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# DEVELOPMENT OF A TEMPLATE FOR THE PROFITABILITY STUDY OF STRANDED NATURAL GAS PROCESSING OPTIONS

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**Key Words:** Profitability study, stranded natural gas, gas processing,economic analysis, template

## ABSTRACT
In this work, a parametric study of the technology and economic imperatives for stranded natural gas processing was carried out, the economic analysis was done using a template developed on Microsoft Excel to calculate the cash flows, evaluate the Net Present Values (NPV), and obtain the Internal Rate of Return/Discounted Cash flow Rate of Return (IRR/DCFRR) which are key economic indices for ranking of projects. Discounted Cash Flow economic model is preferred here for the validation of the stranded natural gas concept select because it is the only economic system that takes into account variations in inflation, tax rate and other parameters. To validate my model, parameters from the Escravos GTL Plant and the proposed Nigeria LNG Train 7 plant were used. The template provided values for these economic indices (NPV and IRR) for the plants under various scenarios when the values of key input economic parameters were varied. The impact of variation of the following economic parameters on the NPV and IRR were assessed: the plant capital expenditure (CAPEX), the discount rate, the tax rate, the plant operating expenditure (OPEX), the feed gas cost, the crude oil price, the LNG price, and the product shipping cost. An economic sensitivity analysis of the plants was also carried out using Tornado charts. To provide a basis for proper economic comparison, the capacities of both plants were scaled up to obtain their CAPEX if they were both processing 1500 MMSCFD using standard cost-capacity relationships. The results obtained at the base case scenario using the most likely values of the economic input parameters, indicate that the NLNG T7 has a CAPEX of $11.77 billion, NPV of $0.89 billion, and IRR of 11.45% while the EGTL has a CAPEX of $23.15 billion, NPV of -$7.34 billion, and IRR of 2.51%. This implies that the NLNG T7 is more viable than the EGTL because of its lower CAPEX, higher NPV and higher IRR at the base case scenario values. The analysis also indicated that for the EGTL to be profitable, the crude oil price has to be at least $85/barrel or the interest on capital lower than 2.51%. The results from the sensitivity analysis show that the profitability of the EGTL is most affected by the plant CAPEX followed by the crude oil price, while the profitability of the NLNG T7 is most affected by LNG price followed by the plant CAPEX. From the results obtained, the LNG option is more viable than GTL option for gas monetisation in Nigeria .

## INTRODUCTION
Natural gas has played an important role in the supply of daily energy requirements for industrial and domestic use. The total global annual gas consumption is forecasted to rise to 2.9 trillion cubic meters by 2015 accounting for approximately 27% of the total primary energy supply; and will further rise to 4.59 trillion cubic meters by 2020 with an annual increase rate of 3.2%.

Most of this gas is supplied to the ultimate consumers by pipeline distribution. However, a considerable portion of the world natural gas reserves fall into the category termed as “stranded”where conventional means of transportation via pipeline is not practical or economical because of geographical, political, or diplomatic limitations. “Stranded” natural gas reserves are either located remotely from consumers or are in the region where the demand for gas is limited. The owners of the “stranded” gas face a challenge on how to monetize the large stranded gas resources. The options for utilization of these significant quantities of Natural Gas reserves include Liquefied Natural Gas (LNG) and Gas-To-Liquid (GTL) technologies.

LNG is essentially a physical change process converting natural gas to liquid for ease of transportation while GTL is a chemical change process yielding naphtha, transportation fuels and specialty chemicals such as lubes and base stocks.

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LNG trade to-date has been dominated in the Far East primarily due to the proximity of the suppliers and consumers with Japan and Korea accounting for the lion's share of the market. The birth of the North American and European market is about to radically change the LNG trade fundamentals bringing about a new era for LNG.

Until recently, the viability of GTL did not look promising when compared to alternative transportation fuels production from crude oil refining. Developments in GTL technology and stringent environmental specifications for transportation of fuel oils have paved the way for GTL projects. The use of GTL technology spearheaded by Qatar has the potential for becoming a prominent alternative for stranded gas monetization in the next two decades

This research work focuses mainly on the comparison of LNG and GTL gas monetisation technologies. Other methods of gas monetization such as pipeline transportation, Compressed Natural Gas technology (CNG), and Gas to Wire options are mainly highlighted but not considered in the analysis. Also, although the economic models developed are generic and can be applied for economic evaluation of any gas utilization process, the economic analysis carried out in this work is limited to a comparison of the Nigeria Escravos GTL and NLNG Train 7.

