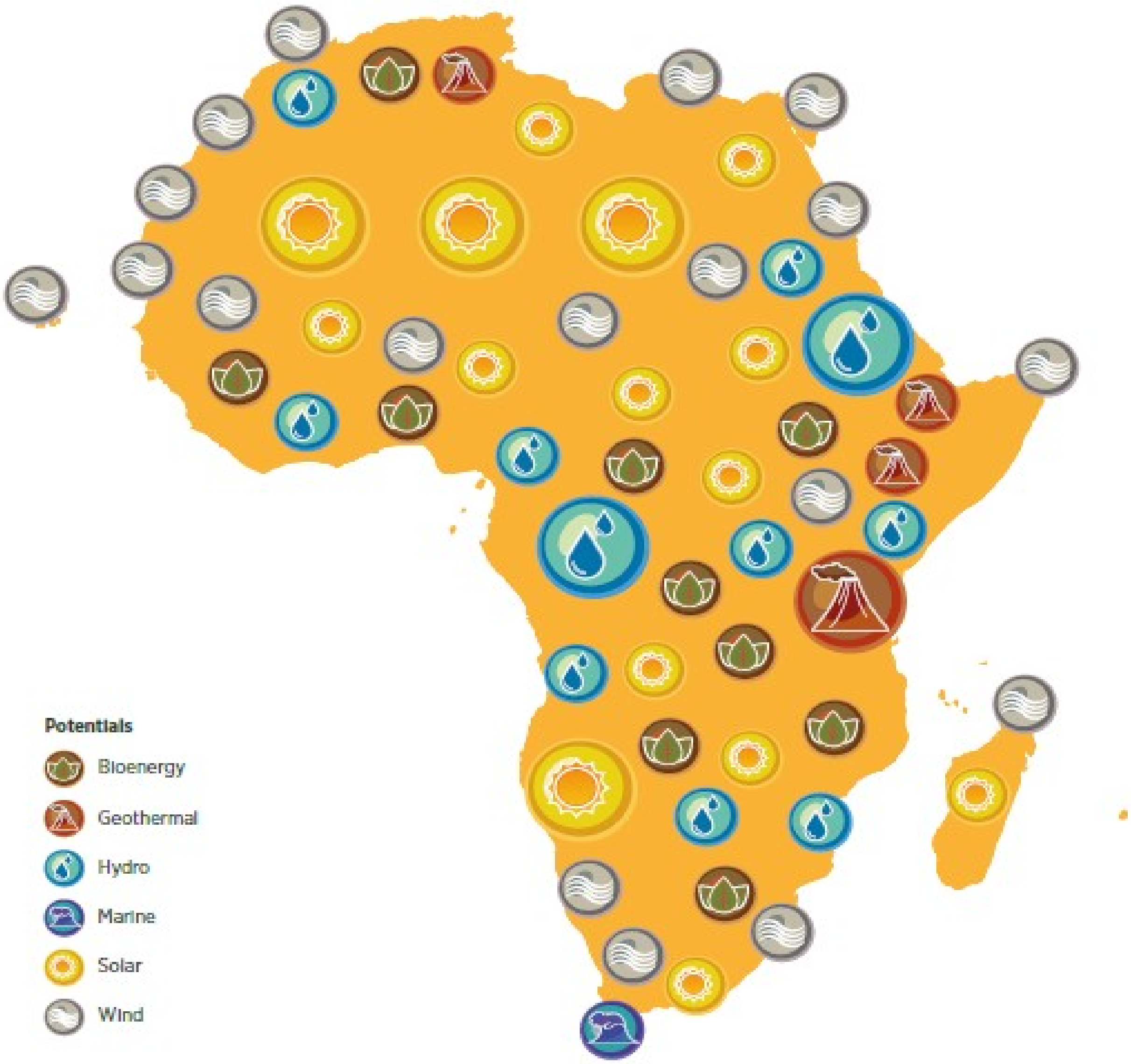
These energy issues have hindered economic growth and development thus contributing to both economic and energy poverty in the Africa region. Regardless of these problems, the huge reserves of fossil fuels in the continent offer Africa abundant opportunities to increase access to energy, speed up economic growth and alleviate poverty. Nevertheless, the over reliance on fossil fuels to produce energy has also been a contributing factor to a so many social and environmental challenges at the global, regional and local levels and this also includes the weakening the ozone layer, acidification and global warming. The involvement of energy generation to the latter is mainly significant because of carbon dioxide (CO2) emissions and other greenhouse gases (GHGs) created during combustion of different fossil fuels, which has worsened the effects of climate change. In 2008, fossil fuels combustion for energy generation account for about 65 per cent of the greenhouse gas emissions globally. Therefore, it is very glaring that continuation with this trend raises concerns (IEA, 2010a).




**Source: International Energy Agency (IEA)*, 2012***

**Figure 2.1: Africa's Share of the Total Primary Energy Supply in 2012**

The figure above, Figure 2.1, represents the aggregate share of the primary energy supply in Africa. The figure shows that bio fuel and waste is mostly used in Africa and this takes the highest which is 47.60 per cent. The second largest share came from oil which amounts to 22.40 per cent while coal represents 15.70 per cent of the share. Natural gas represents 12.40 per cent of the share. Renewable energy sources such as hydro, geothermal, solar, wind and biomass together represent 1.50 per cent of the share of total primary energy supply while nuclear energy takes 0.50 per cent.




**Source: International Renewable Energy Agency (IRENA), 2017**

**Map 2.1: Distribution of Identified Renewable Energy Potential in Africa**

The map above, Map 2.1 represents the various distribution of renewable energy potential in Africa regions (North, South, East, West and Central).

North Africa is highly blessed with solar and wind energy. This means that if properly harnessed, this can improve the electricity supply challenges facing Africa at the moment. Geothermal is mostly concentrated in the Eastern region of Africa. Central Africa has more of bio energy, wind and solar. This shows that these forms of renewable energy can be used instead of the over reliance on oil and also on foreign energy sources and most importantly over reliance on conventional energy sources which is fossil fuels that causes the carbon dioxide emission with presently. According to the map, western Africa has great potential for wind energy and solar energy.In the South, there is huge potential for energy to be gotten from bio energy, solar and wind  and this why they have to be properly harnessed and used for electricity generation.

## 2.2 Energy and Sustainability in Africa

### 2.2.1 Biomass

Any fuel that is gotten from plant matter is referred to as biomass which includes crops, animal waste, wood and crop residues. In the past decades, fossil fuel used to be termed as biomass. The original source of energy for humanity was biomass even since the innovation of fire. Currently this energy source still accounts for roughly ten percent of global primary supply of energy and also the world's largest only source of green energy, since most of the world's inhabitants make use of various forms of energy such as straw, charcoal, animal dung and even wood for cooking (IEA, 2012). In its basic state, biomass can be burned in the form of chips or sawdust and wood pieces. Likewise, crop residues and that of grass can be reduced to bricks or pellets in order to be burned. Biomass incineration can also be used for heating purpose (in the case of a wood stove) or it can even generate electricity in a power plant, comparable coal burning.

### 2.2.2 Hydropower

The world's biggest source of renewable electricity is Hydropower which generates about 16% of worldwide electricity in 2008 (IEA, 2010). In an encouraging situation, hydropower is a cheap green energy source which is usually less expensive as compared to fossil fuels. As a result, this energy source has recently been extensively developed in different countries across the globe.

Hydropower entails precipitation and advancement alteration for electricity generation. Mountainous and wet environments offer the greatest means by which hydropower can thrive.

The amount of energy accessible from this form of energy is subject to the amount of water accessible that is, the flow, and also the vertical fall which is the head. The Niagara Falls is the best hydropower locations which comprises of both the high flow and high head in which such locations make available a huge quantity of electricity at reasonably very low price. Global hydropower generation was 3,288 TWh or about 2% to 3% out of the energy consumed globally while technical prospects is approximately about 5 times greater than 16,400 Terrawatts hour, equal to about 11% of energy being consumed globally (IEA, 2008).

### 2.2.3 Wind power

Energy in moving air produces wind power, and available energy fluctuates with the cube of wind speed. Doubling wind speed equals 2*2*2 = 8 times more the potential energy whereby tripling the speed equals 3*3*3 = 27 times additional energy. Additional potential energy in general results to lower cost for a particular amount of energy. Generally these locations are offshore and coastal just along the ridges of mountain, and in a massive open space like the U.S. Great Plains.

### 2.2.4 Solar energy

Solar energy is in three forms which are referred to as the high-temperature solar thermal energy, solar electric or photovoltaic (PV) and the low temperature solar thermal. The low-temperature solar applications comprise of solar space heating and solar water heating. Low temperature solar energy usually uses simple and verified technologies. Solar water heating is at present financially competitive with fossil fuels in several countries. There is high potential for solar space heating, but the problem with its economics is that periodic supply and demand are exactly contrary. During the least supply of the sun that is when the most demand is which is in the winter in which the most sunshine usually take place when the demand for heating energy is very low (Timmons et.al., 2014).

### 2.2.5 Geothermal Energy

The word geothermal refers to a numerous number of technologies which is differentiated primarily geothermal temperature. The earth temperature rises gradually with depth, and the core of the earth is in fact molten. For geothermal energy use, the crucial questions are really how high the temperature is and also at what depth, and how effortlessly the heat can be excerpted. In the utmost unadulterated and most economical technique of geothermal energy consumption, temperatures high enough to boil water are usually found close to the surface of the earth (Timmons et.al., 2014).

**Table 2.1: Renewable Energy Consumption by African Countries in Terrajoules**

| Years | Congo, Dem. Rep. | Egypt, Arab Rep. | Ethiopia | Nigeria | South Africa |
|---|---|---|---|---|---|
| 1990 | 406,845.40 | 74,901.56 | 744,589.60 | 2,166,562.00 | 326,004.70 |
| 1991 | 420,690.90 | 77,488.67 | 771,364.80 | 2,225,275.00 | 334,858.00 |
| 1992 | 434,677.60 | 77,426.89 | 799,706.70 | 2,282,309.00 | 335,990.90 |
| 1993 | 449,632.90 | 81,250.38 | 828,873.00 | 2,341,770.00 | 340,353.50 |
| 1994 | 461,329.00 | 86,092.79 | 858,338.60 | 2,401,998.00 | 349,869.20 |
| 1995 | 475,847.40 | 85,063.05 | 887,468.70 | 2,464,968.00 | 355,387.80 |
| 1996 | 490,689.90 | 87,927.71 | 916,096.30 | 2,529,784.00 | 363,260.00 |
| 1997 | 506,157.60 | 90,694.01 | 944,380.20 | 2,597,341.00 | 370,388.10 |
| 1998 | 522,275.80 | 92,229.84 | 972,518.40 | 2,667,667.00 | 374,479.00 |
| 1999 | 540,172.70 | 100,603.20 | 1,000,973.00 | 2,740,576.00 | 381,332.90 |
| 2000 | 560,336.50 | 95,898.99 | 1,030,460.00 | 2,816,985.00 | 390,795.60 |
| 2001 | 581,599.00 | 101,609.20 | 1,060,641.00 | 2,895,388.00 | 401,776.10 |
| 2002 | 600,761.40 | 95,841.02 | 1,092,337.00 | 2,979,576.00 | 409,343.90 |
| 2003 | 621,759.10 | 98,157.62 | 1,124,363.00 | 3,066,632.00 | 409,564.90 |
| 2004 | 643,024.00 | 98,728.38 | 1,157,129.00 | 3,152,683.00 | 415,594.00 |
| 2005 | 665,734.30 | 100,239.70 | 1,190,596.00 | 3,248,713.00 | 422,267.00 |
| 2006 | 691,390.30 | 102,639.80 | 1,224,271.00 | 3,342,934.00 | 432,401.50 |
| 2007 | 715,429.90 | 112,239.20 | 1,257,832.00 | 3,481,160.00 | 432,546.00 |
| 2008 | 738,882.70 | 111,083.50 | 1,293,008.00 | 3,580,265.00 | 440,827.80 |
| 2009 | 765,256.20 | 107,495.10 | 1,329,398.00 | 3,679,508.00 | 448,082.30 |
| 2010 | 773,767.80 | 110,947.90 | 1,369,480.00 | 3,829,803.00 | 456,893.30 |
| 2011 | 816,730.20 | 113,437.70 | 1,409,211.00 | 3,975,347.00 | 463,775.40 |
| 2012 | 668,029.80 | 116,437.20 | 1,449,682.00 | 4,167,970.00 | 468,555.00 |
| 2013 | 752,493.10 | 114,584.10 | 1,490,084.00 | 4,216,090.00 | 476,741.60 |
| 2014 | 836,391.70 | 119,451.30 | 1,528,974.00 | 4,207,480.00 | 489,605.90 |
| 2015 | 915,691.20 | 124,450.10 | 1,551,140.00 | 4,226,050.00 | 498,603.20 |

**Source: Energy Information Administration (EIA), 2017**

The table above, Table 2.1 shows the renewable energy consumption in the chosen African Countries measured in Terrajoules.

According to the table, in 1990, Nigeria has the largest share of renewable energy consumption among all the other African Countries of 2,116,562 terrajoules and this renewable energy indicator includes sources from biogas, wind, solar, marine, liquid biofuels, waste, geothermal, solid biofuels and hydro. Ethiopia was the second largest consumer if renewable energy in 1990 while Egypt has the lowest share of their consumption from renewable energy sources with 74,901.56 terrajoules. These countries maintained their rank in 2015 in terms of their renewable energy consumption.

**Table 2.2: Renewable Electricity Output by African Countries in Gigawatthour**

| Years | Congo, Dem. Rep. | Egypt, Arab Rep. | Ethiopia | Nigeria | South Africa |
|---|---|---|---|---|---|
| 1990 | 5,625.00 | 9,932.00 | 1,062.00 | 4,387.00 | 1,010.00 |
| 1991 | 5,259.00 | 9,900.00 | 1,082.00 | 5,931.00 | 1,980.00 |
| 1992 | 6,054.00 | 9,700.00 | 1,151.00 | 6,059.00 | 752.00 |
| 1993 | 5,528.00 | 10,485.00 | 1,263.00 | 5,572.00 | 146.00 |
| 1994 | 5,294.00 | 10,971.00 | 1,354.00 | 5,562.00 | 1,074.00 |
| 1995 | 6,159.00 | 11,413.00 | 1,428.00 | 5,500.00 | 529.00 |
| 1996 | 6,091.00 | 11,555.00 | 1,510.00 | 5,500.00 | 1,379.00 |
| 1997 | 5,024.00 | 11,987.00 | 1,566.00 | 5,593.00 | 2,238.00 |
| 1998 | 4,709.00 | 12,222.00 | 1,605.00 | 5,775.00 | 1,826.00 |
| 1999 | 5,282.00 | 14,683.00 | 1,625.00 | 6,148.00 | 923.00 |
| 2000 | 5,979.00 | 13,834.00 | 1,651.00 | 5,628.00 | 1,408.00 |
| 2001 | 5,957.00 | 15,351.00 | 1,993.00 | 5,909.00 | 2,292.00 |
| 2002 | 6,092.00 | 13,063.00 | 2,023.00 | 8,234.00 | 2,642.00 |
| 2003 | 6,140.00 | 13,387.00 | 2,280.00 | 7,448.00 | 966.00 |
| 2004 | 7,057.00 | 13,167.00 | 2,521.00 | 8,108.00 | 1,224.00 |
| 2005 | 7,367.00 | 13,196.00 | 2,833.00 | 7,768.00 | 1,609.00 |
| 2006 | 7,497.00 | 13,541.00 | 3,259.00 | 6,263.00 | 3,179.00 |
| 2007 | 7,795.00 | 16,341.00 | 3,385.00 | 6,227.00 | 1,153.00 |
| 2008 | 7,452.00 | 15,595.00 | 3,310.00 | 5,721.00 | 1,501.00 |
| 2009 | 7,768.00 | 13,996.00 | 3,548.00 | 4,529.00 | 1,711.00 |
| 2010 | 7,819.00 | 14,750.00 | 4,949.00 | 6,374.00 | 2,433.00 |
| 2011 | 7,811.00 | 14,681.00 | 6,299.00 | 5,883.00 | 2,384.00 |
| 2012 | 7,586.00 | 15,581.00 | 7,596.00 | 5,659.00 | 1,574.00 |
| 2013 | 8,231.00 | 14,469.00 | 8,711.00 | 5,326.00 | 1,737.00 |
| 2014 | 8,820.00 | 15,541.00 | 9,606.00 | 5,346.00 | 3,468.00 |
| 2015 | 8,916.00 | 15,030.00 | 10,433.00 | 5,718.00 | 8,173.00 |

**Source: Energy Information Administration (EIA), 2017**

According to the table above, Table 2.2, which shows the trend of renewable electricity output overtime in various countries under study measured in Gigawatt hour. This renewable electricity output is electric output of power plants and the sources includes biogas, wind, solar, marine, liquid biofuels, waste, geothermal, solid biofuels and hydro except the generation of electricity derived from hydro pumped storage.

