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(INCLUDING CLIMATE CHANGE)

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ENERGY POLICY

Presented by

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MODELLING THE NEXT ENERGY TRANSITION IN NIGERIA TO ACHIEVE SUSTAINABLE DEVELOPMENT AND MITIGATE CLIMATE CHANGE

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DECLARATION

I **Sunkanmi Abimbola DAIRO**, hereby declare that this thesis represents my personal work, realized to the best of my knowledge. I also declare that all information, material and results from other works presented here, have been fully cited and referenced in accordance with the academic rules and ethics.

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ABSTRACT

Projections for future energy demand have time and time again been employed for the planning and sustainable utilization of available energy resources. Having in perspective the current energy transition occurring globally, and in Nigeria, and the need to use available energy resources sustainably this study employed scenario based modelling to explore and analyse what the future national energy demand in Nigeria could look like. Energy demand is highly influenced by demography and economic growth among other factors, hence for the sake of analysis, four (4) growth scenarios were explored; the business-as-usual (BAU) scenario, low growth (LG) scenario, medium growth (MG) scenario and high growth (HG) scenario. Each scenario has its own unique average annual economic growth rate of 4.6%, 6.08%, 7.37% and 10.18% per annum for the BAU, LG, MG and HG respectively.

The findings of this study provide adequate indications that the household sector will continue to lead all other groups with regards to total annual energy demand regardless of the growth rate of the economy within the period under study (2010-2030). In the manufacturing, agriculture, construction, mining and service sector, energy efficiency would play a pivotal role in determining future energy demand, for the transport sector passenger activity would play a major role while in the household sector the fuel of choice for cooking and water heating is pivotal in influencing future energy demands.

To quicken the rate of energy transition in the household sector to achieve sustainable development an alternative energy transition scenario was considered for the household sector which was done to explore what the future demand could be if LPG becomes the fuel of choice in the household sector.

Keywords: ***energy transition, sustainable development, scenario based modelling, energy demand, energy supply, energy efficiency***

RÉSUMÉ

Les projections de la future demande en énergie ont été maintes fois utilisées pour la planification et l'utilisation durable des ressources énergétiques disponibles. Ayant en perspective la transition énergétique actuelle au niveau mondial et au Nigeria, et la nécessité d'utiliser durablement les ressources énergétiques disponibles, cette étude a utilisé une modélisation basée sur des scénarios pour explorer et analyser ce à quoi pourrait ressembler la future demande énergétique nationale au Nigeria. La demande d'énergie est fortement influencée par la démographie et la croissance économique parmi d'autres facteurs, par conséquent, pour des raisons d'analyse, quatre (4) scénarios de croissance ont été explorés ; le scénario de statu quo (BAU), le scénario de faible croissance (LG), le scénario de croissance moyenne (MG) et le scénario de forte croissance (HG). Chaque scénario a son propre taux de croissance économique annuel unique de 4,6%, 6,08%, 7,37% et 10,18% par an respectivement pour le BAU, le LG, le MG et le HG.

Les résultats de cette étude fournissent des indications adéquates selon lesquelles le secteur des ménages continuera de diriger tous les autres groupes en ce qui concerne la demande énergétique annuelle totale, indépendamment du taux de croissance de l'économie au cours de la période étudiée (2010-2030). Dans le secteur manufacturier, agricole, de la construction, des mines et des services, l'efficacité énergétique jouera un rôle déterminant dans la future demande en énergie, car l'activité passagers du secteur des transports jouera un rôle majeur tandis que dans le secteur ménages, le chauffage est essentiel pour influencer les demandes d'énergie dans le futur.

Pour accélérer le taux de transition énergétique dans le secteur des ménages afin de parvenir au développement durable, un scénario de transition énergétique alternatif a également été envisagé pour le secteur des ménages afin d'explorer ce que la demande future pourrait être si le GPL devenait le carburant de choix.

Mots-clés : ***transition énergétique, développement durable, modélisation par scénarios, demande énergétique, approvisionnement énergétique, efficacité énergétique***

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LIST OF ABBREVIATIONS

AAGR	–	Average Annual Growth Rate
AGO	–	Automotive Gas Oil
ATC&C	–	Aggregate Technical, Commercial and Collection
ATK	–	Aviation Transport Kerosene
BAU	–	Business-As-Usual
BOI	–	Bank of Industry
CCPP	–	Combined Cycle Power Plant
CNG	–	Compressed Natural Gas
DISCO	–	Distribution Company of Nigeria
ECN	–	Energy Commission of Nigeria
E.D	–	Energy Density
E.I	–	Energy Intensity
EPSRA	–	Electricity Power Sector Reform Act
FGN	–	Federal Government of Nigeria
FMP	–	Federal Ministry of Power
GDP	–	Gross Domestic Product
GENCO	–	Generation Company of Nigeria
GHG	–	Greenhouse gas
HG	–	High Growth
HHK	–	Household Kerosene
Ktoe	–	Kiloton of oil equivalent
LEAP	–	Long Range Energy Alternatives Planning system
LG	–	Low Growth
LNG	–	Liquefied Natural Gas
LPFO	–	Low Pour Fuel Oil
LPG	–	Liquefied Petroleum Gas
MG	–	Medium Growth
MWh	–	Megawatt hour
MYTO	–	Multi Year Tariff Order
NBET	–	Nigerian Bulk Electricity Trading plc
NEPA	–	National Electricity Power Authority

NERC	–	Nigerian Electricity Regulatory Commission
NG	–	Natural Gas
ONEM	–	Operator of the Nigerian Electricity Market
PHCN	–	Power Holding Company of Nigeria
PMS	–	Premium Motor Spirit
PTFP	–	Presidential Taskforce on Power
PV	–	Photovoltaic
TCN	–	Transmission Company of Nigeria
Toe	–	ton of oil equivalent
UNDP	–	United Nations Development Programme
UNFCC	–	United Nations Framework on Climate Change

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CHAPTER ONE: PURPOSE AND SIGNIFICANCE OF STUDY

1.1 General Introduction

Energy undergirds civilization and has powered the sweeping worldwide economic changes that have transformed the world over the last two and a half centuries(World Economic Forum, 2013). The economic change of world nations over time was brought about by some fundamental change in the energy mix (and the energy sector in general). The most significant motivation for worldwide energy transitions is the security of energy supply, new forms of energy and new technology to harness such energy have been developed over time, shifting the energy balance and expanding the menu of energy sources and thus guaranteeing the security of supply.

Energy transition can be defined as the gradual (rather than swift change) process that unfolds over time and brings about more diversity to the energy system(World Economic Forum, 2013). Previous energy transitions were driven by a variety of reasons over the past 250 years, the dominant fuel in the global energy mix gradually transitioned from biomass to coal and then to oil, all being carbon-based fuels. For each case, the transition occurred due to the fact that the new fuel was perceived to be better, cheaper, faster or more suited to its purpose than the fuel that was previously being used. In all of these previous transitions, technological innovation did not play a back role as it brought new uses to fuels that transformed the energy system. For example, when coal replaced biomass as principal fuel it brought with it industrialization and facilitated mass transportation and when oil was brought into the picture it helped increase private mobility.

Since the beginning of this century, two major factors have played a pivotal role in the need to transition yet the global energy system. The first factor is the growing concerns about the impact that the present-day energy mix, that is made up of majorly fuels that are carbon positive, is having on the climate of our mother earth. The second 2factor is the shift of the world's centre of gravity towards emerging markets in developing countries and the increase in global energy demand brought about by these emerging markets. Figure 1.1 shows that in the year 2000, developed countries share of global oil consumption was 55% but a decade later it was 46% of the global oil consumption. This trend is expected to continue for the foreseeable future.

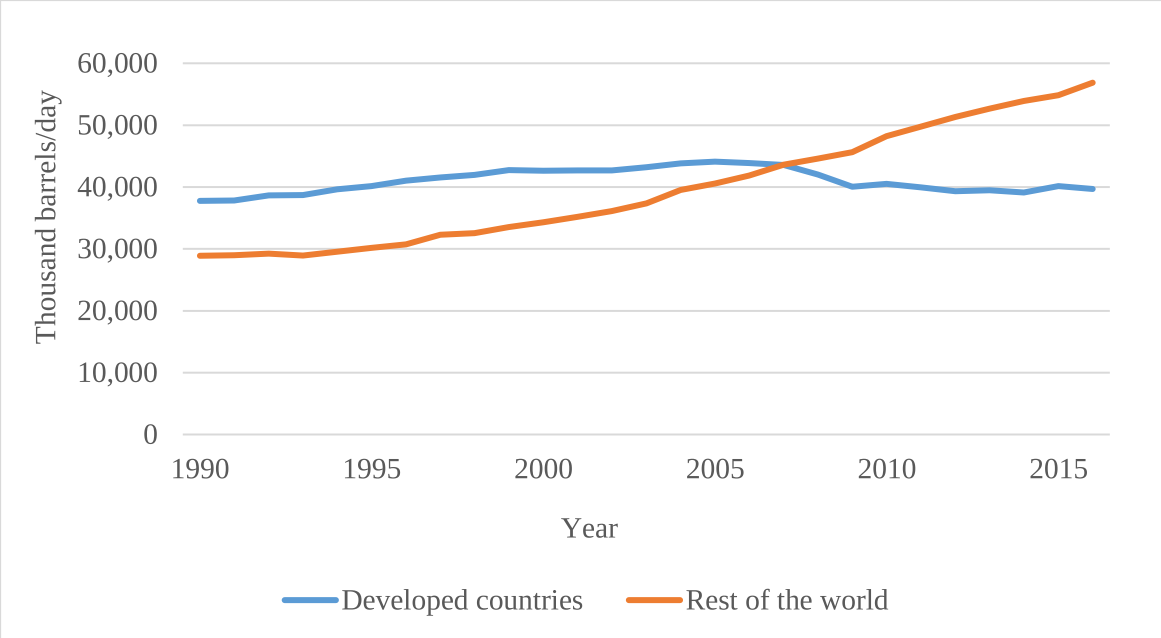

Figure 1.1 Global Oil Consumption
Source: British Petroleum, 2017

1.2 Trends in Global Energy Transitions

The first major energy transition was by far the longest, more than 400,000 years ago people started to use biomass, basically wood (but also agricultural residue and animal wastes) as fuel, primarily for cooking and water-heating purposes (World Economic Forum, 2013). Wood was widely used due to its ready availability. But using wood as fuel gave rise to increase indoor pollution which subsequently led to health hazards and also the continued use of wood led to an increase in deforestation.

1.2.1 Transition from biofuel dominated to coal dominated

The discovery in 1709 by an ironmaster, Abraham Darby, of a method of producing pig iron in a blast furnace fuelled by coke rather than charcoal was a major step forward in the production of iron as a raw material for the Industrial Revolution. Furthermore, the advent of coal powered steam engines between 1712 and 1770s contributed immensely to both the rise in demand and supply of coal. From then onwards the use of coal gradually started rising with increased use in the transportation sector. Also, the first power plants used steam engines to produce electricity and they consumed coal as fuel. Coal's energy density made it a better option when compared to wood as 1 kilogram of coal contains in excess of three times the energy inherent in wood. Yet it should be duly noted that as described above, energy transition is a gradual process and coal didn't rise to full prominence until the early 1900s when coal's share of the primary energy supply had increased considerably and was around 50% of the total, as shown in figure 1.2 below.

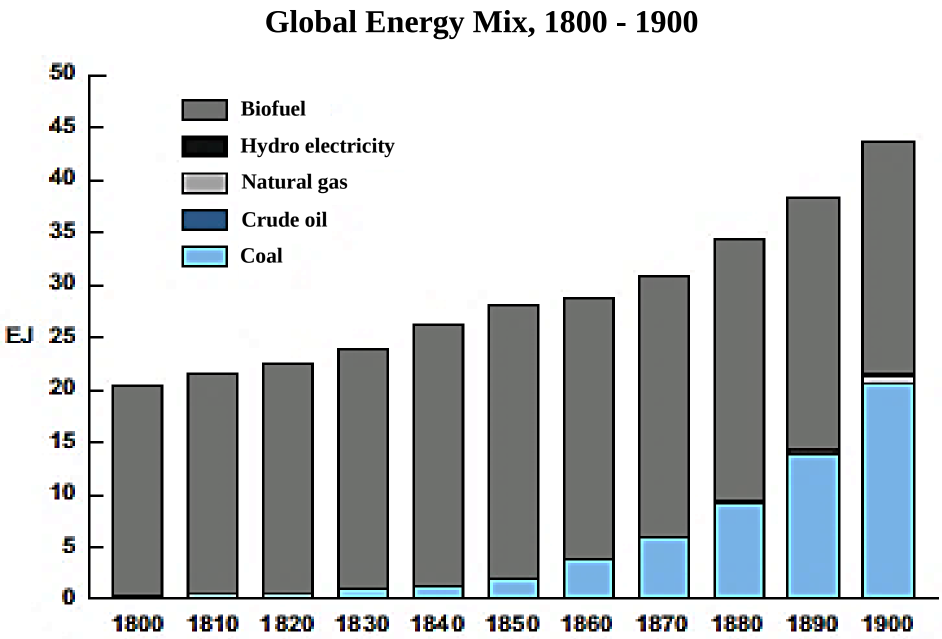

Figure 1.2 Global Energy Mix (1800 – 1900)
Source: Vaclav Smil, 2010

Over the next 100 years, progress was made in developing thermal generating technology but in spite of this coal remained the most widely-used fuel source for power generating plants. This status was challenged by the gradual inclusion of oil and natural gas into the global energy mix and soon afterward, coal's share of primary energy consumption gradually began to decline.

1.2.2 Transition from Coal to Oil and Natural gas

By the 19th century, there was a widespread need for illumination and this need was soon met with the discovery of oil outside of Titusville, Pennsylvania in the Oil Creek Valley in 1859. Oil quickly rose to prominence in the lighting market and its inherent virtues were made clear almost immediately. By 1861, kerosene, which is one of the products of oil refining was already being shipped to some countries in Europe from the United States. But despite this wealth gained from oil its share of global primary energy remained marginal at a mere 1.5% as compared to wood and coal whose shares were 51% and 47% respectively as shown in figure 1.3 below.

Global Energy Mix, 1900 - 2000

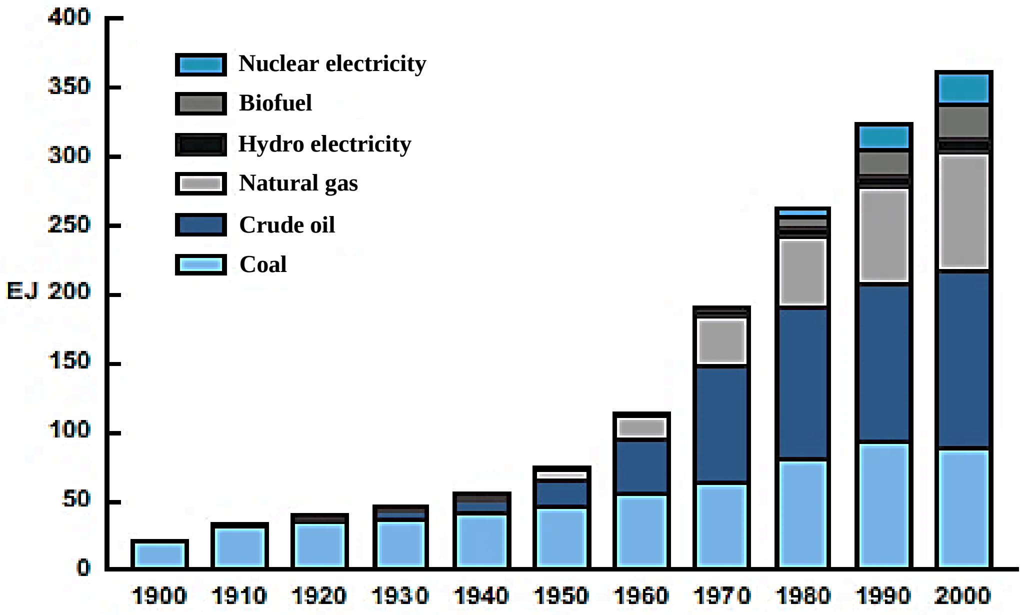

Figure 1.3 Global Energy Mix (1900 – 2000)
Source: Vaclav Smil, 2010

By the late 19th century, improvements in electric lights for illumination threatened the oil's markets and just at that point when it's market was slipping away, another market opened with the advent of internal combustion engines (ICEs) in the transport sector.

Internal combustion engines first ventured into the global market in the year 1876 as a competitor to the conventional steam engines of those days. And by the year 1908 largely due to efforts by Henry Ford, the adoption of ICEs over steam engines as the first choice came to influence oil demand as gasoline (World Economic Forum, 2013), one of the products of refining of crude oil became the fuel of choice owing to its energy-density, reliability, versatility, and ease of transportation.

Before the advent of automobiles, gasoline was merely a by-product of the refining process but then the use of automobiles revolutionised the market and gasoline gradually became an essential commodity. In addition to gasoline, some other by-products of the refining process also saw an increase in their use, for example, fuel oil saw an increased use in boilers of factories, trains, and even ships. From there onward its share of global energy mix gradually increased and by 1964 (105 years after its initial discovery) oil finally overtook coal to become the most used source of energy as indicated in figure 1.3.

It should be duly noted that in the present-day global energy mix, oil's superiority as fuel in the transportation means that substituting it would prove to be particularly difficult (World Economic Forum, 2013). The reason is not farfetched as a switch would require a large-scale change in the massive infrastructure that is already in place to support the world's automotive and trucking sector.

Albeit oil's dominance in the energy mix through the transportation sector, natural gas took a lengthier route into the global energy mix. Its inherent characteristics made it difficult to transport and much of the initially discovered gas was often wasted. But from the 1950s onwards its use for industrial heating and domestic and commercial heating gradually grew as an alternative to coal whose smoke was beginning to cause pollution issues. In the 1970s, gas became widely used in Europe countries with the construction of gas pipelines from the Soviet Union to markets in Western Europe. The clean combustion and flexibility of natural gas lead it to be largely accepted across some sectors, including the power generation sector.

Liquefied natural gas (LNG) also contributed to the global acceptance of natural gas as fuel as it solved the transportation challenge earlier mentioned and thus global trade in natural gas was made possible.

1.2.3 Transition into a Hydro Inclusive Energy mix

Water in motion had previously been used to provide mechanical energy for thousands of years (World Economic Forum, 2013). The mechanical energy from moving water was used to grind wheat into flour, drive sawmills and even pump water with the aid of water wheels. In the early 1800s, American and European factories used water wheels to power machines. By the late 1800s, the electric generator was developed and could be coupled with hydraulics to generate power.

The world's first hydroelectric project was used to power a single lamp in the Cragside county house in Northumberland, England in 1878, by 1882, four years later, the first plant to serve a system of private and commercial customers was commissioned on the Fox River in Appleton, Wisconsin, USA. A decade later, hundreds of hydropower plants were constructed to tap the kinetic energy in flowing water. Rising demand for electricity, the development of electric generator and improvements to the hydraulic turbine went a long way to stimulate the development of hydro projects globally. Consequently, the energy mix expanded again, this time with the first non-combustion based fuel source implemented on a broad scale.

By the beginning of the 20th century, hydropower technology was spreading rapidly around the globe, with Germany taking the lead by producing the first three-phase hydro-electric system in 1891, and Australia launching the first publicly owned hydropower plant in the Southern Hemisphere in 1895 (Smil, 2010). By 1910, more than 500 small hydropower stations were generating electricity worldwide (Smil, 2010).

As shown in figure 1.3, from the 1950s onward, hydropower has made a rapid development around the world. Today, the share of hydropower in the electricity mix in countries with large resource endowments is high, for example, Norway's share of hydropower in their energy mix is 95%, also it stands at 65% as well as 80% in Venezuela and Brazil respectively. China is currently the world's largest producer of hydroelectricity, with a total installed hydropower capacity of 319 GW as of 2015 (World Energy Council, 2016). For more than 20 years, hydropower has maintained 2% share of primary energy consumption (World Economic Forum, 2013). In the same year, 2015, China had the largest addition to it hydropower capacity by including an additional 19.37 GW (International Hydropower Association, 2016).

Apart from the developments made in China, significant new deployment was seen in the emerging markets of some Asian countries for example in India, Russia, Turkey, and Vietnam (World Energy Council, 2016). Although globally Asia has the largest unutilised potential, with an estimate of 7,195 TWh/year, Africa is expected to be a key market for future deployment of hydropower plants (World Energy Council, 2016).

The World Economic Forum in its Energy Vision report states that hydropower is unlikely to gain substantial global market share in the future, except in regions with untapped hydropower potential (World Economic Forum, 2013). In Africa where hydropower potential is about 300GW with only 8 % of it being currently utilised, hydropower is expected to considerably contribute to its future energy mix (International Hydropower Association, 2016). In particular, the markets of the Democratic Republic of the Congo, Angola, Ethiopia, and Cameroon have significant undeveloped potential (World Energy Council, 2016). The regional African co-operation bodies, like the Eastern Africa Power Pool, the West African Power Pool and the Southern African Power Pool, have the potential to influence further development of hydropower projects within their respective regions.

1.3 Trends in Nigeria's Energy Transitions

Nigerian energy transition is divided into 5 different eras of energy use according to the technologies that were being introduced and used at different times in the history of Nigeria as well as the different primary resources which were being exploited at those times (Edomah, Foulds, & Jones, 2016). Just like the energy transitions that were experienced on the global level, the primary resources that were adopted in Nigeria successively had higher energy densities than the ones previously in use; for example, wood to coal, and then coal to crude oil and natural gas.

The 5 Nigerian energy eras as identified are as follows (Edomah et al., 2016):

- Pre-Industrial (agricultural) era – up till mid-1800s,
- Early Industrial (advanced metallurgy) era –late 1800s,
- Industrial (steam engines) era – early 1900s to mid-1900s,
- Late industrial (dynamo, internal combustion engines) era – mid 1900s to late 1900s, and
- Information (microprocessor) era – early 2000s onwards.

1.3.1 Energy use in the Pre-Industrial (Agricultural) and Early Industrial (Advanced Metallurgical) Eras up till late 1800s

The pre-industrial era spanned several centuries from 1500 up to mid-1800s (Edomah et al., 2016). The energy resource used in this era was agriculture based and was well suited to the societal needs of that time. Manual work was applied in this era in the production of agricultural products and in the transportation of this product to places where they were sold. Energy from food was essential for both manual labour and animal labour. The energy that was needed for heating and cooking was provided from fuel-wood and agricultural by-products and illumination was provided by burning oils derived from food and other agricultural by-products.

The essential factors that influenced the transition to the next energy era during this period were trade and European exploration of Africa.

The early industrial era saw the continued use of wood for heating and cooking purposes (Edomah et al., 2016).It also brought with it the extensive use of metallurgical based technology, typically for use in the agricultural sector. This advancement in technology of those days brought with it the mechanization of some agricultural process and the effect was felt in the production of cash crops for export purposes, especially in northern Nigeria (Jochens, 1980). This intervention also led to the development of the railway transportation sector in Nigeria and by 1898 the construction of the first rail line in Nigeria started from Lagos to Ibadan, it was completed in 1901(Edomah et al., 2016).

1.3.2 Transition from biofuel to coal (Industrial Era – early 1900s to mid-1900s)

Coal is the oldest commercial fuel in Nigeria with early mining of production of coal for commercial purposes dating back to 1916 (Nwaobi, 2005). Although the transition from wood to coal on the global scene started in the late 1700s to early 1800s, the mainstreaming of coal into the Nigerian energy mix did not start until early 1900s when coal was discovered in 1909 in Enugu, a city in south-eastern Nigeria. Its discovery brought about the increased use of coal for water-heating and as fuel for steam engines.

By 1923, the first coal-fired power plant in Nigeria was commissioned in Lagos, south-western Nigeria. This brought about the use of coal not only for steam engines but also for electricity generation. This new power plant was labelled as the first major milestone in the development of electricity infrastructure in Nigeria, it had a total installed capacity of 3.6MW. Another coal-fired power station was also commissioned in Enugu in July 1924. This era saw the gradual increase in the use of coal for electricity generation, mass transportation (transportation by rail), and other industrial application of coal (Edomah et al., 2016).

Figure 1.4 shows the rise, and subsequent decline, in the use of coal as the source of energy. This decline can be credited largely to the discoveries of crude oil in 1956 and also to a lesser degree, the Second World War and the Nigerian Civil War (Edomah et al., 2016).

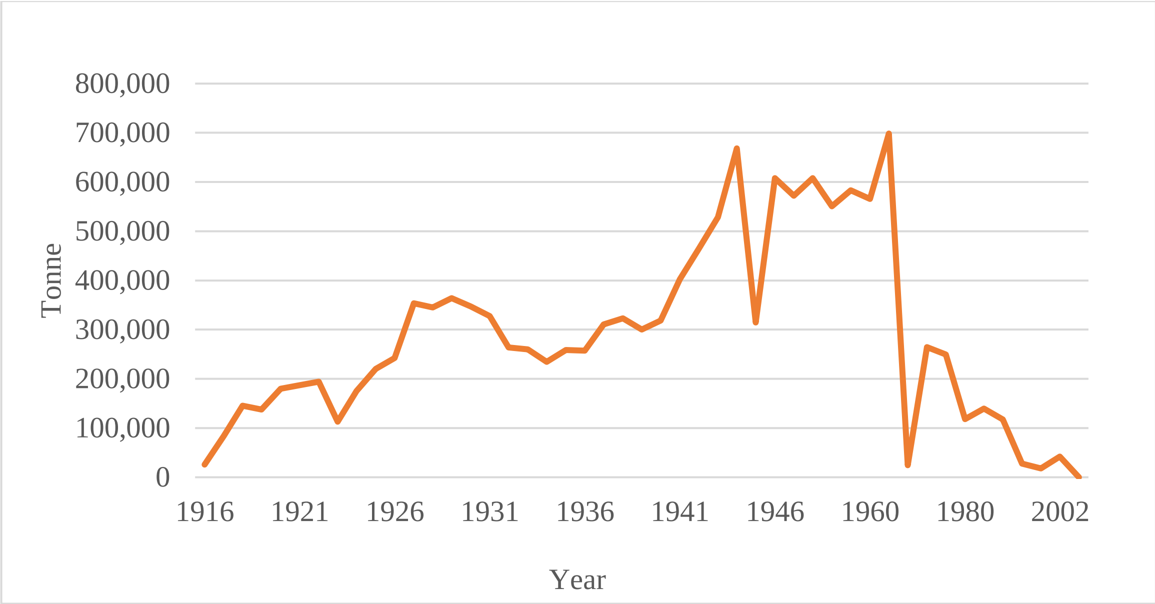

Figure 1.4 Coal Production in Nigeria
Source: Nwaobi, 2005; Odesola, Samuel, & Olugasa, 2013

Figure 1.5 shows how the total installed capacity and electricity generated in Nigeria grew from the period from 1900 up to 1960.

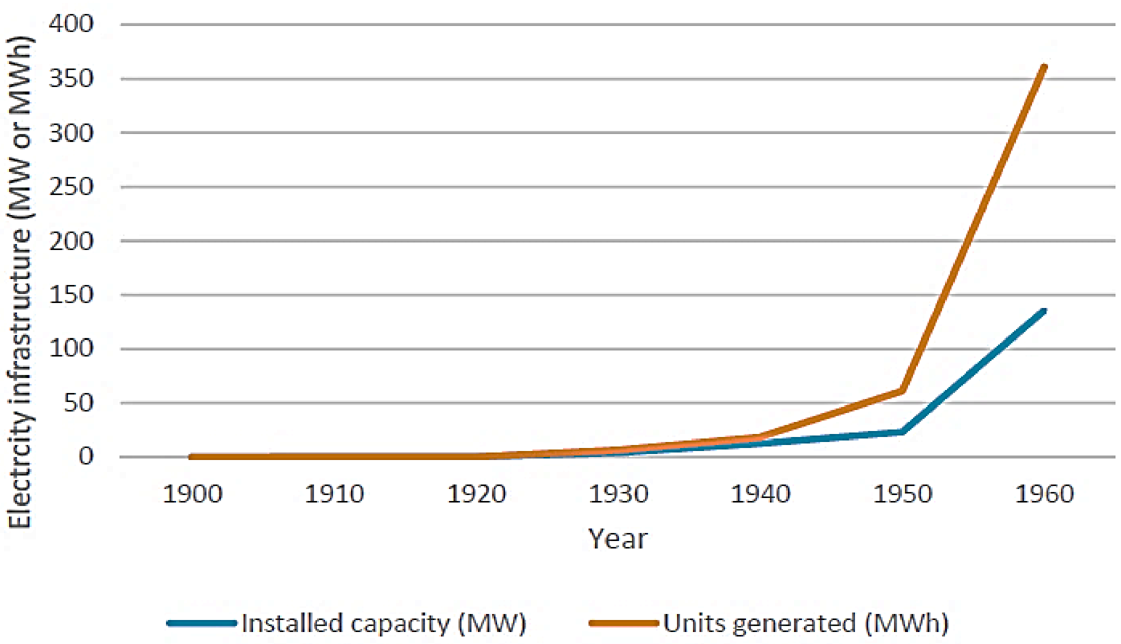

Figure 1.5 Electricity infrastructure growth in Nigeria (1900–1960) in Megawatts (MW) or Megawatt hours (MWh).
Source: Francis, 1997

1.3.3 Transition from coal dominated energy mix to oil, natural gas and hydro (Late Industrial Era to Information Era – from mid-1900s till date)

Transitioning from coal to oil and natural gas came about due to a number of reasons. The discovery of oil in Nigeria in 1956, the increased need for individualised rather than mass transportation and some other factors. Additionally, this period saw a focus on the development of hydropower potential in Nigeria. Two years after the discovery Nigeria joined the ranks of oil producers with a production of 5100 barrels per day and by 1971 had joined the Organisation of Petroleum Exporting Countries (OPEC) and by 1977 it established a state-owned and controlled company, Nigerian National Petroleum Company (Nigerian National Petroleum Company, 2017).

This transitioning period saw a growing use of petroleum primarily due to the widespread use of internal combustion engine as well as the rising use of petroleum and its by-products in the petrochemical industry for the production of plastics and other chemicals.

