CONGO-NIGERIA HYDROELECTRIC SUPERHIGHWAY GRID

(AN ECONOMIC VIABLE OPTION)

Anieheobi Callistus C.

20976976

Dissertation submitted in partial fulfillment of the requirements for the degree of *Master of Engineering* at the Potchefstroom Campus of the North-West University

Supervisor: Prof P. W. Stoker

November, 2008

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Abstract

Electricity availability and stability have a great contributory share of industrialization growth rate, poverty statistics, unemployment, foreign investors' participation, medium and small scale encouragement, crime and mortality rates recorded in any country. Nigeria as a country has been challenged with unstable and unreliable power supply.

There are many problems associated with electricity production in Nigeria. Such problems are recorded in the generation, transmission and distribution facets of electricity production.

With a multi-faceted problem, this document has been developed to deal with the economic aspect of power generation in Nigeria. Out of numerous technologies that are used in power generation, Nigerian predominantly sources its electricity supply from gas power plants and hydropower systems located within the country. Unfortunately, the Nigeria hydropower has been challenged with hydrological shortfalls. The gas power plant which is now conventional is being challenged with the developing gas technology around the globe. This development has adversely affected the cost of gas and subsequently the cost of power production using gas power plants.

As a result of hydrological limitations on Nigerian hydropower dams, effect of gas price on cost of energy produced and diversifying gas technology, harnessing electric energy from Inga falls of River Congo was considered as an economic choice of power production in Nigeria. The choice of power production adopted in this document was made from an economic viability studies carried out between Nigerian gas power plants and hydropower production from the River Congo.

The choice of technology employed for harnessing electric energy is largely dependent on the economic factors that go with the development. While some of these technologies go with large initial capital investment some are challenged with geometric increase of running cost. As applied in this work, the Net Present Value, Internal Rate of Return, Levelized Cost of Energy and Cash Flow Trend Analysis are suitable tools to determine choice of power plant. These tools were integrated and developed as an NILC model.

In the analysis presented in this dissertation, the economic viability of the two power plants selected was determined with the use of the Net Present Value, Internal Rate of Return, Levelized Cost of Energy and Cash Flow Trend Analysis (NILC) model. The model was used to measure the economic viability quantities of the two power plants selected for economic comparison.

After the completion of economic comparative analysis, hydropower production from the River Congo was concluded to be a better choice of power production compared to the conventional gas power plant option in Nigeria.

Key Words

An Economic Viable Project	A project that is considered worthwhile from an economic point of view
Inga Hydropower System	A hydropower structure located at the Inga falls of River Congo.
Levelized Cost of Energy	The present value of the total cost of building and operating a generating plant over its economic life, converted to equal annual payments.
Megawatts	Unit of electric power that is one million Watts.
Power Holding Company of Nigeria PLC	A Nigerian national electricity utility organization
Superhighway Grid	A transmission highway designed for very high voltage transmission or multiple transmission lines.

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Acronyms

A	-	Annuity
A/CAPEX	-	Projected Annualized Discounted CAPEX
AfDB	-	African Development Bank
APC	-	Annualized Plant Cost
B/C	-	Benefit-Cost Ratio
BBC	-	British Broadcasting Cooperation
BTU	-	British Thermal Units
CAPEX	-	Capital Expenditure
CCF	-	Cumulative Cash Flow
CEO	-	Chief Executive Officer
CNG	-	Compressed Natural Gas
COE	-	Cost of Energy
CRF	-	Capital Recovery Factor
DoE	-	Department of Energy
DR	-	Discounted Rate
DRC	-	Democratic Republic of Congo
E/O	-	Energy Output
ECN	-	Electricity Cooperation of Nigeria
EIA	–	Energy Information Administration
ENE	-	Empresa Nacional de Electricidade (Angola Power Utility Company)
Eskom	-	South African Power Utility Company
ESMAP	-	Energy Management Assistance Program
EUEC	-	Economic Unit Energy Cost
GHG	-	Green House Gasses
GTL	-	Gas-To-Liquid

GW - Giga Watt

GWH - Giga Watt Hour

HEP - Hydro Electric Power

HPP - Hydro Power Plants

HVAC - High Voltage Alternating Current

HVDC - High Voltage Direct Current

IPP - Independent Power Plants

IRR - Internal Rate of Return

Km - Kilometer

Kv - Kilo Volts

LCOE - Levelized Cost of Energy

LNG - Liquefied Natural Gas

M - Meter

m^3/s - Meter Cubed per Second

MAN - Manufacturers Association of Nigeria

MD - Managing Director

MMSCF - Million Metric Standard Cubic Feet

MW - Mega Watt

MYTO - Multi-Year-Tariff-Order

NDA - Niger Dams Authority

NEA - Nuclear Energy Agency

NEB - National Energy Board

NEPA - National Electric Power Authority

NEPAD - New Partnership for African Development

NERC - National Electricity Regulatory Commission

NESCO - Nigerian Electricity Supply Company

NGC - Nigerian Gas Company

NGL - Natural Gas Liquid

NGO - Non Governmental Organization

NILC - Net Present Value, Internal Rate of Return, Levelized Cost of Energy and Cash Flow Trend Analysis

NPV - Net Present Value

NYMEX - New York Mercantile Exchange

OECD - Organization for Economic Co-operation and Development

OPEX - Operating Expenditure

PHCN - Power Holding Company of Nigeria PLC (Nigerian Power Utility Company)

PLC - Public Liability Company

REAP - Renewable Energy Action Plan

SADC - South African Development Community

SCE - Selling Cost of Energy

SNEL - Societe Nationale d'Electricite (Democratic Republic of Congo Power Utility Company)

SV - Salvage Value

TCF - Trillion Cubic Feet

TW/an - Trillion Watt per Annum

USD - United States Dollars

WEC - World Energy Commission

Chapter One

Introduction

1.0 Chapter Overview

The Nigerian power sector has been challenged with unstable and insufficient power supply. This chapter will be dealing with the background of the Nigerian power sector and the problem associated with the ill situation. The objective of the research work which has been designed to deal with the economic aspect of the power sector problem will be defined. The work has been designed to solve some problems which will benefit the Nigerian populace in particular and the African continent at large. The outlines and boundaries for which the work has been designed are to be defined on completion of this chapter.

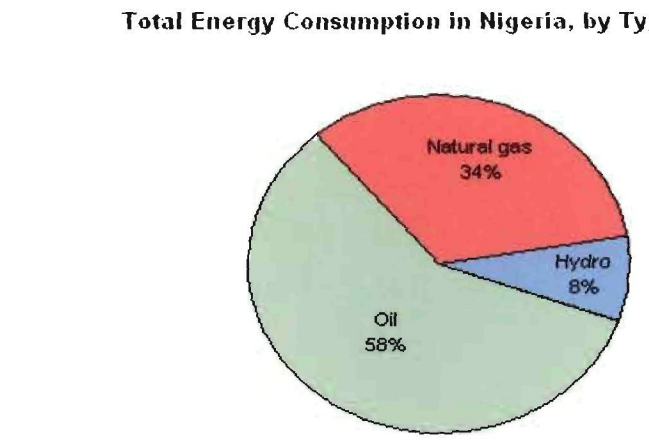
1.1 Background

Nigeria is the most populous country in Africa with a population of 148 million people [United Nations, 2007] with a population growth of 2.37 percent [Microsoft Encarta, 2005]. Nigeria has a land mass of 923, 786 sq km (356, 669 sq mi).

In 2004, Nigeria's energy consumption mix was dominated by oil (58 percent), followed by natural gas (34 percent) and hydroelectricity (8 percent). Coal, nuclear and other renewable energy source are currently not part of the country's energy consumption mix. From 1984-2004, the share of oil in Nigeria's energy mix has decreased from 77 percent to 58 percent. Natural gas consumption increased from 18 percent to 34 percent. Hydroelectricity has seen a slight increase as well from 5 percent to 8 percent [Energy Information Administration, 2007]. Meanwhile, the energy from crude oil is used mainly in automobiles, while 70 percent of natural gas goes to power generation [NGC[1], 2008].

[1] Nigerian Gas Company

Figure 1.1: Total Energy Consumption in Nigeria by Type (2004)



Source: EIA International Energy Annual 2004

It is not economically encouraging that Nigeria in pursuit to be the continent's economic hub has electricity per capita of less than 29 watts. This is barely enough to light a domestic light bulb [Ishiekwene, 2008]. With present population growth rate of 2.37 percent and a population of approximately 150 million, if the present domestic electricity load demand stands at 6, 000 MW by 2007, then Nigeria need to develop a minimum of 150 MW in 2008 and a cumulative increase in the subsequent years to meet a sustainable electricity per capita.

A typical scenario that describes the Nigerian power availability status is the Manufacturers Association of Nigeria (MAN) saga. In July 2007, MAN submitted a document to the Presidency, which shows that its 1,500 members (number of local manufacturers that registered with MAN) will not require more than 864 MW of electricity to achieve substantial production capacity at a lower and more efficient cost. As at the time MAN made this request, their 1,500 members had generators with a combined capacity of about 600 MW, for which they had to buy over 8.6 million litres of diesel weekly at over ₦90 (approximately $1.00) per litre. The association demanded that 864 MW be 'squeezed' out of the national grid to service the firms, if not for 24 hours, then at least for 16 hours. The impact would have ranged from increased capacity to more employment opportunities and perhaps from lower prices to a cooling of the pressure on the pump price of

diesel. The request was not granted due to insufficient poor power availability on the national grid. [Ishiekwene, 2008].

Presently the gap between domestic energy demand and supply is 4, 000 MW [Usman, 2006]. Should Nigeria be considered for industrial development, then a reasonable amount of power must be generated to support such development. Unfortunately, the reverse has been the case. Nigeria energy crisis has set the country back in terms of national economic development. Some of the problems are as discussed below.

1.2 Problem Definition

The problem with Nigerian power sector cannot be overemphasized. For the past decade, the magnitude of the power generated swings between 1, 300 MW to 2500 MW [Makoju, 2006]. Earlier before the past decade, the Nigerian power problem was insignificant due to the low energy demand that more or less conformed to the generated output. Sixty two percent of the generated power in Nigeria is dependent on gas turbines. Hydro power generation which is not stable due to fluctuating seasonal water level and other factors accounted for 30 to 38 percent [Ogunleye, 2007]. Mega and mini factories and plants have closed down due to this epileptic power supply. Statistics of unemployment has tolled to the maximum. Insecurities and criminal activities have been the bane of Nigerian environment due to unemployment caused by this power quake.

Notwithstanding, the efforts that have been put in place to stabilize power supply in Nigeria, curb gas pipeline vandalism, deregulate cost of gas and increase gas supply, gas power plant sited across the nation cannot deliver dependable output. Due to these problems, many Nigerians now depend on private petrol and diesel generators for supporting their power needs. Unfortunately, due to the flammability of fuels (PMS and AGO)[2] used in private generators, houses are unconsciously set ablaze on a regular basis; people are dying from suffocation

[2] Premium Motor Spirit *and* Automobile Gas Oil

that is caused by the carbon monoxide that is emitted from the potable generators.

Not only that the effort to put this problem at rest by the Nigerian government is insufficient, over-dependency on gas for power generation in the country has been underlined to be a major contributing factor to the insufficient and unstable power supply. [Makoju, 2006]

With the growing energy demand in the world and diverse natural gas utilization, natural gas can attract a huge income to the nation if an alternative power source is put in place to take care of the Nigerian power demand.

Consumers are reluctant to pay their bills due to undependable service offered by PHCN. Invariably, the poor revenue generation has led to the accumulation of debt accrued from cost of gas supplied to gas power plants. At a regulated price of gas, it is expected that the gas power plants run at a profitable status. Unfortunately, the gas power plant is not operating at its best.

As at 2007, Power Holding Company of Nigeria incurred a debt of eleven and half billion Naira (N11.5bn)[3] [Onabu, 2007] being the cost of gas supplied to the power plants. This debt accounts to 72.2 percent of debt owed Nigerian Gas Company [Onabu, 2007].

Increasing the electricity tariff to accommodate the hiking cost of gas cannot be the best solution to this national power menace. Resorting to dependency on National Hydro plants cannot solve the problem either.

The Nigerian hydropower plants are posed with the limitations of seasonal water fluctuations, shortage of water by irrigation, evaporation, utility water projects and limited area of the river watershed. Construction of dams will not also provide the best solution as this poses disaster to the occupants of the region.

[3] Exchange rate of US Dollar to Naira estimated at $1.00 : ₦118.00

With the above problem cited, it is a fact that the problems of Nigerian Power sector are linked with under-generation, cost of energy production and sabotage of the technology of generation presently practiced.

Even when the Nigerian power supply is epileptic, cost of energy is not cheap. The willingness of consumers to offset their bills is a function of reliable service and cost of service offered. Invariably, poor revenue generation by the power utility company adversely affects the running of the power business. With a cheaper cost of energy and reliable power supply, consumers will be willing to pay their energy bills while the power utility company will generate sufficient income to run their business.

With the limitations of Nigerian hydropower stations, cost of gas and subsequent cost of generating electricity from gas turbines, Inga hydroelectric power system has been considered by this research work, to determine if it is an economic viable alternative.

The total energy potential from the Inga Hydroelectric power is estimated at about 100, 000 MW. This dissertation has been designed to consider economic advantages of harnessing part of the power from the Grand Inga phase of 40, 000 MW at a more cost effective manner when compared to the conventional gas power plants in Nigeria. A sample size of 4,000 MW was used for the economic studies.

However, comparing the economic viability quantities of two or more power plant needs an accurate determination of the plants' economic characteristics. These characteristics are partly dependent on the political and economic factors surrounding the plant site. Therefore, to formulate a model that will determine the economic viability quantities is an issue that needs to be defined and rectified.

1.3 Research Objectives

The research objective intended by this work are as follows:

- To survey the limitations of Nigerian gas power plants.
- To carry out some fundamental hydrological analysis of the Nigerian Hydropower dams.
- To survey the hydrologic advantages and hydropower potential of Inga Hydroelectric power system when measured against Nigerian Hydropower systems.
- To carry out economic viability analysis between the gas power plant and the Inga power system.
- To develop an economic (NILC) model that will compare the viability of the Nigerian gas power plant and the Inga hydroelectric system using a sample size of 4,000MW.

The research work has been designed to expand knowledge on cost benefits of different power generating options. The economic analysis tool employed in the research work has also provided a professional analysis tool known as NILC model that can be used to compare two or more power options in terms of their economic values and benefits. The work has provided a fundamental knowledge which will serve as basis of important information for further research work as it may relate to this research.

1.4 Scope of Studies

There are many areas that need to be developed in order to make an encompassing decision as it relates this research work. Such areas are environmental and risk analysis of the selected option. Technology of transmission lines, converter stations and other technical analysis are not covered by this work. The research work has been specifically designed to measure the economic viability quantities of conventional gas power plant in Nigeria and the Congo hydroelectric power project. The conclusion made is strictly based on the scope so defined.

1.5 Research Outline

The research has been compiled in a sequential manner to present from fundamental point of view to conclusive deductions. It is developed in seven chapters. The chapters and their contents are inter-linked to a give an understanding of the process employed to achieve results.

The chapters and their contents are designed to cover some specific aspect as summarized below:

Chapter one dealt with the Nigerian power sector background, the associated shortcomings of the sector, the solution as suggested by the research work and the objectives of the work. It went further to state the scope of the work done, the beneficiaries, the merits and knowledge to be gained from the work.

In chapter two, it presents in a more elaborate manner the challenges of the present power generation practices in Nigeria. The Nigerian hydropower limitations are presented based on hydrological studies. The hydrological advantages and the hydroelectric power potential of the Congo River were studied; these factors gave the hydropower production from River Congo the consideration for further economic studies.

The economic viability tool that was used in the research work is introduced in chapter three. The experimental procedure that was used is presented ranging from gathering of data to outlining the economic viability measurement techniques to be employed in achieving result.

Chapter four presents an empirical analysis of the research work by applying the economic viability tool introduced in chapter three. The economic viability tool was used to compare the economic viability quantities of a sample size of a 4000MW gas power plant sited in Nigeria with that of the Congo Hydroelectric power project of the same size. The metrics considered are Net Present Value, Internal Rate of Return, Cost of Generating Electricity and Cash Flow Trend Analysis.

Chapter five presents the summary of the results achieved in chapter four. The results include the Net Present Values, Internal Rate of Return, Levelized Cost of Energy, initial cost of investment, size of revenue yielding energy and cash flow trend figures. The analyses of these results were made which provide the premise that was used in drawing conclusion.

Chapter six presents the conclusion that was made from the premise provided in chapter five. Recommendations were also made based on the conclusion drawn.

1.6 Conclusion

It has been established that problem exists in the Nigerian power sector. A solution to the power problem, the research benefits and aims has been presented in this chapter. The next chapter will study the limitations of the existing power plants, and limit the research on two power options that will be selected.

Chapter Two

Literature Review

2.0 Chapter Overview

Nigerian natural gas reserve is enormous (about 160 trillion cubic feet) but not renewable [NGC, 2008]. The use of gas fired power plants to generate electricity has been a common practice in the Nigerian power environment. Another technology for harnessing electric power is through hydropower systems. Presently, there are three hydropower stations in Nigeria which are faced with some power output optimization problem. This chapter has been developed to present some literal, scientific and historical facts about the power harnessing options as found in the present Nigeria. Also harnessing the electric power from the Inga falls of Congo River was considered for studies.

The target of the research work is to carry an out economic viability analysis of the power plants. However, due to the limitations of the Nigerian hydropower stations, the conventional gas power plant and the Congo hydropower option was selected for analysis.

The research work is intended to study and present an economic proof why importing power from the Inga falls of River Congo is an economic viable option when compared with the dominant gas fired power systems in the present Nigeria.

The research x-rayed the background and relevant hydrologic studies of the River Niger (housing the Kainji and Shiroro Dams), the Kaduna River (supplying the Jebba Dam), the Nigerian gas reserve, the River Congo basin as they affect the Nigerian Power Sector. The limitations, potentials, conditions, challenges of each element of the studies were critically done; the effects of the limitations put forward and solutions to be proffered through further studies that will employ economic evaluations. This chapter employed the use of numerous figures,

graphs, tables and associated terms to provide a better understanding of the subject matter.

2.1 The Nigerian Power Sector

Electricity generation in Nigeria began in 1896 in Ijora, Lagos. In 1929, the Nigerian Electricity Supply Company (NESCO) commenced operations as an electric utility with the construction of now defunct hydroelectric power station in Kuru, Jos. [NEPA, 2001]. "In 1951, the Electricity Corporation of Nigeria (ECN) was established to control the diesel and coal plants while the Niger Dams Authority (NDA) was established in 1962 due to rapid urbanization and increasing demand that led to the exploitation of the country's water resources". [NEPA, 2001].

In 1972, NDA and ECN, which were 100% wholly government-owned public utilities companies were merged to form the National Electric Power Authority (NEPA). NEPA was obliged to carry out the business of generation, transmission and distribution and marketing of electric power to the generality of country. The Electricity Act and the NEPA Act guided NEPA's activities and operations and it started with four major power stations namely: Ijora, Delta and Afam thermal power stations and Kainji Hydro power station serving more than two million customers nationwide [NEPA, 2001].

Considering that most of these power stations were installed between 1968 and 1990, NEPA has been unable to meet the ever growing demand for electricity power due to the old, obsolete state and neglect that has plagued the industry.

As at 1998, NEPA ceased to have the exclusive monopoly of electricity generation, transmission, distribution and sales of electric energy. The authority had an approximate installed capacity of 5,906 MW and with the supplemented capacity from Independent Power Producers (IPPs) which has only been able to generate a total of 3,400 MW in 2004. As at April 2005, NEPA had ten power stations of which three are hydro stations (Kainji, Jebba and Shiroro), six are thermal

(Afam, Ijora, Delta, Sapele, Egbin and Calabar) and one coal power station (Oji – now obsolete) [NEPA, 2005]. Considering that most of these power stations were installed between 1968 and 1990, NEPA has been unable to meet the ever growing demand for electricity power due to the old, obsolete state and neglect that has plagued the industry.

Nigerian power sector problems set in with the total neglect of the industry by the then military government between 1980 and 1999. The near collapse of the industry was due to the poor funding by government, mismanagement of the utility, poor maintenance culture, corruption, use of substandard materials, inadequate generation output, poor service delivery leading to load shedding, electricity theft, poor revenue drive, non-payment of bills by consumers, technical and non-technical losses, etc. It has also affected the national economy by increase in decaying infrastructure, large fiscal deficits, declining industrial capacity utilization, inefficient public utilities, low quality of social services, external debt overhang, high poverty level, low per capita income and significant unemployment record.

Today, the crux of the problem has been limited to inadequate generated output, poor management practices, poor maintenance culture, inter alia. To bring back the industry's glory, the Nigerian power sector has left researchers, international bodies, students, power experts, governmental and non-governmental organizations (NGOs) with the challenge of reforming the sector through their numerous inputs.

This research work has however not intended to solve the entire problem of the Nigerian power problem rather it limits its scope to study of inefficient generation practices. The study critically analyzes the generating conditions in Nigeria, criticizing the shortcomings and subsequently proffering solution to the best proven practice.

With the present power generating conditions, Nigeria basically uses only two types of power generation technique to generate electricity – the dominant gas turbine and the large hydroelectric systems. The options adopted so far have been shown to have some conditions militating against their effective output ranging from hydrological limitations on national hydropower systems to the cost impact, environmental issues and instability of the gas fired power plants.

2.2 The Niger River and Hydropower Development

"The Niger River, with a total length of about 4100 km, is the ninth largest system in the world, the third-longest river in Africa, after the Nile and the Congo Rivers, as well as the longest and largest river in West Africa" [Zarma, 2006]. It takes source from Fouta Djallon highland in Guinea at an approximate altitude of 800m before traversing over distance of 4,200 km to empty into the Atlantic Ocean in Nigeria. The Niger basin has an active catchments area of about 1,500,000 sq km covering the following countries: Algeria, Benin, Burkina Faso, Cameroun, Chad, Ivory Coast, Guinea Bissau, Mali and Nigeria [Zarma, 2006].

Unfortunately, being the major source of portable water for over 100 million people, the river Niger has in the recent years been adversely affected by the menace of drought. In 1985, for the first time in history the river was completely dry in Niamey of Niger Republic. Similarly, the flow recorded during 1984/1985 and 2002/2003 hydrological data along the River Niger were the lowest in the past 50 years [IEA, 2007].

Subsequently, for the past 4 decades the basin has been experiencing series of hydro-climatic changes that has resulted in the persistence drought causing the Sahara Desert movement southward towards the Atlantic Ocean; erosion and river silting that is causing flood with its attendance loss of lives and properties; continued low flow reducing reservoir storage capacity with consequences on acute water shortages and increasing water demands [IEA, 2007]. It has been evident that the countries within the Niger basin are facing serious shortages of surface water for meeting rising demands of from population growth.

The quantity of water entering Mali from guinea which is 40km^3/year is greater than the quantity of water entering Nigeria from Niger Republic which is 36km^3/year. This is due to the enormous reduction in runoff in the inner delta in Mali through seepage and evaporation combined with almost no runoff from the whole of the left bank in Mali and Niger [REAP, 2006].

While some man made factors can be corrected or controlled as it affects the Niger River water level, most of the natural consequences like rainfall seasonality and drought have posed an irreparable challenge as discussed below in details. As most of the Niger Basin's country like Mali and Niger are located in the core of Sahara Desert characterized by excessive drought rely on irrigation activities for their agricultural and other water resources needs, the hydroelectric dams downstream like the Kainji and Jebba dams suffer unbearable drops in power output when compared to their initial design outputs.

2.2.1 Effects of Water Fluctuation on Hydropower Generation

Channelized water with dependable flows backed by appropriate water engineering superstructure in form of dam and the associated reservoir are vital to the economic harnessing of water resources for a sustainable hydroelectric power production. Channelized water is the main and cheapest input for turning turbines which generates electricity. Water is not only cheap; it is renewable using the hydrological cycle as a driving force.