This study will provide the Nigerian NNPC and DPR with a useful guide for judging several competing proposals which they receive from investors, particularly those interested in the Independent Power Projects (IPP) on stranded gas utilization. Also, the twin need of reducing gas flaring and utilizing our abundant gas reserves in an economically, technologically and environmentally sustainable manner serves as a justification for this study.

## METHODOLOGY

**Financial and Economic Analysis of the FT-GTL and LNG Technologies**

Although products from LNG and GTL plants are destined for entirely different energy markets, it is possible to carry out a comparative economic analysis between the two. The basis used for this analysis is 1500 MMSCFD (Million Standard Cubic Feet per Day) of gas feed utilisation for the two plants, with the CAPEX (Capital Expenditure) and others economic parameters of the plants scaled up accordingly for the case study of NLNG train 7 and Escravos FT-GTL. The major aspect of this economic evaluation was done by using a Microsoft Excel template developed for this purpose and shown in the procedure below,. This template took into account the various variables that affect the viability of the projects such as plant life, construction period, CAPEX, tax, depreciation schedule, etc.

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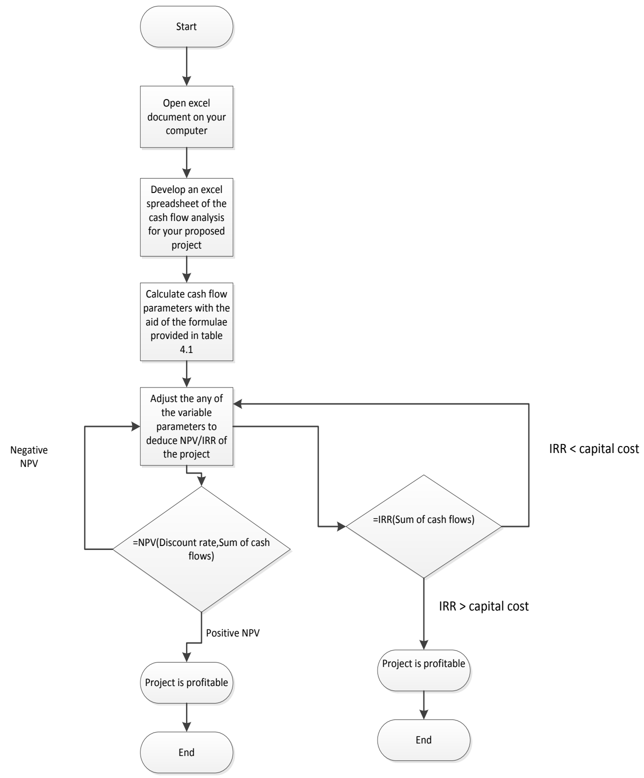


*Figure 2.1: Algorithm of cash flow deduction using excel program template*

*Table 2.1: Formulae for calculating the parameters on the excel program template*

| PARAMETERS | LNG FORMULA | GTL FORMULA |
|---|---|---|
| SALES REVENUE | Capacity(MMBTU)*LNG Price*Plant load factor( 90% for the 1st year) | Plant operating time(330)*{72% of 150000 bbl/d for diesel (crude price + Diesel premium) + 28% of 150000 bbl/d for naphtha (crude price + naphtha price)}*Plant load factor( 50% for the 1st year) |
| CAPEX | $ 11.77B. Year 1-3 construction capital spending = 25%, 35% and 40% of Capex respectively *capex factor | $ 23.15B. Year 1-3 construction capital spending = 25%, 35% and 40% of Capex respectively *capex factor |
| OPEX | Opex value (0.5)*Plant capacity(MMBTU) + Shipping value (0.7)*Plant capacity(MMBTU) + Feed gas cost (0.5/MMBTU)*Feed gas capacity (1500 mmfcd or 1500000 MMBTU) | Opex value*Product capacity(150000bbl/d) * operating time(330 days) + Shipping factor * Product capacity * operating time + Feed gas cost * Product capacity * Operating time. |
| DEPRECIATION | 5 Year MACRS Depreciation of Capex = 20%,32%,19.20%,11.52%,5.76% of $ 11.77B. | 5 Year MACRS Depreciation of Capex = 20%,32%,19.20%,11.52%,5.76% of $ 23.15B. |
| TAX | Tax rate (35%)*(sales revenue-total opex-depreciation) | Tax rate (35%)*(sales revenue-total opex-depreciation) |
| CASH FLOW | Sales revenue – Capex – Opex– Tax. | Sales revenue – Capex – Opex – Tax. |
| DISCOUNTED CASH FLOW | Cash flow*(1 + Discounted rate (10%)) ^ -year. | Cash flow*(1 + Discounted rate (10%)) ^ -year. |

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The financial and economic analysis was carried out using the technique of discounted cash flow (DCF) analysis. The DCF analysis yielded project performance criteria such as net present value (NPV) and internal rate of return (IRR) which were obtained from the cash flow of the projects under consideration. Sensitivity analyses were then carried out by varying the values of some of the economic parameters and determining their impacts on the project performance criteria within predetermined ranges. The essence of a sensitivity analysis is to determine the economic parameter which has the most profound impact on the project economics.

