FOSSIL FUEL SUBSIDY REFORM FOR SUSTAINABLE DEVELOPMENT IN NIGERIA: THE ROLE OF RENEWABLE ENERGY DIFFUSION

by

Babatunde Idrisu

A dissertation submitted to the Faculty of the University of Delaware in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Energy and Environmental Policy

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LIST OF ABBREVIATIONS AND ACRONYMS

AEE	Renewable Energies Agency
ALRI	Acute Lower Respiratory Infection
APSA	African Peace and Security Architecture
ASUU	Academic Staff Union of Universities
BRP	Baseline Renewable Energy Penetration
CBN	Central Bank of Nigeria
CGE	Computable General Equilibrium
CIMA	The Inter-ministerial Council for Sugar and Alcohol
CLO	Civil Liberty Organization
CNG	Compressed Natural Gas
CO	Carbon monoxide
CO_2	Carbon dioxide
COPD	Chronic Obstructive Pulmonary Disease
DISCOs	Distribution Companies (Electricity)
DPR	Department of Petroleum Resources
ECN	Electricity Corporation of Nigeria
EEG	Renewable Energy Sources Act
EOMP	Expected Open Market Price
EPSRA	Electric Power Sector Reform Act
EU	European Union
EV	Electric Vehicles
FAO	Food and Agriculture Organization
FEC	Federal Executive Council
FMP	Federal Ministry of Power
GDP	Gross Domestic Product
GEF	Global Environment Facility
GEM	Global Economic Monitor
GENCOs	Generation Companies (Electricity)
GGFR	Global Gas Flaring Reduction Partnership
GHG	Greenhouse Gas
HDI	Human Development Index
HEV	Hybrid Electric Vehicles
HHK	Household Kerosene
HRP	High Renewable Energy Penetration
IAA	Instituto do Açúcar e do Álcool

IBC	Integrated Benefits Calculator
IEA	International Energy Agency
IFC	International Finance Corporation
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IPP	Independent Power Producers
KOSAP	Kenya Off-grid Solar Energy Access Project
LCOE	Levelized Cost of Energy
LEAP	Long Range Energy Alternatives Planning
LRP	Low Renewable Energy Penetration
MARKAL	MARKet ALlocation
MDG	Millenium Development Goals
MLP	Multi-level Socio-technical Perspective
MRP	Medium Renewable Energy Penetration
MYTO	Multi-Year Tariff Order
NANS	National Association of Nigerian Students
NBET	Nigerian Bulk Electricity Trading
NBS	National Bureau of Statistics
NDA	Nigerian Dams Authority
NEEAP	National Energy Efficiency Action Plan
NEMSF	Nigeria Electricity Market Stabilization Facility
NEPA	Nigeria Electric Power Authority
NERC	Nigerian Electricity Regulatory Commission
NESCO	Nigerian Electricity Supply Company
NESI	Nigerian Electricity Supply Industry
NLC	National Labor Congress
NNOC	Nigerian National Oil Corporation
NNPC	Nigerian National Petroleum Corporation
NOAA	National Oceanic and Atmospheric Administration
NOC	National Oil Company
NREAP	National Renewable Energy Action Plan
NREEEP	National Renewable Energy and Energy Efficiency Policy for Nigeria
NUEE	National Union of Electricity Employees (NUEE)
NUPENG	National Union of Petroleum and Natural Gas Workers
ODA	Official Development Assistance
OECD	Organization for Economic Co-operation and Development

OPEC	Organization of the Petroleum Exporting Countries
PAG	Payment Assurance Guarantee
PAIF	Power and Aviation Intervention Facility
PAYGO	Pay as You Go
PCOA	Put-Call Option Agreement
PHCN	Power Holding Company of Nigeria
PMTI	Photovoltaic Market Transformation Initiative
PPA	Power Purchase Agreement
PPP	Purchasing Power Parity
PPPRA	Petroleum Products Pricing Regulatory Agency
Proálcool	National Fuel Ethanol program
PV	Photovoltaics
REA	Rural Electrification Agency
REFIT	Renewable Energy Feed in Tariff
RISE	Regulatory Indicators for Sustainable Energy
SAP	Structural Adjustment Program
SDG	Sustainable Development Goals
SE4ALL-AA	Sustainable Energy for All Action Agenda
SEI	Stockholm Environment Institute
SHS	Solar Home System
SPL	Solar Portable Lighting
SSA	Sub-Saharan Africa
SURE	Subsidy Reinvestment and Empowerment Program
TCN	Transmission Company of Nigeria
TIMES	The Integrated MARKAL-EFOM System
TUC	Trade Union Congress
UFA	Universal Financial Access
UN	United Nations
VAT	Value Added tax

ABSTRACT

One of the indicators of the Sustainable Development Goal 12 (“Ensure sustainable consumption and production patterns”) is the phasing out of fossil fuel subsidies “in a manner that protects the poor and the affected communities” (UN, 2019). Fossil fuel subsidies exacerbate a wide range of adverse economic, environmental, and social conditions such as fiscal imbalances, petroleum product smuggling, greenhouse gas emissions, and social inequities. These subsidies also reduce resources that governments could invest to meet sustainable development goals and other development objectives.

Attempts to reform fossil fuel subsidies are often faced with strong resistance for a variety of reasons, including the associated inflationary impacts and price shocks, poor energy security, lack of viable alternatives, and negative welfare impacts on some of society’s most vulnerable. The resistance to fossil fuel subsidy reform in Nigeria accounts for the persistent underinvestment in critical infrastructure and social development.

This dissertation analyses the reasons for fossil fuel subsidy reform inertia in Nigeria by studying the history of subsidy reform, and the factors that influence it. It asserts that the diversification of the energy system to include sustainable technology options would reduce dependence on fossil fuel sources, increase energy security and potentially reduce the political barriers to fossil fuel subsidy reform. To validate this

assertion, a scenario analysis of renewable energy penetration was done based on Nigeria's sustainable energy for all action agenda (SE4ALL-AA). The study utilized the Long-range Energy Alternative Planning (LEAP) tool to project the sustainable development benefits of clean energy diffusion. The study examined the opportunities and challenges of renewable energy development and reviewed case studies to derive policy recommendations

Chapter 1

INTRODUCTION

1.1 Introduction

Fossil fuels play a central role in Nigeria's energy mix, dominating energy consumption in the transportation and electricity sectors. Fossil fuel subsidies in Nigeria sustain this dominance by encouraging the use of fossil fuels, adversely affecting domestic energy security (Plante, 2014). These subsidies also place fiscal pressure on domestic budgets, and adversely affect the environment (IEA, 2017; Plante, 2014).

Despite these strong reasons for reform, there has been limited progress towards fossil fuel subsidy reform in Nigeria. One factor influencing this lack of progress is the strong political resistance towards fossil fuel subsidy reform. Advances in technology and business models make renewable energy technologies viable alternatives to fossil fuels; for instance, ethanol is used for transportation and off-grid solar for electricity. The diversification of the energy mix towards cleaner energy sources would increase energy security, reduce dependence on fossil fuel resources, and provide sustainable development benefits. Reduced reliance on fossil fuel resources would potentially reduce the political pressure associated with fossil fuel subsidy reform.

The International Energy Agency (IEA) defines energy subsidies as government action that "lowers the cost of energy production, raises the price received by energy producers or lowers the price paid by energy consumers" (IEA, 2011).   Subsidies can be applied to renewable and fossil fuel-generated energy. Some objectives of fossil fuel subsidies include the alleviation of poverty, stimulation of economic development, and the promotion of energy equity. These subsidies have in practice often failed to achieve desired goals and have instead led to market distortions that create inefficient energy use, increased environmental degradation, and limited energy sector investment (IEA, 2011). Fossil fuel subsidies often constitute unsustainable financial burdens, taking up a significant portion of government revenue that could be utilized towards other development goals (Rentschler, 2016). In 2015, In 2015, IEA estimated fossil fuel consumption subsidies to be about $325 billion (IEA, 2016). This estimate is more than three times larger than the annual $100bn climate finance pledge agreed upon at the 15th Conference of Parties (COP15) for developing countries (UNFCCC, 2009) and two times larger than subsidies to renewable energy sources in the same year (IEA, 2016).

In 2015, the United Nations set up Sustainable Development Goals (SDGs) to address global development challenges and provide a blueprint towards achieving sustainable environmental, social, and economic growth for all. The SDGs are made up of 17 interrelated goals tackling issues such as poverty, hunger, inequality, climate change, environmental degradation, and conflict to be achieved by the year 2030 (UN, 2015). In developing countries, fossil fuel subsidies act against these goals by encouraging fossil fuel consumption and its attendant environmental impacts. These subsidies also worsen inequality by mainly benefiting the wealthiest households and reducing government finances that could be used to improve health, education, and access to clean water (IISD, 2017).

These subsidies are often very difficult to reform. Fossil fuel subsidy reform is associated with price shocks and negative welfare implications for the most vulnerable in society (Coady, et al., 2012). Historically, attempted fossil fuel subsidy reforms have been met with popular resistance, which sometimes turns violent (Bacon & Kojima, 2006). Reform attempts in Bolivia (2010), Venezuela (1989), Nigeria (2012), and Yemen (2005 and 2014) have had to be abandoned due to widespread protests.

Petroleum subsidies fell in value during the last quarter of 2014 as a result of low oil prices, which narrowed the gap between international prices and subsidized prices (Kojima, 2016). This drop enabled the removal of petroleum subsidies in countries such as India, Nigeria, and Indonesia with lesser associated welfare impact (IEA, 2015). However, the high political and economic cost of removal ensured that as international prices of oil rebounded in the first half of 2015, many of the countries that adopted subsidy reforms failed to raise prices accordingly (Kojima, 2016).

Perhaps the most cogent reason for the high political cost of subsidy removal is the high dependence of fossil fuels. Globally, fossil fuels constitute the dominant energy source, making up approximately 85% of total primary energy consumption in 2016. In Africa, over 92% of energy consumption comes from oil, natural gas, and coal (BP, 2017). This dependence on fossil fuels has environmental implications and shapes society, technology, and institutions. Climate change and its associated effects are perhaps the most significant environmental challenges associated with the continued dependence on fossil fuels. Fossil fuels are the dominant energy source for industrial, commercial, transportation, and residential sectors and have established institutions that govern their production, transformation, and use.

A transformative energy transition to low carbon, higher efficiency energy sources is critical to addressing climate change and create low carbon development pathways. Renewable energy penetration can also lower dependence on fossil fuels and reduce the resistance against fossil fuel subsidy reform, making it easier to reform subsidies. Strong renewable energy policies enable developing countries to leapfrog over the traditional fossil fuel dominated development pathways and move towards low carbon development pathways (Dasgupta, Laplante, Wang, & Wheeler, 2002). Renewable energy policies remove the barriers to renewable energy deployment, promote technological innovation, and influence the cost and prices of renewable energy supplies (Verbruggen, et al., 2010). Figure 1 below illustrates how policies and policy instruments affect renewable energy supply and potential. Appropriate renewable energy policies can influence the cost and viability of renewable energy investment and promote technological innovation. Policies could also be used to target identified barriers to renewable energy diffusion and directly support research and development.

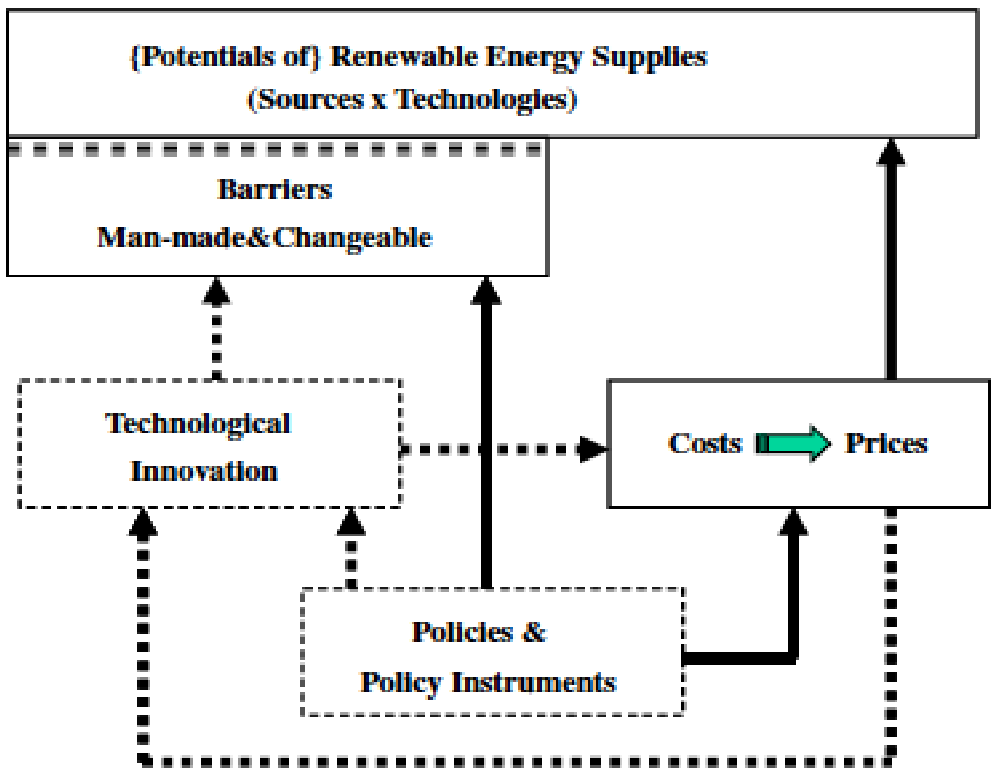

Figure 1: Factors influencing supply and potential of renewable energy supply. (Source: Verbruggen, et al., 2010)

This dissertation analyzes the conditions that have led to the persistence of fossil fuel subsidies and the high political cost of reform in Nigeria. It examines the role of renewable energy in reducing the cost of fossil fuel subsidy reform and promoting sustainable development. It utilizes the Long-Range Energy Alternatives Planning (LEAP) software to carry out scenario-based analysis of renewable energy diffusion and study the impacts of renewable energy technology penetration to sustainable development. Also, the barriers and opportunities for renewable energy diffusion are examined, and lessons from case studies are reviewed to inform renewable energy policy and implementation.

1.2 Statement of Problem

In 2015, the United Nations (UN) adopted a set of 17 ambitious Sustainable Development Goals. These Sustainable Development Goals (SDGs) encompass a range of developmental goals that aim to address issues of societal, economic, and environmental growth by 2030. The goals are interrelated and include 169 associated targets agreed upon by all 193 UN member countries. The 17 goals are highlighted below:

Figure 2 Sustainable Development Goals

A key challenge to achieving these developmental goals on the African continent is the mobilization and utilization of financial resources. Given the high developmental deficit on the continent, the scale of financing needed to achieve these goals is daunting. Estimates of annual incremental investment required to meet these goals in Africa are put between $600 billion and $1.2 trillion (Kedir, Elhiraika, Chinzara, & Sandjong, 2017; Schmidt-Traub, 2015 ; UNCTAD, 2014). Domestic budgetary allocations alone are unable to address these challenges, so external assistance is needed to reduce the burden. A low hanging fruit for increasing local budgets for developmental needs is to reform fossil fuel subsidies. For instance, Ghana was able to increase the coverage of its Livelihood Empowerment against Poverty (LEAP) cash transfer program from 100,000 to 150,000 people during the process of fossil fuel subsidy reform in 2014, and the Philippines invested more in renewable energy and safety nets after removing subsidies between 1996 and 2001 (IISD, 2017).

Fossil fuel subsidies are of various types, including:

1. Direct financial transfers: In this case, grants are provided directly to producers or consumers.
2. Trade instruments: This is usually in the form of tariffs on imports to make domestic production more profitable.
3. Regulation: This takes the form of regulations that keep gasoline prices from being sold at market prices or promote the use of domestic fossil fuel sources.
4. Tax breaks: This involves favorable tax laws for fossil fuel production companies.
5. Credit: This takes the form of loan guarantees or preferential loan rates to fossil fuel producers.

6. Risk transfers: An example of this is Insurance provided to fossil fuel producers at below market.
7. Below full cost access to government goods and services.

Fossil fuel subsidies have adverse social, economic, and environmental implications for sustainable development. They take up a significant portion of government revenue, perpetuate inequality, harm public health, and increase the inefficiency of energy use. Estimates of the size of fossil fuel subsidies differ based on the method used. Fossil fuel subsidies, including electricity subsidies in 30 Sub-Saharan Africa (SSA), were estimated to be about $26 billion in 2015, falling from $30 billion in 2013 due to lower oil prices. The International Monetary Fund (IMF) puts the cost of mispricing fossil fuel products was $49 billion by 2015 in SSA (Coady, Parry, Sears, & Shang, 2015). Considering environmental externalities, the negative impacts of fossil fuel subsidies cost SSA $75 billion in 2015. Countries like Nigeria, South Africa, Angola, and Tanzania were providing fossil fuel subsidies upwards of $ 1 billion in 2015 (Whitley & van der Burg, 2015). Table 1 shows the estimated size of subsidies in different SSA countries in 2018 in millions of US dollars.

Nation	Oil (Million dollars)	Electricity (Million dollars)	Gas (Million dollars)	Coal (Million dollars)	Total (Million dollars)	Total subsidy as share of GDP (%)
Angola	1,382.4	517.1	-	-	1,899.6	1.80%
Gabon	121.3	0.9	0.8		123.0	0.70%
Ghana	164.4	-	6.7	-	171.1	0.30%
Nigeria	2,467.5	411.5	20.0	-	2,899.0	0.70%
South Africa	-	4,157.9	-	-	4,157.9	1.10%

Table 1 Size of subsidies in Africa in millions of US dollars (Source: IEA, 2019)

Despite these negative environmental implications and the huge fiscal burden of fossil fuel subsidies, governments are often reluctant to undertake subsidy reform. Several reasons have been suggested for this inertia, including the lack of knowledge about the negative impacts, special interests in maintaining subsidies, and weak institutions (Whitley & van der Burg, 2015). Attempts to reform subsidies have often been met with widespread protests and strikes, which have forced governments to review their position. Some examples of failed fossil fuel reform are detailed below:

i. Sudan 2013

On September 23, 2013, the Sudanese government announced cuts in petroleum subsidies, raising prices of gasoline, diesel, and liquefied petroleum gas (LPG) by 65-75 percent (James, 2014). The resultant protests were strongly resisted by government forces leading to an official death estimate of 84 protesters, but some death estimates are put at over 200 (Amnesty International, 2013; James, 2014). Cars and petrol stations were burnt, and internet access in the country was cut off.

Compensation measures announced by the government were minimal and, as such, could not cushion the resultant inflationary effects.

The secession of South Sudan in 2011 led to the loss of over 75% of Sudan's crude oil field, resulting in a significant decline in revenue. This created economic pressure, forcing the central bank to print money to fund government expenditure and fiscal imbalances. This prompted the government to make several attempts to reduce subsidies, but these attempts are followed by protests and government crack-down (BBC, 2013; James, 2014).

ii. Yemen 2005

In Yemen, fossil fuel subsidies are the most significant expenditure in the national budget—exceeding spending on education, health, and social protection. In 2012, these subsidies made up 10% of the Gross Domestic Product (GDP), after peaking at 14% of GDP in 2008 (Clements, et al., 2013). A significant proportion of household income is expended on fuel consumption and transportation by both rural and urban dwellers. As a result, attempts to increase prices have often been met with violent protests (Breisinger, Engelke, & Ecker, 2012).

The Yemeni government increased domestic fossil fuel prices by an average of 130% in 2005, sparking widespread protests that resulted in dozens of deaths. The protests led to a partial restoration of the subsidies, but price increases remained substantial, including a 71 percent increase in gasoline prices, a 106 percent increase in diesel, and a 119 percent increase in kerosene. The benefits of reforming these subsidies were quickly wiped out by inflation in the prices of commodities. Fossil fuel subsidies still make up a significant portion of national expenditure (Clements, et al., 2013).

iii. Bolivia in 2010

On December 26, 2010, the Bolivian government announced an increase in the prices of petroleum products, including a 73% increase in gasoline and an 83% increase in the price of diesel fuel. This led to strikes by teachers and bus-drivers as well as riots to protest the rise. A 20% increase in the wages of government employees did little to mitigate the situation as a nationwide strike was announced soon after. The government reversed the price increases a day after the nationwide strike begun (GIZ, 2011).

Even though the fuel subsidies in Bolivia benefit mainly the rich, there are negative welfare implications for the poorest for reforming subsidies. Ad-hoc price setting[1] and the overall lack of information regarding the size of fossil fuel subsidies make them challenging to reform (GIZ, 2011). People are generally unaware of the fiscal cost of subsidies and believe that wealth from extractive activities should be shared amongst the population. (Laserna, 2018)

[1] The price of petroleum products is not dependent on the market price fluctuations or any formula but by the government's decisions.

iv. Nigeria, 2012

The Nigerian government spent an estimated ₦2.19 trillion ($7.2 billion at 2018 exchange rate) on fuel subsidies, more than 4% of the GDP in 2011, and 118% of capital budget (Moyo & Songwe, 2012; IISD, 2012). On January 3, 2012, in a surprise move, the Nigerian government announced the removal of these subsidies. This led to two weeks of nationwide strikes and protests that eventually led to the government reinstating part of subsidy (IISD, 2012).

The government sets a fixed pump price for gasoline through the Petroleum Products Pricing Regulatory Agency (PPPRA) and pays the difference between the pump price and the market price. High crude oil prices raise the cost of fossil fuel subsidies and increase the fiscal burden of paying for the difference.

Increases in the prices of gasoline affect the costs of transportation, food, and the operation of small businesses. This is a result of the high dependence on gasoline for daily activities. A significant proportion of businesses and households depend on gasoline and diesel-powered generators for power, since over 70 million people lack access to electricity in Nigeria, and 60% of firms depend on backup generators that run on diesel or gasoline. This proportion is higher than in most places in Africa. These generators are used to make up for frequent power outages, which are estimated to account for 10% of revenue lost by the formal private sector (Foster & Pushak, 2011). Increases in the prices of petroleum products reduce the profit margins of small business operators by increasing the cost of operation. It also increases the cost of household access to modern energy.

The central theme in these countries is the dependence on fossil fuel for critical products and services. Fossil fuel consumption makes up 85.2% and 98% of total energy consumption in Bolivia and Yemen, respectively. In the case of Nigeria, energy supply is dominated by inefficient, traditional solid biomass and waste with fossil fuel consumption making up only 19% of overall energy consumption (The World Bank, 2014). However, petroleum products are the dominant energy sources for transportation and electricity. They account for 100% of transportation fuels, which accounts for approximately 70% of total fossil fuel use in Nigeria. Gasoline accounts for the largest share in the transportation fuel consumption accounting for up 58% of fuel consumption (Chukwu, Isa, Ojosu, & Olayande, 2015). In addition, over 80% of electricity generation comes from natural gas, but electricity is still supplemented by gasoline and diesel-powered generators (IEA, 2018).

Renewable energy diffusion in critical areas can reduce fossil fuel dependence and the high political cost associated with fossil fuel subsidy reform. This would free up funds for developmental activities and provide sustainable development benefits.

1.3 Rationale for Research

One of the most difficult challenges facing policymakers in Africa is mobilizing resources for financing developmental goals. Post-tax fuel subsidies cost oil-exporting countries in Africa a median of 1.9% of GDP and 0.8% of GDP for oil importers in 2012. In Nigeria and Angola, fuel subsidies are above 3% of the GDP in the same year (IMF, 2013). The size of these subsidies places a substantial fiscal burden on these countries and diverts resources from other human development activities.

Domestic public financial resources remain the largest source of financial resources for most countries. However, international financial flows to developing countries have increased significantly over the last decade, driven mainly by private capital flows and remittances (UN, 2014).

The World Bank has indicated that economic growth in Africa averaged 4.5% annually since the mid-1990s. The poverty rate (living on less than $1.25 a day) also dropped from 57% in 1990 to 43% in 2015, but this drop is much lower than other regions of the world, and the actual number of poor people has increased by over 100 million people in that period (World Bank Group, 2016). The global concentration of poverty is also falling in every region of the world, but SSA, as shown in figure 3. Africa also suffers from low rates of clean water, sanitation, infrastructural development, and energy access (World Bank Group, 2016). Addressing these challenges would require considerable domestic and international as well as private and public financial resources.

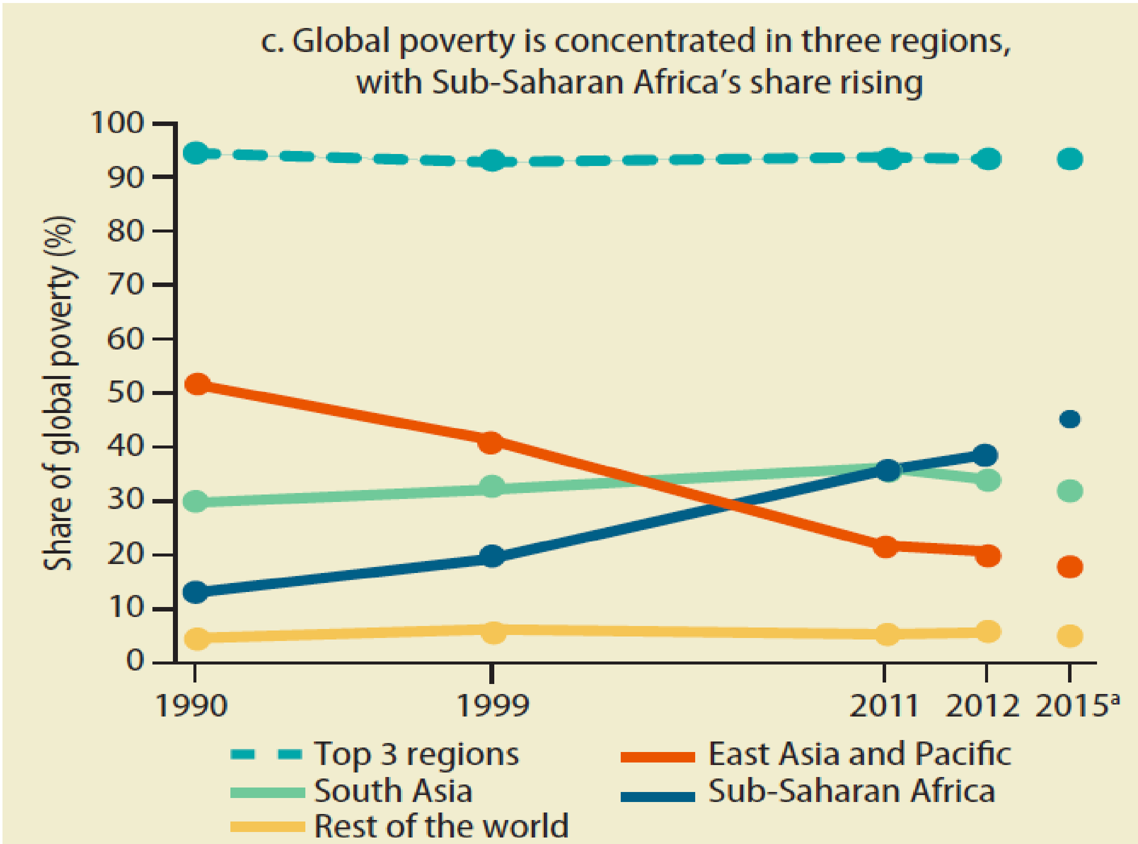

Figure 3 Concentration of global poverty (Source: World Bank Group, 2016)

Fossil fuel subsidy reform could free up funds that can be utilized for development, but dependence on fossil fuel resources by much of the population for essential services makes reform very politically difficult. In 2017, fossil fuels accounted for about 92% of primary energy consumption on the continent (BP, 2017). Attempts to reform are often associated with strikes and popular protests that sometimes turn violent, as in the case of Nigeria in 2012.

This dissertation explores the role of renewable energy diffusion in reducing the political cost of fossil fuel subsidy reform, making it easier to carry out reforms and free up resources for other developmental goasls. It analyses the political dynamics in Nigeria, the factors that support the retention of fossil fuel subsidies, and the opportunities for renewable energy penetration. The research also develops scenarios of renewable energy diffusion and analyzes the potential impacts of renewable energy penetration in Nigeria.

1.4 Rationale for Topic Selection

I have selected the topic to carry out my research for the following reasons:

1. The political economy of fossil fuel subsidies (fossil fuels and electricity) in Nigeria is complex because of the size of the country, the number of actors, and the importance of oil and gas to the country's economy. An understanding of the factors that influence the perpetuation of these subsidies in Nigeria could provide insights for sustainable energy development and fossil fuel subsidy reform in other parts of Africa.
2. Energy access challenges in Nigeria offer a unique opportunity to take concrete steps towards energy system transition and less dependence on established energy forms.
3. Familiarity with the conditions in Nigeria as it relates to fossil fuel subsidies would make it easier to locate data sources for scenario analysis.

4. The topic helps me examine different types of environmental, political, social and technological issues surrounding energy, and fossil fuel subsidies, especially from the African perspective.

1.5 Research Questions

1. What are the conditions that enable the persistence of subsidies in Nigeria's petroleum and electricity sectors? Why are they so difficult to remove?
2. What are the opportunities/barriers for cleaner alternatives to subsidized fossil fuel resources?
3. What are the potential environmental, social, and economic benefits of making the transition to cleaner energy sources in Nigeria and the implication for sustainable development?
4. What lessons can we draw to improve policy formulation and implementation in fossil fuel subsidy reform and the diffusion of cleaner alternatives?

1.6 Organization of Chapters

Chapter 1: Introduction

This chapter introduces the research topic and explains the rationale behind the research focus and topic selection. It also presents the statement of the problem and the research questions that this research intends to answer.

Chapter 2: Literature Review

This chapter reviews relevant literature on the topic and introduces the major concepts that will be analyzed, including fossil fuel subsidies, the Nigerian experience with subsidies and renewable energy diffusion.

Chapter 3: Conceptual Framework

In this chapter, important concepts relevant to the dissertation are discussed. These concepts include sustainable development in Africa, energy access and fossil fuel subsidies and the politics of fossil fuel subsidy reform.

Chapter 4: Research Design and Methodology

This chapter will define the methodology that will be applied to conduct this research. It outlines the steps that would be taken to complete this dissertation. It also contains sources of data required to do the research and the research approach adopted.

Chapter 5: Analysis

This chapter contains the analysis needed to answer the research questions.

Chapter 6: Discussion and Conclusion

The final chapter will summarize the results of the dissertation. It contains the policy recommendations for fossil fuel reform and renewable energy penetration, as well as the successes and limitations of the study. It will also highlight areas for future research.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

This literature review looks at relevant studies tied to fossil fuel subsidies, their reform, and renewable energy penetration in Nigeria. The literature provides an understanding of subjects pertinent to this study and offers insights into addressing the questions posed by this dissertation. This dissertation adds to the existing literature by examining the reasons for the persistence of fossil fuel subsidies in Nigeria and the role of renewable energy penetration in reducing the political cost of fossil fuel subsidy reform and promoting sustainable development.

2.2 Fossil Fuel subsidies

The literature on fossil fuel subsidies usually take three different forms, the first estimates the costs of fossil fuel subsidies, the second looks at the impacts of fossil fuel subsidies and the third examines the effects, challenges, and design of effective fossil fuel subsidy reform.

The design of subsidies is dependent on the objective of the policy and where the benefits accrue. Subsidies can operate on the demand-side and supply side of the energy economy and are designed to achieve goals such as energy security, domestic energy production, and affordable access to energy (Whitley & Van der Burg, 2015). Supply-side subsidies are geared towards reducing the cost of energy production and protecting firms from competition and surplus production. It takes the form of direct funding of research and development, indirect subsidies to producers (such as production tax credits, accelerated depreciation and loan guarantees), and direct monetary prizes. Demand-side subsidies are aimed at market creation and include tools such as price controls (World Economic Forum, 2013).

2.2.1 Cost of Fossil Fuel Subsidies

Fossil fuel subsidies place a lot of burden on economies, the environment, and societies. Estimates of the cost of fossil fuel subsidies differ depending on the definition of what comprises a subsidy and the method applied in calculating the subsidies. Jakob Skovgaard (2017) contrasts definitions of fossil fuel subsidies from two international economic organizations, the International Monetary Fund (IMF) and the Organization for Economic Co-operation and Development (OECD). OECD takes a more conventional approach and defines subsidies as benefits conferred to a group while the IMF takes into consideration the environmental externalities in estimating subsidies (Skovgaard, 2017).

Government support for fossil fuel subsidies remains high across the world. China, the United States, Russia, the European Union, and India are the biggest subsidizers, according to IMF estimates (Coady, Parry, Sears, & Shang, 2015). The IMF estimated that the cost of energy subsidies when environmental and social externalities are included were as high as $5.3 trillion in 2015. These subsidies made up 6.5% of global GDP and were dominated mainly by fossil fuel subsidies (Coady, Parry, Sears, & Shang, 2015). In a similar study, Koplow (2014) estimated that energy subsidies between 2007 and 2011 were above $2 trillion annually when environmental externalities are taken into consideration. As in the case with the Coady et al. (2015) study, fossil fuel financial subsidies were found to make up a significant proportion of energy subsidies, accounting for 69% of all energy subsidies between 2007 and 2011 (Koplow, 2014). These estimates are higher than the International Energy Agency (IEA) 2015 energy subsidy estimate of $325 billion based on a more conventional definition of subsidies (IEA, 2016).

An analysis of subsidy programs and tax cuts used in 34 OECD countries and six emerging economies (Brazil, China, India, Indonesia, Russia, and South Africa) estimated that $160-200 billion was spent annually between 2007 and 2014 to subsidize fossil fuels (OECD, 2015). On the other hand, global subsidies to renewable energy are estimated to be about $150 billion, 80% of which goes to the power sector (IEA, 2016). In China alone, fossil fuel subsidies, excluding residential energy consumption, were estimated to be about $160.23 billion between 2006 to 2010 (Li & Lin, 2015). Subsidies can place significant burdens on government resources. Fossil fuel subsidies in the Pacific Island of Kiribati were estimated to make up 2.2% of GDP, 3.7 % of government revenues, and 29 % of government health expenditure over the period 2011–2014 (Peltovuori, 2017).

2.2.2 Impact of Fossil Fuel Subsidies

Other studies look at the overall effects of subsidies and their effects on their desired goals. The impacts of fossil fuel subsidies can be economic, environmental, and social (FFFSR, 2015). The economic goals behind the implementation of fuel subsidies include boosting local industrial development, income buffering, redistribution of wealth, and fostering economic growth and development (De Oliveira & Laan, 2010). These are often justified by the potential for subsidies to reduce poverty and promote access to affordable energy (Commander, 2012; Rentschler & Bazilian, 2017). Fuel subsidies, on the contrary, have been shown to inhibit growth by causing fiscal imbalances and worsening debt. They also lead to inefficient allocations of resources and other macroeconomic distortions (Plante, 2014). Also, fuel subsidies reduce incentives to invest in the energy sector and diminish the competitiveness of the private sector in the short and long term (Bauer, et al., 2013). Increased smuggling of products is another adverse consequence and is widespread across countries that have fuel subsidies. It is estimated that more than 80% of the gasoline consumed in Benin in 2011 was smuggled from Nigeria. This is because marketers could get a higher price for products outside Nigeria (Mlachila, Ruggiero, & Corvino, 2016).

Fossil fuel subsidies, when poorly targeted, are known to be socially regressive— benefitting wealthy households that consume more of the subsidized product. It is estimated that the bottom 40% of the population in several developing countries receive only about 15%-20% of the total benefits from energy subsidies

(Coady, et al., 2006). Soile and Mu (2015) estimate that the top 20% of households in Nigeria enjoy twice the benefits of fossil fuel subsidies than the bottom 20% of the households (Soile & Mu, 2015). Therefore, fuel subsidies can perpetuate existing patterns of poverty, energy inequity, and inequality. The household welfare impact for subsidy reform is mixed for different economies. Negative welfare impacts can often be mitigated with compensation (Dennis, 2016). Fossil fuel subsidies could also have negative effects on traffic congestion, water availability for agriculture and health by increasing consumption of fossil fuels. The elimination of fuel subsidies by 2024, combined with a 20% increase in oil prices, is estimated to result in savings of roughly 0.04 percent of GDP in Egypt in terms of mortality and morbidity[2]. The reduction in morbidity and mortality comes from a reduction in the use and combustion of fossil fuels (Commander, Nikoloski, & Vagliasindi, 2015).

Fossil fuel subsidies encourage increased and wasteful consumption of fossil fuel resources (Plante, 2014)—and its attendant deleterious impact on the environment. Fossil fuel combustion accounts for about 80% of CO_2 emissions and about two-thirds of total greenhouse emissions (IEA, 2017).

[2] Increased use of fossil fuels caused by subsidies is responsible for environmental pollution, which results in death and diseases. Reducing subsidies would discourage the use of these fuels and reduce the rate of death and diseases. Commander et al (2015) express the reduction in injury and loss of lives from the elimination of subsidies in terms of GDP.

2.2.3 The Impacts, Challenges, and Design of Fossil Fuel Subsidy Reform.

Some studies indicate that the phasing-out of fossil fuel subsidies could serve as viable mitigation of greenhouse gas emissions. Burniaux, J. & Chateau, J. (2014) estimates that removing fossil fuel subsidies can reduce global greenhouse emissions by 8% by 2050. (Burniaux & Chateau, 2014) Emissions could be reduced by as much as 23% when complemented with appropriate fuel taxes (Parry, Heine, Lis, & Li, 2014). Jewell et al (2018) disputes this and suggest that removing fossil fuel subsidies would have a limited impact on global energy demand, greenhouse emissions, and renewable energy penetration. The authors estimate that the largest CO_2 emission reductions from subsidy removal come from high income, petroleum exporting countries. However, it estimates that subsidy removal would result in smaller emission reductions than the Paris Agreement (2015) climate pledges in most regions. In some countries, it was projected that the elimination of subsidies would lead to increased emissions as countries substitute unsubsidized oil and gas for coal (Jewell, et al., 2018). It is, therefore, important that renewable energy policies accompany the removal of fossil fuel subsidies.

In a similar study to Jewel et al (2018), Li & Sun (2018) argue that removal of subsidies cannot on its own, lead to a reduction in CO_2 emissions, and would instead increase the use of cheaper fossil fuels like coal. Like other studies, it proposes that additional policies will be needed to achieve this (Li & Sun, 2018). Schwanitz et al (2014) also argue that without complementary climate and sustainable energy policies, the environmental benefits of fossil fuel reform are limited in the long term and can slow down the transition to a more sustainable energy system. (Schwanitz, Piontek, Bertram, & Luderer, 2014).

Using a multi-region computable general equilibrium (CGE) model, Wessel & Lin (2017) estimated the macroeconomic impacts of refined oil subsidy reform in Ghana. The authors concluded that whilst reform increases government savings, it also results in negative impacts, including an increase in the price of land, a reduction in the GDP and a decrease in labor wages, household income, and trade. This study suggests that the removal of oil subsidies will increase the output of fuel-intensive sectors such as transportation and manufacturing. Complimentary policies that improve agricultural productivity and reduce trade transaction costs can mitigate undesirable effects associated with reform (Wesseh jr. & Lin, 2017). A study carried out on fossil fuel reform and the recycling of the savings to promote rooftop photovoltaic (PV) in the European Union (EU) suggests that there is an increase in CO_2 emission reduction from 1.8% to 2.2% by 2030. Fossil fuel subsidy reform on its own has a small impact on CO_2 emissions as people just switch from coal to gas (Sampedro, Arto, & González-Eguino, 2018).

When it comes to examining the impacts and challenges of subsidy reform, China presents a useful example. Zhujun Jiang & Boqiang Lin (2014) suggest that fossil fuel reform will have negative macroeconomic impacts in China even if there is a decline in energy demand and CO_2 emissions. The researchers suggest that sustainable programs from the revenue saved from subsidy reduction will be needed to mitigate the adverse impacts of removing fossil fuel subsidies (Jiang & Lin, 2014). Ouyang and Lin (2014) contend that increasing renewable energy subsidies will make energy consumption structure cleaner, improve energy efficiency and address the challenge of unbalanced distribution and consumption of energy in China (Ouyang & Lin, 2014).

Allen's (2016) analysis considers the impacts of fossil fuel subsidy reform to be more positive. According to their assessment, the welfare implications of subsidy reform in developing countries were unambiguously positive for government and overwhelmingly positive for private households. Allen contends that negative impacts can be mitigated by government compensation in such a way that it sustains household income and achieve fiscal savings from subsidy removal (Allen, 2016). Despite these positive welfare impacts, Allen (2016) argues that the political economy of subsidy reforms remains a serious impediment to governments implementing fossil subsidy reforms (Allen, 2016).

The design of reform is important to reduce challenges and the adverse effects of reform. Rentschler & Bazilian (2017) provide guidelines for effective fuel subsidy reform. Some of the recommendations include communication and compensation to increase knowledge and reduce adverse effects of subsidy removal, transparent systems for the reinvestment and allocation of reform revenue, smart timing of reform, and the use of complementary policies to support price deregulation (Rentschler & Bazilian, 2017).

Socio-economic concerns associated with subsidy reform cause delays and reluctance on the part of the government to implement reform. These delays increase the cost of sustainable development, increase environmental costs, threaten national energy security, discourage energy investments, and hinder the development of alternatives to fossil fuels (Lin & Ouyang, 2014). Subsidy reforms have significant distributional impacts and lead to price shocks that are felt across different income groups. Whilst subsidies benefit mainly the rich, the implementation of reforms could also have significant negative effects on the welfare of the most vulnerable people (Rentschler, 2016). The lowest-income households suffer the most significant hardships with the large welfare losses due to their low level of consumption (Arze del Granado, Coady, & Gillingham, 2012). Subsidies can become very difficult to reform and are politically sensitive. One of the most common barriers identified by literature is public opposition (Victor, 2009; Overland, 2010; Cheon, Urpelainen, & Lackner, 2013). Other barriers identified include vested interests and lack of institutional capacity (Victor, 2009; Cheon, Urpelainen, & Lackner, 2013). These barriers, as well as sharp international price increases, have forced countries to go back on subsidy reform. (IMF, 2013)

Public support for fuel subsidy reforms can be boosted by informing consumers about the deleterious effects of existing subsidies and the benefits of reform. Effective public information would highlight the fact that subsidies provide incentives for inefficient energy consumption, show that local retail prices are affected by international price fluctuations, inform the population of how savings will be utilized and provide information on how benefits accrue to the most wealthy in the society. (Arze del Granado, Coady, & Gillingham, 2012).

Smith & Urpelainen (2017) investigated how international organizations can directly support the enactment and implementation of national fossil fuel subsidy reforms. They suggest that international organizations can incentivize countries to stick to fossil fuel subsidies reforms by facilitating formal commitments from countries to reform fossil fuel subsidies. These commitments increase the reputational risks of backsliding for countries. International organizations can utilize tools such as public announcements, peer review mechanisms, and benchmarks to increase a government's reputation cost of policy reversal. Since reputation is an important mechanism for cooperation in international governance regimes, the authors argue that a high reputational risk would make governments less likely to withdraw from subsidy reforms (Smith & Urpelainen, 2017).

Schmidt, Matsuo, & Michaelowa (2017) examined fossil fuel subsidies from economic, political, and technological perspectives. They argue that fossil fuel subsidies are maintained by feedbacks between institutions, economic actors, policymakers, and technologies. Technologies influence and are influenced by the economy, institutions, and politics in society, and as technologies become dominant, they create economic, institutional, and technological feedbacks that make society dependent on them hereby making reform difficult. Figure 4 illustrates the role of feedbacks in maintaining the fossil fuel subsidies Schmidt et al. describe: From the political (1) and economic (2) perspective, subsidies are promoted as a form of political rent (3) designed to boost equity, economic growth, and development (4). Once established, fossil fuel subsidies become a social contract between political leaders and society and can affect political stability (5). These subsidies soon lead to a growing fiscal deficit (6) and economic inefficiency (7), which are sustained by the dominant fossil fuel technological system (8). Subsidies encourage more investment in fossil fuel generation (9) and create a host of complementary networks and systems. (10) This leads to increased competencies in fossil fuel technological systems (11) and the lock-in of technologies. A fossil fuel-dependent economy is created with energy-intensive local industries, and the removal of these subsidies could lead to economic loss and a loss of jobs (12). This makes policymakers averse to fossil fuel subsidy reform. Besides, the development of large fossil fuel industries and actors leads to increased market power for them and the development of vested interests in the maintenance of subsidies. (13)

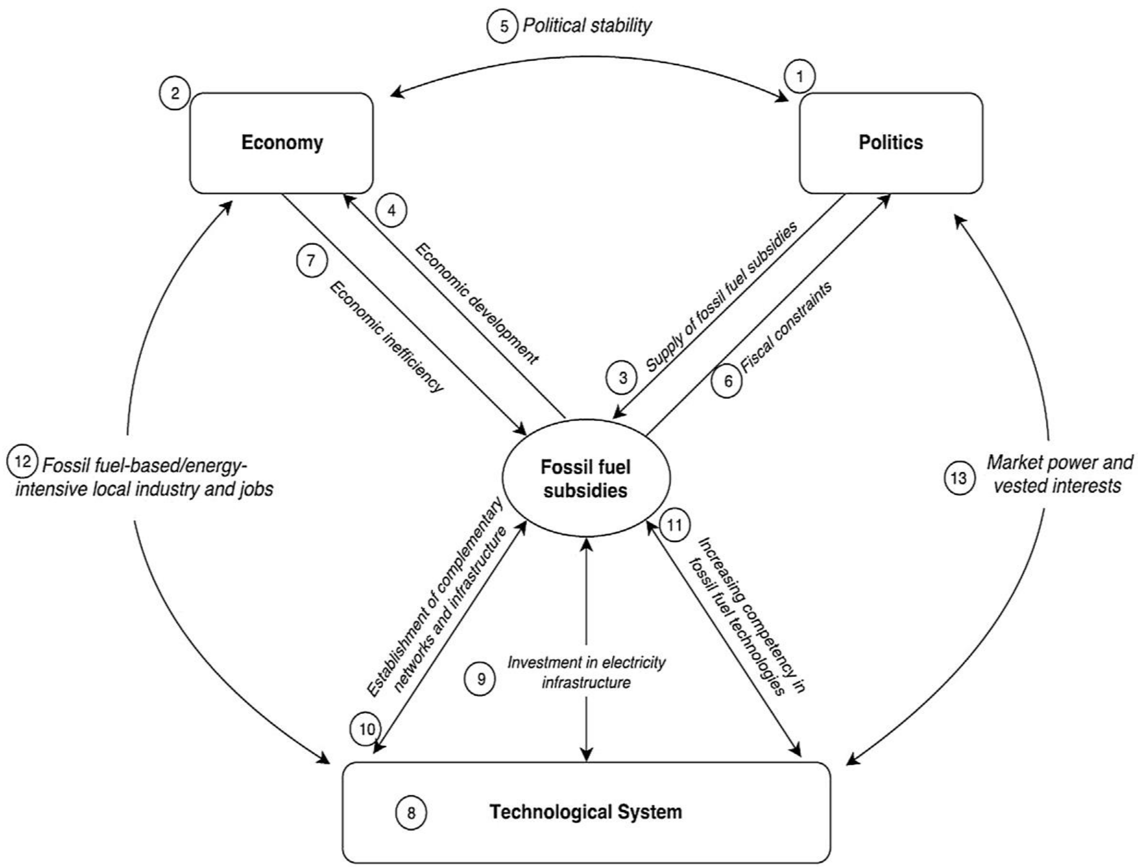

Figure 4: Energy Subsidies in three perspectives (Source: Schmidt, Matsuo, & Michaelowa, 2017)

2.3 Nigeria and Fossil Fuel Subsidies

Fuel subsidies and their reform is a very contentious issue in Nigeria and plays a vital role in fossil fuel demand. It is estimated that fuel subsidies account for about 50% of petroleum demand (Nwachukwu & Chike, 2011). This means that petroleum demand can be significantly reduced by removing the subsidies. An empirical study by Nwachukwu et al (2013) on the relationship between petroleum subsidies and price concluded that subsidies accounted for 79% of fuel price, and consumers pay only 21% of the actual price of petroleum products. They argued for a gradual removal of subsidies and the application of fiscal savings to mitigating the negative effects on the poor (Nwachukwu, Mba, Jiburum, & Okosun, 2013). A similar conclusion was reached by Soile & X. Mu (2015). The authors argue that fuel subsidies in Nigeria are regressive as most of the benefits accrue to the wealthy. They contend that the poor targeting of subsidies and the huge financial burden on the government make it untenable and propose a gradual removal of petrol subsidies. However, the authors support the retainment and restructuring of kerosene subsidies in the short-medium term since they are more widely used by the poor (Soile & Mu, 2015).

Some other studies present a case for the continuous implementation of petroleum subsidies in Nigeria. Ezeani (2014) argues that the practical realities of a developing, mono-economy like Nigeria do not make the removal of subsidies advisable. The author contends that the argument that subsidies benefit the rich is an appeal to populism and that the problem is as a result of poor application/targeting. He argues that there are no guarantees that palliative measures will reach the poor/vulnerable and that the lack of an enabling environment for businesses could inhibit the development of a liberalized energy market (Ezeani, 2014). In a similar study, Bazilian and Onyeji (2012) conclude that the common arguments for subsidy removal do not reflect the realities on the ground in the context of developing economies like Nigeria. The authors assert that the infrastructural and institutional deficiencies present in Nigeria are not factored in the arguments for removing subsidies. They argue that existing power shortages and the resultant increased fuel cost from petroleum subsidy removal would reduce the cost-competitiveness of firms. The authors suggest that alternative policies must be put in place as building blocks before fuel subsidies are removed (Bazilian & Onyeji, 2012). Akanle et al (2014) argue that subsidy reform that will lead to high prices of petroleum products is unjustified given the low wages of Nigerian workers compared to other oil-producing countries (Akanle, Adebayo, & Adetayo, 2013).

Asekunowo (2012) adopts a middle position. He asserts that removing subsidies suddenly will have adverse social implications on the poor and that Nigeria lacks the mechanisms needed to shield the poor from the adverse effects of price increases. However, the author accepts that the fiscal cost of fossil fuel subsidies makes them unsustainable. Between 2006 and 2008, subsidy payments were in the range of N1.8 billion (approximately $5.1 million), outstripping spending budgets for health, infrastructure, human capital development, and food security (Asekunowo, 2012). The author proposes a targeted application of subsidies to the poor, which should be supported by an effective pre-implementation publicity campaign. It also proposes the repair and maintenance of domestic refineries to boost local fuel production (Asekunowo, 2012).

Fossil fuel reform has distributional, economic, and technological impacts. Rentschler (2016) estimates that national poverty will increase by 3-4% in Nigeria with subsidy removal. These effects are unevenly distributed, with some states having worse outcomes than others. The worst welfare shocks are expected in Lagos and Abuja, which were the hotbeds of violent popular protests when there was an attempt to reform subsidies in 2012. The paper suggests that tailored regionally disaggregated compensation[3] and social programs will reduce or maintain the pre-subsidy poverty rate and protect the most vulnerable populations (Rentschler, 2016). In a related study, Siddiq et al (2014) utilized an economy-wide framework to examine the effects of fossil fuel removal on the Nigerian economy and how alternative policies can be used to meet the goals of fossil fuel subsidies. The authors concluded that whilst the removal of subsidies boosted national GDP, it had unfavorable effects on poor households. They suggested that targeted monetary compensation aimed at poor households as well as increased domestic production, can reduce the effects of reform (Siddig, Aguiar, Grethe, Minor, & Walmsley, 2014). Lin & Atsagli (2017) examined the potential for inter-factor and inter-fuel substitution between capital, labor, petroleum, and electricity in Nigeria. The paper concluded that adopting competitive pricing and petroleum subsidy reform will lead to increased use of electricity in industrial applications as well as increase the capital and labor intensiveness of industry. The authors also established that the shift away from petroleum to electricity would reduce CO_2 emissions (Lin & Atsagli, 2017).

[3] This refers to compensation designed to the needs of each region affected by subsidy removal. Since the welfare impacts of subsidy removal differ across the country, the compensation should be tailored to meet local needs.

Akanle, Adebayo, & Adetayo (2014) studied the context and perspectives of Nigeria's petroleum subsidy issues considering its developmental challenges. They discuss the corruption associated with the fossil fuel subsidy regime and the factors that led to the 2012 violent opposition to subsidy reform. The authors highlight the positions of the different actors in the Nigerian petroleum industry and propose that anti-corruption mechanisms and networks be put in place to sanitize the petroleum sector. They also suggest that palliative measures like public transportation and targeted social services for the poor must be put in place before subsidies are removed. Akanle, Adebayo, & Adetayo (2014) argue that Nigerians are unprepared for the complete removal of subsidies without measures put in place to mitigate the adverse effects of price surges. It argues that the dependence on petroleum by businesses and households for power during regular blackouts and transportation means that there will always be stiff opposition to attempts to remove petroleum subsidies (Akanle, Adebayo, & Adetayo, 2013).

2.4 Renewable Energy Diffusion in Nigeria

A key element to reducing the resistance to fossil fuel subsidy reform is to reduce the dependence on petroleum products. The diffusion of clean alternatives would provide options for those affected by price surges associated with fossil fuel subsidy reform/removal and reduce the political cost of reform. It would also reduce dependence on imports, constrain the growth of petroleum prices, reduce greenhouse emissions, and provide income for other sectors of the economy (Sobrino, Monroy, & Pérez, 2010).

