OPTIMAL INVESTMENT DECISION MAKING ON GAS TO POWER PROJECTS IN NIGERIA

By

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ABSTRACT

The increasing demand for electric power in Nigeria,due to population and industrial growth coupled with inadequate supply from hydropower stations is stimulating interest in Gas to Power Projects (GtPP) investments. Most reported investment decisions have focused on planning and designing of the investment on GtPP with little attention to optimisationconditions of investment. This study was therefore designed to determine the optimal investment conditions for electricity generation in Nigeria either at natural gas sources or at central locations away from the gas fields.

Keynes, Hayek and Fisher Theories of investments provided the framework. Cost data for gas and electricity productions were obtained between January 2013 and December 2017 fromEgbin Thermal Power Station(>100km to the gas source); and Transcorp Power Ughelli, Sapele Power Station, Niger Delta Power Holding Company, Sapele and Nigeria Gas Company, Ekpan(≤100km to the gas source). Real option analysis and Monte Carlos Simulation were used to obtain an optimal investment model. The model was applied to obtain optimal gas and electricity prices for GtPP located away and near the gas source. Volatility was varied to determine waiting and investment regions for the GtPP.Data were analysed using descriptive statistic.

Gas price for plants located near the gas fields increased from \$1.70/mbtu (Million British Thermal Unit) to \$6.83/mbtu, while plants located away from the gas fields also increased from \$3.60mbtu to \$9.50/mbtu. There was a sudden fall in price from \$4.04/mbtu in April 2015 to \$2.16/mbtu in May 2015. The price of electricity generated near the gas fields rose from \$0.03/kWh to \$0.07/kWh. It rose sharply to \$0.08/kWh in January, 2015 before a fall. Price of electricity generated away from the gas fields rose to \$0.09/kWh from \$0.05/kWh.Analyses show that gas price for plants located near the source stood at \$4.32±2.07/mbtu, and away from the source at \$6.30±2.06/mbtu, exhibited wide variation, while electricity price for plants located near the source stood at \$0.06±0.02/kWh, and away from the sources at \$0.08±0.02/kWh, exhibitednarrow variation. The real option analysis of gas prices revealed that the plant gave higher net present value of the investment at higher levels of volatility. Simulation runs with 20 paths indicated high level of uncertainties in the future prices of gas and electricity; as a result of no clear patterns shown between the different paths. Alternatively, the random movements of gas and electricity prices are seen to have mimicked the Brownian motion theory.

Optimal investment conditions for electricity generation exist in Nigeria and itis economical to invest in gas plant near the source when the volatility and prices of the gas is within the region while it is economical to investment in gas plant away from the source when the volatility and prices of the gas is within the region for gas plant away fromthe source.The optimisation of electricity cost, gas prices and distance to gas fields will make it easier to take final investment decision on Gas to Power Projects in Nigeria.

Keywords: Optimal investment, Gas to Power Projects, Gas utilization.

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DEDICATION

This thesis is dedicated to my late mother, AlhajaSariyuAyoniAyinde.

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Taofeek Olayinka Ayinde.

CERTIFICATION

I certify that this work, being the effort of TaofeekOlayinka AYINDE (Matric number: 189216) of The Centre for Petroleum, Energy Economics and Law, University of Ibadan, was carried out under my supervision.

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CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Nigeria is Africa's largest oil producer, holds the continent's largest natural gas reserves, and was the world's fourth largest liquefied natural gas (LNG) exporter in 2015. (BP, Statistical Review of World Energy, 2015). In 1971, more than a decade after oil production started in the oil-rich Bayelsa State in the 1950s, Nigeria became a member of the Organisation of the Petroleum Exporting Countries (OPEC) (OPEC, 2015). Although Nigeria is the leading oil producer in Africa, production is affected by sporadic supply disruptions, which have resulted in unplanned outages of up to 500,000 barrels per day (b/d).Nigeria's oil and natural gas industry is primarily located in the southern Niger Delta area, where it has been a source of conflict. Local groups seeking a share of the wealth often attack the oil infrastructure, forcing companies to declare *force majeure* on oil shipments (a legal clause that allows a party to not satisfy contractual agreements because of circumstances beyond their control). At the same time, oil theft leads to pipeline damage that is often severe, causing loss of production, pollution, and forcing companies to shut in production.

Aging infrastructure and poor maintenance have also resulted in oil spills. Natural gas flaring (the burning of associated natural gas that is produced with oil) has contributed to environmental pollution. Protests from local groups over environmental damages from oil spills and natural gas flaring have exacerbated tensions between some local communities and international oil companies (IOCs). The industry has been blamed for pollution that has damaged air, soil, and water, leading to losses in arable land and decreases in fish stocks. Nigeria's oil and natural gas resources are the mainstay of the country's economy. According to the International Monetary

Fund (IMF), oil and natural gas export revenue, which was almost $87 billion in 2014, accounted for 58% of Nigeria's total government revenue in that year. Oil and natural gas revenue is the country's main source of foreign exchange, making up more than 95% of Nigeria's total exports to the world in 2014(IMF Country Report, 2015).Nigeria's generation capacity was 10,022 megawatts (MW) in 2013, of which 7,892 MW (79%) was from fossil fuel sources, 2,040 MW (20%) was from hydro sources, 88 MW from biomass and waste (<1%), and 2 MW (<1%) from wind. Net electricity generation falls well below capacity and was 27.5 billion kilowatthours (3,140 MW) in 2013, or less than half of capacity. Nigeria's power sector suffers from poor maintenance of electricity facilities, natural gas supply shortages, and an inadequate transmission and distribution network. Only 45% of Nigerians have access to electricity and actual electricity demand in Nigeria is estimated at 10,000 MW.54

The demand to plan an investment is influenced by the investor's past profit experience and his guesses about profit future profit opportunities. Investors are willing to invest in stocks as well, where their decision depends on their past experience and the expected rate of sales. "In making his plans a businessman takes account on the one hand on the expected rates of profit and the riskiness of the various potential investment opportunities to him; and, on theother hand, of the cost of finance. If the expected rate of profit exceeds the cost of finance by the margin required to cover the risk element, businessman would wish to undertake project (Harcourt *et al.*, 1967, p151)."The decision of the investor to invest is subjective.Investor's decision depends on the expected costs, his knowledge ofthe improved techniques and his risk perception, which is entirely a subjective factor. Investors want to know the investment project's pay-off period to decide whether they actually will make the investment expenditure or not(Harcourt *et al.*, 1967).For a good investment decision, the investor needs to understand completely and correctly thepossible opportunities and these decisions should not be made in a rush.

A wrong investment decision can leadcompanies even to bankruptcy. It is necessary to understand the basic ideas of the investmentdecisions to obtain themaximum value from the appraisal process. In investment evaluation, the indicators should be chosen regarding thespecific nature of the project and the information held by the decision maker(Avram *et al*., 2009). Investment is an allocation of resources for medium or long term and the expected effect is to recover theinvestment costs and have a high profit. Besides financial resources, material and human resources are used as well.The economic and financial environments influence investments, so expected results are uncertain (Avram *et al*.,2009). Investment decisions are made after a complete analysis of the investment project. One of the basic factorsthat influence the decision is the risk factor of the investment. This risk exists because it is uncertain that the cost ofthe investment will be recovered and a profit will be gained.In other words, the central focus of this study is to determine an optimal investment decision making for gas-to-power project in order to create a room for effective production and use of natural gas in Nigeria.

1.2 Problem Statement

Nigeria has a huge proven reserve of about 187 tscf (scf) (BP, 2013; NNPC, 2015). This makes Nigeria the world's ninth largest. These gas reserves can increase to 600 trn (scf) with intensive gas exploration (Oxford Business Group, 2013). In recent years, gas has become the preferred fuel for electricity generation due to higher transformation efficiency, lower relative capital investment and modularity, ease of delivery and reduced maintenance, lower pollutant emissions, increased availability, and lower relative price.The country's production is estimable of 8.24 billion standard cubic feet per day and comprises associated gas (98tscf) and non-associated gas

(89tscf). However, even with the huge resources, electricity supply is not adequate to satisfy local demand needed to achieve development. One of the reasons for insufficient power supply is gas supply shortage for generating electricity. A substantial volume of the associated gas produce is flared, leading to loses estimated at about US$18.2 million daily from revenue losses from flared (PTFP, 2015).

Over 70 percent of Nigeria's electricity generation as at 2015 uses gas as the source of fuel and it is expected that the thermal power plants will continue to be a major driver of domestic utilization of gas after privatization (World Bank, 2015). Also, Gas Monetization Projects would encourage investment in gas infrastructure as well as utilization of gas that would otherwise have continued to be flared. A number of investments in gas-based industries will increase the domestic use of gas.The oxygen of any economy is electricity and access to electricity is a measure of prosperity for any nation (World Economic Forum 2014). In 2015, Nigeria reached an average peak generation about 4,800 Mw. Failure to attain more than 5000MW is attributed to gas supply outage.

The shortages of natural gas severely affect the country's electricity generation network. These arise from the existing competition between domestic supply and export in which gas producers prefer to export rather than selling domestically at a much lower price; from inadequate security to protect gas pipelines; and absence of effective policy and commercial framework for gas-to-power operators. The issue of gas supply was ignored when establishing gas power plants but the new leaf is emerging after the privatization in 2013. Generation segment of the electricity sector would be seriously affected as a result of inadequate gas supply because gas-fueled plants account for over 70 percent of the entire electricity generation in the country, and this share is expected to increase even with significant contribution form hydro, renewables and coal. The

Gas Master Plan of 2008 was aimed at addressing three fundamental issues which include policy of gas prices, legal agreement of the supply of local gas, and a blueprint for gas basic facilities and services. Prior to November 2013, all segments of the electricity sector was mainly owned and managed by Nigerian government which also acted as the investor of the whole electricity system. The electricity investment cost was covered through sale price and state subsidies or profit surrender. Spending over US$60 billion to resuscitate the sector has been proved to be abortive because of inadequate supply of electricity to meet the continuous demand for electricity in the country. In addition, majority of Nigerians still live without access to electricity.

The sector witnessed another landmark in November 2013 by transferring the ownership of generation and distribution segments to the private investors for the purpose of closing the existing gaps in the area of infrastructure and investment. However, with the changes of ownership in the sector, the country has not been able to generate more than 6000MW for over the past two years of privatization. In addition, without adequate gas supply to generate the electricity, the capacity of the country's economy to achieve sustained inclusive growth will be unrealistic.

However, due to capital intensive nature of the sector with long payback period, there is need for a stable policy framework that would invest into electricity infrastructure. In the light of this, the study intends to provide answers to these research questions: When is it more economical to generate power from gas at source and transmit power? When is it more economical to transfer gas from fields to a central location and generate power there? What must be done to incentivize optimal investment needed in improving gas supply for small or household gas-power projects?

1.3 Objectives of the Study

The main objective of the study is to determine an optimal investment decision making for gas-to-power project in order to create a room for effective production and use of natural gas in Nigeria. To achieve this, the following specific objectives are to:

1. Investigate when it is more economical to generate electricity either at gas source or a central location away from the gas source.
2. Determine optimal investment needed in boosting gas supply for power plant projects
3. Analyze the economic viability of small or households Gas to Power Projects.

1.4 Significance for the Study

Numerous studies such as Juan and Xueqian (2012); Wilko and Reinhard (2014); Zhe and Yanzhong (2015); Li *et al*. (2013) have investigated the optimisation of power investment. For instance, Juan and Xueqian (2012) utilized linear programming model to design economic decision-making for production while Li *et al*., (2013) developed a 2-Stage optimal design and planning approach for combined heat, coolingand power micro-grid system.

Studies on Nigeria mainly focus on gas domestic utilization, gas pricing and legal and regulation framework (see Oyewumi, 2015; Omisakin 2012, as cited in Akande, 2015). Scanty researches have been conducted on investment decision making in gas-power projects. Therefore, this serves as the main justification for the study by filling the existing gaps in the area of gas-power research and methodology in Nigeria.

Gas is generally considered the preferred input for power plants due to low costs and low emissions, but ensuring a reliable gas supply to power producers is a great challenge in the country. However, government has been put in place different measures to encourage investment into gas-power project such as a three-to-five year tax holiday and other tax breaks; Solidified regime for guarantees to help stimulate investment; supply contracts at various points in the process; higher tariffs and additional infrastructure to transport gas to plants.

On the other hand, competition in the market means that private producers have to determine whether to spend generation power and what kind of production engineering to choose from. This calls for producers to evaluate investment performance in the energy sector and to examine the economic output of generation technologies with a view to optimizing gains or reducing investment risks.

However, the restructuring of the industry has radically altered the boundary conditions and created a great deal of instability in the power structure. The sources of volatility in line with the generation expansion plans include energy production, power supply, transmission and use, as well as pollution emissions. This obliges decision-makers to consider primary factors in addition to risks and uncertainties. Decision-making on generation investment requires investment in both resources and technology. It is therefore important to model generation investment optimization in particular in order to find an optimum solution to the problem of generation development choices.

The need to boost the efficient domestic use of gas complemented with environmental consequence of gas flaring has led to a significant shift towards natural gas as the backbone for the country's hydrocarbon industry. Therefore, the main issue in the country is how the gas could be exploited to boost the power sector since over 70 percent of electricity generation companies use gas as their fuels. This study provides significant contributions in formulating and implementing policies towards effective and efficient exploitation of natural gas to generate optimal electricity.

In determining optimal investment decisions in gas-to-power projects, the investors have to ensure that there is sufficient gas flows and adequate electricity distribution to receive the amount of electricity generated.

1.5 Scope of the Study

The study used cost data and other related parameters from selected thermal power plants in Nigeria between 2013 and 2017.and simulated parameters for between 2018 - 2030 (from Egbin Thermal Power Station, Egbin, Transcorp Power, Ughelli, Sapele Power Station, Niger Delta Power Holding Company, Sapele and Nigeria Gas Company, Ekpan). This period is based on the reason that privatization of generation segment concluded in 2013, and Paris Conference in December 2015 had taken 2030 as year to end global gas flaring.

1.6 Study Area

This study covers power stations in Nigeria (see Figure 1.1), primarily thermal power stations. There seem to be reportedly two primary categories of energy plants operating in the country: hydro-electric and fossil fuel stations. By a combined volume built of 25 units,255.2MW of which roughly 4978MW is eligible for delivery (see Appendix 3). There were dual main forms of fossil fuel stations in the area: coal-fired and gas-fired.

More than 45 years ago, Nigeria electricity generation has evolved from gas-fired, oil fired and hydro-electric power stations to coal-fired stations. At present, hydro-electric power systems and gas fired system take precedence in the energy-mix. The southern part of the country hosted gas-fired plants, and the hydro-electric powered plants are located further Jebba, Kainji and Shiroro.

The private generation companies (GenCos), Independent Power Producer (IPP) and the generation stations under National Integrated Power Project (NIPP) control the operations of the power generation sector.

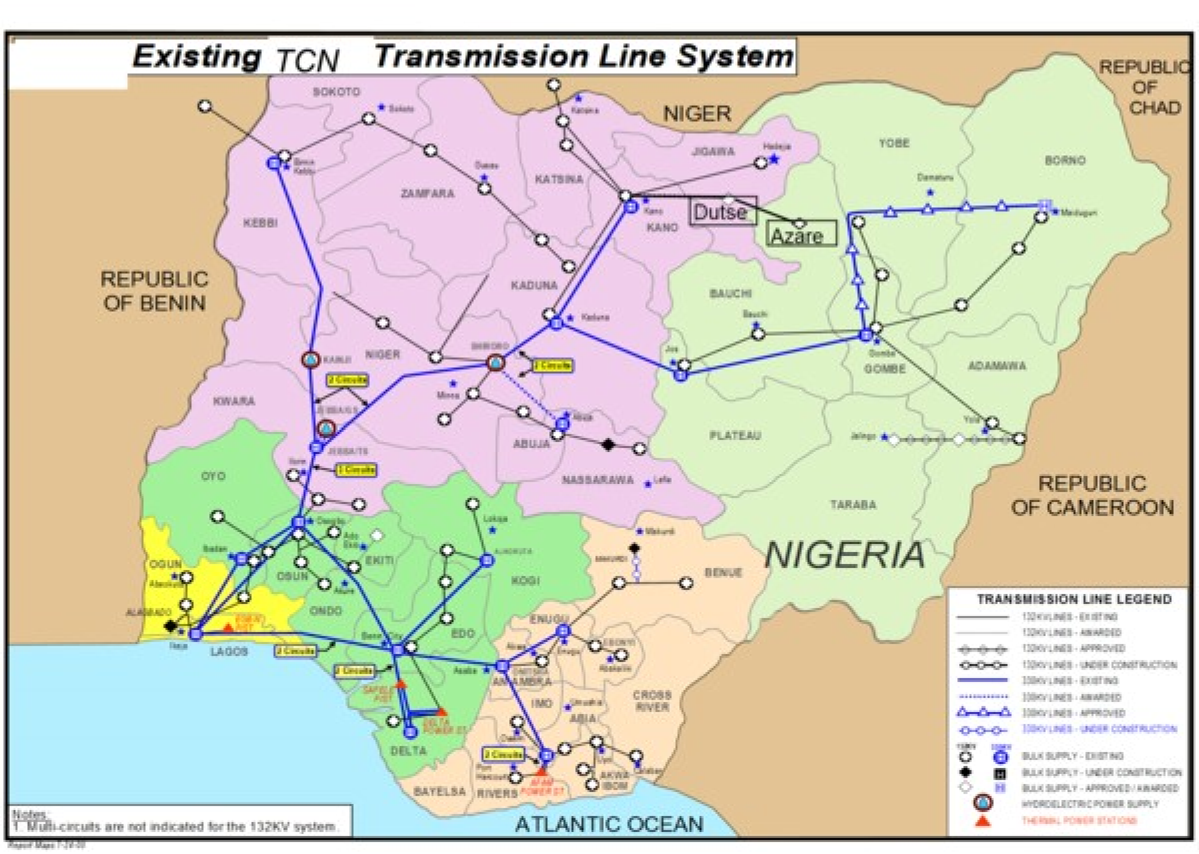


Figure 1.1: Map of Nigeria Showing thermal power plants and location
Source: Nnaji (2011) Power Sector Outlook in Nigeria: Government Review Priorities

1.7 Plan of the Study

This study is structured into five chapters. Chapter one introduced the backgrounds and the main objectives of the study. Chapter Two entails extensive reviews on existing studies on investment decision making in electricity systems while Chapter Three provides theoretical framework and methodology developed to address the main objective of the study; the empirical analysis is presented in Chapter Four. Chapter Five summarizes the findings, making conclusion and recommendation as well as limitation of the study. In addition, it identifies further areas of research.

CHAPTER TWO

LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.0 Introduction

This chapter extensively reviews the previous studies in relation to investment decision making in energy sector especially in the electricity sub-sector.

2.1 Theoretical Reviews

According to Keynes and Fisher (1936), investment decisions are made when the actual value of the projected future revenues at margin is the same as the opportunity cost of equity (Gao, 2004). This assumes investments are generated before the net present value is zero. To them, the net present value can be expressed as follows:

$$NPV = -C_0 + \int_0^{\infty} C(t)e^{(g-r)t}dt \qquad 2.1$$

Where g represents growth rate and r denotes the opportunity cost of capital (discount rate); while C is the cash flow. The investment will be worthwhile if the expected return on investment exceeds the opportunity cost of capital. Keynes considers the return on investment as the marginal efficiency of capital while Fisher uses it as internal rate of returns.

However, both Keynes and Fisher have different views on risk and uncertainty. Keynes did not consider investment as an equilibrium change method, since he belief that human was animal spirited, encompassing irrational and volatile expectations. on the opposite direction, Hayek (1941) and Fisher (1930) interpreted investment as an efficient change direction towards an optimum capital stock.

Many modern investment theories have emanated from Keynes and Fisher. These theories include neoclassical theory of investment (Jorgenson's 1960); accelerator theory of investment (Samuelson, 1939); Tobin's Q (Brainard and Tobin, 1968; and Tobin, 1969); and marginal q (Mueller and Reardon, 1993) etc.

The neoclassical theory, accelerator principle and Tobin's Q-theory of investment are based on the assumption of optimization behaviour on the behalf of the investor. However, all the three theories with the exception of the accelerator theory explicitly assumes profit/value maximization. The accelerator theory implicitly assumes that investment is determined by an optimal capital stock.

The neoclassical theory of investment assumes that capital changes automatically and fully to the capital stock required, the purpose of the investment is effectively removed. This implies that Jorgenson's theory of capital rather than investment.

- *The accelerator method* is linked with a Keynesian approach because of fundamental assumption of fixed prices. Prices related to output and inputs are assumed to be constant. This leads to the assumption that the optimal capital stock is supposed to be proportional to demand, and expenditure would therefore depend on production growth in any time span. If there is adjustable pricing and modification to the required capital stock, the output and supply costs and interest rates (financial cost) are calculated for each cycle of investment. The edition assumes the capital stock is balanced in full and instantaneously.An alternative version called the mobile accelerator that has capital stock lags, is utilized by studies such as Eisner and Strotz (1963), Lucas (1967), Eisner and

Nadiri (1968). However, all these versions are linked to Keynes who did not agree the investment is calculated as a balance-adjustment towards equilibrium.

- *Q-theory of investment* addresses the two basic problems associated with both the accelerator theory and the neoclassical theory investment. The Q-theory applies the modification of the cost function to the optimization problem as a way of addressing the expectation that the capital stock will be automatically modified to its desired level, as postulated in the other theories. Second, the q-theory corrects the assumption of no role for expectation in neoclassical and accelerator theories by adding marginal adjustment cost function to the profit function.

The Q-theory foreshadows Keynes (1936) argument that "it makes no sense to build a new business at a cost greater than that at which a current one can be bought."The theory considers that investment is made until the market value of assets is equivalent to the replacement cost of assets. In addition, it encapsulates all the assumption made in the neoclassical theory of investments but imposes a restriction on the speed of capital stock adjustment by including an adjustment cost function.

There are several ways for a company to control its allocation of properties, either to introduce more to the allocation or to withdraw it. Also, it may take a decision to make do with its assets now or delay them till future. Different values are attached to different options considering the level of global uncertainty. Therefore, real options are segmented into the following: wait to invest; sell an asset; be flexible; and expand etc. Among those that formulated the real option theory are Schwartz and Brennan (1985), Pindyck and Dixit (1994) and Trigeorgis (1996), Pindyck (1988).

2.1.1 Energy Sector and the Real Options

Real choice research is very important for energy technologies because the design of the projects encompasses the properties that are consistent with the principle of real options.These properties include large sunk investment cost in power plants, flexible production; option to expand capacity;

Recent studies have employed real options analysis to value many energy projects. For example, Deng *et al*., (2001) used specific options analysis to assess peak demand power stations and transport efficiency. Thomson (1995) explored the importance of take-up or pay contracts by applying the principle of real options. In fact, Dobbe*et al*., (2003) performed a specific choice analysis to determine the interest of a peak-load gas-fired power station in Norway and to analyze an unlimited license to build such a facility. Fleten and Näsäkkälä (2003) use the actual choice principle to agree on an appropriate investment plan for the CCGT base load project.

The need for stochastic model in investment decisions for power generation assets is very crucial because the high level of uncertainty arising from highly volatile price, technical change and change in regulatory conditions.

Although, in recent years, several researchers have applied stochastic simulations to the energy market. For example, Reinelt and Keith (2007) explored the cost impacts of regulatory instability on retrofit construction by applying a two-dimensional model for various coal-fired power plants based on the Bellman (1957) optimisation theory. Moreover, there are few reports on the quantitative study of the optimum pacing of investment and the optimum combination of technology. This constraint is discussed by the Real Options (RO) models (Dixit and Pindyck,

1994) while the actual options study is expanded to include the waiting factor (McDonald and Siegel, 1986).

Recently, the application of real option models has been tremendously increased in energy literature but more attention is on a single stochastic variable at a time. According to Siddiqui and Fleten (2010), stochastic processes that capture multiple technology choices or risk adjusted discounting as a result of the correlation of underlying assets in question, are still rare. In addition, they argue that a two-dimensional problem is discussed in order to provide answers to the question of whether the phased R&D system might be optimally applied in the light of fluctuating energy rates and running costs.

In the same vein, Fleten and Nasakkala (2010) modeled the spread of sparks and the price of electricity in a stochastic manner. Furthermore, Rohlfs and Madlener (2010) pointed out that the analytical approach is appropriate for the determination of the option value for the two-dimensional problem and for the determination of the threshold value for higher dimensional issues. On this basis, Gahungu and Smeers (2009) applied the Monte Carlo approach, incorporating the estimated number of option values, in order to address the identified issue.

Likewise, Abadie et al. (2010, 2011) used a three-dimensional RO model to assess the optimal timing of the closure of a coal-fired power plant in the European Union. The Kienzle and Anderson (2009) study explored the versatility of management in their multi-real choice model to tackle various sources of risk. In addition, a comparative study was carried out on two combined heat and power (CHP) plates using a Monte Carlo simulation of three properties.

The model of this study considers a situation where an investor is faced with a preference between various power plant technologies and has the added flexibility to delay investment decisions. This is due to the fact that all the technological options considered to produce electricity and the future return on investment relies on fundamental variables such as fuel, electricity and carbon prices. Consequently, the economic risk of such prospective returns depends on the uncertainty of the single underlying and the combination thereof, which are technologically specific (Rolfs and Madlener, 2012).

2.1.2 Natural Gas and Its Sources

Natural gas is known as a cleaner burning and more flexible alternative to other fossil fuels at present. It is widely used in residential, commercial, industrial, transportation sectors as well as expanding its use in generating electricity. However, methane which constitutes 8 to 72 times as potent as carbon dioxide is the main component of the natural gas. The losses of methane as well as its associated emissions differ across locations as a result of sources of natural gas, formation and the available technology employed to extract the gas.

The identified seven sources of natural gas as well as their features are presented below:

1. Onshore: Conventional onshore natural gas is recovered through the process of vertical drilling. This does not require any preparation or stimulation before the recovery of natural gas once it has been discovered.
2. Offshore: the method of its recovery is similar to onshore. However, the natural gas reservoir has to be large in order to make it economically viable. There is a high tendency to produce at very high rates.
3. Associated: associated natural gas is extracted with crude oil but the process of extracting the onshore associated natural gas is the same as the conventional onshore natural gas.

The losses with the extraction of associated natural gas arise from well completion, workovers, and fugitive emissions. The use of oil/gas separators is required to recover natural gas from the mixed product stream. However, the associated natural gas wells do not need liquid unloading because the flow of petroleum safeguards the accumulation of liquids in the well.

4. Tight Gas: This gas is dispersed by impermeable rock or non-porous sand formations. Among technologies used in extracting tight gas are hydraulic fracturing and acidizing. The hydraulic fracturing enhances the production of tight gas by breaking separately the impermeable substances that prevent gas flow, while other agents such as acidification pump acid dissolve limestone and other minerals that impede gas flow (NGSA, 2010).
5. Shale: This natural gas is formed through shale and can be recovered through the use of horizontal drilling and hydraulic fracturing (hydro fracking). Owing to the reduction of wellbore liquids during workover operation, shale gas does not need liquid unloading.
6. Coal Bed Methane: the use of shallow horizontal drilling is highly required to recover natural gas from coal seams. The coal bed methane exhibits almost the same features with shale gas wells.
7. Liquefied Natural Gas (LNG): This implies the compressed natural gas in order to promote the natural gas.

Natural gas extraction involves the construction and development of wells, steady-state operations, and intermittent maintenance activities (US DOE, 2014).

2.1.3 Gas Explorations, Gathering and Utilization Technologies and Electricity Sector

The 1990s marked a significant event as more power generators commenced to utilize natural gas to generate electricity. This led to a substantial demand growth for natural gas. Technological innovations have been contributing to produce greater amounts of natural gas in order to meet the continuous increasing demand. In addition, these innovations have encouraged the development of natural gas from unconventional sources such as natural gas, and conventional offshore and onshore production.

Technological progress has provided the gas industry with the facilities necessary to constantly increase natural gas supply to satisfy the increasing demand. In addition, these revolutionary technologies make natural gas exploration and generation more effective, safe and good for the environment. For instance, these innovations triggered up the size of U.S resources to about 39 percent since 2006 (DOE, 2010). Based on the report of the US Department of Energy, technical advancements mean that at present one well will yield two times as much as one well in 1985. There is a significant decline in drilling waste of nearly 148 million barrels as a result of improved well profitability and lesser wells; and the drilling footprint of well pads has reduced by almost 70% thanks to modern exploration technologies, which is particularly important for exploration in vulnerable areas. So far as environmental impacts are concerned, modern research approaches suggest less reliance on explosives and attenuate the environmental influence of discovery.

Major recent exploration technologies include the following:

3-D and 4-D seismic imaging – the invention of three-dimensional seismic scanning has greatly changed the essence of natural gas exploration. This research utilizes conventional seismic imaging methods, by incorporating powerful computers and processors, to construct a three-dimensional subsurface layer model. Whereas 4-D seismology applies to this, with time as an aspect, enabling the drilling crew to investigate how topography properties evolve over time. They may also more efficiently assess the opportunities for natural gas, position wells more effectively, reduce the number of drilled holes, minimize drilling costs, and minimize exploration time. This will invariably bring economic and beneficial to the environment.

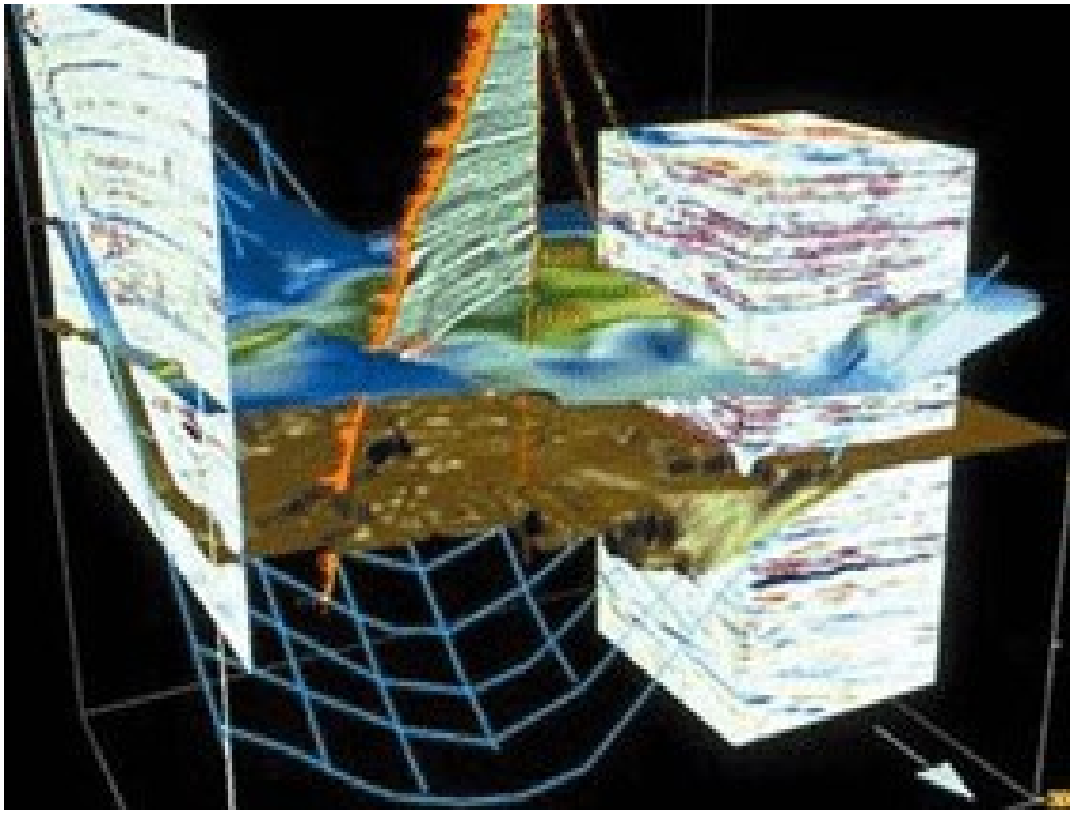


Figure 2.1: Advanced 3-D Seismic, Washington D. C, USA
Source: NGSA

CO_2-Sand Fracturing – The use of fracturing techniques has been dated back to the 1970s. Such fracking techniques help to increase the rate of release of natural gas from groundwater output. CO_2-Sand crack combines sand proppants and liquid CO_2 to fracture formations, building and expanding cracks through which the movement of natural gas is free. The CO_2 then vaporizes, keeping only sand in the formation, with the newly enlarged cracks open. Owing to the absence of leftover from the fracturing process, this type of fracturing effectively boosts an increased recovery of natural gas and oil without any damage to the accumulation as well as the conservation of freshwater supplies.

Coiled Tube–Coiled tubing technology replaced the traditional flat, bent drilling pipe with a wide, flexible and wrapped pipe line. This dramatically reduces the value of drilling, combined with the existence of a smaller drilling density; needs minimal drilling puddles; sets up equipment triggers; and reduces the time usually taken to make drilling pipe contacts.In comparison, combining with slim-hole drilling can be used to have very economical drilling conditions and less environmental effects.

Measurement When Drilling (MWD)–MWD programs enable the gathering of data from the bottom while it is being drilled;which provide up-to-date information about the exact nature of rock formations obstructed by the drill bit to engineers and drilling teams. This contributes an improvement in drilling efficiency and accuracy, and provides better evaluation of the formation as well as reducing the risk of injury to the framework these mismatches.

Slimhole Drilling – This is an act of drilling a slimmer hole in the ground to get to natural gas and oil deposits. Slimhole drilling can substantially boost the efficiency of drilling operations, as well as decrease its environmental impact. Because of its low cost pattern and minimized effects on the environment, slimhole drilling is a tool for efficiently drilling offshore drilling rigs in new locations, drilling deeper wells in developed fields and offering an effective way of producing more natural gas and oil from un-depleted regions.

Offshore Drilling Technology – Offshore gas production is often linked to the aviation industry and NASA because of its deep-water exploration accomplishments, which have been improved by state-of - the-art software. Emerging technology, like advanced offshore drilling rigs, fluid positioning equipment and complex navigation systems, allows efficient and safe offshore drilling in more than 10,000 feet deep waters.

Figure 2.2: Offshore Production-NASA of the Sea, United State
Source: Anadarko Petroleum Corporation

Hydrostatic Cracking sometimes referred to as "Fracking" or "Frac'ing": is embraced for the recovery of natural gas contained in shale mountain ranges. A fluid mixture of 99 per cent water and sand is pumped into the rock at a very high pressure, causing cracks within the rock that allow the natural gas a route to the well. Fracking fluid mixture also helps to keep the structure more stable. Shale gas is now commonly used, with far more than 90% of the oil and gas wells throughout the United States using it to expand production at a certain point in time.Adequate local gas supplies continue to help fuel the U.S. for a considerable amount of time, and innovation plays an important role in providing minimal-cost, eco-friendly means of leveraging such supplies.

Two key technologies reinventing the oil and gas market make growing utilization of photovoltaic crude oil and natural gas. Such innovations will be discussed below.

Liquefied Natural Gas (LNG)

This forms by cooling natural gas to about-260°F at normal pressure results in the condensation of the gas into liquid form. LNG can be very useful, especially in transporting the natural gas because it accommodates nearly one six hundredth of the volume of gaseous natural gas. The effects of LNG liquefaction and regasification are declining due to advances in technology. It will aim to economize depleted oil and gas reserves around the planet in which the building of infrastructure is unprofitable.

Figure 2.3: LNG Delivery Facility with Tanker, United State
Source: NGSA

The rapid use of LNG boosts the production and sale of now commercially unrecoverable natural gas reserves. While it actually accounts for just about 10 percent of the natural gas consumed in the Nigeria LNG imports are projected to provide a stable and secure supply of natural gas for U.S. consumption.

Fuel Cells of Natural Gas

Natural gas driven fuel cells are an incredibly exciting and ambitious emerging technology for safe and effective energy generation. To produce electricity, fuel cells can generate electricity by means of electrochemical reactions against the combustion of fossil fuels.

"A fuel cell functions by moving fuel streams (usually hydrogen) and oxidants over electrodes isolated by an electrolyte. It causes a chemical reaction that creates energy without involving fuel combustion, or heat addition as is typical in conventional electricity generation. When pure hydrogen is used as a fuel and pure oxygen is used as an oxidant, the reaction within a fuel cell only produces gas, heat and electricity (NGSA, 2010)"

The benefits of using the natural gas-powered fuel cells entails the following:

1. Clean Energy–Fuel cells include the cleanest way to generate electricity from fossil fuels. Although its output of carbon dioxide is centred, it can be quickly captured, instead of being exposed to radiation.

2. Generation Distributed – The Fuel Cells Can be built anywhere electricity is necessary. That covers the private, business, manufacturing and even transport industries.

3. Dependability–Fuel cells are a reliable renewable energy source that can run for countless hours. These are also very silent and secure energy sources. Fuel cells often don't have electrical surges, which ensures that they are being used where a constant, reliable supply for energy was needed.

4. Performance – Fuel cells transform stored energy into electricity in renewable energy sources far more effectively than conventional generation of electricity by combustion.This means that less gas is actually needed to maintain that level of energy. A National Energy Development Laboratory estimates that fuel cell power projects will generate between 1 and 20 megawatts with a 70 per cent output range with the use of natural gas turbines, which is much better than the performance that traditional generation technology would achieve within that production range.

