Gas Monetisation: A Techno-Economic Comparison Of Gas-To-Liquid and LNG

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Reading, UK

7th World Congress of Chemical Engineering
Glasgow 2005

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1.0 BACKGROUND

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 metres by 2015 accounting for approximately 27% of the total primary energy supply.

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. 'Stranded' gas reserves are either located remotely from consumers or are in the region where the demand for gas is limited.

The drive to monetize large stranded gas resources, coupled with prudent utilization of gas resource and environmental considerations lead to the developments in Liquefied Natural Gas (LNG) and in Gas-to-Liquid (GTL) Fischer-Tropsch technologies. The former is essentially a physical change process converting natural gas to liquid for ease of transportation while the later is a chemical change process yielding naphtha, transportation fuels and speciality chemicals such as lubes and basestocks.

The use of LNG and GTL products offer environmental benefits over other conventional fuels such as coal and products derived from crude oil. LNG and GTL serve entirely different energy markets with different marketing systems, policies and strategies. The comparison between LNG and GTL is the most prominent debate for resource owner, developer and investors alike. LNG has the obvious advantage of being established for the past 40 years and has to-date enjoyed robust growth and has an excellent safety record. GTL on the other hand is an emerging technology on the verge of demonstrating, commercial viability, technology robustness, and safety performance.

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 fuel oils have paved the way for GTL projects. The use of GTL technology spearheaded by Qatar is on the verge of commercial viability and has the potential for becoming a prominent alternative for stranded gas monetization in the next two decades.

This paper examines; the market potential for LNG and GTL products comparing the full chain capital costs for LNG and GTL ventures with a brief assessment of technical and economic performances. It provides a perspective on portfolio diversification, investment and resource development.

2.0 MARKET POTENTIAL

Since its inauguration in 1964, LNG has consistently increased its share of fuel used in the power industry by replacing coal and fuel oil. In recent years LNG has grown from an industry of 80 MMtpa in 1993 to 140 MMtpa today and is set to double in the next 10 years. There has been an unprecedented 90 MMtpa of liquefaction capacity under construction since the beginning of 2004 which is due to be commissioned by 2008. It is estimated that 35 MMtpa will be destined to the North American market which currently imports about 14 MMtpa.

The predominant market growth in LNG is forecasted to be in North America where by 2010 the proposed and planned LNG import capacity is forecast to grow to a staggering 325 MMtpa. This is more than double the current global LNG supply capacity and is unlikely that this demand will materialize or can be delivered by 2010.

LNG in recent years has also penetrated into the pipeline gas market primarily in Mediterranean Europe. It is now poised to take a bigger share of deliveries of pipeline gas in places like the UK, and the US where conventional gas supply is beginning to decline.

Since the dawn of the 21st century, the North American natural gas production is failing to meet the increasing demand and as a result prices of natural gas in the region have risen averaging $4.50/MMbtu since 2000. The average price for the previous five years was $2.25/MMbtu. Contracts concluded in the Asia Pacific sector in the past couple of years indicate that LNG sellers are more willing to sell on a long-term basis at a much lower net-back price than is currently achievable from sales in the US. Pricing around $2.60/MMbtu pegged to $20 crude have been reported in the press.

Consequently, despite the large growth potential in the LNG market the supply-demand balance for LNG in the short to medium term is forecasted to remain very competitive. The potential supply of LNG exceeds demand. This will be particularly true in the Pacific and Atlantic Basins where there are several sources of existing and potential LNG supply. This unbalanced supply /demand situation will also put considerable pressure on the players to develop competitive projects and gain market share while the LNG prices remain fairly aggressive.

In contrast, GTL is still in its infancy. There are only three new generation plants in the execution stage. However, a number of technology licensors and global oil companies are pursuing the development and commercialisation of the technology. The primary market for GTL products is the ever-increasing transportation fuels sector. The current world diesel demand derived from crude refining is enormous at around 28 MMbpd. GTL is considered a very small player in this vast diesel market and such market potential for GTL products can essentially be considered unlimited. In addition with its superior environmental qualities the market for GTL diesel is expected to be unhindered. In addition the GTL diesel is considered to be an important component in meeting the stricter environmental limits which are being continuously introduced within the transportation fuels industry. Given this market potential and superior product quality it is perhaps only a matter of time before F-T -GTL becomes a formidable industry.

