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AN APPRAISAL OF THE ECONOMIC VIABILITY OF PRODUCING SYNTHETIC DIESEL FROM NATURAL GAS IN NIGERIA

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Abstract

The economic viability of producing synthetic diesel from natural gas in Nigeria was examined with the Chevron Escravos GTL project taken as a case. Plant procurement and installation cost, shipping and tanker facilities costs, the expected capacity of the GTL plant and the feed gas volume needed to produce that capacity of liquid product were gathered with which the costs analyses and revenue analyses were conducted. Concentration was on the possibility that diesel would be the only product of the GTL project. The price of diesel in $/bbl and the volume of diesel production per day were used for profitability analyses through the expected revenue. It was shown that the GTL project is economically viable having an Internal Rate of Return (IRR) of 13% and pay-out period of 9.16 years.

Key words: economics; gas; liquid; diesel; costs; revenue; profitability; analysis; investment; NPV; payout; IRR.

1. Introduction

Natural gas is converted to diesel and other products using a technology known as Gas to Liquids (GTL) technology in a process called the Fischer-Tropsch (FT) process. The Fischer–Tropsch process is a collection of chemical reactions that converts a mixture of gases into liquid hydrocarbons. It was first developed by Franz Fischer and Hans Tropsch at the "Kaiser-Wilhelm-Institut für Kohlenforschung" in Mülheim an der Ruhr (Germany) in 1925. The process, a key component of gas to liquids technology, produces a synthetic lubrication oil and synthetic fuel, typically from coal, natural gas, or biomass [10]. The Fischer–Tropsch process has received intermittent attention as a source of low-sulfur diesel fuel and to address the supply or cost of petroleum-derived hydrocarbons.

GTL is the term used to describe the chemical conversion of a gas into synthetic fuels by the Fisher-Tropsch (FT) synthetic process. The synthetic fuel is then refined by traditional methods to produce ultra clean liquid transport fuels.

GTL represents one of three major alternatives for owners of natural gas to monetize their gas. While pipeline and liquefied natural gas (LNG) options focus on the natural gas markets; GTL provides an option for gas producing nations to diversify into the transportation fuel market like diesel and jet fuel.

Due to the removal of impurities before the gas is converted to liquid, GTL products have superior properties in terms of combustion efficiency and emission of some pollutants. GTL fuels are compatible with old, existing and future diesel engine technologies. This means that FT fuels can be directly substituted for traditional fuels without any large scale modification to fleets or infrastructure. GTL products include diesel, naphtha, DME, LPG etc. In this work, the concentration is mainly on diesel which is the major product of GTL technology.

FT diesel is considered superior to conventional diesel as it has no sulphur content, near zero aromatics and a high cetane number ie its combustion quality during compression ignition, providing excellent combustion properties. FT diesel has superior environmental performance compared to conventional crude oil refinery diesel providing significant reductions in emissions of particulates NO_x, SO_x, carbon monoxide and light hydrocarbons. FT diesel is highly valuable as a blending stock for petroleum based diesel fuel. It is spotlighted as a clean fuel for next-generation diesel engine. Table 1.1 shows a convention of the products of GTL technology and their compositions.

Table 1.1 Convention of GTL Fuel Names and Composition

Name	Synonyms	Componensts
Fuel gas		C_1 - C_2
LPG		C_3 - C_4
Gasoline		C_5 - C_{12}
Naphtha		C_8 - C_{12}
Kerosene	Jet Fuel	C_{11} - C_{13}
Diesel	Fuel Oil	C_{13} - C_{17}
Middle Distillate	Light Gas Oil	C_{10} - C_{10}
Soft Wax		C_{19} - C_{23}
Medium wax		C_{24} - C_{35}
Hard wax		C_{35+}

1.1 Technology overview

According to Onaiwu [6] the current applications of modern natural gas based FT technology can be categorized into two *viz*:

- The high temperature FT process: this process uses iron as a catalyst within a temperature range of 300-350°C. The products from the process include petrol and gas oil which has almost zero sulphur but contains aromatics.
- The low temperature FT process – this process uses cobalt as a catalyst within a temperature range of 200-240°C. The process produces GTL fuel and very clean synthetic fractions of gas oil.

There are various commercial applications of the FT processes, the difference in the application of the technology relate to the design of the reactor and catalyst technology. Virtually all of them however include the following key steps;

1. Natural gas separation and treatment to remove water and impurities.
2. Production of sales gas (CH_4).
3. Fischer- Tropsch conversion to produce hydrocarbon waxes.
4. Final upgrade of finished products.

