An Economic Evaluation of Electricity Generation Options in Nigeria

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ABSTRACT

Over the past two decades, electricity prices have been highly subsidized for consumers in Nigeria. Because of this, investment in the power sector has not been competitive, leaving the economy with a capacity deficient power sector. The country loses approximately $13bn yearly on imported captive generating plants used for self-generation. This study aims at analyzing the various power generation options for Nigeria. The evaluation uses an economic cost-benefit analysis approach to estimate the cost of various options that can be explored in Nigeria, and computes the consumers' willingness to pay for electricity (taking into account the high level of self-generation presently in the country).

In this study, taking a series of hypothetical plant capacity as would be required to meet the current shortages; results show that the Nigerian economy could realize a net benefit of $4.9 billion, in present value terms, if the country embarks on hydro power investment as replacement for the current shortages. If solar PV is chosen, the economy could realize a net benefit of $21.1 billion in present value terms. If open cycle gas as replacement, the economy could benefit a net present value of $25.6 billion, and if the country goes for combined cycle gas plant, the economy could benefit $29.3 billion in net present value terms. These results are sensitized for different prices of fuel over the period of analysis covered in this study. Therefore, there is strong evidence that the country stands to benefit from any amount of electricity supplied through the national grid as a replacement for the self-generation.

Keywords: Power Generation, Nigeria, Economic Analysis

ÖZ

Nijerya'da tüketicilere sunulan elektrik enerjisi tüketim bedelleri özelikkle son yirmi yılda oldukça sübvanse edilmiştir. Bunun sonucu olarak elektrik enerjisi piyasası rekabetçi olmayan bir yapıya bürünmüştür. Bu da ülke ekonomisinde ciddi bir elektrik enerjisi açığı yaratmaktadır. Bu açığı giderme çabaları sonucu ithal mobil üretim alternatiflerinin Nijerya ekonomisine maliyeti ise yıllık 13 milyar dolar civarındadır. Bu çalışmanın amacı Nijerya için çeşitli elektrik enerjisi üretim alternatiflerini araştırmak ve analiz etmektir. Değerlendirme için ekonomik fayda-maliyet analizi yaklaşımı kullanılarak çeşitli elektrik enerjisi üretim alternatiflerinin maliyetleri Nijerya için hesaplanmıştır. Aynı zamanda tüketicilerin mevcut üretim alternatiflerinin maliyetlerini de dikkate alarak, elektrik için ne kadar fiyat ödemeye meyilli oldukları da hesaplanmıştır.

Bu çalışmada, mevcut elektrik kıtlıklarını gidermek için bir dizi hipotetik santral kapasitesine ihtiyaç duyulduğu dikkate alınmıştır. Çalışma bulguları Nijerya'nın hidroelektrik santrallerle bu açığı gidermesi durumunda 4,9 milyar dolar kâr edeceğini ortaya koymuştur. Ülkenin güneş enerjisini mevcut durumda alternatif çözüm olarak ele alması durumunda 21,1 milyar dolar kâr edeceği hesaplanmıştır. Nijerya açık çevrim gaz tesislerini kıtlığı gidermek amacıyla kullanırsa 25,6 milyar dolar, kombine çevrim gaz santrallerini kullanırsa 29,3 milyar dolar kâr edecektir. Çalışma bulguları elde edilirken çalışma için dikkate alınan yıllardaki yakıt fiyatları da hesaba katılmıştır. Bu yüzden çalışmadaki alternatif yöntemlerden herhangi birisini kullanarak elektrik enerjisi üretmek Nijerya için büyük bir avantaj olacaktır.

Anahtar kelimeler: Enerji Üretimi, Nijerya, Ekonomik Analiz

This is dedicated to my loving father, Lekwuwa Kalu Eziyi, and my sweet mother, Ugo Lekwuwa Kalu Eziyi,

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LIST OF ABBREVIATIONS

MW	Megawatt
kWh	Kilowatt hour
PV	Photovoltaic
EITI	Extractive Industries Transparency Initiative
EPC	Engineering, Procurement, and Construction
MYTO	Multi-Year Tariff Order
PHCN	Power Holding Company of Nigeria
TCN	Transmission Company
GenCos	Generation Company
DisCos	Distribution Company

Chapter 1

INTRODUCTION

1.1 Background Study

With a population of over 160 million people, Nigeria, known as the giant of Africa, is the most populous country in Africa and the largest economy in West African Region. According to World Bank (2013), Nigeria is the biggest oil exporter in Africa, with the largest natural gas reserves in the continent and oil accounts for 95% of foreign exchange earnings and about 80% of budgetary revenues. Over the past 10 years, Nigeria has been motivated to carry out reform agenda. Nigeria was among the very first countries to implement the Extractive Industries Transparency Initiative (EITI) in order to improve the oil sector. The Nigerian EITI Act was approved in 2007, and the country became EITI compliant in 2011. Nigeria is also one of the two countries from Africa that is among the 11 Global Growth Generators.

Nigeria, oil-rich country has been hindered by period of military regime, corruption, and system mismanagement (African Economic Outlook Nigeria 2011). The government has been engaging in reforms to tackle these challenges, for instance, the Federal Government is planning to privatize the power sector which will encourage economic growth.

There has been so much pressure on government budgets resulting from declining oil revenues. The fiscal reserve balance of the country (Excess Crude Account) declined from over $9 billion in early 2013 to $5 billion by mid-2013. However, employment remains the major issue in Nigeria with an estimation of 50 million underemployed youths. Job creation will be included as an important agenda in economic strategy as stated by the government.

Nigeria's requirements to become one of the world's top 20 economies by 2020 which the country desires is by government building a globally competitive economy that is less over dependent on the oil and gas sector and focus on other sectors to create employment, reduce poverty in the country, and boost the economy towards the next decade (LightUpNigeria, 2010). There is need for growth and development of industries too by enhancing competitiveness in the country through structural reforms and investment in infrastructural development particularly in power generation, transmission, and distribution, transportation and railway, telecommunication, and agriculture etc.

Nigeria is a nation with abundant prospective for renewable energy as a solution to the present power supply deficiency, including sunlight used to produce solar power, and much bio-waste for producing biomass energy, wind for producing wind power, and river for hydropower production (National Planning Commission, 2009).

Within the last decade, Nigerian economy has witnessed accelerated growth averaged about 6.5 percent annually, compared to the almost stagnant-no growth period experienced during the military regime off the 1990s. A major disturbance to a sustainable growth trend has been identified by the Nigerian Government as electricity outage which is necessary to support the productive activities especially in the industrial and manufacturing sectors.

With an output of 2.2 million barrels per day, Nigeria is the 11th largest producer of oil in the world, and oil revenue accounts for 85% of government revenue, one-fifth of GDP and 90% of export earnings (World Bank, 2013). However, this has had just a little beneficial impact on the country’s drive towards strengthening its power sector. As of December 2012, Nigeria had about 8,664 MW of installed capacity, out of which only 4,842 MW was available to generate electricity for consumption (Energy Commission of Nigeria, 2012). With an estimated electricity demand of 11,230 MW, there is supply deficit of 6,400 MW. This implies that the electricity demand is considerably suppressed and blackouts are inevitable as part of daily life in the country. An adverse effect of this on the economy is the impact on the Gross Domestic Product, with reported losses estimated at USD 135 billion annually from its Gross Domestic Product (GDP) due to the frequent power outages (Energy Commission of Nigeria, 2012).

Only about 45 percent of Nigerians have access to electricity with just 30 percent of their electricity requirement being met by the supply from national grid. The remaining 55 percent of the population are people not served from the national grid. From period 1981 to 1999 – during the military epoch, investment activities in the power sector crumbled almost to stagnancy. In 1991, out of the 79 power plants that existed, only 19 was operating, and generating about 1,750 MW daily-averages. There was no new power infrastructure project implemented in the country for over a decade, with over independence on the existing ones. As a result, the economic life of the existing power infrastructures degraded faster than expected.

Electricity subsidies are attempted by the government by ascribing tariffs that are too low to cover the cost of electricity production. To some length, state utility businesses are refunded for as part of the lump sum they are paid to cover all their activities. To another extent, the subsidy is talked by under-charging the electrical sector for the cost of natural gas. This method was pursued in 2008 by a 15-year roadmap in the direction of cost-reflective tariffs, called the multi-year tariff order (MYTO).

The first two stages, 2008–2011 and 2012–2017, are conceived to hold buyer charges somewhat reduced, though still influencing cost rises in a gradual step (Tallapragada, 2009).The last regime is proposed to supply the essential inducements for power manufacturers and investors to function and sustain electrical power infrastructure. Regardless of its aim to confirm that tariffs cover all charges, the scheme still envisages the use of some subsidies to sustain a sustenance tariff for low-income buyers and a scheme to defend buyers contrary to price surprises (the costs of fast hikes in tariffs) (Federal Republic of Nigeria, 2005).

Despite previous aims to end all electricity subsidies by 2012 (LightUpNigeria, 2010), cross-subsidies have not been operationalized because tariffs stay too low. Instead, a share of ₦110 billion ($0.68 billion) has been broadcast lately by the government under the MYTO II. In the current situation of low generation, power can be dispatched in an open and transparent manner as a subsidy for electrical power utilization for the next two years (consumers amounting to ₦60 billion (us$0.37 billion) in 2012 and ₦50 billion (us$0.31 billion) for 2013 (Center for Public Policy Alternatives, 2012).

As a response to the deteriorating situation of electricity power supply in the country, in 2004 Nigerian Government proposed a number of sector reforms which aimed to improve the power generating capacity in Nigeria. These reforms were targeted at:

(a) Unbundling, inter alia enactment of enabling legislation, the monolithic National Electric Power Authority (NEPA, the public utility as at then), establish an independent regulator to oversee the activities in the sector.
(b) Increasing power generating capacity from the existing 4,000 MW in 2012 to above 35,000 MW by 2020, through aggressive rehabilitation of existing plants and promotion of private investments in the sector to encourage the building of new plants.
(c) The government also targeted improving the transmission system, through the rehabilitation of existing network and adding new transmission lines to support the easy evacuation of electricity that would be generated from expected new plants.
(d) In addition, it aimed at providing a more efficient distribution system to minimize the huge losses experience during distribution which as at 1999 was about 18 percent. Also rural electrification program was initiated.

Prior to this period, investment in the power sector was almost stagnated. Most of the existing facilities before then were those that were provided in the years following the oil price shocks of the 1970s. Through the 1980s and early 90s there were no major investment in the power sector. This had resulted in the power sector crisis of the mid-1990s.

Although the sector in recent times has received much attention from the Government, little had been done to change the poor power situation in the country, the transmission and distribution networks are so poorly maintained and inefficiently operated thereby making it difficult to move power from generation sites to consumption points.

The strategic objective for the power sector - as stated in the Country Strategic Plan (Roadmap for Power Sector Reform, 2010), is to ensure that the sector is able to efficiently deliver sustainable, adequate, quality, reliable and affordable power in a liberalized electricity market. It is expected that the power sector will be private sector driven with the Nigerian government providing the institutional support, and legal framework that will make private partners in the sector comfortable business environment.