The literature on renewable energy diffusion in Nigeria can be divided into three main categories. The first category examines the context, challenges, opportunities, and policies needed for renewable energy development in Nigeria, and the second category of studies examines technologies, their advantages, feasibility, and potential for diffusion given the Nigerian context. The last category of research looks at the potential effects of renewable energy diffusion in Nigeria.

Akuru et al (2017) examined the possibilities and challenges of renewable energy diffusion in Nigeria. The study concluded that renewable energy diffusion is important for national development given the energy deficit prevalent in Nigeria but asserted that the lack of political leadership at the government level is a major impediment. The authors believe that 100% percent renewable energy is possible in Nigeria, but such a transition will have to be led by the private sector due to a lack of commitment by the government (Akuru, Onukwube, Okoro, & Obe, 2017). In a related study, Oseni (2012) assessed the role of renewable energy in improving household access to modern energy services. Much of Nigeria is still dependent on traditional sources of energy supplies to meet its energy demand. Lack of access to electricity as well as intermittent supply for areas with access means that many households must depend on diesel and gasoline generators for power. The study asserts that renewable energy can play an important role in rural electrification and economic development. However, there are challenges to the development of renewable energy in Nigeria. Inadequate policy, legal and regulatory frameworks as well as a non-existent market were identified as the main challenges to renewable energy penetration (Oseni, 2012).

Like Oseni (2012), Aliyu et al (2015) also identified the lack of clear government policies as one of the main challenges to renewable energy penetration in Nigeria. The cost of renewable energy technology is also identified as an impediment to renewable energy development. The authors argue that both on-grid and off-grid renewable technologies will be needed and could be promoted through government incentives, public-private partnerships, manpower training, and research and development investment (Aliyu, Dada, & Adam, 2015).

Shaaban & Petinrin (2014) looked at the potential role of renewable energy in meeting the energy demands of rural Nigeria. The study advocates for the adoption of renewable energy sources in rural areas to bridge the gap between energy demand and supply in Nigeria and improve the overall health of rural dwellers. The authors discuss the potential of renewable energy in Nigeria and conclude that many renewable energy sources are closer to rural areas and, therefore, could be easier to develop. They, however, highlight the lack of political will and resolve to implement government policies designed to support the development of renewable energy (Shaaban & Petinrin, 2014).

An assessment of the readiness for renewable energy in Nigeria and Cameroon showed that Nigeria had developed policy roadmaps and research institutes for the development of renewable energy, unlike Cameroon, but still faces significant challenges to adopting renewables in the energy mix. Security threats, the dearth of technical capacity, high capital cost, and the lack of political will and awareness are some of the main challenges to solar development in both countries despite high solar potential in northern Nigeria and Cameroon (Mas'ud, et al., 2015). Elum & Momodu (2017) looked at the potential of renewable energy in mitigating greenhouse gas emissions and tackling climate change in Nigeria. The authors recommend the elimination of fossil fuel subsidies, policy coherence, and the maintenance of current and accurate energy data to enhance the development of renewable energy. The study highlights the importance of renewable energy in sustainable development and suggests the need for more public sensitization on the benefits of renewable energy (Elum & Momodu, 2017). In a similar study, Emodi & Boo (2015) state that sustainable energy development will be enhanced not only by renewable energy policy but by improved energy-efficiency/conservation policies (Emodi & Boo, 2015).

Osunmuyiwa & Kalfagianni (2017) examined the conditions that explained variations in the adoption of renewable energy in all the states of Nigeria. It utilized the multi-level socio-technical perspective (MLP), which involves the assessment of three main analytical levels and their interactions. These three levels of analysis are Niches, Regimes, and Landscapes. The study illustrates the importance of macro and micro-level factors in driving a transition toward renewable energy diffusion. The Niches refers to micro levels of energy transition, which serve as the protective space for the experimentation, development, and diffusion of alternative technologies. It involves research, learning through niche projects, which gradually gain popularity and widespread diffusion. Niche technologies must reach a degree of maturity to take over from established energy systems. Regimes refer to the actors, institutional structures, and interests that influence the adoption of renewable energy technologies while the landscapes refer to macro-scale exogenous factors that influence energy transition, such as climate change, oil prices, and food security. The authors concluded that regimes(institutions) and political actors played the most important roles in energy transition in Nigeria. The transition trajectories for renewable energy in relation to the dominant structural conditions can be influenced using tools such as policies and investment (Osunmuyiwa & Kalfagianni, 2017).

In a related paper, Osunmuyiwa et al, 2017 developed an integrated framework for renewable energy transition using the MLP on socio-technical transitions (niches, regimes, and landscapes) and the political economy of energy transitions in Nigeria. Nigeria is a rentier state which depends on oil as the major source of its national revenue. The study offers a nuanced inquiry on the key actors, institutions, and the strategies employed to block energy transition attempts. Rentier states face opposition to energy transition because of the importance of the dominant energy source. Any attempts to change or reform the energy system can potentially lead to political instability. Figure 5 illustrates the integrated framework showing the interaction between political-economic, socio-technical, and other actors in the Nigerian Energy space. The political economy actors include political actors and civil society groups, while socio-technical actors include regulatory bodies, research institutes, and labor unions. Other actors include multinational oil corporations and indigenous people with claims to the oil. These actors interact in a space that involves ethnic narratives[4], lobbying, vested interests, and patronage. (Osunmuyiwa, Biermann, & Kalfagianni, 2017)

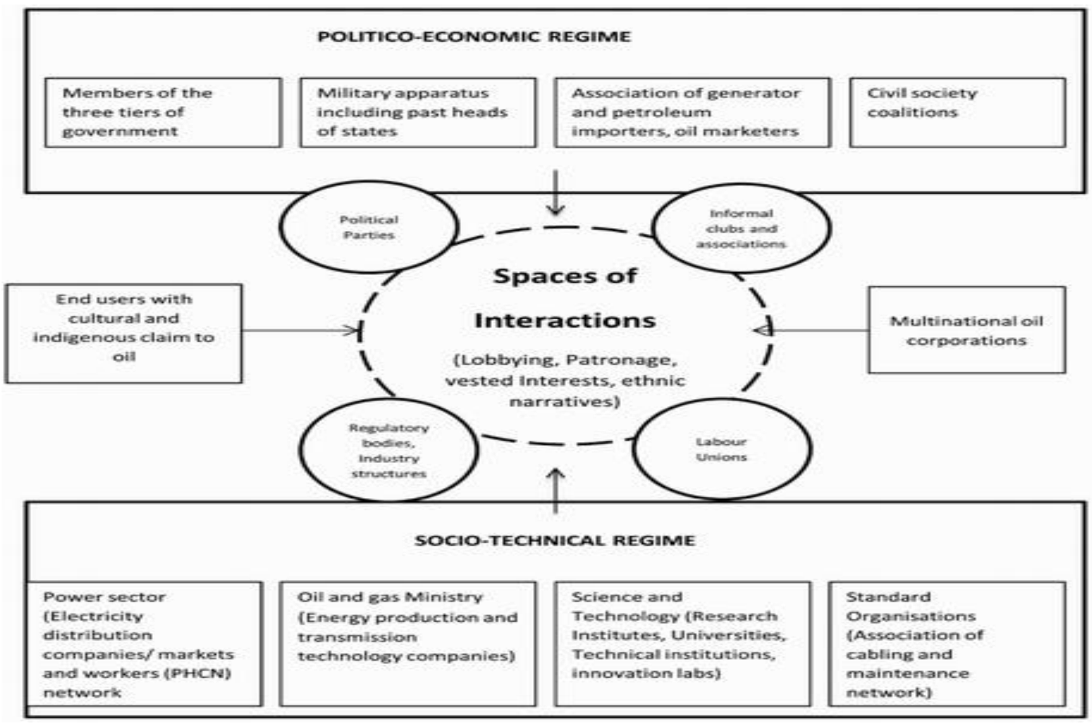

Figure 5: Integrated framework for energy transition in Nigeria (Source: Osunmuyiwa, Biermann, & Kalfagianni, 2017)

An empirical analysis of the drivers of renewable energy in SSA between 1980 and 2011 carried out by Nyiwul (2017) suggests that unlike other developing regions, income is only weakly associated with renewable energy consumption in SSA.

[4] Many ethnic groups in Nigeria, especially in oil-producing areas, feel politically and economically marginalized due to the state's control of oil resources. (Koos & Pierskalla, 2016)

Instead, population growth and industrial expansion were identified as the significant determinants of renewable energy development and consumption. The author argues that environmental concerns are also drivers of increased renewable energy consumption in Sub Saharan Africa as renewable energy consumption continued to increase despite the fall in the prices of fossil fuels (Nyiwul, 2017).

The literature on renewable energy technologies in Nigeria is mainly focused on solar, biofuels, wind, and hydro. A comparison of the prospects of these technologies in South Africa, Nigeria, and Egypt was carried out by Aliyu et al (2018). The authors concluded that South Africa had made the most progress in integrating renewable energy technologies, especially wind and solar energy. Hydro and solar energy development are viewed as promising in Egypt, while Nigeria has had the least progressive in the development of renewable energy technologies despite enormous potential. The study posits that access to renewable energy for off-grid small scale applications is critical for addressing the energy crisis in the African continent (Aliyu, Modu, & Tan, 2018).

Elum et al (2017) examined the potential of bioenergy from agriculture as a climate change mitigation strategy and a source of renewable energy supply. The authors propose that agriculture could serve a major role in addressing energy deficit, climate change mitigation, and sustainable economic development. The study analyzed the potential of biofuels in Nigeria and concluded that renewable energy from the energy crops, waste and other biomass sources in Nigeria could contribute significantly to global climate change mitigation, the energy supply deficit, economic development and social well-being (Elum, Modise, & Nhamo, 2017). In a related study, Anyanwu et al (2015) assessed the sustainability of cassava (Manihot esculenta) as industrial feedstock, energy, and food in Nigeria. The study concludes that cassava wastes could be utilized in the production of bioethanol to satisfy the government's E10 program. The E10 program aims to introduce 10% ethanol into conventional gasoline by 2020. The authors discourage the use of cassava roots for biofuel production as it competes with food supply and could result in an increase in food prices, imbalances in the food chain and indirect land use (Anyanwu, Ibeto, Ezeoha, & Ogbuagu, 2015). Ishola et al (2013) evaluated the potential of biofuels in Nigeria to reduce fossil fuel dependence, increase modern energy access, and improve environmental conditions. The study concluded that biofuel development in Nigeria has been very slow despite good geographical conditions and high investment. Production of sugarcane is below the domestic demand for sugar, and the cost of energy and enzymes to produce ethanol from cassava might prove prohibitively expensive. The authors propose the development of biogas from waste as the energy source with the most immediate benefits as it requires no irrigation or land input, reduces negative health and environmental impacts, can act as a substitute for firewood and can be utilized in the production of fertilizer (Ishola, Brandberg, Sanni, & Taherzadeh, 2013). A similar conclusion is reached by Olugasa et al (2014) in their study of biogas energy use in Nigeria. The authors conclude that biogas can address some of the prevalent energy and environmental challenges associated with oil and gas exploration in Nigeria (Olugasa, Odesola, & Oyewola, 2014).

Ozoegwu et al (2017) looked at the status of solar energy integration and policy in Nigeria. The authors assert that the past and current integration of solar energy in Nigeria is negligible, and the future of solar looks bleak. The disparity between commendable solar energy policies and poor solar utilization and integration was highlighted and blamed on the poor implementation of existing policies. The authors suggest the energy challenges faced by Nigeria and the potential for solar energy offer a great investment opportunity. They propose that the proper implementation of existing policies could lure investors into the market (Ozoegwu, Mgbemene, & Ozor, 2017). Ohunakin et al (2014) look at the drivers and barriers to solar energy development in Nigeria. The study identifies cost, grid unreliability, lack of awareness and information, insecurity, competition with other land uses, poor quality of materials, and inadequate government policies as barriers mitigating against solar development in Nigeria. The drivers of solar development were identified as the power sector reform, reduction of CO_2, economic development, energy security, rural electricity access, and growing energy demand. The authors propose that enabling policies in the area of capacity development, financial incentives, support for research and development, and local ownership and participation are crucial for solar integration in Nigeria (Ohunakin, Adaramola, Oyewola, & Fagbenle, 2014). Giwa et al (2017) reached a similar conclusion stating that the feasibility and environmental significance of solar energy and bioenergy for sustainable development is site-specific and dependent on incentives, financing, research and development, public education, private investments, and government policies. The study asserts that more attention is currently being paid to fossil fuels through subsidies, and the policies in place to support the development of renewable energy are vague and poorly implemented (Giwa, Alabi, Yusuf, & Olukan, 2017).

Okoye et al (2016) assessed the solar resource potential of three strategically located Nigerian urban cities, Onitsha, Kano, and Lagos. These cities have large populations and are known to be commercial hubs, but frequent power outages hinder socio-economic development. The results of the study show that the unit cost of standalone PV systems is less than those for widely used diesel generators. The authors conclude that standalone systems in these urban Nigerian cities are currently technically and economically feasible. They suggest that decentralized energy systems can be utilized to bridge the energy deficit in Nigeria (Okoye, Taylan, & Baker, 2016). This conclusion is corroborated by a similar study by Muhammad et al (2017), who looked at the application of micro-grid technologies and autonomous energy for sustainable energy development in Nigeria (Mohammed, Mustafa, Bashir, & Ibrahem, 2017).

Emodi et al (2017) carried out a scenario-based analysis of different low carbon energy scenarios in Nigeria using the Long-range Energy Alternative Planning (LEAP) model between 2010 and 2040. The authors explored the impacts of renewable energy penetration on greenhouse gas emissions, energy demand, and supply. They concluded that the adoption of low carbon technologies reduced energy demand and greenhouse gas emissions (Emodi, Emodi, Murthy, & Emodi, 2017).

The high fiscal, environmental, and social costs of fossil fuel subsidies make reform imperative. However, the reform of these subsidies faces public opposition due to the economic and social importance of fossil fuels. The diffusion of alternatives can reduce dependence on these resources, but as the literature has shown, cleaner alternatives also face huge developmental challenges in Nigeria.

The next section reviews important concepts relevant to this dissertation.

Chapter 3

CONCEPTUAL FRAMEWORK

3.1 Sustainable Development in Africa

There are many definitions of sustainable development, but the most frequently used one is that from the Brundtland Commission report titled "Our Common Future," which defines sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". (World Commission on Environment and Development, 1987). This means that today's development should consider economic, social, and environmental factors in such a way that it does not compromise the economic, social, and environmental well-being of future generations.

In the year 2000, 189 member states of the United Nations, including 147 heads of states and governments, adopted eight international development goals to be achieved by 2015. These goals were known as the Millennium Development Goals (MDGs) and were designed to eradicate poverty and hunger, achieve universal basic education, promote gender equality and empower women, reduce child mortality, improve maternal health, combat HIV/AIDS, malaria, and other diseases, ensure environmental sustainability and develop a global partnership for development (United

Nations, 2000). Progress on the MDGs has been mixed and not evenly distributed. For instance, estimates of the people living on less than $1.25 reduced from 43.6% in 1990 to 17% in 2011, but extreme poverty reduced significantly in other regions except for SSA. Figure 6 shows the number of people still in extreme poverty across different regions based on those living on $1.25 a day. (2005 Purchasing Power Parity (PPP)[5]). It shows SSA as making the least progress on poverty eradication. Figure 7 shows that 45% of the countries in SSA are well off-track from the millennium development goals. SSA also failed to achieve the goal of reducing undernourishment and the prevalence of underweight children under age 5 (Feng J. , 2015).

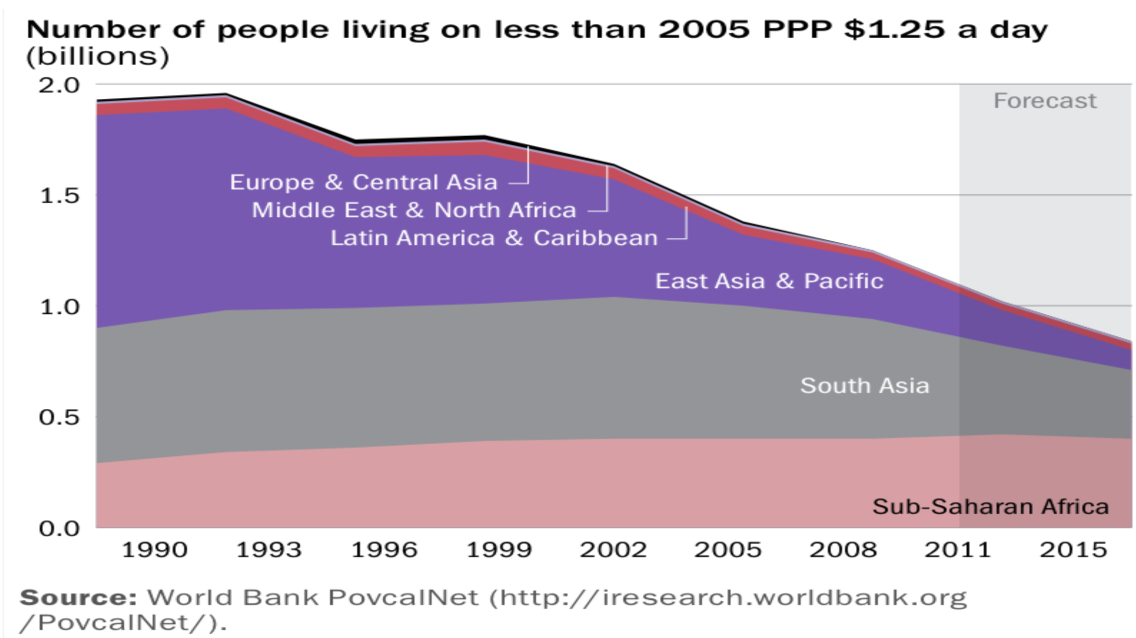

Figure 6 Number of people in extreme poverty per region. (Source: Feng, 2015)

[5] Purchasing Power Parity is a measure used to compare purchasing power between different currencies using the prices of common goods.

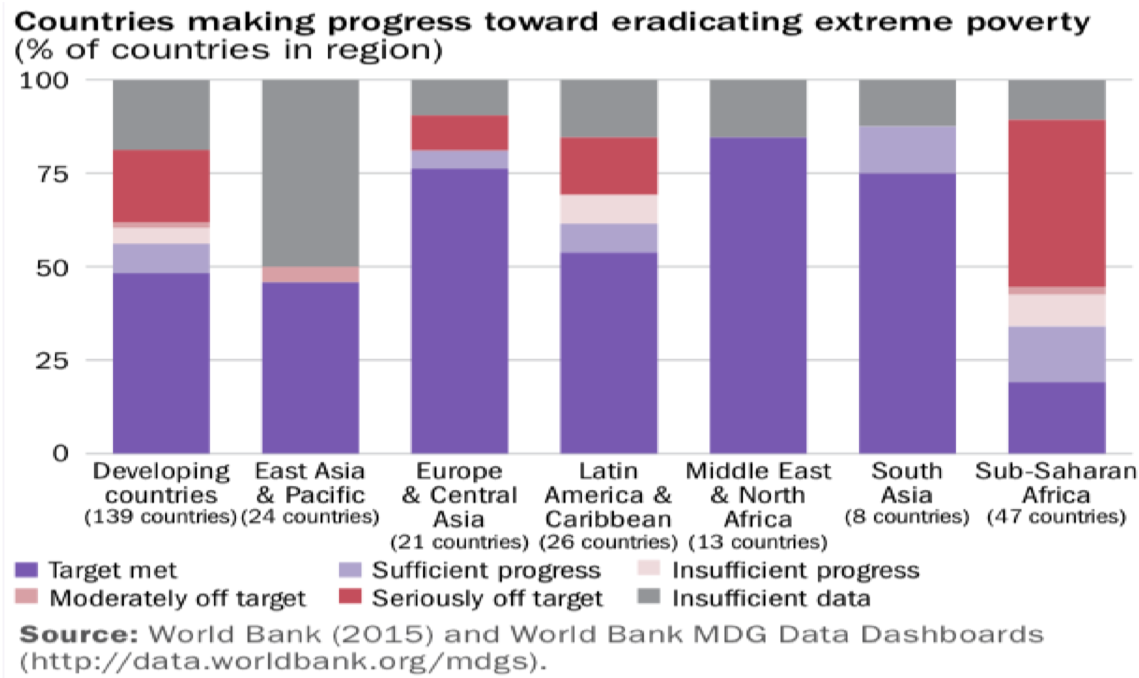

Figure 7 Countries making progress in tackling extreme poverty (Source: Feng, 2015)

The MDGs had set goals of 67% reduction of under-five mortality rate and 75% reduction in maternal mortality rate between 1990 and 2015, but by 2013, SSA has only managed to reduce the under-five mortality rate by 45% and reduced the maternal mortality rate by 48% (United Nations, 2014). Only a handful of countries in the region were on track to meet the development goals set (Makuta & O'Hare, 2015; Ayittey, 2015). Some of the factors attributed to the failure to achieve these goals include poor leadership, low institutional capacity, and paucity of funds due to overreliance on aid (Ayittey, 2015; Hanson, Puplampu, & Shaw, 2018). Also, developmental aid from developed countries to reduce poverty is limited, and many of the developed countries including the United States, Germany, and the United Kingdom have not increased their ODA to 0.7% of their GDP as required by the MDG goal 8 (Stein & Horn, 2012). Recent low oil prices in oil-rich countries like Angola and Nigeria have also presented significant financial challenges for meeting developmental goals (Ighobor, 2015).

In 2015, Sustainable Development Goals (SDGs) were adopted by all member nations of the United Nations to advance economic, social, and environmental development across the world by 2030. SDGs expanded upon areas that were not covered by the MDGs, such as affordable and clean energy and climate action (UNECA, AUC, & AfDB, 2015). The enhancement of local sources of financing would aid the attainment of SDGs, support continental growth, and partially mitigate the challenge associated with financing MDGs through developmental aid.

On a continental scale, African leaders adopted their framework for the socio-economic development of the continent named Agenda 2063. Agenda 2063 outlines seven aspirations for the continent: prosperity, continental integration, good governance and democracy, peace and security, strong cultural identity, people-driven development, and becoming a strong, united global player. Under these aspirations are 20 goals which are interrelated and align with the SDGs and national development plans, but Africa still faces significant challenges to meeting these kinds of goals. Figure 8 shows the aspirations of the Agenda 2063 and what they entail (African Union, 2015).

This first goal of Agenda 2063 is achieving “A high standard of living, quality of life and well-being for all citizens”. The priority areas under this goal include creating income and jobs, ending poverty, inequality and hunger, social security protection, and modern, affordable habitats. This goal aligns with SDG 1 (End poverty in all its forms everywhere in the world), SDG 2 (End hunger, achieve food security and improved nutrition and promote sustainable agriculture), SDG 8 (Promote sustained, inclusive and sustainable Economic growth, full and productive employment and decent work for all) and SDG 11 (Make cities and human settlements inclusive, safe, resilient and sustainable). (African Union, 2019) Table 2 shows how the goals of Agenda 2063 align with SDGs.

Figure 8 Agenda 2063 (Source: African Union, 2015)

Agenda 2063 Goals	UN Sustainable Development Goals
1. A high standard of living, quality of life and well-being for all citizens	1. End poverty in all its forms everywhere in the world
	2. End hunger, achieve food security, and improved nutrition and promote sustainable agriculture.
	8. Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all.
	11. Make cities and human settlements inclusive, safe, resilient, and sustainable.
2. Well educated citizens and skills revolution underpinned by science, technology, and innovation.	4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.
3. Healthy and well-nourished citizens.	3. Ensure healthy lives and promote well-being for all at all ages.
4. Transformed economies	8. Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all.
	9. Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation.
5. Modern agriculture for increased productivity and production.	2. End hunger, achieve food security, and improved nutrition and promote sustainable agriculture.
6. Blue/ocean economy for accelerated economic growth.	14. Conserve and sustainably use the oceans, seas, and marine resources for sustainable development.
7. Environmentally sustainable and climate-resilient economies and communities.	6. Ensure availability and sustainable management of water and sanitation for all.
	7. Ensure access to affordable, reliable, sustainable, and modern energy for all.
	13. Take urgent action to combat climate change and its impacts.
	15. Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat

	desertification, and halt and reverse land degradation and halt biodiversity loss.
8. A United Africa (Federal or Confederate).	
9. Continental financial and monetary institutions established and functional.	
10. World-class infrastructure crisscrosses Africa.	9. Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation.
11. Democratic values, practices, universal principles of human rights, justice, and the rule of law entrenched.	16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable, and inclusive institutions at all levels.
12. Capable institutions and transformative leadership in place	16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable, and inclusive institutions at all levels.
13. Peace, security, and stability is preserved	16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable, and inclusive institutions at all levels.
14. A stable and peaceful Africa	
15. A fully functional and operational African Peace and Security Architecture (APSA)	
16. African cultural renaissance is pre-eminent.	
17. Full gender equality in all spheres of life.	5. Achieve gender equality and empower all women and girls.
18. Engaged and empowered youth and children.	4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.
	5. Achieve gender equality and empower all women and girls.

19. Africa as a major partner in global affairs and peaceful co-existence.	17. Strengthen the means of implementation and revitalize the global partnership for sustainable development.
20. Africa takes full responsibility for financing her development Goals.	10. Reduce inequality within and among countries.
	17. Strengthen the means of implementation and revitalize the global partnership for sustainable development.

Table 2 AGENDA 2063 and the SDGs relationship (Source: African Union, 2019)

3.2 Energy Security and Sustainable Development

Energy security is multidimensional and can be defined from different perspectives (Sovacool & Brown, 2010). One dimension of energy security is the threat of international political occurrences in one country, affecting the supply of energy in others. A historical example of this is the oil crisis, of 1973 where OPEC countries cut oil supplies leading to a surge in global oil prices and exposing the vulnerability of the global oil system (Cherp & Jewell, 2011). For this dissertation, energy security is viewed from the perspective of the minimization of risk associated with energy-dependent services such as transportation and electricity generation. The lack of access to and reliability of energy sources and the adverse health effects of specific energy sources such as traditional biomass are some of the features of energy insecurity from this perspective (Dannreuther, 2017).

One of the most significant challenges to achieving developmental goals in Africa is the lack of energy access, especially in SSA. As of 2016, 600 million people, approximately 58% of the population, still lack access to electricity in SSA and this has negative implications for health, quality education, food security, availability of clean, usable water, agricultural productivity, industrial development and other key indicators for sustainable development. Also, the percentage of people using traditional biomass in SSA is greater than any other region in the world. Traditional biomass is the most common source of energy for cooking and heating, with over 80% of the total population relying on it (IEA, 2017). Uncontrolled use of traditional biomass could lead to deforestation, natural resource depletion, and loss of animal habitat (IEA, 2017). Approximately 4.3 million people die from household pollution that comes from burning solid fuels annually (World Health Organization, 2016). Access to modern energy services would reduce the incidences of respiratory diseases caused by burning traditional biomass. It would also help health centers and schools provide better quality services. Students would be able to read better and longer at night, and farmers can increase their productivity. Infrastructural services like clean, drinking water and streetlights can be improved with better energy, and this will, in turn, boost the health and security of the region.

The threat posed by anthropogenic climate change means that improved energy access must be achieved without compromising the ability of present and future generations to survive and thrive. Besides having the lowest electricity access globally, Africa also has the smallest share of greenhouse gas emissions in the world, accounting for only 3.8% of emissions. In addition to this, SSA is one of the most vulnerable regions to the effects of irreversible climate change. Increased floods, droughts, and extreme weather events could permanently alter the socio-economic life of the region (Sy, 2016). The capacity to adapt is affected by a dearth in technical expertise, poverty, poor infrastructure, and a deficit of climate change knowledge.

The relationship between electricity access and development is shown in Figure 9. The chart shows a linear relationship between accessibility to electricity and the Human Development Index (HDI)[6]. HDI is a measure that considers the health, education, and standard of living of citizens living in a country (UNDP, 2019). It measures this by considering indicators such as the expected life expectancy, mean years of schooling, and the Gross National income per capita, respectively. Figure 8 shows that the HDI increases as the electricity access increases.

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[6] Some limitations have been identified with the use of HDI as a measure, including the fact that it may conceal significant pockets of population or differences in gender conditions (Bilbao-Ubillos, 2013). The difficulty in comparing different periods is another weakness identified for the HDI (Herrero, Martínez, & Villar, 2010).

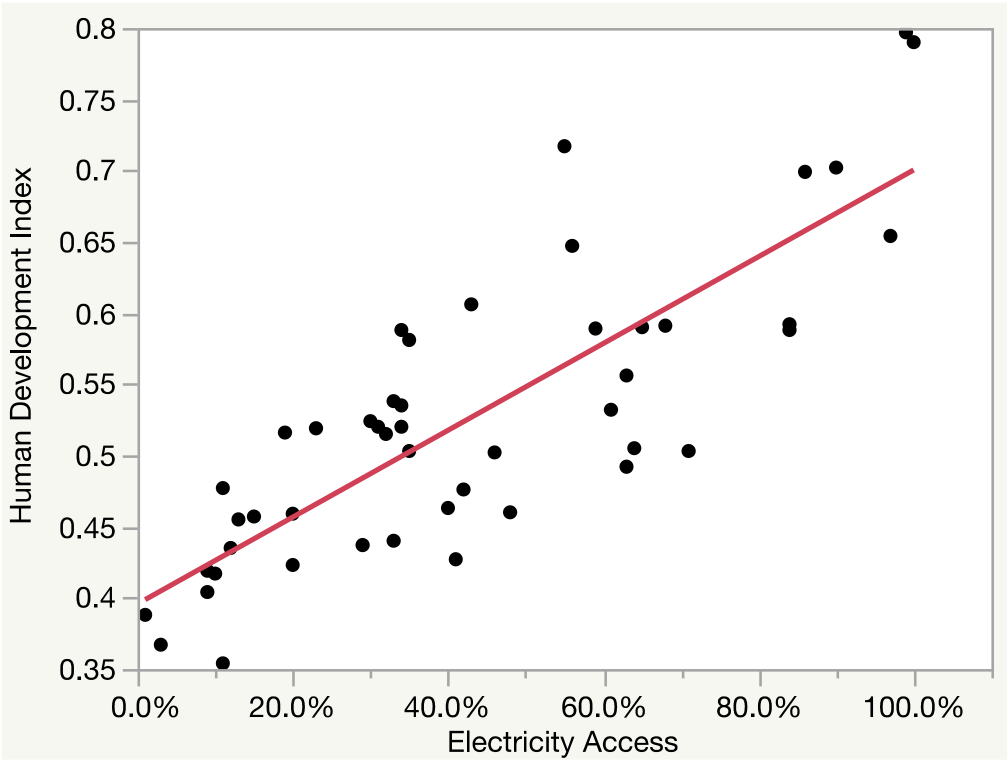

Figure 9 Human Development Index and Energy Access

3.3 The Politics of Fossil Fuel Subsidy Reform

Governments across the world continue to offer subsidies in the form of tax breaks, transfers, economic guarantees, and goods and services to aid the production and consumption of fossil fuels despite evidence of the negative economic, social, and environmental effects of fossil fuel subsidies. This situation worsens energy security concerns for poorly developed energy systems as it encourages more fossil fuel energy consumption and discourages investments (Bauer, et al., 2013).

Commitment from top political levels like the leaders of the G20 who, in 2009, committed "phase out over the medium-term inefficient fossil fuel subsidies while providing targeted support for the poorest" have failed to significantly reduce these subsidies (G20, 2009, p. 3). It is important, therefore, to understand the political dimensions of fossil fuel subsidies as economic and environmental factors cannot explain the persistence of these subsidies and the lack of action on reform. The political dimension will help us explain why subsidies are sustained or reformed on a national and the positions taken by International organizations on subsidy reform.

Skovgaard & Van Asselt (2018) developed a framework for analyzing the international and domestic level politics that influence the politics of fossil fuel subsidy reform or maintenance. The framework identifies factors that influence the politics of fossil fuel subsidy reform through each stage of the policy cycle for both international institutions and the domestic political environment.

At international institutions, Skovgaard and Van Asselt describe the factors influencing the political dynamics as including the role of individual actors, the constellation of Member State Interests, Ideational factors, and Interaction with other Institutions. Individual actors refer to employees or member nations of these institutions. They include policy entrepreneurs or norm entrepreneurs and other important actors. Policy entrepreneurs are those involved in the promotion and advancement of new policies using financial, material, and reputational resources, while norm entrepreneurs promote the development of new norms within institutions. The interests of the member states refer to the economic and social interests that each member country espouses. Fossil fuel exporters are often averse to the promotion of subsidy reform at an international stage due to the possible impact on the global demand of fossil fuels. In some institutions, such as the UN, decisions can be blocked by a single member state with veto power if they go against its interests. Ideational factors refer to how fossil fuel subsidies and their reform are framed in organizations considering their structures and objectives. For instance, environmental organizations are likely to frame fossil fuel subsidies and their reform as environmental issues, while economic organizations would frame them as economic issues. Interactions with other international institutions can also influence the position an international organization would take when it comes to subsidy reform (Skovgaard & Van Asselt, 2018). For instance, Institutions like the G20 exert a powerful influence on the operations of international organizations such as the IEA, the Organization of the Petroleum Exporting Countries (OPEC), and the World Bank. According to Putnam & Bayne (1987), such organizations can exert influence in other institutions in three basic ways, catalysts, core group, or parallel treatment. As catalysts, they influence change in other institutions by providing incentives or compelling them to change. As the core group, they provide political leadership to other international organizations, and as parallel treatment, they work in conjunction with existing institutions to attain goals (Putnam & Bayne, 1987).

On a domestic level, Skovgaard & Van Asselt (2018) described the factors influencing fossil fuel subsidies include the interests, strategies, and organization of actors, ideational factors, and structural factors. Domestic politics is made up of protagonists and opponents of fossil fuel subsidies. The position taken by these actors determines how fossil fuel subsidy reform is framed. For protagonists, subsidies are often framed as poverty alleviation mechanisms, while opponents emphasize the economic and environmental costs of these subsidies. Each group form alliances to promote their agenda and try to influence political action and public opinion. These actors have their strategies and organize to influence the maintenance or reform of fossil fuel subsidies. The level of organization of each group could determine the size of fossil fuel subsidies (Victor, 2009). Ideational factors include the norms, beliefs, ideas, and knowledge and other ideational factors that guide the actions of different actors in the fossil fuel subsidy regime. Existing and new knowledge about fossil fuel subsidies plays an important role in the public support or disapproval of fossil fuel subsidies. International actors and norm entrepreneurs can influence existing norms and beliefs on fossil fuel subsidies and their reform. Structural factors refer to the socio-political climate in which a country operates and how they influence fossil fuel subsidies. It includes the governance capacity, local power dynamics, and macro-economic factors that often result in the lock-in of subsidies (Skovgaard & Van Asselt, 2018). Governance capacity refers to the ability of actors to solve collective problems and is shaped by institutional and structural settings as well as individual actors (Dang, Visseren-Hamakers, & Arts, 2015). Low governance capacity means that the ability of the actors to resolve the fuel subsidy challenge is limited. Local power dynamics refer to the balance of power between different players in the subsidy regime. Actors with more power can exert more influence in support of their position. Also, macroeconomic factors such as a lack of economic diversity and dependence on fossil fuels can influence the success of subsidy reform (Skovgaard & Van Asselt, 2018).

Figure 10 illustrates the different factors that influence the politics of fossil fuel subsidy reform on the international institutions and domestic stage. (Skovgaard & Van Asselt, 2018). This framework is used in analyzing the conditions influencing subsidy reform efforts in Nigeria.

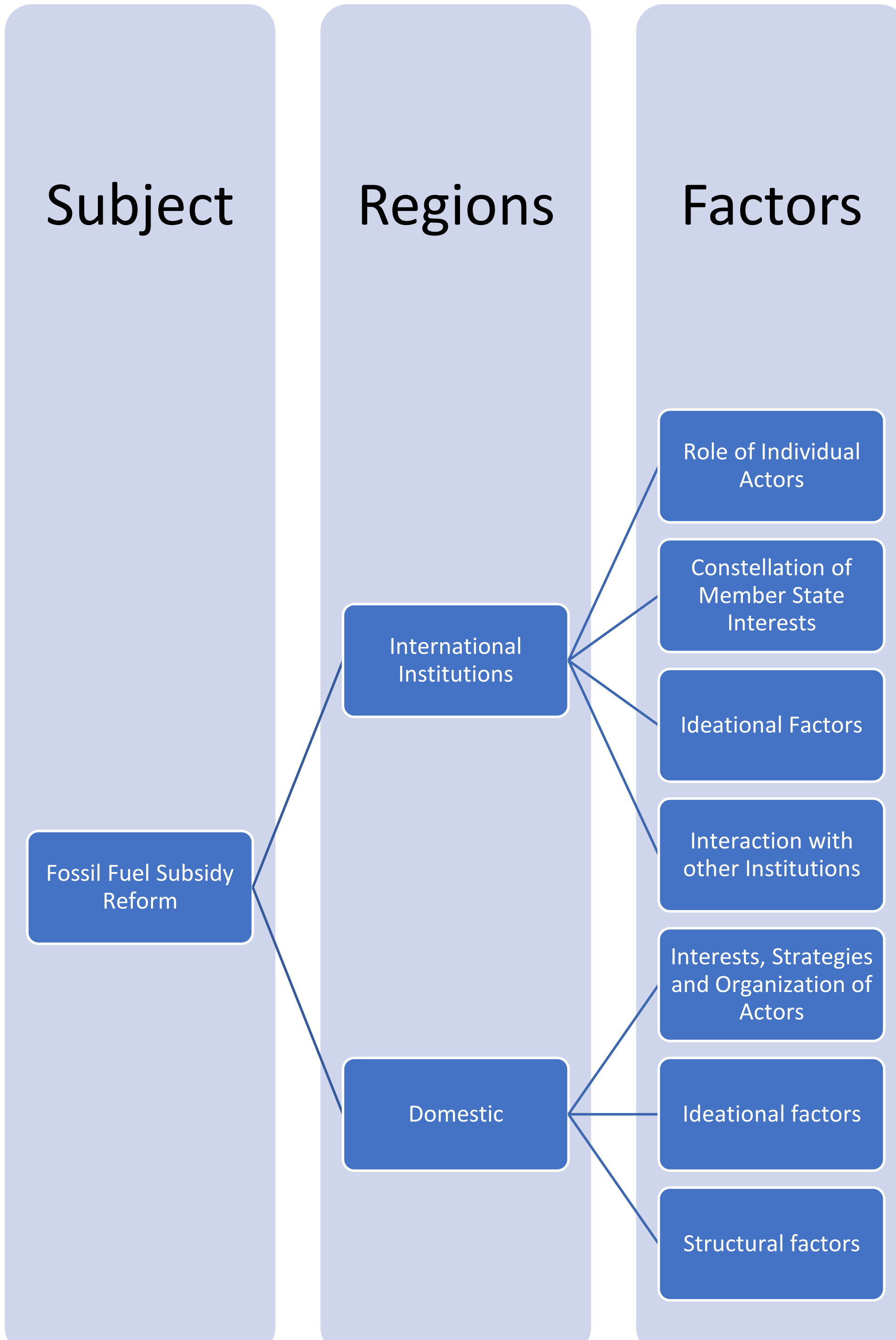

Figure 10 Framework of Factors Influencing Fossil Fuel Subsidy Reform (Image by author, the framework by Skovgaard & Van Asselt, 2018)

Chapter 4

METHODOLOGY

4.1 Introduction

This study applies theoretical analysis, case studies, and the Long-range Energy Alternative Planning (LEAP) model to understand how renewable energy diffusion can reduce the political cost of fossil fuel subsidy reform and promote sustainable development objectives.

First, an analysis of the fossil fuel energy system is carried out to understand the development of fossil fuel subsidies in Nigeria. The factors influencing the persistence of the fossil fuel subsidy regime in Nigeria are identified and discussed. This section will make use of the framework developed by Skovgaard & Van Asselt (2018) to analyze the political dynamics of fossil fuel subsidy reform. The authors divide the factors affecting fossil fuel subsidy reform on a domestic level into three parts, namely interests, strategies, and organization of actors, ideational factors, and structural factors. Opportunities and barriers for renewable energy diffusion are also discussed in this section. Figure 11 shows an illustration of the Skovgaard & Van Asselt framework showing the factors influencing fossil fuel subsidies in countries.

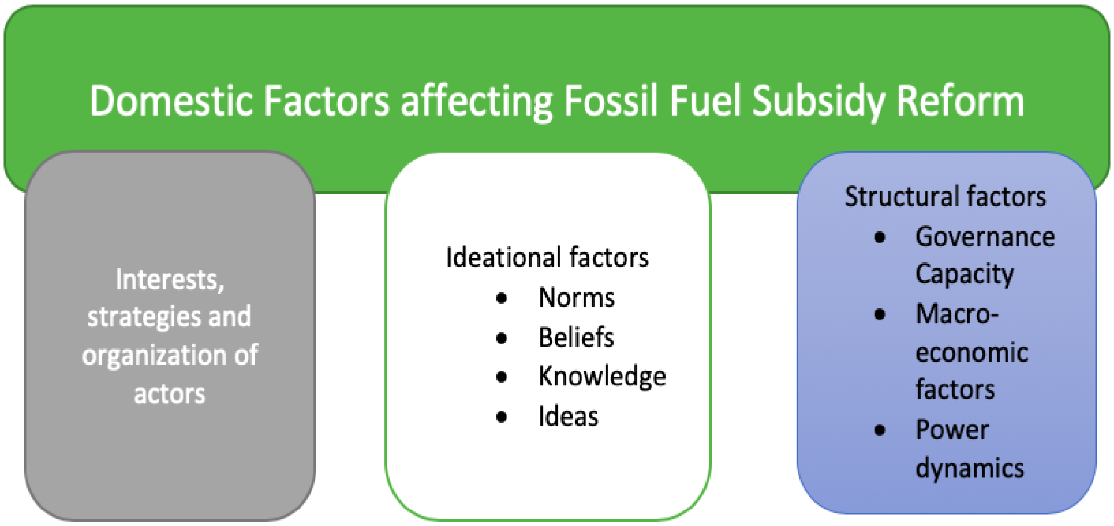

Figure 11 Political factors influencing fossil fuel subsidy reform in countries

The second part of the analysis explores the potential economic social and environmental impacts of the replacement of fossil fuels with renewable energy. A few Energy-Economy-Environment (E3) model applications were assessed to decide which one to use. For this dissertation, I examined the MARKet ALlocation (MARKAL) energy system modeling platform, The Integrated MARKAL-EFOM System (TIMES), and the Long-range Energy Alternatives Planning (LEAP)[7]. These applications are utilized to examine the energy, economic, and environmental impacts of policy options over several decades at a local, national, or global level. A comparison of MARKAL, TIMES, and LEAP using several criteria including the approach, geographical coverage, activity coverage, level of disintegration, technology coverage, data need, skill requirements, portability to another country is utilized to make a choice (Bhattacharyya & Timilsina,

[7] LEAP is more accessible and can be obtained for free by students while the other applications are not available for free.

2010). Based on this comparison, LEAP was selected for this dissertation for several reasons. First, one of the challenges of modeling in a developing country context is the lack of reliable data. LEAP is more applicable in a developing country context because it can work with both limited and extensive data. The informal sector can also be incorporated into LEAP, making it more flexible and applicable to developing countries. Also, LEAP covers energy system and environment activities while MARKAL and TIMES mainly cover energy system activities. Energy and non-energy inputs can be used in the LEAP modeling tool. A more detailed explanation of each of these models can be found in the Appendix. Table 3 shows the comparison used to arrive at the choice of LEAP.

Criteria	**MARKAL**	**TIMES**	**LEAP**
Approach	Optimization	Optimization	Accounting
Geographical Coverage	Country or multiple countries	Local, regional, national or multiple countries	Local to national to global
Activity Coverage	Energy system	Energy system and energy trading	Energy system and environment
Level of disaggregation	User defined	User defined	Pre-defined sector structure
Technology coverage	Extensive	Extensive	Menu of options (extensive)
Data need	Extensive	Extensive	Extensive but can work with limited data
Skill requirement	High to very high	Very high	Limited

Portability to another country	Difficult	Difficult	Difficult
Documentation	Extensive	Good	Extensive
Capability to analyze price-induced policies	Exists	Exists	Does not exist
Capability to analyze non-price induced policies	Very good	Very good	Very good
Rural energy	Possible	Possible	Possible
Informal sector	Not possible	Not possible	Possible
New technology addition	Possible	Possible	Possible
Energy shortage	Not explicitly	Not explicitly	Possible explicitly
Subsidies	Possible but normally ignored	Possible but normally ignored	Not considered explicitly
Rural-urban divide	Possible and covered	Possible and covered	Possible and covered usually
Economic transition	Not covered	Can be covered	Usually covered through scenarios

Table 3 Comparison of MARKAL, TIMES and LEAP (Source: Bhattacharyya & Timilsina, 2010)

The LEAP tool is an important tool for accessing and quantifying the long-term implications of energy policy alternatives. It provides information on the supply and demand projections of different energy policy and technology options (Raskin, 1986) as well as the environmental implications of these options. It is an integrated bottom-up accounting modeling tool developed by the Stockholm Environment Institute (SEI) that makes use of scenario analysis to track energy production, consumption, environmental impacts, as well as the social costs and benefits across an economy (Stockholm Environment Institute, 2014). It is a flexible, easy to use software that provides decisionmakers with the tools to project energy supply and demand, identify future challenges, and make informed decisions on energy planning. Figure 12 shows the structure of LEAP calculations. LEAP takes into consideration the demographics and macro-economic conditions in tracking energy extraction, production, and consumption across all sectors of an economy. It can be utilized to estimate greenhouse gas emissions and other air pollutants in the energy and non-energy sectors. The environmental and social benefits of local air pollution reduction can also be estimated using the LEAP software.

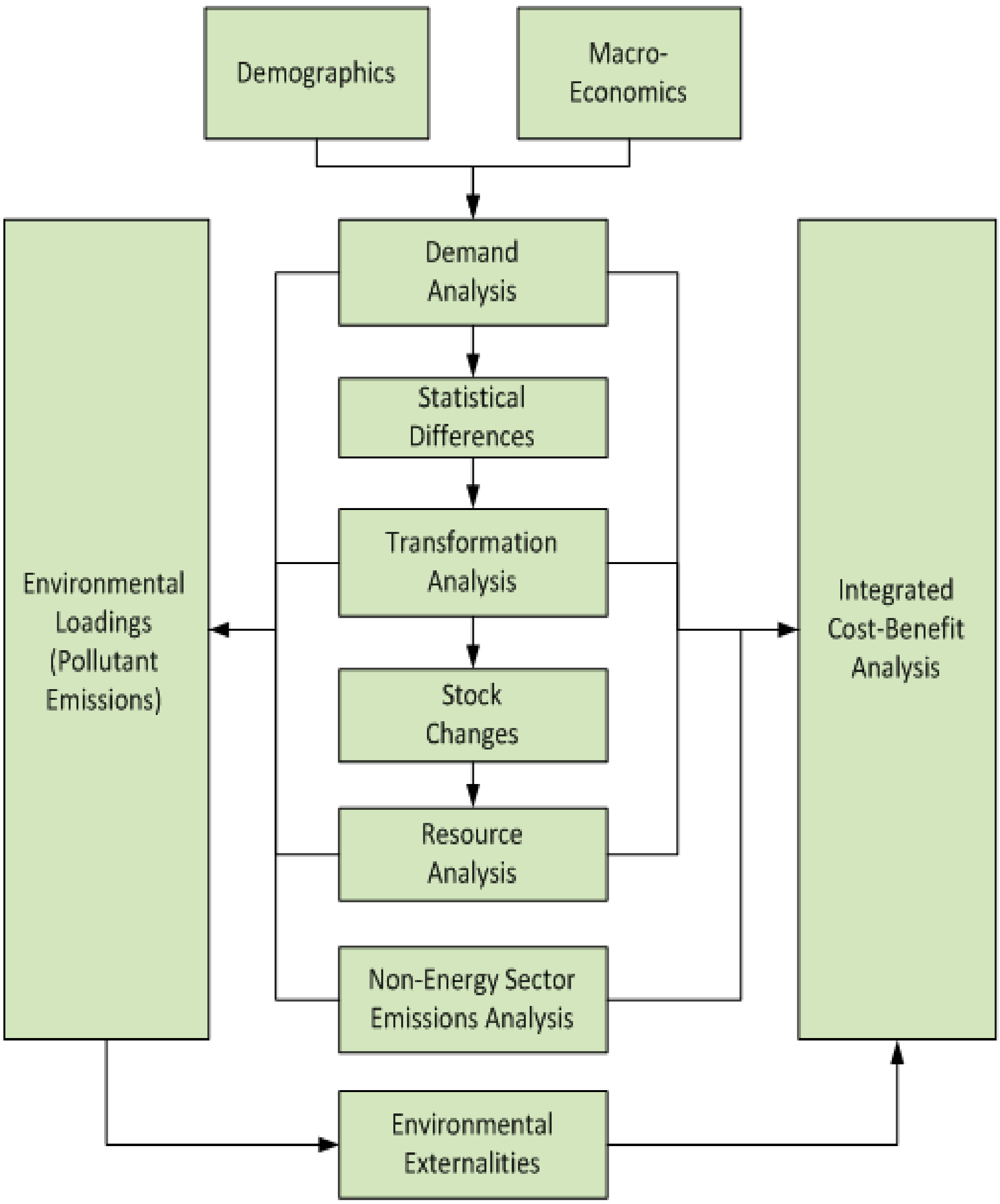

Figure 12 Structure of LEAP (Source: SEI)

Huang et al (2011) utilized the LEAP tool to make long term projections of energy supply and demand in Taiwan as well as the green-house emissions for several energy policy scenarios (Huang, Bor, & Peng, 2011). Emodi et al (2017) carry out a similar study in the case of Nigeria (Emodi, Emodi, Murthy, & Emodi, 2017). This dissertation includes the health and other social implications of different energy policy scenarios. Other studies have focused on specific sectors, Shabbir, R., & Ahmad, S. S. (2010) estimated total energy demand as well as the vehicular emissions in Pakistan between 2000 to 2030 (Shabbir & Ahmad, 2010). Azam et al [2016] also examined the energy consumption and emission for road transportation in Malaysia. (Azam, Othman, Begum, Abdullah, & Nor, 2016) In the residential sector, Ibitoye (2013) utilized the LEAP software to analyze and project household energy consumption in Nigeria. (Ibitoye, 2013) Shin et al (2005) carried out an economic and environmental assessment of the impact of the penetration of land-fill gas electricity in Korea (Shin, Park, Kim, & Shin, 2005).

This study utilizes the LEAP Software to project the sustainable development impacts of the long-term changes in the Nigerian energy system towards a more diversified, cleaner energy system relative to a base position.

Fossil Fuels in Nigeria are used mainly for transportation and, to a lesser extent, off-grid, and on-grid electricity applications. Renewable energy transition faces several significant barriers and challenges in Nigeria. I examine case studies of successful renewable energy penetration for each of the fossil fuel end uses and derive lessons for policy to overcome these challenges in the last part of the analysis. Successful case studies for each of these end uses are selected for analysis in this section. For transportation, Brazil's success with ethanol is analyzed. For the off-grid generation, we review Kenya's off-grid solar development while Germany's photovoltaic energy penetration is looked at for on-grid generation. Each case study is reviewed with an emphasis on government policies, success factors, and potential drawbacks. Lessons for renewable energy policy and implementation are derived from these three case studies. Brazil is chosen because of its success from a developing country perspective in driving transportation alternatives. Brazil is second only to the United States in the production of biofuels, with over 500 million barrels per day (EIA, 2016). Brazil is also a major oil producer like Nigeria, producing 3.36 million barrels per day in 2017, making it the ninth-largest producer in the world (EIA, 2019). Both countries also have similar population sizes, with about 200 million people (The World Bank, 2018a). The choice of Kenya is because of its leadership in off-grid solar penetration, especially in rural areas, and Germany is chosen because of the global leadership role it plays in on-grid solar PV penetration.

In Brazil, flex-fuel vehicles that use both gasoline and ethanol make up over 50% of the national vehicle fleet and 90% of all light commercial Otto-cycle vehicles licensed in Brazil. The domestic consumption of ethanol surpassed that of gasoline in April 2008 (De Moraes & Zilberman, 2014). Kenya is one of the global leaders in the sale of pico-solar systems and solar home systems. In the second half of 2018, 750,000 off-grid products were sold in Kenya made up of mainly of lanterns with mobile charging and 21-49 Wp Solar Home System

(SHS). This amount of sales was second only to China, where 1.18 million products were sold in the same period (GOGLA, 2019b). Electricity generation from photovoltaics in Germany rose from 0.0002% in 1990 to 6.4% in 2016 (The Federal Ministry for Economic Affairs and Energy, 2017). Renewable energy surpassed coal, nuclear and natural gas in Germany as the most abundant energy source for power generation making up over 30% of total generation, up from less than 5% in 1990 (Berlin Energy Transition Dialogue, 2016). Table 4 shows a summary of why each case study was chosen.