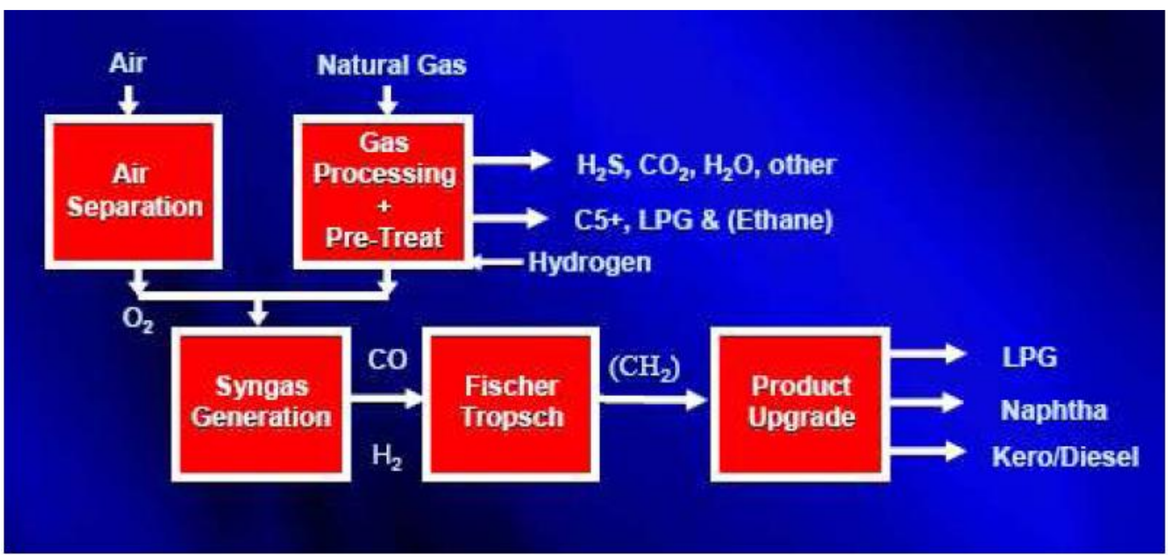

Fig 1.1 Schematic of GTL product extraction from produced gas

2. GTL actors

The scale of a GTL plant currently represents an important dimension for strategic positioning in the gas market. Some actors are positioning themselves in search of greater-scale natural trajectory of chemical processes aiming to reduce the cost of production and increase profitability on the large investments needed. The large petroleum companies which possess aiming great reserves of stranded natural gas are the most interested in large-scale plants. On the other hand, some companies seek efficient plants on a smaller scale capable of exploring a large number of small stranded natural gas fields. Some of the main natural gas operators are Chevron, Shell, ExxonMobil *etc.* [3].

Some of the already existing commercial GTL plants and yet-to-commence-operation GTL plants are outlined in Tables 2.1 and 2.2.

Table 2.1 Existing commercial GTL plants

Year	Operator	Location	Size	Product
1955	SASOL	South Africa	124,000	Light olefins and gasoline
1991	MOSSGAS	South Africa	22,000	Gasoline and diesel
1993	SHELL	Malaysia	12,500	Wax, Chemical, Diesel
2006	SASOL	Qatar	34,000	Liquid fuels

Table 2.2 Proposed GTL plants

Operator	Location	Size	Product
RENTECH	USA	1,200	High grade waxes and liquid fuel
SYNTROLEUM	Australia	10,000	High margin products
SHELL	Indonesia	70,000	Liquid fuels
EXXON MOBIL	Qatar	100,000	Liquid fuels
SASOL/CHEVRON	Nigeria	33,000	Liquid fuels
SICOR	Ethiopia	20,000	Liquid fuels
PDVSA	Venezuela	15,000	Liquid fuels

3. Theory

To analyze the Gas-to-Liquid technology process, and the underlying motivations of the oil and gas operators, the economic viability of the project is often taken into consideration. The economic viability of the project is composed of two broad branches *viz*:

- Costs analyses
- Revenue analyses.

3.1 Costs Analyses

The flow chart for the economic evaluation of the GTL is shown in Fig 3.1. It consists of the various costs at different stages: plant cost, plant installation cost, cost of pipelines and metering stations and storage tanker cost and tanker installation cost, which are summed up to get the total cost of investment. The direct production cost, extra fixed charges, plant overhead, cost of natural gas and shipping cost make up the annual cost.

Several items contribute to the total investment necessary to put a GTL plant into use and market the product for sales, as demonstrated in Fig 3.1; they include:

i. Cost of procuring and installing the plant
ii. Cost of pipelines and metering stations.
iii. Cost of buying the storage tankers and installing them.

The total investment cost is given by equation 3.1:

Total investment cost = Plant cost + Plant Installation cost + Cost of Pipelines and Meters + Cost of Storage Tanker (3.1)

It is represented mathematically as:

$$I = P + P_i + C_{pm} + T \quad (3.2)$$

The Annual cost = GTL Product Manufacturing cost + Cost of Natural Gas + Shipping cost (3.3)

