

Gas utilization in Nigeria – an economic comparison of gas-to-liquid and liquefied natural gas technologies

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DEDICATION

This research work is dedicated to God Almighty for his grace and to my parents, Stephen and Mabel Nwankwo, whose support and encouragement gave me the strength to accomplish my goals.

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To my dear wife Maureen, who has been a source of joy. To my Parents, Stephen and Mabel Nwankwo, I thank you for the love you gave to me. To Vera Emihe, Charity Edeh, Julie Edeh, Chuks, Amobi and Chinedu Nwankwo, I thank you for the prayers and encouragement. I love you all.

ABSTRACT

Natural gas is a versatile resource that can be used as a fuel or as a feedstock for conversion to higher priced products. Nigeria has a huge natural gas reserve of about 187 trillion cubic feet (TCF) and the drive to utilize and subsequently monetize these gas resources has led to the development of the Nigeria gas sector. Two technologies that are poised to play vital roles in this regard are the Liquefied Natural Gas (LNG) and Gas-To-Liquid (GTL) technologies. It is therefore, imperative that an economic comparison of both technologies be done. This comparison shall be the focus of this research work.

The GTL and LNG technologies were economically evaluated for a plant capacity capable of utilizing 1,000 MMSCF/D of natural gas. The capital expenditure (CAPEX) applied in this research work for plants employing both LNG and GTL technologies were based on the CAPEX of LNG and GTL plants that are currently under construction in Nigeria.

Five economic indicators were used in developing a model for proper comparison of the two technologies. Of these indicators, net present value (NPV), internal rate of return (IRR), and profitability index (PI) gave results that were too close for an outright choice to be made from LNG and GTL. On the other hand, GTL performed better with the other two economic indicators – break-even and benefit-cost ratio. GTL will break-even at a lower cost compared to LNG; and the overall benefit-cost ratio for the GTL plant was better than that of the LNG.

The results show that GTL technology will be better placed compared to LNG technology to help the Nigerian government achieve its objective of recovering maximum revenue possible from natural gas.

KEYWORDS

Gas to Liquid

Liquefied Natural Gas

Gas Utilization

Benefit-Cost Analysis

Market Risk

Technological risk

Carbon Efficiency

Thermal Efficiency

Profitability Index

Break-Even Analysis

Economic Indicators

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CHAPTER I

INTRODUCTION

1.1 BACKGROUND

The Nigerian government through the Nigerian National Petroleum Corporation (NNPC) in 1998 set up the Nigerian Gas Company (NGC) limited with the aim of increasing gas utilization in Nigeria. The specific task given to NGC was the developing, harnessing and marketing of natural gas for the domestic market.

The NGC was to utilize the huge natural gas resources that are continuously flared in the Niger Delta region of Nigeria. Little progress has been made because the Country lacks the necessary gas utilization facilities and so millions of dollars are lost daily because of the continued flaring of the natural gases. It is reported that one-eight of all the gas flaring in the world, about 2 million cubic feet of natural gas is flared in the Delta region of Nigeria on daily basis during crude oil production and that amount is equivalent to the total annual power generation in Sub-Saharan Africa, yet most of the Delta region is without power supply and the country as a whole is still experiencing irregular power supply daily (Obadina, T. 1999; Ford, N. 2005; Nigerianoil-gas, 1999).

Most of Nigeria's natural gas is 'associated gases' produced during crude oil exploitation and the annual production over the years from NNPC statistical data has been over 2,000 billion standard cubic feet of gas. The amount of gas produced annually in 2005, 2006 and 2007 in Nigeria are respectively 2,091 BSCF, 2196 BSCF and 2,427 BSCF from crude oil exploitation and related activities. Nigeria is the seventh largest gas reserve

country in the world with about 187 trillion cubic feet (tcf) of gas as at December 2004 (NNPC, 2005a: 3; Kupolokun, F. 2006:8; Ibikunle, A. 2006:5).

The authorities in Nigeria aim to eliminate gas flaring by 2008 and by 2010 earn 50% of crude oil revenue from her natural gas. As a result of the directives from the Authorities in Nigeria to eliminate gas flaring together with mounting pressure by environmentalists, all the major oil producing companies are executing projects aimed at utilizing the gas resources currently flared in the course of their operation in the Niger delta (Belguedj, M. 2006).

This has translated into significant progress that is recorded in the last few years in the gas sector with the Nigeria Liquefied Natural Gas (NLNG) starting production in 1999 with trains 1 and 2. The capacity of Nigeria's Liquefied Natural Gas (LNG) is expected to increase with the on-going expansion to train 7 in which front end engineering design (FEED) has been done and the commissioning schedule for the last quarter of 2007. Other LNG projects that are on the pipeline include the Olokola LNG which is expected to deliver 22 million tonnes per year to the global gas market by 2010, and the 10 million tonnes per year capacity Brass LNG project which is expected to come on stream in 2011 (Kupolokun, F. 2006).

Aside the huge investments by major multi-national companies in the Liquefied Natural Gas projects, the gas sector has witnessed huge investments in a bid to help monetize Nigeria's natural gas resources. These investments include that in the West African Gas Project (WAGP) in which a 630 km pipeline is to deliver gas to Benin Republic, Ghana

and Togo, the Trans-Saharan Gas Project to Europe through Algeria and the Escravos Gas to Liquid Project (EGTL) in which about 300 million standard cubic feet per day (mmscf/d) natural gas is converted into nearly 34,000 barrels of premium-quality diesel, naphtha and little quantity of LPG through the Fischer Tropsch technology.

According to Kupolokun (2006), “The gas exports from the Liquefied Natural Gas Projects (LNG), the Escravos Gas to Liquid project (EGTL) and the West African Gas Project (WAGP), will exceed two million barrels of oil per day”. On the environment, the EGTL plant will offer a unique benefit to Nigerians by not only producing far cleaner diesel fuels, but also utilizing the natural gas that would otherwise be flared which is a plus to the environment (NNPC, 2005a).

1.2 NATURAL GAS AND THE NIGERIAN ECONOMY

Natural gas is rapidly growing in global importance both as an energy source and as a feedstock for the downstream industry. It is one of the world’s most abundant energy resources, with proved reserves estimated at more than 6,000 tcf of which 60% can be classified as stranded. EIA (2004) reported natural gas as the fastest growing primary energy source and that it now represents almost 60% of the contribution made by oil in terms of energy equivalence (EIA, 2004; Glenn, G. 2007). The growth can be attributed to the environmental premium placed on natural gas since it is far less polluting than the main fossil fuels of coal and oil as well as the expansion witnessed in the economy.

Since the end of 1995 when the Final Investment Decision (FID) was taken by Shareholders of Nigerian Liquefied Natural Gas (NLNG) Limited to construct a two train LNG plant with a capacity of 5.8 million tonnes of LNG per annum at Bonny Island in Rivers State in Nigeria, the gas sector has witnessed tremendous growth. According to Kupolokun, “Remarkable progress has been made in Nigeria’s gas sector and the country is growing LNG capacity rapidly and on course to having about 30% of total Atlantic LNG capacity by 2012” (Kupolokun, F. 2006).

The Nigerian Gas industry, a sub-sector of the energy industry, can best be described as an industry on the verge of a boom in investment which is attributable to high oil prices, advances in technology, stringent environmental regulations, amongst others. Funso Kupolokun, the former Group Managing Director of the NNPC, stated that the investment level in the Nigeria’s oil and gas industry have been projected at about \$99.8 billion between 2005 and investments in the industry have increased tremendously in the past few years with level of activities in the last three years surpassing that of previous 14 years.

In a paper presented by Dr. Edmund Daukoro, the former minister of state for petroleum resources in Nigeria, the breakdown of the estimated investment for natural gas showed that upstream natural gas sector will gulp \$12.4 billion while downstream natural gas sector will gulp \$20.3 billion making a total of \$32.7 billion that will be spent on the natural gas sector (Daukoro, E.M. 2006). These are huge investment by any standard and the Authorities are ensuring that policies that will sustain these growths are implemented.

The Nigerian gas industry is well positioned to meet the supply needs and ensure the ongoing wealth creation in the domestic economy. This is seen in its ability to attract investments for growth as observed in the continued expansion of the NLNG from the initial two trains in 1999 to six trains in 2007 and the seventh train is Ready for Start-Up (RFSU). Also tremendous progress is being witness in other projects like OKLNG, Brass LNG, WAGP, EGP 3, EGTL, TSGP, etc.

The industry has been able to stimulate the growth of domestic labour and capital as seen in the gas to power projects in which 15 independent power projects (IPP) is being built in various parts of the country. Availability of power is important if small and medium scale industries will spring up. Also, the availability of power will lead to growth of the manufacturing and service industries and ensure that economy is positively affected.

The reforms in the downstream sector of the oil and gas industry has witnessed the re-emergence of the chemical companies like the fertilizer company, methanol company, Iron smelting company, aluminum smelting company, etc. This has contributed in no small measure to the wealth creation being witnessed in the economy.

According to President Obasanjo, "Nigeria's abundant natural gas reserve will be used to create jobs, wealth, generate power, stop desertification and move Nigeria forward" (Nigeriafirst, 2006). To realize value for the natural gas produced in Nigeria, a considerable market must be found. Economides, Fasina and Oloyede (2004) reported that Nigeria has the potential to produce gas for the next 70 years based on the production

to reserves ratio if the production rate is maintained (Economides, M.J., Fasina, A.O. & Oloyede, B. 2004).

With the construction of new power plants in some of the Nigerian cities, it is believed that gas will play a vital role in the transformation of the Nigerian economy. Funso Kupolokun reported that Gas is being leveraged as the fuel to power Nigeria's economy. He said that the power sector growth will translate to a significant growth in gas demand and so far, the gas sector is supporting the growth of over 15 new power plants which will add over 7 GW of electricity to the national grid (Kupolokun, F. 2006:10). This will stimulate domestic growth as energy costs will be reduced. Other growth area includes the agricultural sector with the proposal to build new fertilizer plants as well as methanol plants for the chemical industry.

Other projects include the West African Gas Pipeline (WAGP), LPG plants, Gas to Liquid plant (GTL), Trans Saharan Gas Pipeline (TSGP) and Equatorial Guinea Gas Supply. The foregoing has transformed the Nigerian gas sector. According to Kupolokun (2006), "There is now an unprecedented growth demand and investment proposal for the sector. Gas demand is estimated to grow from 1.5bcf/d to 15bcf/d by 2010 and the annual growth rate in Nigerian gas demand now ranks about the highest in the world" (Kupolokun, 2006).

1.3 OBJECTIVE

The drive to utilize the abundant stranded natural gas resources in Nigeria has led to the development of the gas industry through pipeline projects, gas to liquid projects and

Liquefied Natural Gas projects for the local and export market. The objective of this research work was to do an analysis of the economics of LNG and GTL technologies in Nigeria and determine which of the options is more viable. Though the products from both processes are destined for different market, the debate amongst resource owners, developers, oil and gas commentators as well as investors has been the comparison between LNG and FT-GTL. Goswami reported that resource holders increasingly have to make a choice between commercialization options such as GTL and LNG. (R. Goswami, 2007:17; Economides, M.J., Aguirre, M., Morales, A., Naha, S., Tijani, H., & Vargas, L. 2005; IFP, 2006:3).

The Nigerian government has the objective of recovering maximum revenue possible from natural gas. The outcome of this dissertation will contribute to the government's meeting of this objective. It will enable the authorities in Nigeria to readily give priority attention to the option in terms of capital investment and resource allocation. An economic model used for the study was developed. It incorporated all the economic parameters including those listed in table 3.8 in arriving at the result.

1.4 PROBLEM STATEMENT

With an overriding need to meet its flare down targets and the talk about environmentally friendly fuel, there is a growing interest for organizations to invest in the gas sector of the Nigerian economy. The gas-to-liquid (GTL) potential to consume large amounts of gas on the one hand and produce useful and immediate products on the other is hindered by concerns over immature technology. Liquefied Natural Gas (LNG) is a mature

technology and the plant in Nigeria has been successful since 1999 when the first plant was commissioned.

With Chevron's investment in the gas-to-liquid (GTL) technology and the continued expansion of the Nigerian Liquefied Natural Gas (NLNG) plant as well as other proposed LNG projects, there is the need to examine both technologies to determine which of the two options is more viable. The result from this research work will enable the authorities in Nigeria to make better evaluation and prioritization of investment proposals.

The beneficiaries of this research will include the Nigerian government, the oil and gas companies, Nigerians as well as other stakeholders in the oil and gas sector.

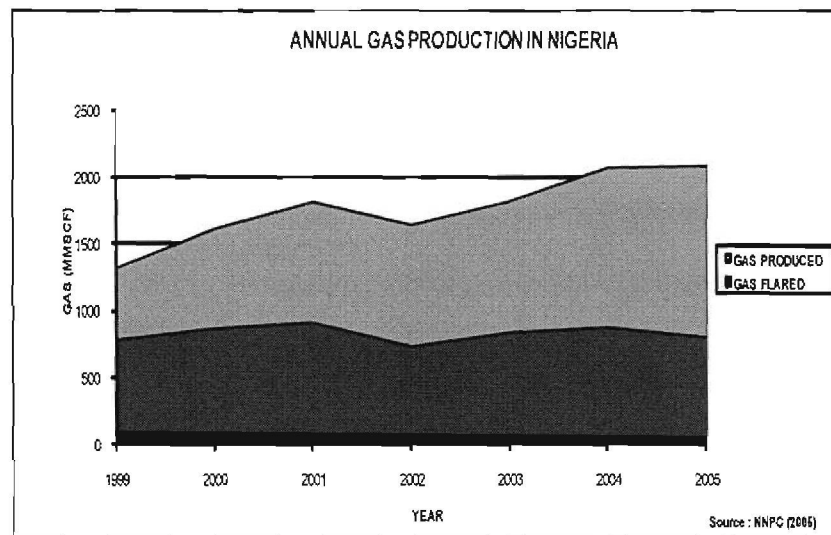
CHAPTER II

LITERATURE REVIEW

2.1 GAS UTILISATION IN NIGERIA

The aspiration of the Nigerian government for the gas sector include creating a new industry from the old oil industry, capturing economic value and generating as much revenue from gas as from oil by 2010, developing the domestic gas market and ending gas flaring by 2008. Remarkable progress has been recorded towards the realization of these objectives. Of the current annual gas production of about 2,000 billion standard cubic feet (bscf), about 40% is flared. See fig. 2.1. This is a drastic drop from the 70% proportion flared before 1999 (Ibikunle A., 2006:5; Kupolokun, F. 2006).