In 1990, Egypt takes the lead in its own renewable electricity output and has an output of 9,932GWh; even though it was the last among the other Africa countries in terms of renewable energy consumption as at 1990 (see Table 2.1 - the lowest with 74,901 Gigawatt hour), it still was able to put it to good use. Democratic Republic of Congo ranked the second in terms of renewable electricity output with 5,625 Gigawatt hour followed by Nigeria with 4,387GWh. The largest country in terms of GDP and population in the Eastern region of Africa, Ethiopia ranked the fourth as regards its renewable electricity output with 1062GWh while South Africa which is also the largest country in the southern area of Africa is the last among the chosen countries with about 1010GWh in 1990. According to the table, between 1999 and 2000, the renewable electricity output of Egypt decreased from 14, 683GWh to 13,834GWh and this can be referred or caused by the fall in the renewable energy consumption in Table 2.1 between those years but this rose again in 2001 to about 15,351GWh of electricity output as a rise in the renewable consumption.

In 2015, Nigeria's renewable electricity output fell drastically as compared to what it was producing in 1990 which made it the second largest Country in terms of renewable electricity output, thereby making it the last among other countries with 5,718GWh and this simply means that Nigeria did not put the renewable energy being consumed as shown in Table 2.1 into good use by converting it to electricity output and even made the country the least country in terms of electricity supply to its citizenry.

**Table 2.3: Share of Energy Consumption in Africa**

| **Energy Sources** | **Congo** | **Egypt** | **Ethiopia** | **Nigeria** | **South Africa** |
|---|---|---|---|---|---|
| Biomass | 93.60% | 0% | 92.20% | 51% | 8% |
| Hydro | 2.90% | 3% | 1.60% | 3% | 0.30% |
| Coal | 1.30% | 2% | 0.40% | 0.10% | 64% |
| Natural Gas | 0.03% | 53% | 0.00% | 5% | 3% |
| Petroleum Products | 2.17% | 41% | 5.70% | 41% | 20% |
| Geothermal/Solar &Wind | 0.00% | 1% | 0.10% | 0% | 2% |

**Source: British Petroleum Statistics and Energy Information Administration (EIA), 2015**

Table 2.3 above, shows the share of consumption of various energy sources in Africa in 2015.

Nigeria, Democratic Republic of Congo and Ethiopia consumes more of Biomass. Hydro energy is consumed mostly in Nigeria, Egypt and Democratic Republic of Congo with 3 per cent each. Coal is used mostly in South Africa which ranks the highest with 64 per cent, followed by Egypt . Natural gas is mostly consumed in Egypt which indicates that the country consumes about 53 per cent followed by Nigeria with 5 per cent and the table also shows that Ethiopia does not consume Natural gas at all because Nigeria and Ethiopia depend solely on petroleum products. Petroleum products such as oil, kerosene, diesel are also mostly used in Egypt and Nigeria in which they both ranked 41 per cent, followed by South Africa which takes 20 per cent and Democratic Republic of Congo ranked the lowest with 2.17 per cent.

For renewable energy such as geothermal, wind and solar, South Africa is the largest consumer as shown in the table with 2 per cent. According to EIA (2015), Nigeria and Democratic Republic of Congo does not consume geothermal, wind and solar.

**Table 2.4: Carbon dioxide Emissions by African Countries in Million tonnes**

| Years | Congo, Dem. Rep. | Egypt, Arab Rep. | Ethiopia | Nigeria | South Africa |
|---|---|---|---|---|---|
| 1990 | 3.4 | 91.9 | 3 | 82.6 | 305.6 |
| 1991 | 3.4 | 93.8 | 2.5 | 88.6 | 300.1 |
| 1992 | 3.9 | 94.2 | 3.6 | 94.0 | 305.0 |
| 1993 | 4.1 | 95.9 | 3.3 | 96.9 | 306.5 |
| 1994 | 3.1 | 99.6 | 2.2 | 94.9 | 317.4 |
| 1995 | 3.2 | 109.1 | 2.4 | 99.9 | 326.4 |
| 1996 | 3.4 | 112.8 | 1.7 | 101.4 | 332.0 |
| 1997 | 3.3 | 121.8 | 1.7 | 91.6 | 339.8 |
| 1998 | 3.1 | 115.8 | 2.6 | 88.6 | 333.3 |
| 1999 | 2.7 | 118.4 | 3.3 | 84.5 | 344.7 |
| 2000 | 2.3 | 130.1 | 3.5 | 80.5 | 343.4 |
| 2001 | 1.7 | 134.2 | 3.6 | 91.2 | 348.1 |
| 2002 | 1.5 | 144.3 | 3.9 | 90.9 | 337.0 |
| 2003 | 1.5 | 153.1 | 4.2 | 92.4 | 370.3 |
| 2004 | 1.736237 | 160.4 | 4.3 | 92.0 | 408.5 |
| 2005 | 1.759115 | 152.8 | 4.6 | 105.6 | 392.7 |
| 2006 | 1.75614 | 159.2 | 5.2 | 101.4 | 401.3 |
| 2007 | 1.936184 | 186.3 | 5.7 | 100.4 | 411.5 |
| 2008 | 1.841191 | 187.2 | 6.4 | 100.8 | 447.5 |
| 2009 | 1.73291 | 202.1 | 7 | 69.4 | 447.1 |
| 2010 | 2.444235 | 203.6 | 6.5 | 79.7 | 449.2 |
| 2011 | 1.841013 | 204.2 | 7.1 | 83.4 | 440.7 |
| 2012 | 1.462272 | 206.1 | 8.2 | 95.1 | 435.6 |
| 2013 | 3.244228 | 206.2 | 8.8 | 95.5 | 439.4 |
| 2014 | 5.279175 | 207.3 | 9.6 | 96.8 | 444.0 |
| 2015 | 5.8 | 211.4 | 10.3 | 98.6 | 421.8 |

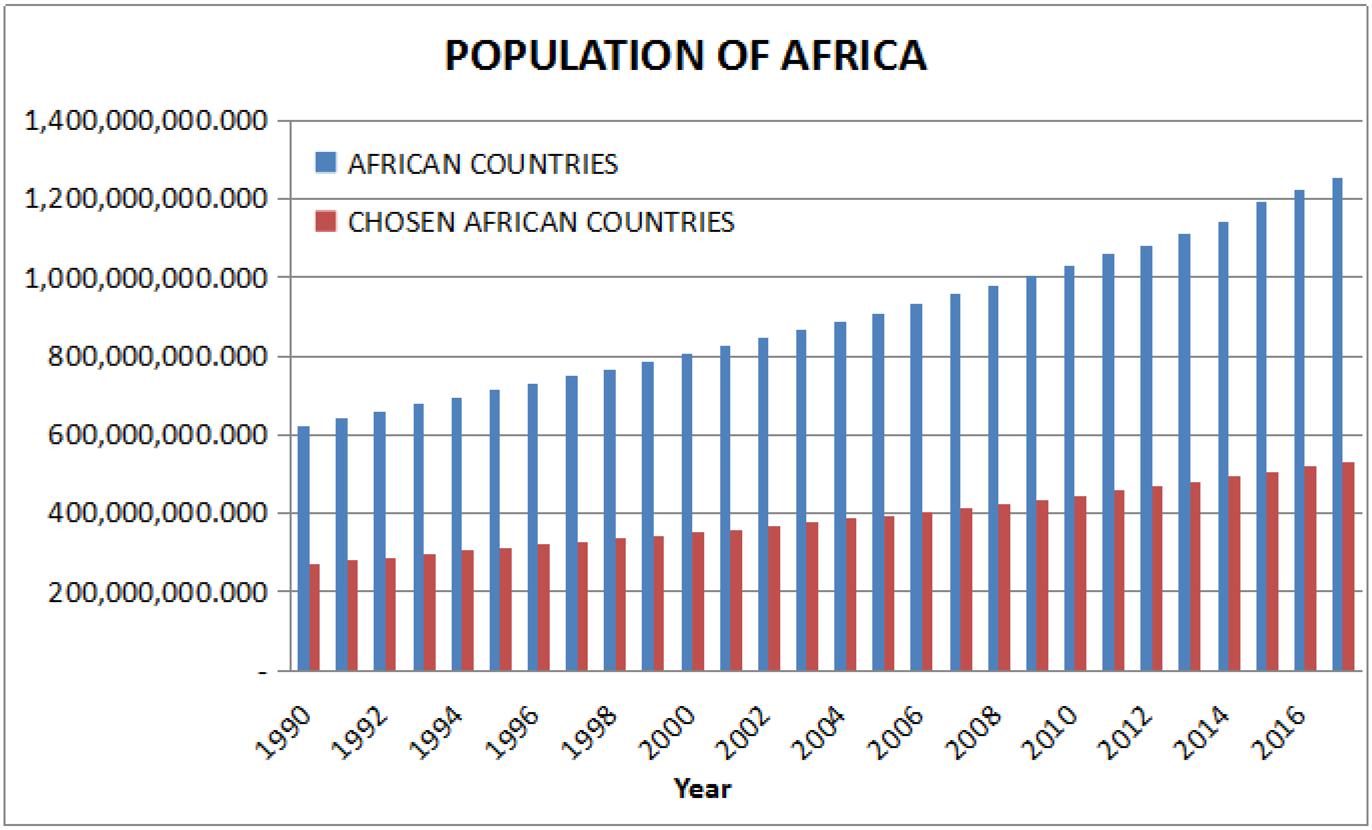
**Source: Energy Information Administration and British Petroleum Statistics (BP), 2017**

The table above, Table 2.4 shows the carbon dioxide emissions by all the chosen Africa countries measured in million tonnes.

According to the table, in 1990, the highest emitter of carbon dioxide was South Africa which is the largest country in Southern region of Africa and emits 305.6 million tonnes of carbon dioxide because this country is the largest consumer of coal with 64 per cent share of its energy consumption in 2015 as shown in Table 2.3 above. Coal emits a lot of carbon dioxide because it is fossil fuel and this one one of the causes of the growing clamour of the use of renewable energy in the world against these conventional fuels due to the health issues, environmental challenges and climate change. Egypt ranked the second largest emitter of carbon dioxide in 1990 with 91.9 million tonnes while Nigeria emits 82.6 million tonnes of carbon dioxide followed by Democratic Republic of Congo with 3.4 million tonnes and the lowest emitter of carbon dioxide was Ethiopia with 3 million tonnes.

In 2015, it is shown in the table that South Africa still maintained its rank as the largest emitter of carbon dioxide while Egypt is the second largest but it is indicated that this emissions from Egypt increased greatly from 91.9 million tonnes to 211.4 million tonnes and this can be seen from its share of energy consumption in Table 2.3 that Egypt's major energy sources are petroleum products and Natural gas in which these are fossil fuels that emits the highest carbon dioxide. Nigeria ranked the third, followed by Ethiopia which uses more of petroleum products in its share of energy consumption inn Table 2.3 as compared to Democratic Republic of Congo with 5.70 per cent and 2.17 per cent respectively.