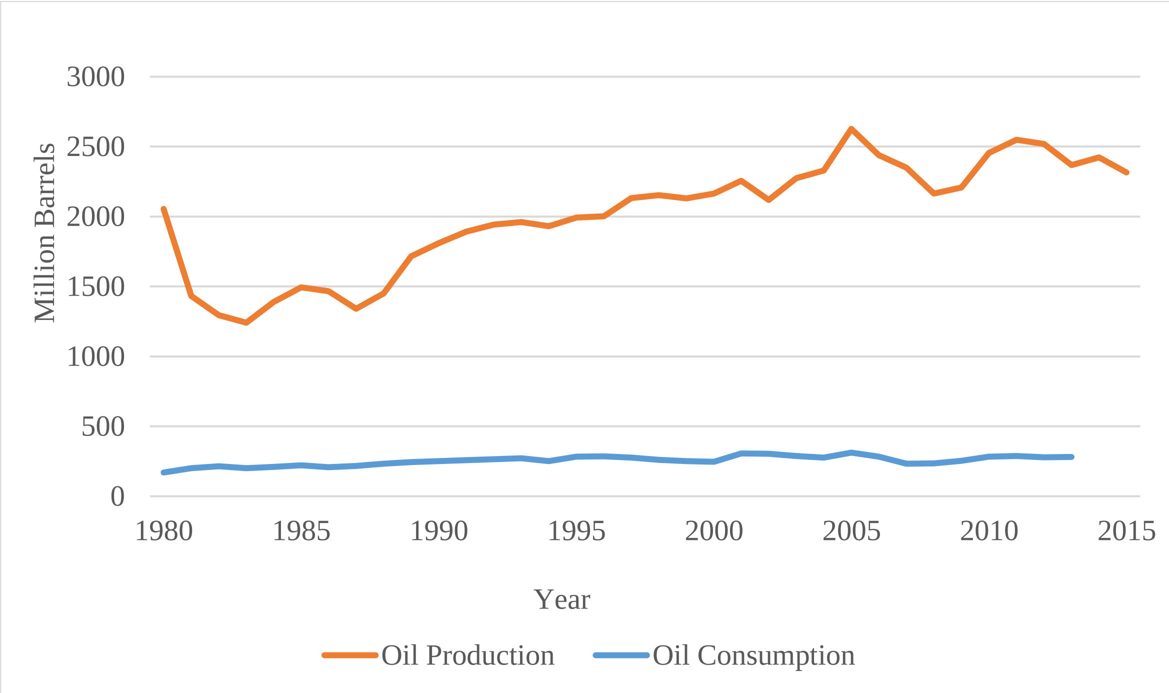

Figure 1.6 Oil production and consumption in Nigeria
Source: EIA, 2017

Figure1.6 Shows the crude oil production and consumption in Nigeria. During this period, Nigeria saw an upsurge in its gas reserve and natural gas was introduced into the energy mix. This led to an increased use in natural gas for electricity and subsequently, the country started exporting Natural gas in 1999 (as shown in Figure 1.7, *when production surpassed local consumption*). Nigeria currently stands as the African Country with the largest proven natural gas reserves of 186.6 trillion cubic feet, (British Petroleum, 2017).

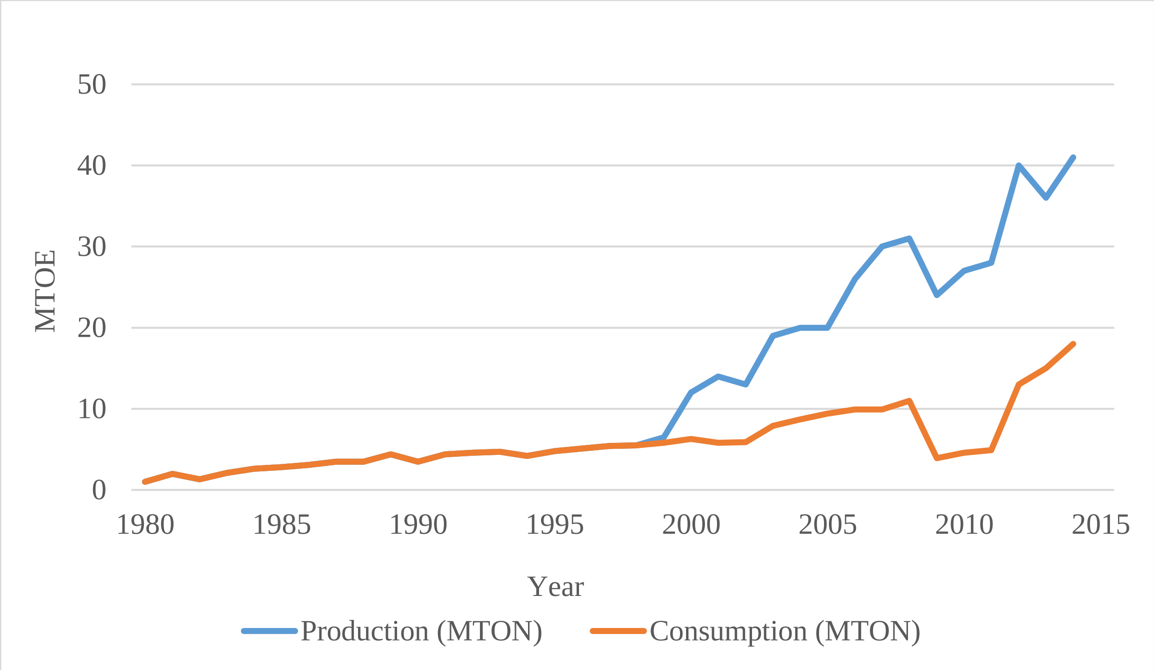

Figure 1.7 Natural gas production and consumption in Nigeria
Source: EIA, 2017

1.4 Statement of the problem

A lot has been said about the relationship between energy use and economic buoyancy, about how the energy sectors especially in emerging markets are vulnerable to the impact of climate change and also about the potential for emerging markets to transition yet again their energy mix to achieve their economic dreams and mitigate the impacts of climate change. But little has been done in exploring exactly what role energy transition would play in the economic transformation in emerging markets in Africa within the space of a couple of decades.

This study seeks to explore what the future energy system in Nigeria could look like by exploring a business-as-usual path (this path excludes the adoption of policies to boast the energy transition a bit more aggressively) as well as some policy driven paths aimed at the speedy transformation of the energy sector to consolidate on the gains already made in the sectors.

1.5 Objective

The general objective of this study is to develop and model energy demand scenarios for Nigeria using the Long Range Energy Alternative Planning (LEAP) software and explore the role policies have to play to consolidate on the gains already achieve in the transition of the Nigerian energy sector.

1.6 Specific Objectives

- Analyse energy demand and supply of the base year 2010,
- Analyse the dynamics of energy demand and supply from 2010 to 2017,

- Simulate four (4) energy demand scenarios; Business-as-usual, low growth, medium growth and high growth scenarios by exploring different growth rates of the economy from 2018 to 2030, and
- Simulate a policy driven energy transition scenario for the household sector.

1.7 Scope of the Study

During the study, the renewable energy sources that was be taken into consideration for these energy transitions are; third and fourth-generation biofuels, biogas, geothermal energy, hydropower (both small-hydropower and large-hydropower), solar energy (photovoltaic (PV)), and wind energy. Natural gas and nuclear energy will also be considered with its implications.

This study was carried out in Nigeria from April 1, 2018 and spanned a period of 4 months.

1.8 Justification

With renewed global focus on the economies of African countries and the increased awareness for the sustainable use of energy, there is a need to carry out a detailed analysis of possible pathways for the use of energy, and what ‘energy transition’ and ‘sustainable use of energy’ mean in the context of African countries. Also, there is need to explore the consequences that today’s actions will have on tomorrow’s energy systems. One way to go about this is to employ a modelling approach to give an idea of what the future will look like given the decisions that are being made today.

1.9 Limitation of the study

This study does not put into consideration any future change in technology that may arise in any of the sectors to impact energy demand.

CHAPTER TWO: LITERATURE REVIEW

2.1 The Nigerian Energy Sector

Nigeria is the most populous country in Africa with a current population of over 186 million people but only 57.65% of the population had access to grid electricity as at 2016 as shown in table 2.1 below. About a decade ago, the population with access to electricity was 52% and to this population connected to the grid, electricity was available just about 40% of the time (Aliyu, Ramli & Saleh, 2013). Much hasn't changed after a decade.

The Nigerian power sector is afflicted by frequent blackouts to the extent that a substantial number of industrial consumers, residential and other non-residential consumers provide their own power at an enormous cost to themselves and consequently to the economy of Nigeria. Approximately 80% of Nigerians use alternative sources of electricity supply such as diesel or petrol generators or in other cases solar inverters. Around 8,000 and 14,000 MW of decentralised diesel generator capacity is currently installed in the country (GIZ, 2015).

TABLE 2.1 : ENERGY STATISTICS OF NIGERIA

	1995 Estimates		2015 Estimates		Change (%) [4]
Population [1]	108,011,465		181,181,744		67.74
Electricity access rate (%) [1]	37.18		57.65*		57.96
Energy Use per capita (tonne of oil equivalent) [1]	0.682		0.763*		11.88
Energy Mix					
Resources	**MW [2]**	**% of total**	**MW [3]**	**% of total**	**Change (%)**
Hydro	2,341	40.08	1,930.0	15.99	- 17.56
Thermal (*Natural Gas, Coal, Fuel Oil)*	3,500	59.92	10,137.0	84.01	189.63
Renewable (*Wind, Solar, Biomass)*	-	-	-	-	-
Total Installed Capacity	**5,841**	**100**	**12,067.0**	**100**	**105.19**

Data Sources;
1 World Bank data on Nigeria
2 UN Data
3 Energypedia
** 2014 values used where 2015 values are not available*

As shown in table 2.2, in the year 2010, 72.2% of households (approximately 22,162,516 households) in Nigeria use the tradition fuelwood stove for cooking, this is closely followed by kerosene stoves at 23.8% while the other sources trail behind. With the Nigerian population increasing at an annual average of 3.2%, this is not sustainable as the increased use of fuelwood for cooking which first of all is bad for human health will eventually lead to deforestation in the long run if not curbed.

TABLE 2.2 : PERCENTAGE DISTRIBUTION OF HOUSEHOLDS BY SOURCE OF COOKING FUEL, 2010	
Fuel	**Percentage of household (%)**
Electricity	0.4
LPG	1
Kerosene	23.8
Fuelwood	72.2
Coal	1.3
Agricultural Residue	0.9
Others	0.2

Source: NBS, 2012

Table 2.3 below shows that from the year 2011 to 2015 much did not change. Less than half of the population rely on the national grid for lighting their homes, this implies that they have to rely on other sources, majorly battery powered touch light and kerosene lamps, as fuel to provide light. Due to the unreliability of grid electricity for lighting, a lot more people are seen to embrace torchlights while to a lesser degree more people are using generators as a lighting source.

TABLE 2.3: SOURCE OF FUEL FOR LIGHTING IN NIGERIA				
Fuel Type	**2011 (% of Population)**		**2015 (% of Population)**	
Grid Electricity	45.2	**1**	44.8	**1**
Kerosene	25.6	**2**	16.6	**3**
Battery/Dry cell	19.1	**3**	26.6	**2**
Collected Fuelwood	3.7	**4**	4.1	**5**
Generator	3.4	**5**	4.7	**4**
Others	1.1	**6**	1.1	**7**
Purchased Fuelwood	0.7	**7**	1.3	**6**
Candles	0.7	**8**	0.6	**8**
Grass	0.4	**9**	0.1	**9**

Source: (NBS, 2017)

In the last 2 decades, the population of Nigeria almost doubled with an estimated percentage increase of 67.74% as shown in table 2.1 above. The population increase is largely due to a matrix of factors like early marriage, polygamy, prohibition of the use of contraceptives by some religious sects, male child preference which results in continuous childbirth in an attempt to have male children among a number of other factors. During this period, the percentage of the population with access to electricity only rose to about 57.65% leaving almost have of the population still without access to electricity, this percentage without access to electricity reside mostly in the rural communities. Like the electricity access rate, the energy use per capita only appreciated a little within the previous 2 decades, it currently stands at 0.763 toe as compared to the world average of 1.929 toe, this is less than half the global average.

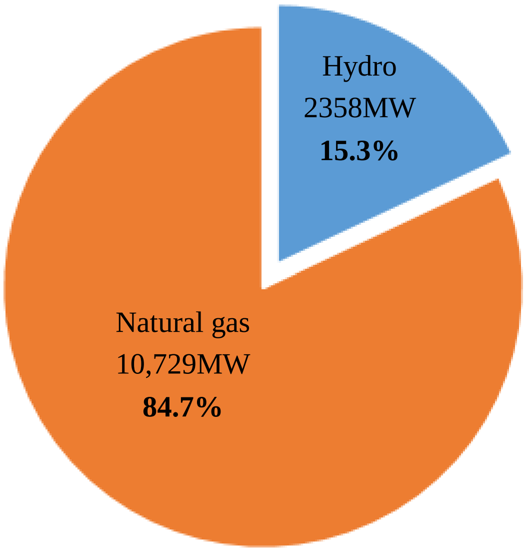

Figure 2.1 Nigeria's on-grid Energy Mix
Source: African Energy Live Data, 2018

Within each of these main sources there exists structural problems that undermine the overall efficiency of each type of infrastructure's energy-producing capacity.

The Nigerian on-grid energy mix as of February 2018 includes only hydropower and natural gas-fired thermal plants with percentages of 15.3% and 84.7% respectively (African Energy Live Data, 2018).

2.1.2 Evolution of the Nigerian Electricity market

Preceding the establishment of the Electricity Power Sector Reform Act (EPSRA) in 2005 the Federal Government of Nigeria (FGN) was in charge of policy formulation, regulation, operation, and investment in the Nigerian power sector. The Federal Ministry of Power (FMP) conducted regulation of the sector with the operation handled by the National Electric Power Authority (NEPA), an exclusively state-owned entity responsible for power generation, transmission and distribution. From 1972 to its defunct in 2005 NEPA ran a monopoly system, it controlled about 94% of the power generation capacity while transmission, system operators, distribution, and their marketing sector was 100 % owned by them (GIZ, 2015).

As an attempt to rectify NEPA's twin issues of operational ineffectiveness and poor financial performance, the FGN in 1998 amended the prevailing laws to eliminate NEPA's monopoly and encourage the participation of the private sector. A reform agenda was specified in the National Electric Power Policy in 2001, while the legal basis for the unbundling of NEPA and formulation of successor companies (including privatization) was provided in the EPSRA. NEPA was restructured to form the Power Holding Company of Nigeria (PHCN) in 2007. From 2007 until 2013 PHCN acted as the state-owned agency responsible for generating, transmitting and distributing electricity for the entire country. In the interim, the FGN sought various means to sell off their stake in the electricity services industries, however retaining the transmission grid as a public entity (Aladejare, 2014).

The first move by the FGN was to put up the government-owned generating companies (GENCOs) for sale. The competitive bidding process was finalised in November 2013 with the assets handed over to the new 6 GENCOs and 11 DISCOs. FGN retained the control and operation of the transmission and system operation under the auspices of the Transmission Company of Nigeria (TCN), which acts as a system and a market operator division (KPMG, 2013). Sequel to this move, the FGN founded the Nigeria Electricity Regulatory Commission (NERC), and the Nigerian Bulk Electricity Trading Plc. (NBET), NBET exists until such a time as the electricity market becomes fully privatised, after which the purchasing power agreements it has previously signed will be passed on to the DISCOs. The FGN also established the Operator of the Nigerian Electricity Market (ONEM) within TCN which acts as wholesale market and settlement operator. It, therefore, manages the metering system among generation, transmission and distribution companies. After the establishment of these agencies, the FGN then put all the ten new National Independent Power Project (NIPP) power plants up for sale. Although most of the GENCOs companies were bound to suffer a loss, the FGN allocated N50 billion (US$ 312.5 million) to them so as to reduce the impact of the loss (KPMG, 2013). The NBET buys electric energy generated from the GENCOs and sells it to the DISCOs for sale to the final electricity consumers (African Development Fund, 2013).

TABLE 2.4: TIMELINE OF THE EVOLUTION OF THE NIGERIAN ELECTRICITY MARKET	
2001	Adoption of the National Electric Power Policy
2005	Enactment of the Electric Power Sector Reform Act (EPSRA)
2005 – 2007	Establishment of the Nigerian Electricity Regulatory Commission (NERC); formation of the Power Holding Company of Nigeria (PHCN); unbundling of the PHCN into 18 independent companies
2009 - 2009	Publication of the Multi Year Tariff Order (MYTO); the Power Sector Reform Committee was formed
2010 – 2012	The Nigeria Vision 20:2020 was launched; the Presidential Action Committee on Power (PACP) and the Presidential Task Force on Power (PTFP) were established; the Roadmap for Power Sector Reform was released; the Bulk Trader was established
2012	MYTO II was approved and released
2013	full privatisation of the generation and distribution subsectors; the transmission subsector was retained by Government but its management is currently under concession
2015	MYTO 2.1 was approved and released. Petitions by various consumer groups, evoked by electricity price increases of up to 80%, led to amendment of MYTO 2.1 and a price drop of about 50%
February 2015	commencement of TEM, after NERC declared all Conditions Precedent listed in the market rules as satisfied
May 2015	unbundling of TCN into an Independent System Operator (public) and a Transmission Service Provider (private) has begun

Source: GIZ, 2015

2.2 Energy in the context of Sustainable Development in Nigeria

According to the Brundtland report, humanity is capable of making development sustainable to ensure that it caters for the needs of the present generation without compromising the ability of the future generations to meet their own needs. At the heart economic growth, progress and development, as well as poverty eradication lies the challenge of energy security. Uninterrupted access to energy is a vital issue for all emerging markets in developing countries today.

Maintaining a focus on sustainable development, future economic growth depends on the long-term availability of energy from sources that are affordable, accessible and environmentally friendly. Keeping in mind that there is yet to be a universally accepted definition of modern energy access (AGECC, 2010), energy access can be defined as "a household having reliable and affordable access to clean cooking facilities, a first connection to electricity and then an increasing level of electricity consumption over time to reach the regional average" (WEO,2011).

Within the African context, the unique nature of its dual energy system where both traditional and modern energy systems and practices coexist poses an exceptional challenge first to the provision of modern energy services for communities that lack it in Africa. Thus within this same context, energy access can be defined to be access to electricity and access to modern fuels for cooking and heating to replace traditional biomass. For simplicity sake AGECC presents three tiers of energy access as shown below;

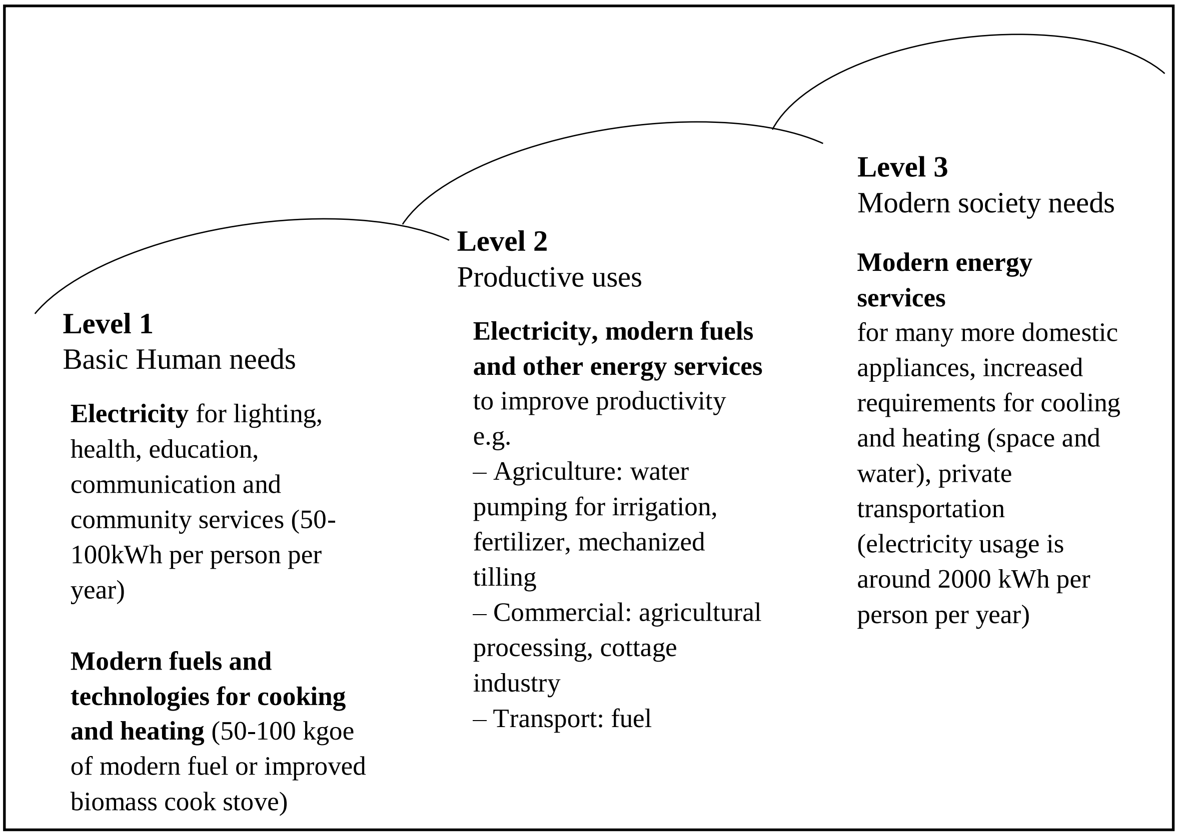

Figure 2.2 Incremental levels of access to energy services
Source: AGECC, 2010

According to the World Bank's list of countries income levels, Nigeria falls under the lower middle-income countries. To achieve sustainable development, countries in this category are faced with a challenge to tackle the development of energy systems in such a way that enables them to progressively decouple growth from energy consumption through improved energy efficiency and reduced energy-related GHG emissions by gradually shifting towards the deployment of low-GHG emission technologies (AGECC, 2010).

Nigeria though an energy resource-rich country, blessed with an abundance of both renewable and non-renewable energy sources still stands as an energy-poor country in terms of energy access. The country has failed to make good use of its energy resource base to provide it's growing population with access to clean and affordable energy. The "energy-poor", who reside mainly in the rural communities, suffer from the health consequences of inefficient combustion of solid fuels in inadequately ventilated buildings, also they suffer the economic consequences of insufficient power for productive income-generating activities and for other basic services such as access to good healthcare and education. Access to electricity in Nigeria from 1990 up till date has been lower than the world average as shown in figure 2.2;

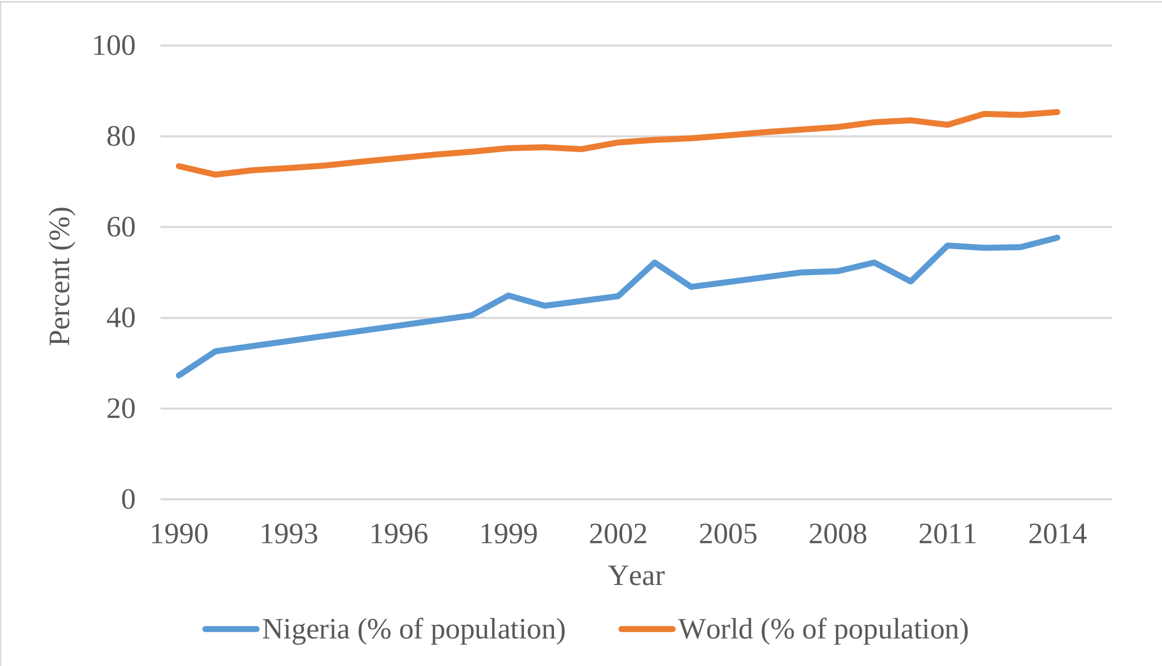

Figure 2.3 Electricity Access in Nigeria as compared to the global average
Source: World Bank Group, 2017

Studies of electricity planning in Africa show that electricity utilities often focus attention on the expansion of their networks to existing grid in urban areas; rural households seldom receive electrification because of their relatively low demand (Sanoh, Parshall, Fall, Kum, & Modi, 2012).

In the case of Brazil, access to energy for both rural and urban centres ran concurrently and within a short time, the country was able to reach 99% of its urban population and also saw a shift from the use of traditional biomass to LPG by the poor communities, this shift was brought about by government subsidies which made the adoption of LPG possible. A 12% reduction was recorded within 4 years from 2006 to 2010 (Coelho & Goldemberg, 2013).

In the year 2009, the percentage of Nigeria's population without access electricity was about 49% and the percentage of its total population relying on the use of traditional biomass for cooking was 67% (WEO, 2010). To attain development that is sustainable in Nigeria, the challenge would be the equitable provision (for rural and urban populations) of energy services to its growing population (increasing demand) and also make such services affordable to them.

2.3 The Nexus of Sustainable Development and Climate Change

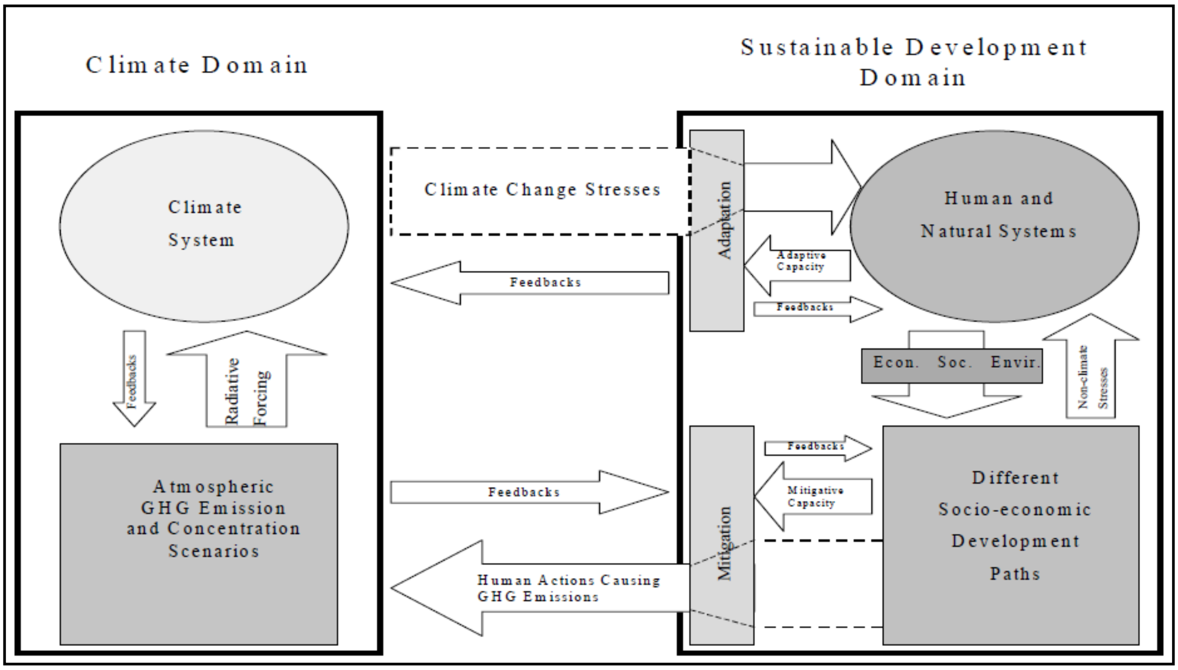

Figure 2.4 Integrated Assessment Modelling Framework for Analysing Climate Change and Sustainable Development linkages
Source: Munasinghe, 2002

There is a fast-rising emphasis in the literature on the mutual relationship between climate change mitigation and sustainable development (Sathaye et al., 2007). The idea is that policies aimed at both sustainable development and climate change mitigating more often than not, mutually reinforcing. The full cycle of the cause and effect relationship that exists between climate change and sustainable development is summarised in figure 2.3 above.

The climate and sustainable development domains interact in an ever-changing cycle, categorised by substantial time delays. For example, impacts and emissions are both linked in intricate ways to fundamental socio-economic and technological development paths. Adaptation, on one hand, lessens the consequence of climate stresses on both human and natural systems, whereas mitigation lessens potential greenhouse gas emissions. Sustainable development paths strongly affect the capacity of any region to both adapt to and mitigate climate change (Munasinghe, 2002). In this way adaptation and mitigation tactics are dynamically linked with climate system changes and the prospects for long-term economic development (Munasinghe, 2002).

Three climate-change occurrences will have a precise impact on the energy sector: global warming, fluctuating regional weather patterns (affecting hydrological patterns within the region) and an upsurge in life-threatening weather events. In addition to the effect that these occurrences will have on the patterns of energy demand, it will also affect the entire spectrum of the production and transmission of energy within some regions (IPCC, 2014).

The 21st conference of the parties of the United Nations Framework on Climate Change (UNFCC) held on 12 December 2015 in Paris, France with the purpose of embracing a new global agreement to limit greenhouse gas (GHG) emissions. The ultimate objective adopted at the conference was to limit global warming to an average of no more than 2 °C, relative to pre-industrial levels. This decision involves the consequential revolution of the global energy sector, as it accounts for approximately two-thirds of all anthropogenic (man-made) GHG emissions today (WEO, 2015). Nigeria signed the Paris Agreement on 22 September 2016, ratified it on 16 May 2017 and it entered in force on 15 June 2017 (UNFCC, 2017).

The economic conditions prevailing in emerging markets actually present viable prospects to achieve both sustainable development goals and emissions reductions measures at a relatively lower cost than in the industrialized countries (Sathaye et al., 2007). The fifth assessment report of the Intergovernmental Panel on Climate Change (IPCC, 2014) identified a number of mitigation options for reducing emission and among those options, this study will be exploring the increased use of renewable energy technology and improved energy efficiency.

2.4 Energy Transition, an approach to achieve Sustainable Development and Mitigate climate change in Nigeria

Over the last couple of decades, there have been growing debate globally and on a national level on the need to use energy sources with a low carbon content as a way to make development sustainable and mitigate climate change. Renewable energy technology though erroneously perceived to be a costly luxury only affordable to those living in developed countries by some critics some that presumption defeated when in 2015 investments in non-hydro renewables was actually higher in developing countries, with roughly US$ 156 billion invested, mainly in Brazil, Chain, and India (UNEP, 2016). Likewise, renewable energy markets within some African countries like Kenya, Tanzania and Tunisia are growing at rapid rates (REN21, 2010).

The world is fast catching on to renewable energy's promise as a tool for rapid economic development in isolated rural areas where electricity grid extensions are often not economical. Off-grid renewable technologies thus provide a sustainable and cost-effective means of deploying energy access projects in such areas (IEA, 2011). Renewable technologies can thus help to displace unsustainable energy sources such as kerosene lamps and traditional biomass that are presently in use in both urban and rural communities in Nigeria.

Owning to Nigeria's immense potential and opportunities for a large-scale roll-out of utility-scale renewable power plants, specifically biomass-to-power, waste-to-power, solar PV projects, solar thermal projects and small and medium-sized hydropower stations (on-grid) the aspired transition that favours the inclusion of renewable energy into its energy mix is possible.

For on-grid renewable energy technologies, the manufacturing and industry market in Nigeria is well underway to gain competency and financial strength for the execution of large-scale renewable energy projects with the support of international partners and financing institutions. Numerous joint ventures of international and national corporations and financial institutions are currently engaged in, for instance, utility-scale solar IPP projects that are either in the license application stage or in solar panel fabrication and installation stage(GIZ, 2015). Within the last couple of years, a number of renewable energy projects have been commissioned in Nigeria;

- A 24kW solar microgrid value at US$ 22 million scheme was commissioned by Nigeria's Bank of Industry (BOI) and the United Nations Development Programme (UNDP) for the Obayantor 1 community in Edo State, Nigeria in May 2016 (ESI Africa, 2017),
- A 10 kW solar photovoltaic off-grid electrification project was commissioned by the Governor of Sokoto state in Danjawa village of Wamakko local government area of Sokoto, Nigeria (Nigeria's Ministry of Environment, 2017), and
- A 100 kW rooftop solar energy project was commission by the Nigerian minister of Power, Works and Housing at the Citadel and Towers of House of the Rock, in Abuja Nigeria (ESI Africa, 2017).