According to National Planning Commission (2009), analysis of the power generation capacity required to support the Nigeria Vision20:2020 reveals that, the country will need to generate addition electricity of about 35,000MW capacity by 2020. This is based on the assumption that the country will take a low energy intensity (less than 0.4) growth path, mid-way between the energy intensity of India (0.18) and China (0.91). Therefore, the overall target for the power sector is to grow installed power generation capacity to 20,000MW by 2015 and 35,000MW capacity by 2020 (National Planning Commission, 2009).

The first phase of this strategic plan for the power sector involves a rehabilitation of all existing electricity Utility plants, and support the completion of the on-going Independent Power Project (IPP) initialized projects in the short term. In the medium term, existing IPPs will be encouraged to increase capacity to achieve the targeted 20,000 MW of electricity by 2015. It is estimated that the IPPs will generate an incremental 2000MW of electricity annually between 2011 and 2020. In the long term, other generating plants including renewable power generating plants will be added to the system to further increase power generation to 35,000MW of usable electricity by 2020.

1.2 Problems of Study

According to Federal Republic of Nigeria (2010) in Roadmap for Power Sector Reform, the country loses approximately $13bn yearly on imported captive generating plants used for self-generation. This is to the detriment of the environment, as the use of these generators not only causes noise pollution but also contribute greatly to global warming (breakthrough institute). Nigeria's energy crisis is further compounded by the lack of enabling environment for private investors to embark on investments due to low and regulated prices, corruption, lack of transparency, inflation and high interest borrowing rates.

Generation: Inadequate funding for investment in new power projects and maintenance of existing ones as well as a limited gas processing and supply infrastructure to support an efficient electricity generation system for Nigeria. Also, the country has not put adequate effort in exploring the alternative power generating technologies.

Transmission*:* High transmission losses and poor voltage stability due to poor maintenance of the existing transmission lines and lack of incremental investment to add new lines. This has contributed to a high number of power system failures.

Distribution*:* High technical and non-technical losses, low collection efficiency and a poor maintenance regime undermine performance.

Institutional*:* There is need for a cost-reflective tariff system. This cost-reflective tariff will help create a conducive and competitive environment for independent power producers. Presently in Nigeria, the current rates are too low to recover the incremental financial cost of expansion. There is a large gap between the current rates and the long-run marginal cost. Under a cost-reflective regulatory system, tariffs are set in order to recover (i) Fixed cost which includes the cost of capital, an expected equity return margin, and fixed operating and maintenance cost. (ii) Variable costs to include fueling costs, income tax liability, and variable operating and maintenance costs.

1.3 Methodology for Research

Since this research aims at economic evaluation of power generation options in Nigeria, simple algebraic modeling will be used to arrive at a levelised cost estimate per kWh of electricity for alternative power generation technologies, including the cost of self-generation. To showcase the economic cost of not providing reliable and affordable power, this thesis would rely on the current information from the power sector and then a reasonable projection of events for the near future will be made to cover period till the end of designed V20:2020.

The situation in Nigeria is a more complicated one in the sense that the willingness of consumers to pay for public electricity is not explained by what they actually pay for self-generation. A major reason for this is the reliability issue. The electricity prices have been highly subsidized in the past decade, which has caused investment in the power sector uncompetitive and leaving the economy with a capacity deficient supply of electricity. The country loses approximately $13bn yearly on imported generators which is why this study aims at analyzing various power generation options that can be explored in Nigeria. Therefore, for the purpose of this study, the economic value of electricity from national grid will be measured as the average willingness to pay for both peak and off-peak cost of electricity and also the cost of self-generation.

1.4 Organizational Structure of the Thesis

This work is structured into five sections. The starting chapter sets the background study of the energy sector in Nigeria. The chapter further identifies the major problems in the sector that this research work will make as a center focus. Objectives of the study are stated thereafter.

Chapter two provides a review of existing literatures that are related to this topic. It will provide cases of countries with success stories in their power sector. Examples of these countries include China, India, and Gabon among other countries.

The third chapter gives a general overview of energy sector reforms in Nigeria. It also gives a brief explanation of the available power technologies that the utility could consider and take advantage of to improve the current situation.

Chapter four starts with a brief description of the methodology used for this research. Same chapter will provide an economic analysis of the electricity generation in Nigeria. Using real data, this work will estimate the cost of generating electricity from various power options. Data on the supply and demand balances, provided in the country strategic plan, will be used to estimate and analyze the economic cost and value of avoided blackouts in Nigeria.

Chapter five is the concluding section. It provides policy implication of findings on the economic cost of blackout that is done in the analysis. Presently, electricity consumers are enjoying more than 50 percent subsidy on the electricity they consume. The chapter will then give a summary of our findings and conclusion.

Chapter 2

LITERATURE REVIEW

For two decades now, the Nigerian power sector have been making relentless effort to attend to the excess need of electricity in the country, with their efforts it seems to be an underlying problem for the power sector to generate, transmit, and distribute electricity to the required amount.

Reforms in the power sector have taken another dimension all over the world with the aim of paying attention to the demand and supply of electricity in order to meet the needs of its citizens and help in economic development and sustainability.

Nigerian power sector have failed to provide adequate electricity supply with its abundance of energy resources. The setback from insufficient power supply which has led to constraints to growth in the country has awakened the minds of the government to promote competition through reforms. Looking at the past records of the country, the reforms in the power sector was made in order to restructure the sector for economic growth and development by attracting foreign direct investment (FDI).

Several researches on the electricity need and the accessibility to constant power supply to encourage and promote development in the world have been carried out with results. Yuan, Zhao, Yu, and Hu (2007), adopted error correction model (ECM) to examine the casual relationship (Granger causality) between electricity use and real

GDP for China during the period of 1978-2004. It was conducted by first testing for stationarity and co integration between real GDP and energy use in China. From the estimation result, it was seen that real GDP and electricity use are co integrated for China and that only unidirectional Granger causality is running from electricity use to real GDP. Furthermore, the Hodrick-Prescott (HP) fitter was used to disintegrate movement between real GDP and electricity use, the result from the estimation showed that co integration exist not only between their movement but also the cyclical components of GDP and electricity use, which means that there might be a relationship between Granger causality and business cycle. Shiu and Lam (2004) used error-correction model to examine the causal relationship between electricity consumption and real GDP in China for the period of 1971-2000. The estimation result shows that electricity consumption and real gross domestic product (GDP) are co-integrated for China and unidirectional Granger causality runs from electricity consumption to real GDP. Hou (2009) investigates the causal relationship between energy consumption and economic growth in China applying ADF techniques, co integration, and Hsiao's Granger causality and using time series data for the period of 1953-2006, the result propose that there is a bi-directional Granger causality in China for this time period.

A research carried out by Odularu and Okonkwo (2009), for Nigeria for the period of 1970-2005 investigates the relationship between the consumption of crude oil, electricity, and coal by using co-integration technique. This shows that there is a positive relationship between the energy consumption and economic growth for the period of study. Moreover, without including coal, the lagged values of the mentioned energy components were negatively related to economic growth. Granger causality test based on vector error correction was used by Orhewere and Machame (2011) to examine the relationship between energy consumption and economic growth in

Nigeria for the period of 1970-2005. The report shows that there is a unidirectional causality from electricity consumption to GDP for both in the short-run and in the long-run. In the long-run, there is a unidirectional causality from oil consumption to GDP and for the short-run neither unidirectional nor bi-directional causality is found between oil consumption and GDP.

A study conducted by Akinlo (2008) for eleven countries in Sub-Saharan Africa used autoregressive distributed lag (ARDL) bounds test to study the relationship between energy consumption and economic growth. The result of the study shows that energy consumption is co-integrated with economic growth in Ghana, Senegal, Sudan, Cameroon, Cote d’Ivoire, Gambia, and Zimbabwe. Furthermore, the study proposes that energy consumption has a long-run positive impact on economic growth in Ghana, Kenya, Senegal, and Sudan. Granger causality test based on vector error correction model (VECM) indicates bi-directional relationship between energy consumption and economic growth for Gambia, Ghana, and Senegal. In the case of Sudan and Zimbabwe, the Granger causality test runs from economic growth to energy consumption. The case for neutrality hypothesis works for Nigeria, Kenya, Togo, Cameroon, and Cote d’Ivoire. Using the Gregory and Hansen testing approach to threshold co-integration, Esso (2010) did a research on the causality relationship and long-run relationship between energy consumption and economic growth for seven Sub-Saharan African countries during the period of 1970-2007. The research result shows that energy consumption is co-integrated with economic growth in these countries: Nigeria, South Africa, Ghana, Cameroon, and Cote d’Ivoire ; and economic growth has long-run positive impact on energy consumption before period of 1988, after 1988, the effect turns out negative in Ghana and South Africa. The causality test carried out proposes bi-directional causality between energy consumption and real

GDP in Cote d'Ivoire and unidirectional causality runs from real GDP to energy consumption for Congo and Ghana.

Some researchers have argued the issue of unemployment and power supply as the most common challenges faced by most economies hindering industrial development. Ayodele (2001) argued in his work that economic development in Nigeria depends on adequate supply of electricity. Similarly, Okafor (2008) supported this argument that major setback of Nigeria economic development is poor power generation (poor infrastructure caused by poor power generation is a challenge confronting Nigerian industrial development). In line to this, Rabiu (2009) suggests that for three decades, inaccessibility to sufficient electricity supply remains a big challenge to Nigerian economic growth and development. If this issue can be resolved, it will go a long way to reduce unemployment, boost economic growth in the country, etc. Tsani (2010), applying Toda and Yamamoto technique based on times series data examines the causal relationship between energy consumption (both aggregated and disaggregated levels) and economic growth for Greece during the period of 1960-2006, the result shows that there is a unidirectional relationship excluding consumption of energy in the transportation sector at disaggregated level. Tsani conducted another research for the period of 1971-2006 in India using time series data through the application of ARDL model and Toda and Yamamoto multivariate model. The findings indicates that there is bidirectional Granger causality between energy consumption and the emission of CO_2 in the long-run but there is a neutral relationship between energy consumption and economic growth.

Following Dasaraju and Murthy (2011), the importance of power sector, consumer utility, demand and supply of power were discussed. The study pointed out various problems in the generation, production, and distribution of power and gives recommendation to the government for the growth in India power sector which can be imbibed by Nigerian government. Attempts made by the government through reforms have not yielded much result. The study suggested that consumers who benefit from electricity use need to play their role in the exchange of the service they receive from government. The consumers should be able to have a sense of responsibility by making proper use of power and its equipment, by accounting for power used by proper and regular payment of bills. There should be a collaborative work of government and citizens to see to sufficient availability of power and no party should be neglected in this struggle of power sector improvement. The electricity Act established in India and used by all states is a device for restructuring through reforms in the power sector. The Act enforces open access to the sector and includes a plan on how to control frequency, current, line loading which is very important in this sector, and reducing risk of power failure. If this Act is properly taken into consideration could be of help to many African countries facing electricity problem, especially the case of Nigeria.