**Summary of the Parameter Values Used for the Analysis**

The summary of the parameter value estimates used for the economic assessment of the NLNG train 7 and FT-GTL are shown in the following tables with the most likely values, minimum expected values and maximum expected values for the sensitivity analysis also tabulated.

***Table 2.2: Summary of parameter assumptions used in the study***

***Table 2.3: Parameter values used for ft-gtl sensitivity analysis***

| PARAMETER | Most Likely Value | Minimum Expected Value | Maximum Expected Value |
|---|---|---|---|
| Crude Oil Price ($/bbl) | 45 | 30 | 60 |
| Feed Gas Cost ($/MMBTU) | 0.50 | 0.25 | 1.00 |
| CAPEX Factor | 1 | 0.7 | 1.3 |
| OPEX ($/bbl) | 5 | 3.5 | 6.5 |
| Shipping Cost ($/bbl) | 1.2 | 0.8 | 1.6 |
| Discount Rate (%) | 10 | 8 | 12 |
| Tax Rate | 35 | 20 | 50 |
| GTL Diesel Premium ($/bbl) | 5 | 3.5 | 6.5 |
| GTL Naphtha Premium ($/bbl) | 3 | 2 | 4 |

***Table 2.4: Parameter values used for nlng train 7 sensitivity analysis***

| PARAMETER | Most Likely Value | Minimum Expected Value | Maximum Expected Value |
|---|---|---|---|
| LNG Gas Price ($/MMBTU) | 5 | 3 | 7 |
| OPEX ($/MMBTU) | 0.5 | 0.35 | 0.65 |
| CAPEX Factor | 1 | 0.7 | 1.3 |
| Shipping Cost ($/MMBTU) | 0.7 | 0.5 | 0.9 |
| Feed Gas Cost ($/MMBTU) | 0.5 | 0.25 | 1.00 |
| Discount Rate (%) | 10 | 8 | 12 |
| Tax Rate (%) | 35 | 20 | 50 |

## RESULTS AND DISCUSSION

### Results

The results obtained from the techno-economic comparison of the NLNG T7 and the EGTL plants are outlined here in.

***Economic Assessment of NLNG Train 7 and Escravos FT-GTL for the Base Case Scenarios***

The templates for the Discounted Cash Flow analysis for both the Escravos FT-GTL and the NLNG Train 7 are shown in appendices 1 and 2. The results shown are for a scaled up gas utilisation of 1500MMSCFD for both

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plants. At this feed rate, the NLNG plant would be producing 11.23 MMTPA of LNG while the FT-GTL plant would be producing 150,000 bbl/d of products comprising 72% FT-GTL diesel and 28% FT-GTL naphtha.

The CAPEX for the FT-GTL is $23.15 billion. From the economic analysis using the "most likely values" shown in table 2.2, the Internal Rate of Return (IRR) for this plant is 2.509% and the Net Present Value (NPV) is -$7,335,723,418.43 at a discount rate of 10%.

The CAPEX for the NLNG Train 7 is $11.77 billion. From the economic analysis using the "most likely values" shown in table 2.3, the Internal Rate of Return (IRR) for this plant is 11.455% and the Net Present Value (NPV) is $885,227,865.36 at a discount rate of 10%.

The following subjections are dedicated to showing the impact of the various parameter values on the economic analysis.

***Impact of Varying Capital Expenditure***

The capital expenditure is a key economic parameter whose value has significant effects on the plant economics. Table 3.1 shows the impact of varying CAPEX on the NPV and IRR of the EGTL and NLNG T7 when the other parameters are held constant at their base/most likely values.