Fig.2.1 ANNUAL GAS PRODUCTION



The flared gas is being channeled into gas powered projects for rapid utilization and monetization with a view to maximizing value addition to the nation's natural gas

resource by 2010. The government also set in motion the policy on natural gas, legislative reviews as it concerns natural gas, gas master plan and other fiscal reforms relating to the development and commercialization of natural gas.

The major oil companies have embarked on projects aim at utilizing the gas that is currently being flared. Most of these projects are reaching advance stages while some are already completed. Fig.2.2 and Fig.2.3 shows the gas produced and gas flared by the major oil companies operating in Nigeria.

Fig.2.2 GAS PRODUCED IN NIGERIA

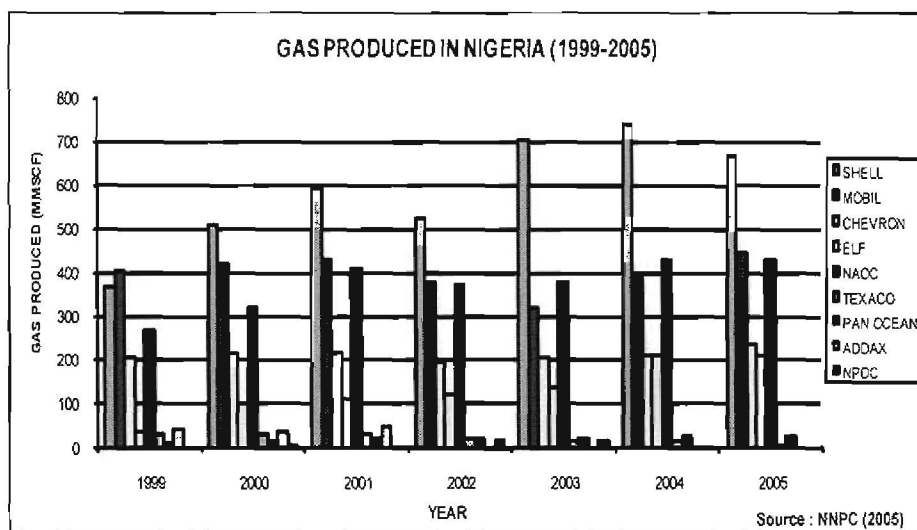
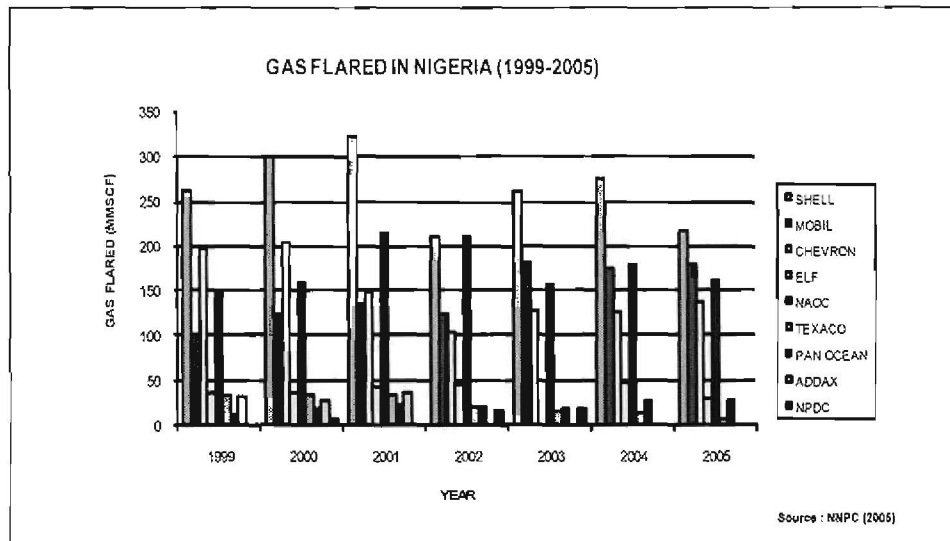


Fig.2.3 GAS FLARED IN NIGERIA



Despite the gas flaring by the major oil companies operating in the Niger Delta, Nigeria's per capita carbon emissions, which in 2001 stood at 0.20 metric tons of carbon equivalent, remain lower than Africa's other major energy-producing states. Libya's per capita carbon emissions for the same year were 2.31 million metric tons of carbon equivalents, while Algeria (0.71), Egypt (0.51), and Angola (0.27) all registered higher rates (EIA, 2003).

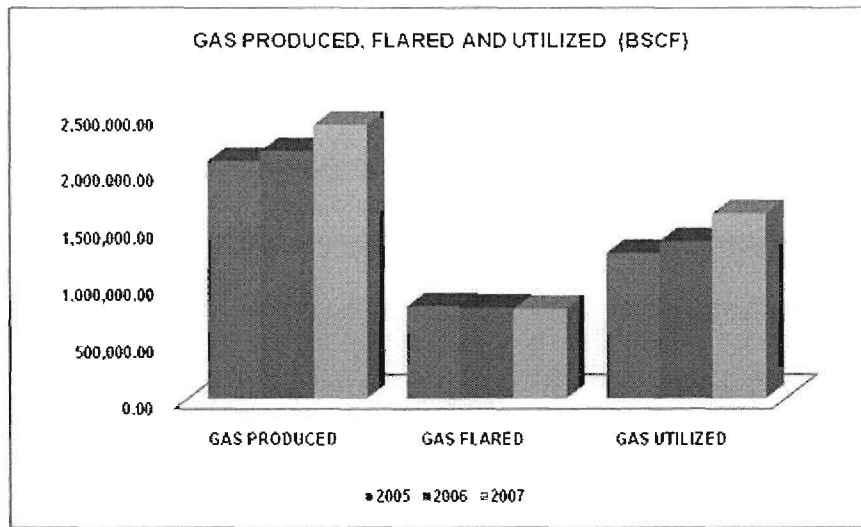
Nigeria's per capita carbon emissions have fluctuated over the past 20 years, but generally have stood at or near 0.20 metric tons of carbon equivalent, ranking the country the lowest among OPEC members. By way of comparison, Saudi Arabia's per capita carbon emissions in 2001 were 4.02 million metric tons of carbon equivalent, while Venezuela's totaled 1.57, Iran were at 1.40, and Indonesia's ranked second-lowest in OPEC at 0.41 million metric tons of carbon equivalent (EIA, 2003).

The reduction in gas flared is as a result of utilization in a number of industries. Ibikunle (2006) reported that domestic usage of the gas in existing power plants which includes Afam, Egbin, Sapele, Ughelli and Okpai power plants. There is also the WAGP, EGP 2 and NLNG trains 6 and 7 projects where the gases are utilized. On the industrial front, these gases are being channeled to industrial areas at Agbara and Ikorodu, Greater Lagos areas as well as to the Aluminium Smelting Company of Nigeria, National Fertilizer Company of Nigeria and Steel plants in Aladja and Ajaokuta.

According to the EIA report, Nigeria could be one of the beneficiaries of the Kyoto protocol if implemented as a result of her low carbon emission rate and the continued reduction in gas flaring. One of the benefits to the country will be an increase in the foreign direct investment (FDI) that will flow into the country as part of the clean development mechanism (CDM), which is a market based mechanism that will assist developing countries in achieving sustainable development (EIA, 2003) and the FDI is a direct boost to the economy.

The main impetus of gas utilization projects in Nigeria had been the desire by the federal government of Nigeria to create more wealth and diversify the economy and also to attain self sufficiency in power generation for which a target of additional 10,000 MW has been set by 2007. In 2005, the gas produced in Nigeria stood at approximately 2,094 BSCF and the amount of gas utilized is approximately 1,281 BSCF while in 2007, the amount of gas produced is approximately 2,415.65 BSCF and the gas utilized is about 1,626 BSCF.

Fig. 2.4 GAS PRODUCED, FLARED AND UTILIZED (2005-2007)



The increase can be attributed to high demand by 3rd party customers for electricity generation and the continued expansion in the LNG trade. Other projects that will need more of the gas produced include the GTL, Independent Power Plant and the Chemical Industries. It can be seen from figs 2.5, 2.6 and 2.7 that the amount of gas utilized by the LNG plants has been on the increase for 2005, 2006 and 2007.

Fig. 2.5 GAS UTILIZED (2005)

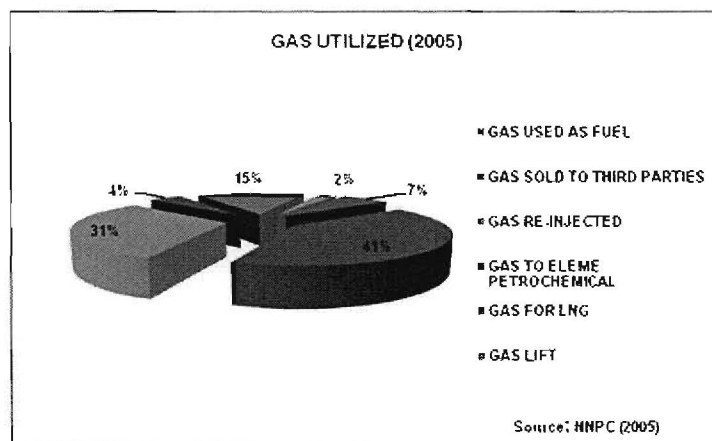


Fig. 2.6 GAS UTILIZED (2006)

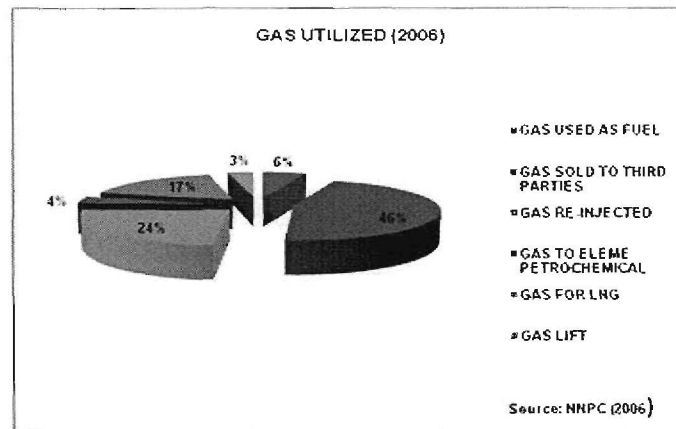
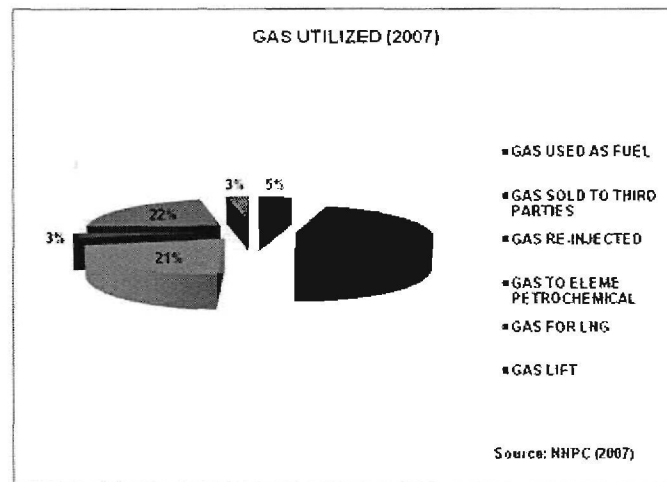


Fig. 2.7 GAS UTILIZED (2007)



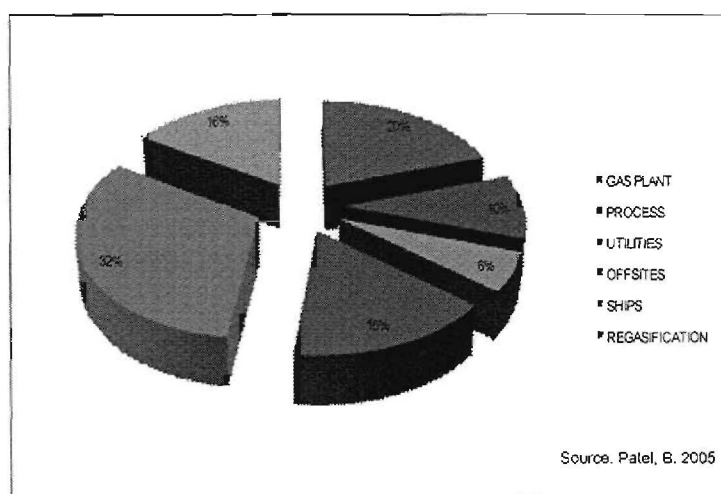
Two of the gas utilization and monetization options for the export market, LNG and FT-GTL shall henceforth be discussed.

2.2 LIQUEFIED NATURAL GAS

Liquefied Natural Gas (LNG) is natural gas that has been cooled to a very low temperature to the point where it condenses to liquid. The temperature at which this occurs is approximately -160°C at atmospheric pressure and the volume reduces to one six-hundredth of its volume allowing transportation by specialized LNG tanker ships over long distances (Subero, Sun, Deshpande, McLaughlin & Economides, 2004).