Ministry of Mines and Energy (2008), in their research notified the government of Namibia the financial and economic implications of implementing various policies on electricity supply, the challenges and the use of renewable resources as a possible solution to electricity problem in Namibia. The method used in this research is the result gotten from both technical analysis and economic analysis. An electric dispatch model was developed to solve the problem of rapid increase in the price of electricity supplied. For the economic analysis, cost benefit analysis and macroeconomics analysis were used. Study was made in eight different contexts, in accordance with the policy options of Energy White Paper of 1998. It has been found that there is a tradeoff between the various policy options. This policy helps decision makers on the consequences of different policy options. It was conducted that management measures on the demand side should be taken into account because it is cost effective. In the short run, it will reduce the impending power outages and in the long run will reduce the need for generation capacity. The generation for renewable resources is good because it will create thousands of jobs, contribute to an effective economy.

Brundtland (1987) defined sustainable development at the World Commission on Environment and Development (WCED) as “development that meets the needs of the present without compromising the needs of the future generation.” In a research conducted by Ilskog (2011), there is argument that the day to day accessibility to electricity in the developing countries is a key instrument to achieving economic progress in a country. The Ilskog study emphasizes on the economic and the social aspect of the effect of power failure based on the events that occurred in Zanzibar. The lack of maintenance plus inadequate support on existing facilities as a cause of one month blackout in 2008 and three months blackout in 2009-2010 which can influence the development of Zanzibar in a negative way. Regarding to the issue of power outages, power failure inflict a notable cost on trade and firms, and small scale medium enterprises are mostly affected by this power failures. This study is fortified by the research carried on by Steinbuks and Foster (2009), saying that the cost of self-generation are around three times as high as purchasing electricity from the public grid. Self- generation of electricity helps firms to still be in business during the period of power outages. Steinbuks and Foster went ahead to argue that through self-generation, the large amount of incorporated firms will still be in business and will be protected from the influence of erratic power supply. For the informal firms however, they are the main prey of inconsistent power supplies although the evidence is in a limited survey.

2.1 Importance of Electricity on National Income

Irrespective of the size of a country, economic development of the country depends on the growth of the power sector. Power is the key to economic growth in so many sectors in Nigeria (agricultural sector, industrial sector, mining sector, household and commercial, etc.). How progressive and successful Nigeria handles its power sector, determines its economic development and growth (which implies uninterrupted and adequate power supply). Depending on the structure of power consumption, electricity has a great impact on economic development. For instance, comparing a country where power demand mainly comes from individual consumption versus a situation where power demand mainly comes from industries (processing, manufacturing, mining, etc.), and there is supply deficit; it is expected that a shore up in electricity generation in the country will have bigger economic impact for countries with higher industrial power consumption. Industries tend to have higher multiplier effect from empirical studies because the cost of production is reduced, output potentially increases, more labor can be employed, and income per capita increases.

Using ARDL approach, Dantama, Abdullahi, and Inuwa (2012) investigated the relationship between economic growth and energy consumption for period of 1980-2010 for Nigeria. In their findings, it shows that electricity consumption have positive impact on economic growth in the long run. Using regression techniques, Ebohon (1996), studied the causal relationship between energy consumption and economic growth in Nigeria and Tanzania, and the result read the same for both countries. The result shows that there is a concurrent causal relationship between energy consumption and economic growth.

A study carried out in Pakistan by Javid, Javid, and Awan (2013), for the period of 1971-2008, tested the long run relationship between real GDP per capita and electricity consumption. The finding shows that there is a unidirectional causality from electricity consumption to real GDP per capita and a long run relationship between the two. An empirical study carried out for Pakistan shows that electricity is a limiting factor to economic growth, shocks to electricity supply will have a negative impact on economic growth. Only if sufficient power supply is being adopted as a growth policy, it will help improve and grow the economy which will result into more employment opportunities for the country.

In a study for Turkey by Azgun (2011), using structural VAR model for Turkish economy, he examined the impact of the aggregate electricity consumption and the various categories of electricity consumption (industrial energy consumption, commercial energy consumption, residential energy consumption, government offices electricity consumption, and street illuminations) on real GDP for the period between 1968 and 2008. The result shows that aggregate electricity consumption and the various components of electricity consumption has no effect or impact on real gross domestic product (GDP), while real GDP has impact on both electricity consumption and various categories of electricity consumption. The most important result of this research shows that the relationship between industrial electricity consumption and economic growth is very weak which means that the use of imported energy like coal, petroleum, and natural gas rather than the use of electrical energy produced by all the national resources is increasing relatively in the industrial production.

Jumbe (2004), amongst others, stated that if there is causal relationship from energy consumption to GDP, that means the economy depends on energy and any shortage of energy will affect the country's economic growth negatively. Compared to Masih and Masih (1997), if there is causal relationship from GDP to energy consumption, this means that the economy does not depend on energy and any energy conservation policy implemented in that economy will not have any adverse effect on economic growth of that country. But in the case where there is no causal relationship in either direction by Jumbe (2004), this implies that energy consumption is not correlated with GDP.

For developing countries, electricity consumption is expected to have positive impact on real GDP; however, this may not be the case for developed countries (see findings from Chima and Freed, 2005). The developed countries are already operating at their steady state of electricity so any additional supply of electricity will result to a declining marginal utility, and for the developing countries that are faced with insufficient electricity, any addition to the supply of electricity will be a much higher marginal value. This is the reason why electricity consumption is expected to have a positive impact on real GDP in developing countries than developed countries.

Despite the fact that rural areas form the foundation for any country's economic development, such community is not attractive for habitation. Economic development of any country cannot be attained without developing the rural area. Making efforts to develop the rural areas means increasing people's living standard, improving health sector, increasing life expectancy which will boost rural development and overall economic development. Sufficient supply of electricity in the rural areas will help to minimize unemployment seen amongst inhabitants of rural community. This is mostly good for the women who engage themselves with domestic production, agricultural activities for means of income and survival.

Since the liberalization of the power sector in many countries, there has been focus on electricity supply as an important objective. Increase in the demand for electricity in developing countries is as a result of higher living standards and the rise in economic activity. A two-minute power outage in Taiwan in May 1997 cost Formosa Plastics and other petro chemical producers over $11 million. The event also cost China's Petroleum Corp $2.6-11 million. The power outage that occurred in Taiwan at the end of July, 1999 which was a huge cost to the entire chip manufacturing industry cost the industry $62 million.

Wintrob (1995) noted that a 15 minute power outage that happened in Vancouver, British Columbia, caused a shutdown in the Vancouver stock exchange market for a whole day. The stock exchange lost revenue that was about CAN $30 million and also lost the commissions for its member firms that accounted to millions.

Chapter 3

OVERVIEW OF ENERGY SECTOR REFORMS IN NIGERIA

3.1 The Nigerian Power System

Nigeria is one of the largest electricity generating plant importer in the world due to the problem of electricity shortage across the federation. The issue of lack of maintenance of existing power plants has plagued the energy sector, leaving the country in a state of energy poverty. Several solutions have already been proposed and some implemented to help Nigeria move from poverty to abundance. The Federal Government has plans to minimize the importation of electricity generator plants that emits hazardous gas to the environment by improving the power sector.

Nigeria is a country with over 160 million population and according to report from The Bureau of Public Enterprise (BPE) over 100 million population do not have access to electricity supply. The power sector is a capital intensive sector, meaning it requires machinery (huge amount of fund) for its generation, transmission, and distribution. Nigeria is a country with abundance of energy resources (natural gas) proven with 176 trillion cubic feet of natural gas in 2005, over 185 trillion cubic feet in 2008 and 5.292 trillion cu m in January 2011, and 8,664 megawatts (MW) of installed electric generating capacity by December 2012. Nigeria has the largest gas deposit in Africa, ranks 9th in the world, and accounting for 1.75% world's gas reserves (World Bank, 2013).

Electricity Industry which is linked to accessibility and employment of energy power is one of the major sectors that contribute to economic sustainability and development of any nation. Energy facilitates all human endeavors, and is used for numerous activities such as industrial, commercial, and household purposes, and it is essential for good quality of life. Nigeria is a country endowed with primary energy resources, namely crude oil, natural gas, coal, tar sand, biomass, biogas, solar, geothermal, and high potential for hydro-electricity etc. (Okoro and Madueme, 2004), and this country suffers from electricity deficiency. This has led the Federal Government to embark on reforms to solve this energy puzzle although no much benefit has been seen.

The deficiency of electricity infrastructure had been identified as one of the constraints to growth in Nigerian economy. The power supply industry suffers from perpetual power outages with a current average generation of 4,842MW against an estimated suppressed demand of over 11,230MW (Energy Commission of Nigeria, 2012) resulting in the immense importation of power generating sets from all over the world. Self-generation of electricity is at a significant cost to both citizens and economy. The cost of self-generation of electricity is about ₦54 per KWh compared to the present average regulated tariff of ₦22 per KWh which is subsidized for certain categories of the customer base. The table 1 below shows historical supply of electricity through the national grid.

Table 1. Historical trend in electricity supply from national grid

	1980	1990	2000	2005	2006	2007	2008	2009	2010
Power Supply (GWh)									
Domestic Supply									
Hydroelectric	2,782	4,389	5,626	7,768	6,263	6,227	5,721	4,529	4,755
Oil	1,269	1,844	221	2,425	1,987	1,976	1,858	2,531	2,658
Gas	3,119	7,216	8,800	13,347	14,860	14,775	13,532	12,717	13,353
Coal		13							
Sub-total	7,169	13,463	14,727	23,539	23,110	22,978	21,110	19,777	20,766
Imports	-	-	-	-	-	-	-	-	-
Total Supply	7,169	13,463	14,727	23,539	23,110	22,978	21,110	19,777	20,766
System Losses	2,172	5,172	5,618	5,580	7,181	2,650	1,989	1,160	1,218
Available Supply	4,997	8,291	9,109	17,959	15,929	20,328	19,121	18,617	19,548
Power Supply (% of total supply)									
Domestic Supply									
Hydroelectric	38.8	32.6	38.2	33	27.1	27.1	27.1	22.9	20.9
Oil	17.7	13.7	1.5	10.3	8.6	8.6	8.8	12.8	13.3
Gas	43.5	53.6	60.3	56.7	64.3	64.3	64.1	64.3	65.8
Coal	-	0.1	-	-	-	-	-	-	-
Sub-total	100	100	100	100	100	100	100	100	100

Source: World Bank development indicators database 2012.

An average Nigerian gets approximately 226KWh per year of electricity supply which is very low and significantly contributes to the underdevelopment of Nigerian economy. The high cost of self-generation of electricity has made Nigerian domestic manufactured goods less or uncompetitive compared to similar goods produced or manufactured abroad. For Nigeria to meet the government's target of 40,000MW by 2020, the country's generating capacity needs to grow by 4.3GW yearly. This level of investment can be achieved by the government with the help of private sector's participation. The private sector would be required to invest at least $4 billion per annum in the power generating capacity for 10 years.