Nigeria's Renewable Energy Master Plan (REMP) in its revised draft edition as prepared by the Energy Commission of Nigeria (ECN, 2014) seeks to increase the contribution of renewables to the Nigerian energy mix for electricity supply from 17% in 2015 to 19% in 2025 and finally to 20% by 2030 based on a 7% economic growth rate. By 2030, renewable electricity (excluding hydro) would account for 10% of Nigeria's total energy consumption (ECN, 2014). The renewable energy potentials identified by the REMP are;

TABLE 2.5 : RENEWABLE ENERGY POTENTIALS IN NIGERIA			
RESOURCE		**RESERVE (POTENTIAL)**	**CURRENT UTILISATION AND OTHER REMARKS**
Large Hydropower		11,250 MW	1,900 MW exploited
Small Hydropower (<= 30MW)		3,500 MW	64.2 MW exploited
Solar PV		3.5 – 7.0 Kwh/m^2/day	15 MW dispersed solar PV installations [estimated]
Wind		2 - 4 m/s at 10 m height	Wind speeds in Nigeria range from a low 1.4 to 3.0m/s in the Southern areas, except for coastal line and 4.0 to 5.1m/s in the North. The Plateau area particularly interesting.
Biomass (non-fossil organic matter)	**Municipal Solid Waste**	30 million tonnes per year	18.5 million tonnes produced in 2005 and now estimated at 0.5 kg per capita per day
	Fuel Wood	11 million hectares of forest and woodland	43.4 million tonnes per year fuel wood consumption
	Animal Waste	245 million assorted animals in 2001	-
	Agricultural Residues	72 million hectares of Agricultural land	91.4 million tonnes/year produced
	Energy Crops	72 million hectares of Agricultural land	24.2 million hectares of arable land; 8.5% cultivated

Source: ECN, 2014

2.4.1 Energy Efficiency, a means of consolidating on Sustainable Development in Nigeria

Energy Efficiency simply means consuming a lesser amount of energy to produce the same amount of service (GIZ, 2015). It has been established that the access to energy services is a prerequisite for human well-being and productivity and that in the long run, it is the demand for energy services that drive the energy system and its expansion. Thus as a means for possibly dissociating demand for energy services from economic growth, energy efficiency represents a promising central lever for policies to target (Riahi et al., n.d.). Energy efficiency should be an integral part of sustainable development strategies.

In the emerging markets of China, Mexico, Tunisia and Turkey the wide spread adoption of energy efficient technology and practices have helped them in realising their sustainable development and climate change mitigation goals (ATKearney & WEO, 2014; Brand & Missaoui, 2014; Riahi et al., n.d.; Sathaye et al., 2007). Also, IRENA's analysis in REmap 2030 shows that increasing the share of renewable sources in total final energy consumption by a factor of two from 18% in 2010 to 36% by 2030, combined with significant improvements in energy end-use efficiency is vital to limit global temperature increases to under 2˚C (IRENA, 2015).

In Nigeria, the mains drivers of energy efficiency are savings gotten from a reduced need for investment in infrastructure (economy level) or savings on expenses made on fuel (individual level) along with the mitigation of environmental effects and climate change (global level) by reduction of GHG emissions brought about by energy efficiency (GIZ, 2015).

Any cost-related choice regarding energy efficiency, at the individual level, is based on a compromise between an immediate cost incurred and a decrease in energy expenses overtime anticipated from improved efficiency. Though the focus today in Nigeria's energy sector is on increasing the generation of power, there is need to formulate and implement energy efficiency programs across all sectors of the economy to consolidate of the gains that would be made in the supply side. This will have a ripple effect not only on lessening the recurring shortage of power but also increase the competitiveness of the industrial sector by bringing down the energy intensity per unit product.

Potential gains from energy efficiency can be exploited both on the consumption or demand side (transport, residential, industrial and services sectors) and supply side (generation, transmission, and distribution).

Table 2.4 shows the energy efficiency indicators for the years 2000, 2005, 2010 and 2014. The potential for investment in energy efficiency by manufacturers and vendors (profiting from machinery or appliance substitution) shown in the table is quite vast. The scope for institutions supporting rural and lower-income households in dropping their energy consumption is similarly huge, as previously noticed with regards to stoves and fuelwood consumption (CREDC, 2008).

On the supply side, according to the available data on the efficiency of thermal power plants in Nigeria by the World Energy Council, the efficiency of electricity generation is around 38.3% (GIZ, 2015). Nigeria's overall efficiency in base-load could be increased by making a technology switch for example to combined heat and power technology or to combined cycle power plants (CCPP), this switch has already been done in some power stations like the Afam VI, Alaoji, Okpai and Olorunsogo stations (GIZ, 2015). Since Nigeria's privatisation is still a couple of years old, the distribution companies (DISCOs) have leaned towards the side of recuperating their investments first before seeking to make a switch to energy efficient technologies in their chain of distribution.

CHAPTER THREE: METHODOLOGY

Long-range modelling of energy systems and its interactions with other systems such as socio-economic and technical aspects of a country is quite complex and daunting. Forecasting the development of any country and its constituent sectors, like the economic sector whose development or decline is closely linked with that of the energy sector, always poses peculiar challenges to modellers everywhere in the world. The constraint in modelling arises from the uncertainty inherent in the interactions between in-country as well as external factors that affect model choices and key assumptions. Scenario-based models based on plausible and acceptable descriptions of the future are time and again employed in such cases to study the effect of an evolving system. It should be noted that outputs from such scenario-based models give a probable range of what the future could look like rather than a deterministic one.

A bottom-up (*End-Use*) modelling approach was used for this study due to its in-depth accounting of all sectors, sub-sectors, end-uses and devices that consume energy. It also has the advantage of providing a fundamental understanding of why energy is used in an economy as compared to the top-down (*Econometric*) modelling approach, likewise it captures the effects of structural shifts and from technology-based policies such as energy efficiency. Furthermore, a bottom-up modelling approach is very useful since it is largely independent of market behaviour and production frontiers, especially for developing countries (Urban, Benders, & Moll, 2007).

3.1 Classification of Fuel types

In this research, the fuels are classified into 5 broad fuel groups based on use;

A. <u>Fossil Substitutable</u>

Fuels in this group refer to fossil based fuels whose use do not include combustion in a spark ignition or compression engine. The fuels listed in this category include;

i. Premium Motor Spirit (PMS)

ii. Automotive Gas Oil (AGO)

iii. Household Kerosene (HHK)

iv. Liquefied Petroleum Gas (LPG)

v. Natural Gas (NG)

vi. Acetylene

vii. Fuel Oil (LPFO)

viii. Coal

B. Motor Fuel

Fuels in this category are fossil based fuels used exclusively in combustion engines. Fuels listed in this category include;

i. Premium Motor Spirit (PMS)

ii. Automotive Gas Oil (AGO)

iii. Aviation Turbine Kerosene (ATK)

C. Feedstock

Fuels in this category fall under fossil based fuels that are used as feedstock in a manufacturing process. Those listed include;

i. Natural Gas (NG)

ii. Liquefied Petroleum Gas (LPG)

iii. Household Kerosene (HHK)

D. Electricity

Electricity is listed as one of the groups and it is subdivided based on its end use as;

i. Captive Electricity Generation

ii. Grid Electricity

E. Traditional Fuel

Another class of fuel is the traditional fuel. The listed fuels include;

i. Fuelwood

ii. Charcoal

iii. Agriculture residue

iv. Animal Waste

F. Solar

The last in the group is solar and was subdivided as;

i. Solar PV

ii. Solar thermal

3.2 Energy Demand Structure and Computation Procedure

3.2.1 Structure of Energy Demand in the Industry Sector

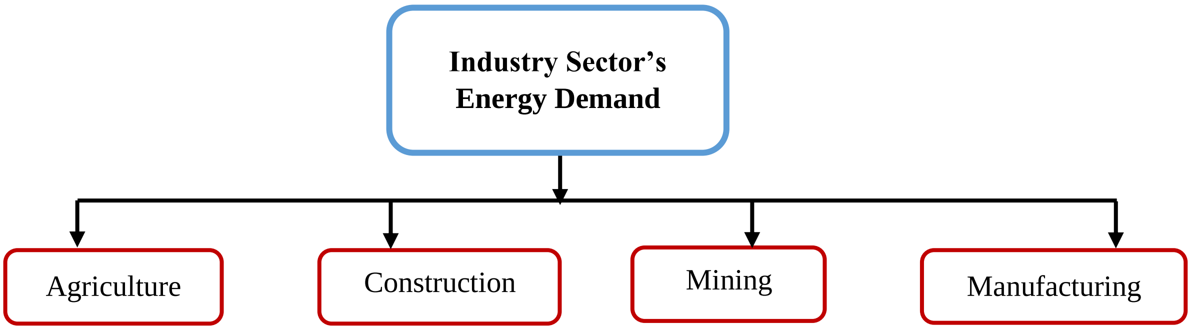

Figure 3.1 Structure of the energy demand in the Industry sector
Source: Author

Energy demand in the Industry sector is modelled to come from the four main subsectors of Agriculture industry, Construction industry, Mining industry and Manufacturing industry. Manufacturing Industry takes the largest percentage of the total (90.5%). In this research, energy is consumed in the Industry Sector in the form of; Fossil Substitutable (AGO, HHK, LPG, NG, Acetylene, FO and Coal), Motor Fuel (AGO), Electricity, Feedstock (NG, LPG and HHK), and Traditional fuel (Fuelwood and Charcoal).

3.2.1.1 Energy Demand Computation Procedure in the Industry Sector

Adapted from LEAP planning tool, the equation that was used to calculate the final demand in the Industry sector is given below;

$$E.D_{Industry} = E.D_{MAN} + E.D_{AGR} + E.D_{CON} + E.D_{MIN}$$

$$E.D_{MAN} = \sum_{FG} GDP_{MAN} * E.I_{FG}$$

$$E.D_{AGR} = \sum_{FG} GDP_{AGR} * E.I_{FG}$$

$$E.D_{CON} = \sum_{FG} GDP_{CON} * E.I_{FG}$$

$$E.D_{MIN} = \sum_{FG} GDP_{MIN} * E.I_{FG}$$

Where;

$E.D_{Industry}$ = Energy Demand in Industry Sector in Ktoe

$E.D_{MAN}$ = Energy Demand in the Manufacturing Sector in Ktoe

$E.D_{AGR}$ = Energy Demand in the Agriculture Sector in Ktoe

$E.D_{CON}$ = Energy Demand in the Construction Sector in Ktoe

$E.D_{MIN}$ = Energy Demand in the Mining Sector in Ktoe

GDP_{CON} = Gross Domestic Product of the construction sector in Billion Naira

E.I = Energy Intensity in Ktoe/Billion Naira

FG = fuel group (that is, fossil substitutable, motor fuel, electricity, feedstock, traditional fuel or solar)

3.2.2 Structure of Energy Demand in the Transport Sector

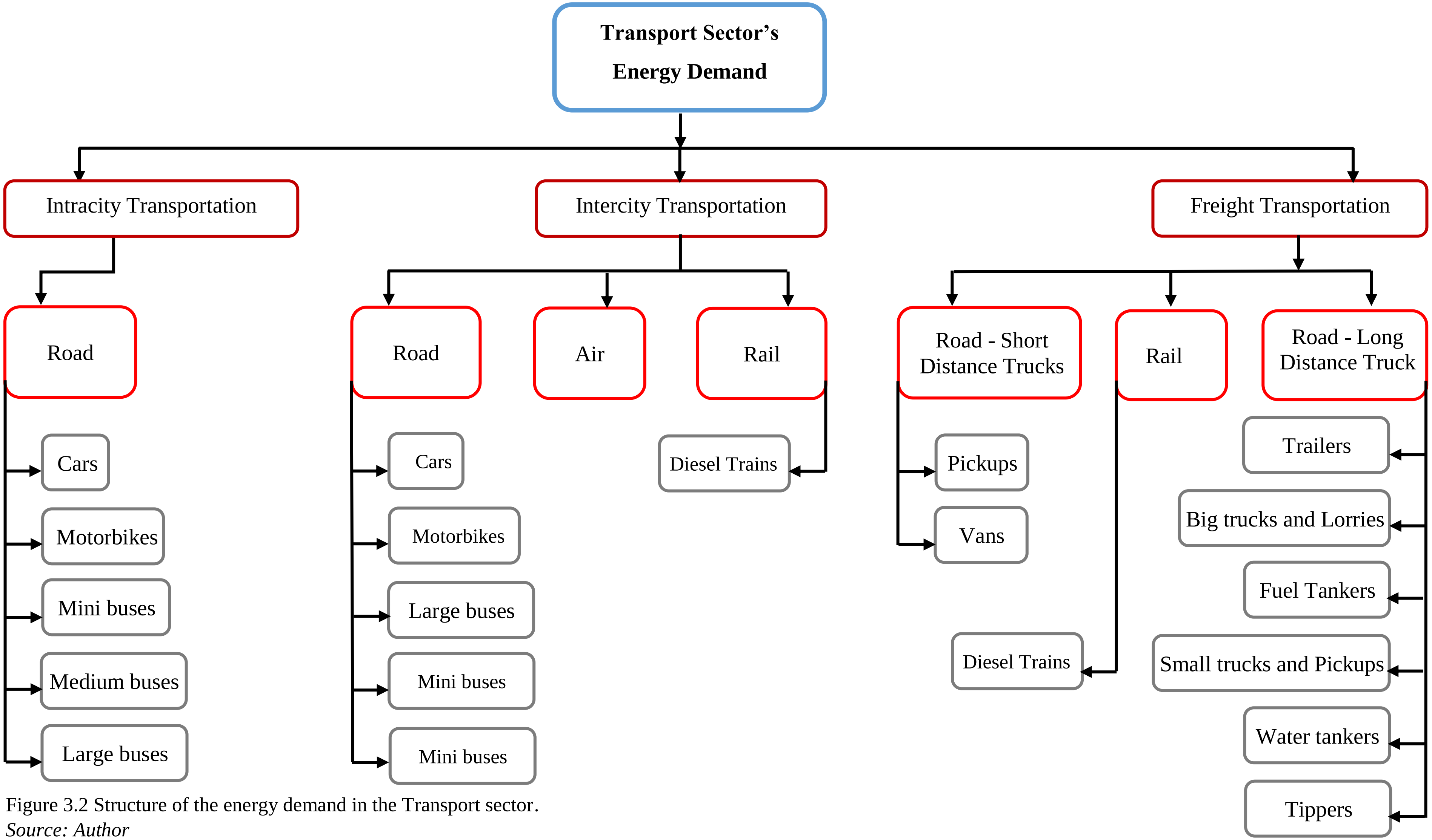

Figure 3.2 Structure of the energy demand in the Transport sector.
Source: Author

Energy demand in the Nigerian transport sector is modelled to come from three (3) main sources as shown in figure 3.2 above; Intracity transportation, Intercity transportation and Freight Transportation, each with its subcategorization as shown above. Table in ANEXX 1 shows the details of the Nigerian transport sector for the base year 2010. In this research, energy is consumed in the form of; Motor Fuel (PMS, AGO and ATK).

3.2.2.1 Energy Demand Computation Procedure in the Transport Sector

Adapted from LEAP planning tool, the equation that was used to calculate the final demand in the transport sector is given below;

$$E.D_{Transport} = E.D_{Intracity} + E.D_{Intercity} + E.D_{Freight}$$

$$E.D_{Intracity} = \sum_{means} \{GDP_{Transport} * Activity_{Intracity} * E.I_{means}\}.$$

$$E.D_{Intercity} = \sum_{means} \{GDP_{Transport} * Activity_{Intercity} * E.I_{means}\}.$$

$$E.D_{Freight} = \sum_{means} \{GDP_{Transport} * Activity_{Freight} * E.I_{means}\}.$$

Where;

$E.D_{Transport}$ = Energy demand in the transport sector in Ktoe

$E.D_{Intracity}$ = Energy demand in Intracity transportation in Ktoe

$E.D_{Intercity}$ = Energy demand in Intercity transportation in Ktoe

$E.D_{Freight}$ = Energy demand in Freight transportation in Ktoe

$GDP_{Transport}$ = Gross Domestic Product of the Transport in Billion Naira

$Activity_{Intracity}$ = Activity level of Intracity transportation in Passenger-Km per Billion Naira

$Activity_{Intercity}$ = Activity level of Intercity transportation in Passenger-Km per Billion Naira

$Activity_{Freight}$ = Activity level of Freight transportation in Passenger-Km per Billion Naira

$E.I_{means}$ = Energy Intensity of the specific means of transportation

3.2.3 Structure of Energy Demand in the Household Sector

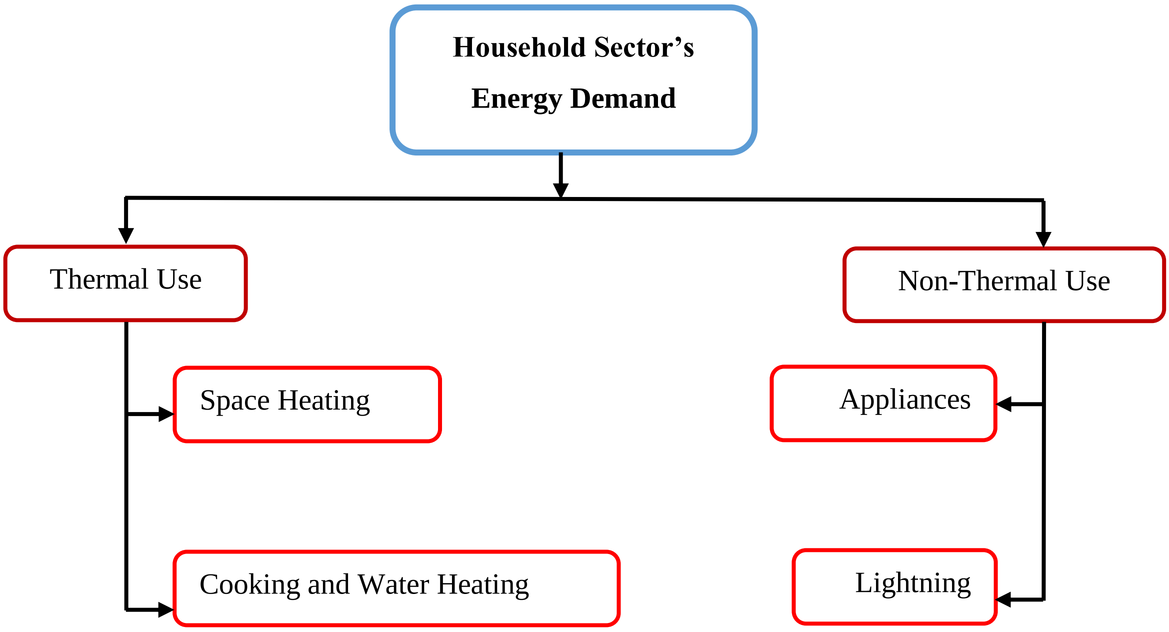

Figure 3.3 Structure of the energy demand in the household sector
Source: Author

The household sector's energy demand is modelled to come from two main sources; *thermal and non-thermal use* and further sub-classified as shown in figure 3.3 above. How each of these sources interact to account for the total demand in this sector depends on the quantity consumed in each household, the type of technology and the efficiency of the technology among others. In this study, energy is modelled to be consumed in the form of; Fossil substitutable (HHK and LPG), Electricity and Traditional Fuel (Fuelwood, Charcoal, Agriculture residue and Animal waste).

3.2.3.1 Energy Demand Computation Procedure in the Household Sector

Adapted from LEAP planning tool, the equation that was used to calculate the final demand in the household sector is given below;

$$E.D_{HH} = E.D_{Space\ heating} + E.D_{Cooking\ \&\ Water\ heating} + E.D_{Lighting} + E.D_{Appliances}$$

$$E.D_{Space\ heating} = \sum_{Fuel} \{N * E.I\}_{Fuel}$$

$$E.D_{Cooking\ and\ Water\ heating} = \sum_{Fuel} \{N * E.I\}_{Fuel}$$

$$E.D_{Lighting} = \sum_{Fuel} \{N * E.I\}_{Fuel}$$

$$E.D_{Appliances} = \sum_{Type} N * E.I_{type}$$

Where;

$E.D_{HH}$ = Energy Demand in the household sector in Ktoe

$E.D_{Space\ heating}$ = Energy Demand for space heating in Ktoe

$E.D_{Cooking\ and\ Water\ heating}$ = Energy demand for cooking and water heating in Ktoe

$E.D_{Lighting}$ = Energy demand for lighting Ktoe

$E.D_{Appliances}$ = Energy demand for household appliances in Ktoe

N = Number of households in Ktoe

$E.I_{Fuel}$ = Energy intensity of specific fuel type in Ktoe/household

$E.I_{type}$ = Energy intensity of specific type of appliance in Ktoe/household

3.2.4 Structure of Energy Demand in the Service Sector

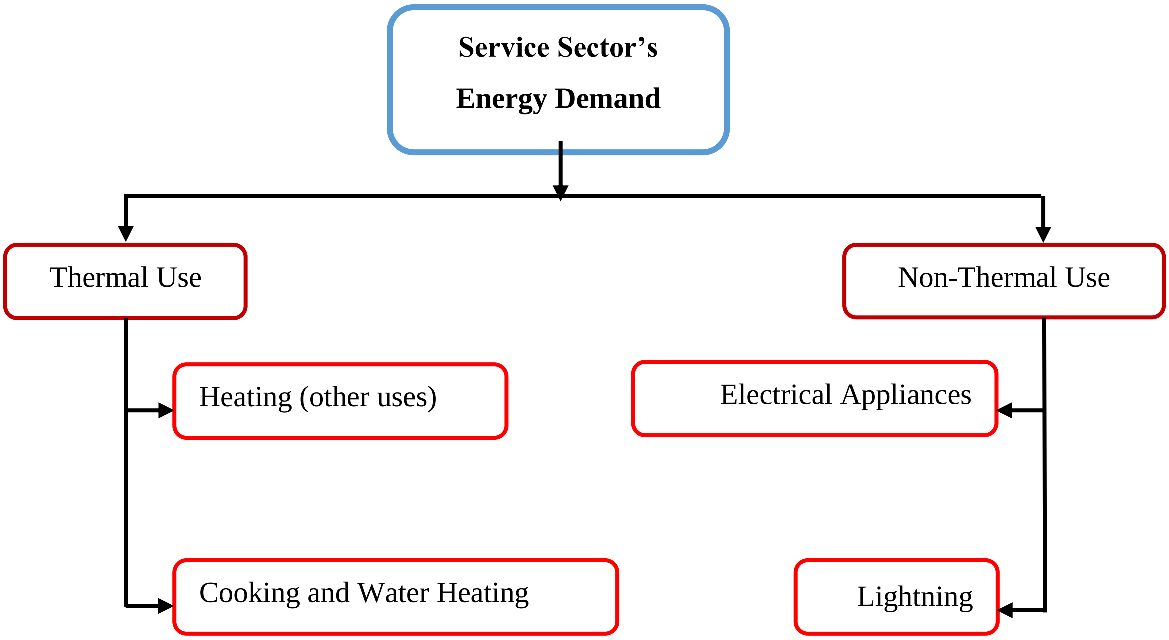

Figure 3.4 Structure of the energy demand in the service sector
Source: Author

The service sector's energy demand much like the household sector is modelled to come from two main sources based on end use; *thermal and non-thermal use* and further sub-classified as shown in figure 3.4 above. The total demand in this sector is determined by the contribution of individual end use demand. In this study, energy is modelled to be consumed in the form of; Fossil substitutable (AGO, HHK and LPG), Electricity and Traditional Fuel (Fuelwood, Charcoal).

3.2.4.1 Energy Demand Computation Procedure in the Service Sector

Adapted from LEAP planning tool, the equation that was used to calculate the final demand in the household sector is given below;

$$E.D_{Service} = E.D_{Space\ heating} + E.D_{Cooking\ \&\ Water\ heating} + E.D_{Lighting} + E.D_{Appliances}$$

$$E.D_{Space\ heating} = \sum_{Fuel} GDP_{service}\{Activity * E.I\}_{Fuel}$$

$$E.D_{Cooking\ and\ Water\ heating} = \sum_{Fuel} GDP_{service}\{Activity * E.I\}_{Fuel}$$

$$E.D_{Lighting} = \sum_{Fuel} GDP_{service}\{Activity * E.I\}_{Fuel}$$

$$E.D_{Appliances} = \sum_{Type} GDP_{service} * Activity * E.I_{type}$$

Where;

$E.D_{Service}$ = Energy Demand in the service sector in Ktoe

$E.D_{Space\ heating}$ = Energy Demand for space heating in Ktoe

$E.D_{Cooking\ and\ Water\ heating}$ = Energy demand for cooking and water heating in Ktoe

$E.D_{Lighting}$ = Energy demand for lighting Ktoe

$E.D_{Appliances}$ = Energy demand for household appliances in Ktoe

$GDP_{service}$ = Gross Domestic Product of the Service sector in Billion Naira

Activity = Percentage share of $GDP_{service}$ in percenage

$E.I_{Fuel}$ = Energy intensity of specific fuel type in Ktoe/Billion Naira

$E.I_{type}$ = Energy intensity of specific type of appliance in Ktoe/Billion Naira

3.2.5 Energy Supply Data Collection Procedure

1. Data for the supply of Petroleum products (PMS, HHK, ATK, AGO and LPG were sourced from the Department of Petroleum resources for the years 2010, 2011, 2012, 2013, 2014, 2015 and 2016.

2. Electricity generated (grid) was obtained from the National Bureau of Statistics for the years 2010, 2011, 2012, 2013, 2014 and 2015.

3. For tradition fuels, actual data was not available as surveys on a nationwide level have not been conducted in a long time. The total energy consumed in the base year 2010 was obtained from the Central Bank of Nigeria as 115, 137.78 Ktoe. The consumption of traditional fuels was then calculated by deducting the energy consumption of petroleum products and grid electricity from this total and disaggregated by the percentages provided by the Energy Commission of Nigeria.

CHAPTER FOUR: FINDINGS

4.1 Analysis of the energy demand for the base year

The total energy demand in Nigeria in the year 2010 was 115,137.78 Ktoe. The share of the household sector was 76.53%, the transport sector 11.50 %, the service sector 9.58% while the industry sector's share was 2.39%. This is not unusual for most developing countries. The table below shows the energy and econometric data of Nigeria for the base year.

TABLE 4.1: ENERGY DEMAND, GDP AND ENERGY INTENSITY FOR THE BASE YEAR

Sector		Energy demand		GDP		Energy Intensity
		Ktoe	*%*	*Billion ₦*	*%*	*Ktoe / Billion ₦*
Industry	Manufacturing	2406.94	2.09	3,578.64	6.55	0.672584
	Agriculture	65.98	0.06	13,048.89	23.89	0.005057
	Construction	268.09	0.23	1,570.97	2.88	0.170652
	Mining	10.18	0.01	8,454.55	15.48	0.001204
Transport		13,235.64	11.50	694.77	1.27	19.050343
Services		11,035.64	9.58	27,264.43	49.92	0.404763
Household		88,115.31	76.53	-	-	-
Total		**115,137.78**	**100.00**	**54,612.26**	**100.00**	-

Source: Author

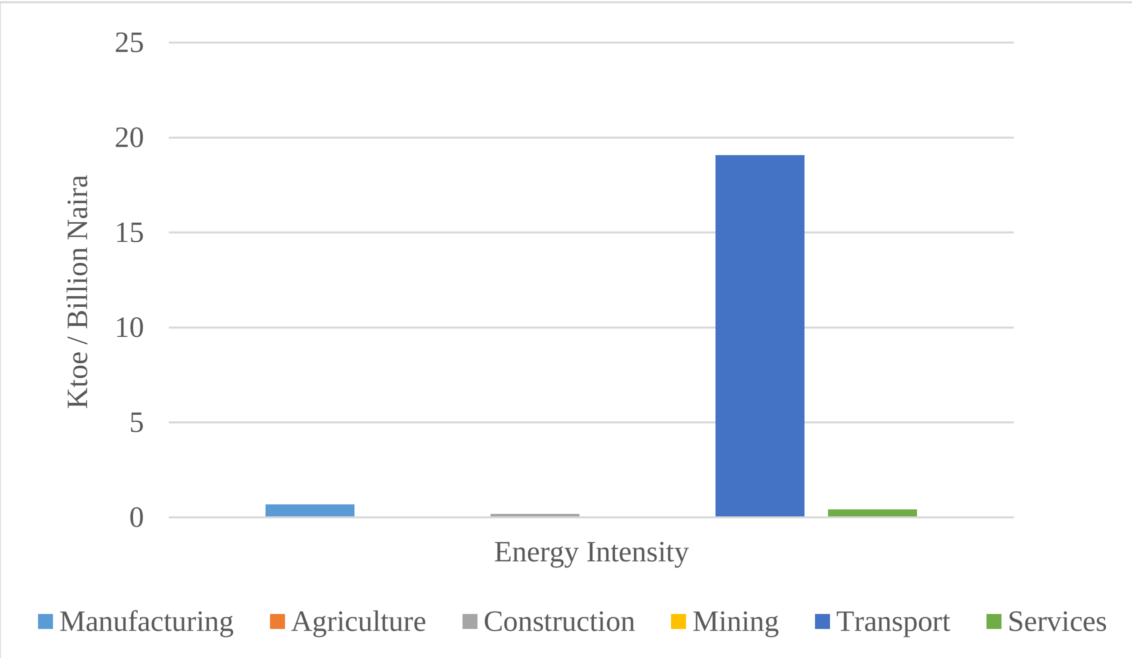

Figure 4.1 Energy Intensity in each sector for the base year 2010
Source: Author

Data from table 4.1 indicates that the transport sector is energy intensive, the most energy intensive of all sectors. The transport sector in Nigeria is highly dependent on the availability of motor fuel (AGO and PMS), hence any shortage in supply of motor fuel to the transport sector greatly impacts negatively on its productivity. With regards to energy transition, the major difference overtime is that within the sector there are now more vehicles with improved fuel economy. One possible way to induce transition within this sector could be with the adoption of biofuels to improve the energy efficiency of this sector.

The next energy intensive sector is the manufacturing sector. The manufacturing sector consumes fuel from the four fuel groups of fossil substitutable, electricity, feedstock and traditional fuel with electricity taking the largest share of the total energy demand in this sector followed by fossil substitutable, feedstock and traditional fuel respectively. The manufacturing sector in Nigeria is rather labour intensive due to the deficient supply of electricity to the sector. There is widespread self-generation within the sector by the use of AGO and NG to generate electricity. Within the sector, demand for fossil substitutable increases usually whenever there is a shortage in any other fuel. For example, the is an increased demand for LPFO to provide heat energy to boilers in some manufacturing companies whenever the supply of natural gas decreases, or in some cases AGO is mixed with other additives like grease and used as gear oil. There is high potential for growth in this sector by scaling up the supply of grid electricity or by exploring self-generation options that could be cost effective depending on the demand of their manufacturing facilities, for example using LPG or CNG could be a better option, also they have the advantage of being cleaner fuels when compared with AGO. For example, in a facility where the typical demand is less than 150KW, CNG is a more effective generator than AGO.

