Economics of Gas-to-Liquids (GTL) Plants

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Abstract: This work evaluates the economics of GTL plant using two synthesis gas methods. The first method called the base case utilizes oxygen as fuel for combustion of natural gas, while the proposed case uses steam/CO_2 instead of Oxygen. The aim is to ascertain a more economically viable GTL configuration for an optimal GTL process. The associated flare gas at Egbema production sites in the Niger Delta has been chosen as case study. The gas flowrate is 50MMscfd of raw natural gas which was pre-treated before being fed into the main GTL plant. The liquid yield result shows that the proposed method has a liquid yield of 5730b/d over the 5430b/d gotten from the base case representing an increase in product yield of 5.5%. The economic analyses show a quicker pay-out time of 4.9 years from the proposed model compared to 5.9 years from the base case. Using the proposed method gave an annual cashflow increase of 20.9% and NPV increase of 59.7% at 10% discount rates. Also the DCF-ROR from the proposed method was 20.3% compared to 16.6% gotten from the base method. Thus the proposed method is more profitable in terms of NPV. The project is recommended for application in the Niger Delta stranded and remote gas locations that have before now been subjected to flaring.

Keywords: Gas-to-Liquid, Natural Gas, Monetization, Pressurization, Energy, Syngas Generation

1. Introduction

The basic problem of natural gas lies in its transportation and storage. Unlike oil which is liquid, natural gas takes the shape of its container; thus, special containers must be deployed for its transportation and storage. Because of the nature of gases, construction of these vessels are rather more costly than that of crude oil making natural gas technologies relatively more expensive. Manufacturers of gas technologies seek ways that natural gas can be conveniently phased to enable its easy transportation to user locations. Most times, the gas can be used in the new phase when there is a permanent chemical conversion step or regasified to gas phase before usage when the conversion process is only a temporal physical one. These conversions are mainly to liquid phase through refrigeration, pressurization or use of catalyst, or to solid states through very low temperature refrigeration relying on its dewpoint and hydrate formation characteristics. The technologies available for natural gas conversions are Liquefied natural gas (LNG) technologies, compressed natural gas (CNG) technologies, Gas-to-wire (GTW) technologies, Gas to hydrates (GTH) technologies, Gas to liquids (GTL) technologies, natural gas liquids (NGL) extraction technologies [1].

Gas-to-Liquids (GTL) technologies can offer adequate monetization of small associated gas volumes in scattered locations in the Niger Delta. These associated gases were flared before because they were not needed and as such were seen as nuisance, but now the emergence of gas projects have created a window for utilization of these gases. GTL presents one of the technologies for utilising these gases. A technological breakthrough in GTL technologies made available small-scale mini modular plants capable of handling small volumes of gases at a lower capital cost. Initially GTL was viewed as a capital intensive project requiring huge capital expenses and availability of large volume of gas for economic viability. Because of these constraints, only very few large scale commercial plant are

operational [2-5]. The only plant in Nigeria is the Escravos GTL facility in Escravos Delta state. The project costs more than 5 billion dollars for its construction and expected to run at a capacity of 34000b/d of product fuels like diesel, gasoline etc. Economies of scale made available smaller plants for improve utilization of associated stranded gases [6]. A number of studies have attempted to evaluate the economic attractiveness of GTL technologies [7]. As is the case for any investment, four major parameters are used to determine the economic viability of GTL technology: i) Capital expenditures, ii) Feedstock costs, iii) Processing costs and iv) Product values.

Research has shown that among the various steps present in the GTL system, the syngas generation step is the most capital intensive. This is because of its high energy consumption, cost of construction and complexity of configuration as an additional unit. This paper evaluates the economics of GTL plant using two synthesis gas method- an autothermal reforming method and a newly proposed steam/CO_2 method [8].