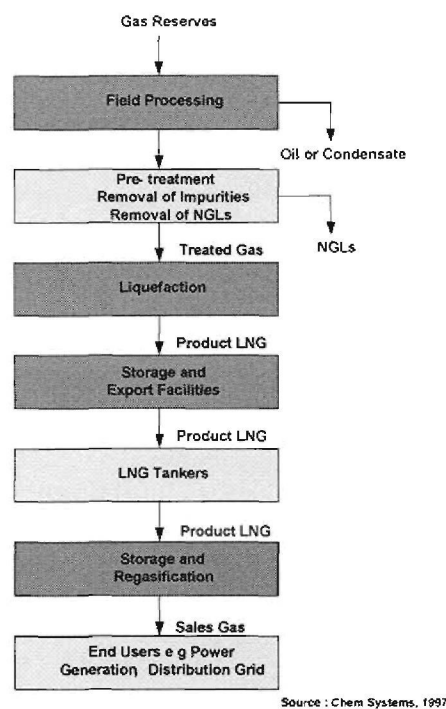
LNG is stored in heavily insulated tanks before being re-gasified from liquid to gas for industrial and domestic use. The whole supply chain for LNG includes: gas liquefaction, shipping, storage, and re-gasification facilities. The 2006 Encyclopedia of LNG by Petroleum Economists showed that about 188 MTPA of LNG was traded between 13 LNG exporting countries and 15 LNG importing countries in 2005. The total fleet used was over 200 ships (Petroleum Economists, 2006:56).

Fig. 2.8 PERCENTAGE CAPITAL BREAKDOWN FOR LNG



The full chain LNG plant consists of the gas plant, the liquefaction processes, utilities, offsites, LNG ships and regasification terminals. The percentage capital breakdown as reported by Patel (2005) is shown in fig. 2.8 above while a block flow diagram of the LNG processes is shown in fig. 2.9.

Fig.2.9 LNG FULL CHAIN



According to the report by Kupolokun (2006), the Nigeria Liquefied Natural Gas (NLNG) has been one of the fastest growing endeavours in the world since production started from trains 1 and 2 in 1999. By the time train 6 becomes operational in late 2007/early 2008, the NLNG output will total about 22 MMTPA. The shipment to the US from the NLNG plant is expected to increase with the addition of the sixth train.

It is in response to the ever increasing global energy demand that the two additional LNG projects, namely Brass LNG and Olokola LNG (OKLNG) were launched. The demand increases are largely driven by new markets such as China and India in Asia and re-emerging markets, such as US and the UK in the Atlantic basin (Petroleum Economist, 2006:5). These two LNG projects (Brass and Olokola) will be fully operational from 2009 onwards, contributing additional 32 MMTPA to Nigeria's LNG output, a major addition to the Atlantic basin volume (Kupolokun, F., 2006; Daukoru, E., 2006). Table 2.1 below shows the summary of LNG projects in Nigeria

Table 2.1 SUMMARY OF LNG PROJECTS IN NIGERIA

PROJECT NAME	TRAINS	COMPANY (Shareholders)	START-UP YEAR	CAPACITY (MMTPA)
NLNG Base Project	Trains 2 Train 1	NNPC, Shell, Total, Agip	Aug. 1999 Feb. 2000	5.90
NLNG	Train 3	NNPC, Shell, Total, Agip	Nov. 2002	2.95
NLNG Plus	Trains 4 Train 5	NNPC, Shell, Total, Agip	Nov. 2005 Feb. 2006	8.20
NLNG Six (under construction)	Train 6	NNPC, Shell, Total, Agip	2007/2008	4.10
Brass LNG (Proposed)	Trains 1 & 2	NNPC, Agip, Total, ConocoPhillips	2011	10
OKLNG (Proposed)	Trains 1,2,3 & 4	Chevron, Shell, BG, NNPC	2010+	22
NLNG SevenPlus	-	NNPC, Shell, Total, Agip	2010	8.0
NLNG T8 (Speculative)	-	NNPC, Shell, Total, Agip	2010+	8.0
Southeast LNG (speculative)	Train 1	NNPC, ExxonMobil	2010	4.8

2.3 FISCHER TROPSCH GAS TO LIQUID TECHNOLOGY

Gas-to-Liquid (GTL) technology involves the conversion of natural gas into clean burning liquid hydrocarbons, primarily diesel and naphtha. Davies (2005) reported that while diesel is considered the GTL product of primary importance, naphtha produced in the FT process is an ideal feedstock to produce ethylene, one of the basic building blocks of the petrochemical industry. He stated that GTL has the environmental edge in an increasingly demanding world.

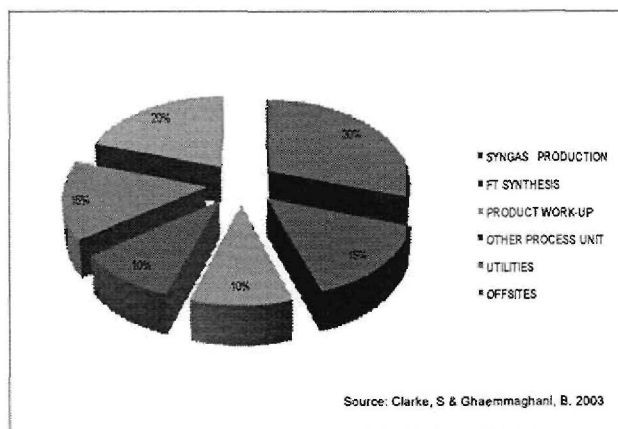
GTL has been ‘pushed’ in the past few years by the need to reduce flaring and the opportunities to develop stranded gas reserves. GTL not only adds value, but is also capable of producing products that could be sold or blended into refinery stock as superior products for which there is a growing demand. Pirog (2004) reported that GTL can be viewed as an alternative to oil refining since the process could convert natural gas to hydrocarbon mixture which could then be upgraded into petroleum products.

The term “Gas-to-Liquid” refers to processes used for the conversion of natural gas to liquid fuels. The liquid fuels may be transportation fuels (diesel and gasoline) produced via Fischer-Tropsch synthesis, or alternative fuels from syngas such as methanol (MeOH) and dimethyl ether (DME).

Huge Capital investments are needed for construction of a GTL plant and it runs in billions of dollars. The percentage capital breakdown for the GTL process as given by

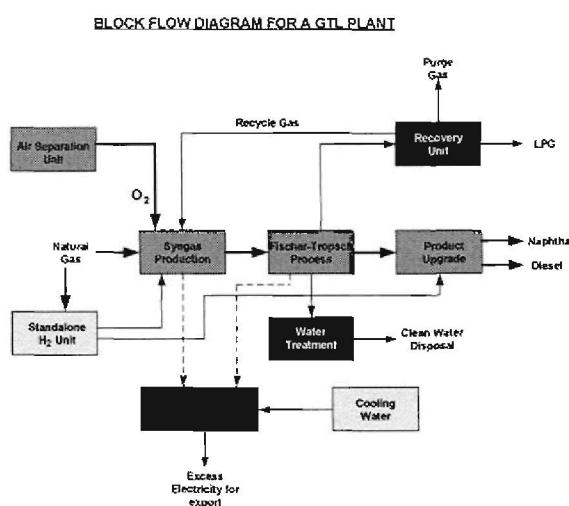
Clarke & Ghaemmaghami (2003) is shown in fig. 2.10 below. For the purpose of this research work, GTL shall mean FT-GTL.

Fig. 2.10 PERCENTAGE CAPITAL BREAKDOWN FOR GTL



The FT-GTL plant uses a 3-step approach to convert the natural gas to liquid fuels. These are Syngas Production, Fischer-Tropsch Synthesis and Product Upgrade (Morita, Y. 2001; F. Thackeray, 2000). Fig. 2.11 shows a typical block flow diagram for a GTL plant as shown in a report by Sadaghiani, Manafi and Bakhtiary (2004:15).

Fig. 2.11 GTL FLOW DIAGRAM



2.3.1 SYNGAS PRODUCTION

The Syngas generation step involves the conversion of natural gas to hydrogen and carbon monoxide by partial oxidation, steam reforming or a combination of the two processes. Oxygen, introduced either as steam, air, or pure gas, produces a mixture of hydrogen and carbon monoxide.

The desired Syngas produced is hydrogen to carbon monoxide ratio of 2:1. The Syngas unit is very important in determining the thermal and carbon efficiencies of the GTL process. The technical development in the GTL process is most intensive in the reforming step since greater percentage of the capital for the full chain GTL process as well as the most of the energy is used in this step (Subero, Sun, Deshpande, McLaughlin & Economides, 2004).

Thackeray (2000:23) reported about the research on the use of ceramic membrane technology to supply pure oxygen from air to mix with natural gas in the production of Synthetic gas which if successful will eliminate the need for an Air Separation Unit (ASU) and cut the capital cost of a GTL plant by at least 25% (Thackeray, F. 2000:23; Brook, P. 2004?:6).

Vosloo (2006?) on his part reported that the thermal efficiency of the plant can also be improved by combining the oxygen removal and reforming sections into one unit. Early indications are that this technology should significantly reduce the capital cost of the syngas generation section of the GTL plant (Vosloo, A. 2006?).

Six principal syngas production technologies that have been commercialized or are currently at an advanced stage of development are

- Steam methane reforming (SMR)
- Autothermal reforming (ATR)
- Non-Catalytic Partial Oxidation (POX)
- Catalytic Partial Oxidation (CPOX)
- Heat Exchange Reforming (HER)
- “Compact” Reforming (CPR)

Apanel (2005) and Smith and Asaro (2005) in their reports stated that of all the alternatives for syngas generation, ATR is most suited for large scale FT-GTL, because it strikes a balance of energy, efficiency and scalability.

2.3.2 FISCHER-TROPSCH PROCESS: The conversion of the syngas to liquid hydrocarbon is a chain growth reaction of carbon monoxide (CO) and hydrogen (H₂) on the surface of a heterogeneous catalyst. The temperature, pressure and catalyst determine whether a light or heavy syncrude is produced. Pirog (2004) reports that GTL can be viewed as an alternative to oil refining since the process could convert natural gas to hydrocarbon mixture which could then be upgraded into petroleum products.

The catalyst employed in most processes is either cobalt-based or iron-based catalyst. One of the most vital factors in enhancing the Fischer-Tropsch processes is the development of improved catalyst with higher selectivity and productivity (Thackeray, F.

2000:11; Adegoke, A. A. 2006:20; Chemlink, 2005?; Verghese, J.T. 2003). The Fischer-Tropsch process reaction is an exothermic reaction.

2.3.3 PRODUCT UPGRADE: This is the third stage of the FT-GTL process where the long chain hydrocarbon product is subsequently hydro-cracked to produce finished products. A variety of products can be produced such as transportation fuels like diesels and jet fuels, petrochemical feedstock like naphtha and liquefied petroleum gases (LPG). The product slate from the GTL process can vary widely depending upon the process used and a high yield of cetane and low emission diesel oil is a key feature of the process. The paraffinic product can thus be converted to any required molecular weight product (Patel, B. 2005; Thackeray, F. 2000:12; Al-Saadoon, F. 2005; Rahman & Maslamani, 2004). The products from the Fischer Tropsch process have physical properties similar to petroleum products and thus can be stored in similar storage facilities as conventional petroleum products and also transported in the same ships and tankers in which petroleum products are transported (Ahmad, Zughaid & Araf, 2002).

The GTL and LNG projects are high capital intensive ventures. The LNG industry, according to Gass, J & Davies, P (2005) has demonstrate how over time, the technology has improved and costs have been reduced, allowing the industry to become more competitive. GTL is at the very beginning of the process, but as it develops, it can reasonably expect to enjoy much the cost-reduction/ technology-enhancement process experienced by LNG (Gass, J. & Davies, P. 2005).

The continued reduction of the overall cost of the various processes involved remains the key focus of the GTL technology and the development and improvements on the catalyst used is vital to the success of the whole process. Brooks (2004?) reported that improved catalyst activity for the GTL process would lower the required amount of catalyst per barrel and increase the reactor output for a fixed size of reactor.

Similarly, cost reduction in the GTL process can also be achieved during the oxygen generation process once the ongoing research into the use of ceramic membrane is successfully concluded and commercially viable (Patel, B. 2005:7; Thackeray, F. 2000:23).

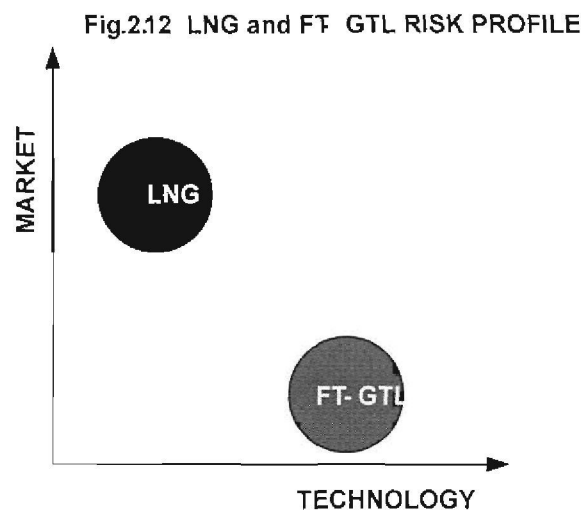
Anton Vosloo (2006?), reported that in order to have the greatest impact on the economics of the process, future breakthroughs should be in areas that decrease the capitals cost of syngas generation which is almost one-quarter of the capital expenditure for an integrated GTL plant and/or improve the thermal efficiency of the plant as a whole which he can obviously be improved by combining it with a power generating plant (Vosloo, A. 2006?).

2.4 RISK PROFILE OF LNG AND FT-GTL

The risk associated with the LNG and FT-GTL projects were examined and weighed against the economic returns. Two of the risks associated with the LNG and FT-GTL technologies are technological and market risks.

2.4.1 TECHNOLOGICAL RISK: LNG process is a mature technology, with very low technical risk while the FT-GTL process is still emerging into a commercially operational industry with few plants in existence. A lot of processes are still been tried out to come up with one that will give an optimum result. There is little room for cost reduction for the LNG process unlike the FT-GTL which has rooms for improvement and further cost reduction.

Fig. 2.12 RISK PROFILE FOR LNG AND GTL



The thermal efficiency and carbon efficiency of both technologies are examined. According to Patel (2005), how best the carbon atom in the feedstock is utilized to produce the final product is known as the carbon efficiency while the thermal efficiency on the other hand is a measure of how best the total energy in the feedstock is utilized to produce the final hydrocarbon product. The FT-GTL process has a carbon efficiency of 77% while the LNG process has a carbon efficiency of 92%. Technological advances are projected to increase the carbon efficiency for the FT-GTL process to 90% (Patel, B. 2005).

