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Optimal Investment Designed On Gas to Power Plant Projects In Nigeria

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Abstract
Nigeria has a huge proven gas 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. Nigeria, being the most populous country in Africa and having the largest gas reserves in the continent, the need to invest and diversify in power plant project in imperative. The total final energy consumption in Nigeria as at 2012 was 121 Million tons of oil equivalent (Mtoe), which will increase by 64% in year 2040. This signifies significant increase in energy demand in the country in the future, which justifies the need for more investment and diversification in power plant project in the country. The study objective is to determine optimal investment needed on gas for power plant project in Nigeria. The study employed mathematical programming. The paper employs this approach by building a deterministic optimization model to capture an energy system and also experiments Monte Carlo simulation in terms of the results to capture uncertainties. Gas price for plants located near the gas fields increased from $1.70/mbtu (Million British Thermal Unit) in January 2013 to $6.83/mbtu in December 2017 while plants located away from the gas fields also increased from $3.60mbtu in January 2013 to $9.50/mbtu in December 2017. There was a shock fall in price from $4.04/mbtu in April 2015 to $2.16/mbtu in May 2015. Analyses further shows that gas price for plants located near the source ($4.32±2.07/mbtu) and away from the source ($6.30±2.06/mbtu), exhibited wide variation. The real option analysis of gas prices revealed that the plant gives 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; as a result of no clear patterns shown between the different paths. Conclusively, it is 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 from the source.

Keywords: *Optimal Investment, Profitability, Gas, Power Plant*

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I. Introduction

Nigeria has a huge proven gas 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).

Nigeria, being the most populous country in Africa and having the largest gas reserves in the continent,the need to invest and diversify in power plant projectin imperative (EIA, 2014). It was estimated that, by the year 2040,around 50 million people will still live without access to electricity (*BP Statistical Review of World Energy*,2015).Ibitoye (2007) estimated that electricitysupply from gas will continue to dominate energy supply mix and will constitute 70% of the total electricitygeneration in Nigeria by 2030 (Ibitoye and Adenikinju, 2007). Going by this estimate, the country will witness additional 7% increase in the share ofsources of electricity from natural gas in 2030 from 2011. The total final energy consumption in Nigeria as at 2012 was 121 Million tons of oil equivalent (Mtoe),which will increase by 64% in year 2040. This signifies significant increase in energy demand in the country inthe future, which justifies the need for more investment and diversification in power plant project in the country.

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 reach 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.

The electricity sector witnessed another landmark on November 1, 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 6000 mw for over the past two year 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.

The objective of the study is to determine optimal investment needed on gas for power plant project in Nigeria. In other word, to investigate when is it more economical to transfer gas from fields to a central location and generate power there.

Scanty researches have been conducted on investment decision making in gas-power projects. Therefore, thisserves as the main justification for the paper 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 on 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.

II. The Prices of Natural Gas

On the international market, crude 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/mBtu as shown in Figure 1. 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).

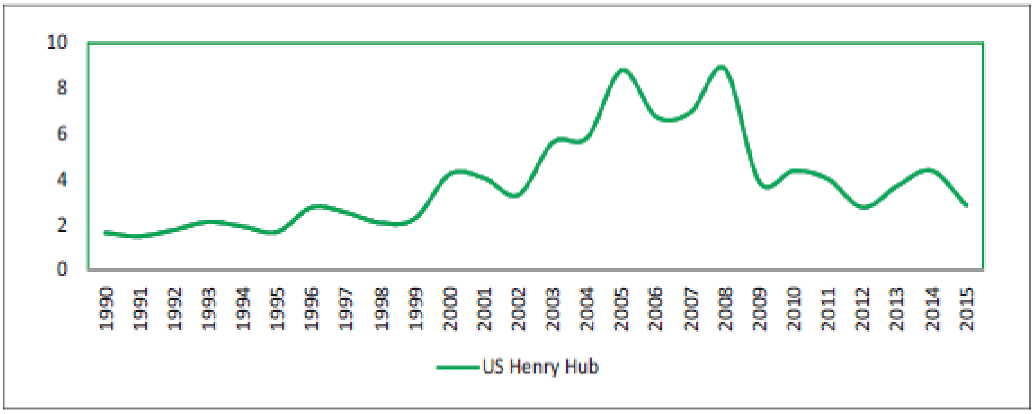

Figure 1: The Valuations of Natural Gas (US$/mBtu) (1990 - 2015)

Source: EIA

2.1.1 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. 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. 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 kilowatthours per 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).