The processes involved in GTL plant operations are divided into four main units given below: The natural gas pre-treatment units, the synthesis gas unit, the Fisher Tropsch unit, the product upgrading unit

These four main units in the GTL plants have their peculiar operations, processes, considerations and objectives. A full GTL plant process is an integration of these units and processes for a common goal. Each unit is peculiar and distinct from the other and is important to the overall integrated system [9]. The raw gas is pretreatment in the pretreatment unit to remove impurities such as acid gases and some entrained liquids (e.g. wateror heavier end hydrocarbon). The pretreatment depends on the volume of gas and the mole composition of the gas. In the synthesis gas unit, the treated gas composed almost entirely of methane is converted to synthesis gas. The synthesis gas is composed of hydrogen and carbon monoxide – a precursor for most petrochemical industries. The synthesis gas unit comprises the pre-reformer unit and the reformer unit. The several types of synthesis gas units available are: the steam methane reforming, the partial oxidation reforming, the autothermal reforming, the dry reforming (CO_2 reforming) and steam/CO_2 reforming [10]. The pre-reformer cracks heavier hydrocarbons in the pre-treated natural gas stream before being sent to the reformer. Here all hydrocarbons heavier than methane are converted to methane or synthesis gas. The reformer converts the methane to synthesis gas. In the Fischer Trospch unit, the synthesis gas is reacted to form synthesis crude which is upgraded in the product upgrading unit [11, 12].

2. Economics of GTL Plant

Considering the economics of GTL plant, factors relating to the project economics are of interest. The factors affecting the viability of GTL are summarized below: i) Capital Investment, ii) Operating expenditures, iii) Crude oil price,

iv) Natural gas price.

2.1. Capital Investment

The capital investment (CAPEX) for GTL plant comes from various units and represent the largest economic expenditure of the GTL plant. The capital investment for a GTL plants includes the following [13]:

(1) The cost of the equipment (Ce): This includes all the equipment to be used in the GTL facility and includes individual equipment from all the units in the GTL process plant. The various units start from the gas pre-treatment stage down to the product work-up. But in most GTL operations, the pre-treatment stage is not usually part of the main GTL process operation, this is because the treatment of the gas is sub-contracted out to companies and treated gas is delivered on purchase to the GTL operators. Although in some situation, the operators may wish to accomplish the pre-treatment of the natural gas onsite as part of the GTL operation especially in large commercial plants.

(2) The installation cost (Ci): This includes the cost of installing the various equipment onsite. The sum of the total equipment cost and installation cost is called the inside battery limit cost (ISBL). The installation cost comprises the following operations: (a) Piping, (b) Electrical, (c) Equipment erection, (d) Instrumentation and control, (e) Civil works, (f) Structures and building, (g) Lagging and paint

(3) The outside battery limit cost (OSBL): This includes other costs such as the engineering and design, offsites, contingents.

(4) The working capital (Wc): The working capital is additional money needed in order to run the plant until the plant starts to earn income. The working capital is returned at the end of the project time. For petrochemical industries the working capital is typically 15% of fixed capital investment [14].

$$ISBL = C_e + C_i \qquad (1)$$

$$\text{Total fixed cost } (T_{fc}) = ISBL + OSBL \qquad (2)$$

$$\text{Total investment cost} = T_{fc} + W_c \qquad (3)$$

$$\text{Total investment cost (CAPEX)} = C_e + C_i + OSBL + W_c \quad (4)$$

2.2. Equation for Estimation of CAPEX

To address the plant capacity, economies of scale relate the CAPEX to the plant capacity and may be expressed in the equations below [15].

$$Cost\ Ratio = (Capacity\ Ratio)^Y \qquad (5)$$

$$Cost = Base\ Cost * \left[\frac{Capacity}{Base\ capacity}\right]^Y \qquad (6)$$

$$Cost = constant * (Capacity)^Y \qquad (7)$$

Where Y reflects the degree to which a particular facility

benefits from economies of scale. A value of 1.0 implies the facility does not benefit from economies of scale. For example, the construction of parallel trains (instead of larger ones) would yield Y values approaching 1.0. Y values for refining and petrochemical plant are typically 0.5 to 0.88. The value for GTL plant is estimated at 0.66.

2.3. The Operating/Production Cost Estimation

These are costs which are dependent on production, such as electricity and operators. For the purpose of this work the natural gas cost is excluded from the operating cost. This is done for easy evaluation of the sensitivity of the project economics to changing natural gas price since the operating cost (OPEX) is given as a percentage of the CAPEX.