The thermal efficiency of the LNG process is 92% while the thermal efficiency of the FT-GTL process is about 60%, meaning thermal energy of about 40% is lost in the process. The ability to capture and utilize most of this energy is a big challenge to the GTL technological process. Technological advances are projected to increase the FT-GTL process to 73% (Patel, B. 2005; Clarke, S & Ghaemmaghami, B. 2003).

Basically, the LNG process is non-catalytic while all major units for the FT-GTL processes require catalysts that are changed periodically. The continuing improvement in the catalyst used in the FT-GTL process will further reduce the operating expenditure, and hence the profitability of the plant. Thackeray (2000) reported that the development of improved catalyst with higher selectivity and productivity is proving to be one of the most vital factors in enhancing the economics of the Fischer Tropsch processes.

2.4.2 MARKET RISK: The potential supply of LNG exceeds demand in both the Atlantic and Pacific basin where there are several sources of existing and potential LNG supply. Though LNG markets are becoming harder to capture, the increase in energy demand by some countries including China, India and US has necessitated more demand for LNG. FT-GTL is a very small player in the vast diesel market where the process is expected to be unhindered with its superior environmental qualities. The market size for the FT-GTL products is 2 billion tonnes per annum while the reported market share is 0.2%. The market size for the LNG is 100 million tonnes per annum while the market share is 4% (Jacometti, J., Koh, G. & Nagelvoort, K. 2002:104).

An analysis of the economics of LNG and GTL processes shall be discussed in chapter III. The income that will accrue from the excess electricity/steam produced from the GTL process as shown in fig. 2.11 was not factored into the economics of the GTL process for this research work

CHAPTER III

3.0 ECONOMIC ANALYSIS OF FT- GTL AND LNG TECHNOLOGIES

The economic evaluation of FT-GTL and LNG was done taking into account the variables that affect the viability of both projects. The FT-GTL plant is affected primarily by the crude oil price while the LNG plant is related to the price dynamics of the gas market. The capital expenditure for both plants is quite huge and is essentially similar (Patel, B. 2004:8). The model used for the study was developed using Microsoft Excel. It incorporated a plant life of 20 years, a construction period of 3 years, an owners' equity of 100% and a 5-year MACRS depreciation schedule. A comprehensive list of economic parameters used in this study is listed in table 3.7.

The economic model use five economic indicators namely net present value (NPV), internal rate of return (IRR), profitability index (PI), break-even analysis (BE) and benefit-cost ratio (B-C) on the after-tax cash flow for the projects under consideration. The discounted cash flow (DCF) techniques are applied in the model. The DCF is any method of investment project evaluation and selection which adjusts cash flows over time for the time value of money.

The product slate from a GTL plant varies depending on the technology and the processes used. For the EGTL plant, the Sasol technology is used for the processes and Smith and Asaro (2005) reported the GTL product slate for Sasol technology as 28% Naphtha and 72% middle distillates. The percentage of LPG produce is quite small and it is reported

by Smith and Asaro (2005) as by-products. For the purpose of this research work, the product slates shall be assumed to be 72% for Diesel and 28% for Naphtha.

3.1.0 RANKING OF PROJECTS

In evaluating mutually exclusive projects, ranking is used to weigh the economic indicators used in evaluating the projects. From various literatures, it is seen that the net present value method always provides correct rankings of mutually exclusive investments projects, whereas the internal rate of return method is the most important alternative to NPV (Ross, Westerfield & Jordan, 1996:190). For the purpose of this thesis, the NPV, IRR, PI, BE and B-C shall be used to compare the results of both projects.

3.1.1 NET PRESENT VALUE (NPV): The Net Present Value (NPV) of an investment proposal is the present value of the proposal's net cash flows less the proposal's initial cash outflow. The expected cash flows on an investment are set out year by year and brought to a present value by the use of present values factors at the appropriate rate (Mott, 1989:25).

NPV compares the value of a dollar today to the value of that same dollar in the future, taking inflation and returns into account. If the NPV of a prospective project is positive, it should be accepted. However, if NPV is negative, the project should probably be rejected because cash flows will also be negative (Ross, Westerfield & Jordan, 1996:183). An investment with the best NPV is ranked first when considering two or more investments that are mutually exclusive.

3.1.2 INTERNAL RATE OF RETURN (IRR): The internal rate of return for an investment proposal is the discount rate that equates the present value of the expected net cash flows with the initial cash out flows. The IRR is closely related to the NPV since it is the discount rate used when the NPV is equal to zero. An investment is acceptable if the IRR exceeds the required return, otherwise it should be rejected (Ross, Westerfield, Jordan, 1996). The acceptance criterion generally employed with the internal rate of return method is to compare the internal rate of return to a required rate of return, known as the cutoff, or hurdle rate. The discount rate assumed for the purpose of this research work shall be 10% (Gradassi, M.J 2001; Robertson, E.P. 1999:14).

3.1.3 PROFITABILITY INDEX (PI): The profitability index (PI) is the ratio of the present value of future net cash flows to the initial cash out flows. It is also known as the benefit-cost ratio. The acceptance criterion for the profitability index of an investment proposal is to accept the proposal if the PI is 1.00 or greater than 1.00 or reject the proposal if otherwise.

3.1.4 BREAK-EVEN ANALYSIS: The break-even analysis, also known as the economic-production analysis is a method for presenting costs and income in a form to aid interpretation and analysis. Variations in either income or costs will result in the slopes of respective lines varying, causing the break-even point to either slide up or down (Jelen & Black, 1983:135; Lockyer, Muhlemann & Oakland, 1983:39; Peters, Timmerhaus & West, 2003:231).

3.1.5 BENEFIT-COST ANALYSIS: This analysis consists of determining the ratio of project benefits to project costs. It is a practical way of assessing the desirability of projects and used sometimes in a broad way to describe the appraisal of a cost-saving investment. They identify the capital and running costs of the investment and relate the yearly benefits to those costs in terms of NPV or DCF yield (Mott, G. 1999:140; Black, J. 1984:146).

3.20 DEFINITION OF ECONOMIC TERMS USED

3.2.1 CASH FLOW: Cash flow is the movement and timing of cash with respect to a project. Movement can be further defined as in- or out-of-pocket movement. Cash flow is calculated on an after-tax basis. The cash flows to be used in the appraisal of the project under consideration are

- a. Total Capital Investment
- b. Sales Revenue
- c. Production Cost
- d. Tax Rate

3.2.2 TOTAL CAPITAL INVESTMENT (TCI): The total capital investment for a project comprises the fixed-capital investment in the plant and equipment as well as the working capital excluding the cost for the land. The cash flow for the fixed capital investment is usually spread over the construction period (Peters, Timmerhaus & West, 2003:233). Fixed capital is the total cost of the plant up to the point when the plant is ready for start-up while the working capital is the additional investment needed, over and

above the fixed capital, to start the plant up and operate it to the point when income is earned. The total capital investment shall also be known as the capital expenditure estimated in section 3.2.2.1 below.

3.2.2.1 ESTIMATING CAPITAL EXPENDITURE: The Capital expenditure for the LNG and FT-GTL plants is based on the cost of the Nigeria Liquefied Natural Gas NLNG train 6 in which production is expected to commence in the fourth quarter of 2007 (NLNG, 2006) and the Escravos Gas to Liquid (EGTL) project which is scheduled to be completed in 2008. The capital expenditure (CAPEX) for the NLNG train 6 is \$2.5 billion (NNPC, 2005:12; Thisdayonline, 2004) while the plant will be able to process about 800 MMSCF/D of feed gas. The CAPEX for the EGTL plant is \$1.7 billion (Chevron, 2005; MBendi, 2007; Maisonnier, G. 2006) while it will process about 340 MMSCF/D of feed gas. Both CAPEX and Capacities are the base cases used to estimate the CAPEX of the LNG and GTL plants capable of processing 1,000 MMSCF/D of feed gas in this thesis.

The cost-capacity relationship is applied and it is given by the equation where n is found to be 0.6 (Black J, 1984:94; Signot, 2005) for a chemical plant in which C2 is the capital cost of a plant of capacity S2 and C1 is the capital cost of a plant of capacity S1.

$$C2 = C1 * \left(\frac{S_2}{S_1} \right)^n$$

This equation is used to estimate the CAPEX of LNG and FT-GTL plant capable of processing 1,000 MMSCF/D. The CAPEX for the LNG and FT-GTL plant under consideration is given in the table below.

Table 3.1 - FT-GTL ESTIMATED CAPEX

GAS UTILIZED (MMSCF/D)	FT-GTL PLANT CAPACITY (bbl/d)	FT-GTL PLANT CAPEX (\$Bn)
1000	100,000	3.25

Table 3.2 - LNG EXTIMATED CAPEX

GAS UTILIZED (MMSCF/D)	LNG PLANT CAPACITY (MMTPA)	LNG PLANT CAPEX (\$Bn)
1000	7.67	3.64

3.2.3 PRODUCTION COST: The total cost of production is a major component of an economic analysis. It is the total of all cost of operating the plant, cost of selling the products including shipping, cost of feedstock and raw materials used for production as well as contributing to corporate functions such as management and research and development (Peters, Timmerhaus & West, 2003:259).

3.2.3.1 ESTIMATING OPERATING EXPENDITURE

The annual Operating Expenditure (OPEX) used in the research work includes cost for materials and supplies, labour, utilities and maintenance. It however did not include the cost of the feedstock which was estimated separately. Patel (2004), in a report gave the operating costs of the FT-GTL plant to be between \$4.00/bbl and \$5.50/bbl while for the LNG plant was between \$0.20/MMBTU and \$0.30/MMBTU.

Al-Saadoon (2005) gave the annual operating expenditure for large projects to be in the range of 5-7% of the capital expenditure, Economides et al. (2005) reported the FT-GTL

OPEX to be \$5.00/bbl while Gradassi (2001) gave the OPEX for FT-GTL as \$4.00/bbl. Avellanet et al (1996) gave a GTL OPEX of \$7.00/bbl and LNG OPEX as 7% of cumulative investment.

Chang (2001) reported the LNG OPEX as \$0.50/mmbtu and the FT-GTL OPEX as \$10.00/bbl while Halstead (2006) in a report estimated the OPEX for the Oryx GTL plant to be \$4.50/bbl. The EGTL plant will use similar process as the Oryx GTL plant. (Economides, M.J., Aguirre, M., Morales, A., Naha, S., Tijani, H., & Vargas, L 2005; Gradassi, 2001; Al-Saadoon, 2005:3; Patel, 2004:8; Avellanet, Thomas & Robertson, 1996:536; Chang, 2001:5; Halstead, K. 2006). For the purpose of this thesis, the OPEX for the FT-GTL project shall be assumed to be \$5/bbl which is close enough to that given by Halstead (2006) and in line with that given by Patel (2004) and Economides et al. (2005). The OPEX for the LNG project shall be assumed as \$0.5/MMBTU.

3.2.3.2 FEEDGAS COST: The cost of natural gas used as the feed gas in chemical plants ranges from \$0.00/MMBTU to \$1.00/MMBTU (Economides, M.J., Aguirre, M., Morales, A., Naha, S., Tijani, H., & Vargas, L. 2005; Al-Saadoon, 2005; Patel, 2004; Morita, 2001). At 60% thermal efficiency, 10MSCF of 1000BTU/SCF gas are required to produce 1bbl of GTL products (Al-Saadoon, 2005). For the purpose of this research work, gas prices of \$0.25/MMBTU, \$0.50/MMBTU, and \$1.00/MMBTU shall be used in the analysis while the base case price shall be \$0.50/MMBTU.

3.2.3.3 SHIPPING COST: Shipping Cost varies considerably between projects and it is a function of the distance between buyer and seller as distance is directly proportional to the operating cost of the ship. Seddon (2004) in his report gave the LNG shipping cost as \$0.7/GJ while Chang (2001) reported the shipping cost for the LNG as \$0.2/MMBTU per 1000 KM and that for the FT-GTL as \$1.35/bbl per 1000 KM. Subero et al. (2004) estimated the LNG shipping cost to be in the range of \$0.43/mmbtu and \$0.71/mmbtu. Lee (2005) gave the average shipping cost from Nigeria to the United States of America as \$0.85/mmbtu.

Gradassi (2001), in his report gave the FT-GTL product shipping expense as \$2/bbl, Gaffney, Cline and Associates (2001) gave the cost of delivering FT-GTL products as \$1.0/bbl while Economides et al. (2005) gave the shipping cost as \$1.20/bbl (Gaffney, Cline & Associates, 2001; Gradassi, 2001; Economides, M.J., Aguirre, M., Morales, A., Naha, S., Tijani, H., & Vargas, L. 2005; Seddon, 2004; Chang, 2001; Subero, G., Sun, K., Deshpande, A., McLaughlin, J. & Economides, M.J; Lee, H. 2005:6). For the purpose of this thesis, the shipping cost for the FT-GTL project shall be assumed to be \$1.20/bbl while the shipping cost for the LNG project shall be assumed to be \$0.7/MMBTU. For each of these values, two other values shall be investigated using the tornado graph to analyze the effect of high and low values from the base case on the economics of both project.

3.2.4 SALES REVENUE: The revenue generated by the sale of product from a plant is a key factor in analyzing the cash flow pattern for a given plant. The total annual

revenue from the product sales is the sum of the unit price of each product multiplied by its rate of sales. Smith, R & Asaro, M (2005) in a report gave the product slate from a GTL plant using the SASOL technology as 72% for middle distillates and 28% for naphtha since the little quantity of LPG produced is treated as a by-product. For the FT-GTL plant, the product distribution shall be assumed to be 72% and 28% for diesel and naphtha respectively.

