Financial Costs and Benefits Analysis of Gas Development Projects in Nigeria

Ahmed Adamu*
Department of Economics, Umaru Musa Yar'adua University, PMB 2218, Katsina, Katsina State

Muttaqah Rabe Darma
Pleasant Engineering and Technical Services

Abstract
Natural Gas possesses huge potential to addressing energy and petrochemical needs of Nigeria. Despite the abundance of this resource, inadequacy and relative expensiveness of power and energy fuels/feeds pose threat to the economic prosperity of the country. To address these challenges and to harness the potentials of gas in Nigeria, there is need for increased investment for gas development to meet latent energy demand in the country. Therefore, this research explored the viability of two important gas development projects to provide a case for investors to invest in the gas sector of the country. As a result, costs and benefits of two gas development projects (CCGT and GTL plants) were analysed using net present value, internal rate of return and payback period accounting methods, and CCGT project was found to be viable and GTL project not viable in the country. Even though GTL project was found to be unviable at the market scenarios in the country, incentives are recommended to attract investment for this important gas development project.
Keywords: CCGT, GTL, NPV, IRR, Payback Period, Nigeria, Natural Gas, Economic Growth

1. Introduction

The main concern of this research is domestic gas supply in Nigeria, and specifically two out of the various gas development projects are considered for the costs and benefits analysis. These two projects are Gas to Power (GTP) and Gas to Liquid (GTL). The costs and benefits analysis of the case studies for these gas transformation/development projects will be discussed in this research i.e. GTP and GTL.

The natural gas can be used for its energy value or it can be used for its chemical value, and since one of the research enquiries is the economic analysis of the relevant and specific gas uses or development projects, this research tries to explore the economic costs and benefits of one case study each for the two types of the gas uses (energy and chemical use), which are Gas to Power for the energy use and Gas to Liquid for the chemical use. The specific choice of electricity and synthetic fuels projects is justified by their ability to transform the lives of the population in the country, through improved access to electricity, cleaner and competitive transport fuels as well as industrial feedstock, which will help improve the welfare and productivity of the economy. More specific justifications for these two projects are mentioned below.

1. 1 CCGT project

The CCGT project is used as the case study for the energy use of the gas, and it was selected for this comparison, because Nigeria is lacking sufficient electricity supply. Like highlighted earlier, only 48% of Nigerians have access to electricity in 2010 (World Bank, 2015) , and in 2014, Nigeria was ranked 185th in terms of access to electricity per capita (World Bank, 2014). In 2011, the Nigerian electricity consumption per capita was 189kWh (World Bank, 2014). This lowered economic opportunities in the country and makes the cost of production more expensive, where cost of energy is estimated to contribute 40% of the cost of production in the manufacturing sector (Adaramola, Paul, & Oyewola, 2014) Similarly, 63% of the electricity production comes from the gas turbines in 2012 (Nigerian Electricity Regulatory Commission, 2013), and this proportion is estimated to reach up to 70% in 2030 (Ibitoye & Adenikinju A., 2007). Some of the existing gas turbines are not operating at optimum level due to technical issues and shortage of gas supply, and they are largely concentrated at one region (South) (Lookman, 2014). This led to the increasing loss of energy in the process of transmitting the electricity, and also pose the challenge of the limited operational capacity of the Nigerian electricity transmission networks, which is 4, 800MW in 2015 (Nigerian Bulk Electricty Trading Plc, 2015). The electricity demand is expected to grow up to 1 billion MWh by 2030, which indicates that there will be significant increase in demand for energy in the residential, industrial and service sectors, which all necessitate for consideration for more efficient sources of energy, which the CCGT project can help achieved (Ibitoye & Adenikinju A., 2007).

Therefore, in order to enhance electricity supply and accessibility in the country, which will lead to cheaper cost of production, more efficient gas power plants need to be established. This will also help spread the electricity production across the country, and help create job opportunities and reduce the electricity loss in the process of transporting the electricity to far distance places. Improving electricity will help encourage foreign and local investment, which will eventually boost the economic productivity. Therefore, the CCGT projects are essential for economic development and for improvement of domestic gas utilization in line with the objective of the gas master plan, hence the choice of the project in this comparison.

1.2 GTL project

In 2012, more than 80% of the Nigerian total primary energy consumption came from traditional solid biomass and waste (EIA, 2015). The residential sector largely use traditional biomass for cooking purposes, and these cause harmful effect on the health of the households and cause deforestations. The supply of the cooking kerosene and gas are not sufficient and unaffordable to many households. Air transport is increasing with many airports and airliners are now operating in the country, the demand for jet kerosene is also increasing. “GTL kerosene is an alternative to conventional oil-based kerosene. It can be used for heating and lighting, but its primary use is expected to be for aviation, contributing to the diversification of the aviation fuel supply” (Shell Petroleum Company, 2015). The diversification of sources of a cleaner heating and jet kerosene will help provide more affordable access to the energy products due to the resulting competition and low cost as a result of domestic production, and it will end the dominance of the oil products. This will also help enhance movements of goods and services within and outside the country due to improved supply of transport fuels, it will also help improve the wellbeing of the people and improve the environmental condition in the country due to use of cleaner fuel. Therefore, the GTL project is essential in providing alternative fuel that can be used in residential and commercial sectors of the economy, which were estimated to consume more of energy as earlier mentioned. The export of gas is also projected to slightly reduce, which indicates possibilities of more demand within the country that will necessitate domestic supply, which the GTL can help facilitate.

Similarly, 70% of the Nigeria’s domestic petroleum products are imported from abroad, thereby making the price of these products relatively expensive. Motor gasoline is largely consumed for road transport, and the government subsidises consumption of this product, and this costs government around $7 billion in 2012 (Ola Ajayi, 2015). In order to provide alternative to the motor gasoline, reduce the cost of importing the petroleum products, increase domestic supply of petroleum products, provide cleaner product and reduce the cost of subsidy, GTL gasoline need to be supplied at relatively competitive volume. The GTL products supply chain has the potential to create job opportunities as well. These are also reasons why the GTL project is considered in this comparison.

In addition, Nigeria is at the process of diversifying its economy and establishing more manufacturing industries, and with the new administration in 2015, there are hopes that the existing refineries will be optimised and new ones built. One of the industrial inputs that can be used to facilitate production of many petroleum products in manufacturing sector and refineries is Naphtha, which GTL plant produces. “GTL Naphtha is an alternative to high quality feedstock for chemical manufacturing that make the building blocks for plastics. It offers superior yields of ethylene/propylene and lower feedstock costs than conventional Naphtha” (Shell Petroleum Company, 2015). GTL Naphtha can be used “to produce additional high-octane gasoline components, and it can be used as solvents, cleaning fluids, paint and varnish diluents, asphalt diluents, rubber industry solvents, dry-cleaning, cigarette lighters, and portable camping stove and lantern fuels. It can also be used in the petrochemicals industry as feedstock to steam reformers and steam crackers for the production of hydrogen (which may be converted into ammonia for fertilizers), ethylene and other olefins” (Ola Ajayi, 2015).

This means the GTL Naphtha can be used in production of ammonia for fertilizer production, which will help boost agricultural productivity, and help substitute the oil and gas sectors as the major sources of income in the economy. The GTL products do not require unique transportation infrastructures and can be mixed with the conventional petroleum products. These are the reasons why the GTL plant is considered important, and it is in line with delivering economic advantage using the natural gas, which is the main concern of this research. Therefore, the viability of the two identified important projects will now be assessed in order to inform investors and government of the business profitability of these projects in the country.

Based on the above mentioned relevance of these two projects, an economic assessment of the viability and sensitivity of these projects in Nigeria were made, so that investors can make informed decision when deciding among these two important projects in the country. The viability assessment is also useful in order to identify the less viable and less attractive project among the two, so as to provide recommendations and possibilities of incentivizing investment for the unviable project (if any) given its relevance as earlier mentioned.

2 Concepts and Literatures on Gas Transformation Options

These are gas development projects that can be used to transform gas into different useful energy products, these include GTL and GTP.

2.1 GTL Project

2.1.1. GTL Concept

According to (Panahi, 2012), “A GTL (gas to liquids) plant consists of three main sections: synthesis gas production, Fischer-Tropsch (FT) reactor, and FT products upgrading". It is the process of utilizing natural gas, where the hydrocarbon feedstock (natural gas or any Gaseous feedstock) can be transformed into synthesis gas (contains mainly Hydrogen and Carbon Monoxide), and later the generated syngas pass through Fischer-Tropsch reactor to convert it into hydrocarbon liquids. These liquids can be used as transport fuels like gasoline or diesel, or any other desired liquid products, like kerosene for jet aircraft, naphtha for petrochemical use etc. The syngas process includes auto-thermal reforming, compact reforming, and catalytic and non-catalytic partial oxidation" (Larry & Burke, 2006). GTL-FT process (referred to as GTL in the remaining parts of the research) is a special technological innovation that provides an alternative source of energy that can be used to tackle the global fear of possible oil depletion and to provide solution to the continuous raising concern of the huge stranded and associated natural gas reserves in the world.

Fischer and Tropsch invented the FT process in 1920, which made it possible to convert synthesis gas to different fuels. Fischer Tropsch (FT) GTL is the technological option for converting syngas to transport fuels and other petroleum liquids (Panahi, 2012). Recently, two oil companies SASOL and Royal Dutch Shell have improved such technology for commercial purposes. Royal Dutch Shell built the largest GTL plant in Qatar as at 2011, apart from the one it built in Malaysia. Similarly in 2008, a three hour test flight was flown within the borders of Britain and France with a fuel consisting of 60% ordinary jet kerosene and 40% GTL jet fuel supplied by Shell (Dunn, 2008). The GTL fuels are designed suitable to be mixed with any conventional fuel, as such there is no need for modification of combustion engine technologies. In 2009, Qatar Airline tested the GTL fuel mixture with Jet Kerosene on a commercial flight from London to Doha. There are lots of other technological test of GTL products and all proved excellent (Peter, 2010). GTL plant can be of different sizes and efficiency level, the highest GTL capacity that was built was 140, 000 barrels of petroleum liquids per day (Pearl GTL plant in Qatar). The plant size can be reduced by decreasing the size of the hardware to produce up to a minimal capacity of 500 barrels per day (Holwell, 2011).