2.4. Crude Oil Price

The price of crude oil affects GTL product price. This is because GTL products compete with conventional crude oil products. If crude oil price is generally low, the cost of crude oil products will be low and it will affect the demand for GTL products. This is because GTL conversion technologies are generally capital intensive and can only thrive if crude oil price is high to justify investment.

2.5. Natural Gas Price

Natural gas price is one of the single factors that affect the total operating expenditure for a GTL project. The price of gas utilized as feedstock by GTL is usually negotiated between the host nation and the investor with little reference to market prices. Studies have shown that for a GTL project to be viable, the price of gas must not exceed \$0.5/MMBTU. IOCs who have partnered with producing nations on GTL projects may obtain preferential gas prices for their GTL facility. In some cases because the natural gas is flared, it can be given at no cost initially for a contract agreement to investors on agreement with host government in bid to develop the resource, monetize the gas and stop gas flaring in the country.

3. Methodology

The methodology comprises the economic indicators for the GTL plant. They are discussed and evaluated below.

3.1. Economic Evaluation Variables

The following economic evaluation variables shall be considered: The Payout time (POT), the discounted cash flow rate of return (DCF-ROR), the net cash flow, the net present value, Profit per investment ratio.

i). *Cash Flow/NCR*

The cash flow is calculated from the formula given below:

$$C_f = \{(R_a - A_{toc} - d_a) * (1 - F_{it})\} + d_a \qquad (8)$$

Where C_f = cashflow/NCR, R_a = Annual Revenue in dollars, A_{toc} = Annual total production cost, d_a = Annual

depreciation, F_{it} = fractional income tax.

The taxable income (T_{in}) is given by

$$(T_{in}) = R_a - A_{toc} - d_a \qquad (9)$$

The depreciation used here is the straight-line depreciation method and is given by

$$\text{Depreciation} = \frac{\text{Equipment cost} - \text{Salvage value}}{\text{Life period of Equipment}} \qquad (10)$$

The total annual operating cost is the total cost per year of the non-feedstock cost and the natural gas price.

ii). *Payout Time (POT)*

Mathematically the pay-out time is calculated as

$$POT = \frac{Capital\ cost}{Cashflow/NCR} \qquad (11)$$

iii). *The Discounted Cashflow Rate of Return (DCF-ROR)*

This is the discount rate at which the net present value is equal to zero.

iv). *Net Present Value (NPV)*

The following is the formula for calculating NPV

$$NPV = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} - C_0 \qquad (12)$$

Where: C_t = net cash inflow during the period t, C_o = total initial investment costs, r = discount rate, and, t = number of time periods.

3.2. Project Case Study

The case study here describes the location under investigation. For this project, we consider the conversion and monetisation of the flare natural gas at Egbema production sites. This region has been heavily impacted by gas flaring. The construction of GTL facility in this area is expected to convert the flare gases into premium quality transport fuels like diesel, gasoline and kerosene for home usage. The GTL products are to be mostly utilized in the nearby Owerri, the capital city of the state while surplus will be sold to Portharcourt and Onitsha, the adjoining cities. Literature reveals that more than 50MMscfd of gas is being flared in this region. This volume becomes our target volume for monetisation. We employ mini modular technology because of the relatively small volume of the gas and to ensure project optimisation and private investor partnership. The project is expected to yield 5000b/d of GTL liquid fuels, this is the plant capacity.

To determine the capital cost of this 5000b/d, plant we make comparison with existing mini GTL facilities currently in operation in other areas. For this project analysis we make use of the capital cost of CompactGTL facility at Kazakhstan. This facility has a capacity of 2500b/d of GTL liquid products with an overall capital cost of US\$275MM. from these we can calculate the capital cost of our proposed GTL plant using equation 6.

From the calculation the total capital cost of our proposed plant is US\$434,522,721 which is approximated to be US\$434.5MM. The capital cost calculated includes all the

units which also comprise the ASU plant for generation of oxygen. But since the ASU will be operated by independent licensed operators and oxygen sold to the GTL operators, we shall exclude the cost of ASU plant from the capital investment cost (CAPEX) of the GTL plant.