Subsidized Fossil Fuel Applications in Nigeria	**Selected Case Studies**	**Rationale for Selection**
Transportation	Brazil	i. Similar population sizes and both are major oil producers. ii. The largest producer of Biofuels among developing countries. ii. Much progress has already been made in biofuel development. Brazil's light vehicle fleet is made up of 80% flex-fuel cars, which run on ethanol or a blend of gasoline and ethanol (Ionova & Teixeira, 2018). iii. A long history of biofuel production.
Off-grid Generation	Kenya	i. The largest sale of off-grid products in Africa and the second-largest in the world. (GOGLA, 2019b). ii. Kenya provides an excellent example of an African country, making progress in off-grid electrification.
On-grid Generation	Germany	i. Rapid on-grid solar electrification growth.

		ii. Germany has the largest Solar PV watt per capita installed globally at 548 watts per capita in 2018. (IEA, 2019)

Table 4 Justification for the selection of case studies

4.2 Research Approach

This research will be broken down into the following steps:

4.2.1 Step 1: Theoretical Analysis

This step involves a detailed analysis of the fossil fuel subsidies in Nigeria. It looks at the origin, nature, and trends of petroleum and electricity subsidies through the history of the program was first reviewed. Common features of petroleum and electricity subsidies are identified and discussed. The historical challenges associated with subsidy reform are also identified and discussed.

After a historical study of subsidies, the factors influencing fossil fuel subsidy reform in Nigeria are analyzed. The framework developed by Skovgaard & Van Asselt (2018) was used to analyze the factors that impact fossil fuel subsidies in Nigeria. The framework identifies actors, ideational, and structural factors as the major factors that influence fossil fuel subsidy reform. The main actors in Nigeria's fossil fuel regime are identified, and their roles in perpetuating the fossil fuel subsidies are discussed and analyzed. The norms, beliefs, and ideas associated with fossil fuel subsidies in Nigeria are identified, and their role in the perpetuation of fossil fuel subsidies examined. The structural factors affecting fossil fuel subsidies and their reform are also assessed.

This section reviews existing literature on the subject and builds the political, economic, social, and environmental picture of fossil fuel subsidy Nigeria. The opportunities and barriers of renewable energy penetration were analyzed and reviewed in this section. This section aims to answer the first two research questions: “What are the conditions that enable the persistence of subsidies in Nigeria’s petroleum and electricity sectors? Why is it so difficult to remove?” and “What are opportunities/barriers for cleaner alternatives to subsidized fossil fuel resources?”.

4.2.2 Step 2: LEAP Scenario Analysis for Renewable Energy Penetration

Fossil fuels are the most important sources of fuel for transportation in Nigeria. They are also utilized for off-grid applications and electricity generation. As a result of the dependence on fossil fuels, there is political pressure associated with fossil fuel subsidy reform. The diversification of the energy mix towards cleaner alternatives can contribute towards the reduction of this political pressure and promote sustainable development.

The sustainable development effects of making the transition to renewable energy were modeled on the Long-range Energy Alternatives Planning (LEAP) System. LEAP is utilized for energy policy analysis. Different scenarios are developed for

Business as Usual and renewable energy penetration scenarios. Nigeria's Sustainable Energy for All Action Agenda (SE4ALL-AA) was used as a basis for the design of LEAP scenario analysis. This section aims to answer the third research question: "What are the potential environmental, social, and economic benefits of making the transition to a low carbon energy system in Nigeria and the implication for sustainable development?".

LEAP provides a framework for estimating *energy consumption, transformation, and carbon emissions*. The LEAP framework calculates total energy consumption as follows (Feng & Zhang, 2012):

$$EC_n = \sum_i \sum_j AL_{n,j,i} \times EI_{n,j,i}$$

Where

EC is the aggregate energy consumption of a sector

AL is the activity level (a measure of the social or economic activity for which energy is consumed)

EI is the energy intensity (final annual consumption of energy per unit of activity level)

n is the fuel type

i is the sector (household, industry, etc.)

j is the device

The Net Energy consumption for transformation is calculated as follows:

$$ET_s = \sum_m \sum_t ETP_{t,m} \times \left(\frac{1}{f_{t,m,s}} - 1\right)$$

Where

ET is net Energy consumption for transformation

ETP is the product of energy transformation (e.g., electricity or refined products)

f is the efficiency of energy transformation (ratio of output over input)

s is the type of primary energy

m is the equipment

t is the type of secondary energy.

Carbon emissions from final energy consumption are calculated as follows:

$$CEC = \sum_i \sum_j \sum_n AL_{n,j,i} \times EI_{n,j,i} \times EF_{n,j,i}$$

where CEC is the carbon emission from energy consumption,

AL is the activity level,

EI is the energy intensity, and

EF is the carbon emission factor

n is the fuel type

i is the sector

j is the device

Carbon emissions from energy transformation are calculated as follows:

$$CET = \sum_{s}\sum_{m}\sum_{t} ETP_{t,m} \times \frac{1}{f_{t,m,s}} \times EF_{t,m,s}$$

CET is the carbon emission from energy transformation,

ETP is the product of energy transformation

f is the efficiency of energy transformation

EF is the emissions factor,

s is the type of primary energy

m is the equipment

t is the type of secondary energy.

4.1.2.1 LEAP Inputs and Assumptions

The model builds on a base scenario known as the Baseline Renewable Energy Penetration (BRP) scenario, which shows the future projection based on current trends. Three other policy scenarios with increasing levels of renewable energy penetration are modeled. Low, medium and high renewable energy penetration levels are modeled on LEAP. Key inputs in the model include:

i. GDP

ii. GDP growth rate

iii. Income

iv. Population

v. Population growth rate

vi. Residential Energy Use

vii. Industry Energy Use

viii. Commercial Energy Use

ix. Agriculture Energy Use

x. Diseases rate

xi. Crop Production

xii. Emission factors

xiii. Livestock Population

xiv. The volume of gas flaring

The LEAP model is designed to estimate savings from the replacement of fossil fuel resources. It is also used to estimate future energy demand, supply, and Greenhouse gas (GHG) emissions as well as health and social benefits such as deaths and crop losses caused by air pollution.

4.2.3 Step 3: Case studies of Fossil fuel Alternatives

The potential, status, and barriers to the development of cleaner alternatives are identified and lessons drawn from case studies to inform policy on clean energy diffusion. To do this, countries that made significant progress in introducing cleaner alternatives in transportation and other fossil fuel application are identified. The case study of Brazil traces the diffusion of ethanol in the transportation industry. The history of policy development, governance of the energy system, and the process of cleaner alternatives penetration are studied. The same is done for alternatives to other fossil fuel applications. The primary focus of the case studies is to identify the success factors and drawbacks associated with each case study. Policy recommendations are drawn from these case studies for policy design and implementation in Nigeria. The section aims to answer the fourth research question: “What lessons can we draw to improve policy formulation and implementation in fossil fuel subsidy reform and the diffusion of cleaner alternatives?”.

4.2.4 Sources of Data

Literature sources for this research include published books, peer-reviewed articles, internet resources and published reports. The theoretical analysis of Nigeria’s fossil fuel subsidy reform and the case studies are based on these sources. Input data sources for the LEAP model are obtained from local and international sources. Important local sources include the Nigerian National Bureau of Statistics (NBS), the Nigerian

National Petroleum Corporation (NNPC) and relevant Nigerian agencies and regulatory bodies. International sources of data come from the World Bank's world development indicators and reports, IEA reports, IMF reports and other relevant reports from international organizations.

Chapter 5

ANALYSIS

5.1 Background, History, Size and Nature of fossil fuel subsidies in Nigeria

5.1.1 Background

The federal government of Nigeria is made up of three distinct branches, namely the legislative, the judiciary, and the executive. The constitution of Nigeria outlines the powers of each branch of government. Executive powers are vested in the hands of the president, who serves as the head of government. He is responsible for the policy priorities of the government. The legislative branch called the National Assembly serves as a check on the executive arm of government and is responsible for making laws and confirming appointments made by the executive. It is made up of two chambers, namely, the House of Representatives and the Senate. The judiciary is responsible for the interpretation of the law, and it consists of the different types of courts. The Supreme court is the highest in Nigeria. Elections are held every four years for executive and legislative offices. The president is elected by the popular vote and has a maximum of two 4-year terms (Central Intelligence Agency, 2019).

Nigeria is made up of 36 states and the federal capital territory, Abuja. Each state has an executive governor and a state house of assembly. It is also made up of 774 local government areas which represent smaller administrative units closer to the people.

A local government chairman governs each local government. Nigeria is a multi-ethnic, multi-cultural country with over 250 ethnic groups (Central Intelligence Agency, 2019).

It is the most populous country on the Africa continent, with an estimated population of 190 million people in 2017 (The World Bank, 2018a). Crude Oil exploration and production is a critical part of the Nigerian economy as it is the primary source of government revenue and foreign exchange earnings. Crude oil and other oil products made up over 95% of foreign exchange earnings and 75% of government revenues (National Bureau of Statistics, 2018; IMF, 2013). Nigeria extracted an estimated 1.9 million barrels of oil per day in 2016, making it the world's 15th largest oil producer that year (US Energy Information Agency, 2018). Nigeria also has the ninth-largest proven reserves of natural gas in the word at an estimated 187 trillion cubic feet. A good proportion of the gas produced from oil and gas fields is flared due to the cost and the lack of adequate infrastructure to transport the gas to end-users. Between 2013 and 2015, Nigeria was the 7th largest gas flaring country in the world, flaring over 7 billion cubic meters (247billion cubic feet) in 2015 (The World Bank, 2016).

Despite abundant energy resources, access to electricity in Nigeria is 61% , with an estimated 74 million people without power. This access is largely inequitable as rural areas only have electricity access of 34% (IEA, 2017). Much of those with electricity access suffer regular blackouts with the average Nigerian enterprise experiencing over 36 outages a month that account for a 4% loss in GDP (Rentschler, 2016). Nigeria's electricity consumption per capita is one of the lowest in SSA at

144kWh per capita in 2014 compared to 4,198.4 kWh in South Africa in the same year (The World Bank, 2018b). Figure 13 shows electricity consumption in Nigeria compared with other countries in SSA. Over 80% of Nigeria's electricity production comes from Natural Gas, with large hydro making up the rest. Renewable energy generation is negligible (IEA, 2018).The lack of diversity in the energy mix poses a challenge for energy security. Figure 14 shows the mix of fuels used in electricity generation in Nigeria.

Electricity Consumption per Capita ('000 KWh)

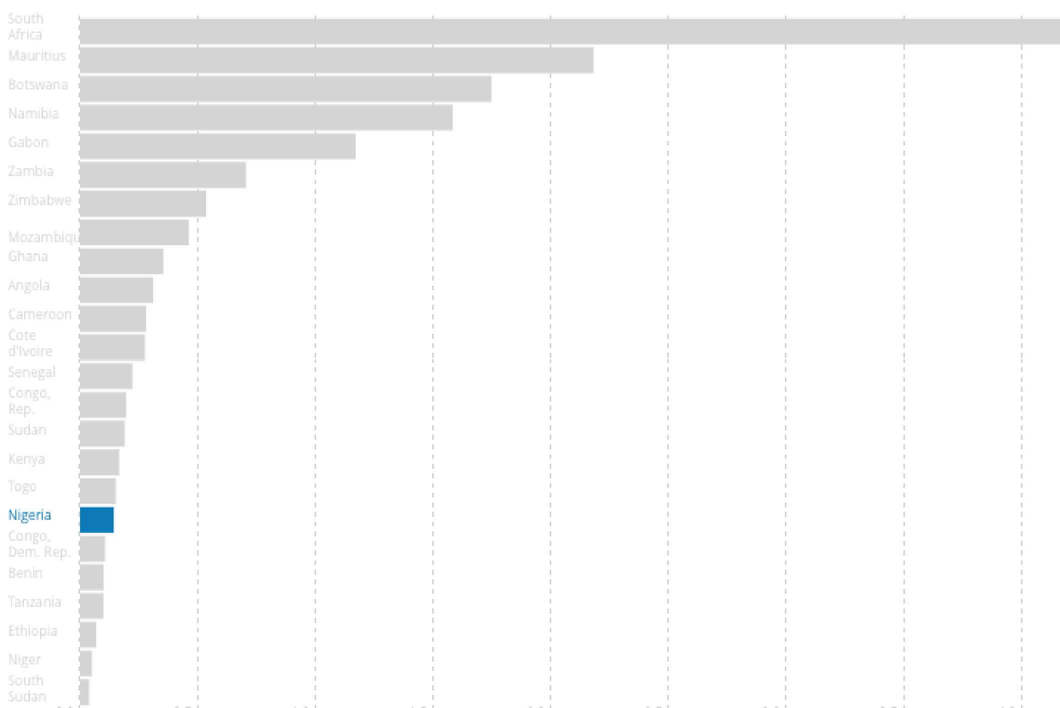

Figure 13 Electricity Consumption per Capita (1000 KWh)

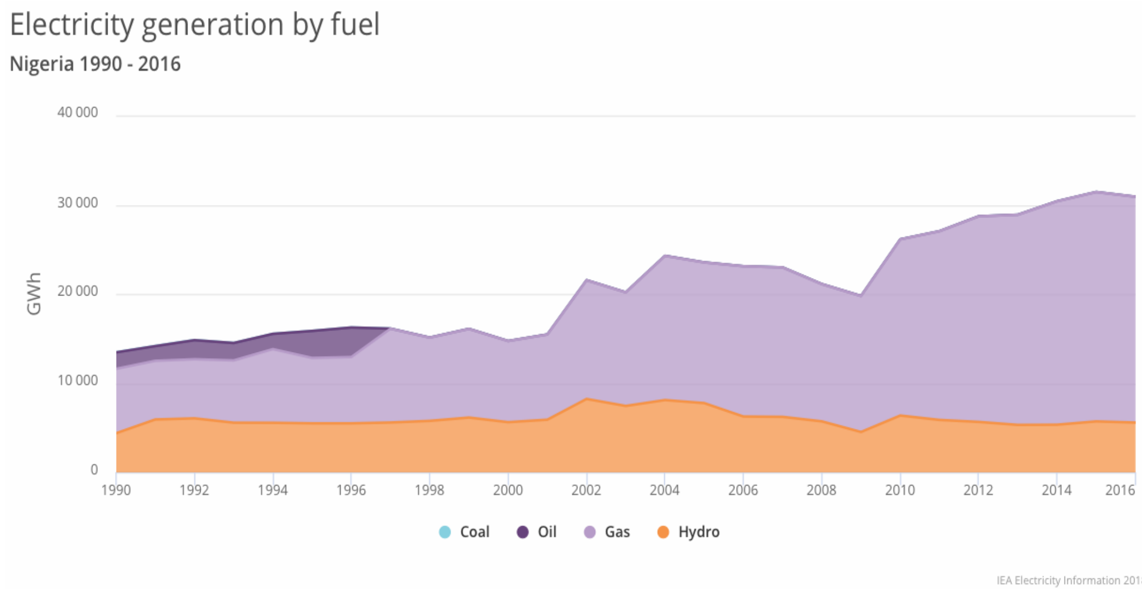

Figure 14 Electricity Generation by Fuel Nigeria (Source: IEA, 2018)

Nigeria also has a weak local capacity to refine the oil and hence depends on imported petroleum products to meet domestic demand. Nigeria has four refineries with a total refining capacity of 445,000 barrels a day. These refineries have not operated at full capacity in the last few decades due to operational failures, fires, and sabotage (EIA, 2016). In 2014, the combined refinery utilization rate was only 14.4% (EIA, 2016). The local refineries meet only 20% of the petroleum products demand and 80% of the petroleum products utilized for residential, commercial industrial and transportation purposes is imported (National Bureau of Statistics, 2017; NNPC, 2017). Gasoline makes up 94% of imported petroleum products and is heavily subsidized at the pump for consumers. The Nigerian Petroleum Products Pricing Regulatory Agency (PPPRA) determines the regulated price at the pump, and the government pays the difference between the pump price and the expected open market price (EOMP). This difference is the subsidy. Figure 15 illustrates how the value of subsidies is determined. The EOMP is the sum of the landing cost of petroleum, which includes the cost of production, shipping and port charges, and the distribution cost plus profit margins. (IISD, 2012) The main drivers of these costs are the global market price of crude oil, the exchange rate, and the cost of transportation (SDN, 2015).

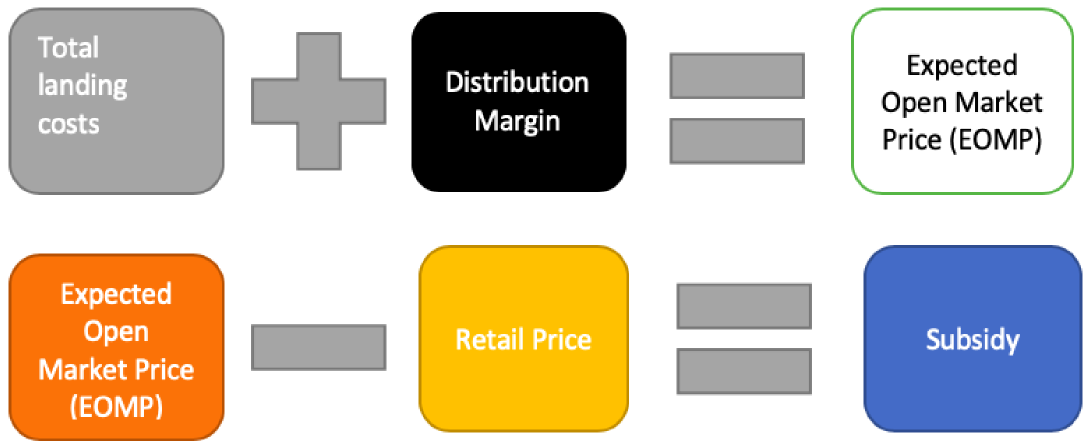

Figure 15 Determination of Gasoline Subsidies in Nigeria

5.1.2 Gasoline Subsidies

5.1.2.1 The Development of Subsidies

Oil subsidies were introduced in 1973 to stabilize the retail price and insulate Nigerians from the global oil price fluctuations (Zaccheus, 2013). Before then, prices were determined by the market, and they differed across geopolitical zones of the country. Before 1973, there was only one refinery in Nigeria, located in Port Harcourt, Nigeria. It was owned jointly by the federal government and Shell but managed by Shell.

The government took full control of the refinery in 1973 and made petroleum prices uniform across the country (Olorunfemi, 1985). The goals identified by the government for intervening in the market include the promotion of industrialization, the promotion of balanced regional development, controlling inflation, and the sharing of oil benefits among the citizens of the country (Adenikinju, 2012).

***5.1.2.*2 History of Crude Oil Subsidies**

In 1973, the subsidy was 35.7% of the total cost. The domestic price of crude oil at the time was fixed at $1.93 per barrel, compared with the global market price of $3.00 per barrel. In 1978, the subsidy was reduced to just 2% of the total cost. The market price of oil was $14.10 per barrel, while the domestic cost of crude was raised to $13.80 per barrel (Adeyeye, 1991). By 1980, the subsidized percentage of subsidy increased to 65.5% as global oil prices rose to $40 per barrel. By 1988, the global price of oil was $15.11 per barrel, but local crude oil prices were just $2 per barrel, amounting to a subsidy of 86.2% (Adeyeye, 1991).

5.1.2.3 History of Gasoline Retail Prices

5.1.2.3.1 Years 1978-1982

Table 5 shows the history of gasoline price fluctuations in Nigeria through military dictatorships and civilian administrations. Price increases are often associated with strikes and violent street protests, which sometimes result in the reversal of policy by the government. Price reductions are commonly used by the government to buy political capital and gain support from the population. The first major retail price increase occurred in 1978 under the military leadership of General Obasanjo. Gasoline prices were increased by 70%, rising from 9 kobo per liter to 15.3 kobo per liter. The reason given for the price increases was that the government needed more money to conduct the upcoming 1979 elections and to provide social services for Nigerians (Ering & Akpan, 2012). In 1982, there was a 30% increase in the prices of gasoline as part of austerity measures adopted by the government to reduce government spending in the face of dwindling revenues from the sale of crude oil due to falling oil prices. Global oil prices fell from $40 per barrel in early 1981 to $28 in 1982 due to the oversupply of oil in the world market and a recession in some industrialized oil consumers (Oates, 1999). Oates (1999) states that OPEC members (including Nigeria) agreed to cut production to curtail the fall in prices. Nigeria oil production dropped to 650,000 barrels a day by April 1982 compared to more than 2 million barrels a day in early 1981. The result was a 63% drop in government revenues from the beginning of 1982 to April of the same year. This drop in revenue forced the government to introduce measures aimed at reducing government spending, including the reform of petroleum subsidies.

5.1.2.3.2 Years 1986-1994

The Structural Adjustment Program (SAP)[8] was introduced by the military administration of Ibrahim Babangida in 1986. The SAP included several policies, including the devaluation of the currency, a move towards trade liberalization and the removal of oil and fertilizer subsidies. These policies were designed to expand and improve local manufacturing, reduce dependence on the oil sector and imports, and boost private sector growth. The prices of petroleum products were gradually adjusted to completely remove subsidies between 1986 and 1993. The reduction of petroleum subsidies resulted in riots and a rise in transportation, food, and medical costs. It also led to a sharp decline in the standard of living (Oyejide, 1991; Walker, 2000; Ekpenyong, 1995). On November 8, 1993, the civilian government of Chief Ernest Shonekan announced a 614% increase in the pump price of gasoline, citing the high budgetary burden of maintaining petroleum subsidies (Eregha, Mesagan, & Ayoola, 2015). Gasoline prices rose from 70 kobo (k) to 5 Naira (₦)[9], leading to massive protests and labor strikes across the country. Less than two weeks later, the government was overthrown by another military regime headed by General Sani Abacha (LeVan & Ukata, 2018). In a bid to garner public support, the new military government reduced gasoline prices by 35% but increased prices by a further 362% just a year later in 1994 - raising the price to ₦ 15.

[8] Structural Adjustment Policies refer to economic reform policies designed to encourage free-market systems and fiscal restraint. These economic reforms often must be adhered to for a country to secure a loan from the IMF or the World Bank.

[9] Naira and kobo are official currencies of Nigeria. 100 kobo = 1 Naira

Public protests and strikes by labor and civil society groups made the government review prices and reduced the price by 20% (Nwosu, 1996; Asuelime & Okem, 2017).

5.1.2.3.3 Years 1998-2007

Four years later, in December 1998, a new military government increased gasoline prices by 127% but was forced to reduce the price by 20% less than three weeks later after days of sustained protests and strikes (Fanimo, Aduba, Okere, Adepetun, & Salau, 2011). On May 29,1999, a new civilian government headed by former military leader Olusegun Obasanjo took power and made oil subsidy reform an important policy priority for the government. Between 1999 and 2007, there were several increases in the prices of petroleum products resulting in many protests, fuel shortages, and strikes that again led to the government making some form of compromise (Iliffe, 2011). On June 1, 2000, the government raised gasoline prices from ₦20 to ₦30, prompting another wave of strikes and protests by labor, civil society groups, and ordinary Nigerians. Just five days later, the government reduced the price back to ₦ 22 per liter (Iliffe, 2011). Several other price increases occurred between 2000-2007, with a cumulative 241% increase during that period ending with a price of ₦ 75 per liter (Vanguard, 2017).

A new civilian government led by Umar Musa Yar'adua took over in May 2007, and the government was forced to reverse the latest petroleum prices due to pressure and strike from labor unions. Gasoline prices were reduced by 13.33%, and this built public support for the new government (Ploch, 2010).

5.1.2.2.4 Years 2011-2020

In Mid-2011, a campaign targeted to convince the public on subsidy removal was started by a new civilian government led by Goodluck Jonathan. High oil prices above $100/barrel had significantly raised the fiscal cost of subsidies taking away from funds needed for developmental projects. This campaign sparked debates between all segments of society from the press, legislators, business owners, and civil society groups (Amakom, 2013). The government instituted the Subsidy Reinvestment and Empowerment (SURE) Program in November 2011 to redirect savings from subsidy reform into social safety net programs designed to mitigate the suffering of the poor. The SURE Program included initiatives such as urban mass transit development, maternal and child health services, vocational training, and temporary employment opportunities to youth and women (Amakom, 2013).

In a surprise move, the government increased the price of gasoline by 117% (₦ 141 per liter) on January 1, 2012, setting off massive violent protests and strikes across the country. Just over a week later, the National Labor Congress (NLC)[10] announced a nationwide strike that crippled economic activities across the country (IMF, 2013). Two weeks after the increase was announced, it was partly reversed with a 31% reduction in price, setting the retail price at ₦ 97 per liter. In the run-up to the 2015

[10] The National Labor Congress is the umbrella body for all trade unions in Nigeria.

presidential elections, the government announced another 10% reduction in the price of petroleum that was perceived as a tool to win public support for the upcoming elections (IMF, 2013).

In May 2015, a new civilian government led by Muhammadu Buhari, a former military dictator, came to power amid low oil prices and dwindling revenues. Low oil prices brought market prices closer to the subsidized rates. As a result, the Nigerian government announced a reform of subsidies on petroleum products, increasing the pump price of gasoline by 67%. NLC responded with calls for a strike, but this did not gain much traction and fizzled out (Gaffey, 2016). However, as the price of crude rebounded and the naira lost value against the dollar, the price of gasoline did not increase in response. The subsidy regime continues to be maintained.

Important observations from this history show that price increases above 100% have always had to be reversed due to public pressure or to gain political support. Attempts at reforms have occurred in both civilian and military administrations. These attempts have often forced by changes in the global market price of oil, the devaluation of the currency, and the state of government revenues. The government is more likely to reform subsidies in response to low oil prices and dwindling revenue. Figure 16 shows a timeline of gasoline price fluctuations. As seen on the chart, increases in the price of gasoline are often associated with a fall in global crude oil market prices.

Year	Old Price per liter (₦)	New Price per liter(₦)	% Increase	% Decrease	Type of Government
1973	0.06	0.0845	40.83%		Military (Gowon)
1976	0.0845	0.09	6.51%		Military (Muhammad)
1978	0.09	0.153	70.00%		Military (Obasanjo)
1982	0.153	0.2	30.72%		Civilian (Shagari)
1986	0.2	0.395	97.50%		Military (Babangida)
1988	0.395	0.42	6.33%		Military (Babangida)
1989	0.42	0.6	42.86%		Military (Babangida)
1991	0.6	0.7	16.67%		Military (Babangida)
1993	0.7	5	614.29%		Civilian (Shoneken)
1993	5	3.25		35.00%	Military (Abacha)
1994	3.25	15	361.54%		Military (Abacha)
1994	15	11		26.67%	Military (Abacha)
1998	11	25	127.27%		Military (Abubakar)
1999	25	20		20.00%	Military (Abubakar)
2000	20	30	50.00%		Civilian (Obasanjo)
2000	30	22		26.67%	Civilian (Obasanjo)
2002	22	26	18.18%		Civilian (Obasanjo)
2003	26	42	61.54%		Civilian (Obasanjo)
2004	42	50	19.05%		Civilian (Obasanjo)
2004	50	65	30.00%		Civilian (Obasanjo)
2007	65	75	15.38%		Civilian (Obasanjo)
2007	75	65		13.33%	Civilian (Yar'adua)
2012	65	141	116.92%		Civilian (Jonathan)
2012	141	97		31.21%	Civilian (Jonathan)
2015	97	87		10.31%	Civilian (Jonathan)
2016	87	145	66.67%		Civilian (Buhari)

Table 5 Gasoline price Fluctuations in Nigeria (Table by Author)

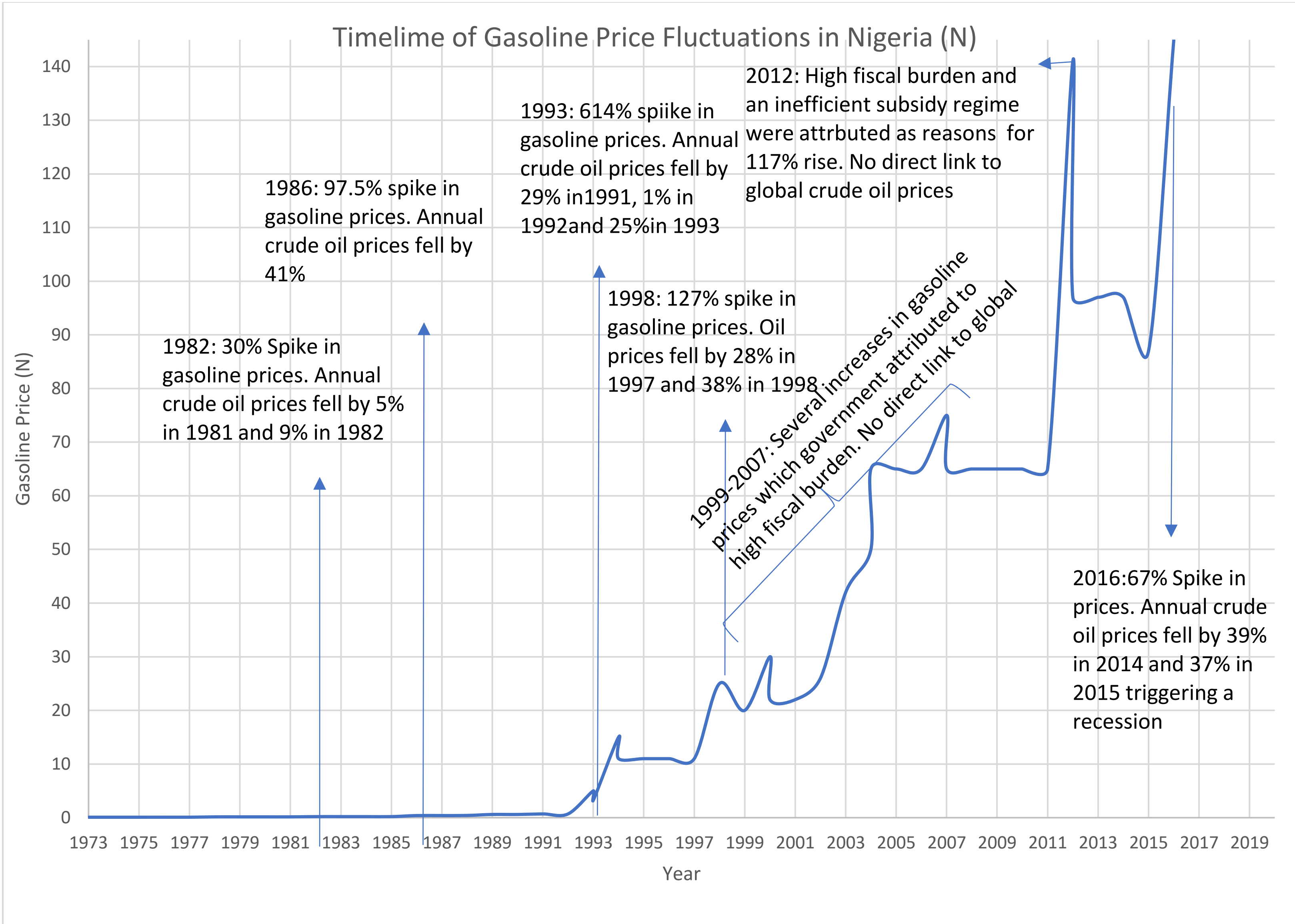

Figure 16 Timeline of Gasoline price fluctuations (Oil price data from Amadeo, 2020 and Macrotrends, 2020)

5.1.3 Kerosene (HHK) and Other Petroleum Subsidies

Reactions to changes in the prices of gasoline have been far more dramatic than other petroleum products even though they also have impacts on businesses and households. Diesel subsidies were eliminated in 2009 in a bid to free up revenue for infrastructural development (GIZ, 2015). However, a similar presidential directive on kerosene subsidies has been less effective as subsidies continued to be paid. In 2015, kerosene subsidies were said to cost over $1 billion (Eboh, 2016).

On the back of low crude oil prices in 2016, kerosene subsidies were eliminated in the government's "price modulation" policy, which saw an upward review of the prices of gasoline and kerosene (Ohaeri & Adeyinka, 2016). The price modulation policy, according to the government, is a policy where fuel prices are adjusted upwards or downwards depending on the global market prices sometimes making a profit and, at other times, paying a subsidy. As global market prices of crude oil increased, the subsidies returned as the official prices were not adjusted in response. Official kerosene prices jumped from ₦ 50 to ₦ 83 per liter in January 2016, but the scarcity of supply ensured that kerosene was sold at levels far above the official price (Ohaeri & Adeyinka, 2016). As at October 2018, the average kerosene price across the country was ₦ 307.28 per liter higher than the average cost of gasoline (₦ 147.20 per liter) and diesel (₦ 216.75 per liter) (National Bureau of Statistics, 2018a; National Bureau of Statistics, 2018b; National Bureau of Statistics, 2018c). The fact that low-income earners mostly use kerosene for cooking and lighting makes this situation worse. Increases in the price of kerosene lead consumers to the increased dependence on traditional biomass resources that are associated with negative health and environmental impacts, including respiratory diseases and deforestation. Over 95.76 million metric tons of firewood was estimated to be used in 2015 (Eboh, 2016).

Some of the reasons attributed to the scarcity of kerosene include the low price of the product, the diversion of household kerosene for other uses including industrial uses, and as aviation fuel, the smuggling of kerosene to neighboring countries, pipeline vandalism and dishonest practices by middlemen (NNPC, 2014). The ability to sell at high rates and earn bigger margins encourages marketers to smuggle petroleum products across the border to neighboring countries (Mills, 2014). The scarcity of kerosene has worsened the contamination of kerosene for economic gains. The contamination of kerosene has been attributed as the cause of kerosene explosions in parts of the country (Lawal, 2011). Figure 17 shows a comparison between kerosene prices in Nigeria and its neighboring countries between 2011 and 2015. As seen on the chart, Nigeria has the cheapest rates, thereby creating an incentive for marketers to sell products in neighboring countries.

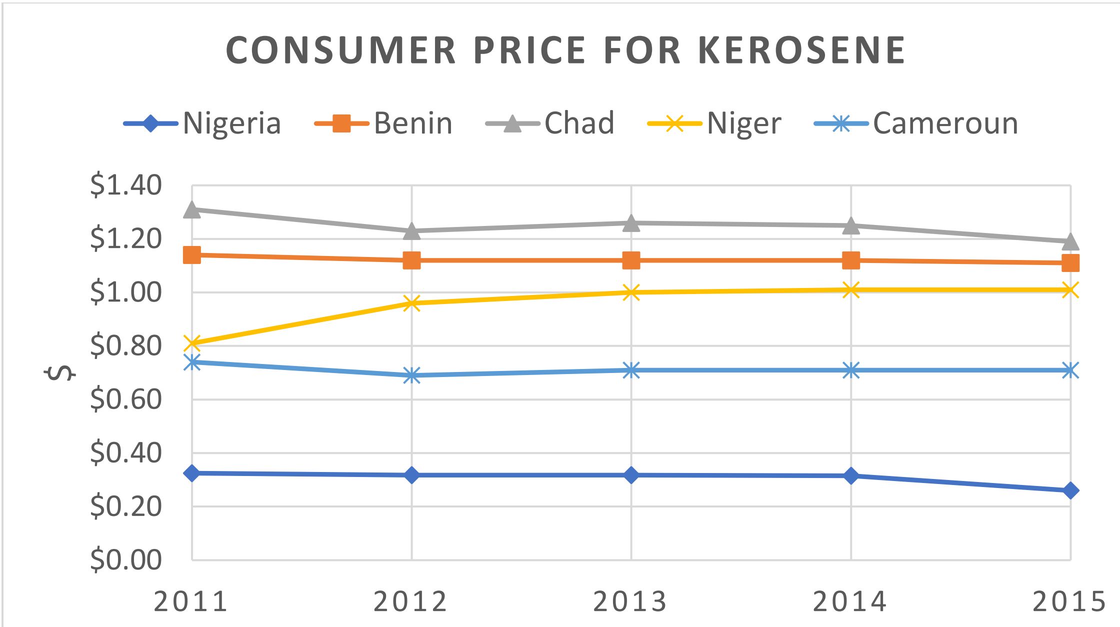

Figure 17 Consumer price for kerosene in Nigeria and neighbors (Data for neighbors from IMF Energy Subsidy Template, Official average annual Naira-USD exchange rate obtained from Central Bank of Nigeria, 2018)

5.1.4 Electricity Subsidies

5.1.4.1 Development and Structure of the Electricity System in Nigeria

Electricity was first generated in Lagos, Nigeria, in the late 1800s, but the first utility, Nigerian Electricity Supply Company (NESCO), was established in 1929 (Obafemi, et al., 2018). NESCO was managing the hydroelectric plant constructed in cities Kuru, Jos, and served locations mainly in northern Nigeria. In 1946, the colonial government transferred the supply and development of electricity to a central body, the Electricity Corporation of Nigeria (ECN). The Nigerian Dams Authority (NDA) was also set up by the parliament to manage the construction and maintenance of dams along the river Niger. The NDA sold the electricity generated from dams to the ECN for distribution (Onyi-Ogelle, 2016). In April 1972, the NDA and the ECN were merged into a vertically integrated monopoly, the Nigeria Electric Power Authority (NEPA) responsible for the generation, transmission, and distribution of power (Aji, Gutti, Highina, & Hussaini, 2015). The goal of this new organization was to ensure the effective utilization of the human, financial, and other resources needed to supply electricity (Niger Power Review, 1985).

After over three decades of operation, NEPA failed to meet the electricity demands of most Nigerians. Thermal and hydropower plants were built in the 1970s - 1980s, but until 1999, no new power plants were built by NEPA, and existing power plants were poorly maintained, leading to increased power outages (Folorunso & Olowu, 2014). Corruption, inefficiency, bureaucracy, and ineptitude were a common feature with NEPA (Onyi-Ogelle, 2016).

In a bid to improve the power supply, the power sector was reformed again with the introduction of the Electric Power Sector Reform Act of 2005. As a result, NEPA was renamed Power Holding Company of Nigeria (PHCN) and was later broken into eighteen separate companies, including six generation companies, one transmission company, and eleven distribution companies. The act also established the Nigerian Electricity Regulatory Commission (NERC) as the regulatory commission. The NERC determines the eligibility of and issues licenses to Independent power producers (IPPs) who produce and sell power through power purchase agreements (PPA)[11] with the Nigerian Bulk Electricity Trading (NBET) Plc, which manages and administrates the electricity pool.[12]

NERC introduced the Multi-Year Tariff Order (MYTO) in 2008 to set the wholesale and retail tariff path 15 years in the Nigerian electricity sector. These tariffs are designed to create cost-reflective tariff paths for distribution companies (DISCOs) and generation companies (GENCOs). Provisions are made for bi-annual minor reviews and 5-year major reviews of the assumptions made in the MYTO. These reviews take into consideration the rate of inflation, foreign exchange rates, the cost of natural gas, and the generation capacity. In 2012, a review of the MYTO assumptions was carried out, and MYTO 2.0 was issued. After another minor review in December 2014, the MYTO 2.1 was introduced (Gershon & Ezurum, 2018).

Despite this tariff regime, liquidity[13] is still a serious problem in the Nigerian Electricity Supply Industry (NESI). There is a liquidity gap estimated at over N1 trillion and over N534 billion of revenue was lost in 2016 by the power sector due to poor gas supply, line and frequency limitations, and water level constraints (Ahiuma-Young, Obasi, & Ejoh, 2017). The DISCOs are still forced to sell electricity at an average retail

[11] NBET enters a PPA with generators to buy electricity at agreed rates.

[12] The electricity pool refers to the system of wholesale trading of electricity where generators are dispatched, and the price of generated power determined.

[13] Liquidity refers to the financial resources to meet the demand for electricity.

rate of ₦32 per kilowatt-hour when it should sell at an average rate of above ₦80 per kilowatt-hour as of 2018 (The Guardian, 2018). The DISCOs are the primary revenue source in the electricity value chain, but they are unable to meet their obligations to the electricity market. Non-technical losses as a result of inefficient DISCO operations account for the bulk of losses in the NESI. Sixty percent (60%) of consumers are not metered, and consumers unable to pay, engage in theft, meter bypass, or simply refuse to pay. The GENCOs, gas producers, and gas suppliers are owed billions of naira, creating an unsustainable situation that forces government intervention (Omonfoman, 2016).

5.1.4.2 Nature of subsidies

The electricity sector is heavily subsidized, but the cost of these subsidies is much harder to ascertain as the government does not make specific payments to cover for low-cost electricity. Instead, lump sums are paid to electricity companies to cover all their costs. (IISD, 2012) Some estimates put electricity subsidies between ₦232.5–356.5 billion ($ 1.5–2.3 billion) between 2005 and 2009. (Foster & Pushak, 2011) The underpricing of natural gas sold to the electricity sector represents a part of the subsidy accounting for an estimated $50–90 million annually. It is a disincentive to investment in gas infrastructure (Machunga-Disu & Machunga-Disu, 2012).

In March 2017, the Nigerian government, through the Central Bank of Nigeria (CBN), issued a 2-year ₦701 billion payment assurance guarantee (PAG) for the power sector to solve the liquidity problem in the power sector. This guarantee provides the finances to back up power purchase agreements (PPAs) obligations with generating companies so that they can pay for liabilities to their gas suppliers. This is one of several interventions by the government in the electricity sector (Omonfoman, 2017). Previous interventions include a ₦300 billion, Power and Aviation Intervention Facility (PAIF), and the ₦213 billion, Nigeria Electricity Market Stabilization Facility (NEMSF).

The ₦213 billion NEMSF is a ten-year facility provided to electricity market participants to settle outstanding gas supply debts. The ₦300 billion, Power and Aviation Intervention Facility (PAIF) was designed to help fast track the development of power plants (CBN, 2015; CBN, 2012). Cost recovery is a critical problem in Nigeria. Intermittent and insufficient gas supply due to poor infrastructure and vandalism, the lack of cost-reflective tariffs, and poor revenue collection make it difficult for DISCOs and GENCOs to recoup costs and leads to liquidity challenges in the industry. These challenges also pose challenges to prospective investors in the industry (Idemudia & Nordstrom, 2016). An attempt to raise electricity tariffs in early 2016 was followed by protests by the labor unions who cited the lack of regular electricity supply, poor metering, and the failure to follow extant laws for such increments as reasons for resisting the proposed increase (Ahiuma-Young, 2016).

5.1.5 Fiscal burden, Corruption, and Inefficiency of the Petroleum Subsidy Regime

5.1.5.1 High Fiscal Burden

The subsidy regime has placed an enormous financial burden on the Nigerian economy over the last few years. The cost of fossil fuel subsidies rose by over 1300% between 2006 and 2011. Between 2008 and 2013, subsidy payments are estimated to make up over 100% of capital expenditure, meaning more money is expended on paying subsidies than on infrastructural development. In 2013, subsidy payments were ten times more than the allocation for agriculture, three times the allocation for health, and twice the allocation for education (IISD, 2016). Figure 18 shows the estimated cost of oil subsidies in real 2018 USD between 2012 and 2018 from the IEA fossil fuel subsidy database. In 2018, subsidies were estimated to be $2.5 billion, greater than the 2018 budget expenditure for power, works, and housing ($1.5 billion), transportation ($721 million), agriculture ($326 million) and health ($195 million) and education ($169 million) (IEA, 2019; Punch Newpapers, 2017).

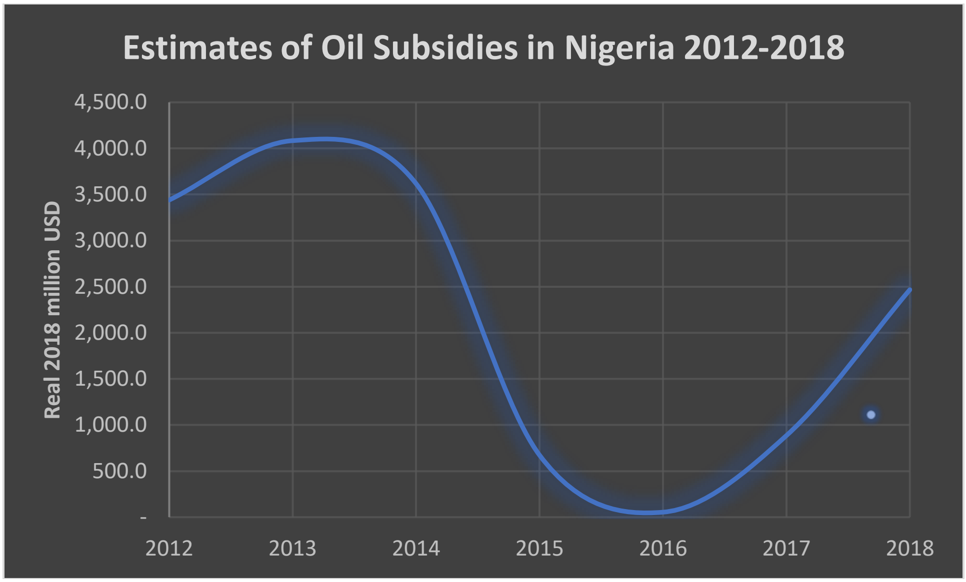

Figure 18 Oil subsidies 2012-2018 (Data from IEA, 2019)

Available estimates for electricity subsidies in Nigeria are shown in figure 19. In 2018, electricity subsidies were estimated to be $400 million greater than the2018 budget expenditure on agriculture ($326 million) and health ($195 million) and education ($169 million) (IEA, 2019; Punch Newpapers, 2017).

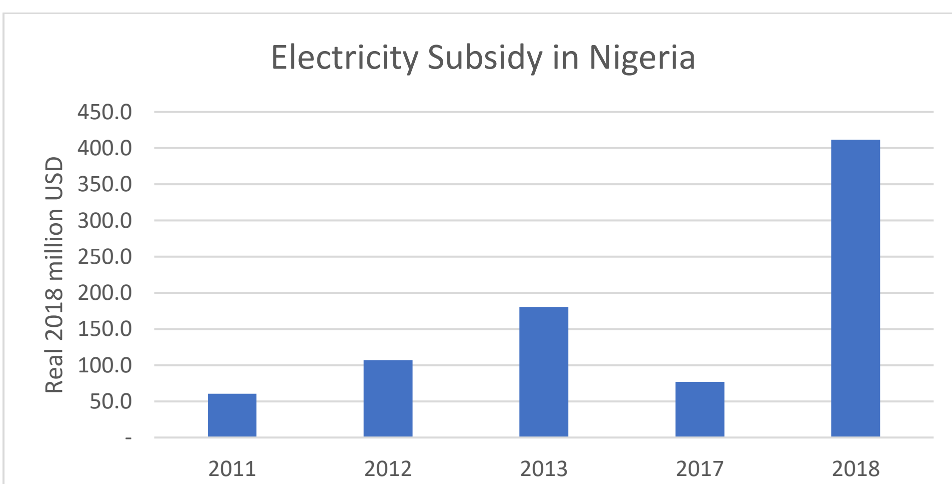

Figure 19 Size of Electricity Subsidies in Nigeria. Data Source (Source: IEA, 2019)

5.1.5.2 Inefficiency and Corruption

In addition to the high fiscal burden, the inefficiencies and corruption associated with the subsidy regime are well recorded. A parliamentary report in 2012 revealed several corrupt practices between 2009 and 2011 that resulted in an exponential increase in the cost of subsidies during that period (Nigeria House of Representatives, 2012). Several petroleum products importers, including the state-owned oil company, the Nigerian National Petroleum Corporation (NNPC), were deemed culpable in a $6.4 billion fraud associated with the subsidy scheme. The NNPC was found to be unaccountable to anyone as they continued to pay subsidies on kerosene worth over N300 billion between 2009-2011, even though a presidential directive had been issued to stop subsidies in 2009 (Nigeria House of Representatives, 2012).

The report notes that even though petroleum demand was at 39 million liters per day, subsidy payments were made to importers for 59 million liters. The amounts paid out for subsidies were often not as a result of fuel consumed. Many firms existed only on paper and collected subsidies on fuel that was never imported (Nigeria House of Representatives, 2012). Suspicious payments to undisclosed beneficiaries were common, including one involving the disbursement of N127.872 billion made up of 128 equal installments of N999 million made within 24 hours on the 12th and 13th of January 2009 (Nigeria House of Representatives, 2012).

The inefficiencies and corruption surrounding the subsidy regime led to the indictment of some notable marketing firms, but several of them were never prosecuted, and there has been limited reform carried out in the sector (Akanle, Adebayo, & Adetayo, 2013). Some of the indicted firms such as Masters Energy, Oando PLC, and Eterna Oil and Gas are still involved in the import of petroleum products even though they face charges of fuel subsidy fraud (Ezeamalu, 2017).

5.2 Factors Influencing Fossil Fuel Subsidies Reform in Nigeria.

The framework developed by Skovgaard and Van Asselt is utilized to analyze the factors influencing fossil fuel subsidy reform in Nigeria. The framework looks at three factors that influence the maintenance or reform of subsidies. The three factors are as follows:

i. Interests, Strategies, and Organization of Actors

ii. Ideational Factors

iii. Structural factors

We analyze each of these factors for petroleum and electricity subsidies.

5.2.1 Interests, Strategies and Organization of Actors

5.2.1.1 Petroleum Sector

Several actors influence the maintenance or removal of fossil fuel subsidies. Petroleum subsidies are politically contentious in Nigeria and are often a subject of heated debates between stakeholders on different sides of the arguments. The typical case in support of subsidy reform takes the view that these subsidies have negative fiscal, distributional, and environmental implications. Several international finance and development organizations like the World Bank, the IMF, the OECD, and the IEA take this position (Lockwood, 2015). These institutions support a liberal market viewpoint, and international financial institutions have often included oil sector and pricing reform as part of economic policy conditions to lending to developing countries (Lockwood, 2015; Independent Evaluation Group (IEG), 2009). The IMF often requires fuel subsidy reform as a condition for its programs, citing macroeconomic stability, sustained economic growth, and reducing poverty as some of the goals of the conditionalities (IMF, 2018).

Some other groups of actors are traditionally for the maintenance of subsidies in developing countries. These actors include labor unions, lobby groups of vested interests, and energy-intensive industries that highlight the benefits of subsidies and the negative distributional effects of the removal of subsidies (van Beers & de Moor, 2002; de Moor, 2001). The interest groups that support the maintenance of subsidies are often very well organized. In Nigeria, the Nigerian Labor Union has historically been at the forefront of resistance against petroleum subsidy reform, and oil marketers have a financial interest in maintaining subsidies.

The declared objectives of petroleum subsidies include protecting citizens from international price fluctuations and helping poor households, but in practice, they also serve as a form of political rent. Many analysts see these subsidies are employed as a means of transferring benefits in exchange for political support (Victor, 2009;

Commander, 2012). Political leaders utilize subsidies to maintain political support and/or prevent dissent and social upheaval. As earlier highlighted, the maintenance or removal of subsidies in Nigeria historically has been influenced primarily by political capital considerations and higher oil prices.

5.2.1.1.1 Actors in the Nigerian Petroleum Subsidy Regime

It is important to know the actors and interest groups in the petroleum subsidy regime and their roles in influencing the maintenance or reform of petroleum subsidies in Nigeria. The actors in the Nigerian petroleum subsidy regime represent the different conflicting opinions that influence government policy. These actors do not have permanent alliances but converge or diffuse based on self-interest (Akanle, Adebayo, & Adetayo, 2013). Domestic actors in the Nigerian subsidy regime include the federal government, government agencies involved in the administration of petroleum subsidies, civil society groups, labor unions, and independent oil marketers. International actors in the petroleum subsidy regime include international development and financial organizations.

The Nigerian federal government sets the policy of fossil fuel subsidy reform and often utilizes it as a tool to obtain popular support. This approach has been seen with both civilian and military governments. The Federal Ministry of Petroleum Resources is tasked with the responsibility of the development, implementation, and regulation of oil and gas policies on behalf of the federal government. Petroleum subsidies are tools for political control and are utilized by the government to provide benefits for targeted constituencies such as urban households with cars in exchange for political support (Cheon, Lackner, & Urpelainen, 2015). The political relevance of subsidies in Nigerian political circles is evident through the history of reforms and price reductions. Reform in Nigeria has historically been motivated by the need for political support, external pressures from international financial organizations like the IMF, and the World Bank and by the financial pressures associated with global oil prices. At low oil prices, government revenues are small, and the fiscal burden of subsidies is more pronounced, forcing the government to be more amenable to subsidy removal. Subsidy reform attempts in 1982, 1986, 1993, 1998, and 2016 were associated with low oil market prices. Price reductions in 1993 by the Military government of Abacha and in 2007 and 2015 by the civilian governments of Yar'adua and Jonathan respectively were motivated by political considerations and gaining public support (Lewis, 1994; Akanle, Adebayo, & Adetayo, 2013).

Other vital players that play a critical role in the petroleum subsidy regime are the civil society groups, labor unions, and the general populace. Traditionally, this group has always been opposed to subsidy reform or removal. They are the forefront of the populist opposition to subsidy removal leading several protests and strikes over the decades. These protests have occasionally led to the reversal of attempted petroleum subsidy reform. In 1994, 1999, 2000, and 2012, widespread protests and strikes led the government to reverse subsidy removal partially. The foremost civil society and labor unions in Nigeria include the Nigerian Labor Congress (NLC), Trade Union Congress (TUC), Civil Liberty Organization (CLO), National Union of Petroleum and Natural Gas Workers (NUPENG), Petroleum and Natural Gas Senior Staff Association of Nigeria (PENGASSAN), National Association of Nigerian Students (NANS) and Academic Staff Union of Universities (ASUU). The most influential of these groups is the NLC, which is responsible for organizing several strikes and protests in response to increases in the prices of petroleum products. The inelastic nature of petroleum products, the lack of viable alternatives, and the potential hardship to their members are some of the reasons for opposing subsidy reform.