Tonkovich, et al (2011) in their paper titled "Micro-Channel Gas to Liquids for monetizing associated and stranded Natural Gas Reserves", looked at an innovative way of monetizing stranded natural gas reserves by way of processing the gas in a small scale GTL plants. They explored the possibility of applying "Micro-channel technology" to steam methane reforming and Fischer –Tropsch Synthesis (GTL) to reduce the economic costs involve in the two steps hydrocarbon process. Their research discussed extensively on the gas to liquids process that is enabled by Micro-Channel process technology "to improve the volumetric productivity and efficiency, reduce the capital cost and shrink the facility footprints, which is essential for economical small-scale on and offshore GTL facilities". They observed that conventional GTL technologies can only be used for large quantity of natural gas resource and requires huge amount of money to construct, which discourages investment, so the micro channel process of gas to liquids allows for low cost technological options for converting natural gas to liquids. According to them, "The challenge of monetizing smaller gas resources hinges on the ability to economically scale-down reaction hardware while maintaining sufficient capacity. By reducing the size and cost of chemical processing hardware, Microchannel process technology holds the potential of enabling cost effective production of synthetic fuels in smaller scale facilities, such as those needed for flare abatement" (Tonkovich & Jarosch, 2011).

They also highlighted some few natural gas technological options like Compressed Natural Gas (CNG) and LNG, which they argued to be insufficient in developing the global stranded and associated natural gas unless complemented by GTL synthesis especially the Micro-Channel GTLs (World Bank, 2013). However, CNG and LNG can still process large volume of gas at a time, and micro channel process of GTL can complement by processing small amount of feed gas mainly for local use within the industry. Therefore, with gas pipelines, GTL, CNG and LNG plants operating at relative capacity can provide markets for huge portions of gas reserves in the country. This research will consider GTL plant as a project meant for utilizing the natural gas for domestic usage, which can spread around the country and turn large portions of gas reserves useful. However, Tonkovich, et al (2011) did not report on whether the small-scaled GTL plant is profitable or not. Details of GTL plants in the world as at 2002 is presented in Appendix A, as quoted directly from (Fleisch, Sills, & Briscoe, 2002).

2.1.2. Economic Analysis of FT-GTL Plants

Shabbir, G. (2014) reckoned that GTL is a viable gas project that can be relied on as a means of developing the stranded and/or associated gas, he identified several other projects that he considered reliable, but failed to rank between them in terms of viability. However, Wilhelm et al (2001) compared all feedstock that can be transformed to synthesis gas, and found that the least cost feedstock for synthesis gas production that can be used for FT synthesis is natural gas. They considered different technological options for developing syngas from natural gas and found that among the five technological options for generating synthesis gas from natural gas only two of them were found more economically viable for the syngas production, which are "two-step reforming and Auto-thermal Reforming (ATR)" especially for large scale GTL plants. They mentioned that due to the possible improvement in FT catalyst and reactor design, GTL facilities will be less costly in the future (Wilhelm & Simbeck, 2001). They equally mentioned, "In the near-term, associated gas may offer the greatest potential, particularly where such gas is subject to flaring constraints and associated reinjection costs (for enhancing oil recovery)." However, before that improvement in the FT synthesis is achieved (which help in reducing the overall cost of GTL process) different economies of scale could be achieved to optimize the production of syngas and subsequent conversion to hydrocarbon products.

They identified that production of syngas cost lot more in the GTL value chain and tried to see how the syngas production cost can be reduced to the lowest economically possible level. According to them the predominant technology used in generating syngas is the "steam methane reforming (SMR)", where methane and steam are converted to hydrogen and carbon monoxide. SMR acquired its dominance due to the high production of methane/hydrogen ratio over other available syngas producing technologies (two-step reforming, ATR, partial oxidation (POX), and heat exchange reforming) (Wilhelm & Simbeck, 2001). Finally, they made selective recommendations for Qatar and Nigeria, where they recommended application of only ATR for the two countries without stating reasons for that peculiarity. "ATR also known as catalytic partial oxidation, can closely control the final syngas composition by combining steam reforming with partial oxidation. The use of the process also results in higher operating pressures and improved thermal efficiencies" (Alan, 2010).

However, they have not considered the economic implication of combining two reforming technologies as they suggested. Additionally, a profit maximizing investor would have chosen the single reforming technology to minimize the cost if the syngas composition is sufficient for the FT synthesis.

Lee et al (2009) studied the economic evaluation of three different GTL products that are used as transportation fuels namely: F-T Diesel, Methanol (MeOH) and Dimethylether (DME). Since the profitability of a product in the process industry is dependent on the cost of its raw material and its product price, they varied the cost of natural gas (the raw material) two times, using high ($7.92/MMBtu) and low ($3/MMBtu) scenarios. Using payback period method to identifying the most profitable among the three GTL products, F-T Diesel was found to be more lucrative in the High Scenario, followed by DME and then MeOH, with the payback periods of 5.91, 9.76 and 13.24 years respectively (Lee, 2009).

In the low scenario, the order changed where DME was observed to be more profitable, then F-T Diesel, then MeOH. This is because the DME uses more raw materials (NG) than other products; as such any change in the price of the feedstock will immediately affect its manufacturing cost more than the remaining other two products. When the prices of each of the products were forecasted for the year 2012, the order of the viability as in the second scenario was maintained (Lee, 2009). Their analysis was based on the assumption that the three GTL plants are based in the Middle East and the end products are to be transported to South Korea with 5000 km distance and they assumed that 200mscf/d of the feedstock is consumed by each of the plants. Their research is very important in making investment decisions among the three GTL products at a particular place and time. However, using Middle East as the case study makes their economic analysis not applicable to many gas producing countries that produce it more expensive. An average cost producing country would have been used as the case study. Similarly, using payback method alone in the assessment is not reliable as some investors are not interested on how early they can make profit but how big the profit is or the present value of future profits, as such they would have included the method of Net Present Value or Internal Rate of Return (IRR).

Another economic analysis of GTL plant was conducted by Wood et al (2012) where they used IRR accounting method in examining the economic viability of the project (Wood, 2012). Their analysis was based on certain parameters such as cost of gas feedstock, price of petroleum products (GTL products prices are strongly influenced by the price of petroleum products, usually a bit above the petroleum products prices), capital cost, plant efficiency, operation and maintenance costs, cost of transporting the products, taxes and depreciations. Based on these factors, variation of the petroleum products prices and unit capital cost per barrel were made. Oil price per barrel was varied from $50 to $200, and production level between 50,000 and 200, 000 of barrels per day was varied. IRR percentage was calculated while varying the price of feed gas three different times at each combination of the oil price and production level. Their analysis concluded that the commerciality of a GTL plant is more sensitive to the price of oil and production capacity, and less sensitive to the cost of gas feeds. Their method of analysis particularly the assumptions are significant in making any economic analysis of GTL projects.

Another sensitivity analysis of GTL plant was made by Uzoh and Bretz (2012) where they evaluated the economic sensitivity of a small-scale GTL plants (Uzoh & Bretz, 2012). Their rational was based on the realization of the fact that most of economic evaluations consider large-scale GTL plants, with average capacity of 50, 000 barrels of GTL products per day. Uzoh and Bretz (2012) used similar economic method (IRR) like that of Wood et al (2012) in analysing the profitability of a small-scale GTL plant with the capacity of 1,000 barrels per day. Additionally, they complemented that with the use of Net Present Value (NPV) in confirming the commerciality of the project, which is a good practice. Almost similar parameters as used by Wood et al (2012) were adopted in their research. These parameters are capital cost, cost of feed gas, plant capacity, product price and cost of transportation. This is one of the strength of Uzoh's and Bretz's (2012) evaluation, because the price of the products and cost of transportation were additionally considered in the profit sensitivity analysis, unlike in that of Wood et al (2012), where only cost of feed gas, capital cost and oil price were used in the sensitivity analysis.

Uzoh and Bretz (2012) used spider diagram in detecting the level of sensitivity of each of the above parameters. Different scenarios were observed, where each of the parameters was at a time varied while holding the remaining parameters constant. According to their results, the most sensitive factor to profit is the product price, followed by capital cost and plant capacity (same level of sensitivity with capital cost though), and then the cost of feed gas. The least sensitive factor is the cost of transportation. However, they found that a small-scale GTL plant can be profitable. Their analysis did not consider different possible circumstances in locations, which might significantly affect GTL profit, and making it more sensitive to transportation cost, and this is why they should have consider a particular location and distance to markets. Cost of transportation can be the most sensitive factor in some countries where there is large disconnect (distance) between the plant and the market. Cost of transportation can be important also in countries where the transport fuel price is very high, which can affect the profitability of the project. Therefore, their results are not generic.

Patel B.(2005) found that the capital cost of LNG is 10-15% higher than that of GTL, but did not consider the operation and maintenance cost as well as profitability of the GTL project (Patel, 2005). Buping B. et al (2010) stated that it is difficult to arrive at the exact estimate of GTL capital cost, as it varies by countries, but mentioned that its fixed capital expenditure is around 85% of the total initial capital investment. They also estimated $2.5 billion as the total annual operation and maintenance cost for a plant with a capacity of 118,000 bbl/d, and $10.8 billion as the initial capital investment cost (Buping, Mahmoud, & Elbashir, 2010). The strength of their work is that, they went further to assess the profitability of the GTL using Return on Investment (ROI), Internal Rate of Return (IRR), and Payback method, which they found 10.7% as the ROI, 9% as the IRR and 8 years as the payback period. They found that cost of gas and price of GTL products are significant in determining the profitability of GTL plant. However, their analysis was generic, and may not be applicable in some countries. They should have selected a particular country to assess how viable the GTL plant will be in that country.

The above economic studies of the GTL project gives economic background on one of the gas development options that this study will consider. These studies serve as the conceptual description of one of the major gas development options, in line with this study, and it is apparent that very little has been written (from the survey conducted) on the profitability of GTL plant on country specific. This is why this research will consider the cost and profitability of the GTL project in Nigeria, so that investors can have an idea whether the project is viable in the country or not especially in comparison with other gas investment options. Similarly, some of the methodologies and approaches as used in the literature above will be applied for the purpose of this study.

2.1.3. GTL in Nigeria

The Nigerian first ever GTL Plant is an investment collaboration (joint venture) between the country's National Petroleum Corporation (NNPC) and Chevron Nigeria Limited (CNL), which has the estimated capacity of 33, 000 b/d and has economic interest ratio of 75 to 25 for the CNL and NNPC respectively (Quinlan, 2014). The plant site is located 100 kilometres away from Lagos, which is planned to receive its gas feeds from the Chevron-operated Escravos gas plant (EGP), while Sasol Chevron provides the marketing, technical and managerial services required for the project on behalf of the two shareholders. The plant is expected to mainly be producing petrol, diesel, kerosene and GTL naphtha products with Europe as the major market or place of export after domestic allocations (Ukpohor, 2009). The project has taken long time before it took off in September, 2014 (Quinlan, 2014), it was initially expected to start operation in 2013, but it does not seem to see the light of the day at that projected time due to the continuous upward adjustment of the project cost, the last cost review was at $8.4bn. In 2011, the leading partner sent some Nigerians to South Africa to train on how to operate and manage the plant. The plant has the capacity to convert 350 million cubic feet of natural gas per day to produce Naphtha and Diesel (Hydrocarbon Technology, 2012).