***Table 3.1: Effect of varying CAPEX on the NPV & IRR of EGTL and NLNG T7***

| CAPEX ($, Bn) | NPV for EGTL ($,Bn) | NPV for NLNG ($, Bn) | IRR for EGTL (%) | IRR for NLNG (%) |
|---|---|---|---|---|
| **2** | 5.644 | 6.881 | 40.44 | 48.72 |
| **4** | 4.417 | 5.654 | 25.22 | 29.85 |
| **6** | 3.190 | 4.426 | 18.39 | 21.72 |
| **8** | 1.962 | 3.199 | 14.24 | 16.92 |
| **10** | 0.735 | 1.972 | 11.36 | 13.64 |
| **12** | -0.493 | 0.744 | 9.20 | 11.21 |
| **14** | -1.720 | -0.483 | 7.48 | 9.30 |
| **16** | -2.948 | -1.711 | 6.07 | 7.75 |
| **18** | -4.175 | -2.938 | 4.89 | 6.45 |
| **20** | -5.403 | -4.166 | 3.87 | 5.33 |
| **22** | -6.630 | -5.393 | 2.97 | 4.37 |
| **24** | -7.857 | -6.621 | 2.19 | 3.51 |

***Impact of Varying Feed Gas Cost***

Table 3.2 shows the impact of varying feed gas cost on the NPV and IRR of the EGTL and NLNG T7 when the other parameters are held constant at their base/most likely values.

***Table 3.2: Effect of Varying Feed Gas Cost on the NPV & IRR of EGTL and NLNG T7***

| Feed Gas Cost ($/MMBTU) | NPV for EGTL ($,Bn) | NPV for NLNG ($, Bn) | IRR for EGTL (%) | IRR for NLNG (%) |
|---|---|---|---|---|
| **0.25** | -6.851 | 0.887 | 3.12 | 11.46 |
| **0.50** | -7.336 | 0.885 | 2.51 | 11.45 |
| **0.75** | -7.820 | 0.884 | 1.88 | 11.45 |
| **1.00** | -8.305 | 0.882 | 1.21 | 11.45 |
| **1.25** | -8.790 | 0.881 | 0.52 | 11.45 |
| **1.50** | -9.275 | 0.879 | -0.22 | 11.45 |
| **1.75** | -9.760 | 0.878 | -1.00 | 11.44 |
| **2.00** | -10.244 | 0.876 | -1.83 | 11.44 |
| **2.25** | -10.729 | 0.875 | -2.72 | 11.44 |
| **2.50** | -11.214 | 0.873 | -3.69 | 11.44 |

***Impact of Varying Discount Rate***

Table 3.3 shows the impact of varying discount rates on the NPV and IRR of the EGTL and NLNG T7 when the other parameters are held constant at their base/most likely values.

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*Table 3.3: Effect of Varying Discount Rate on the NPV & IRR of EGTL and NLNG T7*

| Discount Rate (%) | NPV for EGTL ($,Bn) | NPV for NLNG ($, Bn) | IRR for EGTL (%) | IRR for NLNG (%) |
|---|---|---|---|---|
| **2** | 0.874 | 10.622 | 2.51 | 11.45 |
| **4** | -2.196 | 7.081 | 2.51 | 11.45 |
| **6** | -4.452 | 4.427 | 2.51 | 11.45 |
| **8** | -6.113 | 2.417 | 2.51 | 11.45 |
| **10** | -7.336 | 0.885 | 2.51 | 11.45 |
| **12** | -8.231 | 0.291 | 2.51 | 11.45 |
| **14** | -8.881 | -1.198 | 2.51 | 11.45 |
| **16** | -9.345 | -1.901 | 2.51 | 11.45 |
| **18** | -9.667 | -2.446 | 2.51 | 11.45 |
| **20** | -9.880 | -2.869 | 2.51 | 11.45 |

***Impact of Varying Tax Rate***

Table 3.4 shows the impact of varying tax rates on the NPV and IRR of the EGTL and NLNG T7 when the other parameters are held constant at their base/most likely values.

*Table 3.4: Effect of Varying Tax Rate on the NPV & IRR of EGTL and NLNG T7*

| Tax Rate (%) | NPV for EGTL ($,Bn) | NPV for NLNG ($, Bn) | IRR for EGTL (%) | IRR for NLNG (%) |
|---|---|---|---|---|
| **5** | -8.199 | 2.576 | 2.94 | 13.60 |
| **10** | -8.055 | 2.294 | 2.88 | 13.28 |
| **15** | -7.911 | 2.012 | 2.81 | 12.96 |
| **20** | -7.767 | 1.731 | 2.75 | 12.61 |
| **25** | -7.623 | 1.449 | 2.67 | 12.24 |
| **30** | -7.480 | 1.167 | 2.59 | 11.86 |
| **35** | -7.336 | 0.885 | 2.51 | 11.45 |
| **40** | -7.192 | 0.603 | 2.42 | 11.02 |
| **45** | -7.048 | 0.321 | 2.32 | 10.56 |
| **50** | -6.904 | 0.040 | 2.21 | 10.07 |

***Impact of Varying LNG Price***

Table 3.5 shows the impact of varying LNG price on the NPV and IRR of the NLNG T7 when the other parameters are held constant at their base/most likely values.