2.2 Linear Optimization in Natural Gas Utilization

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 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).

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 Western parts 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.

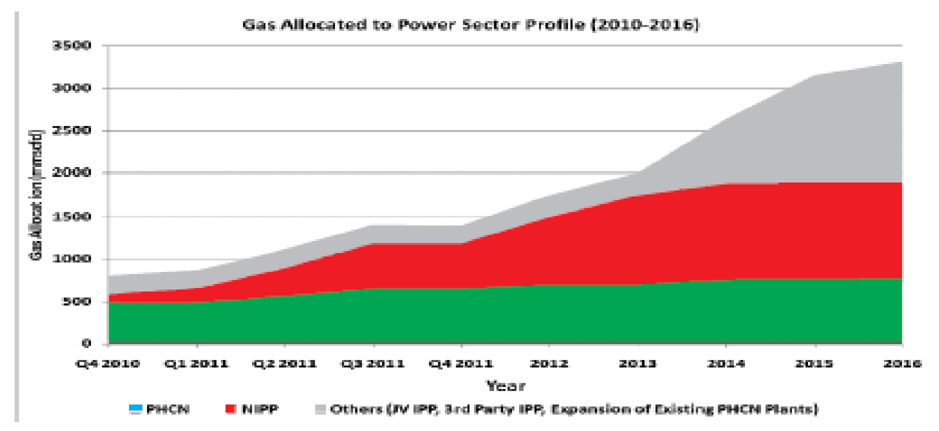

Figure 2: The Profile Allocationof Gas Power Sector (2010 -2016)

Source: **TheGas Company in Nigerian**

2.4 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 1) 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 1: 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.

2.5 Nigerian Energy Market Difficulties

2.5.1 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).

2.5.2 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).

2.6 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).

2.7 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 (Chavas, 2004).

In order to understand better the behavior of investment and decision-making, very important to research 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 indicates that progress can be made in the investment behavior analysis by analyzing economic models of such behavior within the theoretical framework he 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.

III. Theoretical Framework

The study theoretical framework was 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 design optimal investment on gas for power plant project, 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.

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 minimize or maximize a criterion (costs or benefits) or multiple criteria concomitantly (costs and risks). The decision variables capture decisions to be made to solve the problem while constraints refer to conditions that have to be satisfied by any solution. Put differently, constraints limit the values decision variables can take.

The optimization problems are expressed in forms of mathematical models that attempt to determine the values of decision variables that minimize or maximize the goal function among the set of all decision variables under given constraints. These constraints employed to ensure the power and energy demand of an energy system. Additional constraints include technological limitations, environmental constraints, fuel system over the entire planning period (Hobbs, 1995). This section builds an economic condition model that entails mathematical programming and Monte Carlo simulation in order to provide answers to the objective of the paper. Combining the two models is a complex task but this paper adapted a technique similar to Feretic and Tom sic (2005) and Hawk (2010). The paper employs its approach by building a deterministic optimization model to capture an energy system and also experiments Monte Carlo simulation in terms results to capture uncertainties.The study decides 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 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. The cost of gas is of high uncertainty. The two parameters (the gas cost and the electricity cost) are line with the Brownian motion of:

$$\frac{dP_G(t)}{P_G(t)} = \alpha_G dt + \delta_G du_1(t) \quad 3.1$$

$$\frac{dP_E(t)}{P_E(t)} = \alpha_E dt + \delta_E \sigma_{GE} du_1(t) + \delta_E \sqrt{1 - \sigma^2{}_{GE} du_2(t)} \quad 3.2$$

Where α_i and δ_i are constants of cost drift and cost fluctuations. dt represents infinitesimal time increment. du_1 and du_2 denoting 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 σ_{GE} is established even though electrical power is partially influenced by gas cost. The normalized Brownian motion of the price is specified as:

$$P_G(t) = P_G(0)e^{(\alpha_G - 0.5\delta_G^2)t + \delta_G u_1(t)} \quad 3.3$$

$$P_E(t) = P_E(0)e^{(\alpha_E - 0.5\delta_E^2)t + \delta_E \theta u_1(t) + \delta_E \sqrt{1-\theta^2 u_2(t)}} \quad 3.4$$

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:

$$C_j\big(P_G(t), P_E(t)\big) = \frac{P_G(t)}{\varphi_j} + \frac{1-\pi\omega j}{\pi} P_E(t) \quad 3.5$$

Where φ_j measures thermal efficiency, πdenotes the heat concentration (the heat of per kilowatt hour) that is considered as a fixed number.ωjrepresents 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:

$$\tau_j\big(P_G(t), P_E(T)\big) = R_\gamma - K_{Gj}P_G(t) - K_{Ej}P_E(t) \quad 3.6$$