From literature conventional ATR plants with ASU has its ASU contributing about 20% of the total investment cost (CAPEX) of the overall process plant. If we subtract 20% from the estimated cost of the GTL, then the new GTL CAPEX without ASU plant will be US$347,618,177, approximately US$347.6MM. Thus, the capital cost of the ATR configuration for use in this work is US$347.6MM.

3.2.1. Base Case (Case 1)

In this case, a GTL plant was designed using Autothermal reforming method as the method for the synthesis gas production. The synthesis gas here is the precursor to the actual Fischer Tropsch reaction. The Autothermal reformer (ATR) uses oxygen from air separation unit (ASU) as one of the reactants. Other reactants includes steam and the pre-treated natural gas.

3.2.2. Alternative Case (Proposed Method)

Alternative case, we design a process plant that will minimize cost and enhance performance and less pollution. In this work we propose a method that is CO_2 reductive, this method uses steam and CO_2 as the reactant fuels instead of oxygen as in base case. Furthermore CO_2 is supplied externally from the market to get the required amount necessary for the synthesis gas production.

3.3. Project Economic Parameters

The economic parametres for the project is given below.
i. Plant capacity is 5430b/d for ATR GTL plant and 5730b/d for steam/CO_2 GTL plant from natural gas inlet flowrate of 50MMscfd
ii. Capital cost is US$347.6MM (ASU excluded)
iii. Feedstock cost is $2.5/MMBTU since gas is flared gas
iv. OPEX is 5% of CAPEX (excluding natural gas price and cost of O_2 or CO_2)
v. Plant operational period of 25 years
vi. 350 plant operational days per year
vii. Refined GTL product price of $100/bbl for diesel and kerosene, $90/bbl for gasoline
viii. Straight line depreciation method
ix. Salvage value of zero
x. Income tax of 35% base case

4. Result and Discussions

Result of economic analyses are presented based on the total barrels of liquid products produced. The economic analyses are determined concurrently for the ATR reforming and for the steam/CO_2 reforming GTL plants.

4.1. GTL plant Product Yield

The GTL simulation yield is summarized in the table below.

Table 1. *GTL plant product yield for ATR syngas method.*

Component	Volume (b/d)	
	ATR	Steam/CO_2
Gasoline	3025	3120
Kerosene	1380	1425
Diesel	1025	1185
Total	5430	5730

From table 1 above, the product yield from the steam/CO_2 reforming is 5730b/d while that of the ATR method is 5430b/d. For a rule of thumb the liquid product yield for GTL plant is 1 barrel for 10,000 scf of pre-treated natural gas feedstream. From this calculation our feedstream corresponds to a conventional production of 5000 b/d. Both the ATR reforming method and the steam/CO_2 reforming method gave high product yields. When compared with the expected yield from the rule of thumb, the product yield from the steam/CO_2 reforming method represents a 14.6% increase while the product yield from the ATR plant represents an 8.6% increase. Thus, the steam/CO_2 has more product yield and is preferred as a choice over the ATR reforming GTL plant method.

4.2. Result for Revenue

Revenue was calculated on annual basis. The annual revenue comprises the money accrued from the sales of the GTL product per year. The annual revenue calculation is presented in table 2 below.

Table 2. *Revenue presentation for both cases of the GTL project.*

GTL Product	Market Price (US$)/Bbl	Production Capacity (B/D)		Total Daily Revenue (US$)		Total Annual Revenue (US$)	
		ATR	Steam/CO_2	ATR	Steam/CO_2	ATR	Steam/CO_2
Gasoline	90	3025	3120	272250	280800	95287500	98280000
Kerosene	100	1380	1425	138000	142500	48300000	49875000
Diesel	100	1025	1185	102500	118500	35875000	41475000
Total	-	5430	5730	512750	541800	179462500	189630000

From the table above, the annual revenue for ATR and steam/CO_2 reforming are US$179462500 and US$189630000 respectively. The revenue from the steam/CO_2 reforming of the GTL plant gave a 5.67% increase in revenue from that of the ATR, thus more revenue is realized from the use of steam/CO_2 reforming GTL plant than the ATR reforming GTL method.