The principal government agencies involved in the administration of the fuel subsidy regime include the Nigerian National Petroleum Corporation (NNPC), the Department of Petroleum Resources (DPR), the Petroleum Product Pricing Regulatory Authority (PPPRA), The Central Bank of Nigeria (CBN) and the Petroleum Equalization Fund Management Board (PEFMB). NNPC was formed in 1977 through a government Act CAP 320, which led to the merger of the Nigerian National Oil Corporation (NNOC) and the Ministry of Petroleum Resources. NNPC now combined both the commercial and regulatory features of the two. NNPC is charged with the responsibility of developing the upstream and downstream sectors on behalf of the Nigerian government. NNPC is one of the most influential agencies in the country and is involved in the refining, marketing, importation, and distribution of petroleum products (Ariweriokuma, 2009). NNPC plays a big part in the subsidy regime as they play the role of an importer, marketer, claimant, payer, and recipient in the subsidy regime (Ezeani, 2014). They operate 36 “mega stations” across the country where petroleum products are sold directly to consumers. (Ariweriokuma, 2009). Petroleum products are sold at subsidized rates at these mega stations. Historically, the corporation has been associated with many corruption scandals, including the 2012 petroleum subsidy scandal discussed earlier. The public image of the NNPC is one of corruption and mismanagement of resources as a result of its role in several probes over the decades (Nwokeji, 2007). The DPR is a department under the Federal Ministry of Petroleum Resources that serves as the petroleum regulatory agency in Nigeria. They ensure that petroleum operations are carried out legally with the relevant licenses and leases and that these operations align with the objectives of government as well as health, safety, and environmental regulations (DPR, 2018). In the 2012 petroleum subsidy scandal, DPR was found to have failed to accurately monitor the quality and quantity of petroleum products brought in by marketers, and they lacked data on the number of products supplied between 2009 and 2011. They also failed to sanction defaulters of the subsidy regime and provide information to the PPPRA (Nigeria House of Representatives, 2012). The PPPRA is the agency of government that sets the retail price for petroleum products and is responsible for the supply and distribution of petroleum products. The CBN oversees the foreign exchange policy and the disbursement of subsidy funds to Marketers. Marketers can purchase foreign currency at a below-market rate from the CBN to bring in petroleum products into the country. PEFMB was established by Decree No 9 of 1975 with the role to ensure that the Uniform Pricing Mechanism works effectively across the country (PEFMB, 2018).

Due to the inability to locally refine petroleum products, independent marketers play a critical role in the petroleum subsidy regime. They import petroleum products into the country and are paid subsidies to sell the products below the market rate. The inefficiency, lack of data, and infrastructure of the subsidy regime have led to several corrupt practices by these marketers. An Investigation into the subsidy regime in 2012 showed that the actual volume of petroleum products imported into the country could not be ascertained by relevant authorities (Nigeria House of Representatives, 2012). The investigation by Nigeria's House of Representatives (2012) showed that some marketers used falsified documents to benefit from the subsidy scheme without supplying petroleum products. Marketers are also known to engage in the diversion of petroleum products, round-tripping and other corrupt practices. Collusion and greed by operators of the downstream sector are said to be responsible for the low capacity utilization of the four local refineries despite frequent turn around maintenance (Nigeria House of Representatives, 2012). Prosecution of corrupt marketers indicted in the 2012 petroleum subsidy report has been filled with delays and adjournments, with some getting dismissed. Some reasons identified for the lack of progress in the prosecution of these cases include the endemic corruption in the judiciary and the selective prosecution by the Nigerian government. In addition to this, some of these marketers have a lot of clout in political circles and are members of the dominant ruling class (Chikwem, 2016). The major petroleum marketers in Nigeria, such as Mobil, NNPC Retail, Oando, Conoil, Total, AP, and MRS Oil, capture 50% of the subsidies in the industry (CPPA, 2011). The core responsibilities of major actors and their roles in the 2012 petroleum subsidy fraud are summarized in the table below:

Stakeholder/Actor	Core Responsibility	Role in subsidy fraud (2006-2011)
Nigeria National Petroleum Corporation (NNPC)	i. Importer of petroleum products but not subjected to the eligibility requirement of other importers.	i. Payment of subsidy on kerosene contrary to the presidential directive. ii. Inefficient system of importation of petroleum products that led to piling up of demurrage payments. iii. Lack of transparency in its operations
Department of Petroleum Resources (DPR)	i. Issue of import permits. ii. Verification and certification of the quantity of petroleum products imported by marketers. iii. Analysis of the quality specification of the products iv. Monitoring of the products supply and distribution chain v. Enforcement of the prices set by the Government vi. Provide the PPPRA with necessary information and data relating to product procurement, supply, and distribution vii. Collaborate with the PPPRA and PEF(M)B on intelligence monitoring to check malpractices	i. Failure in quantity certification ii. Failure in product quality supervision iii. Non-imposition of sanctions for selling kerosene above subsidy price iv. Failure to furnish PPPRA with data. v. Poor monitoring of trucked -out products

Petroleum Products Pricing Regulatory Authority (PPPRA)	i. Plan the receipt and distribution of petroleum products to ensure an uninterrupted supply. ii. Monitor and verify data on imported product reception and distribution at the jetties, refineries, and depots. iii. Monitoring of product evacuation from the depots to the retail outlets.	i. Making payments to itself. ii. Failure of monitoring and verification. iii. The fraudulent proliferation of marketers. iv. Poor record keeping. v. Non-compliance with guidelines.
Central Bank of Nigeria (CBN)	i. Issue foreign exchange to petroleum products importers. ii. Confirmation of subsidy payments to importers.	i. Easy falsification of records of quantity of petroleum products discharged due to forex policy.
Petroleum Equalization Fund Management Board (PEF(M)B)	i. Provide the PPPRA with regular data on product distribution.	i. They did not carry out the functions required of it.
Oil Marketing/Trading Companies	i. Import, supply, and distribute petroleum products nationwide. ii. Comply with rules and regulations set by regulatory agencies.	i. Non-compliance with their responsibilities. ii. Falsified documentation and non-supply of petroleum products are some of the major faults discovered.

Table 6 Responsible of Petroleum subsidy actors and the roles played in petroleum subsidy fraud (Source: Nigeria House of Representatives, 2012)

Figure 20 shows an illustration of the positions of the different stakeholders in the petroleum subsidy regime and the influences that guide their interaction. Politics has a significant impact on the persistence of subsidies. Civil society groups and labor unions are well organized and powerful, so their opposition to subsidies raises the political cost associated with subsidy reform. This political cost influences the federal government's reluctance to reform subsidies and makes subsidies a tool for gaining political support. Also, financial benefits and other vested interests by politically influential marketers and government workers make them oppose reform by lobbying and supporting the opposition to reform. The federal government, international organizations, and potential investors view the regime more from an economic standpoint. As earlier illustrated, the government is more open to reform in times of economic downturn when revenue from oil production is low. International organizations and investors support reform because of the potential to increase economic efficiency and make the industry more investment-friendly. Corruption and inadequate administrative capacity act as an incentive for those on both divides of the petroleum subsidy argument. Those who benefit financially or otherwise from the inefficiencies and corruption are more likely to oppose reform as the removal of subsidies will eliminate the corruption associated with it.

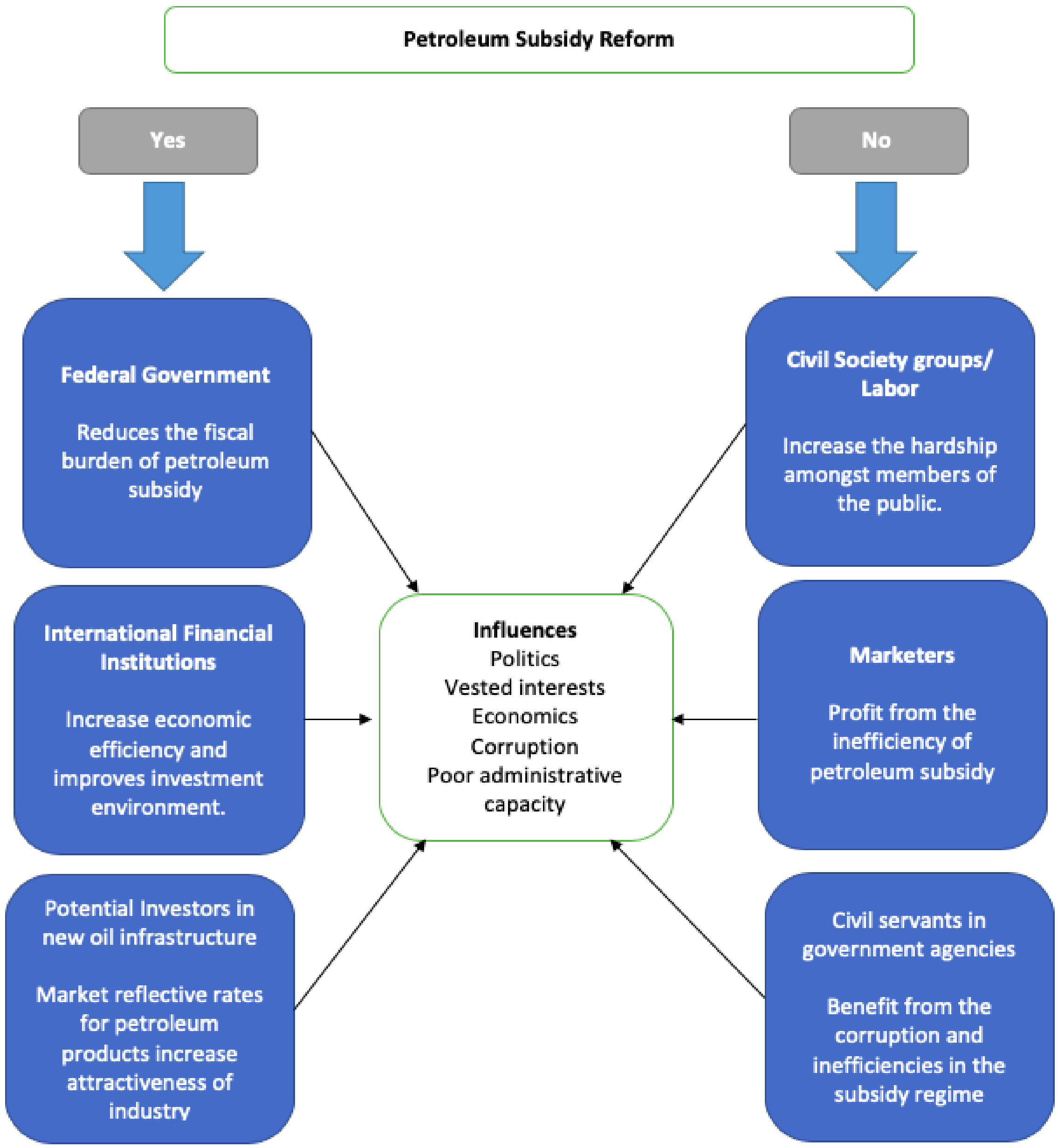

Figure 20 Positions of Different Actors in the Petroleum Subsidy Regime

5.2.1.2 Actors in the Electricity Sector

The most important actors in the electricity subsidy regime include the federal government, the regulatory agency known as the Nigerian Electricity Regulatory Commission (NERC), labor, and civil society groups. Other market actors include the Nigerian Bulk Electricity Trading (NBET), the Transmission Company of Nigeria (TCN) DISCOs, GENCOs, Independent Power Providers (IPPs), and consumers. Figure 21 shows an illustration of the roles played by the different stakeholders in the Nigerian power sector.

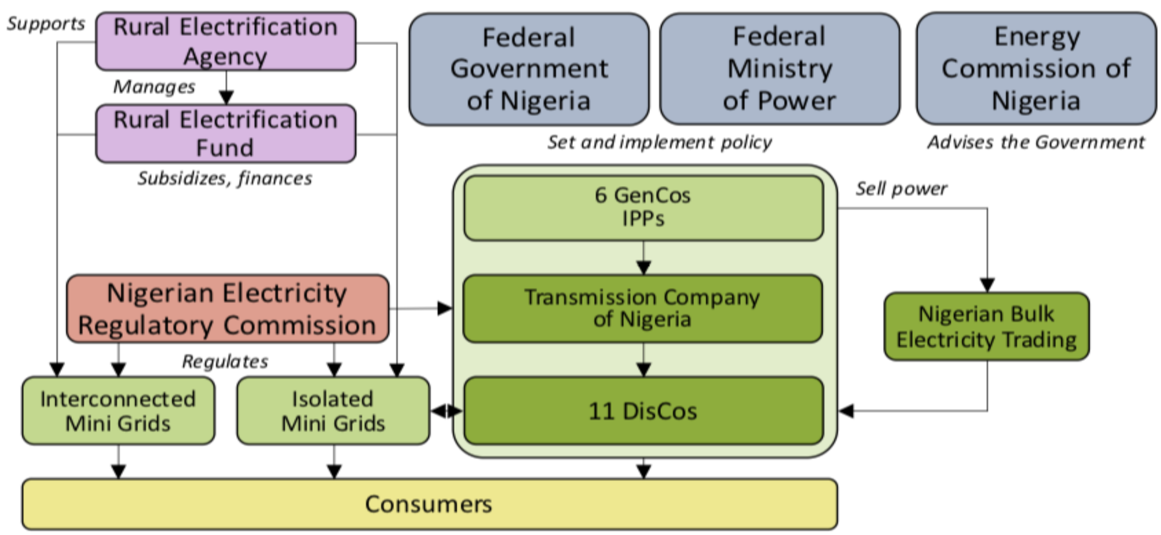

Figure 21 Actors in the Nigerian Power Sector (Source: Castalia, 2017)

The federal government, through the federal ministry of power, is responsible for the design and implementation of policies for the power sector. The Electric Power Sector Reform Act (EPSRA) of 2005 is the overriding legislation guiding the power sector and provides guidelines for the regulation of electricity tariffs. The executive arm of the federal government has also given multiple bailouts for the industry due to common liquidity issues faced by the industry. Attempts to raise tariffs by the NERC have met resistance from the legislative arm of government. The NERC, through the MYTO, determines electricity tariffs needed to ensure cost recovery for the different actors in the market. In 2018, The national assembly objected to tariff increase, citing the Nigerian electricity market stabilization fund (NEMSF) that had already injected into the industry to aid liquidity. Also, the assembly noted that the 140% increase in electricity tariffs between 2007 and 2017 had not led to an improvement in power supply across the country (Olafusi, 2018).

The NBET is the country's bulk trader and was established in 2010. It purchases electricity from GENCOs and IPPs through PPAs and sells to DISCOs and eligible consumers through vested contracts and PPAs, respectively. (Ezea, 2016). The current structure of the power market is shown in figure 22. Insolvency issues faced by DISCOs have prompted the government to provide financial bailouts to supports PPAs contracted by NBET and DISCOs. The market actors support increases in tariffs to reflect cost levels and improve the attractiveness of the sector to investments. Underpricing of power impairs the revenues of the market actors, limits their efficiency and willingness to invest in system improvement, and encourages them to seek government subsidies (Ezea, 2016).

Pressure from labor and civil society groups also influence the regulation of electricity tariffs in Nigeria. The Nigeria Labor Congress (NLC), Trade Union Congress (TUC), and the National Union of Electricity Employees (NUEE) are some of the leading bodies opposing the increase of electricity tariffs. The lack of reliable power supply and the inefficiency of DISCOs is often cited as a reason for opposing tariff increase.

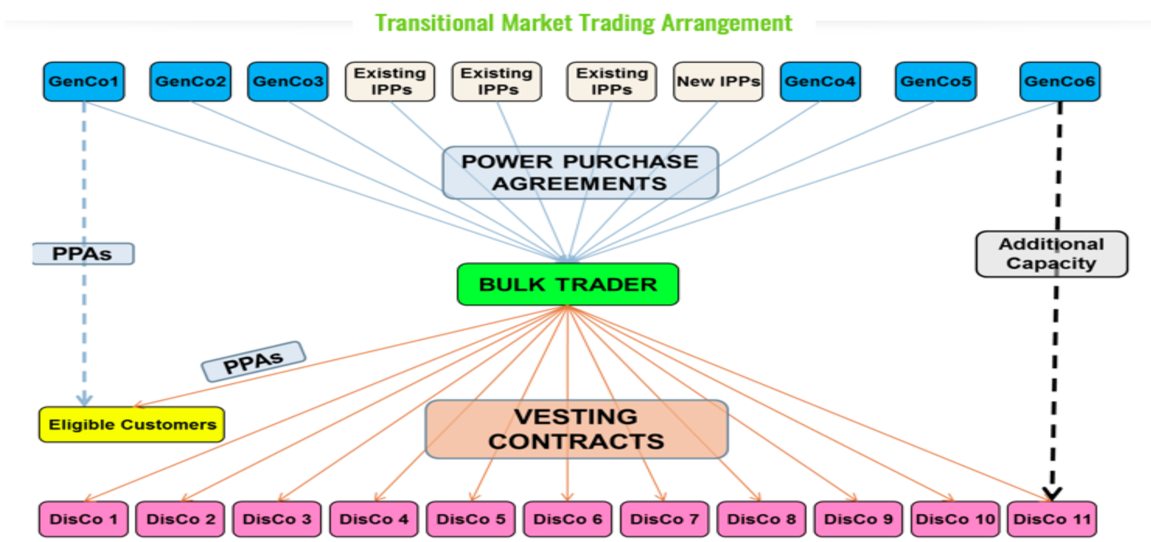

Figure 22 Power Market Actors (Source: NBET, 2018)

5.2.2 Ideational Factors

5.2.2.1 Petroleum Sector

Another dynamic in the maintenance of fossil fuel subsidies is the ideational factors that guide different actors (Jenkins-Smith, Nohrstedt, & Weible, 2014). These ideational factors include the norms, ideas, beliefs, and knowledge held by different actors in the subsidy regimes.

Norms refer to behavioral patterns that people adhere to because they know that people within their network, society, or group conform to that behavior (Bicchieri, 2017). For something to become a norm, it must have enough people that know that it exists, believe in it, and prefer to conform to it (Bicchieri, 2006). Actors within a society conform to certain social norms that are prevalent in that society.

In Nigeria, one of the most important norms that influence the petroleum subsidy is corruption. Corruption in Nigeria can be analyzed utilizing institutional theory. Institutional theory is applied to understanding institutional structures as well as individual and institutional practices across different countries (Glynn & Abzug, 2002; Dacin, Goodstein, & Scott, 2002). It posits that institutional arrangements shape the actions and behavior of individuals, and these arrangements are influenced by the prevalent culture in a country (Pillay & Dorasamy, 2010; Kostova, Roth, & Dacin, 2008). Rodriquez et al. (2005) divide corruption into two main dimensions *pervasiveness* and *arbitrariness.* Pervasiveness refers to how widespread corruption is within an institution. Arbitrariness refers to the degree of ambiguity associated with corrupt practices. High arbitrariness refers to uncertainty as to the number of corrupt practices needed to achieve an objective. These two dimensions of corruption do not always occur together. Corruption can be pervasive but not arbitrary or arbitrary but not pervasive (Rodriguez, Uhlenbruck, & Eden, 2005).

Corruption in Nigeria is widespread, notorious, resilient, and banalized (Pierce, 2016). It is both pervasive and arbitrary. As in several African countries, the civil service, political coalition, and groups in Nigeria view public service as a chance for self-enrichment. (Mbaku, 1996). Corruption, as a social norm, influences the persistence of petroleum subsidies. The inefficiencies of the fuel subsidy regime create opportunities for corruption through the value chain of petroleum products importation, marketing, and retail. Government officials, petroleum marketers, and even fuel attendants benefit from the system. Government officials and petroleum marketers have been known to collude in corrupt practices and illegal financial transactions. The monetary benefits gained from fraudulent activities make these parties resistant to the idea of petroleum subsidy reform.

Another factor that influences the lack of acceptance of petroleum subsidy reforms in Nigeria is the alienation of the citizens in important national initiatives. The government rarely consults with citizens on important initiatives, and as such, Nigerians do not identify with the initiatives or support them. As a result of this, there is no notion of public or national interest amongst Nigerians who identify more with tribal, ethnic, or community interests (Ocheje, 2018). Governments have arbitrarily announced petroleum products increases without consulting with the citizens and civil society groups. There have been several arbitrary and sudden increases in the prices of petroleum products prompting resistance, strikes, and protests. Education about the importance of petroleum subsidy reform is non-existent, and even when there have been attempts to educate the public like in 2012, sudden action by the government to reform subsidies undermined those efforts.

In oil-exporting countries, oil subsidies are prevalent due to a sense of oil nationalism, which leads to a strong sense of ownership of the oil and an expectation of low oil prices (Segal, 2012). It is no surprise that major oil and gas producers tend to be large subsidizers. Oil producers tend to be net subsidizers of petroleum products, while non-oil producers tend to be net taxers (Gupta, Clements, Fletcher, & Inchauste, 2003). This pattern holds in Nigeria, as many believe subsidies to be part of their rightful benefits from the petroleum resource in their country and do not understand why they cannot enjoy petroleum subsidies when the resource is so abundant in the country. (Nwachukwu, Mba, Jiburum, & Okosun, 2013). In addition to this, there is a high level of distrust of the government's ability and willingness to utilize the saving from subsidy reform for infrastructural and social development. Public suspicions is heightened by the level of corruption and lack of accountability associated with the subsidy scheme (Akanle, Adebayo, & Adetayo, 2013).

In Nigeria, subsidy reform is associated with inflation, the destruction of small businesses, and worsened socio-economic conditions of poor people. Previous experiences of petroleum price increases and subsidy reform inform this feeling. Increases in the cost of goods and services follow hikes in the prices of petroleum products. Petroleum prices influence the cost of public transportation, the cost of operation for small businesses, and the output of all sectors in the Nigerian economy (Nwachukwu, Mba, Jiburum, & Okosun, 2013).

Like with all subsidies, petroleum subsidies in Nigeria exhibit path dependency and lock-in (Victor, 2009). The practice of uniform subsidized petroleum prices has been so ingrained that it is expected by the population and is often a measure of good governance. Politicians use the promise of reducing petroleum prices to gain politic support as people use it as a measure of which politician serves their best interests. The government has been unwilling to undertake petroleum subsidy reforms unless they are in financial distress due to low oil prices.

There is also an evident lack of information about subsidies in Nigeria. The public rarely has accurate information on how much subsidies they receive or the potential benefits of subsidy reform. They are unaware of the impacts of low petroleum prices on the distributional effects of subsidies or the implications for economic efficiency and budgets. In 2012, information about the petroleum subsidy reform program called Subsidy Reinvestment and Empowerment (SURE) program was introduced to the public just six weeks before the petroleum subsidy reform was introduced (Whitley & van der Burg, 2015). This lack of information left the population largely uninformed and contributed to the backlash associated with the price increases.

5.2.2.2 Electricity Sector

Historically, Nigeria has always had electricity tariffs too low to meet the operating cost of producing and distributing electricity to meet the demand. Low tariffs from the vertically integrated NEPA meant that electricity infrastructure was left neglected. In addition to low tariffs, poor metering and collection rates contribute to inadequate cost recovery forcing the government to provide financial assistance to meet the shortfall in returns. Nigerians are used to pay low tariffs for electricity and are unwilling to pay higher tariffs without improved electricity supply. Previous increases in electricity tariffs have not resulted in improved power supply.

The unreliability of power supply in Nigeria has forced several to rely on alternative generators to supplement the power from the grid. An estimated 81% of Nigeria relies on alternative sources of energy, such as diesel generators, petrol generators, inverters, and traditional sources of energy (NOI Polls, 2013). A history of inadequate funding, lack of maintenance, lack of infrastructure, policy inconsistency, and vandalism have contributed to the low generating capacity and intermittent power supply (Emovon & Samuel, 2017). The inability to adequately generate or distribute power and the poor metering of distributed electricity perpetuates the cycle of inadequate funding, maintenance, and infrastructural decay. This self-perpetuating cycle is illustrated in the figure below.

Figure 23 Self Perpetuating cycle of electricity generation in Nigeria.

Inadequate power supply is caused by the inability to adequately fund the value chain of electricity supply in Nigeria. Lack of funding also leads to a lack of maintenance of gas infrastructure and the technical and non-technical inefficiencies of DISCOs. Consequently, the industry is unable to raise enough funds to keep it afloat, leading to a call for an increase in tariffs to more cost-reflective levels. Tariff increases are resisted by most of the population, the legislative arm of government, and civil society groups because of inadequate supply and limited improvements from previous tariffs increases. Electricity theft is also a common trend in Nigeria and is the most common non-technical loss in the Nigerian electricity supply industry alongside non-payment of electricity bills. Increased tariffs increase the likelihood of non-payment and theft. Theft also increases the cost of electricity for legal consumers (Dike, Obiora, Nwokorie, & Dike, 2015). The industry is thus stuck in a cycle of inadequate funding requiring government financial support to keep afloat.

One reason for this cycle is the attitude and overall lack of knowledge amongst electricity consumers. Electricity theft is justified by the poor service of DISCOs and the belief that DISCOs already make a lot of money. There is limited knowledge as to the effects of theft on the revenues and the operations of electricity sector actors. Also, there is the view of electricity as welfare and should, therefore, be cheap. This feeling is used to justify theft from the state and utility companies (Dike, Obiora, Nwokorie, & Dike, 2015). Also, weak governance, accounting mechanisms, institutions, and the negative perception that electricity sector reform hurts the poor by increasing tariffs and benefitting the wealthy reduces the social legitimacy of reform and creates the conditions that promote power theft (Scott & Seth, 2013). Corruption by utility employees also plays a big part in this cycle as power theft occurs with their cooperation. Some employees collect bribes to look the other way when electricity theft occurs (Dike, Obiora, Nwokorie, & Dike, 2015).

Government interference for political reasons also plays a factor in this cycle. In 2015, the government froze the tariffs for residential consumers for 15 months, and several minor tariff reviews have not been implemented. Also, the collection losses component of the MYTO was removed, causing a reduction in the electricity tariffs. These actions appeared to have been motivated by political considerations as they happened close to the national elections. The regulatory agency, NERC, does not seem to have the independence required to efficiently manage the industry (Williams & Ghanadan, 2006; Ikechukwu, 2018).

5.2.3 Structural factors

5.2.3.1 Petroleum Sector

5.2.3.1.1 Governance Capacity

A major challenge with subsidy reform in Nigeria is the lack of institutional capacity and other mechanisms for more effective targeted policies (Hayer, 2017). Wealth can be redistributed in several different ways, including direct income transfers and the redesign of the tax system to benefit the most vulnerable in society. However, these alternatives would require a robust institutional capacity made up of competent bureaucratic agencies. For countries like Nigeria with low institutional capacity, fossil fuel subsidies represent a more straightforward solution as they do not require a strong administrative capacity and are politically appealing. As the local institutional capacity increases, the ability to implement more efficient and sophisticated policy instruments increases (Victor, 2009; Cheon, Lackner, & Urpelainen, 2015; Cheon, Urpelainen, & Lackner, 2013). Olowu (2001) attributes the weak institutional capacity in Nigeria to the politicization and the undermining of the civil service. This politicization has led to institutionalized corruption and a lack of accountability (Olowu, 2001). Nigeria's low institutional capacity also has macroeconomic implications as it inhibits its ability to achieve macroeconomic objectives, including poverty alleviation and unemployment (Iyoboyi & Pedro, 2014).

5.2.3.1.2 Macroeconomic Factors

Nigeria is Africa's biggest economy, with an estimated GDP of $394.8 billion in 2017 (IMF, 2017). As earlier discussed, this economy is mostly dependent on oil for much of government revenue and foreign exchange earnings, and as such, Nigeria is highly vulnerable to fluctuating oil prices. Nigeria's economic growth pattern in Nigeria is mainly dependent on the price of oil. Economic growth is high during periods of oil boom and crashes during periods of low oil prices. Economic growth in Nigeria averaged 5.7% between 2006 and 2016, but low oil prices forced the country into a recession in 2016 (The World Bank, 2018). Figure 24 shows the recent trend between GDP growth rate and global oil prices in Nigeria from 2011 to 2018. The chart shows that a significant drop in oil prices in 2015 led to a decline in economic fortunes culminating in the 2016 recession.

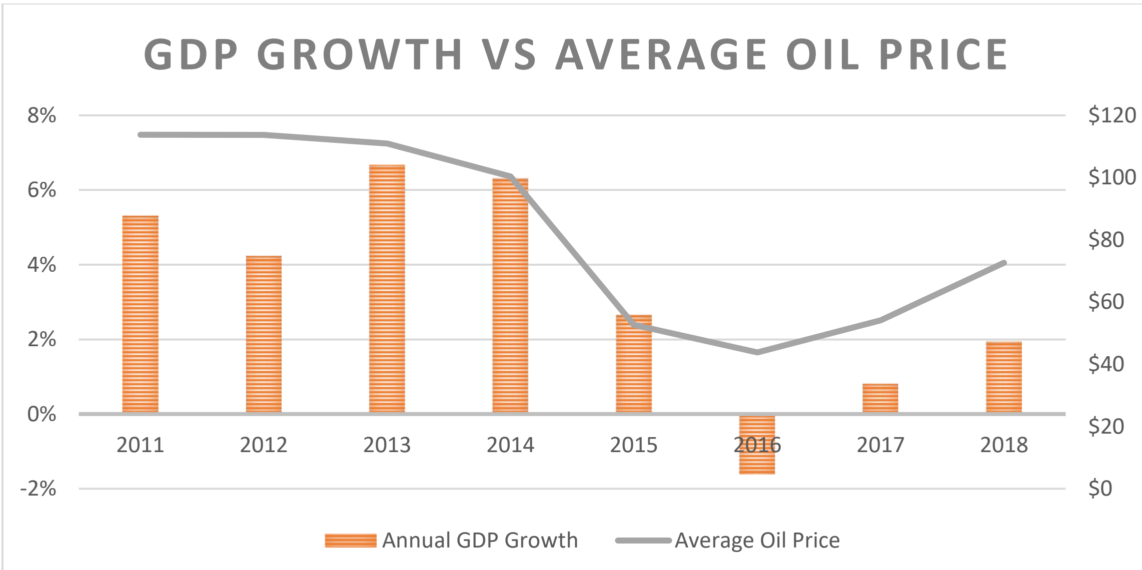

Figure 24 GDP Growth vs. Average Oil Price (Data sources: CBN, 2019, World Bank, 2019b)

Oil revenue is shared amongst the 36 states of the federation and the federal government using a revenue-sharing formula. Most states in Nigeria are dependent on the allocation of oil revenues for the running of their affairs (Onuigbo & Eme, 2015). Oil earnings and the size of petroleum subsidies affect the revenues shared to the states for capital and recurrent expenditures. In times of low oil prices, the impact of petroleum subsidies is felt more as the amount that would be shared to states is reduced. Low oil prices between 2015 and 2016 left several states unable to pay salaries or complete capital projects (MacEbong, 2015; Mitchell, 2016). The fiscal pressure of subsidy payments forced the government to remove subsidy payments in 2016, leading to an increase in the price of petroleum products (Gaffey, 2016).

Nigeria faces significant social and economic development challenges ranging from high inequality and poverty levels to weak institutions and lack of basic infrastructure. In 2018, Nigeria overtook India as the country with the largest number of impoverished people in the world. As of January 2019, an estimated 90 million people, about half of the population live on less than $1.90 per day. An estimated 15.3% of the people living in extreme poverty in the world reside in Nigeria, and the country is currently off-track to meet the sustainable development goals at current rates (World Data Lab, 2018). The lack of economic opportunities worsens this situation and create conditions for social and political unrest. For many in Nigeria, petroleum subsidies are the only benefits from the government, so hikes in the prices of petroleum products face serious resistance.

Low inflation, high economic growth, and income make people less resistant to subsidy reform (Hayer, 2017). Higher household income will help households afford the higher cost of petroleum products. However, statistics from the National Bureau of Statistics (NBS) (2018) show unemployment and underemployment rate have continued to rise. Unemployment rose from 7.8% in 2014 to 23.1% by the third quarter of 2018, and underemployment rose from 17.5% to 20.21 in the same period. Youth unemployment/ underemployment is estimated to be 55.4% as of October 2018. The inflation rate in Nigeria has averaged 12.5% between 1996 and 2018 (National Bureau of Statistics, 2018). High rates of inflation contribute to the resistance to petroleum subsidy reform and increases in petroleum prices are associated with increased inflation in Nigeria.

5.2.3.1.3 Power Dynamics

Petroleum subsidies can be utilized as an instrument for political control as they are often used by the government to provide benefits to politically influential constituencies (Victor, 2009; Overland, 2010). As earlier illustrated, Nigeria's attempts at subsidy reform has often been linked with the need to garner public support. National Oil Companies often play a dominant role in petroleum subsidy. The government can hide the cost of subsidies from the budget by requiring the national oil company (NOC) to sell at subsidized rates. The NOC benefits from high oil prices as they can sell local crude at the global market. Government can utilize their control of these entities to obscure subsidies in the sale of refined petroleum products (Cheon, Lackner, & Urpelainen, 2015). This situation was replicated in Nigeria when NNPC was solely responsible for the importation of petroleum products between 2016 and 2018 due to a shortage of foreign exchange (Asu, 2018).

The most powerful opponent of subsidy reform is organized labor represented by the Nigerian Labor Congress (NLC) and the Trade Union Congress (TUC). These organizations have been at the forefront of the resistance against fossil fuel subsidy reform and other political causes through the decades, and this has placed them in confrontation with the federal government (Erapi, 2011).

5.2.3.2 Electricity Sector

The same structural factors discussed above are also applicable to the electricity sector. Some of the other structural issues peculiar to the electricity sector are discussed below.

As of February 2019, Nigeria's electricity peak demand is estimated to be about 23,960MW, but peak electricity supply still ranges between 4000MW to 5,300 MW (Nigeria Electricity System Operator, 2019). The massive electricity deficit is bound to worsen with the burgeoning population that is expected to grow to an estimated 411 million people by 2050 and almost 800 million by 2100 without drastic growth in the generation and distribution of electricity. This population will be dominated by young people between the ages of 0-24 (UN, 2017). The growing population comes with an increased demand for affordable and reliable energy supply. Resistance to cost-reflective tariffs could grow with increased population, especially without a proportionate increase in income and economic growth. Constant electricity supply is critical for boosting economic and revenue growth, but that cannot occur with cost-reflective tariffs. Government aid to the industry would continue without cost-reflective tariffs or increased efficiency from DISCOs.

Electricity generated in Nigeria is transmitted and distributed mainly through the centralized grid system. Off-grid solutions are dominated by petrol and diesel generators, which cost an estimated N3.5 trillion (approximately $9.7 billion (February 2019 exchange rate)) annually to power for Nigerian manufacturers, small businesses, and households (Obinna, 2013). About 60 million Nigerians own petrol and diesel generators in their homes, and this has attendant environmental and economic implications. The cost of electricity generation from generators is over three times greater than the cost of grid electricity. These generators, as well as the refined products used to fuel them, are imported. With the growing population, the increased demand for imported products is bound to increase environmental degradation and worsen energy security (Adhekpukoli, 2018).

The Regulatory Indicators for Sustainable Energy (RISE) show that Nigerian Utilities score 0 out of 100 in “Utility Transparency and Monitoring” and “Utility Creditworthiness” indicators under the electricity access indicators. A high score of 94 out of 100 is given to the “Consumer affordability of electricity” indicator, which reflects the relatively low tariffs. Nigeria scored low in the “Scope of officially approved electrification plan” and the “framework for grid electrification” indicators. These scores show a weak policy framework for boosting grid electricity. For both categories, Nigeria scores 17% (RISE, 2019). The radar chart below shows the policy framework state of the Nigerian electricity sector.

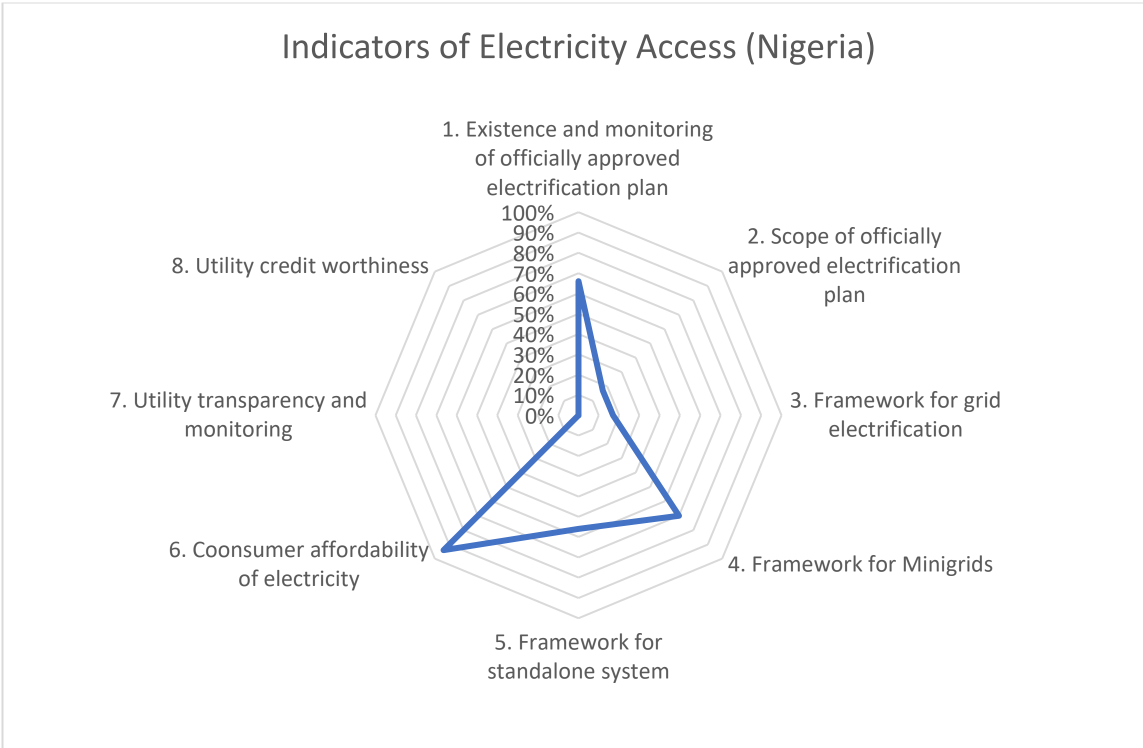

Figure 25 Indicators of electricity access in Nigeria (Source: RISE)

It is crucial to improve the policy and regulatory framework to boost electricity access and the financial sustainability of the electricity sector.

5.3 Fossil Fuel Applications, Impact of Subsidies and Opportunities for Renewable Energy Penetration

The most common application of fossil fuel products in Nigeria is transportation, with over 90% of petroleum products in Nigeria utilized for transportation purposes (IEA, 2019). Road transportation is the most dominant mode of transport in Nigeria, accounting for over 90% of distances traveled in Nigeria while water and rail transport accounts for 1.6% and 0.5%, respectively (Gujba, Mulugetta, & Azapagic, 2013; Oni, 2010). To address the reduce the political cost associated with fossil fuel subsidy reform, finding alternative fuels for transportation would go a long way. The subsidized fossil fuels in Nigeria are gasoline for transportation, kerosene for off-grid lighting. Kerosene is utilized to provide off-grid lighting during blackouts and for areas without electricity access. Other applications for fossil fuels include the use of natural gas for on-grid electricity generation.

CO_2 emissions in Nigeria are estimated to be about 86 metric tonnes in 2017, with oil accounting for 66% of all emissions while natural gas accounts for the rest. (IEA, 2019) Finding clean alternatives to fossil fuels would reduce emissions and create a sustainable energy path for Nigeria.

5.3.1 Transportation

As earlier stated, Road transportation is the dominant mode of transporting goods and services in Nigeria and the number of vehicles on the Nigerian road is projected to reach 33.9 million in 2030 up from 8.7 million in 2010, representing an annual rise of 19% (Cervigni, Rogers, & Dvorak, 2013). The increase in the number of vehicles has implications for fuel consumption and air pollution and health.

Gasoline is the most commonly used transportation fuel primarily due to fuel subsidy, which keeps gasoline prices below market rates (Cervigni, Rogers, & Dvorak, 2013). When compared with neighboring countries, Nigeria has the highest usage rate of gasoline. The figure below shows the proportion of gasoline and diesel using in Nigeria and neighboring African countries. Nigeria has subsidies on gasoline but not on diesel. The removal of gasoline subsidies in Nigeria is expected to increase the consumption of alternatives such as diesel closer to what obtains in neighboring countries (Cervigni, Rogers, & Dvorak, 2013).

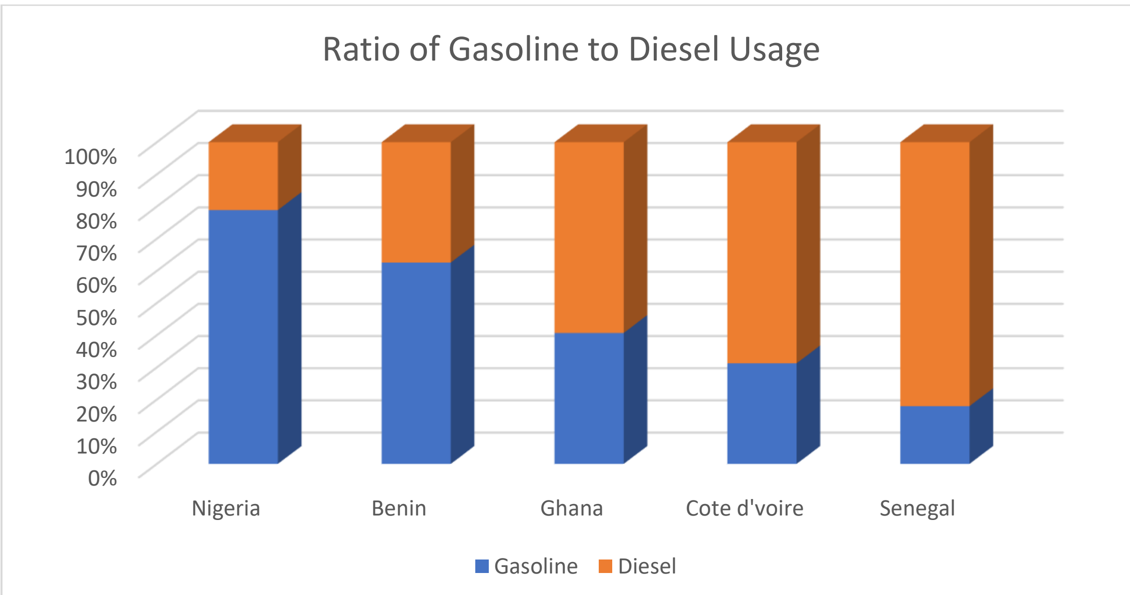

Figure 26 Ratio of Gasoline to Diesel Usage (Source: IEA, 2019)

Private cars and motorcycles account for most vehicles on Nigeria roads and the highest consumers of gasoline. Figure 27 shows the composition of motor vehicles on Nigeria roads in 2010.

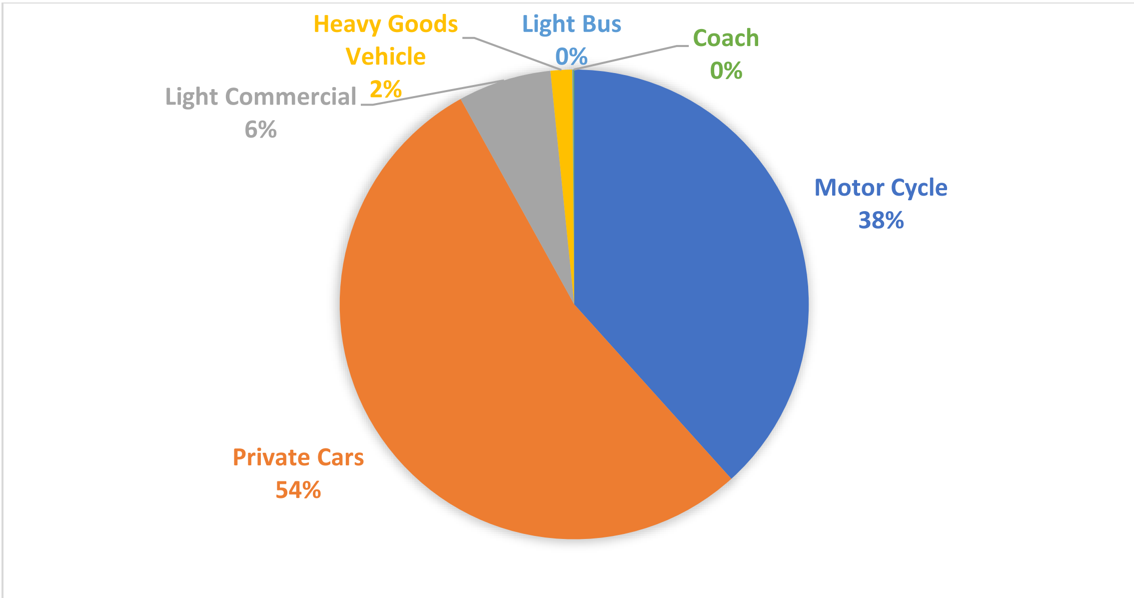

Figure 27 Composition of Vehicles in Nigeria 2010 (Source: Cervigni, Rogers, & Dvorak, 2013)

5.3.1.1 Alternative Fuel Technologies for Transportation

There are a few cleaner alternatives that can replace subsidized gasoline for transportation. Some of these alternatives include compressed natural gas (CNG), biofuels, and electricity.

5.3.1.1.1 Compressed Natural Gas (CNG)

As earlier discussed, Nigeria has a lot of natural gas reserves, much of which is flared. CNG is a fossil fuel but it is a cleaner alternative to gasoline. CNG vehicles emit 85-90 percent less carbon monoxide and 10-20 percent less carbon dioxide than gasoline-powered vehicles, but the energy output is as much as three times less than gasoline vehicles (US DOE, 2014).

5.3.1.1.2 Biofuels

Bioethanol and biodiesel from crop and forest products can also be utilized for transportation purposes. Ethanol is made from the fermentation of sugars found in grains. Gasoline containing blends of ethanol is widely utilized as a transportation fuel and can result in as much as a 25% reduction in carbon monoxide emissions when compared to conventional gasoline. Biodiesel can also be mixed with conventional diesel and used in diesel engines and can significantly reduce the sulfur content in diesel supply (US DOE, 2014).

5.3.1.1.3 Electricity

Electric vehicles (EV) make use of a battery that stores electric energy, which is used to power the motor. Batteries are charged by plugging to a source of power. Hybrid electric vehicles (HEV) are made up of two types of power sources. These usually include an internal combustion engine to burn conventional transportation fuel and a battery to store electrical energy. (US DOE, 2019)

5.3.2 Lighting

Petroleum products are also utilized for residential and industrial purposes to a lesser degree. Residential applications of petroleum products accounted for 2.3% and 3.2% of total consumption in 2017 (IEA, 2019). Subsidized kerosene is used primarily for Residential applications and makes up is 90% of fossil fuels use in residential applications (IEA, 2019). Kerosene is used primarily for off-grid lighting purposes but also for cooking. Electricity generation in Nigeria is dominated by thermal gas plants and large hydro facilities that feed into a centralized grid. Natural gas is the most dominant fuel, as it makes up over 80% of the total electricity generation (IEA, 2018).The breakdown of fossil fuel usage for industrial and residential processes is shown in the figure below:

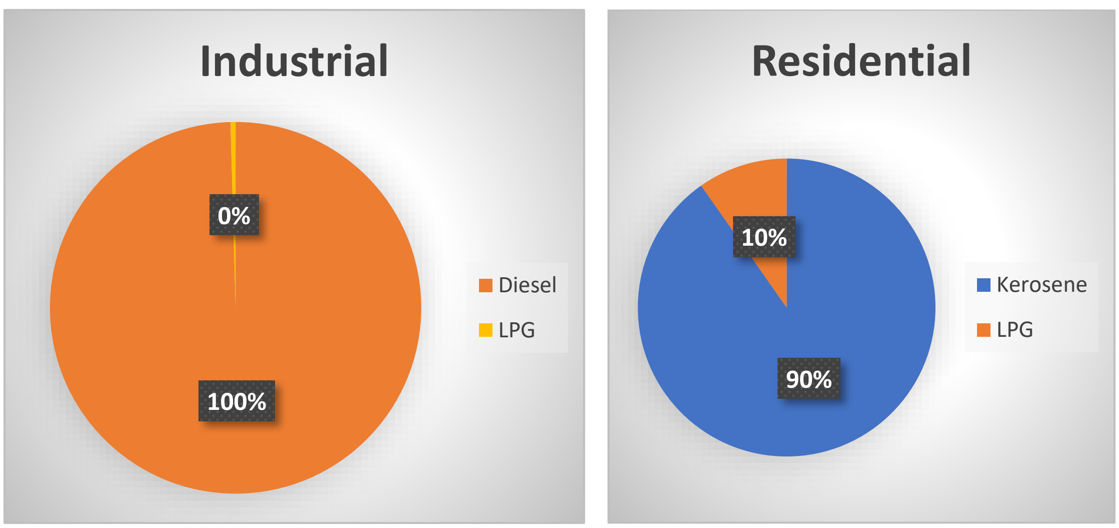

Figure 28 Petroleum Use in Industrial and Residential Applications (Source: IEA, 2019)

5.3.3 Renewable Energy Alternatives

Renewable energy alternatives can replace fossil fuels for transportation, off-grid lighting, and on-grid electricity generation as well as other industrial and residential purposes. The development of renewable energy would improve the environment by reducing GHG emissions, health by reducing dependence on fossil fuels and traditional sources of energy, energy security by improving the reliability of the electricity grid and fiscal sustainability by reducing the cost of fossil fuel subsidies. This will move Nigeria closer to attaining sustainable development goals and other development objectives.

Alternative transportation fuels could significantly protect the country from volatile global crude oil prices, reduce oil dependence and greenhouse emissions and free up resources that would have been used to subsidize petroleum products. (National Academy of Sciences, National Academy of Engineering & National Research Council, 2009) Distributed renewable energy would introduce new business models that would enable modern energy sources to reach unserved populations despite liquidity issues faced by DISCOs. It could also reduce the cost of grid expansion and potentially reduce the cost of subsidizing petroleum products and DISCOs in the long term. Pay as you Go (PAYGO) schemes utilize mobile technologies for flexible payments to own, lease, and rent energy products (GOGLA, 2018).

Nigeria has enormous renewable energy potential in small hydro, wind, biomass and solar. Exploiting these resources can provide employment, boost economic development and

provide Nigerians with environmentally friendly sources of energy. Large hydro dams are currently, the only significant renewable energy facilities employed for electricity generation.

Table 7 shows the reserves and current utilization of renewable energy resources in Nigeria.

	Resource	Potential	Current Utilization
1	Large Hydropower	11,250 MW	2062 MW
2	Small Hydropower	3500 MW	
3	Solar	4.0 kWh/m^2/day - 6.5 kWh/m^2/day	15MW
4	Wind	2-4 m/s at 10m height (mainland)	-
5	**Biomass**		-
I	Fuel Wood	11 million hectares of forest land and woodland	0.120 Million tons /day
Ii	Animal Waste	-	0.781 million tons of waste/day
Iii	Agricultural residue	-	0.256 Million tons of assorted crops/day
Iv	Energy crops	28.2 hectares of arable land	8.5% cultivated
V	Municipal waste		0.5kg/capita/day

Table 7 Potential and Utilization of Renewable Energy Resources in Nigeria (Sources: Center For Renewable Energy Technology, 2015, International Hydropower Association, 2018, Sambo, 2009)

5.3.3.1 Biomass

Biomass has a broad range of applications, including transportation electricity generation and cooking. It refers to organic material from plants and animals, which can be burnt directly to produce heat or converted to biogas or liquid biofuels such as ethanol and biodiesel (EIA, 2018). Bioethanol and biodiesel can be blended with gasoline and diesel, respectively, to make more environmentally friendly fuels for transportation.

Common crops that could be used to produce bioethanol in Nigeria include sugarcane, cassava, and sorghum. The major constraints in the production of ethanol in Nigeria include the competition with food, the potential strain on water resources, and the low efficiency of production. Nigeria is currently the world's largest producer of cassava, producing 59.5 million tons of cassava in 2017 but over 80% of production is utilized for food (Obayelu, Afolami, & Agbonlahor, 2013). Exploiting cassava for ethanol production on a large scale could affect domestic food supply. Besides, production yield per hectare in Nigeria is low compared to major ethanol producers. In 2017, Brazil produced 74.5 tons per hectare compared to just 16.8 tons per hectare in Nigeria (FAO, 2019a). Aside from production inefficiency, increased production of these crops could put a strain on existing water resources. A study by Adeoti (2010) estimates that replacing 5% of gasoline use by ethanol would consume an estimated 3% of Nigeria's water resource. Improved water management could significantly reduce this estimate (Adeoti, 2010).

Similar challenges are faced with crop products that can be used for Biodiesel production. In Nigeria, Oil palm, soybeans, and jatropha can be utilized in the production of biodiesel. In 2017, Nigeria was the 4th largest producer of oil palm and the 15th largest producer of soybeans globally (FAO, 2019a). There is a lot of potential for utilizing these crops for biodiesel production, but the current domestic production is less than the demand. Domestic demand is met by importation. In 2016, Nigeria imported about 111 thousand tons of soybeans and about 1.15 million tons of oil palm (FAO, 2019b). Also, these products have alternative applications; soybean is used in the production of vegetable oils and industrial food production while oil palm is also for human consumption.

Based on 2017 crop production levels and biofuels production efficiency, Nigeria can replace 4% of gasoline production with ethanol if 10% of domestic production of cassava, sugarcane, and sorghum were dedicated to ethanol production. 824.5 million liters of ethanol could have been produced compared to 18.4 billion liters of gasoline consumed in the same year (NBS, 2018). Table 8 shows how the figures were arrived at.