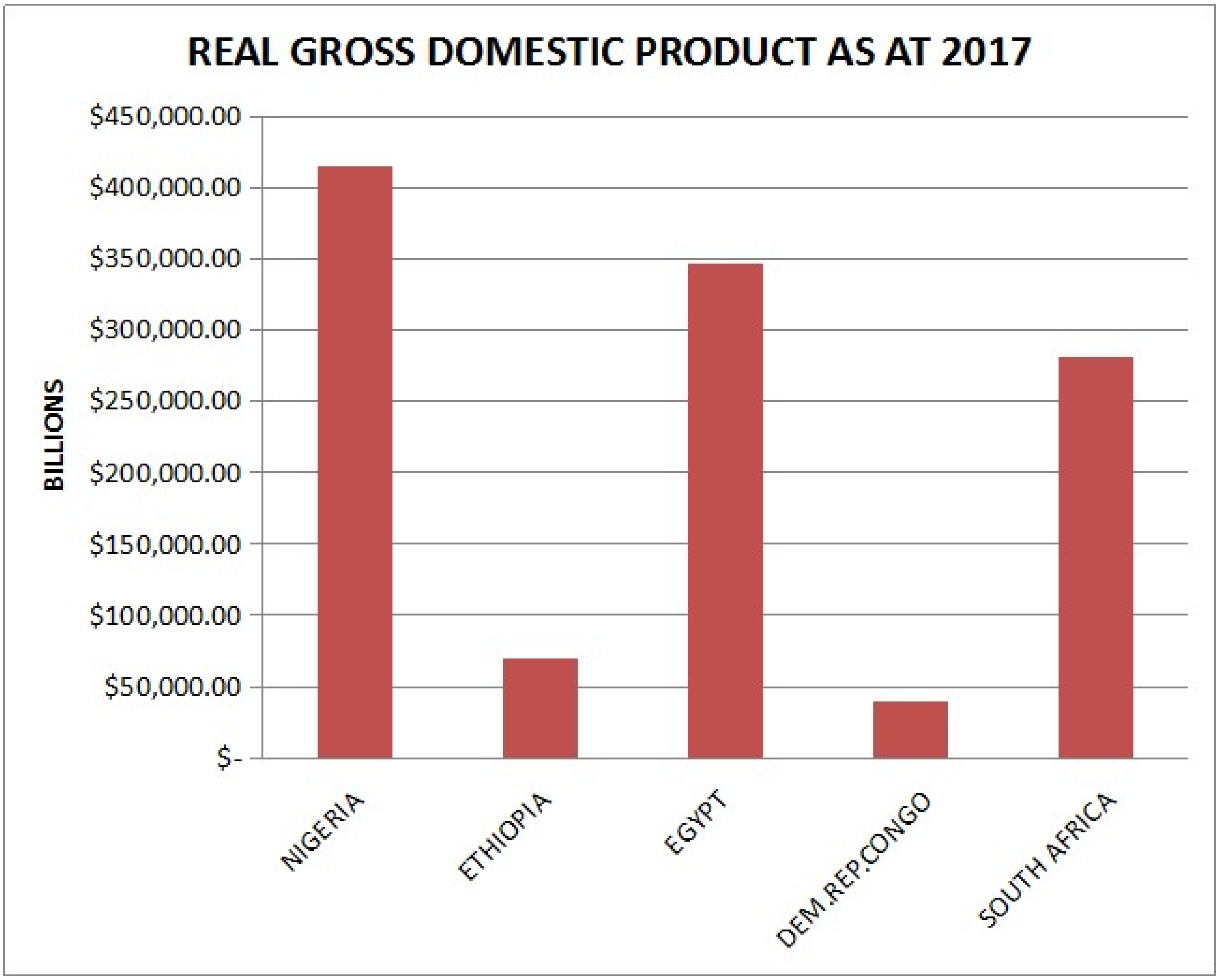
## 2.3 Trend Analysis of Key Variables




**Source: World Development Indicators, 2017**

**Figure 2.2: Trend of African Population from 1990-2017**

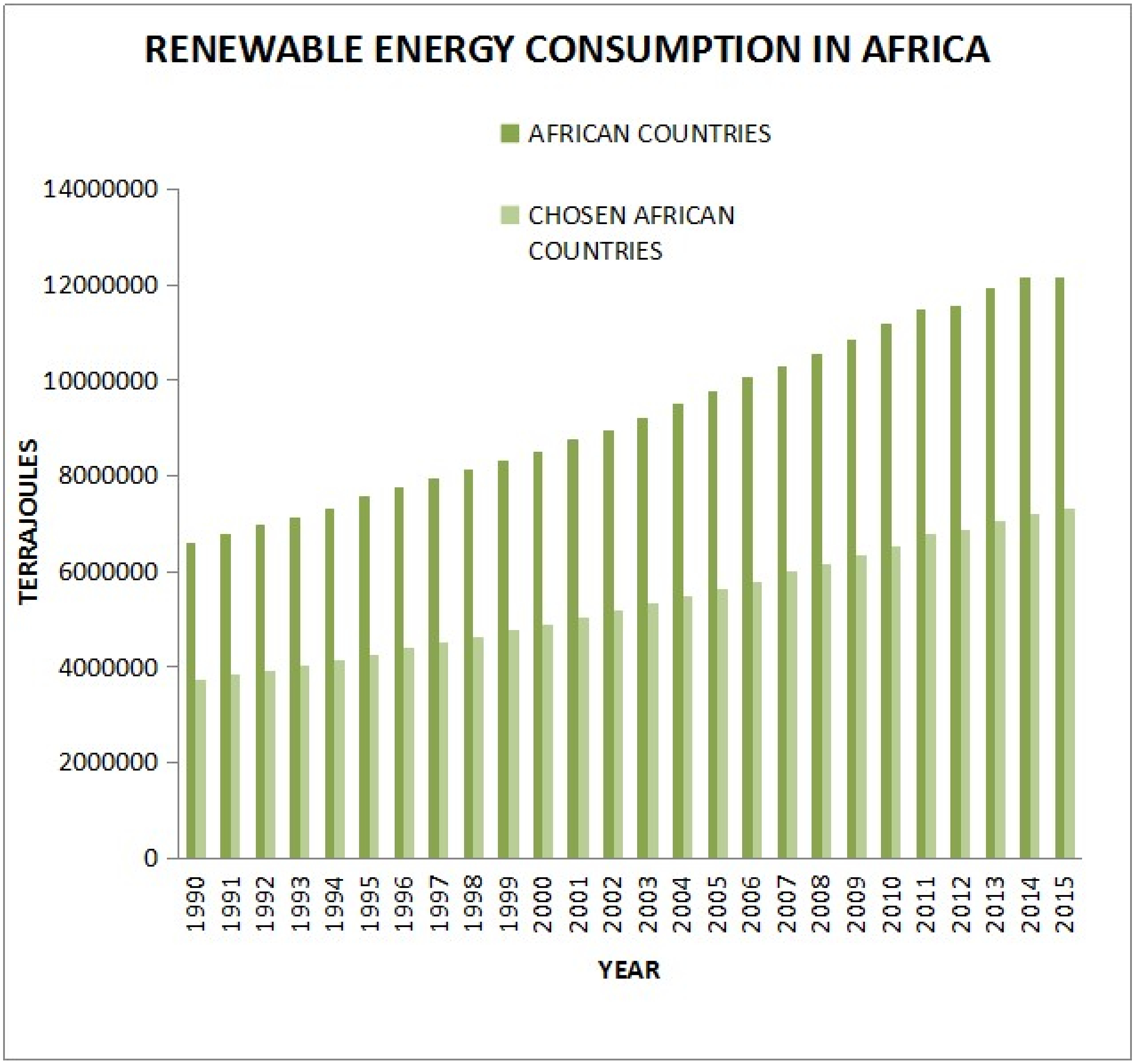
Figure 2.2 above shows the whole of Africa population which contains about 1.256billion people (UN, 2017). African population continues to increase overtime between 1990 and 2015 from about 600 million to 1.3 billion and this shows clearly that as the population increases, Africa needs more than one means of energy supply in order to meet her needs adequately. The summation of the Africa countries population under consideration is about 532million population. Therefore, the proportion of these countries combined in Africa as a whole is 0.4231 which is 42% of the population of Africa. This implies that these five (5) countries under study represent 42 per cent of the the entire Africa continent of about 54 countries.




**Source: United Nations (UN), 2017**

**Figure 2.3: Real Gross Domestic Product in African Countries**

The real gross domestic product (Real GDP) which is measured in billions US dollars in figure 2.3 indicates that Nigeria has the highest real GDP of 415 billion US dollars in Africa followed by Egypt with  346 billion US dollars. South-Africa took the third position of more than 280 billion US dollars, Ethiopia has 69 billion US dollars and finally out of the five (5) biggest African countries, Democratic republic of Congo has the least real GDP of 39 billion US dollars. The GDP of all the chosen countries is 1.151trillion dollars out of 3.3 trillion for all the 53 African Countries in 2018 (UN, 2018). This represents 34.9% of Africa GDP combined.

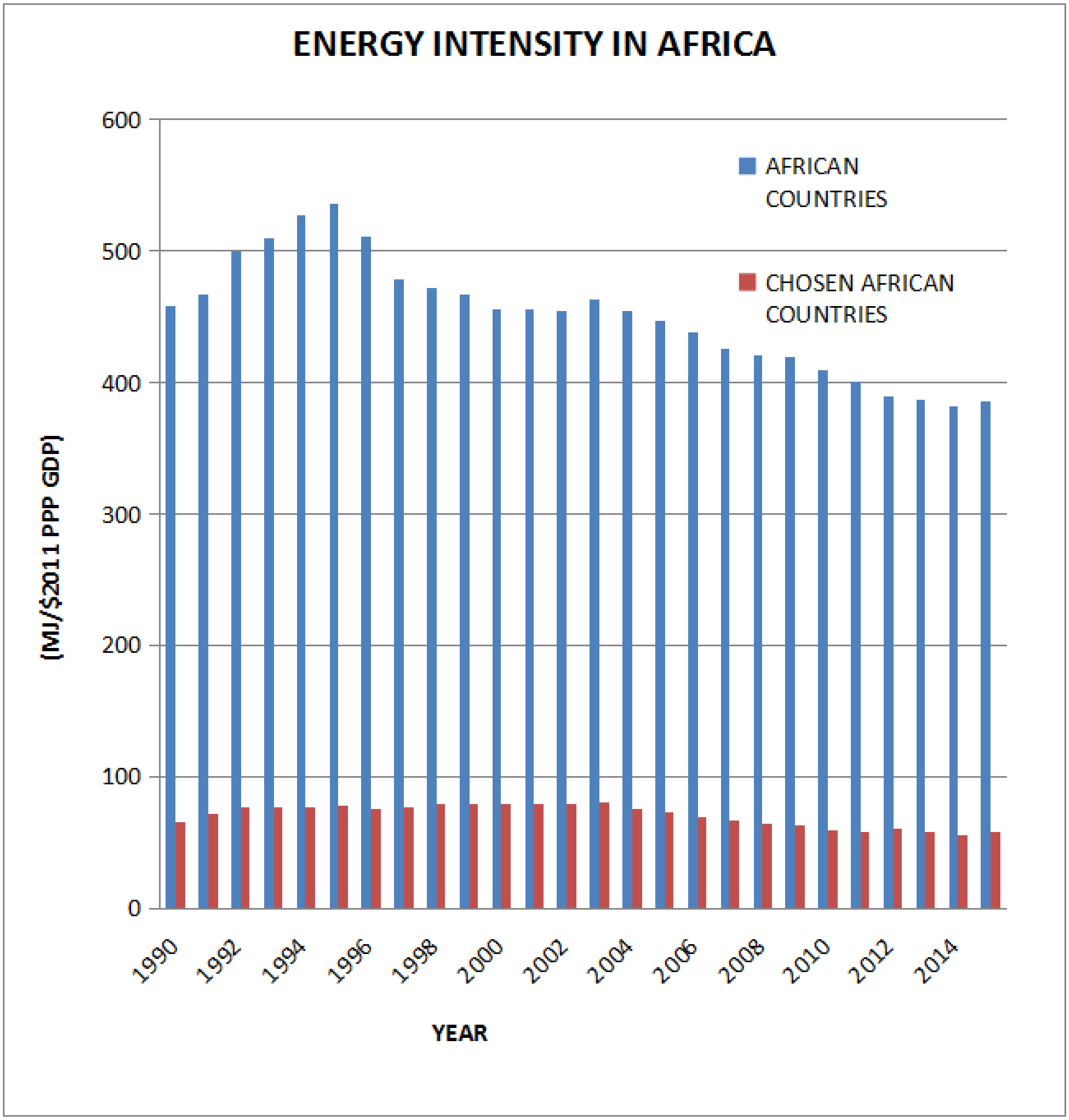



**Source: World Bank, 2017**

**Figure 2.4: Trend of Renewable Energy Consumption in Africa from 1990-2015**

Figure 2.4 shows the trend analysis of renewable energy consumption of the whole African countries as compared to the five (5) African countries under consideration measured in terrajoules.

Renewable energy consumption in Africa as a whole was close to 7 billion as compared to that of the Africa countries under study which is close to 4 billion and eventually increased. In 2015, the renewable energy consumed by all the African countries was 12,144,108.43 terrajoules which the chosen African countries consumed 7,315,934.5 terrajoules. Therefore, the proportion of these countries combined to Africa as a whole is 0.602 which represent 60.2 percent of renewable energy consumed in Africa.

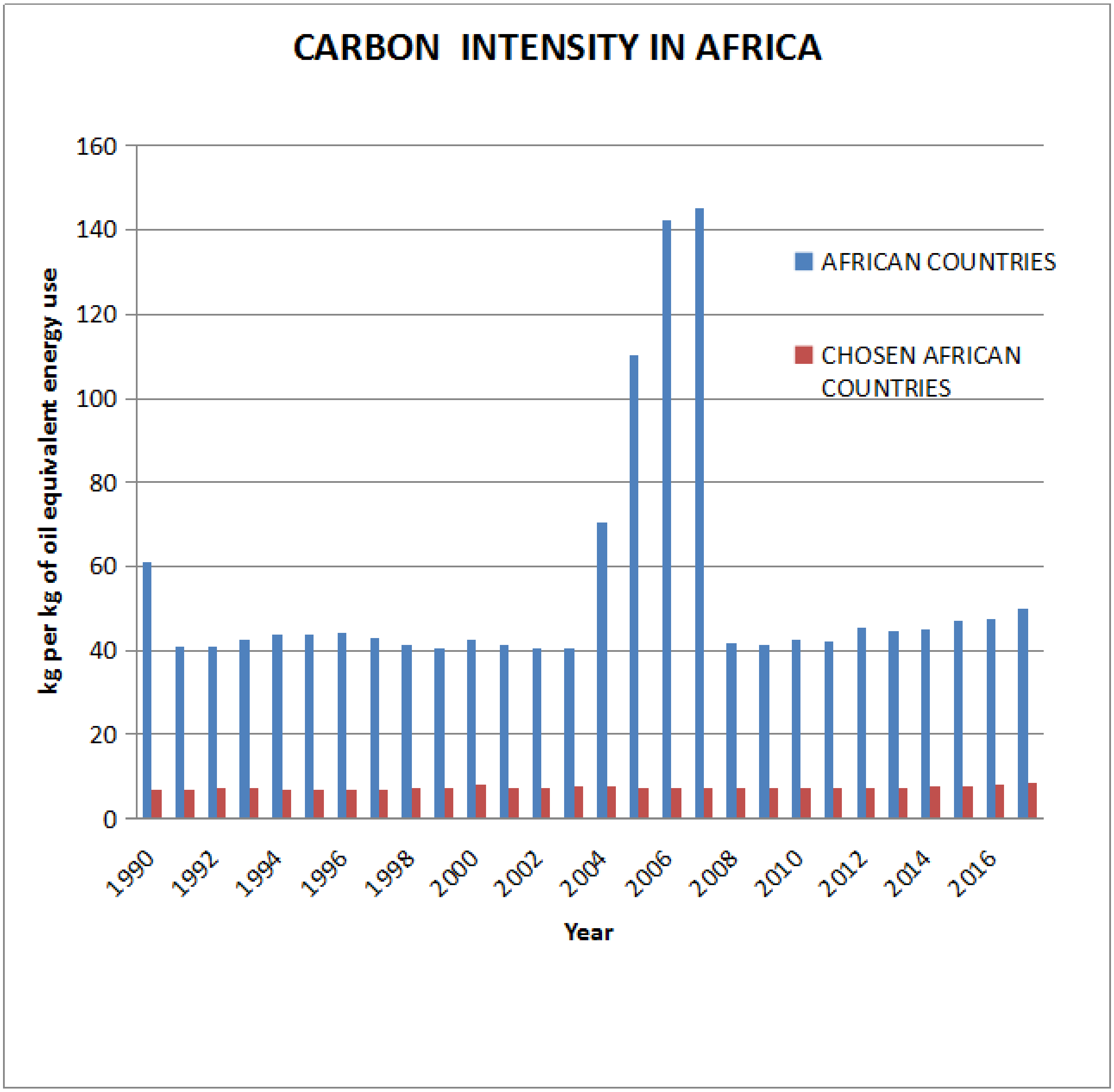



**Source: World Development Indicators, 2017**

**Figure 2.5: Trend of Energy Intensity in Africa**

Figure 2.5 indicates the trend of energy intensity in Africa from 1990 to 2015. The energy intensity is simply an indicator which shows the efficiency of a particular country's economy. This is usually calculated as units of energy per unit of the nation's GDP. The actual rate of the energy intensity in Africa over the years has been unstable. The figure below shows that in 1990, energy intensity of African countries combined was 459.01 megajoules while that of the five most populous and biggest economy in Africa combined was 65.78 megajoules and rose to 535.84 and 77.76 in 1995 respectively and then fell to 385.54 and 58.09 in 2015 respectively.

The proportion of these countries combined to Africa as a whole is 0.15 which represents 15 per cent of Africa. This also implies that the energy intensity for the most populous and biggest economies in Africa is low and that is why these countries need to consume more renewable energy.



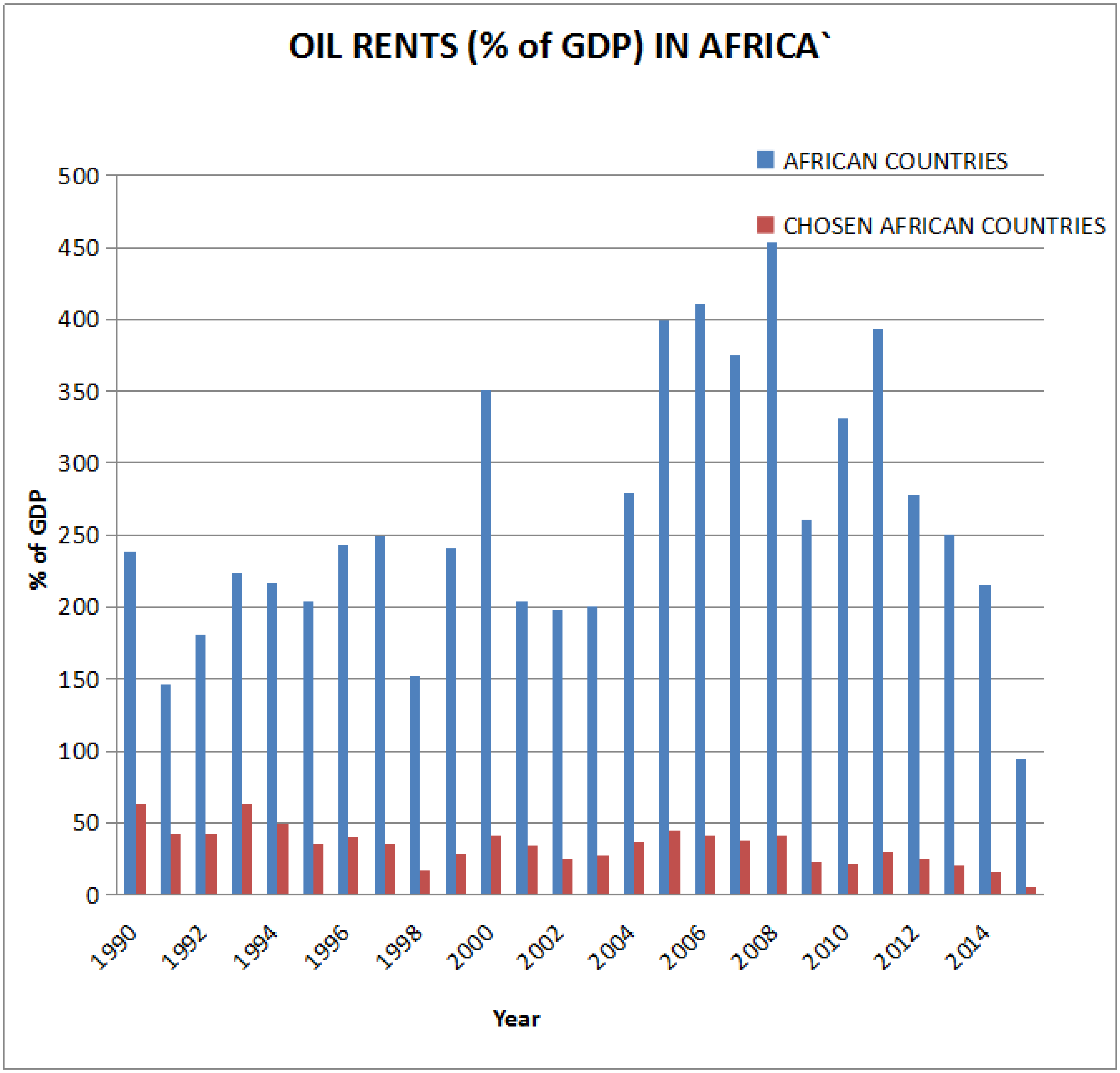

**Source: World Development Indicators, 2017**

**Figure 2.6: Trend of Carbon dioxide Emission Intensity in Africa**

With respect to figure 2.6 which shows the history of carbon intensity sometimes refer to as emission intensity measured in kilogram per kilogram of oil equivalent of energy use. Carbon intensities are usually used to estimate greenhouse gas emissions or air pollutant which is usually based on the quantity of fuel burnt in a country.