3.2.5 PRODUCT PRICING: The pricing of products from the FT-GTL plant is dependent on the prevailing crude oil price, the refined product premium as well as the FT-GTL product price premium (Gaffney, Cline and Associates (2001). Overall, the premium for FT-GTL products over crude oil ranges between \$2.0/bbl and \$10/bbl or more (Al-Saadoon, 2005; Gaffney, Cline and Associates, 2001; Pyrdol, J and Baron, B. 2006). The report by Khataniar, et al (2004) gave the FT-GTL product a premium of 125% over the crude oil price (Khataniar, Chukwu, Patil & Dandekar, 2004). However, the FT-GTL diesel and Naphtha premium shall be assumed as \$5/bbl and \$3/bbl respectively (J. Pyrdol and B. Baron, 2006).

Crude oil price has been on the rise and as at July 31, 2007, the crude oil price stood at \$78.20/bbl (EIA, 2007). However, Crude oil price from 1986 to 2006 as seen in fig 3.1 averaged \$25.95/bbl and fig 3.2 shows the monthly Crude oil price from January 2005 to March 2007 averaged \$60.90/bbl. Three different crude oil price values for the base case, high case and low case of \$45/bbl, \$70/bbl and \$20/bbl respectively as shown in fig 3.1 shall be used in the sensitivity analyses of the FT-GTL project (see fig 4.7).

Fig. 3.1 – CRUDE OIL PRICES (1986-2006)

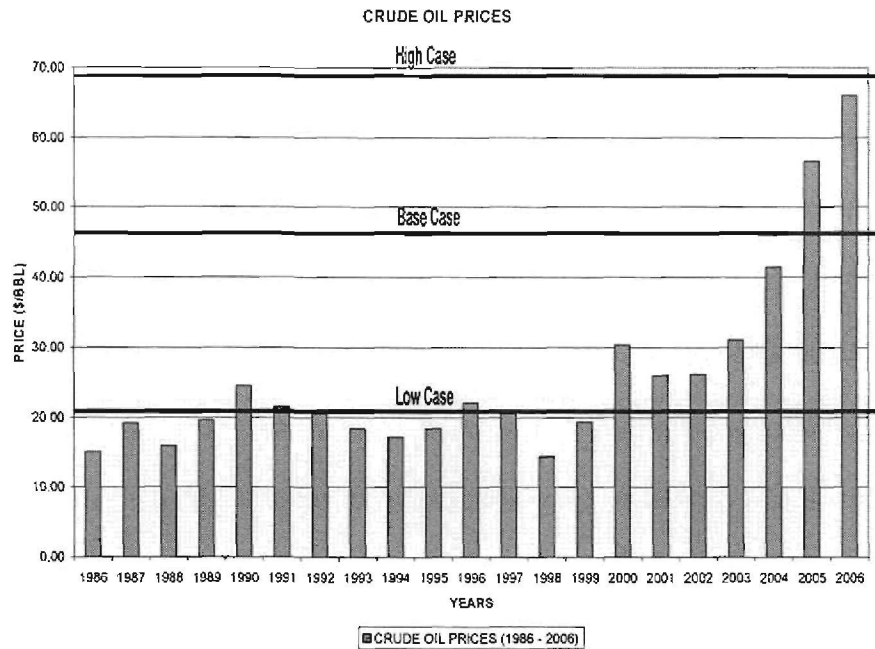
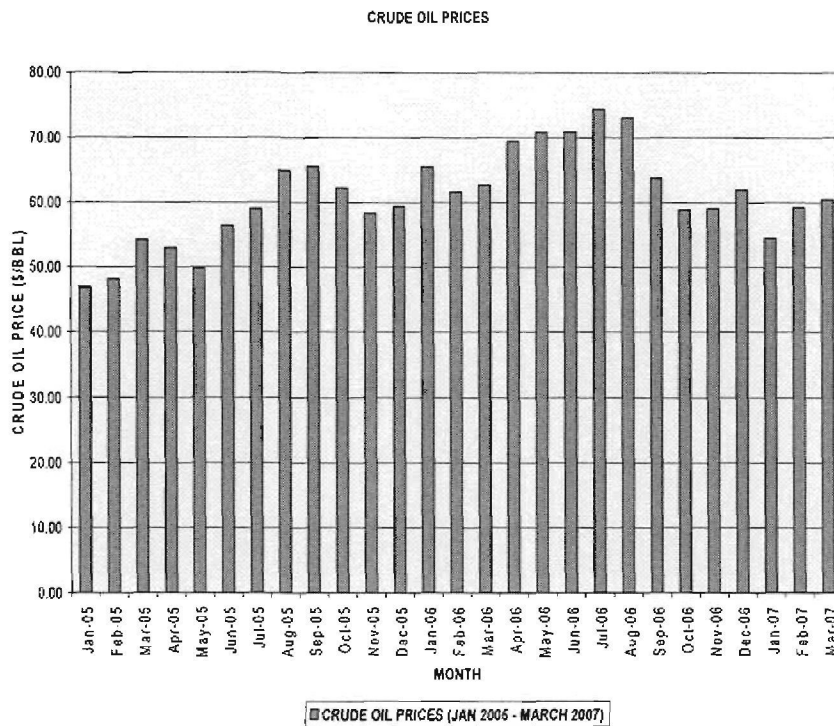


Fig. 3.2 – MONTHLY CRUDE OIL PRICES (JANUARY 2005 – MARCH 2007)



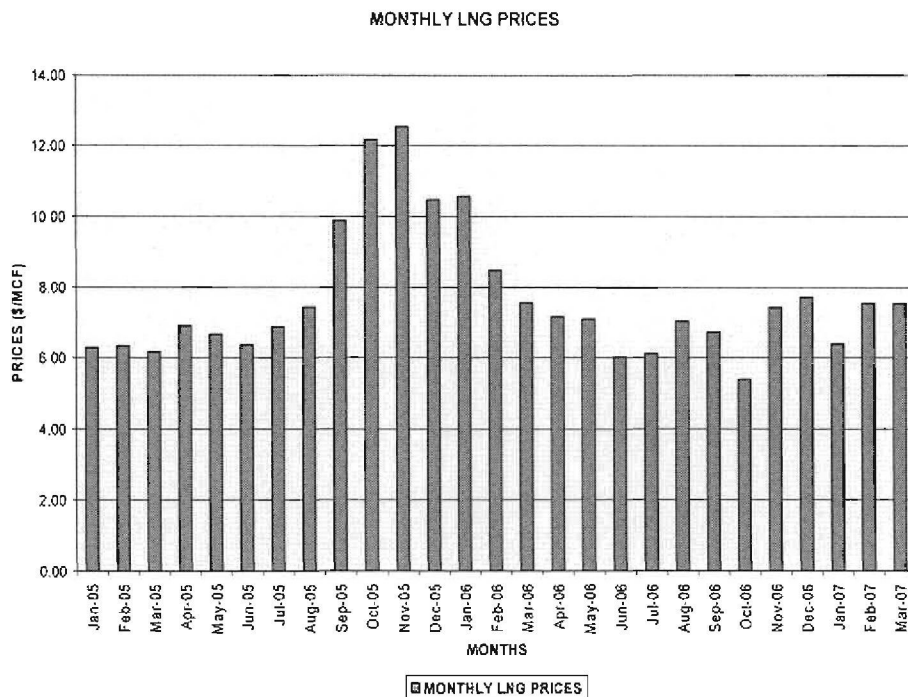
For the purpose of this research work, a crude oil price of \$45/bbl shall be assumed as the base case price while \$20.00/bbl and \$70.00 shall be assumed as the low case price and high case price respectively.

Table 3.3 – CRUDE OIL PRICES FOR ANALYSIS

CRUDE OIL PRICE SCENARIOS			
	LOW CASE	BASE CASE	HIGH CASE
PRICE, \$/bbl	20	45	70

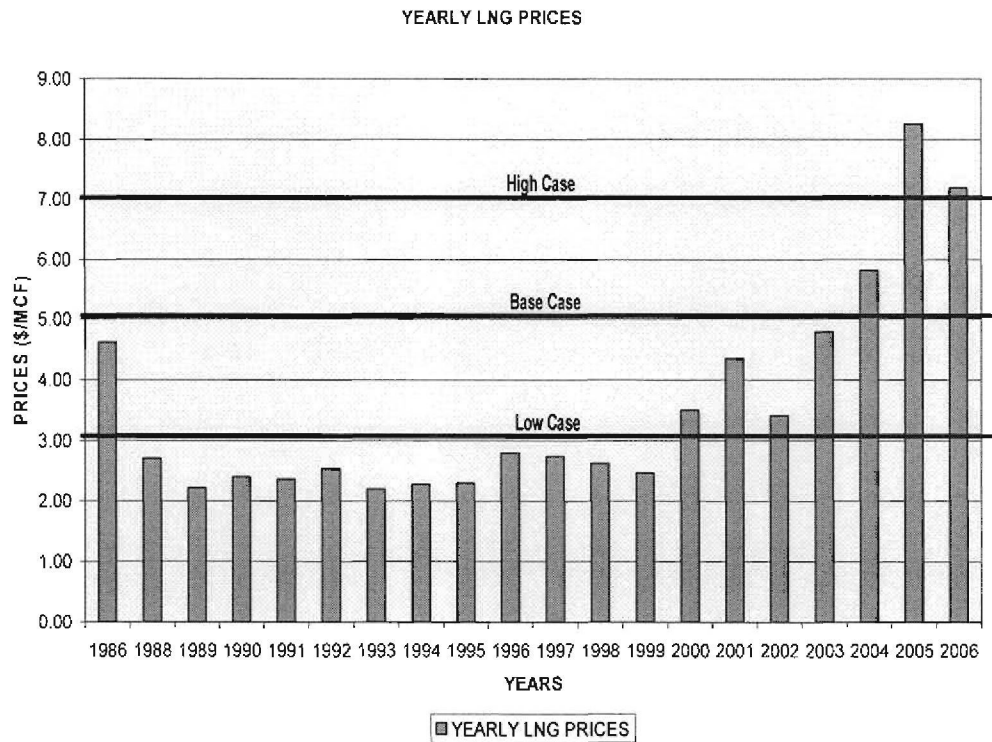
Patel (2005) and Seddon (2004) gave the LNG product price to be between \$3.0/MMBTU and \$3.5/MMBTU, while recent prices have been in the region of \$7.00/MMBTU. The average LNG price between January 2005 and March 2007 is \$7.66/MCF. This is seen in fig. 3.4 below from LNG data on the EIA website (EIA, 2007).

Fig. 3.3 - MONTHLY LNG PRICES (JANUARY 2005 – MARCH 2007)



Also, the average LNG price between 1986 and 2006 is \$3.58/MCF (EIA, 2007). The base, low and high case marks are shown in fig. 3.5 and these values shall be used in the sensitivity analyses for LNG (see fig 4.6).

Fig. 3.4 – LNG PRICES (1986-2006)



A price of \$5.00/MMBTU shall be assumed as the base case price for LNG while the low case price and high case price used in the sensitivity analysis (see fig 4.6) shall be \$3.00/MMBTU and \$7.00MMBTU respectively.

Table 3.4 - LNG PRICES FOR ANALYSIS

LNG PRICE SCENARIOS ASSUMED			
	LOW CASE	BASE CASE	HIGH CASE
PRICE, \$/MMBTU	3.0	5.0	7.0

3.2.6 PLANT LOAD FACTOR: The plant load factor (utilization capacity) for FT-GTL plant is assumed to be 50% for year 1 and 100% for year 2 to year 20 while the LNG plant load factor is assumed to be 90% for year 1 and 100% for year 2 to year 20 (Morita J, 2001; SRI, 1975). The difference is due to the fact that the LNG is a proven technology commercially, while the FT-GTL is still in its early years as a commercially proven technology.

3.2.7 OPERATING TIME: The operating time of a plant is the planned time required for the process plant to be in operation. Allowance is normally made for downtime and it is typically 10 to 20 percent, based on a 24 h/day, 7 days/week, and 52 weeks/year production for continuous process. The actual operating time for a chemical plant is approximately 300 to 330 days per year (Peters, Timmerhaus, and West: 2003:259). Unless otherwise stated, 330 days shall be assumed as the operating time per year for the purpose of this research work.

3.2.8 PLANT USEFUL LIFE: The useful life for most chemical plant is between 20 and 25 years from start-up (SRI, 1975:52; Gaffney, Cline and Associates, 2001:36; Adegoke, A. 2006:26; Peters, Timmerhaus & West, 2003:261; Al-Saadoon, 2005:3). According to the Encyclopedia of LNG, 2006 published by Petroleum Economist, 15 of the 19 customers of LNG producers in Nigeria signed 20 years LNG contract with them (Petroleum Economists, 2006). This probably means the customers expect the best from these plants at approximately 20 years of production.

An assumed plant life of 20 years is used for the purpose of this thesis. The scrap value at the end of the plants useful life shall be assumed to be zero. The cost of the land was not included in the total capital investment as stated in section 3.2.2.

3.2.9 TAX RATE: Taxes are levies on organization by the government. The Nigeria Investment Promotion Commission (NIPC) and the Nigerian Minister of State for Petroleum Resources, Daukoru Edmond (2006) reported an income tax rate of 30% and a royalty of 5-7% in the oil and gas sector. SasolChevron (2001) reported a tax rate of about 50% for Nigeria while Peters et al (2003) had an income tax rate of 35% (Peters, Timmerhaus, West, 2003:306, NIPC, 2006; FIRS, 2006; SasolChevron, 2001:49; Daukoru, 2006:24).

A 30% company income tax rate and a 5% Royalty is assumed for this thesis while company income tax rates of 20% and 50% is investigated to determine its effect on the economic of both projects. The company income tax rate and the royalty are grouped as tax rate for this research work.

3.2.9.1 DEPRECIATION: Depreciation is a non-cash expense that provides a source of free cash flow for an organization. According to Ross et al (1996:207), depreciation has cash flow consequences only because it influences the tax bill. It is one of the sources of the differences between cash flow and accounting income (Ross, Westerfield & Jordan, 1996:207; Trading Glossary, 2007). Income tax is computed using the Modified Accelerated Cost Recovery System (MACRS) depreciation method.