The service sector is next after the manufacturing sector with regards to energy intensity. This sector is actually a combination of several subsectors with vastly different energy intensities. With the prevailing conditions across the other sectors, it is not farfetched to say that this sector likewise suffers from inadequate supply of energy, especially electricity and the sector also compensates for this shortage with self-generation. This sector can as well checkmate the exponential growth of its demand for energy by employing the adoption of energy conservation and increasing the use of energy efficient technologies.

The construction sector cannot be side-lined whether in terms of its contribution to the economy or in terms of energy demand in the sector. The growth of energy demand in this sector is induced by the requirement for expansion in the other sectors hence the demand for energy in the construction sector can be viewed as an externality of what is happening in the other sectors. The overall demand of this sector comes majorly from its demand from AGO. In 2010 the demand for AGO was around 180.989 Ktoe in total, 100.495 Ktoe for use in off-road vehicles and 80.494 Ktoe (around 93.05 Million litres) for self-generation of electricity. A considerable amount of HHK was likewise consumed as fossil substitutable.

The Agriculture sector in Nigeria is highly labour intensive. The lack of use of agriculture machineries (especially for crop production) or the non-adoption of advanced technology overall in the agriculture sector to increase production is the reason this sector's energy intensity is rather very low.

The mining sector in Nigeria sees very little in terms activity and given the condition prevalent in the other sectors, it is likewise labour intensive hence the very low energy intensity. It is unsure whether or not this activity level will considerably increase in the foreseeable future as the exploration of crude oil (the major mining activity) has been on a decline since the base year 2010 with renewed government efforts to shift the economy from an oil based one.

The demand for energy in the household sector is by far the highest in 2010 in Nigeria (at 76.53%) most of the demand comes from the widespread consumption of traditional biomass for cooking and heating purposes. This poses a big challenge not only to the eradication of energy poverty in Nigeria but also to the mitigation of climate change due to deforestation. In 2010, the final demand in the household sector was 88, 115.31 Ktoe of which 80,102.707 Ktoe came from the demand for fuelwood and charcoal alone, this is equivalent to about 30 times the total energy demand by the manufacturing, construction, mining and agriculture sectors put together. To put things in perspective, in the year 2010, the final demand for energy in Algeria, Cameroun, Ghana, Kenya and Zimbabwe was 40,086.68 Ktoe, 6,779.14 Ktoe, 7,406.95 Ktoe, 19,519.63 Ktoe and 9,458.95 Ktoe respectively to give a total of 83, 251.34 Ktoe and in the same year in the Nigerian household sector the demand for traditional fuel for the purpose of cooking and water heating alone was 82, 803.67 Ktoe.

Have in mind that in Nigeria, supply almost always fall short of demand and consumers across all sectors have to employ different forms of demand side management (albeit unconventional most of the time) to ensure that their needs are met given what little resources they have at their disposal. Table 4.6 Shows how much petroleum product was supplied, it can be noticed that most of the time, due to the inadequate capacities of the local refineries, there is need to import in a bid to meet demand.

With regards to grid electricity, it has already been established that what is being generated falls short of demand and across all sectors there is the widespread self-generation of electricity in attempt to meet their demand, table 4.7 shows in detail how much electricity was generated by individual generation plants in Nigeria. Most of these plants generate electricity using NG which is an abundant resource in Nigeria. There is much that can be done to further utilise the abundant NG resource in Nigeria for the purpose of electricity generation given that in the same year 2010, 19.32% and 26.66% of total gas produced was flared and re-injected respectively and a considerable amount of LNG was exported for sales.

Given this available resource of NG, there is huge potential for the utilization of NG for the generation of electricity. Within the power sector there exists huge irregularities inherent in the transmission and distribution channels that have severed as a deterrent to the expansion of the generation capacity in Nigeria. These irregularities come in the form of Aggregate Technical, Commercial and Collection losses (ATC&C losses).

Technical losses represent all losses incurred as a result of inefficiencies inherent in the physical equipment that are used in the transmission and distribution of electricity, Commercial losses on other hand arise when billing is not optimal, that is, the billing process fails to adequately account for all electricity that has been consumed by billable consumers (this arises as a result of inadequate metering of electricity consuming facilities), while Collection losses occur due to the failure of utilities to collect revenue in consonance with billed quantities, in this case, some consumers are overbilled as a way of recuperating the loses from inadequate metering. The types of energy loss described above are not abnormal but it becomes tricky when values recorded are above prescribed thresholds. The baseline ATC&C loses differs from one electricity distribution company to another but the average is around 40%.

The question in the mind of a non-expert can be; why have meters (and in this case, prepaid meters are the option of choice in the Nigerian electricity market) not been provided to solve this twin challenge of commercial and collection loses? The solution of providing meters may look simple but the question of who foots the cost of the meters has been a bone of contention since the privatisation of the power sector. Distribution companies are not willing to cater for the cost of the meters and on the consumers' side, there is also a big challenge; a good number of consumers live in rented apartments, apartment owners are not always eager to foot the cost of purchasing an electricity meter and since meters are not movable a consumer who is living in a rented apartment will most likely not opt for the option of buying the meter.

All these make dealing with the web of challenges in the power sector quite complex.

TABLE 4.2 : ENERGY DEMAND IN THE INDUSTRY SECTOR FOR THE BASE YEAR 2010 (Ktoe)

FOSSIL SUBSTITUTABLE

Sector		Fossil (Substitutable)						
		AGO	HHK	LPG	Acetylene	LPFO	Coal	TOTAL FOSSIL
Industry	Manufacturing	20.1190	0.5487	4.9803	0.5200	152.1951	0.0039	**178.3675**
	Agriculture	-	50.1443	-	-	-	-	**50.1443**
	Construction	-	61.2862	-	0.0338	-	-	**61.3200**
	Mining	-	-	3.7687	0.0194	-	-	**3.7881**

ELECTRICITY AND FEEDSTOCK

Sector		Electricity Generation				Feedstock		
		Captive		Grid	TOTAL ELECTRICITY	NG	LPG	TOTAL FEEDSTOCK
		AGO	NG					
Industry	Manufacturing	1,147.2322	178.9352	457.4188	**1,783.5862**	29.8200	0.6727	**30.4927**
	Agriculture	1.0697	-	0.3426	**1.4123**	**-**	-	-
	Construction	80.4944	-	25.7803	**106.2747**	**-**	-	-
	Mining	2.4430	-	0.7824	**3.2254**	**-**	-	-

TRADITIONAL FUEL AND MOTOR FUEL

Sector		Traditional Fuel			Motor Fuel	
		Fuel Wood	Charcoal	TOTAL TRADITIONAL FUEL	AGO	TOTAL MOTOR FUEL
Industry	Manufacturing	312.2678	102.2234	**414.4912**	-	-
	Agriculture	-	-	**-**	14.4280	**14.4280**
	Construction	-	-	**-**	100.4948	**100.4948**
	Mining	-	-	**-**	3.1654	**3.1654**

Source: Author

TABLE 4.3 : ENERGY DEMAND IN THE SERVICE SECTOR FOR THE BASE YEAR 2010 (Ktoe)									
		Fossil Fuels			**Electricity (Grid and Captive)**	**Solar**	**Traditional Fuel**		**GRAND TOTAL**
		AGO	**HHK**	**LPG**		**PV**	**Fuelwood**	**Charcoal**	
Heating		63.244	-	-	-	-	-	-	63.244
Cooking		-	178.739	11.844	13.577	-	7,879.439	1,056.309	9,144.458
Water Heating		-			4.549	-			
Lighting		-	45.686	-	853.875	1.100	-	-	900.662
Appliances	Electrical Appliances	-	-	-	263.229	0.430	-	-	927.274
	Air conditioners	-	-	-	663.616	-	-	-	
Total		**304.7759**			**1,798.847**	**1.530**	**8,935.748**		**11,035.638**

Source: Author

TABLE 4.4 : ENERGY DEMAND IN THE HOUSEHOLD SECTOR FOR THE BASE YEAR 2010 (Ktoe)										
		Fossil Fuels		**Electricity (Grid and Captive)**	**Solar**	**Traditional Fuel**				**GRAND TOTAL**
		HHK	**LPG**		**PV**	**Fuelwood**	**Charcoal**	**Agriculture residue**	**Animal Waste**	
Space Heating		-	-	34.805	-	-	139.897	-	-	**174.703**
Cooking		856.6401	113.329	71.941	-	77,853.791	2,109.018	2,181.627	519.333	**84,320.832**
Water Heating				615.151	-					
Lighting		1,047.005	-	1,309.541	0.0100	-	-	-	-	**2,356.556**
Appliances	Electrical Appliances	-	-	701.137	0.2600	-	-	-	-	**1,263.220**
	Air conditioners	-	-	561.823	-	-	-	-	-	
Total		**2,067.3307**		**3294.398**	**0.270**	**82,803.667**				**88,115.311**

Source: Author

TABLE 4.5 : ENERGY DEMAND IN THE TRANSPORT SECTOR FOR THE BASE YEAR 2010 (Ktoe)					
	Mode of Transport	**Specific Means of Transport**	**Energy Demand**	***Specific Motor Fuel Type***	**Total Energy Intensity**
Intracity Transportation	Road	Car	2,543.57	*PMS*	**4,726.72**
		Motorbikes	984.01	*PMS*	
		Large Buses	78.02	*AGO*	
		Medium Buses	276.92	*AGO*	
		Mini Buses	844.20	*PMS*	
Intercity Transportation	Road	Cars	3768.23	*PMS*	**6,415.11**
		Motorbikes	0.00	*PMS*	
		Large Buses	240.70	*AGO*	
		Mini Vans	557.85	*PMS*	
		Mini Buses	1380.25	*PMS*	
	Rail	Train	0.18	*AGO*	
	Air	Airplane	467.91	*ATK*	
Freight Transportation	Long Distance Truck	Trailers	201.29	*AGO*	**2,093.82**
		Big Trucks and Lorries	407.57	*AGO*	
		Fuel Tankers	293.78	*AGO*	
		Small Trucks and Pickups	276.39	*AGO*	
		Water Tankers	3.31	*AGO*	
		Tippers	38.04	*AGO*	
	Short Distance Truck	Pickups	798.21	*PMS*	
		Vans	74.67	*PMS*	
	Rail	Train	0.55	*AGO*	

Source: Author

TABLE 4.6 : SUMMARY OF PETROLEUM PRODUCTS SUPPLY IN NIGERIA FOR THE BASE YEAR 2010				
Fuel	**Imported**	**Produced**	**Total**	**TOTAL (Ktoe)**
PMS	15,961.28 ML	1,148.80 ML	17,110.08 ML	**13,688.75**
AGO	3,032.56 ML	1,299.07 ML	4,331.62 ML	**3,747.03**
HHK	1,863.07 ML	829.06 ML	2,692.13 ML	**2,239.58**
LPFO	179.05 ML	-	179.05 ML	**152.20**
ATK	454,277.28 MT	-	454,277.28 MT	**467.91**
LPG	-	124,625.21 MT	124,625.21 MT	**134.60**

Source: 2016 Oil and Gas Annual Report (Department of Petroleum Resources, 2016)

TABLE 4.7 : ELECTRICITY SUPPLY STATISTICS FOR THE BASE YEAR 2010					
Power Station	**1st Quarter**	**2nd Quarter**	**3rd Quarter**	**4th Quarter**	**TOTAL**
	MWh	**MWh**	**MWh**	**MWh**	**MWh**
Geregu Power Plc	106,398.00	276,270.00	132,235.00	187,061.00	**701,964.00**
Afam Power Plc (General Company)	55,262	-	-	40,685.40	**95,947.40**
AES Power	110,472.93	131,434.80	135,355.20	120,361.27	**497,624.20**
NAOC JV IPP	289,240.78	235,142.20	292,273.91	236,238.68	**1,052,895.57**
Omotosho Electric Energy Company Ltd	32,806.67	48,639.00	31,660.00	16,410.00	**129,515.67**
Mainstream Energy Solutions Ltd	5,717,100.00	5,828,129.00	9,579,453.00	9,310,433.00	**30,435,115.00**
					32,913,061.84

Source: Electricity supply statistics 2010-2014 (National Bureau of Statistics, 2015)

4.2 Analysis of Energy Demand and Supply from 2010 – 2017

Energy demand globally is heavily influenced by demography (those consuming the energy), economy (what they use it for) and by technology (how energy is being converted from one form to another, for productive use).

With respect to demography, the population of Nigeria (as sourced from the National Bureau of Statistics) has been growing at a steady rate of about 3.2% from 2011 to 2015, it is expected that in the absence of any force majeure, this growth rate will be sustained from 2015 up to the end of the study period, that is, up to 2030. Figure 4.2 shows how the population of Nigeria has increased from the base year 2010 to the present day 2017.

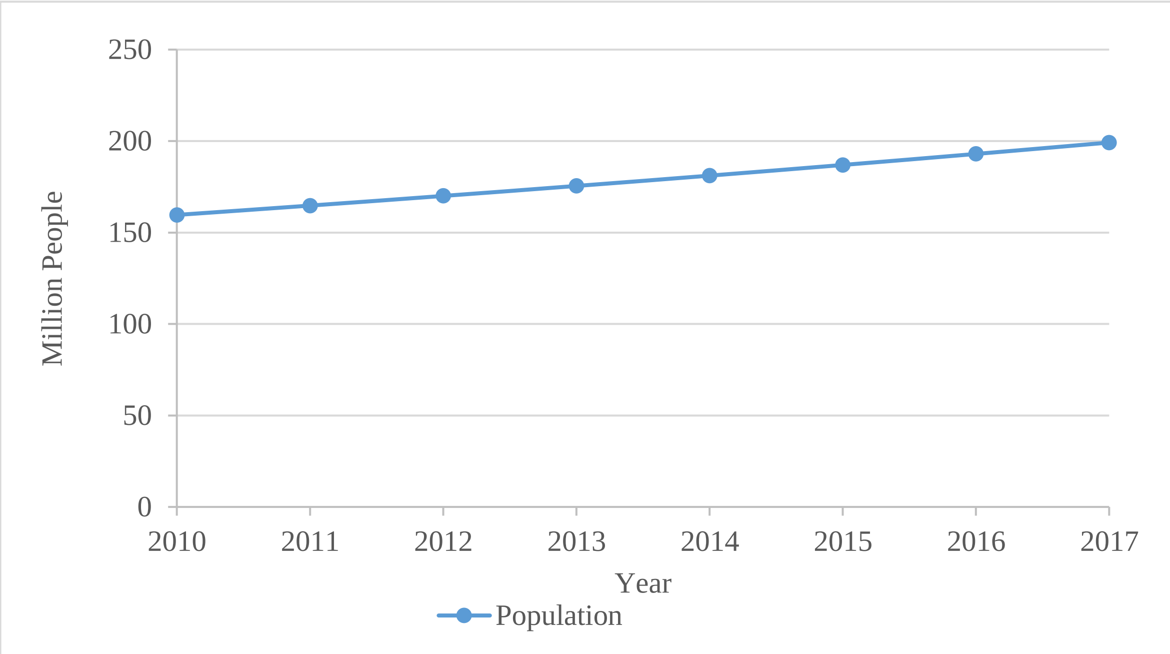

Figure 4.2 Nigeria population 2010 – 2017

Source: 2011 – 2015 data sourced from the National Bureau of Statistics, 2016. Other years calculated using the average growth rate within this period

TABLE 4.8 : NIGERIAN POPULATION (MILLION PEOPLE)								
Year	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Population	159.62	164.73	170.01	175.46	181.11	186.94	192.97	199.19

Source: 2011 – 2015 data sourced from the National Bureau of Statistics, 2016. Other years calculated using the average growth rate within this period

The Nigerian economy unfortunately did not enjoy such good fortune of a steady and stable growth since its rebasing in 2010. From the data obtained from the National Bureau of Statistics, positive GDP growth rates were recorded from 2010 up to the end of year 2015, by the year 2016 the economy had gone into recession. This was due to the global fall in price of crude oil; the Nigerian economy is largely reliant on crude oil as the main product of export from the country and the largest contributor to its foreign earnings. The figure below shows how the economy has changed from 2010 to 2017 and what impact it had on the GDP/capita.

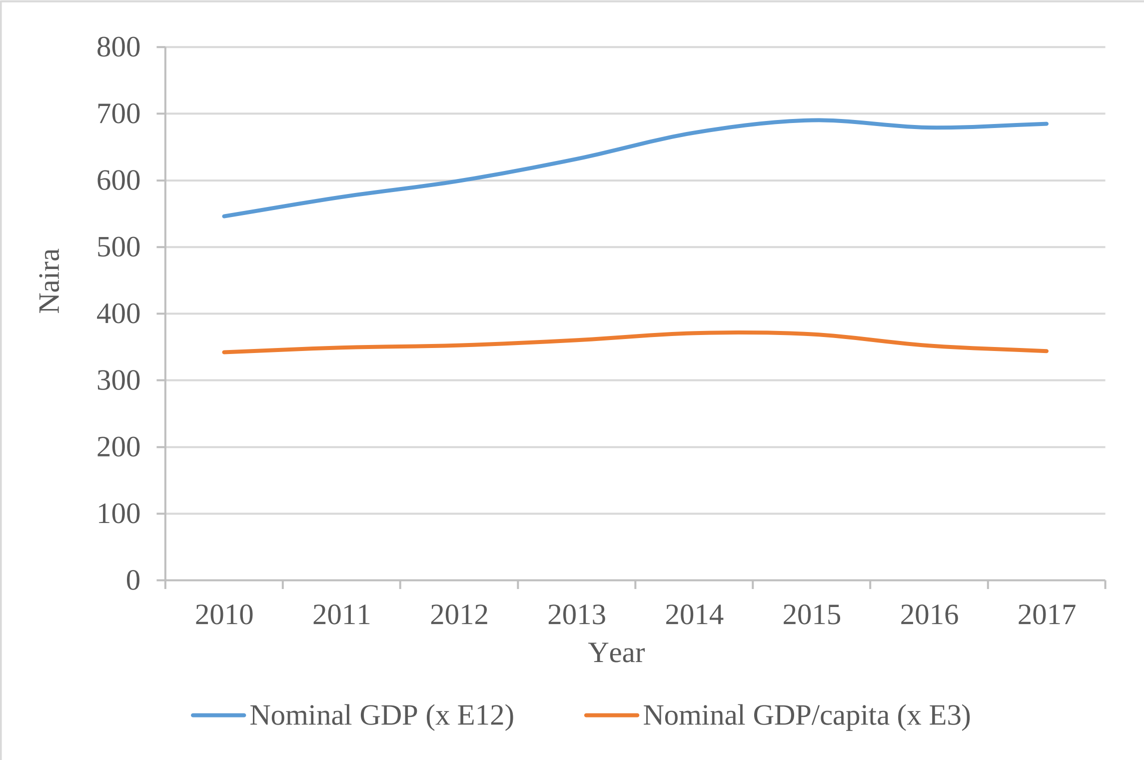

Figure 4.3 Nominal GDP and GDP/capita data of Nigeria (2010 – 2017)
Source: National Bureau of Statistics

Moving on, it is paramount to inspect what transpired within each sector, how the two main influencers that were mentioned above have affected the demand for energy and the implication with regards to energy transition within the context of sustainable development.

4.2.1 Manufacturing Sector

Before the recession of 2015 this sector saw a steady increase in its demand for energy, this was as a result of the double digit growth recorded within this sector between 2010 and 2014 in terms of GDP. As the demand for energy within this sector increased, the sector experienced some transitioning as more energy efficient technologies were adopted, indicated in the energy intensity that gradually declined.

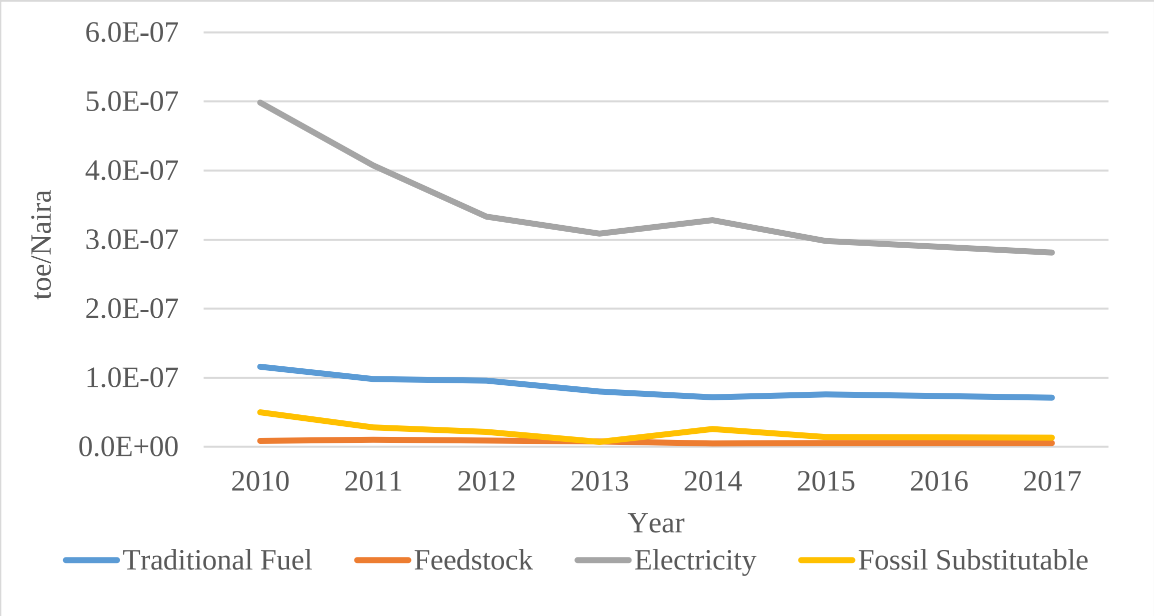

Figure 4.4a Energy Intensity in the Manufacturing Sector (2010 – 2017)
Source: Author

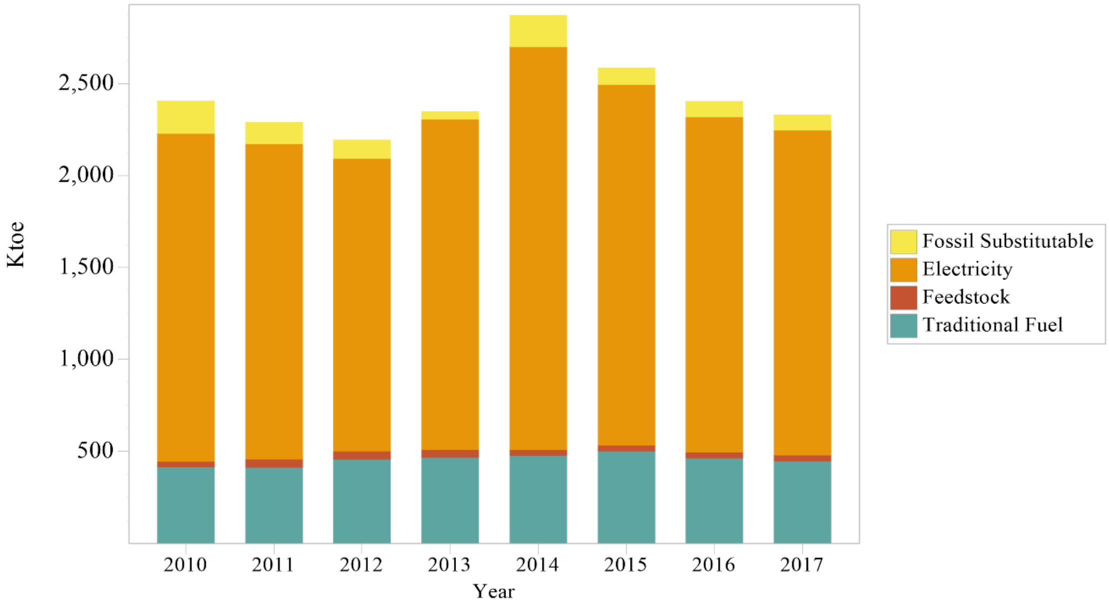

Figure 4.4b Energy demand in the Manufacturing Sector (2010-2017)
Source: Author

4.2.2 Agriculture Sector

The agriculture sector is quite resilient, it continued to grow in spite of the economic recession of 2015-2017 and consequently influenced the demand for energy within the sector. The energy intensity of this sector also generally saw a decrease, probably signifying an increase in the overall efficiency in this sector but overall the demand for energy demand rose from the period between 2010 and 2017.

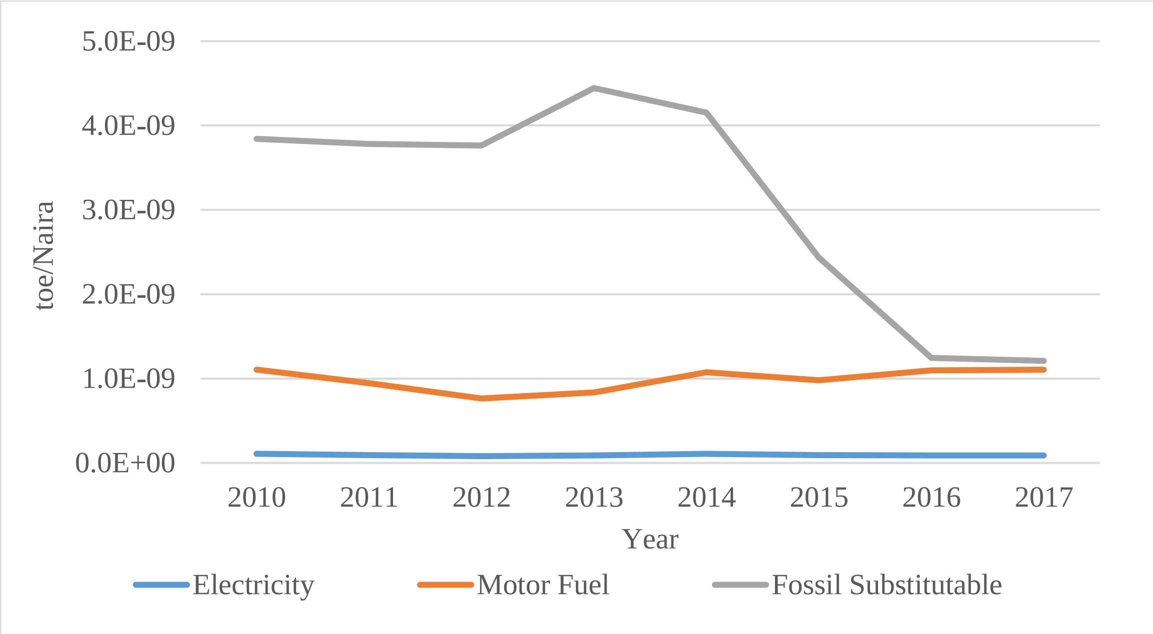

Figure 4.5a Energy Intensity in the Agriculture Sector (2010-2017)
Source: Author

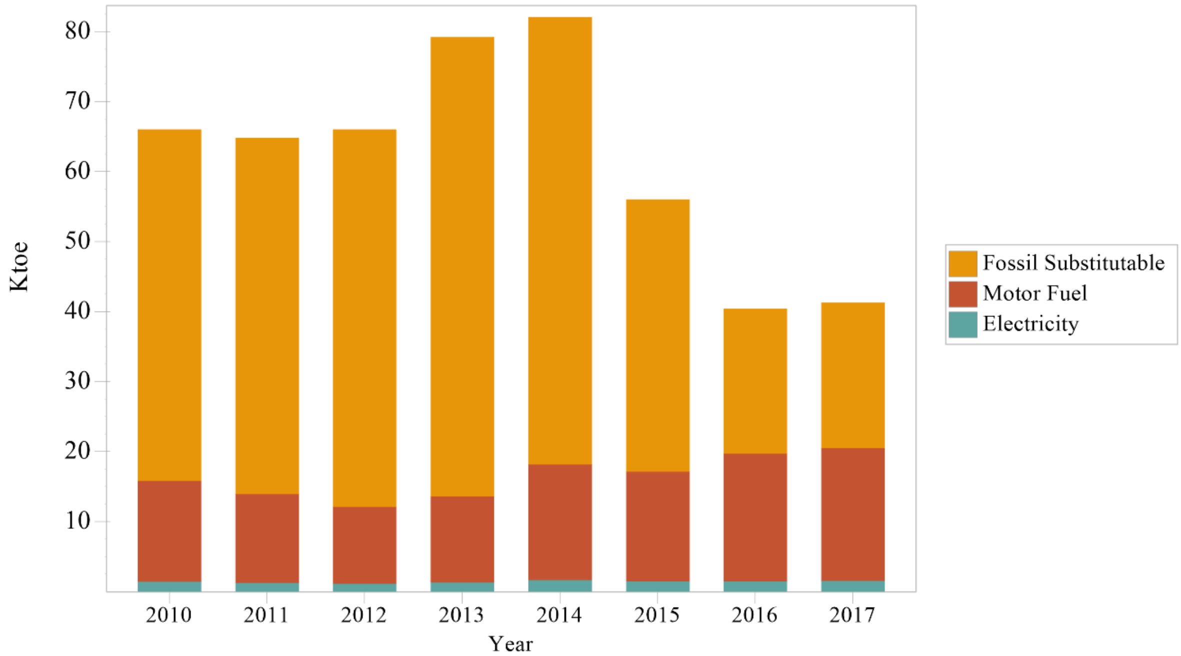

Figure 4.5b Energy Demand in the Agriculture Sector (2010-2017)
Source: Author

4.2.3 Construction Sector

The construction sector much like the manufacturing sector recorded double digit growth rates from 2010 to 2014, then the recession hit and steadily started to decline in terms of activity. With regards to energy intensity, the sector likewise saw a decline in the annual energy intensity, this means that energy efficiency of the sector improved considerably. The final energy demand in the sector actually declined from 2010 to 2012 and rose steeply due to the increased demand for AGO for use as motor fuel and also for use in the generation of electricity. Generally during the recession, the demand for energy declined.