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

$$K_{Gj} = \frac{1}{\varphi_j}; K_{Ej} = \frac{1-\pi_{\omega j}}{\pi} \quad 3.7$$

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

$$\beth_j(t) = E_t\left[\int_t^\infty \tau_j\big(P_G(t), P_E(t)e^{-\theta(\vartheta - t)}dt\big)\right] \quad 3.8$$

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.

$$\beth_j(t) = \frac{R_\gamma}{\theta} + \frac{K_{Gj}P_G(t)}{\theta - \alpha_G} - \frac{K_{Ej}P_E(t)}{\theta - \alpha_E} \quad 3.9$$

Projected cost 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 factor ϑ.

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

$$\theta V_j\big(P_G(t), P_E(T)\big) = \frac{E[dV_j]}{dt} \quad 3.10$$

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:

$$\frac{E[dV_j]}{dt} = \frac{1}{2}\delta_G^2 P_G^2 \frac{\partial^2 V_j}{\partial^2 P_G^2} + \sigma_{GE}\delta_G\delta_E P_G P_E \frac{\partial^2 V_j}{\partial^2 P_G^2} + \frac{1}{2}\delta_E^2 P_E^2 \frac{\partial^2 V_j}{\partial^2 P_E^2} + \alpha_G P_G \frac{\partial V_j}{\partial P_G} + \alpha_E P_E \frac{\partial V_j}{\partial P_E} \quad 3.11$$

The temporary differential of equation can be specified as

$\frac{1}{2}\delta_G^2P_G^2\frac{\partial^2V_j}{\partial^2P_G^2}+\sigma_{GE}\delta_G\delta_EP_GP_E\frac{\partial^2V_j}{\partial^2P_G^2}+\frac{1}{2}\delta_E^2P_E^2\frac{\partial^2V_j}{\partial^2P_E^2}+\alpha_GP_G\frac{\partial V_j}{\partial P_G}+\alpha_EP_E\frac{\partial V_j}{\partial P_E}-\theta V_j=0$ 3.12

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

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

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:

$O_j\big(P_G(t),P_E(T)\big)=max\left[\frac{R_Y-K_{Gj}P_G(t)-K_{Ej}P_E(t)}{\theta}-C_{1,0}\right]$ 3.14

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

$\theta V_j\big(P_G(t),P_E(T)\big)>\frac{E[dV_j]}{dt}$ 3.15

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:

$V_j=\frac{R_Y-K_{Gj}P_G(t)-K_{Ej}P_E(t)}{\theta}-C_1$ 3.16

$\frac{1}{2}\delta_G^2P_G^2\frac{\partial^2V_j}{\partial^2P_G^2}+\sigma_{GE}\delta_G\delta_EP_GP_E\frac{\partial^2V_j}{\partial^2P_G^2}+\frac{1}{2}\delta_E^2P_E^2\frac{\partial^2V_j}{\partial^2P_E^2}-\theta V_j\leq 0$ 3.17

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

$V_j>\frac{R_Y-K_{Gj}P_G(t)-K_{Ej}P_E(t)}{\theta}-C_1$ 3.18

$\frac{1}{2}\delta_G^2P_G^2\frac{\partial^2V_j}{\partial^2P_G^2}+\sigma_{GE}\delta_G\delta_EP_GP_E\frac{\partial^2V_j}{\partial^2P_G^2}+\frac{1}{2}\delta_E^2P_E^2\frac{\partial^2V_j}{\partial^2P_E^2}-\theta V_j=0$ 3.19

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 $P_E(0)=0$

$V_j(t)=\frac{R_Y-K_{Gj}P_G(t)}{\theta}$ 3.20

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

$\frac{1}{2}\delta_G^2P_G^2\frac{\partial^2V_j}{\partial^2P_G^2}-\theta V_j=0$ 3.21

The generation solution can be deduced as

$V_j(P_G(t),0)=\ A_{Gj}P_G(t)^{\alpha G}+B_{Gj}P_G(t)^{bG}$ 3.22

$\alpha_G=\frac{1}{2}-\sqrt{\frac{1}{4}+\frac{2\theta}{\delta_G^2}}<0$ 3.23

$b_G=\frac{1}{2}-\sqrt{\frac{1}{4}+\frac{2\theta}{\delta_G^2}}>1$ 3.24

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.