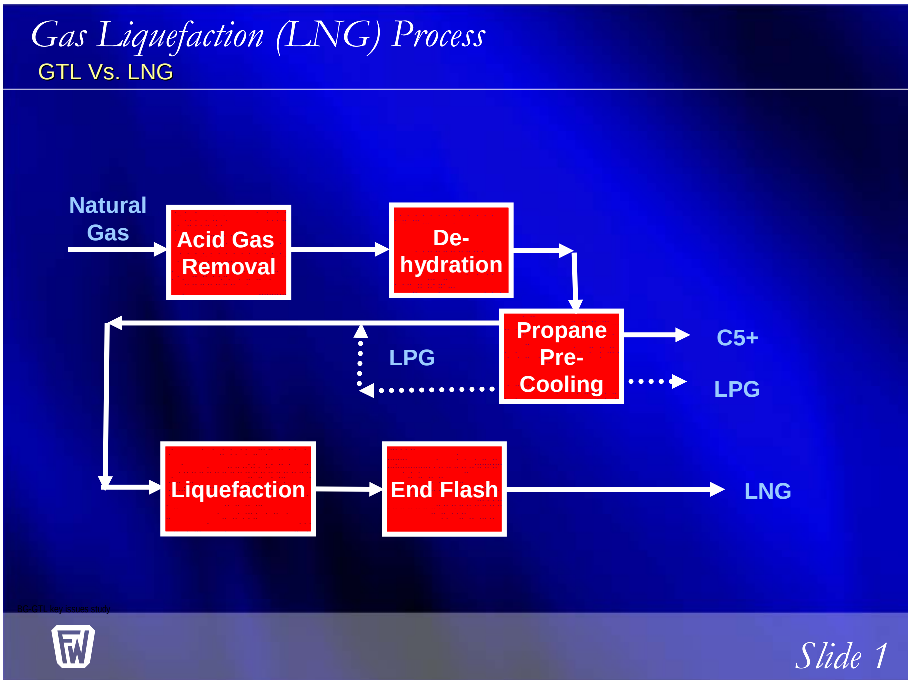
Unlike LNG commerce GTL products are a commodity and do not require long term sales and purchase agreements and can be sold in the open market. Although GTL diesel is environmentally superior to diesel derived from crude oil the pricing mechanism for the GTL products will essentially be similar to that of the refined products which is essentially benchmarked on crude oil prices. There may be some price premium associated with the GTL diesel in the near term depending upon the intended market. Since 2000 the crude oil prices have averaged $25 per barrel corresponding to approximately $28-30 per barrel of GTL Diesel.

The 140 MMtpa of LNG represents approximately 19 billion SCFD of natural gas monetization. Using the same natural gas the amount of GTL diesel produced would amount to approximately 1.5 MMbpd accounting for only 5% of the global diesel market. GTL therefore has a much higher gas monetization potential than LNG.

3.0 TECHNOLOGY OVERVIEW

The LNG process involves a gas treatment plant for removal of sulphur, carbon dioxide, water, and other contaminants. The gas is then cooled to separate the heavier hydrocarbons such as C3, C4 and C5+ components. These heavier components are then fractionated to produce C5+ and LPG products. The lean gas is then liquefied in cryogenic exchangers. The liquefied LNG is then flashed to atmospheric pressures and stored in specialized atmospheric tanks prior to shipping.

A simplified LNG process is shown in Slide 1.



Gas Liquefaction (LNG) Process

GTL Vs. LNG

BG-GTL key issues study

Slide 1

Unlike the LNG process the GTL process involves complex reactions kinetics with the release of considerable amount of heat energy. In addition compared to LNG, which is essentially carried out under low temperature conditions, the GTL plant involves both high temperature (synthesis gas unit) and the low temperature (oxygen plant) operations.

The GTL-Fischer-Tropsch process also involves a gas plant for removal of sulphur, carbon dioxide, water, other contaminants and heavier hydrocarbon components. A GTL–F-T unit comprises of three core technologies:

- **Natural Gas Reforming**

The lean gas from the gas plant is combined with oxygen and reformed to synthesis gas (H_2+CO) consisting of a predetermined mixture of hydrogen and carbon monoxide.