Unfortunately, this process is not as simple as described above. It involves complex tangle of the amount seasonality and annual variability of rainfall, which feed the river system upon which a hydropower power station is sited. Consequently, experts believe that a dam on stream is no assurance that there would be adequate water to run the turbine all-year-round. Some of the problems that limit this assurance of water availability are natural while others have human dimensions. These problems include too little water (drought), too much water

level (flood), low water level, water pollution, siltation, irrigation, water hyacinth infestation, et al.

Despite man's technological advancement and management skills, these problems have continued to pose monumental challenges to man. All the man made factors that affects water level fluctuation can arguably be amended unlike the natural factors which will be treated in the latter part of this chapter.

2.2.2 PHCN Dams and Water Storage for Hydropower Generation

Dams of various sizes are increasingly becoming an important component of river basins in West Africa sub-region particularly in Nigeria as forms of engineering structure to harness and manage the water resources for various reasons including power generation for economic and industrialization process.

The objective of a dam and its associated storage reservoir is to regulate the discharge of the river on which it is located so that the impoundment can be released almost uniformly. The three national hydro-dams at Kainji, Jebba and Shiroro have been built to store large volume of river flows in their equally large storage reservoirs of 15, 3.88 and 6 billion cubic meter of water respectively for later use during the dry period thus expected to fulfill their main objective of hydropower generation all-year-round [Idemudia, 2002]. Unfortunately, the dam operators empty or draw down the reservoir prior to the onset of the following season's flood. The shortage of water during the dry period is due to some natural influences on the run-of-the-river.

2.2.3 Water Level Fluctuations in Kainji, Jebba and Shiroro Dams

Low/high water levels and water level fluctuations in the three national hydropower dams are normal hydrologic and operational events brought about by various factors vis-à-vis:

2.2.3.1 Rainfall Seasonality in Niger Basin and Kaduna River

Unlike the Congo River which has its tributaries spread across the equator, the Niger River is affected by seasonal rainfall. The seasonal variation of rainfall over the Niger's catchment is very simple. Rainfall generally begins in March/April, increases until the month of September and decreases thereafter until cessation takes place completely in November.

Field studies and explorative data analysis by researchers have shown that about 50% of the total annual rainfall accumulates in the two heaviest rainy months of July and August and lowest in the months of January, February and December [Ajibade, 2005]. Besides, rainfall could be delayed in onset, could be of low intensity, short or long term durations. Most important of all, in terms of onset, cessation amount and distribution of rainfall events could cause the year to be generally dry, normal, wet or very wet.

With particular reference to the Kainji lake basin, the pre-construction period of Kainji Hydroelectric Power Plant in 1960's was wet. The 1970's and 80's were generally dry except for isolated case due to the Sahelian drought [Ajibade, 2005]. The consequences were that river Niger flows and annual runoff into the water levels at Kainji dam were significantly reduced and power generation was severely affected. Consequently, the run-of-the-river of Jebba hydro plant operated 100Km downstream of Kainji undoubtedly suffered the same fate [Ajibade, 2005]. The drop in the Niger River run-of-the-river has been dropping significantly with date due to increased human activities and unavoidable natural influences.

The Kaduna river basin on which the Shiroro hydroelectric power station is on stream is slightly different. Most worrisome is that the Shiroro reservoir, which is being fed by Kaduna River and other seasonal and flashy streams, has also been ill-affected by less inflow than envisaged. This less inflow necessitates the drawing down of the reservoir faster that it is being replenished. For instance, in

July 2004, Shiroro reservoir level fell to 358.84 meters compared to the design capacity of 360 meters [Ajibade, 2005]. It is envisaged that the water level fall will increase down the years.

2.2.3.2 Rainfall Water Resources Availability

Many literal works abound to show the importance of rainfall in the development of water resources as well as being the source of water on land, the rate of inflow into a reservoir. Unfortunately, field studies and research efforts by scholars have shown that West African sub-region's water supply suffers from two major setbacks [Bernacesek, 1984] as pointed out below:

- A high seasonal rainfall pattern resulting in most of the unusable total annual runoff being available only a few months of the year and;
- A low runoff coefficient due to high evaporation, which is aggravated by frequent droughts. In fact, scientific field studies have shown that even if rainfall within the basins of a river is less variable from year to year (like the Congo River) but it is highly variable from month to month; the run-of-the-river is apparently more stable. Thus, seasonal variability of rainfall has significant impact on water levels and hence water availability for power generation in Kaiji, Jebba and Shiroro dams/power stations.

2.2.4 Effects of Drought on Dams at Niger and Kaduna Rivers

There are two known hydrological extreme events affecting the flow regime of all rivers particularly in the tropics. These are flood and drought. The first represents over abundance while the second represents scarcity. Limiting our topic to drought as it affects the field of study; there are different types of droughts. With the scope of the work this work is concerned with hydrological drought. Hydrological drought is a situation below normal rainfall required to generate stream flow [Ajibade, 2004]. The well documented Sahelian drought, which

strated in 1973 and lingered till date with its effects on Kainji and Jebba dams comes to mind. This ill effect called drought has taken it tolls on inflow reduction, low and below normal water level (even below the minimum operating level), significant drop in hydropower output and massive load shedding/rationalization of electricity. While the West African Sahelian Drought persisted, Kainji dam recorded its low unprecedented low annual runoff of 17.2 billion cubic meters of water in 1984 and has thus persisted [Bernacesek, 1984]. Such could be disturbing dimension of the effects on hydro dams as it is in Kainji and Jebba dams.

2.2.5 Effects of Irrigation on Nigerian Hydropower Dams

The world's largest desert, the Sahara occupies parts of ten countries in northern Africa and has an approximate area of more than 9,065,000 sq km (3,500,000 sq mi). Stretching from the Atlantic Ocean eastward to the Red Sea, the Sahara covers a varied geographic region, incorporating sandy dunes, rock-strewn plains, mountain ranges, and fertile oases. The Sahara receives less than 127 mm (5 in) of rain a year; some areas remain without rain for many years [Encarta, 2006].

Irrigation which is artificial application of water unto crops involves "total consumptive use of water" unlike hydropower generation where water is merely used in turning the turbines (non consumptive). The fact thus remains that regardless of the irrigation method adopted, any quantity of water drawn from the River Niger to service irrigation process at the upper reaches of the river is regarded as irrecoverable loss, as this water does not return to the stream.

There is a natural problem at the Upper Niger. It is the water retention, detention and evaporation process taking place at the Inner Delta in Mali Republic. The natural water loss is aggravated by desert high temperature conditions which contribute to the increased drought recorded at the River Niger. Due to the poor rainfall in the desert region and poor mineral deposits in the Sahara, the countries found in this sub-region majorly depend on agriculture for their

economic sustainability. Mali and Niger Republic are located in this area. The tributaries of the river Niger are well faceted in these countries. The international character of the river Niger which transverses climatic and political boundaries create fears of water level drops as the Nigerian Dams are located at the lower reaches of the river. Any engineering intervention such as the irrigation practices found in Niger Republic and Mali affects the river hydrology particularly at the lower reaches hence; drop in the hydropower output at Kainji and Jebba dams.

2.3 Overview on the Nigerian Natural Gas

Natural Gas reserves in Nigeria are, in energy terms, at least twice that of crude oil reserves, natural gas being in the region of 160 trillion cubic feet (TCF) of gas proven and another 45 TCF which remain undiscovered in recoverable reserves. Ultimate associated gas and non-associated gas reserves are estimated at 300TCF making it the seventh largest reserve of natural gas in the world [NGC, 2008]. At present utilization levels, this will last for over 100 years.

Natural Gas is a naturally occurring gaseous mixture of hydrocarbon gases found in underground reservoir. It consists mainly of methane (70% - 95%). With small percentages of Ethane, Propane, Butane, Pentane and other heavier hydrocarbons with some impurities such as water vapour, Sulphides, Carbon dioxide, etc. The ethane, propane, butane, pentane etc, hydrocarbon components of natural gas are collectively called natural gas liquids (NGLs). These NGLs are found in larger quantities in associated gas streams than in non-associated gas streams.

Natural gas is a versatile and environmentally preferred fuel when compared to other fossil fuels as it produces no soot or ash, nor pollutants and as such has a major role to play in alleviating air pollution problems. It is also cheaper than most competing fuels and has become a major source of energy for both commercial and industrial consumers as well as a chemical feedstock for numerous processes.

2.3.1 Natural Gas Utilization and Demand Growth

Initially, the utilization of natural gas in Nigeria was applied only on the Shell operated thermal power plant in Afam in Rivers State. With the trend of developing world technology and global economic growth, natural gas utilization has been diversified. The discovery of natural gas has given rise to some utility plants such as Gas-to-Liquid (GTL), Liquefied Natural gas plants, Petrochemical industries, compressed natural gas plants, inter alia.

As natural gas has been discovered to be more environmentally friendly when compared to other fossil fuels (coal, petroleum, etc), its global demand has been on a geometric progression. For instance, natural gas is now used in steam turbines, furnaces, as CNG used in automobiles, green diesel, preferred raw materials in fertilizer and petrochemical industries. It is used both as a fuel and as raw material in the manufacture of chemicals. As a residential fuel (LNG), Natural Gas is used for domestic heating, water heaters, cooking stoves, and clothes dryers; while as an industrial fuel, it is burned in kilns used to bake bricks and ceramic tiles and to produce cement. It is also used for generating steam in water boilers and as a source of heat in glass making and food processing. Natural Gas equally serves as a raw material for creating petrochemicals, which are chemicals that are specifically derived from natural gas or petroleum. In turn, petrochemicals are used as a base product for making fertilizers, detergents, pharmaceuticals, plastics, and numerous other goods.

Due to the law of demand and supply, the cost of natural gas is rapidly increasing as global demand of gas is hitting the skies. Which this trend of growth, there is no doubt that natural gas will be the 'holy grail' in future of world energy demand.

2.3.2 Impact of the Growing Gas Sector on Power Generation and Distribution

Irrespective of type of generation, the primary principle of the type of technology selected for power generation is aimed towards producing rotary motion. The rotary motion turns the turbine through a shaft transmission system. The type of technology selected is mainly dependent on the unit cost of energy output. Other factors are also considered in the choice of technology selected for power generation. Such factors include environmental, energy source (renewable and non-renewable), social and political considerations.

Though not within the scope of this work, in terms of environmental considerations, natural gas has the lowest operating impact on the environment when compared to other fossil fuels (indicated in table 2.1) but cannot outweigh the environmental advantage of hydropower alternative.

Table 2.1: Fuel/Hydro Emission Levels in Pounds per Billion Btu of Energy Input

Pollutant	Natural Gas	Hydro	Oil	Coal
Carbon Dioxide	117,000	0	164,000	208,000
Carbon Monoxide	40	0	33	208
Nitrogen Oxides	92	0	448	457
Sulfur Dioxide	1	0	1,122	2,591
Particulates	7	0	84	2,744
Mercury	0.000	0.000	0.007	0.016

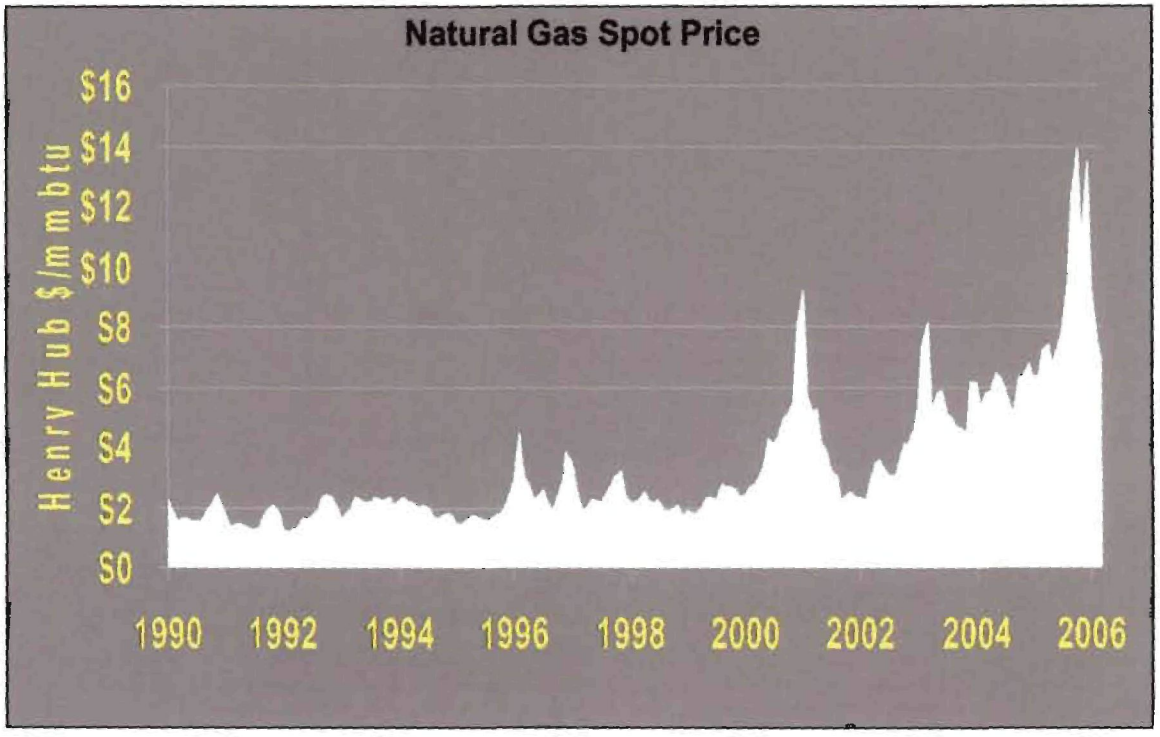
Source: EIA - Natural Gas Issues and Trends 1998

Moreover, as a matter of concern, economic consideration of natural gas to hydropower generation is an issue to be discussed. Cost of generating one unit of electricity and cost of selling the unit provides a guide in choosing alternative to be employed due to economic benefits of one over the other.

In Nigeria, though the selling cost of unit of electricity is equalized, the generating cost of the energy varies from one generating mode (hydro, gas, solar, wind, biomass, etc) to the other. While the cost of generating unit of electricity is stable in hydro systems, cost of generating one unit of the same quantity of

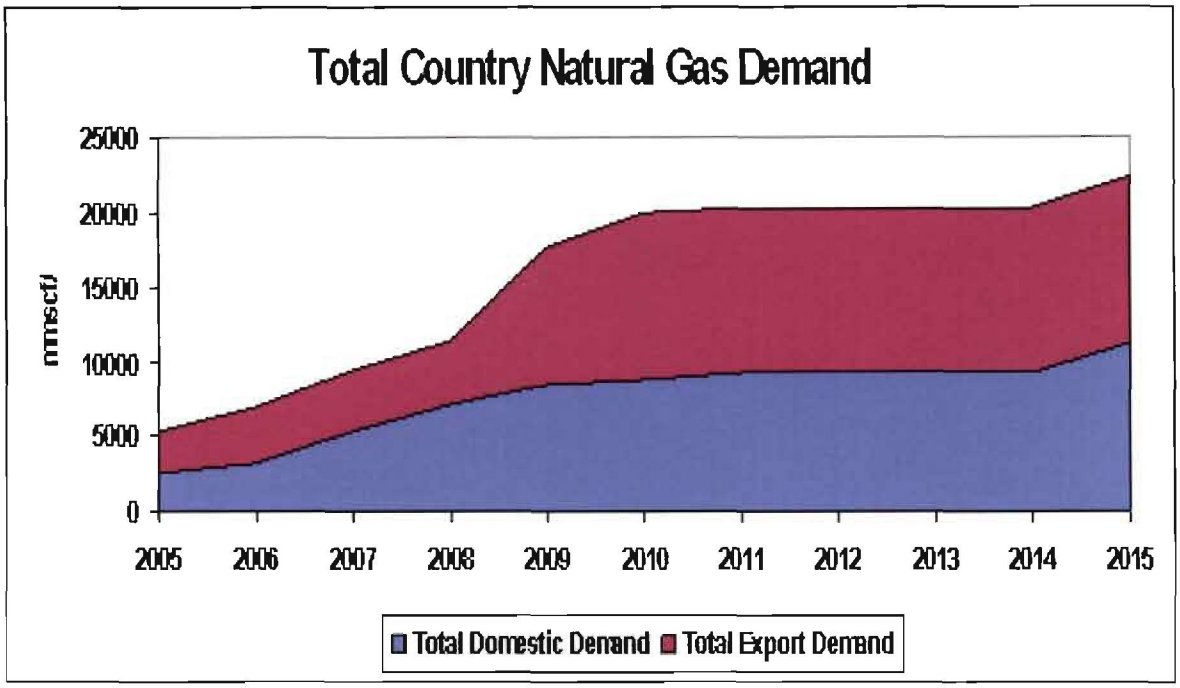
energy varies greatly along the time line in gas power plants due to geometric increase in the cost of natural gas. The figure (Figure 2.1) below indicates the cost of natural gas and its corresponding increase down the year. The increase already forecasts/indicates that there will be a continuous increase along the time line hence, a continual increase operating cost of the plant and subsequently hike in electricity tariff.

Figure 2.1: Cost of Natural Gas versus Time in Years



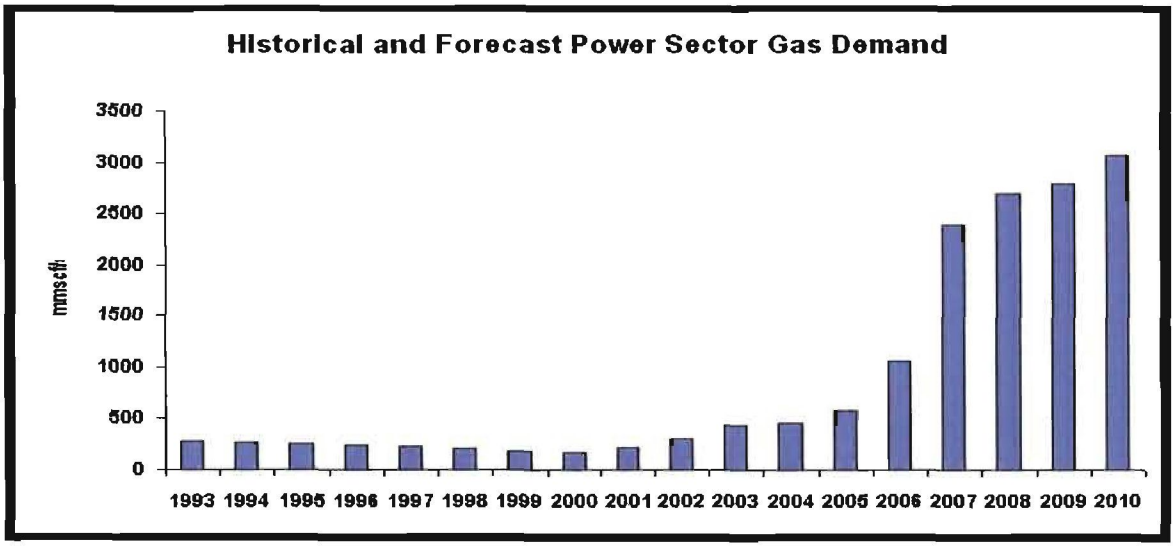
Source: Nigeria Gas Infrastructure Blueprint- An Investor Primer 2007

Figure 2.2: Total National Natural Gas Demand



Source: Nigeria Gas Infrastructure Blueprint- An Investor Primer 2007

Figure 2.3: Historical and Forecast Power Sector Gas Demand



Source: Nigeria Gas Infrastructure Blueprint- An Investor Primer 2007

Interpolating on year 2006, from figures 2.2 and 2.3 above, it can be depicted that while the overall demand of natural gas stands at 2500 million metric standard cubic feet per day (mmscf/d), only the power sector is expected to gulp 1100 mmscf/d accounting for 44 percent of national gas demand. To reduce high cost impact of natural gas on consumers through payment of ever increasing electricity bills, the Nigerian government is already paying subsidy on gas supplied to the power plants. Also through the National Electricity Regulatory Commission in Nigeria, the government has initiated payment in form of subsidy to cushion the effect of cost of electricity on consumers [Owan, 2008]. For instance, if the cost of generating unit of electricity with gas turbine is $x, and $(x = y + z), government pays the y component while the consumer pays the z component. This action does not encourage private sector investment in the Nigerian Electricity Industry.

For the reasons given above, this research work will not totally condemn the use of natural gas to generate electricity in Nigeria rather it will suggest the use of hydropower system (from River Congo) to sustain at least the base load while gas turbines stands as auxiliary generating system during peak load demands.

2.4 Overview on Congo River and its Hydropower Potentials

"The River Congo (for a time known as Zaire River) is the largest river in Western Central Africa. Its overall length of 4,700 km (2,922 miles) makes it the second longest in Africa after the Nile" [Encarta, 2006]. The river and its tributaries flow through the second largest rain forest area, second largest flow, and with the second largest watershed of any river in the world. The first is the Amazon Rainforest in South America. Because of the large sections of the river basin which lie above and below the equator (Figure 2.4), its flow is stable with an average flow capacity of 40,000 cubic meter per second (Figure 2.5), as there is always at least one river experiencing a rainy season.

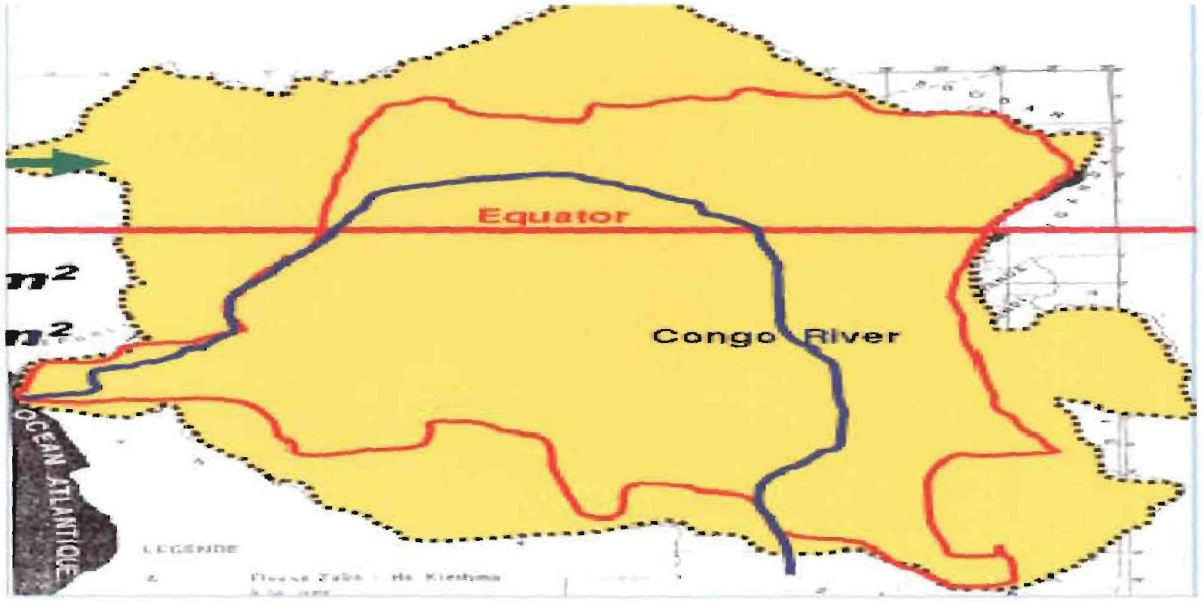
The sources of the Congo are in the highlands and mountains of the East African Rift, as well as Lake Tanganyika and Lake Mweru, which feed the Lualaba River, which then becomes the Congo below Boyoma Falls. The Chambeshi River in Zambia is generally taken as the source of the Congo in line with the accepted practice worldwide of using the longest tributary.

The Congo River has one of the highest hydropower potentials in the world, which is only marginally utilized at present. Due to the river's geographical positions, the Congo River, in the Democratic Republic of Congo (DRC), has, together with its tributaries, a huge hydropower potential of 100, 000MW or more [World Energy Council, 2007]. About forty-four percent of this potential is concentrated at the Inga falls. "Its yearly minimum flow rate makes it a very stable river, suitable for power generation. It is the only big river in the world that has a significant slope in its lower course" [World Energy Council, 2007].