$V_j\big(\bar{P}_{Gj},0\big)=ב_j\big(\bar{P}_{Gj},0\big)-C_1$ 3.25

$\frac{dV_j(\bar{P}_{Gj},0)}{dP_G(T)}=\frac{dב_j(\bar{P}_{Gj},0)}{dP_G(T)}$ 3.26

Then the following expression is obtained:

$V_j(P_G(t),0)=\ A_{Gj}P_G(t)^{\alpha G}$ 3.27

$A_{Gj} = -\frac{K_{Gj}}{\theta_{\alpha G}}(\frac{\alpha G}{\alpha G-1} \cdot \frac{R_Y-\theta I_j}{K_{Gj}})^{1-\alpha G}$ 3.28

$\alpha_G = \frac{1}{2} - \sqrt{\frac{1}{4} + \frac{2\theta}{\delta_G^2}} < 0$ 3.29

$\bar{P}_{Gj} = -\frac{\alpha G}{1-\alpha G}\frac{R_Y-\theta C_1}{K_{Gj}}$ 3.30

$ב_j(\bar{P}_{Gj}, 0) = \frac{1}{1-\alpha G}(\frac{R_Y}{\theta} - \alpha G C_1)$ 3.31

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:

$V_j(P_G(t), 0) = \begin{cases} \frac{R_Y-K_{Gj}P_G(t)}{\theta} - C_1 P_G(t) \le \bar{P}_{Gj} \\ A_{Gj}P_G(t)^{\alpha G}P_G(t) > \bar{P}_{Gj} \end{cases}$ 3.32

$V_j(P_E(t), 0) = \begin{cases} \frac{R_Y-K_{Ej}P_E(t)}{\theta} - C_1 P_E(t) \le \bar{P}_{Ej} \\ A_{Ej}P_E(t)^{\alpha E}P_E(t) > \bar{P}_{Ej} \end{cases}$ 3.33

$V_j(P_G(t), P_E(t)) = 0 \ \lim \quad P_G(t) \to \infty$ 3.34

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

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:

$P_{G,K} = P_{G,K-1} + g \quad P_{G,0} = 0 \quad k = 0,1, \ldots., m$ 3.36

$P_{E,j} = P_{G,j-1} + h \quad P_{G,0} = 0 \quad l = 0,1, \ldots., n$ 3.37

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

$\frac{\partial^2 V_j}{\partial P_G \partial P_G} \approx \frac{1}{4gh}(V_{j,k+1,l+1} - V_{j,k+1,l-1} - V_{j,k-1,l+1} + V_{j,k-1,l-1})$ 3.38

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

$\frac{\partial^2 V_j}{\partial^2 P_E^2} \approx \frac{1}{h^2}(V_{j,k,l+1} - 2V_{j,k,l} - V_{j,k-1,l+1} + V_{j,k,l-1})$ 3.40

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

$P_{1j,k,l}V_{j,k+1,l+1} + P_{2j,l}V_{j,k,l+1} - P_{3j,k}V_{j,k+1,l} - P_{4j,k,l}V_{j,k,l} + P_{3j,k}V_{j,k-1,l} - P_{1j,k,l}V_{j,k+1,l-1} + P_{2j,l}V_{j,k,l-1} + P_{1j,k,l}V_{j,k-1,l-1} \le 0 \quad \perp \varepsilon_{j,k,l} \le 0$ 3.41

$V_{j,k,l} - \left(\frac{R_Y-K_{Gj}P_G(t)-K_{Ej}P_E(t)}{\theta} - C_1\right) + \varepsilon_{j,k,l} \ge 0 \perp -\infty < V_{j,k,l} < +\infty$ 3.42

The boundary conditions are as follows

$V_{j,k,l} = \begin{cases} \frac{R_Y-K_{Gj}P_G(t)}{\theta} - C_1 P_G(t) \le \bar{P}_{Gj} \\ A_{Gj}P_G(t)^{\alpha G}P_G(t) > \bar{P}_{Gj} \ and \ k \ne 0 \end{cases}$ 3.43

$V_{j,0,l} = \begin{cases} \frac{R_Y-K_{Ej}P_E(t)}{\theta} - C_1 P_E(t) \le \bar{P}_{Ej} \\ A_{Ej}P_E(t)^{\alpha E}P_E(t) > \bar{P}_{Ej} \ and \ k \ne 0 \end{cases}$ 3.44

$V_{j,m,l} = 0 V_{j,k,n} = 0$ 3.45

$P_{1j,k,l} \equiv \frac{\sigma_{GE}\delta_E P_{G,k}P_{E,l}}{4gh}$ 3.46

$P_{2j,k,l} \equiv \frac{\delta_E^2 P_{E,l}^2}{2h^2}$ 3.47

$P_{3j,k,l} \equiv \frac{\delta_G^2 P_{G,k}^2}{2g^2}$ 3.48

$P_{4j,k,l} \equiv \frac{\delta_G^2 P_{G,k}^2}{g^2} + \frac{\delta_E^2 P_{E,k}^2}{h^2} + \theta$ 3.49

3.2.3 Data Source

The paper 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, including Nigeria.