3.2 Electricity Reforms in Nigeria

3.2.1 The Pre-Independence Era

Public Works Department was the first body to build generation plant with a 20MW at Ijora near Lagos in 1896, fifteen years after the launch of Britain's commercial electric power activities. In 1929, another electric company, The Nigerian Electricity Supply Company (NESCO), privately owned commenced operation at Kurra near Jos with the construction of a hydroelectric power station. There was no government body to manage nationwide electricity generation, transmission, and distribution, so in 1950, Energy Corporation of Nigeria (ECN) was initiated as a government body to regulate and control the private generation plants built in different towns in Nigeria. Noticing the deficiency in the installed electric capacity of existing power plants, the ECN commenced a study on the River Niger and its hydroelectric potentials to supply electricity in huge amount and cheaper. This led the Federal Government to license the Netherlands Engineering Consultants (NEDECO) in 1953 to carry out a survey on hydro electrical potentials of River Niger and River Benue. Another company known as Balfour Beatty Company Ltd was licensed by Electricity Corporation of Nigeria (ECN) to conduct same study on River Niger. A combined report was published by NEDECO and Balfour Beauty in 1961 concerning this survey. The report proposed that Kainji dam should be built. In an attempt to enhance the existing power capacity in Nigeria, the Ijora B hydroelectric power station was built with a capacity of 2MW in 1956, in 1961 it was increased to 30MW and another 30MW in 1962, and finally in 1966, 36.5MW was added.

3.2.2 The Post-Independence Era

In 1962, the Niger Dam Authority (NDA) was established by the government to manage dams in Nigeria. The idea was for the Niger River to be developed which was were the Kainji Dam originated from and began operation in 1968. In 1972, the Federal Government of Nigeria merged NDA and ECN to form The National Electric Power Authority (NEPA) responsible for generation, transmission, distribution, and the trading of electricity to all parts of Nigeria starting with only four major power stations namely: Ijora near Lagos, Delta, Port Harcourt Afam Thermal Station, and Kainji Hydro Power Station. The main source of electricity generation for National Electric Power Authority (NEPA) was from hydro and thermal power.

Federal Government after the adoption of democracy in 1999 has developed a number of research and interventions many of which until presently have failed. Since 1999, the electricity supply industry has experienced several changes. The Nigerian Electricity Supply Industry has grown from a vertically united utility with governmental control, into an unbundled system consisting of 18 separate companies, out of which 15 of these companies are being privatized, 2 are being licensed, and 1 has been assigned to an administrative worker. The authorized framework has also been setup to back the private sector participation in the industry. Despite the numerous limitations encountered by National Electric Power Authority (NEPA), the power authority played an important and active role in the country's economic development and sustainability. National Electric Power Authority has been in charge of generation, transmission, and distribution of electricity supply in Nigeria not until it was privatized as The Power Holding Company of Nigeria (PHCN) by the Federal government and the management and finance of the operations of NEPA was transferred to The Power Holding Company of Nigeria (PHCN).

In view to solve the problem of low quality supply of electricity in Nigeria, the Federal government transferred the management and finance of NEPA to the private sector to promote stable electricity supply. The Federal Government of Nigeria integrated NEPA into one transmission company (TCN) managed by a private operator but still owned by government, six generation companies (GenCOs) which opens way for privatization, and eleven distribution companies (DisCOs) which also opens way for privatization. A Market Operation unit has been taken out from the Transmission System Operator, to manage the trade of electric power from private and public generation companies to distribution companies and other big domestic and international companies. This unit's operation is constrained by the market instructions that have been launched by the supervisory board. A system's operations unit (SO) has been established to report regularly the generated and distributed electricity in the country (NEPA, 1995).

3.3 Legal Framework

National Energy Policy was sanctioned by the Federal Government through the Federal Executive Council in 2003. Energy Commission of Nigeria established this policy in view for sustainable development supply and usage of energy resources in Nigeria and for the utilization of such resources in international trade. National Electric Power Policy (NEPP), was approved in March 2001 by the Federal Government from the fact that electricity supply has impeded the country's development. A key feature of this policy includes the following:

- To boost and attract private investment home and abroad in the power sector.
- To develop a translucent and active guiding structure for the electricity industry.
- By improving and increasing original generating capacity in the power industry.
- Promote competition in the industry by complete liberalization of the energy market in order to meet up with the growing needs of its citizens on access to sufficient electricity supply.
- To assess and appraise power sector laws in conformism with familiarizing the private sector's operation and competition in the electricity market.

National Integrated Power Project (NIPP), in the year 2004 was initiated by the Federal Government to boost the country's generating capacity. Electric Power Sector Reform Act was introduced because of inadequate electricity supply to meet the needs of Nigerians. This prompted the Federal Government to enact the Electricity Power Sector Reform Act (EPSRA) in March 11, 2005 to enable private companies to take part in electricity generation, transmission, and distribution. This act conforms to the features of National Electric Power Policy (NEPP). This Act brought to an end by the Federal Government monopoly in the power sector, thus opening it up to private sector investment, and organization of electricity generation, transmission, and distribution.

A key feature of this Act includes:

- This act provides for the unbundling of NEPA and establishment of Power Holding Company of Nigeria.
- Set the creation of the 18 successor companies with the motive to take over liabilities and extra duties that are not transferrable with ease from Power Holding Company of Nigeria to successor companies.
- Prescribes the transfer of NEPA's staffs to the PHCN and sees to the upkeep of transferred staffs with their pensions.
- Establishment of Nigerian Electricity Regulatory Commission (NERC). NERC plays a serious part by distributing licenses and regulating the electricity sector. It offers assurance that operational rules will be monitored, followed, and imposed. NERC has spurred the investment environment through the endorsement of the Multi-Year Tariff Order (MYTO), which became effective in June 1, 2012. The tariff order gets the electricity tariff to cost-reflective stages (keeping moderate, monopolistic, gains through over-calculated tariffs by grid operatives as well as

unnecessary tariff-reductions which might risk the maintenance of the distribution network, and quality of customer service), therefore making it possible for private sector investors to invest in the industry with justifiable yield on investment. This act alone has been accountable for attracting many investors into the sector and the granting of licenses to over 40 companies to date. The NERC has also developed network and regulatory standards for instance the grid code, the metering code, etc. The Federal government of Nigeria has re-formed, strengthened, and reinforced the leadership of NERC.

- Provides a basis for competition in the electricity market.
- Recommends a structure for tariffs, principle implementation, and customer's safety.
- Forms Electricity Consumer Assistance Support.
- Creates the Rural Electrification Agency (REA), the Rural Electrification Fund (REF), and the National Electricity Liability Management Company (NELMCO).

In 2008, the government planned to increase the power supply industry's capacity from 6,000MW to 10,000MW by the end of 2009 and 2010 respectively but this plan has not been fully implemented. So the government commenced a key investment enterprise in the power sector, involving the construction of 10 power generating stations, over 100 transmission lines, and over 200 distribution projects, known as the National Integrated Power Project. The Federal government has also involved the private investors to invest and develop additional power generation capacities to see to the implementation of power sector reform.

3.4 Power Sector Structural Reforms

President Goodluck Jonathan stated in the power sector roadmap that the progress, development, growth, and security of any country are disparagingly reliant upon the effective and adequate supply of electricity by the electricity supply industry. The Power Sector Reform Roadmap defined the serious areas necessary to eliminate difficulties to private sector investment as the following:

The establishment of a suitable pricing system: In order for the sector to be fiscally feasible all through the assessment chain, the final consumer's tariff must be cost-reflective. Subsequently, the Nigerian Electricity Regulatory Commission embarked on a major review of the tariff regime and on June 1, 2012 the national tariff was replaced using new cost reflective tariff on final-users, widely known as MYTO. In the direction of protecting against amount knock-back and to make sure that low income users were provided with the support tariff, a favoring block tariff was announced, where the amount waged for power varies by certain level of electricity usage. The MYTO offers a stable price track into the future .The MYTO is responsible for a 15 years tariff track for the electricity industry, with slight reviews each year taking note of changes in a limited number of factors (according to varying rates of inflation, the cost of input fuel for electricity generation (primarily gas and exchange rate fluctuation) and major reviews every 5 years, when all of the inputs are revised with stakeholders (the major 5 yearly tariff review will consider each of the input assumptions for the tariff model in order to update them to appropriate current values). Major reviews will be undertaken at less than 5 years interims if industry members can prove to NERC that industry factors have changed from those used in the MYTO to such an extent that a review is required urgently to maintain industry viability.

- **The institution of a wholesale buyer**: Conformism to the Electricity Power Sector Reform Act (EPSR), the power sector needs to move to a higher level, such that a bulk purchaser in government's possession embarks on the administration and larger part of trading in place of the distribution companies until the industry develops the power structures vital for effective joint contract. The Nigerian Bulk Electricity Trading Company PLC at the moment is merged with hope of being capable to assign suitable power purchase contracts with beneficiary generating companies and present sovereign power plant producers (IPPs) and also prospective competitors into the electricity market.
- **The organization of FGN credit improvement**: Towards going into a power purchase agreement (PPA), independent power producers (IPPs) will demand for a creditworthy business partner at the other end. Though, it could last four years before some of the distribution companies grow into sustainable and creditworthy bodies. To hasten private sector investments in electricity generation, the Ministry of Finance will through a set of options over which the Federal Government may possibly make available credit boost to the bulk purchaser that will enter into power purchase contract. Few years will be needed for IPP projects to be active and successful.
- **Forming an efficient and motivated workforce**: The fiscal risks posed by the government's inability to reach a contract with the labor unions on the clearance of due debts (of salaries, pensions, and other benefits) and on compensation has hither the progress of the reform to prospective purchasers of successor companies. Knowing that the authentic application of the reforms will result into an abundant and more active division with members loving substantial profits, consumers loving improved package and, essentially, staffs enjoying better service

environments; the Federal Government lately has involved in dynamic negotiation with the front-runners of the labor union. The discussion is in progress and productive. Certainly, the government's prospect is that a broad agreement on all due issues will have been resolved by the end of the year.

- **Operationalizing the Nigerian Electricity Liability Management Company (NELMCO):** NELMCO was set up as a government main legal entity to undertake and supervise existing assets, liabilities and other responsibilities that could not be simply reassigned from PHCN to any of the Beneficiary Companies. The Federal Government is working very hard to make sure that NELMCO is made completely operative without more delay and whichever doubts with regard to the transfer of outstanding liabilities are detached. In the process, the Federal Government will also make open and clear the complementary roles to the investors to be played (in the organization of legacy liabilities) of both NELMCO and the bulk purchaser.
- **Contracting out the management of the Transmission Company of Nigeria (TCN):** Shareholders will be unenthusiastic to make comprehensive investments in the power sector not until they are guaranteed that appropriate investments halfway through the industry will likewise happen. If so, the organization of TCN will be signed to a company from Canada that has the basic project capacity to accomplish the Nigerian Grid. The integration process for this is going on.
- **Expounding and Reinforcing the Licensing Regime**: Investing in electricity industry enfolds high fixed costs for a long period of time and stakeholders anticipates that the lifespan of the license will match with the time needed to recover their investments, usually 20-25 years' time. Nonetheless, the EPSR Act issues licenses that cannot exceed 10 years interval even though NERC might prolong the validity of the licenses for additional 5 years. To be responsible for

investors comfort, devices are being industrialized that will make possible the renewal of their license as long as they meet essential conditions.