The big advantage of the River Congo is that it crosses the equator twice collecting water from rain in different parts of DRC – both north and south of the equator – keeping the level of the river almost constant throughout the whole year (Figures 2.4 and 2.5).

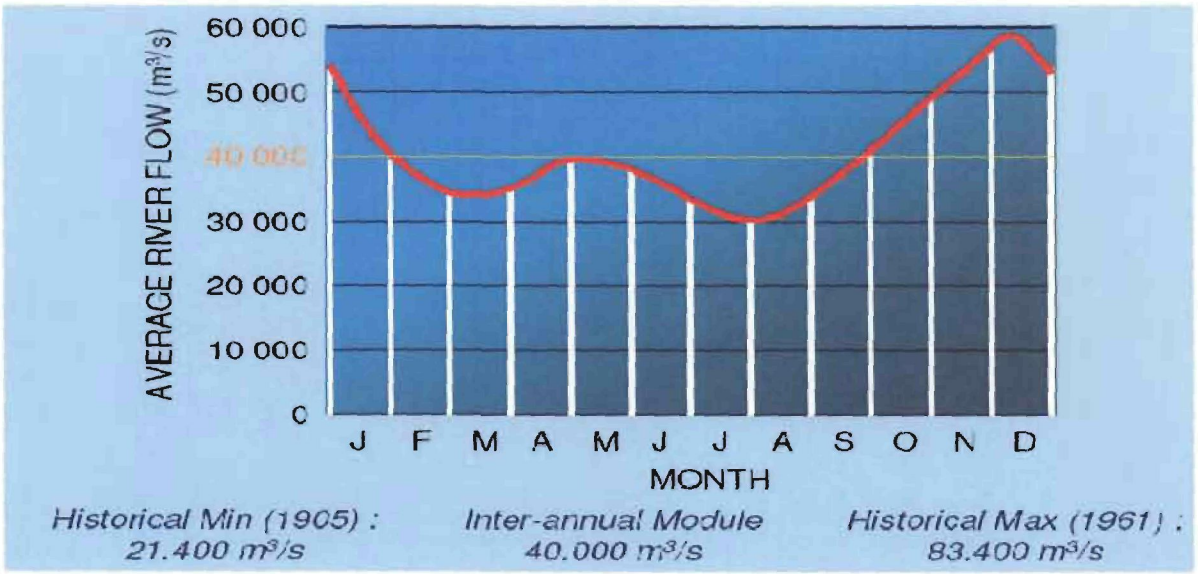
"The long cascading falls and the series of rapids on a distance of 15km between the Sikila Island and the mouth of the Bundi tributary with a natural difference of 102 m in height, make the Inga falls the most important and biggest source of hydropower in the world concentrated at a single point, with an annual energy dissipation of 370,000 GWh" [World Energy Council, 2007]. The natural and suitable topography makes it easy and cheaper to develop in progressive stages.

Figure 2.4: Part of River Congo Showing Its Position on the Equator



Source: Societe Nationale D'Electricite, CongoDR (Congo DR National Electricity Utility Company) 2006

Figure 2.5: River Congo Historical Flow Characteristics



Source: Societe Nationale D'Electricite, CongoDR (Congo DR National Electricity Utility Company) 2006

2.4.1 Grand Inga Hydroelectric Power Project: The Journey so Far

Within the New Partnership for African Development (NEPAD) framework, the Inga Dam[4] in the Democratic Republic of Congo has been portrayed as a key for NEPAD's future success. Tender bids for the rehabilitation of the Inga I (350 MW) and Inga II (1,424 MW) dams took place in mid-2004, with a total cost estimated at $500 million [NEPAD, 2006]. Most of the money ($400 million) was provided by the World Bank, which has been highly active on Congo's electricity front. The Congolese authorities had earmarked $80 million for the first phase of the Inga dam rehabilitation program. Several groups are struggling to get a good position for the Inga contract, among which are South Africa's Eskom and Germany's Siemens [NEPAD, 2006].

"Inga's next stage, Inga III (between 1,700 and 3,500 MW with an estimated cost of US $4 billion) and the "Great Inga Final Stage" (39,000 MW with 52 units of 750 MW each), are also being piloted by the World Bank, plus the EDF Group (France), and Lahmeyer (Germany)" [NEPAD, 2007]. The pre-feasibility studies have been done by the two companies mentioned above.

The construction of a 3,500 megawatt Inga III hydropower station will be executed by five Southern African Development Community (SADC) members. The Inga III will supply the Westcor Power Project -formed by South Africa's Eskom, the Botswana Power Corporation, Angola's Empresa Nacional de Electricidade (ENE), NamPower of Namibia and Societe Nationale d'Electricite (SNEL) of the Democratic Republic of Congo.

The Great Inga, at the Inga Falls on the River Congo, where the river drops 102 meters, has a potential output of some 39 GW with an estimated cost of US$ 6 billion [NEPAD, 2006]. That is three times as much as any existing hydroelectric dam and more than twice that of China's famous Three Gorges scheme.

It is of great advantage to execute Inga hydroelectric power project because the river runs strongly all year, no large dams will be needed. As most power

[4] The Inga Dam is a dam on the Inga Falls in the Congo where the Congo River drops 102 meters

generated through the scheme may be generated through "run-of-river" at Inga Falls, one big challenge is the effect on fisheries and river ecology. Experts have proposed fish ladder to ameliorate the would-have-been environmental disadvantage thus making the project sustainable worthwhile.

The plan to build the world's largest hydroelectric project on the River Congo which will have the capacity of supplying the current electricity demands of the entire continent have been confirmed a welcome development by groups from the civil society and stakeholders. Table 2.2 indicates the relevant particulars of Inga Hydroelectric Power development.

Most African economies are based on subsistence and commercial activities involving small and micro enterprises with structural features that are often overlooked by policy makers. Conversely, Inga Hydroelectric Power Project will provide a platform of mega commercial activities particularly in Nigeria.

According to the evidence provided by Paul Boleilanga, as shown in Table 2.3, the western transmission corridor from Congo to Nigeria has been measured to be approximately 1600Km of 700KV HVDC system. The length of the Western Transmission Corridor is approximately 915 miles (**Appendix A**).

Nigeria is projected to benefit from the first phase of the Grand Inga project as indicated in figure 2.7 with its associated project cost. After the pre-evaluation studies in 1998, a lot of work has been done in line to accomplishing this project. On 21st of April, 2008, seven African governments, the world's largest banks and construction firms met in London under the auspices of World Energy Commission to further plan on the hydropower project on the Congo River. The World Energy Commission's information on the project is a valid document that has been found useful in accomplishing this research work.

Table 2.2: Inga Hydropower Particulars

Parameters	Inga I	Inga II	Inga III	Grand Inga
Date Commissioned	1972	1982	Feasibility completed	Pre-feasibility completed
Water Head (m)	50	58	60	150
Turbine Water Flow (m^3/s)	780	2800	6300	26400
Number of Units	6	8	16	52
Capacity (MW)	351	1424	3500	39000
Production (TWh/Annum)	2.4	10.4	23.5	334.0

Source: Societe Nationale D'Electricite, CongoDR (Congo DR National Electricity Utility Company) 2006

2.4.2 Inga – Nigeria Superhighway Transmission Grid

With its high potential, Inga as well as other power projects can be interconnected to the rest of Africa and beyond through power superhighways. With Inga 1 & 2, Inga is connected to Southern Africa by the Southern Highway via the 1774 km long Inga – Kolwezi HVDC System, and the Zambia, Zimbabwe and South Africa HVAC network.

"The Westcor highway will improve the lives of southern African communities, as a significant contribution to sustainable development. It will be a factor of development of African cooperation, a tool for fruitful business benefit to all parties due to the low cost of supply, a factor of peace and stability between African nations, a backup for Africa's industrial integration through NEPAD, and

a factor of environment preservation for those countries that will be receiving energy from Inga" [NEPAD, 2007].

With the construction of Grand Inga, Inga would be interconnected to West, North and East of Africa by means of transmission highways using the HVDC and HVAC technologies (figure 2.6).

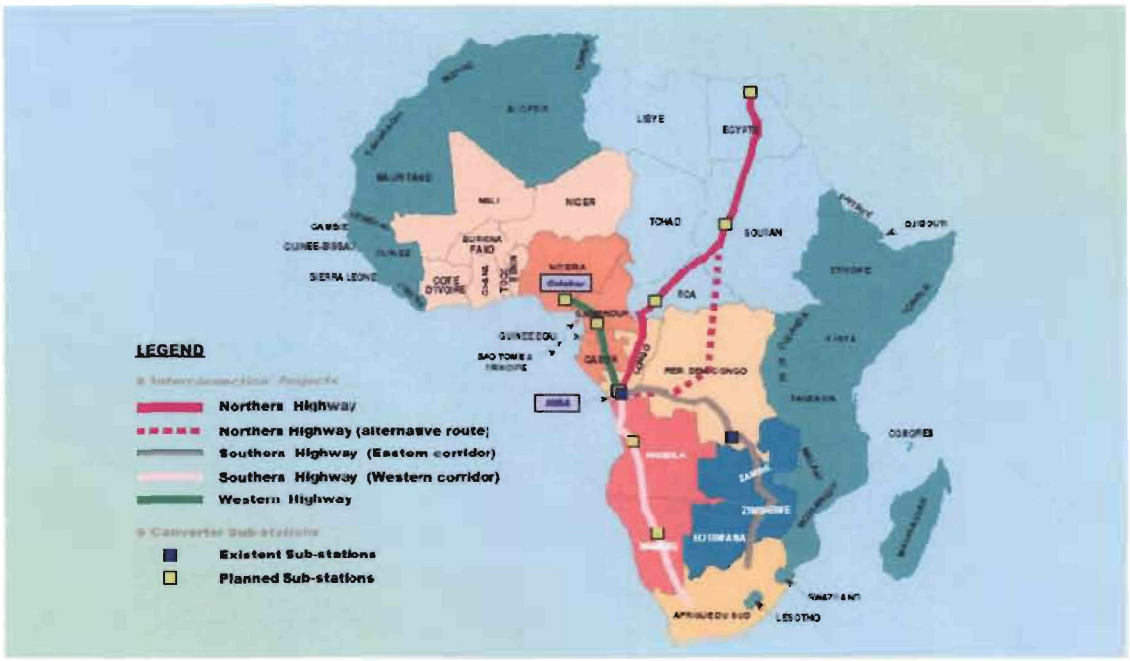
It is clear that Africa has a huge hydropower potential to generate clean, cheap and renewable power, which can be developed into a big powerhouse and be transmitted to all the corners of the continent through superhighways of HVDC and HVAC systems in order to light the African continent.

The superhighway that will be connecting Inga to Nigeria is known as Western Highway (figure 2.7). The length of the transmission line has been measured to be 1600KM at a cost of 600 million US Dollars with tapping station in Cameroun.

As the western highway has been proposed to be HVDC system, a converter station is also proposed to be located in Calabar, Nigeria where the HVDC system will be to the existing national grid of HVAC. At Inga, another converter station will be located to convert the generated AC voltage to HVDC.

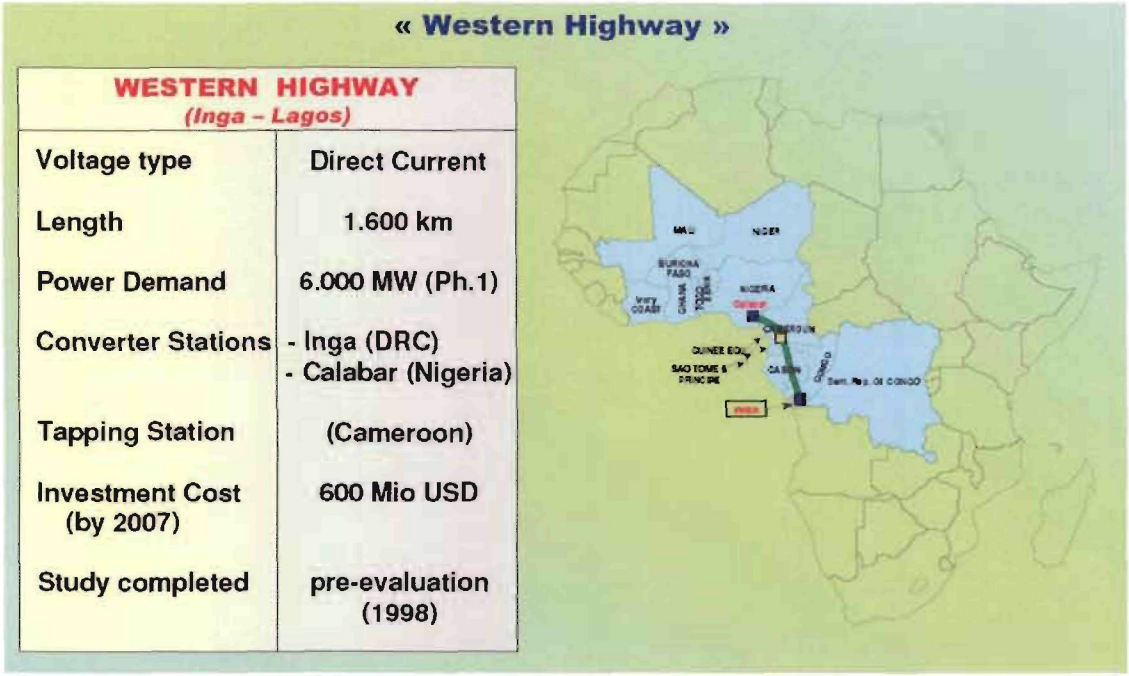
The essence of transmitting with HVDC system is to reduce line losses (I^2R) along the line. This is another field of studies that can be further developed by other researchers. Due to the reliability of the hydro system and magnitude of the voltage transmitted, the superhighway will be on a steady potential providing the line from vandalism hence, supporting system security.

Figure 2.6: Inga – Northern, Southern (Westcor and Eastcor), and Western African Superhighways



Source: SNEL/NEPAD 2006

Figure 2.7: Inga - Western African Superhighways



Source: SNEL/NEPAD 2006

Table 2.3: Summary Table of Investment Cost [Bolelinga, 2006]

	BY THE YEAR					Total
	2007	2009	2012	2017	2023	
Inga I &II Rehabilitation						
Installed Capacity (MW)	1775					
Guaranteed Capacity (MW)	1540					
Investment Cost (M. USD)	103					103
Inga III Power Station						
Installed Capacity (MW)		3500				
Guaranteed Capacity (MW)		2750				
Investment Cost (USD)		3500				3500
Grand Inga Power Station						
Installed Capacity (MW)			6000	12750	19500	
Guaranteed Capacity (MW)			4000	8000	12000	
Investment Cost (M. USD)			4024	x	y	4024+x+y
Power Highway Investment Cost (M. USD)						
Northern Highway	-	-	5753	4858	4649	15260
Southern Highway/East	569	-	-	-	-	569
Southern Highway/West	-	1052	-	-	-	1052
Western Highway	600	-	-	-	-	600
Total Cost (M. USD)	**1,272**	**4,552**	**9,777**	**4858 + x**	**4649 + y**	**25,108 + x + y**

2.5 National Gas-Fired Power plants and the Nigerian Hydropower Stations : A Statistical Synopsis

In Nigeria, the mere existence of a dam in on-stream for hydro generations is no guarantee that there would be adequate water for the hydro plant [Okafor, 2005]. For instance, Kainji hydro power station on the River Niger with its dual flood regime enjoys adequate water flow into its reservoir in only six months of the calendar year.
Worse still, Shiroro power station on the Kaduna River, with single flood regime enjoys appreciable water inflow in only three months a year and out of over 600 MW installed capacity, the available capacity is under 200MW.

On August 12, 2004, hydro generation from Kainji, Jebba and Shiroro[5] hydro plants which recorded 1300 MW dropped to 812 MW at the end of November 2004. These have been the trend of record for the succeeding years.
Customers are directly affected as they are not left out with load shedding in form of unstable and inadequate power supply for domestic and industrial chores.

Significant loss of revenue pervades the electricity industry impacting on both the PHCN and its customers. It has been made evident that seasonality, stream flow variability, evaporation, irrigation and water consumption by communities are responsible for the water fluctuations. Even if the human activities like irrigation can be controlled – though will have adverse economic effect on some countries, it is imperative that the natural factors cannot be controlled.

On the other hand, since the discovery of gas reserves in Nigeria, all attention in Nigerian power sector have been channeled towards harnessing of the resource to generate electricity. Conversely, due to the increasing demand of natural gas in the world market today, it will not be economically wise if Nigerian government will focus all their effort in revamping the collapsed power sector by construction of only gas turbines. The table below shows the existing, on going and proposed

[5] The Three Nigerian National Hydro Power Plants

power station plants in Nigeria. The table demonstrates the statistical representation of power generation technology in Nigeria.

Table 2.4 Existing, Proposed and On-going Power Plants Projects in Nigeria. [Obikwelu, 2005]

Existing Power Stations	On-Going Projects	Seven New Federal Government Projects in Niger Delta	Commissioned IPP Projects	On-Going IPP Projects
Egbin Thermal Power Station, Lagos State **1320MW**	Geregu Thermal Power Station Kogi State **414MW**	Omoku Thermal Power Station Rivers State **100MW**	AES Lagos **300MW**	Omoku Thermal Power Station Rivers State **150MW**
Afam Thermal Power Station, Rivers State **969MW**	Omotosho Thermal Power Station Ondo State **335MW**	Gbarain/Ubie Thermal power station Delta State **250MW**	AGIP Okpai **480MW**	Obajana Thermal Power Station **350MW**
Sapele Thermal Power Station Delta State **1,020MW**	Papalanto Thermal Power Station Ogun State **335MW**	Sapele Thermal Power Station Delta State **500MW**		Ibom Thermal Power Station Akwa-Ibom State **188MW**
Delta Thermal Power Station Delta State **912MW**	Alaoji Thermal Power Station Abia State **504MW**	Ikot Abasi Thermal Power Station Akwa-Ibom State **300MW**		
Ijora Thermal Power Station Lagos State **40MW**		Eyaen Thermal Power Station Edo State **500MW**		
Kainji Hydro Power Station Niger State **760MW**		Egbema Thermal Power Station Imo State **350MW**		
Jebba Hydro Power Station Niger State **578.4MW**		Calabar Thermal Power Station Cross-River State **500MW**		
Shiroro Hydro Power Station Niger State **600MW**				
Total = 6200MW	**Total = 1588MW**	**Total = 2500MW**		**Total = 688MW**

By statistics, 62.5 percent of the existing power plants are powered by natural gas while 37.5 percent is hydro generated. As can be seen from the table above, all the

ongoing and proposed power plants are 100% gas fired power stations. This strongly contends with the fact that renewable energy is considered in Nigeria for Power generation. As this is the fact, environmental issues are neglected while siting and proposing the thermal power plants all over the country.

In February, 2006, PHCN recorded 600 MW loss in power generated due to pipeline vandalism. Sequel to this, the Nigerian Gas Company embarked on emergency maintenance which caused them to shut down all its gas supply to power plants [Makoju, 2006]. This brought all the thermal power station in the country to zero output. This is just one out of many occurrences.

The fuel cost is another factor that challenges the gas power plants. The fuel cost component of the electricity produced depends on both the thermal efficiency and the cost of the fuel itself, together with the cost related to the fuel consumed – such as the transportation/transmission, reprocessing and waste charges. These costs are roughly directly proportional to the amount of power produced rather than a function of the capacity factor [Hicks, 1986]. With the above inefficiencies, this document has been developed to consider another power generating alternative from an economic point of view.

Harnessing power from the Inga Dams of Congo is the option that has been selected for this research work.

2.6 Nigerian Gas and Hydropower Systems versus Inga Power Project: A Comparative Study

In summary, in the early 60's when the first hydropower station (Kainji dam) was commissioned in Nigeria, the power demand of the electricity consumers was well met. Though the dam was designed to give an output of 960 MW, 800 MW that was the installed capacity was sufficient. Due to the geometric increase of population growth, industrialization, rural/urban water schemes, sahelian drought, irrigation activities, water level and seasonality effects, the Kainji power system was forced to operate far well below its installed capacity. To proffer solution to the ill effect, Shiroro and Jebba dams were completed in 1990 by the

government of Sani Abacha. During this period, some other power stations were built at federal and state levels. At federal levels, the Egbin and Afam thermal power stations were oil fired while the Oji River thermal power station was operating on coal.

On discovery of crude oil, the Egbin and Afam power stations were converted to gas fired stations with some of its unit abandoned due to the new system incompatibility. The gas that was used in these power stations is associated crude oil gas that would have been flared. The wake of crude oil discovery affected the Nigerian Coal Cooperation hence giving reasons for the dearth of the Oji River thermal station. Before the President Obasanjo's regime, the total national power output was standing at 2617MW (Egbin – 1320 MW, Afam – 969 MW, Kainji – 760 MW, Jebba – 578 MW and Shiroro – 600 MW). At this point in time, the national power demand was already standing at 6,000 MW. The magnitude of the load demand was thus under evaluated as most of the mega factories like multinational oil companies are running on independent power supply. To meet with the increasing power demand, the government built more power stations giving an approximate output of 2,000 MW (Sapele – 1,020 MW, Delta – 912 MW and Ijora 40 MW). All are gas fired power plants. The total installed output was put close to 6.5 GW.

From table 2.4 above, more power stations are under construction, feasibility studies and proposed. By statistics as given above, 37.5% of existing power plants in Nigeria are hydro powered while the rest 62% are gas fired. The ongoing and proposed projects stand at 100% gas fired stations. It is pertinent to note that while all the hydropower stations are supplying about 90% of installed capacity at high water level season the gas power plants supplies below 50% of its installed capacity at all seasons. The downtime of the gas power plants has been confirmed to be attributes of gas pipeline vandalism and worst still the ever increasing cost of gas supplied to the power plants. Even when an electricity subsidy of 177 Billion Nigerian Naira has been provided by the federal government under

the NERC MYTO[6] initiative for the next three years [Owan, 2008], PHCN still battles with a whooping dept of 11.5 Billion Nigerian Naira accruing from the cost of gas supplied to the thermal power plants by the NGC.

The idea of using gas fired power plants to generate electricity in Nigeria is not to be totally condemned but owing to the very fact that the early gas power plants were put up due to the low utilization of natural gas in the early 90's when gas were flared, the discovery of new technologies should give reasons why alternative source of power supply in provided. Large hydro systems potentials within the country have been marginally harnessed hence; the alternative solution to use a sustainable and renewable energy is harnessing the under-harnessed bulk of hydropower potentials lying in the Inga falls of the river Congo.

Construction of larger dams would have been an alternative to boost the hydropower potential in the Nigerian National Dams, but the larger the dams the more environmentally vulnerable it becomes. While the Nigerian National Dams depend on water storage reservoir system (dam) to sustain its efficiency, the Congo River with its low drought characteristics and natural 102m water falls at the Inga site uses run-of-the river with shallow dams supporting the use of renowned Francis high efficiency water turbines.

2.7 Conclusion

With the conviction of the limitations of the Nigerian National Dams potential and subsequent challenges, this research work will in further chapters evaluate the economic advantage of the Inga hydropower supply system and the dominant gas fired power system as found in the present Nigeria. The economic evaluations will involve the some fundamental calculations of generating Cost of Energy in hydro and gas power plants, using the Net Present Values, Internal Rate of Return and cash flow trend analysis.

[6] A Nigerian Federal Government subsidy initiative implemented through NERC known as Multi Year Tariff Order aimed at *spreading likely increase in tariff over a given period in a way that consumers will not experience tariff shock.*

Chapter Three

Empirical Investigation

3.0 Chapter Overview

This research work has been developed to measure the economic viability of Hydropower scheme from Inga site of the Congo Democratic Republic. In Nigeria, the use of Gas turbines to generate electricity is a normal practice. The research work has been formulated to measure the economic viability of the gas power plant in Nigeria against the Congo hydropower option.