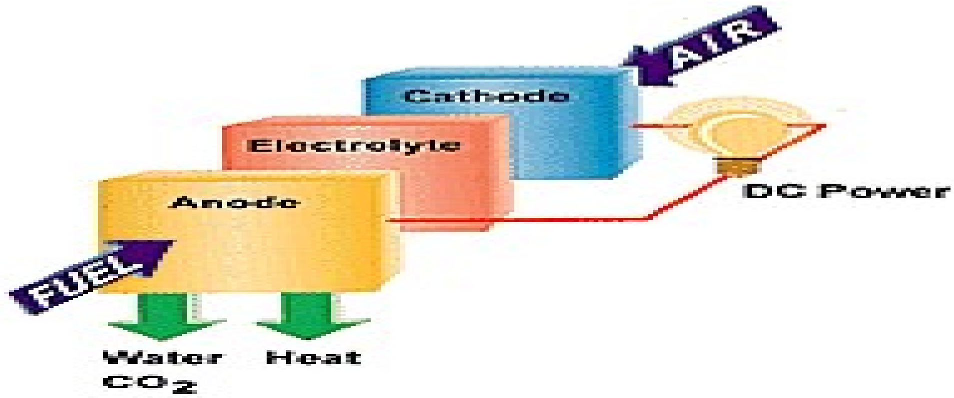


Figure 2.4: Fuel Cell Mechanism
Source: U.S Department of Energy (DOE) 2010

Modern way of producing energy is a very polluting and inefficient operation. However, with the advent of modern fuel cell technologies, the future of power supply is projected to change drastically in the next 10 to 20 years. In fact, intensive work has been conducted to make the fuel cell cost-effective.

2.1.4 Gas Plants and Turbines and Electrical Alternators

Any generating station that utilizes gas turbine as the means of producing electricity is named as a gas turbine power plant. The gas turbine controls the alternator that transforms mechanical energy into electrical energy. Compressor, gas turbine and the alternator are made on the same shaft in order to use the part of mechanical power to operate the compressor (see Figure 2.5).

The gas turbine power plant has utilized as an alternative to hydro power plants in supporting power plants as a starting plant. The gas turbine-based power stations reduce power plant construction time due to their standardized units as well as provide quick returns for investors. In addition, the flexible nature of their gas engines to operate on broad range of fuels coupled with increasing number of distributed power generation as a result of deregulation in the electricity industry provides an additional advantage for gas turbine engine in generating electricity. Nigeria has recorded a rapid increase in the use of gas turbine-based power stations with the construction of 18 new power plants between 2002 and 2014 (Anosike, El-Suleiman, and Pilidis, 2016).

Electricity generation companies in Nigeria realizes the benefits by utilizing gas-fired generators to create electricity in forms of lower capital costs, higher fuel efficiency, shorter construction lead times and lower emissions.

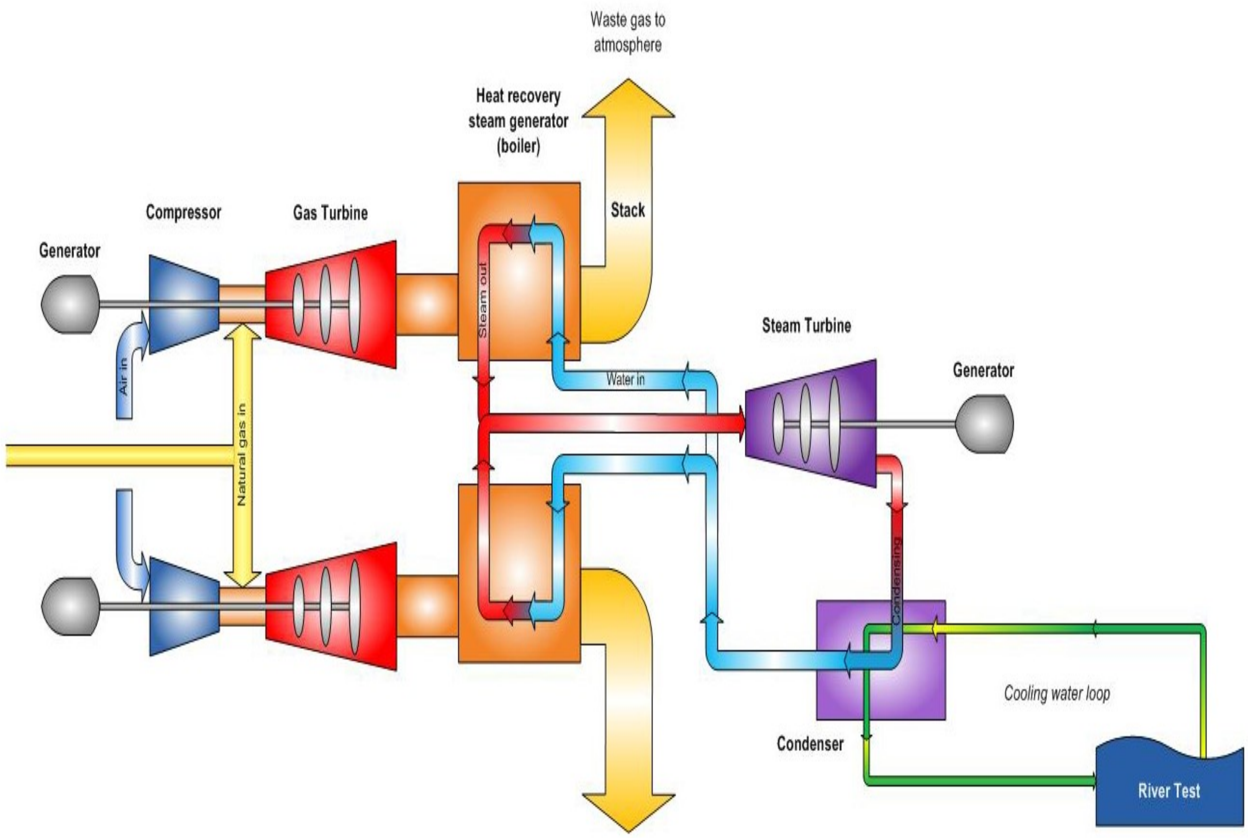


Figure 2.5: Combine Cycle Gas Plant (CCGP)
Source: NGSA

2.1.5 Production and Utilization of Stranded Natural Gas

About 50 percent of the current world natural gas reserves are considered to be stranded, that is uneconomic to deliver to market. The stranded natural gas exists when identified reserves are situated in a remote area or under the ocean floor and/or in complex geologic formations. Other types of stranded natural gas are associated gas or gas discovered in relation with the development of large oil fields.

In Nigeria, the production level of oil influences the volume of associated gas as well as the amount of gas to be flared. For instance, every barrel of oil is accompanied by the production of about 1000 standard cubic feet (scf) of gas on average (Anothny and Anyadiegwu, 2013). This implies that with the production of about 1.4 million barrels per day, nearly 1.4 billion scf of associated gas is produced on daily basis. In the year 2014, it was estimated that gas production of 2.5 trillion scf is wasted with about 11.5 percent or close to 289 billion scf being flared (NNPC, 2014). The export of natural gas by operators in Nigeria's gas sector against domestic usage is higher because the former does not require massive oil infrastructure investment. Therefore, to incentivise investors, the price of the gas-to-power project must be increased.

In addition, gas powered plants in the country face the supply problem of low quality and wet gas (i.e., gas with small amount of liquid present) because the gas suppliers would not invest extra funds to strip and clean up the gas before delivery. The huge capital investment needed to commercialize gas for purposes of power plants is another great challenge facing the sector (Carim and Onyekonwu, 2016).

The practice of flaring gas has no longer been acceptable because of environmental concern as well as the growing economic value of these reserves in a high energy price environment.

According to Aldorf (2008), adding flared gas resources to stranded gas reserves will provide value-added opportunities and protect the environment.

In the light of this, many methods have been employed to bring stranded gas to market. The need to monetize large stranded gas resources complemented with effective utilization of gas resources with environmental concerns has led to the development of liquefied natural gas (LNG), and gas-to-liquids (GTL) Fischer-Tropsch technologies. Other alternative technologies that make the development of small fields- of under-five tcf in size- economically viable, include i) floating LNG ii) GTL floating production storage and offloading(GTL-FPSO), iii) Gas-to-solids iv) compressed natural gas (CNG). Besides, there is a gas-to-wire technology that moves gas or electricity derived from it over short and medium distances with the aid of high voltage direct current (HVDC).

2.1.6 Infrastructure and Accessibility

Most of the gas in Nigeria has been referred to as strandedbecause it remains unusable for either physical or economic reasons. The current infrastructure for the use of gas inside Nigeria includes a transportation network and some gas utilization projects. The infrastructure in use depends on whether the gas field is located onshore or offshore.

2.1.6.1 Onshore Location

When the producing oil field is located onshore, whether land or swamp, the producing well is tied to a flow station, which serves as the collection centre for many wells, and the facility is used to separate gas from the remaining hydrocarbon fluid. Much of the separated gas is flared at the flow station while some is sent to the gas gathering system for treatment for domestic or export use. Gas producing fields are connected directly to the processing plants for treatment (World Energy, 2004).

2.1.6.2 Shallow offshore and Deep offshore

A well located in shallow waters, may be tied to a fixed platform where the gas is partially separated from the remaining hydrocarbon fluid. Offshore wells have been developed with the use of an FPSO, which enable full treatment and storage of the hydrocarbon for immediate export. Associated gas produced in deep offshore via an FPSO can be connected to an offshore gas gathering unit and sent to the nearest LNG facility where it can liquefied and exported (World Energy, 2004).

2.2 Strategies for Nigerian Gas Utilization

Utilization of natural gas in Nigeria has been a topic of discussion in recent years. There are two potential markets for Nigerian Natural gas: domestic markets and foreign or export markets. Domestic markets include power generation, cement industry, Iron and Steel Industries, Fertilizer Industry, Petrochemicals, etc. Export include Natural gas as LNG, pipeline export, NGL, etc. The National Gas Company (NGC), is responsible for local utilization of natural gas. A large potential market exists for investors in this area. Domestic gas demand is about 400 million cubic feet a day (400 MMscf/d), which is very low compared to the size of Nigeria's population and its gas resources. The domestic market is limited by the low level of industrialization and the inadequacy of the gas transmission and distribution infrastructure. The power sector currently accounts for almost 90% of domestic gas sales (CEE, 2006).NNPC and other major E & P operators are currently embarking on several gas utilization projects for export. The major existing and future expected projects include the Gas liquefaction project, Gas to liquid project, Gas transportation by pipeline project, etc. These utilization strategies, both domestic and foreign are discussed in details below.

2.2.1 Linear Optimization in Natural Gas Utilisation

The concept of optimization is an important tool in natural gas transportation problems. Optimization is the act of obtaining the best result under given circumstances. In design, construction, and maintenance of any engineering system, engineers have to take many technological and managerial decisions at several stages. The objective of solving optimization problems is to minimize or maximize some function called the objective function (Kreyszig, 2006).The ultimate goal of all such decisions is either to minimize the effort required or to maximize the desired benefit. Since the effort required or the benefit desired in any practical situation can be expressed as a function of certain decision variables, *optimization* can be defined as the process of finding the conditions that give the maximum or minimum value of a function(Rao, 2009).Linear programming or optimization consists of methods of formulating and solving Linear optimization problems with constraints, i.e., methods of finding a maximum (or minimum) of a linear objective function.

2.3 Global Market in Energy

2.3.1 The Price of Energy (Gas and Electricity)

2.3.1.1The Price of Oil Crude

World oil prices have continued to remain unstable and dangerous, attracting broad interest from decision-makers, investment companies, financial firms, and the university. Figure 2.6 displays the 15-year historical record of values for specified oil and gas sources, including United

Kingdom Brent, West Texas Intermediate andBonny Light on a western oil mart for regulation of dollar within 2000-2015 length of time.

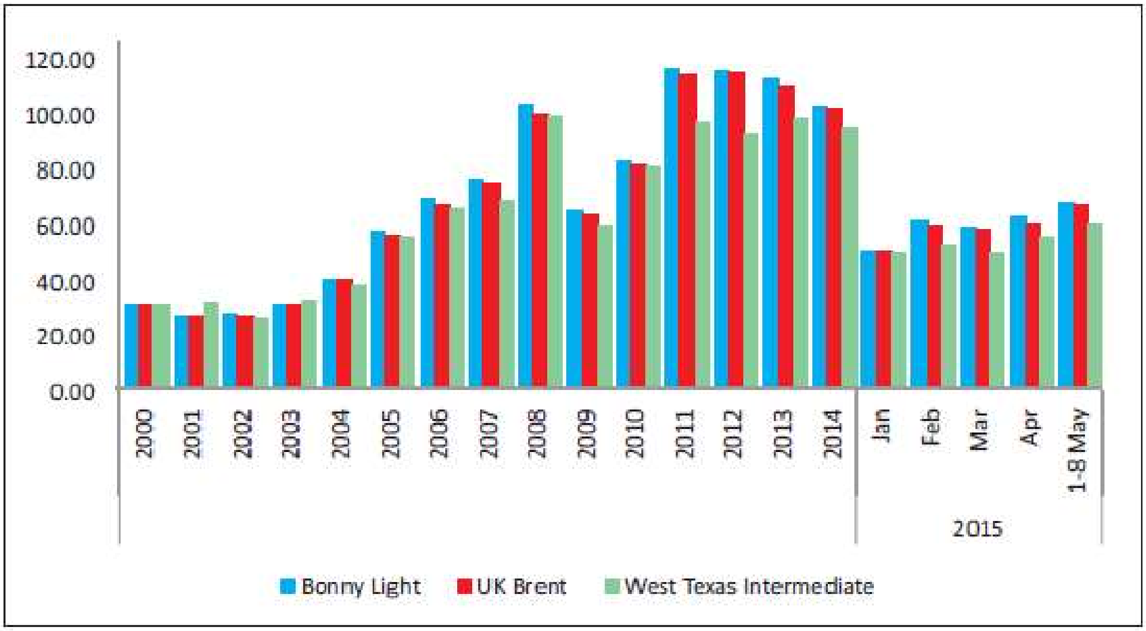


Figure 2.6: Natural Gas Mean Prices (USD$/barrel, from 2000 to First week of May, 2015)
Source: Reuters, May 2015.

Between 2000 through 2003, global oil procurement was limited to keep pace with the increased production largely fueled by global economic growth, mainly in Asia, contributing to a rise in global natural gas prices. As a result, foreign crude oil prices grew gradually with such a level of USD$ 38 per one barrel of oil in 2004 hitting roughly USD$ 97 and USD$ 101 for a one barrel of Bonny Light andoil forBrent, respectively, from 2008 through 2011. Protracted increment in the requirement for natural gas that originated in some European countries, China, and the United States, which was activated through continuous development in the market growth of these countries led to the oil expansion. However, certain factors that contributed to this include lower labor output of the largest global-producing countries as a direct consequence of reduced funding; political upheaval, particularly Mideast region; and speculation on both the likelihood of more natural disasters such as a severe tropical cyclone often known as hurricane that presaged the supplies of oil and naturalgas and placed more price pressure on them (Rapu*et al*., 2015).

Crude oil prices actually dropped sharply at the end of 2008 amid the international financial crisis that occurred in the US residential and financial industries.Expansion given rise to an unexpected drop in the price of crude oil, not motivated by the fundamentals of the oil market. As the crisis spiraled out of control, global oil prices plummeted at the same time from an average of USD$ 100 a barrelto maybe over USD$ 60 a barrel in 2009. Nevertheless, the price drop did not last long as it was returned to the average price in the following year. The year 2010 which marks the beginning of the global economy’s recovery, oil prices continued to rise to about USD$ 80 a barrel, fueled by Libya's political upheaval, which interrupted supplies to Europe. While the slowdown occurred, prices decreased slightly, just to start rising again, uploading the highest level of more than USD$ 112 a barrel in North America's rapid expansion of oil shale production, mitigated out of supply shortages in the Mideast region (WBCMO, 2015), international oil mart valued crude basket ofOPEC worth well higher than USD$ 100 a barrel. Nevertheless, oil prices as at 2013 to 2014 actually fell from USD$ 105.87 to USD$ 96.29 a barrel. This has resulted in multiple causes, such as increased supply of US oil shale, a new border shift for main OPEC suppliers, and low growth for major Asian customer nations. Average world oil prices held below USD$ 60 a barrel during the first half of 2015 (Figure 2.7). The uninterrupted role of essential OPEC members in preserving sales target in oil markets could be one of the reasons for this result (Rapu*et al*., 2015).

Moreover, the OPEC basket price action as shown in Figure 8 displayed the same pattern as the latest crude sources. The OPEC content value was a mixture of different refinery products components that are in turn pointing to other 12-member refinery productswhich include Algeria which has Sahara blend, Angola with Girassol, the nation of Ecuador which has Oriente, Iran with Iran-heavy, the nation of Iraq which has Basra light,Qatar with Qatar marine, the republic of Saudi Arabia with Arab light, UAE with Murban, the republic of Kuwait with Kuwait export, Libya republic has Es Sider, Nigeria nation has Bonny light and Merey in Venezuela. The basket has a broad price range (USD$ 11) from the most costly heavy crude like the Nigerian Bonny Light to theleast expensive part, Venezuelan Merey, which makes themean carted price of OPEC to be lower than the globe's costlyrefinery products like the Brent, Urals, Dubai andIsthmus (Rapu*et al*, 2015).

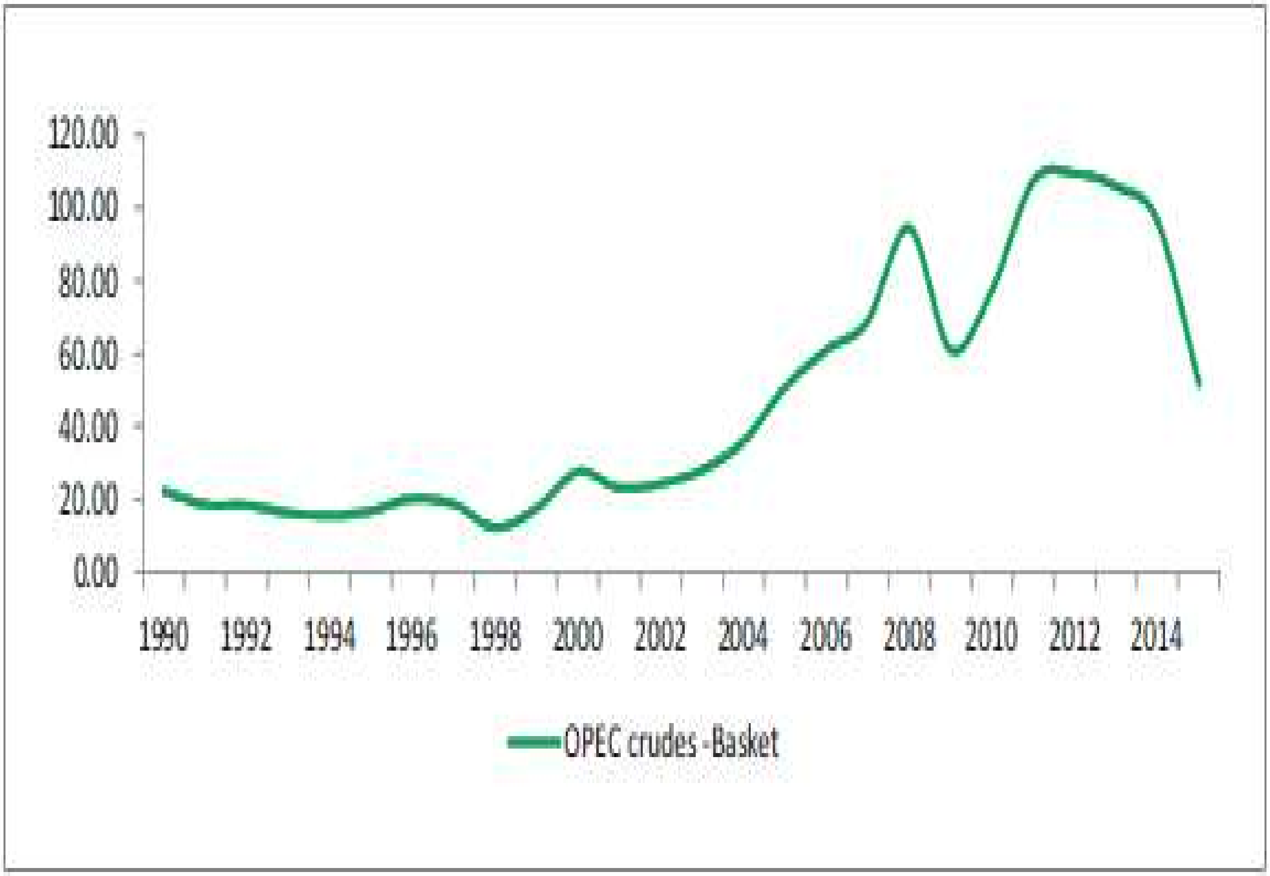


Figure 2.7: OPEC Crude CartedAverage Valuations (USD$ a barrel from 1990 to 2015)
Source: Reuters, 2015

2.3.1.2 The Prices of Natural Gas

On the international market, gas prices are indexed on a henry hub and traded on trends in LNG. The prices are determined on the national market by the Oil Producers Exchange Segment (OPTS) NGC and NNPC. On a global scale, price levels between 1991 and 2000 ranged around USD$ 1.70/mBtu-USD$ 4.23/mBtuas shown in Figure 2.8. Between 2003 and 2008, costs increased from USD$ 5.63/mBtu- USD$ 8.85/mBtu. Crude prices have risen over all these years as a result of exits from current nuclear and coal-fired plants, resulting in increased use of developed gas-fired power stations and new plant production. Following the Kyoto resolution, the constant search for clean power resulted in demand for gas to generate electricity amid controlled supply. The energy transition strategy described gas as the optimal fuel for generating electricity in Nigeria (Energy Information Agency, 2014).

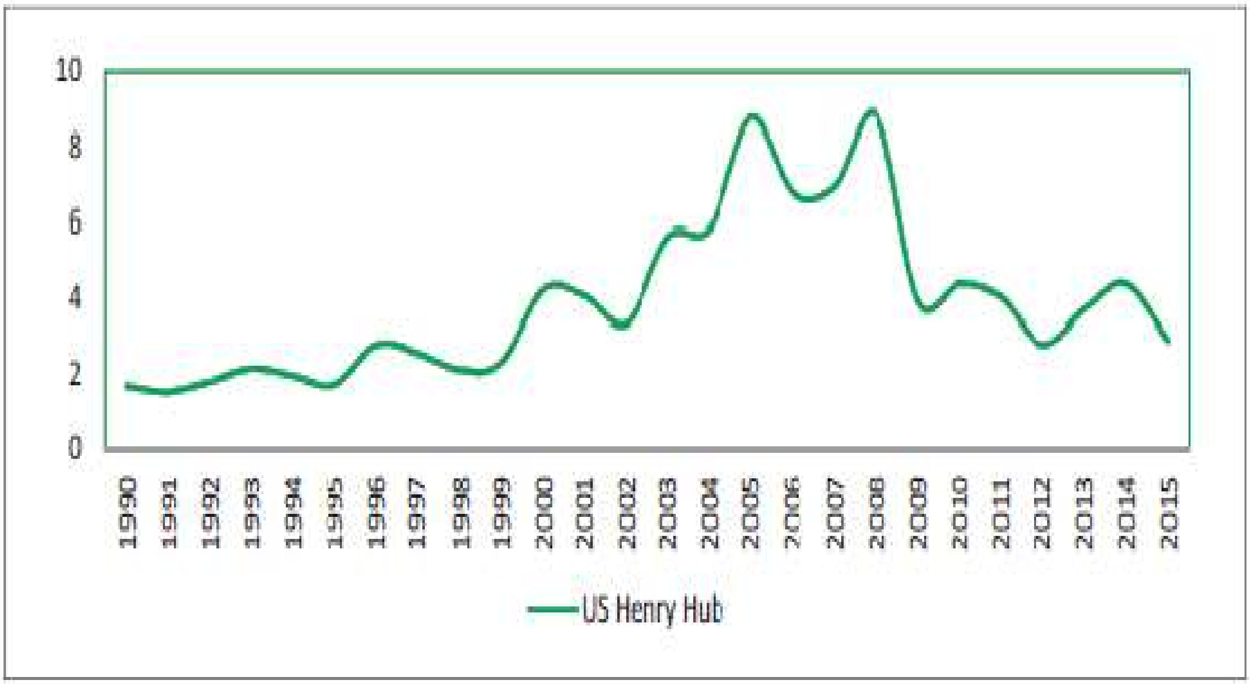


Figure 2.8: The Valuations of Natural Gas (US$/mBtu) (1990 - 2015)
Source: EIA

2.3.2 The Energy Production and Usage

The cost of producing and supplying carbon (energy) remains a major limiting factor for a sustainable supply of electricity to support economic integration. While statistics from the Energy Information Administration (EIA) have shown an increase in generating power in the last few years, Nigeria remain behind countries like South Africa, India, Brazil and several others as the country struggles to meet the level of consumption and the supply of electricity to its citizens. The World Bank (2015) observed that Nigeria's overall power production witnessed a 54.5% increase between 2000 and 2011 (Table 2.1). As of 2000, the overall power production was 14.73 billion kilowatt-hours, however, bumped to 27.03 billion kilowatt-hours in 2011. Furthermore, the state of electricity has not been improved. In 2000 and 2011, respectively, the percentage of total energy production from hydroelectric power stations fell from 38.2% to 20.9%. Conversely, the proportion of overall energy produced from 60.3 and 1.5 per cent in 2000 to 63.3 and 15.8 per cent in 2011 improved. The contribution of 5.6 billion kilowatt-hours of renewable energy in 2000 increased to 8.1 billion kilowatt-hours produced in 2004, but steadily decreased mostly from 7.8 billion kilowatt-hours in 2005 to 7.2 billion kilowatt-hours in 2013.

Prior to the global recession, private energy investment in Nigeria experienced significant growth between 2001 and 2005, rising from USD$ 295 million to as high as USD$ 828 million (Table 1). The consequence of the slowdown was a loss of momentum in the funding of the corporate sector, although it rebounded in 2013, as the spending contribution of the corporate sector rose to approximately USD$ 407.3 million (World Bank, 2015).

Indicators for the growth of the World Bank (2015) showed that overall energy consumption rose by 8.9% between 2012 and 2013. Total energy consumption increased steadily from 9.10 billion kilowatthours in 2000 to 18.00 billion kilowatthours as of 2005, which then substantiallybumped to 30.30 billion kilowatthours as of 2013. Energy usage concentrations were only 178.38 kilowatthours per unit of population as of 2013 liken to 74.13 kilowatthoursper unit of population marked as far back as the year 2000, indicating a huge bump of 140.6 per cent during the time of study. Over the last few decades, this growth has been due to the massive demand for energy consumption from residential buildings and businesses. The overall local population rate with available electric power supply between 2000 and 2010 rose from 28% to 35% as new villages connected to the electricity grid. Nevertheless, the majority of the population in urban areas in terms of access to electric power supply generally recorded between 2000 and 2010 declined from 84% to 79% which was attributed to constant interruption in the regular flow of electric power supply caused byoverloading. As documented over the century, the proportion of the overall sum of power transmitted witnessed a slight decrease from 5.62 billion kilowatthoursto 2.58 billionkilowatthours or from 38% to 10% between 2000 and 2011. Nigeria was rated 141 out of 148 countries in the 2014-2015 World Economic Forum Global Competitiveness Report on electricity efficiency (World Bank, 2015).

Table 2.1: Indicators for NigeriaEnergy (2000 – 2013)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012*	2013*
Electric power consumption (kWh per capita)	74.13	75.20	104.15	101.43	123.02	128.66	111.15	138.11	126.45	119.82	135.40	148.93	163.83	178.38
Electric power consumption (kWh) (Million)	9,109.00	9,476.00	13,459.00	13,444.00	16,730.00	17,959.00	15,929.00	20,328.00	19,121.00	18,617.00	21,624.00	24,453.00	27,400.67	30,318.67
Electric power transmission and distribution losses (% of output)	38.15	38.72	37.53	33.39	31.08	23.71	31.07	11.53	9.42	5.87	17.22	9.55	14.56	16.40
Electric power transmission and distribution losses (kWh) (Million)	5,618.00	5,987.00	8,085.00	6,739.00	7,545.00	5,580.00	7,181.00	2,650.00	1,986.00	1,160.00	4,497.00	2,581.00	4,167.00	4,877.50
Electricity production (kWh) (Million)	14,727.00	15,463.00	21,544.00	20,183.00	24,275.00	23,539.00	23,110.00	22,978.00	21,110.00	19,777.00	26,121.00	27,034.00	31,567.67	35,196.17
Electricity production from hydroelectric sources (% of total)	38.22	38.21	38.22	36.90	33.40	33.00	27.10	27.10	27.10	22.90	24.40	20.90	20.73	19.73
Electricity production from hydroelectric sources (kWh) (Million)	5,628.00	5,909.00	8,234.00	7,448.00	8,108.00	7,768.00	6,268.00	6,227.00	5,721.00	4,529.00	6,374.00	5,650.00	6,638.67	7,199.17
Electricity production from natural gas sources (% of total)	60.29	54.68	40.19	57.40	54.52	56.68	64.34	64.32	64.14	64.29	64.29	63.30	62.97	62.48
Electricity production from natural gas sources (kWh) (Million)	8,879.00	8,455.00	8,659.00	11,586.00	13,234.00	13,343.00	14,868.00	14,779.00	13,541.00	12,715.00	16,794.00	17,113.00	19,938.67	22,137.67
Electricity production from oil sources (% of total)	1.49	7.11	21.59	5.69	12.08	10.31	8.56	8.58	8.75	12.81	11.31	15.80	16.29	17.79
Electricity production from oil sources (kWh) (Million)	220.00	1,099.00	4,651.00	1,149.00	2,933.00	2,428.00	1,978.00	1,972.00	1,848.00	2,533.00	2,953.00	4,271.00	4,990.28	5,859.28
Electricity production from oil, gas and coal sources (% of total)	61.78	61.79	61.78	63.10	66.60	67.00	72.90	72.90	72.90	77.10	75.60	79.10	79.27	80.27
Electricity production from renewable sources (kWh) (Million)	5,628.00	5,909.00	8,234.00	7,448.00	8,108.00	7,768.00	6,268.00	6,227.00	5,721.00	4,529.00	6,374.00	5,690.00	6,638.67	7,199.17
Energy imports, net (% of energy use)	(122.53)	(123.03)	(101.23)	(118.49)	(125.86)	(119.50)	(120.37)	(115.95)	(106.97)	(108.76)	(121.28)	(117.14)	(124.11)	(128.30)
Energy production (kt of oil equivalent)	201,602.98	211,655.86	196,974.18	216,318.83	229,619.19	239,791.65	236,608.72	232,537.45	230,206.53	228,077.68	254,779.14	256,927.28	275,444.28	289,869.08
Energy use (kg of oil equivalent per capita)	737.29	751.03	753.64	746.94	748.17	763.04	746.64	731.61	735.58	703.14	720.93	720.64	732.40	741.15
Energy use (kg of oil equivalent) per $1,000 GDP (constant 2011 PPP)	259.98	260.09	257.90	207.59	182.58	184.75	171.53	161.58	157.05	144.26	140.98	138.13	134.99	131.92
Energy use (kt of oil equivalent)	90,595.51	94,633.01	97,388.86	99,007.38	101,791.11	106,509.4	107,004.76	107,668.10	111,224.98	109,255.20	115,137.76	118,324.59	1220658	127,843.26
Investment in energy with private participation (current US$Mn)	_	295.00	462.00	34.00	na	828.00	na	280.00	na	na	na	na	na	407.30
Fossil fuel energy consumption (% of total)	17.74	19.32	19.47	18.90	19.07	20.71	19.31	17.81	18.47	15.00	17.16	17.40	18.91	20.11
Fuel exports (% of merchandise exports)	99.64	99.66	94.04	97.90	na	na	98.24	93.61	91.74	90.36	87.13	89.13	84.04	87.62
Fuel imports (% of merchandise imports)	1.72	2.17	1.35	16.03	na	na	2.87	1.79	1.61	1.02	1.40	9.95	2.38	20.17
Oil rents (% of GDP)	40.49	36.63	25.67	28.60	32.63	38.24	34.17	31.13	32.04	23.73	16.36	19.12	16.43	13.43

Note: * Indicate authors' projections

Source: World Bank Development Indicators

2.3.3 Causative agents ofConditions for Energy

Global level, most countries have similar predictors of the energy market situations (Bean and Atallah, 2015). These researchers typically involve changes in supply, changes in demand, consumption and production of crude oil, price increases and pricing for energy, amongst others.

2.3.3.1On Demand Changes

The number of people living within a geographical boundary, that is, population is reported as one of the main determinant factors of demanding strength. The United Nations Demographic Division reported that the international number of people in the world is projected to rise through to almost 9.0 billion in 2040from more than 7.2 billion in 2014. It is projected that more than 90% of the population increase will emerge from third world countries. India was expected to become more populated than the Republic of China by 2028. The world's Gross domestic product rose 4%, slightly below expectations, driven by increases in exports, consumer spending and investment in 2020.Whilst the total number of people increases exponentially, there is an increase in overall demand in the provision of higher living standards. As a result, the long-term effects of population expansion, particularly increasing age systems, will also have implications for power needs and industrial growth. Energy demands, which are expected to grow significantly around 52.0% between 2010 and 2035 that is forecast to become largely determined by economy as well as political development in non-OECD countries (CRA, 2014).

Global oil demand, moreover, has been said to be averaging 1 mb/d per year increase since 2013, and has been projected to extend to 96 mb/d in 2019. As a result, OECD demand is forecast to drop to 45.2 mb/d in 2019from 45.9mb/d in 2013. Whereas request from Russia and other Eurasia was projected to rise sluggishly, with a yearly increase of 1.1 mb/d, the highest increase on demand is supposed to come from developing nations. In the same vein, in 2015, a demand for non-OECD oil would for the first time be higher than the need for the OECD oil (OPEC 2014). It is very important for a nation abundant in oil resources, such as Nigeria, and gives the government continuous opportunities to adopt sustainability policies (Ward and Asiodu, 2013).

2.3.3.2 The Supply Changes

The recent explosion in US domestic oil production has contributed to a significant shift in production and consumption outlook for the country. The U.S. production of oil had risen from 7million barrels per day to more than 8million barrels between 2012 and 2014 and now risen to more than 9million barrels per day between the first two months of 2015 according to the EIA (2014). Thus, the US is expected to become one of the major oil suppliers in the world by 2020, mainly determined by a huge increase in oil shale production. The US is developing a lot of interest in transitioning from a country that imports oil to a country that exports oil in 2025.

As of 2019, it was reported that the exportation of natural gas in Nigeria is around 2.08m barrels a day with the United States being the country's biggest buyer. Nevertheless, the need for US oil has declined since 2010, when the economy slowly reached an overflowing amount of energy regarding the production of oil. This distribution complexity as well as chances that the United States will struggle with cheaper energy for the same export market does not necessarily mean that the supply market is somehow constraining, particularly in the case of crude Nigeria. Despite competition still high in non-OECD countries such as China and India, Nigeria was expected to take advantage of this and look for new opportunities outside of us. The bank stated that: "Government oil revenue would be down by over 70 per cent, cutting total general government revenue to 5.3% of GDP for the year."It further stated that faced with large and widening fiscal deficits, mounting pressure on health spending, and less room to borrow, "Nigeria can be expected to cut capital spending, especially subnational, further diminishing its already low levels of investment and limiting service delivery at all levels" (EIA, 2020).

2.3.4Production and Use of Natural Gas

The British Crude oil (2015) analysis found the verified traditional resource to be 606.4 tcf. It constitutes 40.0% of world fuel, while 60.0% was unorthodox. The largest distributors are ten countries, part of which included Iran with 18%, Russia with 17%, Qatar with 13%, USA with 5% followed by Nigeria with 2.7%. EIA (2014) noted that the demand for crude oil is bound to rise rapidly compared to other global fuels having a demand estimated at5.4tcm by 2040. They further projected liquefaction of coal to be the next most important fuel wellspring. It was also unfurled that Non-OECD nations will pay for over 70% of the overall increase in production and consumption of crude oil throughout the period. Nevertheless, the unconventional US gas supply has changed the dynamics of the global LNG industry using recent technologies that fuel local production at significantly low prices; thereby offering greater volumes of Liquefied natural gas to Europe and the Mideast regions. In 2013, Nigeria exported natural gas of more than 28.27million standard cubic meters rendering the nation the fifth world's biggest exporter to mostly Europe, which is the country's biggest buyer in throughout the Atlantic region.Although, Nigeria's challenge lies in the United States' capability to quickly trade its Shale gas for moneyinternationally. The verified gas fields in Nigeria which is roughly 187 tcf (trillion cubic feet) is best known to be a region where gas is exploited. While the country has ample gas wealth, many of it has not been exploited due to the country's main focus on the output of crude oil. This has made local gas industries to be developed inadequately recording a high degree of gas flaring and a huge rate of accessible natural gas to be transported as liquefied natural gas. However, Nigeria should create consistent regulatory and economic laws to transform its economy as well as concentrate on becoming a sustainable, low cost and relatively inexpensive provider to the international market.

2.4 Stylised Nigeria Energy Market Facts

2.4.1 Aptitudes

Over the years, Nigeria's concerted effort to generate power has shown an excess of power supplies as regards to oil and natural gas which are sun, hydro,coal, periodic waves, wind, gas, as well as certain components of uranium nuclear energy. In order to promote a robust electricity market, such forms of energy for the generating electric power must prevail in substantial commercial amounts in the greatest natural composition all over the nation. Studies by Ministry ofSteelProduction and Mining, NNPC and Council for Export Growth in Nigeria have shown that Nigeria is blessed with natural and human energy resources. In its 2012 mineral search, the Ministry of Mines and Steel Production discovered an additional quantity of coal found in Kogi, Benueand Nassarawa states, as regards the Enugu state reserves.

Nevertheless, Nigeria was obviously enriched as far as oil and gas is concerned, making it stand out on the global energy market among all the other nations. The gas inventory is appraised at 196 tcf of proven reserves (P1 + P2), including substantial desirable geological upside assets of negligible sulphur and enriched fluids. British Petroleum (2014) has estimated Nigeria's confirmed modern gas deposits to be 182 tcf, rendering it the seventh largest modern gas reserves in the world and Africa’s largest. A BMI (2015) estimated that the country had the 9th highest gas reserves in the world, while the NNPC expected a total of 165 tcf of oil and gas reserves, such as 75.4 tcf that are unassociated oil.