Crop	**Production (tons)**	**10% of Production (tons)**	**Ethanol yield (L ton−1)**	**Ethanol (liters)**
Cassava	59,485,947	5,948,594.7	137	814,957,473.9
Sugar cane	1,497,757	149,775.7	43.9	6,575,153.23
Sorghu m	730,000	73,000	41.1	3,000,300
				824,532,927.13

Table 8 Estimated ethanol production if 10% of crop produced is used in 2017 (Ethanol yield from Ishola, Brandberg, Sanni, & Taherzadeha, 2013, Crop production from FAO, 2019a)

Biodiesel could replace 40% of diesel consumption if 10% of crop produced is utilized based on the same assumptions. About 1.8 billion liters of biodiesel can be produced compared to 4.7 billion liters of diesel consumed in 2017 (NBS, 2018). This estimation is illustrated in table 9. This is illustrated in table 9.

Crop	Production	10% of Production	biodiesel yield (L ton−1)	Ethanol (liters)
Oil Palm	7759426	775,942.6	1,937.6	1,503,470,415
Soybeans	6939000	693,900	458.2	317,969,177
				1,821,439,592.34

Table 9 Estimated biodiesel production if 10% of crop produced is used in 2017 (biodiesel yield from (Ishola, Brandberg, Sanni, & Taherzadeha, 2013), Crop production from (FAO, 2019a)

Biogas is a methane-rich gas produced from the bacterial conversion of biomass under anaerobic conditions. It has the potential of replacing traditional fuels such as wood and charcoal and fossil fuels like kerosene in providing services such as cooking. With an estimated 350,000 hectares of forests and natural vegetation lost annually, deforestation is a serious problem in Nigeria. The situation is expected to get worse as demand for traditional fuels is expected to rise from 39 million tons today to 91 million tons by 2030 (Sambo, 2009). Indoor air pollution from the combustion of traditional fuels is responsible for 1.6 million deaths globally, mostly from developing countries (WHO, n.d.). Indoor pollution has harmful implications for sustainable development as it affects health, the environment, and food security. Biogas could offer a cleaner alternative and reduce the consumption of traditional fuels and kerosene. There are some pilot biogas plants already constructed, but the technology is yet to be commercialized in Nigeria. An assessment of the biogas potential in Nigeria suggests that Nigeria has a biogas potential of $138.7 \times 10^6 m^3$ from domestic livestock excrements and household solid waste. This value is equivalent to 0.69 X 10^6 tons of fuelwood or 480,000 barrels of crude oil (Adeotu, Adegboyega, & Ayelegun, 2001).

5.3.3.2 Solar Energy

Nigeria has an estimated solar potential of 207,000 GWh per year, assuming only 1% of the land area was covered by polycrystalline PV modules (GIZ, 2015). This estimate is more than six times greater than the total electricity generation of 30 897 GWh in 2016 (IEA, 2018). Most of this potential is concentrated in the northern part of the country, as seen in figure 29. The figure shows that PV potential is concentrated in Nigeria's core north, and reduces as you move down south (The World Bank Group, ESMAP, Solaris, 2016). Northern Nigeria has the highest solar potential but some of the lowest electricity access in Nigeria (NBS, 2009)

Solar energy can be used in a wide variety of household, industrial and agricultural applications like lighting, cooking, water heating and incubation. (Tyagi, Agarwal, Chakraborty, & Powar, 2018) Photovoltaics (PV) can help bring power to areas disconnected from the grid

without the burden of high transmission costs. The scale of demand in rural, isolated areas often does not justify the high cost of grid expansion (IRENA, 2013). It can replace petroleum products such as diesel and kerosene in industrial and residential applications and natural gas in electricity generation.

Exploiting this renewable source will boost the productivity of rural artisans and reduce energy poverty in rural areas. By connecting rural communities to solar energy, dependence on traditional biomass and fossil fuels will be reduced, and the population will enjoy better health conditions. (Kabir, Kim, & Szulejko, 2017; GOGLA, 2018c)

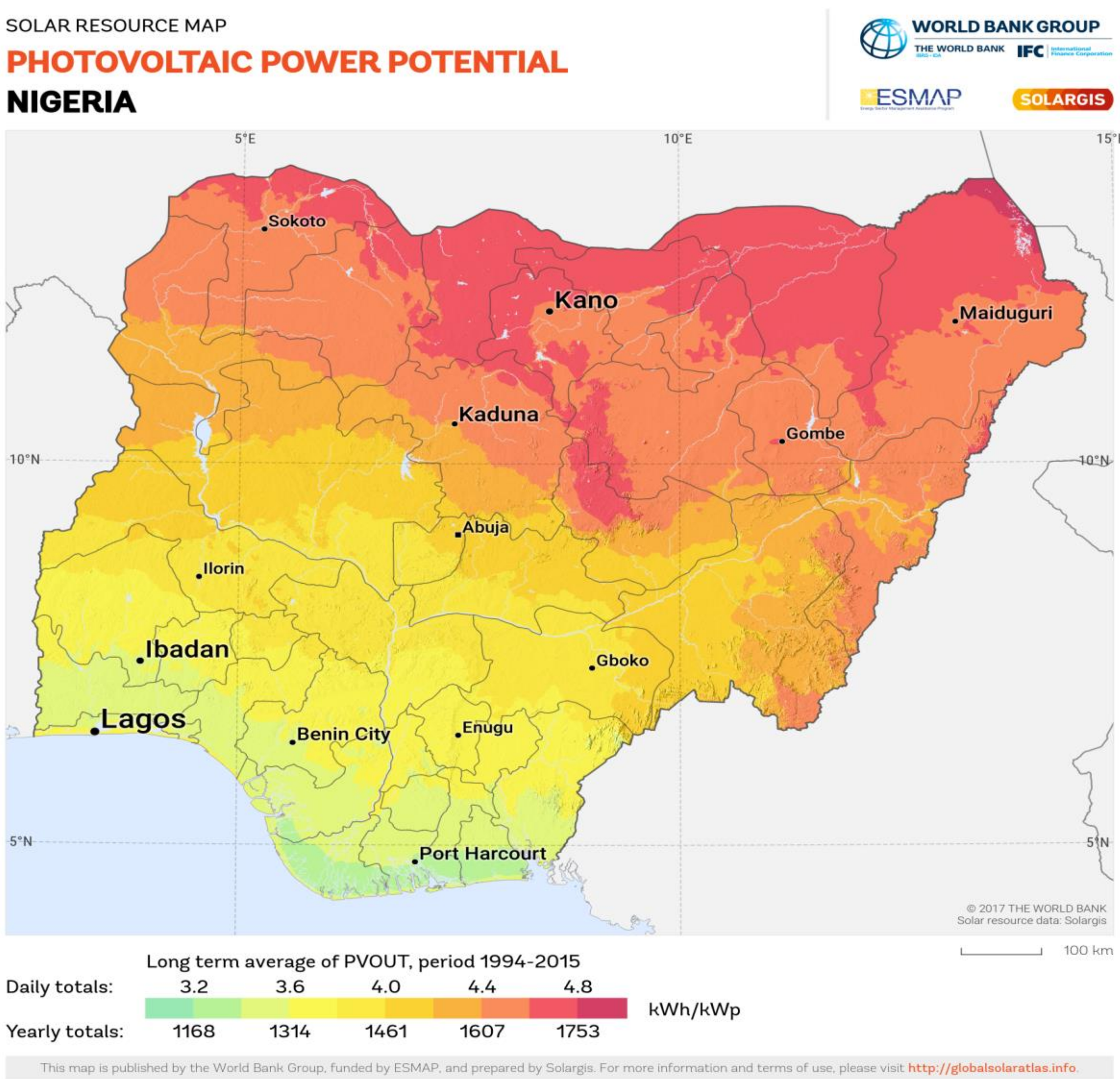

Figure 29 Photovoltaic Power Potential in Nigeria (Source: The World Bank Group, ESMAP, Solaris, 2016)

Off-grid solar solutions such as pico-solar systems, solar home systems (SHS), and solar mini-grids can bring modern quality energy services to areas cut off from the grid. They could be a cost-effective way to bring electricity access to energy services to regions far away from the grid (International Energy Agency (IEA), The World Bank, 2015). It is estimated that the provision of solar lanterns and solar home systems for 100,000 households would cost $3 million and $20 million, respectively, as opposed to $150 Million for grid extension (International Energy Agency (IEA), The World Bank, 2015).

Solar home systems provide high quality LED lighting with lumens ranging between 380-400 lumens, but commonly used kerosene wick lamps produce lighting quality of about 10 lumens. When adjusted for lighting quality, the Levelized Cost of Energy (LCOE)[14] of SHS with batteries is competitive to the retail price for kerosene per kWh, even with massive kerosene subsidies in Nigeria. The LCOE of SHS was estimated using the following assumptions in table 10 and compared with the consumer price of kerosene converted to $/kWh. Figure 30 shows the LCOE and the Kerosene price per kWh when adjusted for lighting quality.

[14] LCOE is the present value of the price of the produced electrical energy given all the costs and the economic life of the energy source.

Description	Value ($)	Source
Overnight capital cost/kW	9,000	(IRENA, 2016)
PV Module cost/kW	1500	(IRENA, 2016)
Battery Cost/kW	2500	(IRENA, 2016)
Battery Life (years)	5	(IRENA, 2016)
Life span	10	(IRENA, 2016)
O & M cost/kW	15	(Fu, David, Margolis, Woodhouse, & Ardani, 2017)
Discount factor	10%	
Capacity factor	19.2%	(IRENA, 2018)

Table 10 Assumptions for LCOE of SHS

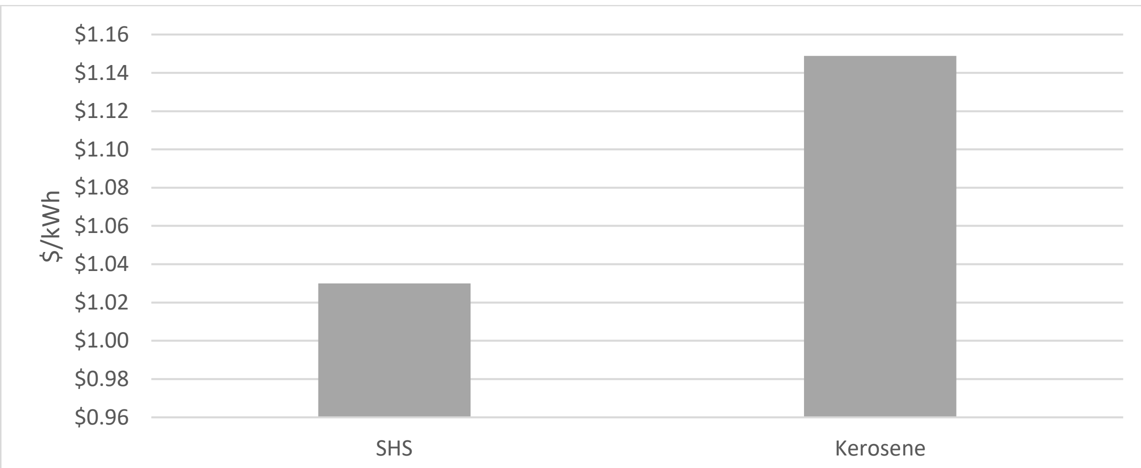

Figure 30 Comparison between costs of SHS and Kerosene when adjusted for lighting quality. (SHS=380 lumens, Kerosene= 10 Lumens)

Technological advancements, cost reductions, and innovative business models make off-grid solar solutions more accessible, giving it the potential to reduce fossil fuel dependence and provide alternative electricity supply models in Nigeria.

Common business models range from rental, perpetual lease, lease to own, upfront sales with financing partners, and direct cash sales (GOGLA, 2018). In the rental or perpetual lease model, the company maintains ownership of the solar system, and the consumer pays to enjoy the energy services provided by the system. In the lease to own model, the consumer leases the solar system for a given period, after which he owns the system. Upfront sales with a financing partner involve overtime payment with a financing partner for ownership while cheaper solar systems are often sold for cash. The PAYGO payment system is increasingly popular in SSA to manage incremental payments (GOGLA, 2018).

5.3.3.3 Hydro

Nigeria has an estimated 1,800 m^3 per capita per year of renewable water resources available (International Hydropower Association, 2018). Despite this, it suffers from economic water scarcity due to a lack of investment in its water resources (WRI, 2009). The Rivers Niger and Benue and their tributaries, as well as the lake Chad basin, are some of the major water resources for hydropower in Nigeria. Currently, Hydropower accounted for only 18% of total electricity generation with about 2,062 MW total capacity, most of which come from large hydro plants that feed into the grid. However, large hydropower has a potential of over 14,000 MW, of which only about 13.5% has been utilized. Small hydro potential is estimated to be about 3,500 MW, of which only 60.58MW has been utilized (Center For Renewable Energy Technology, 2015). The small hydro could be harnessed to boost generating capacity in rural and remote areas, thereby reducing dependence on fossil fuels and traditional fuels, creating alternative business models for electricity generation, and reducing the need and cost for grid expansion. The Nigerian Federal Ministry of Power (FMP) classifies hydropower plants capacities less than 30 MW as small plants, between 30 MW and 100MW as medium plants, greater than 100MW as large plants and those between 500kW and 1MW as mini-hydropower plants. (Bagu, Dietz, Hanekamp, Phil-Ebosie, & Soremekun, 2016) Hydro can be an alternative for on-grid and off-grid electricity supply and can be alternatives for diesel and natural gas. Figure 31 shows the rivers networks in Nigeria, while figure 32 below shows the major dams in Nigeria.

Figure 31 Rivers Network in Nigeria (Source: Styles, 2015)

Figure 32 Major Dams in Nigeria (Source: Bagu, Dietz, Hanekamp, Phil-Ebosie, & Soremekun, 2016)

5.3.3.4 Wind Energy

Studies on wind energy potential in Nigeria reveal low/moderate potential for wind energy with wind speeds of between 1 to 5.1 m/s at 10 meters height. Wind speed range from 1.4 to 3.0m/s in the south to 4-5.12 m/s in the extreme north. In Northern Nigeria, wind speed is greatest in the hilly and mountainous regions while in the south, wind speeds are highest in the coastal and offshore regions (ECN, UNDP, 2005) (Lehmeyer (International) Consultants, 2005). Nigeria has an estimated annual wind energy potential of 50 GWh concentrated mainly in the northern and west-central regions if only 1% of suitable land was utilized. However, more studies are required to identify the most promising inland areas for commercial wind energy development (Cervigni, Rogers, & Henrion, Low-Carbon Development Opportunities for Nigeria, 2013). Figure 33 shows a 3D wind resource map for Onshore wind in Nigeria at 80M above the ground.

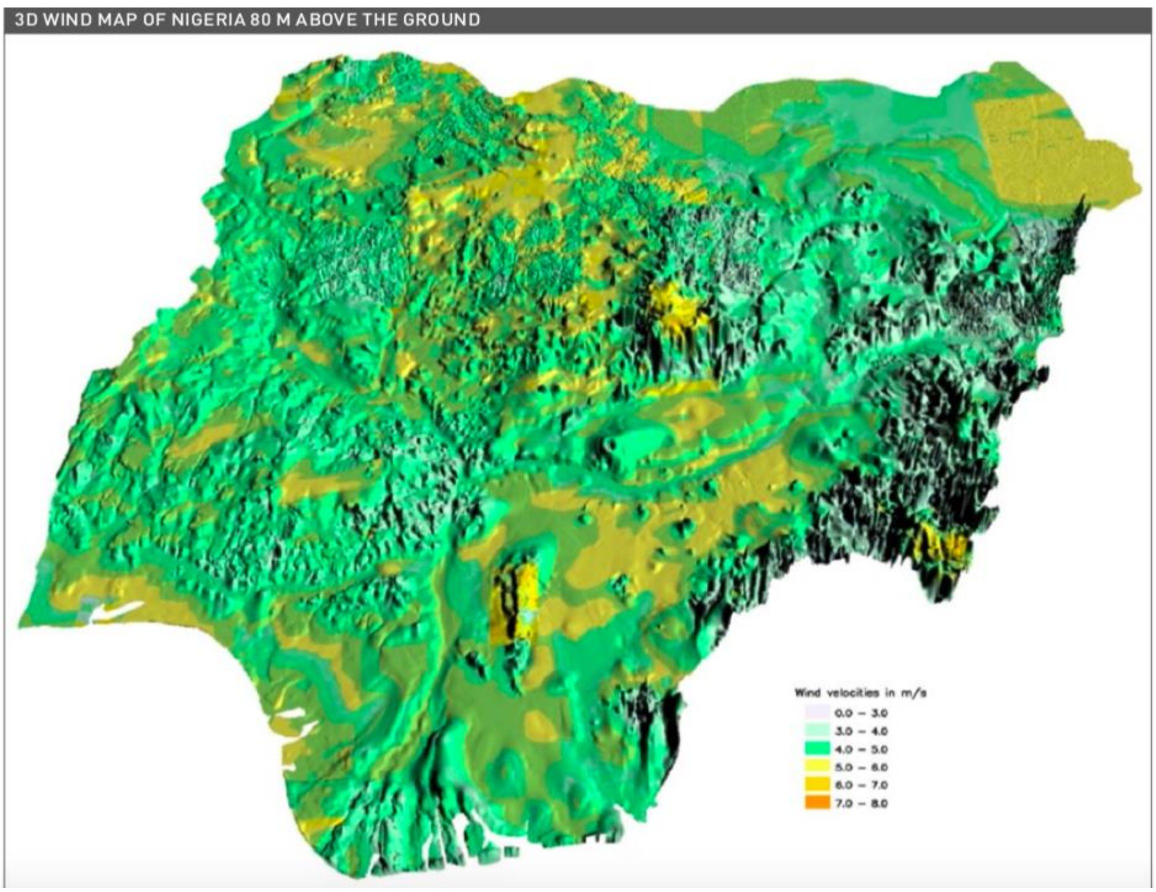

Figure 33 Wind Map of Nigeria 80 M Above the Ground (Source: Lehmeyer International Consultants, 2005)

5.3.4 Status of Renewable Energy Policy in Nigeria

The transportation sector is completely dominated by gasoline and diesel engine cars. Seventy-five (75) percent of current electricity demand is fulfilled by self-generation mainly through diesel/gasoline generators. (BloombergNEF, 2018) Nigeria had an installed generation capacity of 13 GW as at the end of 2017, with over 84% coming from natural gas and about 15.6% coming from hydro. Hydro is the only renewable energy source on-grid in Nigeria. Much of the installed thermal plants are not generating power due to the lack of gas infrastructure needed to transport gas to existing plants (BloombergNEF, 2018). Nigeria has a power generation on-grid capacity target of 30 GW by 2030, with 30% expected to come from renewable energy. The challenges already highlighted with grid electricity make clean, distributed electricity generation an attractive prospect in Nigeria today.

Nigeria has a few economic, regulatory, fiscal, and policy support instruments designed to support the development and installation of renewable energy in the country. These policy instruments support the penetration of ethanol blends in transportation and aim to have 5.3GW from mini-grids and 2.8GW from SHS to reduce the total population without access to electricity. There are also policy instruments designed to introduce cleaner cookstoves to replace dirtier fuels used for cooking (National Council on Power (NACOP), 2016). Some of the most important renewable energy policy instruments are outlined below in Table 11.

Policy Name	Year	Policy type
Biofuels blending mandate	2013	Mandate, codes/standards
Nigeria Feed-in Tariff for Renewable Energy Sourced Electricity	2016	Economic Instrument
Nigerian Electricity Regulatory Commission Mini-Grid Regulation 2016	2016	Regulatory Instrument
National Renewable Energy and Energy Efficiency Policy for Nigeria (NREEEP)	2015	Policy Support>Strategic planning
Sustainable Energy for All Action Agenda (SE4ALL-AA)	2016	Policy Support>Strategic planning
Rural Electrification Strategy and Implementation Plan of Nigeria	2006	Policy Support>Strategic planning

Table 11 Major Policy Instruments in Nigeria

5.3.4.1 Biofuels blending mandate

In 2007, Nigeria launched a program designed to supply the transportation market with a set mandatory blend of ethanol in conventional gasoline and biodiesel in conventional diesel. The program mandated a 10% ethanol blend in gasoline known as

E10 and a 20% biodiesel blend in diesel known as B20 (NNPC, 2007). It was designed to stimulate development in the agricultural sector by utilizing agricultural products as a means of improving the quality of automotive fossil fuels. The program also aimed to develop the local biofuel industry, reduce the dependence on imported gasoline, and to achieve 100% domestic biofuel production by 2020. It targeted a demand to 2 billion liters of ethanol and 900 million liters of biodiesel by 2020 (NNPC, 2007).

The program was divided into 2 phases. The first phase involved the blending of up to 10% ethanol into conventional gasoline through the importation of ethanol until local capacity can be built (NNPC, 2007). This stage is known as the "Seeding the Market" phase. The second phase of the program, which was expected to run concurrently with the first phase involves the establishment of plantations and the construction of biofuel plants. The government aimed to achieve this by creating a conducive environment for private-sector investments (NNPC, 2007).

The program has however, enjoyed little success even with over US$ 3.86 million investment in the construction of 19 ethanol bio-refineries as ethanol produced by existing plants are utilized for other than transportation uses (Ishola, Brandberg, Sanni, & Taherzadeha, 2013). As of May 2019, only 6% of ethanol demand was met by domestic production, with about 300-350 million liters imported annually, a far cry from the 2 billion liters needed to meet this mandate by 2020 (Ibirogba, 2019; NNPC, 2007).

Inconsistencies in the implementation of this government policy and the lack of infrastructure to transport ethanol to fuel depots and stations have been identified as major inhibiting factors in the success of government policy. An example of the inconsistency in policy is the government's failure to implement recommendations from feasibility studies for integrated cassava and ethanol plant projects (FGN, 2012).

5.3.4.2 Nigeria Feed-in Tariff for Renewable Energy Sourced Electricity

The Nigerian Electricity Regulatory Commission (NERC) established regulations for feed-in tariffs (FiTs) for renewable energy sourced electricity in Nigeria. The regulations came into force in February 2016 and are designed to boost power supply, support the attainment of renewable energy targets and encourage private sector participation in the development and exploitation of renewable energy resources (NERC, 2015).

Feed-in-Tariffs were designed to apply to selected renewable energy installations above 1MW. The Nigerian Bulk Electricity Trading (NBET) is obligated to buy 50% of renewable energy capacity while the distribution companies are required to take the remaining 50%. The program aimed to have 2,000MW of renewable energy power by 2020, but there is currently a negligible renewable energy grid connection (NERC, 2015).

5.3.4.3 Nigerian Electricity Regulatory Commission Mini-Grid Regulation 2016

This regulation guides the operation and management of mini-grids that are up to 1MW capacity. It is part of efforts to support the attainment of 180MW of mini-grids generation capacity by 2020 and 5.3GW by 2030. It applies to both isolated mini-grids and interconnected mini-grids. Developers of Isolated mini-grids require a permit to own, operate, and maintain such mini-grids in a designated underserved area. Developers would also need a commission approved Tripartite Contract agreed upon by the community connected and the distribution Licensee to construct, own, and operate an interconnected mini-grid (NERC, 2016).

Isolated mini-grids of less than 100kW can either elect to get a permit or simply get registered to be protected from future grid expansions. Permits are required for mini-grids between 100kW and 1 MW. There are two options for an isolated grid operator when a distribution company extends its network to where an isolated mini-grid is located. The first is to convert to an interconnected grid operator, while the second is to transfer assets to the distribution company in return for compensation (NERC, 2016).

5.3.4.4 National Renewable Energy and Energy Efficiency Policy (NREEEP)for Nigeria

This is Nigeria's first renewable energy-specific policy, and it provides the legislative framework for renewable energy and energy efficiency development in Nigeria. It was approved by the Federal Executive Council (FEC) in April 2015. The policy focuses on the generation of power from hydro, biomass, solar, wind, geothermal, wave and tidal energy resources and the enhancement of energy efficiency. The policy document is expected to be implemented by a National Renewable Energy Action Plan

(NREAP) and a National Energy Efficiency Action Plan (NEEAP) (Ministry of Power, 2015).

The NREEEP provides a qualitative approach to the development without providing specific details as to how renewable energy goals will be achieved. The NREAP, on the other hand, is expected to guide the development of renewable energy growth in Nigeria by outlining details of tools and policy instruments needed to support renewable energy development (Ministry of Power, 2015).

5.3.4.5 Sustainable Energy for All Action Agenda (SE4ALL-AA)

The SE4ALL Action Agenda for Nigeria outlines the targets for energy access, energy efficiency, and renewable energy penetration by the year 2030. Nigeria aims to raise energy access to 90% by 2030 with 30GW coming from On-grid generation, 8GW from off-grid, and 5GW from self-generation. Also, the percentage of people with access to clean cooking is projected to rise to 80% in 2030 from 10% in 2016. There are also targets for biofuels as a percentage of conventional fuel consumption. A 10% blend of ethanol in conventional gasoline is projected for 2020 using locally sourced resources. Grid-connected renewable energy resources are expected to make up 30% of total energy generation (National Council on Power (NACOP), 2016).

In addition to this, energy efficiency targets include 100% efficient lighting, curb firewood demand, reduce distribution losses to less than 10% and increase energy efficiency in high energy-consuming industries by 50% by 2030 (National Council on Power (NACOP), 2016).

5.3.4.6 Rural Electrification Strategy and Implementation Plan of Nigeria

The Rural Electrification Strategy and Implementation Plan of Nigeria was adopted in 2006 as a plan to promote rural electrification in Nigeria. The Rural Electrification Agency (REA) oversees the implementation of the Rural Electrification Strategy and Plan for Nigeria under the supervision of the Ministry of Power (IEA, 2017a).

Under the plan, Nigeria targets 75% electrification rate by 2020 and attain full electricity access by 2040. The goal was to electrify 471,000 rural households each between 2007 and 2020 and 513,000 homes each year between 2020 and 2040 (IEA, 2017a).

The Rural electrification fund is set aside and administered by the REA to achieve these objectives. In 2013, the federal government set aside $97 million to fund the activities of the REA. Despite this, rural electrification is still at 34% as of 2016, with 74 million Nigerian lacking access to electricity (IEA, 2017b).

5.3.5 Barriers to Renewable Energy in Nigeria

Barriers to renewable energy penetration can be divided into six groups, namely economic/financial barriers, market failure/distortions, institutional/governance barriers, technical barriers, social/cultural norms, and infrastructural barriers.

5.3.5.1 Economic/Financial Barriers

One of the major challenges associated with the renewable energy technology diffusion in Nigeria is the high initial capital cost, the lack of access to credit, and the high discount rate associated with loans. Nigeria is one of the 25 priority nations identified by the world bank Universal Financial Access (UFA) 2020 initiative, where 73% of all financially excluded people live. Financially excluded refers to people without access to any form of financial services. In 2017, an estimated 60% of adults did not have access to a transaction account according to the World Bank's Global Findex data (The World Bank, 2017). The small market size of renewable energy technologies means that they do not benefit from the economies of scale, which could drive prices down.

5.3.5.2 Market Failures/ Distortions

Market failures occur when the market violates neoclassical market assumptions and operates in a manner contrary to those assumptions. When neoclassical market assumptions such as rational behavior, costless transactions, and perfect markets are violated, a market failure is said to have occurred. Market failures can be caused by misplaced incentives, distortionary fiscal and regulatory policies, unpriced costs (externalities), unpriced (public goods), and insufficient/incorrect information (Brown, 2001).

In the Nigerian context, distortion from high fossil fuel subsidies and the failure to internalize all the costs associated with them give conventional fuels a competitive advantage over renewable energy sources and create high barriers to market entry for renewable energy technologies. Import duties and Value Added Tax (VAT) in Nigeria also increase the cost of renewable energy equipment.

There is also insufficient information and public awareness of renewable energy resources and potentials across the country. Studies on wind potential are still very limited. This increases the perceived risk of investments and discourages private investments. Inadequate information on existing government incentives and policies also slows the rate of renewable energy investments and adoption.

5.3.5.3 Institutional/governance barriers

Inconsistent government policies and the lack of capacity of government institutions to follow through with government targets and goals is a significant challenge facing renewable energy development in Nigeria. Many of the existing renewable energy targets like the rural electrification and biofuels blending mandates are way off target, and there are no assurances that anything will change with the more recent targets. This could be attributed to inadequate policy implementation and the lack of coordination between agencies, ministries, and renewable energy programs.

Like in many developing countries, the consumption pattern is largely import-dependent. Most of the renewable energy technologies and their inputs must be imported as they are not produced locally. This scenario means that private investments are largely dependent on foreign exchange availability and rate (Ekpo, 2016). Unstable macroeconomic and monetary policies affect the rate of inflation and the real exchange rate (Feridun, Folawewo, & Osinubi, 2005). Government efforts at influencing foreign exchange rates create uncertainty that discourages investments. Between January 2014 to June 2019, the Naira to USD exchange rate rose from ₦ 160 Naira to $ 1 to ₦ 306 to $ 1, a rise of over 90% (Central Bank of Nigeria, 2018). Higher exchange rates mean that imports are more expensive to acquire thereby increasing the cost of renewable energy technologies.

5.3.5.4 Technical Barriers

The common technical barriers with renewable energy technology in Nigeria include poor product quality due to lack of standards and the dearth of skilled personnel and training facilities. Poor quality products lead to poor public acceptance and image of products. This situation is particularly common among solar products and has affected the perception of these products. A lack of standard and quality control and the preference for cheap products is responsible for this. The shortage of skilled personnel is a challenge for potential investors and producers of solar products, operation, and maintenance of installations as well as integration to the grid since most renewable sources are intermittent (Giwa, Alabi, Yusuf, & Olukan, 2017; Ohunakin, Adaramola, Oyewola, & Fagbenle, 2014).

5.3.5.5 Social/cultural norms

Social, cultural, and behavioral norms could affect the uptake of renewable energy technology. A study on the public perceptions of renewable energy in Nigeria by Wojuola & Alant (2017) found that lack of knowledge about the structure of power reform and the distrust of public office was common amongst Nigerians. These conditions could affect the success of renewable energy policies and initiatives in Nigeria. Many do not trust the government and still view the government as in charge of power generation even though this sector is mainly private sector driven. Lack of trust affects public participation and support for renewable energy initiatives. Besides, many believe that renewable energy is too expensive and would increase the cost of getting electricity. Some have concerns about the potential health and environmental implications of renewable energy. These views could prevent the adoption of renewable energy. There is also the general perception of a lack of technical expertise, which raises skepticism about the effective operation of renewable energy systems (Wojuola & Alant, 2017).

5.3.5.6 Infrastructural Barriers

The infrastructural deficit in Nigeria is another factor that impedes renewable energy development, especially in remote locations. Long-distance to remote areas and poor transportation infrastructure could increase the cost of transporting renewable energy products and make them more inaccessible to people (Oseni, 2012).

5.4 LEAP Model: The case for Sustainable Development

This section explores the impacts of using fossil fuel alternatives on energy demand, greenhouse gas emissions, health, and food security in Nigeria by applying a scenario-based analysis utilizing the LEAP tool. Other studies on energy modeling in Nigeria, such as Emodi et al. (2017), Aliyu et al. (2013), and Ibrahim & Kirkil (2018), have focused primarily on energy demand and greenhouse emissions. (Emodi, Emodi, Murthy, & Emodi, 2017; Aliyu, Ramli , & Saleh, 2013; Ibrahim & Kirkil, 2018) The implication of clean energy on food security and health in this dissertation adds to the existing body of literature on the subject.

The Scenario analysis is based on Nigeria's Sustainable Energy for All Action Agenda (SE4ALL-AA), which was developed with the collaboration of over twenty ministries, departments, and agencies in Nigeria. Nigeria's SE4ALL-AA contains sustainable energy targets which Nigeria aims to achieve by the year 2030 towards sustainable development goals (National Council on Power (NACOP), 2016). These targets include:

a. 30% renewable energy in the electricity mix by the year 2030.
b. Reducing the use of traditional biofuels for cooking to 20% by 2030 from almost 80%
c. 100% efficient lighting by 2030

d. The achievement of biofuel mandates, including a 10% mix of ethanol in gasoline and a 20% mix of biodiesel in diesel.

These targets form the basis for developing our four scenarios. Four (4) different policy scenarios are applied on LEAP for the period 2010 to 2030. The first is the baseline scenario, which assumes no changes from the current situation. SE4ALL-AA targets are assumed to be met in the medium penetration scenario (MRP) scenario. The low renewable energy penetration (LRP) scenario assumes that Nigeria falls short of its SE4ALL-AA targets while the high penetration scenario (HRP) assumes that the goals are met or surpassed.

The information used for this model includes demographic information such as population, population growth rate, and the ratio of the population for each age range and economic data, which included the GDP, GDP per year, GDP per sector. Other inputs include average income per year and disease risks, which cover the risk of death from respiratory and pulmonary diseases in Nigeria. Energy demand and the fuel use from residential, commercial, transport, industry, agriculture, energy industry own use, and other unspecified sectors are also obtained. From the non-energy sector, the population of livestock and the agricultural residue burning were also considered in each scenario.

The base assumption and inputs for developing the scenarios are discussed in the next section.

5.4.1 Assumptions and Inputs

5.4.1.1 Demographic Assumptions

Population figures for 2010 were taken from population estimates by the National Population Commission (NPC). The average population growth rate and population size for each age group were also obtained from the NPC. The table below shows the demographic assumptions and sources:

Assumption	**Data (based on base year)**	**Source**
Population	159.6 Million People	(National Population Commisssion, 2016)
Population Annual Growth	3.2%	(National Population Commisssion, 2016)
Population Fraction by age	Five-year intervals (<5, 5-9, etc)	(National Population Commisssion, 2016)

Table 12 Demographic Assumptions

5.4.1.2 Economic Assumptions

Total GDP for Nigeria for the base year of 2010 in US dollars was obtained from the International Monetary Fund (IMF), and GDP growth is assumed to be the average GDP growth between 2010 and 2018. The GDP share of industry, agriculture, and services sector was obtained from IMF statistics and assumed to be constant since very little change has occurred between 2010 and 2018. The economic assumptions and data sources are highlighted in the table below:

Assumption Base year	Data (based on base year)	Source
GDP	US$369.062 billion	(IMF, 2019)
GDP Growth	4%	(IMF, 2019)
GDP by Sector	2010: Agriculture: 24% Industry: 25.2% Services: 50.8% 2018: Agriculture: 21% Industry: 27% Services: 52%	(The World Bank, 2019c)

Table 13 Economic Assumptions

5.4.1.3 Diseases Rates/Risks

The disease rates of death for major respiratory and pulmonary diseases for Nigeria were obtained from the Global Burden of Disease compare/Viz Hub visualization tool. (GBD, 2017) The rate of death of each illness per age group is obtained from the tool. Figure 34 shows the visualization tool.

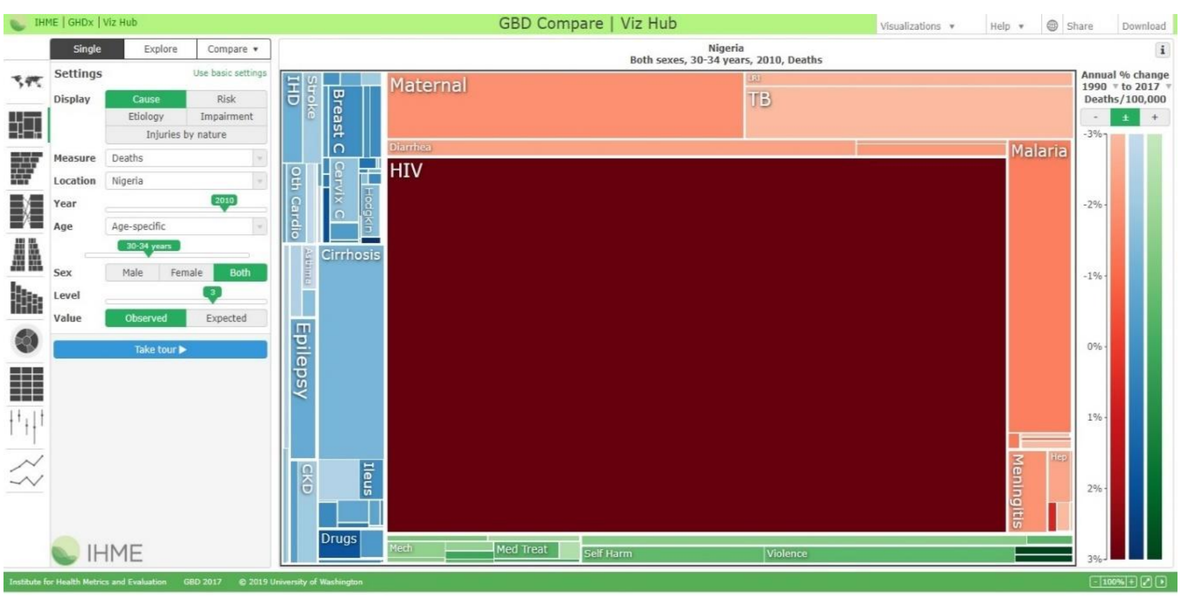

Figure 34 GBD Compare/Viz Hub Visualization tool

The diseases rates taken into consideration include Ischaemic heart disease rate for all age group, Chronic Obstructive Pulmonary Disease (COPD) rate for all age groups, Stroke rate for each group, Lung cancer rate for all groups, Acute Lower Respiratory Infection (ALRI) rate for kids less than 5, Cardiopulmonary disease rate for all age groups and Respiratory disease rate for all age group. Data is collected from 2010 to 2017, and the data trend is utilized to estimate the rates up till 2030.

5.4.1.4 Crop Production Assumptions

Crop production for four (4) staple crops, namely rice, maize, soybeans, and wheat, were collected from the Food and Agricultural Organization of the UN. The average growth rate between 2010 and 2017 for each crop is assumed as the growth rate till 2030. The table below shows the assumptions made and the sources of data.

Assumption Base year	Data (based on base year)	Growth rate	Source
Rice	4.47 Million tons	15.24%	(FAO, 2019a)
Maize	7.68 Million Tons	4.92%	(FAO, 2019a)
Soybeans	0.11 Million tons	-2.74%	(FAO, 2019a)
Wheat	0.365 Million tons	1.21%	(FAO, 2019a)

Table 14 Crop Production Assumption

5.4.1.5 Energy Demand Data/Assumptions

Energy demand data for the base year was collected from IEA energy balance statistics for Nigeria. Energy consumption data was gathered for Residential, Commercial, Industrial, Agriculture, energy industry own use, and non-specified uses. The fuel share for each sector was also collected from IEA statistics data. For residential energy use, fuels utilized for cooking in Nigeria were obtained from the 2015 Nigeria Malaria Indicator Survey (NMEP, NPopC, NBS, ICF International, 2016). The 2015 Nigeria Malaria Indicator Survey was developed by Nigeria's Federal Ministry of Health, the National Population Commission (NPC), the National Bureau of Statistics (NBS), and ICF International.

5.4.1.6 Non-Energy Inputs/Assumptions

Some non-energy inputs used for the model include Natural gas flaring data, livestock population, and agriculture residue burning.

5.4.1.6.1 Gas Flaring

Nigeria is one of the largest gas flaring countries in the world, ranking number 7, and accounting for 5% of global totals in 2018. Gas flaring statistics were obtained from the National Oceanic and Atmospheric Administration (NOAA) and the World Bank Global Gas Flaring Reduction Partnership (GGFR). Data trend is utilized to project Gas flaring statistics until 2030 (NOAA, 2017).

Assumption Base year	Data (based on base year)	Growth rate	Source
Gas Flaring	15 Billion Cubic Meters (2010) 7.47 Billion Cubic Meters (2017)	Data trend (2010-2017)	(GGFR, 2013) (NOAA, 2017)

Table 15 Gas Flaring Data

5.4.1.6.2 Livestock Population and Emissions

Livestock population was obtained from the National Agricultural Sample Survey 2010/2011 developed by the National Bureau of Statistics (NBS) and the Federal Ministry of Agriculture and Rural Development. The livestock population is utilized to estimate the emission from livestock (NBS, Federal Ministry of Agriculture, 2011). Emission factors for Methane and Ammonia from Manure management are obtained from chapter 10 of the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories (IPCC, 2006).

5.4.1.6.3 Fertilizer Use and Agricultural Residue Burning Assumptions

The latest data on fertilizer use and crop production is collected from the Food and Agriculture Organization (FAO) statistics and residue to crop ratio, and the dry matter fractions were obtained from the "EMEP /EEA air pollutant emission inventory guidebook 2016". The crops selected include rice, maize, wheat, millet, soybeans, cotton groundnut, and sugar cane.

Assumption Base year	Data Source
Fertilizer Use	(FAO, 2019c)
Crop Production	(FAO, 2019a)
Residue to crop ratio	(EMEP/EEA, 2016)
Dry matter fractions	(EMEP/EEA, 2016)

Table 16 Fertilizer Use and Agricultural Residue Burning Assumptions

5.4.2 Scenarios

5.4.2.1 BRP Scenario

The baseline scenario (BRP) is based on current trends of energy development and serves as a benchmark for comparison. It makes assumptions based on the current level of transportation, electricity, lighting, and cooking. Alternative scenarios analyzed have increasing levels of environmentally friendly policies.

5.4.2.2 LRP Scenario

The low renewable energy penetration (LRP) scenario is based on Nigeria's SE4ALL-AA. It assumes that Nigeria falls short of all targets. The Ethanol blend for gasoline in the LRP scenario is assumed to be 5% by 2030, lower than the 10% target set by Nigeria. Biodiesel blend in diesel for the LRP scenario is 10% compared to the target of 20% by 2030. The use of traditional biomass is assumed to remain at 40% by 2030, significantly higher than the target of 20%. Renewable energy penetration for electricity generation is assumed to be 10%, as opposed to the target of 30% by 2030. Kerosene lighting is set at 20%, and solar lighting is put at 10% by 2030.

5.4.2.3 MRP Scenario

The medium renewable energy penetration (MRP) scenario assumes that the targets outlined by the SE4ALL-AA are met. The goals of the E10 and B20 biofuel blends are reached, and renewable energy penetration in the electricity sector is at 30%. Also, traditional biomass for cooking is modeled at 20%, while kerosene and solar lighting are set at 0% and 20%, respectively, by 2030.

5.4.2.4 HRP Scenario

The high renewable energy scenario (HRP) has the most aggressive renewable energy penetration. This scenario assumes a more ambitious clean energy penetration scenario in line with SDG 7. It assumes that there are more electric stoves and increased renewable energy penetration in electricity. Biofuel blends are kept at 10% ethanol blends in gasoline and 20% biodiesel blend in diesel. Also, it is assumed that 100% renewable energy penetration for electricity generation is achieved under this scenario. Traditional biomass for cooking is projected to be at 0% by 2030 with electricity and clean biomass making up 35% each and LPG making up the rest.

Kerosene and solar lighting are set at 0% and 30% respectively by 2030, and solar lighting is assumed to be at 30%.

5.4.2.5 Policy Levers

The scenarios are built for the years 2010 to 2030, with the first policy year starting in 2018. A summary of the policy levers and assumptions made for each scenario for the Nigerian LEAP model are presented in table 17 below.

Sector	Description of Policy Lever	Scenarios			
		BRP	**LRP**	**MRP**	**HRP**
Driving Philosophy		This scenario follows the existing energy trends and assumes there are no significant changes.	This assumes that Nigeria falls short of the goals set by the SE4ALL-AA	This assumes that Nigeria falls short of the goals set by the SE4ALL-AA	This scenario assumes a more ambitious clean energy penetration scenario in line with SDG 7. It assumes that there are more electric stoves and increased renewable energy penetration in electricity.
First Policy Year		2018	2018	2018	2018
Transport	Ethanol by 2030	0% of gasoline	5% of gasoline	10% of gasoline	15% of gasoline
	Biodiesel by 2030	0% of Diesel	10% of Diesel	20% of Diesel	25% of Diesel
Lighting	Kerosene by 2030	50%	20%	0%	0%
	Solar Lanterns by 2030	0%	10%	20%	30%
Cooking	Electric stove share by 2030	0%	15%	25%	35%
	Traditional Biomass by 2030	73%	40%	20%	0%
	Clean Biomass/biofuel stove by 2030	0%	15%	25%	35%
	LPG share by 2030	2%	5%	5%	27%
Electricity Generation	Renewable share by 2030	0%	10%	30%	100%

Table 17 Policy Levers for Nigeria Leap Scenario Analysis

5.4.2.6 LEAP-IBC Output and Sustainable Development

LEAP- Integrated Benefits Calculator (IBC) is an integrated tool that enables one to assess how the greenhouse gases and other pollutants from different scenarios affect climate, vegetation, and human health. The output from the Nigeria LEAP scenario analysis includes energy demand from each scenario, pollutant concentrations, the number of deaths from pollutants, crop loss as a result of pollutants, the climate impacts of each scenario and the economic damages from crop loss under each scenario.

The outputs address several sustainable development goals, including SDG 1, which relates to the end of poverty and SDG 2, which relates to achieving food security and zero hunger. They also address SDG 3, which is concerned about the healthcare and well-being of people, SD7, which relates to the provision of clean and affordable energy and SDG 13, which relates to climate action.

The results in the next section will show that renewable energy penetration can also have direct impacts on sustainable development targets and make a strong case for aggressive renewable energy policies.

5.4.3 LEAP Scenario Analysis Results

The outputs from LEAP for each scenario include energy demand, climate impacts, pollution concentration, and its impact on human mortality and crop loss. This section contains an analysis of the effects of clean energy diffusion on fossil fuel subsidies and sustainable development. An investigation into the cost of sustainable energy diffusion shows the potential financial implication.

5.4.3.1 Effect of Clean Energy Diffusion on Fossil Fuel Subsidies

This sub-section includes the effects of clean energy diffusion on the fossil fuel subsidy. The transportation and lighting energy mix show increasing penetration of clean energy transformation. Fossil fuel subsidy savings are estimated using the volume of gasoline saved from changes in the transportation mix and the volume of kerosene saved from changes in the lighting mix.

5.4.3.1.2 The Transportation Mix

Figure 35 shows the transportation mix for each scenario. Increases in the penetration of biofuels in the transportation mix displace gasoline and diesel. These increases have implications for fossil fuel subsidies. The table below shows gasoline saved from the baseline scenario by 2030 for each of the scenarios. Subsidy savings are obtained by multiplying the gasoline saving by the average subsidy per liter. This calculation results in estimated savings of $193 million in 2030, which can be utilized to overcome some of the barriers associated with clean energy diffusion and fund sustainable development objectives.

	Volume of Gasoline Avoided (Liters) by 2030	Size of Subsidy Avoided (at N30 per liter) (real 2018 $)
LRP	**771,570,692**	**$ 64,297,557.67**
MRP	**1,543,141,384**	**$ 128,595,115.35**
HRP	**2,314,714,949**	**$ 192,892,912.43**

Table 18 Gasoline Subsidy Savings by 2030

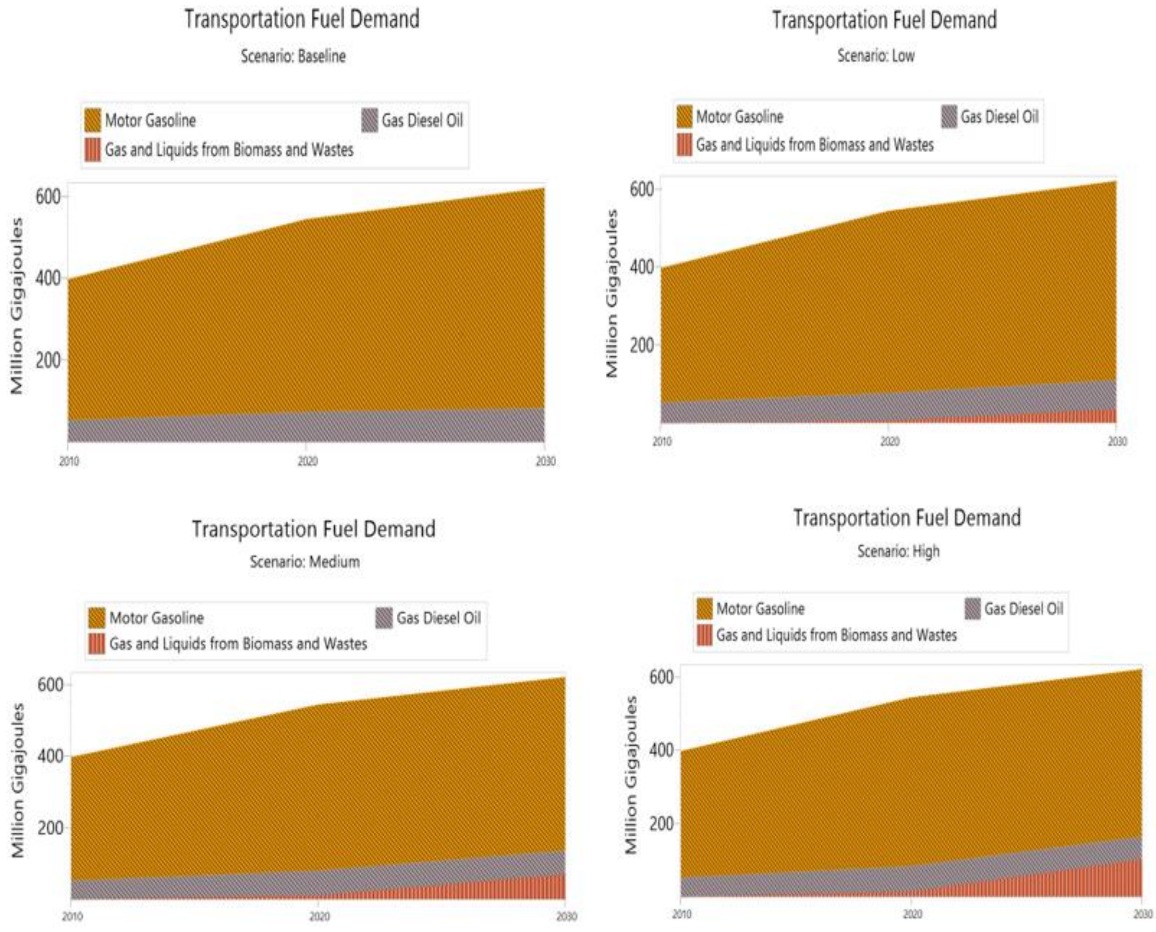

Figure 35 Transportation mix for each scenario

5.4.3.1.3 The Lighting Mix

Figure 36 shows the lighting mix for each scenario. Subsidized kerosene is replaced by cleaner alternates such as solar lighting in the energy mix. Kerosene is phased out in the MRP and HRP scenarios. Table 19 shows kerosene avoided from the baseline scenario by 2030 for each of the scenarios. It shows that kerosene avoided can result in 2030, resulting in subsidy savings of $441 million in 2030.

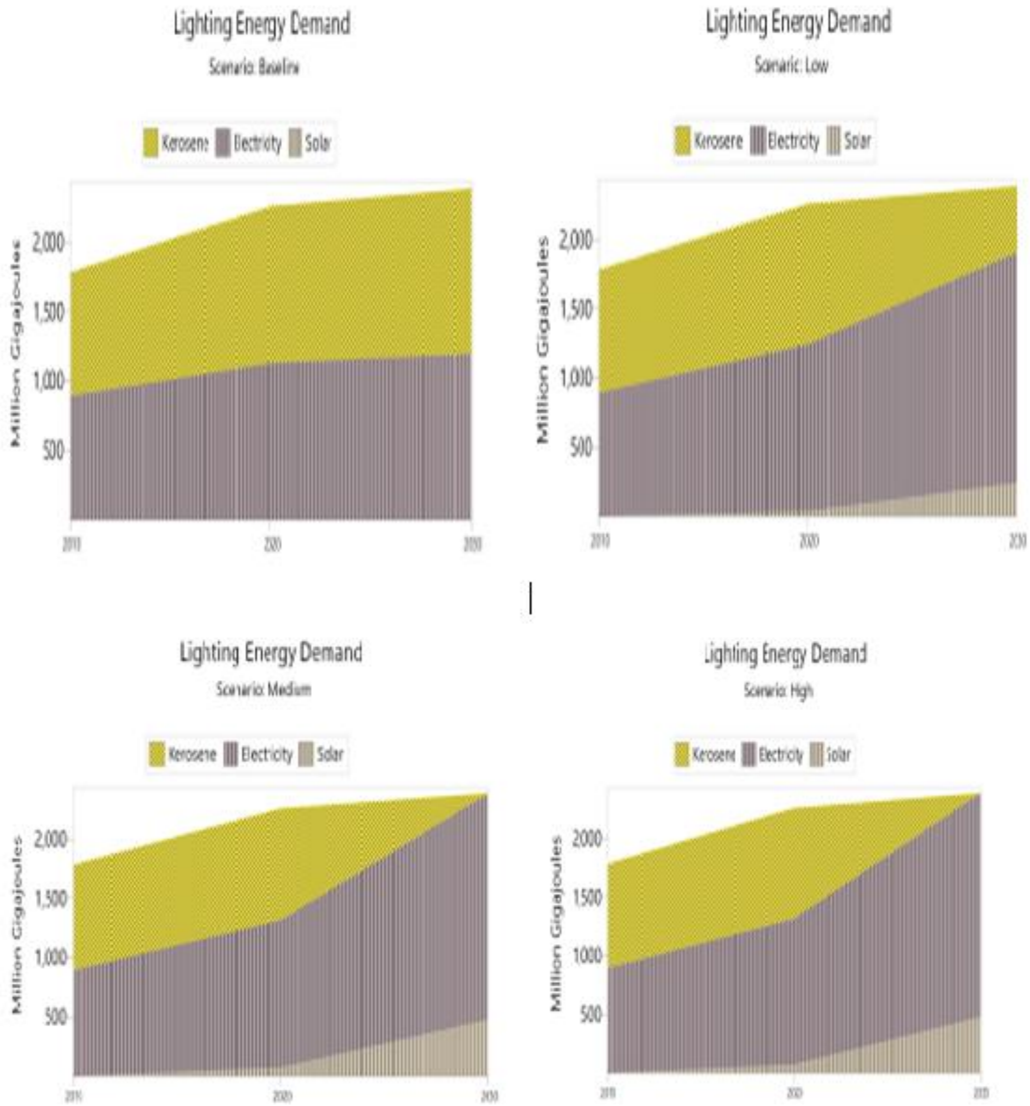

Figure 36 Lighting Energy Demand for Each Scenario

	Volume of Kerosene Avoided (Liters) by 2030	**Size of Subsidy Avoided (at N5 per liter)**
LRP	19,049,512,466	$264,576,562.02
MRP	31,749,276,179	$440,962,169.15
HRP	31,749,276,179	$440,962,169.15

Table 19 Kerosene Subsidy Savings by 2030

5.4.3.2 Other Sustainable Development Benefits

5.4.3.2.1 Energy Demand

The final energy consumption from each of the scenarios is shown in figure 37. The baseline scenario (BRP) shows an energy demand of 4557.75 petajoules in 2010 and 9223.37 petajoules by 2030, a rise of 102%. Energy demand rises less steeply in the LRP and MRP scenarios increasing by 65% and 42%, respectively, by 2030. In the HRP scenario, energy demand rises by just 2% from 2010.