As at early 2015, the Nigerian GTL plant produces only Naphtha and it is mainly for exports purpose. Only two trains are operational as at first quarter of 2015. GTL technology has enormous potentials of creating demand for the Nigerian stranded and associated natural gas that is concentrated in one region (Niger Delta),which constitutes 6% of the country's population (National Population Commission, 2010), with larger population densities in far northern region, this indicates huge potential gas demand far from the gas reserves. This also underlines the need for gas transmission pipelines to the population concentrated regions. Therefore, establishment of GTL plants will help in producing various gas liquids that can be transported via conventional trucks to those regions or the plants can be spread around the country. Consequently, research (like this one) needs to be conducted to assess the investment as well as costs and benefits of GTL project in Nigeria with a view to utilize more of the gas within the country and provide energy fuels and inputs substitute to the presently available petroleum products which have become relatively unaffordable to Nigerians following the deregulation policy embarked by the Nigerian government.

2.2. Gas to Power using CCGT

2.2.1. Concept, economics and challenges of CCGT

Gas to power technology usually called Combined Cycle Gas Turbine (CCGT) is a technological innovation that uses natural gas's hot exhaust to drive electric generators and generate electricity; it is an advancement of the ordinary heat engine (known as open cycle turbine), which helps improve energy conversion efficiency (Merkl, 1996). Most countries use CCGT in generating electricity including Nigeria, North America and Europe, it can be built within 2 years and can start generating electricity in one year, it's flexibility in terms of manipulating the energy output and its short payback periods attracts investors' confidence (Kehlhofer, 2009) .

Kehlhofer, R. (2009) mentioned in his article that the economics of CCGT surpassed other steam power turbines, apart from it being the most environmentally favourable compare to other power turbines like Nuclear, Coal, and Biomass Power Turbines, CCGT appears to be most efficient with the recent improvement in its technology. Economic concern in comparing these power turbines is the energy efficiency, which is the ratio of the energy output (electricity) to the energy inputs (fuel feed). The thermal efficiency of the combined gas turbine is around 60% which is higher compare to the efficiency of coal power turbines which is around 32% to 42% (Carapellucci & Giordano, 2013).

Therefore, for economic selection of the type of fuel and power plant to be established, Kehlhofer, R. (2009), as the major point of considerations, has identified the following issues. "Long-term availability of the fuel at a competitive price, alternative for the primary fuel as backup, risk of supply shortages due to political interference, environmental considerations that favour a relatively clean fuel, such as natural gas, independence from a single fuel source, strategic reasons to use a domestic fuel, financing requirements (e.g., uninterruptible fuel supply)" (Kehlhofer, 2009). One of his major findings is that, CCGT is found to be less expensive in terms of its construction and operation cost, but the gas feeds is more expensive than other hydrocarbon feedstock required in other turbines. He also suggested that long term agreement need to be considered to address the issue of fuel price volatility. They discovered that coal power station has more fuel flexibility (compatibility with other fuels), but CCGT plants have cheaper capital cost even though more expensive to run because of its high fuel cost.

He further mentioned that, eyes always have to be on the electricity price and compare with the prevailing or forecasted price of gas that is used in generating the electricity. Another observation is that, CCGT can achieve low cost of electricity when supplying for lower number of hours in a year, but other power plants acquire huge cost when supplying for shorter hours, that is to say CCGT is economical even when the demand is low. In terms of environmental friendliness, it was discovered that CCGT plant emits CO_2, which is only 40% of what coal power generating plant emits. (Khalilpour & Karimi, 2012) (Kehlhofer, 2009).

Even though Kehlhofer (2009) observed the environmental cleanness of the CCGT plants, he has not put more consideration on the cost of capturing the CO_2 emission in their cost analysis. However, Rubin et al (2012) have given a thorough concern on the cost of CO_2 capture and storage (CCS) for CCGT, where they found that CCS installation on CCGT plant will lead to increase on levelised cost of electricity (LCOE) by \$20-32/MWh (constant 2007\$) or \$22-40/MWh (2012 US dollar value). This is further confirmed by EIA in its 2014 energy outlook, which shows that an ordinary CCGT plant has an average LCOE of \$66.3/MWh, while CCGT plant with CCS technology will have an LCOE of \$91.3/MWh (EIA, 2014) (Rubin & Zhai, 2012).

As at 2012, almost 46% of the total electricity generated (34GW) in UK was from CCGT plants, this was due to its 55-60% efficiency (net calorific value basis), while open cycle turbines generated 1.6GW, which is 2.16% of the UK total electricity generation in that year (DECC, 2012). Yet, the UK CCGT power generation is expected to increase in the future. However, the UK reliance on gas for power generation will not be sustainable in the long future due to its more reliance on gas import, which is almost 55% of the total gas supplied in the country in 2014 with the remaining percent being supplied from the UK North Sea (DECC, 2014). In Nigeria, more than 60% of electricity generation is from CCGT plants (Energy Information Administration, 2013). Countries like Japan being the second largest net importer of gas in 2012 also face sustainability challenge as it is exposed to the volatility of the price and supply of gas. Japan increased its dependency on imported gas following the Japan's suspension of nuclear plants in the country as a result of the Fukushima disaster in 2011 (US EIA, 2013).

CCGT takes 3-4 years and longer than 30 years for its construction and operational period respectively (US EIA, 2014). Despite its long operational span, CCGT has high marginal cost (74% of its total levelised costs as fuel cost) and low capital cost (only 17% of the total levelised costs) compare to coal plant. It means that, CCGT plant is convenient for immediate construction due to its low capital requirement and short period of construction. Colpier (2002) argued that CCGT plant may not be economically viable for base load purpose but can be used to follow up load (Colpier & Cornland, 2002). However, Starr (2007) mentioned that using it to follow up load will increase the maintenance costs due to the increasing thermal stress (Starr, 2007).

Applying GTL technology in Nigeria would have yielded more benefits than in United States, because of the electricity shortage in the country, which led to additional cost for electricity generation in oil productions and manufacturing sectors. If the associated gas and the stranded gas will be fully utilized for electricity generation, per-capita energy access will be significantly improved, thereby boosting the economy and saving the environment. As mentioned earlier, natural gas is more environmentally friendly for generating electricity than other fossil fuels; this is technically supported by the IEA facts on the CO_2 emissions from different fuels per unit of energy output. The comparison is presented in table 1(US EIA, 2013).

Table 1: CO2 Emission by fuels: Pounds of CO2 emitted per million Btu of energy for various fuels adopted from US EIA, 2013.

Fuel	CO_2 (pounds per mBtu)
Coal (anthracite)	228.6
Coal (bituminous)	205.7
Coal (lignite)	215.4
Coal (subbituminous)	214.3
Diesel fuel & heating oil	161.3
Gasoline	157.2
Propane	139
Natural gas	117

From table 1, natural gas emits carbon dioxide less than any of the fuels considered when burning the same value of heat. Despite the little emissions from the natural gas plants, technologies have been developed to ensure 100% emission abatement. A Science City Professor of Energy, Dermot Roddy who studied how the CCS technology can be retrofitted into existing natural gas power plants and other industrial facilities, looked at how the whole carbon emissions can be collected and transported in a single network; he also estimated the cost implications of these technologies. He mentioned that it will be difficult to have a consistent cost of transportation and storage as CO_2 compression and booster stations varies from systems (Roddy, 2012). However, Svensson et al (2004) attempted to estimate the cost of transporting the CO_2 to be around €1–2 per tonne of CO_2 for a pipeline length of 600km and a capacity of 40 Mte/year (Svensson R, 2004). Using a smaller distance network (30km) with a capacity of 4.67 Mte/year, McCoy and Rubin estimated \$0.34 per tonne of CO_2 as transportation cost, and a storage cost of \$0.80 per tonne of CO_2 (McCoy & Rubin, 2008). CO_2 emission capture, transportation and storage systems can be installed to the existing and new gas plants for electricity generation.

3. Profit Comparisons of GTP and GTL Projects

The two projects are assumed to be completely opened for private investments to complement the effort of the government in exploring the necessary gas utilization potentials in the country. The decision for private investment is always motivated by the level of economic returns on the investment, hence the need to assess the viability of these two investment opportunities in the country. Therefore, profit comparisons will be administered on the two projects (Gas to Power using CCGT project and GTL) using NPV, IRR and payback period techniques. The three profit comparison techniques are essential as each of the techniques has a peculiar advantage and possibly different finding.

3.1. Data and parameters

3.1.1. CCGT plant in Nigeria

In order to analyse the net cash flows of a CCGT plant in Nigeria, we will need to have an idea of the plant's maximum capacity, the investment cost of each capacity (per MW or GW), the rate of energy output in one year (MWh or GWh), and the electricity price per unit of electricity sold (MWh or GWh). First we will assume that a single CCGT plant with a capacity of 400 MW, where multiple of these plants in one site gives us one power station. The assumption for 400 MW capacity per plant was made in line with Cosic M. and Puharic, M. (2011), who stated that "the commonly used CCGT power plant installed capacity is around 400 MW" (Cosic & Puharic, 2011). The proposed Nigerian power stations are projected to be located at gas pipelines' ends, making it possible for a more distributed power stations in the country. If these power stations can be developed, it can meet the highest capacity target in the country.

For this analysis, the Nigerian Domestic Supply Obligation (DSO) gas price will be used, which is the transitional regulated gas price at which gas suppliers must sell for the domestic power generation, this ensures minimal of 15% profit margin on the cost of the gas production. Under the DSO, the gas suppliers must also sell a portion of their produced gas to the domestic market before selling abroad. On 2nd August, 2014, the Nigerian government adjusted the DSO gas price to \$2.50/MMBtu from \$2.00/MMBtu (CSL Stockbrokers, 2014). This made the DSO gas price closer to the market price, but still lower as at that time. The market gas price in the country was then (in 2014) \$3.50-\$4 per MMBtu, and as at June 2015 the market price of natural gas in the country was \$2.87/MMBtu (Nigerian National Petroleum Corporation, 2015). The DSO gas price is adjusted regularly, but last adjustment as at July 2015 was in August 2014. Similarly, the cost of transporting the gas to the power plant need to be accounted in the fuel cost, as the DSO gas price does not include the cost of transporting the gas. Like already established under the gas pipeline economics, the gas transportation cost in Nigeria is $0.80/MMBtu, and the total fuel cost will then be $3.30/ MMBtu.