According to Peters et al. (2003), MACRS is the depreciation method used for most income tax purposes and also for most economic evaluations. It is based upon the classical double declining balance method but with no salvage value allowed, a switch to straight-line at a point, and the use of the half-year convention. Ross et al (1996) and Peters et al (2003) described some typical depreciation classes and associated percentages (Peters, Timmerhaus & West, 2003:313; Ross, Westerfield & Jordan, 1996:219). The 5-year property recovery schedule is shown in table 3.5 and it is used in calculating the depreciation.

Table 3.5 – DEPRECIATION SCHEDULE

MACRS DEPRECIATION SCHEDULE	
RECOVERY YEAR	MACRS PERCENTAGES (%)
1	20.00
2	32.00
3	19.20
4	11.52
5	11.52
6	5.76

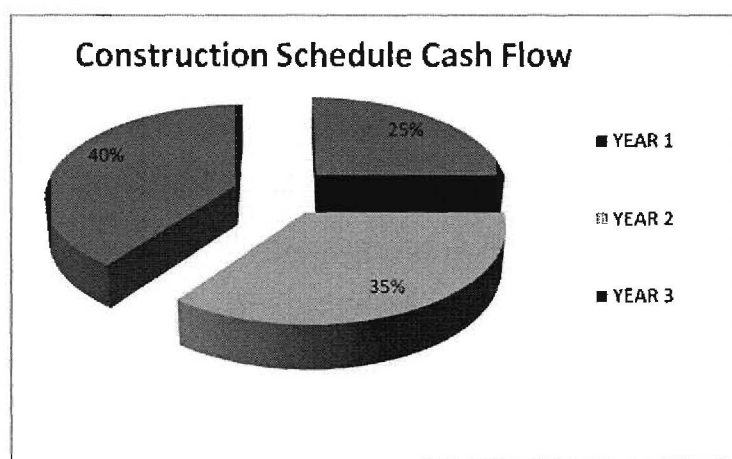
3.2.10 PLANT CAPACITY: The plants under consideration in this research work will process 1000 MMSCF/D of natural gas. The LNG plant is based on the APCI technology used in the NLNG train 6 in Nigeria while the GTL plant is based on Sasol technology for the EGTL project currently under construction in Nigeria.

Table 3.6 – PLANT CAPACITIES FOR LNG AND FT-GTL

GAS UTILIZED (MMSCF/D)	FT-GTL PLANT CAPACITY (bbl/d)	LNG PLANT CAPACITY (MMTPA)
1000	100,000	7.67

3.2.11 CONSTRUCTION AND CASH OUTFLOW: The time schedule assumed for the construction of the LNG and FT-GTL plants and the percentage cash outflows of the capital investment is given in the table below (Morita Y, 2001).

Fig 3.5 – PLANT CONSTRUCTION SCHEDULE



3.2.12 BASE CASE: The base case for the LNG plant is the NLNG train 6 plant capable of processing about 800 MMSCF/D of natural gas while the base case for the GTL plants is the EGTL plant capable of processing about 340 MMSCF/D of natural gas. The other base assumptions include crude oil price of \$45/bbl, gas price of \$5/mmbtu, feed gas cost of \$0.5/mmbtu and discount rate of 10%.

3.3.0 GENERAL ASSUMPTIONS: The general assumptions used in this research work are given in the table below.

Table 3.7 – ECONOMIC ASSUMPTIONS

ECONOMIC ASSUMPTIONS	
PARAMETER	VALUE
Plant life	20 years
Plant Construction Period	3 years
Plant Construction Capital Spending	25%, 35%, 40%
Depreciation Schedule	5-year MACRS
Owner's Equity	100%
Tax Rate	Company tax rate : 30%
	Royalty : 5%
Plant Stream day production profile	330 days/ year
Feedgas cost (Base case)	\$0.50/MMBTU
Discount Rate (R)	10%
General Inflation	None
OPEX	LNG : \$0.50/MMBTU; FT-GTL : \$5.00/bbl
LNG product price (Base case)	\$5.00/MMBTU
Crude oil price (Base case)	\$45.00/bbl
FT-GTL product premium	Diesel :\$5.00/bbl Naphtha : \$3.00/bbl
LNG Shipping cost	\$0.70/MMBTU
FT-GTL Shipping cost	\$1.20/bbl

An economic model for the LNG and GTL technology was developed using the various values of the parameters in this chapter. The result obtained is presented and discussed in

chapter IV below. It is important to state here that the result could be different when the values used are different from the values used here.

CHAPTER IV

4.0 RESULT AND DISCUSSION FOR LNG AND FT-GTL PROJECTS

4.1 PROFITABILITY ANALYSIS: Investigation into the profitability of both gas monetization options, LNG and FT-GTL were done with the aim of arriving at the most viable and profitable option for all stakeholders in the Nigerian gas industry. Both technologies were analyzed for a plant capacity utilizing 1000 MMSCF/D of natural gas.

The model developed for this research work was used to evaluate the effect of the economic parameters on the LNG and FT-GTL projects. The effect of the product price and the plant capacity on the net present value for the base case is shown in fig.4.1.

The crude oil price was plotted on the same axis as the gas price. The underlying assumption used here is to relate both products to their energy values. Al-Saadoon (2005) and Rahman et al (2004) reported that with an overall thermal efficiency of 60% for the FT-GTL process, 10MSCF of 1000 BTU/SCF of natural gas (NG) is required to produce 1bbl of GTL products (Al-Saadoon, 2005; Rahman, A.O. & Maslamani, M.A., 2004).

Mathematically, at 60% thermal efficiency:

$$1 \text{ bbl} \equiv 10 \text{ MSCF of } 1000 \text{ BTU/SCF}$$

$$\text{But } 1 \text{ MSCF} \equiv 1 \text{ MMBTU}$$

$$\text{Therefore } 1 \text{ bbl} \equiv 10 \text{ MMBTU of } 1000 \text{ BTU/SCF}$$

1000 BTU/SCF of NG represents the heating value of natural gas. This paved the way for the crude oil price (\$/bbl) and gas price (\$/MMBTU) to be plotted on the same axis.

Fig. 4.1 – NPV FOR LNG AND FT-GTL

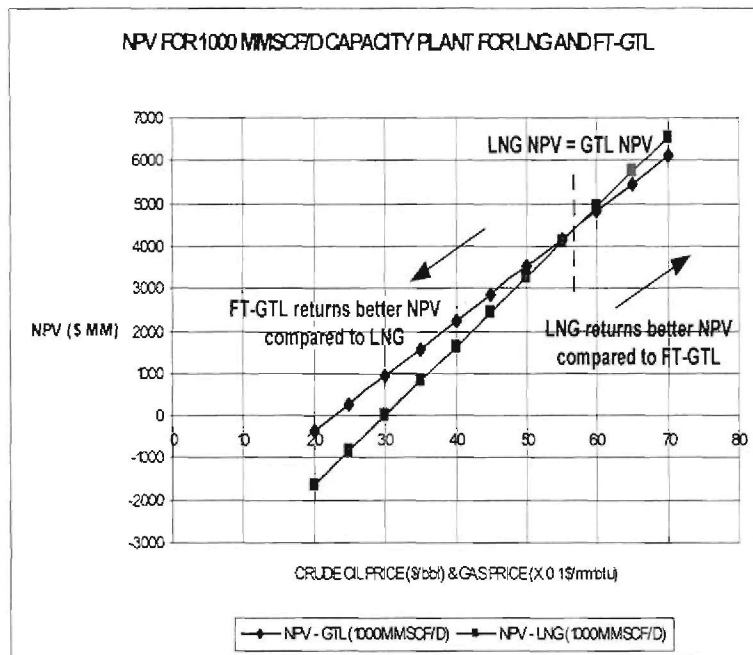


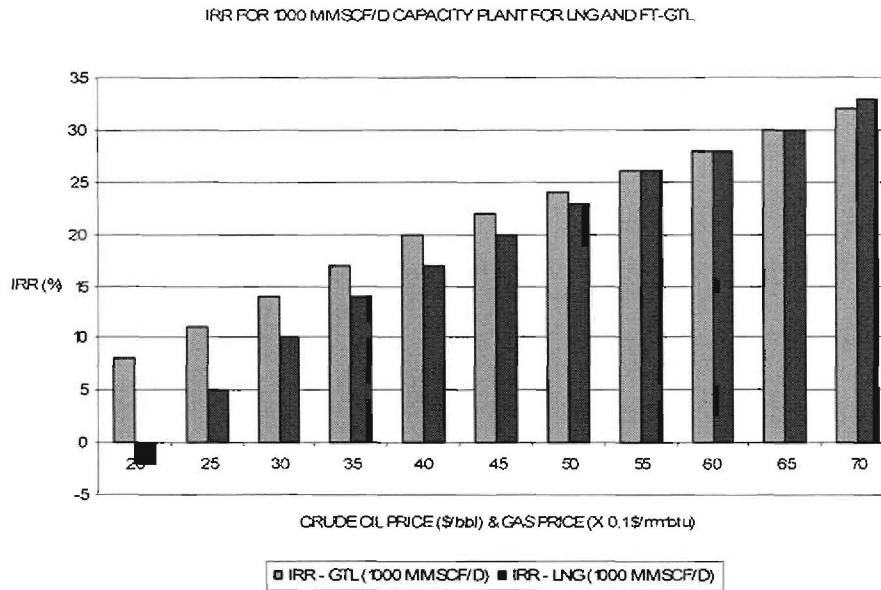
Fig. 4.1 shows that at a crude oil price of between \$55/bbl and \$60/bbl and a gas price of between \$5.5/mmbtu and \$6.0/mmbtu, the resultant net present value for the LNG and FT-GTL are approximately equal. However, on the left of these points, FT-GTL offered better returns to the project compared to LNG while on the right of these points, LNG offered more returns.

The internal rate of return (IRR) and the profitability index (PI) for both projects were examined and compared. The effects of the economic indicators used were also examined. Sensitivity analysis was performed for both LNG and FT-GTL.

The rate of return for both projects followed the same pattern as the net present value shown in fig.4.1. At a hurdle rate of 10%, LNG will be viable at a gas price of \$3.00/mmbtu while the FT-GTL will be viable at a crude oil price of \$23.00/bbl.

However, for both projects to return at least 30% on the investment, then the crude oil price should not be less than \$65.00/bbl while the gas price should not be less than \$6.50/mmbtu as shown in fig. 4.2

Fig. 4.2 – IRR FOR LNG AND FT-GTL



The profitability index as shown in fig.4.3 measures the benefit delivered for each dollar invested in present value. At a crude oil price of \$70.00/bbl and a gas price of \$7.00/mmbtu, each \$1 invested for the FT-GTL project delivers \$3.32 while each \$1 invested for the LNG project delivers \$3.38 and rate of return of 32% and 34% respectively.

A break-even analysis was done for the LNG and FT-GTL projects shown in fig. 4.4. For the base case under consideration for this research work, the LNG project will break-even at a gas reserve of 0.99 trillion cubic feet (TCF) while the FT-GTL will break-even at a gas reserve of approximately 1.20 trillion cubic feet (TCF).

Fig. 4.3 PI FOR LNG AND FT-GTL PLANTS

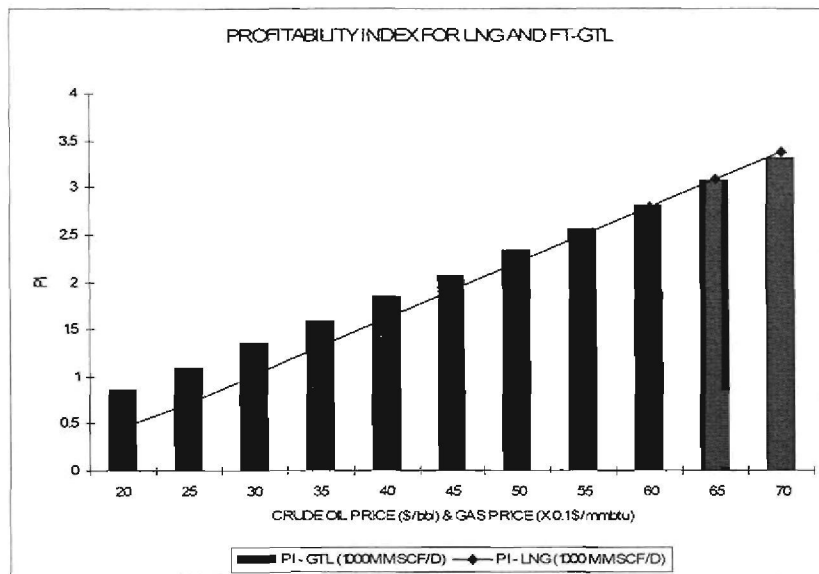
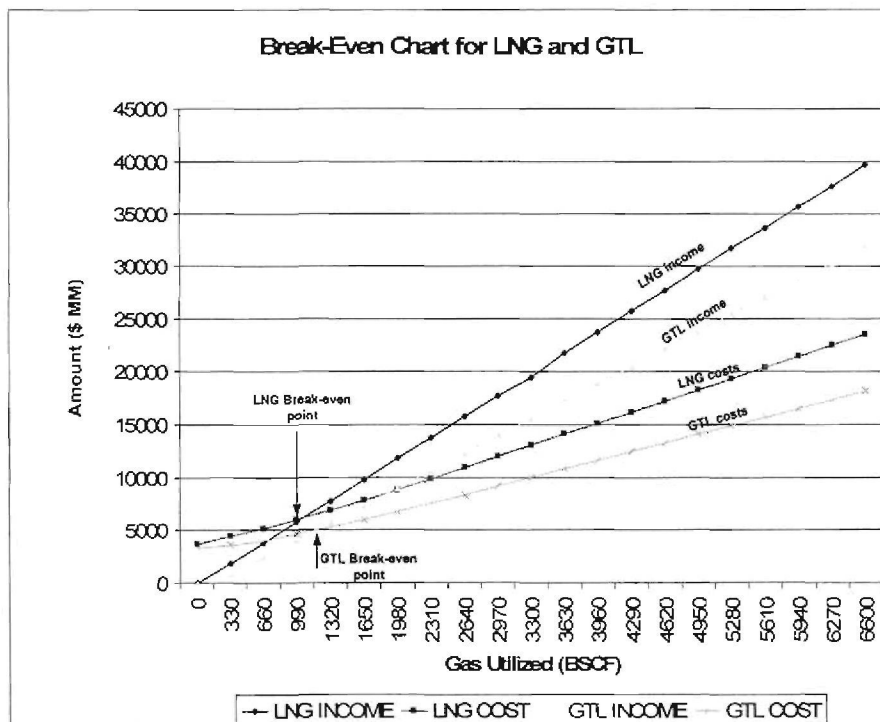