Carbon intensities can also be used to relate the environmental effect of various fuels on an economy. The above figure depicts that the carbon intensity of Africa as compared to the five most populous and biggest economies in Africa was 61.04 and 6.92 in 1990 respectively and this decreased in 2003 to 40.45 and 7.62 respectively.

The emission intensity in Africa then skyrocketed in 2007 to 145.02 and 7.26 respectively and this also fell in 2017 to 49.98 and 8.58 kilogram per kilogram of oil equivalent of energy consumed respectively. The proportion of the carbon intensity of these countries combined to Africa as a whole is 0.17 which represents 17 per cent of Africa as at 2017.

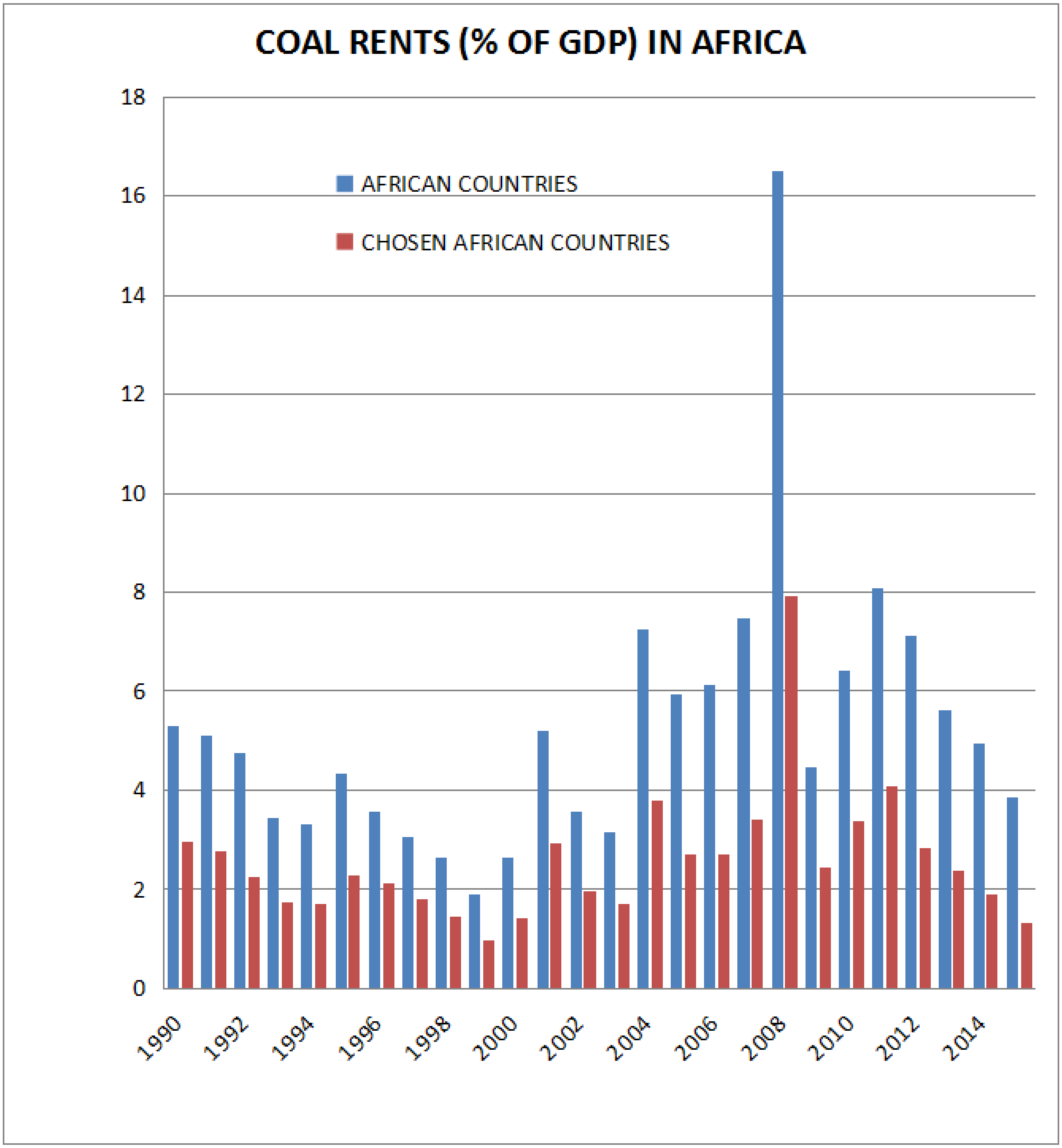



**Source: World Development Indicators, 2017**

**Figure 2.7: Trend of Oil rents in Africa**

Figure 2.7 depicts the movement of oil rents which is as a percentage of GDP in Africa as a whole as compared to the five most populous and biggest economies in Africa. Oil rents was at 238.68 and 63.25 respectively and then increased to 454.10 and 41.10 in 2008 respectively.

The oil crisis in 2008 was triggered by the rising price trend of crude oil which was in accordance with the fluctuations in the market rudiments that is, the increase in the demand and declining supply in the oil market. But this oil rents fell in 2015 to 94.88 and 5.90 as a percentage of the GDP in Africa. Given the volatility of oil rents in Africa, which was as a result of the instability of global oil prices, this actually resulted in huge instability in the percentage of the GDP in Africa as a whole.




**Source: World Development Indicators, 2017**

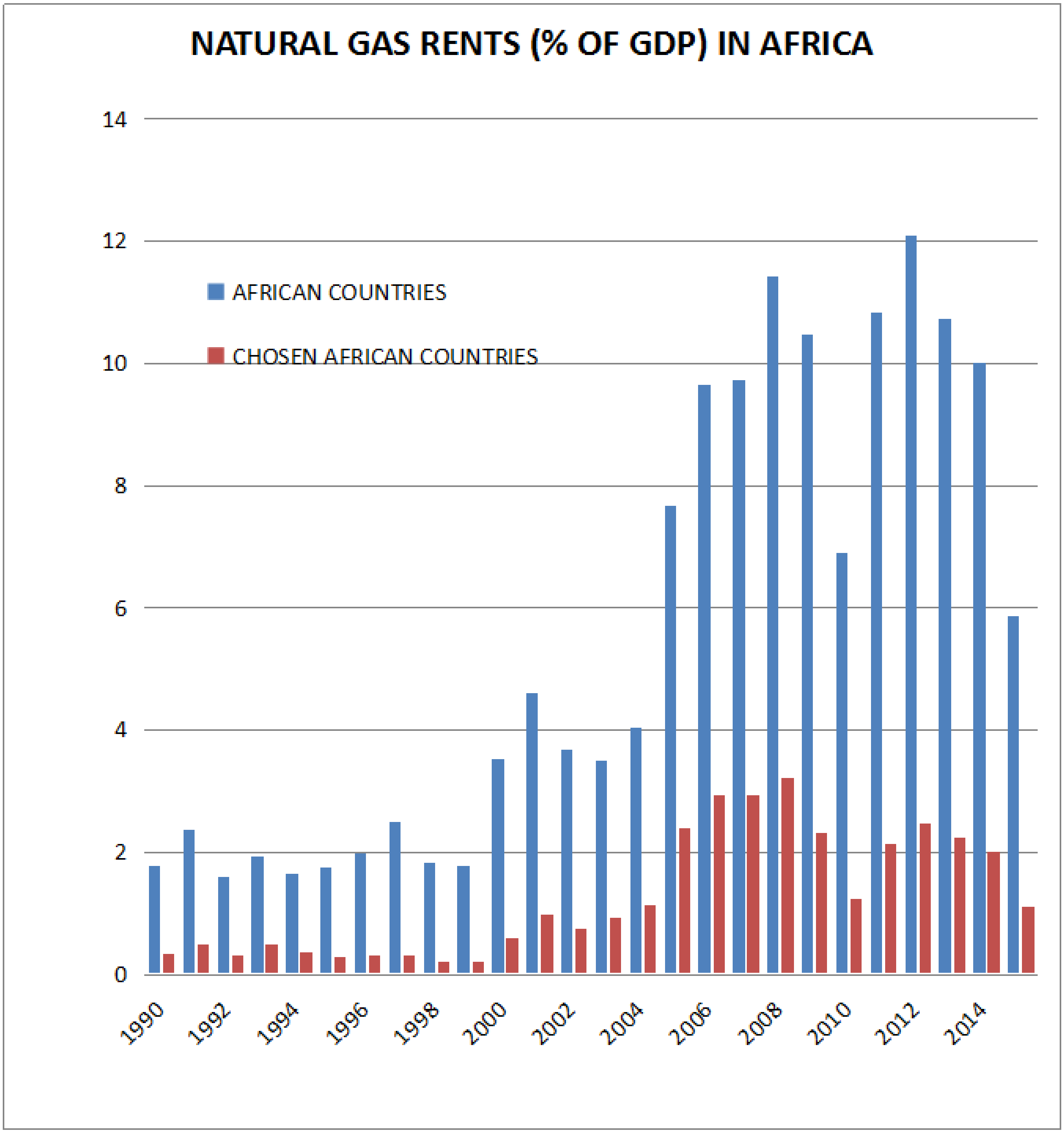
**Figure 2.8: Trend of Coal rents in Africa**

In the figure below, Figure 2.8, the historical trend of the rents of coal which is the variance between the price of the production of both soft and hard coal at global prices and also their aggregate production costs in Africa is matched with that of the five most populous and biggest economies in Africa.

Rents of coal measured as a percentage of GDP stood at 5.30 and 2.97 in 1990 and then fell in 1999 to 1.89 and 0.97 in Africa respectively. These rents skyrocketed in 2008 to 16.48 and 7.91 respectively and this was as a result of instabilities in the supply and demand of energy prices in energy market in Africa. The proportion of the coal rents of these countries combined to Africa as a whole is 0.34 which represents 34 per cent of Africa's price of production of both soft and hard coal as a percentage of GDP in 2015.

Figure 2.9 shows the movement of natural gas rents as a percentage of GDP in Africa as a whole as compared to the five most populous and biggest economies in Africa. The natural gas rents which has triggered the fluctuations in GDP over the years as shown above in the graph has been as a result of natural gas price instabilities in the demand and that of the supply of natural gas in the market.

Therefore, this simply implies that any alteration in the demand and also in the supply for natural gas for a short period will definitely leads to a major changes in price and thereby leads to instabilities in the GDP of an economy. This was evident above when natural gas rents stood at 1.78 in Africa and 0.32 in the five most populous and biggest economies in Africa and then increased to 12.10 and 2.46 in 2012 respectively and in 2015, the rents fell to 5.87 and 1.11 respectively.




**Source: World Development Indicators, 2017**

**Figure 2.9: Trend of Natural gas rents in Africa**

# CHAPTER THREE

# LITERATURE REVIEW

This chapter presents review of literature for the study. The review covers the theoretical, empirical and methodological literature.

## 3.1 Theoretical Review

### 3.1.1 Growth Theory

Energy as an important factor of production was not recognized by the classical economists not even in the process of production and the same thing goes for the neoclassical economists. Economists such as Alam (2006) revealed in his research on 'The Economic Growth with Energy' that energy does not just function as a factor of production, it likewise acts as an enhancer to the growth of a country. There were other growth models which thrived before the growth model put together by Romar; the Solow growth model was part of such models which gained acceptance as at then. The Solow growth model was also accepted as an extrinsic theory since it recognized technology as an external element which defines development. One major conjecture of the Solow theory is the diminishing returns to labour and capital and also regular returns to scale as well as competitive market equilibrium and persistent savings level. Notwithstanding, what is vital about the Solow growth model is the fact that it determines the long run rise per capita by the rate of technological development, which emerges from outside the model.

Therefore, the research set out to review the four (4) theories on the relationship between economic growth and renewable energy consumption which are the neutrality, conservation, feedback and growth hypotheses.

#### 3.1.1.1 The Growth Hypothesis

According to Stern (1993), this theory is advanced by ecological economists, who argued that all the other inputs (capital, technological improvement and labour) could not substitute for the vital role that energy plays in the production method. This therefore implies that a country's economic development depends basically on consumption of energy, so that any fall in the consumption of energy may bring about a decline in economic growth. Hence, energy is a limiting element to economic growth, so that any shocks to supply of energy will definitely have a negative effect on economic growth (Ozturk, 2010a). This model postulates that the consumption of renewable energy is a vital supplement in the economic growth process and/or is established on the existence of unidirectional causality from energy use to economic growth. This implies that the fall of renewable energy use or energy conservation strategies is targeted at reducing the quantity of renewable energy consumption and enhancing environmental quality will have a damaging effect on economic growth and affect the entire economy in a negative direction.

Some studies have discovered that energy use leads to economic growth which is the growth hypothesis. These studies include Smyth and Narayan (2008); Kraft and Kraft (1978); Apergis and Payne (2009); Yildirim and Aslan (2012); Bowden and Payne (2009); Payne and Apergis (2010) and Chontanawat *et al.* (2008) and Apergis and Tang (2013), examined the effectiveness of the growth which is dominated by growth hypothesis using an unequivocal model design and phases of economic development for about eighty-five selected countries. Generally, these researchers discover a systematic pattern, even though the outcome for the specially selected nations are mixed. In particular, their results give reinforcement for the energy-dominated growth hypothesis of emerging nations or countries with low income per capita when compared to the developed ones.

#### 3.1.1.2 The Conservation Hypothesis

This assumption is supported if a unidirectional causality mainly from economic growth to the use of renewable energy exists and the reduction of energy use will not establish an adverse effect on the economy. Evidence in this hypothesis indicates that an upward movement (reduction) in real GDP raises (reduces) renewable energy consumption. The conservation theory supported unidirectional hypothesis going from gross domestic product to renewable energy. It shows that economic growth enables the development of the consumption of renewable energy. Tugcu et al.(2012) studied the relationship among GDP and non-renewable and renewable categories of energy by a multivariate model. They established that conservation theory is established in Germany between 1980 and 2009. Ocal and Aslan (2013) postulated unidirectional causality emerging from GDP to renewable energy in Turkish research from 1990 to 2010. Salim et al. (2014) exhibited unidirectional correlation amongst GDP and renewable energy consumption in OECD nations between 1980 and 2011. Unidirectional relationship was discovered by Huang et al. (2008) and Lise and Montfort (2007)from economic growth to energy use and this can be refered to as the conservation hypothesis.

### 3.1.1.3 The Feedback Hypothesis

This notion claims that there exist bidirectional causality between renewable energy consumption and also that of economic growth. This correlation proposes that energy conservation have a negative effect on economic growth and then vice versa. In this instance, it is sustained by the causation in both ways between renewable energy consumption and economic growth. Proof for feedback hypothesis advocates that energy consumption alters economic growth and that the development of economic activities will also alter the consumption of renewable energy extensively. It is of the belief that gross domestic product (GDP) and sustainable energy consumption are intertwined. In the Latin American nation's research, Al-mulali *et al*. (2014) employs a variable panel data model by including non-renewable energy, labour and capital and also trade in a Cob-Douglas production function. The results show a two-way causality against a background of renewable energy and output. This means that the policymakers need to encourage the use of sustainable energy sources.

Apergis and Payne (2010) focused on Eurasian nations to study the correlation that exist between output and renewable energy from 1990 to 2007. The results represent feedback between both variables by constructing panel data models with other variables which include labour and capital. Apergis and Payne (2012), made use of about eighty nation's statistics in order to test the correlation between economic growth and renewable energy. The studies give a feedback link between them into a panel data growth model, stating that those nations need to enforce renewable energy advancement. Lin and Moubarak (2014), inquired the link between GDP and renewable energy by combining labour and carbon dioxide in a variable model. They discovered a consequent belief found in China between 1977 and 2011 which implies that the development of renewable energy is very important.

Pao and Fu (2013), authenticate the feedback causality between green energy and gross domestic product in Brazil between 1980 and 2010. Shahbaz *et al*. (2015), also scrutinized the connection which exists between output and green energy by means of a multivariate model using labour and capital forces as additional variables. They promoted the bi-directional connection between output and green energy in the case of Pakistani data from 1972 to 2011. Fetters and Ohler (2014), found out a feedback link between several kinds of gross domestic product and renewable energy in the OECD nations between 1990 to 2008. Several studies for instance, Belke *et al*. (2011); Kaplan *et.al*, (2011); Eggoh *et al*. (2011); Fuinhas and Marques (2012), made a survey that the consumption of energy regulates economic growth, and economic growth also enhances pollutant emissions and energy consumption.

**3.1.1.4 The Neutrality Hypothesis**

This view according to the neoclassical economists argued that energy does not influence economic growth (Stern and Cleveland, 2004). Both economic growth and consumption of energy are not so different from each other, this implies that labour and capital are the major production factors while energy is regarded as an intermediate production input which is exhausted in the entire production process (Tsani, 2010) and (Alam et.al., 2012). The neutrality assumption argues that there is certainly no causality between economic growth and the consumption of renewable energy. As regards the neutrality hypothesis, the renewable energy consumption fall will not really have a negative effect on economic growth and this includes the lack of any relationship among them. For instance, Payne (2009) utilized the annual data of United States all through the period 1949 to 2006 and realized that the neutrality hypothesis is acknowledged.