We will use a single plant in estimating the annual cash flows, and the net cash flows of one plant can be multiplied by the number of the plants in the station. For the estimated maximum annual energy output of the plant, we will multiply the plant's capacity by the total number of hours in one year. Therefore, there will be 3,504,000 MWh of electricity if the plant is to operate at the maximum capacity in particular year (8,760 hours in a year multiplied by 400MW of the plant's maximum power generating capacity). However, we have to account for the plant's capacity factor, which is the ratio of the actual energy output of a plant to its maximum potential output. For example, the CCGT average capacity factor in the UK between 2007 and 2012 as estimated by the UK department of energy and Climate Change was 56% (Department for Energy and Climate Change, 2012). In USA, it was observed to be around 70% in the first seven months in 2014 (US EIA, 2014). Due to low energy mix and supply of electricity in Nigeria, the Nigerian Bulk Electricity Trading Company set up 80% as capacity factor for new CCGT plants, availability rate of 95% (Nigerian Bulk Electricty Trading Plc, 2015) and a thermal efficiency of 60%, going by the work of Carapellucci, R. and L. Giordano (2013) and Seebregts A.J. (2010). From 2001 to 2010, the average capacity factor of existing power plants in Nigeria was between 20.8% and 78.2%. Some of the plants were not fully operational due to technical issues or short of gas supply. However, if these plants would have been in good technical conditions and have sufficient gas supply, they would have an average capacity factor of 80%, hence the choice of 80% as capacity factor in our analysis (Oyedepo S.O. et al., 2014).

For the wholesale electricity price, we will use the data as internally sourced from the Nigerian Bulk Electricity Trading Company (NBET) for 2015 for a new entrant, which is stipulated at N12, 615/MWh, and converting this to US dollars using exchange rate as at June 2015 (N198.85=$1) (Central Bank of Nigeria, 2015), the wholesale contract price per MWh is $63.44 (Nigerian Bulk Electricity Trading Plc, 2015).

For the investment cost, we will adopt $1.2m per Megawatt capacity as sourced from the NERC (Nigerian Electricity Regulatory Commission, 2013). EIA reported $962 thousand per Megawatt capacity as investment cost for Nigeria in 2009, which is 25% increase in four years compare to the 2013 figure reported by NERC (EIA, 2015). IEA reported $1.1m per Megawatt capacity in 2009 (IEA, 2010). The estimate by the Energy Technology Systems Analysis Programme (ETSAP) is also similar to that of IEA. ETSAP estimated it to be $1.1m per Megawatt capacity (Seebregts, 2010). The estimate by NERC will be adopted because it is the official electricity regulatory body in Nigeria, and its figure is peculiar to Nigeria and is more recent. The investment cost includes the cost for "engineering, building, procurement, construction of transmission and fuel delivery facilities, etc." (Kaplan, 2008).

This means that the capital cost of the referenced plant with 400 MW plant capacity is $480 million, without consideration of carbon capture technology (Wakil, 2013). This amount is not so much different with the reported cost figure of CCGT plant in US with 483 MW capacity by the congregational research service, as they used $1,200/kW as capital cost to estimate the capital cost of $530 million for the Avenal Power Project (Kaplan, 2008). For the annual operation and maintenance costs, we will adopt the cost percentage reported by International Energy Agency (IEA) in 2010, which is 4% of the investment costs per year, and which is $19.2 million (International Energy Agency, 2010). Operation and maintenance costs include but not limited to periodic servicing of machines, wages to staff and engineers who operates the machines, supervision of workers, safety and security, communications, chemical supplies, facility fees, administrative expenses, plant transport equipment, electric charges, lubricants, leases, insurance, periodic overhauls and overheads (Pablo, Santiago, & Carlos, 2014)

Now to generate 2,663,040 MWh (at 95% availability rate and 80% capacity factor of 3,504,000 MWh) of electricity, we will need 15132772.03 MMBtu of natural gas feeds, which is derived by dividing the 2,663,040 MWh by 60% thermal efficiency and then multiply by approximately 3.41 as a conversion factor from MWh to MMBtu [249, 259]. This gives the total fuel cost of approximately $50 million (averagely $18.75/MWh as fuel cost per MWh) in a year. Where $7.21/MWh is going to be the average O and M cost per MWh (US EIA, 2013).

The choice of 30 years as operational period of the plant was informed by the work of Carapellucci, R. and L. Giordano (2013), Yu. A. Radin, and Kontorovich T. S. (2012), and Seebregts, A.J. (2010), who argued that the average economic lifetime of a CCGT power plant is 30 years. However, the operational period of CCGT plant can be more than 30 years (Carapellucci & Giordano, 2013) (Seebregts, 2010).

The CO_2 from the energy combustion in the plant is going to be 53.07kg/MMBtu (53.07*15132772.03 MMBtu), which is equals to 803096211.5kg of CO_2. According to Ewah O. et al (2011), there is no emission/carbon tax for power plants in Nigeria, which is why carbon tax will not appear in the plant's costs. Several other searches and contacts also proved absence of the carbon tax for power plants in Nigeria (Ewah, Okechukwu, & Precious, 2011). However, there are emission taxes for gas flaring at production sites, which is about \$3.5 per Mcf of gas flared as at 2008 reviewed regime (Abba, 2012).The price and share of feed gas cost underlines the rising concern about the costs of running a CCGT plant especially in a place where the price of feed gas is very expensive. CCS technology is not assumed on the referenced CCGT plants, but in the case of future installations, CCGT plants with CCS technology are 35%- 60% more expensive than the CCGT plants without it (Alfredo, Vladimir, & Vladimir, 2014) (Rubin & Zhai, 2012). Even though, this is an American multiplier, but few researches on the cost of CCS technology in Nigeria have shown that there will be a similar cost percentage increase in the overall costs of the CCGT plant in Nigeria (Anastassia, Fredrick, & Malcolm, 2009) (Galadima & Garba, 2008).

Similarly, the Nigerian corporation tax rate of 30% is used as a tax rate against the gross annual profit. The Nigerian Electricity sector is regulated by the Nigerian Electricity Regulatory Commission (NERC) who operates a Multiyear Tariff Order (MYTO), which set up the final electricity tariff constant for over long period of time (15 years) with little adjustment annually to capture the inflation effects and accommodate any sudden change in the price of natural gas (Nigerian Electricity Regulatory Commission, 2013).

The Nigerian prime lending interest rate of 16.90% as at March 2015 is used, as the investment capital is assumed to be funded through a capital structure of 70:30 for debt and equity as already established and assumed in the current Nigerian MYTO model (Nigerian Electricity Regulatory Commission, 2013) (CSL Stockbrokers, 2014). The prime lending rate is used because of the capital intensiveness of the projects and long period of the loan. In addition, because the government want to encourage investment in the gas development projects, and as such can encourage commercial bank to give loans aim for investment in the gas development sector at the prime lending rate. Therefore, the cost of debt for the CCGT plant after tax will be:

$$k_d = 0.169 * (1 - 0.30) = 11.83\% \qquad (1)$$

The cost of equity as defined in equation 1 will capture the expected investors return and the business risk. The business Beta of 0.50 for the Nigerian new CCGT plant is adopted from the Nigerian MYTO II model as already explained under methodology (Nigerian Electricity Regulatory Commission, 2013). The business Beta measures the level of risk or reaction of a price of a share in a company to the overall stock market (Peterson & Fabozzi, 2004). Like already discussed under the gas pipeline capital cost analysis, the free risk rate of 13.04 percent, which is the average yield of a government bond in the country (Trending Economics, 2015) is used, and an expected market return of 24.19 percent is assumed, which is in line with the estimated Equity Risk Premium (ERP) of 11.15 percent accounting for the country's risks factors as already discussed under cost of capital methodology discussion for the gas pipeline analysis. The expected market return is a combination of the ERP and the risk free rate. Therefore, the cost of equity for the CGGT plant will be:

$$k_e = 0.1304 + 0.5(0.2419 - 0.1304) = 0.18615(18.62\%) \qquad (2)$$

Now, the weighted average cost of capital will be:

$$WACC = (0.30 * 0.1862) + (0.70 * 0.1183) = 0.13867(13.87\%) \qquad (3)$$

Therefore, 13.87% will be the weighted average cost of capital for the project and will be used to account for cost of capital and time value of money in the cash flows of the project.

This will then be used as the discount factor, which will be used to deflate the annual cash flows to account for cost of time and capital. With reference to depreciation function, a depreciation rate of 3.33% was derived, which is the rate at which the plant depreciate annually to arrive at a book value of zero at the end of the period. However, the plant is expected to have a salvage value of \$174 million. The remaining capital value of the asset was depreciated using the straight line depreciation method, which is around \$10 million as annual depreciation. The tax saving as a result of depreciation is approximately \$3 million, which is deducted from the total tax payment to arrive at total tax payable. The tax benefit was derived by multiplying the tax rate by the annual depreciation figure. The annual cash flow of \$73 million was derived by deducting the fuel cost, operating cost and total tax payable from the total revenue. These are all summarised in table 2.

3.1.2. GTL plant in Nigeria

For the Nigerian GTL plant assumptions, we will consider a GTL plant capacity that is equivalent to the CCGT plant's capacity considered above, this is because, we want to rank the two projects in Nigeria to see which one will be more profitable at the prevailing economic situation in the country. We will convert the CCGT plant's maximum annual capacity of 3504000 MWh into barrels per year, which is 2,067,360 barrels per year (using conversion factor of 1 MWh equals to 0.59 of oil barrel equivalent). Still adopting the 60% thermal efficiency, 95% availability factor and 80% capacity factor, the annual output will then be 1,571,193.6 barrels per year.

Therefore, our referenced GTL plant's annual operational output will be 1,571,193.6 barrels per year of oil diesel, kerosene and naphtha. The plant total output is assumed to be shared between the three products on the ratio of 53 percent to 20 percent and to 27 percent for oil diesel, kerosene and naphtha respectively going by the relevance of their uses and this is in line with the proposed Nigerian E-GTL plant scheduled output. (Hydrocarbon Technology, 2012). That means, the plant will be producing 832,732.61 barrels of oil diesel, 314,238.72 barrels of kerosene and 424,222.27 barrels of naphtha yearly for the period of 30 years, similar economic lifetime with the CCGT plant is adopted. The oil diesel will serve as a substitute to the conventional transport fuels, and the Kerosene will be used for jet fuel in the aviation industry, and can be used for heating, lighting. The Naphtha is for industrial and petrochemical feedstock . However, it is important to note that this level of output is used just for the purpose of comparison with the CCGT plant. It is at low level considering the average GTL plant capacities in the world. The on-going Nigerian Escravos GTL project has the proposed capacity of 34,000 barrels per day at the initial stage (Fleisch, Sills, & Briscoe, 2002).