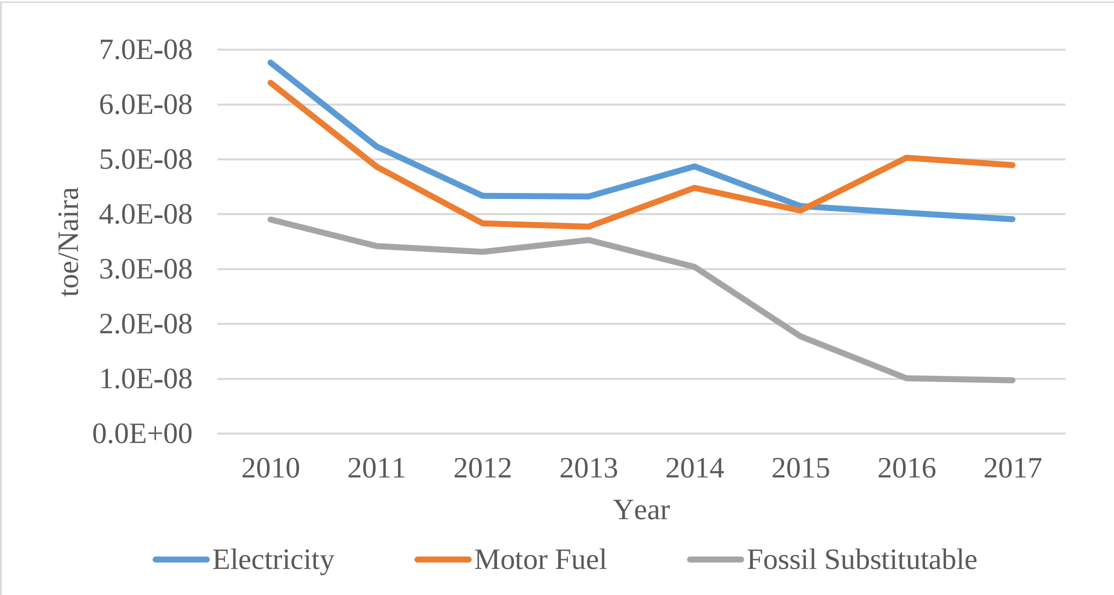

Figure 4.6a Energy Intensity of the Construction Sector (2010-2017)
Source: Author

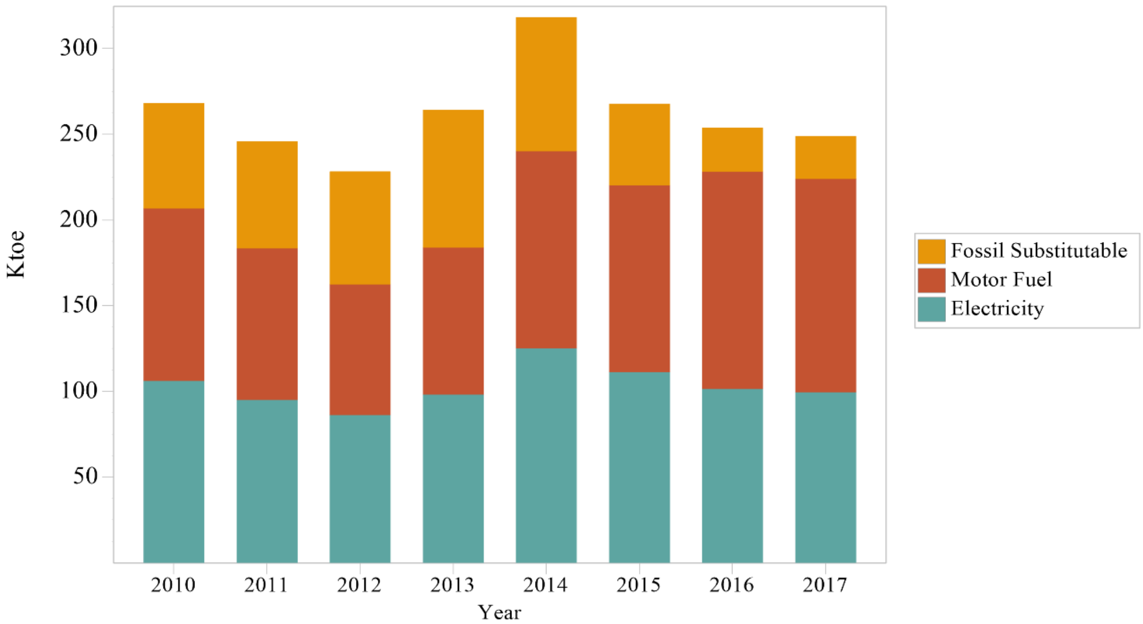

Figure 4.6b Energy demand in the Construction sector (2010-2017)
Source: Author

4.2.4 Mining Sector

The dynamics in the mining sector bears no resemblance to what is happening in the other sectors described above. The overall GDP of this sector has experienced a steady decline since 2010. The reason is largely due to the decline in activity in the main contributor to this sector which is the crude oil and natural gas mining. While other subsectors like coal mining, metal ores mining, quarrying and mining of other minerals are actually growing in terms of GDP, that of crude oil mining is rather decreasing. The reason for this decline can be attributed to government policies targeted at diversifying the Nigeria economy away from its over reliance on crude oil.

The overall energy demand of this sector also increased considerably as shown in figure 4.7b this increase came as a result of the increased demand for fossil substitutable, that is LPG and acetylene in the mining sector.

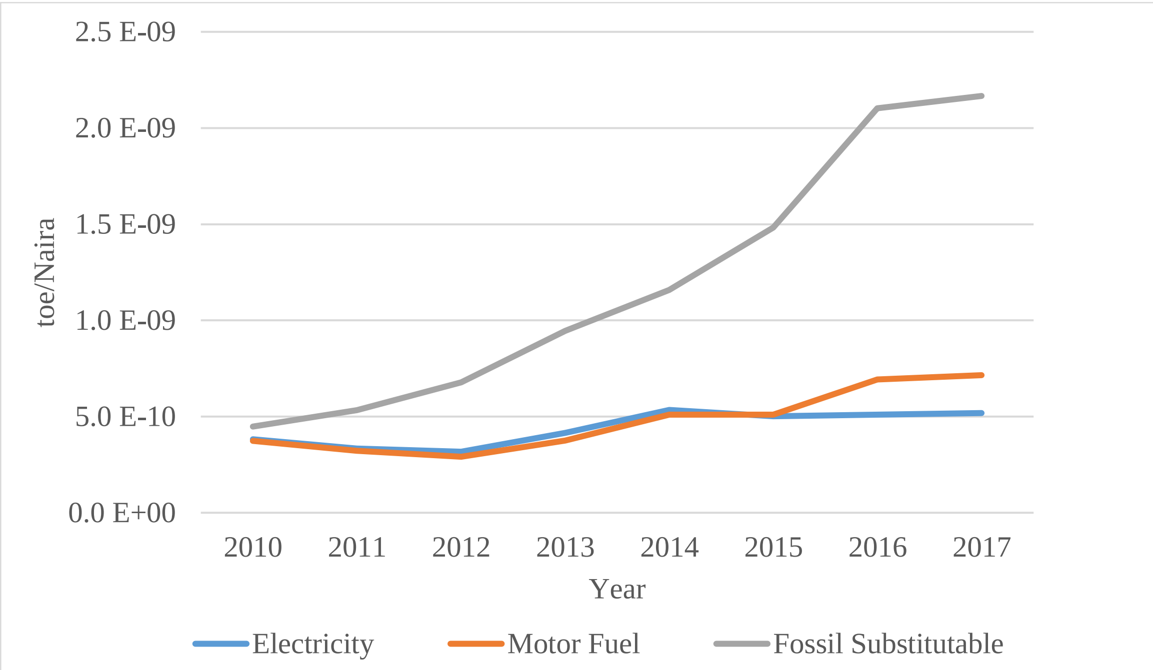

Figure 4.7a Energy Intensity in the Mining Sector (2010-2017)
Source: Author

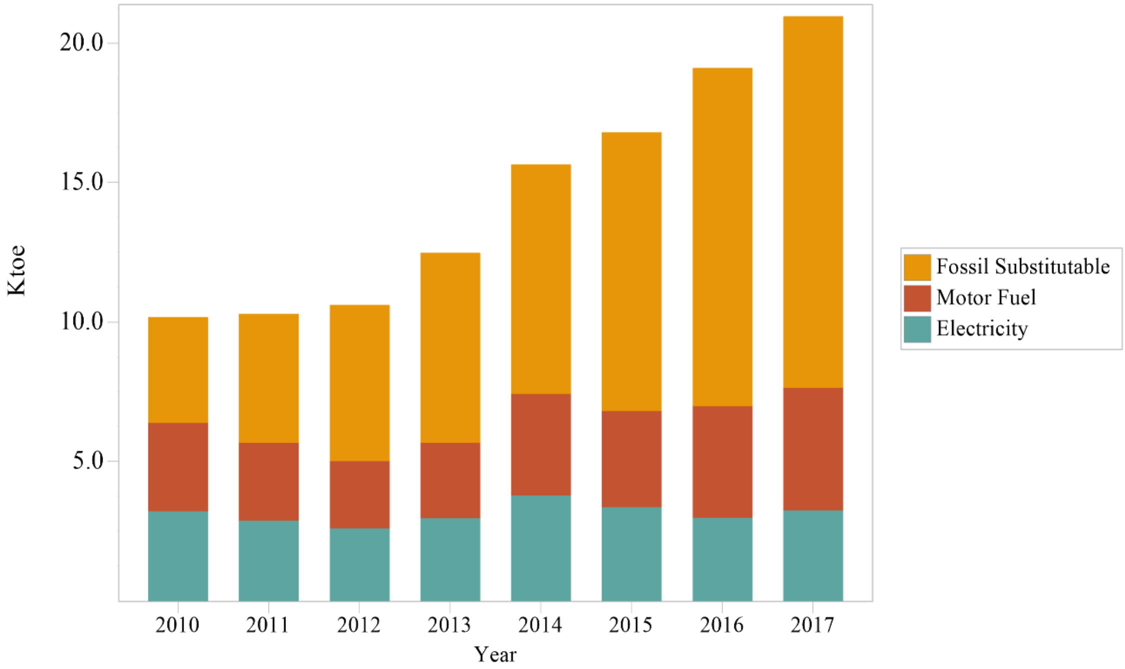

Figure 4.7b Energy demand in the Mining Sector (2010-2017)
Source: Author

4.2.5 Transport Sector

Overall in the transport sector there was increase in the GDP, vehicle activity and passenger activity from 2010 to 2017 and this trend is expected to continue in the coming years. Figures 4.8b to 4.8d presents the energy intensities across the sector, generally there wasn't much change in the energy intensity for road travel but some change was recorded in rail and air travel. All together there was an overall increase in the demand for energy in the transport sector.

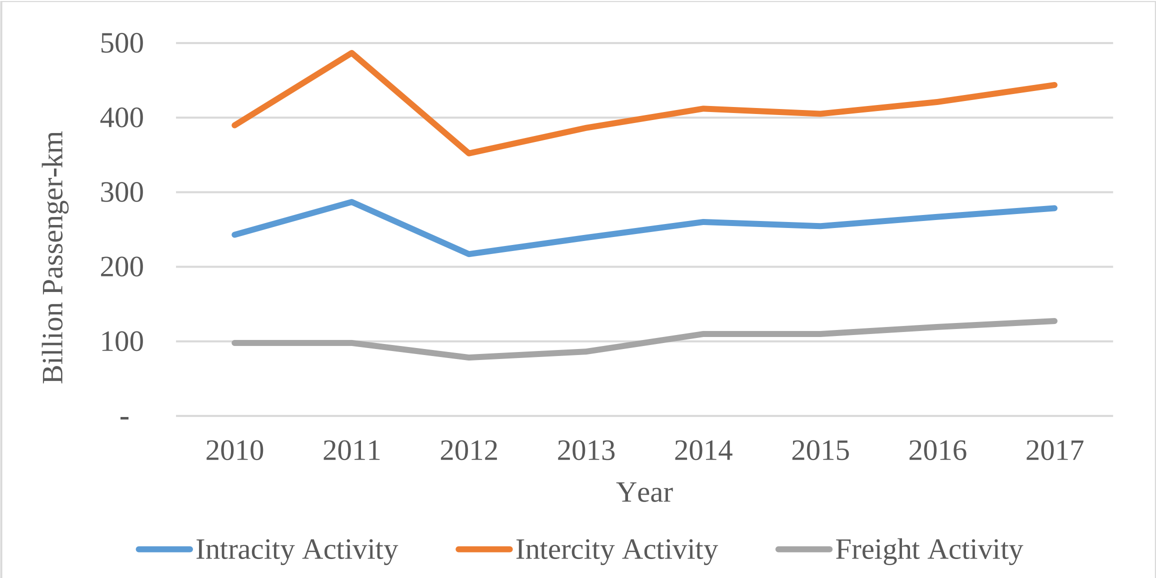

Figure 4.8a Activity in the Transport Sector (2010-2017)
Source: Author

Figure 4.8b Energy Intensity in Intracity Transport (2010-2017)
Source: Author

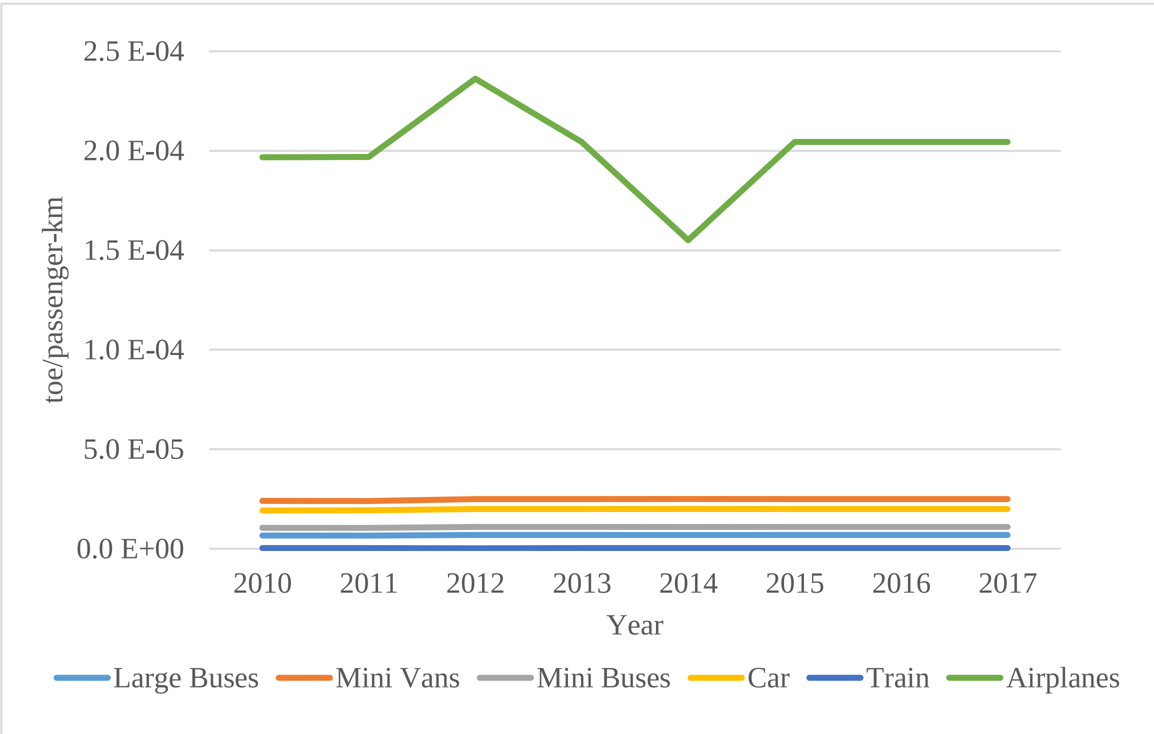

Figure 4.8c Energy Intensity in Intercity Transport (2010-2017)
Source: Author

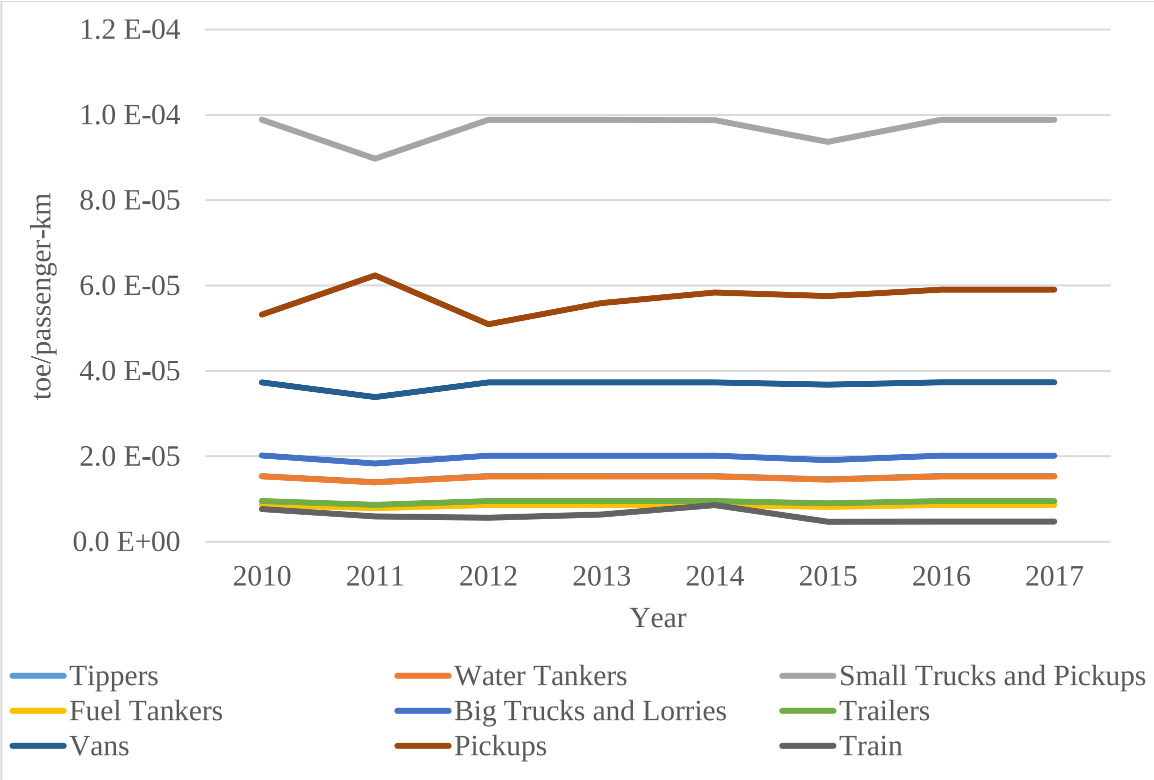

Figure 4.8d Energy Intensity in Freight Transport (2010-2017)
Source: Author

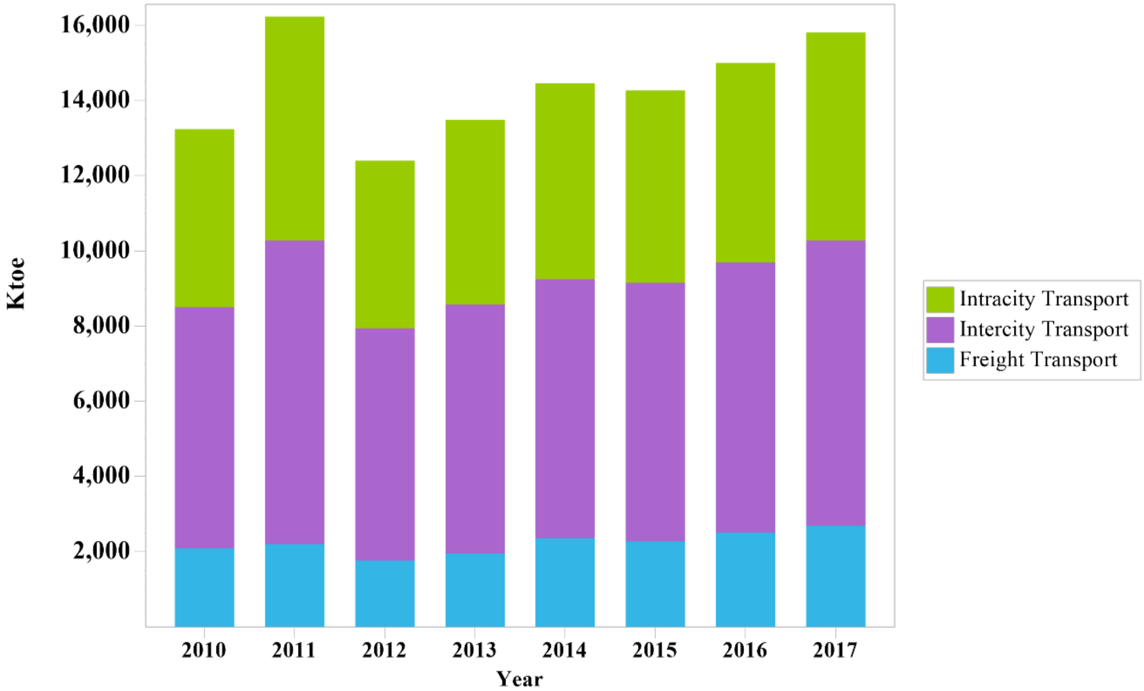

Figure 4.8e Energy Demand in the Transport Sector (2010-2017)
Source: Author

4.2.6 Household Sector

The change in demography has already been recorded in figure 4.2 and the average number of persons per household is held constant at 5.2 persons per household, hence since the population is increasing, the number of households will increase as well. Figure 4.9a shows how the number of households has increased from 2010, due to the increased population of Nigeria.

Figure 4.9b shows the distribution based on the choice of fuel for cooking; as evident the predominant fuel for cooking is fuelwood. Villages and other areas far from cities are well known for the widespread use of fuelwood for cooking and water heating. These areas are not normally the destination of choice for retailers of other fuels due to low demand. Big cities on the other hand have a mix of other types of fuel. The fuel that has maintained a steady course in its penetration of cities is LPG as indicated in Figure 4.9b; in 2010 about 3.13% of Nigerian households used LPG but by 2017 about 9.50% used LPG.

The energy intensity of the technologies used in space heating and the fuels used for cooking and water heating in the household sector didn't change much from 2010 to 2017 but those of lighting and appliances saw considerable improvements. The energy intensity in the lighting reduced largely due to the adoption of energy efficient technologies, the same goes for appliances, the adoption of energy efficient appliances is the reason for the decrease in the energy intensity recorded in figure 4.9d.

The final energy demand in the household sector is shown in figure 4.9e, as shown, the energy demand for cooking and water heating over shadows the demand for the others.

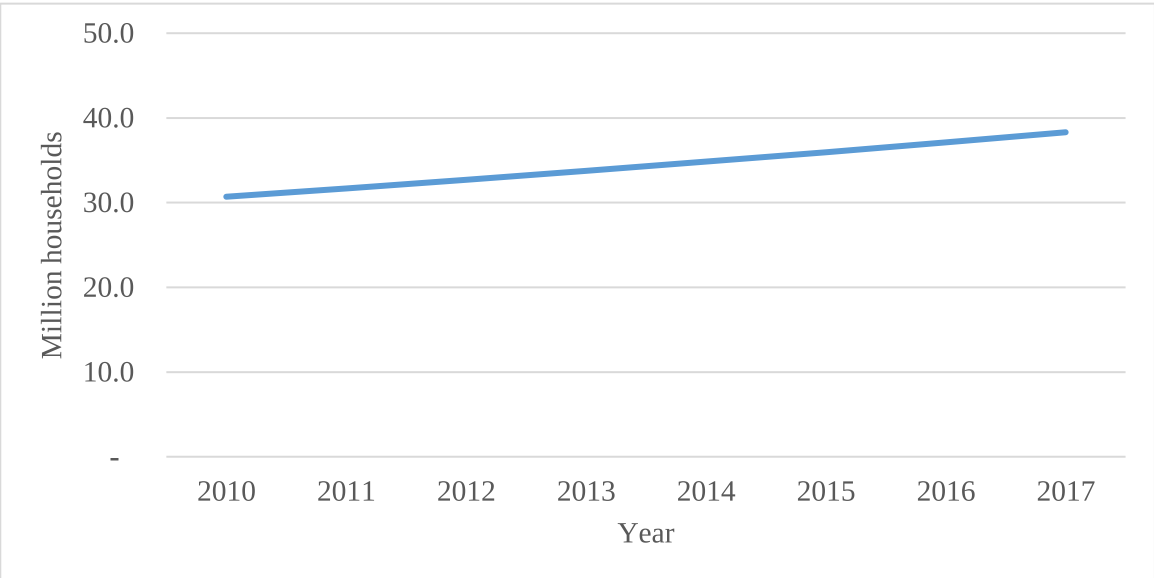

Figure 4.9a Number of households in Nigeria (2010-2017)
Source: Author

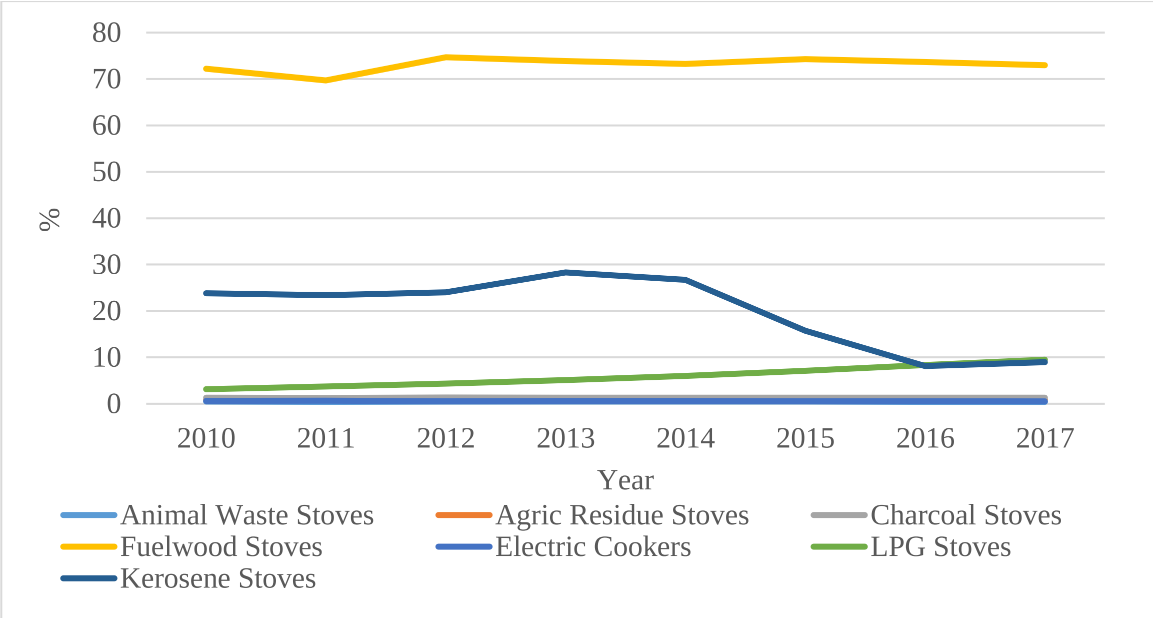

Figure 4.9b Percentage distribution of households based on fuel used for cooking and water heating (2010-2017)
Source: Author

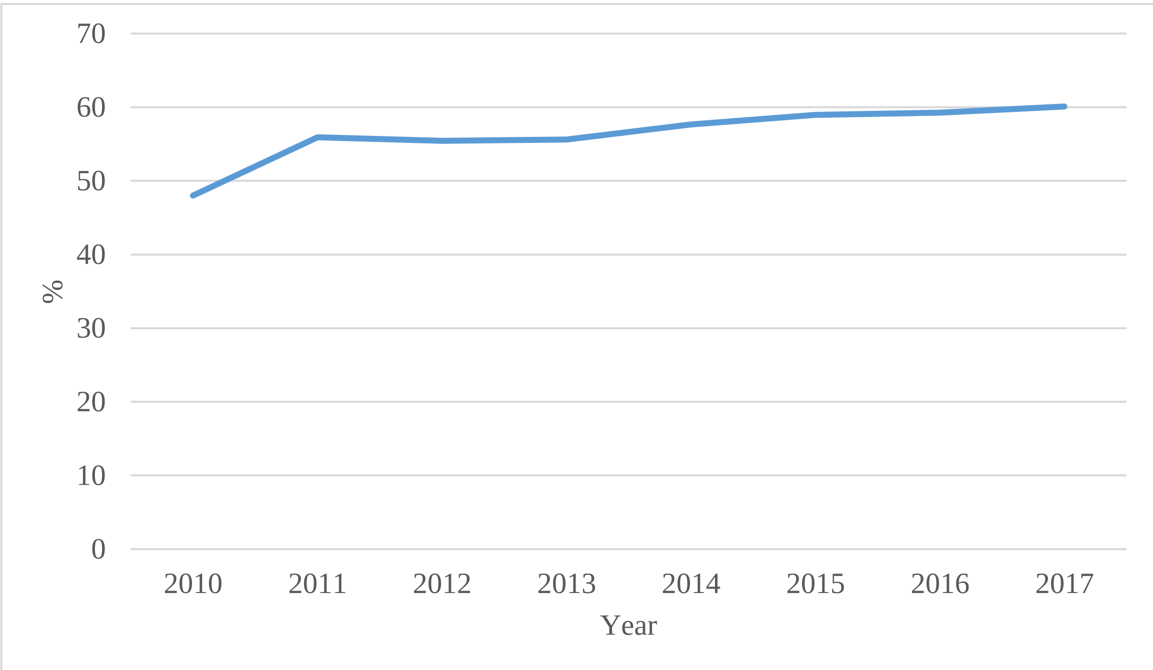

Figure 4.9c Percentage of Nigerian households with access to grid electricity (2010-2017)
Source: Author

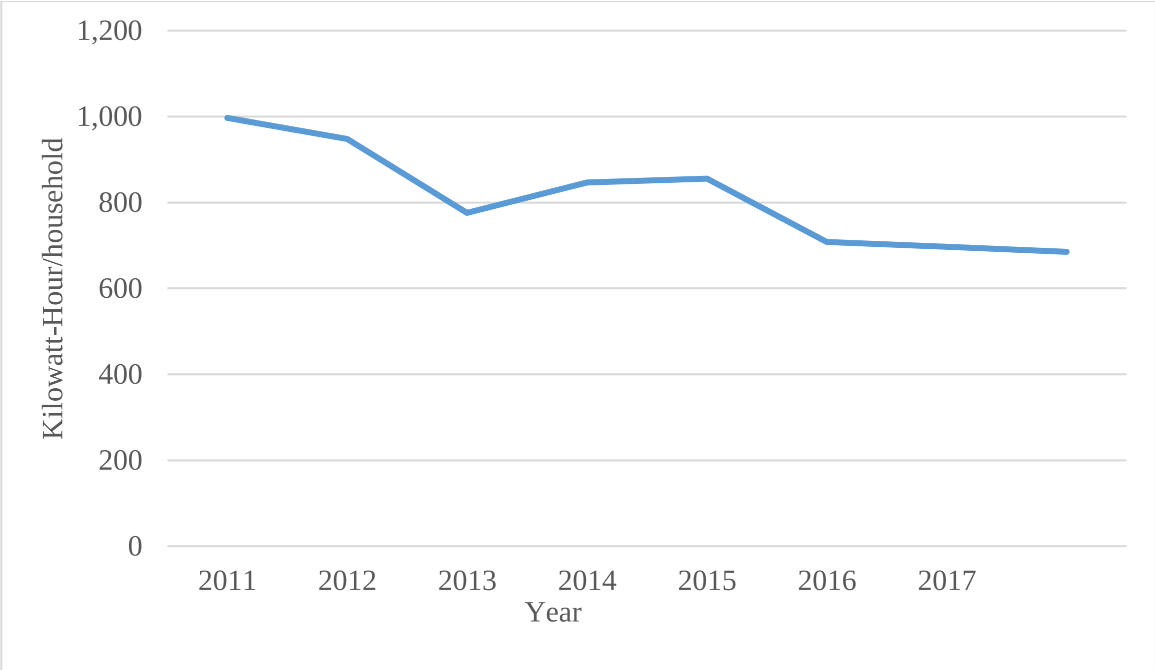

Figure 4.9d Energy Intensity of appliances used in the household sector (2010-2017)
Source: Author

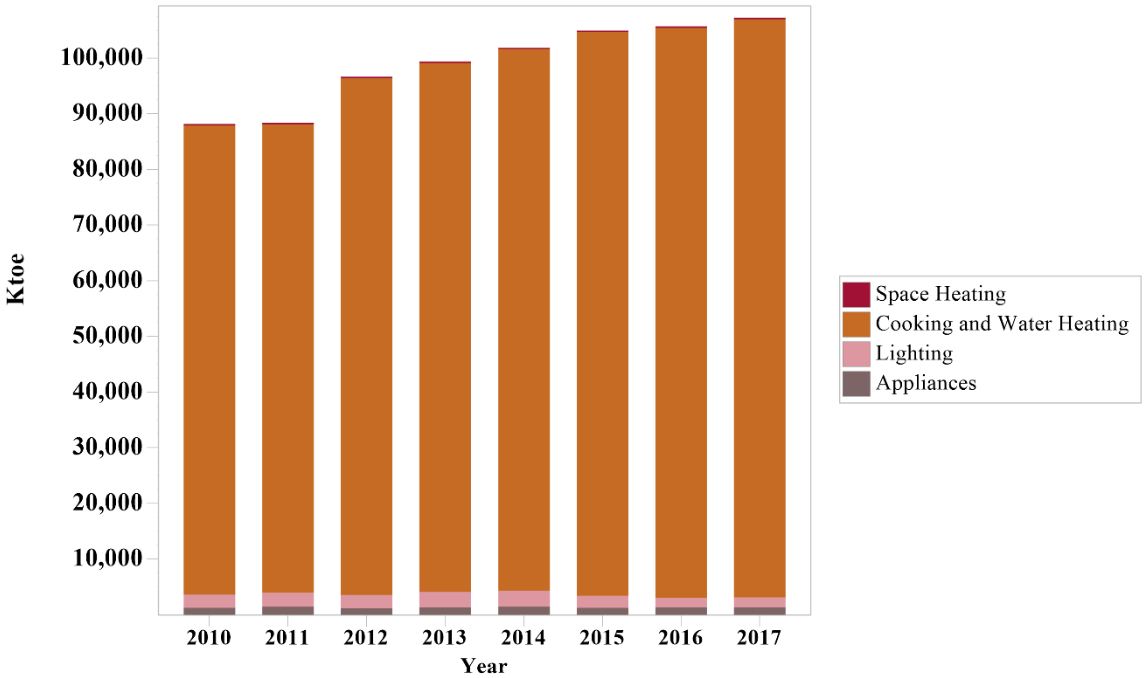

Figure 4.9e Energy demand in the household sector (2010-2017)
Source: Author

4.2.7 Service Sector

The Service sector refers to the combinations of other subsectors as mentioned above. The sector's contribution to the total annual GDP is the highest at about 50% per annum. The overall energy intensity in this sector illustrated in figures 4.10a to 4.10c showed a decline indicating the role energy efficiency has played in this sector. Figure 4.10d shows how the energy demand changed over time from 2010 to 2017.