4.3. Result for OPEX of the GTL Plant

The Operating expenses for the GTL project for both cases

are presented in the table below. The table below gives the   result of the OPEX used in this work.

***Table 3.** Calculation of Total OPEX of the GTL project.*

| Component | Flowrate (MMscfd) | Cost per (Mscf) | Annual cost (US$) | |
			ATR	STEAM/CO_2
Natural gas	50	2.5	43750000	43750000
Oxygen	50.19	2	35133000	-
CO_2	50.19	1.5	-	26349750
Variable OPEX (5% of CAPEX)	-	-	17380908.85	17380908.85
Total OPEX	-	-	78883000	70099750

From table 3 above, the total OPEX for the ATR and the steam/CO_2 reforming GTL plants are US$78883000 and US$70099750 respectively. There was a reduction of 11.13% in the OPEX from the use steam/CO_2 reforming technique for the GTL plant making the proposed method less costly to operate than the base case method.

4.4. Result for Key Economic Indicators of the GTL Project

Table 4 below gives the economic indicators of the project. Comparison is made for both cases.

***Table 4.** Presentation of Economic Indicators for the GTL project.*

Economic Parameter	ATR	Steam/CO_2	Difference
Annual Cashflow/NCR (Us$)	58945738.7	71263726	20.9%
NPV (Us$)	187434652	299245518	59.7%
DCF-ROR (%)	16.6	20.3	4.7
Pay-Out Time, Pot (Yrs)	5.9	4.9	1
P/$	3.24	4.13	0.89

From table 4 above, it can be seen that using steam/CO_2 method for the reforming of the GTL improves the profitability in all the indices considered. There is a 59.7% difference in the NPV when steam/CO_2 method was chosen instead of the ATR for the GTL plant project. This amounts to a net profit of US$111810866 from the use of steam/CO_2 reforming method.

The DCF-ROR for the GTL project for US$2.5/Mscf natural gas price are 16.6% and 20.3% respectively while the Pay-out time are 5.9 years and 4.9 years for the ATR and steam/CO_2 reforming method respectively. The figure 1 below gives the POT and the DCFROR for both cases considered.
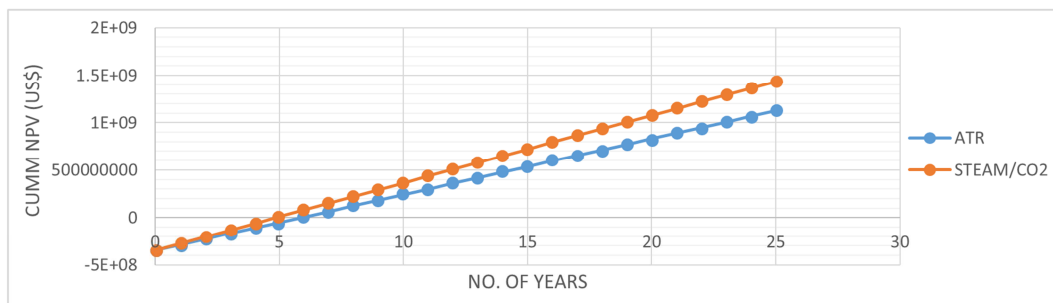

***Figure 1.** Figure showing Pay-Out Time for US$2.5/Mscf natural gas price for both cases of the GTL plant considered.*

From figure 1, it can be seen that using steam/CO_2 reforming gives a faster pay-out time than the ATR method for the synthesis gas production during GTL plant operation.

***Figure 2.** DCF-ROR for the project natural gas price of US$2.5/Mscf.*

The discounted cashflow rate of return is the discount rate that will yield an NPV of zero. From figure 2 above, the DCF-ROR is 16.6% for ATR reforming GTL method and 20.3% for steam/CO_2 reforming GTL method. The DCF-ROR of 16.6% and 20.3% calculated shows that the project is economically viable for the two cases considered since the discount rates for most gas projects are not greater than 10%. Despite that, the steam/CO_2 is more preferable when considering the DCF-ROR because it gave a higher value at the economic prevalent considered.