The amount of gas feeds of 14537115.85 MMBtu is required, which is derived by dividing the annual output of 1,571,193.6 barrels by the 60% thermal efficiency and then multiplied by the conversion factor of approximately 5.5 MMBtu per barrel. This amount is almost similar to the quantity of gas as required by the CCGT plant. Similarly, the cost of the gas feeds of $3.30 per MMBtu is used as the price of gas as already established, which constitute the DSO gas price and transportation cost. The total amount for the gas feeds for a year will be approximately $48 million.

For the capital cost, the average capital cost of the Nigerian Escravos GTL (EGTL) plant is adopted. As mentioned above, Nigerian Escravos GTL plant is proposed to have the annual output of 12410000 barrels per year (34000 barrels per day), and it has the estimated capital cost of $8.4 billion as at the final review of the capital cost. The EGTL plant initial estimated cost was $1.7 billion, which was revised twice. In the first review, the project was escalated to $5.9 billion, and in the second review it escalated to $8.4 billion (Hydrocarbon Technology, 2012) (Energy Information Administration, 2013). Therefore, the latest figure, which is $8.4 billion for Nigerian GTL plant is adopted. That means the per capita capital cost will be $8.4 billion divided by the number of barrels in a year (12410000), which gives us $677 per barrel. Pearl GTL plant faced similar cost escalation from $5 billion to $18 billion. Now, for our referenced GTL plant that has the annual estimated maximum capacity of 2,067,360 barrels per year will then have the capital cost of $1,399,602,720.00 (2,067,360 barrels per year multiplied by $677). For the annual operating cost, we will adopt the $5 per barrel of yearly output as reported in many literature and in GTL economic reports (Shimin & Rory, 2014).

For the prices of the products; the GTL products prices are influenced by the crude oil price, as the crude oil price affects the prices of oil products, which are substitute to gas products, and also affects the cost of the gas feeds used in the GTL plant, being substitute commodities. Therefore, the GTL products' prices are gauged with the crude oil value at the refinery gate, which is the cost of the crude oil plus the transportation cost and other fees paid by the refiner (Al-Shalchi, 2008), which is termed crude oil refinery acquisition price (RAC). Some additional amount are also added to account for the GTL products' treatment and higher cleanness. For the GTL distillate prices (in this analysis, Diesel and Aviation Turbine kerosene (ATK)), an additional cost was suggested to be between $4-$8/bbl on top of the crude oil price (RAC) (Chedida, Kobroslya, & Ghaja, 2007). Alsalchi (2008) and Fleisch (2002) suggested an additional cost for wholesale GTL distillate to be around $5.60/bbl, which this research will adopt, because it is also the approximate average of the range proposed by Chedida (2007). For the Naphtha wholesale price, an additional cost of $4/bbl is used going by the work of Michael (2005) (Michael, 2005).

The projected average crude oil price for the period of 29 years from 2012 to 2040 is used, which is projected to be averaged around $100.43/bbl as reported in the Annual Energy Outlook 2015 by US EIA (US EIA, 2015) using West Texas intermediate spot and 2013 constant dollar. The period of this projection is very close to the period of the project's lifespan of 30 years, and the projection covers the current realities of the market. The crude oil price was above $100/bbl in 2008, 2011, 2012, 2013 and up to mid-2014 for the Nigerian Forcados spot price as reported in the 2015 BP statistical review for world energy (BP, 2015), therefore, it is not surprising to have the average forecast real price of oil up to $100/bbl.

Therefore, the crude oil RAC price can be derived by adding the Nigerian crude oil transportation cost of $1.5 per barrel, which is assumed to be constant for the period (Agbon, 2011), which means the crude oil RAC price will be $101.93 per barrel. The idea of using projected price was informed by the work of Chedida and Ghaja (2007), and because the business is estimated for the future period. The crude oil price is fluctuating, and the price might go higher or lower than the forecast, which will affect the price of the GTL products. Therefore, for the price of GTL Diesel and ATK, it will be $107.53/bbl, and for the Naphtha price, it will be $105.93/bbl. Using the crude oil price as at July 2015, which was $43.87/bbl, and comparing what would have been the price of the domestic GTL diesel ($50.97/bbl) with the Nigerian oil diesel maximum indicative benchmark depot price of $89.68 (N112.16/litre) as at 16th July 2015 [272], the GTL diesel price will be lower by $38.71/bbl. The price of the Nigerian oil diesel also fluctuates regularly (PPRA, 2015).

Comparing with the Nigerian ATK, according to the Nigerian petroleum product pricing regulatory agency, the landing cost of the ATK was N103.76 per litre as at 16th July 2015, which was $82.96 per barrel using the specified exchange rate ($1=N198.85) (PPRA, 2015). This means the cost of domestic GTL ATK at this oil price level is $31.99/bbl lower. This is again likely due to the low crude oil price in 2015 as highlighted above. Comparing the GTL Naphtha price with the European Naphtha price of $66 per barrel (Qoutenet.com. , 2015), which is the average price for June 2015, the price of the Nigerian GTL Naphtha at the July 2015 oil price would have been lower by \$16.63/bbl. The European Naphtha price is used, because there is no active Naphtha market in Nigeria. This price is similar to that of the US, which was also \$66 per barrel (EIA, 2013). A corporation tax payment of 30% is also applied to the gross annual profit as applied in the CCGT plant.

A depreciation rate of 3.33% is the rate at which the plant depreciates annually to arrive at a book value of zero at the end of the period. However, the plant is expected to have a salvage value, which was derived with reference to equation 3.8 as \$506 million. The remaining capital value of the asset was depreciated using the straight line depreciation method as earlier explained, which is approximately \$30 million as annual depreciation. The tax saving as a result of depreciation is approximately \$9 million, which is deducted from the total tax payment to arrive at total tax payable. The tax benefit was derived by multiplying the tax rate by the annual depreciation figure.

The cost of capital for the GTL plant will also account for the cost of debt and equity, as the project's capital structure of 60:40 for debt and equity is applied, and this is in line with the capital structure of an average oil and gas listed companies in the country, with particular reference to Nigerian Oando plc (Financial times, 2015). To arrive at the weighted average cost of capital, the cost of debt and cost equity will be calculated as follows. The after tax cost of debt for the GTL plant using the prime lending rate of 16.90% as earlier explained will be:

$$k_d = 0.169 * (1 - 0.30) = 11.83\% \tag{4}$$

The cost of equity as defined in equation 3.12 will capture the expected investors return and the business risk. Because there is no available data for Nigerian stock market for GTL business, as there are no listed GTL companies in the country, the average $Beta$ of a seven listed oil and gas companies (BOC Gases Nigeria PLC, Conoil PLC, Eterna Plc, Forte Oil Plc, Mobil Oil Nigeria Plc, MRS Oil Nigeria Plc, Oando Plc) in the country is used as the proxy Beta for the investment, which was 0.86 as at July 2015 (Financial times, 2015). This Beta is higher than what Usman (2006) assumed for Nigerian GTL project, where he adopted a Beta of some major oil and gas companies in US in 2006, which was 0.77 (Usman, 2006).

Like already discussed under the gas pipeline's capital cost analysis, the free risk rate of 13.04 percent, which is the average yield of a government bond in the country (Trending Economics, 2015) is used, and an expected market return of 24.19 percent is assumed, which is in line with the estimated equity risk premium of 11.15 percent accounting for the country's risks factors as already discussed under cost of capital methodology discussion for the gas pipeline analysis. The expected market return is the combination of the ERP and the risk free rate. Therefore, the cost of equity for the GTL project will be:

$$k_e = 0.1304 + 0.86(0.2419 - 0.1304) = 0.22629\ (22.63\%) \tag{5}$$

Now, the weighted average cost of capital will be:

$$WACC = (0.40 * 0.2263) + (0.60 * 0.1183) = 0.1615\ (16.15\%) \tag{6}$$

Therefore, 16.15% will be the weighted average cost of capital for the project and will be used to account for cost of capital and time value of money in the cash flows of the project, by using it as a discount rate. The project's annual cash flow of \$88 million was derived and these are all summarised in table 2.

3.2. Net Present Value:

Using NPV in assessing investment projects provides opportunity to measure the real time value of money. Monetary values of investment projects are adjusted (discounted) based on timing. For example, an investor will prefer to have \$100 today than \$110 in a later day, in order to avoid the risk of something going wrong before the later date or to provide him/her the opportunity to make another investment that will generate more revenue before the later date. The NPV technique accommodates the possibility of currency devaluation due to the natural rate of inflation. Over a period of years, purchasing power of every unit currency reduces no matter how little, that is to say the money at hand today is preferred than money at hand on later date. So in order to appraise the future capital investment return, there is need to adjust (discount) the future monetary returns to the present value of the money today, so that investor can have idea on the real future cash flow of the business based on the present value of the cash flows (Brealey & Myers, 2006).

GTL products being a substitute to the existing petroleum products in the country especially petrol can have a favourable market in the country. The supply of the GTL products especially GTL diesel will immediately create its demand. The GTL products can be well preferred as long as there is a relative lower price of crude oil and gas feeds. To academically prove the project's profitability in the country, a Fischer Tropsch GTL project is assumed to be established in Nigeria based on the parameters identified above.

Table 2 indicates all the project assumptions as well as the estimated cash flows of the GTL project in Nigeria, other assumptions are adopted from the work of Nwaoha et al (2014) and Michael (2005) (Nwaoha & Brian, 2012).

Table 2: Annual Cash flow of the GTL project in Nigeria

GTL maximum output (bbl/yr)	2,067,360
Capacity Factor	80%
Operational availability	95%
Annual GTL output (bbl/yr)	1,571,193.6
Thermal Efficiency	60%
Gas feeds (MMBtu)	14,537,115.85
Natural Gas Feedstock price ($/MMBtu)	3.3
Crude oil price (projected average $2013) $/bbl	100.43
Crude oil RAC price $/bbl	101.93
Diesel Price ($/bbl) whole sale	107.53
Naphtha Price ($/bbl)	105.93
Aviation Turbine Kerosene Price ($/bbl)	107.53
Period of the business covered (years)	30
Capital Cost ($)	1,399,602,720
Debt ($)	839,761,632
Equity ($)	559,841,088
Cost of Equity	22.63%
Cost of debt	11.83%
WACC	16.15%
Tax rate	30%
Operation and transportation cost ($/bbl)	5
Annual diesel output (bbl)	832,732.61
Annual Naphtha output (bbl)	424,222.27
Annual ATK output (bbl)	314,238.72
Annual sales ($)	168,271,692.17
Annual operating cost ($)	7,855,968.00
Annual cost of feed gas ($)	47,972,482.32
Gross profit ($)	112,443,241.85
Depreciation rate	3.33%
Salvage Value ($)	506,182,437.96
Annual Depreciation ($)	29,780,676.07
Annual Tax saving from depreciation ($)	8,934,202.82
Annual tax payment ($)	33,732,972.56
Net Tax payable ($)	24,798,769.74
Annual Cash flow ($)	87,644,472.12
Additional cash flow in final year	
Salvage value ($)	506,182,437.96
Tax on selling at salvage value ($)	151,854,731.39
End year Net Gain ($)	354,327,706.57

Table 2 summarises the basic inputs and the cash flows of the GTL plant in Nigeria, which will be used for the NPV calculations. The GTL project will have an after tax annual cash flow of approximately $88 million. This will then be discounted using the WACC of 16.15% every year as earlier established. The investment capital as earlier mentioned is funded through debt and equity. The sum of $840 million will come from debt and the sum of $560 million will come from equity. Therefore, going by the nominal annual net cash flow, the business will earn around $3 billion for the period of 30 years. The end year cash flow will have an addition of after tax net cash flow of $354 million as a result of the sale of the plant at the salvage value. Other parameters in table 2 were earlier discussed. Table 3 shows the NPV calculations of the GTL in the country.