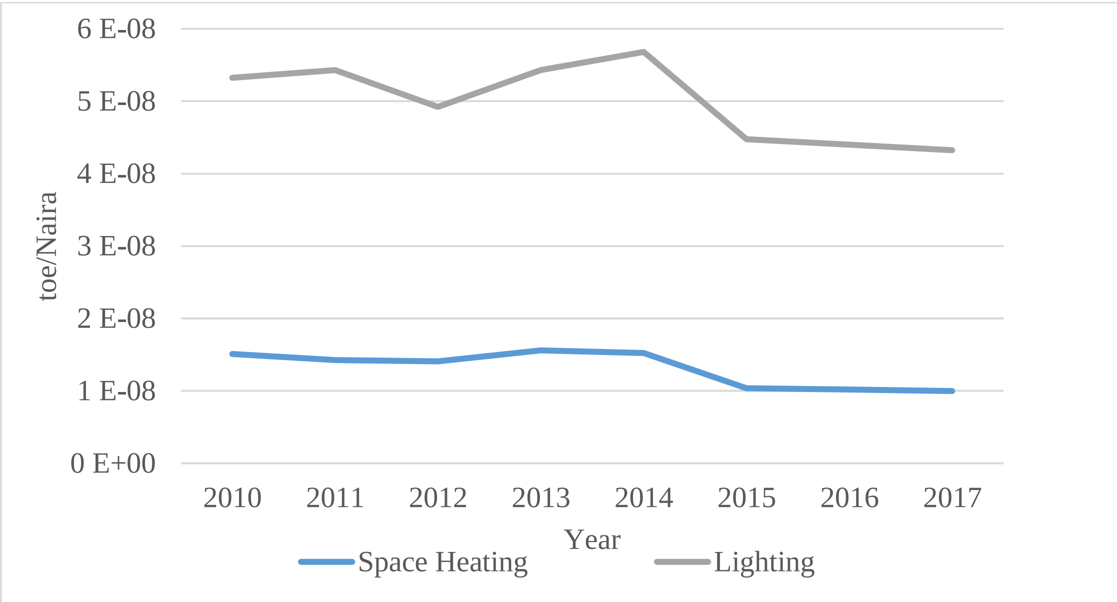

Figure 4.10a Energy Intensity of Space heating and Lighting in the service sector (2010-2017)
Source: Author

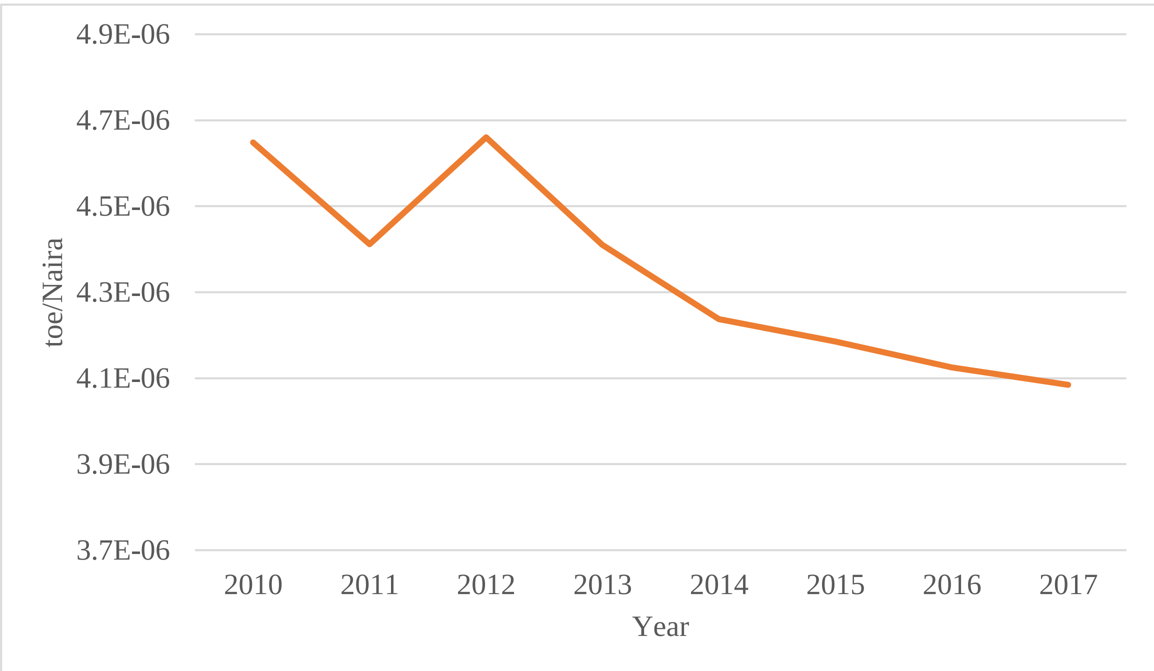

Figure 4.10b Energy Intensity of cooking and water heating in the service sector (2010-2017)
Source: Author

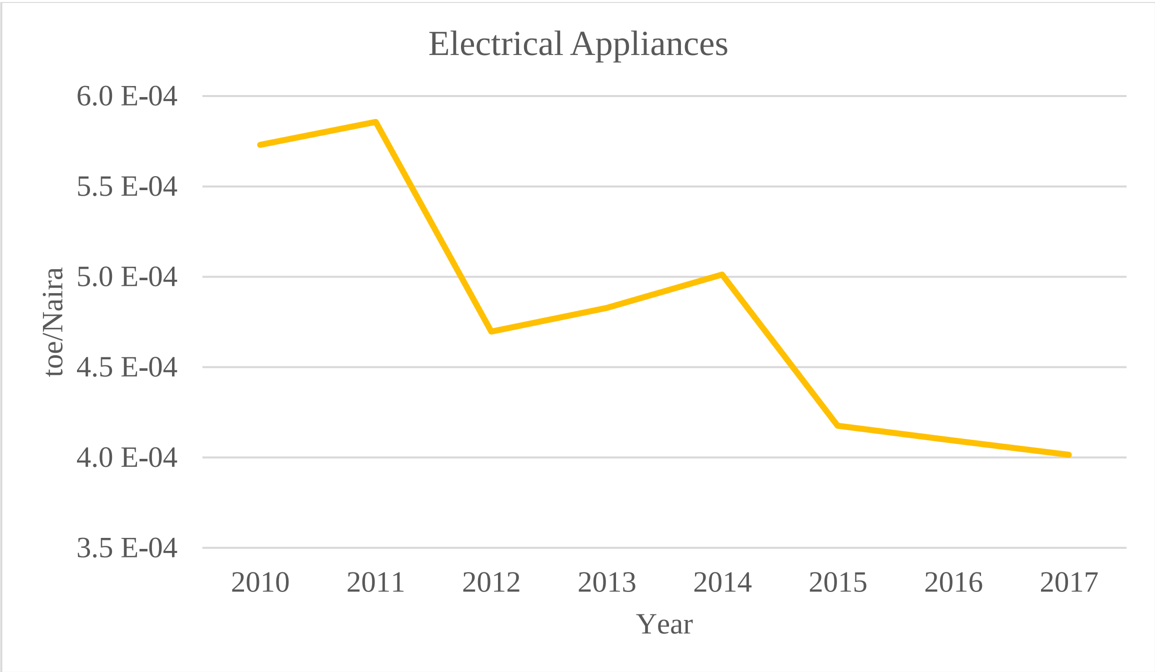

Figure 4.10c Energy Intensity of appliances in the service sector (2010-2017)
Source: Author

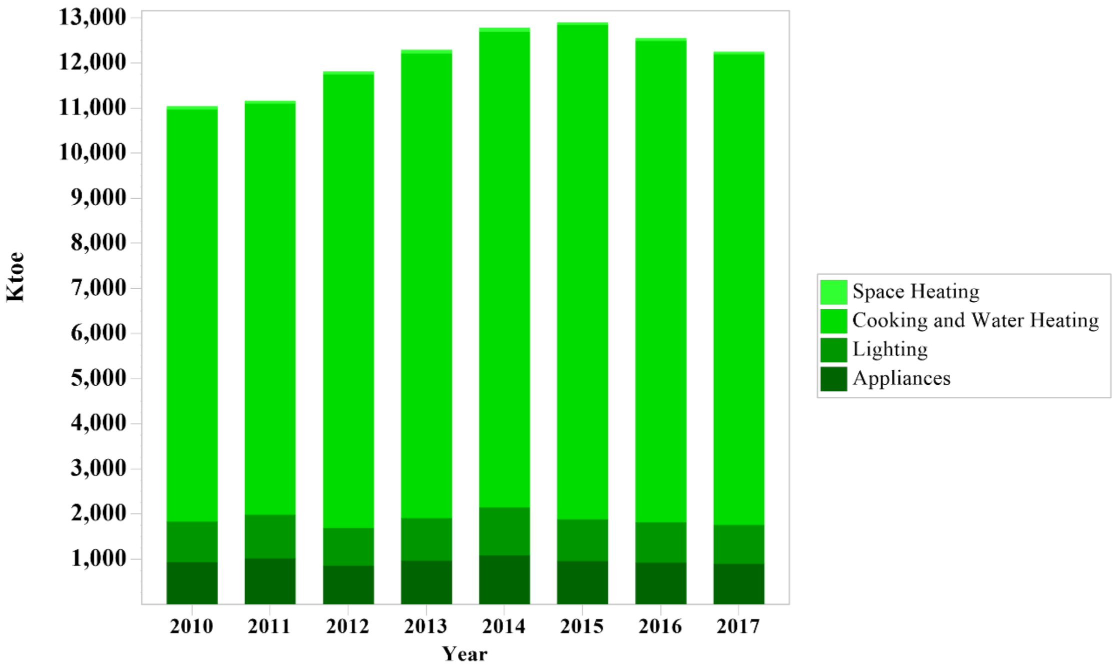

Figure 4.10d Energy demand in the service sector (2010-2017)
Source: Author

4.2.8 Final Energy Demand

As illustrated with the aid of several charts in the previous section of this chapter a lot has changed in the energy demand landscape of Nigeria between 2010 and 2017, GDP has increased and decreased, population has increased, activity level has changed across sectors and energy intensity has changed as well. Most sectors have started embracing energy efficient technologies with varying levels of penetration from one sector or sub-sector to another, others have adopted some form of energy conservation while some have not.

One thing is observable from the preceding charts, the demand side has recorded some change in one form or another in the line of energy transition and sustainable development. Energy efficient technologies have been adopted across sectors and LPG is gradually finding its way into the household sector. Presented in the chart below is the overall energy demand from 2010 to 2017 in Ktoe.

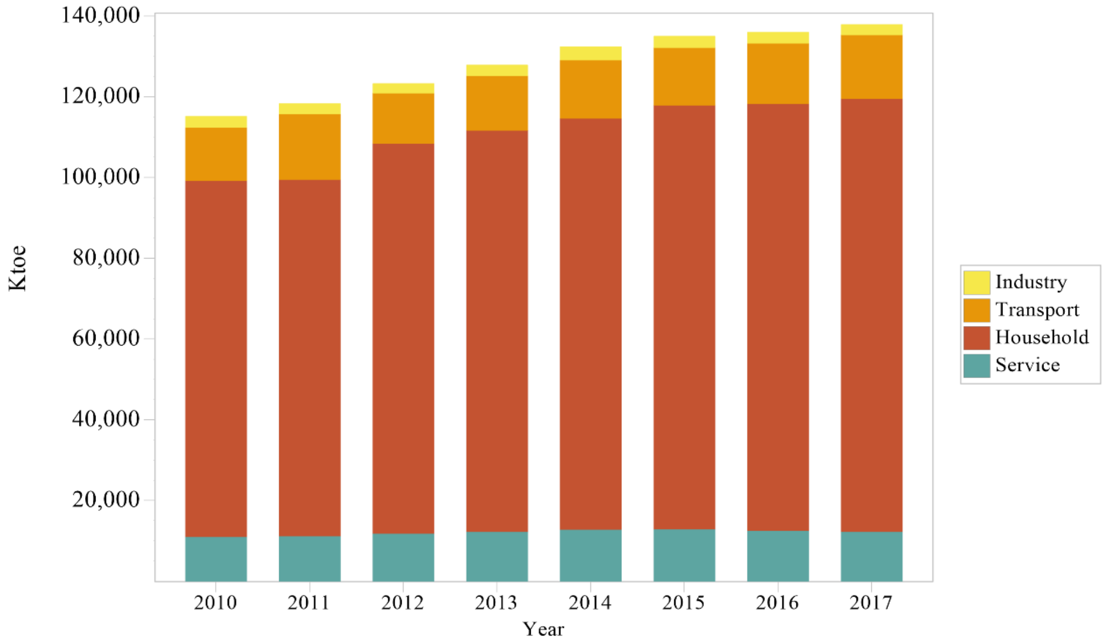

Figure 4.11 Final energy demand in Nigeria (2010-2017)
Source: Author

TABLE 4.9 : DEMOGRAPHIC, ECONOMETRIC AND ENERGY DATA OF NIGERIA (2010-2017)				
Year	**Population *(People)***	**GDP (Nominal) *(Billion ₦)***	**GDP/capita *(₦)***	**Energy Demand *(Ktoe)***
2010	159,619,228	54,612.26	342,140.89	115,137.78
2011	164,728,579	57,511.04	349,126.07	118,324.58
2012	170,006,980	59,929.89	352,514.31	123,308.58
2013	175,463,716	63,218.72	360,295.13	127,844.97
2014	181,105,578	67,152.78	370,793.58	132,365.16
2015	186,939,754	69,023.92	369,230.88	135,032.17
2016	192,909,115	67,931.23	352,031.30	136,951.49
2017	199,101,497	68,490.98	343,841.72	139,556.34

Source: Author

4.2.9 Energy Supply in Nigeria

The supply of energy in Nigeria can broadly be classified into the supply of; petroleum products, electricity and traditional biomass. Petroleum products refer to PMS, AGO, DPK, ATK, LPFO and LPG, electricity refers to grid electricity generated from natural gas power plants and from hydro power plants and traditional biomass refer to fuelwood, charcoal, agriculture residue and animal waste.

On the supply side there has not been much change. Supply still comes from the 3 classes listed above and traditional biomass is still the main fuel that is supplied. The supply of LPG has gradually risen and could possibly increase in the coming years. Within the context of sustainable development, Nigeria hopes in the near future to add to its local refining capacity to reduce importation of petroleum products. Electricity generation may also see some changes in the coming years with the adoption of off-grid or mini-grid generation but with no reference point, this study will assume that the previous trend will continue within the period under study.

4.3 Simulation of four (4) sectoral energy demand scenarios

Given the steady growth profile of the population, this thesis will explore four (4) different energy demand scenarios as a function of four (4) average annual growth rates (AAGR) of the Nominal GDP (at 2010 constant basic price) that will be referred to as the business-as- usual, low growth, medium growth and high growth scenarios throughout this study. Across all the scenarios the population growth rate will be at an average of 3.2% per annum.

TABLE 4.10: AVERAGE ANNUAL GROWTH RATE IN EACH SCENARIO

Scenario	**AAGR (%)**
Business-as-Usual	4.60
Low Growth	6.08
Medium Growth	7.37
High Growth	10.18

Source: Author

4.3.1 Simulation of future energy demand in the Manufacturing Sector

The projections of future energy demand in the manufacturing sector by making use of the business-as-usual (BAU), low growth (LG), medium growth (MG) and high growth (HG) scenarios is presented in the chart below. It is observable from figure 14.12 the role GDP would play in the coming years in the demand for energy within this sector, the trends in the energy intensity in the manufacturing sector was also taken into consideration in all the scenarios presented below.

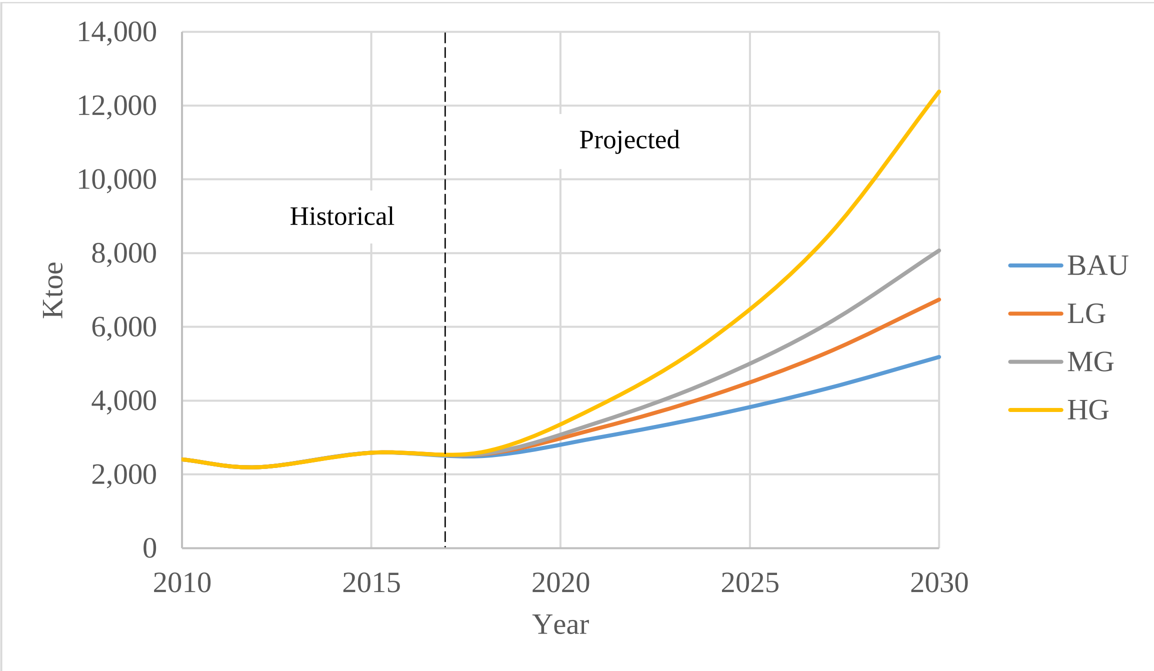

Figure 4.12 Energy Demand in the Manufacturing Sector
Source: Author

The projected energy demand in each scenario is presented in the table below. By the year 2030 the projected demand in the manufacturing sector is expected to have increased to 5,185.01 Ktoe, 6,740.60 Ktoe, 8,071.50 Ktoe and 12,380.75 Ktoe, increasing by a factor of 2.15, 2.80, 3.35 and 5.14 for the BAU, LG, MG and HG scenarios respectively.

TABLE 4.11: DEMAND PROJECTIONS FOR THE MANUFACTURING SECTOR (KTOE)

Scenario (AAGR in the sector)	2018	2021	2024	2027	2030	Ratio [2030/2010]
BAU (8.83%)	2,501.38	3,000.15	3,599.29	4,319.31	5,185.01	2.15
LG (11.05%)	2,552.37	3,252.40	4,145.47	5,285.27	6,740.60	2.80
MG (13.27%)	2,563.58	3,413.44	4,546.21	6,056.65	8,071.50	3.35
HG (17.82%)	2,619.94	3,858.50	5,686.33	8,386.61	12,380.75	5.14

Source: Author

4.3.2 Energy demand in the Agriculture Sector

The projections for the demand for energy in the agriculture sector was done as well by making use of the business-as-usual (BAU), low growth (LG), medium growth (MG) and high growth (HG) scenarios and is presented in the chart below. GDP growth would play a pivotal role in the coming years in the demand for energy within this sector, the increase in demand of motor fuel especially in the MG and HG scenario as a results of increased mechanization was likewise taken into account.

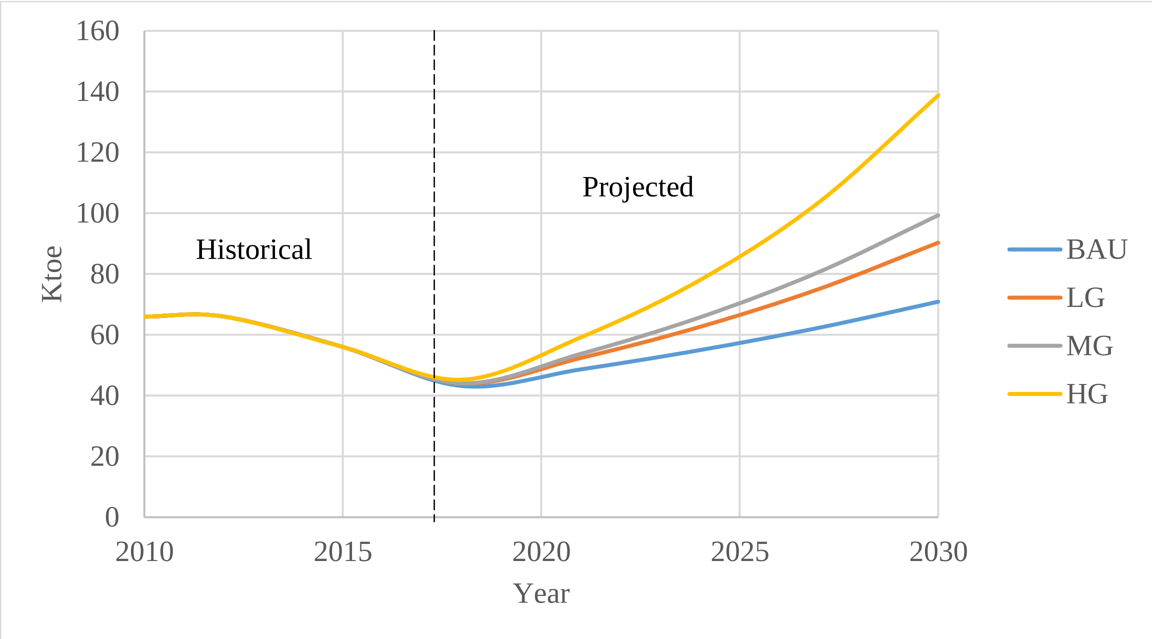

Figure 4.13 Energy Demand in the Agriculture Sector
Source: Author

The final energy demand for each scenario is presented in the table below. By the year 2030 the projected demand in this sector is expected to have increased to 70.88 Ktoe, 90.31 Ktoe, 99.33 Ktoe and 138.75 Ktoe, increasing by a factor of 1.07, 1.37, 1.51 and 2.10 for the BAU, LG, MG and HG scenarios respectively.

TABLE : 4.12 DEMAND PROJECTIONS FOR THE AGRICULTURE SECTOR (KTOE)

Scenario (AAGR in the sector)	2018	2021	2024	2027	2030	Ratio [2030/2010]
BAU (4.77%)	43.16	48.63	54.98	62.33	70.88	1.07
LG (6.74%)	43.97	52.40	62.63	75.09	90.31	1.37
MG (8.11%)	44.08	53.76	65.76	80.70	99.33	1.51
HG (10.06%)	45.24	59.18	78.03	103.67	138.75	2.10

Source: Author

4.3.3 Energy demand in the Construction Sector

Projections of energy demand in the construction sector was equally done with the aid of the business-as-usual (BAU), low growth (LG), medium growth (MG) and high growth (HG) scenarios and the results are presented in the chart below. Recognisably, GDP growth would play a pivotal role in the coming years in the demand for energy within this sector. Energy efficiency is also expected to play a role in the demand of the coming years, energy intensity was taken into account when making projections especially for the HG and MG scenarios where it is expected that high GDP growth rates will drive the need to be more efficient in the consumption of energy.

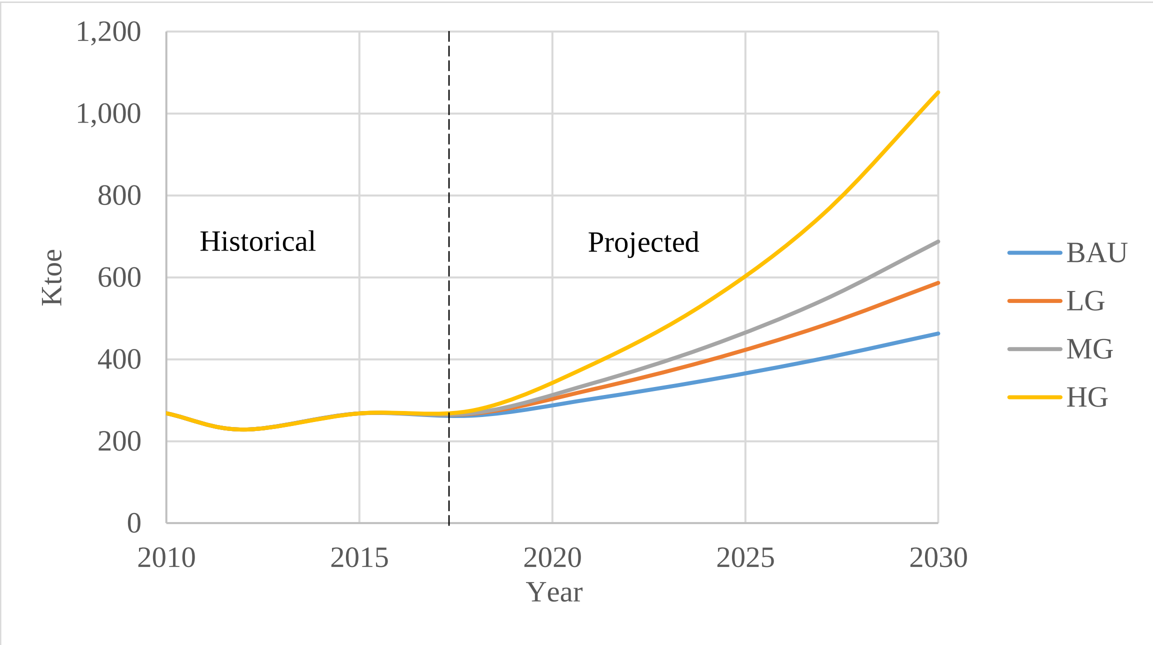

Figure 4.14 Energy Demand in the Construction Sector
Source: Author

The final energy demand for each scenario is presented in the table below. By the year 2030 the projected demand in this sector is expected to have increased to 462.75 Ktoe, 586.45 Ktoe, 687.32 Ktoe and 1,051.58 Ktoe, increasing by a factor of 1.72, 2.19, 2.53 and 3.92 for the BAU, LG, MG and HG scenarios respectively.

TABLE : 4.13 DEMAND PROJECTIONS FOR THE CONSTRUCTION SECTOR (KTOE)

Scenario (AAGR in the sector)	2018	2021	2024	2027	2030	Ratio [2030/2010]
BAU (7.40%)	262.73	302.66	348.66	401.67	462.75	1.72
LG (9.38%)	267.57	325.54	396.09	481.95	586.45	2.19
MG (11.35%)	269.06	340.13	430.00	543.63	687.32	2.53
HG (15.71%)	276.16	385.75	538.85	752.74	1,051.58	3.92

Source: Author

4.3.4 Energy demand in the Mining Sector

Projections for the demand for energy in the mining sector was likewise carried out with the aid of four scenarios; business-as-usual (BAU), low growth (LG), medium growth (MG) and high growth (HG) and is presented in the chart below. GDP growth would play a pivotal role in the coming years in the demand for energy within this sector.

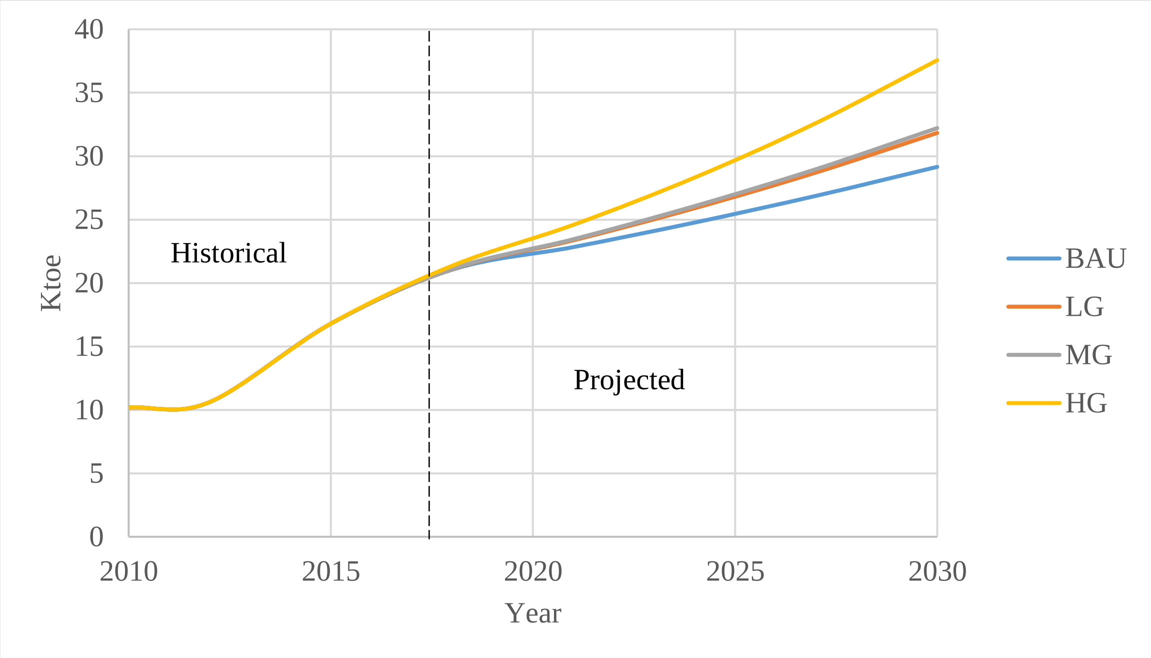

Figure 4.15 Energy Demand in the Mining Sector
Source: Author

The final energy demand for each scenario is presented in the table below. By the year 2030 the projected demand in this sector is expected to have increased to 25.64 Ktoe, 28.09 Ktoe, 29.79 Ktoe and 32.70 Ktoe, increasing by a factor of 1.72, 2.19, 2.53 and 3.92 for the BAU, LG, MG and HG scenarios respectively.