This is represented mathematically as:

$$A = Pc + N + S \quad (3.4)$$

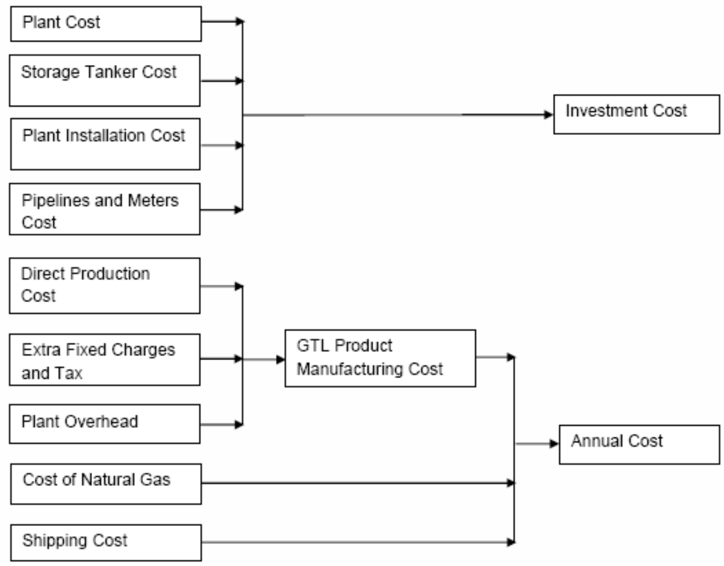

Fig 3.1 GTL economic viability flow diagram

3.1.1 Total Investment Cost, (I)

3.1.1.1 Plant Cost, (P)

Plant cost is the cost of procuring the gas-to-liquid technology plant and all the necessary facilities for its operation. The most available gas-to-liquid technology facility at present is the Fischer-Tropsch (FT) plant. The Fischer-Tropsch plant has many installations that take in natural gas to give chemical products.

3.1.1.2 Plant Installation Cost, (P_i)

It is not all about buying or procuring the FT plant, the plant has to be put into workability. Plant installation cost is the cost of installing the FT plant and all its parts for operation. The installation cost comprises the cost of all the connections put in place in the FT plant for it to be able to perform the gas-to-liquid operation.

3.1.1.3 Cost of Pipelines and Metering Stations, (C_{pm})

The pipelines and metering stations in this context are the piping facilities for transporting the bought natural gas from the buying point to the FT plant site. The essence of the metering station is to take measurement of the amount of natural gas that is fed into the FT plant at any point with time for conversion; the volume of the products yielded by the FT plant after conversion. The metering station installed for natural gas measurement would be able to read the volume of gas fed into the FT plant in scf while the metering station installed for measuring the volume of the yielded liquid product would read the volume in bbl. The amount of natural gas received by the FT plant as read by the metering station per day is represented in scf/d while the volume of product yielded by the FT plant per day is represented in bbl/d. Pipeline diameters of 12′, 14′ and 18′ and length of about 40 miles are commonly used, and 2 metering stations are installed; one for natural gas measurement and the other for the measurement of the liquid product volume.

3.1.1.4 Cost of Tanker, (T)

The tankers are the storage tankers procured for storing the liquid product manufactured through the FT process. Since shipping facilities are booked on hire, it is advisable to maximize the shipping capacity by storing the liquid product manufactured over time till the volume reaches the maximum capacity of the ship, and then the ship could be hired to carry the yielded product to market points overseas. For this cause, storage tanker is needed for the product of the FT process. The amount of money spent in buying the tanker and installing it for use is termed Cost of Tanker.

3.1.2 Annual Cost, (A)

Annual cost is the amount of money spent in producing the liquid product and shipping it out for sales in a year. It comprises the GTL product manufacturing cost, natural gas cost and the shipping cost.

3.1.2.1 GTL Product Manufacturing Cost, (P_c)

This comprises the whole expenses incurred in running the FT plant in a year apart from the cost of buying the natural gas. GTL Product Manufacturing cost comprises the cost of direct production, extra fixed charges and plant overhead. The GTL Product Manufacturing Cost is expressed below:

P_c = Direct Production Cost + Extra Fixed Charges + Plant Overhead (3.5)

It is estimated mathematically as shown below:

$$P_c = D_p + F_c + O_p \quad (3.5a)$$

3.1.2.1.1 Direct Production Cost, (P_c)

The Direct Production cost, D_p= Utilities + Maintenance Cost + Cost of Operating Supplies + Labour Cost + Cost of Direct Supervision + Laboratory Charges + Royalty (3.6)

It is represented mathematically as:

$$D_p = U + M_c + C_{os} + L + D_s + L_c + R \quad (3.6a)$$

According to Douglas, (1988), certain clues and correlations are used in estimating the values of parts of the annual costs. The clues and correlations were modified taking more real cases into consideration to give the ones below:

- **Utilities**
- **Maintenance Cost**

This comprises the maintenance costs of the FT plants and the storage tankers. It is expressed as a function of the investment cost as shown:

Maintenance Cost = 0.0024 * Total Investment Cost (3.7)

- **Cost of Operating Supplies**

This is the cost of procuring the supplies and extra materials for running the FT plant annually. It is estimated as shown:

Cost of Operating Supplies = 0.53 * Maintenance Cost (3.8)

- **Labour Cost**

Labour cost is the remuneration of the manpower that would operate service and maintain the FT plant and the tankers annually.