Menegaki (2011), also discovered the connection between gross domestic product (GDP) and the use of green energy in Europe for eleven years that is between 1997 and 2007 but they eventually rejected the possible link between them. Similarly, Omri *et al.* (2015), inserted panel data models to discover the link between nuclear energy, green energy and also gross domestic product for seventeen developed and emerging countries. Their results brought about the neutrality hypothesis in Brazil, Switzerland and Finland from 1990 to 2011. Also, as regards Yildirim *et al.* (2012), there is no link between different types of renewable energy and GDP in the USA from 1949 to 2010.

## 3.2 Empirical Review

Sadorsky (2009) tested the factors that determine renewable energy and discovered a link oil prices, carbon dioxide emission and renewable energy consumption for G7 countries from 1980 to 2005 using panel co-integration method. Sadorsky found that the growth in the real GDP per capita in the long run and carbon dioxide emission per capita are the main factors that drives renewable energy use. He came to a conclusion that renewable energy use is directly and highly affected by carbon dioxide emissions, gross domestic product per capita and prices of oil. Meanwhile, an increase in the prices of gasoline adversely affect different renewable energy sources. However, since this research lacked existing data, it made the author to be very cautious in choosing appropriate econometric method that is right for small sample sizes.

Apergis & Payne (2010) investigated the relationship that exists between green energy use and economic growth in thirteen various countries between 1992 and 2007 in Eurasia. Error correction and panel co-integration approach were employed in the research. Relying on the results analysis, they discovered that previous correlation existed among renewable energy use, gross domestic product, labour force and also real gross capital formation. Real gross capital formation and economic growth Economic have a positive effect on the use of renewable energy and it is also statistically significant.

Shuddhasattwa Rafiq & Khorshed Alam (2010) researched on the drivers of renewable energy use in six (6) large progressive investors of renewable energy countries that are anticipated to fast-track the approval and also the acceptance of renewable energy globally. They discovered that the long run elasticities from the two (2) panel methods they utilized which are the dynamic least square approach and the fully modified ordinary least square method and then they also made use of the time series method of the autoregressive distributed lag which appear to be really dependable. For Indonesia, Brazil, China and India in the long run, the use of renewable energy is substantially being determined by revenue and carbon dioxide emission. On the other hand, for Turkey and the Philippines, revenue appears to be the major force of the use of energy from renewable sources. Likewise, the short run analysis was designed for China and Brazil and two-way causalities was discovered between revenue and renewable energy and also found between carbon dioxide emission and renewable energy.

Menegaki (2011) examined the connection between economic growth and renewable energy use for up to twenty-seven countries in Europe from 1997 to 2007. In this study which was done by the use of panel data analysis, no causality was found between renewable energy consumption and GDP. In addition, the causal connection between employment, carbon dioxide and the consumption of renewable energy was attained. Due to the fact that investing in renewable energy is quite expensive, from the initial cost of capital to invest, this makes $CO_2$ emissions to rise from the use of fossil fuels. Menegaki (2011) disclosed that a rise in renewable energy consumption will lower carbon dioxide emissions. This is due to the competitive relationship between Carbon dioxide emissions and the use of renewable energy.

In a study done on the European Union countries between 1990 and 2004, it was shown by Faet and Bengoche (2012) that an increase in $CO_2$ emissions will eventually results into a rise in green energy supply globally. Similarly, Apergis & Payne (2012) disclosed the connection between economic growth, non-renewable and renewable energy use through panel error correction estimation for about eighty countries from 1990 to 2007. The results they got from this analysis reveals that there is a bi-directional causality among those three variables in the long run and short run as well. This simply means that these types of energy necessary for economic growth and even vice versa, that economic growth has also boosted and supported these two forms of energy. Moreover, the replacement between these two sources of energy has given rise to a lot of attention and this is solely based on the fact that renewable energy utilization has an adverse effect on non-renewable energy utilization.

Parallel to Apergis & Payne (2012)'s research, Tugcu *et al.* (2012) conducted their research on G7 countries between 1980 and 2009. In their work, autoregressive distributed lag method has been widely accepted. This study found out the causal link between economic growth and consumption energy and showed that there is no causal link between green energy use and gross domestic product GDP in countries like France, Canada, Italy and US. Furthermore, bi-directional causality was set up in Japan and Britain.

Mudakkar *et al.* (2013) have studied the multivariate function energy consumption for the South Asian Association for Regional Cooperation (SAARC) nations. They made use of foreign direct investment (FDI), economic growth, various energy prices and also financial development as the driving forces of energy use and discovered causal connection among these variables. Nguyen (2014) also studied the driving force of renewable energy consumption for sixty-four nations from the year 1990 to 2011 through a dynamic system-GMM panel technique. They were aware of the fact that trade openness and CO2 emissions are the key drivers of renewable energy consumption.

Doğan & Seker (2016) also acknowledged the relationship among some key elements like financial development, real output, non renewable and renewable energy, CO2 emissions and also trade through the Environmental Kuznets Curve (EKC). They revealed that the environment will diminish at an increasingly rate with the continuous use of the conventional energy such as coal, oil and gas by using twenty-three nations which falls within the Renewable Energy Country Index between 1980 and 2011. It is thus obvious that non-renewable energy resources are not as costly as renewable energy resources currently. Nevertheless, they depend on the notion that cheaper and less expensive production procedures ought to be used for renewable energy sources. On the other hand, both net environmental effect and trade openness of financial development is positive and decreases pollution in the environment. The nations included in the study also gain from the technology emission through both of these mechanisms. This is therefore a possibility that products that are non-energy-intensive and ecologically friendly are being exported.

Nasreen & Anwar (2014) state that there is emphatically a long run bi-directional causality between trade openness, GDP and energy use. The researchers made use of causality tests and panel co-integration for about fifteen Asian nations between 1980 and 2011. During their research, they discovered that a rise in trade openness and revenue also cause an upsurge in energy use. It was also discovered that excluding a few nations out of the fifteen Asian nations, brought about an increase in the prices of oil and a decline in energy consumption.

Omri *et al.* (2015) appraised renewable energy consumption and the determining factors using panel data model for about sixty-four nations between 1990 and 2011. They separated the nations into low, middle and high income levels and then they found out that the growth in gross domestic product and CO2 leads to growth in green energy use. They found out that a better environment will be produced by high carbon intensities and this will eventually promote the use of an alternative source of energy which is energy from renewable sources. Conversely, it was discovered that the price of oil also slightly affects green energy consumption. In their own view, they also said that renewable energy use is not an alternative for crude oil at least not yet.

Ackah & Kizys (2015) studied the green energy in African countries that produce oil by using panel data estimation between 1985 and 2010. They showed that the core handlers of renewable energy consumption are per capita consumption, gross domestic product per capita, carbon emission per capita, prices of energy and also of various forms of energy. Thus, their study revealed that energy consumption and gross domestic product per capita have a great impact on the use of renewable energy and this impact is positive. The effect of energy prices and CO2 emissions are also negative but its statistically significant.

Jebli & Youssef (2015) explained the relationship between international trade, non renewable and renewable energy by making use of the panel co-integration technique for about sixty-nine countries between 1980 and 2010. Just like Granger causality test results, in the short run, uni-directional correlation originates from renewable energy to trade output and in the long run, there is a bi-directional connection between these variables. There was a bidirectional link between output and renewable energy in the long run but there was none in the short run. The study also revealed that greenhouse gas emission can be reduced only if there is an increase in trade output and this can only happen if full attention can be directed to to the major driver of green energy which is trade output. Hence, there should be a policy on energy in which the main aim will be to advance the share of green energy in the aggregate energy consumption of these nations and this policy have to be implemented and not just made, if this is done, this will decrease green house gas emission.

Saidi & Hammami (2015) used panel data method to estimate the impact of carbon dioxide emissions and economic development on the use of energy for fifty-eight countries between 1990 and 2012. Their research revealed a positive link exists and the connection among the factors is statistically meaningful. Therefore, this means that a rise in GDP and CO2 emissions will definitely boost the energy use. Cheng and Zhang (2009) made use of error correction model and vector auto regression (VAR) for China and they found a connection between CO2 emissions, energy consumption and also economic growth between 1960 and 2007. They eventually found out that there is binary unidirectional Granger causality between the factors in the long run. The relationship between energy use and GDP have the topmost causality and this is a unidirectional Granger causality while the second relationship is between CO2 emissions and energy use. This means that severe energy use widely raise the amount of carbon dioxide emissions and as a result increase the environmental debasement in a nation like China.

## 3.3 Review of Methodology

Kraft and Kraft (1978) estimated the relationship between GDP and energy inputs from 1947 to 1974 in which they made use of Sims causality approach or technique and they found a causal relationship between high energy consumption and GDP. Utilizing employment as an alternative to economic development, Akarca and Long (1979) revealed that the consumption of energy growth results into greater degree of employment. On the other hand, when applying another approach which is the Sims Causality experiment and distinctive set of data such as the U.S annual data from 1950 to 1970, Akarca and Long (1980) were not able to find a causal relationship that exist between consumption of energy and the gross national product.

With respect to Akarca and Long, Murray and Nan (1992) and also Erol and Yu (1987a) appropriated employment as an alternative to economic development. Similarly, Erol and Yu (1987a) also employed the Sims causality method to United States yearly data from 1973 to 1984 and therefore there was no history of any causal relationship between employment and energy consumption. Murray and Nan (1992) employed the use of the Granger causality method and United States monthly data from the year 1974 to 1988 in which they actually discovered that if employment increases, it will definitely lead to a rise in energy consumption.

In another study, Erol and Yu (1987b) appropriated the Granger causality method along with the Sims causality test to ascertain the causal relationships between gross national product (real) and energy consumption in Canada, Italy, Japan, United Kingdom, France and Germany and the results of this showed that there exist a bi-directional causality between GNP and energy consumption in Japan. And for Canada, it showed that high energy consumption results into high GNP. Italy and Germany shows that the more GNP increases, the more the consumption of energy. Nevertheless, the results show that for United Kingdom and France, there is no causal relationships between the two (2) variables.

The previous studies above have an aspect which is the reliance on bivariate causality test of the use of energy and employment or gross domestic product. On the other hand, a bivariate inquiry has a common challenge which is the chance of excluded variable preference in which this could actually lead to false or equivocal statistical outcomes (Payne 2010 and Stern 2000).

Identifying this bivariate analysis problem, Stern (1993) and Yu and Hwang (1984) integrated other variables in their studies for example, for United States of America, Yu and Hwang (1984) added employment to examine the relationship that exists between the consumption of energy and also gross national product (GNP). They then applied Granger causality approach and the Sims test and they discovered that high employment results into increased consumption of energy, whereas they did not find any relationship between gross national product and energy consumption. Stern (1993) as well included capital and employment in his study and then found that increased energy consumption will actually leads to rise in the real gross domestic product.

Traditional Ordinary Least Square approach was normally used in early researches in order to evaluate variables and to also achieve statistical test results. These approaches do not some of the distinct attributes of time series data into consideration for example, the non stationarity of the variables and also the high probability of the presence of endogeneity of the explanatory variables in which both of the attributes could lead to spurious regressions and also results into ambiguous statistical test results (Granger and Newbold, 1974).

Error Correction Model and the Johansen Julius Co integration have been used extensively and most the studies are actually established on a bivariate model of analysis which incorporates only employment or output and also energy as the major variables for example, in Masih and Masih

(1996), Soytas and Sari (2003), Yoo and Jung (2005), Chen et al. (2007), Zachariadis (2007) and Yoo (2005, 2006a, 2006b, 2006c). And for other studies which integrated 1) labour and/or capital as their major variables are Soytas and Sari (2006a, 2007), Ghali and El-Sakka (2004), Yuan et al. (2008), Stern (2000), Paul and Bhattacharya (2004) and Oh and Lee (2004a, 2004b) 2) Consumer prices : Asafu-Adjaye (2000) and Masih and Masih (1997, 1998).

Glasure (2002); integrated different variables in the analysis which are real money supply, government expenditure (real), oil price shocks (as a dummy variable) and also real oil prices. Though a lot of the studies have applied aggregate energy consumption data, Zachariadis (2007); Yoo (2005, 2006a, 2006b, 2006c); Hondroyiannis *et al.* (2002); Yuan *et al*. (2008); Ghosh (2002); Yoo and Jung (2005); Soytas and Sari (2007); Shiu and Lam (2004) and also Chen *et al.* (2007), all applied the use of several broken down procedures of energy use by sector and also by source. Inconsistent and unclear results are however filed and described across studies.

In the case of Masih and Masih (1996, 1997, 1998), they did not find any causal connection between economic growth and energy consumption in Singapore, Malaysia and in the Philippines, whereas they discovered a bi-directional relationship between energy use and growth in Taiwan, Pakistan and South Korea. They also discovered that improved energy consumption actually results into economic growth in Sri Lanka, India and also in Thailand but conversely for Indonesia, a country in which their very high rise in energy consumption is as a result of their economic growth.

Stern (2000) proved that greater consumption of energy surely leads to economic development in U.S, whereas Soytas and Sari (2003) found out that 1) There is a unidirectional causality together with higher energy use resulting into increased gross domestic product in countries like West Germany, Japan and also France; 2) Existence of causal relationship with high GDP leading to higher energy use in South Korea and also in Italy; 3) Non-existence of a causal connection in Poland, the United States, Canada, the United Kingdom and in Indonesia; 4) There is a bi-directional causality in Turkey and Argentina.

Disagreeing to Soytas and Sari's result (2003), Ghali and El-Sakka (2004) showed that there exists is a bi-directional relationship between economic growth in Canada and its energy consumption. While Oh and Lee (2004a, 2004b) found incoherent results for Korea when various sets of data and models were used. Though the Johansen Juselius/Engle- Granger cointegration methods and error correction models have been extensively employed to study a causal connection between economic growth and energy use, these approaches have been really criticized due to the fact that the methods have low power and small sample sizes relating to the standard cointegration experiments and that of the unit root (Harris and Sollis, 2003)

With respect to the various methods that have been used over the years, more recent studies have been able to use the autoregressive distributed lag (ARDL) approach, the bounds testing technique and also the Toda-Yamamoto (1995) as well as Dolado- Lütkepohl (1996) long run causality tests, in which can surely be implemented whether or not the variables under study have unit root and co-integration relationships exist among them or not.

Lee (2006) applied the causality test of Toda Yamamoto and discovered that there is no causal relationship between real gross domestic product per capita and energy consumption in Sweden, United Kingdom and Germany but there exists a bi-directional causality between the above variables in the U.S.A. For Switzerland, Belgium and Canada, higher level of energy usage results into increased real gross domestic product. Increase in real gross domestic product (GDP) per capita leads to increased consumption of energy in countries such as Italy, Japan and France. Similarly, Soytas and Sari (2006b) made use of Toda-Yamamoto causality approach for their analysis using variables such as real gross domestic product, labour force and gross fixed capital formation (real) and energy consumption to test the causal link between economic growth in China and their energy consumption. Therefore, the results of their analysis indicated a lack of causal relationship between the two (2) variables.

Zachariadis (2007) used several methods, as well as the Toda-Yamamoto causality approach and the Autoregressive distributed lag test to examine the causal correlation that exist between income procedures and also the disaggregated measures of energy usage in United Kingdom, France, Canada, Japan, United States, Germany and also in Italy. In the study, incoherent results were achieved using several econometric techniques. The causal link between the disaggregated techniques of energy use by different sectors and also the real gross domestic product in the U.S.A was studied by Bowden and Payne (2010) by applying the Toda-Yamamoto causality method. They involved employment variables and also incorporated the real gross capital formation in the analysis and discovered the non-existence of a causal relationship between gross domestic products (real), real gross capital formation and also renewable energy use and they also realized that there is a bi-directional causality between GDP (real) and the commercial renewable energy use. Unidirectional causality exists between industrial non-renewable energy use and the residential renewable energy use resulting into a rise in the GDP (real).

On the other hand, a study in the United States conducted by Sari et al. (2008) incorporated employment factor using auto regressive distributed lag bounds method to examine the causal correlation between the productions in the industry and energy consumption by sources. The outcome of the above revealed that there exist a uni-directional causality with improved industrial production resulting to increased consumption of energy, with the exception of the consumption of coal and this was found to lead to economic growth of the Country.

A different methodology that put into consideration energy consumption is the panel co-integration method. Co-integration and panel unit root approaches are very useful when incorporating the cross sectional data along with the time series analysis in which this gives rise to analyzing the heterogeneity across nations/economies (Payne, 2010). Narayan and Smyth (2007); Lee and Chang (2008); Chen *et al*. (2007); Lee (2005) and also in Lee *et al*. (2008), all made use of this method but Sharma (2010), and Huang *et al.* (2008), used the dynamic panel estimation technique to study the correlation that exists between economic growth and energy use.