Table 3: NPV of the GTL plant in Nigeria

Years	Net cash flow	Discount factor	Discounted net cash flow	Cumulative DCF
0	- 1,399,602,720.00	1	-1,399,602,720.00	- 1,399,602,720.00
1	87,644,472.12	0.8609586	75,458,264.27	- 1,324,144,455.73
2	87,644,472.12	0.7412498	64,966,443.51	- 1,259,178,012.22
3	87,644,472.12	0.6381854	55,933,419.93	- 1,203,244,592.29
4	87,644,472.12	0.5494512	48,156,360.35	- 1,155,088,231.94
5	87,644,472.12	0.4730547	41,460,633.83	- 1,113,627,598.11
6	87,644,472.12	0.4072806	35,695,890.33	- 1,077,931,707.78
7	87,644,472.12	0.3506517	30,732,684.68	- 1,047,199,023.10
8	87,644,472.12	0.3018966	26,459,569.97	- 1,020,739,453.13
9	87,644,472.12	0.2599205	22,780,595.00	- 997,958,858.12
10	87,644,472.12	0.2237808	19,613,149.77	- 978,345,708.36
11	87,644,472.12	0.192666	16,886,110.47	- 961,459,597.89
12	87,644,472.12	0.1658775	14,538,242.46	- 946,921,355.43
13	87,644,472.12	0.1428136	12,516,825.25	- 934,404,530.17
14	87,644,472.12	0.1229566	10,776,468.67	- 923,628,061.50
15	87,644,472.12	0.1058606	9,278,093.66	- 914,349,967.85
16	87,644,472.12	0.0911416	7,988,054.76	- 906,361,913.08
17	87,644,472.12	0.0784691	6,877,384.65	- 899,484,528.43
18	87,644,472.12	0.0675587	5,921,143.64	- 893,563,384.79
19	87,644,472.12	0.0581652	5,097,859.69	- 888,465,525.10
20	87,644,472.12	0.0500778	4,389,046.27	- 884,076,478.83
21	87,644,472.12	0.043115	3,778,787.25	- 880,297,691.58
22	87,644,472.12	0.0371202	3,253,379.48	- 877,044,312.10
23	87,644,472.12	0.0319589	2,801,025.12	- 874,243,286.98
24	87,644,472.12	0.0275153	2,411,566.74	- 871,831,720.24
25	87,644,472.12	0.0236896	2,076,259.19	- 869,755,461.05
26	87,644,472.12	0.0203957	1,787,573.26	- 867,967,887.80
27	87,644,472.12	0.0175599	1,539,026.61	- 866,428,861.18
28	87,644,472.12	0.0151183	1,325,038.24	- 865,103,822.94
29	87,644,472.12	0.0130163	1,140,803.10	- 863,963,019.84
30	441,972,178.69	0.0112065	4,952,943.54	- 859,010,076.30
	2,983,661,870.11		**-859,010,076**	

Reference to table 3, investing the sum of approximately $1.4 billion in a Nigerian GTL project with the combined production output of 1571193.6bbl/yr for diesel-oil, jet kerosene, and Naphtha, at a discount rate of 16.15%, an NPV after tax of negative $859 million was derived. Despite the positive cumulative nominal net cash flow of around $3 billion in addition with the salvage value after 30 years, once the cost of capital and time value of money are accounted, the cumulative discounted cash flow becomes negative of $859 million. This means that the GTL project is not viable in Nigeria based on the specified market parameters and time value of money, because the difference between the present values (discounted value) of future net cash flows and the current initial investment is negative. Meaning that, the present value of future net cash flows cannot meet up the initial investment cost. The investor will therefore have negative cumulative discounted cash flows, and hence the negative NPV.

For the CCGT plant, the summary of its market inputs and assumptions are presented in table 4.

Table 4: Annual Cash flow of the CCGT project in Nigeria

CCGT POWER PLANT	Figure
Plants maximum capacity (MW)	400
Annual maximum output (MWh)	3,504,000
Capacity factor (%)	80%
Availability Factor	95%
Annual output (MWh)	2,663,040
Thermal Efficiency	60%
Gas feeds (MMBtu)	15,132,772.03
Interest rate	16.90%
Cost of debt ($)	11.83%
Capital cost ($)	480,000,000
Debt ($)	336,000,000
Equity ($)	144,000,000
Cost of Equity	18.62%
Cost of debt	11.83%
WACC	13.87%
Price per $/MWh	63.44
Annual operating cost (4% of capital cost) ($)	19,200,000
Fuel cost ($)	49,938,147.69
Annual sales revenue ($)	168,943,257.60
Depreciation rate	3.33%
Salvage Value ($)	173,597,526.46
Annual depreciation ($)	10,213,415.78
Tax Rate	30%
Annual Tax saving from depreciation ($)	3,064,024.74
Annual tax payment ($)	29,941,532.97
Net tax payable ($)	26,877,508.24
Annual cash flow ($)	72,927,601.67
Additional cash flow in final year	
Salvage value ($)	173,597,526.46
Tax on selling at salvage value ($)	52,079,257.94
End of year Net gain ($)	121,518,268.52

Table 4 summarises the inputs and the cash flow calculation of the CCGT plant in Nigeria, which will be used for the NPV calculations. The CCGT project will have an after tax annual cash flow of approximately $73 million, with the end year having additional cash flow as a result of salvage value of the plant. The investment capital as earlier mentioned is funded through debt and equity with a prime lending interest rate of 16.90%. However, the weighted average cost of capital of 13.87% is used as already explained, which will then be used as the discount rate, which will be used to deflate the annual cash flows to account for cost of time and capital. The end year cash flow will have an addition of after tax net cash flow of $122 million as a result of the sale of the plant at the salvage value. Other parameters in the table were earlier discussed. Table 5 shows the NPV calculations of the CCGT project in the country.

Table 5: NPV of the CCGT plant in Nigeria

Year	Cash flow	Discount factor	Discounted net cash flow	Cumulative DCF
0	- 480,000,000.00	1	-$480,000,000	- 480,000,000.00
1	72,927,601.67	0.878229139	64047144.81	- 415,952,855.19
2	72,927,601.67	0.77128642	56248068.83	- 359,704,786.36
3	72,927,601.67	0.677366209	49398693.04	- 310,306,093.32
4	72,927,601.67	0.594882742	43383371.65	- 266,922,721.67
5	72,927,601.67	0.522443358	38100541.12	- 228,822,180.56
6	72,927,601.67	0.45882498	33461005.41	- 195,361,175.14
7	72,927,601.67	0.402953467	29386429.97	- 165,974,745.18
8	72,927,601.67	0.353885477	25808019.08	- 140,166,726.10
9	72,927,601.67	0.310792537	22665354.37	- 117,501,371.73
10	72,927,601.67	0.272947062	19905374.65	- 97,595,997.08
11	72,927,601.67	0.239710064	17481480.03	- 80,114,517.04
12	72,927,601.67	0.210520363	15352745.15	- 64,761,771.89
13	72,927,601.67	0.184885117	13483228.15	- 51,278,543.73
14	72,927,601.67	0.162371497	11841363.85	- 39,437,179.88
15	72,927,601.67	0.14259938	10399430.78	- 29,037,749.11
16	72,927,601.67	0.125234931	9133083.134	- 19,904,665.97
17	72,927,601.67	0.109984965	8020939.735	- 11,883,726.24
18	72,927,601.67	0.096592001	7044222.996	- 4,839,503.24
19	72,927,601.67	0.08482991	6186441.895	1,346,938.65
20	72,927,601.67	0.074500099	5433113.537	6,780,052.19
21	72,927,601.67	0.065428158	4771518.623	11,551,570.81
22	72,927,601.67	0.057460915	4190486.691	15,742,057.50
23	72,927,601.67	0.05046385	3680207.517	19,422,265.02
24	72,927,601.67	0.044318823	3232065.478	22,654,330.50
25	72,927,601.67	0.038922082	2838494.081	25,492,824.58
26	72,927,601.67	0.034182506	2492848.213	27,985,672.79
27	72,927,601.67	0.030020073	2189291.939	30,174,964.73
28	72,927,601.67	0.026364503	1922699.974	32,097,664.70
29	72,927,601.67	0.023154075	1688571.142	33,786,235.85
30	194,445,870.20	0.020334583	3953975.715	37,740,211.56
	2309346318.72		**$37,740,212**	

Using net present value accounting method for the CCGT plant, where the future values of the cash flows were discounted at 13.87%, the plant reported a positive NPV figure of approximately $38 million. That is to say, investing $480 million for 30 years in CCGT plant in Nigeria, the plant will generate a profit of approximately $38 million at present value. This means the investor will have a positive $38 million as the difference between the discounted future net cash flows of the investment and the initial investment cost for the 30 years. The present value of the future cash inflows can meet up all the present and future cash outflows with even a surplus, which means the project is viable.

In summary, using NPV to estimate profitability of the two projects, GTL and CCGT plants returned negative $859 million and positive $38 million respectively. The GTL project is found to be not viable due to its negative NPV, while CCGT project was found to be viable due to its positive NPV value.

However, GTL project is equally important project as its products can provide an affordable and cleaner alternative fuels for residential and commercial usage, which will be significant in boosting the economic performance, safeguarding the environment and improving the wellbeing of the people in the country. Similarly, with more gas pipelines to be in place, potentials for GTL plants will increase, where we earlier estimated 40% of the gas supply from the gas pipeline can be used for GTL projects, chemical and cement industries etc. GTL project is very essential, and should also be considered. Therefore, the government should consider providing some investment incentives to offset the potential loss in the project. More judgement, specific recommendations and sensitivities will be made after looking at the IRR and payback periods of the projects.