Economic viability means the measure of degree to which a project is justified to yield an income. If the benefit of the project outweighs the cost, the project is classified to be economically viable. Invariably, if the cost outweighs the benefit, the project is classified as non-profitable hence, economically non-viable.

A comparative model for the viability study has been developed in a spreadsheet format for the measurement of the viability of the two scenarios. The spreadsheet was developed to present procedures towards achieving the desired result. As a comparative study, the work will be compiled in a sequential procedure from gathering past related information, viability model application, result presentation, conclusion and recommendations.

3.1 Data Gathering

A certain procedure was employed in the data gathering of this research work. Firstly, from what is required to accomplish the work, the sources of information were divided into two parts; the primary data and the secondary data source. The primary data source includes all the information gathered from directly concerned institutions. The primary sources are data gathered from Power Holding Company of Nigeria (PHCN) PLC, The Nigerian Gas Company (NGC), Societe Nationale D'Electricite, CongoDR (SNEL). Example of data gathered are in-house journal of the organizations, interview with relevant personnel of the institutions, information gathered from their official websites, books from the

primary source's library and some of the verified projects that are related to the subject matter of this work.

On the secondary level, other data and information were collected. Such data are open literature published on the websites, publications and documents on the subject matter, relevant information as published by some professional organization that are of proven standard as it regards the topic under study. Adequate care was taken to read through most of the document used in the development of this research work. Some of the data collected helped to give some basic principles that guided in the development of this work. The source also made it easier to access information that gave insight on the work that has been done so far in the area of interest as it relates this research work. Other secondary sources are data collected as documents published by New Partnership for African Development (NEPAD), Energy Information Administration (EIA), Canada Energy Research Institute, World Energy Council, US Army Corps of Engineers, African Development Bank (AfDB), ESKOM off South Africa and many more.

3.2 Research Approach

With the current challenges facing the power sector in Nigeria, Congo-Nigeria Superhighway Grid was chosen for study as an option of solving the power problem. In Nigeria, there are basically two approaches employed in power generation schemes. They are Hydropower Systems and Gas Turbine plants. The Hydropower plants in Nigeria are faced with the challenges of drought, intensive irrigation, and other hydrological factors as presented in the literature survey. These problems facing the hydro systems were characterized to have some limitations which hinder the efficient harnessing of energy from the Kainji, Shiroro and Jebba hydropower plants. These limitations gave rise to the conventional gas power plant that dominates the system of generating electric energy in Nigeria.

However, since the adoption of gas power plant in Nigeria as a major source of generating electric energy, economic concerns gave rise to the development of this work. This research work has been designed to compare the economic viability of harnessing electric energy through the gas power plants against the importation of energy from the 39,000 MW Congo Hydropower project. The 4000 Mw (phase 1) was considered for the analysis.

With the survey conducted in this work, gas power plant in Nigeria is posed with some economic issues. Such issues include the economic effects of subsidies paid by government to cushion the cost of generating electricity, the effect of the plant availability to stable energy supply, the environmental issues that are economically related and impact of regulated price of gas supplied to the power plants.

Invariably, importation of energy through the Congo-Nigeria transmission grid has been a better option to the conventional gas power plant. For this reason, an economic viability model has been developed to measure the economic advantage of the Congo hydroelectric power system over the dominant gas power plant in Nigeria.

The research work will cover only a limited area. It will be based on economic viability of the two systems. Other related research areas will be provided for further research.

3.3 The Comparative Model Technique

The NILC model is an economic viability tool which makes use of four standard tools for the measurement of power plant viability. It makes use of the determination of Net Present Value, Internal Rate of Return, Levelized Cost of Energy and Cash Flow Trend Analysis. The model which is an economic comparative tool is developed in a spreadsheet format such that the entire plant life and discounted value of money are considered. For this study, it can also be referred to as spreadsheet model.

In the economic viability study, the entire plant life was taken into consideration. The Cost of Energy, Cash Flow Trend Analysis, Net Present Value, and Internal Rate of Return were all measured across the entire plants life cycles. The aim of the life cycle consideration was to reflect the effect of discounted value and inflation in the values achieved.

A spreadsheet format of the values calculated was developed to show process of achieving results and attached as appendices. The spreadsheets portrayed the cash flow analysis which showed the discounted values of money, cash inflows, cash outflows, net electricity generated per year per life cycle and profits made per year. The Cash Flow Trends presented were determined from the spreadsheet and represented graphically as a break-even trend equivalent of the two power plants. The results achieved from the two power plants were measured with equal standard so as to reflect the economic benefit of one power plant over the other.

Furthermore, parameters that cannot be directly measured mathematically were also considered for the viability test. Some of the parameters are the effects of Multi-Year Tariff Order on the cost of gas power plant investment and operation costs as well as economic-environmental related issues such as cost of gas plant retrofitting.

All the parameters measured in the economic viability study were presented in the result presentations section. Other economic values were measured, collated and finally used to determine the degree of viability of the two power plants. The two power plants selected for economic viability measurement were critically analyzed. The result showed the economic advantage of the hydropower plant over the gas power plant as suggested by this research.

3.4 Result Validation

The economic viability studies carried out on the two power plants selected were measured for result validity. A standard economic threshold was used to measure the economic quantities. Verified sources of document were also used for

procedure and result validation. The result thresholds that was used are as described below.

For the Net Present Value, if the value is less than zero, then the project will be classified non-viable. If the value is greater than zero, the project will be classified as viable. The project with the greater NPV will be admitted to be viable over the one with a less figure.

In the case of the Internal Rate of Return that was determined, the project with the greater percentage was considered to be more economically viable than the plant with a lower value of IRR.

The cost of energy generated with the two technologies was measured against established standards. The cost of energy generated is expected to be within the range of the acceptable cost as provided by the World Energy Commission Assessment. Moreover, the system with the less cost of generating energy will be considered more viable.

To justify the technique used in the viability process, an existing project was referenced. The reference is expected to have employed the same technique in the viability measurements. Formula used was as determined by the Energy Information Administration, and other institutions with acceptable model techniques.

3.5 Conclusion

From the data gathered, the economic viability tool introduced in this chapter will be used to measure the economic quantities of the two power options selected for studies.

Chapter Four

Empirical Evaluation and Economic Analysis

4.0 Chapter Overview

For any economy, electrical energy is very important. The choice of selecting power plant is a rigorous process. There are many factors that must be considered in the choice of power plant. Such factors are economic, environmental, social and political aspects. One of the major factors is the economic factor. The use of economic viability tool is an indispensable technique for choice of selecting power plants. This chapter deals with only the economic viability studies of two power plants under review.

There are many tools that can be used for the economic viability analysis of a project. For the purpose of this work, a spreadsheet model has been developed for estimating the viability degree of two power plants (Conventional gas power plant in Nigeria and the Congo-Nigeria power import option). The comparative model developed in the spreadsheet format is intended to measure the Net Present Value (NPV), Internal Rate of Return (IRR), Levelized Cost of Energy (LCOE) and Cash Flow Trend Analysis. The fundamental calculations will be presented in this document while the in-depth analyses are presented in the spreadsheet.

However, there are some literatures that have been presented, like the investment cost of developing the Congo Hydropower plant. There is also an existing model developed by Obikwelu for the estimation of the cost of a gas power plant. The available literature and Obikwelu's model did not put into consideration such aspect of economics like discounted value of money. The information provided by these two sources will provide some fundamental figures like the quantity of generated energy and gas consumption cost analysis.

4.1 Definitions of Relevant Terms

Overnight Cost: According to Wikipedia free encyclopedia, "overnight cost is the cost of a construction project if no interest was incurred during construction, as if the project was completed "overnight." An alternate definition is: the present

value cost that would have to be paid as a lump sum up front to completely pay for a construction project. The **overnight cost** is frequently used when describing power plants. The unit of measure typically used when citing the overnight cost of a power plant is $/kW. For example, the overnight cost of a nuclear plant might be $1200/kW, so a 1,000 MW plant would have an overnight cost $1.2 billion". (Interest on the $1.2 billion spent during construction would be extra.)[Wikipedia, 2008]

Levelized cost of Energy: The present value of the total cost of building and operating a generating plant over its economic life, converted to equal annual payments is known as Levelized Cost of Energy. [EIA, 2008]

"Levelized Cost of Energy is a measure of total costs of a system (over its expected lifetime) divided by the expected energy output (over its useful lifetime), with appropriate adjustments for time, value of money, etc". [Wikipedia, 2008]

Amortization is the gradual elimination of a liability in regular payments over a specified period of time. For instance, mortgage. Such payments must be sufficient to cover both principal and interest components. [Investor Words, 2008]

"**NYMEX Market Data**" means information and data pertaining to futures contracts and options contracts traded on New York Mercantile Exchange, Inc. and its subsidiary, Commodity Exchange, Inc. ("NYMEX"), that includes opening and closing range prices, high-low prices, settlement prices, current bid and ask prices, last sale prices, price limits, requests for quotations, estimated and actual contract volume data". [nymex.com, 2008]

4.2 Economic Analysis of a Gas Power Plant

The economics analysis of a gas power plant as limited in this document is the calculation of the parameters that will measure the viability of the power plants under study. To accurately achieve a comparative analysis of the two power

plants selected, evaluation will be done based on equal size of plants in both scenarios. Hence, the size of power plant evaluated in this document will not necessarily be the capacity that will stabilize the power demand in Nigeria but can at least justify beyond reasonable doubts the generation technology that is best practiced. The choice of plant will be based on the economic evaluations to be done.

4.2.1 Domestic Natural Gas Consumption

Figure 2.3 shows that domestic natural gas demand is approximately 50% of natural gas exported. From the figure, it is shown that domestic natural gas consumption stands at Ten Thousand Million Standard Cubic Feet (10,000 mmscf). First quarter 2008, power generation consumes over 70% of the total gas supply for local consumption [NGC, 2008]. Also from the table below, shows the potential and existing gas consumers in Nigeria.

Table 4.1: Natural Gas Projects in Nigeria

Commercial Customers in Nigeria					
S/N	**Customer**	**Application**	**Location**	**Gas Requirement (MMSCF/D)**	**Link Diameter (Inches)**
1	UNICEM	Fuel	Calabar	64	14
2	Calabar Free Trade Zone	Fuel/Feedstock	Calabar	20	-
3	Total Support	Fuel	Port Harcourt	1	-
4	ICS Power	Fuel	Alaoji	134	24
5	SUPERTEC IPP	Fuel	Akwete	250	24
6	INDEX Thermal	Fuel	Onne	450	36
7	Energy Soft Solution	Fuel	Nkwelle Ezunnaka	250	24
8	LYK/Ibom Power	Fuel	Ikot Abasi	84	16
9	Owerri Industrial	Fuel/Feedstock	Owerri	50	14
10	NAFCON 2	Feedstock	Onne	20	-
11	PHCR	Fuel	Port Harcourt	3.5	-
12	DRAKE Projects	Fuel/GTL	Obigbo	200	24
13	BOSKEL	Fuel	Port Harcourt	0.01	-

14	BCC	Fuel	Gboko	4	-
15	Oku Iboku Paper Mill	Fuel	Okuiboku	18	-
16	Aba Phase II	Fuel	Aba	5	-
17	Nkalagu Cement	Fuel	Nkalagu	33	12
18	Dangote Cement	Fuel	Obajana	90	18
19	NEPA Geregu	Fuel	Geregu	210	24
20	NEPA Omotosho	Fuel	Omotosho	84	26
21	Abuja IPP	Fuel	Abuja	250	24
22	NEPA Papalanto	Fuel	Papalanto	84	12
23	NEPA Kaduna	Fuel	Kaduna	100	24
24	Ikorodu Industries	Fuel/Feedstock	Ikorodu	10	-
25	Benin Industries	Fuel/Feedstock	Benin	11	-
26	Warri Industries	Fuel/Feedstock	Warri	5	-
27	Lekki Methanol	Feedstock	Lekki, Lagos	200	24
28	ROCKSON Engineering	Fuel	Sapele	750	36
29	Madewell Products	Fuel	Jesse	700	36
30	West African Well Services	Fuel	Warri	3	-
31	Edo State IPP	Fuel	Eyean	12	-
32	Delta State IPP	Fuel	Oghara	12	-
33	WEMPCO	Fuel	Ibafo/Ogere	5.07	-
34	UNICLAY	Fuel	Lapeleke	0.25	-
35	13M Power	Fuel	Ibafo	56	-
36	Andre Robins Limited	Fuel	Lekki, Lagos	173	24
37	Alliance Energy	Fuel	Kwara	126	20
38	Khombinded Energy	Fuel	Ogun	60	-
	TOTAL			4467.83	

Source: Nigerian gas Company, 2008

Legend

	Power Plant
	Industrial Uses

From the table above, gas consumption of a particular size of power plant can be determined by iterating the gas consumption magnitude to corresponding size of plant in Table 2.4. For instance, the Geregu Power station will produce 828 MW

(Phase I and II = 414 MW each) [afdevinfo.com, 2008] of electricity at 1.0 plant availability factor and consumption of 210 million metric standard cubic (MMSCF) of gas per day; Omotosho power plant will produce 335 MW of electricity at 1.0 plant factor and consumption of 53 MMSCF; Thirdly, Papalanto power plant will produce 335 MW of electricity at 1.0 plant factor and consumption of 53 MMSCF.

Mathematically, Using this three power plants to measure the amount of natural gas per Megawatt of electricity (MWe) per day

- **Case 1: Geregu Power Station**
  828 MW (Phases I and II) consumes 210 MMCF
  Therefore, 1 MW consumes 3.94 MMCF of natural gas per day.
- **Case 2:**
  335 MW consumes 84 MMSCF
  Therefore, 1 MW consumes 3.99 MMCF of natural gas per day.
- **Case 3:**

  335 MW consumes 84 MMSCF

  Therefore, 1 MW consumes 3.99 MMCF of natural gas per day.

From the above, it can be deduced that the amount of natural gas to generate 1 MW of electricity per day is given as approximately 4.0 MMCF (Million Standard Cubic Feet).

4.2.2 Gas Power Plant Generation Unit Cost Model [Obikwelu, 2006]

According to Obikwelu, Generation Unit Cost Model (GUC Model) is an alternative model used in evaluating the cost of gas power plant, cost of energy in $/kWh, plant capital cost, indirect cost, expected revenue yielding energy, cost of operation and maintenance based on the plant capacity characteristics. The model lacks the use of discounted values but can be used to generate some fundamental quantities applied in the spreadsheet comparative model developed for this work.

4.2.2.1 GUC Model Application Using 4,000 MW Gas Power Plant

1.) Capital cost

[a] Cost of Gas Turbine at $350,000.00 per MW capacity = 350,000.00 x 4, 000 = 1, 400, 000, 000 = $1.4 billion USD.

[b] Cost of capital at 10% Cost of Gas Turbine

$1.4 billion x 0.10 = $140Million USD

Total Capital Cost = $1.54 Billion USD.

2.) Operating Cost

[a] Yearly cost of personnel at 3% cost of gas turbine [world Bank Recommendation]

$1.4 billion x 0.03 = $42 million

[b] Yearly Cost of Maintenance at 4% cost of Gas Turbine

$1.4 billion x 0.04 = $56 million

[c] Overhaul Cost to be incurred every 4 years at the rate of 4% cost of Gas Turbine

$1.4 billion x 0.04 = $56 million.

Hence, equivalent yearly cost accruing from overhaul

$56 million/4 = $14 million

[d] Facility Cost (FC) per year at 1% cost of Gas Turbine

$1.4 billion x 0.01 = $14 million

[e] Yearly consumption of natural gas:

Daily consumption is given by (4.0 x 4,000MW) = 16,000MMCF

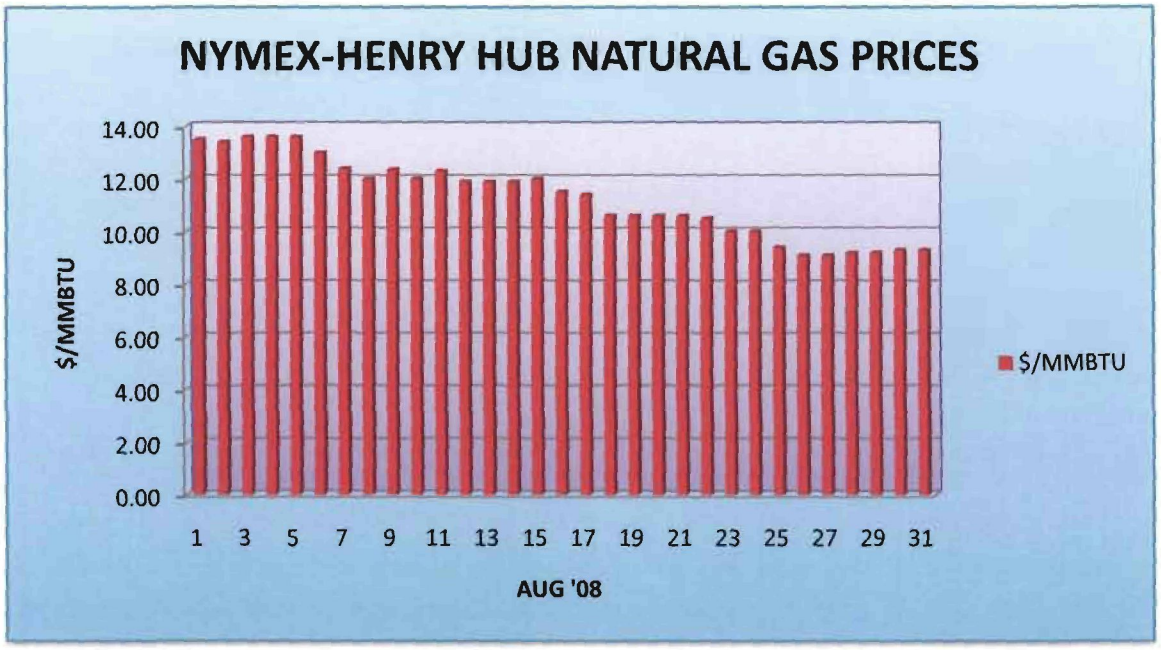
Therefore, yearly consumption is at full operating capacity = 16,000 x 365 = 5,840,000 MMCF of natural gas.

The gas plant is not expected to be running at maximum efficiency. Therefore, the availability index (plant factor) for a gas power plant assumed is 75% [Royal Academy of Engineering, 2004].

Hence, total yearly consumption of natural gas = 16,000 x 365 x 0.75 = 438,000 MMCF.

[e] Yearly Cost of natural gas = 438,000 MMCF x n; (let n be cost of natural gas in SCF)

Figure 4.1 NYMEX-Henry Hub Natural Gas Prices



From NYMEX Henry Hub Natural Gas Daily Price (Figure 4.1), the average cost of natural gas per Million British Thermal Units is $11.204. But one standard cubic of gas is 1 MBTU. ie., 1 SCF = 1 MBTU.

Therefore cost of natural gas consumed by the plant in one year = 438000 x 11.204 = $4,907,352.

For a proper siting of the project, the Nigerian economic environment is to be considered since all the gas supplied to the gas turbines is locally sourced. The cost of natural gas is at N67.63 per standard cubic unit in August 2008 [Alike, PPMC 2008]. It is considered that standard cubic unit is one thousand cubic feet. That is N/MSCF = N67.63 = 67.63/120 = $0.56[7]. $/MCF = $0.56.

The cost of gas in Nigeria is far cheaper than the international prices due to proximity to raw materials, Multi-Year Tariff Order (**MYTO**) program, subsidization and other economic factors.

Local cost of natural gas consumed by the plant = 438,000 x $0.56

= **$246,849.5**

Therefore total yearly cost (Yc) of running the 4000MW gas turbine is given as ${[yearly cost of gas turbine + yearly cost of personnel + yearly maintenance cost + yearly overhaul cost + yearly facility cost] + yearly cost of gas}

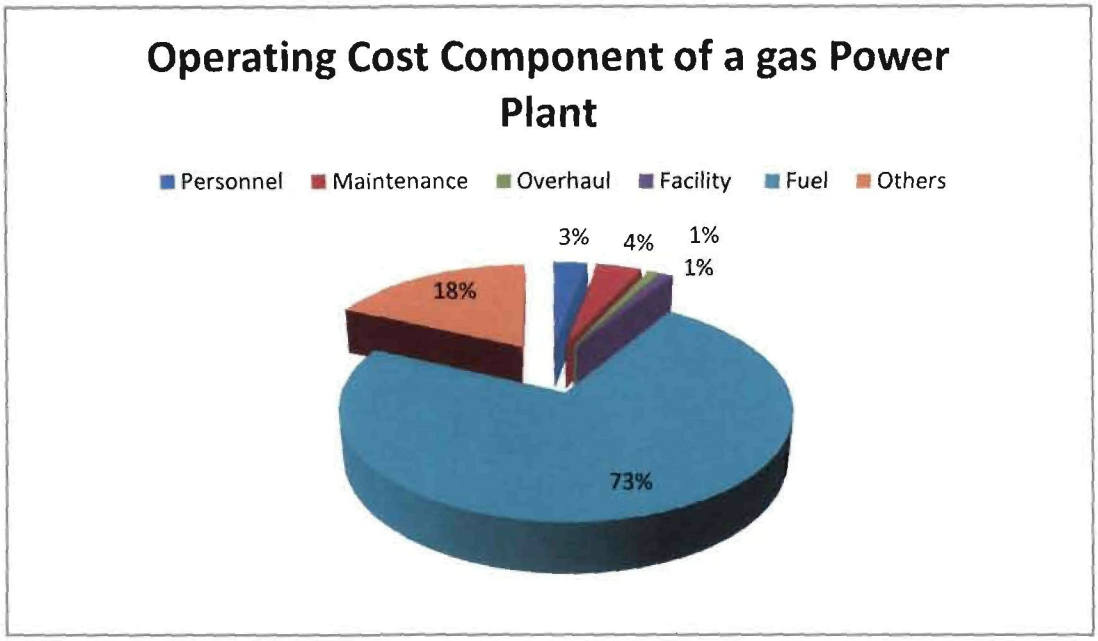
Yc =$90 Million

Table 4.2: Operating Cost Components of Gas Power Plant [Obikwelu, 2006]

Component	Percentage
Cost of Personnel	**3**
Cost of Maintenance	**4**
Overhaul Cost	**1**
Facility Cost	**1**
Fuel Cost	**73**
Others	**18**

[7] It is assumed that $1 is 120 Nigerian Naira (N) equivalents.

Figure 4.2: Operating Cost Component of a Gas Power plant



3). Expected Revenue-yielding energy

Expected total Energy Generated (**Eg**) in a year at 75% plant factor,

Eg = 4000 x 24 hr/day x 365 days/year x 0.75 x 1000 kW/MW

= 26,280,000,000 kWh/Annum

The auxiliary equipments, line losses and power supplied to staff residents and offices accounts for parasitic losses. This is assigned 2.5% of total energy generated.

Parasitic losses = $26.28 billion x 0.025 = 657,000,000 kWh/Annum.

Therefore, power supplied to the national grid = $(26280 \times 10^6) - (657 \times 10^6)$

= 25,623 MWh/Annum

4.3 Economic Analysis of Congo-Nigeria Hydropower System

The basic purpose of economic analysis is to provide a general estimate of the potential power benefits and the costs of a project, and reasonable alternatives to project selection [Robert, Bruce, et al, 1998]. The analysis helps to support an informed decision concerning what is in the public interest with respect to a proposed power project. In the context of hydropower planning, benefits are the goods and services produced by the development and costs are the goods and services used in the construction and developmental maintenance. There are lots of factors that attract attention in economic evaluation of hydropower plant. Inflation rate, discount rate, plant life cycle, salvages value, rate of return, cost of generating and selling energy are examples of such factors.

However, the Inga financial particulars have not provided information beyond the pre-feasibility studies. The economic viability study will depend on the EIA standard of measurements. Such standards will include estimations of cost based on overnight costs and cost per MWh.