The geologic time scale reports of the Federal Ministry of Petroleum Resources as well as NNPC aroundthe year 2008 in the month of May revealed an enormous potential in Nigeria's oil deposits, which might be increased to 600tcf. Correspondingly, theOPECorganisation also revealed productionof Nigeria's oil deposits which was estimated to be 37.1 billion barrels, and have a daily meanproduction of around crude oil of about 2.0 mbpd, which makesproduction of oil in Nigeria the biggest source in Africa Continent. Majority is shipped except the mandatory 445,000 bpd used entirely for local refining. Nigeria's crude oil, referred to as Bonny Light on the global oil market, contains multiple variants priced on such a crude geological basis and calculated by Sulfur Content, API Gravity, Pour Point, BS and W, RVP and its density. Regarded as light and sweet, it is, however, the best crude. It receives a large price premium reliably beyond the average OPEC basket price (BMI, 2015).

2.4.2 Establishment Provision

The market activity of oil and gas trail inthree interconnected systematic ways consisting of exploration and pre-production (upstream), production (midstream), and refining and selling (downstream) processes controlled exclusively by only the NNPC. The exploration and pre-production stage process involve mining, oil and natural gas development and collaboration operations. Between 1937 and 1993, oil and gas production and extraction activities were limited to on-shore operations;with little offshore operations not reaching 200m water surface. According to the NNPC, the industry experienced significant operations in deep water activity from 1993 to the present, surpassing 2,500m of water surface. Because gas was not made to be the main objective, the gas obtained was bubbled before old fields and environmental problems were required to re-inject, capture and recover gas for additional applications (www.nnpcgroup.com).

Partnership movements are collaborations made together with the NNPC and large oil firms that are also needed by the high advanced techniques and comprehensive reserve prerequisites of an exploration and pre-production. The NNPC was in charge of overseeing the auctioning of oil fields, the awarding of drilling as well as manyother mining certificates. Additional collaborations include Production Sharing Contracts (PSCs), Joint Operating Agreements (JOAs)and Service Contracts. Financially, IOC mostly managed the deepwater company and received USD$864 million for oil and gas exploration operations at the beginning of the deep-water project for six years, which later rose to about USD$ 1.3 billion by the end of 1998 (www.nnpcgroup.com).

The mid-stream covered several NNPC projects, like the Renewable Energy, Fuel to Energy, Greenfield Refinery,Gas Master Planin Nigeria, among others. Nigeria's downstream industry was established by 4 power stations,1 each in Warri and Kaduna, and2 in Port-harcourt. For regulatory domestic crude oil, the gross energy capacity of the power plants is 445,000 bpd. The two Port Harcourt refineries were situated in Elesa-Eleme, having a total CDU efficiency of 210,000 bpd for the name plate. It has a jetty situated 7.5 km from the power plant complex for the import and export of goods. Both the Kaduna and Warri refinerieshave CDU identification plate maximum amounts of 110,000bpd and 125,000bpd respectively. The oil channels alongside the Chemicals Marketing Company (PPMC) finalize the retail market network system under the oversight of the Petroleum Products Price Regulatory Authority (PPPRA) (www.nnpcgroup.com).

2.4.3 Momentum of Market

The market dynamics are characterized by the exchange structure and methods used in the Nigerian electricity market. Beginning with gas sub-sector, two entities work on a market for undisputed exports and domestic exchange. They are two, the first being the NGC, with the second,NLNG. NGC conducts production locally, whereas the second company does only exportations and engage in lengthy-term contracts spanning about 20 years and distributes the goods to the planned stations via pulverized trains discharged into regasified plants (NLNGAR, 2013). In 2013, Asia was responsible for 74% of international sales. The second company really is a stable as well as a competitive industry because the production of shale gas does not jeopardize its sustainability.In 2013 the NLNG produced income after tax of USD$ 1.4 billion after selling 280 LNG cargoes (NLNGAR, 2013). However, the first company owns the local gas economy and renders services to only its clients (fired gas electric power companies, industrial together with commercial industries). The first company releases gas for money to the business subdivision - the lowest customer base, to industry at USD$ 7.3 per mbtu, and US$ 4.30 per mbtu. It is forced to sell at USD$ 2.5 per mbtu to its major customers (electric power firms), which is a major impediment to the Company's revenue.

Trade in oil begins with raising the crude in accordance with each well's corporate structure. The government entered into a partnership agreement with main energy producers and collects tax revenues. From different stations, primarily Okoro and Erha,Bonga, Agbami, Escravos,Forcados, Bonny-Akpo, lifting operations averaged around 40 counts per month. The crudes that have been evacuated are mainly sold to Europe, Asia and South America, in particular to Brazil. The estimated problem of NXP is a major selling tool, and because there is no testing of a well-headed system, output predictions are often dependent on NNPC forecasts. Those make it difficult to account for actual revenue invoices. Electricity trade includes private organizations such as generators (Gencos) and distributors (Discos) there under NERC by means of a multiple year tariff order (MYTO) mechanism. As seen by NERC, MYTO provides Nigerian Electricity

Supply Industry (NESI) with at least fifteen years levy schedule (1st July, 2008 -30th June, 2023). A marketing standard that underlie the MYTO direct the industry's activities.

It was noted that NERC was reasonable to approve of an integrative together with a scientific strategy to adjust electricity prices across the board and ensure the gradual evolution of the market through a value-reflective and rational tariff system. Addressing the issue of power supply and decent distribution of power within Nigeria,the involvement of consumers and investors is being considered in this approach. The approach involves NERC introducing the Multi-Year-Tariff-Order (MYTO) approach. The MYTO is the current tariff action that computes the price of electricity premised on industry-wide revenue requirements. This strategy is intended to ensure the support needed for the different sub-sector's operating and operating expenses, that is, generation, transmission, as well as distribution. It is intended to promote the most fair and equitable way of pricing energy (NERC, 2008).

The MYTO was focused on a broad-based market assessment of present and future risks. The costs may include: the nominal electricity prices produced sold to the power grid; the transmission charge; the retail subsidy schedule; the transmission facilitator; the PHCN’s head officefee; the law-guiding fee; as well as the refund together with cost of the tariff transfer paid in shared confidence of the distributors for the maintenance of a national standard contract. Price arrangements will also be checked on a periodic basis and changes will be made to the fixed rates if there are substantial variations in inflation, exchange rate and gas prices more than or less than 5.0 per cent (in magnitude) (NERC, 2008).

2.4.4 Economy Commitment

The energy sector contributes to the economy in three loads which include local demand that brings about economic activity; the basis of domestic together with foreign revenues; as well asthe tool of global political bargaining.Energy is so crucial for the economy it has been called the economy's oxygen. The absorption of GDP is important in determining the allocation of resources to the country's economic operations. The IEA gathers oil baskets of nations of common interest to reflect the entire nature of resources in the economy that Nigeria serves. Nigeria's 2012 IEA Energy Product Cart(Table 2.2) summarized Nigeria's power business deals, showing the nation's leading role in oil and gas revenues and a strong focus on unclean energy, including wood, faeces from animals as well ashousehold wastes to sustain the economic system. The nation generated 176m tons of energy (only determined by calories), of which 74% was crude oil, although gas accounted for around 6%. Of the overall production, 148m tons were delivered, leaving just 23m tons of localusage.

Table 2.2: Nigeria's 2012Power Cartin ktoe, classified by Net caloriescontent

	Coal	Crude Oil	Oil Products	Gas	Hydro	Biomas	Elect	Balances
Production	30	129,409		33,645	487	108,142	2469	274,182
Import	-	-	8440	-	-	-	-	8440
Export	-	126,413	755	21,032	-	-	309	148,509
Domestic Consumption	-	2,996	7,685	12,613	-	108,142	2,164	133,600

Source: International Energy Agency, 2015

2.4.4.1 Keeping the Nation Powered

Nigeria's economy is sparked by impure and typical energy at net calorific value, which accounts for 80.9% of total usage. Safer and more contemporary power, such as electricity and gas, amounted to only 11.1%. This shortcoming is revealed by the massive gap in domestic market between production and consumption of gas and electricity. Nigeria's per capita electricity supply rated among the world's poorest, at 155 kilowatthoursin comparison with Ghana's 384 kilowatthours, South Africa's 4,410 kilowatthours, and Qatar's 15,904 kilowatthours for Qatar (WES, 2014). It gives a massive domestic market potential for gas and electricity use, with a population projected at 170 million (NERC, 2008).

2.4.4.2 RevenueSource

Table 2.2 above have shown that much of the domestic energy generated was exported on the basis of the typical policy of increasing natural endowment revenue, instead of adopting something similar to only meet the sufficiency of energy produced locally. Only the oil and gas production sub-divisionsproduce considerable incomes in the mold of petroleum benefit tax, royalty, gains from exports after trading equity shares for money, corporate tax revenue, employment, investment income and corporate social responsibility benefits. It can be gathered from the graph below that oil revenue made a significant contribution more to the Federation's total revenue profile from 1999 through 2008 to 2014, alongside the distinction associated with non-oil incomes. Given the decline in overall incomes between the odd years 2007, 2009 and 2013, oil share incomes were still higher, respectively, which clearly shows that Nigeria is heavily an oil exports dependent country.

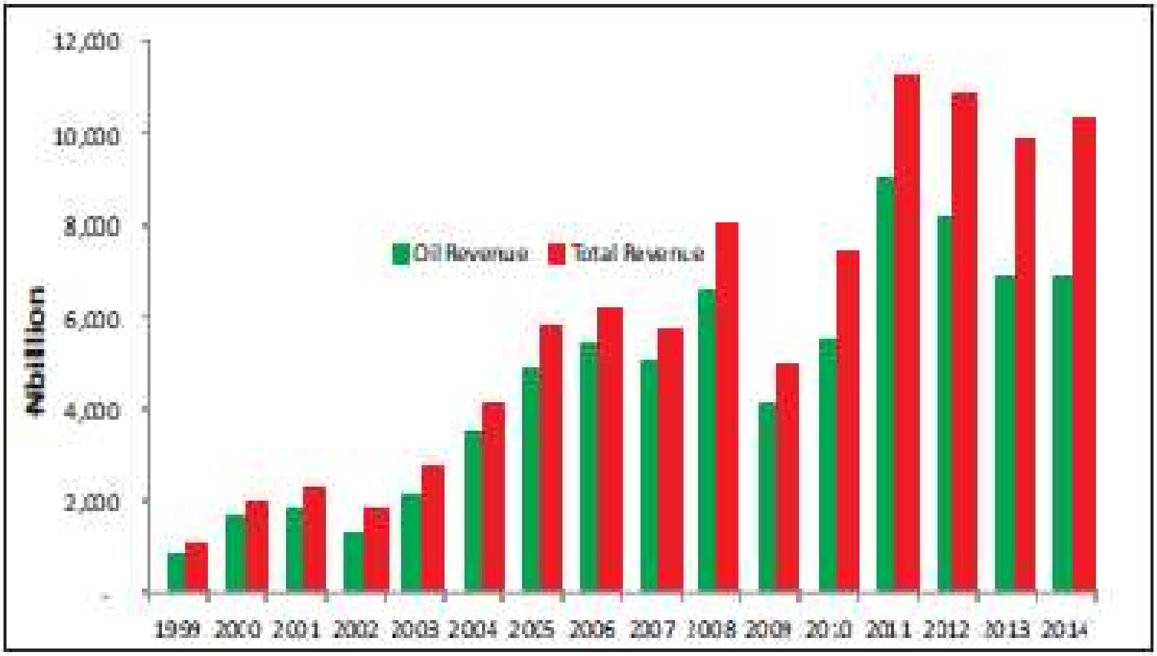


Figure 2.9: Oil Income in Comparison to Gross Income (Between 1990 and 2014)
Source: Central Bank of Nigeria

2.5.4.3 Political Important

Nigeria continues to attract global recognition due to its capacity of the country's oil and natural gas investment portfolio regarding verifiedoil reserves together with the world's market rankings in the oil and natural gas sectors.The energy agencies, investment managers and major corporate investors throughout the world consider Nigeria important because of its natural gas reserves. This is exemplified by the effect production of oil has in forecasting world crude prices, especially during upheavals and expected reduced output. The bilateral relationship between Nigeria and the United States (US) was friendly and optimistic, as the United States continued to provide its key provider of crude–Bonny Light in comparison to several different sub-Saharan African Countries. Moreover, given the country's tiny portion in the OPEC basket, Nigeria's oil geological assets help bolster the OPEC basket level, increasing Nigeria's leverage as a member of the cartel (NERC, 2008).

2.4.5 Negative Effect

A substantial negative effect is the massive foreign exchange spending on generating electricity by replacing spare parts and retrofitting some components with no expected results. Available data from the Accountant General Office for the Federationaround 1999-2007 have shown that the FGN was spending USD$ 3.6 billion on increasing the nation's supply of electricity. The overview of the yearly expenditure together with the prevailing currency exchange for various times are shown in Table 2.3 below.

Table 2.3: FGN Discharge of Resources to the Power Sector

Year	₦ (Billion)	US$ (Million)	Average Exchange Rate (₦ per US$)
1999	6.7	72.28	92.6934
2000	49.8	487.73	102.1052
2001	70.9	633.36	111.9433
2002	44.2	394.84	111.9433
2003	5.2	43.00	120.9702
2004	54.5	421.32	129.3565
2005	70.3	531.97	132.1500
2006	72.4	562.77	128.6500
2007	61.1	485.58	125.8300
Total	435.1	3,632.83	

Source: Accountant GeneralOffice of the Federation, Nigeria.

Subsequently, additional spending was made until 2014 to introduce the Agenda for the Transformation of the Presidential Power Sector and other presently established intentions. The data from 2008 to date, however, has not been published. In spite of this costs, the insufficient condition of energy power supply stayed virtually the same. The graph below reveals that from 1999 to 2001, after the start of the spending, electric power supply became the worst downward trend. Nevertheless, it increased dramatically from 1,700megawatts to 2,700megawatts between 2001 and 2006. However, the rise did not last long because supply reduced to 2,255megawatts as of 2009. Subsequently, it rose steadily in 2013 to a total of 3,300megawatts as shown in Figure 2.10.

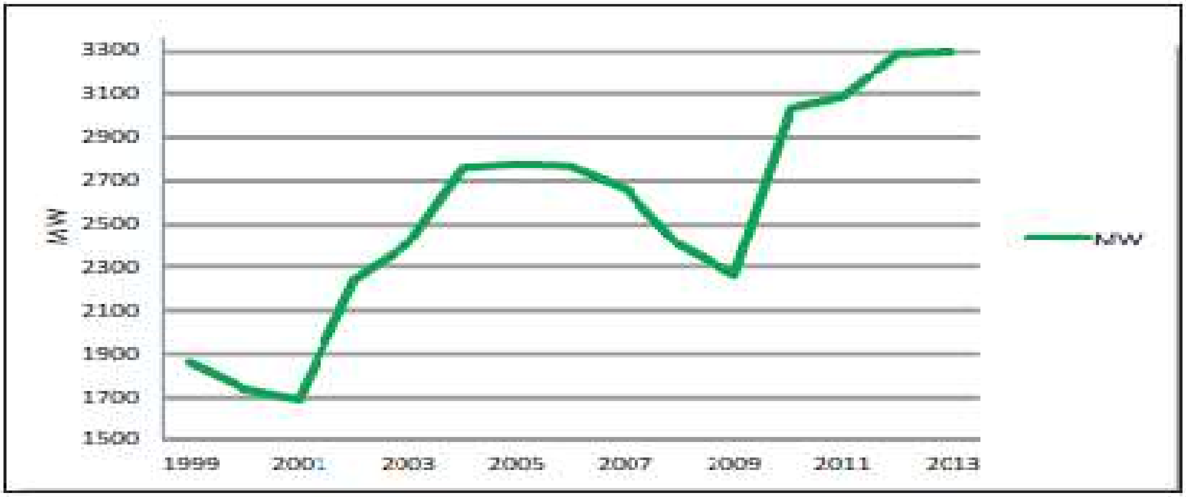


Figure 2.10: The GenerationElectricity (MW)
Source: PHCN

The secondary negative effect is the rebate problem. Throughout Nigeria, subsidies were initially applied to oil, later expanded to all petroleum products and eventually streamlined for the supply of electricity, premium motor spirit (PMS) as well as household kerosene (HHK). In fact, discounts for diesel and kerosene have been reduced. Both sources of energy were influenced by the redistribution of energy prices. As far as power generation is concerned, other consumer groups, such as residential premises (home, flat or multi-story house); housing vicinities accustomed as industrial operations such uniting by heating and ironing, D1 Single and3-phase, D2 low voltageComplete Demand and D3 high voltageComplete Demand (11/33 kilo voltage); and magnificent patronizers which include farm and agriculture-alloy factories, water and relief boards.However, because electricity accounts for only 1.62 percent of the Nigerian energy basket's total energy consumption, the financial aid barely significantly affect government incomes as well as foreign reserves.

Subsidy problems are focused in the subsector of petroleum products, in particular PMS and HHK, where large sales are balanced by subsidies on PMS and HHK imports. PPPRA data showed average retail costs per liter between 2009 and 2014. The average retail cost per liter was 91.39 naira in 2009 which became 111.70 naira in 2010 and increased to 145.99 naira in 2011, then further increased to 153.2 naira in 2012. It slightly reduced to 147.76 naira in 2013 and further dropped to 126.89 naira in 2014. The expenses strongly suggest a distinctive for PMS, which must be sustained by subsidizing regulated pump efficiency. In order to obtain the number of subsidies paid, the price of the pump shall be excluded from the gross landing expense which PPPRA calculated and compounded by the overall consumption of PMS.

2.5 Reform in the Energy Sector

2.5.1 Energy SectorPolicies, Development Programmes and Interventions

Nigeria's energy market has experienced strong and enormous strife from the FGN and a firm establishment of policies, programs and interventions clearly described as an enormous strife from the FGN in the industry's value chain from the exploration and production to the selling aspects of the oil sector. Structural changes, regulatory changes, capacity extension and institutional modernization were some of these measures, each projected to increase the supply of energy.

2.5.1.1 Oil

The privatization of the sector led to the creation of the NNPC in 1975, and in the early 2000s the creation of Greenfield Refinery Projects, PPPRA and the Nigerian Local Content Development Initiative, but since then, none important development projects were further created. As successful as they were, these programs had not been able to address key problems within the sector. As a result, the sector has kept on facing many problems regarding the environment with the inclusion of an inadequate monetary cohesive plan. This resulted in the establishment of the Petroleum Industry Bill (PIB) in 2008 that made the big oil companies diversify their investments in the sub-division. The Gross Domestic Product initiative is an Exclusive Bill providing for an Act to establish a legal, financial and legislative framework aimed at tackling the problems of the environment as well as various different problems existing in the oil sector. Supposing that the exclusive bill was passed, the professional opinion argued that it would have led to positive developments, including the arrest of liquidations; alluring potential investment; enforcing the basic guiding beliefs of the Nigerian Extractive Industry Transparency Initiative (NEITI) Act; petitioning for several issues of the environment and expanding the privatization industry.

2.5.1.2 Gas

The energy sub-division is considered as an essential model that is able toshift the Nigerian economy from the other important energy sub-divisions like oil, petrochemicals, steel, iron, and real estates. The gas sub-division, however, received specific notice from the FGN. The Energy Master Plan is one of the programs,which aims to provide a mechanism to ensure maximum benefit is realized from the gas resources of the country. It is intended to harness the domestic economy's trickle-down effect of gas and maximize the nation's proportion of the export market of high value. Precisely, the plan focused on resolving impediments to domestic gas sector growth, engendering gas monetization, reducing gas flaring, and ensuring Nigeria's long-term gas security. The program should also encourage early as well as economical generation of gas to satisfy global together with regional requirements. The intended actions were classified to three essential components, which include the policy of gas prices,the establishment of a law-guiding for local supply of gas to serve as a control, followed by the gas network roadmap (the layout). The certain programs are as follows; coal-to-power; gas manufacturing facilities; LNG Company Limited from Nigeria; and Gas Company from Nigeria.

The gas sub-sector is a field where significant results have been obtained through government efforts. Gas export earnings in the last 10 years amounted to US$ 9.6 billion, while domestic supplies rose by around 1.827.0 per cent during the same time. In the field of strategy,the right mix involves roadmaps to strategic objectives of completing targeted supply to electricity, business, and consumer sub-sectors.

2.5.1.3 Electricity

The monopoly market structure, poor regulatory system, large investment deficits, deteriorating and inadequate infrastructure, low prices and revenue loss, including management weakness, have hampered the growth of the power sub-sector. Before the adoption of the Electrical Power Sector Reform Act (EPSRA) in 2005, the FGN's enormous strife in this subsector amounted to USD$ 3.6 billion regarding total expenditure on Independent Power Projects (IPP) between 1999-2007. Introduction of the Electrical Power Sector Reform Act (EPSRA) resulted in the efficient privatization of the establishment, the creation of cohesively organized law-guiding committee, the formation of a functioning market association (Nigeria Bulk Electricity Trader),Nigerian Transmission Company (TCN) as well as a lucrative investment mechanism (Multi-Year Tariff Order).

2.5.2 The Gas to Power Projects

The core of the government's new policies in the power sector is to concentrate on less expensive and efficient energy generation and attract foreign investment. Given the huge amount of Nigeria's proven natural resource together with the rising demand for reducing gas flaring, the power-to-energy program, which is part of the Gas Master Plan, seeks to improve the delivery of natural gas to the nation's gas plants. With even more than 75% of Nigeria's gas-based power generation, the performance and efficiency of domestic energy supply must be ensured an importantstep towards achieving the objective of an uninterrupted provision of electricity to consumers. During April 2013, the World Bank signed a $145 million Partial Risk Guarantee (PRG) alongside the coalition of PHCN, Egbin Power Station, Chevron and Deutsche Bank to avoid the risk of default. This pledge will back up the FGN'spayment commitments to a secret lender or financier and ensure to such an extent the creditor is reimbursed by the World Bank once the Nigerian government defaults on transaction. The goal of this historic agreement is to underprop as well as extend the region's capacity to generate and guarantee the growth of the electricity and gas industry. The Power Sector is producing approximately 3bcf / d of gas using the present PHCN facilities as the canonical base load gas customers.

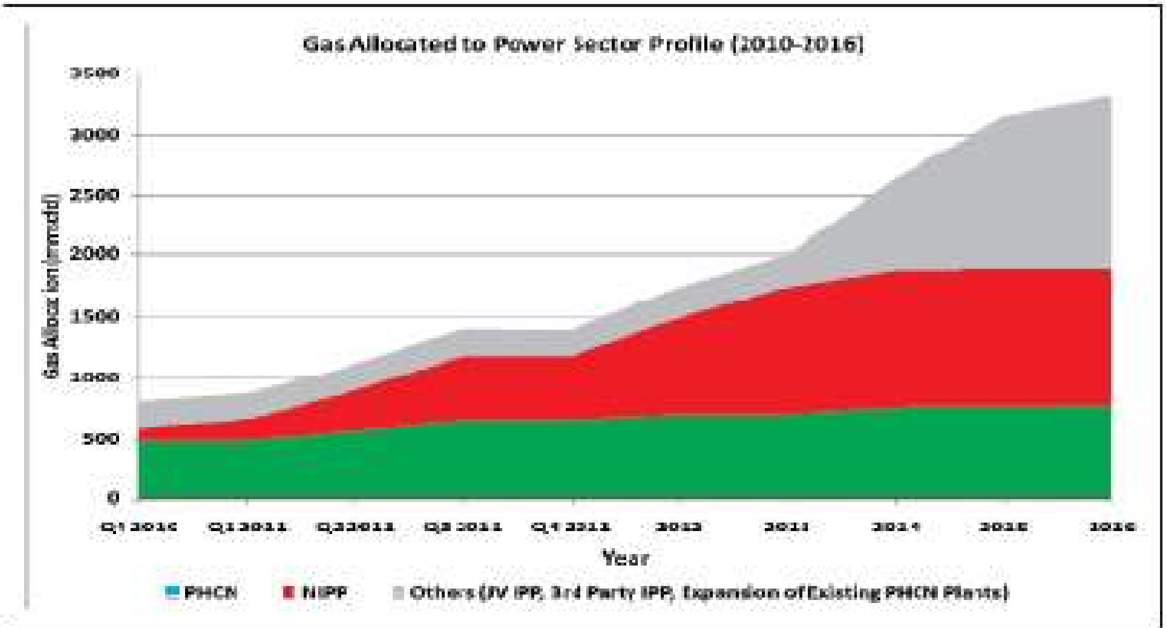


Figure 2.111: The Profile Allocationof Gas Power Sector (2010 -2016)
Source: **TheGas Company in Nigerian**

Approximately twenty-two new coal turbines / gas-fired power stations are currently being built and fifteen are being currently renovated to fulfill local energy needs. The majority of the current power turbines are PHCN plants in the Niger Delta; Egbin plants; Afam VI plants; as well asGeregu I and II plants, etc. Also, three major regional gas projects are ongoing which include the West African Gas Pipeline (WAGP) scheme to deliver gas-fuel to other countries within Westernparts of Africa;Double-bond-Saharan conduit made pipes projectto transport gas via Algeriato Europe; as well as a suggested plan to establish a gas supply network to Equatorial Guinea.

2.6 The Nigeria Energy Market Situation

OPEC has projected a 52% increase in global electricity consumption over the next 35 years from 2010-2035 (El-Badri, 2013). Renewables, like solar, wind, hydropower and geothermal are projected by over 7% per year, providing below 3% of world's energy needs near 2035. Whereas the proportion of the total mass of living materials is estimated to decrease to 9% while the nuclear power is expected to still contribute marginally lower than 6% across at the same time. At almost the same period, renewables are clearly anticipated to win the market having an expected anticipation falling somewhat from 82% to 80%. Oil is likely to remain the major part of energy demand for most of the period having an overall portion expected to reduce from 33% to 27% between 2010 and 2035. The portion of coal is anticipated to still be 27%, while the portion for natural gasis anticipated to witness a bump from 22% to 26% over the course of study. Global need for oil crude refineries was expected to fall from within 78.0 mb/d during waxing lunar phase in 2015 to within 77.3 mb/d in the next lunar phasein 2015 but also can fall lower... until 2035 (IEA, 2015).

Prediction as seen (Table 2.4) reveals such rise in global demand of oil for 2015 will continue to be close to 94 million barrels a day as anticipated. (IEA, 2015) Emerging economies are anticipated to verve global economic growth, with both the largest share being Asia-Pacific as well as the Americas. Development will remain largely guided through the transport features, in particular by land transportation in non-OECD countries having a potential to expand the downstream market.

Table 2.4: International Demand for Oil (2013 – 2016) (million barrels everyday)

	2013	2014	2015 Q1	2015 Q2	2015 Q3	2015 Q4	2015	2016 Q1*
Africa	3.8	3.9	4.1	4.1	4.0	4.1	4.1	4.2
Americas	30.7	30.8	30.7	30.7	31.4	31.6	31.1	31.1
Asia-Pacific	30.3	30.7	31.7	30.8	30.7	32.0	31.3	32.5
Europe	14.3	14.1	14.0	14.1	14.4	14.1	14.1	14.0
FSU	4.8	4.9	4.6	4.6	4.8	4.7	4.7	4.5
Middle East	7.9	8.1	7.9	8.4	8.8	8.1	8.3	8.1
World	**91.9**	**92.5**	**93.0**	**92.7**	**94.1**	**94.7**	**93.6**	**94.4**
Annual Chg. (%)	1.4	0.7	1.4	1.2	1.1	1.0	1.2	1.5
Annual Change (mb/d)	1.3	0.7	1.3	1.1	1.0	0.9	1.1	1.4
Changes from last OMR (mb/d)	0.02	0.00	0.31	0.08	-0.03	0.00	0.09	na

Source: International Energy Agency(IEA), 2015.

The market of OECD countries is expected to fall in 2015 because of lack of increase in business activeness as well as the reduction of utility-related reductions in refineries (IEA, 2015). As a result, the worsening economic climate in several non-OECD nations including Argentina, Iraq,Brazil and Nigeria will lead to lower export sales and a weakening macroeconomic situation. Global demand for crude oil is expected to increase by 1.4 million barrels each day (mb / d) to 95.0 million barrels per day over 2015, mainly due to technological improvements in international economic activity. The estimated growth happens to be more elevated than the anticipated 1.1mb/d increase in 2015, which is predicted to negatively impact revenue profits as it builds on the expectation for economic contraction.

2.6.1 International Supply of Oil

Higher oil imports from OPEC producers throughout the Middle East and continued growth of Shale oil production in the US will keep driving lower global oil supply and low international oil prices. Correspondingly, the world oil supply is expected to increase by 1.0 million barrel a day every month as of March 2015 to 95.2 million barrel a day experiencing the biggest monthly growth input in OPEC output in four years. Likewise, OPEC's crude oil supply is expected to rise by 890K barrels a day to 31.02 million barrel a day as of March 2015 because of increased supplies from Libya,Iraq and Saudi Arabia. The generation of oil and gas from NoneOPEC nations was estimated to grow close to 100K barrels a day to 57.7 million barrels a day as of March 2015 having the substantial support of the United States' leader and Russia with every year non-OPEC supply rising to a projection ofabout 1.8 million barrel a day. However, a declining shift of roughly 160Kbarrel a day is forecast for North-America throughout the second part of 2015 which was compared to a less amount of negative perspective for the United States as well asCanada as of March 2015. The reduction in the predictions illustrated the wider downturn in United States LTO growth in addition to the negative image for non-oil sands development in Canada (IEA, 2015).

The oil market forecast shows more than enough supplies to satisfy the existing demand, with prices maintaining equilibrium between the product's producers and consumers. However, despite the uncertainties existing in the market, in particular the Iran-US Nuclear Agreement, the downside risks remained unchanged in 2016.

Table 2.5: World Oil Production (million barrels per day)

	2014	2015 Q1	2015 Q2	2015 Q3	2015 Q4	2015	2016 Q1
OPEC*	36.6	37.0	38.1	38.1	39.0	38.55	39.5
OECD	22.8	23.8	23.6	22.9	23.5	23.5	23.9
Non-OECD	29.8	29.8	30.4	30.2	29.9	30.1	29.9
Others	4.4	4.0	4.5	4.8	4.5	4.4	4.1
Total World Supply	**93.7**	**95.31**	**96.52**	**97.24**	**97.46**	**95.55**	**96.68**

Sources: International Energy Agency (IEA), 2015.

2.6.2 The Global Demand and Production of Natural Gas

2.6.2.1 International Demand for Natural Gas

It was observed that global demand for crude oil grew from 450 to 1.827 million standard cubic feet in the timeframe 2000 to 2010 (IEA, 2012). Production is set to increase to 40 billion cubic feet a day by the end of 2015 then to more than 50 billion cubic feet a day near 2025. The substantial increase in the expected global demand for crude oil has been due to the increasing willingness in many countries to accept cleaner energy sources as they search for strong economic growth to limit the effect of increasing petroleum-related energy costs. The fore choice of crude oil as an energy source is possibly due to its low carbon emissions that is 43% lower than coal and 30% less compared to oil for each unit of power exerted. Asia's prominent economies, especially China, India, together with the Mideast and South America continent, rate amidst the rapidly increasing gas markets in the globe.

On the global market, the rising prices for gas is further guided through its quality and efficiency using clean energy. Many countries keep up with gas imports since 2007 in which the numbers skyrocketed from 17 as of 2007 to 25 by the end of 2015, across from five continents. This has made some countries in the South America and Europe continents to make plans to construct gas terminals for relevant participation in international gas trade.

2.6.2.2 International Supply of Natural Gas

In the early 2000s after the Kyoto Protocol, international gas production was increased by switching from coal-fired power stations to cleaner energy to reduce carbon emissions. With U.S. fracking technological innovations and the resulting huge generation of unorthodox minimal-cost gas throughShale gas reserves, supply of natural gas situationworldwide has enhanced dramatically over the last ten years.

2.6.3 International Power Consumption/Production

In the world energy market, there is no uniformity since regional markets differ in structure, depth, and regulations. North America has the foremost electric power generation per person, which amounts to 14, 167 kWh / cap, according to Mirchi, *et al*., (2012), this was more than twice the Western Europe output ratio (6,646 kilowattshours/capacity) and three times the Central Europe production ratio (4,411 kilowattshours/capacity). It is over four times the Eastern and Southeast Asian production ratios (3,400 kilowattshours/capacity), eight times the North African ratio (1,771 kilowatthours/capacity) and thirty times the Sub-Saharan African output ratio (490 kilowatthours/capacity). Out of the prominent areas, East and Southeast Asia reported the highest growth in a personin yearly energy production with 6.6 percent on the average, seconded by a yearly mean production of 4.7 percent for North Africa. South Asia and the Mideast yield yearly averages of 4.5 and 3.8 percent, respectively. Owing to its rapid population increase and low investment in electric power generation, the sub-Sahara African region rates the lowest in electric power generation per person.

2.6.4 Effect of International Development on Energy Market in Nigeria

Nigeria's energy environment remains unclear with low oil prices, increased oil and gas divestment, unresolved issues in the moderating environment in addition to a weak law-guiding roadmap. The consequence is a fall in releasing capital gains that increases energy instability and the eventual decline in the administrative activities of the sector. A cursory review of Nigeria's energy situations showed that the nation had not greatly exploited its enormous energy capacity. Due to lower oil prices, the International Monetary Fund (2014), in its WEO as at October, forecast an increase in global demand growth of 3.5% for 2015 as well as 3.7% for 2016. This growth trend means increased competition for crude oil in the US and other allies in the region of Nigeria's energy-intensive economies. The growing economic activity is expected to eventually drive economic activity to which oil prices can in the main time and even in the future respond positively. The effect of the cost rebound will result in possible restoration of extraneous exchange reserves, which will eventually increase the confidence of investors. This helps to boost the amount consumed internally thereby stimulating economic growth (IMF, 2014).

The easing of U.S. penalty against Iran combined with the OPEC's commitment to uphold current levels of generation will ultimately result in excess supply which would ensure oil costs are low for a while. Apart from stimulating growth, the low oil prices would boost buying power and private demand for petroleum-importing countries. As a result, overall energy usage is anticipated to suffer a lift turning into an accelerated future growth as well as motivate the demands on energy primarily through labor, employment, in addition to population growth. The increased price of developing green energy is yet an additional sign of future oil price change. Although the Bonny Light's price saw a reduction from approximately USD$ 107.98 a barrel in the year2014 of the month of July to USD$ 63.01 a barrel by the end of year 2014 in the month of December then a continuousreduction to USD$ 59.5 a barrel in the year of 2015 as of April 15, the pattern was anticipated to rebound as a function of the rising cost of advancing substitute energy production point. The low price of oil acts as a barrier to massive release of capital in clean energy production.

In real terms, the US dollar's appreciation of approximately 6% is not only anticipated to cut United States exports, but to also raise exports among petroleum-exporting economies. A rise in value of currency allows imported goods comparable to domestic products. The reverence makes the oil cheap to Nigeria, which induces oil suppliers to boost their demand. Faced with lower production costs, the lower oil prices are projected to culminate in lower energy subsidies, and increased government revenue as subsidy revenue is used effectively to provide economic and social infrastructures.

2.6.5 International Renewable Energy Movement

It is imperative that as a nation for Nigeria to shift attention from fossil-related energy sources to renewables to fulfill its rising energy demand. This is because not only are fossilfuels non-renewable but they are also more costly with harmful impact on the environment. Renewables include wind, organic materials, geothermal, waves, and energy from the sun that can be continually reused. However, liken to the 74GW installed in the year 2013 (EcoWatch, 2015), the installed wind as well as solar power globally as of 2014 accounted forapproximately 100gigawatts (GW). China surfaced as the prominent renewal-energy investor led by the US. In Denmark, wind output made up for 39% of the total generation of electric power from clean energy sources in 2014, making it a new world record. This outstanding achievement is an indicator that Denmark stands to fulfill its ambition to produce 50% of its power from renewables in 2020.

In the United Kingdom, wind power generation increased from 24.5 terrawatthours in 2013 by 15% to 28.1 terawatthours near 2014. Wind power output is enough to satisfy the energy requirements of more than 6.7 million households. Operating turbines as well wind farms grids both provided about 9% of the 2014 electricity required compared to almost 8% in 2013. Renewables accounted for almost 26% of clean power generation, prominent in 2014 contributing the largest to Germany's electric power production. Over 100 per cent of Scottish homes have their energy demands met through wind power in six months of the year (EcoWatch, 2015).

2.7 Nigerian Energy Market Difficulties

2.7.1 Difficulties to Production Upstream Oil/Gas Sector

2.7.1.1 Difficulties to Production (Upstream)

Government's lack of investment in crude oil output is pointed out one of the fundamental challenges of oil exploration and production. The NNPC notably and repeatedly refused to fulfill its funding commitments towards the Collaborative operations. Nonetheless, the government has introduced new financing mechanisms to provide long-lasting benefits, which includes Production Sharing Contract (PSC) andUpdated Borne Agreement (MCA) alongside the Multinational Oil Companies (MOCs).

2.7.1.2 Rebate Difficultiesin Oil (Downstream)

Subsidies of Oil have tremendous harmful effects in 3 main situations which include economic, social and environmental impacts. The economic impact includesoil subsidies that reduces economic growth, government monetary funds creating economic imperfections. To the degree that this price subsidy decreases the industry's appeal to private investors, it encourages outdated production, insufficient funding for infrastructure upgrades and maintenance, and ultimately serious energy shortages, which significantly disrupt economic activity.