- **Solidifying the Nigerian Electricity Regulatory Commission:** NERC takes a crucial role by handing out operational licenses and modifying the sector. Notably, it offers assurance that a smooth ground will be kept and rules and regulations will be obeyed and imposed. In acknowledgement, the Federal Government takes pivotal steps in strengthening government's position in the NERC by inaugurating reliable governance.

3.5 Status of Power Sector

The Federal Ministry of Power (FMP), controlled by the Minister of Power, is in charge of complete management of the power sector. As provided for in the EPSR Act, the public establishments that are dynamic in the power sector are as follows:

- The Nigeria Electricity Regulatory Commission gives license to private investors, sets tariff for wholesale, and pays attention to stakeholders and make effort to resolves stakeholders problem.
- The Rural Electrification Agency is established to make electricity available to rural areas but might not be attractive to private investors. The REA puts into effect electrification policy and handles their fund.
- The Nigeria Electricity Liability Management Company Limited accepts the existing legal responsibility of NEPA that is not transmittable with private shareholders therefore defusing economic risks of the investors and new managers of the companies. This includes the clearance of amount outstanding of salaries, pensions and other benefits of existing sector staffs.
- The National Power Training Institute of Nigeria (NAPTIN) established to increase power sector's supply capacity.

- The Nigerian Bulk Electricity Trading Plc. (NBET) (also known as "the Bulk Trader") has been established to discourse the concerns of shareholders in generation companies about the wealth of the distribution companies. It will procure electricity in place of TCN and the distribution companies pending when they launch a track record of paying for the power they provide to buyers or users through effective metering, billing and collection.

3.6 Energy sources and existing power generation

Nigeria is very rich in natural resources to meet up her electricity needs and can as well sell to other African countries. Current electricity deficiency facing the country cannot be the problem of resource limitations, but mainly as a result of the absence of extensive development and underinvestment in the power sector.

3.6.1 Renewable Energy

From the electricity generation projection result, it is seen that electricity demand is greater than electricity supply (Energy Commission of Nigeria, 2003). It will be good for Nigeria to invest in renewable energy resource investment. Renewable energy talks about the utilization of biomass, wind, solar energy, and hydro in order to generate electricity and has the capacity to provide jobs to citizens. The demand for renewable energy in the country is as a result of increase in technologies in industrialized zones. The Federal executive council (FEC) in 2003 approved National Energy Policy in Nigeria and the policy mentioned of energy conversation and efficiency and most especially renewable energy are the viable sources mentioned in the policy.

Nigeria is endowed with enormous amount of renewable energy resources and well distributed all over the country. These sources are:

i)Hydro power source: The country is blessed with rivers like River Niger and Benue which offers a large scale of renewable source of energy, small rivers that offers small scale hydropower production, few falls also responsible for hydropower production in the country, and dams such as Kainji and Shiroro dams responsible for huge amount of hydropower reserve. All these are responsible for hydroelectric energy.

Advantage: This form of energy production does not pollute the air so much, less risky to the environment and the water is not damaged because it can be used for other purposes.

Limitations: When the dam is built at the initial stage, there is flood which displaces people and animals in that region.

ii) Solar Energy: Energy that comes from the sun is known as solar energy and can be attracted through the solar panels. Nigeria is found in a sunshine region, and solar radiation is well distributed in the country.

Advantage: This form of energy produces no form of harm to the environment. All over the world, the geographical projection tells almost when the sun will rise and set daily and the quantity of sunlight a particular region can receive a day. There is no monopoly when it comes to sunlight. It is free for all once you can acquire the solar panels at the roof of the house.

Limitations: This form of energy is very expensive although it looks very good. When the sun goes down, the Solar PV panels stop producing electricity which means we get electricity from another source if needed at that particular time. The assurance that the sun will shine bright each day without the cloud covering the sky is not there. The sun does not shine 24 hours daily

iii) Wind Power: When a strong wind turns the turbine, wind power is produced such as electricity by means of wind turbine, mechanical power by means of wind mills and some others are useful forms of wind energy.

Advantage: This form of energy is less harmful to environment and seen in many parts of the country and world.

Limitations: This form of energy is costly and needs high level of maintenance.

There is a shift in policy reform process in Kenya which is in line with privatization and transfer movement in the power sectors and other sectors to attract both foreign and domestic investment, and encourage competition in the sector. In Nigeria, while struggles are made to open up the power sector to private sectors, the government body kept to regulate and monitor this process appeared incompetent to achieve this desired goal compared to the case of Kenya. For example in Kenya, the implementation and introduction of renewable energy resource technologies is the country's prime concern on national development policy program. This approach is not considered in Nigeria because the government seems to be concerned with reinstating old regime under the regulatory framework provided by The Nigeria Electricity Regulatory Commission (NERC). The availability of renewable energy resources is very important in the supply of inexpensive, reasonable, and steady power supply for industrial sector's development, generation of jobs for citizens, poverty eradication in Nigeria. Renewable energy resource options have its challenges but the good side outweighs its negative side if adopted as stated by Okoro and Madueme (2004). If this policy option is seriously undertaken by Nigerian government, it will help generate sufficient energy demanded and at same time promote a business friendly environment that will harness economic development and growth.

3.7 Cost of Self-generation

PHCN can become an exporter of electricity when in excess which will be good for the country and will attract foreign exchange. But in the case when PHCN faces shortage, there is only two ways out. It is either PHCN imports electricity but if they decide not to import, the sector can leave consumers on their own to self-generate electricity themselves. West Africa as a whole faces power deficiency and so the option of importing is not possible for Nigeria. The only option left for the country is to allow self-generation which is six times more expensive than cost of generation by the utility/IPPs. Since import is not available and self-generation is more expensive, it is expected that the country puts effort in producing power other than the self-generation option. The cost of generation by utility/IPPs will vary between 6 cent (which is the cost of hydropower generation in Nigeria currently) and 30 cent (which is the cost of solar PV power generation in the North-Eastern part of Nigeria). Considering that the cost of self-generation in Nigeria is six times more expensive than cost of generation by the utility/IPP's, most industries that have their major cost attributed to electricity consumption avoiding the cost of self-generation for operating their business can reduce the operating cost of business significantly, and this may be the reason why so many of the industries in Nigeria (Dunlop Nigeria PLC, Michelin etc.) moved their production and manufacturing plants to neighboring country, where the problem of electricity is less severe, leaving Nigeria to be a marketing ground for their products.

Chapter 4

METHODOLOGY AND ANALYSIS OF POWER GENERATION

4.1 Data

This chapter covers both the methodological approach to this study and data analysis. Data used in this section are sourced from various databases including the World Bank databank, EIA reports, PHCN annual reports, and other secondary data platforms for period 1979-2012.

Prior to this analysis, many studies have used time series models, structural VAR, ARDL, OLS regression to study the importance of electric generation with so much emphasis on the impact of electricity consumption on economic growth. This study takes into consideration previous studies as analyzed in chapter two to establish the relevance and aims at the economic evaluation of power generation options in Nigeria.

4.2 Methodological Approach

For Nigerian government to achieve sustainable level of economic growth, generating sufficient energy to meet the consumers need is an important and effective instrument to achieve this growth. Given the scarcity of power supply in the country, electric power industry should be the top priority of every administration in the country to meet the power demand of the country.

The government of Nigeria is unable to invest to increase the power generation due to inefficiency of the public sector to generate more power resulting to people now resorting to self-generation. The question now is: a) what is the willingness to pay for electricity utility? b) what is the willingness to pay for self-generation? This is what this analysis will be dealing with.

To avoid complexities in our methodological approach, this analysis will concentrate only on the 45 percent of Nigerians that are presently connected to the national grid. Making proxies for the population that are not serves from the national grid can make results from this analysis very unreliable because it is difficult to get the basic pattern of the electricity consumption by Nigerian population not served. In other words, the starting point of this analysis follows that the actual demand for electricity is 11,230MW as at December 2012 and actual installed capacity is 8,664MW out of which only 4,842MW was available to meet peak demand.

Consumers' willingness to pay for electricity is significantly higher than what they are actually paying for utility supply. This difference can be attributed to the level of reliability of utility supply. In a two scenario the cost of both self-generation and utility supply is reduced, people will rely so much on self-generation because of the unavailability and unreliability of electricity from utility.

4.3 Choice of Technologies

The essence of investment in electricity generation is the fact that the country lacks enough and efficient power plant which has resulted into inability to meet the electricity demand of the consumers and high cost of generation. Nigeria, however, self-generation are mostly used as backup generators which could be avoided if essential investment is made in the sector by the government. Therefore, for this analysis, the benefit side would be the avoided cost of self-generation and the cost side would vary depending on alternative.

Hydro Power Resources: This is one of the main sources of generating power in Nigeria. About 30% of the country's generation capacity comes from hydro power generation. Initially, the capital cost is high, but when in use provides a cheaper electricity use and clean electricity. Nigeria currently has three functional hydropower plants located at Jebba with installed capacity of 640MW, Kainji with 760MW, Shiroro with 600MW. The overall hydro power exploitable potential in Nigeria is in excess of 11,000MW while the small and mini hydropower potential is estimated at 734 MW. About eight small hydro power stations have been installed by both private company and government of Nigeria with an aggregate capacity of 37MW. Only about 14% of Nigeria's hydropower potential has been exploited.

Solar Energy: The annual average of solar radiation varies from about 3.5kWh/m^2-day in the coastal regions, rising to a maximum of 7.0kWh/m^2-day in the north-eastern regions; which gives an average annual solar energy intensity of 1934.5kWh/m^2-yr. An average of 6,372,613PJ/year of solar energy falls on Nigeria land area over the course of a year. With the estimated production capacity of 50GW of cell per annum, demand for solar energy is only 26-35GW as for 2012.

Gas Resources: Nigeria is abundant in gas resources with natural has reserve of over 185 trillion cubic feet in 2008 and as of January 2011, gas resources accounted for 5,292 trillion cu m. Nigeria is yet to exploit her large natural gas reserves. About 1,200 million standard cubic feet of gas per day (mscf/day) is needed to meet the government's short-term goals to increase electricity production from gas-fired plants. The present processing potential for gas in Nigeria is 800mscf/day.