4.5. Sensitivity Analyses

Sensitivity analyses are performed on both cases to ascertain the sensitiveness of economic variables on economic performance indices. This is done by changing some factors while others are kept constant to determine the baseline of profitably of the project under changing economic conditions in the future. The sensitivity was conducted with changes in the

following factors: i) Discount rates of 10%, 15% and 20% are used, ii) Natural gas cost of US$2.5/Mscf and US$3/Mscf, iii) Changes in non-feed stock OPEX of 5% and 6%, iv) Changes in CAPEX of US$80,000 PBLD and US$100,000 PBLD.

4.6. Sensitivity Analyses of the ATR Reformer GTL Plant

For the ATR reforming method, the total product yield is 5430b/d. The capital cost per barrel liquid a day (PBLD) is US$64018 PBLD. Thus, we evaluate the sensitivities for US$80,000PBLD and US$100,000PBLD. The table below gives the sensitivity analyses of the ATR reformer for natural gas price of US2.5/Mscf and for changes in CAPEX to following values: US$80,000PBLD and US$100,000PBLD

4.6.1. Sensitivity ATR Reformer for Natural Gas Price of US$2.5/Mscf

Table 5 below describes the results for sensitivity analyses of the GTL project for natural gas price of US$2.5/Mscf.

Table 5. General economic indices for sensitivity analyses of ATR reformer GTL plant at natural gas price of US$2.5/Mscf.

ATR: NG price US$2.5/Mscf	CAPEX: $50,000/BLPD OPEX (% OF CAPEX)		CAPEX: $64,018/BLPD		CAPEX: $80,000/BLPD	
Discount Rates	5%	6%	5%	6%	5%	6%
10%	276334992	260316286	187434652	166924916	86079971	60450041
15%	118636769	107229162	33415866	18810004	-63743914	-81996085
20%	27106296	18375042	-55979005	-67158168	-150704000	-164674006
NCR	60353925	58589175	58945739	56686221	57340275	54516675
DCF-ROR	21.4	21.4	16.6	15.9	12.5	11.8
POT	4.63	4.63	5.9	6.13	7.58	7.97

From table 5, it can be seen that the NPV decreases as the CAPEX is increased. The CAPEX is a factor that largely affects the NPV as shown in the figure 3 below.

Figure 3. Graph of NPV vs. time for the ATR reforming at natural gas price of US$2.5/Mscf.

Furthermore, we investigate the economic sensitivity of the project when the natural gas price increases from US$2.5/Mscf to US$3.0/Mscf. The table 6 below gives the economic variables.

4.6.2. Sensitivity ATR Reformer for Natural Gas Price of US$3/Mscf

Table 6 below describes the results for sensitivity analyses of the GTL project for natural gas price of US$3/Mscf

Table 6. General economic indices for sensitivity analyses of ATR reformer GTL plant at natural gas price of US$3.0/Mscf.

ATR: NG price US$3.0/Mscf	CAPEX: $50,000/BLPD OPEX (% OF CAPEX)		CAPEX: $64,018/BLPD		CAPEX: $80,000/BLPD	
Discount Rates	5%	6%	5%	6%	5%	6%
10%	224709327	208690621	135808987	115299251	34454305	8824376
15%	81871921	70464314	-3348982	-17954844	-100508762	-118760933
20%	-1033105	-9764359	-84118406	-95297569	-178843401	-192813408

ATR: NG price US$3.0/Mscf	CAPEX: $50,000/BLPD		CAPEX: $64,018/BLPD		CAPEX: $80,000/BLPD	
	OPEX (% OF CAPEX)					
Discount Rates	5%	6%	5%	6%	5%	6%
NCR	5466425	52901675	53258239	50998721	51652775	48829175
DCF-ROR	19.9	19.2	14.8	14.1	11	10.3
POT	4.97	5.13	6.53	6.8	8.41	4.97