Incentives include more substantial public expenditure on healthcare, schooling, health and other critical facets of public facilities. In surrounding countries, higher domestic prices of petroleum products are promoted, particularly in the country's context, illicit trading, and the possibility of smuggling across the territories. It increases the chances of more tax expenditure on drug discounts. Grants have a negative impact on tax revenues and government debt. Incentives gulp revenue for the government affecting cost of the subsidizing currency as well as cause the transaction-rate crisis, leading to a decline in the balance of payments situation due to the current account deficit. The economic impacts of incentives include creating a monetary reward for excessive amounts of oil products that will increase climate change as well as polluting the atmosphere. Many other environmental effects of public monetary support include congestion, higher injury rates and road damage as car traffic is on the rise due to lower as well as manageable premium motor spirits costs, as shown by the International Monetary Fund's Iran report (IMF, 2012). The dominant social consequence of oil incentives is the strengthening of inequalities in society, as the policy scarcely assists the targeted segment of society. Studies clearly show that oil subsidies favor rich people who own a lot of cars and purchase more goods than people living in poverty who do not actually consume certain products.

2.7.1.3 Energy Infrastructure Capacity

a. Insufficient Gas Facilities

Owing to Nigeria's main attention on the output of crude oil, the country's gas inheritances still need to be channeled. This has left the domestic energy supply relatively imbalanced, with a large proportion of verified natural gas transported as oil and gas, reentered or merely flared to boost the repossession of oil. This illustrated the shortcomings in the nation's power generation mix, leaving the power distribution network inefficient and unstable. This precipitated the implementation and adoption of an effective gas pricing scheme, a requirement for the development of the domestic gas industry.

b. Power Infrastructure Security

Despite the continuing destruction of oil and gas facilities in the Niger Delta area, the task of securing energy infrastructure remains overwhelming. This has negatively impacted the supply of refined oil and also the supply of gas to thermal power plants.

c. Incentive to invest and Activities

Problems with the potential of the Nigeria's energy network have prompted several foreign oil companies (IOCs) working across the country to withdraw owned assets in a couple of inland and shallow water fields. The majorityof the blocks are remembered as oil refineries while others are gas fields. Pursuant to agreed bidding agreements, the blocks are sold to streamline the assets portfolios of firms and transfer their strategic growth emphasis to Nigeria's deep offshore activities. Another big functional challenge facing Nigeria's energy industry is the inexperience and expertise needed, especially in the power subdivision which gives the reason why the country must boost power production maximum amount from the current 3.650megawatts per hour to over 45.000megawatts per hour to become one of the top 20 economies around the globe (Adegbulugbe and Adenikinju, 2008). This would certainly be a massive step that requires specific knowledge and expertise to handle the transformation and deal with progress. A variety of expertise, namely engineers, technicians as well as industry professionals, is needed for each extra power industry constructed. Failure to address this properly would undoubtedly characterize a major obstacle for the industry and the region.

d. Facilities in Refinery

The fall in revenues from crude oil exports has once again demonstrated the need to reduce Nigeria's reliance on imported refined petroleum products. More than 90.0 per cent of Nigeria's 5.13 billion liters of petroleum products produced in 2013 were imported and massively subsidized by the Federal Government of Nigeria (CBN, 2015). It was due to the fact that the refineries in Nigeria were running at dismally poor power utilization. The Warri Refinery worked at approximately 38% of the refinery's installed capacity in 2013, the Port Harcourt Refinery at just 8% then the Kaduna Refinery at 29% in 2013 (CBN, 2015). The big, seasonal spending for Turn-Around Maintenance (TAM) was inappropriately used while it yielded barely any significant result becauseof the apparent condition of the outdated machines.

Ironically, the recent turnaround effort at the refinery seems to have provided some reprieve. The Warri refinery was scheduled to raise the quantity of processed petroleum commoditiesto about 4.6m liters a day in July 2015 at efficiency usage level of about 80%, while the refinery in Port-harcourt was scheduled to begin processing the range of 5m liters of processed commodities a day near July 2015. Notwithstanding, the many efforts to maintain the immense supply deficit as well asits impact on economic growth across the nation contributed to the sector's desperate indigence to restructure its organization. Consequently, the Federal Government has announced proposals to allow the Petroleum Resources Department (DPR) to grant licenses for mobile turnkey refineries to private investors (CBN, 2015). The private sector requires huge assets in refining facilities, with the government providing developers with a stable and encouraging climate. It is intended to mitigate the problems of production and transportation, and tackle the ongoing gasoline shortages.

2.8 Pricing of Electricity

Nigeria's electricity cost of electricity can be categorized into two which includes the generating cost and the distributing cost, all in which was controlled by NERC there in the auspices of Multi-Year Tariff Order (MYTO) model. NERC reported guiding beliefs as well as the priorities on which energy prices are classified to enclose repossession of cost, expenditure profitability, efficiency, durability, returns on investment, effective use of the infrastructure and risk distribution. The repossession of cost is directed at a decent ROI, whereas, the project model is modeled to allure domestic as well asinternational partners. The underlying theory in the MYTO is the capacity of the mechanism to efficiently spread risk (Rapu*et al.*, 2005).

2.8.1 Electricity pricing by Energy Information Administration

Energy costs, also recognized as power subsidies or power prices, can vary significantly by area or geographical area within a nation. Energy prices depend on a number, such as power generation costs, state financial assistance or taxation, domestic weather cycles, the act of transmitting and distributing interconnections in a system, as well as multi-layered economic law-guidelines. Also, price levels or scheduled rates of prices may largely depend on the client base, largely for homes, industrial as well as commercial networks. According to the USEIA, "In general, price of electricity represents the costs of development, funding, maintenance and service of power plants and electricity grids." Whereby demand prediction denotes the mechanism through which a manufacturer, a multipurpose company or a huge commercial customer consumer could foresee the bulk price of electric power supply with extreme precision (Weron and Rafał, 2014). Due to problems in electricity generation, the cost of providing energy differs from minute to minute.

Most of the corporations are non-profit organisations and their production costs have a return on investment for holders as well as shareholders. Such utilities will use theadministrative abilities they possess within the present legal and law-guiding cohesive rules to ensure returns on investment as well as to drive down contests with various different sources including thediscos (Prehoda*et al*., 2019).

2.8.2 Electricity price forecasting

Electricity price modeling is a method in which mathematical models are used to estimate future electricity costs.

i. Forecasting Technique

The easiest design for a routine prediction would be to make enquiries from every production input to offer auction on production units and go with the cheaper auctions. Since many auctions will not be received, the cost will be raised but supposing a lot of proposals are dropped, the cost may be zero or negative. The overall cost of the deal includes the production as well as the transmission pricetogether with any benefit. Electricity may be supplied or bought using neighboring sources of power (Fetchen, 2019). The concept of independent system operators (ISOs) creates perverse incentives between bulk supply city square players through the separation of transmission as well as generation operations. ISOs are using valuation founded on systems for commercial dispatch (EIA, 2019).

Wind and solar seem to be anti-dispatchable. This capacity is typically offered at a fixed cost for each producer, compared to any other bid.Some waste has been leased to or retained by some other power grid utilizing injected-storage hydropower or,in the worst case, decreased. Curtailment may theoretically have a significant impact on the environmental and economic advantages of solar power at higher PV penetration rates. Disbursement is made by competition (Lai, 2017).

The influence of the recent acquisition of smart grids and the incorporation of dispersed renewable generation has raised speculation regarding future production, demand and prices (Kang, 2016). Such complexity has led to a great deal of research on the subject of prediction.

ii. Moving factors

Electric power is not as permitted to be accumulated effectively as gas because electric power is generated exactly when it is demanded. As a result, every impact of supply and demand will directly affect electricity prices on the global market. In relation to production prices, the cost of energyis determined by supply and demand (Branker 2011). Moreover, certain major factors were most likely to be perceived.

Simple word-term concentrations are most affected by the climate. Heat exchange demand throughout the lowest temperatures and cooling throughout the highest temperatures become the determinant factors of price changes during seasons (DAO, 2018). Improved gas-fired capacity is riding down power prices in addition to rising demand.

The region's innate source of wealth alongside the measures set presently, has a significant impact on import tariffs. The supply end of energy supply is almost totally impacted by fuel costs as well as CO_2 limits. The European Union carbon costs have increased since 2017, thus, a big supplier of demand (EIA, 2019).

iii. Weather

Research have shown that temperature is a huge determining factor for electric power. Heat pressure in averagely lower temperatures and cooling requirements in higher temperatures are the main reasons for the fluctuations of seasons as seen in almost all areas. The unit measurements of heating and cooling aid to determine the amount of power consumed when compared to ambient temperatures higher or lower than 65°F which is the generally approved standard (EIA, 2019).

At the presence of renewable sources of energy such as wind, solar, the availability of environment is impacted. The California duck graph reveals the disparity in electricity demand as well as the solar energy capacity produced during the day. Featuring a lot of sunshine, solar energy fills the energy production market then afterwards sinks as darkness comes when the demand for electric power increases (DAO, 2018).

iv. Availability of Hydropower

Snowpack, streamflow, seasonality, fish, etc. They both disrupt water level that flow across the dam at a particular moment. Predicting the several considerations forecasts the energy potential required towards a reservoir over a fixed time (DAO, 2018). Some countries which include India, Egypt, China as well as Pacific Northwest, have large numbers of electricity generating dams. As of 2015, SAIDI and SAIFI were to a greater extend capable of producing electricity through hydropower.

2.8.3 Quality of Power

Increased overall harmonic deviations (OHD) and devalued power factors are expensive in all stages of the electric power market. The effect of OHD is hard to assess, although causes heat, noise, breakdown, as well as meltdown. The energy function is the proportion of actual to actual power in the electricity system. Sketching somewhat bigger and actual outcomes in a low energy representative. Higher electric charge needs a cost-effective network to reduce energy loss, so that customers with low electric charge are billed with higher electric power rates through usage (Energy Price Fact Sheet, 2017). Power output is usually regulated at the transmission point. The range of corrective systems mitigates bad outcomes, but only real-time adjustment machines (old-style shifting version, new low-speed DSP shift, as well as fairly close-real-time) can be changed. Most modern devices eliminate issues while increasing investment returns and significantly reducing earthly electric charges. The level of power excellence issues can lead to incorrect reaction from different forms of analog and digital appliances (Energy Price Fact Sheet, 2017).

2.8.4 Balancingthe Process

The most common delivery and generation network is made up of 3 step systems, with special consideration paid to the synchronization of phases and the resultant lessening of electric charges from the earth. It is relevant for manufacturing/commercial channels in which the majority of the electric power is employed in 3-phase equipment, apart from small residential as well as business applications possess little to no real-time Passover switching capability. Usually, problem like this directs to unintended machinery action or failure in addition, to fires in severe situations (EIA, 2019). An instance, critical qualified analog or digital recording facilities should be attached to firmed power grids. In order to ascertain or reduce the burden of an imbalanced electric power grid, electricity companies bill strong unbalanced loads on demand or as a separate section (EIA, 2019). There are a few basic balancing techniques available that require fast computation and real-time modeling.

2.9 Electricity Generation in Nigeria: Sources, Challenges and Reforms

Nigeria's installed generation capacity is 25,255.2MW, of which about 4978MW in available generation capacity (NERC, 2015, see Appendix 3). The average peak generation capacity in 2015 did not exceed 5000MW compared to the Government's target of 6000MW. Present electricity generation in Nigeria is dominated by thermal generation capacity and most power plants are fuelled by natural gas. Of about 3900 MW available generation capacity on average in 2014, nearly 3500 MW (82%) was from gas sources, and 500MW (18%) was from hydro sources (Figure 2.6). The energy sent out by generation companies in 2014 to the national grid. The highest amount of energy sent out was recorded in May (2621.7Gwh), August (2589.3Gwh), and November (2601.4Gwh) 2014 while June (2248.4Gwh) 2014 witnessed the lowest amount (see Figure 2.12). The 4044MW actual available generation capacity as at September 2014 later dropped to 3,206.09MW as at Dec. 2 only to drop to 2,954.51 by Dec. 11, a reduction of 251.58MW in nine days and to 3500MW dated 16th December 2014 despite the federal government attempt to provide 5,000 MW available generation capacity as promised. Nigeria's electricity available generation capacity has fluctuated between 3,500MW and 4,400MW over the last two years, due in part to shortage of gas supply (a significant number of gas pipelines were vandalized across the country, which disrupted gas supply to power plants) as well as high transmission/distribution losses (THISDAY, August 21,2014). The decline in energy sent out by generation companies from February to April 2014 was attributable to shutdown of Forcados pipeline. This made power supply worsen by 1000MW (BusinessDay, 25 March 2014).

The reduction in the number of systems collapse as well as improvement in services delivery increased power generation to 4105.90MW in April 2014 (BusinessDay, 24 April, 2014). The peak grid generation further rose to about 4,044MW in September 2015 with per capita electricity consumption of 136KwH.The improvement in the power supply of 4,600 mw is attributed to the absence of gas pipeline vandalism. Similarly, NERC approved interim rules for TEM with the aim of establishing a framework to govern trading arrangements.

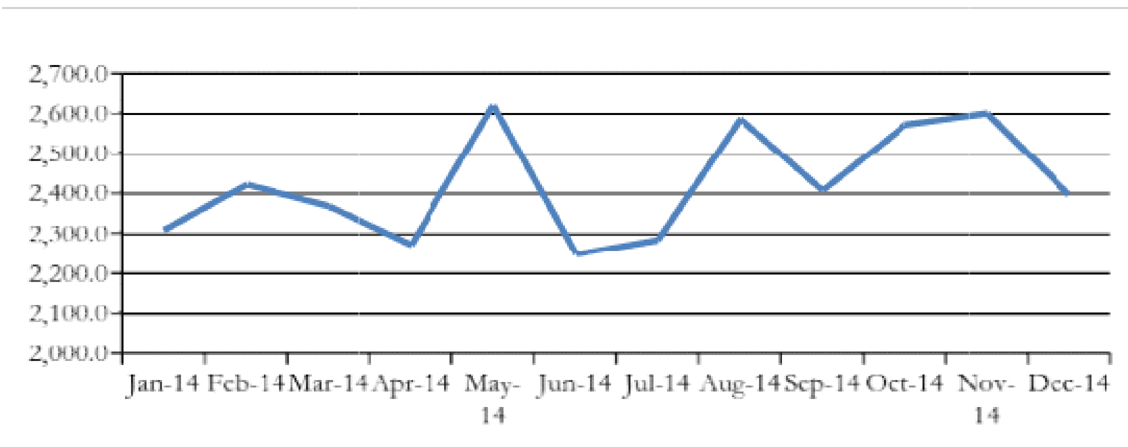


Figure 2.12: Energy Generated (GWH) by Generation Companies
Source: Nigerian Electricity Regulatory Commission (NERC), 2014

Of recent, the country's total energy sent out as depicted in Figure 2.13 exhibits the fluctuations between January 2015 and June 2016. The lowest was recorded in May 2015 while total energy sent out attained the highest in February 2016.

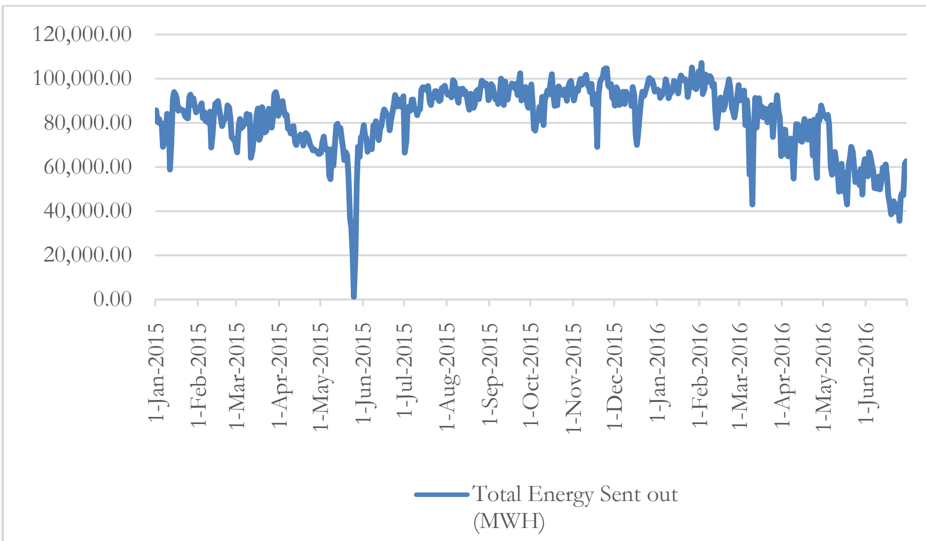
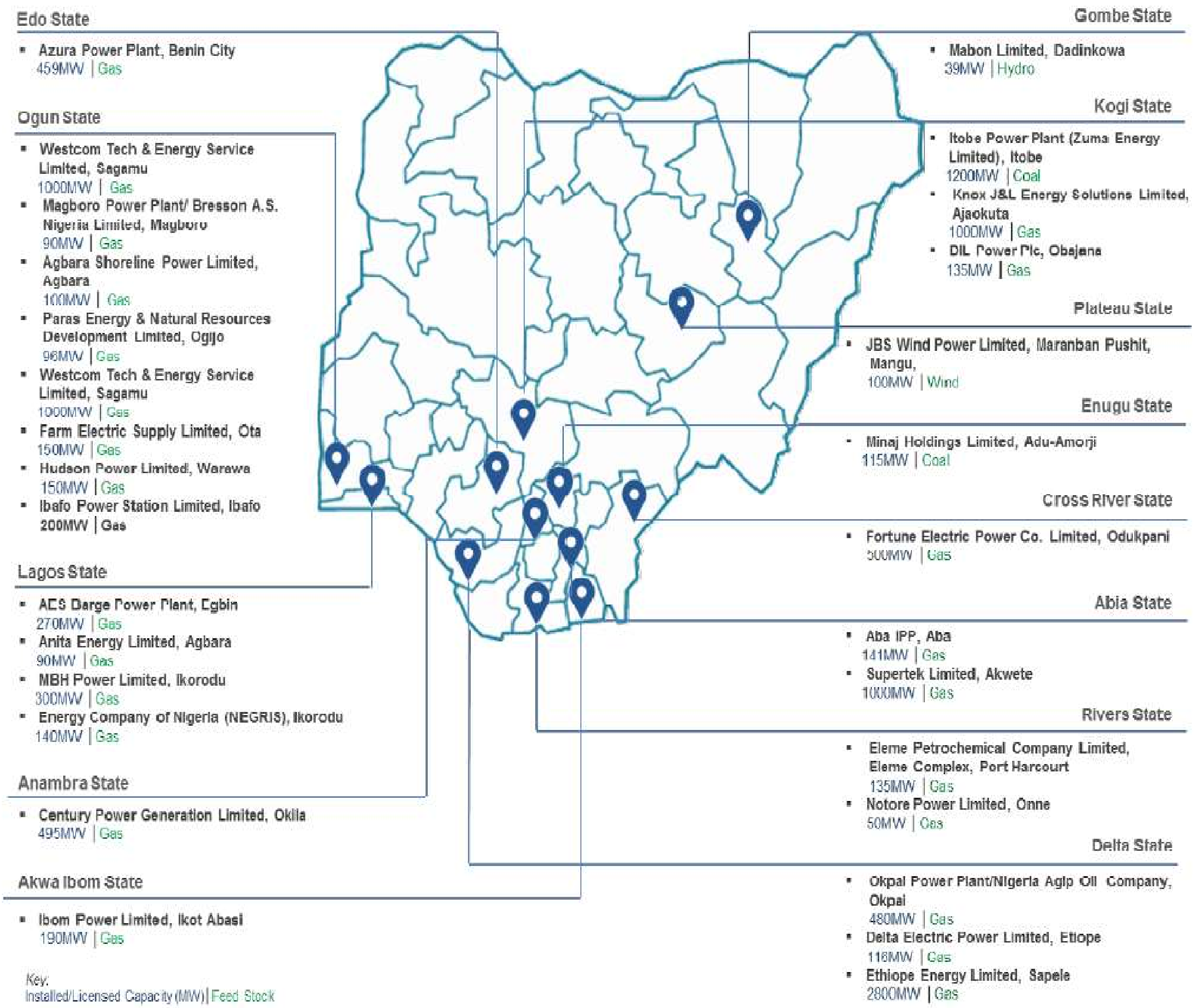


Figure 2.13: Energy Generated (GWH) by Generation Companies
Source: National Bureau of Statistics (NBS), 2016

The Nigerian electricity generation network is hindered by poor infrastructural facilities and natural gas shortages. The gas supply shortage often occurs because it competes with exports through which gas producers earn more profit by exporting the gas rather than selling them in domestic market at a much lower price. Another important contributor to the shortage of power even after the power sector has been privatized is the dual problem of inability to effectively protect gas pipelines and failure to provide effective policy and commercial frameworks for gas-to-power operators. The Chairman of the Nigerian Electricity Regulatory Commission (NERC) stated that before 2010, there was no effective gas to power policy, which reflected in the disarticulation of the two sectors (Bello, 2014). Gas power plants were established without the certainty of gas supply, although the situation is changing in 2014. Electricity generation in the present Nigerian situation is unrealistic without gas supply because gas powered power plants constitutes above 70% of the country's power generation plants. The gas thermal power still expects to contribute 75% of grid power by 2020 despite greater future power generation from hydro and coal. However, Gas Master Plan launched in 2008 to address these issues by focusing three main components specifically: Energy price scheme, Local gas supply Obligation and electricity facilities.

2.9.1 Current NIPPs in Nigeria



*Source: NIGERIAN ELECTRICITY REGULATORY COMMISSION

Figure 2.14: Current NIPPs in Nigeria
Source: Nigeria Electricity Regulatory Commission

2.9.2 The Current Key Players in Nigeria's Reformed Electricity Sector

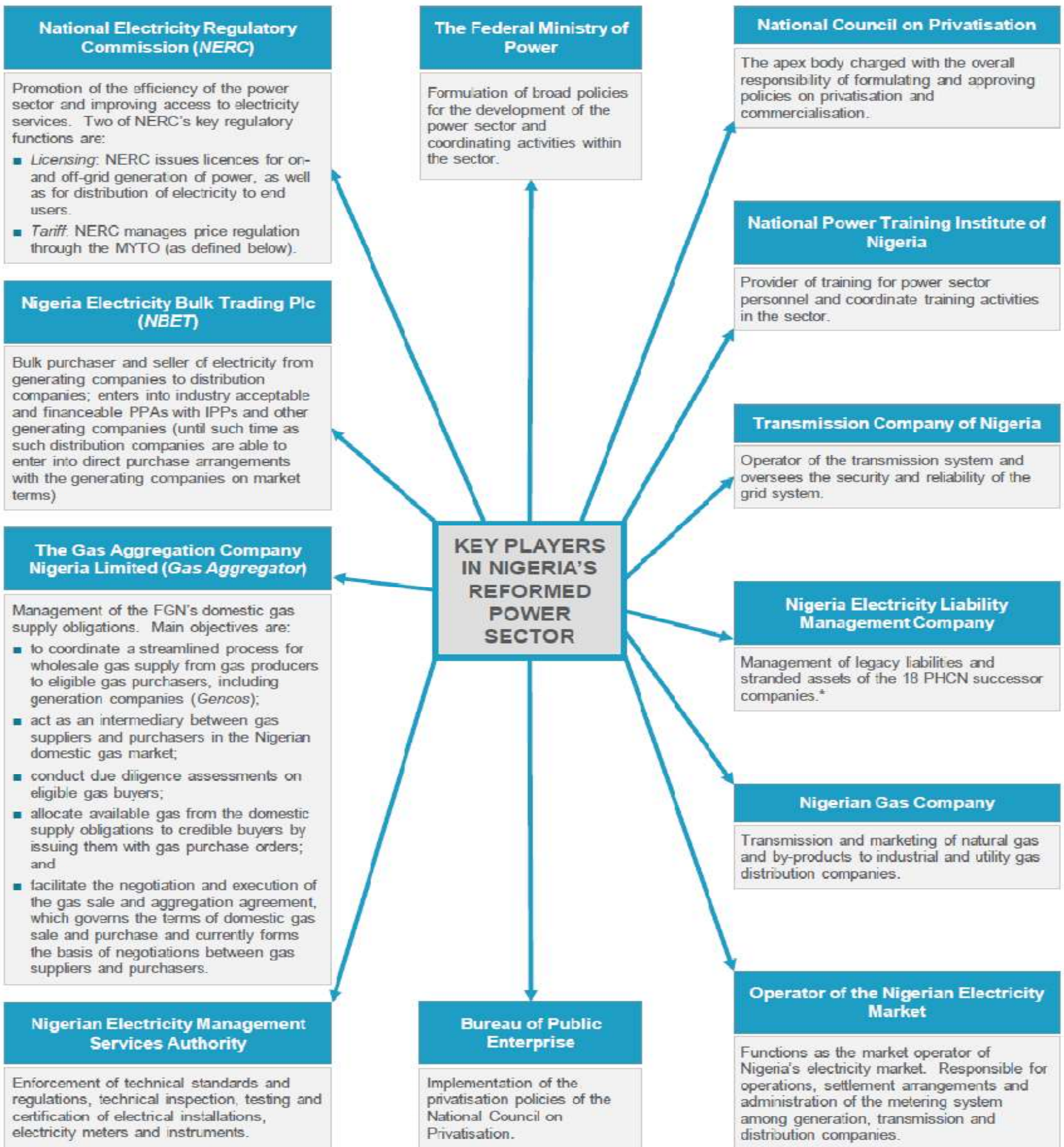


Figure 2.15: The Current Key Players in Nigeria's Reformed Electricity Sector
Source: Latham and Watkins (2016)

2.10.3 Trend Analysis of Key Policy Variables

As depicted in figure 2.16, the country was able to produce more than 6000 mmscfd from January 2015 to October 2016, with the exception of August 2016. The peak production of natural gas in Nigeria was recorded in July 2015 while the least was experienced in August 2016. The export accounts for the largest share, followed by the domestic utilization while the gas flaring constitutes the least. However, the country needs to strategize the means of converting gas flare into commercialized gas. In terms of production structure, figure 18 reveals that the production of natural gas is majorly carried out through the joint ventures' agreement.

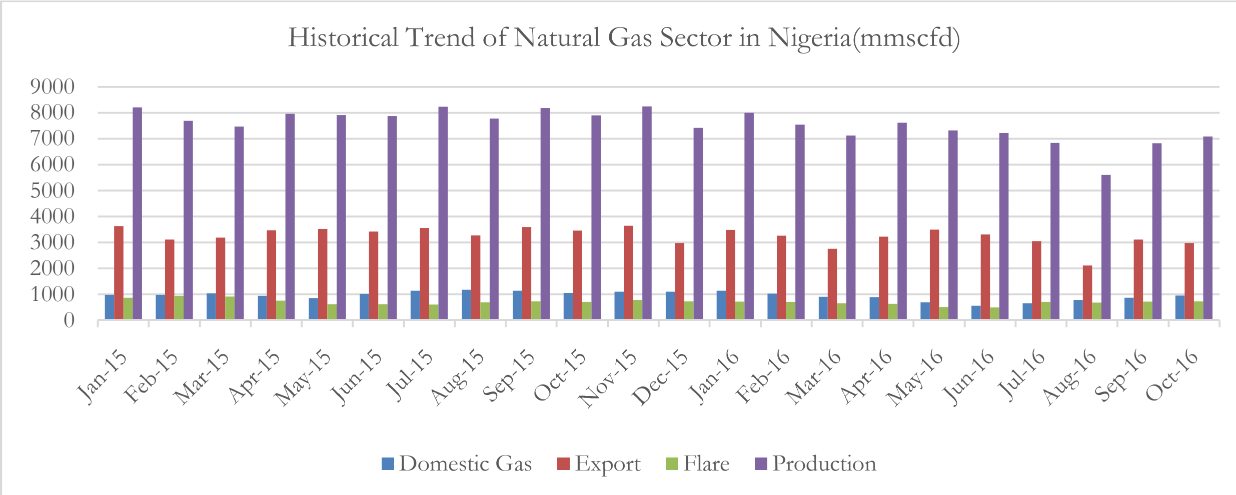


Figure 2.16: Monthly Trend of Nigeria's Natural Gas Sector, January 2015-Octoer 2016
Source: NNPC, Monthly Bulletin 2016

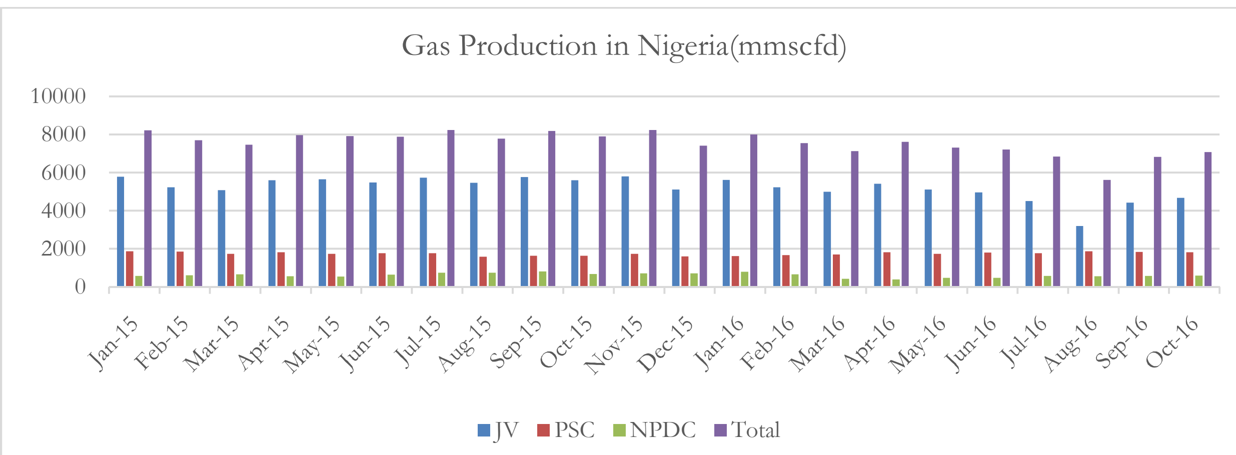


Figure 2.17: Monthly Trend of Nigeria's Natural Gas Sector, January 2015-Octoer 2016
Source: NNPC, Monthly Bulletin 2016

The power sector roadmap reform of 2010 was issued to develop policies and provide incentives for exploiting stranded gas locked up in various fields and for building gas transportation infrastructure as means of overcoming obstacles in the fuel-to-power end of the electricity sector value chain. Figure 2.18 depicts the nature of non-commercialized gas in the country. In addition, re-injection constitutes the largest proportion of non-commercialized gas, followed by the gas flaring while fuel gas accounts for the least.

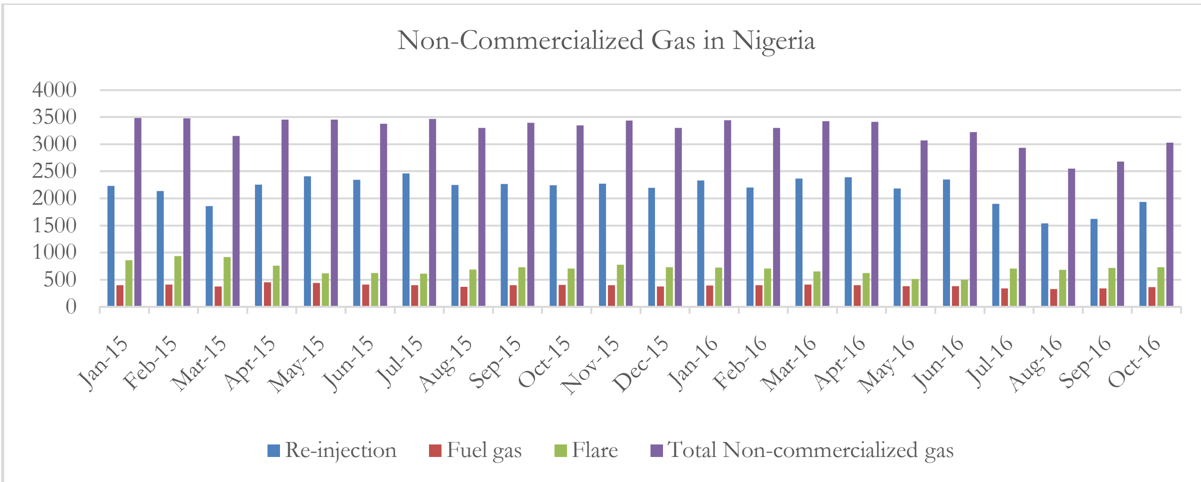


Figure 2.18: Nigeria's Gas Export Composition, January 2015-Octoer 2016
Source: NNPC, Monthly Bulletin 2016

Figure 2.19 shows that more than 80 percent of what the country exports are in form of liquefied natural gas for the covered period. Other forms such as WAPG, EGTL, NGL/LPG only accounts for less than 20 percent of the country's gas export.

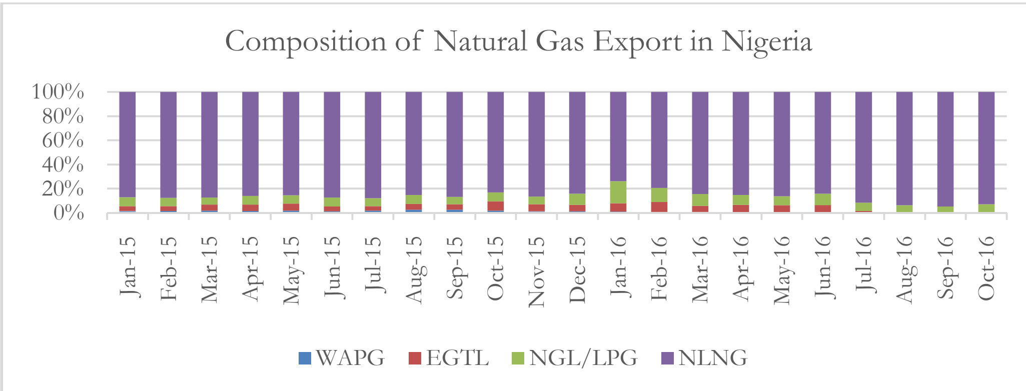


Figure 2.19: Nigeria's Gas Export Composition, January 2015-Octoer 2016
Source: NNPC, Monthly Bulletin 2016

As revealed in Figure 2.20, the total domestic utilization in Nigeria maintained a steady rise from about 1000 mmscfd in January 2015 to more than 1000 mmscfd in March 2015. The domestic use of gas exhibited fluctuations over the period, January 2015-October 2016. The highest total local use of gas of about 1200 mmscfd, was recorded in August 2015 whereas the lowest use of about 600 mmsfcd occurred in June 2016. The domestic use of natural gas in 2015 performed better compared to 2016 on average. Sectorally, domestic gas to power subsector still accounts for the largest share over the covered period. However, the average domestic use of gas for electricity generation recorded in 2016 still far below 2038 mmscfd demand projected for the year 2016. This indicates the existence of wide supply-demand gap in the country.

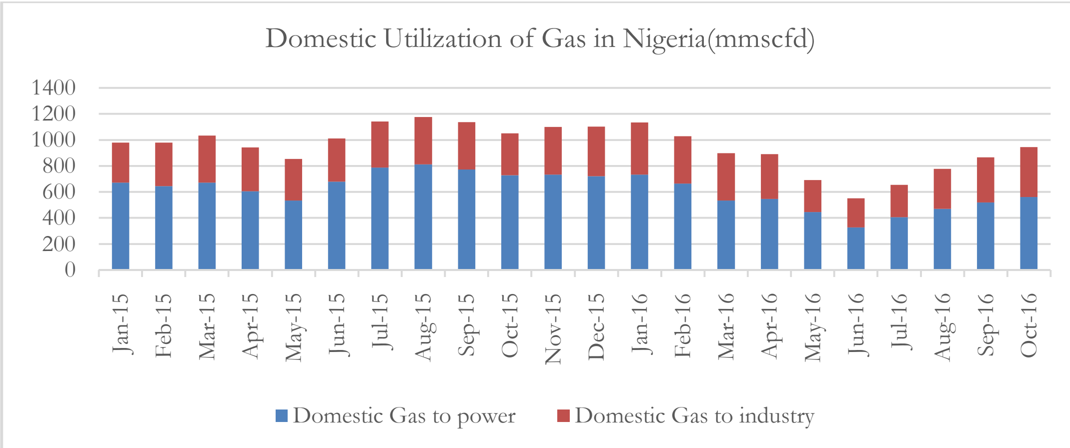


Figure 2.20: Domestic Utilization of Nigeria's Natural Gas, January 2015-Octoer 2016
Source: NNPC, Monthly Bulletin 2016

2.9.4 Gas Policy in Nigeria

The Nigerian Gas Master Plan was launched in 2008 with the aim of tackling challenges facing the advancements of the local gas section, enhancing monetization of gas, reducing gas sudden eruption and guaranteeing stability extending over a long period for the country. The Nigerian Gas Master Plan aims at attaining these goals through transforming the domestic gas market into a full competitive market by 2015, through developing sustainable commercial framework and providing basic infrastructure.

In addition, the federal government put in place the National Gas Supply and Pricing Policy as well as the National Domestic Gas Supply and Pricing Regulations to be embedded in the Gas Master Plan. The policy and the regulations impose a Domestic Gas Supply Obligation (DSO) on all gas producers to set aside a predetermined share of the gas production to be supplied to the domestic market. The policy broadly segments the domestic market into three subsectors: i) power subsector; ii) strategic industrial subsector such as methanol and fertilizer producers; and iii) strategic commercial subsector such as cement and steel manufacturers. The different regulated pricing is applicable to these subsectors with the aim that a pricing regime eventually leads to the competitive pricing.

The plan also includes a Gas Infrastructure Blueprint that provides detailed proposals for the private sector participation in developing infrastructures needed to boost the domestic market. Based on the Blueprint, the country is partitioned into three franchise areas to establish central processing facilities(CPFs), transmission and interconnection infrastructure for distributing gas to off-takers in the domestic market (Garba and Heo, 2014).

Due to the deficiencies of the Nigerian Gas Masterplan of 2008, the nation has developed a new National Gas Strategy to support growth and change in the gas sector. The inability of the Gas Master Plan 2008 to achieve the goal of creating a sustainable domestic gas sector by 2015. In fact, the limited amount of money invested in the sector over the period resulted in a lack of critical gas facilities and a failure to meet domestic gas supply commitments (NESG, 2016).