Lee (2005) involved gross capital formation (real) in the study and discovered that there is a unidirectional causality in which growth in energy use leads to the growth in GDP (real) for the developing economies using panel data analysis. Chen *et al.* (2007) found that there exist a bi-directional causality between real gross domestic product and the consumption of electricity for ten (10) nations such as Indonesia, Taiwan, Philippines, India, Thailand, China, Malaysia, Hong Kong, Singapore and Korea using panel data analysis.

Mehrara (2007) also studied the panel data approach of different countries and found that in oil-exporting nations, real gross domestic product causes commercial energy consumption per capita to increase. Narayan and Smyth (2007) integrated gross fixed capital formation (real) in their investigation and then discovered that the per capita energy usage actually results into GDP (real) per capita to increase for the G7 nations by applying panel data approach.

Lee *et al*. (2008) realized that there is a bi-directional causality between the two (2) above variables for OECD nations but Lee and Chang (2008) included both labour force and the real gross fixed capital formation in their analysis and found that there exist a unidirectional causality between those variables and this leads to growth in the GDP for APEC nations, Asian countries and also for ASEAN economies. Huang et al. (2008) actually categorized the data into four (4) diverse segments and then found out that:

1) There is non-existence of a causal relationship between real GDP per capita also energy use for low income countries
2) Economic growth leads to greater energy consumption for middle income economies and
3) Economic growth adversely affects the use of energy for high income countries using panel data analysis.

Sharma (2010) used different results to verify the effect of electricity and non-electricity consumption on the economic growth for a worldwide panel data together with four (4) regional areas (Latin America and Caribbean region, Middle Eastern region, East/South Asian and the Pacific region, North Africa and also for Europe and Central Asian region, and the sub-Saharan).

# CHAPTER FOUR

## THEORETICAL AND METHODOLOGICAL FRAMEWORK

This chapter talks about the theoretical and methodological framework of the study. It also contains the sources of data, the specification of model, measurement, variables and the methods of evaluation employed.

The theoretical framework of this study is based on the work of Sadorsky (2009) which identifies the determinants of renewable energy consumption for G7 countries. The usual approach to modelling energy consumption or demand is to hypothesize a model that relates energy consumption to own price, income, and the price of a substitute (see, for example, Masih and Masih 1997; Narayan and Singh 2007). Likewise Sadorsky (2009), the variables to be employed in this research are selected in accordance with economic theory and data availability. Oil or products derived from oil are considered to be the most likely substitute for renewable energy, and oil rents, coal rents and natural gas rents are included as the prices of a substitute measured as percentages of GDP. A good way to measure how efficient a country is in its use of energy is Energy intensity which is also included as a vital variable affecting renewable energy consumption demand. Following and Salim ( 2010, 2009) and in accordance with societal concerns over global warming, CO2 intensity or emission intensities are included as important additional explanatory variable affecting renewable energy consumption.

Hence, the equation for renewable energy consumption would take the following form:

$$RE_{it} = \beta_0 + EI_{it}\beta_1 + OR_{it}\,\beta_2 + CR_{it}\,\beta_3 + NGR_{it}\,\beta_4 + CI_{it}\,\beta_5 + \varepsilon_{it} \qquad 4.1$$

### 4.1 Model Specification

The Empirical model for the study is described below as:

$$RE = f\,(CI, CR, EI, NGR, OR) \qquad 4.2$$

This can be re-written in a panel method

$$RE_{it} = X_{it}\beta + \varepsilon_{it} \qquad 4.3$$

To derive the error term:

$$\varepsilon_{it} = \alpha_i + \gamma_t + \eta_{it} \qquad 4.4$$

Therefore

$\alpha_i$ = The specific effects of cross section that is unobservable

$\gamma_t$ = Specific time effects that is unobservable

$\eta_{it}$ = The cross section time series that is mutual

$X_{it}$ encompasses the various variables that will be used in this model from equation 4.3

We can then expresses equation 4.1 in logarithm as shown below:

$$LnRE_{it} = \beta_0 + \beta_1 lnEI_{it} + \beta_2 ln\ OR_{it} + \beta_3 ln\ CR_{it} + \beta_4\ ln\ NGR_{it} + \beta_5\ ln\ CI_{it} + \boldsymbol{\varepsilon}_{it} \qquad 4.5$$

REc is a combination of variables of biomass, hydro, solar, wind and also geothermal consumption which is then measured in terrajoules (TJ)

NGR is identified as Natural gas which is measured as Gross Domestic Product percentage

OR is identified as Oil rents which is measured as Gross Domestic Product percentage

CI is identified as Emission/carbon intensity measured as oil equivalent in kilogram per kilogram

EI is identified as Energy Intensity which is measured in mega joules ($2011) of GDP PPP

CR is identified as coal rents which is measured as Gross Domestic Product percentage

$\beta_1$= Constant term

The coefficients of the model are $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5$

$\varepsilon$ which is identified as the error term explains for other variables that were not reported by the model and have influence on the use of renewable energy

Whereas, t is from 1990 to 2015 and ì is from 1 to 5

Therefore, the error term which is a combination for time series and cross-section and be further divided into:

$\mathcal{E}_{it} = \alpha_i + \eta_{it}$ 4.6

$\alpha_i = 0$

$RE_{it} = \alpha_i + X_{it}\beta + \eta_{it}$ 4.7

Therefore, if $\alpha_i = 0$ in 4.7 above, then this simply means that the model is called a cross section specific effects that is one way

$\gamma_t = 0$

$RE_{it} = \gamma_t + X_{it}\beta + \eta_{it}$ 4.8

Therefore, if $\gamma_t = 0$ in equation (4.8), this indicates a one-way time specific effects model

The joining or merging of equations 4.7 and also 4.8 simply means that our model have time specific and cross section effects and this shows a model that is two way fixed effects.

$RE_{it} = X_{it}\beta + \alpha + \boldsymbol{u}\boldsymbol{u}_i + \eta_{it}$ 4.9

Equation 4.9 above is referred to as the model with random effects in which α is the intercept that is common in the model and the error term is $\mathcal{E}_{it} = \boldsymbol{u}_i + \eta_{it.}$ The model is usually refer to as the error components model because of the breakdown of this error term into two.

Therefore $\boldsymbol{u}_i$ is the same throughout the time series and is usually referred to as the random heterogeneity that is particular to the $i^{th}$ observation

In 1978, Hausman offers:

$H = (\beta_{RE} - \beta_{FE})\ (\sum_{FE} - \sum_{RE})^{-1}\ (\beta_{RE} - \beta_{FE})$ 4.10

Where

$\beta_{RE}$ is a factor evaluated or analyzed from the estimator of random effects

$\beta_{FE}$ is a factor evaluated or analyzed from the estimator of fixed effects

$\sum_{FE}$ is a covariance matrix of factors evaluated or analyzed from the estimator of fixed effects

$\sum_{RE}$ is a covariance matrix of factors evaluated or analyzed from the estimator of random effects

**Table 4.1: Variables, Measurements and Data Sources**

| S/N | Variables | Measurements | Data Sources |
|---|---|---|---|
| 1 | Renewable energy consumption (The dependent variable) | Terrajoules (TJ) | Energy Information Administration (EIA) |
| 2 | Oil rents (OR) | Percentage of GDP | World Bank database |
| 3 | Carbon intensity (CI) | Kilogram per kilogram of oil equivalent | World Bank database |
| 4 | Energy intensity (EI) | (MJ/$2011 GDP PPP) | World Bank database |
| 5 | Natural gas rents (NGR) | Percentage of GDP | World Bank database |
| 6 | Coal rents (CR) | Percentage of GDP | World Bank database |

**Source: Energy Information Administration (EIA) and World Bank database, 2015**

**Table 4.2: Description of variables**

| S/N | VARIABLES | DESCRIPTION OF VARIABLES |
|---|---|---|
| 1 | **Renewable energy consumption** | The resources that will be considered for this variable include hydro, wind, solar, biomass and geothermal. |
| 2 | **Energy intensity** | Energy intensity is a measure of the energy efficiency of a nation's economy. It is calculated as units of energy per unit of GDP. High energy intensity indicates a high price or cost of converting energy into GDP, this also implies that countries with high energy intensity have high industrial output as a portion of GDP. Low energy intensity indicates a lower price or cost of converting energy into GDP. Countries with low energy intensity signify labour intensive economy. |
| 3 | **Oil rents** | Oil rents are the difference between the value of crude oil production at world prices and total costs of production. The volatility of worldwide oil prices will results in large fluctuations in the percentage of GDP if an economy is solely dependent upon the petroleum sector. |
| 4 | **Natural gas rents** | Natural gas rents are the difference between the value of natural gas production at world prices and total costs of production in each country. |
| 5 | **Coal rents** | Coal rents are the difference between the value of both hard and soft coal production at world prices and their total costs of production in each country. |
| 6 | **Carbon intensity** | An emission intensity which can also be referred to as carbon intensity (C.I) is the emission rate of a given pollutant relative to the intensity of a specific activity, or an industrial production process. For example, grams of carbon dioxide released per mega joule of energy produced, or the ratio of greenhouse gas emissions produced to gross domestic product (GDP). Emission intensities are used to derive estimates of air pollutant or greenhouse gas emissions based on the amount of fuel combusted. Emission intensities may also be used to compare the environmental impact of different fuels or activities. In some case the related terms emission factor and carbon intensity are used interchangeably. This is measured in kilogram per kilogram of oil equivalent of energy use. |

**Source: Energy Information Administration (EIA) and World Bank database, 2015**

## 4.2 Estimation Techniques

Like Sadorsky (2009), the variables to be employed in this research are selected in accordance with economic theory and data availability. Energy intensity is included in the model to measure the energy efficiency of a nation's economy. As oil rents, gas rents and coal rents are considered to be the most likely substitute for renewable energy for most of the countries, oil, gas and coal rents are included in the model to proxy rent of a substitute. Following Salim (2009) and in accordance with societal concern over greenhouse effects, carbon intensity which can also be referred to as emission intensity which is to measure the emission rate based on the amount of non-renewable fuel combusted is included in the model as an important additional explanatory variable affecting renewable energy consumption. The renewable energy variable used in this study is a composite variable reflecting renewable energy from several different sources (hydro, biomass, geothermal, solar and wind) for which no reliable price measure is available.

To achieve to aforementioned objectives, both cross-sectional and time series analysis will be used. Correlation analysis will be carried out to show the correlation between the variables. A unit root test based on panel data which is to test the time series features of the variables and check for stationarity of the variables will be used. If they are all I(0) series that is, stationary at level, there will be no need for co-integrating test but if they are all I (1) at 1$^{st}$ difference and its stationary, there shall be necessity for co-integration to be carried out. The study will employ the pooled regression model but the pooled model ignored the panel structure of the data by simply pooling together data on the countries. Pooled is impractical and not efficient of providing the exact picture of the relationship that exist between the determining factors and the renewable energy use across the countries.

The heteroscedasticity in the countries will be tested by conducting the Levene's robust test statistic. This is to test for constant variance in the error across countries. The study will also conduct the least square dummy variable (LSDV) to test whether all the intercepts in these countries are equal, in which case there is no country heterogeneity and also the random and fixed effects test will also be carried out and in order to choose the suitable panel model, then the Hausman test would be used.

# CHAPTER FIVE

# EMPIRICAL ANALYSIS AND DISCUSSION OF RESULTS

## 5.0 Introduction

The results of the determinants of the use of renewable energy in Africa are presented and then discussed in this chapter.

## 5.1 The Discussion and Evaluation of Results

The descriptive analysis of the different variables used in this research are described in this segment. This study also indicates the average, standard deviations, minimum, observation number and maximum of all variables used.

Table 5.1 illustrates the descriptive statistics summary of both the dependent variables and independent variables used for the data. Specifically, the renewable energy consumption figure is from 00.0750 million to 04.02 million, a standard deviation of 01.132 million and also takes a mean of 1.0750 million. Likewise, natural gas rent varies between 0 to 02.36% with standard deviation of 00.504% and then average of 0.25%.

Oil rent possesses a minimum value of 0 and 54.09% as a maximum value and it takes 6.830% as the mean and also 10.20% as the standard deviation. Additionally, minimum rate of 0.058 kilogram per kilogram of oil equivalent energy use was accrued to carbon intensity together with an average rate of 1.4450 kilogram and maximum rate of 3.518 kilogram and then standard deviation of 1.395 kg per kg of oil equivalent of the use of energy. Accordingly, the maximum degree assigned to coal rent is 7.850% with an average of 00.515% and also the minimum is 0 and then has 1.18 as its standard deviation. Energy intensity stood between 3.029% and 38.026%, and has a standard deviation of 9.520% using the average of 14.018%.

**Table 5.1: The Descriptive Statistics**

| Variables | Natural Gas Rents ( NGR) | Oil Rents (OR) | Renewable Energy (RE) | Carbon intensity | Energy Intensity | Coal Rents (CR) |
|---|---|---|---|---|---|---|
| N | 130.0 | 130.0 | 130.0 | 130.0 | 129.0 | 130.0 |
| Min | 0.0 | 0.0 | 0.1 | 0.1 | 3.3 | 0.0 |
| Mean | 0.3 | 7.0 | 1.1 | 1.4 | 14.2 | 1.0 |
| Max | 2.4 | 54.09 | 4.2 | 3.5 | 38.3 | 8.0 |
| S.D | 0.5 | 11.0 | 1.1 | 1.4 | 10.0 | 1.2 |

**Source: Author's Computation (STATA Output), 2018**

## 5.2 The Correlation Estimation

The table below which is Table 5.2 shows the correlation estimation among the variables under study. The figure between energy intensity and that of consumption of renewable energy of r= 0.07 shows a correlation that has very low degree between the two (2) variables, is negative and also not significant.

However, for oil rents and the consumption of renewable energy, they both have a correlation that is positive and also significant at r= 0.600.

Furthermore, a negative and an average correlation degree of r= 0.44 is evidenced between carbon intensity and renewable energy use whereas, there exists a negative correlation between renewable energy use and coal rents with a figure of -0.26.

**Table 5.2: Correlation Estimation**

| | Oil rents | Carbon intensity | Renewable Energy Consumption | Natural Gas rents | Energy intensity | Coal rents |
|---|---|---|---|---|---|---|
| Oil rents | 1 | | 0.600*** | | -0.39*** | |
| Carbon intensity | -0.13 | 1 | -0.44*** | 0.29*** | -0.67*** | 0.61*** |
| Renewable Energy Consumption | | | 1 | | | |
| Natural Gas rents | 0.26*** | | -0.03 | 1 | -0.49*** | -0.21*** |
| Energy intensity | | | -0.070 | | 1 | |
| Coal rents | -0.28*** | | -0.26*** | | -0.12*** | 1 |

**Source: Author's Computation (STATA Output), 2018**

## 5.3 Pre-Evaluation Analysis: For Unit Root Test

The research employs Im, Pasaran and Shin (IPS, 2003) to conduct panel unit root estimation in order to evaluate components of the variables in its time series. The key power of IPS test is that it tolerates heterogeneity on the coefficient of the variables involved while still planning a test technique made on each of the average statistics of the unit root.

The hypothesis of this heterogeneity on the coefficient of the factors enables Im, Pasaran and Shin usage to be fit and appropriate for panel data analysis. Likewise, because of the diverse political structures an d socio-economic behaviors for a lot of nations, this makes it easy to apply Im, Pasaran and Shin type of unit root test. Thus, the outcomes in the table below, table 5.3, shows that all the variables (the renewable energy use, natural gas rents, energy intensity, coal rents, carbon intensity and also coal rents) are all stationary at levels, and this implies that all the variables are incorporated of order (0). Therefore, since all the variables under study are incorporated of order (0), there is no necessity for panel co-integration experiment.

**Table 5.3: Unit Root / Stationary Tests Results**

| Variables | Renewable Energy Consumption | Natural gas rents | Oil Rents | Carbon intensity | Energy Intensity | Coal rents |
|---|---|---|---|---|---|---|
| Im, Paseran and Shin (2003) Unit Root Test (Value) | -2.25 | -2.98 | -2.78 | -2.86 | -2.65 | -2.79 |
| Im, Paseran and Shin (2003) Unit Root Test (Probability) | 0.07 | 0.03 | 0.04 | 0.01 | 0.01 | 0.01 |
| Remarks | I (0) | I (0) | I (0) | I (0) | I (0) | I (0) |

**Source: Author's Computation (STATA Output), 2018**

## 5.4 Analysis of Panel Data Model

This section reveals the results using the panel regression analysis. Therefore, for us to determine the relationship, we evaluated the pooled regression supposing that across countries and years, the intercept is the same. For each country, we also assume various constant and then carry out both random effect and fixed effect regressions.