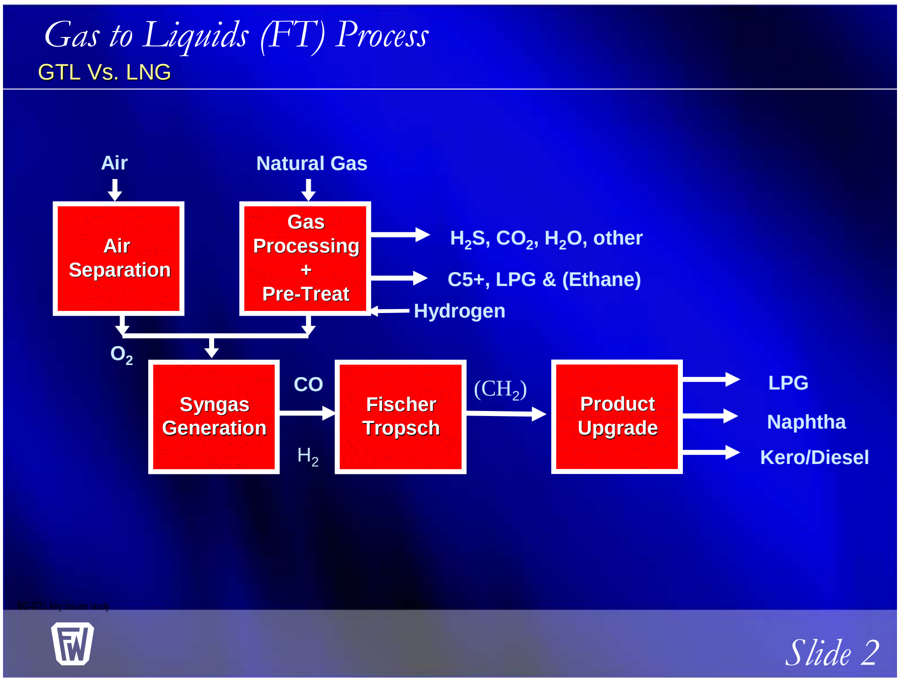
- **Fischer-Tropsch Synthesis**

The synthesis gas is converted to paraffinic hydrocarbon chain (waxes) in a F-T Reactor with the use of cobalt and an iron based catalyst.

- **Product Upgrading**

The long chain F-T hydrocarbon product is subsequently hydrocracked to produce finished products. The primary products include LPG, naphtha (petrochemical feedstock) and transportation fuels such as diesel and jet fuels. GTL is also an efficient process for the production of high quality lubes, waxes and white oils, which are utilized in the food and pharmaceutical industry.

A simplified GTL-F-T process is shown in Slide 2.



Gas to Liquids (FT) Process

GTL Vs. LNG

Slide 2

Some of the comparative aspects of a GTL and LNG a facility processing 1 billion SCFD of gas are highlighted in Table 1 below.

TECHNICAL ASPECT	GTL	LNG
No of complex units	5-8	3-4
No of trains	5-6 integrated trains	2
Sulphur removal (Acid Gas Unit)	Sulphur removal to ppb levels for cobalt based F-T systems. Additional sulphur removal facilities are required	Sulphur removal down to 20 ppm levels. Conventional amine systems adequate for sulphur removal

TECHNICAL ASPECT	GTL	LNG
CO_2 removal	Only requires bulk CO_2 removal.	All CO_2 needs to be removed.
Catalyst Operations	All major units require catalysts which needs periodic replacement	Essentially a non catalytic process
Steam and Power	The facility is utility intensive- and involves large amount of complex integrated steam and power generation systems.	Essentially no process steam generation. Utilizes large GT drivers and compressors.
Product Jetty and shipping	Conventional HC liquid loading and shipping systems.	Requires cryogenic product loading facilities and specialized shipping
Process area plot space	Requires ~ 1 X 1 Km	Requires ~ 0.3 X 0.3 km
Construction	Limited experience, schedule ranges from 38-48 months. Involves several heavy lifts.	Good experience, schedule ranges from 36-38 months
Start-up	Takes long time as units started sequentially.	Start-up relatively fast once the cold becomes available.

4.0 PERFORMANCE

A number of parameters have been used for defining the efficiency of a LNG and GTL facilities. The commonly used bases are Carbon Efficiency (CE) and Thermal (Energy) Efficiency (TE).