The persistence of a full-brown energy crisis in the country amidst the abundance of natural gas resources gave birth the formulation of the policy with a vision of making Nigeria an attractive gas-based industrial economy, focusing on satisfying domestic gas demand requirements and developing a substantial figure in the global markets. However, the program seeks to turn the nation from a crude oil-export economy to an enticing gas-based industrial economy. The following are key policy principles: (a) Separation of activities between the government and the private sector; (b) creation of a national oil regulatory authority; (c) full legal separation of upstream from midstream; (d) full legal separation of control of gas assets and gas marketing operations; and (e) ensuring further internal separation of upstream from midstream (f) adopting a project-based instead of centrally-planned domestic gas development technique; g) considering a strong maintenance and safety culture as a key priority ; h) applying international best practice for protecting the environment; i) building strong links with electricity, agriculture and the real sectors; j) establishing payment culture in the entire energy chain; k) creating stable contract terms ; l) ensuring asset security; and m) ensuring compliance with the Nigerian Content Act.

The strategy finds the domestic market to be massive and largely untapped due to the slow growth rate of local demand. Main issues identified include a lack of resources and investment in the gas sector, insufficient regulations for the gas industry, increased market competitiveness in both the Atlantic and Pacific gas basins, and a gradual decline in global investment flows to Nigeria.

The strategy lays out the expected short, medium and long term mechanism to promote the development of the country's gas market.

i. Short-term strategies: they deal with structural problems, such as the formulation of the Petroleum Regulations and the creation of a single regulatory body, and are required to be introduced within one year of the finalization of the strategy. In addition, the approaches will establish an appropriate Gas Network Code to allow unrestricted access to gas networks and improve wholesale gas processing. The expected industry growth projects to be carried out in the short term include the Energy Resource Management Report, the Natural Gas Industry Analysis and the Gas-Based Industry Strategy (GBI) and the Gas Flare Commercialization Programme. Institutional consolidation steps such as the privatization of the Ministry of Petroleum Resources and the initiation of the vertical integration of the Nigerian Gas Company.

ii. Medium-term strategies: the main medium-term strategies that are supposed to be adopted within one to two years are the review of the international gas market at African and global level, the promulgation of the Petroleum Industry Reform Bill and the Petroleum (Fiscal Reform) Bill, and the introduction of regulatory activities that include the creation of gas laws, technical codes and legislation. In addition, the pilot programs will be performed with the goal of substituting the use of wood / kerosene for LPG, as well as studies to find alternative fuel solutions for compressed natural gas (CNG).

Progress on the Ajaokuta-Kaduna-Kano Pipeline Project (AKK), Assa North and Ohaji South gas production is expected to be made under the medium-term strategies.

iii. Long-term plans: these policies are primarily industry-based, with the aim that they will be enforced starting two years and beyond after the finalization of the program. Significant measures will include the extraction of new gas from dedicated gas fields in inland and offshore basins; the execution of the downstream LNG strategy; the construction and commissioning of the AKK pipeline; and the improvement of the country's gas transmission system. In addition, continuing institutional and organizational capacity building and preparation to develop human resources and skills needed to improve the gas sector are crucial policy elements over the long term.

2.10 The Nigeria Gas Pipelines

SeveralNigerian gas pipelines have in service as at the time the nation discovered gas around the late 1960s, however, possess a short gas supply due to a very few power stations. The Federal Government of Nigeriahas recently decided to increase a few of the gas pipelines still in existence within the region. Examples include the Gas Master Plan (NNPC, 2013). This is shown by the recent contract signed by Nigeria and Algeria to develop a conduit made of pipes to convey gas having a total capacity of 30bcm/yr having a 48-56 inches in diameter (Ese, 2009; Nwahoa and Wood, 2014). Tran-Saharan gas pipeline, which is one of the conduits made of pipes to convey gas, started to make a possible way to link the abandoned natural gas in Nigeria to Algeria acting as a Passover country to a number of countries in Europe.

The conduits made of pipes will be linked to the‘Trans-Mediterranean, Maghreb-Europe,Medgaz and Galsi pipelines’ meant to deliver gas to countries in Europe. "The expected capacity of the pipeline is 4,128 kilometers: 1,037 kilometers in Nigeria, 841 kilometers in Niger then 2,310 kilometers in Algeria" (Ese, 2009). The Trans-Saharan gas pipeline is an expansion of the existing gas pipeline from the south to the north (trans-Nigeria) that linked the gas pipeline in Ajaokuta, Kogi State to Kano. The southern to northern gas pipelines have a diameter of 56 inches and 48 inches, from Calabar to Ajaokuta (490 kilometers) and from Ajaokuta to Kaduna (495 kilometers) respectively (Yar'adua, 2007; Nwahoa and Wood, 2014). The plan is for the double bond gas pipeline in Nigeria (south-north conduits only) to possess diameter of 985 kilometers from the Niger Delta gas manufacturing area to Ajaokuta which is also present in the Gas Master Plan (Ukpohor, 2009). Furthermore, other connecting conduits used to convey gas such as the Escravos gas pipe expansion, comprising of several inches should span about 686 kilometers (Ige, 2008) and the gas which interconnects pipe that is 100km in length and has a diameter of 42 inches. The construction of the east and north gas pipelines is a potential future strategy (Ukpohor and Theophilus, 2010).

The profit motive of the Trans-Saharan conduit-made pipes will be 45 per cent for Nigeria, 45 per cent for Algeria then 10 per cent for Niger. This was calculated to incur about $13 billion (Trans-Saharan Pipeline, 2009) while the Trans-Nigerian was calculated to incur over $2 billion having 60:40 debt/equity ratio (Nwahoa and Wood, 2014). Recently, there has been a great deal of attention paid by some countries all over Europe in contributing to the development of gas pipelines, but the key significant participants are searching for companies that offer technology quality as well as progress to lessen the burden of the cost incurred while retaining the capacity.

The double bond Nigerian conduit-made pipes is an imminent major gasadvancement project targeted to begin early engineering construction as early as 2015.WAPco reported that the largest pipeline has a diameter of 20inches, followed byGhana (Takoradi) with a diameter of 18 inches, then Benin (Cotonou) and Togo (Lome) with diameters 8inches each. "The pipeline network of

Escravos-Lagos possesses a maximum amount of 800 mscfd, however, the WAPCo system is originally expected to possess a maximum amount of 170 mscfd and a total over time of 460 mscfd" (Hamer 2012; WAPco, 2012).According to the firm, this gain is immense because it will lessen the amount incurred to purchase natural gas for countries in West Africa thereby ensuring the secure availability of the purest fossil fuel. It was projected this would attract even more international investment; and help to improve energy supply and commercial growth across the country. The project was analyzed to have incurred $974 million (Ukpohor, 2009). As of May 2008, there are more than 1,000 kilometers of linked gas pipelines in Nigeria, which are focused mainly in the Niger Delta area. Some conduits made pipes further away from the gas manufacturing area include the Ajaokuta gas pipeline as well as the largest Nigerian gas pipeline network, Escravos-Lagos, linking the pipelines to the Lagos shore, connecting the West African gas pipeline and transporting it through liquefied natural gas or the expanded conduits made pipes. The table2.6 summarizes the current major gas pipeline networks in the region.

Nigeria possess around 4 main gas pipelines in Nigeria, occupying over 1,000 kilometers of ground, all of which deliver gas to a number of energy generating plants, cements, together with fertilizers. The NGC, in addition, extended the conduit made pipes that convey gas in the country through a network map by including other limited, remote pipelines and observing the various destinations of these pipes to many industrial/commercial firms as well as power stations as given below (Nigerian Gas Company Limited, 2012):

1. The Aladja Gas Pipeline System that equips the Delta Steel Company, Aladja.
2. Gas is distribution to Ayaokuta Steel Company, Dangote Obajana Cement Company, and the PHCN Genegu Power Plants via the Oben-Ajaokuta-Geregu Gas Pipeline System.
3. Sapele gas supply systems supply gas to Ogorode, Sapele's PHCN power station.

4. The Foreign Glass Industry Limited PZ, Aba Textile Mills and Aba Fair Industry supplies Imo-River-Aba Network for electricity.
5. For the Afam PHCN Power Station the Obigbo North Afam network is available,
6. The pipeline system from Alakiri to Onne Gas now supplies the Notore Chemicals for fertilisation to the National Fertiliser Company (NAFCON);
7. Alakiri -Obigbo North -lkot gas supply system for the former Nigerian aluminum smelting company (ALSCON) Rusal Industries based in Ikot Abasi. Rusal Industries now has a gas supply facility.
8. The pipes of the Escravos-Lagos (ELP) carry gas to the Egbin power plant near Lagos. The next spur lines from the ELP are the supply of Western African Portland (WAPCO), Shagamu and Ewekoro, Ikorodu PZ Factories, Lkeja Lagos, Ughelli PHCN Delta IV, Warri Refining and Peter-Company.
9. Gas is supplied to Ikeja City Gate by Gasslink in the Lagos Indonesia Region (LIA), Ibafo – Ikeja Gasso supplies the Ikaya City Gate with electricity.
10. Gaslink Gas Pipelines for the Greater Lagos Industrial Region, Ikeja – Ilupeju – Apapa Gas Pipeline Network.
11. Ajaokuta – a pipeline facility that supplies gas to the PHCN Power Plant in Geregu.
12. Ajaokuta – Obajana Gas Pipeline System, manufacturer of gas for Dangote's cement plant (OCP). Obajana Gas Pipeline system.

All these systems are made up of more than 1,250 kilometers of pipelines with a combined construction capacity of more than 2,5 billion standard cubic meters of gas per day (bscf / d), 16 compressor stations and 18 metering stations. These plants serve more than N21 trillion market connections as the total asset base, Nigerian Gas Company Limited (Nigerian Gas Company

Limited, 2012). Several pipeline projects are ongoing, and a few being currently suggested for a course of action. Current ventures which are to increase the number of the present pipelines and extend the conduit made pipes to recent regions, particularly the North with absence of specific pipeline network in spite of the huge landmass and populationthat accounts for approximately 56% of Nigeria's overall population of over 160 million people (Nigerian Gas Company Limited, 2012).

Table 2.6: Major Gas Pipeline Networks within Nigerian Border

Project Name	Start Point	End Point	Diameter (inches)	Length (Kilometres)
Transmitting System	Banga Field	Bonny Terminal	32	268
Escarvos-Lagos Pipeline System (ELPS)	Escravos	Lagos	36	340
Aladja System Pipeline	Oben	Ajaokuta	24	294
Greater Ughelli System	Ughelli	Warri	-	90.3

2.11 Investment Decision Making and Risk

Avram *et al*., (2009) describe universal investment as spending that has now been made to make progress in the future. A business that works with international institutions such as European Bank for Reconstruction and Development, the European Commission, World Bankand amongst others. We devise a number of specific techniques for making investment decisions. (Avram *et al*., 2009) Financial spending is made to make money and can be rendered in two ways. Assets can be set on assets such as structures, equipment or on nominal investments including securities, shares, amongst others. The two ways of investment will help a business improve. In other words, investment is like a cover for investment if a real investment is substituted; or investment is like a net investment when new items of value are available to fund the investment, as well as ways to fund it (Harcourt *et al*., 1967). Economics profession analyzes the dangers from point of view of the decision-maker as to how, in the lack of perfect information, they make their choices. The theory and empirical study must be integrated in knowing and researching risk. Pure theory was not without shortcomings, and empiric findingon its own may be restricted and may remain simplistic. Combining theory with experience helps to identified weaknesses and strengths of the theory. On this note, hypotheses may be smoothed and also can assist to clearly understand its vulnerabilities (The Chavas, 2004).

2.11.1 Decisions on Investment in Economic Theory

The market for financial strategy is driven by the developer's previous income and the expectation of future gain prospects. Entrepreneurs are also ready to build in inventories, where the choice of such person relies on their previous experiences and the projected markets volume. When preparing for this, the investor considers it, in other words, the anticipated rate of gain and the probability of various future investment possibilities; and funding costs, on the other hand.When the projected level of gain outweighs the funding around the fringe sufficient to offset the threat factor, entrepreneurs will prefer to pursue the plan (Harcourt *et al*., 1967). The investor's investments decision is arbitrary. The judgment relies on the projected costs, the experience of advanced technologies and his understanding of risk, which is largely a discretionary consideration. Businessmen want to ask the pay-off date of the investment scheme and determine whether or not they will actually make the investment spending (Harcourt et al., 1967). In order to make a great investment decision, the buyer needs to fully and properly understand the potential benefits, and these decisions ought not be made in a rush. The incorrect investment decision can even drive businesses to bankruptcies. In order to obtain the highest value from the assessment process, very essential to know the primary concepts of decisions to invest. The metrics pertaining to the particular nature of the system and the knowledge kept by the decision-maker should be used for the investment appraisal (Avram *et al*.,2009). Spending is the distribution of assets for the mid to long term and the intended result is the return of operating costs as well as huge profits. In addition to monetaryassets, capital and real wealth are also utilised.

Financial and economic climate affects spending, so the actual results are unpredictable. (Avram *et al*.,2009). Decisions to invest are taken when a proposed comprehensive investment analysis have been considered. The risk factor of the investment is one of the fundamental factors that affect the decision. There is threat since it is unknown that project expensesmight be retrieved and that a return might be made. Decisions to invest and behavior of investmentcould be calculated from two angle. Capital outlay can be evaluated and monitored both analytically and logically.Analytical and scientific techniques to investing actions was not so similar. Nonfictional and structural aspects are important to the interpret the behavior of investment.

Jorgenson (1967) argues that it is an inaccurate belief that empiric and analytical work is done independently. Theory of economic is engaged for probabledescriptions of the behavior of investment. This reality distinguishes econometric research from empiric uniformization, that has not been checkedeconometrically. So necessary for the econometric investment behaviourtechniques to be evaluated in hopes of finding out whether or not they do well in the econometric research. (Jorgenson, 1967).

In order to better understand the behavior of investment and decision-making, it is very important to research into the theory of investment behavior and to examine the processes of investment in reality. Findings of empiric analyzes that aid the completeness or incomplete investment hypotheses, or they may simply be better understood. On the other hand, a valid and efficient scientific study and investment studies can be carried out on the basis of investing behaviour theories. Jorgenson (1967) indicates that progress can be made in the investment behavior analysis by analyzing economic models of such behavior within the theoretical framework proposed that they should be evaluated in a bid to know if or not they do well in the research that has to do with econometric (Jorgenson, 1967). He proposed that the investing principle had to be updated and that theoretical and observational research could be mixed.

2.12 Reviews of Empirical Studies

Some studies applied mathematical models in designing the state and national amount of energy processes while others used the linear programming methods mostly in budgets for limited electricity generation at building points(George Mavrotas*et al*., 2010; Rizzoa and Savinob, 2012). Studies such as; Feretic and Tomsic, 2005; Vithayasrichareon*et al.,* 2009; investigated uncertainties in input parameter, based on one-time investments while others (Mirzaesmaeeli*et al.,* 2010) presented multi-year investment plans without accounting for uncertainties. This indicates that little studies utilized energy models to examine the influence of risks on numerous-year investment initiatives.

Mirzaesmaeeli*et al.* (2010) considered a deterministic nonlinear mega - duration methodby limiting a linear modal with the use of a specific linearized model. Mavrotas*et al*. (2010) built a MILP framework for power management in such a guesthouse usingMonte-Carlo simulation (MCS) approach to measure the financial incertitude. Their method investigated how to minimize the annualized costs through the decision on what and type of energy alternatives to be installed to meet the energy services of the hotels.

Numerous studies such as Juan and Xueqian (2012); Wilko and Reinhard (2014); Zhe and Yanzhong (2015); Li *et al*. (2013) have investigated the optimization of power investment. For instance, Juan and Xueqian (2012) utilized linear programming model to design an economic decision-making for generation while Li *et al*., (2013) developed a 2-Stage optimal design and planning approach for mixing heat, cooling and power micro-grid system.

Studies on Nigeria mainly focus on gas domestic utilisation, gas pricing, and legal and regulation framework (see Oyewumi, 2015; Omisakin 2012, as cited in Akande, 2015). Scanty researches have been conducted on investment decision making in gas-power projects. Therefore, this serves as the main justification for the study by filling the existing gaps in the area of gas-power research and methodology in Nigeria.

Several Studies have utilised linear programming models as techniques in power investment and master plan (see Mavrotas, *et al*, 2003; Mirzaesmaeeli*et al.,* 2010). Studies such as, Cormio*et al*., 2003; Mirzaesmaeeli*et al*., 2010).

v. Filling Research Gaps

This study applies both a segregated risk and time-discounting approach. Therefore, its contributions are as follows:

i. Applying a RO-based method that determines the optimal technology including the optimal time to invest for an investor that intends to install a plant to a constant proportion between inputs and outputs. Owing to its mathematical complexity, it requires a mixed binomial lattice and a Monte Carlo technique with a separated time-and risk-reduction. Technology's unique economic risk is used in the discounting technique.
ii. Proposing a model that provides insights for an investor into an optimised decision process for the case of existence of multiple technological options and the absence of replicating the underlying assets
iii. Presenting new strategies in curbing the gas flaring for policy makers. The regulatory uncertainty about climate change policies is captured in the model through an unconstrained stochastic process and a constrained stochastic process with the gas flaring fines.
iv. Evaluating the optimal technology to invest, including the best time to invest for an energy utility that has the option to develop a gas-fired power plant. The basis of the model is a multi-dimensional real options approach where fuel price, electricity price etc. influence the value of all technological options.

Mavrotas*et al*. (2010) analyzed a certain case with the uncertain variables such as electricity price, natural gas price, and discount rate. Their results revealed that a makeshift Combined Heat and Power (CHP) component has been the component of each effective result realised after every reiteration with MCS. High natural gas prices and low electricity prices are recorded in few numbers of scenarios in which setup of CHP may not have been part of the optimisation process. Based on their findings, an investor addresses the framework for singular input parameter with assumption of increased gas prices and low energy costs, and afterwards optimisation method will be considered as sub-optimal in several scenario planning. However, the use of MCS could help policy makers achieve performance index under the model parameters that shift in the input parameters with respect to a particular uncertainty.

Studies such as Awerbuch and Berger (2003) and Roques *et al*., (2008) utilised the asset allocation method to get efficient power investment strategies for huge power systems. For a precise moment in a generation capacity, several other generating devices raise the cost than others in the portfolio. Compared to the risk, an optimal mix and communicate of techniques in the investment reduces over time the entire generation cost of the portfolio.The strategy is considered as an annual variability throughout the energy cost of devices (Awerbuch, 2000).

Some cost and risk are attached with each efficient portfolio. Therefore, the decision maker's perception about the risk influences the choice of the portfolio. However, the portfolio method is based under the assumption of normal distribution for the generation costs of several technologies (Awerbuch and Berger, 2003). Feretic and Tomsic (2005) employed a Monte-Carlo simulation to derive likelihood function of levelised cost of power from 3 distinct energy plants: coal, nuclear and crude oil.They regarded levelised cost of power as an estimated price of an amount of power from a power station throughout its lifecycle; and measured its module as US$/kWh.In addition, they applied probability distribution to unpredictable input variables including capital investment, cost of fuel, and implementation lifetime of power plant. This same research evaluated the influence on power costs as a result of externalities. The cost of energy from coal increases by almost 100 percent, and from natural gas rises by nearly 30 percent because of external cost. They concluded that costs of energy plants in the society and the environment are very important in determining the cost of energy. Therefore, any energy planning has to factor in the environmental costs whilst also assessing fundamentals of an electricity infrastructure program also in long run. However, the approach of Feretic and Tomsic (2005) is only relevant in simulating yielding expense of a particular power innovationon certainty instead of determining an optimal mix of different techniques.

Vithayasrichareon et al., (2009) designed a linear programming framework to examine effective procedure of a product line with the aim of mitigating operational costs. They applied Monte-Carlo Simulation to examine the influence of different complexities on the entire funding charges of several technologies such as coal, combine cycle gas turbine, and gas - fired reactor. The inconsistencies include carbon price coal price and price of gas, which are depicting with regular distributions. Similarly, Hawkes (2010) adopted a stochastic framework to influence the effective setup capabilities of various energy techniques in a power schemeThey based the objection function on minimizing equivalent annual cost (EAC) of power system. The authors carried out two sets of experiment. First set utilized a deterministic optimisation with a focus on specific projections of energy costs while the following set employed Monte-Carlo Simulation (MCS) for the mix of power architectures generated during first set to capture complexities in energy, gas and oil, and wind velocity. They found that MCS indicated that the deterministic optimisation did not account for economic risks. Therefore, their conclusion was that ideal strategy from a probable cost of oil prices leads to suboptimal under dynamic pricing price situations.In addition, a simulation analysis performs excellently than a single deterministic analysis in generation costs.

Rizzoa and Savinob (2012) addressed the power and climatic management challenges at limited scale as well as its municipal level through building a deterministic linear programming model. They described an efficient resource allotment algorithm to mitigate carbon output at educational institutions with the use of the model. In addition, an efficient alternative for such a specific programme is difficult to achieve by obtaining optimal solution to satisfy twice the average the target, and then increasing the principles of each target attribute to reach solution towards the full objective. For instance, they established that a strongest predictor to mitigate carbon pollution by 100 percent was not the same as a measure to minimize carbon output from 0 to 50 % and then increasing this same value attributed to each target attribute.The researchers concluded that well-defined targets and resources available at just the initial stage of a planned period are essential ingredients for the decision makers.

Cormio et al., (2003), on the other hand, developed a dynamic linear programming framework suited for achieving the ideal combination of power innovations for a metropolitan energy system, with the goal of decreasing the system's existing cost throughout the whole planning period of 10-20 years in Italy. They identified energy demand and environment as constraints. In the same vein, Mirzaesmaeeli et al., (2010) utilized a probabilistic multi-period MILP framework to find the ideal configuration of generation innovation which would satisfy power needs and Pollution targets at minimal expense.They centered their target function on minimizing total predicted cost during the planning horizon lifetime but they neglected to account for price volatility that may impact investment decisions.

In the Falode and Ladeinde (2016) report, the discounted cash flow model and the Monte Carlo simulation were used to test the Gas Power Plant Project for Nigeria's first Gas Industrial Park. The analysis has shown that the gas-fired power plant in the industrial park is commercially feasible and would have strong returns on investment under the current fiscal and regulatory system in Nigeria. With the aid of the number of economic indices seen in the results produced, it is a project that investors would be able to pursue. These approaches provided full insight into the context of the investment decision and showed the competitiveness of the generation of gas shot. A net present value of $10.8 million at a discount rate of 15 per cent and an intrinsic rate of return (IRR) of 16 per cent for a payback period of 9 years have been achieved. The probabilistic test offered 62.8% confidence that positive NPV and IRR values were above the investment hurdle limit. Ability factor, capital cost and debt costs were unknown criteria that would have a major effect on the power plant. The report suggests that the gas-fired power plant proposal in the industrial park is economically feasible. However, the total cost of the project, the plant efficiency factor and the leverage used to fund the project would be crucial to taking a final investment decision on the project (Falode and Ladeinde, 2016).

The results of Adamu and Daima (2017) have shown that the lack of adequate fuel supply facilities had created power imbalances in the nation, making the state entirely dependent on the few established reservoirs, making the nation's energy industry susceptible to any effects on those pipelines. The Nigerian Government recently agreed to create newly constructed gas infrastructure as part of the country’s strategy aimed at increasing fuel consumption. Therefore, this study observed how feasible it is to construct new gas pipeline alternatives to determine if investments in new gas infrastructure are feasible throughout Nigeria which pipeline alternatives are more feasible. This work utilized gas pipeline frameworks which already exist in the research to assess the costs of construction, gas supplies, and in addition, the risks and possible benefits of six oil pipeline pathways within the study area. A BSRO pipeline alternative was considered much more achievable and was assessed to have a yearly fuel supply of 37.25 bcm which would cost $1.15 billion to develop; $2.43 billion NPV, 50.38% IRR, 2.60 years repayment duration for a 40 year service. Therefore, regarding the scope or capacity to expand gas supply to larger regions, it is more desirable to open all possibilities for gas pipelines.

Iwayemi (1978) examined the question of long-term investment capital distribution in which divisions and economies of scale occur within a mixed-integer programming context.The basic requirement affects the electricity supply industry in Nigeria. Two different but related concerns have been discussed, including the extension of plant processing capability and pricing problems. The key finding on the energy side is that an effective energy policy driven by gas-fired or coal-fired plants is fundamentally based on the assumption made regarding the future cost of natural gas to the Nigerian economy.

The model's pricing findings indicate that the multi-step block pricing method (based on producing adequate revenue) presently employed by the industry is inefficient in terms of resource allocation. That is because it does not reflect the marginal cost of meeting peak and off-peak demand for electricity. Furthermore, because the amount of energy generated varies between countries, the national price of electricity will be different. There are, however, several enhancements that may increase the organizational utility of the investment model. The lack of evidence on plant reliability precluded the clear inclusion of a constraint on plant reliability into the model. Greater geographic disaggregation of demand is required to tackle the question of transmission line expansion more accurately than we have been able to understand in the model. In order to be able to draw more accurate projections of price and revenue elasticity of demand for electricity for improved market forecasting purposes, more detailed cross-section studies on market and income in the country are desperately needed. The need for improved decision-making in the use of limited economic resources in developed countries cannot be downplayed (Iwayemi, 1978).

Lundmark and Petterson (2008) studied how enhanced business complexities impact the timing and technical option of investment ventures in the power sector, based on the Swedish case, using two separate investment behavioral hypotheses. The investment model assumes stochastic input costs (fuel prices), production prices (electricity) and pollution permit prices.In addition, the Green Certification System currently in use in Sweden is stochastic integrated into the plan. The energy choices shown are offshore wind electricity, gas-fired power and biomass power. The findings indicate that bio-power is the most possible development option under both investment functional expectations and policy-driven investment timing. The probability of preferring gas power increases over time and the likelihood of choosing wind power declines over time, guided by the comparative capital requirements per unit of production for both technologies. Wind power will benefit if a lower rate of interest is used (Lundmark and Petterson, 2008).

Ogbe (2010) focuses on developing techniques for the use of natural gas. The research followed a linear programming model and the formulation is based on the principle of the Transshipment process formulation. The results of the study indicate that the optimization decision required continuity of projects (including both existing and planned) such as the Liquefied Natural Gas Project in Bonny (including selling of LNG and NGL), supply of gas for domestic use and power generation, export to West African countries, transport of natural gas to Algeria through the Trans-Saharan Gas Pipe.

All in all, some studies applied energy techniques which capture uncertainties in different input cost limits (George Mavrotas*et al*, 2010; and Vithayasrichareon*et al*., 2009) with concentration on one-time investment plans. However, researches such as Mirzaesmaeeli*et al.,* (2010), and Zakerinia and Torabi (2010) built power designs based on multi investment plans without provision for uncertainties.

As a result, the paper provides a probabilistic multi-period optimization method to determine the best mix of gas-to-power technologies in a small power system for a given demand.Furthermore, it would use Monte-Carlo Simulation (MCS) to account for unpredictability in power and natural gas prices, among other things.

CHAPTER THREE

METHODOLOGY

3.0 Introduction

This chapter frames the theory that is most appropriate to achieve the objectives of the study. In addition, the nature and the source of data, including the method of analysis is adequately discussed in the chapter. The description of the gas-fired power as well as the technical and non-technical input values needed to answer its research questions is provided.

3.1 Theoretical Framework

Theoretical framework for the study will be based on the irreversible investment theory under uncertainties emanated from the Q-theory of investment. The Q-theory encompasses all the assumption made in the neoclassical theory of investments and also presents appropriate conditions that are more realistic to the electricity generation investment. In order to develop the decision-making process for gas-power investment projects, this analysis would create a decision-making management model by evaluating two technologies, i.e. a single-gas turbine (GT) and a combined-cycle gas turbine (CCGT). The principle has the idea of irreversibility, which implies that once the investment is made, it will be passed to a sunk that isnot re-sellable. Irreversibility under volatility is an acute expression of the asymmetry of investment-adjusted prices. The hypothesis will be used to answer two problems: first, to assess the conditions to be fulfilled at the initial stage of the investment and, second, to define the investment change Anonymously, it is inferred that permanent investment exists as a result of the following: no substitutability across highly specialized items; the selling of capital goods by one investor makes it possible for capital goods to be sold by one investor. The basic features of an unsustainable investment model under uncertainty are as follows: 1) the need to fund irreversibility expenses converted to sunk costs; 2) the high level of volatility and risks associated with potential capital investment revenues; and 3) the inconclusive judgment does not impact investment opportunities (Ming *et al*., 2016).

3.1.1 Decision to Delay an Investment

Having a license by a firm to construct a gas fired power plant is right without any mandate to invest in it. Decision on when to invest lies in the hand of a firm as long as its license does not expire. When a firms decide to make an investment to build a power plant, the investment cost is regarded as the sunk cost that is not retrievable. Therefore, it is widely acceptable that investment is normally made when the net present value of the expected cash flows above zero as expressed in equation 3.1.

Although, this might not be valid because the option to wait (or other options) are ignored. An avenue is made to delay investment, the option to wait provides better returns than today's investment.

With the assumption that investment cost is fully retrievable or a room to invest now or never while focusing the NPV of future expected cash flows, creates absence of the option to wait. This poses a key constraint to the NPV method. This implies that the last day of the license does not make the NPV analysis invalid. Consideration to invest comes before the option of postponing the investment.

$$\text{NPV} = \text{PV (future cash flows)} - \text{Investment} \geq 0 \qquad 3.1$$

$$\text{PV (future cash flows)} - \text{Investment} \geq \text{Option to wait} \qquad 3.2$$

3.2 Methodology

The mathematical programming is designed as a measure to address the problem of optimization. According to Winston and Goldberg (1994), the components of a typical optimization problem are objective function, decision variables, and constraints. The objective function is the goal of the problem which is expressed to help reduce or enhance a set of criteria (costs or economic advantages) or various criteria concomitantly (costs and risks). The selection variables capture decisions to be made to address the issue while limitations refer to circumstances that have to be satisfied by any remedy. Put differently, the limitations of value judgment variables can be restricted.

The optimization problems are expressed in forms of mathematical models that attempt to determine the values of decision factors that reduce or enhance the goal function between the collection of all selection factors under defined circumstances. These limitations employed to ensure the energy and power requirement of a power system. Additional limitations include shortcomings, physical challenges, fuel system over the whole operating phase (Hobbs, 1995). This chapter builds a gas-to-power planning model that entails mathematical programming and Monte Carlo simulation in order to provide answers to research questions raised in the chapter one. Combining the two models is a complex task but this study will adapt a technique similar to Feretic and Tom sic (2005) and Hawk (2010). The study employs its approach in two parts. The first part builds an integer programming optimization algorithm to find an energy system. The second section experiments Monte Carlo simulation in terms of the results from the first part to capture unpredictability.

The research modeled the probability using the endogenous discount rate. Nevertheless, endogenous risk management questions the concept of time-constant parameters (e.g. growth rate and volatility) for stochastic processes. In order to implement the optimal complex efficiency of the investment strategy, the real option approaches include the importance of the waiting period. The general assumption of the multi-asset option models was that, once the transaction has been made, the value of the various underlying assets appears unpredictable over time. It translates to a time-invariant approach, meaning that neither the rate of growth nor the value of the asset portfolio has to evolve and change. However, in a real situation, the fund needs to be re-adjusted overnight. Well-performing assets improve their value over time but otherwise face bad-performing assets. In the case of power generation plants, the preference of the applicable technology determines the quantity of inputs and outputs as well as the relation between them for the lifetime of the plant.

The study decides the optimal investment technology as well as the optimal time to invest in the event that the electricity sector has the option of constructing a new power generation project at specific locations in the world.

Assumptions

The model was built based on the following assumptions:

i. The plant will be generating electricity only, with application of large combine cycle gas turbine using natural gas as fuel source

ii. The plant will be situated either close to existing gas source (<100km) or away from the gas source (>100km). The type and size of the gas turbines installed will determine the plant's part load efficiency and ramping time. The main point for considering the location is that climate conditions influence the thermal efficiency of the process and also minimizing of the infrastructure investment in term of gas transport and electricity transmission system is one of the specific objectives of the study.

Input parameters to be used for real option analysis are: investment costs, operating costs and cost of emissions, efficiency and availability, and input values

3.2.1. Developing Design of Irreversible Investment amid Risks

In relation to the theoretical framework, the design of investment considers gas-to-power generation technologies that are connected with power grid. Both cost of gas and electricity cost are of high uncertainty. The two parameters are line with the Brownian motion of:

$$\frac{dP_G(t)}{P_G(t)} = \alpha_G dt + \delta_G du_1(t) \qquad 3.3$$

$$\frac{dP_E(t)}{P_E(t)} = \alpha_E dt + \delta_E \sigma_{GE} du_1(t) + \delta_E \sqrt{1 - \sigma^2{}_{GE} du_2(t)} \qquad 3.4$$

Where α_i andδ_i are constants of cost drift and cost fluctuations. dt represents infinitesimal time increment. du_1 and du_2denoting two normal Brownian motion amounts insignificant. σ_{GE} captures the importance of P_G and P_E, which costs are known information at time 0. The significance of $\sigma_{GE}$is established even though electrical power is partially influenced by gas cost. The normalized Brownian motion of the price is specified as:

$$P_G(t) = P_G(0)e^{(\alpha_G - 0.5\delta_G^2)t + \delta_G u_1(t)} \qquad 3.4$$

$$P_E(t) = P_E(0)e^{(\alpha_E - 0.5\delta_E^2)t + \delta_E \theta u_1(t) + \delta_E \sqrt{1-\theta^2 u_2(t)}} \qquad 3.5$$

The random parameters of operational costs (gas cost of electricity generation) is simply considered. Fuel cost of power system is denoted as C_{GP} with the following equation:

$$C_j\big(P_G(t), P_E(t)\big) = \frac{P_G(t)}{\varphi_j} + \frac{1-\pi_{\omega j}}{\pi} P_E(t) \qquad 3.6$$

Where φ_j measures thermal efficiency, πdenotes the heat concentration (the heat of per kilowatt hour) that is considered as a fixed number.ωj rrepresents the electricity usage level of the mechanism.

The study intends to evaluate the volatility of the price of gas (input cost variable), and cost of electricity (the output cost variable) by making an assumption of being fixed. The system will realize a specified net revenue, obtaining from electrical power sales. The earning denoted as $R_\gamma$minuses generating charges is the cash flow of the mechanisms. Cash flow,τ_j expressed in term of the gas price and electricity price, can be described as:

$$\tau_j\big(P_G(t), P_E(T)\big) = R_\gamma - K_{Gj}P_G(t) - K_{Ej}P_E(t) \qquad 3.7$$

Where K_{Gj} and K_{Ej} denotes the cost factor, which can be written as:

$$K_{Gj} = \frac{1}{\varphi_j}; K_{Ej} = \frac{1-\pi_{\omega j}}{\pi} \qquad 3.8$$

The investment of electricity generation is expected to maintain a permanent cash flow (τ_j) at the cost of sunk cost (C_t). The value of power plant at any period can be specified as the present discounted value

$$ב_j(t) = E_t\left[\int_t^{\infty} \tau_j\left(P_G(t), P_E(t)e^{-\theta(\vartheta - t)}dt\right)\right] \quad 3.9$$

E_t refers to the approach to transfer future cash into present cash. The present value equation can further be expressed as linear function of prices. ϑ denotes the discount factor.

$$ב_j(t) = \frac{R_\gamma}{\theta} + \frac{K_{Gj}P_G(t)}{\theta - \alpha_G} - \frac{K_{Ej}P_E(t)}{\theta - \alpha_E} \qquad 3.10$$

Projectedcost of gas and electricity cost is expected to rise as time flows with the drift parameter α_i change. This invariably leads to a periodic adjustment of the discount factorϑ.

3.2.2 Decision-making Design on Generation Consoles using Real Option Techniques

Option value of generation technology entailing the gas price $P_G(t)$ and electricity price $P_G(t)$ at time t can be written as

$$\theta V_j\left(P_G(t), P_E(T)\right) = \frac{E[dV_j]}{dt} > 0 \qquad 3.11$$

Where θV_j denotes the return on investment opportunities in unit time; the right side is the capital increment of option holder. The capital increment can be written as:

$$\frac{E[dV_j]}{dt} = \frac{1}{2}\delta_G^2 P_G^2 \frac{\partial^2 V_j}{\partial^2 P_G^2} + \sigma_{GE}\delta_G\delta_E P_G P_E \frac{\partial^2 V_j}{\partial^2 P_G^2} + \frac{1}{2}\delta_E^2 P_E^2 \frac{\partial^2 V_j}{\partial^2 P_E^2} + \alpha_G P_G \frac{\partial V_j}{\partial P_G} + \alpha_E P_E \frac{\partial V_j}{\partial P_E} \qquad 3.12$$

The temporary differential of equation can be specified as

$$\frac{1}{2}\delta_G^2 P_G^2 \frac{\partial^2 V_j}{\partial^2 P_G^2} + \sigma_{GE}\delta_G\delta_E P_G P_E \frac{\partial^2 V_j}{\partial^2 P_G^2} + \frac{1}{2}\delta_E^2 P_E^2 \frac{\partial^2 V_j}{\partial^2 P_E^2} + \alpha_G P_G \frac{\partial V_j}{\partial P_G} + \alpha_E P_E \frac{\partial V_j}{\partial P_E} - \theta V_j = 0 \qquad 3.13$$

The equation 3.12 can be written as follows if the investors focus on input prices and the determined drift parameters ($\alpha_G = \alpha_E = 0$):

$$\frac{1}{2}\delta_G^2 P_G^2 \frac{\partial^2 V_j}{\partial^2 P_G^2} + \sigma_{GE}\delta_G\delta_E P_G P_E \frac{\partial^2 V_j}{\partial^2 P_G^2} + \frac{1}{2}\delta_E^2 P_E^2 \frac{\partial^2 V_j}{\partial^2 P_E^2} - \theta V_j = 0 \qquad 3.14$$

At this time, it will be left for investors to decide whether to invest or to stay on hold. Put differently, investors make decision on whether to use fund $C_1$to exchange the asset in value of $ב_j(t)$ which will return back a permanent cash flow. The revenue function (call option) can be expressed in the absence of time limits as follows:

$$O_j\big(P_G(t), P_E(T)\big) = max\left[\frac{R_\gamma - K_{Gj}P_G(t) - K_{Ej}P_E(t)}{\theta} - C_{1,0}\right] \qquad 3.15$$

Where C_1 represents the sunk cost. Since the option right can be applied at any time, the inherent value of option $[V_j\big(P_G(t), P_E(T)\big)]$ often take the dominant role i.e. $V_j\big(P_G(t), P_E(T)\big) \geq O_j\big(P_G(t), P_E(T)\big)$.