*Table 3.5: Effect of Varying LNG Price on the NPV & IRR of NLNG T7*

| LNG PRICE ($/MMBTU) | NPV for NLNG T7 ($,Bn) | IRR for NLNG T7 (%) |
|---|---|---|
| **2** | -5.542 | -3.62 |
| **3** | -3.400 | 3.15 |
| **4** | -1.257 | 7.75 |
| **5** | 0.885 | 11.45 |
| **6** | 3.028 | 14.65 |
| **7** | 5.170 | 17.52 |
| **8** | 7.312 | 20.15 |
| **9** | 9.455 | 22.61 |
| **10** | 11.597 | 24.91 |

***Impact of Varying Crude Oil Price***

Table 3.6 shows the impact of varying crude oil price on the NPV and IRR of the EGTL when the other parameters are held constant at their base/most likely values. GTL is specifically tied to crude oil price as it is a form of refinery product which cost competes with the crude oil price.

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*Table 3.6: Effect of Varying Crude Oil Price on the NPV & IRR of EGTL*

| CRUDE OIL PRICE ($/bbl) | NPV for EGTL ($, Bn) | IRR for EGTL (%) |
|---|---|---|
| **45** | -7.335 | 2.51 |
| **50** | -6.421 | 3.66 |
| **55** | -5.507 | 4.72 |
| **60** | -4.592 | 5.72 |
| **65** | -3.677 | 6.66 |
| **70** | -2.763 | 7.55 |
| **75** | -1.848 | 8.39 |
| **80** | -0.933 | 9.21 |
| **85** | 0.018 | 9.98 |
| **90** | 0.896 | 10.73 |
| **95** | 1.810 | 11.46 |
| **100** | 2.725 | 12.16 |

***NLNG and EGTL Sensitivity Analysis***

Sensitivity analysis is a way of examining the effects of uncertainties in the forecasts on the viability of a project by giving decision makers a quick overview of the risks involved. To carry out the test, the values of the chosen criteria are first calculated at most probable values to obtain the base case for the analysis. Other values are then obtained for the test criteria at the maximum and minimum expected values to provide the high and low case scenarios. The sensitivity analysis on the NLNG and EGTL plants are done with the aid of tornado diagrams which serve as a standard tool for sensitivity analysis.

Tornado charts are modified versions of bar charts where the largest bar appears at the top of the chart followed by the second largest and so on. They are so named because the final chart visually resembles one half of or a complete tornado. The change in NPV between the base values and the maximum/minimum expected values is used as our test criteria. The parameter with the longest bar has the greatest effect on the NPV while the one with the shortest has the least effect on the NPV. The base case, high and low values used for this analysis are as given in tables 2.2 and 2.3 while the sensitivity plots are given in figures 3.1 and 3.2 below.