TABLE : 4.14 DEMAND PROJECTIONS FOR THE MINING SECTOR (KTOE)

Scenario (AAGR in the sector)	2018	2021	2024	2027	2030	Ratio [2030/2010]
BAU (-0.10%)	20.67	21.80	23.00	24.28	25.64	2.52
LG (1.11%)	20.71	22.34	24.10	26.01	28.09	2.76
MG (1.2%)	20.86	22.80	24.92	27.24	29.79	2.93
HG (2.41%)	20.91	23.38	26.14	29.23	32.70	3.21

Source: Author

4.3.5 Energy demand in the Transport Sector

Future energy projections in the transport sector were likewise carried out using the same four scenarios like the previous sectors and the results of the projections are presented in the chart below. GDP and vehicle activity will play a pivotal in the future energy demand in this sector.

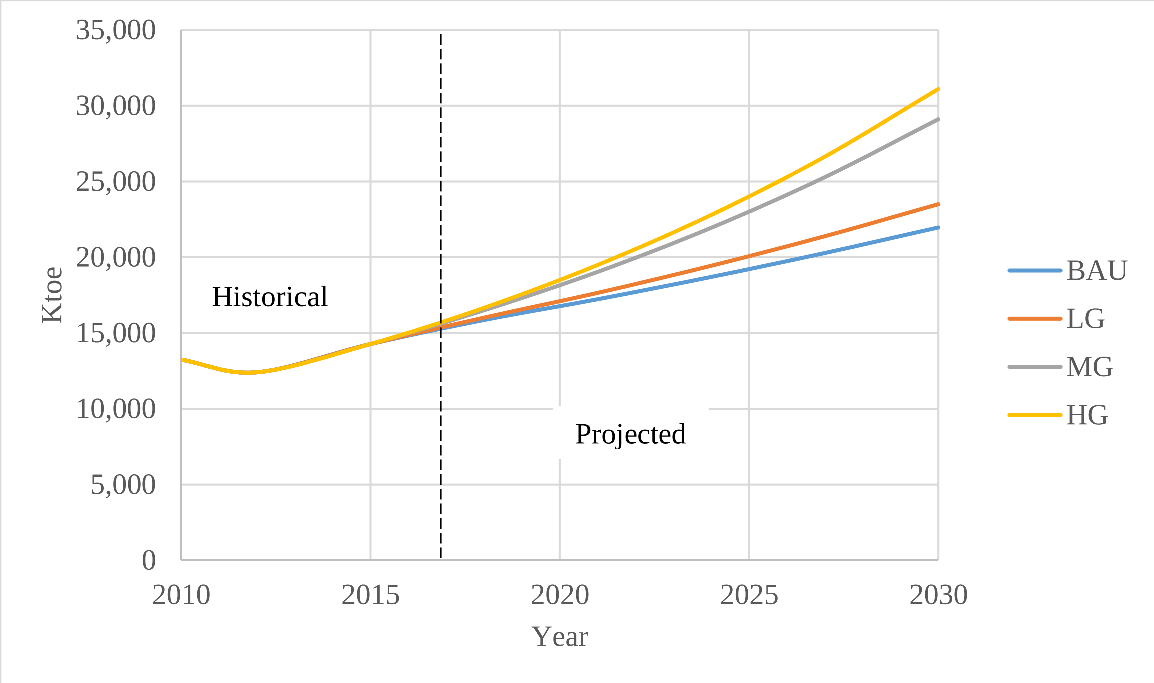

Figure 4.16 Energy Demand in the Transport Sector
Source: Author

Energy demand in the year 2030 is expected to have increased to 21,960.88 Ktoe, 23,498.03 Ktoe, 29,103.72 Ktoe and 31,098.80 Ktoe increasing by a factor of 1.66, 1.78, 2.20, 2.25 in the BAU, LG, MG and HG respectively.

TABLE : 4.15 DEMAND PROJECTIONS FOR THE TRANSPORT SECTOR (KTOE)						
Scenario (AAGR in the sector)	**2018**	**2021**	**2024**	**2027**	**2030**	**Ratio [2030/2010]**
BAU (2.79%)	15,854.05	17,223.57	18,695.69	20,273.96	21,960.88	1.66
LG (2.92%)	16,008.12	17,645.01	19,432.86	21,381.01	23,498.03	1.78
MG (3.06%)	16,497.08	19,028.78	21,938.24	25,277.40	29,103.72	2.20
HG (5.97%)	16,654.24	19,485.10	22,785.81	26,629.50	31,098.80	2.35

Source: Author

4.3.6 Energy demand in the Household Sector

Future energy projections in the household sector was likewise carried out using the same four scenarios like the previous sectors and the results of the projections are presented in the chart below. Average GDP per capita will play a pivotal role in the coming years within this sector.

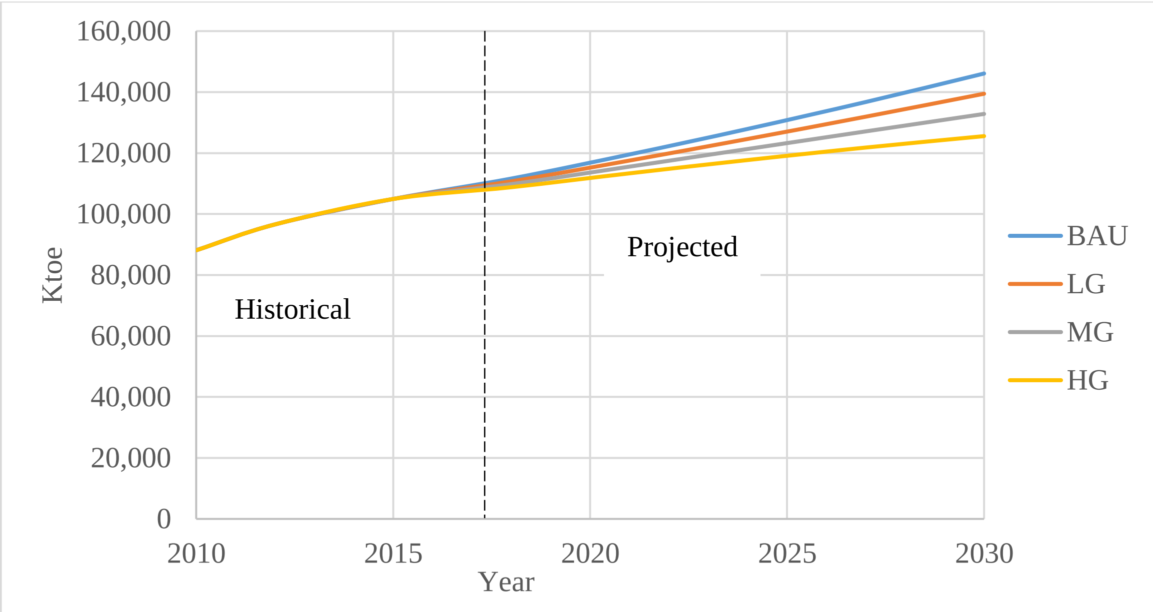

Figure 4.17 Energy Demand in the Household Sector
Source: Author

The final energy demand for each scenario is presented in the table below. By the year 2030 the projected demand in this sector is expected to have increased to 146,089.80 Ktoe, 139,462.27 Ktoe, 132,832.61 Ktoe and 125,550.60 Ktoe, increasing by a factor of 1.66, 1.58, 1.51 and 1.42 for the BAU, LG, MG and HG scenarios respectively.

TABLE : 4.16 DEMAND PROJECTIONS FOR THE HOUSEHOLD SECTOR (KTOE)						
Scenario (AAGR of GDP/capita)	**2018**	**2021**	**2024**	**2027**	**2030**	**Ratio [2030/2010]**
BAU (1.33%)	111,638.45	119,547.14	127,916.74	136,760.51	146,089.80	1.66
LG (2.77%)	110,724.12	117,549.66	124,627.32	131,939.41	139,462.27	1.58
MG (4.01%)	109,809.49	115,551.53	121,336.83	127,116.76	132,832.61	1.51
HG (6.82%)	108,800.19	113,347.55	117,711.46	121,810.92	125,550.60	1.42

Source: Author

4.3.7 Energy demand in the Service Sector

Energy demand projections in the service sector are illustrated in figure 14.18 below. The projections are in line with the business-as-usual, low growth, medium growth and high growth scenarios. The main driver for demand in this sector is the GDP growth rate.

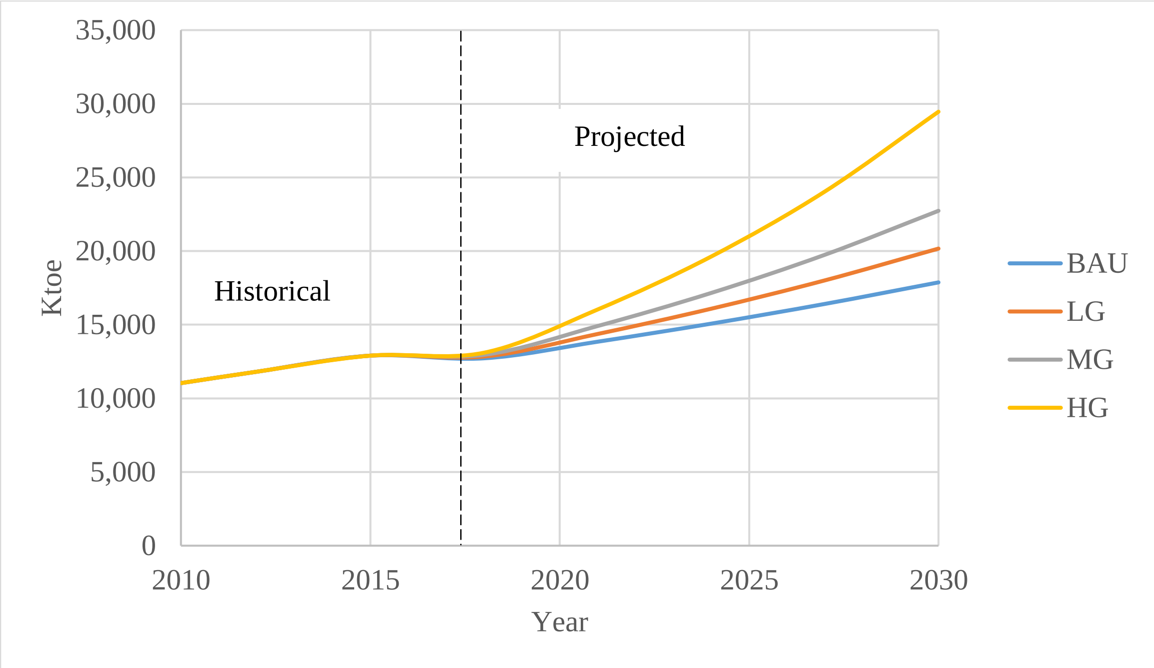

Figure 4.18 Energy Demand in the Service Sector
Source: Author

By the year 2030 the energy demand had increased to 17,873.01 Ktoe, 20,167.94 Ktoe, 22,732.53 Ktoe and 29,460.19 Ktoe by a factor of 1.62, 1.83, 2.06, 2.67 in the BAU, LG, MG and HG respectively. The data is presented in the table below.

TABLE 4.17 : DEMAND PROJECTIONS FOR THE SERVICE SECTOR (KTOE)						
Scenario (AAGR in the sector)	**2018**	**2021**	**2024**	**2027**	**2030**	**Ratio [2030/2010]**
BAU (3.94%)	12,720.95	13,846.27	15,073.56	16,412.33	17,873.01	1.62
LG (4.91%)	12,839.71	14,370.62	16,086.65	18,010.56	20,167.94	1.83
MG (5.88%)	12,958.48	14,909.78	17,157.67	19,747.70	22,732.53	2.06
HG (8.61%)	13,099.01	16,031.81	19,628.62	24,041.98	29,460.19	2.67

Source: Author

4.3.8 Energy Demand across all sectors

The cumulative demand in all four scenarios is hence presented below. Kindly note that the manufacturing, agriculture, construction and mining sectors have been grouped into the industry sector. From the charts presented above, increased overall growth rate of the economy is expected to drive the increase in the overall demand in the Industry sector, the transport sector and the service sector while the reverse is the case for the household sector whose rate of increase in demand slows as the economy's growth rate increases.

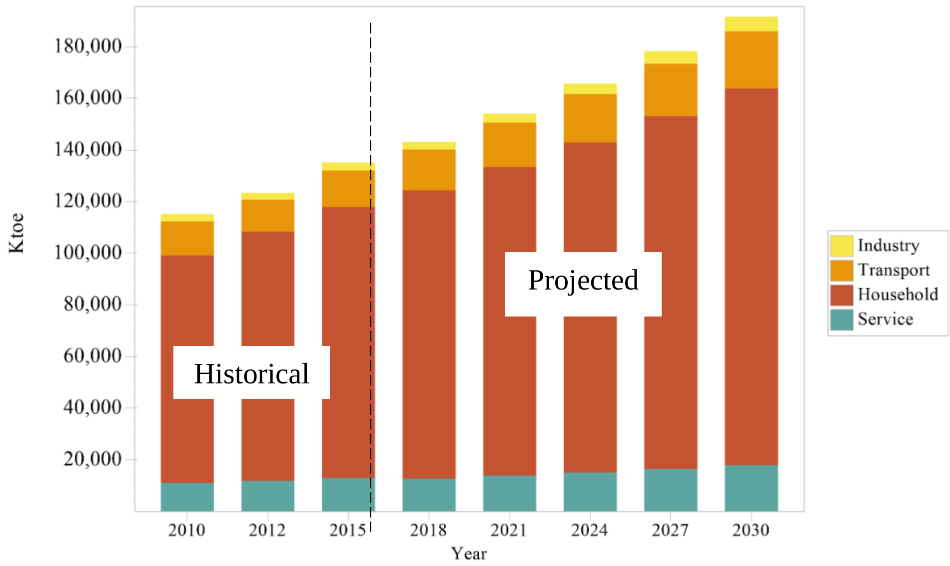

Figure 4.19a Energy Demand in the BAU scenario
Source: Author

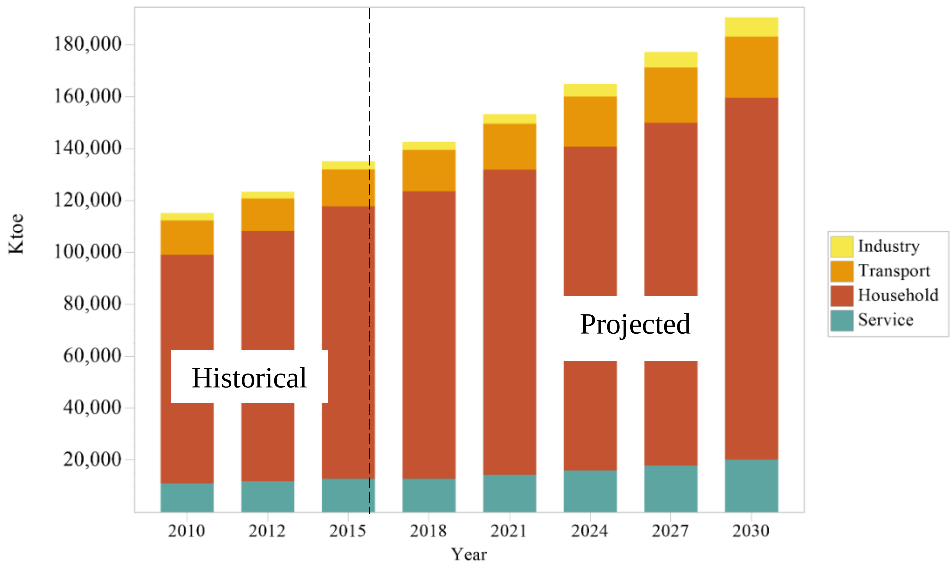

Figure 4.19b Energy Demand in the LG scenario
Source: Author

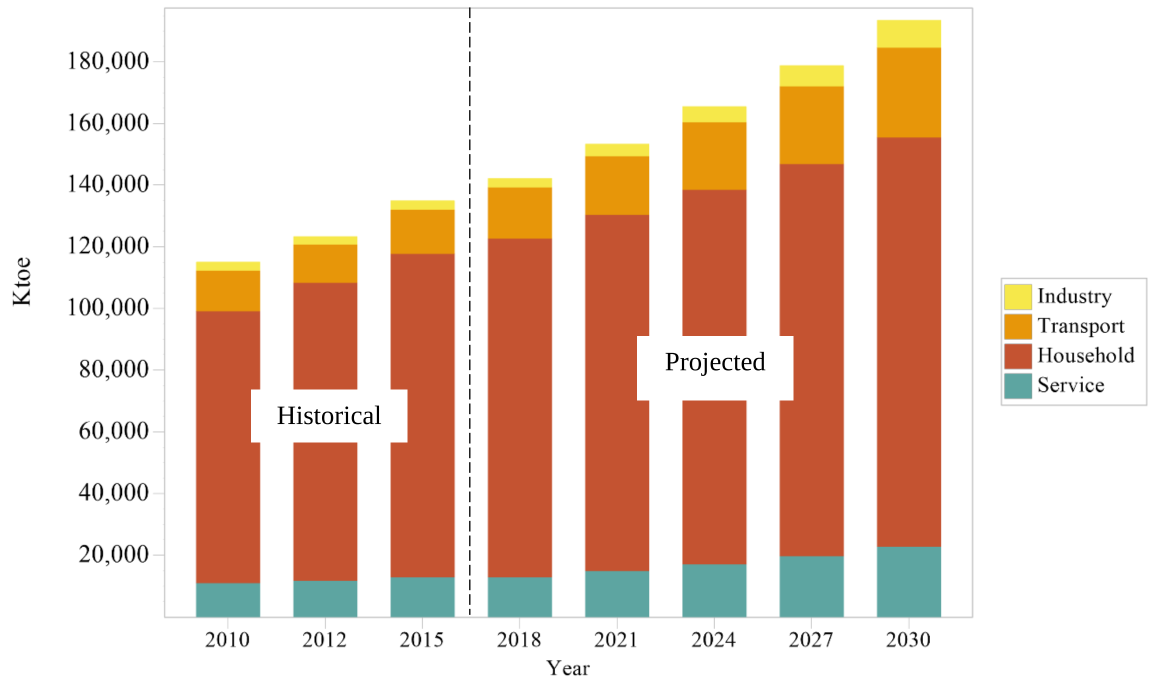

Figure 4.19c Energy Demand in the MG scenario
Source: Author

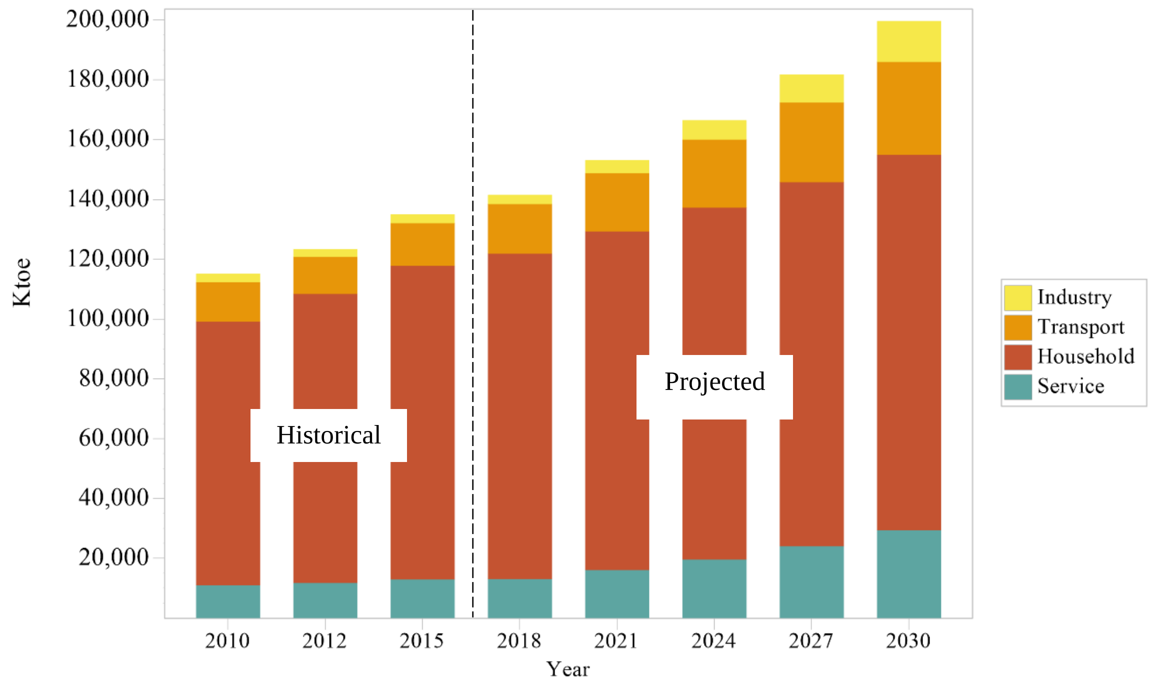

Figure 4.19d Energy Demand in the HG scenario
Source: Author

4.4 Simulation of Policy driven Energy Transition Scenarios

This section will explore ways in which policy can be used to reduce demand for energy across all the sector based on the medium growth scenario.

4.4.1 LPG substitution policy scenario in the household sector

Considering that the household sector still consumes a great deal of fuelwood in the present day and also for the foreseeable future, this is not in line with sustainable development, there is need to consider alternative sources of fuel for cooking and water heating. One fuel that has already seen an increase in its adoption in Nigerian households is LPG. As compared to fuelwood, LPG is a cleaner fuel and thus its adoption as the fuel of choice for cooking and water heating can help eradicate energy poverty, mitigate climate change and even improve the health of household members.

Identified below are constraints that can be tackled with policy to aid the mainstreaming of LPG into Nigerian households.

4.4.1.1 Household-Related Considerations that can affect the adoption of LPG as the Fuel of choice in the Household sector

1. **Cost:** As expected, fuel prices and household income are two main determinants of a household's decision to use LPG and how much of it they will consume. A 10-country analysis of national household expenditure survey that was carried out by the world bank showed that LPG is used predominantly by the upper half of the income groups in low and lower-middle-income countries, Nigeria is an upper-middle income country hence it can be inferred that some of the lower half of the income groups can also afford to use LPG(Kojima, 2011). This same survey showed that regular users of LPG at the current world LPG prices would require in excess of US$4200 annually (about ₦1,512,000 at the current exchange rate), thus making it unaffordable even to households with at least 2 members contributing to the household income by the year 2030;

   $$Average\ Annual\ Income_{2017} = \text{₦}343{,}841.72$$

   Hence for households with a minimum of 2 people contributing to the household income

   $$Average\ Annual\ household\ Income_{2017} = \text{₦}687{,}683.44$$

   This amounts to about US$1910 at the current exchange rate.

   It should be noted that some households in Nigeria still use fuelwood as their choice of fuel for cooking and water heating despite the fact that they can afford LPG, these households can potentially make the switch to LPG without financial assistance provided that market conditions are favourable.

2. **Education:** Another main consideration that could be pivotal to the adoption of LPG as the fuel of choice in the household sector is the education level of the household members.

The higher the level of education attained by members of a household, the more likely they are to select LPG as the fuel of choice.

Public enlightenment particularly targeted at women on the costs and benefits of choice fuel could go a long to trigger the switch to cleaner fuels like LPG.

4.4.1.2 Market-Related Considerations that can affect the adoption of LPG as the fuel of choice in the Household sector

1. **Inadequate Supply and Distribution Infrastructure:** The Nigerian Liquefied Natural Gas previously supplied 150,000 MT, it was increased to 250,000 MT in 2012 and now stands at 350,000 MT from January 2017. This increased supply was what prompted the significant increase in activities in the LPG sector. To consolidate the supply from NLNG 2 additional coastal storage depots with combined capacity of 12,500 MT were established at the Apapa port in Lagos, with an upgrade project of additional 8,000 MT for the two depots currently underway. More LPG depots are at various stages of construction and completion in Calabar, Port Harcourt and around the Lagos coastal areas. The NNPC/PPMC is also reactivating their inland LPG depot network to key into the expanding LPG market. Asides the growth in storage facilities, there has been an increase from 300 in 2009 to about 600 in 2016 of LPG refilling plants. Furthermore, over 60 approvals to construct new LPG filling plants have been granted by the Department for Petroleum Resources (DPR) since 2012(DPR, 2016). This increase in the refilling plants will further make it easier to distribute the LPG product across the country.

   This surge is supply is laudable but it creates some form of regional imbalance since 65% of all LPG facilities and consumption are in the southern regions of the country. Ironically, the population who predominantly use traditional biomass for cooking and heating purposes and who have less biomass resources due to desertification are in the northern regions of the country.

2. **Insufficient LPG Cylinders in Circulation:** There are only a limited number of cylinder in circulation within Nigeria and majority of these cylinders are rather old and no longer suitable for use. Previously there were cylinder manufacturing plants in Nigeria but most of the them have since closed down due to unfriendly business conditions prevalent in the past, importation on the other hand is bad for business due to the high duty tariffs of about 35%, this will monumentally drive up the cost of cylinders and annihilate potential markets.

   A lot needs to be done in order to promote the in-country production of LPG cylinders. A number of policy instruments targeted at the local production of the cylinders can be implemented to attract investors.

3. **Safety:** There exists negative sentiments borne of reported cases of explosion of LPG where household members believe that LPG is not safe for use as a cooking fuel. Education of consumers on ways to prevent leakages and what to do to in the case of an outbreak of fire from LPG would be a good start, also the establishment of regulatory and inspection infrastructure to monitor compliance of cylinders with regards to suitability of use will go a long way to prevent cases of cylinder explosion due to circulation of defective cylinders.

There is a likelihood that the growth of the consumption of LPG remains rather flat or marginally increases in the near to medium term, unless the recognized bottlenecks are decisively tackled. Nevertheless, there is a glimmer of hope within the LPG industry given the renewed government interest in promoting the use of LPG which with high hopes will provide the necessary spur for realising the growth aspirations in the LPG industry.

The Expansion of Domestic LPG in Nigeria Initiative was flagged off in November 2016 with the aspiration to convert an initial 4million households to use LPG as cooking fuel within by 2018, 10 million households by 2021 and setting up the necessary framework to convert an additional 21 million households in the long term. This plan will see demand grow to about 1.6million MT by 2021 and 2.9MT by 2026. If this goal is achieved this is what the future energy demand in the household sector will look like;

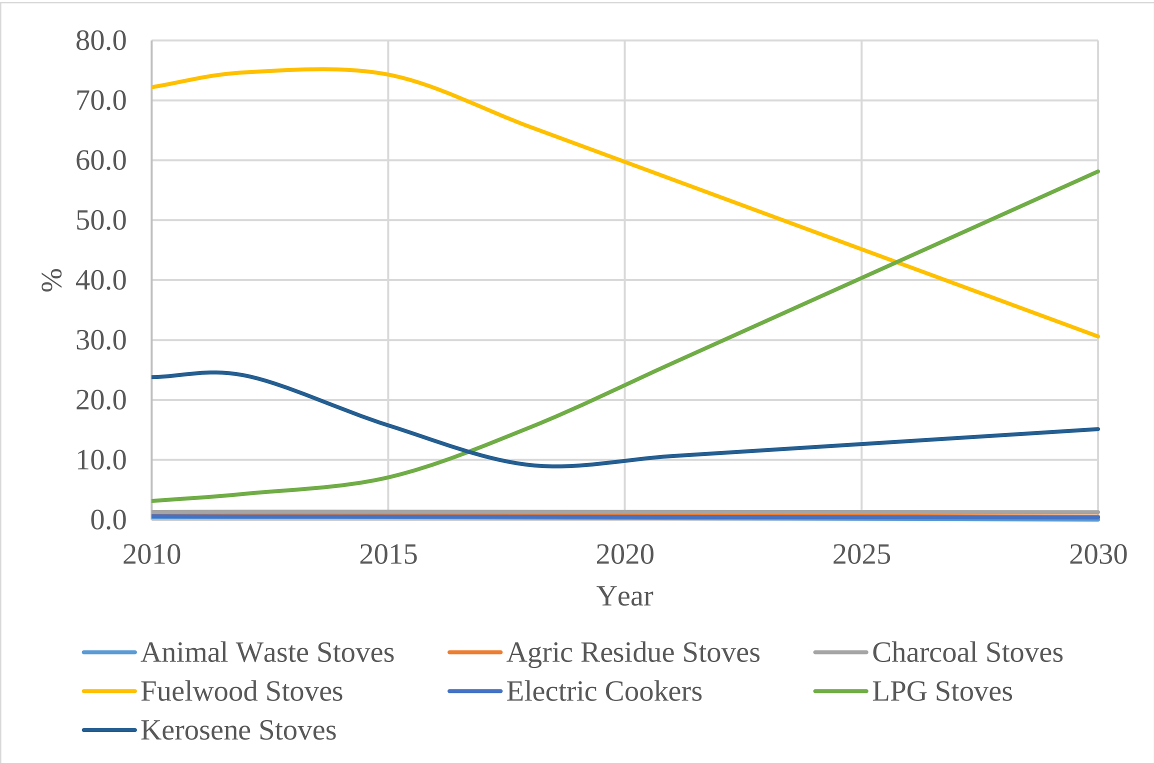

Figure 4.20a Projections of percentage distribution of households based on fuel for cooking and water heating in the LPG substitution policy scenario
Source: Author

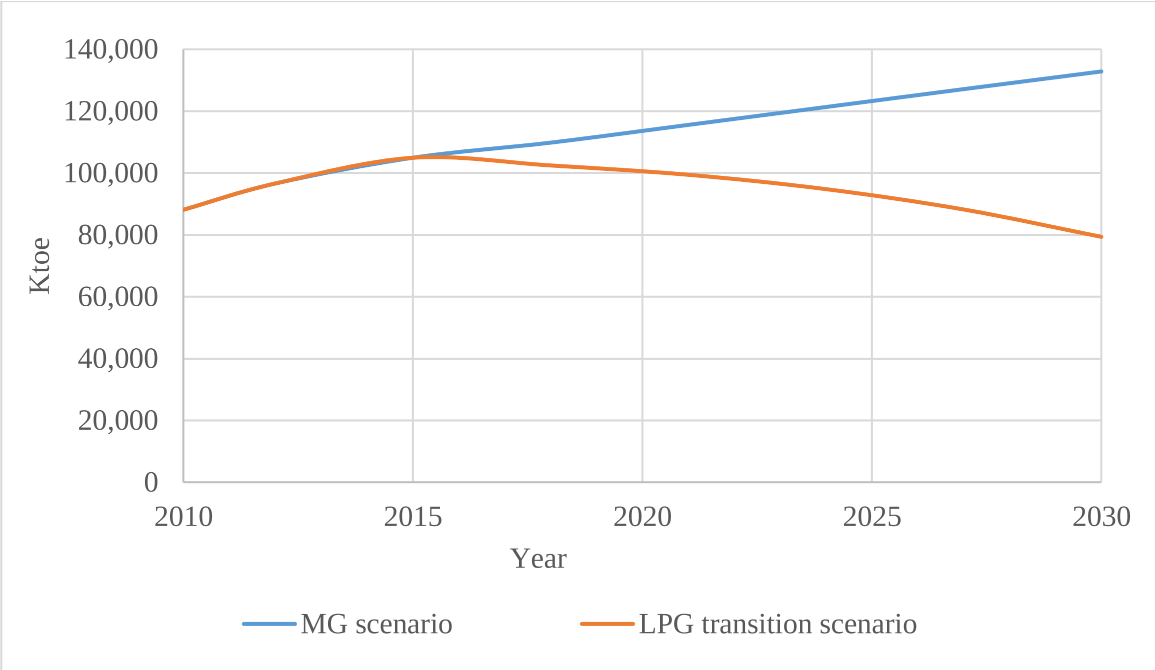

Figure 4.20b Energy demand in the household sector in the LPG transition and the Medium growth scenarios
Source: Author

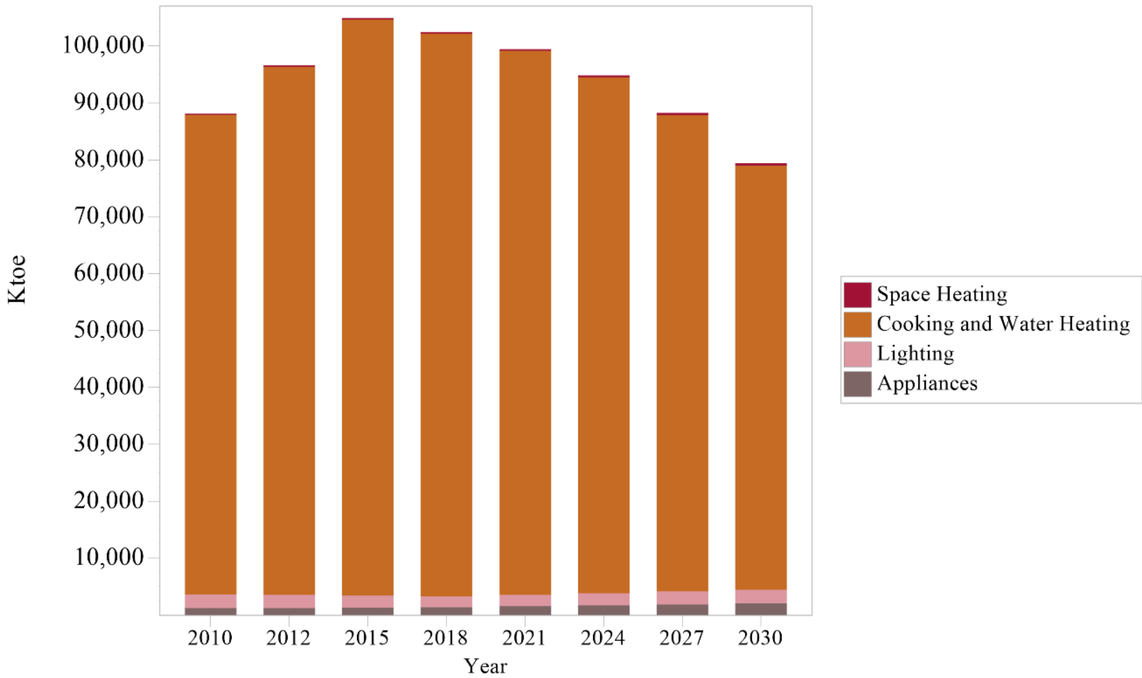

Figure 4.20c Final Energy demand in the household sector for the LPG adoption policy scenario
Source: Author

CHAPTER FIVE: CONCLUSION

Energy transition has rightly been described in this study as the gradual rather than sudden change that unfolds overtime that brings about more diversity to the energy system. The significant motivations for transition is usually centred around need; it could be the need to have a more secure supply, or the need to explore other forms of energy as a result of the depletion of the ones currently in use or another form of energy with higher energy density, in some other cases it comes in form of a need to adopt another technology with higher efficiency. Energy transition in effect gradually shifts the energy balance and expands the menu of energy sources in use.