4.3.1 Expected Revenue Yielding Energy

The hydropower plants tend to be more stable than the other power generating options. Sequel to this, the plant factor is considered to be as high as 95% [WEC, 2007]. There is usually little or no outage from the hydropower plants.

Hence, the expected Power Output or Energy Generated (**Eg**) per annum is given by;

Eg = 4000 x 0.95 x 24 hrs/day x 365 days/annum x 1,000 kW/MW

Eg = 3.3288×10^{10} kWh; = 33, 288 MWh/Annum

Transmission line losses, generator loss, auxiliary power supply are assumed to account for the entire parasitic loss. This parasitic loss is assumed to account for 2.5% [Obikwelu, 2006].

Parasitic Loss = 0.025 x 33.288 billion = 832 MWh/Annum

Therefore, the real Energy Generated per annum is given by;

33,288,000,000 – 832,200,000

Eg = 32,455 MWh/Annum

4.4 Economic Viability Studies Using NILC Model

The above estimations made in subsections **4.2** and **4.3** above are used to generate some parameters that will be applied in the NILC model.

The NILC model will generate values of Net Present Value, Internal Rate of Return, Levelised Cost of Energy and Cash Flow Trend Analysis. The values that will be presented below are output of the model. Uniform formats are used for the two power plant scenarios. Process of achieving results will also be presented for the first year of plant useful life.

This section has been divided into two major categories: the Gas Power Plant Analysis and the Hydropower Plant Analysis. The Gas power Plant has been assigned a useful life of 30years while that of hydropower plant is 40 years for the purpose of this study.

Fundamental Assumptions:

- A discount rate of 12% is used for the purpose of this study.
- Where the cost of investment as given by open literature is not justified, IEA overnight cost standard is applied.
- The exchange ratio used for US Dollar: Nigerian Naira is $1: N120.
- An increased in cost of gas is assumed to be 2% annually.
- It is assumed that the plant capacity factor is constant throughout the entire life cycle of the plant.
- The Selling Cost of Energy, SCE is N6.00 = $0.05 [NERC, 2008]
- The Selling Cost of Energy is assumed to rise in proportion to the cost of fuel per annum. Hence, 2%.
- United States Dollars were used for analysis unless where otherwise stated.
- Salvage value is assumed to be zero.

4.4.1 Levelized Cost of Energy

The cost of energy involves the cost of generating a unit of electric energy measured in $/kWh. The cost of generating a unit of energy will aid in the determination of selling cost per unit (tariff) of energy generated. The selling cost will enable an investor to determine the breakeven point. The amortization period can equally be estimated through the selling cost.

When calculating the costs of electricity generation it is necessary to keep in mind the structure of the investment, their financing costs, as well as the fuel costs. The levelized cost of the production unit quantifies the unitary cost of the product generated during the facility lifetime; and allows the immediate comparison with the cost of other alternative technologies.

According to Javier et al, we can say that the costs of the kWh consist of fixed costs that are generated due to the investment to build the power plant and variable costs that are proportional to the produced energy. In this study we make use of the methodology of standard calculation of levelized cost of energy by EIA. For that, costs corresponding to investment, fuel and operation and maintenance are considered.

According to Energy Information Administration (EIA), standard of estimating the cost of electricity generated by a power plant has been developed. It is achieved by taking the ratio of the cost of the power plant over its entire life cycle to the net electricity generated measured in MWh or kWh. The Cost of Energy (COE) also involves putting into consideration the annuity values as well as the discount rate and the duration of the plant useful life measured in years. This ratio is given by:

$$COE = \frac{\text{Total Plant Life Cycle Cost}}{\text{Net electricity generated}}$$

A mathematical representation of the above quantity has been developed which enables one to determine the cost of energy at a given year and given discount rate within the power plant life. This approach involves spreading the component costing of the power plant into annuities. Hence, for one to determine the actual cost of energy generated per kWh, one has to determine the discount rate, O&M cost as well as forecast of cost of fuel over the entire life of the plant. The approach of calculating the COE brings annualizing factor into play. The annualizing factor is otherwise known as the Capital Recovery Factor (CRF). The CRF distributes the known present value into equal quantities over the entire plant life. The CRF also brings into play the discount rate. The Capital Recovery Factor is given by:

$CRF = [i(1+i)^n] / [(1+i)^n - 1]$ where i = interest rate; n = no of annuities

Where Annuity (A) = Present Value X CRF.

However the mathematical representation of the Cost of Energy as given by International Energy Agency is:

$COE = \Sigma [(I_t + M_t + F_t)(1+i)^{-t}] / \Sigma [E_t (1+i)^{-t}]$

Where: I_t = Investment expenditures in the year t

M_t = Operations and maintenance expenditures in the year t

F_t = Fuel expenditures in the year t

E_t = Electricity generation in the year t

i = Interest or Discount rate

4.4.1.1 The Gas Power Plant Cost of Energy

It is pertinent to note that the gas power plant henceforth refers to the gas power plant introduced in section **4.2** of this chapter. The Cost of energy calculated spans throughout the entire plant life cycle. The cost of energy estimation for year 1 demonstrates the procedure for the remaining years of the plant life. The cost of

energy over plant life is as tabulated in a spreadsheet format as found in ***Appendix B.***

From the assumptions made above, the Cost of Energy in a gas power plant is as given below:

$$COE = \Sigma [(I_t + M_t + F_t)(1+i)^{-t}] / \Sigma [E_t (1+i)^{-t}]$$

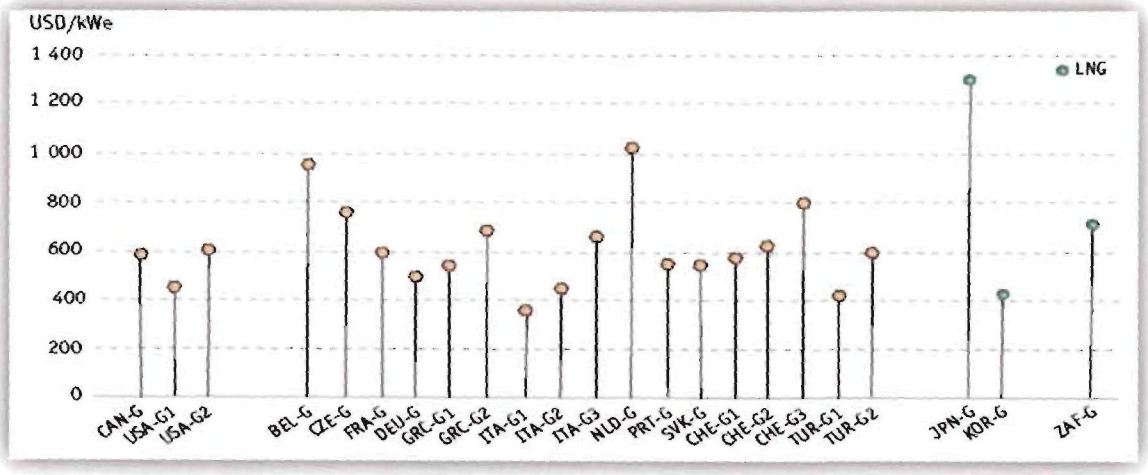
The Annualized Investment cannot be determined without first of all determining the Capacity Recovery Factor (CRF) and the overnight cost of a gas power plant.

$CRF = [\, i(1+i)^n] / [(1+i)^n - 1]$ where i = 12%; n = number of annuities = 30 years

$CRF = 3.59/28.96$

$CRF = 0.12$

Figure 4.3: Specific Overnight Construction Costs of Gas-fired Power Plants (USD/kWe)



Source: IEA 2005 Cost of Energy

From figure **4.3** above, the average overnight cost per kWh of a gas power plant is $700

The investment cost will be given as;

TCR = $700/kW x 4,000 MW x 1,000/kW = 2.8 billion USD.

The Annuity value (A) of the investment cost is then given as;

A = CRF x TCR = $347,592,000

The O&M cost = 4% of Investment cost = 0.04 x $2.8 billion

O&M = $112,000,000

Fuel Cost = 438,000 x 0.56 = $246,849.5

Therefore, Cost of Energy generated for the first year is given as;

$COE = [(I_t + M_t + F_t)(1+i)^{-t}] / [E_t(1+i)^{-t}]$

$COE = [(347,592,000 + 112,000,000 + 246849.5)(1 + 0.12)^{-1}] / [25,623,000,000 \text{ kWh } (1 + 0.12)^{-1}]$

COE = $0.018/kWh

Or **COE = Cents1.8/kWh** for the first year of operation.

From ***Appendix B***, considering the entire plant life and discount rate, the Levelised cost of energy for a gas power plant in Nigeria is **$0.022/kWh**

LCOE = Cents2.2/kWh

4.4.1.2 The Hydropower Plant Cost of Energy

For the purpose of this study, the Congo-Nigeria Hydropower project shall henceforth be addressed as hydropower plant in this chapter. The same model applied in subsection **4.4.1.1** is applied for hydropower plant in the calculation of the cost of energy generated. The calculation involved with the cost of energy generated for the first year of operation of the plant is as demonstrated below which will serve as a basis for estimating the COE parameters presented in ***Appendix C.*** Table 4.3 below gives a guide for evaluating the overnight and maintenance cost of hydropower plant.

Table 4.3: Large Hydro Cost, Resources and Performance (Facilities of 30MW and Above) [Source, EIA 2007]

	2008 Peak value	2020 reference case value (in 2008$)	2020 tech growth case	Range of 2008 values in model	Sources
Base overnight capital cost ($/kW)	$2402	$2,402	$2,402	**$1,122** - $2,193	Reference case: [EIA, 2007] Tech growth case: [Assumed no change.] Range of values: [EIA site data, 2007]
Base Non-Fuel Variable O&M ($/MWh)	$3.55	$3.55	$3.55	**$1.30** - $2.64	[EIA site data, 2007]
Base Fixed O&M ($/kW-yr)	$14.15	$14.15	$14.15	$5.28 - $12.96	[EIA site data, 2007]

Applying the same principle as in the gas power plant;

The Hydropower cost of energy is given as;

$$COE = \Sigma [(I_t + M_t + F_t)(1+i)^{-t}] / \Sigma [E_t (1+i)^{-t}]$$

For the hydropower plant, the Capacity Recovery Factor (CRF)

$CRF = [\, i(1+i)^n] / [(1+i)^n - 1]$ where i = 12%; n = no of annuities = 40years

CRF = 11.16/92.05

CRF = 0.1213

From **Table 4.4** above, the average overnight cost per kWh of a hydropower plant is $1,122 [as projected for year 2008]

The investment cost will be given as;

TCR = $1,122/kW x 4,000 MW x 1,000/kW = $4,488,000,000= $4.5billion

The Annuity value (A) of the investment cost is then given as;

A = CRF x TCR = $544,394,400

According to the EIA standard, the O&M cost for Base Non-Fuel Variable (BNFV) O&M ($/MWh) is $1.30/MWh

From the expected revenue yielding energy, the total annual power output for a 4000MW hydropower plant at 95% plant capacity factor is given by;

Eg = 32,455,800,000/1,000 = 32,455,800 MWh

Therefore, the O&M cost = 1.30 x 32,455,800 = $42,192,540/Annum

Fuel Cost = $0.00 [for hydropower requires no fuel]

Therefore, Cost of Energy generated for the first year is given as;

$COE = [(I_t + M_t + F_t)(1+i)^{-t}] / [E_t(1+i)^{-t}]$

$COE = [(544,394,400 + 42,192,540 + 0)(1 + 0.12)^{-1}] / [32,455,800,000 \text{ kWh}(1 + 0.12)^{-1}]$

COE = $0.018/kWh

Or COE = **Cents1.8/kWh** for the first year of operation.

From ***Appendix C***, considering the entire plant life and discount rate, the Levelised cost of energy for a hydropower plant in Nigeria is

$0.019/kWh

LCOE = Cent1.9/kWh

4.4.2 The Net Present Value Analysis

The value of money varies down the year. Power plants are designed to have a useful life of 20 years and above. The life cycle of plant depends on the technology of operation. As used in this document, the gas power plant is designed to last for 30 years while that of hydropower plant is 40years. 500-dollar equipment may cost $700 dollars in three years time due to inflation, discount rates and some other economic factors. Therefore, $500 invested this

year is greater than same amount invested in the next three years due to a time value of money that is a function of Net Present Value of money.

If a plant has been designed to have a useful year of 40years, the cost and benefit of the plant is calculated based on the present worth. If the present value of the plant is estimated within a given span of time, the present value thus determined is known as the Net Present Value (NPV). This is an important aspect of economic viability analysis. NPV help to determine the actual cost/benefit quantities of a project. A good instance is the cost of $10/MCF of gas today will rise to $11/MCF if the increase in cost of gas has risen by 10% over the period under review. There is a mathematical formula for the calculation of NPV which is given by;

$$\text{NPV} = \sum_{t=0}^{N} \frac{C_t}{(1+r)^t} + \mathbf{SV}$$

Where

t - the time of the cash flow measured in years

N - the total time of the project (project useful Life)

d - the discount rate (the rate of return that could be earned on an investment in the financial markets with similar risk.)

Ct - the net cash flow (the amount of cash) at time t.

S – Salvage Value

Therefore, NPV for N years is given as;

The Net Cash Flow, Ct is the difference between the Revenue/Cash Inflow, CI and the Cash Outflow (Operating Expenditure), OPEX.

Ct = CI - OPEX

$$\text{NPV} = -ICO_0 + \frac{C_1}{(1+d)} + \frac{C_2}{(1+d)^2} + \ldots + \frac{C_{N-1}}{(1+d)^{N-1}} + \frac{C_N}{(1+d)^N} + SV/(1+d)$$

Table 4.4: NPV Threshold of Measurement

Condition	Threshold	Denotation	Implication
1	NPV > 0	The Project Will add value to the organization	The project should not be embarked upon
2	NPV < 0	The Project Will add value to the organization	The project should be embarked upon
3	NPV = 0	There is the possibility that the cost of project maybe equivalent to the benefit.	Decision remains indifference.

With the above threshold of measurement as summarized in table 4.4 above, conclusion will be drawn in the later part of this document.

4.4.2.1 Net Present Value of the Gas Power Plant

The Net Present value of a system consisting of 30 years useful life of operation will be rigorous to calculate, therefore, refer to ***Appendix D*** for the tabulated demonstration of estimations and calculations.

From the results achieved in **4.4.1.1**,

Salvage value = 0

$$\text{NPV} = -2{,}800{,}000{,}000 + \frac{733313527}{(1+0.12)} + \frac{671595355}{(1+0.12)^2} + \ldots + \frac{57818341}{(1+0.12)^{30-1}} + \frac{52663825}{(1+0.12)^{30}} + 0$$

From the above equation as applied in ***Appendix D,***

NPV = $5,186,247,524

NPV = $5.2 Billion

4.4.2.2 Net Present Value of the Hydropower Plant

Calculating the Net Present value of a hydropower system follows same procedure of any other power plant. The useful life of a hydropower plant as applied in this study is 40years. The same procedure applied in gas power plant will be employed in the determination of NPV in this scenario. For ease of understanding, the hydropower NPV calculated over 40years of plant useful life is as attached in ***Appendix E*** of this document. However, basic fundamentals, procedures and results are as found below. From the results achieved in **4.4.1.2**,

Salvage value = 0

$$\text{NPV} = -4{,}488{,}000{,}000 + \frac{925181303}{(1+0.12)} + \frac{850582875}{(1+0.12)^2} + \ldots + \frac{32647160}{(1+0.12)^{40-1}} + \frac{29808991}{(1+0.12)^{40}} + 0$$

From the above equation as applied in ***Appendix E,***

NPV = $6,366,761,630

NPV = $6.4 Billion

4.4.3 Internal Rate of Return Analysis

The internal Rate of Return (IRR) is another economic tool used in the economic viability measurement of a project. IRR is expressed in percentage. It is a tool that is not limited to the determination of how soon one can recover an invested capital over a given time but also a standard tool used to compare the economic viability of two or more projects. According to Wikipedia, the internal rate of return (IRR) is a capital budgeting metric used by firms to decide whether they should make investments. It is an indicator of the efficiency of an investment, as opposed to net present value (NPV), which indicates value or magnitude.

The IRR is the annualized effective compounded return rate which can be earned on the invested capital, i.e., the yield on the investment [Wikipedia, 2008]. Internal Rate of Return is a function of the NPV where the discount rate is adjusted to equate NPV to zero. The internal rate of return is rate of return-on-

investment expressed in percentage. When two or more projects are to be economically compared, the project with the highest value of IRR stands an advantage over the rest.

In this research work, the Internal Rate of Return is basically presented to demonstrate rate of return on investment. It is not totally a judgmental tool used to measure the economic viability of the two projects. The reason for the above decision is that IRR does not reflect rate of return on investment where two projects are not of equal useful life. In the light of this, the COE and the NPV is the strong tool adopted for the purpose of economic viability measurement of the two scenarios.

As a function of Net Present Value, Internal Rate of Return can be mathematically presented as given below;

$$\mathbf{NPV} = -ICO_0 + \frac{C_1}{(1+d)} + \frac{C_2}{(1+d)^2} + \ldots + \frac{C_{N-1}}{(1+d)^{N-1}} + \frac{C_N}{(1+d)^N} + SV\ (1+d) = 0$$

From the above equation, the value of discount rate that will make the NPV = zero is the Internal Rate of Return expressed in percentage.

4.4.3.1 IRR Analysis of the Gas Power Plant

The Internal Rate of Return used the formula as stated in **4.4.3** above to generate the final IRR value. The value presented below is as achieved in appendix D using the NILC model. Therefore, the Internal Rate of Return for the gas power plant is given as;

IRR = 31.5%

4.4.3.2 IRR Analysis of the Hydropower Plant

With the same process applied in **4.4.3.2** above, the Internal Rate of Return for the hydropower system was generated. Using the NILC model developed, the Internal Rate of Return for the hydropower plant is given as;

IRR = 25.9%

4.4.4 Cash Flow Trend Analysis

Cash flow trend is an analysis which presents the rate of investment cost recovery. This is an alternative to breakeven analysis. However, the cash flow trend is specifically developed for this document to demonstrate the year that the plant will start generating positive revenue. The characteristics as displayed below show that with the present cost of gas in Nigeria, gas power plant has an earlier chance of breaking even. This is a condition that will be analyzed in the next chapter. **Figures 4.4** and **4.5** are generated from **Appendix H** and **I** respectively.

Figure 4.4: Cumulative Cash Flow vs. Plant Useful Life for the Gas Power Plant

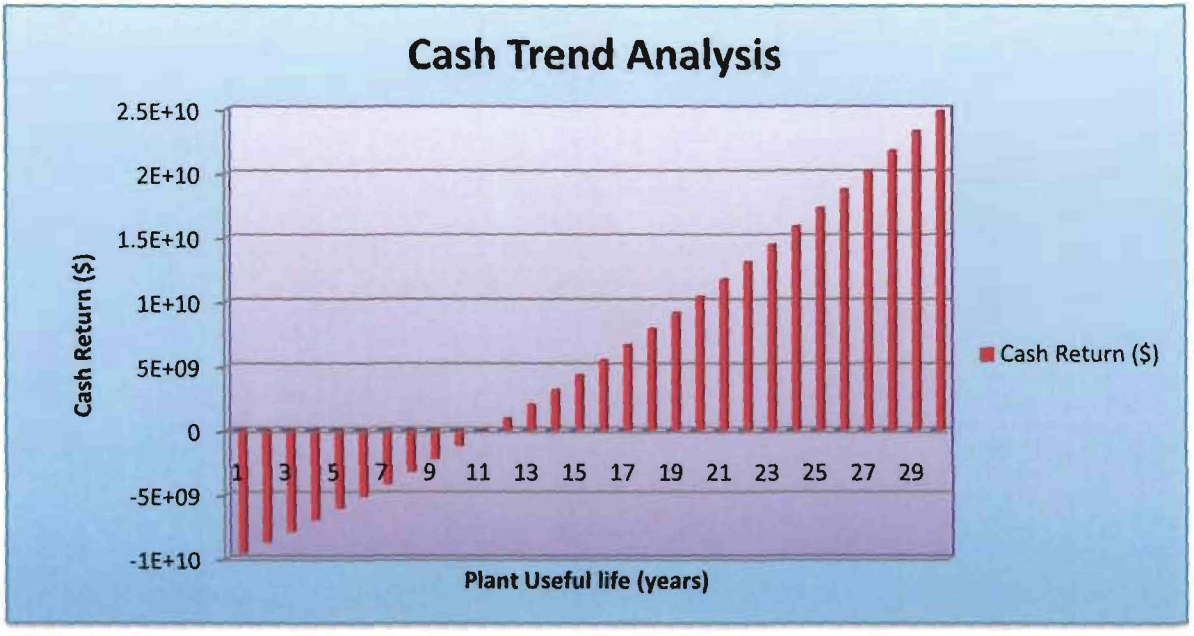
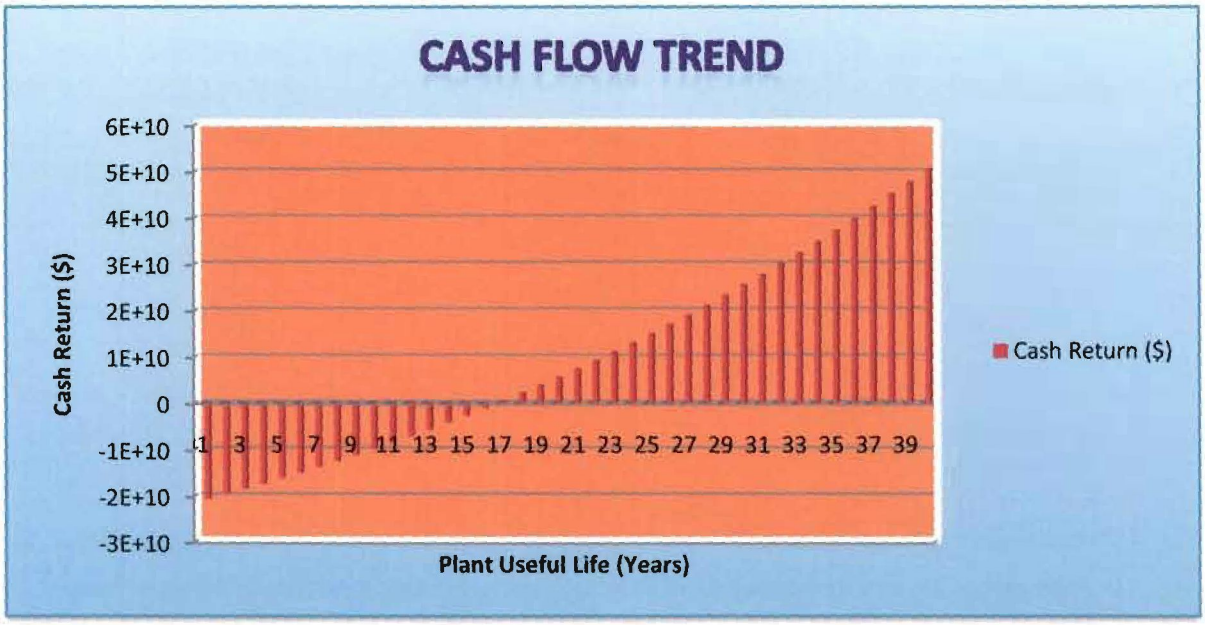


Figure 4.5: Cumulative Cash Flow vs. Plant Useful Life for the Hydropower Plant



4.5 Sensitivity Analysis

The sensitivity analysis is the effect of the output parameter with varying input quantities. The analysis is used as a verification tool to measure the effectiveness of the model used in the economic viability study carried out. The sensitivity analysis shall also serve as an important tool to measure the effect of regulated/deregulated price of gas on the cost of electricity generated.

Given that the Levelized cost of Energy (LCOE) is given as;

$$COE = \Sigma [(I_t + M_t + F_t)(1+i)^{-t}] / \Sigma [E_t (1+i)^{-t}]$$

If the world market-driven (deregulated) cost of gas is $11.204/MSCF,

Therefore cost of natural gas consumed by the plant (4000MW gas power plant) in one year = 438,000 x 11.204 = $4, 907, 352.