IV. Results and Discussion

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

4.1 Trend

This section begins from examining the peculiar behavior of the monthly historical gas price from January 2013 to December 2017.

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

In Figure 3, 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.

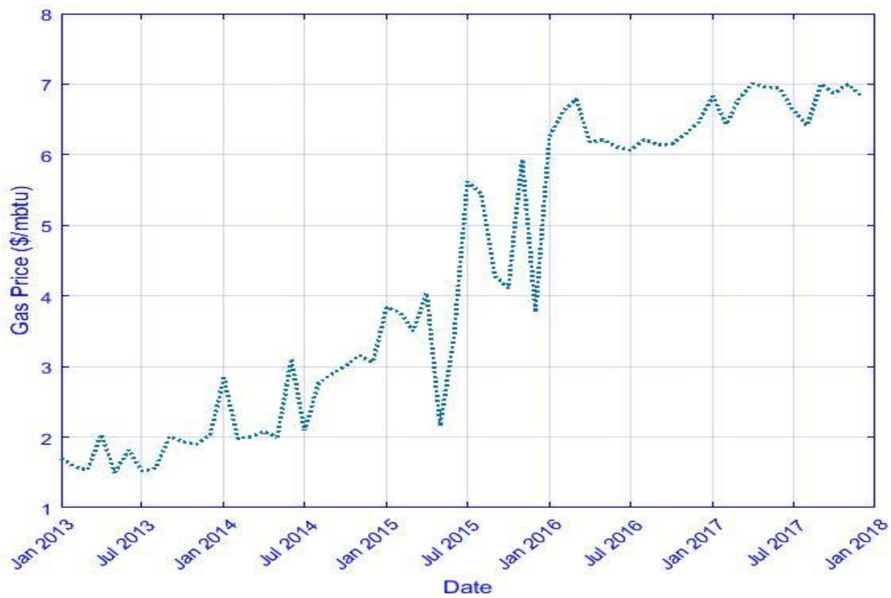

Figure 3: *Gas Price for plants located near the source from January 2013 to December 2017*
Source: Field work (2018)

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

In the Figure 4, 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.

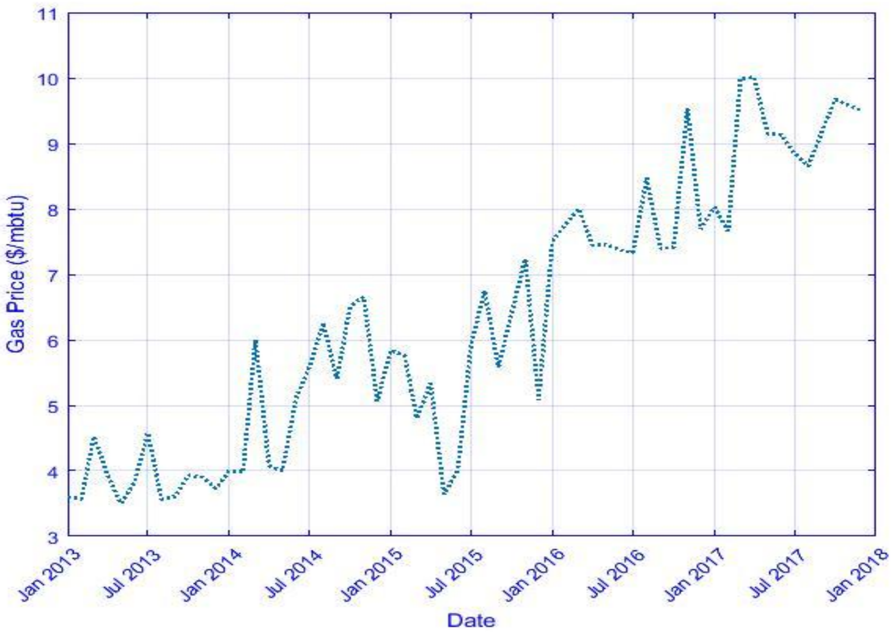

Figure 4: Gas Price for plants located away from the source from January 2013 to December 2017. Source: Field work (2018)

4.2 Summary Statistics

A summary of the descriptive statistics of the monthly historical gas and electricity prices is presented in Table 2 below. From the Table, 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. 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.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.