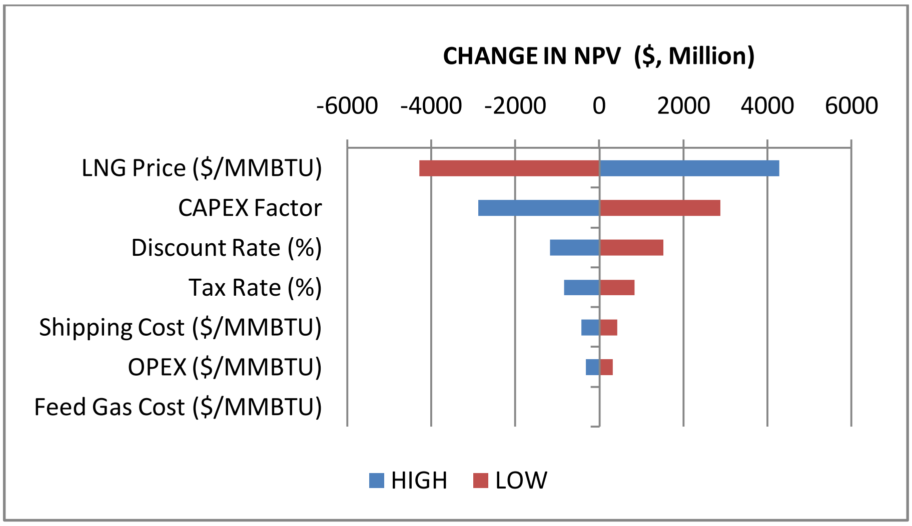


*Figure 4:1: Tornado Plot for NLNG Sensitivity Analysis*

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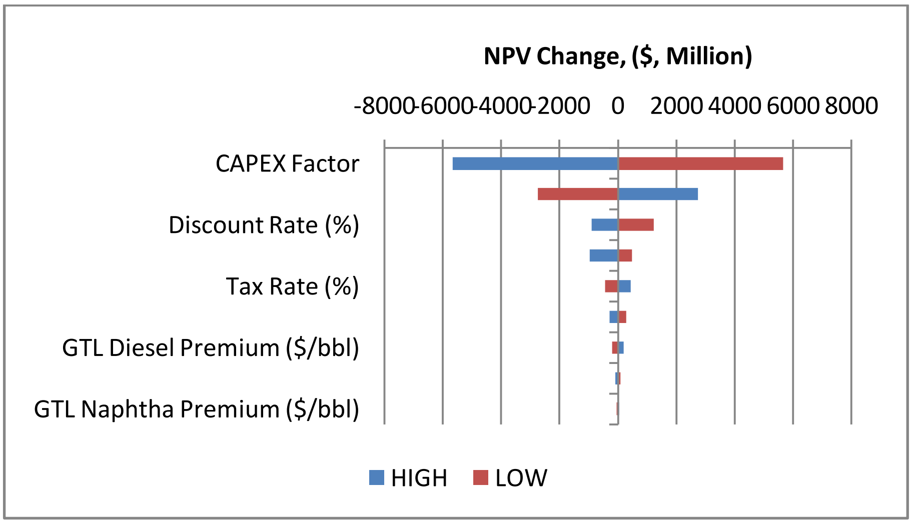


**Figure 4:2: Tornado Plot for EGTL Sensitivity Analysis**

**Discussion**

The results from the technical comparison of the LNG and FT-GTL plants as found in literature show that both of the technologies are about equally matched and none offers any overwhelming advantage(s) over the other. The choice of the preferred route will therefore be based on the plant with the better economics.

From the results of the economic assessment of the NLNG T7 and the Escravos GTL, the NLNG T7 is a better option for gas monetization than the EGTL at values used in the base case scenarios because of its higher NPV value, better IRR and lower CAPEX. In fact, the EGTL would not be profitable at the most likely values used in the base case scenarios because its NPV is negative, and the maximum interest rate it can support is can support is 2.509% as indicated by its IRR. It is most unlikely that one would be able to source capital at an interest rate below 2.5095 as required for profitable operation of the EGTL plant. The major reason for this is the unusually high CAPEX of the EGTL plant. The following sections of the discussion will show that the plant would have been very profitable if it was realized with a lower CAPEX value. Other economic conditions that would result in profitable operation would also be highlighted.

The NLNG on the other hand would be able to operate profitably with a Net Present Value (NPV) of $885,227,865.36 at the base case scenario values which has a discount rate of 10%. A lower discount rate or cost of capital would invariably lead to more profitable operating conditions. The IRR of 11.455% means that the project can be profitable at an interest rate on capital of up to 11.45%.

Table 3.1 shows the effect of varying CAPEX on the NPV of EGTL and NLNG T7. It can be observed that the lower the CAPEX values, the higher the NPV for both plants. At a CAPEX value of $2 billion, the NPV of the EGTL and NLNG T7 would be $5.6 billion and $6.9 billion respectively with the other economic parameters at their most probable values. This is indeed a very desirable scenario and it is also observed that the NPV reduces as the CAPEX increases. From this analysis, the maximum CAPEX for profitable operation of the EGTL plant is about $10 billion and the NPV becomes negative from CAPEX values of $12 billion and higher. For the NLNG T7, the NPV becomes negative at CAPEX values of about $14 billion and higher. Recall that these quoted CAPEX values and those of the other economic parameters refer to the scaled up plant capacity for 1500 MMSCFD of feed gas utilization.

From Table 3.1, a progressive reduction is also observed in the IRR values for both the EGTL and NLNG T7 plants. For the EGTL plant, the IRR drops from 40.44% to 2.19% as the CAPEX increases from $2 billion to $24 billion while for the NLNG T7 the IRR drops from 48.72% to 3.51% for the same range of CAPEX increase. This means that the cost of capital which the projects can accommodate for profitable operation of both plants decreases as the CAPEX increases. At the discount rate of 10% used, the EGTL would not be profitable at a CAPEX of above $10 billion while the NLNG T7 would not be profitable at CAPEX values of $12 billion and above. This agrees with the inference from the impact of the CAPEX on the NPV as earlier discussed.