Energy transition in the 21^{st} century has been rather focused on the need to make a switch from the depleting fossil resources and exploring ways to harness energy from renewable sources especially for the generation of electricity, also some misconstrue renewable energy as only being restricted to "renewable electricity" generated from renewable sources.

The transition occurring globally will not leave developing countries behind, hence the need to have an equitable interpretation of energy transition within the context of sustainable development in developing African countries. Take the case of Nigeria for example, electricity generation is from clean sources, natural gas and hydro, so far the harnessing of natural gas and moving water for electricity generation is sustainable and does not pose an existing threat to climate change. One the other hand, the widespread consumption of fuelwood for use as fuel for cooking contributes immensely to deforestation, affects negatively the overall health of the users and is not in line with sustainable development goals considering the high rate of growth of the population. There are a number of fuel options that can successfully substitute fuelwood as cooking fuel, this study explored the option of LPG.

This study thus elucidates the need to have a wholesome interpretation of energy transition especially for African countries who seek to achieve their sustainable development goals.

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APPENDICES

SUMMARY OF RESEARCH GRANT UTILISATION				
	Naira	**Dinars**	**Quantity**	**Dollars**
INTERNET CONNECTION				
Internet Modem	40,000.00		1	132.60
[1]Internet subscription	134,000.00		1	444.22
TRAVELLING EXPENSES				
*Round trip to Nigeria		136,200.00	1	1,276.60
**Tlemcen to Algiers		5,000.00	1	46.86
**Lagos to Ilorin	3,500.00		1	11.60
**Ilorin to Abuja	25,500.00		1	84.54
**Abuja to Ilorin	25,500.00		1	84.54
**Abuja to Lokoja (roundtrip)	15,500.00		1	51.38
*Ilorin to Lagos	75,000.00		1	248.63
*Algiers to Tlemcen		5,400.00	1	50.61
**Tlemcen Airport to the citè		1,500.00	1	14.06
MATERIALS REQUIRED FOR DATA COLLECTION, COLLATION AND THESIS PRESENTATION				
Printing of templates for initial data collection, data collation, stationaries and final data collation	80,495.00		1	266.85
Printing of master's thesis (for defence)		300.00	4	11.25
Printing of thesis for final submission		500.00	1	4.69
OTHERS				
[2]Hotel Accommodation in Algiers		5,890.00	1.00	55.21
[3]Accommodation during data collection and data collation	4,666.67		14.00	216.59
GRAND TOTAL				**3,000.01**

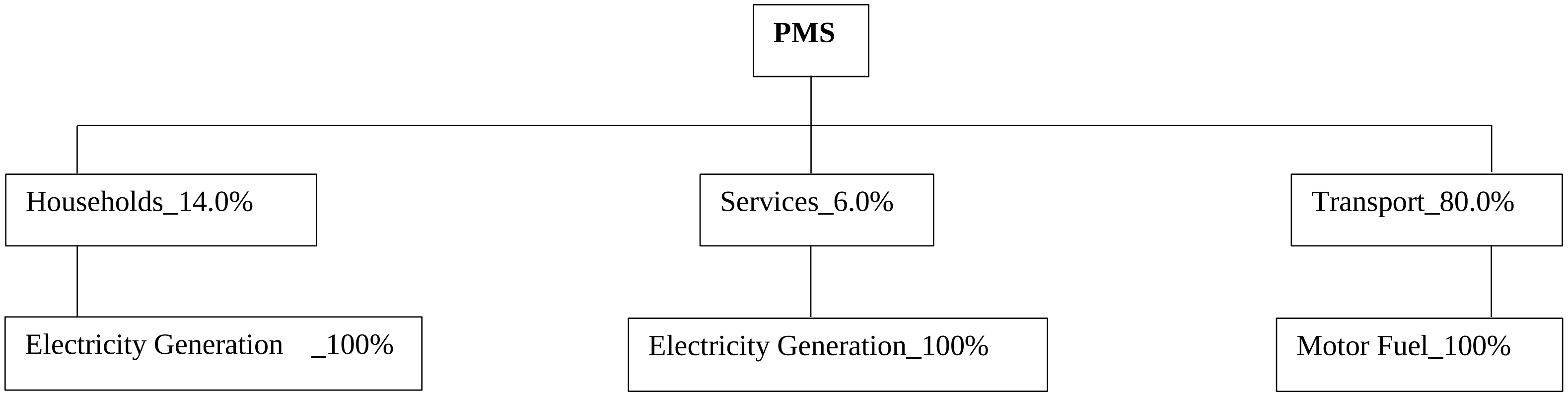
[1]Internet subscription is spread out over 5 months (that is $88.84 per month)

*Air transport

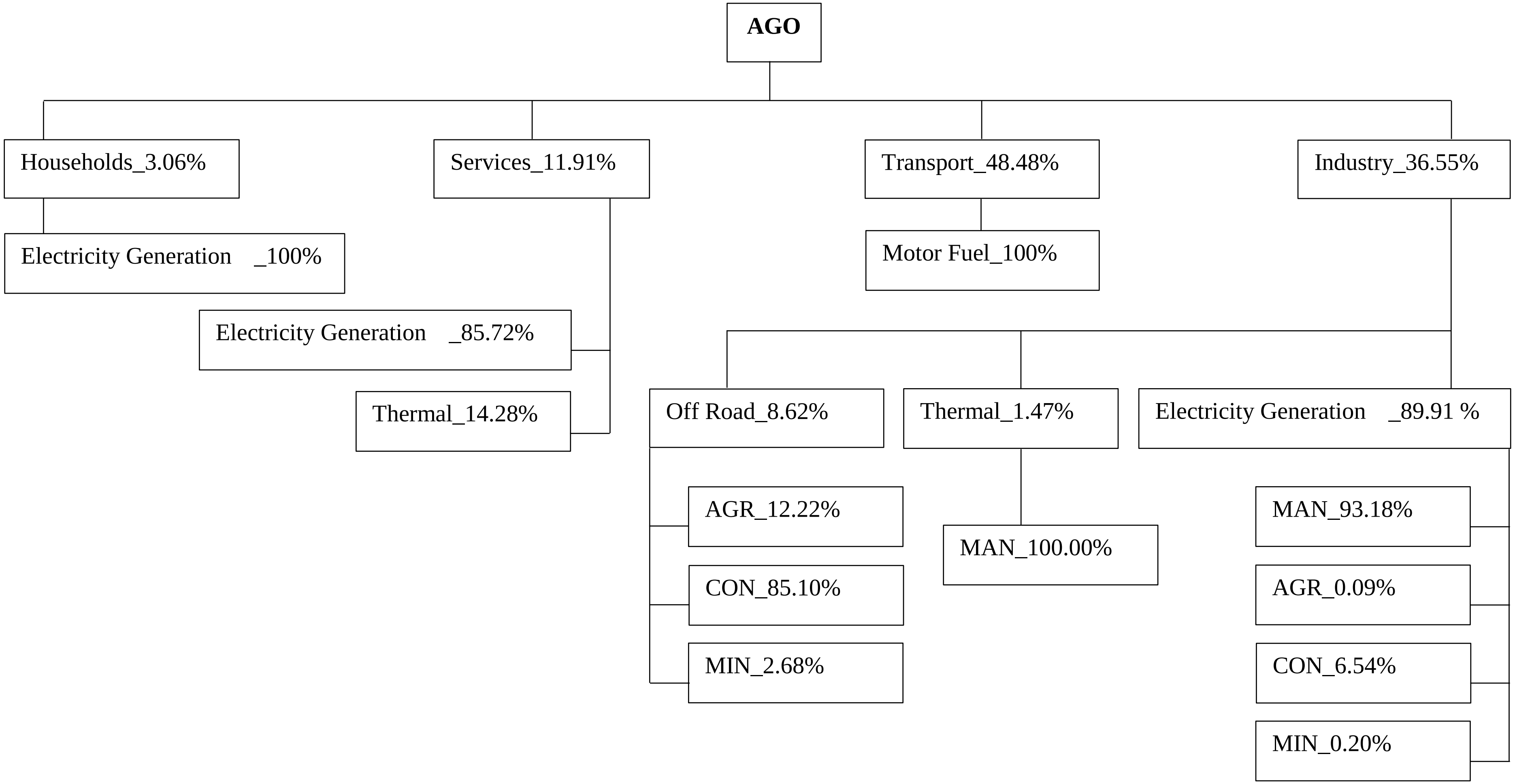
**Road transport

[2]Hotel accommodation was required because I arrived in Algiers at 1300hr on 26 Aug and local flight to Tlemcen was by 0815hr on 27 Aug

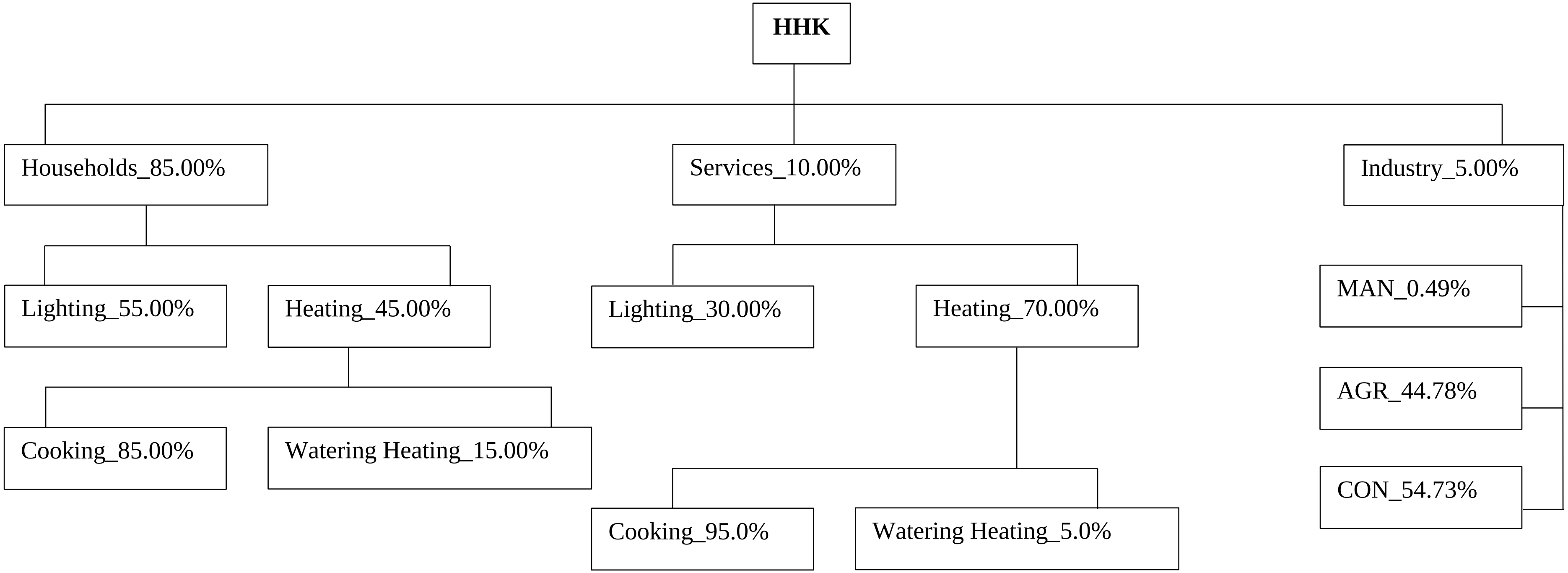
[3]I stayed for a total of 8 weeks collecting and collating data but the balance from the grant could only cater for 14days as indicated here



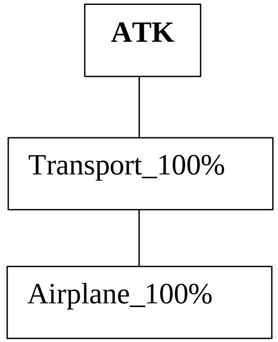
Disaggregation of PMS consumption by sector
Source: ECN Archives



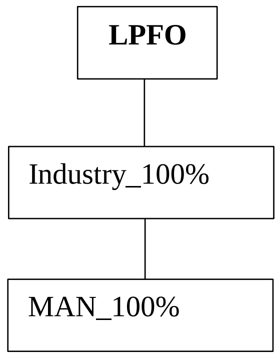
Disaggregation of AGO consumption by sector
Source: ECN Archives



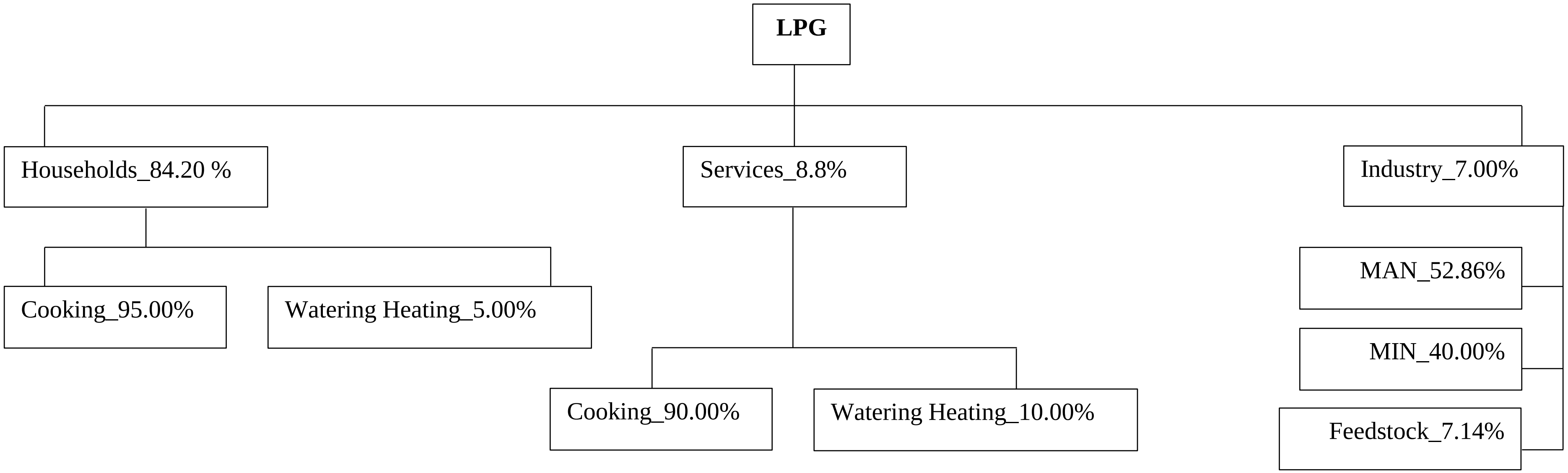
Disaggregation of HHK consumption by sector
Source: ECN Archives



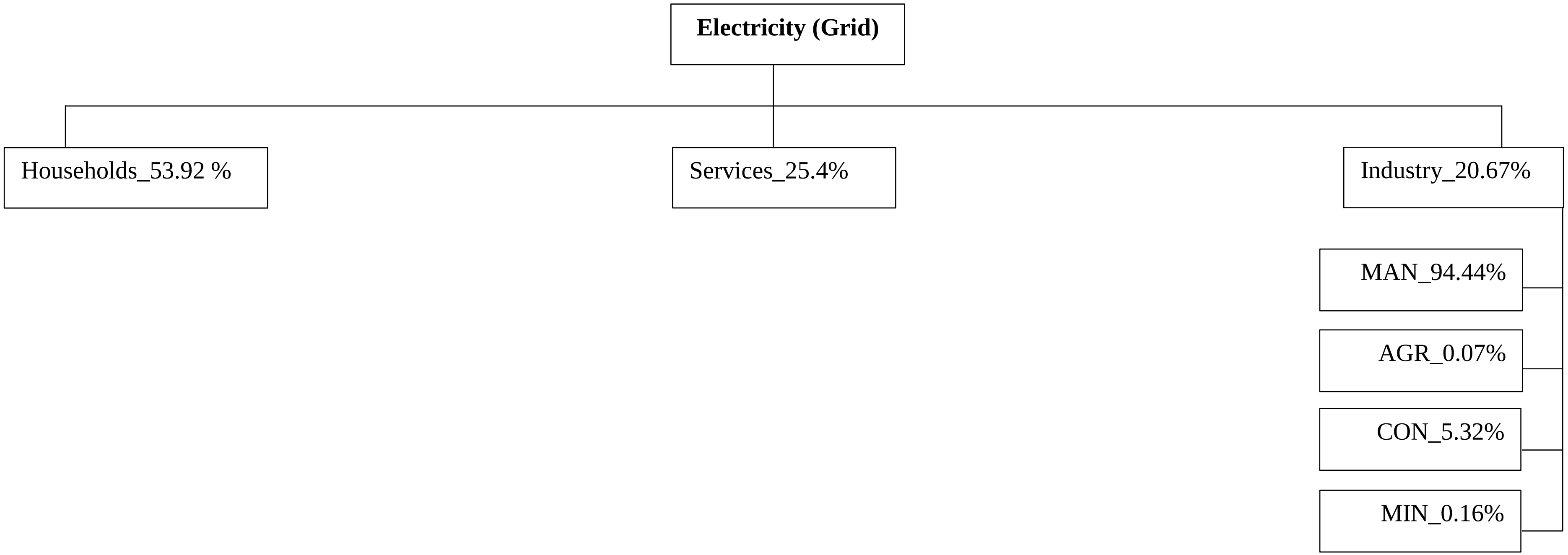
Disaggregation of ATK consumption by sector
Source: ECN Archives



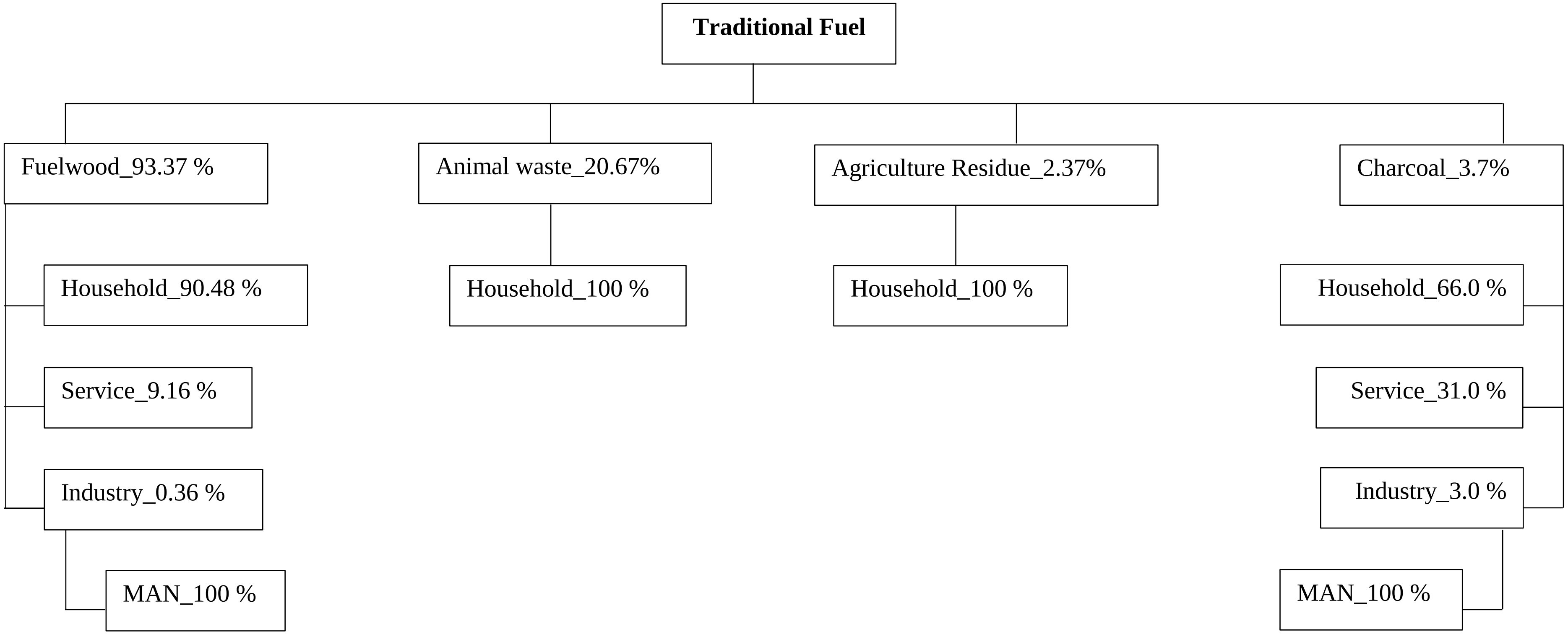
Disaggregation of LPFO consumption by sector
Source: ECN Archives



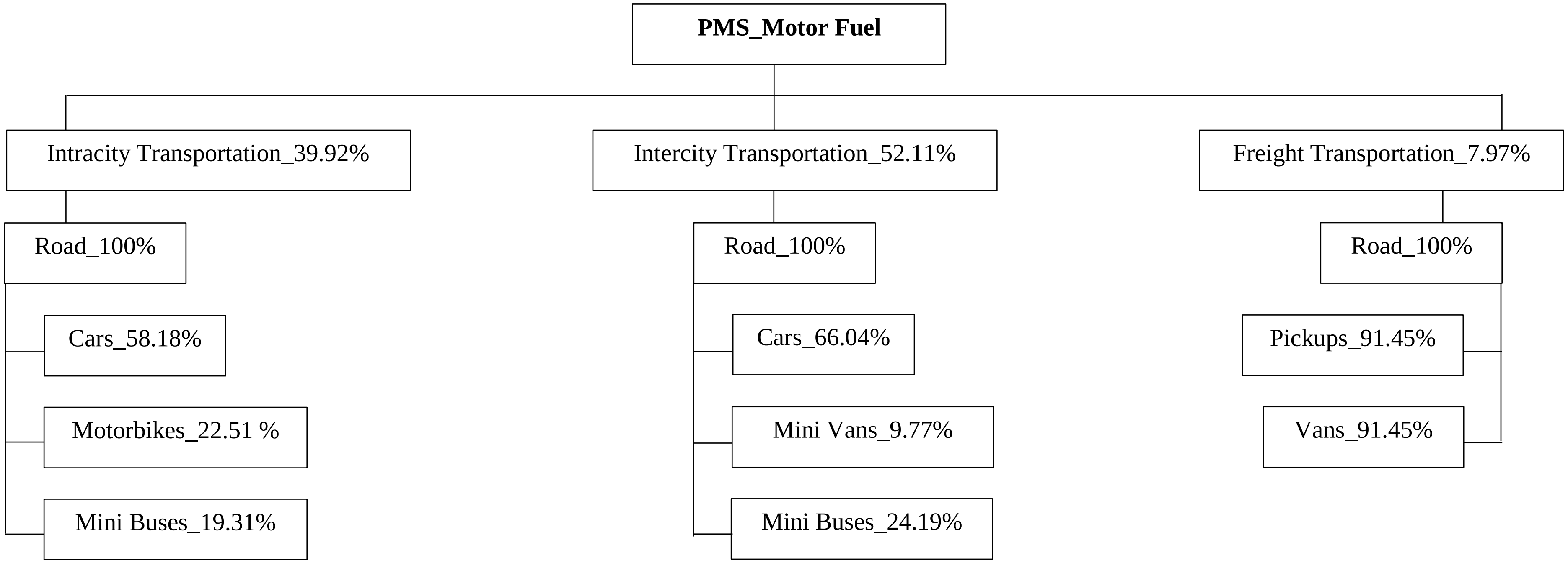
Disaggregation of LPG consumption by sector
Source: ECN Archives



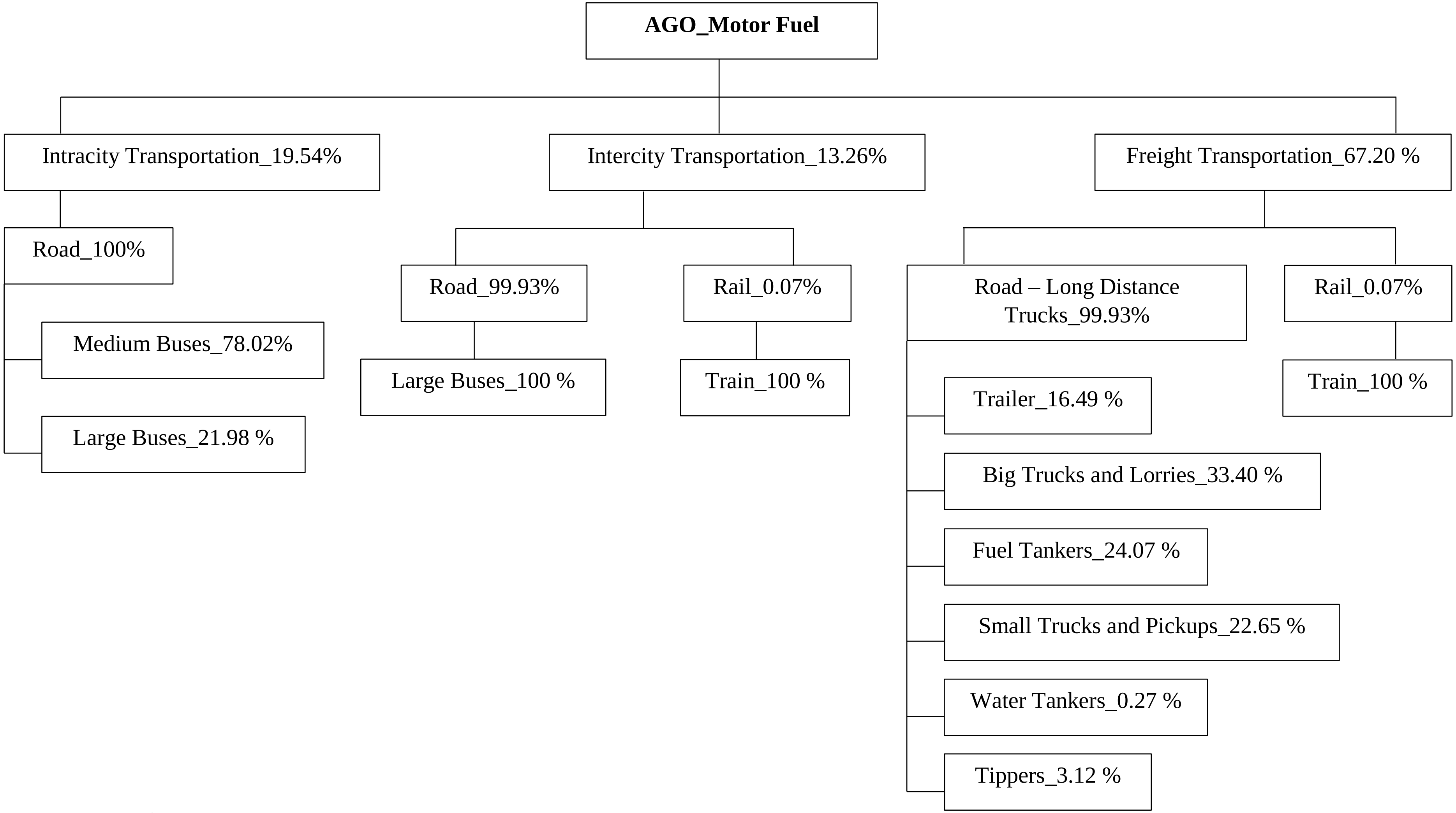
Disaggregation of Grid Electricity consumption by sector
Source: ECN Archives



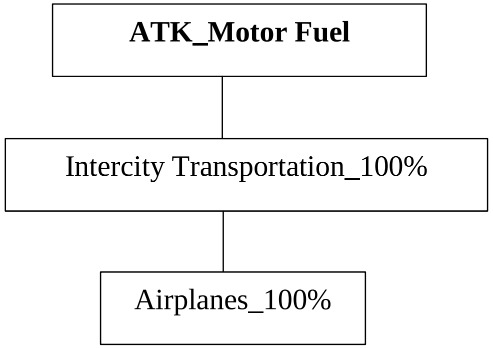
Disaggregation of Traditional Fuel consumption by sector
Source: ECN Archives



Disaggregation of PMS consumption in the Transport sector
Source: ECN Archives



Disaggregation of AGO consumption in the Transport sector
Source: ECN Archives



Disaggregation of ATK consumption in the Transport sector
Source: ECN Archives