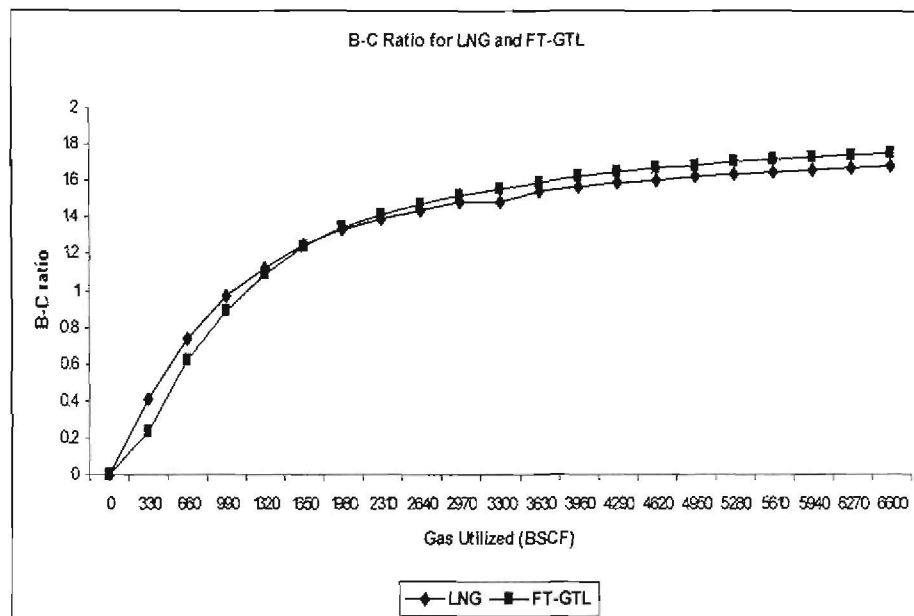
Fig. 4.4 BREAK-EVEN CHART FOR LNG AND FT-GTL PLANTS



Approximately 6.60 trillion cubic feet (TCF) of natural gas is utilized by both LNG and FT-GTL over the plant life of 20years. Nigeria has enormous gas reserve which is estimated to be above 187 trillion cubic feet (TCF) of natural gas. The net income from the LNG project at the end of the plant life is approximately \$16 billion while the net income for the FT-GTL project at the end of the plant life is approximately \$14 billion.

The benefit-cost ratio also at the end of the projects life shows that the GTL process has a better return compared to LNG process. The ratio for the LNG process was only better when compared to the GTL process in the five years that followed the plant start-up while the GTL returned better benefits from the sixth year to the end of the projects life. This is shown in fig. 4.5

Fig. 4.5 BENEFIT-COST ANALYSIS FOR LNG AND FT-GTL PLANTS



4.2 SENSITIVITY ANALYSIS: The sensitivity analysis, shown below in the form of a tornado graph was done using the expected input values as the most likely values and a set of high and low values from it. Much sensitivity can be run on the developed model. This research work shall be limited to the sensitivities on the 100,000BPD FT-GTL and 7.67MMTPA LNG plants.

4.2.1 LNG SENSITIVITIES: Seven parameters were used to ascertain the one that is most sensitive to LNG project. Table 4.1 shows the parameters used in the sensitivity analysis for the LNG plant as well as the most likely value, minimum expected value and the maximum expected value.

Table 4.1 – PARAMETERS FOR LNG SENSITIVITY

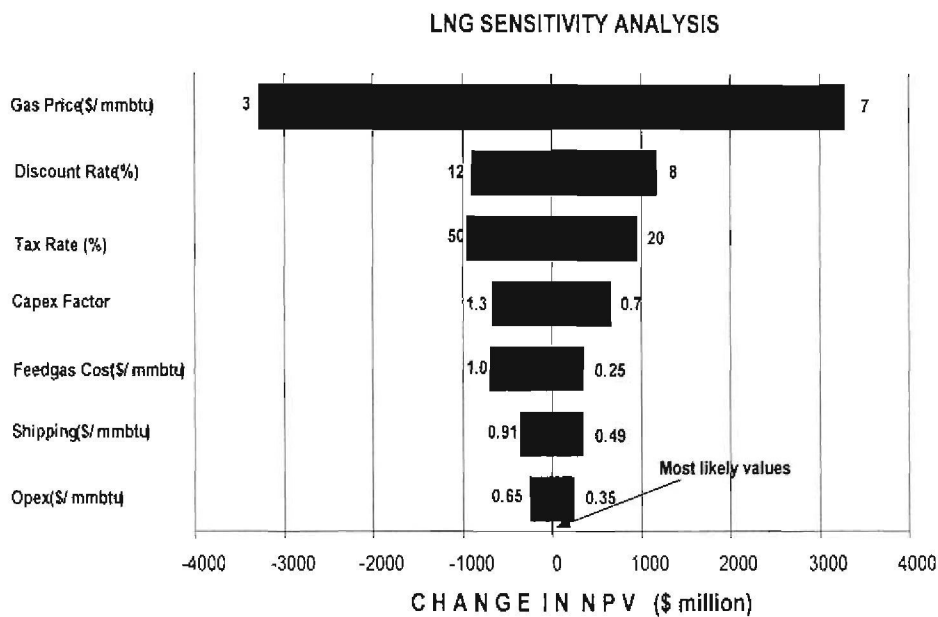
LNG SENSITIVITY ANALYSIS			
Parameters	Most Likely Value	Minimum Expected Value	Maximum Expected Value
Gas price (\$/mmbtu)	5	3	7
OPEX (\$/mmbtu)	0.5	0.35	0.65
CAPEX factor	1	0.7	1.3
Shipping (\$/mmbtu)	0.7	0.49	0.91
Feedgas Cost (\$/mmbtu)	0.5	0.25	1.0
Discount Rate (%)	10	8	12
Tax Rate (%)	35	20	50

Based on the economic assumptions used in this thesis, fig. 4.6 shows the effect of the various input parameters on NPV of the LNG project. The parameter with the longest bar

has the greatest effect on the NPV, and hence IRR of the project while the parameter with the least influence on the project has the shortest bar and it is placed at the bottom of the chart.

The values on the vertical line indicated by the arrow labeled “most likely value” is the most likely value while the values on both end of the horizontal bar indicates the anticipated range of the variable. In general, the impact of the LNG gas price is the most sensitive compared to other parameters. A shift in the price of LNG to \$2.00/mmbtu from the most likely value of \$5.00/mmbtu increases the NPV to \$6.5 billion from \$3.2 billion, an increase of over 100% on the NPV. Other parameters like Feedgas cost, CAPEX, shipping and OPEX will have appreciable impact on the viability of the LNG project.

Fig. 4.6 – TORNADO PLOT FOR LNG



4.2.2 FT-GTL SENSITIVITY ANALYSIS: The parameters used to investigate the sensitivities of the FT-GTL project are nine in total. Table 4.2 shows the parameters used, the most likely value, the minimum value and the maximum value. Fig. 4.7 shows the result of the sensitivity analysis of the various input parameters for FT-GTL plant. The crude oil price has the greatest impact on the viability of the project. A crude oil price of \$70/bbl gives an NPV of \$6.1 billion, up from \$2.8 billion for the most likely values when the crude oil price is \$45/bbl. This is approximately 118% increase from the base case NPV. The tax rate also had an appreciable impact on the economics of the project.

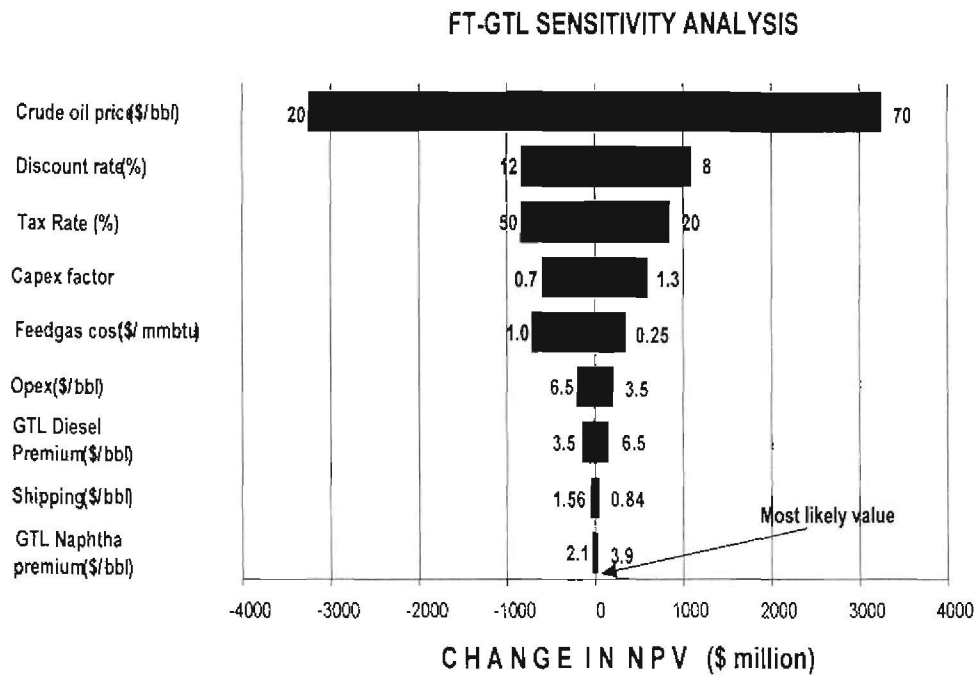
Table 4.2 – PARAMETERS FOR FT-GTL SENSITIVITIES

FT-GTL SENSITIVITY ANALYSIS			
Parameters	Most Likely Value	Minimum Expected Value	Maximum Expected Value
Crude Oil Price (\$/bbl)	45	20	70
Feedgas Cost (\$/mmbtu)	0.50	0.25	1.0
CAPEX factor	1	0.7	1.3
OPEX (\$/bbl)	5	3.5	6.5
Shipping (\$/bbl)	1.20	0.84	1.56
Discount Rate (%)	10	8	12
Tax Rate (%)	35	20	50
GTL Diesel premium (\$/bb/)	5	3.5	6.5
GTL Naphtha Premium (\$/bbl)	3	2.1	3.9

An increase in the tax rate from 35% to 50% will most likely reduce the interest investors will have to participate in the FT-GTL project while a decrease in the rate from 35% to 20% will surely encourage participation in the development of the FT-GTL project.

The Feedgas cost is another parameter that affects the viability of the project. The availability of gas at a low price of \$0.25/mmbtu increases the NPV by \$354 million from the base case value. Also, a 30% decrease in the Capital Expenditure (CAPEX) from \$3,250 million to \$2,275 million increases the NPV by \$599 million.

Fig 4.7 TORNADO PLOT FOR FT-GTL



Finally, the result from the simulation done showed that both LNG and FT-GTL gave approximately equal economic returns at a crude oil price of \$60/bbl and LNG price of \$6/mmbtu.

4.3 VERIFICATION OF RESULT: The result obtained in this research work is verified using the results presented in literature by authors and organizations in the oil and gas industry. The differences and similarities in the result presented here and those in literatures shall be stated.

Goswami and Sisley (2003) showed in a GTL report that while Capex is a significant factor, the swings in the netback value are influenced more by the crude oil price (Goswami, R. & Sisley, H., 2003). Goswami (2007) showed in another report that the GTL economics is driven by four variables namely crude oil price, capital costs, gas price and fiscal terms with crude oil price the biggest driver of GTL economics (Goswami, R. 2007).

The result from the sensitivity analysis in this research work is in line with the result presented in GTL reports by Rajnish Goswami (2007). It however differs from the report by Robertson (1999) who concluded that the plant cost has the greatest effect on the GTL plant economics and that the crude oil price was closely behind that. The conclusion by Robertson (1999) was probably in line with the economics at the time the report was made. The gas price is the principal factor that affects the economics of LNG plant (Patel, B., 2005; ESMAP, 2004). This is also in line with the result obtained. Also, the result of

the NPV analysis shown in fig. 4.1 above for the LNG and the FT-GTL is in the same order as that presented by Economides et al. (2005) in a report.

The capital expenditure for the FT-GTL projects in literatures differs from that assumed in this research work. It ranges from \$20,000 per barrel per day to \$30,000 per barrel per day (SRI, 2005; Patel, B. 2005:7; Patel, B. 2004). However, current estimate for FT-GTL capital cost ranges between \$50,000/BPD and \$60,000/BPD (Pyrdol, J & Baron, B. 2006). The capital cost used in this research work for the FT-GTL plant is between \$32,000/BPD for the 100,000BPD plant. The LNG capital cost used in this research work was within the range of capital costs estimated in literatures. For a 1 BSCF/D of gas plant, the capital cost of \$3.6 billion used in this research fall within the estimated range of \$2.4 billion and \$6.0 billion (Patel, B. 2005:8; Chem Systems, 1996; Simmons, 2005).

Finally, the results from the model showed that both LNG and FT-GTL are viable projects to embark upon, though the GTL plant was able to break-even at a lower cost of about five billion dollars (\$5 bn) compared to LNG plant which broke even at about six billion dollars (\$6 bn). It also return a better benefit-cost ratio compared to LNG.

The conclusion and recommendation based on the result obtained from the model developed for this research work is presented in Chapter V below.

CHAPTER V

5.0 CONCLUSIONS AND RECOMMENDATION

5.1 CONCLUSION

The model developed in the research work gave results that indicate that both LNG and GTL technologies are economically viable. As shown earlier, both LNG and GTL projects are profitable at a discount rate of 10% and at a crude oil price of \$23/bbl and a gas price of \$3.00/mmbtu. These two technologies are therefore, highly profitable with the current crude oil price of \$60-\$70/bbl and gas price of \$6-\$8/mmbtu in the international energy market.