COE for the first year = $0.018/kWh

But LCOE for entire plant life =$0.023/kWh (deregulated) as against

$0.021/kWh (regulated).

The NILC model has demonstrated its sensitivity by showing varying COE for regulated and deregulated price of gas. This value cannot be achieved by calculating COE for only few years of the plant life.

The deregulated cost of gas has shown a varying percentage of 9% as against what is applicable in the cost of generating energy with a regulated system. **Appendix J** shows a spreadsheet format of the deregulated price and its varying impact when measured against the regulated price of gas.

As shown in **Appendix K**, the IRR deviated from 31% for regulated price of gas to 32% for a deregulated scenario.

The values of the Net Present Value, Internal Rate of Return, Cash Flow Trend Analysis and Levelised Cost of Energy are sensitive to the economic assumptions made in this report. The sensitivity of the NILC model was also used to calculate the IRR which shows the effect of varying discount rate on the NPV.

4.6 Conclusion

The economic viability tools used has provided different results for the power options that were studied. The result achieved will be presented in the next chapter. The result will further be analyzed which will be used to draw conclusions on the last chapter.

Chapter Five

Result Presentation and Discussions

5.0 Chapter Overview

Many results have been achieved in the previous chapter. These results will be presented in this chapter for further analysis. The questions to be answered are; is the Congo-Nigeria Superhighway grid economically viable? Does the dominant conventional gas turbine edge over the importation of energy from hydropower scheme from the Inga falls of the Congo DRC? Does the mere comparative analysis based only on NPV and IRR justify the economic advantage of a project over the other? These questions and many more will be addressed before the end of this chapter.

5.1 Result Presentation

In chapter four, some basic economic viability tools have been used to achieve results. The results are as presented in this section. There are other factors that will be put into consideration to justify beyond reasonable doubt the extent of the projects viability. If the local cost of gas has been used for measurement in the economic analysis of the gas power plant, what side effect has it on the national economy? Is the indirect subsidy paid by the Nigerian government in form of the Multi-Year Tariff Order (MYTO) pose an adverse effect to the national economy? Are there some economic implications linked to emissions from the power plants? Can power plants attract other form of revenue generation apart from revenue that accrues from energy sales? Can the environmental factors be equated to some economic values? With the above questions, on completion of this section of the document, Conclusion will be made based on the question's premise.

5.1.2 Result from NILC Analysis

In chapter four, the NILC model was used to achieve some series of result as presented in this section. The parameters measured include the Cost of Generating Electrical Energy from the two power plants under study, the Net Present Value, Internal Rate of Return and Cash flow trend analysis. To avoid drawing conclusion from the base year level, the analyses were made throughout the entire life cycle of the plant with reasonable assumptions. The result achieved is as presented below.

Table 5.1: Viability Test Result Summary

Serial Number	Measured Parameter	Congo Hydropower Plant	Nigerian Gas Power Plant	Comments
1	Cost of Energy (Year 1)	**Cents1.8/kWh**	**Cents1.8/kWh**	
2	Average/levelized Cost of Electricity Generated (LCOE)	**Cents1.9/kWh**	**Cents2.2/kWh**	
3	Initial Cost of Investment	**$4.5 Billion**	**$2.8 Billion**	
4	Net Present Value	**$6.4 Billion**	**$5.2 Billion**	
5	Internal Rate of Return	**25.9%**	**31.5%**	
6	Cash Flow Trend Analysis	17 Years Breakeven Approximate	12 Years Breakeven Approximate	
7	Revenue Yielding Energy	**32.5 TWh/Annum**	**25.6 TWh/Annum**	

The result presented above and other factors considered in this chapter shall provide a guideline for conclusive presentation in the last chapter.

5.1.3 The Economic Impact of Gas Price

In Nigeria, the major sources of income are oil and gas. It is of proven track record that there is geometric increase in the demand of gas in the present world market. This increase in demand is as a result of many technologies that use gas either as source of raw material, heat source and/or exportation purposes. The NYMEX market forecasts the cost of natural gas in the world market which is 1150% above the cost it is being sold in Nigeria. As at August 2008, the international cost of gas per MCF stands at $11.204 while the local price in Nigeria is $0.5. Invariably, subsidizing the cost of gas in Nigeria goes with an opportunity cost. Had this gas been exported, more revenue will be generated. With this point, if the cost of gas variation stands at 1150%, the Levelized cost of energy with gas power plant which stands at Cents2.2/kWh is a mere camouflage of real cost. This reason is drawn from the fact that the cost of gas contributes to about 73% of the O&M of a gas power plant.

5.1.4 The Multi-Year Tariff Order

Multi Year Tariff Order is a regulation set out by the Federal Government of Nigeria with the intention of electricity tariff equalization. In Nigeria, there are other sources of power generation. The cost of generating unit of electricity varies from one form of generation to the other. The price equalization policy has provided for the customer across the nation to pay an equal amount per unit of electricity consumed irrespective of the technology employed in harnessing the energy. With the deterioration of the Nigerian power sector, the government has set down a policy in form of Multi Year Tariff order to cushion the effect of price hike of energy tariff. Based on the current and future cost of energy, the MYTO protocol has been set up to pay in form of subsidy the projected cost of energy.

The major cost of price hike in the cost of energy is the attribute of operation and maintenance cost of power plants. Unfortunately, gas contributes a fair share of this price hike. Drawing reasons from the above premises, government is invariably paying for the cost of the gas in form of subsidy.

According to Nigerian Electricity Regulatory Commission's documentation presented for 2008 to 2013 MYTO policy, it states: "In Nigeria, electricity prices are generally lower than the production cost. The tariff was last reviewed in February 2002 (from an average of N4.50/kWh to about N6/kWh) where it has remained to date. In the intervening years inflation in labour and **fuel costs** and increases in the cost of capital equipment have increased the unit cost of electricity production significantly.

The new tariff order is intended to **provide financial incentives** for increased investments in the industry and for improvements in plant availability, enhanced metering, billing, and collection performance".

5.1.5 The Eco-Environmental Relationships

Most of the power plants make use fuel to operate. Hydropower makes use of water as fuel. One of the desirable features that make hydropower choice of adoption is that it leaves water in the way it was taken in. The water supplied to the turbines is free of charge. Hydropower makes use of difference in water potential by construction of dams or run-of-river in case of natural water falls. The major environmental threat posed by hydropower is restriction to the movement of fishes. Fortunately, technology has made discovered fish ladder which takes care of the environmental threat.

Unlike the hydropower, the gas power plant posses a lot of environmental hazards. Cost of gas supplied to the gas power plant has a geometric increase down the year. The environmental issues and cost of gas has made gas power plants a secondary choice of harnessing electric energy.

Today cost of retrofitting a power plant goes with the recent development of power plants. As the cost of CO_2 emitted to the atmosphere is measure and charged in recent times, the cost of generating clean energy from gas power plant will be well above $0.05/kWh. The pollution of the atmosphere by CO_2 emissions contributes to other environmental disasters which includes acid rain, depletion of ozone layers etc. With the above reasons, the cost of generating clean energy from gas is expensive.

5.2 Result Analysis

There are many parameters that have been measured or considered above. The parameters measured are the cost of generating electricity (base year and useful life period), the Net Present Value, the Internal Rate of Return and the Cash Flow Trend Analysis. The result analysis is as follows:

- **Levelised Cost of Electricity** in both power plants is the same in the first year of operation. Down the time line, cost of generating energy from the gas power plants increased more than the hydropower cost. The increase in the unit cost of energy experienced in the gas power plant scenario is due to the increasing of cost of fuel (gas). The fuel supplied to the gas power plant is projected to be increasing down the time line. This gave the Congo hydroelectric power option an edge over the Nigerian gas power plant.

- **Net Present Value:** The Net Present Value measured on the hydropower plant is greater than the gas power plant NPV. The reason is due to a longer useful life of the hydropower system, zero cost of fuel and less maintenance cost. From the value of the NPV of both plants, Hydropower option has more economic value than the Gas power plant.

- **Internal rate of Return:** The Internal Rate of Returns of the two power plants was not of the same value. The IRR measured from the gas power

plant is greater than that of the hydropower system. The greater percentage of investment return in the gas power plant is due to the lower cost of initial capital. The hydropower plant has a disadvantage of huge initial investment cost. The IRR of the gas power plant though greater is does not have a greater turnover. The return on investment of the hydropower system is greater than that of the gas power plant while the time of return is vice versa. Considering the useful life of both plants, hydropower option is preferred to the gas power system.

- **Cash Flow Trend:** the Cash Flow Trend as used in this studies is an equivalent of breakeven analysis. Due to the huge initial investment of the hydropower plant, it has more extended breakeven point. The breakeven point of the hydropower plant is at approximately 17 years while that of gas power plant is about 12 years. Therefore the rate of return in the gas power plant is expected earlier than the hydropower plant. Invariably, the hydropower plant has a greater return at the end of useful life which gives it a preference over the gas power option.

- **Other Economic Considerations:** Other economic considerations are factors like the cost of retrofitting power plants which is approximately zero in hydropower plants. The gas power plant emits CO2 to the atmosphere therefore, requires extra cost for a cleaner energy production. The hydropower plants also provide recreational activities like game reserves and tourism centre unlike the gas power plant. Extra income can be raised from tourist activities. The hydropower plant also generates more revenue when considered from the point of plant availability factor.

5.3 Discussion

It is clear that many factors contribute to the economic aspects of power generation. The cost of energy can vary from one point to the other depending on

the factors, policies and environmental issues influencing the energy production. Apart from generic aspects, siting of gas turbine within the confines of Nigerian environment has some peculiar challenges. These challenges are as revealed in sub-section 5.2.2 below. Not only does the hydro electric power scheme commended as a renewable source of generating electricity, there are numerous other advantages that comes with it such as those discussed below.

5.3.1 Advantages of Inga Hydropower Scheme

With particular reference to the Inga hydroelectric power resource, there are numerous advantages that go with the scheme implementation.

- It will provide an economic bilateral relationship between Congo and Nigeria and any other country that indulge in the idea thereafter.
- The project initiative does not leave Nigeria with the aspect of financing the project solely rather it is a benefit of New Partnership for African Development initiative.
- The super grid transmission system will employ a "lossless" technology of High Voltage Direct Current (HVDC) Transmission System. This will in no small measure save reasonable percentage of parasitic losses.
- The initiative will reduce the risk of power plant gas pipeline vandalism.
- Just like any other hydropower system, it is a renewable energy source as well as emission-free technology.
- It promotes system stability as the plant capacity factor is near 100%.
- It provides for irrigation which invariably supports water supply scheme and agricultural practices.

5.3.2 Challenges of Gas Power Plants in Nigeria

Gas plant as the conventional source of electric power supply in Nigeria is confronted with many types of challenges. The major challenge is pipeline vandalism. The activities of hoodlums to vandalize gas pipeline have led to other disadvantages.

Pipeline vandalism has led to other economics issues such as;

- It induces fire which destroys economic plants, human and animal lives.
- It causes loss or shortage of gas supplied to the power plants hence, affects gas power plant availability.
- Vandalism of gas pipeline posses environmental threats such as soil spillage and water contamination thereby adversely dealing with floras and faunas.

Another major challenge of the gas power plant in Nigeria is the effect of cost of gas on the world market. Due to the continuous increase in the cost of gas, the local unit price of gas measured in MCF rose from N21 ($0.18) to N68 ($0.57) in a single increase in 2008. This recorded an increase in cost of gas to be about 500%.

The subsidy paid by the Nigerian government does not encourage private investor participation in the Nigerian power sector.

5.3.3 Further Discussions

With the reasons mentioned above, one cannot say that the cost of generating electricity from gas has an edge over the hydropower counterpart. From the revelation made so far in this document, conclusion shall be drawn in the next chapter.

5.4 Result Validation

The result obtained from the viability studies of the two power plants are based on standard measurements of Net Present Value, Internal Rate of Return, Levelized Cost of Energy and Cash Flow Trend Analysis. The result generated supports that gas power plant in Nigeria does not have a greater degree of economic viability than the importation of electrical energy from the Congo Hydropower Scheme.

For the economics quantities measured, Net Present Value, Internal Rate of Return and Cash flow Trend Analysis are all standard economics viability tools.

There are thresholds of measurements which are used to determine the degree of viability a project is assigned. Such thresholds are as follows:

- If NPV is negative, the project is considered non-viable. If the NPV is positive, the project is considered viable. This was used as threshold of measurement in the calculation of the two power plant's net Present Value.
- The system or project with a greater percentage value of IRR is considered more viable than the other option. This was also a standard used in Internal Rate of Return for the two power projects.
- The cost of energy that was measured used EIA standard of measurement. According to EIA standard, the power plant with the less value of COE is considered viable over the rest. This standard was applied in this document for the comparison of the two power plants viability.

To validate the procedure used in this document, the NAMPOWER (Namibia electricity utility company) economic viability analysis for Epupa Hydropower plant and Kudu gas plants were referenced.

- **The Epupa Power Plant vs. the Kudu Combined Cycle Gas Power Plant**

The economics evaluations of the plants were made according to the method of a cost-benefit analysis. A cash flow analysis was used in the financial analysis. In the Namibian case, incremental benefits or revenues and cost of the project were established for further viability studies. The project evaluations were made in the Net Present Value Terms by discounting the annual benefits/revenues and cost to a common point in time taken to be in 1997 which is defined as base year of the study. However, the Namibian case took a national perspective by making an economic evaluations primarily designed to asses whether the development of the project would represent efficient use of the scarce resources relative to other investment alternative else where in the economy. This condition leads to the economic viability test analysis of the projects that were selected.

According to the documentation, the indicators that have been calculated to show the economic merit of the project are the Economic Internal Rate of Return (EIRR), the Net Present Value (NPV), the benefit/cost ratio (B/C) and the Economic Unit Energy Cost of electricity generated by the project (EUEC). According to the table below as culled from the document, the Epupa power plant was tested for viability against the Kudu Gas power plant.

Table 5.2: Viability Summary of the Namibian Epupa Hydroelectric vs. Kudu Gas Power Plants

Economic Evaluation – Base Case		
Economic Viability Test	Epupa Hydropower Plant	Kudu Gas Power Plant
EIRR	11.1%	12.3%
NPV	$41.8 million	$88.6 million

The same standard used in this document to achieve results was also the same standard applied by the United States Army Corps of Engineers and the Federal Electricity Regulatory Commission of the United States in power plants economics.

Chapter Six

Conclusion and Recommendation

6.0 Chapter Overview

The quest to promote stability, reliability, integrity and availability of electric energy in Nigeria has given reasons to suggestions that have been adopted to ameliorate the national power sector shortfalls. As discussed earlier in this document, Nigeria produces electric energy from two major technologies – gas power plants and hydropower technologies. However, the key factor that hinders the development and expansion of hydropower system in Nigeria has been identified to be the hydrological limitations. Invariably, the cost associated with the development of gas power plants in Nigeria has not made it the best choice either. Hence, this document has been developed around finding a lasting solution to the Nigerian power problem measuring from an economic point of view.

With the hydrological and cost implications militating against the current power generation technologies in Nigeria, harnessing power from the Inga hydroelectric power project has been identified to present better economic qualities.

6.1 The NILC Model

With the selection of two power plants (Nigerian gas power plant and Congo hydroelectric power plant) for economic viability comparison a model known as NILC model has been successfully applied to achieve results.

The ideal aspect of the NILC model is that it has been developed to employ standard economic viability tools into a single model. The model employed the integration of Net Present Value, Internal Rate of Return, Levelized Cost of Energy, Cash Flow Trend, sensitivity measurement and revenue-yielding energy into a single model.

The NILC model has been developed to provide foundation for decision making in power plant selection. It features has also made it ideal as a template for economic comparison of two or more power plants.

6.2 Conclusion

The hydrological studies conducted in chapter two reveals that the Kainji, Shiroro and Jebba dams provides inconsistent capacity due to seasonal water flow, irrigation activities and other water supply projects built around River Niger and River Kaduna. It is thus concluded that these dams will not provide reliable and sufficient energy supply.

Conversely, owing to the similar hydrological studies conducted on the River Congo, it is established that due to the geographical position of the river, it will provide a better choice of energy production. The natural falls on the Inga site of the River Congo has also been identified to provide run-of-the-river technology instead of the use of dams to provide artificial falls as found in the Nigerian dams.

As the Nigerian dams have been identified to possess shortfalls of capacity expansion, gas turbine was identified to be the conventional and dominant system of power production in Nigeria. Due to the limitations of hydropower development in Nigeria and subsequent gas turbine project expansion, gas power plant was selected as a base plant for economic comparison against the River Congo hydropower option.

With the application of economic viability tool – the NILC model, the gas power plant and hydropower production from River Congo show seeming evidence that the hydropower option stands a better choice of energy production.

Other economic considerations in chapter five also prove that the hydropower production from the River Congo provides a better economic and environmental advantage over the gas power plant systems.

6.3 Recommendation

Owing to the fast developing statistics in gas technology, government should diversify the utilization of gas resource while other cost effective forms of harnessing electric energy such as Congo hydropower project are developed.

It is also suggested that Nigerian government should allow a deregulated system in gas and power sector development so as to encourage the participation of private investors. The MYTO policy and the regulated cost of gas were identified as such policy of discouragement. Reformations such as establishment of gas market and energy sector reforms through clear and innovative scheme that can match world market standards is suggested to provide an enabling environment for energy sector development.

Nigerian government should prioritize the development of the energy sector around sustainable development demands. Environmental issues are not advised to be undermined. The development of hydropower systems instead of gas turbines is one of a sort.

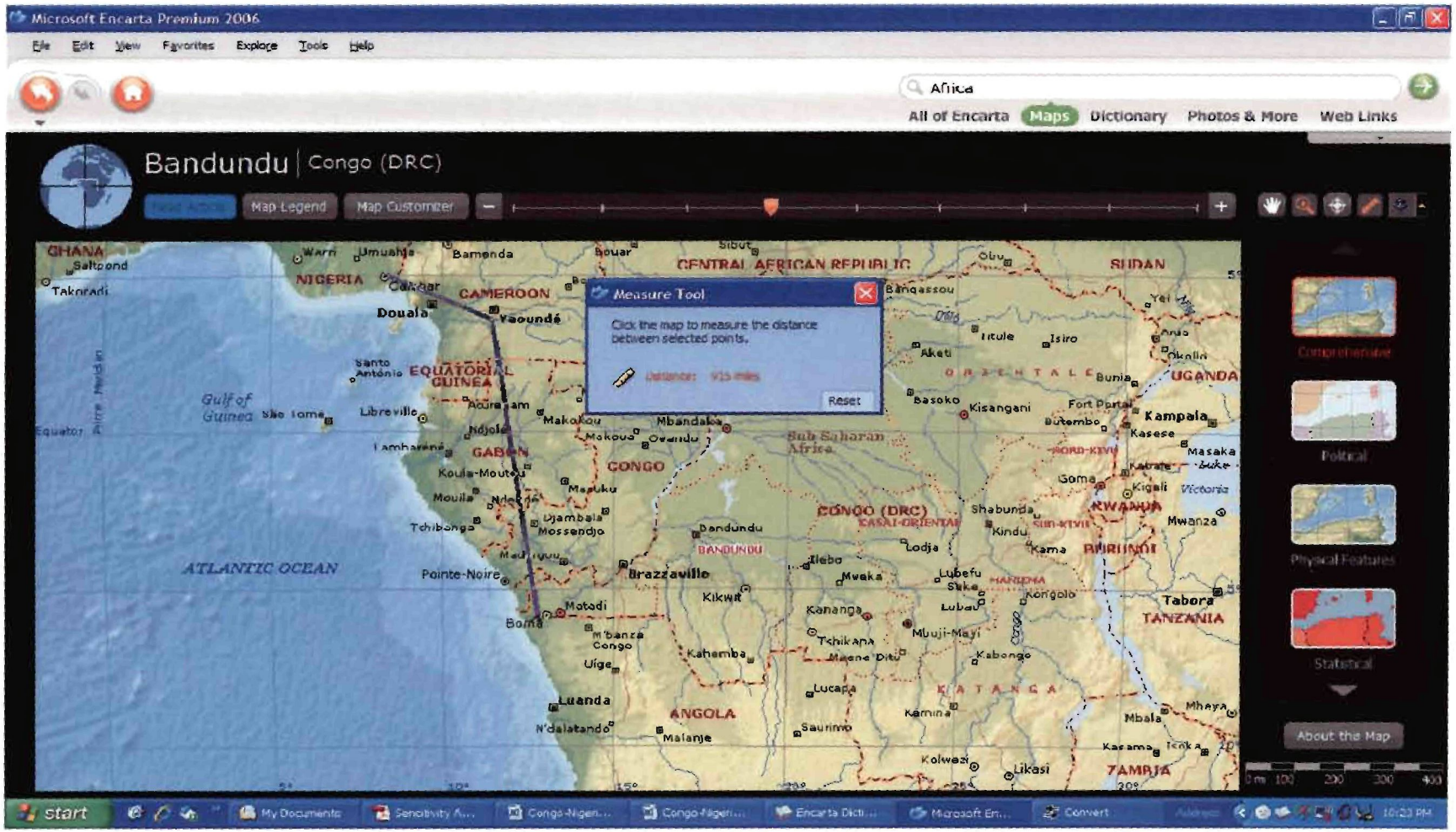
6.4 Further Research

There are some gray areas that need further research and development. As regards this field of study, constant forecast of gas price trend and subsequent effect on the Nigerian power sector development should be a matter of concern. Provision of such statistics at a national level would have provided a better choice of power sector development in Nigeria.

In conclusion, the study carried out in this document has proven beyond reasonable doubt that harnessing electric energy from the Inga falls of Congo provides a better economic deal when measured against the conventional power production system in Nigeria. Though other considerations such as technical, environmental and political aspects need to be developed, transporting power from the hydropower electric system of the River Congo has been strongly suggested by this document measuring from an economic aspect.