- **Cost of Direct Supervision**

The cost of direct supervision refers to the payment to the supervisors monitoring the operations of the FT plant and tankers operators. It is evaluated as 20% of the total labour cost. This is shown mathematically as:

Cost of Direct Supervision = 0.2 * Labour Cost (3.9)

- **Laboratory Charges**

Laboratory charges are the cost incurred in the laboratories of chemical analyses. It is expressed as:

Laboratory charges = 0.15 * Labour Cost (3.10)

- **Royalty**

The royalty is paid as percentage of the total investment cost. It is shown mathematically below:

Royalty = 0.0018 * Total Investment Cost (3.11)

For ease of analysis, the whole of these Direct Production Costs can be compressed to a simple cost in $/bbl of liquid product.

3.1.2.1.2 Extra Fixed Charges and Tax, (F_c)

Extra fixed charges refer to the extra costs incurred in the course of running the project annually, this falls into the extra charges, taxes, settlements or payments made to government and people during the project. It is estimated as a function of the investment cost as shown below:

Extra Fixed Charges = 0.0026 * Total Investment Cost (3.12)

3.1.2.1.3 Plant Overhead, (O_p)

Plant overhead refers to miscellaneous expenses incurred in providing materials, supplies and labour during the project. It is expressed as the function of both labour cost and investment cost as shown below:

Plant Overhead = [0.72 * Labour Cost] + [0.0021 * Investment Cost] (3.13)

3.1.2.2 Cost of Natural Gas, (N)

The cost of natural gas is the amount of money spent in buying the gas that is fed into the FT plant. It is expressed mathematically below as:

N = Gas Price * Feed Gas Volume (3.14)

The price of Natural Gas as at July, 2013 was $4.06/1000scf (Nigeria Gas Report [4].

3.1.2.3 Shipping Cost, (S)

Shipping cost refer to the cost of transporting the liquid product produced from the FT plant from the site to the sales or market point. This sales point in this work refers to overseas where the liquid product which include diesel is used in great capacities. It is rather expensive to own and run a shipping facility for the sake of the GTL project, so shipping facilities are booked on hire. The cost of hiring the ship is then termed the shipping cost. It is advisable to maximize the shipping capacity by storing the liquid product manufactured over time till the volume reaches the maximum capacity of the ship, and then the ship could be hired to carry the yielded product to market points overseas. The annual shipping cost is expressed below:

S = [336 days / (Ship Capacity / Product Daily Production)] * Cost per hire (3.15)

NB: 336 days is used as the working period of the FT plant, the remaining 4 weeks is used for maintenance and services.

3.2 Revenue Analyses

The revenue realizable from the project is estimated as a function of the amount of product yielded and the price of the product. The main product yielded by the GTL process which is considered in this work is diesel. The Gross Revenue from the project annually is estimated as shown below:

Gross Revenue = Diesel price * Diesel Daily Production * 336 days (3.16)

As at July, 2013, the price of diesel in Nigeria is N136 per litre which is $0.84 per litre. $0.84 per litre is the same as $134 per bbl. So the gross revenue can also be estimated as a function of the diesel price as shown:

Gross Revenue = 134 * Diesel Daily Production * 336 (3.17)

Annual Net Revenue is expressed as a function of the gross revenue and the annual cost as shown:

Annual Net Revenue = Gross Revenue – Annual Cost (3.18)

4. Results

The particular case taken for study in this work is the Chevron Escravos GTL Project. The GTL plant is expected to cost US$8.4 billion and to become operational by 2013 [7]. It will have an initial capacity of 33,000 barrels per day of synfuel. Within ten years the capacity would be expanded to 120,000 barrels per day. The plant will use Sasol's Fischer-Tropsch process technology and Chevron's ISOCRACKING technology (SPG Media Limited [8]). The values of the essential factors and parameters for the FT plant operation are presented in Table 4.1

Table 4.1 Gas, oil and ship parameters for the FT plant operation

Ship Capacity	900000 bbl
Tanker Capacity	900000 bbl
Diesel Price	$134/bbl
Natural Gas Price	$4.06/Mscf
Feed Gas Volume	325 MMscf/d
Plant Cost	$8.4 billion
Present Capacity	33000 bbl/d
Capacity after 10 years	120000 bbl/d

4.1 Costs Analyses

4.1.1 Total Investment Cost, (I)

4.1.1.1 Plant Cost, (P)

The cost of procuring the Fischer-Tropsch plant and its installation is $8.4 billion (Chevron Corporation [1]).

4.1.1.2 Plant Installation Cost, (P_i)

The cost of installing the FT plant and its accessories is included in the $8.4 billion in section 4.1.1.1.

4.1.1.3 Cost of Pipelines and Metering Stations, (C_{pm})

The installation and execution of the pipeline installation and associated civil works is at a cost of $10.4 million (Oil Serve Nigeria [5]).

4.1.1.4 Cost of Tankers, (T)

The cost of buying and installing a liquid product storage tanker is set at $700000.
From eqn. 3.1, the Total Investment Cost = $8.4 billion + $10.4 million + $0.7 million = $8.411 billion

4.1.2 Annual Cost, (A)

4.1.2.1 GTL Product Manufacturing Cost, (P_c)

4.1.2.1.1 Direct Production Cost, (P_c)

The general operating cost is given as $4.44/bbl of diesel.