The boundary conditions ($\widehat{P_{GJ}}$, $\widehat{P_{EJ}}$) where the option is exercised are considered as the optimal choice. For instance, Unless the input cost lies under the low border line, the right choice of bearer would be to exercise the option straight, because at this time, the option value is equivalent to the net value of investment. Furthermore, it implies that the return of investment choice in unit time is greater than capital carrying choices. Balance situation can be specified as follows

$$\theta V_j\big(P_G(t), P_E(T)\big) > \frac{E[dV_j]}{dt} \qquad 3.16$$

On the other hand, Whether the input cost surpasses the upper border, then the optimal choice for the investors is to hold the option. Two things are likely to occur when $0 < P_G(t) \leq \widehat{P_{GJ}}$ and $0 < P_E(t) \leq \widehat{P_{EJ}}$, this leads to the following equations:

$$V_j = \frac{R_\gamma - K_{Gj}P_G(t) - K_{Ej}P_E(t)}{\theta} - C_1 \qquad 3.17$$

$$\frac{1}{2}\delta_G^2 P_G^2 \frac{\partial^2 V_j}{\partial^2 P_G^2} + \sigma_{GE}\delta_G\delta_E P_G P_E \frac{\partial^2 V_j}{\partial^2 P_G^2} + \frac{1}{2}\delta_E^2 P_E^2 \frac{\partial^2 V_j}{\partial^2 P_E^2} - \theta V_j \leq 0 \qquad 3.18$$

When $\widehat{P_{GJ}} < P_G(t)$ or $\widehat{P_{EJ}} < P_E(t)$, the below equations emanate:

$$V_j > \frac{R_\gamma - K_{Gj}P_G(t) - K_{Ej}P_E(t)}{\theta} - C_1 \qquad 3.19$$

$$\frac{1}{2}\delta_G^2 P_G^2 \frac{\partial^2 V_j}{\partial^2 P_G^2} + \sigma_{GE}\delta_G\delta_E P_G P_E \frac{\partial^2 V_j}{\partial^2 P_G^2} + \frac{1}{2}\delta_E^2 P_E^2 \frac{\partial^2 V_j}{\partial^2 P_E^2} - \theta V_j = 0 \qquad 3.20$$

The boundary condition is applied to solve the above equations. If the electricity price is assumed to be zero, the investment cost theorem could be expressed as at $P_E(0) = 0$

$$V_j(t) = \frac{R_\gamma - K_{Gj}P_G(t)}{\theta} \qquad 3.21$$

The linear ordinal differential algorithm of second inferred from the temporary differential equation is defined as

$$\frac{1}{2}\delta_G^2 P_G^2 \frac{\partial^2 V_j}{\partial^2 P_G^2} - \theta V_j = 0 \qquad 3.22$$

The generation solution can be deduced as

$$V_j(P_G(t), 0) = A_{Gj} P_G(t)^{\alpha G} + B_{Gj} P_G(t)^{bG} \qquad 3.23$$

$$\alpha_G = \frac{1}{2} - \sqrt{\frac{1}{4} + \frac{2\theta}{\delta_G^2}} < 0 \qquad 3.24$$

$$b_G = \frac{1}{2} - \sqrt{\frac{1}{4} + \frac{2\theta}{\delta_G^2}} > 1 \qquad 3.25$$

This solution is valid on the condition that the fuel cost plummets over a certain scope, and keeping the choice to be feasible for the investment manager.The lesser price the price of gas, the capital expenditure seems to be more desirable. If $P_G(t)$is minimal enough or even attain the finance baseline worth ($\bar{P}_{Gj}$), thereby the option has to be exercised.

In order to solve the equation 3.22, three unknown parameters need to be specified($A_{Gj}, B_{Gj}, \bar{P}_{Gj}$). First step is to make the available choice value equal the asset value at the threshold number, $\bar{P}_{Gj}$as in equation 3.25. Second task is making the two functions tangent to each other; therefore, equation 3.26 is deduced.

$$V_j(\bar{P}_{Gj}, 0) = \text{ב}_j(\bar{P}_{Gj}, 0) - C_1 \qquad 3.26$$

$$\frac{dV_j(\bar{P}_{Gj}, 0)}{dP_G(T)} = \frac{d\text{ב}_j(\bar{P}_{Gj}, 0)}{dP_G(T)} \qquad 3.27$$

Then the following expression is obtained:

$$V_j(P_G(t), 0) = A_{Gj} P_G(t)^{\alpha G} \qquad 3.28$$

$$A_{Gj} = -\frac{K_{Gj}}{\theta_{\alpha G}}(\frac{\alpha G}{\alpha G-1} \cdot \frac{R_{\gamma}-\theta I_j}{K_{Gj}})^{1-\alpha G} \qquad 3.29$$

$$\alpha_G = \frac{1}{2} - \sqrt{\frac{1}{4} + \frac{2\theta}{\delta_G^2}} < 0 \qquad 3.30$$

$$\bar{P}_{Gj} = -\frac{\alpha G}{1-\alpha G}\frac{R_{\gamma}-\theta C_1}{K_{Gj}} \qquad 3.31$$

$$\beth_j\left(\bar{P}_{Gj}, 0\right) = \frac{1}{1-\alpha G}(\frac{R_{\gamma}}{\theta} - \alpha G C_1) \qquad 3.32$$

In addition, unless the input cost becomes too expensive, it will be doubtful for the investor to operate economically. In the above condition, the available choice value is nil. Therefore, some limiting conditions are expressed below:

$$V_j(P_G(t), 0) = \begin{cases} \frac{R_{\gamma}-K_{Gj}P_G(t)}{\theta} - C_1 P_G(t) \leq \bar{P}_{Gj} \\ A_{Gj}P_G(t)^{\alpha G} P_G(t) > \bar{P}_{Gj} \end{cases} \qquad 3.33$$

$$V_j(P_E(t), 0) = \begin{cases} \frac{R_{\gamma}-K_{Ej}P_E(t)}{\theta} - C_1 P_E(t) \leq \bar{P}_{Ej} \\ A_{Ej}P_E(t)^{\alpha E} P_E(t) > \bar{P}_{Ej} \end{cases} \qquad 3.34$$

$$V_j\left(P_G(t), P_E(t)\right) = 0 \ \lim \quad P_G(t) \to \infty \qquad 3.35$$

$$V_j\left(P_G(t), P_E(t)\right) = 0 \ \lim \quad P_E(t) \to \infty \qquad 3.36$$

Optimal solutions are obtained by satisfying the two circumstances. First, the available choice value is the same as the asset value (value fitted condition); second, the border of available choice value and the asset value has to be seamless (seamless pasting circumstance).Whereupon, the asset best possible question is regarded as a linear synergistic decision concern.

The whole study adopts the tacit finite distinction approach to address this issue.The approach is intended to substitute the Taylor series. This partial integral of the approximate discrete value is obtained.

The study defines the gridding with specified-step as follows:

$$P_{G,K} = P_{G,K-1} + g \quad P_{G,0} = 0 \quad k = 0,1, \ldots., m \qquad 3.37$$

$$P_{E,j} = P_{G,j-1} + h \quad P_{G,0} = 0 \quad l = 0,1, \ldots., n \qquad 3.38$$

Where g represents the step width from $P_{G,K}$ to $P_{G,K-1}$, h denotes the step width from $P_{G,l}$ to $P_{G,l+1}$. The function value of $V_j(P_G, P_E)$can be expressed as$P_j(P_{G,k}, P_{E,l}) \equiv V_{j,k,l}$. The partial subset can be outlined in

$$\frac{\partial^2 V_j}{\partial P_G \partial P_G} \approx \frac{1}{4gh}\left(V_{j,k+1,l+1} - V_{j,k+1,l-1} - V_{j,k-1,l+1} + V_{j,k-1,l-1}\right)$$

3.38

$$\frac{\partial^2 V_j}{\partial^2 P_G^2} \approx \frac{1}{g^2}\left(V_{j,k+1,l} - 2V_{j,k,l} - V_{j,k-1,l+1} + V_{j,k-1,l}\right) 3.39$$

$$\frac{\partial^2 V_j}{\partial^2 P_E^2} \approx \frac{1}{h^2}\left(V_{j,k,l+1} - 2V_{j,k,l} - V_{j,k-1,l+1} + V_{j,k,l-1}\right) \qquad 3.39$$

With the introduction of the constricted circumstances of step-length ($P_{G,m} \gg 0$ and $P_{E,n} \gg 0$) and slack variable ($\varepsilon_{j,k,l}$), then Best possible issue may be regarded as a linear synergistic issue like in equation below

$$P_{1j,k,l}V_{j,k+1,l+1} + P_{2j,l}V_{j,k,l+1} - P_{3j,k}V_{j,k+1,l} - P_{4j,k,l}V_{j,k,l} + P_{3j,k}V_{j,k-1,l} -$$

$$P_{1j,k,l}V_{j,k+1,l-1} + P_{2j,l}V_{j,k,l-1} + P_{1j,k,l}V_{j,k-1,l-1} \leq 0 \quad \perp \varepsilon_{j,k,l} \leq 0 \qquad 3.40$$

$$V_{j,k,l} - \left(\frac{R_Y - K_{Gj}P_G(t) - K_{Ej}P_E(t)}{\theta} - C_1\right) + \varepsilon_{j,k,l} \geq 0 \perp -\infty < V_{j,k,l} < +\infty \qquad 3.41$$

The boundary conditions are as follows

$$V_{j,k,l} = \begin{cases} \frac{R_\gamma - K_{Gj}P_G(t)}{\theta} - C_1 P_G(t) \leq \bar{P}_{Gj} \\ A_{Gj}P_G(t)^{\alpha G} P_G(t) > \bar{P}_{Gj} \; and \; k \neq 0 \end{cases} \quad 3.42$$

$$V_{j,0,l} = \begin{cases} \frac{R_\gamma - K_{Ej}P_E(t)}{\theta} - C_1 P_E(t) \leq \bar{P}_{Ej} \\ A_{Ej}P_E(t)^{\alpha E} P_E(t) > \bar{P}_{Ej} \; and \; k \neq 0 \end{cases} \quad 3.43$$

$V_{j,m,l} = 0V_{j,k,n} = 0$ 3.44

$P_{1j,k,l} \equiv \frac{\sigma_{GE}\delta_E P_{G,k} P_{E,l}}{4gh}$3.45

$P_{2j,k,l} \equiv \frac{\delta_E^2 P_{E,l}^2}{2h^2}$ 3.46

$P_{3j,k,l} \equiv \frac{\delta_G^2 P_{G,k}^2}{2g^2}$ 3.47

$P_{4j,k,l} \equiv \frac{\delta_G^2 P_{G,k}^2}{g^2} + \frac{\delta_E^2 P_{E,k}^2}{h^2} + \theta$ 3.48

CHAPTER FOUR

DATA ANALYSIS AND RESULTS PRESENTATION

4.0 Introduction

In this section, the results from the historical data (see Appendix 3) analysis using the charts, mean scores, standard deviation, minimum and maximum for each price are presented. These become necessary to examine the properties of the gas and electricity prices. Also, to find whether the nature of the prices corresponds to Geometric Brownian Model (GBM) outlined in the preceding chapter in developing irreversible investment model under uncertainties and obtain new and more up to date, parameters. In addition, the results from the descriptive analysis in terms of the estimated parameters (growth rate and volatility) under the first part are used to capture future uncertainties where Monte Carlo simulations were implemented.

4.1 Descriptive Analysis

As discussed earlier, this section summarizes the basic statistical features for the price of gas and electricity. These include the trend analysis, mean and coefficient of variation. Specifically, the under consideration are; Gas Price for Plants Located near the Source \$/mbtu, Gas Price for Plants Located away from the Source \$/mbtu, Electricity Price for Plants Located near the Source \$/kwh and Electricity Price for Plants Located away from the Source \$/kwh.

4.1.1 Trend

This section begins from examining the peculiar behavior of the monthly historical gas and electricity prices from January 2013 to December 2017 (see Appendix 1).

4.1.2 Gas Price for plants located near the source from January 2013 to December 2017

In Figure 4.1, it can be seen that the monthly price of gas for plants located near the source shows an upward trend during the period. It is from January 2013 to December 2017, expressed in $/mbtu thus composed of 60 observations. The gas price shows several minor and major spikes and been quiet volatile during the period with a major implication on the strategic decision or planning. It takes values between 1.50 and $7.01/mbtu with some fluctuations. The trend shows a significant fall in prices, particularly around May 2015. There are some speculations that the fall in the price of gas around that time is due many factors such as the strong USD, oversupply of crude oil, OPEC, decline demand of crude oil and political transition.

Figure 4.1: *Gas Price for plants located near the source from January 2013 to December 2017*
Source: Field work (2018)

4.1.3 Gas Price for plants located away from the source from January 2013 to December 2017

In the Figure 4.2, the chart shows the movement of the monthly price of gas for plants located away from the source from January 2013 to December 2017. This is expressed in $/mbtu and composed of 60 observations. Just like the preceding chart, the gas price shows several minor and major spikes and been quiet volatile for the period. It actually hovers around 3.75 and $10.01/mbtu with some instabilities. The trend shows a significant fall in prices, particularly around May 2015. Thus, practically mirroring the price of gas for plants located near the source.

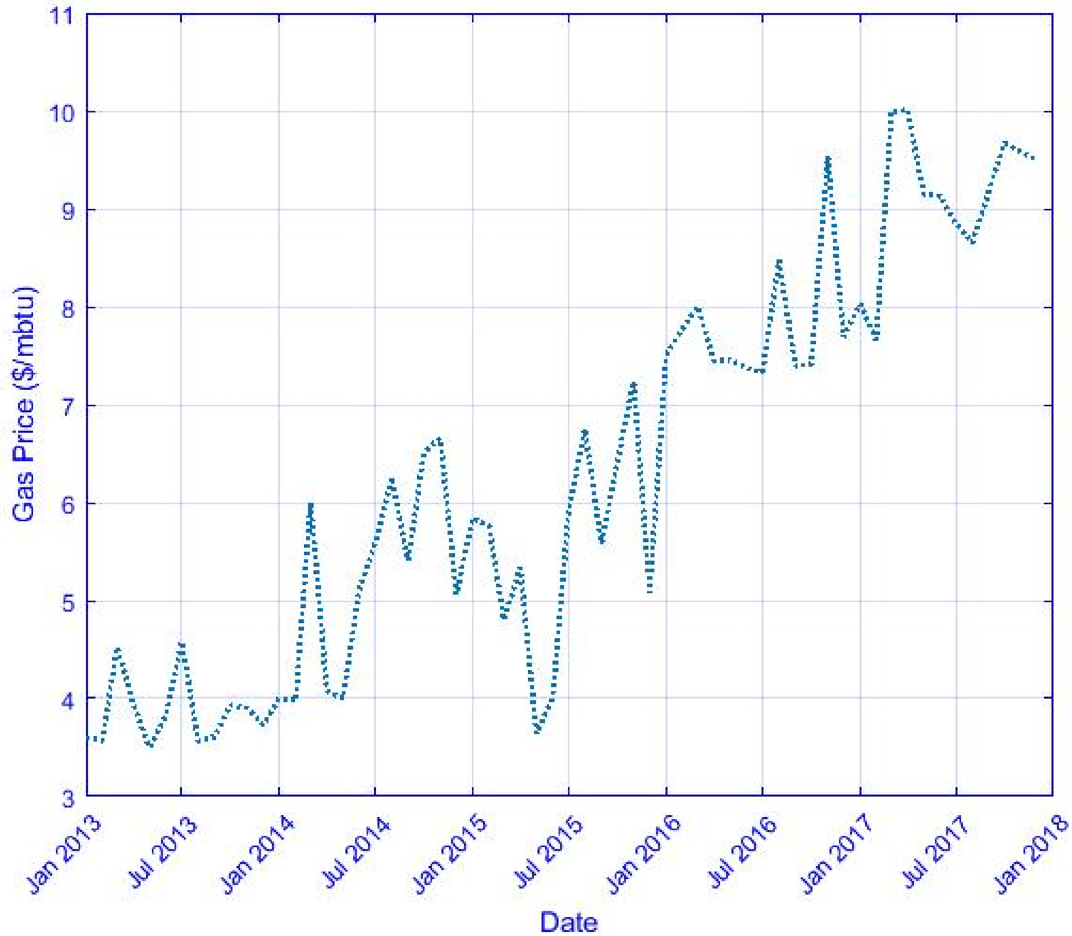


Figure 4.2: Gas Price for plants located away from the source from January 2013 to December 2017. Source: Field work (2018)

4.1.4 Electricity Price for plants located near the source from January 2013 to December 2017

In Figure 4.3, the study plots the monthly historical price of electricity for plants located near the source from January 2013 to December 2017. This is obtained from the source in $/kwh and composed of 60 observations. From the plot, the worst declines are recorded around May 2015 and June 2016. The electricity price shows a number of minor and major spikes during the period thus been quiet volatile for the period with a fundamental implication on the strategic decision or planning. The prices fall into a range between 0.03 and $0.08/kwh.

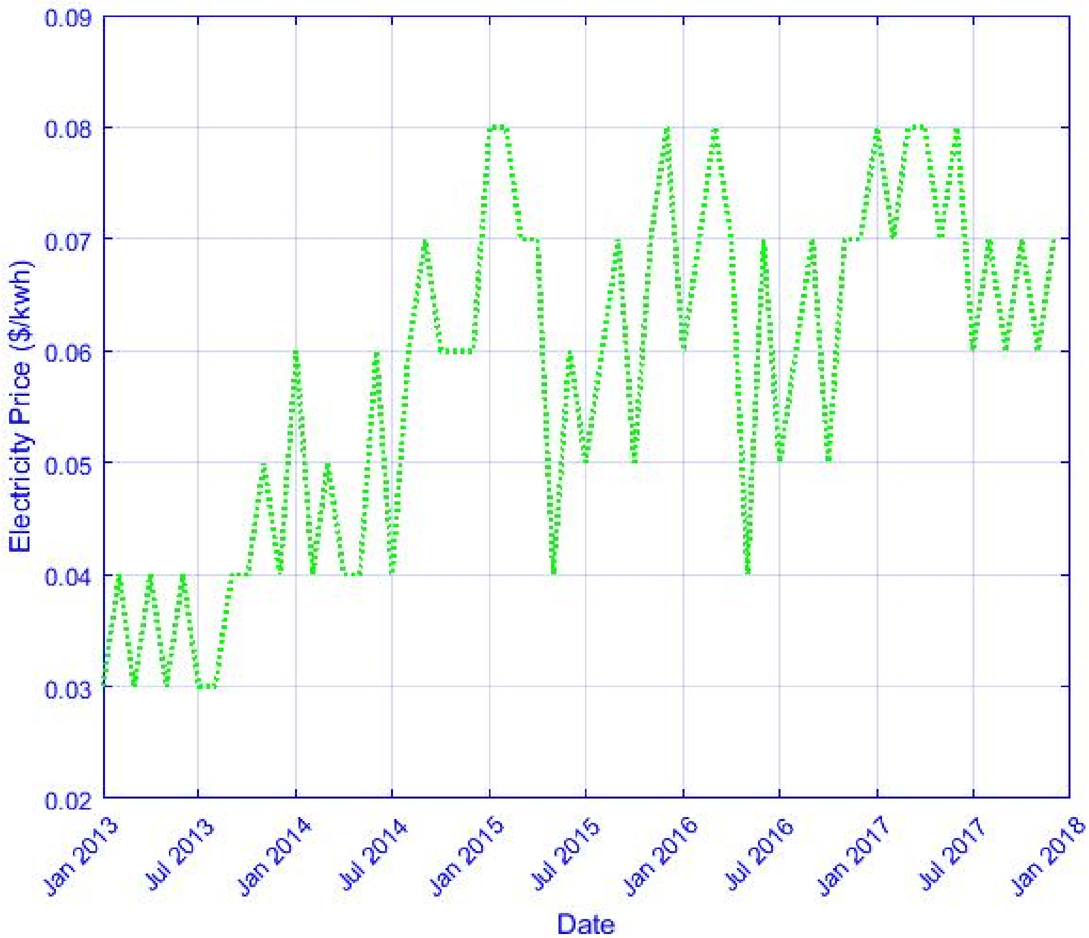


Figure 4.3: Electricity Price for plants located near the source from January 2013 to December 2017. Source: Field work (2018)

4.1.5 Electricity Price for plants located awayfrom the source from January 2013 to December 2017

Again, Figure 4.4 depicts the monthly historical price of electricity for plants located away from the source for a period of 5 years, specifically, from January 2013 to December 2017. Just like the other series, the prices of the series is obtained from the source in $/kwh and composed of 60 observation. From the Figure, the electricity price shows a number of minor and major spikes during the period and this has made it quite volatile for the period with substantial consequence on the strategic decision-making process. The prices fall into a range between 0.05 and 0.10/kwh.

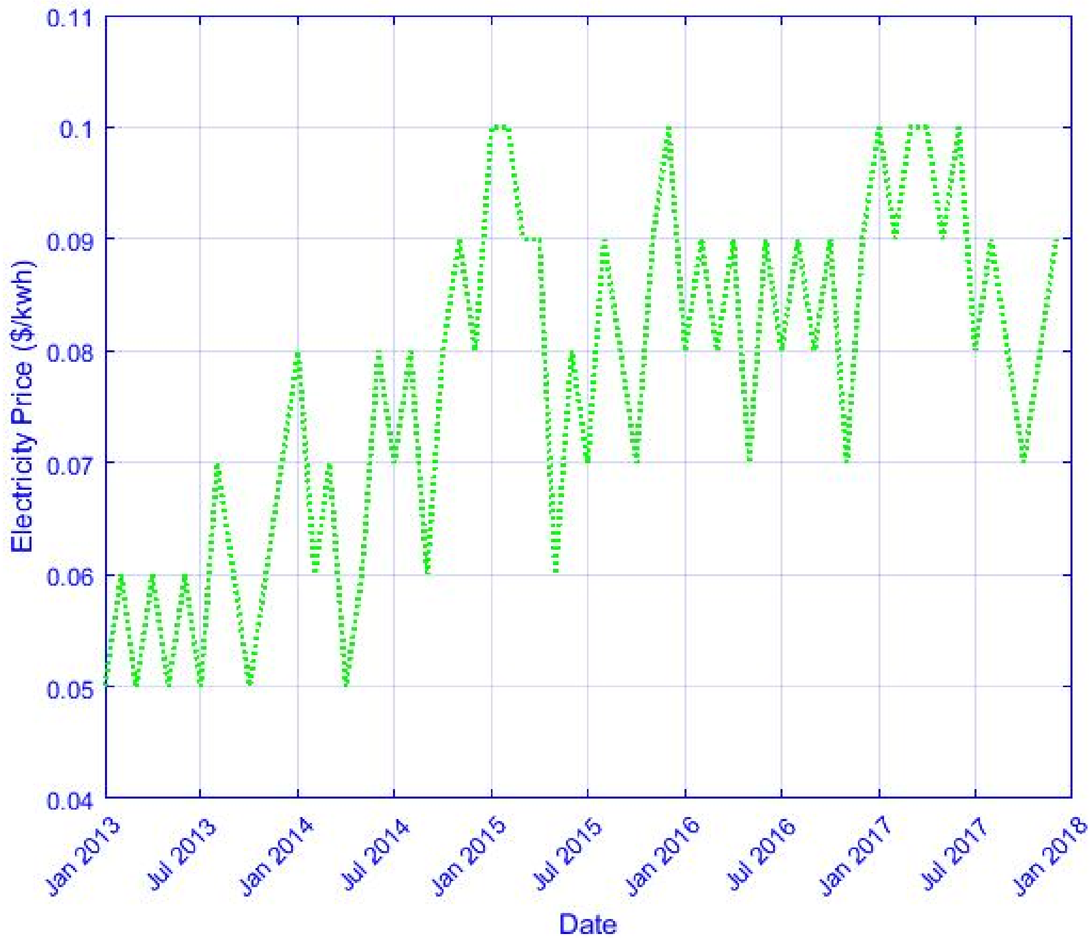


Figure 4.4: Electricity Price for plants located away from the source from January 2013 to December 2017. Source: Field work (2018)

4.2 Summary Statistics

A summary of the descriptive statistics of the monthly historical gas and electricity prices is presented in Figure 4.5 below. From the Figure, it can be seen that the price of gas for plant located near the source ranges from $1.50/mbtu to $7.01/mbtu with an average value of $4.32/mbtu and a standard deviation of 2.07. These show that on average, the gas price stood at $4.32/mbtu with some levels of instabilities.

Similarly, the prices of gas for plant located away from the source has an average value of $6.30/mbtu which is more than that of the price for the plant located near the sources by about 45.8%. The minimum and maximum values of the price for the period are $3.50/mbtu and $10.01/mbtu respectively. These indicate that some prices are relatively low while some are high during the period. The standard error is 2.06 implying that the prices vary.

Furthermore, the average price of electricity for plants located near the source is $0.06/kwh with a standard deviation of 0.02. However, the values range from $0.03/kwh to $0.08/kwh during the period. These simply mean that there is not a wide range in the value of the electricity price for the plant located near the source.

The price of electricity for plant located away from the source takes values between 0.05 and 0.10 for the period considered in this study. However, the average value is 0.08 which is corresponding to the highest price of electricity for the plant located near the source. Also, with a standard deviation of 0.02 it appears that the price standard deviation equals that of the plant located near the source. In other words, the two energy prices possess equal variations on prices.

Following the widely held assumption that the log-returns of energy prices usually follow the normal distribution, the study endeavors to examine the nature of the prices using skweness and kurtosis. Skewness is a measure of asymmetry of the distribution of the series around its mean. The skewness of a normal distribution is zero. Positive skewness means that the distribution has a long right tail and negative skewness implies that the distribution has a long left tail. Kurtosis measures the peakedness or flatness of the distribution of series. The kurtosis of the normal distribution is 3. If the kurtosis exceeds 3, the distribution is peaked (leptokurtic) relative to the normal; if the kurtosis is less than 3, the distribution is flat (platykurtic) relative to the normal. The skewness and kurtosis values of each variable in the Table give mixed result thus indicate that all the variables are not normally distributed. Consequently, the series are transformed to attain normality.

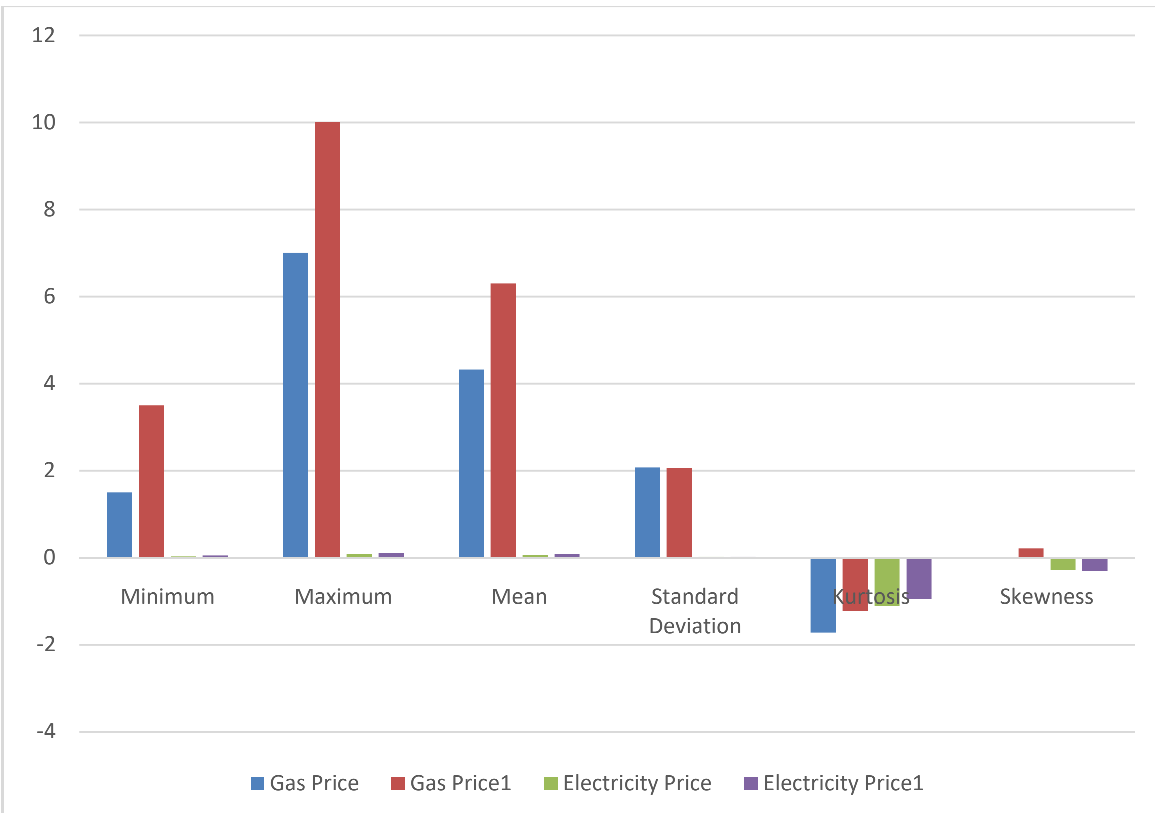


Figure 4.5: Summary Statistics
Source: Author's computation, 2018

4.3 Parameter Estimates

In this study, the value of the prices volatility and its drift are estimated using the monthly historical data with Matlab tool and the results are presented in Table 4.1. This became necessary as the parameters (growth rate and volatility) will be made use of in the subsequent analysis to capture future uncertainties. Generally, the volatility (σ) and growth rate (μ) of the prices show some variation from one energy price to another.

Explicitly, the growth rate of gas price for the plant located near the source is 1.328 while that of the plant located away from the plant is 1.786. These clearly show that growth rate of the natural logarithm of gas price for the plant located away from the source is about 34.5% higher than that of the plant located near the source. Similarly, the growth rate of electricity price for the source located near the source is 0.059 while that of the plant located away from the plant is 0.077. These undoubtedly show that growth rate of the electricity price for the plant located away from the source is about 30.5% higher than that of the plant located near the source.

Additionally, focusing on the stochastic volatility; the Table shows that the corresponding value for the price of gas for plant located near the source is 0.549 while that of the plant located away from the source is estimated to be 0.339. These give a difference of 0.21. In as similar way, the corresponding stochastic volatility value of the price of electricity for plant located near the source is 0.016 while that of the plant located away from the source is assessed to be 0.015 thus give a difference of 0.001.

Table 4.1: Parameter Estimates

	Gas Price (N)	Gas Price (A)	Electricity Price (N)	Electricity Price (A)
mean	1.328	1.786	0.059	0.077
sigma	0.549	0.339	0.016	0.015

Source: Author's computation, 2018

4.4 Uncertainties Simulation

This section focuses on the simulation of the energy prices using the Geometric Brownian Motion (GBM) approach (using equations3.3 and 3.4 in page 126). The choice of this approach is informed by the stochastic nature of the prices. As mentioned earlier, the results from the descriptive analysis in terms of the estimated parameters (growth rate and volatility) under the first part are used to capture future price uncertainties where Monte Carlo simulations are implemented using the models specified in the preceding chapter with the aid of Matlab tools.

4.4.1 Gas Price for Plants Located near the Source

For gas price of the plant located near the source, the N paths for the uncertainties are simulated from time zero until 13 corresponding to the years from 2018 to 2030. In this study, the Monte Carlo simulation is run with 20 paths using the estimated mu = 1.328 and sigma = 0.549. That is, the number of sample is 20 and the output is presented in Figure 4.6. Generally, the Figure shows that the future volatility of gas price located near the source is not constant. Alternatively, there are no clear patterns shown between the different paths. Alternatively, the random movement of the gas price is seen to have mimicked the Brownian motion theory. This indicates that there is high level of uncertainty in the price even in the future.

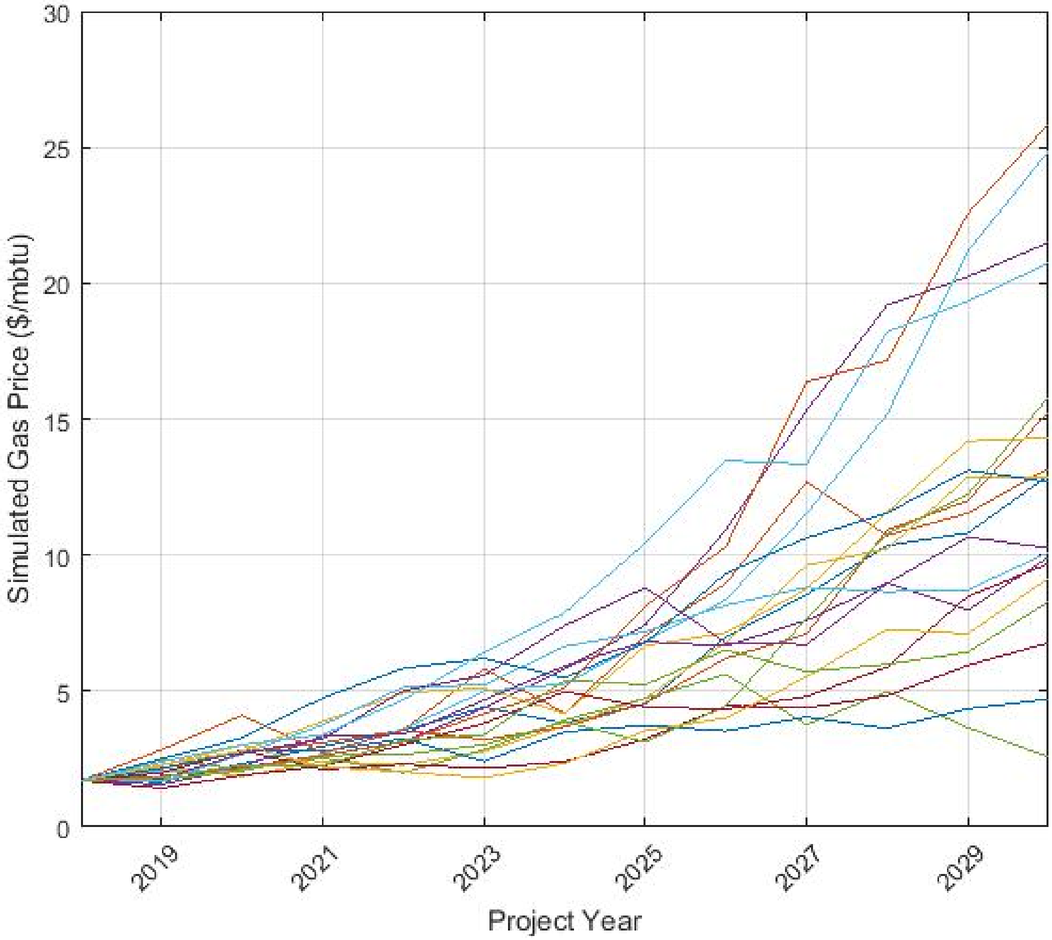


Figure 4.6: Simulated Gas Price for the Plant Located near the Source
Source: Field work (2018)

4.4.2 Gas Price for Plants Located Away from the Source

For gas price of the plant located away from the source, the mu = 1.786 and sigma = 0.339 used in the simulations are the ones estimated by using the data with 60 observations. Also, the N paths for the uncertainties are simulated from time zero until 13 corresponding to the years from 2014 to 2030. Explicitly, the Monte Carlo simulation is run with 20 paths the output is presented in Figure 4.7. In general, the Figure shows that the future volatility of gas price located away from the source have no clear patterns suggesting that there is high level of uncertainty in the future price of gas. Alternatively, the random movement of the gas price is seen to have mimicked the Brownian motion theory.

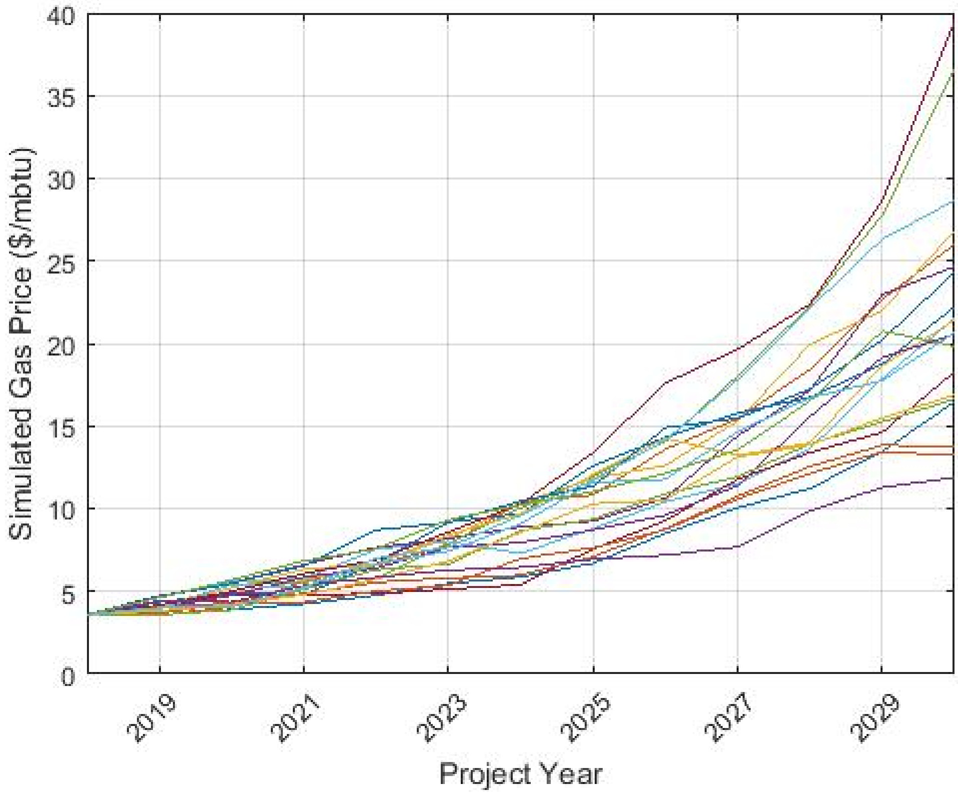


Figure 4.7: Simulated Gas Price for the Plant Located away from the Source
Source: Field work (2018)

4.4.3 Electricity Price for Plants Located near the Source

For electricity price of the plant located near the source, the N paths for the uncertainties are simulated from time zero until 13 corresponding to the years from 2018 to 2030. In this study, the Monte Carlo simulation is run with 20 paths using the estimated mu = 0.059 and sigma = 0.016. That is, the number of sample is 20 and the output is presented in Figure 4.8. Generally, the Figure shows that the future volatility of electricity price located near the source is not constant. Then again, there are no clear patterns shown between the different paths. This indicates that there is high level of uncertainty in the price even in the future. Alternatively, the random movement of the electricity price is seen to have mimicked the Brownian motion theory.