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Table 3.2 shows the effect of varying feed gas cost on the NPV of EGTL and NLNG T7. It can be observed that the feed gas cost does not have any significant effect on the NPV of the NLNG T7 as the NPV remained at about a mean value of $0.8 billion. This inference is valid within the feed gas cost range of 0.25$/MMBTU and 2.50$/MMBTU investigated when the values of other economic parameters were held at their base case scenario values. For the EGTL, the NPV remained negative for the feed gas cost range investigated with other parameters at their base case scenario values. However, a decrease in the NPV was also observed from -$6.9 billion at a feed gas cost of 0.25$/MMBTU to -$11.2 billion at a feed gas cost of $2.5$/MMBTU.

Table 3.2 also shows the change in the IRR of the EGTL and NLNG T7 in response to variation in feed gas cost. For the NLNG, the IRR remained largely unchanged with a mean value of about 11.45% while that of the EGTL decreased from 3.12% to -3.69% as the feed gas cost increased from 0.25$/MMBTU to 2.50$/MMBTU. As usual, the other parameters were maintained at their base case scenario values.

The effect of varying discount rate on the NPV of EGTL and NLNG T7 is shown in table 3.3. For the EGTL, the NPV has a value of $0.874 billion at a discount rate of 2% and the dips to a value of -$9.9 billion at a discount rate of 20%. For the NLNG, the NPV is $10.622 billion at a discount rate of 2% and drops to -$2.87 billion at a discount rate of 20%. The IRR for both plants however remained unchanged from their values of 2.51% and 11.45% for the EGTL and NLNG T7 respectively as shown in table 4.3. The values of the NPV become zero at the discount rates that correspond to these IRR values and negative at discount rates higher than the IRR values. This accounts for the negative NPV value of the EGTL obtained in the base case scenario analysis with a discount rate of 10%.

Table 3.4 shows the effect of varying tax rates on the NPV and IRR of the EGTL and NLNG T7. The NPV of the NLNG T7 remained positive for tax rates up to 50%. This means that the NLNG T7 can accommodate tax rates of up to 50% and still be profitable though marginally when the other economic parameters are at their base case scenario values. The EGTL NPV remained negative for all tax rates. It is observed that the IRR decreased as the tax rate increased for both the EGTL and the NLNG T7 from 2.94% to 2.21% and 13.60% to 10.07% respectively.

Table 3.5 shows the effect of varying LNG market price on the NPV and IRR of the NLNG T7. At LNG prices of below $5/MMBTU, the NPV is negative and hence the plant will not operate profitably. The NPV is favoured by increasing product prices will increase to $11.6 billion at an LNG price of $10/MMBTU. Internal rate of return (IRR) at this LNG price is 24.91% which signifies that the plant will be able to accommodate an interest rate on capital of 24.91% at this product price of $10/MMBTU.

Table 3.6 shows the effect of varying Crude Oil price on the NPV and IRR of the EGTL. From the table, it can be seen that the NPV of the EGTL is negative below crude oil price of $85/barrel and rises to $2.7 billion at crude oil price of $100/barrel. The EGTL plant therefore will not be profitable at the prevailing crude oil price levels of about $60/barrel as the NPV is negative at this price.

The IRR increases from 2.51% at a crude oil price of $45/barrel to 12.16% at a crude oil price of $100/barrel.
Figure 3.1 shows the Tornado plot for the NLNG sensitivity analysis. It can be seen from the figure that the profitability of the plant as indicated by its Net Present Value is most sensitive to the LNG gas price as this has the longest bar. It is further observed that a change in the LNG price of $2 from the most likely value of $5 to the maximum expected value of $7 results in an increase in the NPV from $0.885 billion to $5.2 billion, a change of over 400%. The CAPEX factor is next parameter the profitability of the NLNG plant is sensitive to. A 30% reduction in CAPEX factor from its base value of 1 to 0.7 results in an increase in the NPV from $0.885 billion to $3.8 billion, a change of over 300%. The other factors like the discount rate, tax rate, shipping cost and OPEX also appreciable impact on the NPV as indicated by the length of their bars on the Tornado chart. The profitability of the NLNG T7 is least sensitive to the feed gas cost as a 50% reduction in the cost from its base value of $0.5/MMBTU to $0.25/MMBTU only results in an NPV increase of 0.17% from $0.885 billion to $0.887 billion.

For the EGTL, the profitability of the plant is most sensitive to the change in CAPEX factor as this has the longest bar in the Tornado chart shown in figure 4.2. Here, a 30% CAPEX factor decrease from 1 to 0.7 results in an NPV increase from -$7.34 billion to -$1.66 billion, a change of 77.4%. Similarly, an increase in crude oil price from its base case value of $45/barrel to the maximum expected value of $60/barrel results in an NPV

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increase from -$7.34 billion to -$4.59 billion, a change of 37.5%. The profitability of the EGTL plant is least sensitive to GTL Naphtha premium as a 50% increase in the Naphtha premium from its base case value of $3/barrel to $4/barrel results in an NPV increase from -$7.34 to -$7.28, a change of 0.82%. The other factors like the discount rate, feed gas cost, tax rate and OPEX have an appreciable impact on as indicated by the length of their bars in the Tornado chart of figure 3.2.