Table 2. List of existing power stations

S/No	Name of Generation Company	Operating Years	Location	Installed Capacity (MW)	Available Capacity (MW)	Electricity Generation GWh
	HYDROPOWER					
1	KAINJI HYDROELECTRIC	41	Kainji, Niger State	760	480	2506
2	JEBBA HYDROELECTRIC	24	Jebba, Niger State	540	450	2677
3	SHIRORO HYDROELECTRIC	20	Shiroro, Niger	600	450	2282
	Total Hydro			**1,900**	**1,380**	**7,465**
	THERMAL PLANTS					
1	EGBIN POWER	23	Egbin, Lagos	1320	1100	3384
2	GEREGU POWER	2	Geregu, Kogi	414	276	379
3	OMOTOSHO POWER	2	Omotosho, Ondo	304	76	383
4	OLORUNSOGO POWER	1	Olorunsogo, Ogun	304	76	104
5	DELTA POWER	43	Ughelli, Delta	900	300	1592
6	SAPELE POWER	31	Sapele, Delta	1020	90	121
7	AFAM(IV-V) POWER	46	Afam, Rivers	726	60	151
8	CALABAR POWER STATION	75	Cross River	6.6	Nil	Nil
9	OJI RIVER POWER STATION	53	Oji River, Enugu	10	Nil	Nil
	Total Thermal			**5,005**	**1,978**	**6,113**
	IPPs					
1	AES POWER STATION		Egbin, Lagos	224	224	1681
2	SHELL- AFAM VI STATION		Afam, Rivers	650	650	2129
3	AGIP – OKPAI POWER		Okpai, Delta State	480	480	3079
4	ASG- IBOM POWER		Akwa Ibom	155	76	3
5	RSG- TRANS AMADI POWER		Port Harcourt,	100	24	0
6	RSG- OMOKU POWER		Omoku, Rivers	150	30	422
	Total IPPs			**1,759**	**1,484**	**7,315**
		Summary as at 2012	Installed MW	Available MW	Generation GWh	Sys. Losses
			8,664	4,842	20,893	1,160
				Required MW	Actual MW	Shortfall MW
			Peak	11230	4218	7012
			Off-Peak	8984	4218	4766

Source: Energy Commission of Nigeria, National Energy Master Plan, 2012

4.4 Economic Valuation of Alternative Electricity Generation

Every government electricity utility is to provide the end users with the following services:

a) To supply consumers with the electrical supply they demand to power their electrical appliances both domestic and industrial.

b) To always be ready and willing to supply the electrical need demanded by consumers without restrictions.

Instead of allowing individual self-generation which is 6 times the price of utility, the government decides to invest in alternative electricity supply in order to increase generation capacity to meet the excess demand of consumers. The question is:

a) What is the consumers' willingness to pay for the alternative electricity supply provided by government?

b) What is the consumers' willingness to pay for this service being rendered by the government assuming it is reliable?

c) What will be the gain or benefit the consumer receives for using this government alternative electricity supply instead of going for expensive and reliable self-generation?

It makes no sense comparing the alternative electricity supply based on capital cost because some plants incur higher capital cost with low marginal running cost while some others incur low capital cost with higher marginal running cost. For instance, the capital cost per kW for hydro is estimated at $5,288 whereas combined cycle gas turbine is estimated at $1,917. But, in terms of the marginal running cost, hydro cost almost nothing to run except for the fixed operating and maintenance cost. While the combined cycle gas turbine is expensive to run. Therefore, the comparison of this two in terms of cost efficiency can only be done by looking at the net present value over a finite horizon. The alternative that yields a higher net present value is the cost effective technology.

Though electricity consumption is desirable by most people, consumers demand is constrained by pricing, reliability of supply from utility and availability of alternative sources. In Nigeria where the current supply of electricity from utility is at subsidized price of ₦11 against average cost of around ₦22 for the system. There is no doubt that electricity from utility would provide adequate surplus to consumers especially, considering the fact that the next available source is from self-generation which cost six times as much as the utility tariff.

When there is a constant problem of power supply, a case of Nigeria, industrial users and household users might go ahead to find a way to solve this problem of power shortage without the help of the government by installing their own generators. Some businesses especially the small scale enterprises would either decide not to purchase these generators and run their businesses without electricity or some might decide to cut down on their activities that need electricity. Some firms might decide to move their factories or companies to neighboring countries that have reliable power supply.

An alternative supply of electricity other than utility during blackout period to consumers has a direct impact on consumers in terms of cost-saving and an indirect impact on the economy which is usually referred to as deterred demand. If there is a complete elimination of power shortages in a state, it will be easier to measure the direct benefits of power supply to consumers by their willingness to pay for the power they get from utility.

A consumer's maximum willingness to pay can be measured by the cost of available alternative power supply for the consumer which most times is self-generation with fuel or diesel generator. According to Lim and Jenkins (2000), for self-generation to be rated the same as the power supply obtained from utility in terms of reliability, the self-generation must be supported by another generator. This means that consumer's maximum willingness to pay for power shortage (P^{max}) that is similar to the power reliability obtained from utility can be measured by the cost of self-generation plus the cost of maintaining the second generator as a support to the other generator.

In this analysis, we estimate the economic value of additional supply through the national grid, irrespective of whether the power is generated by utility directly, through PPA arrangements with IPPs. According to Lim and Jenkins (2000), the value of additional supply can be estimated with the following formula:

$$Economic\ value\ of\ Additional\ Supply = [(P^{max} + P_0^m)/2] * \Delta Q^s$$ *..Equation (1)*

In Nigeria, P^{max} would be represented by the cost of self-generation which seems to be the only alternative source for meeting the deficit supply from utility. If we assume that the shortage from utility supply is left as blackout, this would have larger cost for the economy than the P^{max} assumed. But to avoid the complexities of finding what amount of blackout is met, we keep our assumption that electricity demand covered from utility supply would be met by self-generation.

To measure the willingness to pay for electricity from self-generation, P^{max} we categorize electricity users into two: the industrial users and the household users'. For industrial users, they could afford large capacity captive generators and enjoy some kind of economies of scale as compared to the individual users who usually buy small capacity generators ranging between 0.65-15 kVA nominal capacities. Given that the fuel consumption per kWh is same for the two classes of users, we can say that the variable operating cost per kWh would be same but the fixed capacity cost of the generators per kWh would be lower for the industrial users. The estimate of willingness to pay in Nigeria is presented in the table below.

Table 3. Self-generation cost and willingness to pay in Nigeria

Self-generation fuel cost ($/kWh):	
industrial users	0.21
residential users	0.24
Self-generation maintenance cost ($/kWh)	0.04
Maximum willingness to pay ($/kWh):	
industrial users	0.25
residential users	0.28
Share of industrial/ commercial users (%)	0.47
Share of residential users (%)	0.53
Average power retail price ($/kWh)	0.07
Average willingness to pay to utility ($/kWh)	0.17

Source: Estimate from author's model

In Nigeria, as of December 2012, the power generation (actual) was 20,893GWh, which came from the system available capacity of 4,842MW. Whereas, the total required power generation at same period was estimated as 48,457GWh requiring a total operating capacity of 11,230MW. This means that the country currently battles with a shortage of 27,564GWh. As earlier explained, this shortage is being met by self-generation, and this analysis considers various alternatives for replacing this amount of shortage. For projection of electricity shortage in the system over a long period as covered in this study (2013-2035), it is easy to make projection for electricity demand but the amount of electricity that will come through the national grid is unknown as new projects might come on board. Therefore, it is quite illusive to make forecast for shortage because the amount for demand can be projected easily based on historical trend for electricity consumption and level of economic activities going on but the supply is unknown:

$$(\textbf{Demand}_{electricity} - \textbf{Supply}_{electricity} = \textbf{Shortage}_{electricity})$$

Since the shortage at present is known, estimation is made to know the amount of installed capacity that will be required from the various technologies available. If the country decides to go for hydro power generation as a replacement for the current shortage, a total of 6,293MW will be required based on a capacity factor of 0.50. If the country decides to go for solar as a replacement for the current power shortage, a total of 6,293MW will be required with a capacity factor of 0.50. If the country decides to go for open cycle gas turbine as a replacement for the current shortage, a total of 3,496MW will be required based on a capacity factor of 0.9. If the country decides to go for combined cycle gas turbine as a replacement for the current shortage, a total of 3,702MW will be required based on a capacity of 0.85.

This estimate of required installed capacity will be used as hypothetical scenario for the economic analysis of replacing the shortage which currently comes from self-generation. The cost of self-generation that will be replaced will then be the economic benefit of supplying electricity from the alternatives, while the cost would be the generation cost from these alternatives. The result will be presented in present value form because of the difference in the investment outplay for the analysis technologies (it is not reasonable to compare the alternative electricity supply based on capital cost because some plants incur higher capital cost with low marginal running cost while others incur low capital cost with higher marginal running cost).

Table 4. Table of parameters

Replaced energy (2013)	27,564		Base year		2013
Auxiliary consumption	2.0%		Ending year		2035
Degradation Factor	1.0%		Price of natural gas USD/MMBtu		4.0
Transmission losses	8.05%		Conversion Btu/litre		0.096
Type of Technology	**Capacity Factor**	**Capital Cost (KW)**	**Fixed O&M (KW)**	**Variable O&M (kWh)**	**Heat rate (Btu/kWh)**
Hydro	0.50	$5,288	$18	$0.00	N/A
Solar	0.50	$4,183	$27.75	$0.00	N/A
Open Cycle	0.90	$1,979	$7.34	$15.45	10,850
Combined Cycle	0.80	$1,917	$13.17	$3.60	7050

Source: Energy Information Administration, 2013.

The demand for electricity will be growing and it is expected that the generation will be growing as well. However, it is not possible to tell if the amount of growing generation will match the growing demand. For this reason, analysis under this study covers the current shortages and this shortages is taken into the future under the scenario that the shortage is either going to be met by self-generation or if replaced in this present period will be covered by the national grid thereby, the estimated economic net can be realized. For the cost of self-generation through captive own-generators, the cost (C_t) is calculated as the sum of the cost of acquiring the generator set, maintenance cost of the generator set, and then the running cost of the generator which is the fuel cost. This is expressed as the equation below:

$$C_t = M_t + Q_t^f * F_t + CapG \qquad \text{...Equation (2)}$$

Where C_t – Total cost of self-generation per kWh.

M_t – Annual maintenance cost of generator set.

Q_t^f _ The amount of fuel used for running the generator in period t.

F_t – This is the price of fuel in the same period.

$CapG$ – This is the purchasing price of the generator set.

Using the formula in equation (2), Ugwu et al (2012), estimated the average cost of self-generation as ₦46/kWh (0.29usd/kWh) for petrol generator, ₦47.7/kWh (0.30usd/kWh) for diesel generator. In this study, the cost of self-generation is estimated as 0.28usd/kWh for residential users while the large scale users are estimated to be 0.25usd/kWh. This estimate is based on fuel price assumption of ₦97 (0.61usd/liter).

The Cost of Alternative Generation spread over time and the present value of this cost is expressed with the formula given below:

$$\text{PV of Cost} = \sum_{t=0}^{T} \varepsilon \left[\frac{K\left[\frac{r(1+r)^T}{(1+r^T-1)}\right] + fom + 8760 h_t\left(vom + \frac{P_t e}{\emptyset}\right)}{(1+r)^t} \right] \qquad \text{...Equation 3}$$

Where t – year (0, 1…T)

T- Operational life of the plant

ε – Plant's installed capacity

K- Capital investment per kW capacity

r – Required rate of return on investment

fom – yearly fixed operating costs per Kw capacity

h_t – load factor per year as a fraction of total number of hours in a year (8760)

P_t – fuel price in year t per kWh energy content

e – Conversion rate for fuel

ϕ – Efficiency rating of the plant

The cost of the actual energy supplied (**running cost)** depends directly on the amount of electricity generated, transmitted or used (**variable cost**). The cost of always being ready to supply energy whenever it is wanted (**capacity cost**) is independent of the amount of electricity generated, transmitted or used (**fixed cos**t) but directly depends on the installed capacity of the plant. The cost of generating electricity is expressed in terms of a unit cost (pence per kWh). The relevant cost of generating electricity for the purposes of this study is divided into four main categories:

• **Capital Cost-** the initial level of investment required to engineer, procure and construct the plant itself.