Table 2: Summary Statistics

	Gas Price	*Gas Price1*
Minimum	1.50	3.50
Maximum	7.01	10.01
Mean	4.32	6.30
Standard Deviation	2.07	2.06
Kurtosis	-1.72	-1.23
Skewness	-0.01	0.21

Source: Author's computation, 2018

4.3 Parameter Estimates

In this paper, 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 3. 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. 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.

Table 3: Parameter Estimates

	Gas Price	Gas Price1
mean	1.328	1.786
sigma	0.549	0.339

Source: Author's computation, 2018

4.4 Uncertainties Simulation

This sub-section focuses on the simulation of the energy prices using the Geometric Brownian Motion (GBM) approach. 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 section 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 paper, 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 5. 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.

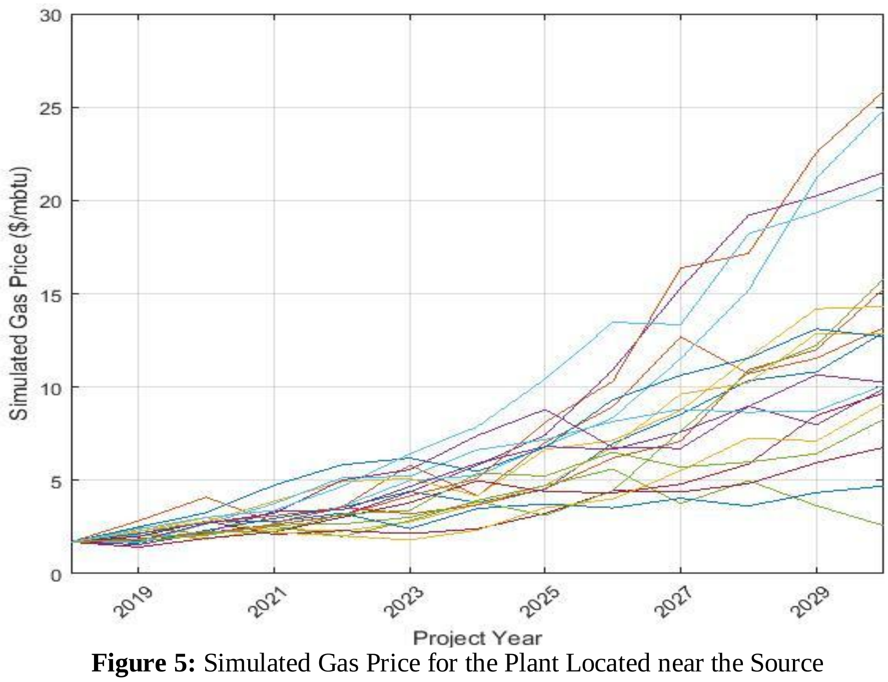

Figure 5: Simulated Gas Price for the Plant Located near the Source

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 6. 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.

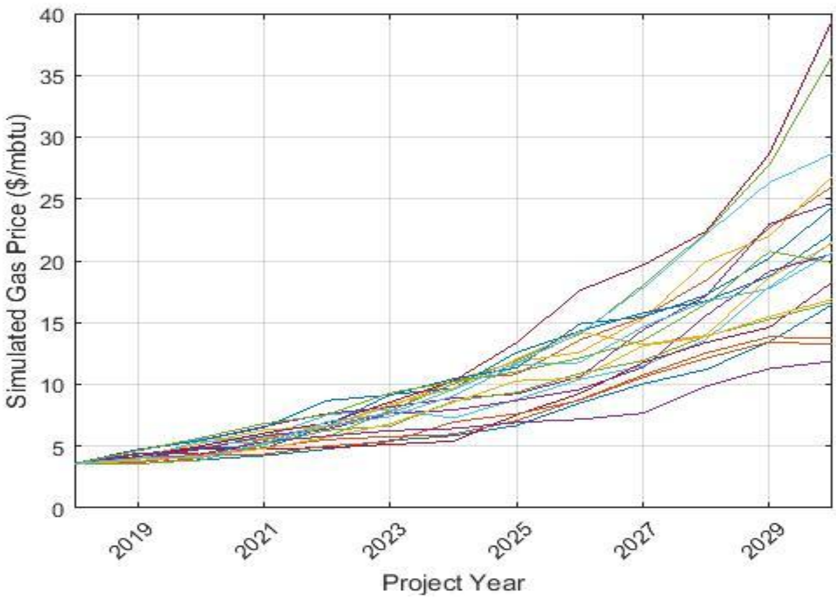

Figure 6: Simulated Gas Price for the Plant Located away from the Source
Source: Field work (2018)

4.5 Real Option Analysis

In order to capture the specific objectives of the paper that says to determine optimal investment needed on gas for power plant project, the study used the decision-making models specified in the preceding section. 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 paper makes use of the ROA with the required input parameters.