## CONCLUSSION

The need to find the most economically viable option for monetisation of stranded gas reserves will remain a priority as long as there are untapped gas reserves waiting to be utilised. It is pertinent to note that the Discounted Cash Flow economic model is preferred here for the validation of the stranded natural gas concept select because it is the only economic system that takes into account variations in inflation, tax rate and other parameters. From the results of the analysis done in this work, the LNG technology is a better option for gas monetization in Nigeria than the GTL technology. In addition to being a more mature technology with considerable expertise in its operation and maintenance, the LNG is more economically viable the GTL plant for gas monetisation in Nigeria at values used in the base case scenarios because of its higher NPV value, better IRR and lower CAPEX. As previously stated, the EGTL would not be profitable at the most likely values used in the base case scenarios analysis because of its negative NPV and its low IRR. The major reason for this is the unusually high CAPEX of the EGTL plant as discussed in the previous chapter. It is worthy of note that the EGTL was initially scheduled to be completed in 2008 with a CAPEX of $1.7 billion but was only realised in 2014 with a CAPEX of $9.5 billion. The ORYX GTL plant in Qatar which has the same capacity and operates on the same technology as the Escravos GTL came on stream in 2006 and was realised with a CAPEX of $1.2 billion. For the EGTL plant to operate profitably even with its high CAPEX, it will require a discount rate (cost of capital) of less than 2.51% or a crude oil price above $85/barrel when the other economic parameters are at their base case scenario values.
From the sensitivity analysis as given by the Tornado charts, the profitability of the EGTL plant is most sensitive to the plant CAPEX followed by the crude oil price while the profitability of the NLNG T7 is most sensitive to LNG price followed by the plant CAPEX. Under the prevailing crude oil price regime and cost of capital, the NLNG T7 is a more viable option for monetisation of stranded gas reserves in Nigeria

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**APPENDIX**

*Table A1.1: NPV values used to plot the Tornado chart for the NLNG T7*

| PARAMETER | NPV at "Most likely value", ($, billion) | NPV at "Minimum expected value" ($, billion) | NPV at "Maximum expected value" ($, billion) | NPV change at "Minimum expected value" ($, billion) | NPV change at "Maximum expected value" ($, billion) |
|---|---|---|---|---|---|
| LNG price | 0.885 | -3.400 | 5.170 | -4.285 | 4.285 |
| OPEX | 0.885 | 1.210 | 0.560 | 0.325 | -0.325 |
| CAPEX factor | 0.885 | 3.770 | -2.000 | 2.885 | -2.885 |
| Shipping cost | 0.885 | 1.319 | 0.452 | 0.433 | -0.433 |
| Feed gas cost | 0.885 | 0.887 | 0.882 | 0.0015 | -0.003 |
| Discount rate | 0.885 | 2.417 | -0.291 | 1.532 | -1.176 |
| Tax rate | 0.885 | 1.731 | 0.040 | 0.846 | -0.846 |

*Table A1.2: NPV values used to plot the Tornado chart for the EGTL*

| PARAMETER | NPV at "Most likely value", ($, billion) | NPV at "Minimum expected value" ($, billion) | NPV at "Maximum expected value" ($, billion) | NPV change at "Minimum expected value" ($, billion) | NPV change at "Maximum expected value" ($, billion) |
|---|---|---|---|---|---|
| Crude Oil price | -7.336 | -10.08 | -4.592 | -2.744 | 2.744 |
| OPEX | -7.336 | -7.045 | -7.627 | 0.291 | -0.291 |
| CAPEX factor | -7.336 | -1.661 | -13.010 | 5.674 | -5.674 |
| Shipping cost | -7.336 | -7.258 | -7.413 | 0.078 | -0.078 |
| Feed gas cost | -7.336 | -6.851 | -8.305 | 0.485 | -0.970 |
| Discount rate | -7.336 | -6.113 | -8.231 | 1.223 | -0.896 |
| Tax rate | -7.336 | -7.767 | -6.904 | -0.432 | 0.432 |
| GTL Diesel Premium | -7.336 | -7.533 | -7.138 | -0.198 | 0.198 |
| GTL Naphtha Premium | -7.336 | -7.387 | -7.285 | -0.051 | 0.051 |

13.