Appendices

Appendix A: A Map Showing 915 Miles (Approx.) Congo – Nigeria Superhighway Grid Distance



Source: As measured with Microsoft Encarta Tool

Appendix B: Leveised Cost of Energy for 4000MW Gas Power Plant in Nigeria

	APPENDIX B: 4000MW GAS PLANT LEVELIZED COST OF ENERGY							
Year (t)	**Annualzed CAPEX ($)**	**Discount Rate (d)**	**O&M Cost ($)**	**Fuel Cost ($)**	**EO (kWh)**	**COE $/kWh**	**APC ($)**	**LCOE $/kWh**
1	347592000	0.12	112000000	246849.5	25623000000	0.0179463	459838850	
2	347592000	0.12	116480000	251786.49	25623000000	0.0181214	464323786	
3	347592000	0.12	121139200	256822.22	25623000000	0.0183034	468988022	
4	347592000	0.12	125984768	261958.664	25623000000	0.0184927	473838727	
5	347592000	0.12	131024159	267197.837	25623000000	0.0186896	478883357	
6	347592000	0.12	136265125	272541.794	25623000000	0.0188943	484129667	
7	347592000	0.12	141715730	277992.63	25623000000	0.0191073	489585723	
8	347592000	0.12	147384359	283552.483	25623000000	0.0193287	495259912	
9	347592000	0.12	153279734	289223.532	25623000000	0.019559	501160957	
10	347592000	0.12	159410923	295008.003	25623000000	0.0197985	507297931	
11	347592000	0.12	165787360	300908.163	25623000000	0.0200476	513680268	
12	347592000	0.12	172418854	306926.326	25623000000	0.0203067	520317781	
13	347592000	0.12	179315608	313064.853	25623000000	0.0205761	527220673	
14	347592000	0.12	186488233	319326.15	25623000000	0.0208562	534399559	
15	347592000	0.12	193947762	325712.673	25623000000	0.0211476	541865475	
16	347592000	0.12	201705673	332226.926	25623000000	0.0214506	549629900	
17	347592000	0.12	209773900	338871.465	25623000000	0.0217658	557704771	
18	347592000	0.12	218164856	345648.894	25623000000	0.0220935	566102504	
19	347592000	0.12	226891450	352561.872	25623000000	0.0224344	574836012	
20	347592000	0.12	235967108	359613.11	25623000000	0.0227889	583918721	
21	347592000	0.12	245405792	366805.372	25623000000	0.0231575	593364597	
22	347592000	0.12	255222024	374141.479	25623000000	0.0235409	603188165	
23	347592000	0.12	265430905	381624.309	25623000000	0.0239396	613404529	
24	347592000	0.12	276048141	389256.795	25623000000	0.0243543	624029398	
25	347592000	0.12	287090066	397041.931	25623000000	0.0247855	635079108	
26	347592000	0.12	298573669	404982.769	25623000000	0.025234	646570652	
27	347592000	0.12	310516616	413082.425	25623000000	0.0257004	658521698	
28	347592000	0.12	322937281	421344.073	25623000000	0.0261855	670950625	
29	347592000	0.12	335854772	429770.955	25623000000	0.0266899	683876543	
30	347592000	0.12	349288963	438366.374	25623000000	0.0272146	697319329	
				10014210	**7.6869E+11**		**1.672E+10**	**0.02175036**

Appendix C: Levelised Cost of Energy for Hydropower Plant

	Appendix C: Levelised Cost of Energy for Hydrpower Plant							
Year (t)	Annualized CAPEX ($)	Discount Rate (d)	O&M Cost ($)	Fuel Cost ($)	EO (kWh)	COE ($/kWh)	APC ($)	LCOE ($/kWh)
1	544394400	0.12	42192540	0	32455800000	0.018073409	586586940	
2	544394400	0.12	43880241.6	0	32455800000	0.018125409	588274642	
3	544394400	0.12	45635451.3	0	32455800000	0.018179489	590029851	
4	544394400	0.12	47460869.3	0	32455800000	0.018235732	591855269	
5	544394400	0.12	49359304.1	0	32455800000	0.018294225	593753704	
6	544394400	0.12	51333676.3	0	32455800000	0.018355058	595728076	
7	544394400	0.12	53387023.3	0	32455800000	0.018418323	597781423	
8	544394400	0.12	55522504.2	0	32455800000	0.01848412	599916904	
9	544394400	0.12	57743404.4	0	32455800000	0.018552549	602137804	
10	544394400	0.12	60053140.6	0	32455800000	0.018623714	604447541	
11	544394400	0.12	62455266.2	0	32455800000	0.018697726	606849666	
12	544394400	0.12	64953476.8	0	32455800000	0.018774699	609347877	
13	544394400	0.12	67551615.9	0	32455800000	0.018854751	611946016	
14	544394400	0.12	70253680.6	0	32455800000	0.018938004	614648081	
15	544394400	0.12	73063827.8	0	32455800000	0.019024588	617458228	
16	544394400	0.12	75986380.9	0	32455800000	0.019114635	620380781	
17	544394400	0.12	79025836.1	0	32455800000	0.019208284	623420236	
18	544394400	0.12	82186869.6	0	32455800000	0.019305679	626581270	
19	544394400	0.12	85474344.4	0	32455800000	0.01940697	629868744	
20	544394400	0.12	88893318.1	0	32455800000	0.019512313	633287718	
21	544394400	0.12	92449050.9	0	32455800000	0.019621869	636843451	
22	544394400	0.12	96147012.9	0	32455800000	0.019735807	640541413	
23	544394400	0.12	99992893.4	0	32455800000	0.019854303	644387293	
24	544394400	0.12	103992609	0	32455800000	0.019977539	648387009	
25	544394400	0.12	108152314	0	32455800000	0.020105704	652546714	
26	544394400	0.12	112478406	0	32455800000	0.020238996	656872806	
27	544394400	0.12	116977542	0	32455800000	0.020377619	661371942	
28	544394400	0.12	121656644	0	32455800000	0.020521788	666051044	
29	544394400	0.12	126522910	0	32455800000	0.020671723	670917310	
30	544394400	0.12	131583826	0	32455800000	0.020827656	675978226	
31	544394400	0.12	136847179	0	32455800000	0.020989826	681241579	
32	544394400	0.12	142321066	0	32455800000	0.021158482	686715466	
33	544394400	0.12	148013909	0	32455800000	0.021333885	692408309	
34	544394400	0.12	153934465	0	32455800000	0.021516304	698328865	
35	544394400	0.12	160091844	0	32455800000	0.02170602	704486244	
36	544394400	0.12	166495518	0	32455800000	0.021903324	710889918	
37	544394400	0.12	173155338	0	32455800000	0.022108521	717549738	
38	544394400	0.12	180081552	0	32455800000	0.022321926	724475952	
39	544394400	0.12	187284814	0	32455800000	0.022543866	731679214	
40	544394400	0.12	194776207	0	32455800000	0.022774685	739170607	
					1.2982E+12		**2.58E+10**	**0.01986174**

Appendix D: Net Present Value of Gas Power Plant in Nigeria

APPENDIX D: The Estimations and Calculations [Cash Flow Analysis] of Net Present Value of a 400MW Gas Power Plant in Nigeria												
Year	A/ CAPEX ($)	Fuel Cost ($)	O&M Cost ($)	(d)	E/O (kWh)	COE ($/kWh)	APC ($)	SCE ($)	Revenue ($)	Cash Flow ($)	Present Value ($)	NPV ($)
1	347592000	246849.5	112000000	0.12	25623000000	0.017946331	459838849.5	0.05	1281150000	821311150.5	733313527.2	
2	347592000	251786.49	116480000	0.12	25623000000	0.018121367	464323786.5	0.051	1306773000	842449213.5	671595355.2	
3	347592000	256822.2198	121139200	0.12	25623000000	0.0183034	468988022.2	0.05202	1332908460	863920437.8	614921503.3	
4	347592000	261958.6642	125984768	0.12	25623000000	0.018492711	473838726.7	0.0530604	1359566629	885727902.5	562896094.6	
5	347592000	267197.8375	131024158.7	0.12	25623000000	0.01868959	478883356.6	0.0541216	1386757962	907874605.2	515152432.6	
6	347592000	272541.7942	136265125.1	0.12	25623000000	0.01889434	484129666.9	0.055204	1414493121	930363454.2	471351079.9	
7	347592000	277992.6301	141715730.1	0.12	25623000000	0.019107276	489585722.7	0.0563081	1442782983	953197260.7	431178033	
8	347592000	283552.4827	147384359.3	0.12	25623000000	0.019328725	495259911.8	0.0574343	1471638643	976378731.4	394342993.7	
9	347592000	289223.5324	153279733.6	0.12	25623000000	0.019559027	501160957.2	0.058583	1501071416	999910458.8	360577735.5	
10	347592000	295008.003	159410923	0.12	25623000000	0.019798538	507297931	0.0597546	1531092844	1023794913	329634561.8	
11	347592000	300908.1631	165787359.9	0.12	25623000000	0.020047624	513680268.1	0.0609497	1561714701	1048034433	301284855.8	
12	347592000	306926.3263	172418854.3	0.12	25623000000	0.020306669	520317780.6	0.0621687	1592948995	1072631215	275317716.7	
13	347592000	313064.8529	179315608.5	0.12	25623000000	0.020576071	527220673.3	0.0634121	1624807975	1097587302	251538681	
14	347592000	319326.1499	186488232.8	0.12	25623000000	0.020856245	534399559	0.0646803	1657304135	1122904576	229768523.9	
15	347592000	325712.6729	193947762.1	0.12	25623000000	0.02114762	541865474.8	0.0659739	1690450217	1148584742	209842138.2	
16	347592000	332226.9264	201705672.6	0.12	25623000000	0.021450646	549629899.5	0.0672934	1724259222	1174629322	191607487.1	
17	347592000	338871.4649	209773899.5	0.12	25623000000	0.021765787	557704771	0.0686393	1758744406	1201039635	174924626.1	
18	347592000	345648.8942	218164855.5	0.12	25623000000	0.022093529	566102504.4	0.0700121	1793919294	1227816790	159664792.1	
19	347592000	352561.8721	226891449.7	0.12	25623000000	0.022434376	574836011.6	0.0714123	1829797680	1254961668	145709554.4	
20	347592000	359613.1095	235967107.7	0.12	25623000000	0.022788851	583918720.8	0.0728406	1866393634	1282474913	132950025.5	
21	347592000	366805.3717	245405792	0.12	25623000000	0.023157499	593364597.4	0.0742974	1903721506	1310356909	121286126.7	
22	347592000	374141.4792	255222023.7	0.12	25623000000	0.023540888	603188165.2	0.0757833	1941795936	1338607771	110625906.7	
23	347592000	381624.3087	265430904.6	0.12	25623000000	0.023939606	613404529	0.077299	1980631855	1367227326	100884909.4	
24	347592000	389256.7949	276048140.8	0.12	25623000000	0.024354268	624029397.6	0.078845	2020244492	1396215095	91985587.15	
25	347592000	397041.9308	287090066.5	0.12	25623000000	0.024785509	635079108.4	0.0804219	2060649382	1425570274	83856757.23	
26	347592000	404982.7694	298573669.1	0.12	25623000000	0.025233995	646570651.9	0.0820303	2101862370	1455291718	76433098.97	
27	347592000	413082.4248	310516615.9	0.12	25623000000	0.025700414	658521698.3	0.0836709	2143899617	1485377919	69654688.03	
28	347592000	421344.0733	322937280.5	0.12	25623000000	0.026185483	670950624.6	0.0853443	2186777610	1515826985	63466565.84	
29	347592000	429770.9548	335854771.7	0.12	25623000000	0.026689948	683876542.7	0.0870512	2230513162	1546636619	57818341.66	
30	347592000	438366.3739	349288962.6	0.12	25623000000	0.027214586	697319329	0.0887922	2275123425	1577804096	52663825.01	
									51973794674	**35254507436**	**7986247524**	**5186247524**

Appendix E: Net Present Value of a Hydropower Plant

APPENDIX E: The Estimations and Calculations of Net Present Value of a 400MW HydroPower Plant in Nigeria												
Year	A/CAPEX ($)	FC ($)	O&M Cost ($)	DR	E/O (kWh)	COE ($/kWh)	APC ($)	SCE ($)	Revenue ($)	Cash Flow ($)	PV ($)	NPV ($)
1	544394400	0	42192540	0.12	32455800000	0.018073409	586586940	0.05	1622790000	1036203060	925181303.6	
2	544394400	0	43880241.6	0.12	32455800000	0.018125409	588274641.6	0.051	1655245800	1066971158	850582875	
3	544394400	0	45635451.26	0.12	32455800000	0.018179489	590029851.3	0.05202	1688350716	1098320865	781763097.3	
4	544394400	0	47460869.31	0.12	32455800000	0.018235732	591855269.3	0.0530604	1722117730	1130262461	718302227.3	
5	544394400	0	49359304.09	0.12	32455800000	0.018294225	593753704.1	0.0541216	1756560085	1162806381	659807568.5	
6	544394400	0	51333676.25	0.12	32455800000	0.018355058	595728076.3	0.055204	1791691287	1195963210	605912182.2	
7	544394400	0	53387023.3	0.12	32455800000	0.018418323	597781423.3	0.0563081	1827525112	1229743689	556273592.8	
8	544394400	0	55522504.23	0.12	32455800000	0.01848412	599916904.2	0.0574343	1864075615	1264158710	510572500.6	
9	544394400	0	57743404.4	0.12	32455800000	0.018552549	602137804.4	0.058583	1901357127	1299219322	468511512.3	
10	544394400	0	60053140.58	0.12	32455800000	0.018623714	604447540.6	0.0597546	1939384269	1334936729	429813899.2	
11	544394400	0	62455266.2	0.12	32455800000	0.018697726	606849666.2	0.0609497	1978171955	1371322289	394222389	
12	544394400	0	64953476.85	0.12	32455800000	0.018774699	609347876.8	0.0621687	2017735394	1408387517	361497996.8	
13	544394400	0	67551615.92	0.12	32455800000	0.018854751	611946015.9	0.0634121	2058090102	1446144086	331418899.7	
14	544394400	0	70253680.56	0.12	32455800000	0.018938004	614648080.6	0.0646803	2099251904	1484603823	303779356.1	
15	544394400	0	73063827.78	0.12	32455800000	0.019024588	617458227.8	0.0659739	2141236942	1523778714	278388674.1	
16	544394400	0	75986380.89	0.12	32455800000	0.019114635	620380780.9	0.0672934	2184061681	1563680900	255070227	
17	544394400	0	79025836.13	0.12	32455800000	0.019208284	623420236.1	0.0686393	2227742914	1604322678	233660519.1	
18	544394400	0	82186869.57	0.12	32455800000	0.019305679	626581269.6	0.0700121	2272297773	1645716503	214008299.5	
19	544394400	0	85474344.36	0.12	32455800000	0.01940697	629868744.4	0.0714123	2317743728	1687874984	195973724.2	
20	544394400	0	88893318.13	0.12	32455800000	0.019512313	633287718.1	0.0728406	2364098603	1730810885	179427565.4	
21	544394400	0	92449050.86	0.12	32455800000	0.019621869	636843450.9	0.0742974	2411380575	1774537124	164250467.1	
22	544394400	0	96147012.89	0.12	32455800000	0.019735807	640541412.9	0.0757833	2459608186	1819066773	150332244.8	
23	544394400	0	99992893.41	0.12	32455800000	0.019854303	644387293.4	0.077299	2508800350	1864413057	137571228.1	
24	544394400	0	103992609.1	0.12	32455800000	0.019977539	648387009.1	0.078845	2558976357	1910589348	125873644.8	
25	544394400	0	108152313.5	0.12	32455800000	0.020105704	652546713.5	0.0804219	2610155884	1957609171	115153044.3	
26	544394400	0	112478406	0.12	32455800000	0.020238996	656872806	0.0820303	2662359002	2005486196	105329758.3	
27	544394400	0	116977542.3	0.12	32455800000	0.020377619	661371942.3	0.0836709	2715606182	2054234240	96330397.32	
28	544394400	0	121656644	0.12	32455800000	0.020521788	666051044	0.0853443	2769918305	2103867261	88087381.61	
29	544394400	0	126522909.7	0.12	32455800000	0.020671723	670917309.7	0.0870512	2825316672	2154399362	80538503.25	
30	544394400	0	131583826.1	0.12	32455800000	0.020827656	675978226.1	0.0887922	2881823005	2205844779	73626519.12	
31	544394400	0	136847179.2	0.12	32455800000	0.020989826	681241579.2	0.0905681	2939459465	2258217886	67298772.05	
32	544394400	0	142321066.3	0.12	32455800000	0.021158482	686715466.3	0.0923794	2998248654	2311533188	61506838.96	
33	544394400	0	148013909	0.12	32455800000	0.021333885	692408309	0.094227	3058213627	2365805318	56206204.04	
34	544394400	0	153934465.4	0.12	32455800000	0.021516304	698328865.4	0.0961116	3119377900	2421049035	51355955.6	
35	544394400	0	160091844	0.12	32455800000	0.02170602	704486244	0.0980338	3181765458	2477279214	46918504.98	
36	544394400	0	166495517.7	0.12	32455800000	0.021903324	710889917.7	0.0999945	3245400767	2534510849	42859326.14	
37	544394400	0	173155338.4	0.12	32455800000	0.022108521	717549738.4	0.1019944	3310308783	2592759044	39146714.55	
38	544394400	0	180081552	0.12	32455800000	0.022321926	724475952	0.1040343	3376514958	2652039006	35751564.05	
39	544394400	0	187284814.1	0.12	32455800000	0.022543866	731679214.1	0.1061149	3444045257	2712366043	32647160.52	
40	544394400	0	194776206.6	0.12	32455800000	0.022774685	739170606.6	0.1082372	3512926162	2773755556	29808991.17	
											10854761630	**6366761630**

Appendix F: Internal Rate of Return of Gas Power Plant in Nigeria

APPENDIX F: The Estimations and Calculations [Cash Flow Analysis] Showing the Internal Rate of Return of a 400MW Gas Power Plant in Nigeria												
Year	A/CAPEX ($)	Fuel Cost ($)	O&M Cost ($)	DR	E/O (kWh)	COE ($/kWh)	APC ($)	SCE ($)	Revenue ($)	Cash Flow ($)	Present Value ($)	NPV($)
1	347592000	246849.5	112000000	0.315	25623000000	0.017946331	459838849.5	0.05	1281150000	821311150.5	624571217.1	
2	347592000	251786.49	116480000	0.315	25623000000	0.018121367	464323786.5	0.051	1306773000	842449213.5	487183110.1	
3	347592000	256822.2198	121139200	0.315	25623000000	0.0183034	468988022.2	0.05202	1332908460	863920437.8	379923790.7	
4	347592000	261958.6642	125984768	0.315	25623000000	0.018492711	473838726.7	0.05306	1359566629	885727902.5	296208362.2	
5	347592000	267197.8375	131024158.7	0.315	25623000000	0.01868959	478883356.6	0.05412	1386757962	907874605.2	230885736.5	
6	347592000	272541.7942	136265125.1	0.315	25623000000	0.01889434	484129666.9	0.0552	1414493121	930363454.2	179927740.2	
7	347592000	277992.6301	141715730.1	0.315	25623000000	0.019107276	489585722.7	0.05631	1442782983	953197260.7	140185313.1	
8	347592000	283552.4827	147384359.3	0.315	25623000000	0.019328725	495259911.8	0.05743	1471638643	976378731.4	109197397.5	
9	347592000	289223.5324	153279733.6	0.315	25623000000	0.019559027	501160957.2	0.05858	1501071416	999910458.8	85041191.34	
10	347592000	295008.003	159410923	0.315	25623000000	0.019798538	507297931	0.05975	1531092844	1023794913	66214856.04	
11	347592000	300908.1631	165787359.9	0.315	25623000000	0.020047624	513680268.1	0.06095	1561714701	1048034433	51545679.67	
12	347592000	306926.3263	172418854.3	0.315	25623000000	0.020306669	520317780.6	0.06217	1592948995	1072631215	40118196.14	
13	347592000	313064.8529	179315608.5	0.315	25623000000	0.020576071	527220673.3	0.06341	1624807975	1097587302	31217943.28	
14	347592000	319326.1499	186488232.8	0.315	25623000000	0.020856245	534399559	0.06468	1657304135	1122904576	24287471.95	
15	347592000	325712.6729	193947762.1	0.315	25623000000	0.02114762	541865474.8	0.06597	1690450217	1148584742	18891948.39	
16	347592000	332226.9264	201705672.6	0.315	25623000000	0.021450646	549629899.5	0.06729	1724259222	1174629322	14692266.34	
17	347592000	338871.4649	209773899.5	0.315	25623000000	0.021765787	557704771	0.06864	1758744406	1201039635	11424035.44	
18	347592000	345648.8942	218164855.5	0.315	25623000000	0.022093529	566102504.4	0.07001	1793919294	1227816790	8881166.6	
19	347592000	352561.8721	226891449.7	0.315	25623000000	0.022434376	574836011.6	0.07141	1829797680	1254961668	6903052.196	
20	347592000	359613.1095	235967107.7	0.315	25623000000	0.022788851	583918720.8	0.07284	1866393634	1282474913	5364556.478	
21	347592000	366805.3717	245405792	0.315	25623000000	0.023157499	593364597.4	0.0743	1903721506	1310356909	4168202.345	
22	347592000	374141.4792	255222023.7	0.315	25623000000	0.023540888	603188165.2	0.07578	1941795936	1338607771	3238074.077	
23	347592000	381624.3087	265430904.6	0.315	25623000000	0.023939606	613404529	0.0773	1980631855	1367227326	2515060.375	
24	347592000	389256.7949	276048140.8	0.315	25623000000	0.024354268	624029397.6	0.07884	2020244492	1396215095	1953143.988	
25	347592000	397041.9308	287090066.5	0.315	25623000000	0.024785509	635079108.4	0.08042	2060649382	1425570274	1516508.365	
26	347592000	404982.7694	298573669.1	0.315	25623000000	0.025233995	646570651.9	0.08203	2101862370	1455291718	1177281.947	
27	347592000	413082.4248	310516615.9	0.315	25623000000	0.025700414	658521698.3	0.08367	2143899617	1485377919	913779.9766	
28	347592000	421344.0733	322937280.5	0.315	25623000000	0.026185483	670950624.6	0.08534	2186777610	1515826985	709134.4026	
29	347592000	429770.9548	335854771.7	0.315	25623000000	0.026689948	683876542.7	0.08705	2230513162	1546636619	550226.4412	
30	347592000	438366.3739	349288962.6	0.315	25623000000	0.027214586	697319329	0.08879	2275123425	1577804096	426855.1194	
									51973794674	35254507436	2829833298	0.00
					IRR = 0.315 = 31.5%							

Appendix G: Internal Rate of Return of a hydropower Plant

APPENDIX G: The Estimations and Calculations [Cash Flow Analysis] Showing the Internal Rate of Return of a 400MW HydroPower Plant in Nigeria												
Year	**A/CAPEX ($)**	**Fuel Cost ($)**	**O&M Cost ($)**	**DR**	**E/O (kWh)**	**COE ($/kWh)**	**APC ($)**	**SCE ($)**	**Revenue ($)**	**Cash Flow ($)**	**Present Value ($)**	**NPV ($)**
1	544394400	0	42192540	0.258	32455800000	0.018073409	586586940	0.05	1622790000	1036203060	823690826.7	
2	544394400	0	43880241.6	0.258	32455800000	0.018125409	588274641.6	0.051	1655245800	1066971158	674204113.3	
3	544394400	0	45635451.26	0.258	32455800000	0.018179489	590029851.3	0.05202	1688350716	1098320865	551680089.9	
4	544394400	0	47460869.31	0.258	32455800000	0.018235732	591855269.3	0.05306	1722117730	1130262461	451291069.4	
5	544394400	0	49359304.09	0.258	32455800000	0.018294225	593753704.1	0.05412	1756560085	1162806381	369066138.4	
6	544394400	0	51333676.25	0.258	32455800000	0.018355058	595728076.3	0.0552	1791691287	1195963210	301740755.7	
7	544394400	0	53387023.3	0.258	32455800000	0.018418323	597781423.3	0.05631	1827525112	1229743689	246632391.8	
8	544394400	0	55522504.23	0.258	32455800000	0.01848412	599916904.2	0.05743	1864075615	1264158710	201537781	
9	544394400	0	57743404.4	0.258	32455800000	0.018552549	602137804.4	0.05858	1901357127	1299219322	164648091.5	
10	544394400	0	60053140.58	0.258	32455800000	0.018623714	604447540.6	0.05975	1939384269	1334936729	134478938.1	
11	544394400	0	62455266.2	0.258	32455800000	0.018697726	606849666.2	0.06095	1978171955	1371322289	109812678	
12	544394400	0	64953476.85	0.258	32455800000	0.018774699	609347876.8	0.06217	2017735394	1408387517	89650862.85	
13	544394400	0	67551615.92	0.258	32455800000	0.018854751	611946015.9	0.06341	2058090102	1446144086	73175084.3	
14	544394400	0	70253680.56	0.258	32455800000	0.018938004	614648080.6	0.06468	2099251904	1484603823	59714747.34	
15	544394400	0	73063827.78	0.258	32455800000	0.019024588	617458227.8	0.06597	2141236942	1523778714	48720561.62	
16	544394400	0	75986380.89	0.258	32455800000	0.019114635	620380780.9	0.06729	2184061681	1563680900	39742746.23	
17	544394400	0	79025836.13	0.258	32455800000	0.019208284	623420236.1	0.06864	2227742914	1604322678	32413119.01	
18	544394400	0	82186869.57	0.258	32455800000	0.019305679	626581269.6	0.07001	2272297773	1645716503	26430384.69	
19	544394400	0	85474344.36	0.258	32455800000	0.01940697	629868744.4	0.07141	2317743728	1687874984	21548055.99	
20	544394400	0	88893318.13	0.258	32455800000	0.019512313	633287718.1	0.07284	2364098603	1730810885	17564540.61	
21	544394400	0	92449050.86	0.258	32455800000	0.019621869	636843450.9	0.0743	2411380575	1774537124	14315009.02	
22	544394400	0	96147012.89	0.258	32455800000	0.019735807	640541412.9	0.07578	2459608186	1819066773	11664725.86	
23	544394400	0	99992893.41	0.258	32455800000	0.019854303	644387293.4	0.0773	2508800350	1864413057	9503583.397	
24	544394400	0	103992609.1	0.258	32455800000	0.019977539	648387009.1	0.07884	2558976357	1910589348	7741622.058	
25	544394400	0	108152313.5	0.258	32455800000	0.020105704	652546713.5	0.08042	2610155884	1957609171	6305361.1	
26	544394400	0	112478406	0.258	32455800000	0.020238996	656872806	0.08203	2662359002	2005486196	5134793.8	
27	544394400	0	116977542.3	0.258	32455800000	0.020377619	661371942.3	0.08367	2715606182	2054234240	4180927.664	
28	544394400	0	121656644	0.258	32455800000	0.020521788	666051044	0.08534	2769918305	2103867261	3403771.397	
29	544394400	0	126522909.7	0.258	32455800000	0.020671723	670917309.7	0.08705	2825316672	2154399362	2770687.973	
30	544394400	0	131583826.1	0.258	32455800000	0.020827656	675978226.1	0.08879	2881823005	2205844779	2255047.61	
31	544394400	0	136847179.2	0.258	32455800000	0.020989826	681241579.2	0.09057	2939459465	2258217886	1835126.339	
32	544394400	0	142321066.3	0.258	32455800000	0.021158482	686715466.3	0.09238	2998248654	2311533188	1493205.627	
33	544394400	0	148013909	0.258	32455800000	0.021333885	692408309	0.09423	3058213627	2365805318	1214836.543	
34	544394400	0	153934465.4	0.258	32455800000	0.021516304	698328865.4	0.09611	3119377900	2421049035	988238.5423	
35	544394400	0	160091844	0.258	32455800000	0.02170602	704486244	0.09803	3181765458	2477279214	803808.362	
36	544394400	0	166495517.7	0.258	32455800000	0.021903324	710889917.7	0.09999	3245400767	2534510849	653718.9504	
37	544394400	0	173155338.4	0.258	32455800000	0.022108521	717549738.4	0.10199	3310308783	2592759044	531592.0003	
38	544394400	0	180081552	0.258	32455800000	0.022321926	724475952	0.10403	3376514958	2652039006	432230.6353	
39	544394400	0	187284814.1	0.258	32455800000	0.022543866	731679214.1	0.10611	3444045257	2712366043	351401.2447	
40	544394400	0	194776206.6	0.258	32455800000	0.022774685	739170606.6	0.10824	3512926162	2773755556	285655.4674	
											4513608320	0.00
					IRR = 0.258 = 26%							