After the LM Statistics test were analysed, a conclusion was drawn that instead of the usual Ordinary Least Square regression the random effects estimation should be chosen for the analysis of the panel model. Variances throughout all the countries for the null hypothesis equal to ZERO and it also indicated that there exists no significant dissimilarities among all the countries, thus, this simply means that there is no panel effect.

In addition, the researcher chose between the fixed and random effects by using the Hausman test statistics in which the null hypothesis (the ideal model is fixed effects) was accepted and then rejected the alternative which states that the random effects is the chosen model. The unique errors ($u_i$) was tested whether they are related or linked with the regressors or they are not. The researcher found out that the unique errors ($u_i$) does not even have a relationship with the regressors as indicated by the null hypothesis.

The table below which is Table 5.4 consists of analysis done to examine the factors that determine the consumption renewable energy in Africa and the outcome shows that 52.74 with probability ($p<0.05$) is the Hausman test figure and this vividly indicated that the null hypothesis should be rejected because of inefficiency of the random effect and so this give us the opportunity to accept the fixed effect.

As a result of the analysis of the study, F-Statistics test value which is 94.15 point out that there exists a joint significance amongst all the factors that are used in the model. In the fixed effect outcome, according to the F-test which showed that $\boldsymbol{u}_i$=0, this denotes that the F-Statistic test in the null hypothesis is that there is no major dissimilarity among the selected nations intercepts.

Furthermore, the R-squared figure of 00.9040 denotes a good fitness of the model and that all the independent variables are able to give details for roughly 90.4% disparity in the consumption of renewable energy. This simply means that the pooled (simple Ordinary Least Square) would be unsuitable.

Therefore, for the regression outcome, coal rent is negative and also significant at 5% level. It can also be seen that a 1% increase in energy intensity makes the consumption of renewable energy to decline by 0.520 per cent and this simply means that the consumption of renewable energy is negatively related to energy intensity.

Furthermore, as for natural gas rent, there is a relationship with the renewable energy consumption because their relationship is significant and also positive. It was also discovered that there exists an inverse and significant link between oil rent and the consumption of renewable energy. Finally, the outcome shows that renewable energy consumption and carbon intensity have a negative relationship.

**Table 5.4: The Panel Data Regression Result**

| Variables under Study | Pooled Regression | Random Regression | Fixed Regression |
|---|---|---|---|
| In_ngr | 0.93*** | 0.93*** | 0.075*** |
| | (0.16) | (0.16) | (0.01) |
| In_ei | 2.78*** | 2.78*** | -0.52*** |
| | (0.53) | (0.53) | (0.053) |
| In_ci | -0.44* | -0.44* | -0.09 |
| | (0.30) | (0.30) | (0.05) |
| In_cr | 0.043 | 0.043 | -0.03*** |
| | (0.0843) | (0.0843) | (0.0090) |
| In_or | -0.13 | -0.13 | -0.06*** |
| | (0.11) | (0.11) | (0.013) |
| Constant | 10.52*** | 10.52*** | 15.05*** |
| | (1.4) | (1.4) | (0.11) |
| | | | |
| R-squared | 0.6552 | 0.6552 | 0.9040 |
| Adj. R-squared | 0.6227 | 0.6227 | |
| F-test (Prob) | 20.15 (0.00) | | 94.15 (0.00) |
| LM Statistics | | 0.00 (1.00) | |
| Wald-chi2 (Prob.) | | 100.7 | |
| Hausman Test | | 52.74 (0.00) | |

Standard errors in parentheses

(*** p<0.01, ** p<0.05, * p<0.1)

**Source: Author's Computation (STATA Output), 2018**

**Table 5.5: Panel Regression Result**

| Hausman fe re | | | | |
|---|---|---|---|---|
| ---- Coefficients ---- | | | | |
| \| | (b) | (B) | (b-B) | sqrt(diag(V_b-V_B)) |
| \| | fixed | random | Difference | S.E. |
| In_ei \| | -.5215948 | 2.775314 | -3.296909 | .5948036 |
| In_or \| | -.0612551 | -.1250307 | .0637756 | .1469947 |
| In_cr \| | -.0301144 | .0426219 | -.0727363 | .0921755 |
| In_ngr \| | .0745958 | .9332881 | -.8586923 | .1283979 |
| In_ci \| | -.0095506 | -.4427637 | .4332131 | .6239746 |

b = dependable in Ha and Ho; acquired from xtreg

B = erratic in Ha, effective in Ho; gotten from xtreg

Test: Ho: variance in coefficients not logical

chi2 (3) = (b-B)'[(V_b-V_B) ^ (-1)] (b-B)

= 52.74

Prob>chi2 = 0.000000

**Source: STATA Output and Author's Computation, 2018**

**Table 5.6: Discussion on the Results of each Objective**

| S/N | Objectives of the Study | Results |
|---|---|---|
| **1** | Identify the pattern of the consumption of renewable energy in Africa; | According to Table 2.1 which identifies the pattern of the renewable energy consumption in the chosen African Countries measured in Terrajoules.<br>In 1990, Nigeria has the largest share of renewable energy consumption among all the other African Countries of 2,116,562 terrajoules and this renewable energy indicator includes sources from biogas, wind, solar, marine, liquid biofuels, waste, geothermal, solid biofuels and hydro. Ethiopia was the second largest consumer if renewable energy in 1990 while Egypt has the lowest share of their consumption from renewable energy sources with 74,901.56 terrajoules. These countries maintained their rank in 2015 in terms of their renewable energy consumption. Renewable energy consumption in these countries has increased significantly. Therefore, this shows that each country has seen renewable energy consumption as an indispensable factor for economic development,energy security, sustainable development, environmental protection and also as a means to alleviating greenhouse gas emissions. |
| **2** | Identify the factors that determine renewable | The factors that drives renewable energy |

| | | |
|---|---|---|
| | energy consumption in Africa; | consumption in these African Countries are:<br><br>EI= Energy Intensity measured in (MJ/$2011 GDP PPP)<br><br>OR= Oil rents measured as a percentage of GDP<br><br>CR= Coal rents measured as a percentage of GDP<br><br>NGR= Natural gas rents measured as a percentage of GDP<br><br>CI= Carbon intensity or called the emission intensity measured in kilogram per kilogram of oil equivalent |
| **3** | Quantitatively measure the consequence of those determining factors on Renewable energy consumption in Africa as a whole; and | Based on the regression results, coal rent is negative and also significant at $p \leq 0.05$. Therefore, this means that a 1% increase in coal rents of these countries will definitely decrease renewable energy consumption by 0.03 and vice versa.<br><br>It can also be seen that a 1% increase in energy intensity makes the consumption of renewable energy to decline by 0.520 and this simply means that the consumption of renewable energy is negatively related to energy intensity.<br><br>Furthermore, as for natural gas rent, there is a relationship with the renewable energy consumption because their relationship is significant and also positive. A 1% increase in natural gas rent will allow renewable energy consumption rise by 0.075 and vice versa for a 1% decrease.<br><br>It was also discovered that there exists an inverse and significant link between oil rent and the |

| | | |
|---|---|---|
| | | consumption of renewable energy which implies that a 1% decrease in oil rent will reduce renewable energy consumption by 0.06.<br><br>Finally, the outcome shows that renewable energy consumption and carbon intensity have a negative relationship and this means that if carbon intensity can be reduced by 1%, this will then increase the consumption of renewable energy by 0.09. |
| **4** | To investigate the homogeneity or heterogeneity of each economy as regards their renewable energy activities. | The variances across countries are ZERO for the null hypothesis and there is no evidence of any significant differences across the countries which mean that there is no panel effect.<br><br>In fixed effect result, the F-test which indicated that $u_i$ =0. This implies that the F-Statistic test in the case of the null hypothesis is that there is non-existence of a significant difference between the chosen countries intercepts. This means that the countries are homogeneous as regards their renewable energy activities. |

**Source: Author's Computation, 2018**

# CHAPTER SIX

# SUMMARY, CONCLUSION AND RECOMMENDATIONS

## 6.0 Introduction

This chapter provides some of the major findings of the research and reliable conclusions. Furthermore, the chapter articulates the limitations encountered as well as offers recommendation and specific suggestions for further studies in this area.

## 6.1 Summary

This research work examined the factors that determine the consumption of renewable energy in Africa between 1990 and 2015. The experimental analysis employed pooled regression, random effects and fixed effects after which the Hausman experiment was used to choose the suitable panel data model.

In order to achieve this, a framework of the structure of the project is contained in the plan of the study as illustrated in section (1.5). The introduction of the project shows the importance of the use of renewable energy in Africa, global investment in green energy for developing nations as compared to the developed countries and also the benefits of renewable energy consumption to African countries.

The benefits of renewable energy consumption includes mitigating carbon dioxide emissions in the atmosphere and thereby play a key role in global effort to combat global warming, employment generation and also reduce energy insecurity which has adversely had effect on local economic integration and thereby enable sustainable development in Africa.

The second section illustrates the trend analysis of renewable energy consumption from 1990-2015 and other key variables such as coal rents, carbon intensity, natural gas and oil rents. There was also a comparative analysis of the variables in Africa to the five (5) largest and most populous economies in Africa continent.

The section also explained the non-renewable (fossil fuels) energy growth in Africa continent, renewable energy and also the state of advancement in Africa continent and also energy policies and targets of few African countries.

The third section denotes the theoretical structure and appraisal of the relevant literature. The theoretical framework illustrated the various theoretical developments in consumption models and was able to illustrate the importance of the use of green energy to the growth of the economy. This section also identifies various consumption theories Keynesian, the choice and the basic forward-looking theory of consumption. The section also provides the various growth theories as related to renewable energy consumption which includes the feedback, conservation, neutrality and growth hypothesis.

The fourth section discussed the methodology and the estimation techniques that are used for the study. The empirical investigation was developed to cover the connection between the key variables of coal rents (CR), natural gas rents(NGR), energy intensity (EI), carbon intensity (CI), oil rents (OR) and also renewable energy use in Africa. Furthermore, the fifth section shows the outcome of empirical analysis and the sixth segment presents the conclusion and key policy recommendations.

The study discovered that:

- There is a negative relationship between renewable energy consumption and energy intensity in Africa.
- There is a positive relationship between natural gas rents and renewable energy consumption in Africa, which implies that natural gas rents induces renewable energy consumption.

- There is a negative relationship between carbon intensity and renewable energy consumption, this means that a decrease in carbon intensity actually increases renewable energy consumption and vice-versa for all the countries. For Africa to contribute to the reduction in global warming then there has to be more environmentally friendly consumption which is renewable energy consumption.
- Oil rents and coal rents also had negative relationship with renewable energy consumption in Africa, this implies that that a decrease in oil and coal rents will lead to an increase in renewable energy consumption African countries need to diversify fossil fuels price risk and to support the cost of renewable energy development, reduce the percentage coal and oil rents take in their GDP and give more attention to the improvement of renewable energy because the volatility in the worldwide prices of these products has resulted in large fluctuations in the percentage of GDP which has negatively affected the growth of these countries.

In response to the environmental and economic threats posed by fossil fuels, attention to the determinants of renewable energy consumption has increased over the last few years globally due to these challenges. The study was able to investigate the factors that drive Renewable energy consumption in the most populous and biggest economy in each of the five regions of Africa, namely; Nigeria (West), Egypt (North), Ethiopia (East), DR Congo (Central) and South Africa (Southern).

## 6.2 Conclusion

Due to the economic and environmental issues and dangers that the conventional energy sources cause globally, over the last few years, attention has been drawn to the factors that determine the consumption of renewable energy. This study yields a number of insights into the determinants of the consumption of renewable energy in the largest and most populous economies in the 5 Africa regions which are Democratic Republic of Congo (Central), Egypt (North), Ethiopia (East),South Africa (South) and of course, Nigeria (West).

In order to examine the relationship of these determining factors over time and country with the consumption of renewable energy and also to study the countries' heterogeneity as regards their use of renewable energy, this research work examined the factors that drive the consumption of renewable energy in Africa between 1990 to 2015.

The empirical evaluation of the models used were fixed effects, pooled regression, random effects and then the Hausman test was used to choose the suitable panel data model. The regression outcome shows that coal rent is negative and also significant at 5% level. It can also be seen that a 1% increase in energy intensity makes the consumption of renewable energy to decline by 0.520 per cent and this simply means that the consumption of renewable energy is negatively related to energy intensity.

Furthermore, as for natural gas rent, there is a relationship with the renewable energy consumption because their relationship is significant and also positive. It was also discovered that there exists an inverse and significant link between oil rent and the consumption of renewable energy. Finally, the outcome shows that renewable energy consumption and carbon intensity have a negative relationship.

The study concluded that the benefits of renewable energy consumption includes mitigating carbon dioxide emissions in the atmosphere and thereby play a key role in global effort to combat global warming, employment generation and also reduce energy insecurity which has effect on local economic integration and thereby enable sustainable development in Africa.

## 6.3 Recommendations

Due to the economic and environmental dangers from conventional fuels, it is vital for nations to change their over reliance on conventional energy sources to the unconventional sources of energy which is the consumption of renewable energy.

There are numerous policy inferences that can be deduced from the findings of this study:

For all nations, low carbon intensity leads to high renewable energy consumption and also vice-versa and this implies that increased tax rate can be assigned to the conventional sources of energy (oil, gas and coal) by all nations and the governments can then subsidize the use of green energy and also its expansion in which these subsidies in development and also in form of research in this area of renewable energy.

The governments of these economies can also give the renewable energy developers access to credits such as production tax credits, reduce their cost of loans or even the interests to be paid on loans in order to encourage the purchase of renewable energy products. In addition, in order to reduce the reliance on fossil fuels in these countries, carbon-fiber compounds industrial policy can be enacted and also implement new energy efficiency.

The use of new technologies to construct and design ultra-light cars, manufacture light weight resources such as carbon-fiber compounds that can be beneficial in cars, large trucks and various buildings using the industrial policy will definitely intensify energy efficiency. Also, in order to reduce the carbon dioxide emissions, the governments of these economies can execute efficient financial development and also economic policies that grows the environment by diverting the resources to projects that are favourable and pleasant to the environment (Shahbaz et al., 2013).

Subsequent research studies on the factors that determine or contribute to the use of renewable energy should research on more African Countries using more variables, with a longer time series.

## 6.4 The Limitations of Study

The key drawback in this research is the limited data (between 1990 to 2015). This hindered the depth of coverage and results that can serve as a basis for generalisation as well as postulations.

## 6.5 Contribution to Knowledge

1. The variables used in this study will give government better tools in order to make appropriate policies and create an enabling environment for renewable energy consumption to thrive in Africa.
2. This study has shown that GDP as a tool to measure the welfare and growth of countries is not enough like most researchers have done because GDP does not always directly correspond

to the welfare of a country. Therefore, this study used Energy intensity as a good to measure the welfare of a country and this shows how efficient the country is in its use of energy.

3. The methodology used in this study which is a combination of Fixed and Random effect models and thereby used Hausman test to choose the appropriate model.

4. This study discovered the determining factors of renewable energy consumption in the five (5) most populous and largest African countries in the five regions of Africa from 1990 to 2015.