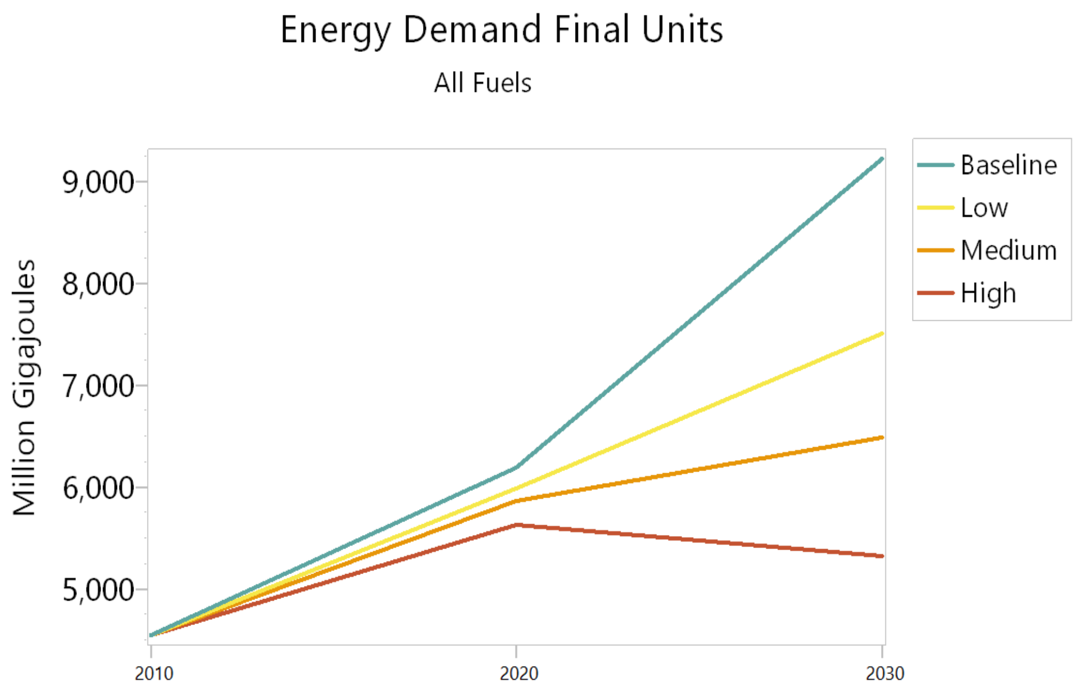

Figure 37 Energy Demand by Scenario

Figure 38-41 show the breakdown of energy consumption by fuel for each scenario. Under the BRP scenario, energy consumption is dominated by traditional biomass (wood, charcoal, and other unspecified biomass) and kerosene in 2010, and this trend continues up to 2030. Traditional biomass and kerosene are the most common sources of energy by 2030.

The LRP scenario shows that traditional biomass as the dominant fuel by 2030, accounting for 46% of total energy demand by 2030. Electricity is the most dominant energy source for the MRP and HRP scenarios accounting for 33% and 37% of energy demand, respectively. Solar energy demand shows considerable growth in the HRP scenario, rising from negligible share in 2010 to 13% in 2030.

Fossil fuels such as kerosene, diesel, and gasoline account for just 11% of energy demand in the HRP scenario by 2030 down from 29% in the reference year, 2010. Reducing this dependence would reduce the political pressures associated with the fossil fuel subsidies and free resources that can be applied to health, education, and other essential development areas, as earlier discussed. Kerosene, diesel, and gasoline account for 15% for the MRP scenario, 19% for the LRP scenario, and 24% for the baseline scenario by 2030.

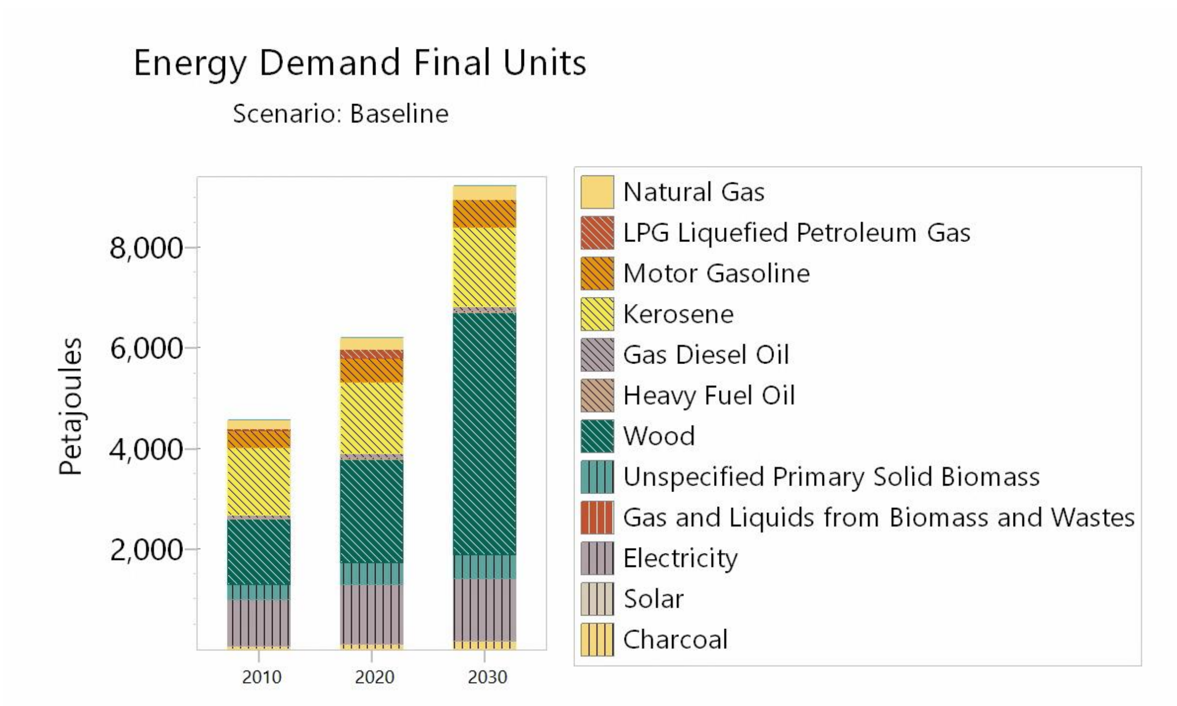

Figure 38 BRP Energy Demand by Fuel

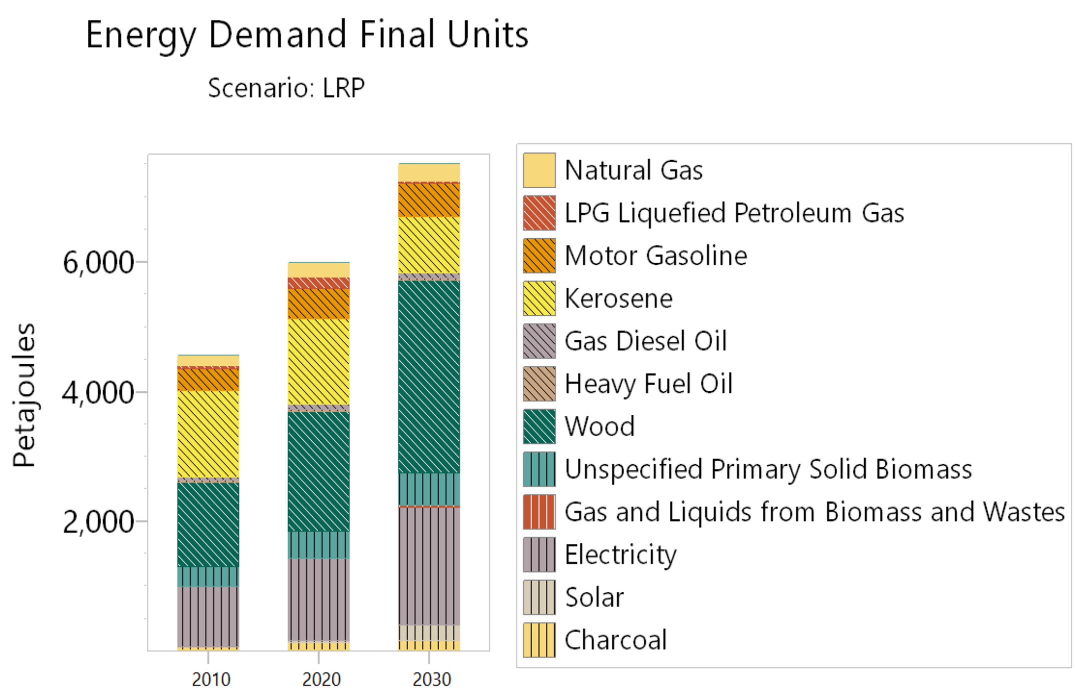

Figure 39 LRP Energy Demand by Fuel

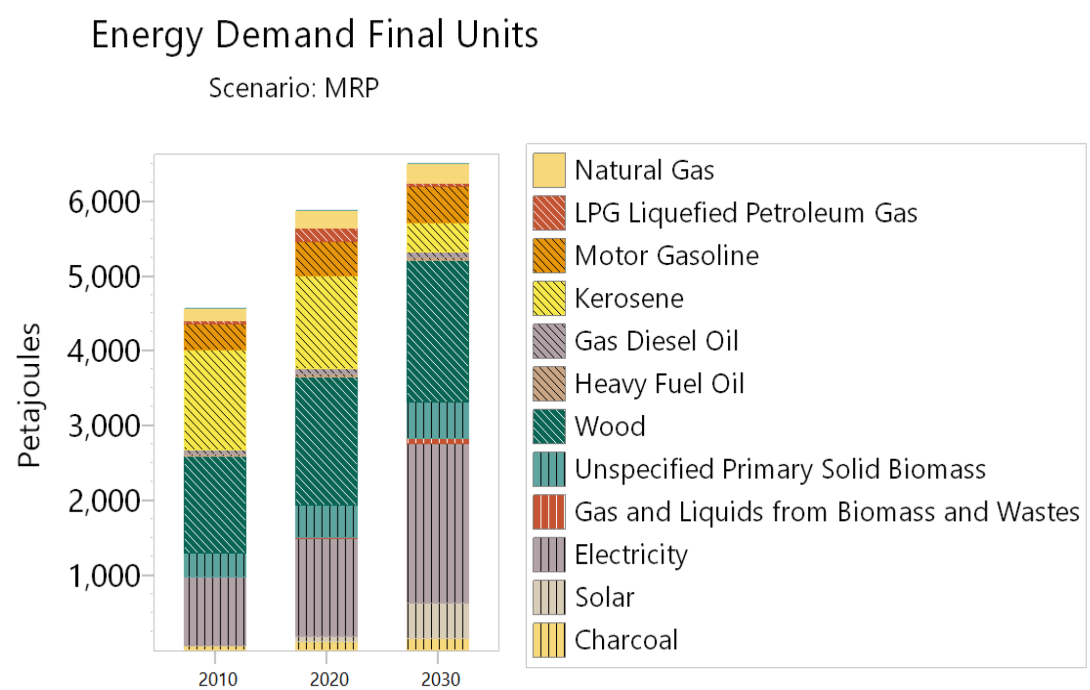

Figure 40 MRP Energy Demand by Fuel

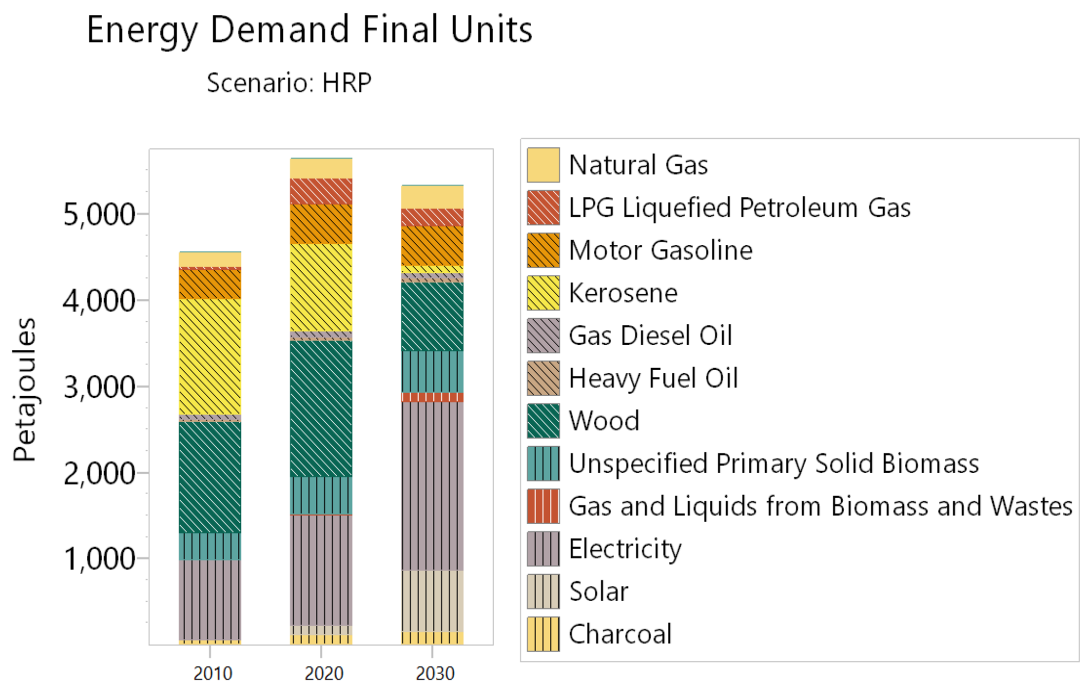

Figure 41 HRP Energy Demand by Fuel

5.4.3.2.2 Environmental Output

5.4.3.2.2.1 Greenhouse Emissions

The LEAP-IBC tool utilizes activity data and emission factors to measure CO_2 (Biogenic and Non-Biogenic) [15] and Short-Lived Climate Pollutants (SLCPs)[16] emissions and resultant atmospheric concentrations of fine particulate matter (PM2.5) and ozone (O_3). As expected, higher penetration of renewable energy results in lower

[15] Biogenic emissions refer to emissions from natural sources such as plants and trees, while non-biogenic emissions refer to emissions from human activities such as the combustion of fossil fuels.

[16] SLCPs include black carbon, methane, and hydrofluorocarbons

emissions and pollutant concentrations in the atmosphere. Figure 40 shows the CO_2 emissions from each of the scenarios. In the baseline scenario, CO_2 emissions rise from approximately 138 million metric tons in 2010 to 177 million metric tons in 2030, a rise of 28%. The LRP scenario experienced a drop of 10% in CO_2 emissions between 2010 and 2030. CO_2 emissions dropped by 37% and 47% in the MRP and HRP scenarios, respectively.

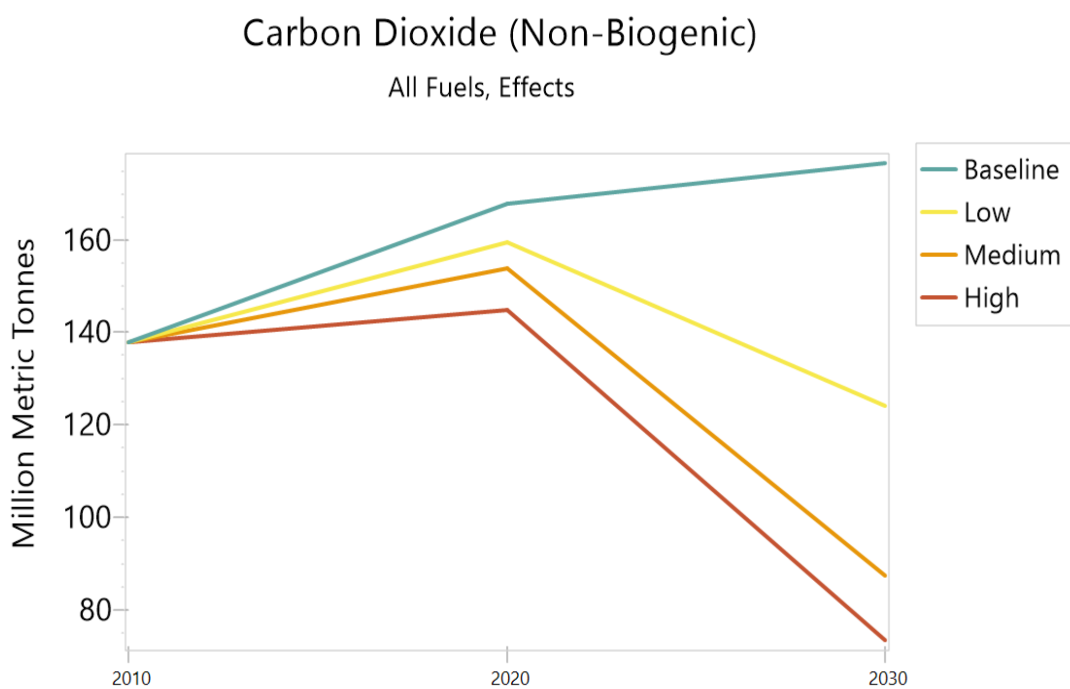

Figure 42 Carbon Dioxide (Non-Biogenic) Emissions

A breakdown of emissions from other pollutants (other than CO_2), including SLCPs, shows a 164% increase in the baseline scenario from 20.9 million metric tons to 55.2 million metric tons. Carbon monoxide (CO) emissions are the highest non-CO_2

emissions, with an average of 52% of all non-CO_2 emissions between 2010 and 2030. Exposure to moderate or high levels of CO has adverse health effects, including an increased risk of heart disease (CDC, 2016). These emissions increase more moderately in other scenarios, increasing by 59% and 22% in the LRP, but fall by 5.7% and 56% in the MRP and HRP scenario, respectively, by 2030 from the base year 2010.

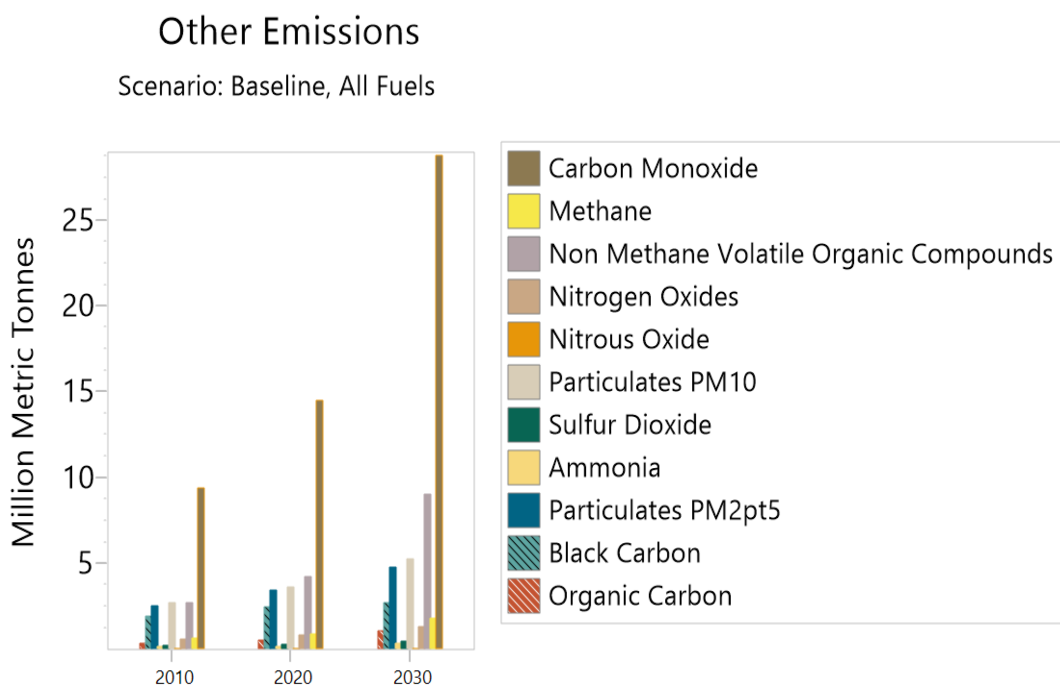

Figure 43 BRP Emissions

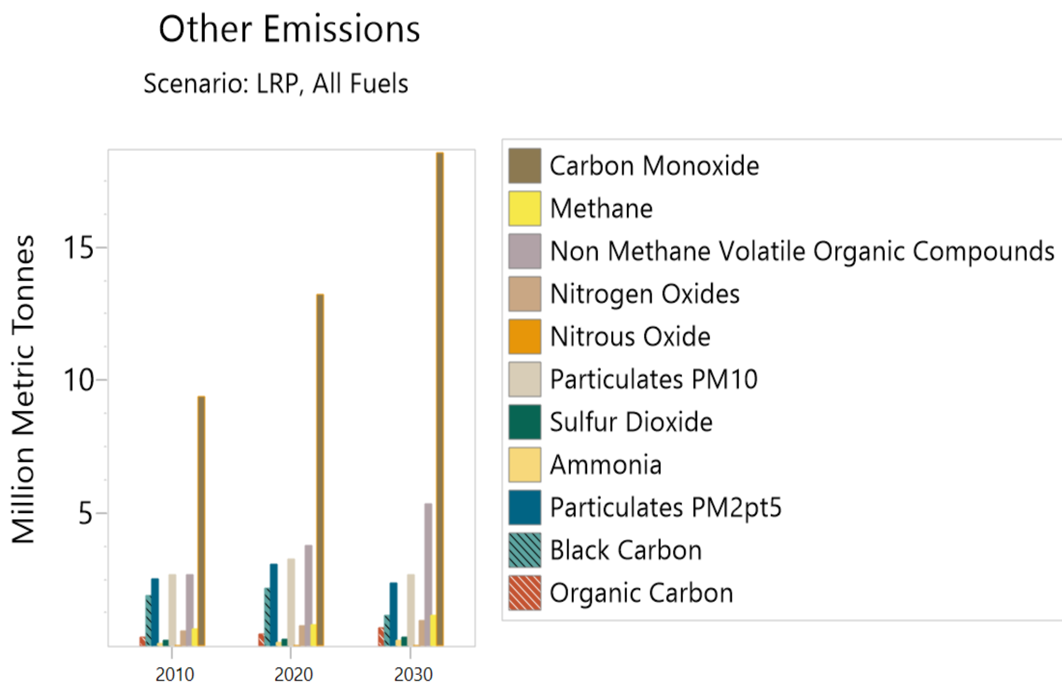

Figure 44 LRP Emissions

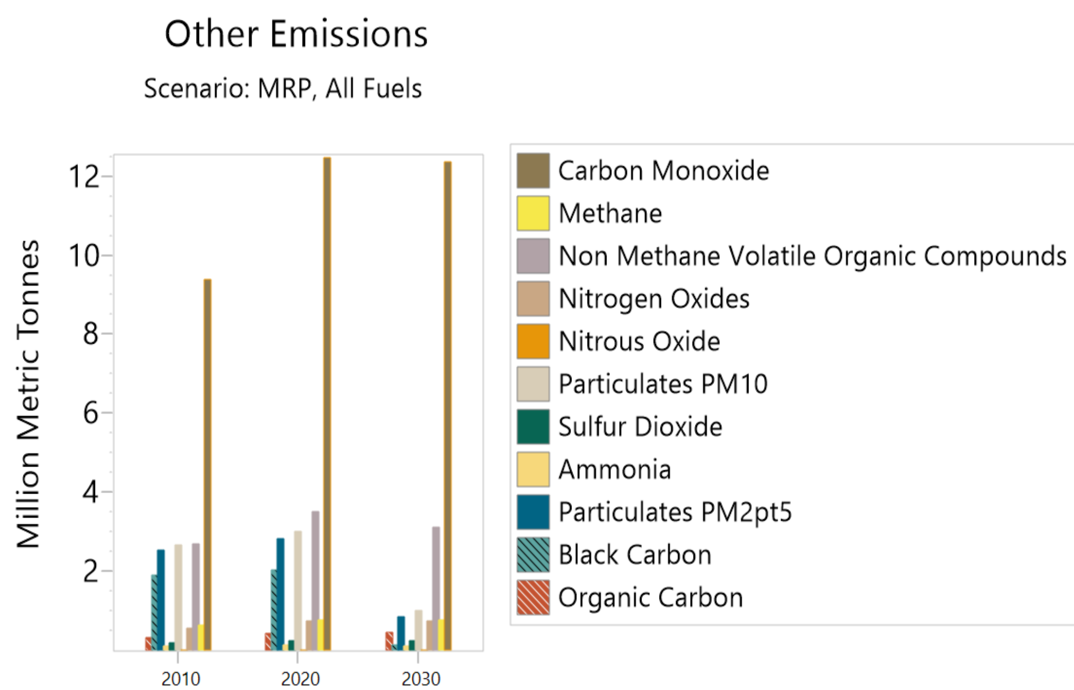

Figure 45 MRP Emissions

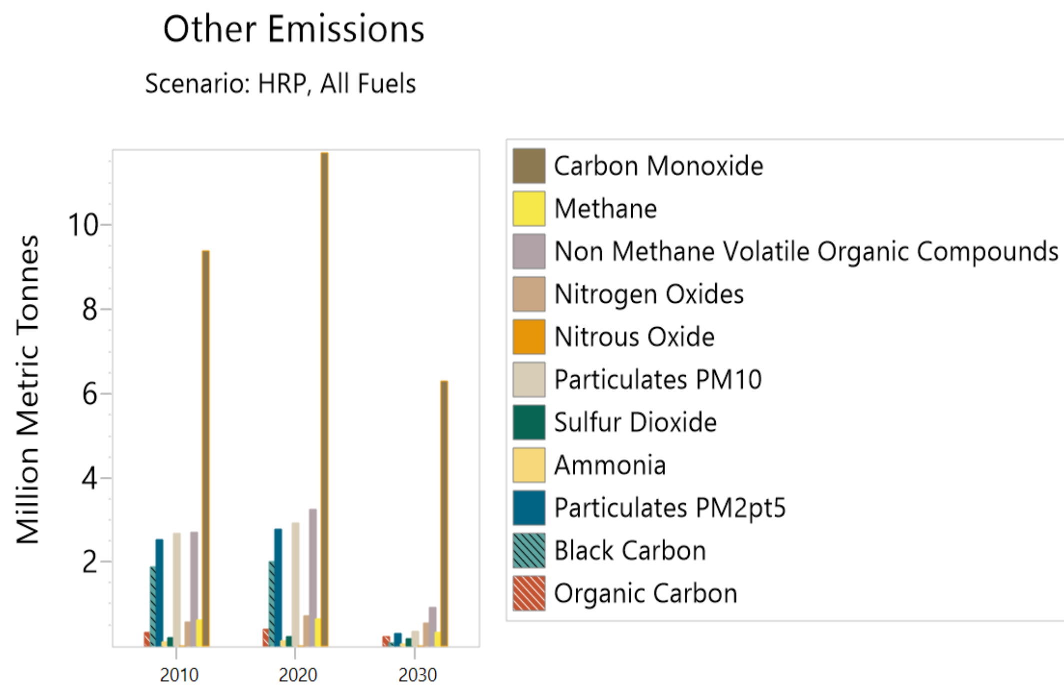

Figure 46 HRP Emissions

5.4.3.2.2.2 Pollutant Concentrations

The LEAP software also evaluates the atmospheric concentration of fine particulate matter (PM2.5) and ozone (O3) in Nigeria based on the scenarios developed. These concentrations have implications for health as increased concentration increase the chance of respiratory and pulmonary diseases. Figure 47 shows the PM2.5 concentration for all the scenarios analyzed. PM2.5 concentration in the atmosphere rose significantly in the baseline scenario from 45.4 micrograms/m^3 to 51.8 micrograms/m^3. Pollution concentrations fall in scenarios with as renewable energy penetration increases. However, the growth is steeper in the baseline scenario than in the scenarios with higher renewable energy penetration. Concentrations of PM 2.5 fell in the LRP, MRP, and HRP scenarios to 44.8, 40.1, and 38.2 microgram/m^3, respectively, by 2030.

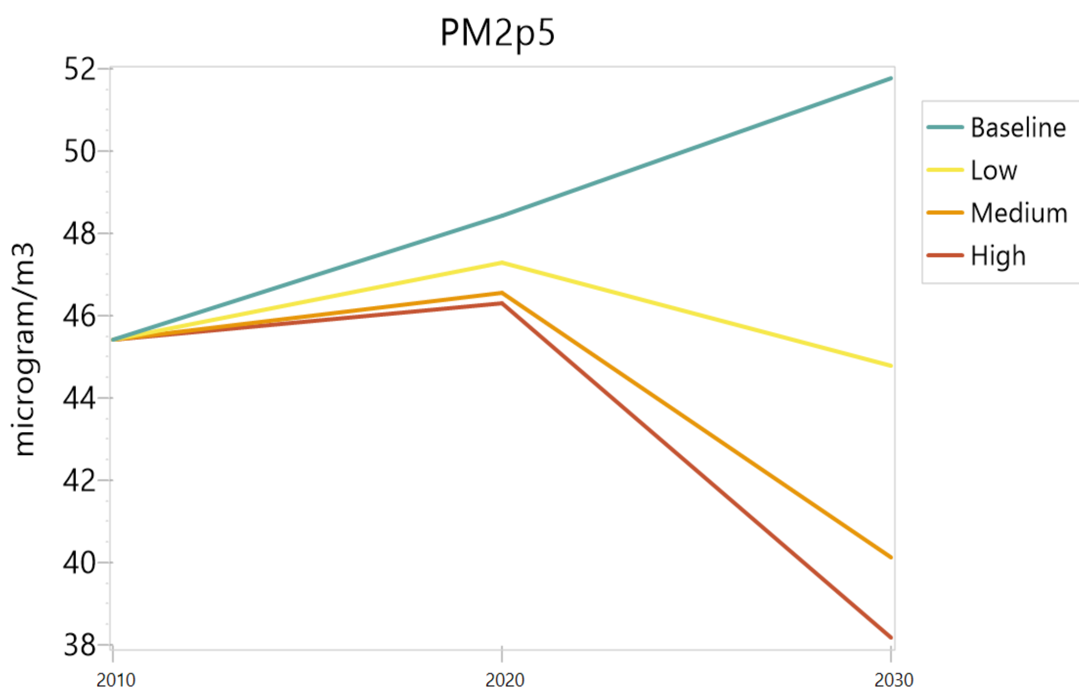

Figure 47 PM2.5 Concentration

Ozone pollutant concentration rose in the BRP and LRP scenarios. Ozone concentration flattens out in the MRP scenario and falls steeply in the HRP scenario. In the baseline scenario, Ozone concentrations increase from 258 parts per billion (ppb) in 2010 to 393 ppb in 2030. LRP rose to 342 ppb, MRP rose to 301 ppb, and HRP dropped to 232 ppb. Figure 48 shows the ozone concentrations for each scenario between 2010 and 2030.

The penetration of more renewable energy and the implementation of environmentally friendly policies would have a positive impact on the concentration of atmospheric pollutants and the emissions of greenhouse gases.

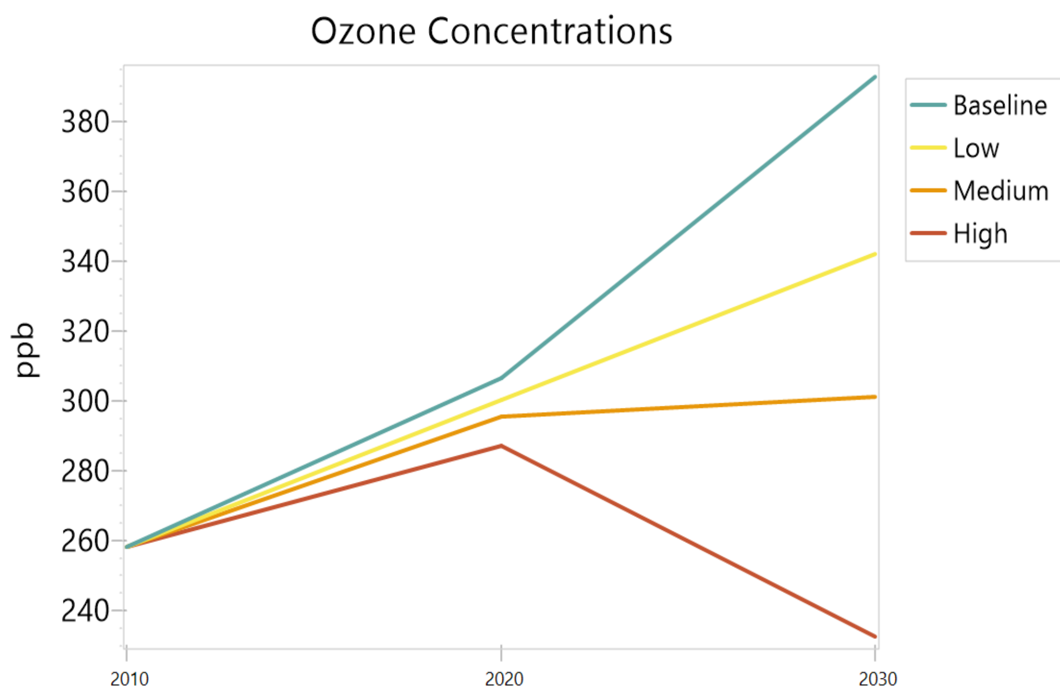

Figure 48 Ozone Concentration

5.4.3.2.3 Deaths

High pollutant concentration in the atmosphere has health implications for human life. LEAP estimates the potential loss of human life for each age group based on pollutant concentrations for each age group and the disease rate already inputted. Figure 47 shows the estimated number of deaths caused by Ozone and PM2.5 concentrations in the baseline scenario. As shown in the figure, the mortality from diseases is reduced as renewable energy penetration increases. Deaths by 2030 in the baseline scenario are estimated to be about 145 thousand people. The avoided deaths from LRP, MRP, and HRP scenarios by 2030 are 13 thousand, 23 thousand, and 31 thousand people, respectively.

PM2.5 accounts for most of the deaths in all scenarios. The number of deaths and the avoided deaths from the baseline in the LRP, MRP, and HRP scenarios are shown in figures 50, 51, and 52. PM2.5 accounts for between 83% to 86% of deaths in all scenarios between 2010 and 2030. As renewable energy penetration increases, the number of deaths from pollutants reduces. Kids under five and adults over 70 account for the most significant shares of deaths caused by PM2.5 pollution for all scenarios. The percentage and number of deaths for kids under five fall from 2010 to 2030 for all scenarios and this improves as cleaner alternatives increase in the energy system. The results show that by transitioning to a more sustainable energy system, Nigeria can preserve the lives of some of the most vulnerable citizens.

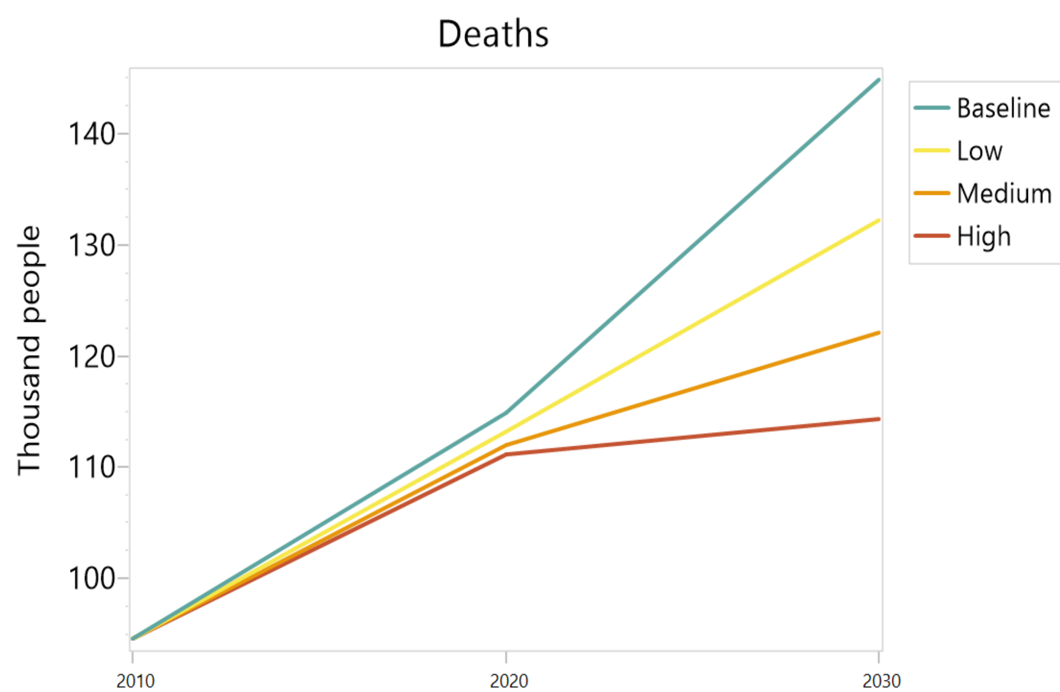

Figure 49 Human Deaths from respiratory and pulmonary diseases

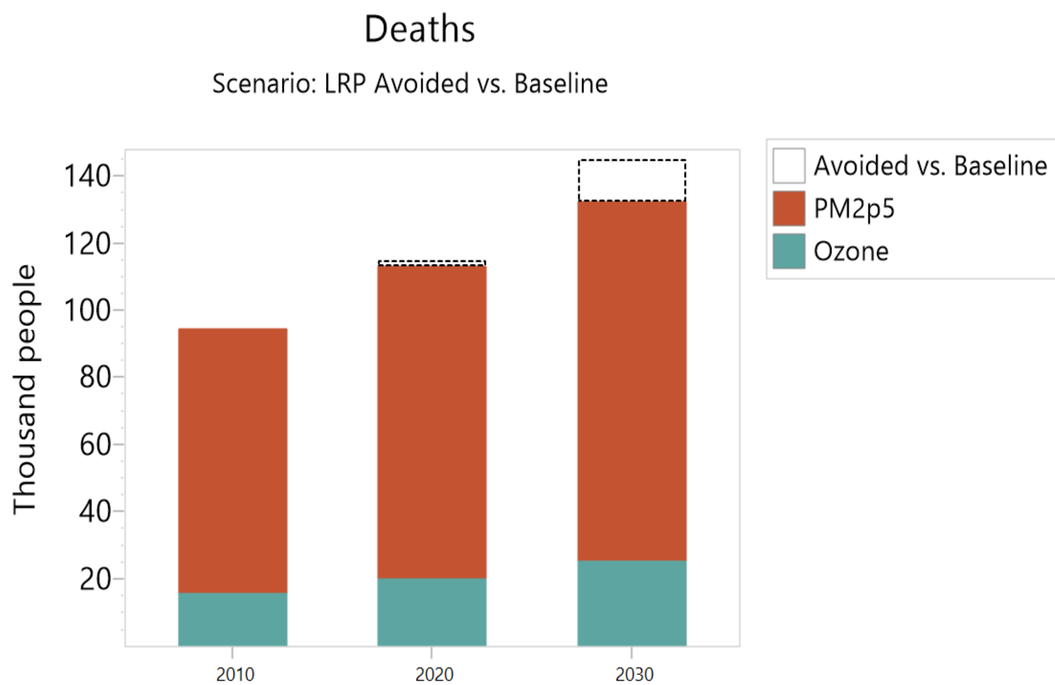

Figure 50 LRP deaths avoided vs. baseline

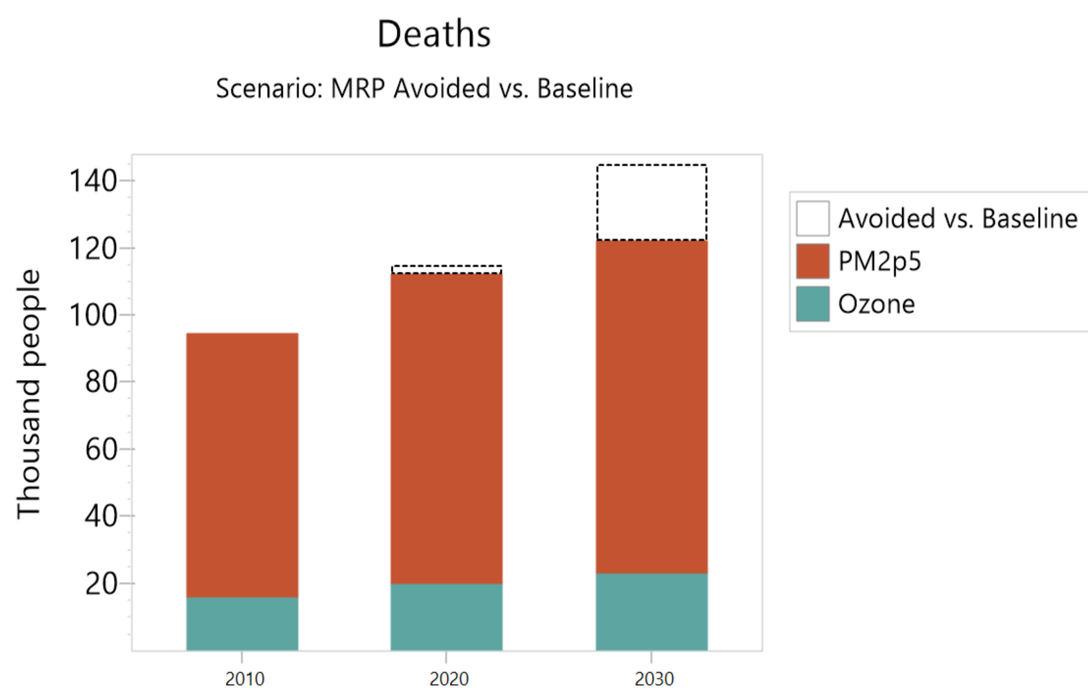

Figure 51 MRP deaths avoided vs. baseline

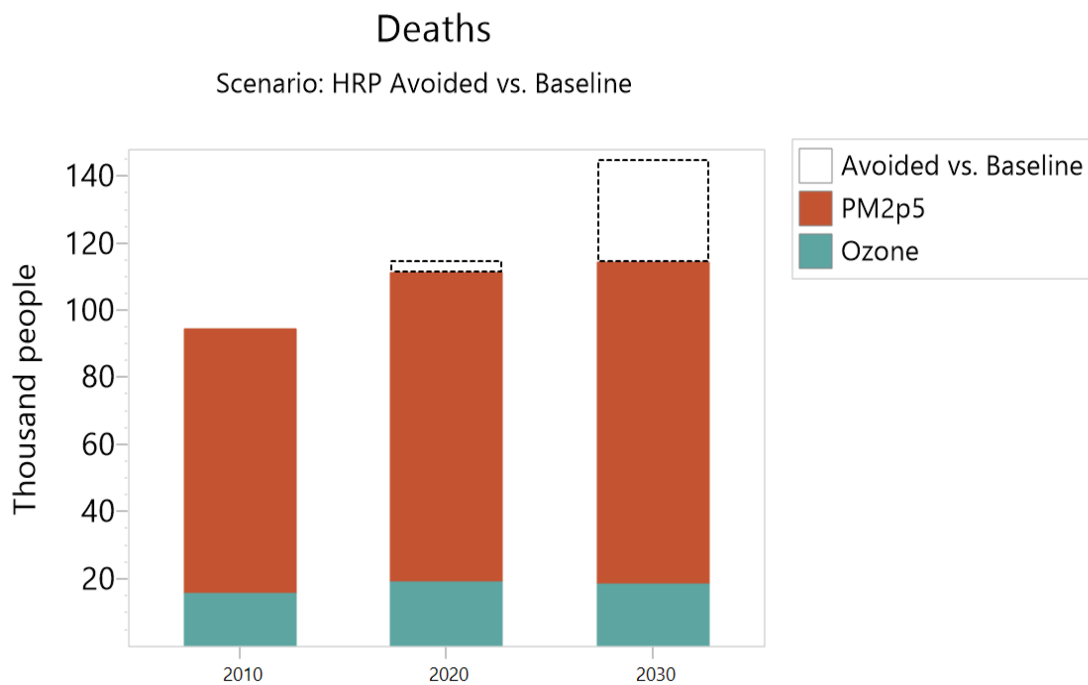

Figure 52 HRP deaths avoided vs. baseline

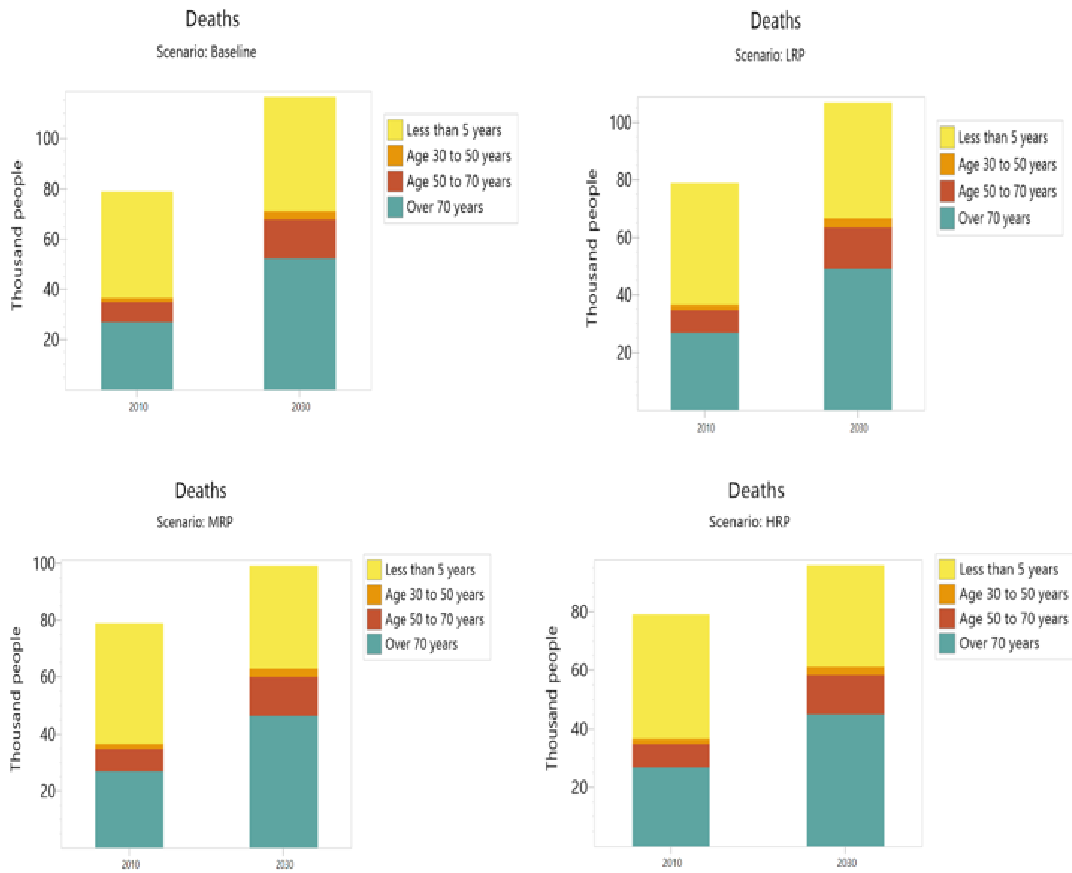

Figure 53 PM2.5 Deaths by age for each scenario

5.4.3.2.4 Crop Loss

Four crops were selected for this analysis, including rice, maize, soybean, and wheat. LEAP estimates the loss of crops because of the national and rest of the world emissions. LEAP also estimates the economic damages because of crop losses. Figure 54 shows the total volume of crops lost in each scenario. The crop loss from the baseline scenario rose from 1 million metric tons in 2010 to about 14.7 million metric tons by 2030. The loss of crops due to emissions has implications for local food security and affects the sustainability of agricultural jobs. Crop losses due to emissions reduce significantly with more sustainable energy systems, and the transition to these systems could save millions of tons of crops that would otherwise be lost. The avoided crop losses from transitioning to cleaner fuels by 2030 are 1.5, 2.4, and 7.9 million tons for the LRP, MRP, and HRP scenarios, respectively, for the four crops selected.

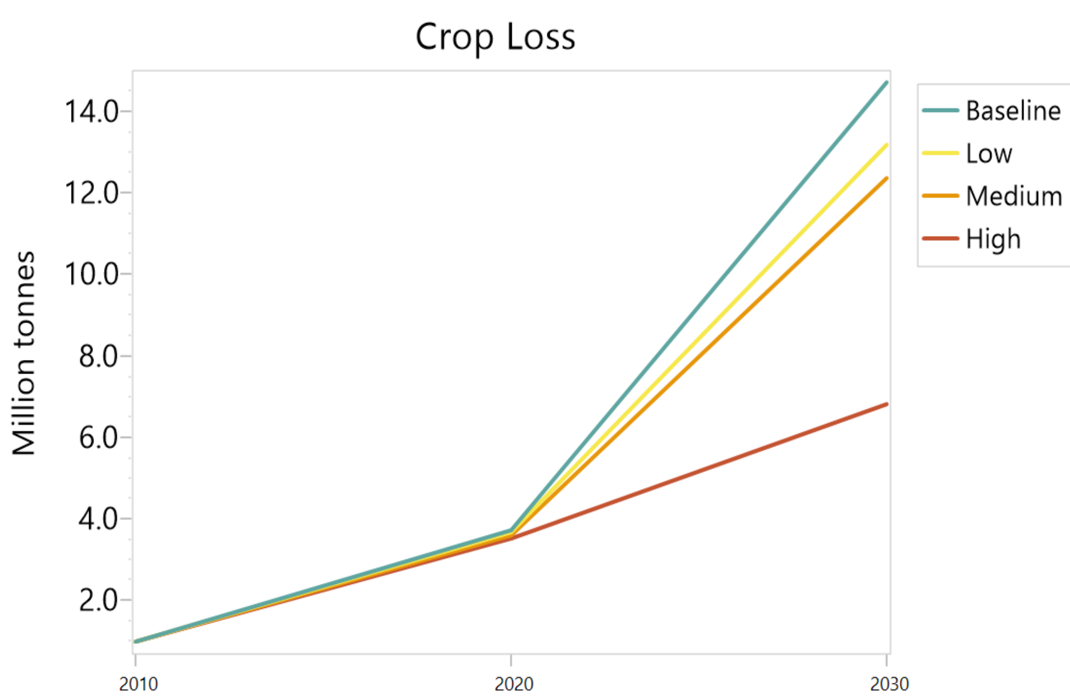

Figure 54 Crop Losses

As air pollution worsens, there are harmful effects on food security, vegetation, human lives. An estimation of the economic damages from crop losses is calculated using the global prices of the crops. The average prices for crops between

2011 and 2018 are used to project the price until 2030. Monthly commodity prices were collected from the Global Economic Monitor (GEM) commodity statistics of the World Bank Group. (World Bank Group, 2019) The table below shows the assumed average prices of crops used in the analysis.

Crop	2010 actual price per metric ton	Assumed average price per metric ton 2011-2030
Rice	$488.90	$454.56
Maize	$185.90	$211.30
Soy	$449.80	$468.50
Wheat	$223.60	$247.70

Table 20 Crop price assumptions (based on data from: World Bank Group, 2019)

The results show the economic damages from all the scenarios between 2010 and 2030. The estimated financial losses from crop losses were $5.7 billion, $5.4 billion, $5.2 billion, and $2.9 billion for the BRP, LRP, MRP, and HRP, respectively.