4.1.2.1.2 Extra Fixed Charges and Tax, (F_c)

From eqn. 3.12, Extra Fixed Charges = 0.0026 * $8.4 billion = $22.5 million

4.1.2.1.3 Plant Overhead, (O_p)

From eqn. 3.13, Plant Overhead = [0.72 * 918000] + [0.0021 * $8.4 billion] = $18.2 million

From eqn. 3.5, GTL Product Manufacturing Cost = ($4 * 33000 * 336) + $22.5 million + $18.2 million = $85 million

4.1.2.2 Cost of Natural Gas, (N)

From eqn. 3.14, Cost of Natural Gas = $4.06/1000 scf * 325 MMscf/d * 336 days = $443 million

4.1.2.3 Shipping Cost, (S)

Cost per hire = $3.15 million (Turton *et al.*, [9]2003).
Ship capacity = 900000 bbl
Then, from eqn. 3.15, shipping cost for diesel transportation = [336 / (900000/33000)] * $3.15 million = $39 million
From eqn. 3.3, Annual cost = $85 million + $443 million + $39 million = $567 million.
NB: 336 days is used as the working period of the FT plant, the remaining 4 weeks is used for maintenance and servicing.

4.2 Revenue Analyses

From eqn. 3.17, Gross Revenue = $134/bbl * 33000 bbl/d * 336 days = $1.48 billion. Gross Revenue after 10 years = $134/bbl * 120000 bbl/d * 336 days = $5.4 billion.

From eqn. 3.18, Annual Net Revenue = $1.48 billion – $567 million = $918 million.

Assuming that the annual operating cost changes proportionately as feed gas volume and capacity change, then the annual operating cost for producing 120000 bbl/d of diesel which starts in the 11th year would be $2.06 billion. Annual Net Revenue after 10 years = $5.4 billion – $2.06 billion = $3.3 billion.

4.3 NPV and IRR for the GTL Project

Net Present Value, (NPV) is a measure of profitability of any project. The net present value of a time series of cash flows, both incoming and outgoing, is the sum of the present values (PVs) of the individual cash flows.

NPV compares the value of 1 dollar today its value in future, taking inflation and returns into consideration. If the NPV of a prospective project is positive, it is accepted. However, if NPV is negative, the project should be discouraged because cash flows will also be negative [10]

The cash flows for the GTL project over the space of 15 years is shown in Table 4.2 below.

Table 4.2 Cash Flows for the GTL Project over the space of 15 years

Time (yr)	CAPEX ($B)	OPEX ($B)	Gross Rev ($B)	NCR ($B)	Cum NCR ($B)	PV @ 5% ($B)	PV @ 10% ($B)
0	8.411	0	0	(8.411)	(8.411)	(8.411)	(8.411)
1	0	0.567	1.485	0.918	(7.493)	0.87	0.83
2	0	0.567	1.485	0.918	(6.575)	0.83	0.76
3	0	0.567	1.485	0.918	(5.657)	0.79	0.69
4	0	0.567	1.485	0.918	(4.739)	0.76	0.63
5	0	0.567	1.485	0.918	(3.821)	0.72	0.57
6	0	0.567	1.485	0.918	(2.903)	0.69	0.52
7	0	0.567	1.485	0.918	(1.985)	0.65	0.47
8	0	0.567	1.485	0.918	(1.067)	0.62	0.43
9	0	0.567	1.485	0.918	(0.149)	0.59	0.39
10	0	0.567	1.485	0.918	0.769	0.56	0.35
11	0	2.06	5.4	3.34	4.109	1.95	1.17
12	0	2.06	5.4	3.34	7.449	1.86	1.06
13	0	2.06	5.4	3.34	10.789	1.77	0.97
14	0	2.06	5.4	3.34	14.129	1.69	0.88
15	0	2.06	5.4	3.34	17.469	1.61	0.80

From Table 4.2, the Net Present Value at an expected rate of return/discount rate (the rate which the capital needed for the project could return if invested in an alternative venture) of 5% is the sum of the present values in that column for 5%. The sum of the PVs at 5% is $7.55 billion

The NPV at a discount rate of 10% = $2.11 billion. The project is worth investing on since the NPV in both cases is greater than zero.

The internal rate of return (IRR) on investment of a project is the rate of return that makes the net present value of all cash flows from a particular investment equal to zero. The higher the IRR of a project, the more desirable it is to undertake the project. Table 4.3 is another table generated from Table 4.2 and it shows the present values of the GTL project at various discount rates over 15 years. The essence of Table 4.3 is for the generation of the IRR of the project. Table 4.3 is shown below:

Table 4.3 Present Values for the GTL Project over the space of 15 years

PV @ 5% ($B)	PV @ 10% ($B)	PV @ 15% ($B)	PV @ 20% ($B)	PV @ 25% ($B)	PV @ 30% ($B)	PV @ 35% ($B)	PV @ 40% ($B)
(8.41)	(8.41)	(8.41)	(8.41)	(8.41)	(8.41)	(8.41)	(8.41)
0.87	0.83	0.80	0.77	0.73	0.71	0.68	0.66
0.83	0.76	0.69	0.64	0.59	0.54	0.50	0.47
0.79	0.69	0.60	0.53	0.47	0.42	0.37	0.33
0.76	0.63	0.52	0.44	0.38	0.32	0.28	0.24
0.72	0.57	0.46	0.37	0.30	0.25	0.20	0.17
0.69	0.52	0.40	0.31	0.24	0.19	0.15	0.12
0.65	0.47	0.35	0.26	0.19	0.15	0.11	0.09
0.62	0.43	0.30	0.21	0.15	0.11	0.08	0.06
0.59	0.39	0.26	0.18	0.12	0.09	0.06	0.04
0.56	0.35	0.23	0.15	0.10	0.07	0.05	0.03
1.95	1.17	0.72	0.45	0.29	0.19	0.12	0.08
1.86	1.06	0.62	0.37	0.23	0.14	0.09	0.06
1.77	0.97	0.54	0.31	0.18	0.11	0.07	0.04
1.69	0.88	0.47	0.26	0.15	0.08	0.05	0.03
1.61	0.80	0.41	0.22	0.12	0.07	0.04	0.02

Table 4.4 is a table of the net present values for the GTL project at various discount rates, which was used in generating a plot of NPV against discount rate as shown in Fig 4.1 for the determination of the IRR which is 13%. The 13% is the discount rate at which the NPV equals zero.

Table 4.4 NPV at various Discount Rates

Discount Rate (%)	NPV ($B)
5	7.555016
10	2.111164
15	(1.03624)
20	(2.94909)
25	(4.16882)
30	(4.98288)
35	(5.54982)
40	(5.96034)

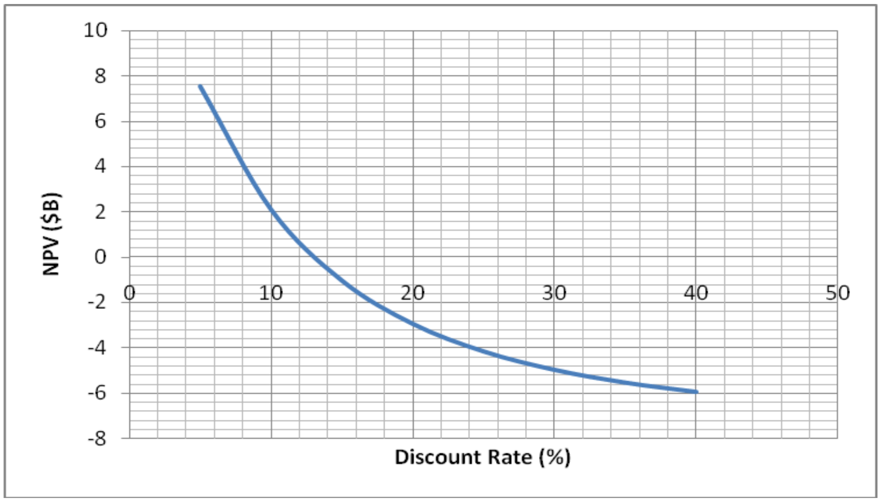

Fig 4.1 Plot of NPV against Discount Rate

4.4 Pay-out (PO) for the GTL Project

The pay-out for a project refers to the time (years) at which the initial investment on the project is just recovered. It is the time at which cumulative NCR becomes zero.

Table 4.5 shows the cumulative NCR and NCR after 10 years while Fig 4.2 represents the graph of time against cumulative NCR in billions of dollars for the GTL project.

Table 4.5 Cum NCR after 7 years

Time (yr)	NCR ($B)	CUM NCR ($B)
0	(8.411)	(8.411)
1	0.918	(7.493)
2	0.918	(6.575)
3	0.918	(5.657)
4	0.918	(4.739)
5	0.918	(3.821)
6	0.918	(2.903)
7	0.918	(1.985)
8	0.918	(1.067)
9	0.918	(0.149)
10	0.918	0.769
11	3.34	4.109
12	3.34	7.449
13	3.34	10.789
14	3.34	14.129
15	3.34	17.469

From Fig 4.2, cumulative NCR becomes zero between the 9th and 10th years. In this research work, 9 and 10 years were used as the initial point (IP) and final point, (FP) respectively.

Applying interpolation:

$$(PO - IP) / (FP - IP) = (0 - \text{CUM NCR at } IP) / (\text{CUM NCR at } FP - \text{CUM NCR at } IP) \quad (4.1)$$

$$(PO - 9yrs) / (10yrs - 9yrs) = (0 - (-0.149)) / (0.769 - (-0.149))$$

PO = 9.16yrs as indicated in Fig. 4.2.