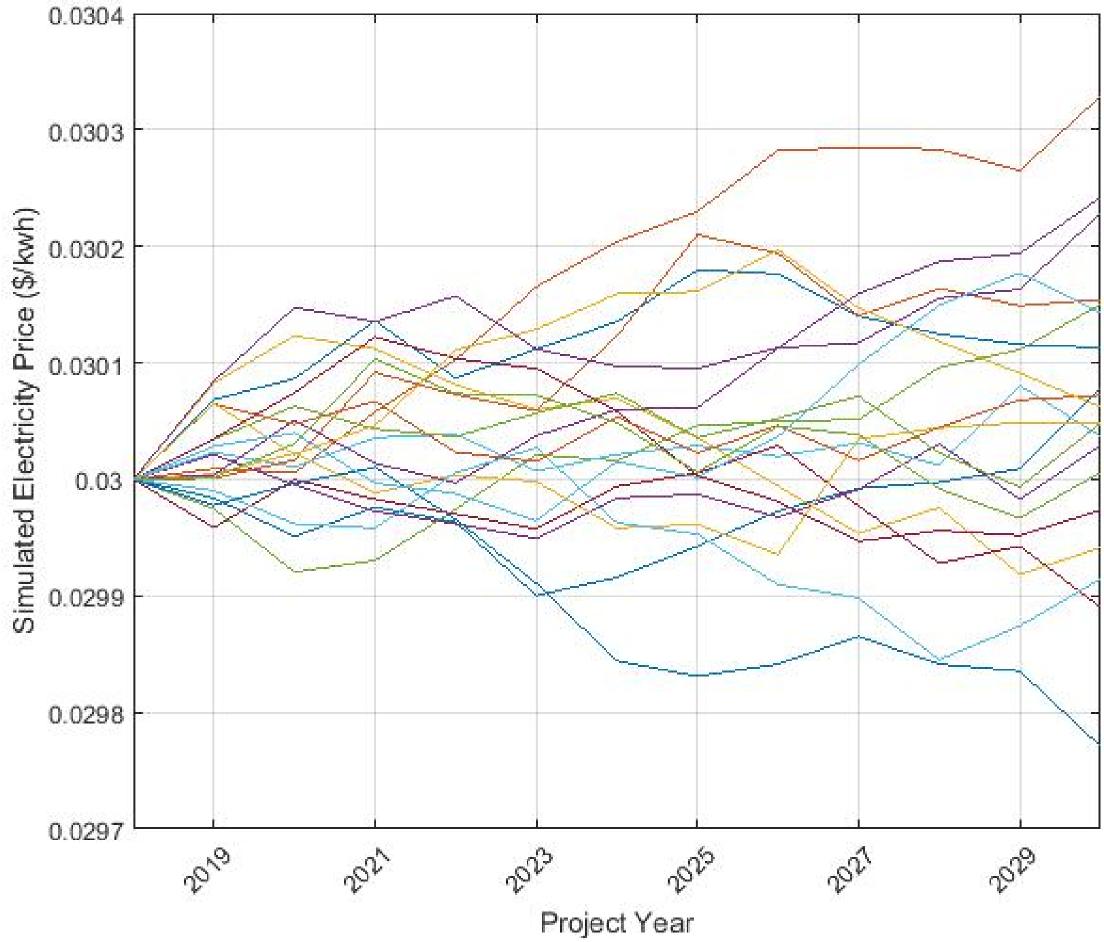


Figure 4.8: Simulated Electricity Price for the Plant Located near the Source
Source: Field work (2018)

4.4.4 Electricity Price for Plants Located away from the source

Again, for electricity price of the plant located away from the source, the mu = 0.077 and sigma 0.015 used in the simulations are the ones estimated by using the data with 60 observations. Also, the N paths for the uncertainties are simulated from time zero until 13 corresponding to the years from 2018 to 2030. Explicitly, the Monte Carlo simulation is run with 20 paths the output is presented in Figure 4.9. In general, the Figure shows that the future volatility of electricity price located away from the source have no clear patterns suggesting that there is high level of uncertainty in the future price of electricity. Then again, the haphazard movement of the electricity price is seen to have mimicked the Brownian motion theory.

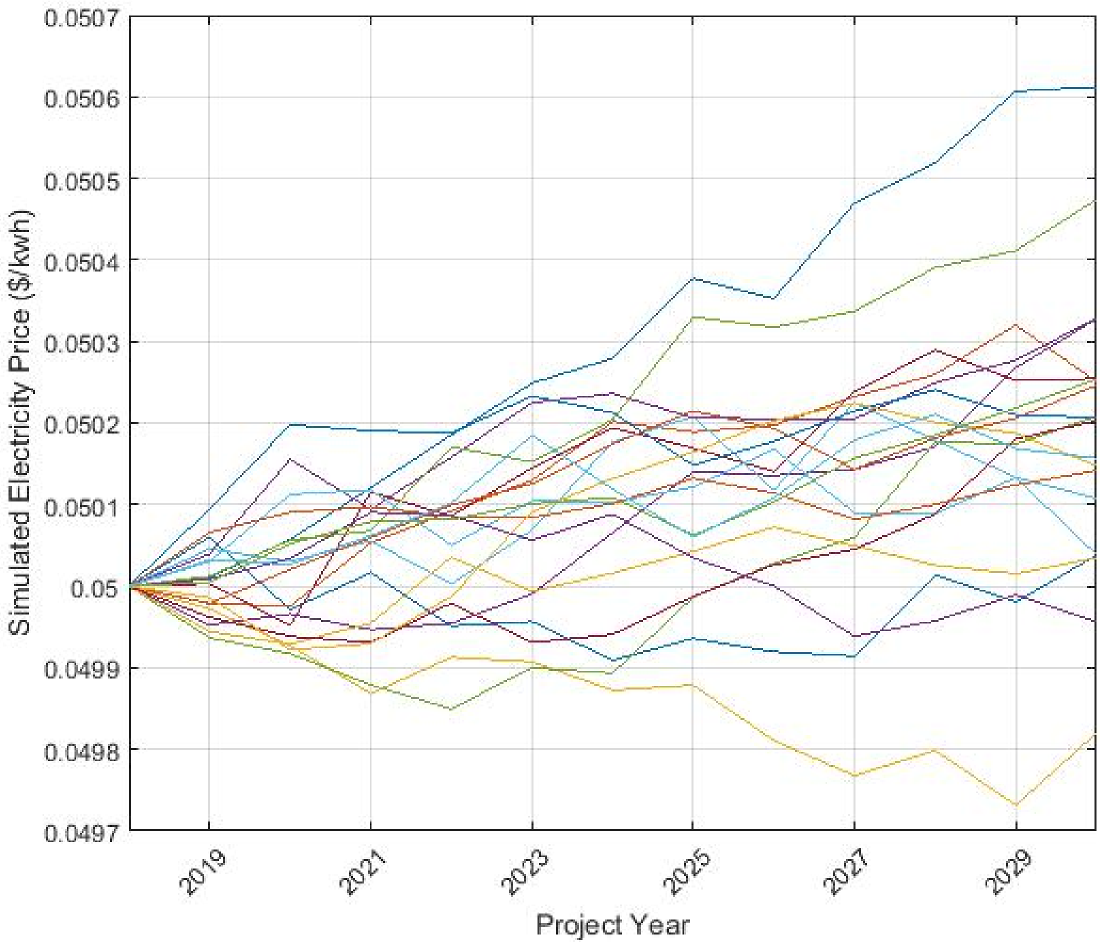


Figure 4.9: Simulated Electricity Price for the Plant Located away from the Source
Source: Field work (2018)

4.5 Economic Conditionsnecessary to generate Electricity either at Gas source or a Central Location away from the Gas source

4.5.1 Real Option Analysis

In order to capture the specific objectives of the study that says to investigate when it is more economical to generate electricity either at gas source or a central location and determine optimal investment needed in boosting gas supply for power plant projects, the study used the decision making models specified in the preceding chapter (using equations 3.12 and 3.13 in pages 128/129). Furthermore, Faiz (2000) has emphasized that real options has not only proven to be a superior asset valuation than the traditional approaches but also offers a great help on whether and how to pursue opportunity under uncertainty. Thus, in decision making the study makes use of the ROA with the required input parameters.

To investigate the objective in this section and the next section, additional simulations with the estimated parameters and varying requirements are run. In this, in addition to the estimated parameter in the preceding section; the study makes use of the available information as summarized in Table 4.2. As in the Table, the current value of cash flows are $4million/BTU and $1.023million/MW respectively for gas and electricity generated. The investment period considered is ten (10) years and fixed cost is $61.8million. In addition, the future cash flows are assumed to be highly uncertain, and there the study used varying volatilities.

Table 4.2: Additional Parameters used in the Investment Options.

Parameter	**Gas**	**Electricity**
Current CF	$4million/BTU	$1.023million/MW
Fixed investment cost	$61.8million	$61.8million
Time to invest	10 years	10 years

Source: Project Record

4.6 Optimal Investment Needed in boosting Gas Supply for Power Plant projects

4.6.1 Option Value of Investment

In other to capture the objective two of the study, Figures 4.10a and 4.10b graphically illustrate the option values (expressed in million dollar per mbtu) of gas price plant located near and away from the source respectively at different levels of volatility (using equations 3.1 and 3.2 in page 123). The 'Gas NPV' represents the maximized expected NPV of the gas plant. It is linearly change as far as the gas price is enough to cover the value of investment. Generally, the charts reveal the sensitivity of option values to uncertainty. From the Figures, it can be inferred that the higher volatility produces a higher gas option value. Thus, a higher investment option value is associated with higher risk. In order words, the plant gives higher net present value of the investment at higher levels of volatility.

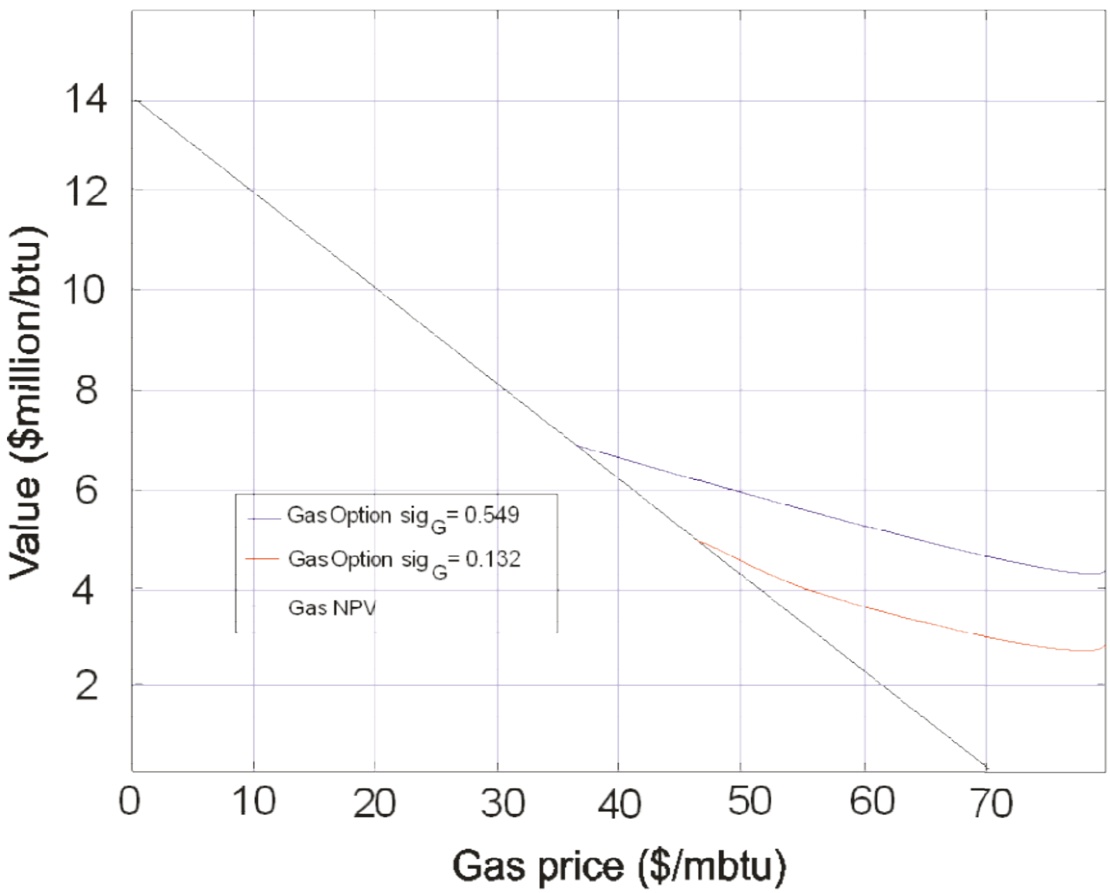


Figure 4.10a: Option Value for Gas Price for Plant Located Near the Source
Source: Field work (2018)

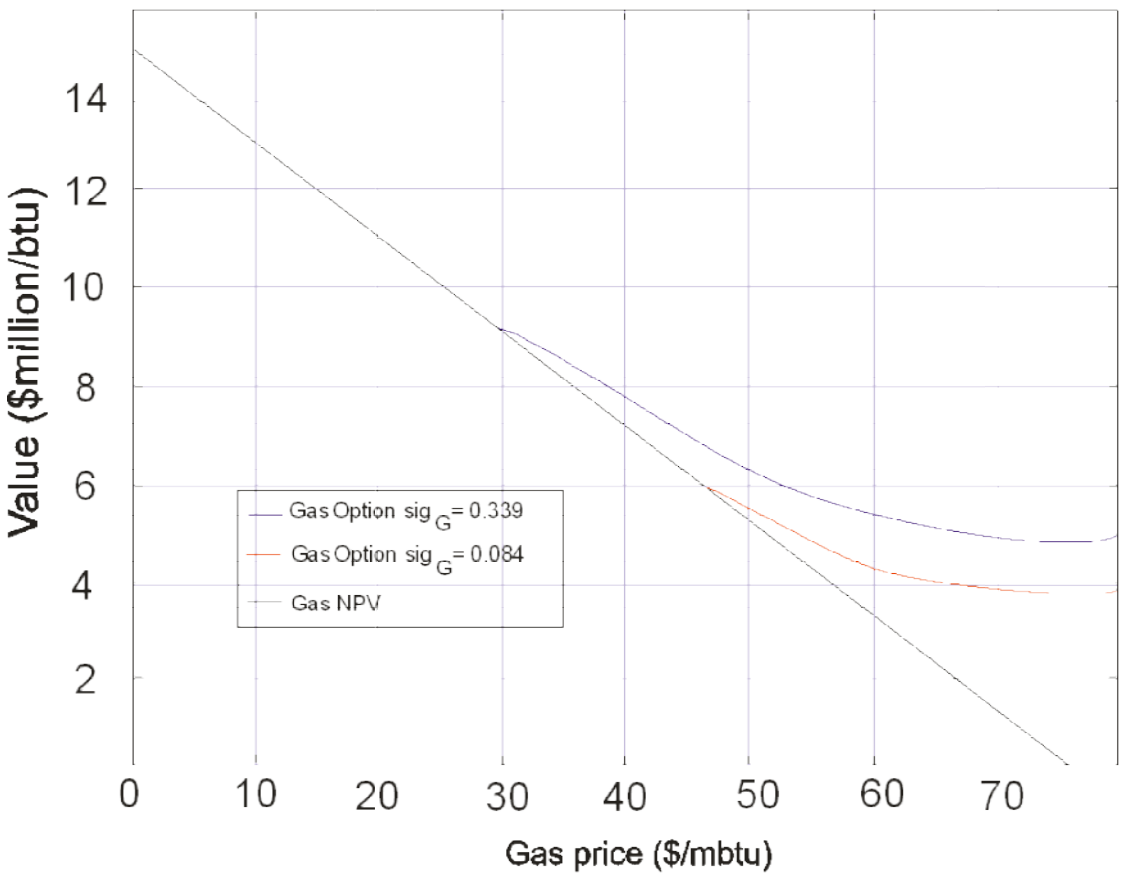


Figure 4.10b: Option Value for Gas Price for Plant Located away from the Source
Source: Field work (2018)

Again, Figures 4.11a and 4.11b graphically illustrate the option values of electricity price for plant located near and away from the source respectively at different levels of volatility. The 'Electricity NPV' signifies the maximized expected NPV of the GtPPand it is linearly change as far as the gas price is enough to cover the value of investment. Generally, the charts clearly show the sensitivity of option values to uncertainty. As in the Figures, it can be deduced that the higher volatility produces a higher electricity option value. Put differently, a higher investment option value is associated with higher risk.

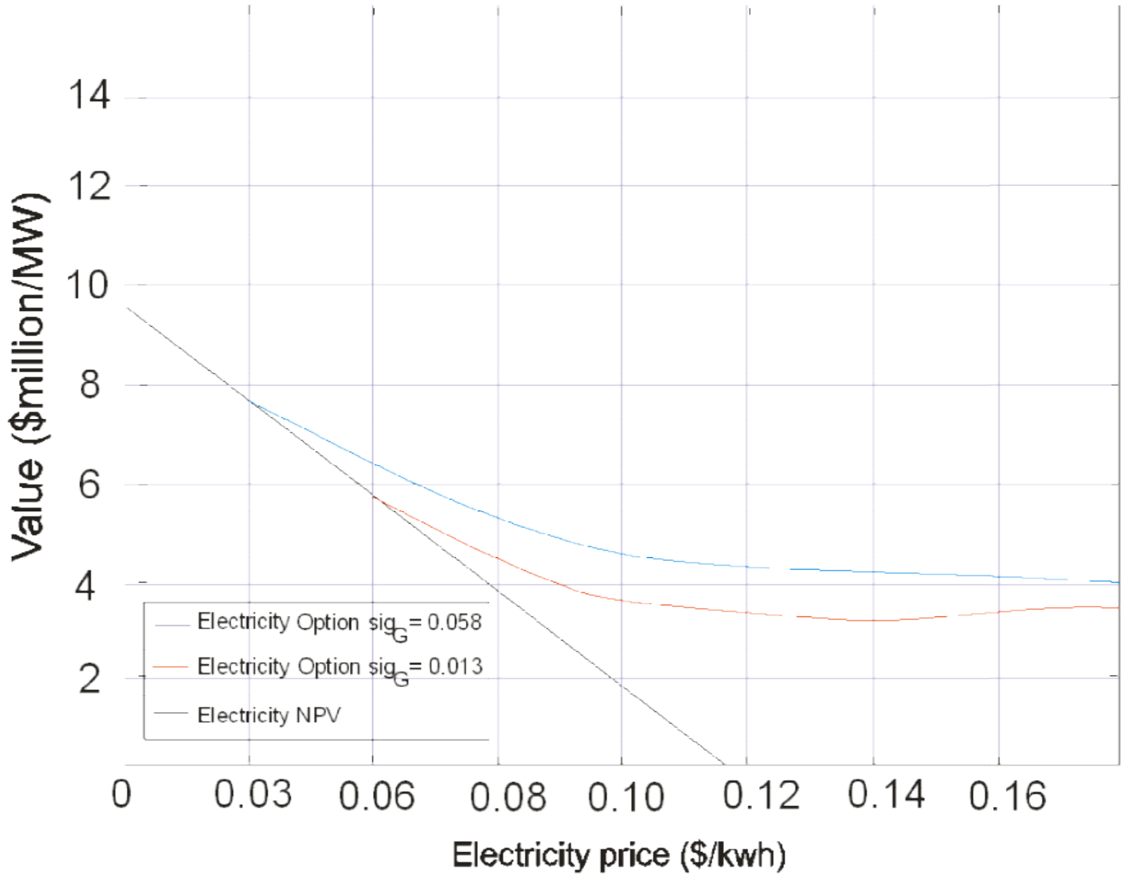


Figure 4.11a: Option Value for Electricity Price for Plant Located near the Source
Source: Field work (2018)

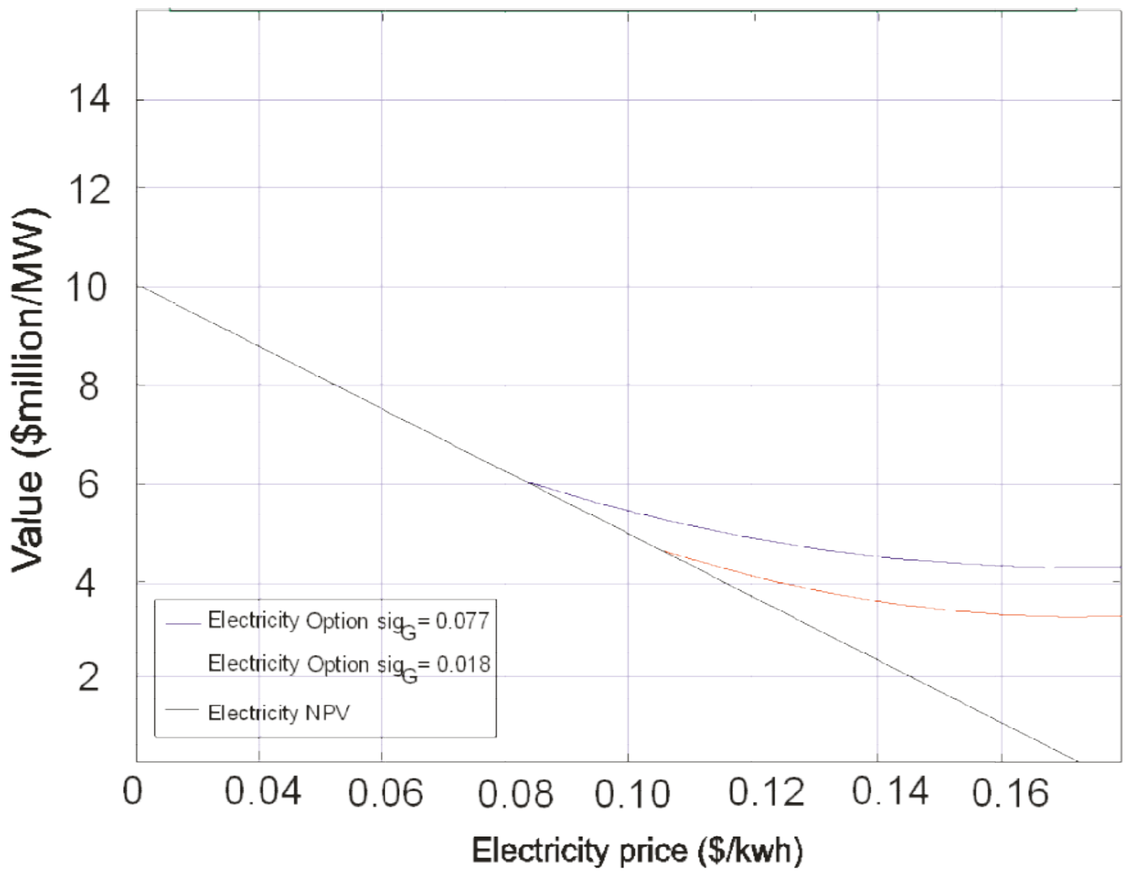


Figure 4.11b; Option Value for Electricity Price for Plant Located away from the Source
Source: Field work (2018)

4.6.2 Threshold Price

In this sub-section, the study investigates the sensitivity of thresholds to variation in volatility by varying the volatility parameter. In Figure 4.12, the threshold prices for gas are presented and this shows that the wider spread threshold between the prices of gas for plant located near the source (G_N) and away from the source (G_A) is associated with higher volatility. This is in line with the saying that higher uncertainty brings about doubtfulness.

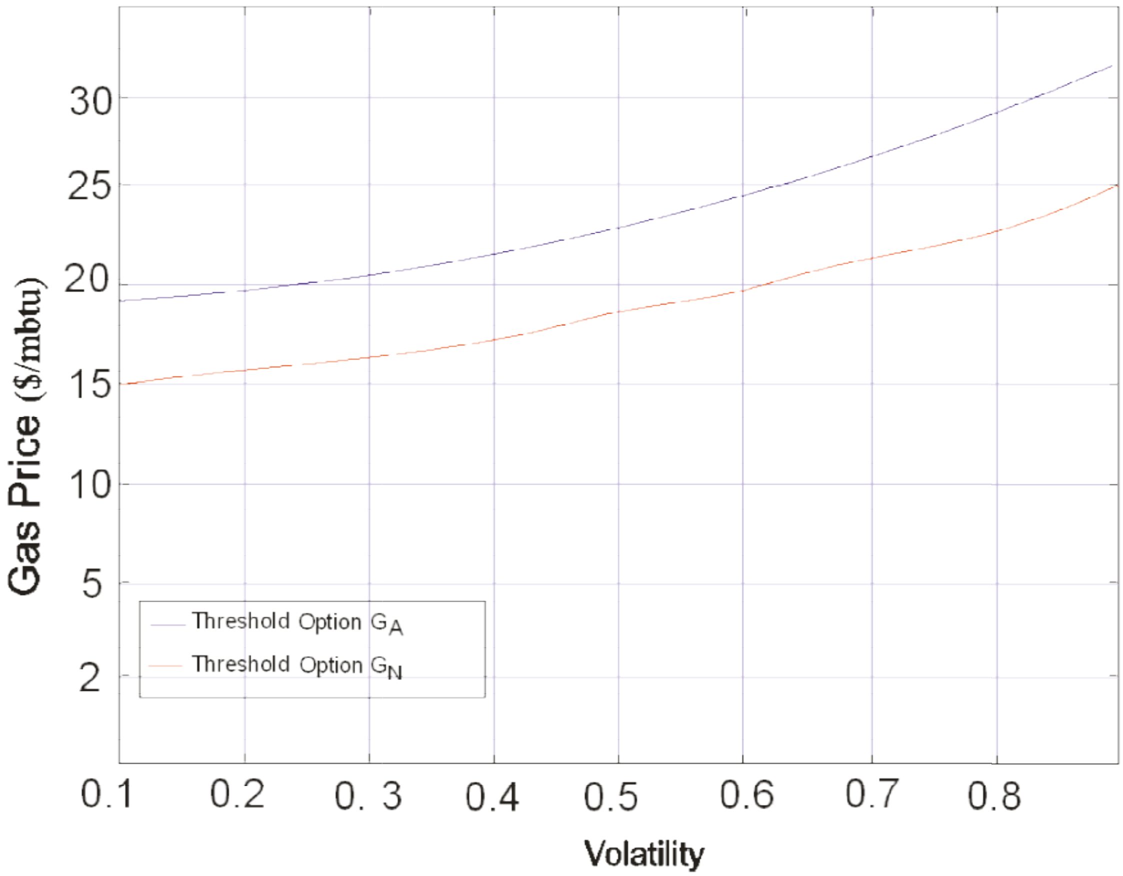


Figure 4.12: Threshold Price for Gas
Source: Field work (2018)

Similarly, in Figure 4.13, the threshold prices for electricity plants are presented and this shows that the wider spread threshold between the prices of electricity for plant located near the source (E_N) and away from the source (E_A) is associated with higher volatility. This is in line with the saying that higher uncertainty brings about doubtfulness.

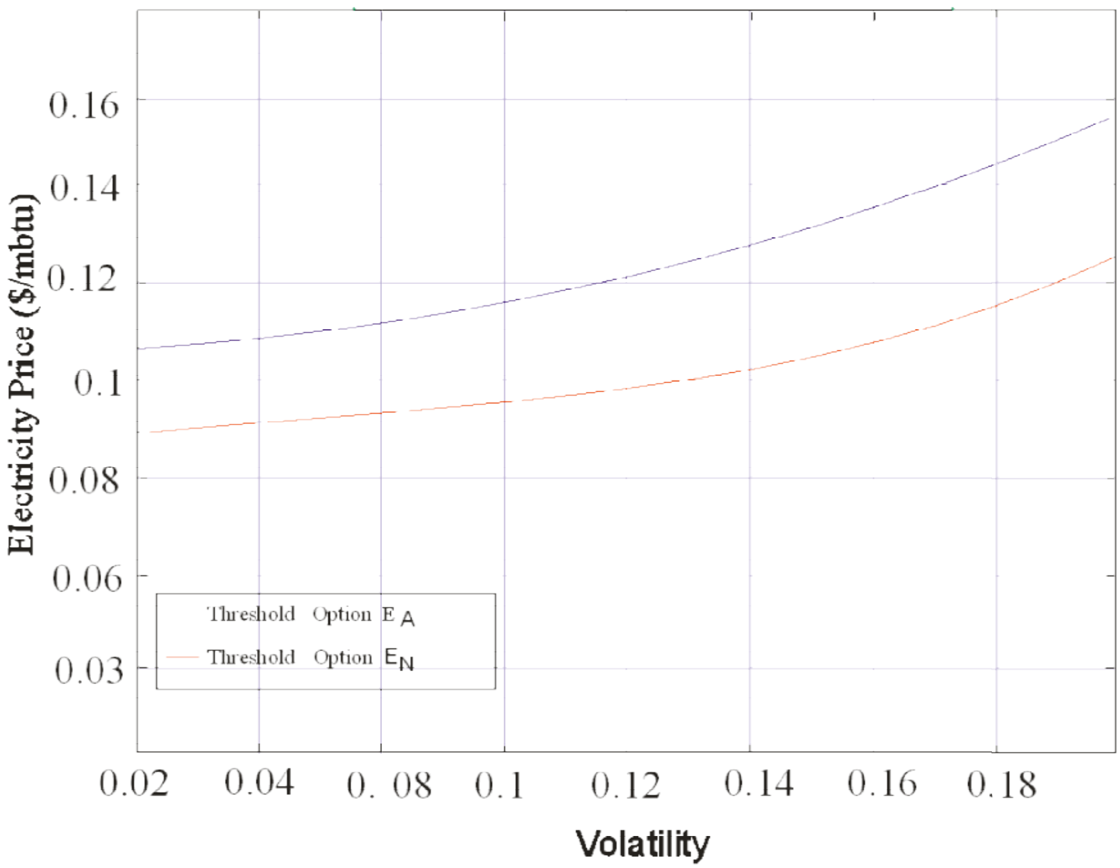


Figure 4.13: Threshold Price for Electricity
Source: Field work (2018)

4.7 Investment Decision-Making

In this section, the study presents waiting and investment regions for the GtPPplants considered in this study based on the best information estimated or available and by varying the volatility. In Figures 4.14a, it can be seen that it more economical to invest in GtPP plant near the source when the volatility and prices of the gas is within the (G_N) region or invest in GtPP plant away from the source when the volatility and prices of the gas is within the (G_A) region otherwise the investor may have to wait. Specifically, under different volatility, we find regions to wait and invest for the GtPP plants in the Figure. For instance, for $\sigma \geq 0.681$ investment decision in GtPP plant near the source is to be ignored. That is, the investor needs to wait. However, for the $\sigma < 0.681$ and the gas prices above lower and upper investment regions (the red lines) decision to invest in GtPP near the source is to be made. For instance, for $\sigma = 0.3$ the investor should wait until the gas price increases to the lower investment region; that is when the price is roughly $/9mbtu. Furthermore, the decision to invest is to be made in GtPP near the source (G_N) when the price is or on the upper region (red line) or in GtPP away from the source (G_A) if the price increases to or above the blue line.

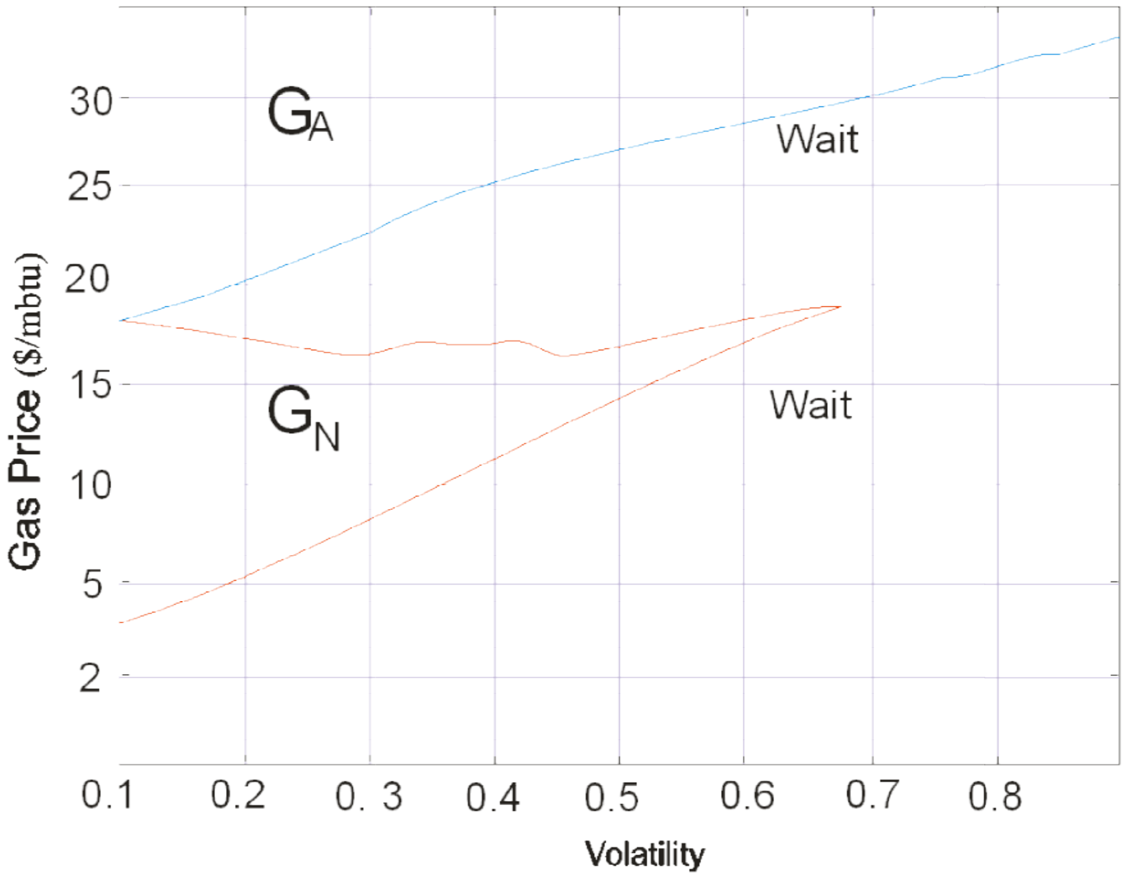


Figure 4.14a: Investment Option
Source: Field work (2018)

In Figures 4.14b, the case is similar to that of gas. Also, it can be seen that that the investor should wait till the price of the electricity for GtPPnear the source and away from the source are within the E_A and E_N regions respectively; otherwise the investor may have to wait. Explicitly, under different volatility, we find regions to wait and invest for the GtPPplants in the Figure. For instance, for $\sigma \geq 0.129$ investment decision in electricity plant near the source is to be ignored. That is the investor needs to wait. However, for the $\sigma < 0.129$ and the electricity prices above lower and upper investment regions (the red lines) decision to invest in GtPP near the source is to be made. For instance, for $\sigma = 008$ the investor should wait until the electricity price increases to the lower investment region; that is when the price is roughly $0.078/kwh. Furthermore, the decision to invest is to be made in GtPP plant near the source (E_N) when the price is or on the upper region (red line) or in GtPP plant away from the source (E_A) if the price increases to or above the blue line.