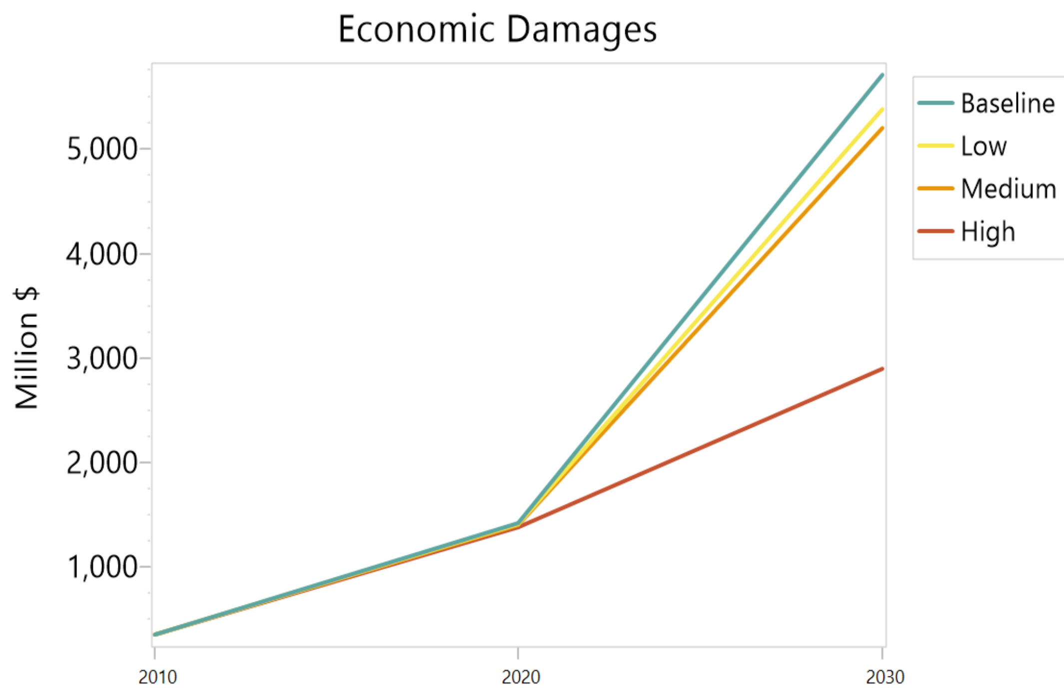

Figure 55 Economic losses from crops

5.4.3.2.5 Climate Impacts

Global temperature change due to Nigeria's emissions from each scenario is shown in figure 56. As expected, the HRP scenario has the least impact on the climate resulting in an estimated 0.0504º Celsius drop in average global temperatures by 2030. Increasing renewable energy penetration has beneficial effects on the climate.

Anthropogenic climate change has effects on the sustainability of ecosystems, the availability of food and water, the displacement of vulnerable communities, and the spread of diseases. These effects could be due to the rise of the sea level, the increased frequency of extreme weather conditions, and the increase in average global temperature. Mitigating greenhouse gas emissions could reduce the worst impacts of climate change on the most vulnerable communities. Nigeria is responsible for most of the greenhouse gases in the atmosphere, but with a burgeoning population and increasing energy demand, adopting sustainable energy policies could contribute to reducing the impacts of climate change.

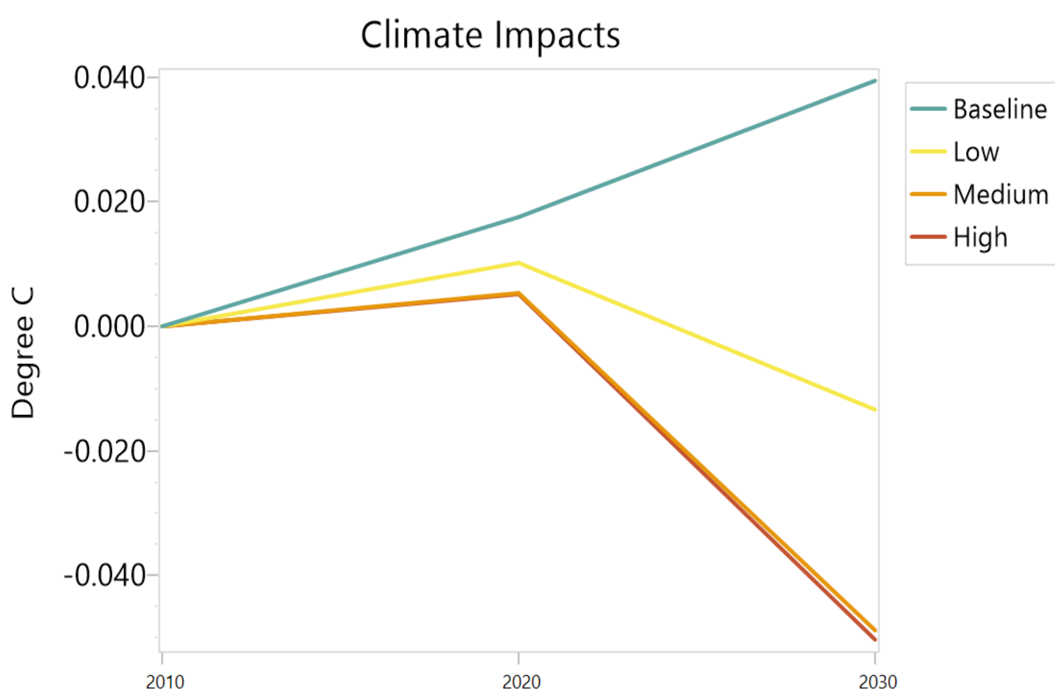

Figure 56 Climate Impacts

5.4.3.3 Cost of Energy Transformation

Energy transition costs are estimated based on a few cost assumptions for each of the scenarios. The table below shows the economic and cost assumptions for different technologies. The net present generation cost of energy transformation from the base year is evaluated using the premises for capital investment and running costs for different generation plants. The cost of clean energy addition in the transportation mix is between $195 million in the LRP scenario to over $560 million in the HRP scenario by 2030. These values are less than the projected savings from replacing subsidized fuels.

Technology	Overnight Costs	O&M Costs	Capacity Factor	Discount Rate	Sources
Biofuels	$2/gallon	$0.42/gallon		10%	(Irwin, 2015)
Solar (Electricity)	$1750/kW	$0.17/kWh	19.20%	10%	(IRENA, 2016) (IRENA, 2018)
Solar Home Systems (Small)	$2000/kw			10%	(IRENA, 2016)

Table 21 Cost and Economic Assumptions

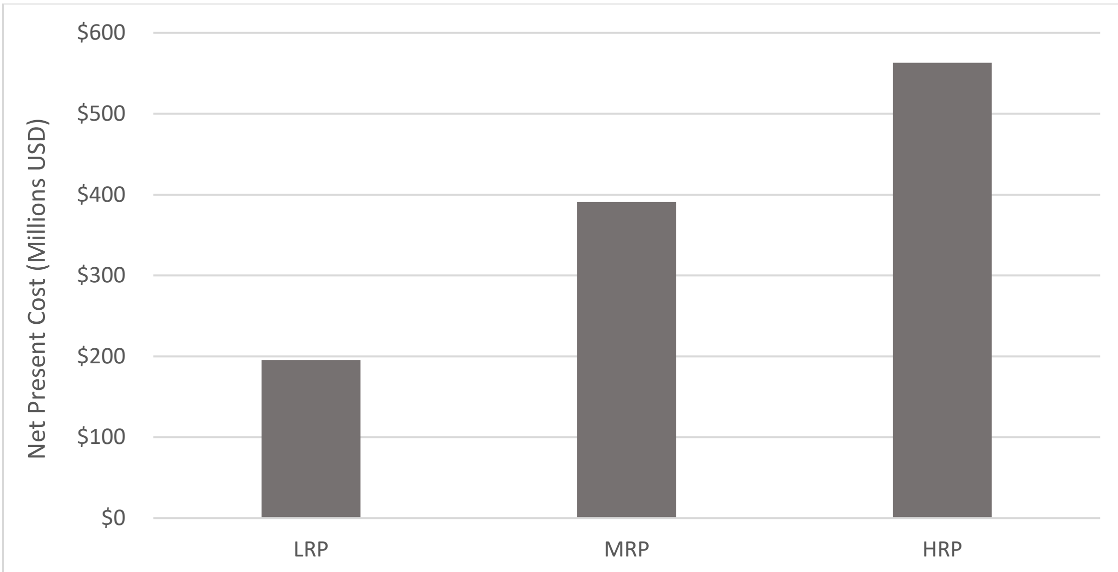

Figure 57 Net present generation costs of biofuels in Transportation

Figure 58 shows the cost of introducing clean energy in the electricity mix. The 100% renewable energy mix in the HRP scenario incurs significant costs estimated to be about $131 billion by 2030. MRP scenario requires an estimated investment of $61 billion, while the LRP scenario needs an investment of about $18 billion. These costs do not consider the environmental and social externalities associated with fossil fuels.

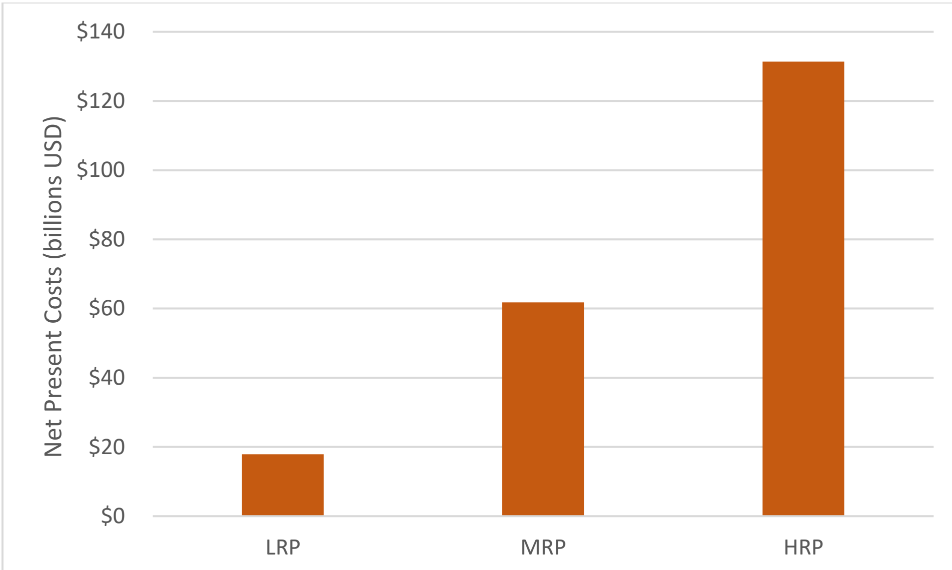

Figure 58 Net present generation costs of Solar in Electrification

5.5 Case studies of Fossil fuel Alternatives

5.5.0 Introduction

To overcome the barriers to cleaner energy resources and support the replacement of fossil fuel resources with cleaner resources. It is important to draw lessons from countries that have enjoyed some success in the diffusion of cleaner alternatives. The most common application of fossil fuels in Nigeria is transport, and for this, Brazil is chosen as the case study.

Like Nigeria, Brazil is a major oil producer and has a population of about 200 million people (EIA, 2019; The World Bank, 2019a). It is the largest producer of biofuels among developing countries and has 80% percent of its light vehicle fleet partially fueled by ethanol (Ionova & Teixeira, 2018). Besides, it has a long history of biofuel development from which lessons can be derived.

For off-grid applications, Kenya was chosen because it is the country with the highest sale of off-grid energy products in Africa and the second-highest sale of off-grid energy products globally (GOGLA, 2019b). It also provides an excellent example from an African context of clean energy penetration.

For grid electricity applications, lessons are drawn from the case of Germany. Germany was chosen as a case study because of its rapid growth in on-grid solar electrification and its global leadership in solar installations. Germany has the largest solar PV watt per capita globally (IEA, 2019). Germany also has more developed policy, legal and regulatory framework for renewable energy development.

5.5.1 Political, Social and Economic Features of Selected Countries

Each country selected for the case studies has political, social, and economic peculiarities that influence energy policy. An understanding of these peculiarities would help us draw context and derive valuable lessons for policy implementation.

Brazil and Nigeria have similar population sizes with estimated population sizes of 209 million and 196 million, respectively. Germany and Kenya have estimated population sizes of 83 million and 51 million, respectively. Population growth also differs across the countries, Brazil and Germany have population growth rates of less than 1% at 0.8% and 0.3% respectively. In comparison, Kenya and Nigeria have population growth rates estimated to be about 2% and 3%, respectively (The World Bank, 2018a). Germany and Brazil have much higher energy consumption per capita but the size of the population and the population growth indicates the size of the challenge to meet energy demand in Nigeria.

Of all the countries selected, Brazil has the largest land area ten times larger than Nigeria. Land density in Brazil is estimated to be about 63.7 people per square mile, while Nigeria has a population density of 549 people per square kilometer (The World Bank, 2018a). There is more land available for agriculture in Nigeria than in Brazil. Total arable land in Brazil is estimated to be about 81 million hectares compared to just 34 million hectares in Nigeria (FAO, 2017). This situation, as well as agricultural productivity, has implications for biofuel production for both countries. Brazil has a much larger capacity to expand biofuel production than Nigeria.

Kenya and Nigeria are smaller lower-middle-income countries with lower GDPs than Brazil and Germany. Brazil is an upper-middle-income emerging economy, while Germany is a high-income economy. Germany and Brazil also have much higher GDP (The World Bank, 2019b). Wealthy countries have more resources to undertake expensive policy initiatives with success as opposed to developing countries.

Nigeria operates a federal government with executive powers in the federal government. Energy regulation is centralized with the state governments having very little say in the regulation of energy (Oke, 2017). For instance, the Nigerian Electric Regulatory Commission oversees the centralized electricity market in the country. The state governments are not involved in the regulation of energy in the country. Even though the constitution allows for state regulation of electricity, the 2005 Electric Power Sector Reform Act confers all powers of electricity regulation on NERC (Oke, 2017). Petroleum regulation and control also lies in the hands of the federal government. A similar situation applies to Kenya where the central government controls policy formulation and implementation (Institute of Economic Affairs, 2015). State governments policies and initiatives promote the development of biofuels in Brazil and receive funding from the federal government (Azevedo & Pereira, 2013). Municipalities in Germany have a large amount of autonomy and can formulate and implement their own energy policies. They are involved in the production and distribution of energy (Schmid, Meister, Klagge, & Seidl, 2020).

	Brazil	**Kenya**	**Germany**	**Nigeria**
Demographics	209 million	51 Million	83 million	196 million
Type of Government	Presidential System	Presidential Representative Democratic	Federal, parliamentary, representative democratic	Federal Republic
Land Area	3.3 million Sq miles	224 thousand sq miles	137 thousand sq miles	356 thousand Sq miles
Economy	$1.87 trillion	$87 billion	$3.95 trillion	$397 Billion
Energy Policy	Decentralized	Centralized	Decentralized	Centralized

5.5.2 Transportation Case Study

5.5.2.1 Brazil Ethanol development

Ethanol is mainly produced from sugarcane in Brazil, and the development of this industry can be divided into two broad stages. The first stage involved extensive government intervention and lasted from the early 1930s to 1999. In this period, the government maintained strict control of production levels for sugar and ethanol for producing facilities, they placed price controls on products, decided who will buy and sell, controlled the exports of sugar and dictated rules for suppliers. The second stage of ethanol development in Brazil was under the free market when the production of sugarcane, sugar, and ethanol was deregulated in 1999. Deregulation changed the dynamics of actors' interactions and led to a market that was controlled more by the forces of demand and supply (Moraes & Zilberman, 2014).

5.5.2.1.1 The era of big government intervention

Government intervention in the sugarcane industry started in 1933 as a result of the worldwide economic decline caused by the great depression in 1929 and the rise in Brazil's agricultural production in the 1920s. Producers called upon the government to deal with the challenges of oversupply and to stop the decline in sugar exports. The government created the Instituto do Açúcar e do Álcool (IAA, Sugar and Ethanol Institute) in 1933 to mitigate the problem of overproduction of sugar and promote the production of ethanol in the country (Szmrecsany, 1979; Szmrecsányi & Moreira, 1991; Moraes & Zilberman, 2014).

Some of the steps taken by the IAA include the ban on new production facilities, the creation of production caps on existing facilities, mandatory registration of all facilities making sugar, and ethanol. The IAA also intervened directly in transactions between mill owners and suppliers to reduce conflicts that used to occur (Moraes & Zilberman, 2014).

5.5.2.1.1.1 World war II period

The outbreak of World War II led to a drop in the markets for sugar and a scarcity of petroleum products imports resulting in a dip in the production of anhydrous ethanol. Ethanol production was also affected by a fall in the supply of sugar. Supply shortages were caused by difficulties transporting sugar to other parts of the country. IAA responded to this by re-evaluating sugar production caps through Decree-Law no. 9,827 of 1946, leading to increased sugar production (Szmrecsányi & Moreira, 1991) supported by powerful lobby by sugar mills (RAMOS, 1991; Moraes & Zilberman, 2014).

5.5.2.1.1.2 1950s-1960s

In the 1950s, urbanization and industrialization led to an increase in demand. This situation forced the IAA to focus on the expansion of production to meet demand.

Pricing policies were put in place to make sugar production more competitive, and the transfer of sugar from one region to another was prohibited (Moraes & Zilberman, 2014).

The government focused on the expansion of sugar exports in the 1960s as a source of foreign exchange. The Cuban revolution and the establishment of the socialist government in 1959 created an opportunity for Brazil to expand sugar exports to the lucrative United States market. Attention was given to boosting agricultural production, but oversupply led to the fall of prices which did not rebound until the late 1960s (Moraes & Zilberman, 2014).

5.5.2.1.1.3 The Oil Crisis: 1970s-1980s

Ethanol as fuel became a part of energy policy as a result of the first oil crisis. In 1973, OPEC sharply increased the prices of crude oil, and this had a significant impact on oil importers. In Brazil, the macroeconomic effects of the oil crisis were significant as inflation rose to 122.6 %. As part of efforts to reduce the dependence on foreign oil, the National Fuel Ethanol Program (Proálcool) was created. The goal of Proálcool was to increase the local production of ethanol for automobile use. Proálcool led a rapid rise in ethanol production such that the IAA did not reduce sugarcane production even when sugar prices were low. The growth in ethanol production helped to avert any sugar overproduction crisis. Ethanol production increased from 580 million to 7.95 billion liters between 1975 and 1983 (Santos, 1993; Moraes & Zilberman, 2014). Figure 59 shows the growth in ethanol production between 1930 and 1983.

The second oil crisis in 1979 led the Brazilian government to take Proálcool more seriously and led to the restructuring of institutions tasked with the program. Proálcool led to an increase in the sale of ethanol-powered cars, as ethanol-powered vehicles accounted for an average of 90% of all new car sales between 1983 and 1989.

5.5.2.1.1.4 A decline in the 1990s

By 1990, the proportion had dropped to just 11%. By 1995, the percentage of ethanol-powered cars was about 2% (Moraes & Zilberman, 2014). Figure 60 shows the sales of ethanol-powered vehicles between 1980 to 1994.

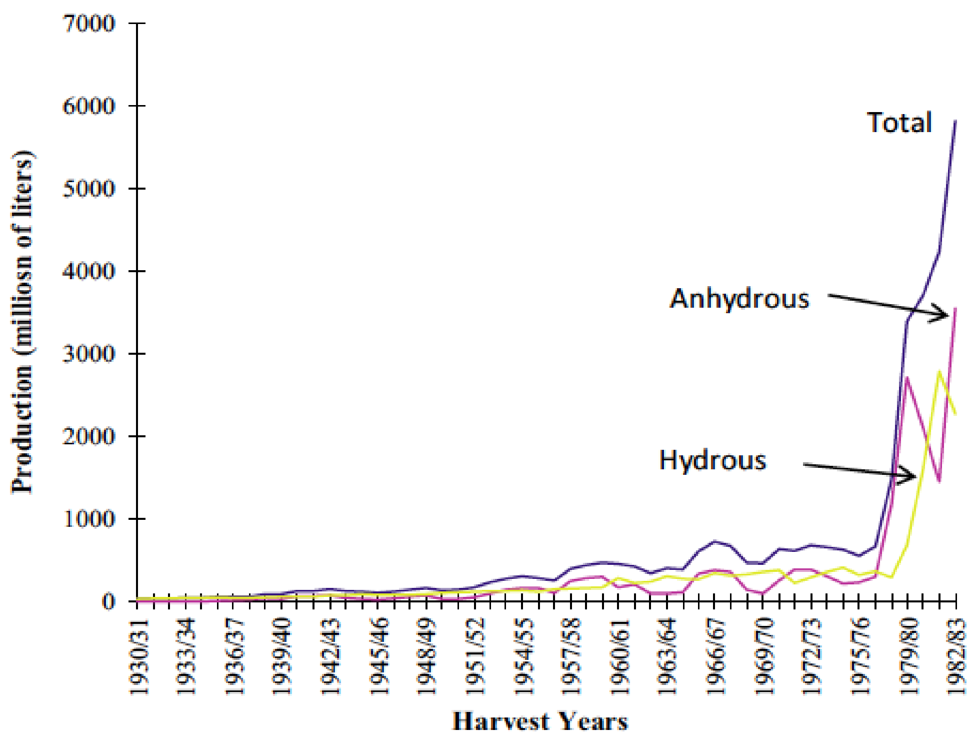

Figure 59 Ethanol production in Brazil 1930 to 1983

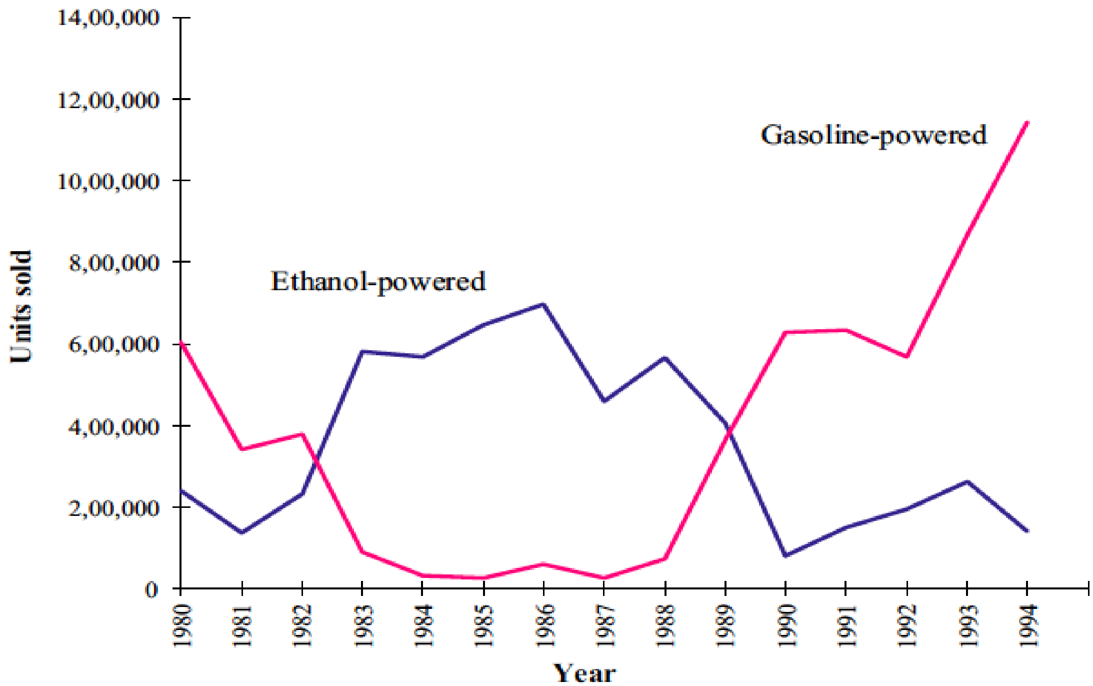

Figure 60 Sale of Ethanol and Gasoline cars from 1980 to 1994.

By 1989-1990, Ethanol production had fallen to 500,000 liters, 28 Proálcool funded ethanol plants had closed, and consumers faced long queues at stations. A decline in government resources and change in the political system to a more democratic one made it difficult for the government to intervene in the sector. The decline in the fortunes of the industry made it clear that the state intervention model was no longer feasible, so the process of reducing government involvement began (Moraes & Zilberman, 2014).

5.5.2.2 Deregulation of the sector

The IAA was dismantled in 1990, and its duties distributed among different agencies as the democratic government. The Inter-ministerial Council for Sugar and Alcohol (CIMA) was set up to analyze existing policies and set up new policies guiding the sector in 1997. CIMA was set up to make the decisions relating to the sugarcane-ethanol industry more centralized and ensure coherence between various ministries involved in the sugarcane ethanol industry. The fuel market was opened in 1995 to make fuel distribution more competitive (Moraes & Zilberman, 2014).

The process of deregulation led to new interest groups and actors in the industry, including associations for producers such as SUCROALCO and for producing states such as CEPAAL. Price supports for ethanol were cut and eventually phased out in October 1999.

Deregulation and the introduction of the flex-fuel vehicles in 2003 reversed the downward trend in the sale of ethanol. Flex-fuel vehicles enable consumers to use ethanol, gasoline, or a mixture of both. Flex-fuel cars accounted for about 50% of the national vehicle fleet in 2012 (Moraes & Zilberman, 2014). Figure 61 shows the light vehicle sales in Brazil between 2003 and 2012, while figure 62 shows the percentage of car sales from light vehicles between 2012 and 2018. Flex-fuel vehicles accounted for an average of 88% of all vehicle sales in that period (Brazilian National Association of Automobile Manufacturers, 2019).

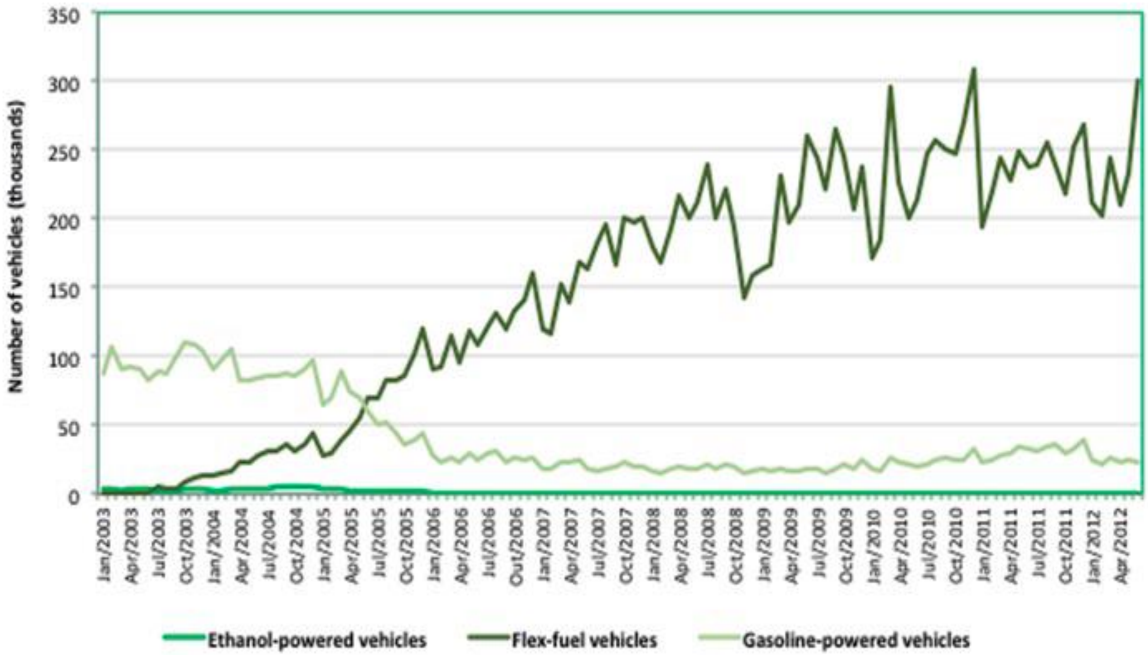

Figure 61 Sale of light vehicles between 2003 and 2012 (Source: Moraes & Zilberman, 2014)

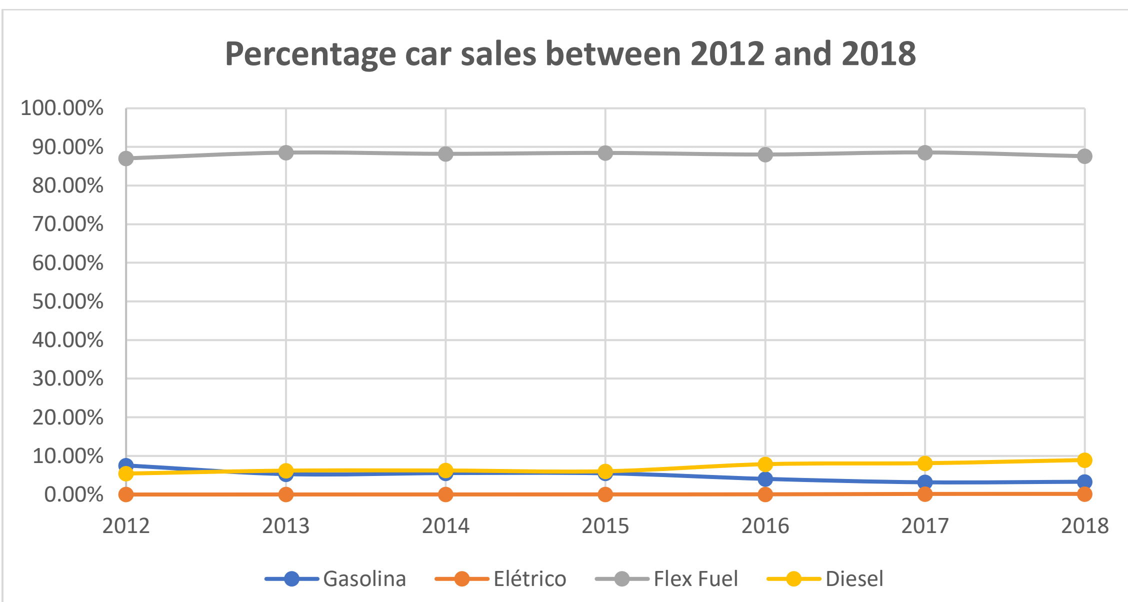

Figure 62 Percentage of car sales from 2012 to 2018 (Source: Brazilian National Association of Automobile Manufacturers, 2019)

5.5.2.3 Key Success Factors

The key elements responsible for the success of ethanol production include the broad powers of decision and enforcement by the military governments, the high production capacity of sugarcane in Brazil, and the lack of competition with food resources.

5.5.2.3.1 Broad Powers of Decision and Enforcement by the Military Governments

For over 60 years, sugarcane development involved a lot of government control and power over production levels, prices, exports, and markets. The military government kept the sugarcane industry heavily regulated and helped to boost production in different regions of the country. As the political system changed, the role of actors changed, and this affected the relationship between the government and the sugarcane/ethanol industry. Other stakeholders, such as congress, had a role to play in the regulation of the sugarcane production chain. Macroeconomic concerns fueled government policy regarding sugarcane during the years of government control. Still, as the political system changed, serious challenges emerged that made the model of government intervention unsustainable. After deregulation, environmental concerns over climate change have played a much more critical role in the development of the sector.

5.5.2.3.2 The High Production Capacity of Sugarcane in Brazil and the Lack of Competition with Food Resources.

A primary concern associated with biofuel production is the competition with land resources, which could be used for food production. However, Brazil does not face this problem as there is enough available land to cater to both needs. Evidence has shown that expanded ethanol production has not affected the production of other crops or restricted areas for cattle rearing as few changes have occurred in other types of land uses as a result (Bordonal, et al., 2018) (Souza Ferreira Filho, 2013). Ethanol production has had no impact on the price of food commodities and poverty in Brazil. Increased efficiency in crop production and general agricultural management practices have also contributed to ensuring that ethanol expansion has not affected food security (Bordonal, et al., 2018).

5.5.2.4 Challenges with Ethanol Development in Brazil

Some of the challenges that could potentially affect the sustainability and growth of Brazil's ethanol industry include:

1. The prospects of second-generation biofuels could threaten the future viability of ethanol exports and slow the growth of ethanol in Brazil.
2. The discovery of new significant oil reserves in Brazil threatens to shift the focus of energy policy towards more oil exploration and production and potentially reduce the demand for Ethanol (Bajay, Nogueira, & Sousa, 2018).

3. Investment is needed to expand ethanol in Brazil. Investments face constraints including the limitation on land ownership by international companies in Brazil, international perceptions that link biofuel production to deforestation, and the dearth of skilled labor in areas where ethanol can be developed (Moraes & Zilberman, 2014).

5.5.2.5 Lessons for Nigeria

The case study of Brazil offers insights into the development of biofuels in Nigeria. Brazil has a much higher potential for biofuel production due to higher production efficiency and a more massive expanse of agricultural land.

One of the most critical factors for promoting the development of ethanol in Brazil is the presence of a strong political will. One of the weaknesses identified in the inability of Nigeria to promote renewable energy is the lack of political will (Akuru, Onukwube, Okoro, & Obe, 2017; Shaaban & Petinrin, 2014). A critical factor in improving policy implementation in Nigeria is a strong political will. As earlier stated, state and city governments in Brazil are also more involved in energy policy than in Nigeria. A decentralized energy policy structure has enabled states to implement support policies to support biofuel development.

Another important point in the development of ethanol in Brazil is a strong legal framework and the flexibility to adapt to changes in global conditions. This flexibility was shown during the oil crisis in the 1970s when the government established the National Fuel Ethanol program (Proálcool). The deregulation of the sector after a decline in ethanol production in the 1990s also showed flexibility. Nigeria would also need a responsive approach to policy implementation to combat changes in global and local conditions. An inadequate legal and regulatory framework is another weakness that has been identified for the poor renewable energy development in Nigeria (Oseni, 2012).

Brazil also engaged in the restructuring of institutions tasked with the development of ethanol and remained consistent in the policy goal of driving ethanol development. Nigeria is known for its weak institutions and policy inconsistency (Elum & Momodu, 2017). For success in the promotion of clean energy, institutions must be strengthened, and government policies must also be consistent over a long period. Inconsistencies in the implementation of Nigeria's biofuel policy is one of the reasons identified for its failure thus far (FGN, 2012).

5.5.3 Off-Grid Case Study

5.5.3.1 Kenya and Off-Grid Solar

Kenya's history with off-grid solar dates back to the 1970s when the government utilized it in power signaling and broadcast installations in remote, distant areas (Jacobson, 2005; Ondraczek, 2013). Off-grid solar can be classified into six major groups illustrated in the table below.

Type	Capacity	Description
Small Pico Systems	1 to 10 Wp	These systems are utilized mainly for phone charging and lighting. They currently occupy the largest segment of the Kenyan market but have relatively short life spans.
Micro Solar Home Systems	5 and 10Wp	Semi-portable systems consisting of solar panels and batteries that are used to power 1-4 lights, radio, and mobile phones.
Solar Home Systems	10 and 100Wp	These systems are used for larger applications such as TV as well as smaller lighting and mobile phone charging application.
Stand-alone Institutional PV Systems	500Wp – 2kWp	These are usually government initiatives designed to power schools, hospitals, and other social services disconnected from the grid.
Mini-Grids	5kW and 1MW	These are used to connect towns and villages disconnected from the central grid.
Telecommunication, Street and Market Lighting	0.2kW to 15kW	These are usually undertaken by private companies in the case of telecommunication or by counties and municipal councils in the case of street and market Lighting

Table 22 Off-grid Systems in Kenya (Source: Kenya Climate Innovation Center (KCIC), 2016)

The solar industry grew into a $6 million industry between 1980 and 1999 in three major stages. (Hankins, 2000) The stages are illustrated in figure 63 below.

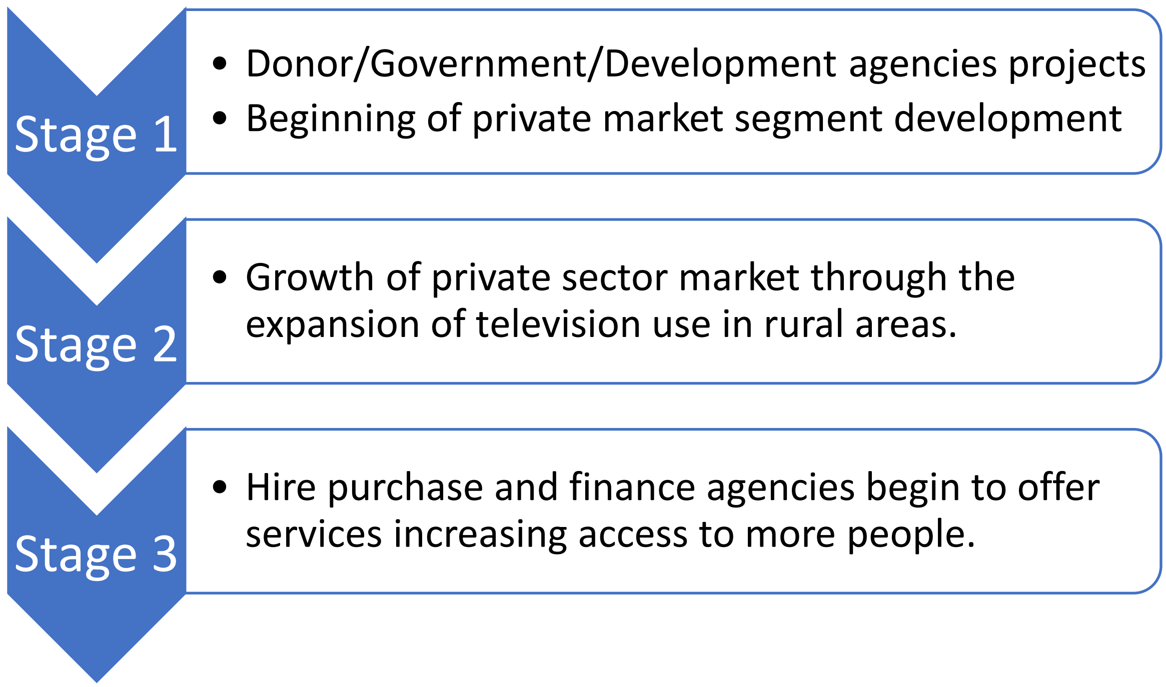

Figure 63 Steps in Off-grid Solar Development in Kenya between 1982-1999

5.5.3.1.1 Stage 1

In the early 1980s, government, donors, and development agencies utilized solar energy to power social services such as water pumps, lighting systems, school electrification, telecommunication, and vaccine refrigeration (Musinga, Hankins, Danielle, & De Schutter, 1997; Hankins, 2000). The actions by government and donors, falling solar prices as well as the awareness created by the UN conference “New and Renewable Sources of Energy" held in Kenya in 1981 led to the development of markets for solar modules. Local companies were set up to meet the donor-driven demand, and private markets gradually developed. The first business to sell solar products to private consumers was set up by Harold Burris, an ex-Peace Corps volunteer from the US in

1984 named “Solar Shamba”, and several other businesses started up after this (Jacobson, 2005). By 1990, Kenya had an estimated 5,000 solar home systems installed and overall solar installed capacity of 0.5MW (Hankins, 2000). The rapid growth in solar sales was facilitated by government policy that removed the 30% import duties on solar modules in 1986 (Musinga, Hankins, Danielle, & De Schutter, 1997). These systems sold in the era were mainly larger systems that needed significant upfront investments.

5.5.3.1.2 Stage 2

The spread of television sets in the early 1990s contributed to the rapid development of the solar market and the introduction of smaller and cheaper PV systems in 1989. As tv signals expanded to remote off-grid areas, these smaller solar home systems (SHS) became more attractive and spread rapidly. Incremental payments for PV systems were also introduced, as many rural users could not make large upfront payments. Between 1990 and 1995, the number of solar home systems installed grew from 5,000 to 35,000. By 1998, 22,000 systems were sold annually, and the market grew from 1.5 MWp in 1990 to 3.9 MWp in the year 2000 (Hankins, 2000).

5.5.3.1.3 Stage 3

Financing mechanisms such as hire purchase and loans by traditional financial institutions became a growing feature as demand started to grow. Hire Purchase service for solar PV started around the late 1990s. With Hire purchase, the system is given to employed consumers on credit, and monthly deductions are made from the consumers' salary. Traditional loans from financial institutions were however, in their infancy because of the reluctance of banks to give loans for purchasing PV systems (Hankins, 2000).

5.5.3.1.4 The modern trends (2000-date)

By 2009, SHS installed capacity had risen to 10MWp and up to 20MWp by 2013. Solar home systems provide access to clean energy for remote rural locations and currently provide about 26% of rural electrification in Kenya (Kenya Climate Innovation Center (KCIC), 2016). About 25,000 – 30,000 solar PV products are sold annually driven by the private sector and government involvement. Kenya has attracted more private investment in off-grid solar than any other country in Africa. International organizations such as the World Bank Group through its Lighting Global have supported the diffusion of Solar Portable Lighting (SPL) and SHS in rural areas. In 2009, Kenya was selected as one of the two pilot countries for the lighting global program. Since then, there have been about 2.7 million solar lamps, and SHS sold. Quality verified system sales also rose from 3% in 2009 to 88% in the second half of 2017 (GOGLA, 2019a). Sales of Pic-Solar and SHS in Kenya are second only to India globally, accounting for about 10-12% of global sales. Figure 64 shows the sales of Pico Solar and SHS between 2016 and 2018 between Kenya and Nigeria. It shows that Pico and SHS sales in Kenya are 4 to 6 times greater than Nigeria, even though Nigeria has a much larger population size and market (GOGLA, 2019b; GOGLA, 2018a; GOGLA, 2018b; GOGLA, 2017b; GOGLA, 2017a; GOGLA, 2016).

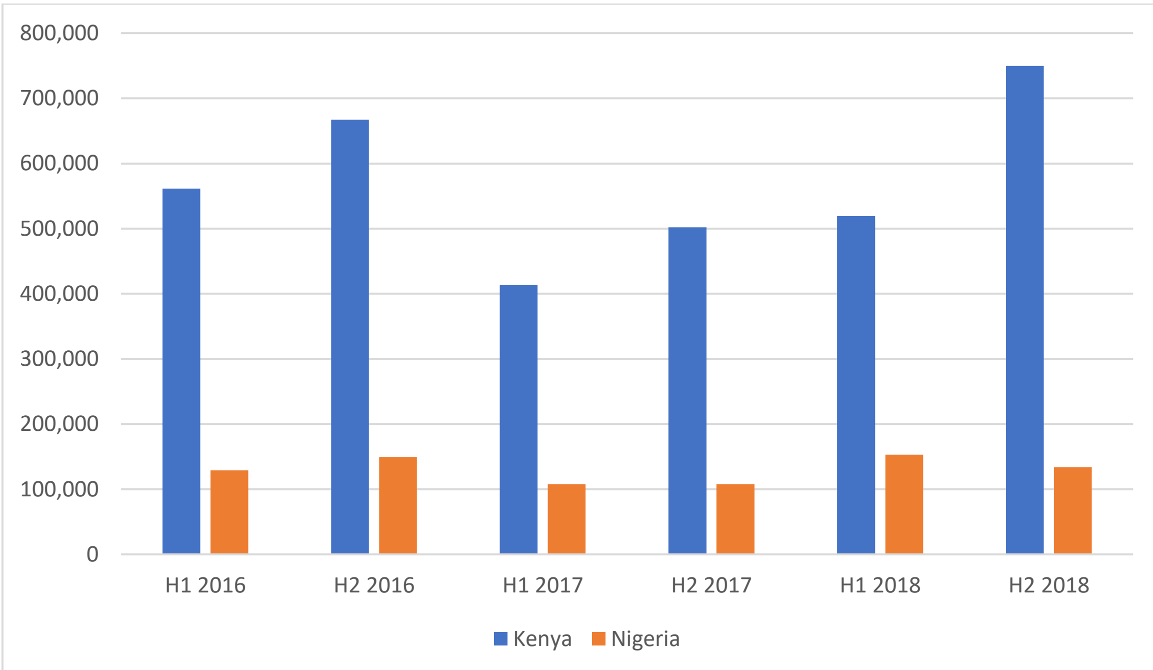

Figure 64 Sale of Pico and SHS in Kenya and Nigeria (Source: GOGLA)

The World Bank-backed Kenya Off-grid Solar Energy Access Project (KOSAP) was launched in 2017 to help extend off-grid solar to 14 under-served counties. It is a $150 Million 6-year program designed to promote off-grid solar solutions, including solar cookstoves and solar pumping. The project aims to reach 277,000 households with solar light and home systems by the year 2023 (GOGLA, 2019a).

5.5.3.1.5 Key Success Factors

The factors responsible for the spread of off-grid solar in Kenya include the following:

5.5.3.1.5.1 Government Policies and Actions

A major factor responsible for the advancement of off-grid solar in Kenya is the government's policies and actions towards solar development. A conducive regulatory environment has encouraged private investments in off-grid solar products. Some of the policy initiatives include the removal of import duties and VAT from solar components, removal of foreign exchange controls, standardized power-purchasing agreements, and feed-in tariffs for solar PV generation (Jacobson, 2005; Hankins, 2000; GOGLA, 2019a). Import duties and sales taxes amounting to up to 30% of value were reintroduced in 2016 as part of the import tax changes introduced in East African countries (Jacobson, 2005) (GOGLA, 2019a).

Also, mandatory standards for pico-systems have ensured that more quality products are brought into the market. Products that enter the country legally undergo a pre-verification of conformity (PVoC) process to ensure that quality is met (GOGLA, 2019a).

5.5.3.1.5.2 Falling Solar prices

The fall in world solar product prices has been critical to the development of solar energy in Kenya. Falling price, the rise of income levels, and the introduction of smaller, cheaper systems made solar more accessible to a more diverse range on consumers in Kenya through the early and mid-1990s. The increased use of locally produced and assembled components has also helped reduce the price of PV systems in Kenya. In 2009, there were three local lead-acid battery manufacturers and eight local solar lamp producers. Ondraczek (2014) suggests that the LCOE of grid-connected PV in Kenya is already below conventional sources like diesel and gas turbines (Ondraczek, 2014). The figure below shows a comparison between the price of solar panels globally and the global solar panel installations between 1975 and 2015 (Lindon, 2016). As prices continue to drop, it is expected that the adoption of solar products will increase in Kenya.

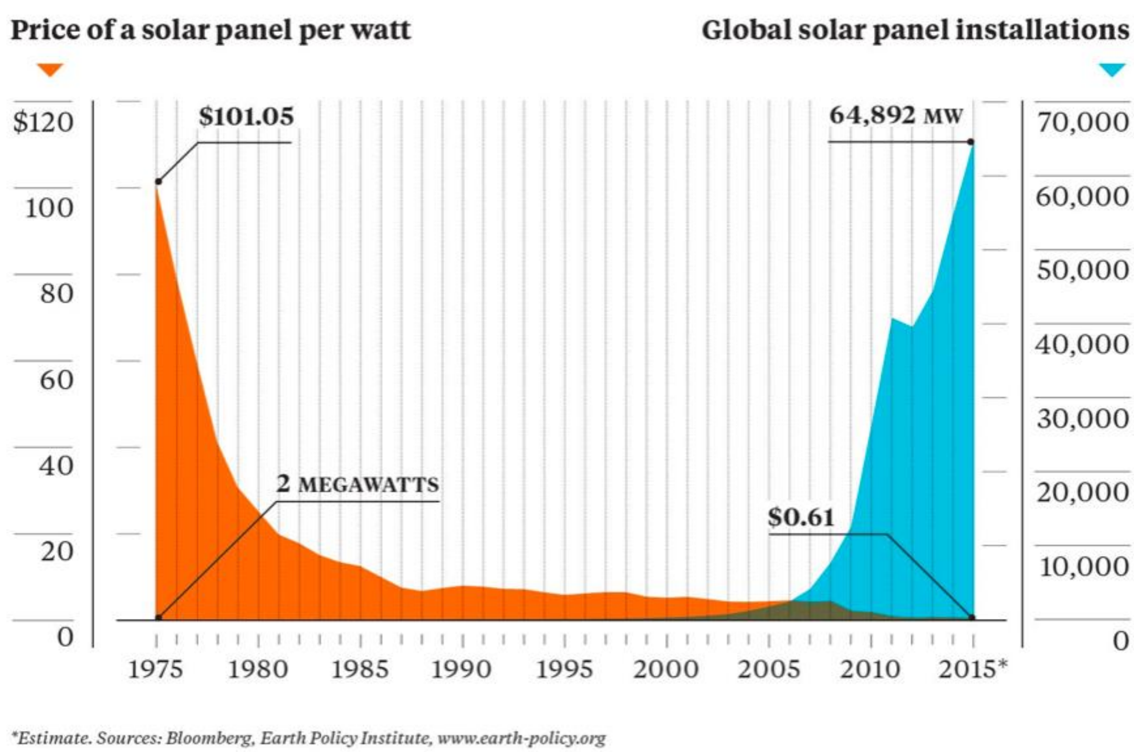

Figure 65 Fall in Solar panel prices and global solar panel installations (Source: Lindon, 2016)

5.5.3.1.5.3 The Important and Sustained Role of Donor Organizations and International Development Organizations

The early development of off-grid solar demand in Kenya was triggered by international donor organizations' social institution projects. The donor market was the most dominant in Kenya in the 1970s and early 1980s and created the demand that allowed private markets to develop and thrive. Nairobi was the regional hub for donor investments and held a comparative advantage to other African countries (Hankins, 2000) (Jacobson, 2005). In 1998, Kenya was one of the three countries (India and Morocco were the other countries) selected for the $30 Million International Finance Corporation/Global Environment Facility (IFC/GEF) Photovoltaic Market Transformation Initiative (PVMTI). PVMTI was designed to provide working capital and end-user financing to small scale entrepreneurs (IFC, 2007). Donor agencies have also provided direct financial support for solar development programs like KOSAP, supported the training of solar energy technicians, organized workshops, training, and public awareness of solar energy in Kenya.

5.5.3.1.5.4 Local innovation, Increased Income and Television

The agricultural boom in the 1990s occasioned by increased income from tea and coffee farming played an important role in increasing the purchasing power of rural consumers. Increased income of farmers, teachers, and civil servants, as well as increased demand for televisions due to the improved signal reach, also played major roles in the development of solar markets in Kenya as more people could access television signals. Most buyers of solar home systems were the rural middle-class households who were disconnected from the central grid and knowledgeable about solar energy. Besides, the slow pace of grid expansion has made these products more attractive to rural dwellers (Acker & Kammen, 1996; Hankins, 2000; Jacobson, 2005).

Also, the emergence of local manufacturing of components such as batteries, wiring, circuitry, and charge controllers has resulted in the reduction of costs, thereby creating jobs and stimulating economic and market growth. Consequently, there is also a reduction in the need for importation as products can be made locally (Acker & Kammen, 1996) (Hansen, Pedersen, & Nygaard, 2014).

5.5.3.1.5.5 Enabling Business Environment and Culture

The aggressive marketing of local entrepreneurs and their introduction of smaller, cheaper systems made solar more accessible to lower-income rural dwellers. A strong entrepreneurial culture in Kenya, as well as local support for foreign investments, is another important factor for the advancement of Solar PV in Kenya (Hansen, Pedersen, & Nygaard, 2014). Kenya ranks number 11 globally for Protecting Minority Investors on the 2019 world bank ease of business index. They place 61 overall in the Ease of Business Index out of 190 countries (The World Bank, 2019d).

5.5.3.1.5.6 Business Models and Technologies

Smart meters and Pay-as-you-go (PAYGO) business models have made it easier for low-income families to access off-grid solar systems and pay in installments. Business models have helped organizations overcome the affordability barrier and enable them to reach consumers who cannot afford the upfront costs of PV systems. Over 82% of all PAYGO sales in SSA in the second half of 2018 were from East Africa. Kenya is a leader in PAYGO product sales, accounting for over 34% of total PAYGO sales in SSA, and about 32% of global sales (GOGLA, 2019b). The high mobile penetration amongst the poorest communities has made this possible. Kenya has the highest mobile penetration rate in Africa amongst the poorest population, with about 70% of adults in the poorest 40% of the population having a mobile account (Mazzoni, 2019).

5.5.3.1.6 Challenges with Off-grid Solar Adoption in Kenya

There are still challenges associated with the adoption of solar in Kenya. Some of the challenges include:

1. Unskilled Technicians: Despite government regulation, which requires that only licensed technicians are allowed to design and install a solar system, unskilled technicians who do not have formal skills are still engaged in the industry (Kenya Climate Innovation Center (KCIC), 2016).

2. There are still fake and/or substandard solar products in the market. An estimated 12% of products sold in 2017 were not quality-verified (Kenya Climate Innovation Center (KCIC), 2016; GOGLA, 2019a).
3. Additional costs added by middlemen make the solar products more expensive for consumers. The low purchasing power of poor rural dwellers, as well as the difficulty in accessing finance, make these products inaccessible to the rural poorest (Kenya Climate Innovation Center (KCIC), 2016).
4. Government policy does not provide subsidies and incentives for household solar PV, which is mainly driven by private sector involvement (Kenya Climate Innovation Center (KCIC), 2016).

5.5.3.1.6 Lessons for Nigeria

The development of off-grid solar in Kenya provides valuable lessons for Nigeria. The role of government and donor agencies in creating markets for these products is critical to enhancing the penetration of off-grid renewable energy products. Kenya has a similar energy policy governance structure as Nigeria, with the central government in control of policy formulation and implementation.

Hurdles facing private sector entry into the market must be removed, and opportunities for local innovation must be enhanced. The provision of grants and loans to private entrepreneurs and engaging local businesses in government off-grid projects will aid the creation of markets. A similar conclusion was reached by Ohunakin et al. (2014), who emphasized the importance of financial incentives and local ownership to promote solar penetration in Nigeria (Ohunakin, Adaramola, Oyewola, & Fagbenle, 2014).

The promotion of an enabling environment for local entrepreneurs will also provide them with the flexibility to tap into the energy demands of those unconnected to the grid and would reduce dependence on petroleum products to supplement electricity shortages. Approximately 60 million Nigerians are dependent on diesel and petrol generators for off-grid electrification (Adhekpukoli, 2018).