To investigate the objectives, 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. As in the Table, the current value of cash flows is $4million/BTU for gas 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: Additional Parameters used in the Investment Options.

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

Source: Project Record

4.5.1 Option Value of Investment

Figures 7a and 7b graphically illustrates 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. 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.

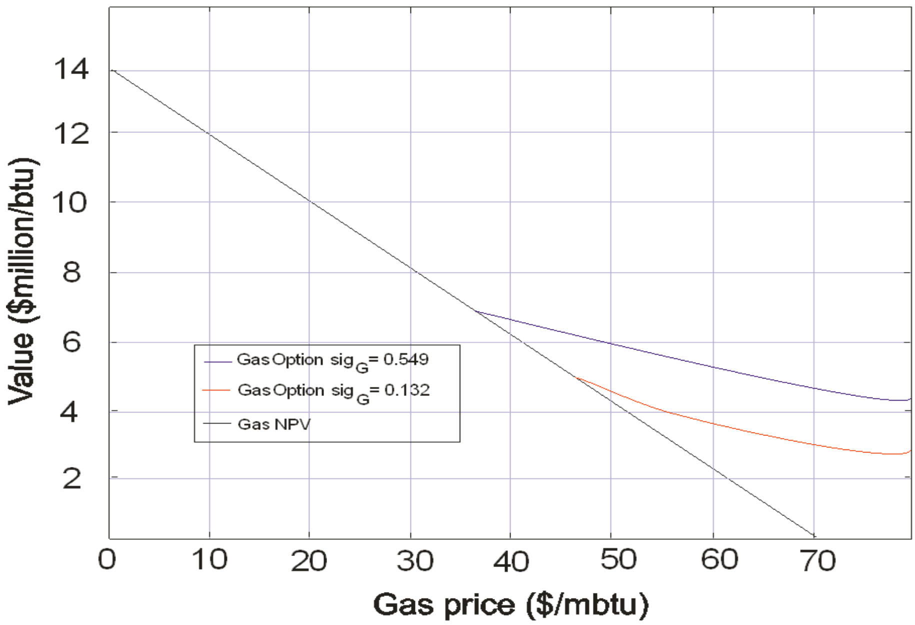

Figure 7a: Option Value for Gas Price for Plant Located Near the Source, (Source: Field work, 2018)

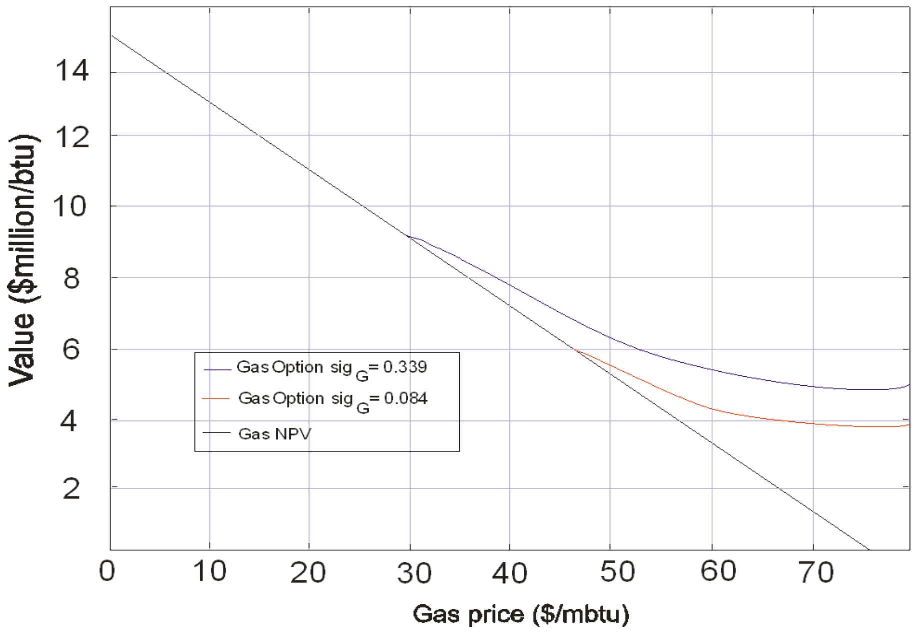

Figure 7b: Option Value for Gas Price for Plant Located away from the Source, (Source: Field work, 2018)

4.5.2 Threshold Price

In this sub-section, the paper investigates the sensitivity of thresholds to variation in volatility by varying the volatility parameter. In Figure 8, 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.