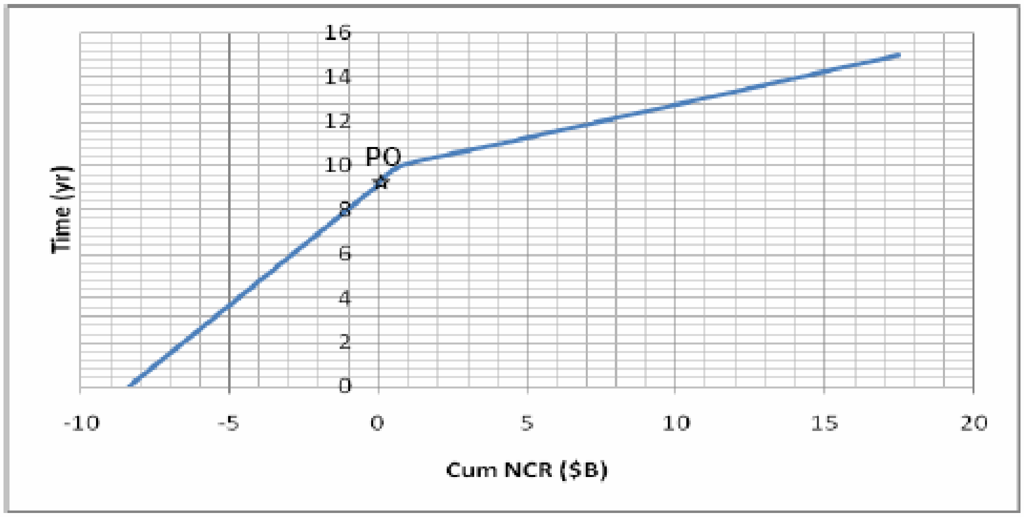

Fig 4.2 Plot of Time (yr.) against Cum NCR ($B)

4.5 Effect of Diesel Price on the GTL Project

The NPV at various diesel prices are as shown in Table 4.6 which was used to plot a chart of NPV ($B) against Diesel Price ($/bbl) as shown in Fig 4.3. From Fig 4.3, if diesel price goes below $95 per bbl, then the NPV becomes negative and so it would not be advisable to invest in the GTL project.

Table 4.6 Table of Diesel Price ($/bbl) and NPV at 5% ($B)

Diesel Price ($/bbl)	NPV @ 5% ($B)
144	9.5
134	7.55
124	5.64
114	3.71
104	1.79
94	(0.14)
84	(2.07)
74	(4)

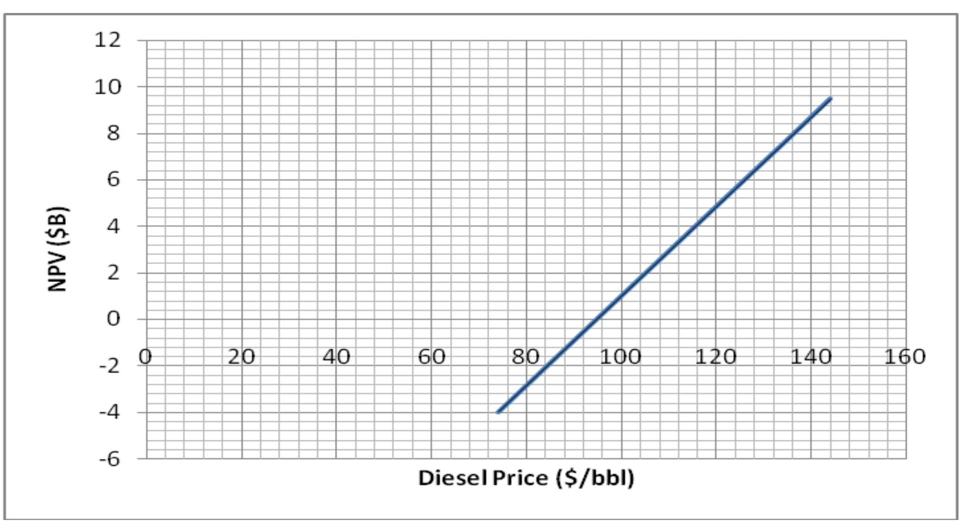

Fig 4.3 Plot of NPV ($B) against Diesel Price ($/bbl)

4.6 Effect of Natural Gas Price on the GTL Project

The NPV at various natural gas prices are as shown in Table 4.7 which was used to plot a chart of NPV ($B) against Natural Gas Price ($/Mscf) as shown in Fig 4.4. From Fig 4.4, if natural gas price goes higher than $8 per Mscf, then the NPV becomes negative and so it would not be advisable to invest in the GTL project.