Depending on the accounting method used, investor's decision can be different under different accounting methods. The investor's choice will be determined by his personal or corporate ambition, some investors will only consider the nominal annual cash flows, some will consider how quickly they can recover their investment, and some will base their decisions on the present value of their future returns. Now we will consider the other two methods, which are Internal Rate of Return (IRR) and payback method.

3.3. Internal Rate of Return:

Internal rate of return is one of the commonly used accounting techniques to analyse the profitability of a business investment. Rate of Return signifies how quickly the money invested comes back to the investor. It is usually given in percentage per annum. It is easy to calculate the rate of return if the return on investment is constant, but in a situation where the annual returns varies and is not continues, then the rate of return becomes Internal Rate of Return (IRR) (Thomas, 2014). IRR considers the cash flows as derived under the NPV calculations to derive the maximum possible rate of investment return. The IRR is the rate of return where NPV is close to or equals to zero. Net present value gives information on how much at present value an investor earns or loses for opting to making such investment decision rather than investing the money in an alternative venture.

In order to optimise the investor's decision, IRR is important as it reveals the discount rate at which present values of future cash flows and the initial investment cost are the same. This means that, there is no lost or gain in the investment considering the time value of money. IRR is used to compare viability of two or more investment projects. Projects with higher IRR are favoured and opted among other alternative ventures. Higher IRR is desirable as currencies devalue relatively at low rate, the higher the IRR the safer the investment. If the discount rate is below the IRR, then the investment is recommended, conversely, if the discount rate is above the IRR, then the investment is not recommendable. IRR is usually driven through trial and error until when the NPV becomes equals or close to zero or using the excel formula. The discount rate, which is also the rate at which an investor wants his investment returns, is preferred to be high but not above IRR, therefore if IRR is high, then the investor can achieve higher investment rate of return. If the calculated IRR is higher than the discount rate then the investment is viable.

Using the previous NPV calculations for the GTL and CCGT projects above, an excel formula for the IRR was applied, and for the GTL project in Nigeria, 5.17% was derived as its IRR, which is lower than the discount rate of 16.15% as used in the NPV calculation. This means that any discount rate or investment return above 5.17%, the investment is not profitable. This means the project is not viable because the IRR is lower than the discount rate and the investment cannot meet the investor's expected rate of return.

For the CCGT plant, the IRR is 15.02%, which means that the project's discount rate (13.87%) is lower than the IRR, which makes it viable. This means that the investor can choose any investment rate of return below 15.02% and yet have a positive NPV. Therefore, based on the IRR accounting technique, the CCGT plant is again the viable project among the two projects in Nigeria.

3.4. Payback Period

Payback period accounts for the length of period required to recover the initial capital investment from the annual cash flow. This is one of the popular accounting techniques, which investors use to assess business ventures. It gives signals on how fast the money invested comes back to the investor. This method is important because most of the initial capital investments are borrowed from bank and the longer the period of the loan, the higher the interest paid, so investors will do their best to reduce the period of interest payments. Payback period technique then is the appropriate accounting technique that informs the investor on the period of cash recovery, so that the terms or the period of bank loan will be as short as possible.

Using the payback period method is significant in countries where there is propensity of political or social instability, where investor wants to make use of the available short-term stability to hit and run. Payback period will then be the best viability indicator for business investments in those circumstances. It is simple to apply, and it is related to the NPV technique, because the NPV reports the running annual cash flows.

Considering the two projects in Nigeria (CCGT and GTL projects) and applying the annual discounted cash flow (adopted from the NPV calculations in table 3 and 5), the period within which the initial cash investment is recovered can easily be identified. Reference to table 3.27 where the discounted cash flows of GTL projects were presented, there is no positive cumulative discounted cash flows, which means the project cannot pay back its investment going by the discounted cash flows, and hence the negative NPV. It is therefore non-recoverable (NR) investment. For CCGT project and reference to table 4, the discounted payback period is calculated as follows:

$$Payback\ Period_{CCGT} = 18 + \frac{-(-4{,}839{,}503.24)}{6186441.90} = 18.78 \qquad (7)$$

The discounted payback period of the CCGT project is 18.78 years. This means that CCGT project which already has positive NPV value will be able to pay back the investor at approximately 19 years of the project operation while GTL project cannot.

Finally, having considered the three different accounting techniques in analysing the capital investment and profitability of the two gas projects in Nigeria (CCGT and GTL projects) in the base scenario, table 6 below summarises all the results, and CCGT project is the recommended gas development project in Nigeria compare to the GTL project going by the viability indicators.

Table 6: Summary of results from the four accounting techniques

Investment Indicator	CCGT Project	GTL Project
Initial Capital Cost	$480 million	$1.4 billion
NPV	$38 million	-$859 million
Internal rate of Return	15.02%	5.17%
Payback period	18.78 Years	NR

Table 6 summarised the viability of the two projects, it shows that the GTL project is not viable, while CCGT project is viable. It is recommendable that incentives be provided to facilitate investment in the GTL project, as its products and its value addition is essential in providing cleaner alternatives to the conventional energy products. Specific recommendations will be made after identifying the most sensitive parameter to the project so that appropriate recommendation can be offered based on the most sensitive parameters.

4. Summary and Conclusion

This research applied three different accounting techniques (NPV, IRR and payback period) to assess the viability of CCGT and GTL projects in Nigeria. All the applied accounting techniques have suggested that CCGT project is viable in Nigeria. GTL project was found to be unviable, but incentives for investment for the project were recommended due to the relevance of its products in providing energy alternatives that will help improve the wellbeing of the people in the country. Therefore, in order to incentivise GTL investment and make it viable in the country, the prices of the products and the capital cost requirements were advised to be further reviewed and incentivised. For example based on the random sensitivity analysis, we found that if the prices of the crude oil can increase by 20% above the average forecast real oil price of $100.83/bbl and its estimated capital cost reduced by 54%, the project will be viable in the country, at which its IRR will be 16.16%, its NPV will be $351 thousand and its payback period will be 29.88 years. The crude oil at this scenario will then be $121/bbl. The crude oil price fluctuates and can likely reach or exceed this price level in the future. Similarly, a 20% reduction in price of electricity can make the CCGT project unviable in the country. Therefore, electricity price has to be above $60.27/MWh for the CCGT to be viable in the country other things being equal.

For the reduction in GTL cost, a careful study is required on why the GTL capital cost keep increasing. As mentioned, the Nigerian GTL capital cost has increased twice in the past, the first increment was 200% more and the second one was by 40%. If the capital cost can be reduced by 54% and the above crude oil price achieved while other parameters remain constant, then GTL project can be viable in the country. The government and investors might consider reviewing the capital cost with a view to reducing the cost of the GTL projects in the country. It is recommended that the proposed incentivised gas pricing regime for GTL projects should be strictly implemented, as it will help reduce the cost of GTL project in the country.

In addition, lowering the interest rate, increasing the thermal efficiency and production at optimal level can also help in further reduction of the cost of GTL project in the country. Tax rate can also be reviewed for this particular project. Local content can be enhanced where local experts are hired and equipment acquired locally if possible to reduce cost. The sensitivity analysis also showed that both projects are more sensitive to their product prices, while output and capital are the medium most sensitive parameters, and discount rate as well as gas feed cost are the least sensitive parameters to the projects' viabilities. One of the recommendations of this research is that, government should own substantial business interest of the gas pipelines projects in order to avoid market distortion and exploitation, as well as to ensure easy supervision of the sector, and so that gas supply to GTL and CCGT plants can be adequate.

Developing gas reserves for domestic consumption (through Gas pipeline, GTL and CCGT) can provide alternative source of energy, thereby creating competition to the major conventional energy fuels (e.g. petrol). It can also boost the industrial and commercial sectors of the economy and attract more foreign investment into the country through cost-effective utilities provision, which will generally improve the economic performance in the country. Consequently, this research also analysed the relationship between the real economic growth and domestic gas consumption in the country.

5. References

Abba, U. (2012). *Gas flaring in Nigeria: is a 'carrot and stick' approach the panacea to ending flaring in Nigeria's oil and gas sector?* Social Science Research Network.

Adaramola, M., Paul, S., & Oyewola, O. (2014). Assessment of decentralized hybrid PV solar-diesel power system for applications in Northern part of Nigeria. *Energy for Sustainable Development, 19*(2014), 72-82.

Agbon, D. (2011, July 16). *The Real Cost Of Nigeria Petrol*. Retrieved 2015, from http://saharareporters.com/2011/12/15/real-cost-nigeria-petrol-dr-izielen-agbon

Alan, J. (2010). *Carbon monoxide.* Nexant: ChemSystems PERP programme.

Alfredo, V., Vladimir, F., & Vladimir, V. (2014). CCS (carbon capture and storage) investment possibility in South East Europe: A case study for Croatia. *Energy, 70*(June 2014), 325-337.