If the cost of natural gas is increased, the profitability of the project reduces. An increase of natural gas price by US$0.5/Mscf gives a 0.36 year increase in pay-out time and a 1.5% decrease in the DCF-ROR for the ATR reforming of the GTL plant.
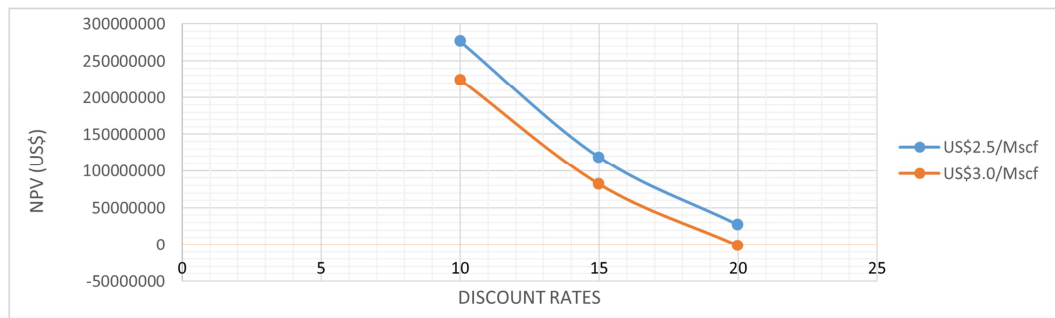

Figure 4. Graph of NPV vs. Discount Rates for the ATR reforming at natural gas price of US$3.0/Mscf.

4.7. Sensitivity for the Steam/CO$_2$ Reformer GTL Plant

Here, we analyze the sensitivity of the economic variables on the economic performance of the GTL plant for the steam/CO$_2$ reformer. First, we evaluate for natural gas price of US$2.5/Mscf and then for natural gas price of US$3.0/Mscf. The table below gives the result.

4.7.1. Sensitivity for Natural Gas Price of US$2.5/Mscf

Table 7 below describes the result for sensitivity analyses of the GTL project for natural gas price of US$2.5/Mscf

Table 7. General Economic Indices for Sensitivity Analyses of ATR Reformer GTL Plant at Natural Gas Price of US$2.5/Mscf.

Steam/CO$_2$: NG price US$2.5/Mscf	CAPEX: $50,000/BLPD		CAPEX: $64,018/BLPD		CAPEX: $80,000/BLPD	
	OPEX (% OF CAPEX)					
Discount rates	5%	6%	5%	6%	5%	6%
10%	388145858	372127152	299245518	278735781	197890836	172260906
15%	198262077	186854470	113041174	98435312	15881394	-2370778
20%	88050611	79319357	4965310	-6213853	-89759685	-103729691
NCR	72671913	70907163	71263726	69004208	69658263	66834663
DCF-ROR	26.7	26	20.3	19.6	15.6	14.9
POT	3.74	3.83	4.9	5.04	6.24	6.5

Table 7 gives the economic performance indices for the steam/CO$_2$ reforming method of the GTL plant for natural gas price of US$2.5/Mscf. From the table, it can be seen that the steam/CO$_2$ reforming process shows better pay-out time and DCF-ROR than that of the ATR.

At 20% discount rate the project is profitable for CAPEX of US$50,000 PBLD and US$64,018 PBLD. The figure below illustrates the relationship of the NPV with the discount rates for steam/CO$_2$ reforming at natural gas price of US$2.5/Mscf.
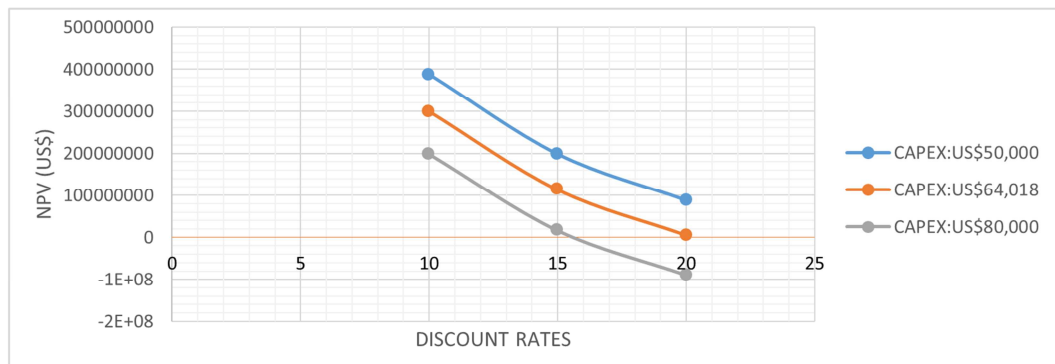

Figure 5. Graph of NPV vs. time for the steam/CO2 reforming at natural gas price of US$2.5/Mscf.