The results from the model were used in the tornado chart for the sensitivity of project parameters on the economics of LNG and FT-GTL. These results are comparable to those given in literatures for similar input values. The model was quite robust as it automatically generates result for any changed parameter. It creates an output value for all input value keyed in and can be used to investigate various scenarios outcomes.

It is noteworthy that the FT-GTL technology is presently at the top of the curve for its commercialization and technological advances. Despite being a less mature technology, GTL still compared favourably with a more mature and fully commercialized LNG technology.

The results from the model developed shows that the NPV, IRR and PI for the LNG and FT-GTL processes were too close for an outright choice to be made. The break-even

analysis and the benefit-cost analysis for both processes shows the FT-GTL has the edge over LNG, though LNG was able to break-even at a lower gas reserve, GTL was able to break-even at a lower cost and the overall ratio of the projects benefit to the project cost was better for the FT-GTL compared to the LNG.

This is important considering the fact that the cumulative cost to run the LNG process for a 20-year period is approximately \$24 billion and this gives a B-C ratio of 1.68 while the cumulative cost to run the FT-GTL process is approximately \$18 billion and a B-C ratio of 1.76 for the same 20-year period. The single most important factor that affects the profitability of the LNG plant is the prevailing gas price while the single most important factor that affects the profitability of the FT-GTL plant is the crude oil price.

The ongoing research into improved catalyst and the generation of oxygen from air for the syngas process through the use of ceramic membrane for the GTL technology will drive down the overall cost in the next few years because the oxygen plant will be eliminated from the process.

An improved process of integration and optimization of the various units in a GTL plant will further reduce the running cost of the plant. As reported by Vosloo (2006?), the thermal efficiency of the plant can also be improved by combining the oxygen removal and reforming sections into one unit. The economy of scale which has been instrumental in the reduction of cost for the LNG process will also help reduce the capital cost for the

GTL process when a larger single train capacity plant is built. Adding more trains to an existing GTL plant will also help better the economics of the plant.

Unlike the LNG which must secure a market before the project can proceed, FT-GTL has a very large market that is not constrained. GTL market share is 0.2% of 2 billion tonne per year market while LNG market share is 4% of 100 million tonne per year market. With increasing measures by government around the world to reduce exhaust emissions, GTL diesel will have the environmental edge.

Finally, with the points and results above, one can conclude that the GTL technology will be better placed compared to the LNG technology to help the Nigerian government achieve its objective of recovering maximum revenue possible from natural gas.

5.2 RECOMMENDATIONS

The possibility of LNG and FT-GTL plants being sited together and synergized should be investigated since utilities like instrument air, flare system, nitrogen purge system as well as LPG storage facilities are common to both processes. Also, there are complementary processes which are common to both plants and they include upstream pretreatment of natural gas, gas compression, the loading jetty and support infrastructure outside the battery limit.

The beneficial utilization of the excess steam/electricity from the GTL process should be investigated. The possibility of having a power generating plant close to the GTL facility to utilize the excess steam/electricity should be studied since the income from the excess steam/electricity will further improve the economy of the GTL process.

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APPENDIX I

ABBREVIATION AND ACRONYMS

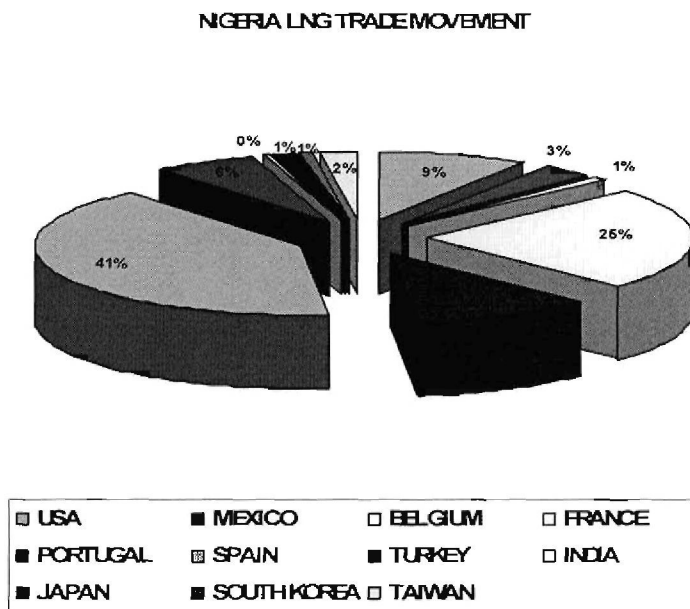
CAPEX	Capital Expenditure
DCF	Discounted Cash Flow
DME	Dimethyl ether
GTL	Gas-To-Liquid
IOC	International Oil Company
IPP	Independent Power Producers
IRR	Internal Rate of Return
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
NNPC	Nigeria National Petroleum Corporation
NPV	Net Present Value
OPEX	Operating Expenditure
PI	Profitability Index
Syncrude	Synthetic Crude Oil
Syngas	Synthesis Gas
WAGP	West Africa Gas Pipeline
B-E	Break-Even
B-C	Benefit-Cost
NGC	Nigeria Gas Company
FID	Final Investment Decision
NLNG	Nigeria Liquefied Natural Gas

EGTL	Escravos Gas-To-Liquid
TSGP	Trans-Saharan Gas Pipeline
GDP	Gross Domestic Product
TCF	Trillion Cubic Feet
BCF	Billion Cubic Feet
MCF	Thousand Cubic Feet
BCM	Billion Cubic Metres
BSCF/D	Billion Standard Cubic Feet Per Day
BBL	Barrel, Barrels
BPD	Barrel Per Day
BTU	British thermal unit
Bn	Billion
GJ	Giga Joule
MMBTU	Million BTU
MMTPY	Million Metric Tons per Year
MTPY	Thousand Metric Tons per Year

APPENDIX II

LNG TRADE MOVEMENT FROM NIGERIA IN 2006

COUNTRY	LNG TRADED (BCM)
USA	1.62
MEXICO	0.54
BELGIUM	0.16
FRANCE	4.23
PORTUGAL	1.97
SPAIN	7.1
TURKEY	1.12
INDIA	0.08
JAPAN	0.22
SOUTH KOREA	0.16
TAIWAN	0.38
TOTAL	17.58



Source: BP, 2007

APPENDIX III UNIT CONVERSIONS

APPROXIMATE CONVERSION FACTORS

Crude oil*	To				
	tonnes (metric)	kilolitres	barrels	US gallons	tonnes/ year
From	Multiply by				
Tonnes (metric)	1	1.165	7.33	307.86	–
Kilolitres	0.8581	1	6.2898	264.17	–
Barrels	0.1364	0.159	1	42	–
US gallons	0.00325	0.0038	0.0238	1	–
Barrels/day	–	–	–	–	49.8

*Based on worldwide average gravity.

Products	To convert			
	barrels to tonnes	tonnes to barrels	kilolitres to tonnes	tonnes to kilolitres
	Multiply by			
LPG	0.086	11.6	0.542	1.844
Gasoline	0.118	8.5	0.740	1.351
Kerosene	0.128	7.8	0.806	1.24
Gas oil/ diesel	0.133	7.5	0.839	1.192
Residual fuel oil	0.149	6.7	0.939	1.065

Natural gas and LNG	To					
	billion cubic metres NG	billion cubic feet NG	million tonnes oil equivalent	million tonnes LNG	trillion British thermal units	million barrels oil equivalent
From	Multiply by					
1 billion cubic metres NG	1	35.3	0.90	0.73	36	6.29
1 billion cubic feet NG	0.028	1	0.026	0.021	1.03	0.18
1 million tonnes oil equivalent	1.111	39.2	1	0.805	40.4	7.33
1 million tonnes LNG	1.38	48.7	1.23	1	52.0	8.68
1 trillion British thermal units	0.028	0.98	0.025	0.02	1	0.17
1 million barrels oil equivalent	0.16	5.61	0.14	0.12	5.8	1

Source: BP, 2007

APPENDIX IV

CASH FLOW FOR GTL PLANT

YEAR,	SALES REVENUE (\$)	CAPEX (\$)	TOTAL OPEX (\$)	DEPRECIATION (\$)	TAX	CASHFLOW (\$)	DISCOUNTED CASH FLOW (\$)
1		812,500,000.00			0.00	-812,500,000.00	-738,636,363.64
2		1,137,500,000.00			0.00	-1,137,500,000.00	-940,082,644.63
3		1,300,000,000.00			0.00	-1,300,000,000.00	-976,709,241.17
4	819,918,000.00		374,550,000.00	650,000,000.00	-71,621,200.00	516,989,200.00	353,110,579.88
5	1,639,836,000.00		374,550,000.00	1,040,000,000.00	78,850,100.00	1,186,435,900.00	736,683,348.75
6	1,639,836,000.00		374,550,000.00	624,000,000.00	224,450,100.00	1,040,835,900.00	587,524,731.01
7	1,639,836,000.00		374,550,000.00	374,400,000.00	311,810,100.00	953,475,900.00	489,283,898.62
8	1,639,836,000.00		374,550,000.00	374,400,000.00	311,810,100.00	953,475,900.00	444,803,544.20
9	1,639,836,000.00		374,550,000.00	187,200,000.00	377,330,100.00	887,955,900.00	376,579,982.41
10	1,639,836,000.00		374,550,000.00		442,850,100.00	822,435,900.00	317,084,642.23
11	1,639,836,000.00		374,550,000.00		442,850,100.00	822,435,900.00	288,258,765.66
12	1,639,836,000.00		374,550,000.00		442,850,100.00	822,435,900.00	262,053,423.33
13	1,639,836,000.00		374,550,000.00		442,850,100.00	822,435,900.00	238,230,384.85
14	1,639,836,000.00		374,550,000.00		442,850,100.00	822,435,900.00	216,573,077.13
15	1,639,836,000.00		374,550,000.00		442,850,100.00	822,435,900.00	196,884,615.58
16	1,639,836,000.00		374,550,000.00		442,850,100.00	822,435,900.00	178,986,014.16
17	1,639,836,000.00		374,550,000.00		442,850,100.00	822,435,900.00	162,714,558.33
18	1,639,836,000.00		374,550,000.00		442,850,100.00	822,435,900.00	147,922,325.75
19	1,639,836,000.00		374,550,000.00		442,850,100.00	822,435,900.00	134,474,841.59
20	1,639,836,000.00		374,550,000.00		442,850,100.00	822,435,900.00	122,249,855.99
21	1,639,836,000.00		374,550,000.00		442,850,100.00	822,435,900.00	111,136,232.72
22	1,639,836,000.00		374,550,000.00		442,850,100.00	822,435,900.00	101,032,938.84
23	1,639,836,000.00		374,550,000.00		442,850,100.00	822,435,900.00	91,848,126.22
	31,976,802,000.00	3,250,000,000.00	7,491,000,000.00	3,250,000,000.00	7,432,530,700.00	13,803,271,300.00	

APPENDIX V

CASH FLOW FOR LNG PLANT

YEAR	SALES REVENUE (\$)	CAPEX (\$)	TOTAL OPEX (\$)	DEPRECIATION (\$)	TAX	CASHFLOW (\$)	DISCOUNTED CASH FLOW (\$)
1		910,000,000.00			0.00	-910,000,000.00	-827,272,727.27
2		1,274,000,000.00			0.00	-1,274,000,000.00	-1,052,892,561.98
3		1,456,000,000.00			0.00	-1,456,000,000.00	-1,093,914,350.11
4	1,615,302,000.00		648,558,000.00	728,000,000.00	83,560,400.00	883,183,600.00	603,226,282.36
5	1,794,780,000.00		648,558,000.00	1,164,800,000.00	-5,573,400.00	1,151,795,400.00	715,174,323.66
6	1,794,780,000.00		648,558,000.00	698,880,000.00	134,202,600.00	1,012,019,400.00	571,258,568.01
7	1,794,780,000.00		648,558,000.00	419,328,000.00	218,068,200.00	928,153,800.00	476,289,657.44
8	1,794,780,000.00		648,558,000.00	419,328,000.00	218,068,200.00	928,153,800.00	432,990,597.67
9	1,794,780,000.00		648,558,000.00	209,664,000.00	280,967,400.00	865,254,600.00	366,952,415.15
10	1,794,780,000.00		648,558,000.00		343,866,600.00	802,355,400.00	309,342,740.21
11	1,794,780,000.00		648,558,000.00		343,866,600.00	802,355,400.00	281,220,672.92
12	1,794,780,000.00		648,558,000.00		343,866,600.00	802,355,400.00	255,655,157.20
13	1,794,780,000.00		648,558,000.00		343,866,600.00	802,355,400.00	232,413,779.27
14	1,794,780,000.00		648,558,000.00		343,866,600.00	802,355,400.00	211,285,253.88
15	1,794,780,000.00		648,558,000.00		343,866,600.00	802,355,400.00	192,077,503.53
16	1,794,780,000.00		648,558,000.00		343,866,600.00	802,355,400.00	174,615,912.30
17	1,794,780,000.00		648,558,000.00		343,866,600.00	802,355,400.00	158,741,738.45
18	1,794,780,000.00		648,558,000.00		343,866,600.00	802,355,400.00	144,310,671.32
19	1,794,780,000.00		648,558,000.00		343,866,600.00	802,355,400.00	131,191,519.38
20	1,794,780,000.00		648,558,000.00		343,866,600.00	802,355,400.00	119,265,017.62
21	1,794,780,000.00		648,558,000.00		343,866,600.00	802,355,400.00	108,422,743.29
22	1,794,780,000.00		648,558,000.00		343,866,600.00	802,355,400.00	98,566,130.27
23	1,794,780,000.00		648,558,000.00		343,866,600.00	802,355,400.00	89,605,572.97
	35,716,122,000.00	3,640,000,000.00	12,971,160,000.00	3,640,000,000.00	5,743,425,800.00	13,351,536,200.00	

APPENDIX VI

NPV FOR LNG AND GTL FOR DIFFERENT PLANT SIZES