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# APPENDIX 1

```
. ***Summary Statistics***

.
. sum re ei oilrents coalrents naturalgasrents carbondioxideintensity

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+---------------------------------------------------------
          re |       130     1075304     1131515   74901.56    4226050
          ei |       129    14.18148    9.515751   3.290803    38.2622
    oilrents |       130    6.831429    10.71959          0   54.08481
   coalrents |       130    .5149997    1.177892          0   7.851874
naturalgas~s |       130    .2516396    .5041593          0   2.356935
-------------+---------------------------------------------------------
carbondiox~y |       130    1.445209    1.395281   .0581669   3.517773

.pwcorr re ei oilrents coalrents naturalgasrents carbondioxideintensity

             |       re       ei oilrents coalre~s natura~s carbon~y
-------------+------------------------------------------------------
          re |   1.0000
          ei |  -0.0707   1.0000
             |   0.4261
    oilrents |   0.5989* -0.3872*  1.0000
             |   0.0000   0.0000
             |
   coalrents |  -0.2565* -0.1775* -0.2784*  1.0000
             |   0.0032   0.0442   0.0013
             |
naturalgas~s |  -0.0270  -0.4886*  0.2625* -0.2057*  1.0000
             |   0.7600   0.0000   0.0026   0.0189
             |
carbondiox~y |  -0.4418* -0.6726* -0.1260   0.6132*  0.2907*  1.0000
             |   0.0000   0.0000   0.1532   0.0000   0.0008
               |

. xtunitroot ips In_re, trend
Im-Pesaran-Shin unit-root test for In_re
----------------------------------------
Ho: All panels contain unit roots           Number of panels  =      5
Ha: Some panels are stationary              Number of periods =     26

AR parameter: Panel-specific                Asymptotics: T,N -> Infinity
Panel means:  Included                                        sequentially
Time trend:   Included
ADF regressions: No lags included
------------------------------------------------------------------------------
                                              Fixed-N exact critical values
                   Statistic      p-value          1%       5%      10%
------------------------------------------------------------------------------
 t-bar              -2.2457                     -3.050   -2.790   -2.640
 t-tilde-bar        -1.9358
 Z-t-tilde-bar      -1.4568        0.0726
------------------------------------------------------------------------------

. xtunitroot ips In_ei, trend
Im-Pesaran-Shin unit-root test for In_ei
----------------------------------------
Ho: All panels contain unit roots           Number of panels       =      5
Ha: Some panels are stationary              Avg. number of periods =  25.80
```

```
AR parameter: Panel-specific                Asymptotics: T,N -> Infinity
Panel means:  Included                                    sequentially
Time trend:   Included

ADF regressions: No lags included
------------------------------------------------------------------------------
                                              Fixed-N exact critical values
                    Statistic      p-value        1%      5%      10%
------------------------------------------------------------------------------
 t-bar               -2.6529                          (Not available)
 t-tilde-bar         -2.2139
 Z-t-tilde-bar       -2.2546        0.0121
------------------------------------------------------------------------------
. xtunitroot ips ln_or, trend demean
Im-Pesaran-Shin unit-root test for ln_or
----------------------------------------
Ho: All panels contain unit roots           Number of panels       =      4
Ha: Some panels are stationary              Avg. number of periods =  23.75

AR parameter: Panel-specific                Asymptotics: T,N -> Infinity
Panel means:  Included                                    sequentially
Time trend:   Included                      Cross-sectional means removed

ADF regressions: No lags included
------------------------------------------------------------------------------
                                              Fixed-N exact critical values
                    Statistic      p-value        1%      5%      10%
------------------------------------------------------------------------------
 t-bar               -2.7847                          (Not available)
 t-tilde-bar         -2.4321
 Z-t-tilde-bar       -2.6290        0.0043
------------------------------------------------------------------------------

.
. xtunitroot ips coalrents, trend
Im-Pesaran-Shin unit-root test for coalrents
--------------------------------------------
Ho: All panels contain unit roots           Number of panels  =      5
Ha: Some panels are stationary              Number of periods =     26

AR parameter: Panel-specific                Asymptotics: T,N -> Infinity
Panel means:  Included                                    sequentially
Time trend:   Included

ADF regressions: No lags included
------------------------------------------------------------------------------
                                              Fixed-N exact critical values
                    Statistic      p-value        1%      5%      10%
------------------------------------------------------------------------------
 t-bar               -2.7929                     -3.050  -2.790  -2.640
 t-tilde-bar         -2.4533
 Z-t-tilde-bar       -2.9363        0.0017
------------------------------------------------------------------------------

. xtunitroot ips ln_ngr, trend
Im-Pesaran-Shin unit-root test for ln_ngr
-----------------------------------------
Ho: All panels contain unit roots           Number of panels       =      4
Ha: Some panels are stationary              Avg. number of periods =  22.00

AR parameter: Panel-specific                Asymptotics: T,N -> Infinity
Panel means:  Included                                    sequentially
Time trend:   Included

ADF regressions: No lags included
------------------------------------------------------------------------------
                                              Fixed-N exact critical values
                    Statistic      p-value        1%      5%      10%
------------------------------------------------------------------------------
 t-bar               -2.9756                          (Not available)
 t-tilde-bar         -2.1015
```

```
 Z-t-tilde-bar       -1.8588       0.0315
------------------------------------------------------------------------------


. xtunitroot ips carbondioxideintensity, trend
Im-Pesaran-Shin unit-root test for carbondioxideintensity
---------------------------------------------------------
Ho: All panels contain unit roots           Number of panels  =      5
Ha: Some panels are stationary              Number of periods =     26

AR parameter: Panel-specific                Asymptotics: T,N -> Infinity
Panel means:  Included                                        sequentially
Time trend:   Included

ADF regressions: No lags included
------------------------------------------------------------------------------
                                              Fixed-N exact critical values
                    Statistic      p-value         1%       5%      10%
------------------------------------------------------------------------------
 t-bar               -2.8608                     -3.050  -2.790  -2.640
 t-tilde-bar         -2.2032
 Z-t-tilde-bar       -2.2213       0.0132
------------------------------------------------------------------------------


. ***Pooled Panel Regression***
. reg In_re In_ei In_or In_cr In_ngr In_ci

      Source |       SS       df       MS              Number of obs =      59
-------------+------------------------------           F(  5,    53) =   20.15
       Model |  54.2095764     5  10.8419153           Prob > F      =  0.0000
    Residual |  28.5221152    53  .538153117           R-squared     =  0.6552
-------------+------------------------------           Adj R-squared =  0.6227
       Total |  82.7316917    58  1.42640848           Root MSE      =  .73359

------------------------------------------------------------------------------
       In_re |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       In_ei |   2.775314   .5270221     5.27   0.000     1.718241    3.832386
       In_or |  -.1250307   .1091992    -1.14   0.257    -.3440565    .0939951
       In_cr |   .0426219   .0843313     0.51   0.615    -.1265252     .211769
      In_ngr |   .9332881   .1561862     5.98   0.000     .6200183    1.246558
       In_ci |  -.4427637   .2512152    -1.76   0.084    -.9466377    .0611103
       _cons |   10.51524   1.364915     7.70   0.000     7.777564    13.25291
------------------------------------------------------------------------------

.
. * Save your results
. est store pooled
. outreg2 using panel_data.doc, dec(4) replace title("Table 1: Panel Regression
Result") ctitle
> (POOLED) keep(In_ei In_or In_cr In_ngr In_ci) addstat(Adj. R-squared, e(r2_a), F-
test, e(F),
> Prob > F, e(p))
panel_data.doc
dir : seeout

. robvar resid, by (country)

Summary of Residuals
Country         Mean   Std. Dev. Freq.

Nigeria    .37257801   .56965963 26
Congo, De   -.41130729   .36522175      10
South Afr    .11197817   .38062733      17
Egypt   -1.0682263   .76845755   7

Total    5.107e-16   .69716507   60

W0  =  1.9313565   df(3, 56)     Pr > F =      0.13497814

W50 =  1.6597660   df(3, 56)     Pr > F =      0.18607607
```

```
W10 =  1.9574864   df(3, 56)     Pr > F =     0.13086302


xi:regress re ei oilrents coalrents naturalgasrents carbondioxide~y i.countrycode
i.countrycode     _Icountryco_1-5     (naturally coded; _Icountryco_1 omitted)

      Source |       SS       df       MS              Number of obs =     130
-------------+------------------------------           F(  9,   120) =  367.72
       Model |  159.382822     9  17.7092025           Prob > F      =  0.0000
    Residual |  5.77911827   120  .048159319           R-squared     =  0.9650
-------------+------------------------------           Adj R-squared =  0.9624
       Total |  165.161941   129  1.28032512           Root MSE      =  .21945

--------------------------------------------------------------------------------------
--
                    re |      Coef.   Std. Err.      t    P>|t|     [95% Conf.
Interval]
----------------------+---------------------------------------------------------------
--
                    ei |  -.0296874   .0056817    -5.23   0.000    -.0409367   -
.0184381
             oilrents |  -.0400974   .0037456   -10.71   0.000    -.0475134   -
.0326814
            coalrents |   .0065526   .0330585     0.20   0.843     -.058901
.0720062
       naturalgasrents |   .0081664   .0070077     1.17   0.246    -.0057084
.0220413
carbondioxideintensity |   .0518832   .1542109     0.34   0.737    -.2534436
.3572101
         _Icountryco_2 |  -2.552608   .2006212   -12.72   0.000    -2.949824   -
2.155392
         _Icountryco_3 |  -3.026354   .1588487   -19.05   0.000    -3.340863   -
2.711844
         _Icountryco_4 |  -3.803663   .4307019    -8.83   0.000    -4.656422   -
2.950903
         _Icountryco_5 |  -3.950564   .3122073   -12.65   0.000    -4.568713   -
3.332416
                 _cons |   4.322192   .1725005    25.06   0.000     3.980653
4.663731
--------------------------------------------------------------------------------------
--

.
. ***Random Effect Panel Regression***
. xtreg In_re In_ei In_or In_cr In_ngr In_ci, re

Random-effects GLS regression                   Number of obs      =        59
Group variable: country                         Number of groups   =         4

R-sq:  within  = 0.0006                         Obs per group: min =         7
       between = 0.8728                                        avg =      14.8
       overall = 0.6552                                        max =        26

                                                Wald chi2(5)       =    100.73
corr(u_i, X)   = 0 (assumed)                    Prob > chi2        =    0.0000

------------------------------------------------------------------------------
       In_re |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       In_ei |   2.775314   .5270221     5.27   0.000      1.74237    3.808258
       In_or |  -.1250307   .1091992    -1.14   0.252    -.3390571    .0889957
       In_cr |   .0426219   .0843313     0.51   0.613    -.1226644    .2079081
      In_ngr |   .9332881   .1561862     5.98   0.000     .6271688    1.239407
       In_ci |  -.4427637   .2512152    -1.76   0.078    -.9351365    .0496091
       _cons |   10.51524   1.364915     7.70   0.000     7.840052    13.19042
-------------+----------------------------------------------------------------
     sigma_u |          0
     sigma_e |   .0527056
         rho |          0   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

```
. * Save your results
. est store random
. outreg2 using panel_data.doc, dec(4) append title("Table 1: Panel Regression
Result") ctitle(
> RANDOM) keep(ln_ei ln_or ln_cr ln_ngr ln_ci) addstat(Wald-chi2, e(chi2), Prob >
chi2, e(p))
panel_data.doc
dir : seeout

.
. * LM test
. xttest0
Breusch and Pagan Lagrangian multiplier test for random effects

        ln_re[country,t] = Xb + u[country] + e[country,t]

        Estimated results:
                         |       Var     sd = sqrt(Var)
                ---------+-----------------------------
                   ln_re |   1.426408      1.194323
                       e |   .0027779      .0527056
                       u |          0             0

        Test:   Var(u) = 0
                              chibar2(01) =     0.00
                           Prob > chibar2 =   1.0000

. ***Fixed Effect Regression***
. xtreg ln_re ln_ei ln_or ln_cr ln_ngr ln_ci, fe

Fixed-effects (within) regression               Number of obs      =        59
Group variable: country                         Number of groups   =         4

R-sq:  within  = 0.9040                         Obs per group: min =         7
       between = 0.2311                                        avg =      14.8
       overall = 0.0138                                        max =        26

                                                F(5,50)            =     94.15
corr(u_i, Xb)  = -0.4248                        Prob > F           =    0.0000

------------------------------------------------------------------------------
       ln_re |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       ln_ei |  -.5215948    .057096    -9.14   0.000    -.6362754   -.4069141
       ln_or |  -.0612551   .0131563    -4.66   0.000    -.0876803     -.03483
       ln_cr |  -.0301144   .0089759    -3.36   0.002    -.0481431   -.0120858
      ln_ngr |   .0745958   .0145265     5.14   0.000     .0454185    .1037731
       ln_ci |  -.0095506   .0483271    -0.20   0.844    -.1066184    .0875173
       _cons |   15.04517    .113922   132.07   0.000     14.81635    15.27399
-------------+----------------------------------------------------------------
     sigma_u |  1.7585035
     sigma_e |   .0527056
         rho |  .99910249   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(3, 50) =  3405.86              Prob > F = 0.0000

. est store fixed
. outreg2 using panel_data.doc, dec(4) append title("Table 1: Panel Regression
Result") ctitle(
> FIXED) keep(ln_ei ln_or ln_cr ln_ngr ln_ci) addstat(F-test, e(F), Prob > F, e(p))
panel_data.doc
dir : seeout

. ***Hausman test***
. hausman fixed random, sigmamore

Note: the rank of the differenced variance matrix (3) does not equal the number of
coefficients being tested (5); be sure this is what you expect, or there may be
problems computing the test.  Examine the output of your estimators for anything
unexpected and possibly consider scaling your variables so that the coefficients are
on a similar scale.
```

```
                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |     fixed        random       Difference          S.E.
-------------+----------------------------------------------------------------
       In_ei |   -.5215948     2.775314       -3.296909        .5948036
       In_or |   -.0612551    -.1250307        .0637756        .1469947
       In_cr |   -.0301144     .0426219       -.0727363        .0921755
      In_ngr |    .0745958     .9332881       -.8586923        .1283979
       In_ci |   -.0095506    -.4427637        .4332131        .6239746
------------------------------------------------------------------------------
                           b = consistent under Ho and Ha; obtained from xtreg
            B = inconsistent under Ha, efficient under Ho; obtained from xtreg

    Test:  Ho:  difference in coefficients not systematic

                  chi2(3) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =       52.74
                Prob>chi2 =      0.0000
                (V_b-V_B is not positive definite)
```

## APPENDIX 2

**Targets and Energy Policies for few African Countries**

| Country | Sector | Targets and Policies |
|---|---|---|
| Nigeria | Buildings | Declared the strategy and execution of least energy performance criteria for appliances and for tools used in industries. |
| | Accessibility | The plan is to make available consistent and reliable electricity to the general populace by 2020 and 2030 to about 75 per cent and 100 per cent respectively which will link an average of 1.5 million people per annum. |
| | Power | Nigeria has a roadmap for power sector restructuring which make the sector' s broad reforms to permit private investment and thereby launch an electricity market that is highly competitive in order to be able to attain power supply that is reliable. |
| | Oil and Gas | Nigerian Government has drafted out the Petroleum Industry Bill but still yet enact the several parts of the existing agenda. |
| Ghana | Efficiency | Ghana has been able to decrease the loses in the transmission lines in 2018 to 18% and equally increase the standards of their air conditioners and lighting. |
| | Oil and gas | The government of Ghana has plans Strategies to surge exploration, alleviate poverty by making use of the revenues, to also develop a petrochemical industry and make the best use of their local participation. |
| | Renewable Energy | There is feed-in-tariff for renewables in the Renewable Energy Act for 2011. |
| Rwanda | Access | Rate of electrification will by 2020 from 17 per cent to at least 60 per cent and also grant access to hospitals and schools in 2017. |
| | General | The government of Rwanda intends to develop the transmission systems network in 2017 by 2100 km and also decrease the share of bioenergy in the primary demand of energy by 2020 to about 50 per cent. |

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| South-Africa | Renewable Energy | The plan from the Integrated Resource plan in 2013 was to diversity the power mix to proceed towards supplying low carbon power sources. |
| | Prices of Energy | Price of electricity is to be amended steadily in order to better show the costs and tax on Carbon dioxide under consideration. |
| Angola | Integration | The government of Angola intends to connect its transmission lines with that of Congo and also Namibia. |
| | Power | To establish new power market model operation which has a sole power purchaser and also the same right for the private and the public power utilities. |
| | Access | Angola plans to raise the rate of electrification by 2025 to 60 per cent from the normal 30 per cent rate. |
| Mozambique | Access | There are strategies to raise electrification rate by 2035 to about 85 per cent from 39 per cent. |
| | Renewable Energy | There is policies to install 2000, 50 000 and also 5000 of televisions, lighting systems and also refrigeration systems respectively which are to be powered by wind turbine or solar photo-voltaic systems in the off grid zones and to also possess solar water heaters of about 10,000 by 2025. |
| | Gas | In order to make the best use of the importance of gas resources, Mozambique government approved the Gas Master Plan in 2014. |
| Kenya | Buildings | Kenya plan to install solar water heaters in their buildings which will be powered by the grid and also intend to eradicate kerosene that is being used by households by 2022. |
| | Efficiency | The Country has been able to set standards for set a standard for energy efficiency for various appliances, electrical appliances and also enforced the right standards for energy efficiency in the 2014 energy bill which gave rise to the Energy Efficiency and Conservation Agency. |
| DR Congo | Power | Has established an electric motors standard which is firmer than the former ones. |

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| | Access | Declared that the electrification rate will rise in 2020 by 26 per cent as compared to 14 per cent in 2015 and 9 per cent in previous years. |
| Egypt | Renewable Energy | In order for Egypt to meet its target of 20 per cent renewable energy generation by the year 2020 and to also attract foreign investors into their renewable energy sector, the government has established new laws and has been executing those laws. |
| Ethiopia | Renewables | Has recently established targets for new renewable energy sources capacity such as wind, geothermal and hydro. |
| | Access | Set targets to allocate improved cooling stoves of about 9 million in 2015. |
| Senegal | Renewable Energy | The government of Senegal had 20 per cent target to derive their total energy supply from various renewable sources of energy in 2017. |

**Source: IEA, 2014**