Appendix H: Cash Flow Trend Analysis of a Gas Power Plant in Nigeria

Appendix H: Cash Flow Trend Analysis for the Gas Power Plant															
Year	A/CAPEX ($)	Fuel Cost ($)	O&M Cost ($)	DR	E/O (kWh)	COE ($/kWh)	APC($)	SCE ($)	Revenue ($)	Cash Flow ($)	Present Value ($)	NPV ($)	CCF ($)	Year	Cash Return ($)
1	347592000	246849.5	112000000	0.12	25623000000	0.017946331	459838849.5	0.05	1281150000	821311150.5	733313527.2		821311151	1	-9506448850
2	347592000	251786.49	116480000	0.12	25623000000	0.018121367	464323786.5	0.051	1306773000	842449213.5	671595355.2		1663760364	2	-8763999636
3	347592000	256822.2198	121139200	0.12	25623000000	0.0183034	468988022.2	0.05202	1332908460	863920437.8	614921503.3		2527680802	3	-7900079198
4	347592000	261958.6642	125984768	0.12	25623000000	0.018492711	473838726.7	0.05306	1359566629	885727902.5	562896094.6		3413408704	4	-7014351296
5	347592000	267197.8375	131024158.7	0.12	25623000000	0.01868959	478883356.6	0.054122	1386757962	907874605.2	515152432.6		4321283310	5	-6106476690
6	347592000	272541.7942	136265125.1	0.12	25623000000	0.01889434	484129666.9	0.055204	1414493121	930363454.2	471351079.9		5251646764	6	-5176113236
7	347592000	277992.6301	141715730.1	0.12	25623000000	0.019107276	489585722.7	0.056308	1442782983	953197260.7	431178033		6204844024	7	-4223915976
8	347592000	283552.4827	147384359.3	0.12	25623000000	0.019328725	495259911.8	0.057434	1471638643	976378731.4	394342993.7		7181222756	8	-3246537244
9	347592000	289223.5324	153279733.6	0.12	25623000000	0.019559027	501160957.2	0.058583	1501071416	999910458.8	360577735.5		8181133215	9	-2246626785
10	347592000	295008.003	159410923	0.12	25623000000	0.019798538	507297931	0.059755	1531092844	1023794913	329634561.8		9204928128	10	-1222831872
11	347592000	300908.1631	165787359.9	0.12	25623000000	0.020047624	513680268.1	0.06095	1561714701	1048034433	301284855.8		1.0253E+10	11	-174797439
12	347592000	306926.3263	172418854.3	0.12	25623000000	0.020306669	520317780.6	0.062169	1592948995	1072631215	275317716.7		1.1326E+10	12	897833775.6
13	347592000	313064.8529	179315608.5	0.12	25623000000	0.020576071	527220673.3	0.063412	1624807975	1097587302	251538681		1.2423E+10	13	1995421077
14	347592000	319326.1499	186488232.8	0.12	25623000000	0.020856245	534399559	0.06468	1657304135	1122904576	229768523.9		1.3546E+10	14	3118325653
15	347592000	325712.6729	193947762.1	0.12	25623000000	0.02114762	541865474.8	0.065974	1690450217	1148584742	209842138.2		1.4695E+10	15	4266910395
16	347592000	332226.9264	201705672.6	0.12	25623000000	0.021450646	549629899.5	0.067293	1724259222	1174629322	191607487.1		1.5869E+10	16	5441539718
17	347592000	338871.4649	209773899.5	0.12	25623000000	0.021765787	557704771	0.068639	1758744406	1201039635	174924626.1		1.707E+10	17	6642579353
18	347592000	345648.8942	218164855.5	0.12	25623000000	0.022093529	566102504.4	0.070012	1793919294	1227816790	159664792.1		1.8298E+10	18	7870396142
19	347592000	352561.8721	226891449.7	0.12	25623000000	0.022434376	574836011.6	0.071412	1829797680	1254961668	145709554.4		1.9553E+10	19	9125357811
20	347592000	359613.1095	235967107.7	0.12	25623000000	0.022788851	583918720.8	0.072841	1866393634	1282474913	132950025.5		2.0836E+10	20	10407832724
21	347592000	366805.3717	245405792	0.12	25623000000	0.023157499	593364597.4	0.074297	1903721506	1310356909	121286126.7		2.2146E+10	21	11718189633
22	347592000	374141.4792	255222023.7	0.12	25623000000	0.023540888	603188165.2	0.075783	1941795936	1338607771	110625906.7		2.3485E+10	22	13056797404
23	347592000	381624.3087	265430904.6	0.12	25623000000	0.023939606	613404529	0.077299	1980631855	1367227326	100884909.4		2.4852E+10	23	14424024730
24	347592000	389256.7949	276048140.8	0.12	25623000000	0.024354268	624029397.6	0.078845	2020244492	1396215095	91985587.15		2.6248E+10	24	15820239825
25	347592000	397041.9308	287090066.5	0.12	25623000000	0.024785509	635079108.4	0.080422	2060649382	1425570274	83856757.23		2.7674E+10	25	17245810099
26	347592000	404982.7694	298573669.1	0.12	25623000000	0.025233995	646570651.9	0.08203	2101862370	1455291718	76433098.97		2.9129E+10	26	18701101817
27	347592000	413082.4248	310516615.9	0.12	25623000000	0.025700414	658521698.3	0.083671	2143899617	1485377919	69654688.03		3.0614E+10	27	20186479736
28	347592000	421344.0733	322937280.5	0.12	25623000000	0.026185483	670950624.6	0.085344	2186777610	1515826985	63466565.84		3.213E+10	28	21702306721
29	347592000	429770.9548	335854771.7	0.12	25623000000	0.026689948	683876542.7	0.087051	2230513162	1546636619	57818341.66		3.3677E+10	29	23248943340
30	347592000	438366.3739	349288962.6	0.12	25623000000	0.027214586	697319329	0.088792	2275123425	1577804096	52663825.01		3.5255E+10	30	24826747436
	10427760000								5.197E+10	3.5255E+10	7986247524	5E+09			

Appendix I: Cash Flow Trend Analysis of a Hydropower Plant

APPENDIX I: Cash Flow Analysis Trend for the Hydropower Plant															
Year	A/CAPEX ($)	Fuel Cost ($)	O&M Cost ($)	DR	E/O (kWh)	COE ($/kWh)	APC ($)	SCE ($)	Revenue ($)	Cash Flow ($)	Present Value ($)	NPV ($)	CCF($)	Year	Cash Return ($)
1	544394400	0	42192540	0.12	32455800000	0.018073409	586586940	0.05	1622790000	1036203060	925181303.6		1036203060	1	-20739572940
2	544394400	0	43880241.6	0.12	32455800000	0.018125409	588274641.6	0.051	1655245800	1066971158	850582875		2103174218	2	-19672601782
3	544394400	0	45635451.26	0.12	32455800000	0.018179489	590029851.3	0.05202	1688350716	1098320865	781763097.3		3201495083	3	-18574280917
4	544394400	0	47460869.31	0.12	32455800000	0.018235732	591855269.3	0.05306	1722117730	1130262461	718302227.3		4331757544	4	-17444018456
5	544394400	0	49359304.09	0.12	32455800000	0.018294225	593753704.1	0.054122	1756560085	1162806381	659807568.5		5494563925	5	-16281212075
6	544394400	0	51333676.25	0.12	32455800000	0.018355058	595728076.3	0.055204	1791691287	1195963210	605912182.2		6690527135	6	-15085248865
7	544394400	0	53387023.3	0.12	32455800000	0.018418323	597781423.3	0.056308	1827525112	1229743689	556273592.8		7920270824	7	-13855505176
8	544394400	0	55522504.23	0.12	32455800000	0.01848412	599916904.2	0.057434	1864075615	1264158710	510572500.6		9184429535	8	-12591346465
9	544394400	0	57743404.4	0.12	32455800000	0.018552549	602137804.4	0.058583	1901357127	1299219322	468511512.3		10483648857	9	-11292127143
10	544394400	0	60053140.58	0.12	32455800000	0.018623714	604447540.6	0.059755	1939384269	1334936729	429813899.2		11818585586	10	-9957190414
11	544394400	0	62455266.2	0.12	32455800000	0.018697726	606849666.2	0.06095	1978171955	1371322289	394222389		13189907875	11	-8585868125
12	544394400	0	64953476.85	0.12	32455800000	0.018774699	609347876.8	0.062169	2017735394	1408387517	361497996.8		14598295392	12	-7177480608
13	544394400	0	67551615.92	0.12	32455800000	0.018854751	611946015.9	0.063412	2058090102	1446144086	331418899.7		16044439478	13	-5731336522
14	544394400	0	70253680.56	0.12	32455800000	0.018938004	614648080.6	0.06468	2099251904	1484603823	303779356.1		17529043301	14	-4246732699
15	544394400	0	73063827.78	0.12	32455800000	0.019024588	617458227.8	0.065974	2141236942	1523778714	278388674.1		19052822015	15	-2722953985
16	544394400	0	75986380.89	0.12	32455800000	0.019114635	620380780.9	0.067293	2184061681	1563680900	255070227		20616502915	16	-1159273085
17	544394400	0	79025836.13	0.12	32455800000	0.019208284	623420236.1	0.068639	2227742914	1604322678	233660519.1		22220825593	17	445149593.2
18	544394400	0	82186869.57	0.12	32455800000	0.019305679	626581269.6	0.070012	2272297773	1645716503	214008299.5		23866542096	18	2090766096
19	544394400	0	85474344.36	0.12	32455800000	0.01940697	629868744.4	0.071412	2317743728	1687874984	195973724.2		25554417080	19	3778641080
20	544394400	0	88893318.13	0.12	32455800000	0.019512313	633287718.1	0.072841	2364098603	1730810885	179427565.4		27285227965	20	5509451965
21	544394400	0	92449050.86	0.12	32455800000	0.019621869	636843450.9	0.074297	2411380575	1774537124	164250467.1		29059765088	21	7283989088
22	544394400	0	96147012.89	0.12	32455800000	0.019735807	640541412.9	0.075783	2459608186	1819066773	150332244.8		30878831862	22	9103055862
23	544394400	0	99992893.41	0.12	32455800000	0.019854303	644387293.4	0.077299	2508800350	1864413057	137571228.1		32743244918	23	10967468918
24	544394400	0	103992609.1	0.12	32455800000	0.019977539	648387009.1	0.078845	2558976357	1910589348	125873644.8		34653834266	24	12878058266
25	544394400	0	108152313.5	0.12	32455800000	0.020105704	652546713.5	0.080422	2610155884	1957609171	115153044.3		36611443437	25	14835667437
26	544394400	0	112478406	0.12	32455800000	0.020238996	656872806	0.08203	2662359002	2005486196	105329758.3		38616929632	26	16841153632
27	544394400	0	116977542.3	0.12	32455800000	0.020377619	661371942.3	0.083671	2715606182	2054234240	96330397.32		40671163872	27	18895387872
28	544394400	0	121656644	0.12	32455800000	0.020521788	666051044	0.085344	2769918305	2103867261	88087381.61		42775031133	28	20999255133
29	544394400	0	126522909.7	0.12	32455800000	0.020671723	670917309.7	0.087051	2825316672	2154399362	80538503.25		44929430495	29	23153654495
30	544394400	0	131583826.1	0.12	32455800000	0.020827656	675978226.1	0.088792	2881823005	2205844779	73626519.12		47135275274	30	25359499274
31	544394400	0	136847179.2	0.12	32455800000	0.020989826	681241579.2	0.090568	2939459465	2258217886	67298772.05		49393493160	31	27617717160
32	544394400	0	142321066.3	0.12	32455800000	0.021158482	686715466.3	0.092379	2998248654	2311533188	61506838.96		51705026348	32	29929250348
33	544394400	0	148013909	0.12	32455800000	0.021333885	692408309	0.094227	3058213627	2365805318	56206204.04		54070831666	33	32295055666
34	544394400	0	153934465.4	0.12	32455800000	0.021516304	698328865.4	0.096112	3119377900	2421049035	51355955.6		56491880701	34	34716104701
35	544394400	0	160091844	0.12	32455800000	0.02170602	704486244	0.098034	3181765458	2477279214	46918504.98		58969159915	35	37193383915
36	544394400	0	166495517.7	0.12	32455800000	0.021903324	710889917.7	0.099994	3245400767	2534510849	42859326.14		61503670764	36	39727894764
37	544394400	0	173155338.4	0.12	32455800000	0.022108521	717549738.4	0.101994	3310308783	2592759044	39146714.55		64096429808	37	42320653808
38	544394400	0	180081552	0.12	32455800000	0.022321926	724475952	0.104034	3376514958	2652039006	35751564.05		66748468815	38	44972692815
39	544394400	0	187284814.1	0.12	32455800000	0.022543866	731679214.1	0.106115	3444045257	2712366043	32647160.52		69460834858	39	47685058858
40	544394400	0	194776206.6	0.12	32455800000	0.022774685	739170606.6	0.108237	3512926162	2773755556	29808991.17		72234590414	40	50458814414
	2.178E+10										10854761630	6.4E+09			

Appendix J: Gas Plant Levelized Cost of Energy (Deregulated Scenario)

	APPENDIX J: 4000MW GAS PLANT LEVELIZED COST OF ENERGY (Deregulated Scenario)							
Year (t)	A/CAPEX ($)	Discount Rate (d)	O&M Cost ($)	Fuel Cost ($)	Energy Output (kWh)	COE $/kWh	APC ($)	LCOE $/kWh
1	347592000	0.12	112000000	4907352	25623000000	0.01812822	464499352	
2	347592000	0.12	116480000	5005499.04	25623000000	0.01830689	469077499	
3	347592000	0.12	121139200	5105609.02	25623000000	0.01849264	473836809	
4	347592000	0.12	125984768	5207721.2	25623000000	0.01868573	478784489.2	
5	347592000	0.12	131024159	5311875.63	25623000000	0.01888647	483928034.3	
6	347592000	0.12	136265125	5418113.14	25623000000	0.01909516	489275238.2	
7	347592000	0.12	141715730	5526475.4	25623000000	0.01931211	494834205.5	
8	347592000	0.12	147384359	5637004.91	25623000000	0.01953766	500613364.2	
9	347592000	0.12	153279734	5749745.01	25623000000	0.01977214	506621478.7	
10	347592000	0.12	159410923	5864739.91	25623000000	0.02001591	512867662.9	
11	347592000	0.12	165787360	5982034.7	25623000000	0.02026934	519361394.6	
12	347592000	0.12	172418854	6101675.4	25623000000	0.02053282	526112529.7	
13	347592000	0.12	179315608	6223708.91	25623000000	0.02080675	533131317.4	
14	347592000	0.12	186488233	6348183.09	25623000000	0.02109154	540428415.9	
15	347592000	0.12	193947762	6475146.75	25623000000	0.02138762	548014908.9	
16	347592000	0.12	201705673	6604649.68	25623000000	0.02169544	555902322.3	
17	347592000	0.12	209773900	6736742.68	25623000000	0.02201548	564102642.2	
18	347592000	0.12	218164856	6871477.53	25623000000	0.02234822	572628333	
19	347592000	0.12	226891450	7008907.08	25623000000	0.02269416	581492356.8	
20	347592000	0.12	235967108	7149085.22	25623000000	0.02305383	590708192.9	
21	347592000	0.12	245405792	7292066.93	25623000000	0.02342777	600289858.9	
22	347592000	0.12	255222024	7437908.26	25623000000	0.02381657	610251932	
23	347592000	0.12	265430905	7586666.43	25623000000	0.0242208	620609571.1	
24	347592000	0.12	276048141	7738399.76	25623000000	0.02464109	631378540.6	
25	347592000	0.12	287090066	7893167.75	25623000000	0.02507806	642575234.2	
26	347592000	0.12	298573669	8051031.11	25623000000	0.0255324	654216700.2	
27	347592000	0.12	310516616	8212051.73	25623000000	0.02600479	666320667.6	
28	347592000	0.12	322937281	8376292.76	25623000000	0.02649594	678905573.3	
29	347592000	0.12	335854772	8543818.62	25623000000	0.02700662	691990590.4	
30	347592000	0.12	349288963	8714694.99	25623000000	0.02753759	705595657.6	
				199081845	**7.6869E+11**		**1.691E+10**	**0.023**

APPENDIX K: The Estimations and Calculations [Cash Flow Analysis] Showing the Internal Rate of Return of Gas Power Plant in Nigeria (Deregulated Scenario)

APPENDIX K: The Estimations and Calculations [Cash Flow Analysis] Showing the Internal Rate of Return of a 400MW Gas Power Plant in Nigeria (Deregulated Scenario)												
Year	A/CAPEX ($)	Fuel Cost ($)	O&M Cost ($)	DR	E/O (kWh)	COE ($/kWh)	APC ($)	SCE ($)	Revenue ($)	Cash Flow ($)	Present Value ($)	NPV($)
1	347592000	4907352	112000000	0.316	25623000000	0.018128219	464499352	0.05	1281150000	816650648	620555203.6	
2	347592000	5005499.04	116480000	0.316	25623000000	0.018306892	469077499	0.051	1306773000	837695501	483698125.6	
3	347592000	5105609.021	121139200	0.316	25623000000	0.018492636	473836809	0.05202	1332908460	859071651	376930881.3	
4	347592000	5207721.201	125984768	0.316	25623000000	0.018685731	478784489.2	0.0530604	1359566629	880782140	293660100.1	
5	347592000	5311875.625	131024158.7	0.316	25623000000	0.018886471	483928034.3	0.05412161	1386757962	902829927.4	228731775.1	
6	347592000	5418113.138	136265125.1	0.316	25623000000	0.019095158	489275238.2	0.05520404	1414493121	925217882.8	178118357.9	
7	347592000	5526475.401	141715730.1	0.316	25623000000	0.01931211	494834205.5	0.05630812	1442782983	947948778	138673554	
8	347592000	5637004.909	147384359.3	0.316	25623000000	0.019537656	500613364.2	0.05743428	1471638643	971025278.9	107940250.6	
9	347592000	5749745.007	153279733.6	0.316	25623000000	0.019772137	506621478.7	0.05858297	1501071416	994449937.3	84000122.85	
10	347592000	5864739.907	159410923	0.316	25623000000	0.02001591	512867662.9	0.05975463	1531092844	1018225181	65355921.2	
11	347592000	5982034.705	165787359.9	0.316	25623000000	0.020269344	519361394.6	0.06094972	1561714701	1042353307	50839370.73	
12	347592000	6101675.399	172418854.3	0.316	25623000000	0.020532823	526112529.7	0.06216872	1592948995	1066836465	39539136.51	
13	347592000	6223708.907	179315608.5	0.316	25623000000	0.020806749	533131317.4	0.06341209	1624807975	1091676658	30744502.07	
14	347592000	6348183.085	186488232.8	0.316	25623000000	0.021091536	540428415.9	0.06468033	1657304135	1116875719	23901348.23	
15	347592000	6475146.747	193947762.1	0.316	25623000000	0.021387617	548014908.9	0.06597394	1690450217	1142435308	18577757	
16	347592000	6604649.682	201705672.6	0.316	25623000000	0.021695442	555902322.3	0.06729342	1724259222	1168356899	14437144.36	
17	347592000	6736742.675	209773899.5	0.316	25623000000	0.02201548	564102642.2	0.06863929	1758744406	1194641764	11217280.39	
18	347592000	6871477.529	218164855.5	0.316	25623000000	0.022348216	572628333	0.07001207	1793919294	1221290961	8713911.32	
19	347592000	7008907.08	226891449.7	0.316	25623000000	0.022694156	581492356.8	0.07141231	1829797680	1248305323	6767977.812	
20	347592000	7149085.221	235967107.7	0.316	25623000000	0.023053826	590708192.9	0.07284056	1866393634	1275685441	5255642.47	
21	347592000	7292066.926	245405792	0.316	25623000000	0.023427774	600289858.9	0.07429737	1903721506	1303431647	4080511.317	
22	347592000	7437908.264	255222023.7	0.316	25623000000	0.023816568	610251932	0.07578332	1941795936	1331544005	3167568.091	
23	347592000	7586666.429	265430904.6	0.316	25623000000	0.0242208	620609571.1	0.07729898	1980631855	1360022284	2458445.42	
24	347592000	7738399.758	276048140.8	0.316	25623000000	0.024641086	631378540.6	0.07884496	2020244492	1388865952	1907739.134	
25	347592000	7893167.753	287090066.5	0.316	25623000000	0.025078064	642575234.2	0.08042186	2060649382	1418074148	1480136.293	
26	347592000	8051031.108	298573669.1	0.316	25623000000	0.025532401	654216700.2	0.0820303	2101862370	1447645670	1148177.823	
27	347592000	8212051.73	310516615.9	0.316	25623000000	0.026004787	666320667.6	0.08367091	2143899617	1477578950	890515.9136	
28	347592000	8376292.765	322937280.5	0.316	25623000000	0.026495944	678905573.3	0.08534432	2186777610	1507872036	690557.0882	
29	347592000	8543818.62	335854771.7	0.316	25623000000	0.027006619	691990590.4	0.08705121	2230513162	1538522571	535405.8141	
30	347592000	8714694.993	349288962.6	0.316	25623000000	0.02753759	705595657.6	0.08879223	2275123425	1569527767	415042.2656	
									5.1974E+10	**35065439801**	**2804432462**	**0.00**
					IRR = 32%							

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