Table 4.7 Table of Natural Gas Price ($/Mscf) and NPV at 5% ($B)

Gas Price ($/Mscf)	NPV @ 5% ($B)
11.06	(5.73)
9.06	(1.93)
7.06	1.86
4.06	7.55
3.06	9.45
2.06	11.35

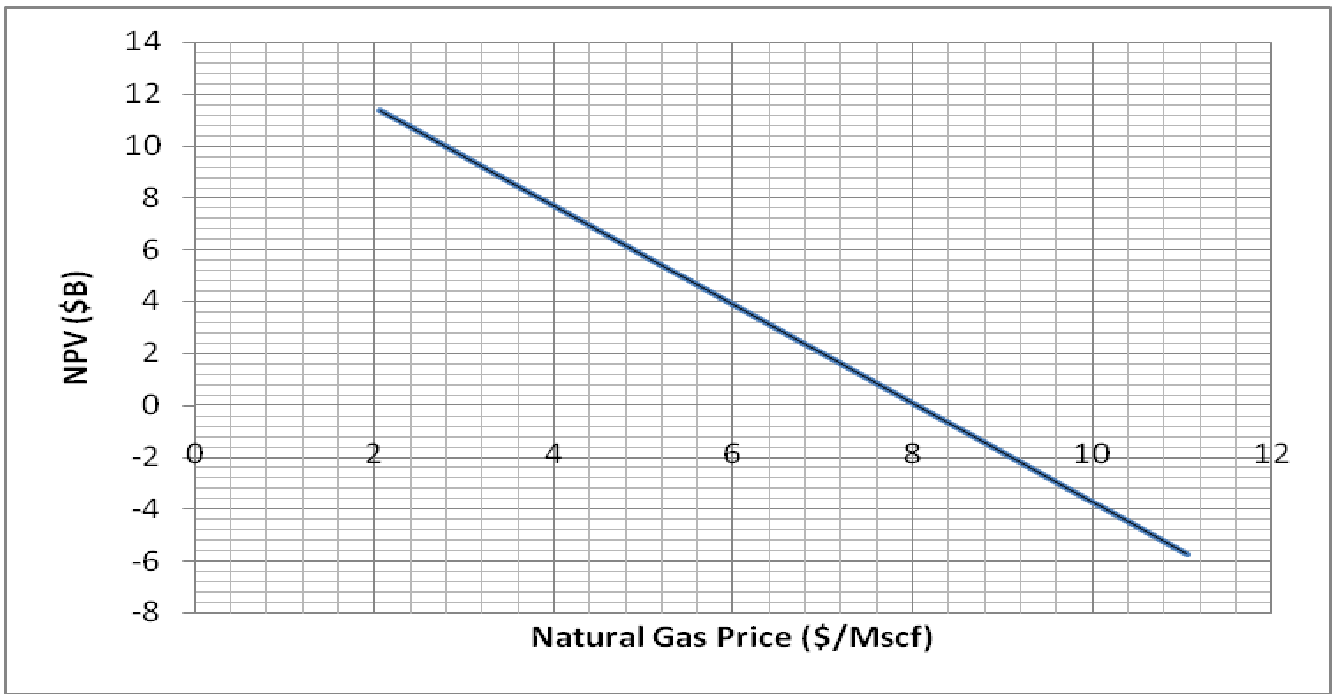

Fig 4.4 Plot of NPV ($B) against Natural Gas Price ($/Mscf)

5. Conclusion

From the analysis made in this work in which EGTL is the case study, it is noted three major profit indicators where used which include NPV, IRR and Pay out.

The NPV that was obtained for this analysis at different discount rate of 5% and 10% were both positive indicating that the project is profitable and acceptable.

The IRR which is the rate of return that makes the NPV of a cash flow equals zero, tells us how efficient a project is. The IRR of 13% obtained from this analysis is very much considerable.

The pay- out period of 9.16 years obtained from this analysis is not a long period which makes the investment look very attractive and profitable.

From Fig 4.3, it is shown that if the diesel price goes below $95/bbl. Then the NPV becomes negative and so it would not be advisable to invest in the GTL project

From Fig 4.4, it is shown that if the natural gas price goes higher than $8/Mscf, then the NPV becomes negative and so it would not be advisable to invest in the GTL project.

From all these economic analysis it is proven that the Gas-to-Liquid project ongoing in Escravos. Delta state, Nigeria would still be economically viable and profitable.

Nomenclature

A	Annual Cost	Mscf	Thousand standard cubic feet
bbl/d	Barrel per day	N	Cost of Natural Gas
CAPEX	Capital Expenditure	NCR	Net Cash Recovery
C_{os}	Cost of Operating Supplies	NO_x	Nitrogen oxides
C_{pm}	Cost of Pipelines and Meters	NPV	Net Present Value
CUM NCR	Cumulative Net Cash Recovery	O_p	Plant Overhead
DME	Dimethyl Ether	OPEX	Operating Expenditure
D_p	Direct Production Cost	P	Plant Cost
D_s	Cost of Direct Supervision	Pc	GTL Product Manufacturing Cost
F_c	Extra Fixed Charges	P_i	Plant Installation Cost
FP	Final Point	PO	Pay-out
FT	Fischer-Tropsch	PV	Present Value
GTL	Gas-to-Liquid	R	Royalty
I	Total Investment Cost	REV	Revenue
IP	Initial Point	S	Shipping Cost
IRR	Internal Rate of Return	Scf	Standard cubic foot
L	Labour Cost	SO_x	Sulphur oxides
L_c	Laboratory Charges	T	Cost of Storage Tanker
LNG	Liquefied Natural Gas	U	Utilities
LPG	Liquefied Petroleum Gas	$	Dollars
M_c	Maintenance Cost	$B	Billion dollars
MMscf/d	Million standard cubic feet per day		

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