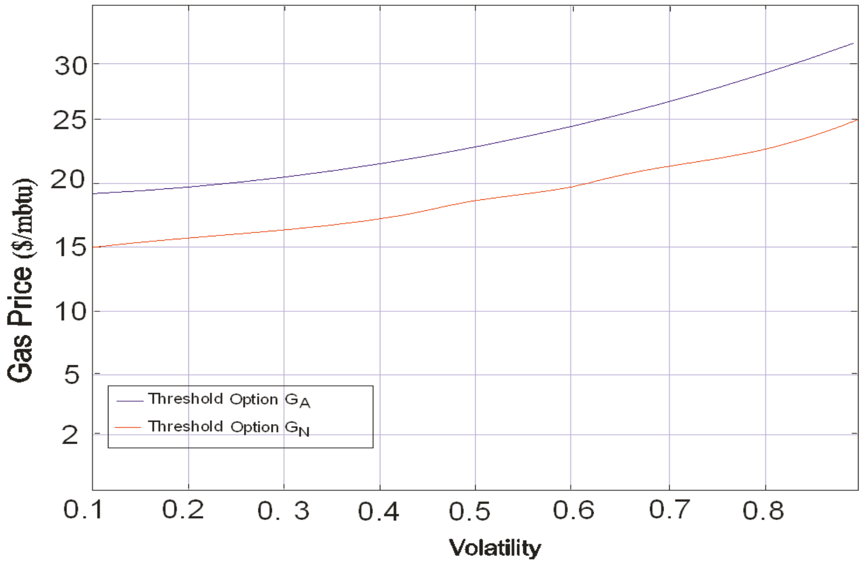

Figure 8: Threshold Price for Gas, (Source: Field work, 2018)

4.7 Investment Decision-Making

In this section, the paper presents waiting and investment regions for the gas to power plants considered in this study based on the best information estimated or available and by varying the volatility. In Figures 9, it can be seen that it more economical to invest in gas to power plant near the source when the volatility and prices of the gas is within the (G_N) region or invest in gas to power 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 gas to power plants in the Figure. For instance, for $\sigma \geq 0.681$ investment decision in gas to power 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 gas to power plant 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 gas to power plant near the source (G_N) when the price is or on the upper region (red line) or in gas to power plant away from the source (G_A) if the price increases to or above the blue line.

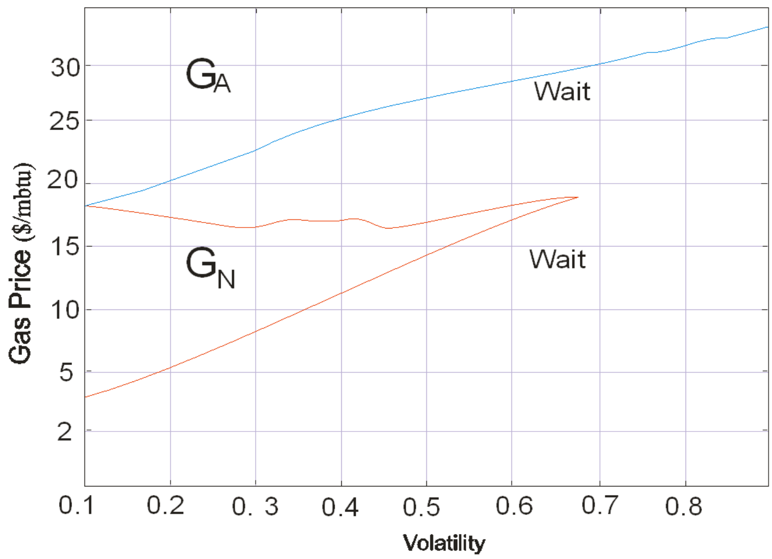

Figure 9: Investment Option, (Source: Field work, 2018)

V. Conclusion

The research studied theoptimal investment needed on gas for power plant project in Nigeria.Given the fact that high level of uncertainty arises from highly volatile price, the dynamic approach and stochastic model employed in this study enables us to make investment decisions at different points in time. 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.

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