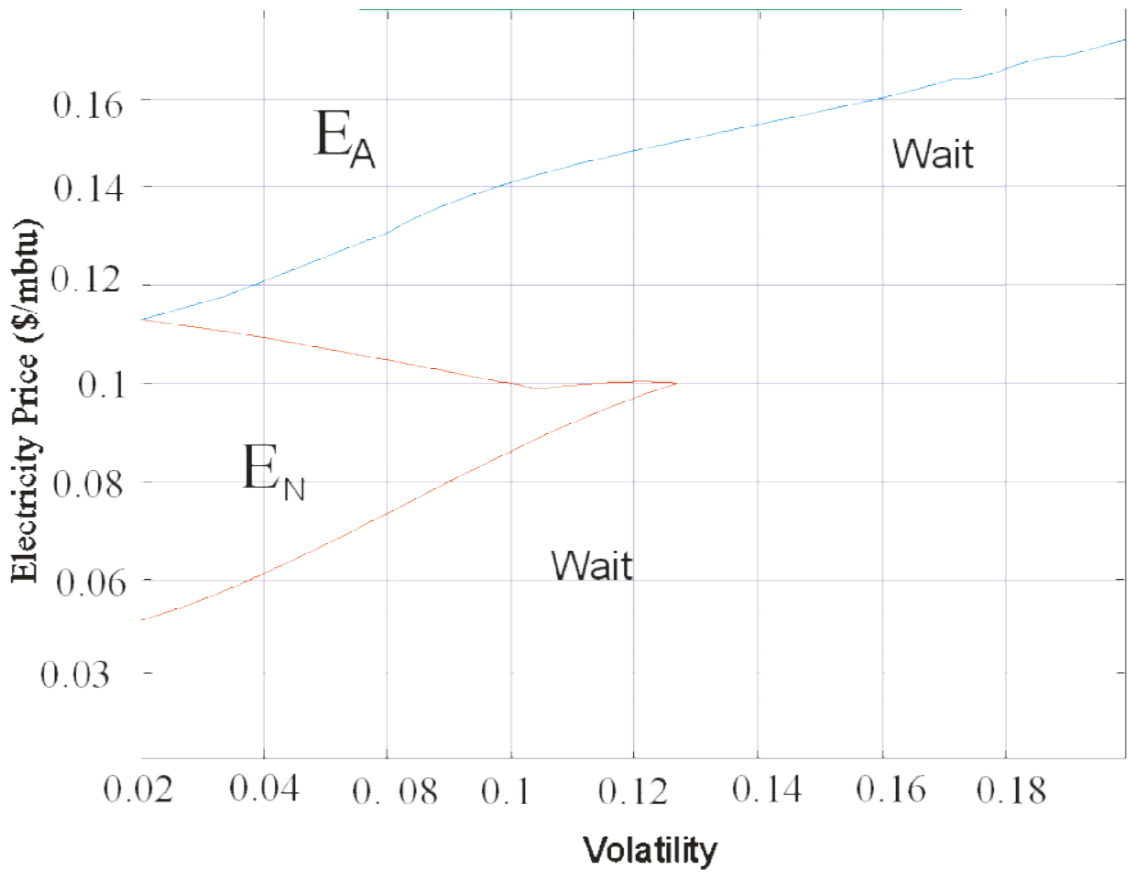


Figure 4.14b: Investment Option
Source: Field work (2018)

4.8 Economic Viability of Gas to Power Projects

This section which is the third objective of this study revealed the economic viability of small or households' gas to power projects (GtPP). According to extant literature (Fleten and Näsäkkälä, 2015; Falode and Ladeinde, 2016; Adamu and Daima, 2017), in a classical valuation; the NPV of a project is the present value of the projects cash flow at time t. The Net Present Value (NPV) of a project that is greater than zero (0) in classical valuation is economically viable. If the Net Present Value (NPV) of a project is zero (0), the project is assumed to have broken even and the investors are at liberty to decide on whether to delay or proceed. However, in a situation where the project's Net Present Value (NPV) is less than zero (0); the project is well-thought-out not economically viable.

Furthermore, NPV can be used to compare several choices. This means that the Net Present Values (NPVs) can be used to choose between two or more projects. Accordingly, the higher the Net Present Value (NPV) the more valuable the decision to invest will be.

In order to investigate viability for available options, the study runs additional simulations with the information provided and the result are given in Table 4.3 below. The Table clearly indicates that the Net Present Value (NPV) of Electricity Price Based Plant and Gas Price Based Plant are greater than zero and these provide the evidences that the available options under the Gas to Power Projects are worth considering. Alternatively, these mean that the gas to power projects is economically viable. Besides, the Table shows that the best choice of project are Gas Price Based Plant as it gives the highest value.

Table 4.3: Economic viability of Gas to Power Projects

	Electricity Price Based Plant ($million)	**Gas Price Based Plant ($million)**
Net Present Value (NPV)	63.64	80.51

Source: Author's computation, 2018

Note:For ***Electricity Price BasedPlant****: Current CF/Initial Price = 1.023$million/MW, Fixed Investment Cost = 61.8$million, Time to invest = 10 years, Discounted Rate = 0.068and Volatility = 0.016. For* ***GasPrice BasedPlant****: Current CF/Initial Price = 4$millionBTU, Fixed Investment Cost = 61.8$million, Time to invest = 10 years, Discounted Rate = 1.557 and Volatility = 0.444.*

4.9 Discussion of Findings

The central focus of this study is to determine an optimal investment decision making for gas-to-power project in order to create a room for effective production and use of natural gas in Nigeria. Investors want to know the investment project's pay-off period to decide whether they actually will make the investment expenditure or not. For a good investment decision, the investor needs to understand completely and correctly the possible opportunities and these decisions should not be made in a rush. It is necessary to understand the basic ideas of the investment decisions to obtain themaximum value from the appraisal process. In investment evaluation, the indicators should be chosen regarding the specific nature of the project and the information held by the decision maker.

The previous sections and sub-sections in this chapter presented and analysed the primary and secondary data used in this study. This section presents a discussion of the research findings obtained from data analysis. The section discusses the outcomes of the research questions for each of the research objectives. Both the results from the primary and secondary data analyses are covered in this discussion. The section brought literature, theory and data together in coherent whole.

On the first objective that investigates when it is more economical to generate electricity either at gas source or a central location away from the gas source and the second objective that determine optimal investment needed in boosting gas supply for power plant projects. The software used is MATLAB R2017a adopting Antonio *et al* (2016) code. Furthermore, Faiz (2000) has emphasized that real options has not only proven to be a superior asset valuation than the traditional approaches but also offers a great help on whether and how to pursue opportunity under uncertainty. Thus, in decision making the study makes use of the ROA with the required input parameters. From the data analyses, the study uncoversthat the price of gas for plant located near the source ranges from $1.50/mbtu to $7.01/mbtu with an average value of $4.32/mbtu and a standard deviation of 2.07. These show that on average, the gas price stood at $4.32/mbtu with some levels of instabilities.Similarly, the prices of gas for plant located away from the source has an average value of $6.30/mbtu which is more than that of the price for the plant located near the sources by about 45.8%. The minimum and maximum values of the price for the period are $3.50/mbtu and $10.01/mbtu respectively. These indicate that some prices are relatively low while some are high during the period. The standard error is 2.06 implying that the prices vary.

Furthermore, the average price of electricity for plants located near the source is $0.06/kwh with a standard deviation of 0.02. However, the values range from $0.03/kwh to $0.08/kwh during the period. These simply mean that there is not a wide range in the value of the electricity price for the plant located near the source. The price of electricity for plant located away from the source takes values between 0.05 and 0.10 for the period considered in this study. However, the average value is 0.08 which is corresponding to the highest price of electricity for the plant located near the source. Also, with a standard deviation of 0.02 it appears that the price standard deviation equals that of the plant located near the source. In other words, the two energy prices possess equal variations on prices. From the result, it can be inferred that the higher volatility produces a higher gas option value. Thus, a higher investment option value is associated with higher risk. In order words, the plant gives higher net present value of the investment at higher levels of volatility. Also, it can be deduced that the higher volatility produces a higher electricity option value. Put differently, a higher investment option value is associated with higher risk.

Furthermore, from the result, the threshold prices for gas are presented and this shows that the wider spread threshold between the prices of gas for plant located near the source (G_N) and away from the source (G_A) is associated with higher volatility. This is in line with the saying that higher uncertainty brings about doubtfulness. The threshold prices for electricity plants also shown that the wider spread threshold between the prices of electricity for plant located near the source (E_N) and away from the source (E_A) is associated with higher volatility. This is in line with the saying that higher uncertainty brings about doubtfulness. These findings were in contrast with Hawkes (2010) who adopted a probabilistic programming approach to influence the effective configuration potential of different power techniques in an electrical network. Hawkes (2010) based the objection mechanism on minimizing equivalent annual cost (EAC) of power system. The authors conducted two sets of experiments. First set utilised a deterministic optimisation with a focus on specific projections of energy costs while the following set employed Monte-Carlo Simulation (MCS) for such mix of power innovations generated during first set to capture unpredictability in energy, oil and gas, and wind velocity.Hawkes (2010) found that MCS indicated that the deterministic optimisation did not account for economic risks. Therefore, the conclusion was that ideal outcome from a single probable cost of oil prices leads to suboptimal under various pricing instances.

The result shows that the investor should wait till the price of the electricity for GtPPnear the source and away from the source are within the E_A and E_N regions respectively; otherwise the investor may have to wait. Explicitly, under different volatility, we find regions to wait and invest for the GtPPplants in the Figure 4.14a&b. Furthermore, the decision to invest is to be made in GtPP plant near the source (E_N) when the price is or on the upper region (red line) or in GtPP plant away from the source (E_A) if the price increases to or above the blue line.

On the third objective that analyze the economic viability of small or households Gas to Power Projects. The findings revealed that according to extant literature (Fleten and Näsäkkälä, 2015; Falode and Ladeinde, 2016; Adamu and Daima, 2017), in a classical valuation; the NPV of a project is the present value of the projects cash flow at time t. The Net Present Value (NPV) of a project that is greater than zero (0) in classical valuation is economically viable. If the Net Present Value (NPV) of a project is zero (0), the project is assumed to have broken even and the investors are at liberty to decide on whether to delay or proceed. However, in a situation where the project's Net Present Value (NPV) is less than zero (0); the project is well-thought-out not economically viable. The result clearly indicates that the Net Present Value (NPV) of Electricity Price Based Plant and Gas Price Based Plant are greater than zero and these provide the evidences that the available options under the Gas to Power Projects are worth considering. Alternatively, these mean that the gas to power projects is economically viable. Besides, the result shows that the best choice of project are Gas Price Based Plant as it gives the highest value.The results support the report of Falode and Ladeinde (2016), the discounted cash flow model and the Monte Carlo simulation were used to test the Gas Power Plant Project for Nigeria's first Gas Industrial Park. The analysis shown that the gas-fired power plant in the industrial park is commercially feasible and would have strong returns on investment under the current fiscal and regulatory system in Nigeria. With the aid of the number of economic indices seen in the results produced, it is a project that investors would be able to pursue.

This result was also supported by evidence from the research of Feretic and Tomsic (2005), who employed a Monte-Carlo simulation to derive probability distribution of levelised cost of power from 3 distinct power stations: coal, nuclear and crude oil.Feretic and Tomsic (2005) regarded levelised price of power as an estimated price of a quantity of electricity from a power station over its lifespan; and measured its unit as US$/Kwh. In addition, they applied probability distribution to unpredictable input variables such as capital investment, fuel cost, and execution lifetime of power station. The scholars examined the influence on electricity pricesas a result of externalities. The cost of energy from coal increases by almost 100 percent, and from natural gas rises by nearly 30 percent because of external cost. They concluded that costs of energy plants in the society and the environment are very important in determining the cost of energy.

A possible explanation for these outcomes can be best explained from the theory adopted for this study.The theory was based on irreversible investment theory under uncertainties emanated from the Q-theory of investment. The Q-theory encompasses all the assumption made in the neoclassical theory of investments and also presents appropriate conditions that are more realistic to the electricity generation investment. To order to develop the decision-making process for gas-power investment projects, this analysis created a decision-making management model by evaluating two technologies, i.e. a single-gas turbine (GT) and a combined-cycle gas turbine (CCGT). The principle has the idea of irreversibility, which implies that once the investment is made, it will be passed to a sunk that isnot re-sellable.

Evidence from the literature and the findings of this research have shown that the best choice of project is Gas Price Based Plant as it gives the highest value. However, more pertinent is that the higher volatility produces a higher gas and electricity option value. Put differently, a higher investment option value is associated with higher risk. Investment decisions are made after a complete analysis of the investment project. One of the basic factors that influence the decision is the risk factor of the investment. This risk exists because it is uncertain that the cost of the investment will be recovered and a profit will be gained.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.0 Introduction

This chapter entails the summary of results as obtained from the empirical analyses and some important concluding remarks and policy recommendations are made. Finally, areas of possible future research and the limitations encountered are presented.

5.1 Summary of Findings

The study determined an optimal investment decision making for gas-to-power project in order to create a room for effective production and use of natural gas in Nigeria with particular emphasis on determining optimal investment needed in boosting gas supply for power plant projects, knowing when it is more economical to generate electricity either at gas source or a central location away from the gas source and analyzing the economic viability of small or households Gas to Power Projects.To achieved this objective, study employed the cost data as well as other pertinent variables from selected thermal power plants in Nigeria and Nigeria Gas Company (NGC) between 2013 and 2017, and simulated for between 2018 to 2030 the proposed period is based on the reason that privatization of generation segment concluded in 2013, and Paris Conference in December 2015 had taken 2030 as year to end the issue of gas flaring in which Nigeria is among the largest gas flaring economies.

With the application of different theories and methodology such as; Keynes theory of investment, Hayek (1941) and Fisher (1930) theories of investment. Other include; neoclassical theory of investment (Jorgenson's 1960); accelerator theory of investment (Samuelson, 1939); Tobin's Q (Brainard and Tobin, 1968; and Tobin, 1969); and marginal (Mueller and Reardon, 1993), Real option analysis, linear programming models and Monte Carlo simulations. The research provides empirical evidence for the purpose of designing the decision-making process of gas-power investment projects (i.e., the optimal technology to invest as well as the optimal time to invest for the case that an electricity sector has the choice of building a new power generation unit in specific locations of the country). First, to determine the conditions which are to satisfy at the initial stage of investment and second, is to identify the investment adjustment.

The descriptive analysis summarizes the basic statistical features for the price of gas and electricity which includes; trend analysis, mean and coefficient of variation. Specifically, the under consideration are; Gas Price for plants located near the Source \$/mbtu, Gas Price for plants located away from the Source \$/mbtu, Electricity Price for plants located near the Source \$/kwh and Electricity Price for plants located away from the Source \$/kwh. The findings for *gas price for plants located near the source from January 2013 to December 2017* revealed that the monthly price of gas for plants located near the source shows an upward trend during the period. It is from January 2013 to December 2017. The gas price shows several minor and major spikes and been quiet volatile during the period with a major implication on the strategic decision or planning. The trend shows a significant fall in prices, particularly around May 2015, and the speculation is that; fall in the price of gas around that time is due to many factors such as the strong USD, oversupply of crude oil, OPEC, decline demand of crude oil and political transition. Moreover, the findings from the *gas price for plants located away from the source from January 2013 to December 2017* revealed that the gas price shows several minor and major spikes and been quiet volatile for the period. It actually hovers around 1.50 and \$7.01/mbtu with some instabilities, practically mirroring the price of gas for plants located near the source.

However, the findings from the *electricity price for plants located near the source from January 2013 to December 2017* revealed a worst decline been recorded around May 2015 and June

2016. There are number of minor and major spikes during the period as shown in gas price thus, been quiet volatile for the period with a fundamental implication on the strategic decision or planning. The prices fall into a range between 0.03 and 0.08$/kwh. Finding from the *electricity price for plants located near the source from January 2013 to December 2017* revealed similar things to the plant located near the source, the gas price shows a number of minor and major spikes during the period and this has made it quite volatile for the period with substantial consequence on the strategic decision making process. The prices fall into a range between 0.05 and 0.10$/kwh. Figure 4.5 in the previous chapter presents the statistical summary of descriptive statistics of the monthly historical gas and electricity prices.

The value of the prices volatility and its drift are estimated using the monthly historical data with Matlab tool and the findings revealed that the growth rate of the electricity price for plant located away from the source is about 30.5% higher than that of the plant located near the source. Also, growth rate of the natural logarithm of gas price for the plant located away from the source is about 34.5% higher than that of the plant located near the plant.

On the simulation of the energy prices using the Geometric Brownian Motion (GBM) approach, the findings show that the future volatility of gas price located near the source is not constant. Alternatively, there are no clear patterns shown between the different paths. This indicates that there is high level of uncertainty in the price even in the future. A similar case to the gas price located away from the source which also revealed that the future volatility of gas price located away from the source have no clear patterns, the implication is that there is high level of uncertainty in the future price of gas. On the other hand, similar findings were also recorded for the future volatility of electricity price for plant located near the source and away from the source.

On the real option analysis, the option values of gas price located near and away from the source respectively revealed that the higher volatility produces a higher gas option value. Thus, a higher investment option value is associated with higher risk. However, for the option values of electricity price for plant located near and away from the source respectively at different levels of volatility. The findings revealed that the higher volatility produces a higher electricity option value. Put differently, a higher investment option value is associated with higher risk. The study also investigates the sensitivity of thresholds to variation in volatility by varying the volatility parameter. It was discovered that the wider spread threshold between the prices of gas for plant located near the source (G_N) and away from the source (G_A) is associated with higher volatility. This is in line with the saying that higher uncertainty brings about doubtfulness. The result was similar for the prices of electricity for plant located near the source (E_N) and away from the source (E_A).

Lastly, the study presents waiting and investment regions for the Gas to power project (GtPP) considered in this study by varying the volatility. It can be seen that it more economical to invest in GtPP when the volatility and prices of the gas is within the gas price for plant located near the source (G_N) region (Figures 4.10a and 4.10b). Otherwise, the investor may have to wait. The case is similar to that of electricity. Also, it can be seen that the investors in GtPPshould wait till gas price of GtPP located away from the source (G_A) and electricity prices of the plant located away from the source (E_A) increases to the blue line before investing in plants located away from the source (Figures 4.11a and 4.11b). The analysis of economic viability of small or households Gas to Power Projects clearly indicates that the Net Present Value (NPV) of Electricity Price Based Plant and Gas Price Based Plant are greater than zero and these provide the evidences that the available options under the Gas to Power Projects are worth considering. Alternatively, these mean that the gas to power projects is economically viable. Besides, it was also revealed that the best choice of project is Gas Price Based Plant as it gives the highest value.

5.2 Conclusion

This study has shown optimal investment decision making on gas-to-power projects for effective gas utilisation in Nigeria. Investment timing and technology choice are of principal interest not only to policy-makers but also to the various market participants. With the help of the range of the economic indices shown in the results obtained, it is a project that investors will be willing to undertake. The model developed help investors and policy-makers to establish an investment pattern that accounts for the uncertainties in costs and revenues, as well as the flexibility of investment timing. However, understanding the trends discovered in the study will be key to making final investment decision on the GtPP and thereby creating a room for effective production and use of natural gas in Nigeriaaimed at maximizing profit or minimizing the investment risks.

The study investigates the optimal technology choice and optimal time to invest for the case that an electricity sector has the choice of building a new power generation unit in specific locations of the country.Given the fact that high level of uncertainty arises from highly volatile price, the dynamic approach and stochastic modelemployed in this study enables us to make investment decisions at different points in time. An interesting result obtained is that future volatility of energy prices has no clear patterns suggesting that there is high level of uncertainty in the future prices. Another one is that a higher investment option value is associated with higher risk. Furthermore, one of the major conclusions that can be drawn from the result obtained is that investment and waiting region depend on energy price volatility. This means that both the optimal technology choice and optimal investment timing are largely price volatility dependent. In relation to the viability of the available options, the conclusion drawn from the result obtained is that the Gas Price Based Project is the best choice of project as it gives the higher NPV value.

5.3 Recommendations

Based on the finding of the study, the following recommendations were made:

1. The investors must have comprehensive understanding on investment trends (timing) in order to make final investment decision on the project, maximizing profit and minimizing the investment risks.

2. The best choice of project is Gas Plant in terms of small and households as it gives the highest value. Government must put in place different measures to encourage investment into gas-power project; as the results in this study shown that gas to power projects was economically viable.

3. Government should advocate and offer incentives for captive power generation, it can be seen from the results that it more economical to invest in GtPP near the source when the volatility and prices of the gas is within the gas plant near the source region or invest in gas plant away from the source when the volatility and prices of the gas is within the gas plant away from the source region otherwise the investor may have to wait. It will thereby, positively affect the profitability of the power project for both local and international investors.

5.4 Contributions ofthe Study toKnowledge

The decision to take on an empirical study is informed by the need for research and gap in existing literature in the subject area. This study is no exception and contributes to the theory and practice of investment decision making in gas to power projects.

1. This study contributes to the theories of modern investment. Such as neoclassical theory of investment (Jorgenson's 1960); accelerator theory of investment (Samuelson, 1939); Tobin's Q (Brainard and Tobin, 1968; and Tobin, 1969); and marginal q (Mueller and Reardon, 1993). Keynes considers the return on investment as the marginal efficiency of capital while Fisher uses it as internal rate of returns. However, both Keynes and Fisher have different views on risk and uncertainty. This study will allow researchers in the area of investment to have information to build on when writing on various aspects of investment decision making and motives for investor's entry into a gas-to-power project. This study provides insights to potential local and foreign investors for opportunities available via the country's natural gas abundance to seek to invest in power generation projects because it was shown in the study that investment decisions are made after a complete analysis of the investment project.

2. To the body of academics, this study will serve as a springboard for further researches. One important question that has troubled scholars is the predominance of risk and uncertainty in the gas-to-power projects in Nigeria despite the massive inflow of multinational corporations. The risk factor of the investment clarifies the puzzle because it is uncertain that the cost of the investment will be recovered and a profit will be gained.

A higher investment option value is associated with higher risk. These will make a major contribution to secondary literature for future studies along this line. It will also be a reference point for future scholars around the world that will want to study the effects of the activities of oil and gas companies on the wider environment and not just on optimal investment decision making in Nigeria.

3. Methodological contribution.This is one of new research that utilises secondary data in a different dimension in one single study.The research philosophy, strategy, approach and analytical techniques such as the use of real option analysis, linear programming models and Monte Carlo simulationsto evaluate the relationship between variables, serves as a reference point to the body of academics and researchers in other countries.

4. Contribution to practice. This study is invaluable because it will help to guide the decisions of economic policymakers and regulators in Nigeria because of the strong base and relevance of the economic variables such as investment in gas-to-power, infrastructuresuch as gas plants located near (≤ 100 km) and away (≥ 100 km) from the source; and electricity plants located near and away from the source that is used in the study. Additionally, this study is expected to have full policy implication, especially for the government of Nigeria and the government of other countries that find themselves in a similar situation of risk and uncertain that is associated with the cost of the investment.

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Appendix 1

Historical gas and electricity prices from January 2013 to December 2017

Date	Gas Price	Gas Price1	Electricity Price	Electricity Price1
Jan-13	1.70	3.60	0.03	0.05
Feb-13	1.58	3.57	0.04	0.06
Mar-13	1.53	4.53	0.03	0.05
Apr-13	2.04	3.94	0.04	0.06
May-13	1.50	3.50	0.03	0.05
Jun-13	1.82	3.82	0.04	0.06
Jul-13	1.52	4.58	0.03	0.05
Aug-13	1.56	3.56	0.03	0.07
Sep-13	2.01	3.61	0.04	0.06
Oct-13	1.93	3.93	0.04	0.05
Nov-13	1.90	3.90	0.05	0.06
Dec-13	2.03	3.73	0.04	0.07
Jan-14	2.84	4.00	0.06	0.08
Feb-14	1.98	3.98	0.04	0.06
Mar-14	2.00	6.00	0.05	0.07
Apr-14	2.08	4.08	0.04	0.05
May-14	2.00	4.00	0.04	0.06
Jun-14	3.11	5.11	0.06	0.08
Jul-14	2.09	5.59	0.04	0.07
Aug-14	2.76	6.26	0.06	0.08
Sep-14	2.90	5.40	0.07	0.06
Oct-14	3.01	6.51	0.06	0.08
Nov-14	3.16	6.66	0.06	0.09
Dec-14	3.06	5.06	0.06	0.08
Jan-15	3.84	5.84	0.08	0.10
Feb-15	3.76	5.76	0.08	0.10
Mar-15	3.50	4.80	0.07	0.09
Apr-15	4.04	5.34	0.07	0.09
May-15	2.16	3.64	0.04	0.06
Jun-15	3.41	4.01	0.06	0.08
Jul-15	5.62	5.92	0.05	0.07
Aug-15	5.45	6.75	0.06	0.09
Sep-15	4.28	5.58	0.07	0.08
Oct-15	4.11	6.41	0.05	0.07
Nov-15	5.94	7.24	0.07	0.09

Dec-15	3.77	5.07	0.08	0.10
Jan-16	6.25	7.50	0.06	0.08
Feb-16	6.62	7.78	0.07	0.09
Mar-16	6.79	8.00	0.08	0.08
Apr-16	6.18	7.44	0.07	0.09
May-16	6.21	7.46	0.04	0.07
Jun-16	6.11	7.37	0.07	0.09
Jul-16	6.06	7.33	0.05	0.08
Aug-16	6.21	8.47	0.06	0.09
Sep-16	6.14	7.40	0.07	0.08
Oct-16	6.15	7.41	0.05	0.09
Nov-16	6.29	9.54	0.07	0.07
Dec-16	6.46	7.69	0.07	0.09
Jan-17	6.83	8.03	0.08	0.10
Feb-17	6.43	7.66	0.07	0.09
Mar-17	6.79	9.99	0.08	0.10
Apr-17	7.01	10.01	0.08	0.10
May-17	6.96	9.15	0.07	0.09
Jun-17	6.94	9.13	0.08	0.10
Jul-17	6.63	8.85	0.06	0.08
Aug-17	6.41	8.65	0.07	0.09
Sep-17	7.00	9.18	0.06	0.08
Oct-17	6.87	9.67	0.07	0.07
Nov-17	7.00	9.58	0.06	0.08
Dec-17	6.83	9.50	0.07	0.09

APPENDIX 2 - Programming Code

Matlab script for Monte Carlo simulation two factor model

```
% Create Plot Gas Price for Plants Located near the Source

plot(DATAAYS5.Date,DATAAYS5.GasPrice)

% Create xlabel

xlabel('Months');

% Create title

title('Gas Price for Plants Located near the Source $/mbtu ');

% Create ylabel

ylabel('Price ($/mbtu)');


% Create Plot Gas Price for Plants away from the Source

plot(DATAAYS5.Date,DATAAYS5.GasPrice1)

% Create xlabel

xlabel('Month');

% Create title

title('Gas Price for Plants Located away from the Source $/mbtu');

% Create ylabel

ylabel('''Price ($/mbtu)');


g1 =
[1.7,1.58,1.53,2.04,1.5,1.82,1.52,1.56,2.01,1.93,1.9,2.03,2.84,1.98,2,2.08,2,3.11,2.09,2.76,2.9,3.
01,3.16,3.06,3.84,3.76,3.5,4.04,2.16,3.41,5.62,5.45,4.28,4.11,5.94,3.77,6.25,6.62,6.79,6.18,6.21,
6.11,6.06,6.21,6.14,6.15,6.29,6.46,6.83,6.43,6.79,7.01,6.96,6.94,6.63,6.41,7,6.87,7,6.83];

G = log(g1)
```

```
me = mean(G);

stand = std(G)

mu = me

sigma = stand


clear; clc;

mu=1.328;      % drift

sigma=0.549;   % std dev

S1=1.70;     % initial cost ($)

N=13;        % number of time steps (projrct year)

K=20;        % number of simulations


dt=sigma/sqrt(N);   % local volatility


St=[S1];

for k=1:K

   St=[S1];

   for i=2:N

      eps=randn;

      S=St(i-1)+St(i-1)*(mu*dt+sigma*eps*sqrt(dt));

      St=[St; S];

   end

   hold on; plot(St);

end

xlim([1 N]);
```

```
xlabel('Project Year')

title('Gas Price for Plants Located near the Source ($/mbtu) ');

ylabel('Simulated Gas Price ($/mbtu)');

grid('on');

box('on');



g2 =
[3.60,3.57,4.53,3.94,3.50,3.82,4.58,3.56,3.61,3.93,3.90,3.73,4.00,3.98,6.00,4.08,4.00,5.11,5.59,6
.26,5.40,6.51,6.66,5.06,5.84,5.76,4.80,5.34,3.64,4.01,5.92,6.75,5.58,6.41,7.24,5.07,7.50,7.78,8.0
0,7.44,7.46,7.37,7.33,8.47,7.40,7.41,9.54,7.69,8.03,7.66,9.99,10.01,9.15,9.13,8.85,8.65,9.18,9.67
,9.58,9.50];

G = log(g2)

me = mean(G);

stand = std(G)

mu = me

sigma = stand


clear; clc;

mu=1.786;      % drift

sigma=0.339;   % std dev

S1=3.60;     % initial cost ($)

N=13;        % number of time steps (projrct year)

K=20;        % number of simulations


dt=sigma/sqrt(N);   % local volatility
```

```
St=[S1];
for k=1:K
   St=[S1];
   for i=2:N
      eps=randn;
      S=St(i-1)+St(i-1)*(mu*dt+sigma*eps*sqrt(dt));
      St=[St; S];
   end
   hold on; plot(St);
end
xlim([1 N]);
xlabel('Project Year')
title('Gas Price for Plants Located away from the Source ($/mbtu)');
ylabel('Simulated Gas Price ($/mbtu)');
grid('on');
box('on');

% Create Plot Electricity Price for Plants near the Source
plot(DATAAYS5.Date,DATAAYS5.ElectricityPrice)
% Create xlabel


% Create Plot Electricity Price for Plants near the Source
plot(DATAAYS5.Date,DATAAYS5.ElectricityPrice1)
% Create xlabel
```

```
e1 =
[0.03,0.04,0.03,0.04,0.03,0.04,0.03,0.03,0.04,0.04,0.05,0.04,0.06,0.04,0.05,0.04,0.04,0.06,0.04,0
.06,0.07,0.06,0.06,0.06,0.08,0.08,0.07,0.07,0.04,0.06,0.05,0.06,0.07,0.05,0.07,0.08,0.06,0.07,0.0
8,0.07,0.04,0.07,0.05,0.06,0.07,0.05,0.07,0.07,0.08,0.07,0.08,0.08,0.07,0.08,0.06,0.07,0.06,0.07,
0.06,0.07];

me = mean(e1);

stand = std(e1)

mu = me

sigma = stand


clear; clc;

mu=0.058;      % drift

sigma=0.016;   % std dev

S1=0.03;     % initial cost ($)

N=13;        % number of time steps (projrct year)

K=20;        % number of simulations


dt=sigma/sqrt(N);   % local volatility


St=[S1];

for k=1:K

   St=[S1];

   for i=2:N

      eps=randn;

      S=St(i-1)+St(i-1)*(mu*dt+sigma*eps*sqrt(dt));

      St=[St; S];

   end
```

```
    hold on; plot(St);
end
xlim([1 N]);
xlabel('Project Year')
title('Electricity Price for Plants Located near the Source ($/kwh)');
ylabel('Simulated Electricity Price ($/kwh)');
grid('on');
box('on');



e2 =
[0.05,0.06,0.05,0.06,0.05,0.06,0.05,0.07,0.06,0.05,0.06,0.07,0.08,0.06,0.07,0.05,0.06,0.08,0.07,0
.08,0.06,0.08,0.09,0.08,0.10,0.10,0.09,0.09,0.06,0.08,0.07,0.09,0.08,0.07,0.09,0.10,0.08,0.09,0.0
8,0.09,0.07,0.09,0.08,0.09,0.08,0.09,0.07,0.09,0.10,0.09,0.10,0.10,0.09,0.10,0.08,0.09,0.08,0.07,
0.08,0.09];
me = mean(e2);
stand = std(e2)
mu = me
sigma = stand


clear; clc;
mu=0.077;      % drift
sigma=0.015;   % std dev
S1=0.05;     % initial cost ($)
N=13;        % number of time steps (projrct year)
K=20;        % number of simulations
```

```
dt=sigma/sqrt(N);   % local volatility


St=[S1];
for k=1:K
    St=[S1];
    for i=2:N
        eps=randn;
        S=St(i-1)+St(i-1)*(mu*dt+sigma*eps*sqrt(dt));
        St=[St; S];
    end
    hold on; plot(St);
end
xlim([1 N]);
xlabel('Project Year')
title('Electricity Price for Plants Located away from the Source ($/kwh)');
ylabel('Simulated Electricity Price ($/kwh)');
grid('on');
box('on');
```

APPENDIX 3

Table 1. Power Generation Companies in Nigeria with On-grid license from NERC and their installed capacities [10, 11]

Name	Site Location	Type	Installed Capacity (MW)	Available Capacity
AES Nigeria Barge Limited		Thermal	270	224
Afam Power PLC	Afam Rivers State	Thermal	987.2	60
Agbara Shoreline Power Limited	Agbara Ogun	Thermal	100	
Alaoji Generation Company Limited (NIPP)	Alaoji Abia State	Thermal	1074	
Anita Energy Limited	Agbara Lagos State	Thermal	90	
Azura Power West Africa Limited	Ihovbor Benin, Edo State	Thermal	450	
Benin Generation Company Limited	Ihonvbor Edo State	Thermal	450	
Calabar Generation Company Limited	Calabar Cross State	Thermal	561	
Century Power Generation Limited	Okija Anambra State	Thermal	495	
Enersys Nigeria Limited	Ado Ekiti State	Thermal	10	
Delta Electric Power Limited	Oghareki Etiope West LGA	Thermal	116	
DIL Power PLC	Obajana Kogi State	Thermal	135	
Egbema Generation Company Limited	Egbema Imo State	Thermal	338	
Egbin Power PLC	Egbin Lagos State	Thermal	1320	1100
Energy Company of Nigeria (NEGRIS)	Ikorodu, Lagos State	Thermal	140	
Enersys Nigeria Limited	Ado Ekiti Ekiti State	Thermal	10	
Ethiope Energy Limited	Ogorode, Sapele Delta State	Thermal	2800	300
Farm Electric Supply Limited	Ota-Ogun State	Thermal	150	
First Independent Power Company Limited	Omokun Rivers State	Thermal	150	60
First Independent Power Company Limited	Trans Amadi, Rivers State	Thermal	136	
First Independent Power Company Limited	Elewe, Rivers State	Thermal	95	
Fortune Electric Power Company Limited	Odukpari, Cross Rivers State	Thermal	500	
Gbarain Generation Company Limited	Gbarain, Bayelsa State	Thermal	225	
Geometric Power Limited	Aba, Abia State	Thermal	140	140
Geregu Power PLC (BPE)	Geregu Kogi State	Thermal	414	276
Hudson Power Ltd.	Warawa, Ogun State	Thermal	150	
Ibafo Power Station Ltd.	Ibafo, Ogun State	Thermal	200	
Ibom Power Ltd	Ikot Abasi Akwa Ibom State	Thermal	190	
ICS Power Ltd	Alaoji, Abia State	Thermal	624	
Isolo Power Generation Ltd.	Isolo, Lagos State	Thermal	20	
JBS Wind Power Ltd.	Maranban Pushit, Mangu, Plateau State	Wind	100	
Kainji Hydro Electric Plc (Kainji Station)	Kainji, Niger State	Hydro	760	450
Kainji Hydro Electric Plc (Kainji Station)	Jebba, Niger State	Hydro	540	450
Knox J&L Energy Solutions Ltd.	Ajaokuta, Kogi State	Thermal	1000	
Lotus & Bresson Nigeria Ltd.	Magboro Ogun State	Thermal	60	
MBH Ltd.	Ikorodu Lagos State	Thermal	300	
Minaj Holdings Ltd.	Agu-Amorji Nike Enugu East LGA, Enugu State	Thermal	115	
Nigeria Agip Oil Ltd.	Okpai Delta State	Thermal	480	361
Nigerian Electricity Supply Corporation (Nigeria) Ltd. (NESCO)	Bukuru, Plateau	Thermal	30	
Notore Power Ltd.	Onne, Rivers State	Thermal	50	
Ogorode Generation Company Ltd (NIPP)	Ogorode Delta State	Thermal	450	
Olorunsogo Generation Company Ltd (NIPP)	Olorunsogo, Ogun State	Thermal	750	
Olorunsogo Power Plc (BPE)	Olorunsogo, Ogun State	Thermal	335	76
Omoku Generation Company Ltd.	Omoku, Rivers State	Thermal	250	60
Omotosho Generation Company Ltd.	Omotosho II Ondo State	Thermal	500	76
Omotosho Power Plc (BPE)	Omotosho Ogun State	Thermal	335	35
Paras Energy & Natural Resources Development Ltd	Ogijo, Ogun State	Thermal	96	
Sapele Power Plc	Sapele, Delta State	Thermal	1020	90
Shell Petroleum Development Company Ltd.	Afam VI	Thermal	642	450
Shiroro Hydro Electric Plc	Shiroro, Niger State	Hydro	600	450
Supertek Electric Ltd.	Ajaokuta, Kogi State	Thermal	500	
Supertek Nigeria Ltd.	Akwete, Abia State	Thermal	1000	
Ughelli Power Plc.	Ughelli, Delta State	Thermal	942	320
Western Technologies & Energy Services Ltd.	Sagamu, Ogun State	Thermal	1000	
Zuma Energy Nigeria Ltd. (Gas Plant)	Ohaji Egbema, Owerri, Imo	Thermal	400	
Zuma Energy Ltd. (Coal Plant)	Itobe, Kogi State	Thermal	1200	
TOTAL			**25,255.2**	**4978**

Questionnaire

i. Company Information

1. Name ……………………………………………….
2. Year of Establishment…………………………………
3. Number of Employees……………………………
4. Ownership…………………………………………..

ii. Nature of electricity generation and the fuel source

5. What is the installed capacity of generating plants?....................................
6. What is their available Capacity (MW)? ……………………………….
7. What fuels do you use in generating electricity?..
8. Where do you get fuels (gas) from?..
9. What is the amount of gas received from the sources?........................
10. What is amount of gas required to generating electricity based on the installed capacity?.................................
11. At what price, the gas is being supplied to your company?
12. What are the challenges facing your power plants?
13. Based on question 11, identify three top challenges?
14. How do you distribute your electricity generations?
15. What is amount of electricity generation that is sent to the grid?

iii. Cost aspect of electricity generation

13. How many generating plants do you have?...........................

14. What is the type of your generating plants (simple gas turbine etc.)?

15. What is the capital cost of each generating plant?

16. What is the average amount of money spent on generation fuels in a month?

17. How much do you spend on operating expenses?

18. What other expenses do you incur?

iv. Revenue profiles and Investment expectation

19. What is the amount of electricity generated get to the grid?

20. At what price is being sold to the grid?

21. Does the price incentivize the amount of electricity generated?

22. Do your company intend to provide additional investment? Yes/ No

23. If No, what are factors that hinder additional investment?

24. List three most key obstacles to investment

25. Would your company prefer to utilize electricity generation within your location than transmitting it to the grid?

26. If yes, what is the reason?