For natural gas price of US$3.0/Mscf, the table below gives the effect of sensitivity on the economic performance of the project.

4.7.2. Sensitivity for Natural Gas Price of US$3/Mscf

Table 8 below describes the result for sensitivity analyses of the GTL project for natural gas price of US$3/Mscf.

Table 8. General Economic Indices for Sensitivity Analyses of ATR Reformer GTL Plant at Natural Gas Price of US$3/Mscf.

Steam/CO_2: NG price US$3.0/Mscf	CAPEX: $50,000/BLPD		CAPEX: $64,018/BLPD		CAPEX: $80,000/BLPD	
	OPEX (% OF CAPEX)					
Discount rates	5%	6%	5%	6%	5%	6%
10%	336520193	320501486	247619853	227110116	146265171	120635241
15%	161497229	150089622	76276326	61670464	-20883454	-39135625
20%	59911210	51179956	-23174091	-34353254	-117899086	-131869093
NCR	66984413	65219663	65576226	63316708	63970763	61147163
DCF-ROR	24.6	23.9	18.6	17.9	14.2	13.5
POT	4.05	4.16	5.3	5.49	6.79	7.1

Increasing the natural gas price from $2.5/Mscf to $3/Mscf increases the pay-out time by 0.21 years and reduces the DCF-ROR by 2.1% for the seam/CO_2 reforming method of the GTL plant operation.

From the sensitivity analyses, natural gas price greatly affects the profitability of the GTL project. A natural gas price difference of US$0.5/Mscf led to a 0.36 year increase in pay-out time and a 1.5% decrease in the DCF-ROR for the ATR reforming of the GTL plant, also 0.4 years increase in pay-out time and 1.7% decrease in DCF-ROR for the proposed steam/CO_2 reforming method

5. Conclusion

Gas to liquids technology has been evaluated economically. Two methods were considered. The difference in configuration of the GTL plant in the two methods was in the synthesis gas unit. The synthesis gas unit for the base case was retrofitted with oxygen gas as fuel for the combustion of the natural gas coming into the GTL system while the alternative case used steam/CO_2 mixture instead of oxygen gas. The economic evaluation first of all shows that regardless of the synthesis gas method used above, the GTL process was an economical project under normal economic conditions and can compete favorably with other gas conversation methods like LNG.

Furthermore, from the evaluation it is seen that the steam/CO_2 method which is the proposed method for GTL plant operation has better economic performance than the autothermal reforming method. The plant yield for the proposed case is 5730b/d while the plant yield for the ATR was 5430b/d a difference of 300b/d. the proposed case have also economically performed better than the ATR method in terms of NCR, NPV, DCF-ROR, POT and P/$ making it more economically justifiable. The proposed method is therefore recommended as the GTL plant configuration method for small scale monetisation of the vast stranded flare associated gases in the Niger Delta.

Nomenclature

ASU: Air Separation Unit
ATR: Autothermal Reformer
b/d: barrels per day
CAPEX: Capital Expenditure
CNG: Compressed Natural Gas
CO_2: Carbondioxide
DCF-ROR: Discounted Cashflow Rate of Return
GTL: Gas-to-Liquids Technology
GtW: Gas-to-Wire
IOCs: International Oil Companies
ISBL: Inside Battery Limit Costs
LNG: Liquefied Natural gas
MMbtu: Million British thermal unit
MMscfd: Million standard cubic feet per day
Mscf: Thousand standard Cubic Feet
MTG: Methanol-to-Gasoline
NCR: Net Cash Recovery
NGL: Natural Gas Liquids
NPV: Net Present Value
OPEX: Operating Expenditure
OSBL: Outside Battery Limit Costs
P/$: Profit-Per-Dollar Invested
P/$: Profit-per-dollar Invested
PBLD: per Barrel-Liquid a Day
POT: Pay-Out-Time
STG: Syngas-to-Gasoline Plus
US$: US dollars

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