• **Fixed operation and maintenance Cost**- for example staff salaries, insurance, rates and other costs, which remain constant irrespective of the actual electricity generated.

• **Variable operation and maintenance Cost**- which are consumed in proportion to the actual amount of electricity generated.

• F**uel Cost-** consumed in generating electricity.

4.5 Analysis of Output from Model

4.5.1 Hydro

Information from the EIA annual report (2013) shows that the overnight capital cost of hydro power plant for a small sized capacity of 250MW is 5288usd/kW, while the FOM of hydro power plant is 18usd/kW and the VOM is 0.00usdkWh. This is also presented on the parameter table (table 2). For fuel, the hydro power benefits from nature and so fuel cost is not applicable.

With the current shortage of 27,564GWh, 6,293MW of installed capacity will be required if only hydropower system will be targeted to replace the current shortage. Hence, making a hypothetical hydro power plant of 6293 MW as a candidate plant for replacing the current shortage, this will cost a total amount of investment of $33.3billion which includes cost of civil works, mechanical and electrical equipment, installation and financing fees. Because hydro power station takes time to construct, this cost is spread over a period of five years starting from 2013.

In present value terms, if the hypothetical hydro-power plant is implemented as the candidate plant, $32.4 billion could be realized as cost savings in the country by avoiding self-generation over the projected time period (2013-2035). But then making this hydro power plant available over the projected period of time will cost $27.5 billion in present value terms; therefore, an economic net present value of supplying electricity to meet the current shortage through the national grid is $4.9 billion .And the estimated economic rate of return for this amount of net benefit is 14.4 percent.

Table 5. Hydro plant as candidate project for replacing self-generation

Currency Unit: USD'Million							Required Capacity: 6293.1 MW	
	Hydro Power Generation							
	Replaced	Cost Savings	Capacity Cost		Running Cost		Total Cost	Net Benefit
Year	Shortage	SG MRC	Capital Cost	FOM	VOM	fuel cost		
2013			$3,328			N/A	$3,328	($3,328)
2014			$8,320			N/A	$8,320	($8,320)
2015			$11,647			N/A	$11,647	($11,647)
2016			$6,656			N/A	$6,656	($6,656)
2017	13,782	$3,498	$3,328	$113	$0	N/A	$3,441	$57
2018	27,288	$6,926		$113	$0	N/A	$113	$6,813
2019	27,015	$6,857		$113	$0	N/A	$113	$6,743
2020	26,745	$6,788		$113	$0	N/A	$113	$6,675
2021	26,478	$6,720		$113	$0	N/A	$113	$6,607
2022	26,213	$6,653		$113	$0	N/A	$113	$6,540
2023	25,951	$6,587		$113	$0	N/A	$113	$6,473
2024	25,691	$6,521		$113	$0	N/A	$113	$6,407
2025	25,434	$6,455		$113	$0	N/A	$113	$6,342
2026	25,180	$6,391		$113	$0	N/A	$113	$6,278
2027	24,928	$6,327		$113	$0	N/A	$113	$6,214
2028	24,679	$6,264		$113	$0	N/A	$113	$6,150
2029	24,432	$6,201		$113	$0	N/A	$113	$6,088
2030	24,188	$6,139		$113	$0	N/A	$113	$6,026
2031	23,946	$6,078		$113	$0	N/A	$113	$5,964
2032	23,707	$6,017		$113	$0	N/A	$113	$5,904
2033	23,470	$5,957		$113	$0	N/A	$113	$5,843
2034	23,235	$5,897		$113	$0	N/A	$113	$5,784
2035	23,002	$5,838		$113	$0	N/A	$113	$5,725
							Economic Net Present Value	$4,920
							Economic Rate of Return	14%

Source: Estimate from author's model

4.5.2 Solar

The capital cost of solar power plant for a small sized capacity of 100MW is $5,067/kW, while the FOM of hydro power plant is $27.75/kW and the VOM is $0.00kWh according to EIA annual report (2013). This is also presented on the parameter table (table 2). Solar PV benefits from nature and so fuel cost is not applicable.

With the current shortage of 27,564GWh, 6,293MW of installed capacity will be required if only solar power system will be targeted to replace the current shortage. Hence, making a hypothetical solar power plant of 6293 MW as a candidate plant for replacing the current shortage, this will cost a total amount of investment of $26.3billion that makes up civil works, maintenance and electrical equipment supply, installation and financial fee. Because solar power field does not take time to be installed unlike hydro power station that takes a longer time for construction, this cost is spread over a period of two years starting from 2013.

In present value terms, if the hypothetical solar power plant is implemented as the candidate plant, $47.1 billion could be realized as cost savings in the country by avoiding self-generation over the projected time period (2013-2035). To make this solar power plant available over the projected period of time will cost $25.9 billion in present value terms; therefore, an economic net present value of supplying electricity to meet the current shortage through the national grid is $21.2 billion .And the estimated economic rate of return for this amount of net benefit is 25.1 percent.

Table 6. Solar PV as candidate project for replacing self-generation

Currency Unit: USD'Million			Required Capacity: 6293.1 MW					
	Solar Power Generation							
	Replaced	Cost Savings	Capacity		Running Cost		Total Cost	Net Benefit
Year	Shortage	SG MRC	Capital Cost	FOM	VOM	fuel cost		
2013			$10,530			N/A	$10,530	($10,530)
2014	13,782	$3,498	$15,795	$175	$0	N/A	$15,969	($12,471)
2015	27,288	$6,926		$175	$0	N/A	$175	$6,751
2016	27,015	$6,857		$175	$0	N/A	$175	$6,682
2017	26,745	$6,788		$175	$0	N/A	$175	$6,614
2018	26,478	$6,720		$175	$0	N/A	$175	$6,546
2019	26,213	$6,653		$175	$0	N/A	$175	$6,478
2020	25,951	$6,587		$175	$0	N/A	$175	$6,412
2021	25,691	$6,521		$175	$0	N/A	$175	$6,346
2022	25,434	$6,455		$175	$0	N/A	$175	$6,281
2023	25,180	$6,391		$175	$0	N/A	$175	$6,216
2024	24,928	$6,327		$175	$0	N/A	$175	$6,152
2025	24,679	$6,264		$175	$0	N/A	$175	$6,089
2026	24,432	$6,201		$175	$0	N/A	$175	$6,026
2027	24,188	$6,139		$175	$0	N/A	$175	$5,964
2028	23,946	$6,078		$175	$0	N/A	$175	$5,903
2029	23,707	$6,017		$175	$0	N/A	$175	$5,842
2030	23,470	$5,957		$175	$0	N/A	$175	$5,782
2031	23,235	$5,897		$175	$0	N/A	$175	$5,723
2032	23,002	$5,838		$175	$0	N/A	$175	$5,664
2033	22,772	$5,780		$175	$0	N/A	$175	$5,605
2034	22,545	$5,722		$175	$0	N/A	$175	$5,547
2035	22,319	$5,665		$175	$0	N/A	$175	$5,490
							Economic Net Present Value	$21,160
							Economic Rate of Return	25%

Source: Estimate from author's model

4.5.3 Open Cycle Gas Turbine

According to the EIA annual report (2013), the capital cost of open cycle gas turbine is $1,979kW, while the FOM of open cycle gas turbine is $7.34/kW and the VOM is $15.45kWh. This is shown on the parameter table (table 2). Though the capital cost is relatively cheap because it operates with fuel, the FOM and fuel cost tends to be the major cost of making open cycle gas turbine available as a candidate plant.

With the current shortage of 27,564GWh, 3,496MW of installed capacity will be required if open cycle gas turbine will be targeted to replace the current shortage. Therefore making a hypothetical open cycle gas plant of 3496MW required installed capacity as a candidate plant for replacing the current shortage; this will cost a total amount of investment of $6.9billion that summarizes civil works, maintenance and electrical equipment supply, installation and financial fee. The cost is spread over a period of three years starting from 2013.

Table 7. Open cycle gas turbine as a candidate project for replacing self-generation

Currency Unit: USD'Million					Required Capacity: 3496.2 MW			
	Open Cycle Gas Turbine							
	Replaced	Cost Savings	Capacity		Running Cost		Total Cost	Net Benefit
Year	Shortage	SG MRC	Capital Cost	FOM	VOM	fuel cost		
2013			$2,076				$2,076	($2,076)
2014			$2,768				$2,768	($2,768)
2015	13,782	$3,498	$2,076	$26	$213	$598	$2,912	$586
2016	27,288	$6,926		$26	$422	$1,184	$1,632	$5,294
2017	27,015	$6,857		$26	$417	$1,172	$1,616	$5,241
2018	26,745	$6,788		$26	$413	$1,161	$1,600	$5,189
2019	26,478	$6,720		$26	$409	$1,149	$1,584	$5,136
2020	26,213	$6,653		$26	$405	$1,138	$1,568	$5,085
2021	25,951	$6,587		$26	$401	$1,126	$1,553	$5,034
2022	25,691	$6,521		$26	$397	$1,115	$1,538	$4,983
2023	25,434	$6,455		$26	$393	$1,104	$1,522	$4,933
2024	25,180	$6,391		$26	$389	$1,093	$1,508	$4,883
2025	24,928	$6,327		$26	$385	$1,082	$1,493	$4,834
2026	24,679	$6,264		$26	$381	$1,071	$1,478	$4,786
2027	24,432	$6,201		$26	$377	$1,060	$1,463	$4,738
2028	24,188	$6,139		$26	$374	$1,050	$1,449	$4,690
2029	23,946	$6,078		$26	$370	$1,039	$1,435	$4,643
2030	23,707	$6,017		$26	$366	$1,029	$1,421	$4,596
2031	23,470	$5,957		$26	$363	$1,019	$1,407	$4,550
2032	23,235	$5,897		$26	$359	$1,008	$1,393	$4,504
2033	23,002	$5,838		$26	$355	$998	$1,379	$4,459
2034	22,772	$5,780		$26	$352	$988	$1,366	$4,414
2035	22,545	$5,722		$26	$348	$978	$1,352	$4,370
							Economic Net Present Value	$25,625
							Economic Rate of Return	58%

Source: Estimate from author's model

In present value terms, if the hypothetical open cycle gas turbine is to be implemented as the candidate plant, $46.7 billion could be realized as cost savings in the country by avoiding self-generation over the projected time period (2013-2035). But making open cycle gas turbine available over the projected period of time will cost $16.0 billion in present value terms; therefore, an economic net present value of supplying electricity to meet the current shortage through the national grid is $25.6 billion .And the estimated economic rate of return for this amount of net benefit is 58.0 percent.

4.5.4 Combined Cycle Power Plant

The capital cost of combined cycle gas turbine is $1,917kW, while the FOM of open cycle gas turbine is $13.17/kW and the VOM is $3.60kWh EIA annual report, 2013). This is shown on the parameter table (table 2). Though the capital cost is relatively cheap because they run with fuel, the FOM and fuel cost tends to be the major cost of making combined cycle gas turbine available as a candidate plant.