Al-Shalchi, W. (2008, July 15). *Gas to Liquids (GTL) Technology*. Retrieved 2015, from https://www.scribd.com/doc/3825160/Gas-to-Liquids-GTL-Technology#scribd.
Anastassia, M., Fredrick, O., & Malcolm, W. (2009). The future of carbon capture and storage (CCS) in Nigeria. *Science World Journal, 4*(3), 1597-6343.
BP. (2015). *BP Statistical Review of World Energy.* British Petroleum .
Brealey, R., & Myers, S. (2006). *Principles of Corporate Finance. 2006:* . The McGraw-Hill Companies.
Buping, B., Mahmoud, M. E.-H., & Elbashir, N. (2010). Simulation, integration, and economic analysis of gas-to-liquid processes. *Fuel Processing Technology, 91*(7), 703–713.
Carapellucci, R., & Giordano, L. (2013). A comparison between exergetic and economic criteria for optimizing the heat recovery steam generators of gas-steam power plants. *Energy, 58*(1), 458-472.
Central Bank of Nigeria. (2015, June 26). *CBN Exchange Rates. Rates Archives*. Retrieved from http://www.cenbank.org/rates/ExchRateByCurrency.asp
Chedida, R., Kobroslya, M., & Ghaja, G. (2007). The potential of gas-to-liquid technology in the energy market: The case of Qatar. *Energy Policy, 35*(10), 4799–4811.
Colpier, U., & Cornland, D. (2002). The economics of the combined cycle gas turbine - An experience curve analysis. . *Energy Policy, 30*(4), 309-316.
Cosic, M., & Puharic, M. (2011). Private investments profitability in the Croatian liberalized energy market. *8th International Conference on the European Energy Market*, (pp. 134-140).
CSL Stockbrokers. (2014). *Nigerian Power Sector report, Cost of Capital in the Power Sector – MYTO II,.*
DECC. (2012). *Energy Statistics.* Department for Energy and Climate Change; inside government.
DECC. (2014). *Energy trends: Chapter Gas.* Department for Energy and Climate Change; inside government.
Department for Energy and Climate Change. (2012). *Chapter 5: Electricity.* Energy.
Dunn, G. (2008). *Airbus conducts A380 alternative-fuel demonstration flight.* 1 February, Flight International.
EIA. (2013, August 23rd). *Gasoil prices. This week in petroleum 2013*. (Energy Information Administration, Editor) Retrieved from http://www.eia.gov/oog/info/twip/twip_gasoline.html
EIA. (2014). *Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2014.* US Energy Information Administration outlook.
EIA. (2015, April 1). *Assumptions to the Annual Energy Outlook*. Retrieved from http://www.eia.doe.gov/oiaf/aeo/assumption/pdf/tbl8.2.pdf
EIA. (2015, April 8th). *Nigeria: Background 2015* . Retrieved from http://www.eia.gov/countries/cab.cfm?fips=ni
EIA, U. (2015). *Annual Energy outlook in with projections to 2040.*
Energy Information Administration. (2013, August 17th). *Nigeria: Background. Natural Gas Analysis 2012* . Retrieved from http://www.eia.gov/countries/cab.cfm?fips=NI
Ewah, O., Okechukwu, U., & Precious, O. (2011). *Low-carbon Africa: Nigeria.* Report on Low-Carbon Africa: Leapfrogging to a Green Future.
Financial times. (2015, July 7th). *Equities. Oando PLC*. Retrieved from http://markets.ft.com/research/Markets/Tearsheets/Financials?s=OANDO:LAG
Fleisch, R., Sills, R., & Briscoe, R. (2002). Emergence of the Gas-to-Liquids Industry: a Review of Global GTL Developments. Journal of Natural Gas Chemistry, 2002. 11(2002). *11*, 1-14.
Galadima, A., & Garba, Z. (2008). Carbon capture and storage (CCS) in Nigeria: fundamental science and potential implementation risks. *Science World Journal, 3*(2), 95-99.
Holwell, A. (2011). Small-scale gas to liquids. *Petroleum Technology Quarterly, 16*(2), 5.
Hydrocarbon Technology. (2012, December 8th). *Escravos Gas-to-Liquids Project, Niger Delta, Nigeria*. Retrieved from http://www.hydrocarbons-technology.com/projects/escravos
Ibitoye, F., & Adenikinju A. (2007). Future demand for electricity in Nigeria. *Applied Energy, 84*(5), 492-504.
IEA. (2010). *Gas Fired Power, Energy Technology Systems Analysis Programme (ETSAP).* IEA ETSAP.
International Energy Agency. (2010). *Gas Fired Power.* IEA Energy Technology Systems Analysis Programme (ETSAP).
Kaplan, S. (2008). *Power Plants:Characteristics and Costs.* CRS report for congress, congregessional research service.
Kehlhofer, R. (2009). *Combined-Cycle Gas and Steam Turbine Power Plants* (2nd ed.). PenWell.
Khalilpour, R., & Karimi, I. (2012). Evaluation of utilization alternatives for stranded natural gas. *Energy, 40*(1), 317-328.
Larry, S., & Burke, B. (2006). The GTL industry. *Hydrocarbon Engineering, 11*(7), 12-16.
Lee, C. e. (2009). Optimal Gas-To-Liquid Product Selection from Natural Gas under Uncertain Price Scenarios. *Industrial & Engineering Chemistry Research, 48*(1), 794-800.
Lookman, O. (2014). The Nigerian electricity sector and its impact on local economic development. *Ledna Knowledge Brief, 6*(March), 1-9.

McCoy, S., & Rubin, E. (2008). An engineering-economic model of pipeline transport of CO2 with application to carbon capture and storage. *Int J Greenhouse Gas Control , 2*(1), 219-29.
Merkl, J. (1996). Combined-cycle heat-power gas turbine plant: Cost-effective deployment - Technical parameters - Operating experiences. *ZUCKERINDUSTRIE, 121*(12), 927-933.
Michael, J. (2005). The Economics of Gas to Liquids Compared to Liquefied Natural Gas 8 (1). *World Energy, 8*(1).
National Population Commission. (2010). *Nigerian 2010 Population Census.*
Nigerian Bulk Electricity Trading Plc. (2015). *Wholesale Generation Prices.* Abuja: NBET.
Nigerian Bulk Electricty Trading Plc. (2015). *Transmission loss.* Internal official Document.
Nigerian Bulk Electricty Tradning Plc. (2015). *Assumptions for the New CCGT entrant.* Internal official Document.
Nigerian Electricity Regulatory Commission. (2013). *Multi-year Tariff Order (MYTO) for the determination of charges and tariffs for electricity generation,transmission and retail tariffs.* Abuja: NERC.
Nigerian Electricity Regulatory Commission. (2013). *Tariff, Charges & Market Rules.* Nigeria: NERC.
Nigerian National Petroleum Corporation. (2015, June 26). *Oil and Gas Prices. Oil and Gas statistics 2015*. Retrieved from http://www.nnpcgroup.com
Nwaoha, C. W., & Brian, F. (2012). Gas-to-liquids (GTL): A review of an industry offering several routes for monetizing natural gas. *Journal of Natural Gas Science and Engineering,, 9*(1), 196-208.
Ola Ajayi. (2015). *2015 budget: Nigerians divided over fuel subsidy removal.* Vanguard.
Oyedepo S.O. et al. (2014). Performance evaluation and economic analysis of a gas turbine power plant in Nigeria. *Energy Conversion and Management, 79*(2014), 431-440.
Pablo, R., Santiago, C., & Carlos, B. (2014). Modeling the Major Overhaul Cost of Gas-Fired Plants in the Unit Commitment Problem. *IEEE Transactions on Power Systems, 29*(3), 1001-1011.
Panahi, M. (2012). A Natural Gas to Liquids Process Model for Optimal Operation. *Industrial & Engineering Chemistry Research, 51*(1), 425-433.
Patel, B. (2005). LNG vs. GTL (F-T): An economic and technical comparison. *GASTECH 2005 Conference*, (p. 28). Bilbao; Spain.
Peter, F. (2010). *Burning Gas Flares into Fuel.* MIT Technology Review.
Peterson, P., & Fabozzi, F. (2004). *Capital Budgeting Theory and Practice.* Hoboken: Wiley.
PPRA. (2015). *Pricing Template – AGO.* Nigerian Petroleum Product Pricing Regulation Agency.
PPRA. (2015). *Pricing Template – ATK. PPPRA PRODUCT PRICING TEMPLATE – ATK.* (Petroleum Product Pricing Regulation Agency, Editor) Retrieved from http://pppra.gov.ng/pricing-template-atk
Qoutenet.com. . (2015, February 20th). *Latest Price Naphtha (European) in USD per Tonne*. Retrieved 2015, from http://www.quotenet.com/commodities/naphtha
Quinlan, M. (2014). Chevron's GTL starts flowing in Nigeria. *Petroleum Economist, 81*(9), 1.
Roddy, D. (2012). Development of a CO2 network for industrial emissions. *Applied Energy, 91*(2012), 459-465.
Rubin, E., & Zhai, H. (2012). The Cost of Carbon Capture and Storage for Natural Gas Combined Cycle Power Plants. *Department of Engineering and Public Policy, 46*(6), 3076-3084.
Seebregts, A. (2010). *Gas-Fired Power.* IEA Energy Development Network.
Shell Petroleum Company. (2015, June 29). *GTL products. Natural Gas to Liquid*. Retrieved from http://www.shell.com/global/future-energy/natural-gas/gtl/products.html
Shimin, D., & Rory, H. (2014). Cascade Utilization of Fuel Gas Energy in Gas-to-Liquids Plant. *Journal of Engineering for Gas Turbines and Power, 136*(2014), 071702-5.
Starr, F. (2007). *Flexibility of Fossil Fuel Plant in a Renewable Energy Scenario: Possible Implications for the UK, G.B. Renewable Electricity and the Grid: the Challenge of Variability.* London: EarthScan.
Svensson R, e. a. (2004). Transportation systems for CO2 – application to carbon capture and storage. *Energy Conver Manage, 45*(2004), 2343–53.
Thomas, A. (2014). On the (non-)equivalence of IRR and NPV. *Journal of Mathematical Economics,, 52*(May), 25-39.
Tonkovich, A., & Jarosch, K. (2011). *Microchannel Gas-to-Liquids for Monetizing Associated and Stranded Gas Reserves.* Plain City, Ohio : Velocys.
Trending Economics. (2015, July 7th). *Nigeria Government Bond Yield*. Retrieved from http://www.tradingeconomics.com/nigeria/government-bond-yield
Ukpohor, E. (2009). Nigerian gas master plan: Strengthening the Nigeria gas infrastructure blueprint as a base for expanding regional gas market . *24th World Gas Conference 2009.* International Gas Union World Gas Conference Papers.
US EIA. (2013). *Japan is the second largest net importer of fossil fuels in the world.* Today in Energy.
US EIA. (2013). *Updated Capital Cost Estimates for Utility Scale Electricity Generating Plants.* EIA Independent statistics and analysis.

US EIA. (2014). *The Electricity Market Module of the National Energy Modeling System: Model Documentation.* US Department of Energy.
US EIA. (2014). *Electric Power Monthly.* Independent statistics and analysis.
US EIA. (2015). *Annual Energy outlook in with projections to 2040.*
Usman, S. (2006). Will GTL Technology be an Economic option for Natural Gas exploitation in Nigeria? *Center for Energy, Petroleum Mineral Law and Policy (CEPMLP)*, 1-25.
Uzoh, O., & Bretz, R. (2012). Economics of gas-to-liquid processing: The effect of scaling on profitability. *Society of Petroleum Engineers, 4*(2012), 3057-3072.
Wakil, M. (2013). *Electricity Prices Are Rising – Why?* Nigerian Electricity Regulatory Commission, NERC.
Wilhelm, D., & Simbeck, D. (2001). Syngas production for gas-to-liquids applications: technologies, issues and outlook. *Fuel Processing Technology, 71*(1-3), 139-148.
Wood, D. (2012). A review and outlook for the global LNG trade. *Journal of Natural Gas Science and Engineering, 9*, 16-27.
World Bank. (2014). *Electric power consumption (kWh per capita), Energy Statistics and Balances.*
World Bank. (2013). *Gas Flaring Reduction.* Global Gas Flaring Reduction Press Release.
World Bank. (2015). *World Development indicators, .* UK Data Service,.