Government policies, like the elimination of import duties and VAT, like what was obtainable in Kenya, will reduce the cost of entry. Off-grid operators in Nigeria have identified these input duties and VAT as barriers to the penetration of renewable energy in Nigeria (Anyaogu, 2018; Ekwealor, 2018)

5.5.4 Electricity Case Study

5.5.4.1 Germany and Solar Energy Development

Germany has one of the world's largest photovoltaic installed capacity with 11% of global capacity, ranking 4^{th} behind China, USA, and Japan in 2017. The total installed PV capacity was about 43 GW (SolarPower Europe, 2018). The transition towards renewable energy in Germany started with the passage of the Electricity Feed-in Act, which came into effect on January 1, 1991. The law regulated the generation of electricity from hydropower, wind and solar energy, landfill gas and biomass, ensuring grid access to renewable energy sources. The law obligated utilities to pay designated feed-in-tariffs to renewable energy power plants. Electricity suppliers and consumers bore the burden of this policy. The feed-in-tariffs were reviewed annually, and utilities had to pay a minimum of 90% of average utility electricity rates for solar power (Kühn, 1999; IEA, 2013). The average feed-in tariffs for solar energy between 1990 and 2000 for solar energy are shown in the figure below.

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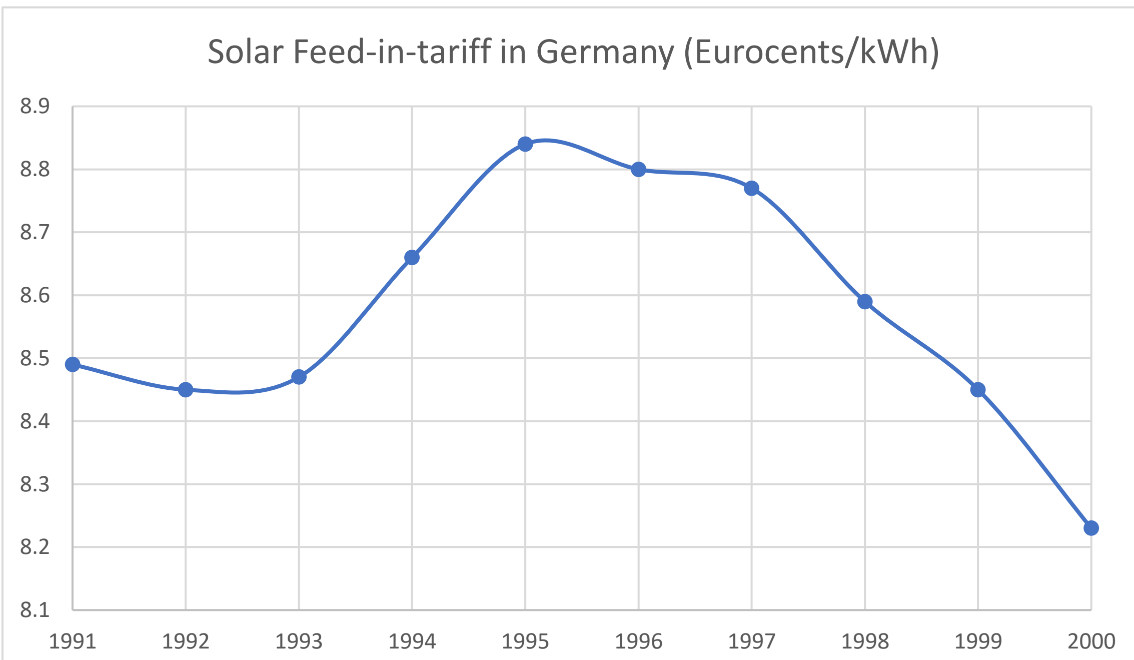

Figure 66 Solar FIT in Germany (1991-2000) (exchange rate of 1,95583 DM/EURO was used) (Source: Kühn, 1999)

The tariffs fell after 1996 due to phasing out of coal levy and the liberalization of the electricity markets. Between 1990 and 2000, the annual solar generation rose from 1 GWh to 60 GWh (Kühn, 1999; IEA, 2013).

In 2000, the Electricity Feed-in Act was replaced by the Renewable Energy Sources Act (2000) (also known as EEG 2000), which came into effect in April 2000. The Act provides technology specific feed-in-tariffs for 20 years and obliges grid operators (as opposed to utilities) to buy renewable energy over conventional sources. Unlike the Electricity Feed-in Act, feed-in tariffs are specified in absolute terms as opposed to the percentage of the average electricity prices. Feed-in-tariffs were reduced at regular intervals to put pressure on renewable energy operators to adopt more efficient technologies over time. The tariffs were also differentiated by the size of the plant. EEG also introduced the 100,000 roofs program, which ran till 2003 and offered low-interest loans to PV installations below 300 MW. After the expiration of the 100,000 roofs program in 2003, the PV Interim Act (2003) was introduced, and it raised PV tariffs for small household PV installations. Solar PV annual generation rose from 60 GWh to 557 GWh between 2000 and 2004 (IEA, 2014) (BMWi, 2001).

EEG was amended in 2004 with a modified tariff structure designed to reflect the cost realities of different renewable energy technologies. The new amendment also set renewable energy targets for the years 2010 and 2020. It aimed to have 12.5% of total electricity consumption from renewable sources by 2010 and 20% by 2020. PV tariffs were increased because of this amendment (IEA, 2016a).

In 2009, EEG was amended again, and new renewable energy targets were introduced. Renewable energy targets were raised to 35% by 2020 (up from 20%), 50%

by 2030, 65% by 2040, and 80% by 2050. Between 2009 and 2010, over 7,000 MW of additional PV capacity was added (IEA, 2016b).

The 2012 amendment of the EEG was designed to cater to market integration, system integration, and grid integration of renewable energy resources. Significant growth of renewable power generation had led to concerns over grid integration due to the intermittent nature of some renewable energy resources. Photovoltaic systems were included in feed-in management, empowering operators to limit the feed-in of PV systems when the grid is overloaded. Also, a rebate in compensation was provided for utilities selling power from at least 50% variable renewable sources. The tariff structure from the 2009 EEG amendment was retained (IEA, 2016c).

On August 1, 2014, another amendment to the EEG was introduced with new renewable energy targets, including 2.5 GW of additional annual solar PV. Overall renewable targets include 40-45% of renewable energy generation by 2025, to 55% - 60% by 2035 and 80% by 2050. The amendment also required new operators of renewable energy plants to market their generated electricity directly, independently, or through a marketer. Renewable energy operators can receive additional support through market premiums for electricity that is directly marketed (BMWi, 2014) (IEA, 2016d).

The latest amendment to the act (EEG (2017)) introduces an auction scheme for renewable energy remuneration in line with EU guidelines. Only successful bids are supported by the EEG for a period of 20 years, starting from the date of entry of operation. The auction scheme is designed to replace the feed-in tariff system (Watson Farley & Williams, 2019).

Figures 42 and 43 show the growth of solar PV in Germany and the percentage of Solar PV to total electricity consumption between 1991 and 2018 (BMWi, 2019).

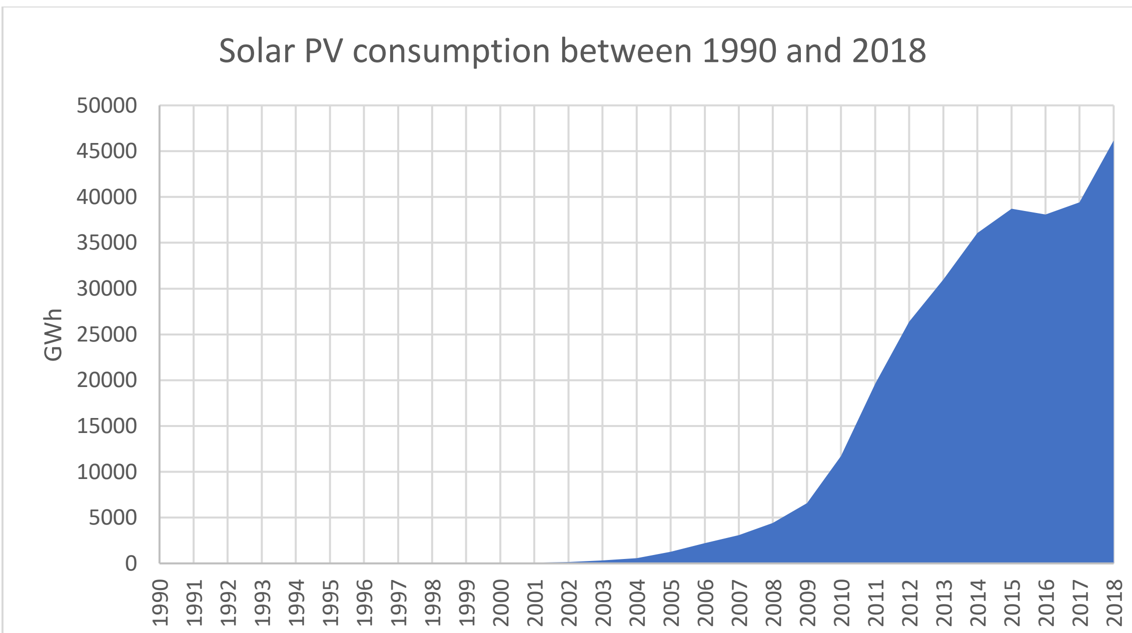

Figure 67 Solar PV consumption 1990-2018

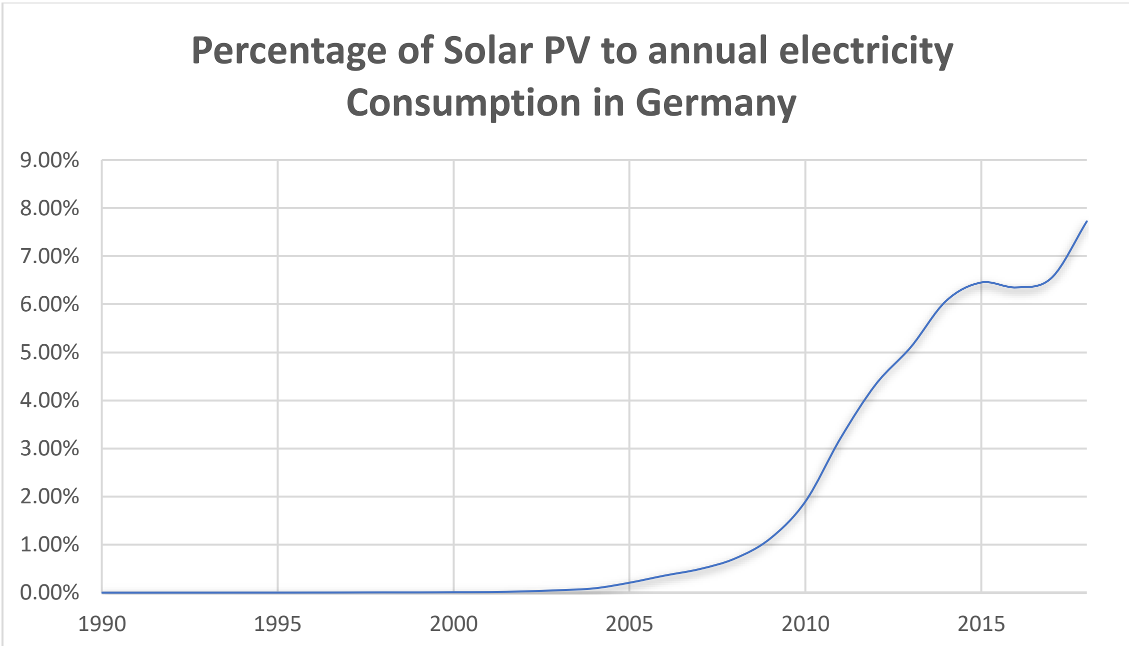

Figure 68 Percentage of Electricity consumption from Solar PV 1990-1018

Feed-in-tariffs for solar have reduced over time and have grown less than gross domestic electricity prices in some cases. Feed-in-Tariffs have reduced 80% for small rooftop installations and 90% for medium-sized installations. For older plants, Feed-in-tariffs expire in 2020, but they are expected to remain competitive with conventional resources due to low fuel and operational costs (Fraunhofer ISE, 2019).

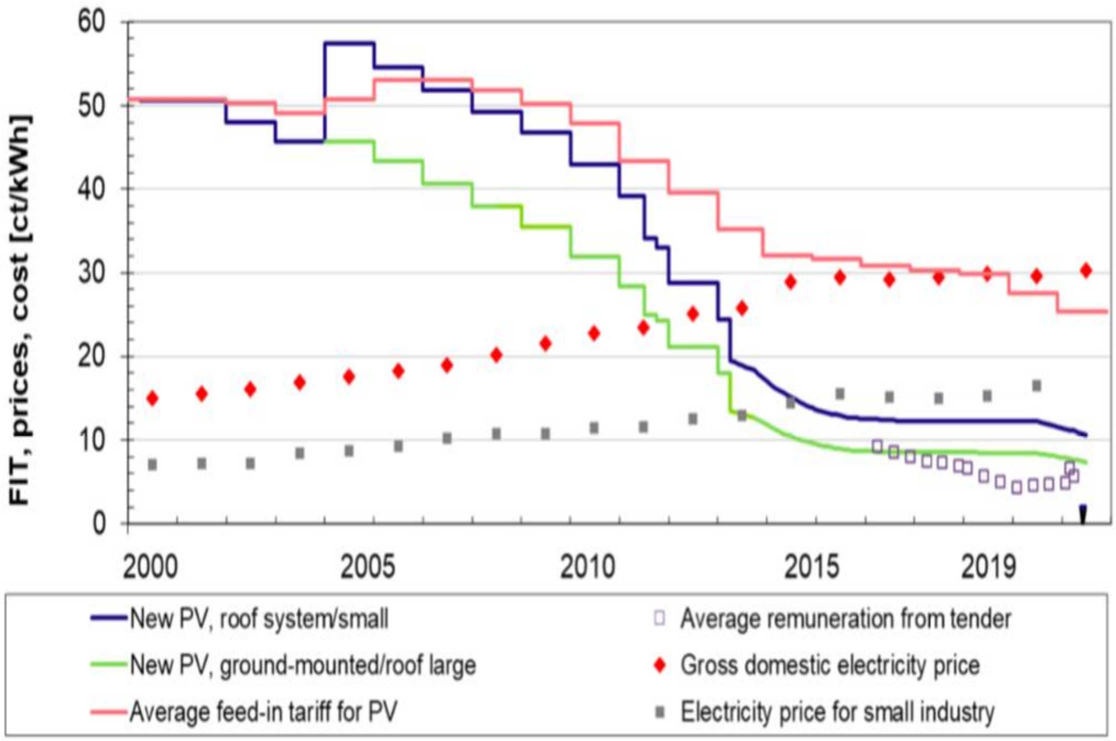

Figure 69 Feed-in Tariffs 2000-2019 (Source: Fraunhofer ISE, 2019)

5.5.4.1.1 Key Success Factors

Factors influencing the growth of grid-connected PV systems in Germany include:

5.5.4.1.1.1 A Strong Legislative Framework

The role of government in the role of PV development was a lot more pronounced in Germany than in Kenya. Perhaps the most important factor in the development of solar in Germany is the strong legislative framework for PV development. Renewable energy legislation has guided the growth and development of renewable energy as they have provided a consistent, predictable tariff structure for Solar

PV and other renewable energy plant operators. A market was created for renewable energy, and investors were assured of attractive prices for the energy produced. Individuals were also allowed to participate and make a profit from selling power to the grid.

5.5.4.1.1.2 Public support for Renewable Energy

A key element of the success of Germany's renewable energy transition is the public support for renewable energy expansion. A 2017 survey by the Renewable Energies Agency (AEE) shows that 95% of Germans consider renewable energy expansion as important or extremely important. Seventy-two percent of respondents also express a positive attitude towards the location of solar parks near their places of residence. Most respondents are also willing to pay more for electricity to support the energy transition (AEE, 2017). An important factor influencing the acceptance of solar energy in Germany is the concern over the potential impacts of climate change (Liebe & Dobers, 2019).

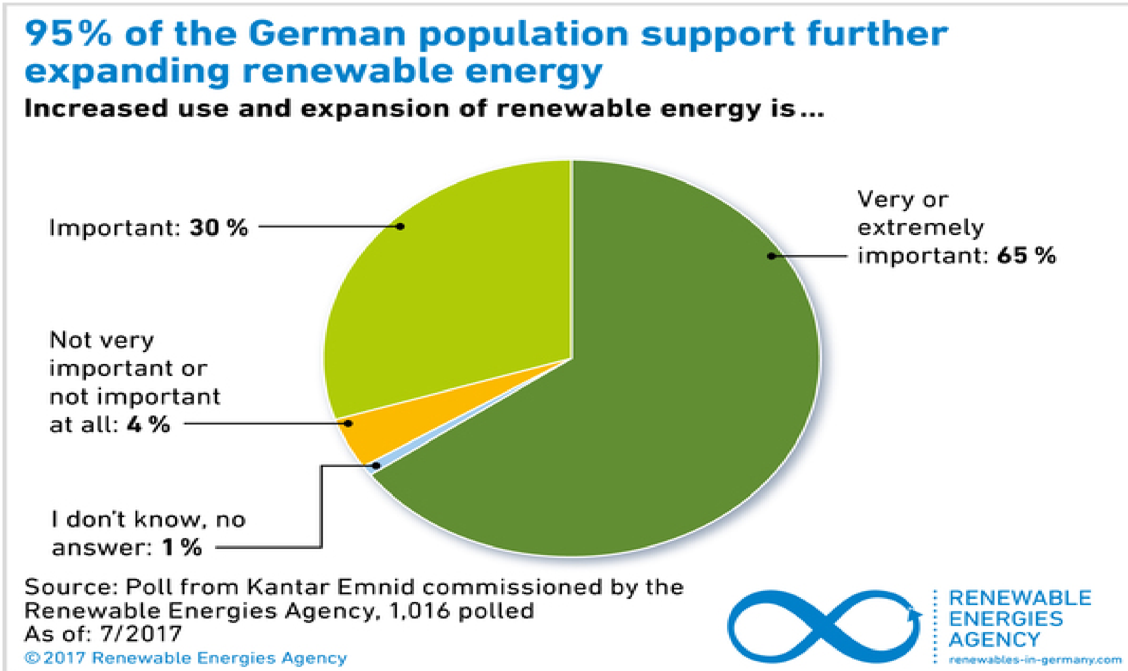

Figure 70 Public Support for Renewable Energy (Source: AEE, 2017)

Much of Germany's energy transition has been driven by private ownership as most of the renewable energy installations in Germany are owned by private individuals. Over 40% of Germany's investment in renewable energy as of 2016 comes from citizens with 31.5% coming from Individuals and 10.5% from farmers (Trend Research, 2017). The total renewable energy capacity in 2016 was over 100 GW with Solar energy accounting for about 40 GW (BMWi, 2019).

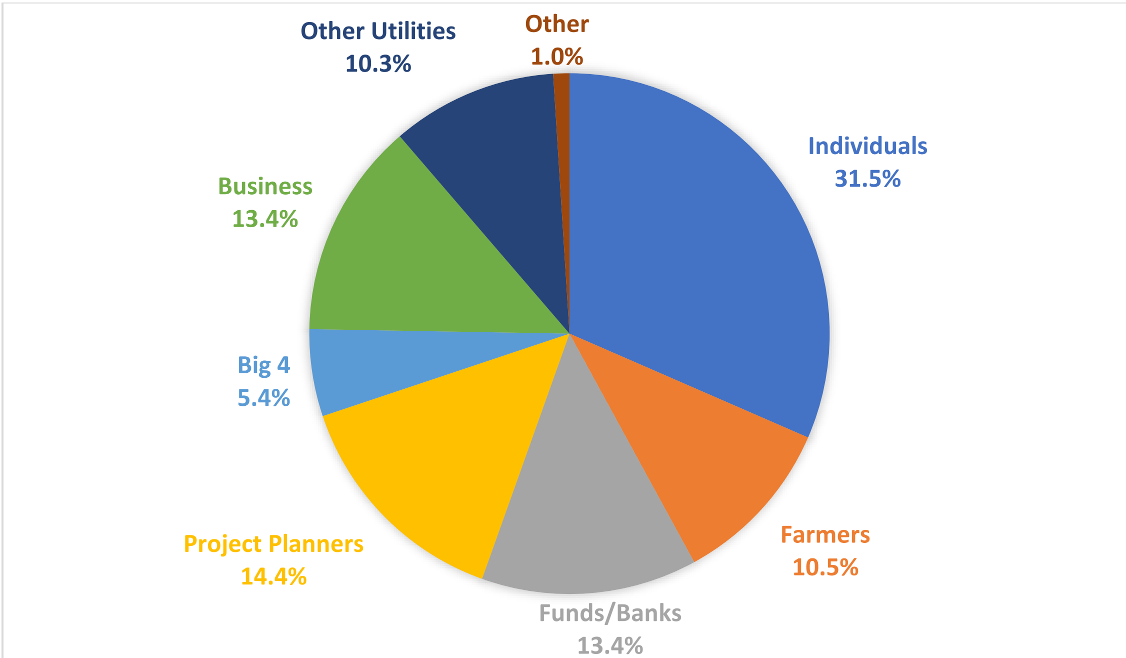

Figure 71 Germany Renewable energy Ownership (Source: Trend Research, 2017)

5.5.4.1.2 Challenges with Solar PV in Germany

Some of the challenges associated with the renewable energy transition in Germany and by extension, solar PV development include

1. The high cost of energy transition: Germany's energy transition is estimated to have cost as much as $200 billion over the last two decades (Reed, 2017). German households pay the highest cost for electricity in Europe. German households were the only households in Europe to pay more than 30 Eurocents/kWh for household electricity in Europe. However, Germans still spend less than 2% of their disposable income on energy (European Commission, 2019).

5.5.4.1.3 Lessons for Nigeria

The most important lesson from the German case study for Nigeria is the importance of a strong legal framework to support energy transition. Also, the consistency of policy over a long period would enhance the possibility of an energy transition. This point has also been proven in the case study of Brazil and Kenya. Policy consistency and implementation is a major challenge with renewable energy diffusion in Nigeria (Oseni, 2012; Elum & Momodu, 2017).

Also, public support for solar in Germany aids the development of solar in the country. A lack of information about clean energy negatively impacts public support for clean energy (Ohunakin, Adaramola, Oyewola, & Fagbenle, 2014). A survey conducted in South west Nigeria by Adewale et al. (2014) concluded that most Nigerian are unaware of the availability and operation of renewable energy sources. However, over 70% are in support of promoting renewable energy sources to address the electricity crisis. Over 80% of respondents indicated a willingness to pay more for electricity if electricity is regular (Akinwale, Ogundari, Ilevbare, & Adepoju, 2014). Wojuola & Alant (2017) reach a similar conclusion in their survey. Most Nigerians believe that renewable energy is more reliable and environmentally friendly than fossil fuels. Respondents also agree that lack of technical knowledge and expertise is a significant hurdle to the development of renewable energy (Wojuola & Alant, 2017). The Nigerian government can leverage this support and raise awareness of clean energy options and benefits.

Government support for relevant programs would be vital to boosting local technical expertise.

The high cost of solar transition as experienced in Germany poses a considerable impediment for a country like Nigeria, given the disparity in wealth. Nigeria has a renewable energy feed-in-tariff (REFIT) program, which has failed to make an appreciable impact in the energy mix. One reason for this is the failure of the government to fulfill its obligations regarding PPAs signed with interested developers (Adeniyi, 2019). Another African country, South Africa, abandoned the REFIT program after it failed to attract clean energy projects partly due to political and legal challenges. A new auction system known as the Renewable Energy Independent Power Producer Procurement Program (REIPPPP) has achieved a lot more success in promoting clean energy with over 3,000 MW of clean energy projects awards. The adoption of alternative policies such as the auction model could help support a cheaper transition to cleaner energy for Nigeria.

Chapter 6

DISCUSSION, POLICY IMPLICATIONS AND CONCLUSION

6.1 Discussion

One of the indicators of the Sustainable Development Goal 12 “Ensure sustainable consumption and production patterns” is the phasing out of fossil fuel subsidies “in a manner that protects the poor and the affected communities” (UN, 2019). The first research question sought to understand the reasons for the persistence of these subsidies in Nigeria. A theoretical analysis of the history of fossil fuel subsidies and the factors affecting reform was carried out based on existing literature, peer-reviewed reports, and books to answer this question.

The history of petroleum subsidy reform in Nigeria shows that subsidy reform started in the early 1970s and was initially designed to insulate Nigerians from the fluctuation of international crude oil prices. Resistance to petroleum subsidy removal attempts became a recurrent feature from 1986 when the IMF-backed Structural Adjustment Program (SAP) was introduced. SAP was touted as a means of diversifying the Nigerian economy in the wake of low oil prices, but it failed to achieve this and resulted in high inflation and lower wages (Oyejide, 1991). The dominant influences observed from the history of petroleum subsidy reform include crude oil prices, increased fiscal burden, political considerations, and public pressure. Nigeria has typically responded to low oil prices with the removal of petroleum subsidies, ostensibly to reduce the financial burden caused by the associated low revenue collection. Subsidy removal has also been applied as to tool to gain public support, especially close to general elections or at the advent of a new government. Widespread opposition to subsidy removal has often made the government partially restore petroleum subsidies.

The Nigerian electricity sector developed in two main phases, the first phase was a government-controlled vertically integrated phase starting from the early 1970s, and the second is a private sector-driven deregulated industry that began in 2005. In both phases, electricity subsidies played a significant role. Inefficiency, corruption, and the inability of the vertically integrated Nigerian Electric Power Authority (NEPA) to meet energy demand informed the decision to move towards the deregulation of the industry. However, deregulation has not led to market reflective tariffs. My analysis shows that the lack of capacity and inefficiency of distributor companies, theft of electricity, and the resistance towards tariff increase are some of the factors responsible for the persistence of low tariffs. Consequently, the government has had to bail out the electricity market with the injection of funds to keep it operational.

The framework developed by Skovgard & Van Asselt (2018) was utilized to understand factors influencing efforts to reform. This framework divides the factors affecting fossil fuel reform into three main categories, the actors (strategies & interests), ideational factors (norms, ideas, knowledge & belief), and structural factors. Amongst the actors, the Nigerian Labor Congress is the most powerful actor in the resistance of subsidy removal for both the petroleum and electricity sectors. They have led several strikes and protests subsidy removal, often forcing the government to relent. Key reasons identified for these protests include the dependence on fossil fuels to meet basic energy demands and the hardship associated with the removal of subsidies.

Also, norms such as pervasive corruption in the oil subsidy regime as well as the public expectation for low prices influence the persistence of fossil fuel subsidy reform. Beneficiaries of corruption in the petroleum sector are less willing to see the removal of subsidies. Some of these beneficiaries include independent petroleum marketers and some workers of government agencies. Also, an expectation of low petroleum and electricity prices because of the abundance of the primary energy resources locally influences the resistance to price hikes. Structural factors like the significance of the oil to the Nigerian economy, the lack of governance capacity, and local power dynamics also influence the reform of subsidies. Oil is the most significant contributor to Nigeria's government revenue and foreign exchange earnings. Therefore, a drop in global oil prices adversely affects revenue available for development objectives and makes the government more amenable to the removal of subsidies. Also, the lack of capacity of government institutions for more targeted subsidies ensures that these subsidies persist in the current form. The NLC is one of the most organized actors in Nigeria's fossil fuel subsidy regime and has utilized that power in resisting government attempts to eliminate subsidies.

The dominance of fossil fuels in the energy mix, especially for transportation, is a key factor in the resistance against petroleum subsidy reform. Akanle, Adebayo, & Adetayo (2014) argue that there will always be stiff opposition to fossil fuel reform if the population is dependent on fossil fuels for their basic energy needs. Diversification of energy resources in the energy mix could reduce dependence on fossil fuels and reduce the political pressure associated with reform. In a related study, Schmidt et al. (2017) argue that that renewable energy diffusion can help destabilize the fossil fuel subsidy regime by weakening the systemic mechanisms that keep subsidies in place. This dissertation argues that the political opposition associated with fossil fuel subsidy reform can be reduced with the diffusion of cleaner alternatives.

The second research question looks at the opportunities and barriers for these cleaner alternatives. The most common application for fossil fuels in Nigeria is transport, of which gasoline is the dominant fuel. Other fossil fuel applications include off-grid applications like cooking and lighting and electrification. A lack of diversity in the energy mix is a common feature for each of these applications. These sectors represent opportunities for the development of alternatives to fossil fuels. However, several barriers that mitigate against clean energy diffusion in Nigeria, including economic and financial obstacles, market failures/distortions, institutional/ governance barriers, technical barriers, and infrastructural barriers.

The third research question examined the impact of clean alternatives to fossil fuels on sustainable development objectives. It utilizes Nigeria Sustainable Energy for All Action Agenda (SE4ALL-AA) to build scenarios and analyze the potential benefits of clean energy penetration on fossil fuel subsidies and sustainable development by 2030. The analysis showed that higher clean energy penetration would reduce the resources expended on fossil fuel subsidies for both gasoline and kerosene. These resources could be directed towards the development and clean energy objectives. They also reduce the dependence on fossil fuel resources. A transition to clean energy would also reduce energy demand, crop loss, and human mortality, improve the environment, and reduce the impact on the climate, thereby enhancing sustainable development objectives from the base scenario. The analysis also shows that a transition towards clean energy could be very expensive and require investment from domestic and international sources.

However, there are still significant barriers to clean energy diffusion in Nigeria. Case studies of successful penetration of clean alternatives in transportation, off-grid lighting, and electrification are reviewed to draw policy recommendations to overcome these barriers. These case studies are used to derive lessons for clean energy policy formulation and implementation. Brazil's development of ethanol for transportation was selected as the transportation case study, and the factors identified for Brazil's success are the influential role played by the government in the development of the sector and the high production efficiency of sugarcane used in the development of ethanol. Potential drawbacks identified include the discovery of third generation of biofuels and oil reserves, which could shift attention from ethanol and current land laws that prevent foreign investors from owning land.

For off-grid applications, Kenya was chosen as a case study. The success factors in the development of the off-grid market in Kenya include an enabling business environment that promoted local innovation and the vital role of donor agencies in the creation of markets. Other factors are government policies such as the removal of import duties that supported the development of markets and innovative business models. Drawbacks identified for this case study include the existence of unskilled technicians and substandard products, additional costs from intermediaries, and the lack of government incentives for households. Germany was chosen as a case study for electrification. Success factors identified include the robust legislative framework for the development of renewable energy and the strong public support for clean energy. The high cost of Germany's feed-in tariff incentive was the most significant drawback identified from Germany's on-grid solar success.

Some valuable lessons from these case studies for Nigeria include the importance of a strong political will and the adoption of consistent, coherent, but flexible policies that can adapt to changing conditions. Other factors include the promotion of the right business environment, the development of a strong legal and regulatory framework, and the promotion of public support for clean energy. Strong political will was critical in the advancement of cleaner alternatives in Brazil and Germany. The long-term government commitment in both cases ensured that policies were maintained over a long period, even with changing governments. Brazil's adaptation in times of world wars, oil crisis, sugar production imbalances, and change of government highlights the importance of policy flexibility and consistency in driving clean energy diffusion. Strong institutions, legal frameworks, and public support were the most critical factors in the advancement of solar energy in Germany. In Kenya, a business environment that promoted local innovation and investment was critical for the growth of off-grid products.

6.2 Significance of this study

Studies on fossil fuel subsidies in Nigeria have focused on the impacts of petroleum subsidies removal on poverty (Siddig, Aguiar, Grethe, Minor, & Walmsley, 2014; Rentschler, 2016; Soile & Mu, 2015), on businesses (Bazilian & Onyeji, 2012) and the debate surrounding whether to subsidize or not (Nwachukwu & Chike, 2011; Asekunowo, 2012). This study attempts to understand the factors influencing the persistence of petroleum and electricity subsidies in Nigeria and the political cost associated with the reform of these subsidies. It explores the role of the diversification of the energy mix in reducing the political cost of fossil fuel subsidy reform, increasing energy security, and sustainable development.

This dissertation concludes that a cleaner energy mix has positive implications for energy demand and the environment. This conclusion is corroborated by similar studies conducted by Emodi et al. (2017), Aliyu et al. (2013), and Ibrahim & Kirkil (2018). It goes further to examine the impacts on crop loss, mortality, and the climate concluding that the attainment of a cleaner energy mix has positive effects on each of these categories, thereby promoting sustainable development. A more diversified energy mix would also reduce the dependence on fossil fuels and enhance energy security. A potential effect of this is lower resistance to fossil fuel subsidies reform.

6.3 Policy Implications

6.3.1 Fossil Fuel subsidy Reform

The reform of fossil fuels subsidies in many countries is almost always politically contentious and controversial despite the strong policy points against the sustenance of these subsidies. This study corroborates the conclusions of Victor (2009) that suggests that subsidies act as a form of political rent in exchange for public favor. This fact was shown through an analysis of the history of subsidies reform attempts in Nigeria. In 1993, 2011 and 2015, petroleum subsidies were partially restored in what analysts considered attempts to gain public favor in the run-up to elections or at the beginning of a new government. Electricity tariffs were also frozen in January 2015 for six months in the run-up to national elections (NERC, 2015). Therefore, an essential part of any successful reform of fossil fuel subsidies is a strong political will to enact subsidy reform despite the political cost of such efforts.

The lack of engagement between political leaders and other stakeholders, including the NLC and the general populace, is a critical factor influencing the resistance towards fossil fuel subsidy reform in Nigeria. Removal of subsidies has often been carried out abruptly with no notice. In 2012, subsidy removal was announced a few days after the new year, leading to a hike in transportation costs, with many stranded outside their primary places of residence. The result was massive protests and strikes, some of which were violent (Saba, 2012) The development of a transparent and effective communication strategy involving all stakeholders and the general public is critical to reform efforts. The public must be informed of the size of these subsidies, their environmental, economic, and social impacts and government measures to mitigate potential deleterious effects of reform. These efforts at communication must be transparent to gain public trust in the process. Lack of public trust in government is one factor influencing the response to fossil fuel subsidy reform, and this is one of the most common themes of previous subsidy protests in Nigeria (Akanle, Adebayo, & Adetayo, 2013). Thus, any communication strategy must involve gaining public trust.

Also, a common theme in the fossil fuel subsidy regime in Nigeria is the inefficiency and corruption associated with subsidy removal. A 2012 investigation carried out into the subsidy regime indicted several government agencies and institutions as well as private petroleum marketers for corruption and ineptitude. The creation of effective anti-corruption mechanisms within government institutions and in the administration of subsidies is vital for any successful reform attempt. Effective anti-corruption mechanisms are needed to guide the administration of subsidies and ensure that financial savings from phasing out subsidies are effectively applied to support developmental objectives. These mechanisms will overtime build public confidence and reduce the resistance to subsidy reform.

The lack of capacity of some key players involved in the administration of subsidies was also apparent in the 2012 investigation into petroleum subsidies. Agencies such as the Department of Petroleum Resources (DPR) and the Petroleum Products

Pricing Regulatory Authority (PPPRA) failed in the performance of their primary functions. Institutions tasked with subsidies, subsidy reform, and the management of fiscal gains must be strengthened for effectiveness and accountability. New institutions might have to be created to support reform.

A look into the history of petroleum subsidies reveals that more substantial increases in the prices of petroleum products are often associated with more massive protests that have often forced the Nigerian government to reverse petroleum subsidy removal. All price increases above 100% have had to be partially reversed due to demonstrations. A gradual phase-out of subsidies could reduce the shock of reform and help to reduce public resistance to reform and allow for complementary policies to gain traction. As complementary policies develop and alternatives become more prominent in the energy mix, resistance to reform is likely to reduce.

In the electricity sector, many of the existing DISCOs lack the financial capacity to meet their financial obligations or boost their technical and non-technical efficiencies. Enhancing DISCOs efficiencies is critical to improving metering and collections. This step will increase the financial sustainability of the electricity supply system and reduce the burden on government subsidies. A lot of investment is needed on the side of the DISCOs to improve their operational efficiencies as they cannot accept all loads and lack the coverage to collect their tariffs. The DISCOs must attract more capital to invest in current limitations so that they can fulfill obligations and improve the liquidity of the sector.

6.3.2 Clean Energy Alternatives

Case studies of the successful penetration of clean alternatives were utilized to draw up lessons for policy and resolve the barriers against the diffusion of clean energy in Nigeria. Nigeria's renewable energy market is still in its infancy with limited clean energy alternatives in its energy mix.

A critical factor in the early development of a renewable energy market in Kenya was the direct involvement of the government in the creation of markets by government and international donor agencies. Government programs to power schools, hospitals, and other government institutions with distributed renewable energy resources in Kenya created markets off-grid solar products and spurred market development. In Nigeria, government involvement in clean energy development has enjoyed little success. For instance, the E10 biofuel mandate for transportation has failed to make considerable headway despite huge government investment and involvement. This failure has been attributed to inconsistency in government policy and the failure to implement the recommendation of studies (FGN, 2012). Renewable energy policy implementation and monitoring in Nigeria are also faced with inconsistency, sudden changes, and discontinuity sometimes in a single term of a government's rule. New governments often reverse many of the initiatives of their predecessors, resulting in a situation where very few government policies stand the test of time (Adinde, 2018). A common thread in all the case studies examined is the persistence of government and continuity in policy objectives and implementation. Off-grid solar has been in development in Kenya since the early 1970s; Germany's renewable energy revolution is close to 30 years old, and Brazil's history with ethanol development dates to the early 30s. The Nigerian government must be consistent in its approach to developing cleaner alternatives and invest in creating markets for sustainable energy options.

In Nigeria, average import duties for components needed for small scale and large-scale solar projects are estimated to be 11% (BloombergNEF, 2018). Eliminating these duties was an essential part of the development of the solar off-grid market in Kenya as it reduced the cost of market entry and end-use applications for consumers. Private investment played critical roles in the advancement of cleaner alternatives in Kenya and Germany case studies. Nigeria currently ranks 146 out of 190 countries on the 2019 World Bank ease of doing business index, placing low on indicators such as starting a business, dealing with construction permits, getting electricity and registering property. Nigeria ranks 120 on starting a business, 149 on dealing with construction permits, 171 on getting electricity, and 184 on registering a property (The World Bank, 2019e). The enhancement of the ease of doing business is essential to attracting private investment in clean energy.

In 2016, 14 solar utility projects totaling 1.4GW signed power purchased agreements (PPAs) with NBET (Nigerian Bulk Electricity Trading). However, none of the projects could reach a financial close with lenders as Nigeria's ministry of finance in 2018, asked developers to reduce the agreed tariff from 11.5 U.S. cents/kWh to 7.5 U.S.

cents/kWh before a Put-Call Option Agreement (PCOA)[17] can be granted (BloombergNEF, 2018). The inability to support preferential pricing policies and maintain consistency in policy implementation must be overcome to increase investor confidence in existing policy initiatives. The German case study highlights the importance of consistent application of preferential pricing policies. The assurance of guaranteed prices over 20 years under the EEG feed-in tariff policies ensured predictable streams of income and built investor confidence.

Brazil's support on biofuels production is hinged on the fact that sugarcane is widely produced, and the competition with food is minimal. In the case of Nigeria, agricultural efficiency is still low, and most of the crops that can be utilized to produce biofuels have competing uses, and production is still below domestic demand. Agricultural production efficiency in Brazil is more than four times higher than in Nigeria (FAO, 2019a). Sugarcane production is still below national demand, and 80% of cassava produced is used for food (Obayelu, Afolami, & Agbonlahor, 2013). Boosting agricultural efficiency is critical to building capacity for ethanol production, and the utilization of the residues of biofuel crops would reduce competition with food.

One of the challenges earlier identified with renewable energy products in Nigeria is the presence of low-quality products in the market and the dearth of technical expertise. In the Kenyan case study, minimum quality standards reduced the share of

[17] A PCOA is a document from the Ministry of Finance guarantee a project in case of default

poor-quality products in the market with quality-verified products rising to 88% in 2017 up from 3% in 2009 (GOGLA, 2019a). Inferior quality products reduce the longevity of projects and their long-term viability. They also negatively influence the public perception of these products (Berlin PI, 2017). The adoption and implementation of minimum standards by Nigeria could boost the overall quality of off-grid solar products.

The overwhelming support of the public for renewable energy in Germany was a vital element in the advancement of clean energy in the country. Augmenting public support for clean energy in Nigeria would be critical for developing clean alternatives to fossil fuel technologies in Nigeria. Trust in government and a well-developed communication strategy are needed to boost public support for sustainable energy policy (Hagen, Middel, & Pijawka, 2016). Poor local engagement in important policy decisions and direction in Nigeria has played a factor in public distrust in the past (Iroghama, 2012). Information about new policies, policy updates, and new government programs must be publicly available to build public trust and help private investors, industries, small businesses, and individuals make informed decisions on sustainable energy adoption.

Endemic corruption in some of Nigeria's energy institutions and agencies make it difficult for them to operate efficiently. Also, the fragmented and overlapping activities from different stakeholders must be coordinated and streamlined to ensure that everyone is on the same page. In other words, different ministries and agencies must work seamlessly to achieve policy objectives and minimize conflicts. An attempt at such coordination was seen in the Brazil case study where the Inter-ministerial Council for Sugar and Alcohol (CIMA) was set up to ensure the coherence of policy direction in different ministries involved in Sugar and Ethanol production. In Nigeria, policy decisions are made by the Federal Executive Council (FEC), but it is not focused on energy policies but all public policies. Strict financial controls and protocols must be put in place in relevant public sector agencies.

6.4 Limitations of Research

This study limits itself to the study of the effects of fuel change on transportation and other fossil fuel applications. The investigation of other alternatives like mass transit is not analyzed here as they lie outside the purview of the study.

Also, in the development of the LEAP model, the availability of data was a challenge. In the transportation sector, there is limited data about aviation and water travel. Since road transport constitutes over 90% of transportation in Nigeria, the data from road transport were utilized. There was also limited information on non-energy sectors such as the industrial process emissions from the production of cement, chemicals, metals, and waste. The scenario analysis developed leaves out these processes.

The study utilizes historical data to make projections of future demographic, economic, health, and agricultural data. This approach is known as trend analysis. The advantage of trend analysis is that it is based on verifiable data that can be replicated and refined. The weakness of this approach is that it does not consider future uncertainties that might change the trend (Gilliland, Sglavo, & Tashman, 2016). This weakness increases the chances of errors in the model as the forecast gets longer.

The LEAP model presents alternate scenarios and does not represent the full picture due to data unavailability and the uncertainty associated with some assumptions. However, it does provide a basis for conversations for how advancing sustainable energy can provide sustainable development gains.

6.5 Directions for Future Research

This section identifies some of the other limitations of this study and makes suggestions for future research. The areas for future research include:

6.5.1 Sustainable Transportation Study

A study of sustainable transportation options that is not limited to fuel change is a potential area of study. A shift to mass transit buses and trains, as opposed to private cars, would have an impact on sustainable development goals.

6.5.2 The Impact of Subsidy Savings on Development

The impact of fossil fuel subsidy savings on specific developmental challenges can be explored further. How far can subsidy savings be employed to address specific developmental challenges?

6.5.3 Developing the LEAP Scenario Analysis Model for other studies

Access to more data on industrial emission processes and other unavailable data can improve Nigeria's LEAP model. An analysis based on current and proposed renewable energy policies could also provide insights on their long-run impacts on Nigeria's energy demand, supply, and other sustainable development indicators if the goals of those policies are achieved.

6.6 Conclusion

The history of petroleum subsidies suggests that reform attempts are not usually a consistent government policy but are pushed forward due to prevailing fiscal and political conditions. Financial health is a significant factor in the government's attempts toward subsidy reform. Since oil is the mainstay of the Nigerian economy, fluctuation in oil prices influence government policy towards reform. Inadequate financial resources in times of low oil prices and high fiscal burden of paying subsidies in times of high oil prices have been shown to push the government to remove or reduce subsidies to make more resources available.

Electricity subsidies exist primarily because of the unsustainability of the current natural gas dominated electricity system. The insolvency of the system means that the main actors are unable to pay for services needed to meet demand. The government has had to intervene in the sector to keep it running.

A lack of clear government policy direction towards fossil fuel subsidy reform is a recurring trend through the history of petroleum subsidy reform. Subsidies have often been reinstated by new governments or during election years, seemingly to gain public support and reduce opposition. Apart from the period between 1999-2007, there has hardly been attempts to reform subsidies without preceding oil price shocks or new political events.

The centrality of crude oil to government revenues means that the trend of policy unpredictability is set to continue without diversification of the Nigerian economy or a fall in demand for subsidized petroleum products. The lack of alternatives for petroleum products and the inflationary trends associated with price hikes are some of the reasons why reform attempts are strongly resisted.

The strengthening and reforming of local institutions and systems are vital to push any coherent policy action to petroleum subsidy reform. Already, there are actors in the fossil fuel regime who benefit from the corruption and inefficiencies of the current system. These actors range from corrupt employees in institutions charged with the regulation and management of the system to marketers who exploit the weaknesses of the system. Any attempts to change or reform the system is likely to be opposed by these parties.

This dissertation explored the applications of fossil fuels and the opportunities to introduce cleaner alternatives. Cleaner alternatives would reduce the sole dependence on subsidized fossil fuels, increase energy security and, by extension, reduce the opposition to reform or reduce subsidies. A reduction in the political cost of subsidy reform would make it easier for the government to act towards reforming subsidies, thereby freeing up essential resources that can be employed towards developmental objectives. New distributed clean energy systems can also introduce new business models that can be tapped into by utilities to boost liquidity in the electricity market, thereby reducing the burden of government to support the sector. Increased liquidity would also enable DISCOs to invest in increasing the efficiency of their operations and improve the ability to collect revenue. Also, this dissertation shows that clean energy penetration promotes sustainable development goals, including providing economic, environmental, health, climate, and agricultural benefits.

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APPENDIX

MARKAL and TIMES

MARKAL was developed by the Energy Technology Systems Analysis Program (ETSAP) of the International Energy Agency (IEA). It is one of the most widely used linear programming optimization model. The application is used for estimating the associated impacts of energy planning policies over a period. MARKAL is a bottom up optimization modelling tool as it considers technological options in evaluating the linkages between the economy and the energy system. The top -bottom approach on the other hand utilizes aggregate economic variables in evaluating energy systems (IPCC, 2001). Future technology configurations, market-based instruments and other policies can be modeled with constraints placed on the rates of penetration and types of technology. MARKAL will provide the least cost solution based on the set of constraints. Figure 72 shows the building blocks of the MARKAL software. It includes all the steps involved in the supply (imports, exports and production), conversion (refinery, fuel processing…) and end use demand (residential, commercial and industrial) for energy services. The MARKAL model has evolved overtime to include different modeling techniques to address the same needs. Table 23 shows the different versions of the MARKAL software in use (Seebregts, Goldstein, & Smekens, 2001).

TIMES (The Integrated MARKAL-EFOM System) was introduced in 1999 by the International Energy Agency's Energy Technology Systems Analysis Program (IEA-ETSAP) and expanded on the robustness of MARKAL with the ability to address new application areas from local energy planning to technology-rich global modeling (Seebregts, Goldstein, & Smekens, 2001). The inputs in TIMES are made up of four types: energy demands, resource potentials, a policy setting, and the descriptions of a set of technologies. Figure 73 shows a schematic diagram of the inputs and outputs of TIMES.

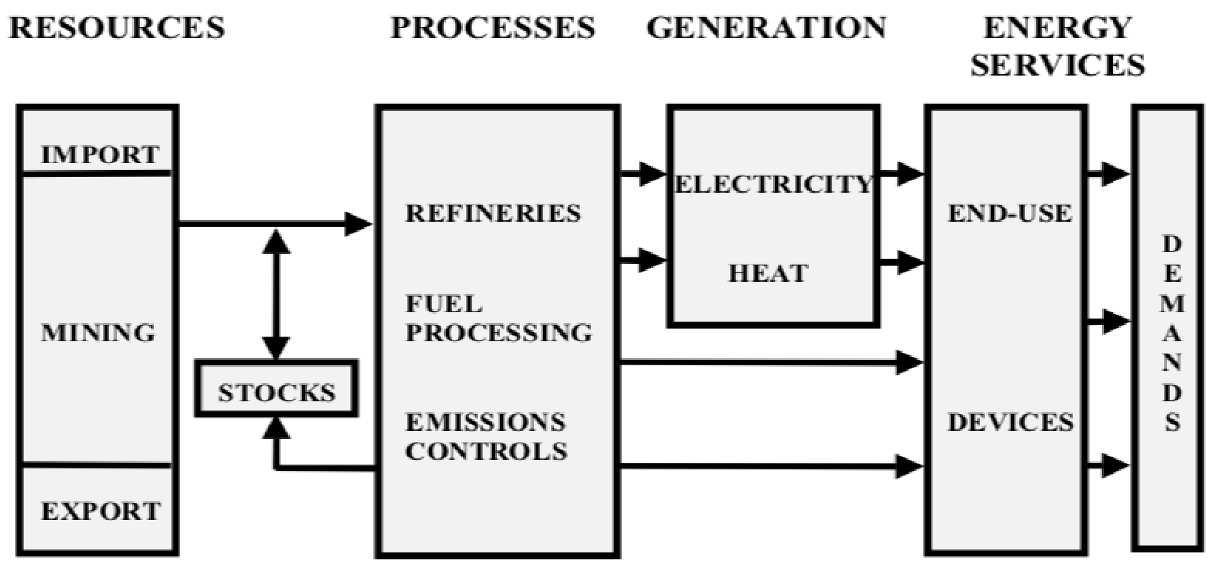

Figure 72 MARKAL building blocks (Source: Seebregts, Goldstein, & Smekens, 2001)

Member/version	Type of model	Short description (Reference or example
MARKAL	Linear Programming (LP)	Standard model. Exogenous energy demand. (Fishbone et al. 1983)
MARKAL-MACRO	Non-linear Programming (NLP)	Coupling to macro-economic model, energy demand endogenous. (Hamilton et al. 1992)
MARKAL-MICRO	NLP	Coupling to micro-economic model, energy demand endogenous, responsive to price changes. (Regemorter and Goldstein 1998)
MARKAL-ED (MED)	LP	As MARKAL-MICRO but with step-wise linear representation of demand function. (Loulou and Lavigne 1996)
MARKAL with multiple regions	NLP	Linkage of multiple country specific MARKAL-MED and MARKAL-MACRO, including trade of emission permits. (Bahn et al. 1998)
MARKAL with material flows	LP	Besides energy flows (electricity, heat) material flows and recycling of materials can be modelled in the RES. (Gielen et al. 1998)
MARKAL with uncertainties	Stochastic Programming	Stochastic Programming. Only with standard model. (Ybema at al. 1998)
MARKAL-ETL	Mixed Integer Programming	Endogenous technology learning based on learning-by- doing curve. Specific cost decreases as function of cu- mulative experience. (Barreto and Kypreos 1999)

Table 23 MARKAL family models (Source: Seebregts, Goldstein, & Smekens, 2001)

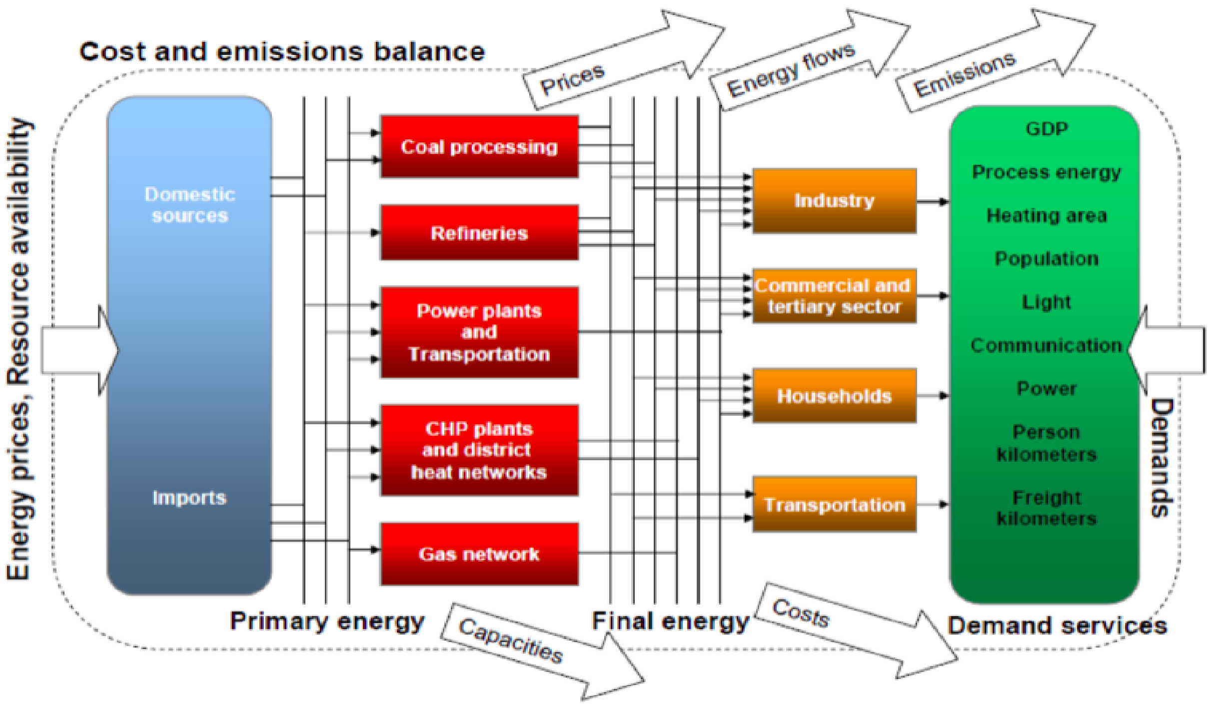

Figure 73 Inputs and Outputs of TIMES (Source: Remme , Goldstein, Schellmann, & Schlenzig, 2001)