With the current shortage of 27,564GWh, 3,933MW of installed capacity will be required if combined cycle gas turbine will be targeted to replace the current shortage. Hence, making use of 3933MW required installed capacity as a candidate plant for replacing the current shortage; this will cost a total amount of investment of $7.5billion that includes civil works, maintenance and electrical equipment supply, installation and financial fee. The cost is spread over a period of three years starting from 2013.

Table 8. Combined cycle gas turbine as candidate for replacing self-generation

Currency Unit: USD'Million			Required Capacity: 3933.2 MW					
	Combined Cycle Gas Turbine							
	Replaced	Cost	Capacity		Running Cost		Total Cost	Net Benefit
Year	Shortage	SG MRC	Capital Cost	FOM	VOM	fuel cost		
2013			$2,262				$2,262	($2,262)
2014			$3,016				$3,016	($3,016)
2015	13,782	$3,498	$2,262	$52	$50	$389	$2,752	$746
2016	27,288	$6,926		$52	$98	$770	$920	$6,006
2017	27,015	$6,857		$52	$97	$762	$911	$5,946
2018	26,745	$6,788		$52	$96	$754	$902	$5,886
2019	26,478	$6,720		$52	$95	$747	$894	$5,826
2020	26,213	$6,653		$52	$94	$739	$885	$5,768
2021	25,951	$6,587		$52	$93	$732	$877	$5,710
2022	25,691	$6,521		$52	$92	$724	$869	$5,652
2023	25,434	$6,455		$52	$92	$717	$861	$5,595
2024	25,180	$6,391		$52	$91	$710	$853	$5,538
2025	24,928	$6,327		$52	$90	$703	$845	$5,482
2026	24,679	$6,264		$52	$89	$696	$837	$5,427
2027	24,432	$6,201		$52	$88	$689	$829	$5,372
2028	24,188	$6,139		$52	$87	$682	$821	$5,318
2029	23,946	$6,078		$52	$86	$675	$813	$5,264
2030	23,707	$6,017		$52	$85	$669	$806	$5,211
2031	23,470	$5,957		$52	$84	$662	$798	$5,159
2032	23,235	$5,897		$52	$84	$655	$791	$5,107
2033	23,002	$5,838		$52	$83	$649	$783	$5,055
2034	22,772	$5,780		$52	$82	$642	$776	$5,004
2035	22,545	$5,722		$52	$81	$636	$769	$4,953
							Economic Net Present Value	$29,332
							Economic Rate of Return	60%

Source: Estimate from author's model

In present value terms, if the combined cycle gas turbine is to be implemented as the candidate plant, $41.7billion could be realized as cost savings in the country by avoiding self-generation over the projected time period (2013-2035). But making combined cycle gas turbine available over the projected period of time will cost $12.3 billion in present value terms; therefore, an economic net present value of supplying electricity to meet the current shortage through the national grid is $29.3 billion .And the estimated economic rate of return for this amount of net benefit is 59.9 percent.

Following this results, the combined cycle gas plant which shows a feasible economic net present value of $29.3 billion seems to be the best candidate among the four alternatives available to replace electricity shortage in Nigeria. This is followed by the open cycle gas plant. Under this hypothetical scenario, the hydro power plant is at best marginally beneficial to the society if chosen as a candidate for replacing the shortages. The estimated net present value for the solar indicates that the solar plant candidate would be preferred to the hydro but this candidate will most likely not yield as much benefit as the gas plant candidate. It is important to note that environmental impact assessment of these four options is not considered under this study.

Practically, the hypothetical hydro and solar plants are not feasible candidate because they run on natural resource which is constrained by availability (i.e. seasonal) and natural resource regulation. In addition, these natural resources are being affected by climate change and so, heavy investment in such candidate projects could pose high level risk of resource availability.

Since Nigeria is endowed with natural gas, the hypothetical open cycle and combined cycle gas plants would be the most feasible options for replacing the current shortage in the country. This does not mean that the hydro and solar are not good candidates under this scenario.

One major reason the results are more favorable for the gas plants is because of the short term period of forecast (2013-2035). The hydro and solar plants require large amount of capital to establish, but very low running cost-almost zero cost because fuel is not applicable for its running; whereas the gas plants are relatively cheap to establish, but very expensive to run, and the stability of running cost will depend on the volatility of oil price which is determined internationally.

If a longer term period, say far beyond the 2035 used under this analysis, the hydro and solar gets better results.

4.6 Sensitivity Analysis

For the base price assumption of $4/MMbtu, combined cycle seems to be better than other candidate plants followed by open cycle, solar and then the hydro power. The price of fuel is very volatile especially in the recent years, a sensitivity analysis is carried out to see the response of the candidate plants in response to the change in fuel price.

Table 9. Sensitivity Analysis for changes in price of natural gas

	Hydro		Solar		Open Cycle		Combined Cycle	
	ENPV	EIRR	ENPV	EIRR	ENPV	EIRR	ENPV	EIRR
Price of Natural Gas	**$4,920**	**14.4%**	**$21,160**	**25.1%**	**$25,625**	**58.0%**	**$29,332**	**59.9%**
$2.5	$4,920	14.4%	$21,160	25.1%	$28,296	61.9%	$31,068	62.2%
$4.0	$4,920	14.4%	$21,160	25.1%	$25,625	58.0%	$29,332	59.9%
$5.5	$4,920	14.4%	$21,160	25.1%	$22,954	54.0%	$27,596	57.5%
$7.0	$4,920	14.4%	$21,160	25.1%	$20,282	49.8%	$25,860	55.1%
$8.5	$4,920	14.4%	$21,160	25.1%	$17,611	45.5%	$24,125	52.7%
$10.0	$4,920	14.4%	$21,160	25.1%	$14,940	41.1%	$22,389	50.2%

Source: Extracted from author’s model

Combined cycle still remains the best candidate plant among the four options. Results presented in Table 9 for sensitivity analysis shows that open cycle and combined cycle candidates are sensitive to the price of natural gas most especially the open cycle because it is a system that only runs on natural gas but the combined cycle runs on both natural gas and steam. Results from table shows that as price of gas increases, economic net benefit from solar becomes larger than the reliable economic net benefit from open cycle (consider a price of $7/MMbtu). In terms of rate of return, one might be tempted to rank the open cycle candidate ahead of the solar candidate plant because the EIRR for the open cycle is better. The EIRR is quite misleading in this case because the study is looking at two mutually exclusive projects with different scale of investment and timing of cash flows. Overall, the combined cycle remains the best candidate plant among the four options and it is also a feasible option considering the fact that Nigeria has abundant of natural gas.

Nigeria can optimize the system by mixing different technologies since hydro and solar are fuel free while open cycle and combined cycle run with fuel.

Chapter 5

CONCLUSION

A key to economic growth in every country is energy and when not available as required puts a constraint to economic development. Nigeria is a country having an array of energy mix, from natural gas to renewable energy resources, but it is still facing the problem of electricity instability. This has made the country less industrialized and the market uncompetitive, and this problem cannot satisfy the need of economic development at desired levels. It turns out that imported goods are less expensive than domestic products due to the power shortage. People tend to depend mostly on reliable and expensive self-generation options to produce and sell in the market.

The challenges of the electricity industry in Nigeria are the main setbacks the country is facing and the inefficient and insufficient power supply have caused many industries to move to neighboring countries where they can be able to have full access to electricity supply for their businesses. Nigeria is the second highest in the world that flares up gas. The country flares about 17 billion tons of carbon gas annually which can be converted into energy to generate more than 24,000MW of electricity per day.

Despite the fact that alternative energy resource option is a solution to reduce the power supply crisis in the country, there has not been much competitive investment in the sector. Factors including price distortion, poor institutional framework, incompetency in policy implementation, corruption, willingness to pay, lack of skilled workers, poor maintenance culture, poor infrastructure, subsidized price of electricity to consumers, and the initial capital cost of installation make it difficult to expand in this alternative energy options. Both the private and the public sectors demand alternative energy technologies in Nigeria. As the population increases, there is an increase in the demand for electricity. This increase in electricity need have created a need for investing in alternative energy technology business in the country. To this regard, the government has set up goals and standards through energy reforms that will be of great benefit to both domestic and foreign investors in the power sector (zero tariff for the product).

Some of the problems with regard power generation in Nigeria are seen to be the following: inadequate funding, low and regulated prices, poor maintenance planning, facility vandalization, lack of energy mix, poor management, corruption, lack of transparency, high interest rate borrowing, and lack of enabling environment for private investors to embark on power sector investment. However, solutions to the above mentioned problems facing power generation in Nigeria includes: full deregulation, energy mix, allowing cost-reflective tariff to promote competition in the sector and in the long-run, it will set price at equilibrium, infrastructural development, provision of security to prevent vandalization of natural gas, electrical equipment and lines. Good budget system should be taken into account for the expansion of the power sector for the next 30 years.

If Nigeria can utilize her abundant energy resources, this will certainly contribute to a huge economic gain for the country, reduce poverty and unemployment rate. If only the government can link energy services to all the sectors in the country such as agriculture sector, domestic sector, mining sector, industrial sector, and commercial sector, it will help reduce electricity shortage for these sectors. This can be achieved by embarking on reforms and policies that are profitable for growth in the power sector. 55% of Nigerian populations are people that are not connected to the national grid and most of them are in the rural areas. The rivers that are used to create hydro power are mostly found in the rural areas that do not have access to national grid.

A core objective of this study is to analyze the various power generation options for Nigeria. The evaluation uses an economic cost-benefit analysis approach to estimate the cost of various options that can be explored in Nigeria, and computes the consumers' willingness to pay for electricity (taking into account the high level of self-generation presently in the country).

Results from study show that combined gas plant which shows a feasible economic net present value of $29.3 billion seems to be the best candidate among the four alternatives available to replace electricity shortage in Nigeria. This is followed by the open cycle gas plant which shows a feasible economic net present value of $25.6 billion. The result further shows that solar plant candidate with a net present value of $21.2 billion would be preferred to the hydro plant with a net present value of $4.9 billion. But this two candidates are not feasible candidates because they run on natural resource which is constrained by availability (i.e. seasonal) and natural resource regulation. Results from sensitivity analysis shows that combined gas plant still remains the best candidate among the four alternatives available, but says otherwise for the remaining three alternatives. As the price of gas increases, ENPV for solar plant becomes larger than ENPV for open cycle gas plant considering the price of gas as

$7/MMbtu. For sensitivity analysis, combined cycle gas still remains the best, followed by solar plant, then open cycle gas plant and finally hydro plant.

5.1 Recommendation

Since Nigeria is endowed with natural gas, the hypothetical open cycle and combined cycle gas plants would be the most feasible options for replacing the current shortage in the country. The government should support the initiative of Independent Power Project investment in gas plant. A detailed national load demand study should be carried out in view of providing practical and reliable information on power generation, transmission, and distribution requirements for Nigeria for today and future forecast for the next 30 years. There should be an institutional arrangement from the Federal government to State government and Local government on their specific roles in the energy sector in order to ensure system efficiency.

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