Carbon Efficiency is essentially a measure as to how best the carbon atom in the feedstock is utilized to produce the final product. Alternatively this could be referred to as how the production of carbon dioxide, a waste stream, is minimized in the process. The Carbon Efficiency of the GTL process is around 77%. LNG production on the other hand has a Carbon Efficiency of around 92%.

Thermal Efficiency is a measure as to how best the total energy in the feedstock is utilized to produce the final hydrocarbon product. The Thermal Efficiency of GTL is considered low and is typically around 60%, LNG on the other hand has a Thermal Efficiency of 92%.

The GTL technology CE and TE are considered drawbacks of the GTL technology and as a consequence considerable efforts are being made by technology developers to reduce the inefficiencies. Advances in the GTL technology are projected to increase these to 90% and 73% respectively within the next 10 years. These higher predicted carbon efficiencies would be comparable to refineries and LNG plants.

Clearly LNG is the winner in the processing efficiency stakes as for a given quantity of natural gas feed; LNG can deliver more 'Btu's' to the market than GTL.

Carbon Efficiency (CE) is defined as:

$$\left(\frac{\text{Carbon molecules in the final product}}{\text{Carbon molecules in Natural Gas Feed}}\right)\times 100$$

Thermal Efficiency (TE) is defined as:

$$\left(\frac{\text{LHV Of Liquid Final Products}}{\text{LHV Of Natural Gas}}\right)\times 100$$

Where LHV = Lower Heating Value

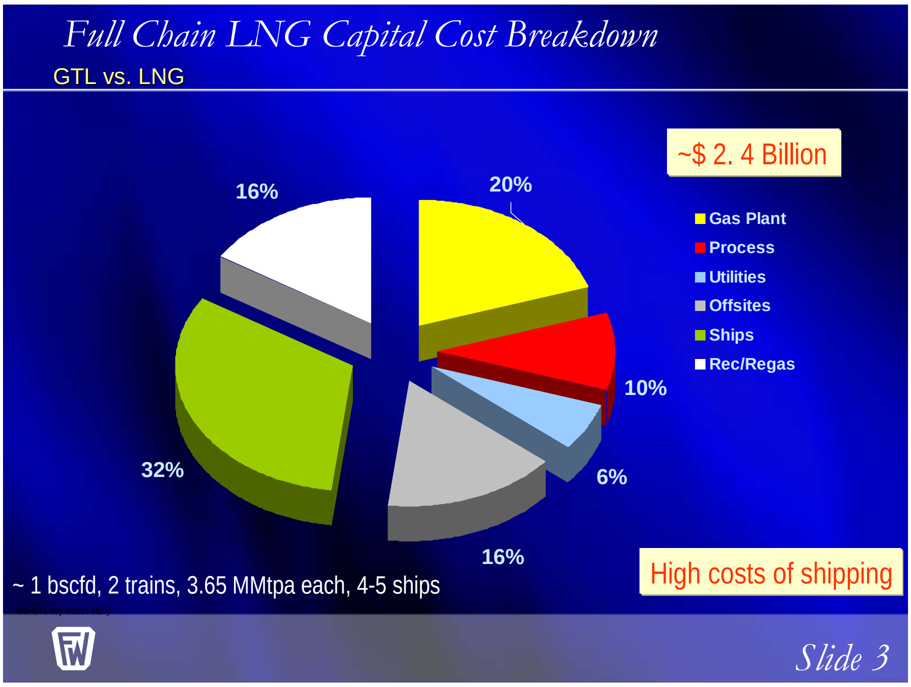
5.0 CAPITAL COSTS

A typical LNG facility processing 1 BSCFD will product approximately 7.3 MMtpa of LNG. It will essentially consist of two trains and would require approximately 4-5 LNG ships. The indicative capital cost for such a facility is estimated at around $ 2.4 Billion. In recent years there has been a considerable drive to reduce the overall costs by increasing the LNG train capacity and reduce the number of LNG ships by increasing the ship capacity.

The capital costs of full chain LNG can conveniently be divided into the following units:

- gas plant
- liquefaction process
- utilities
- offisites
- LNG ships
- receiving regasification terminal

The typical capital cost breakdown of a full chain LNG processing 1 BSCFD is shown in Slide 3.



Full Chain LNG Capital Cost Breakdown

GTL vs. LNG

~$ 2. 4 Billion

~ 1 bscfd, 2 trains, 3.65 MMtpa each, 4-5 ships

High costs of shipping

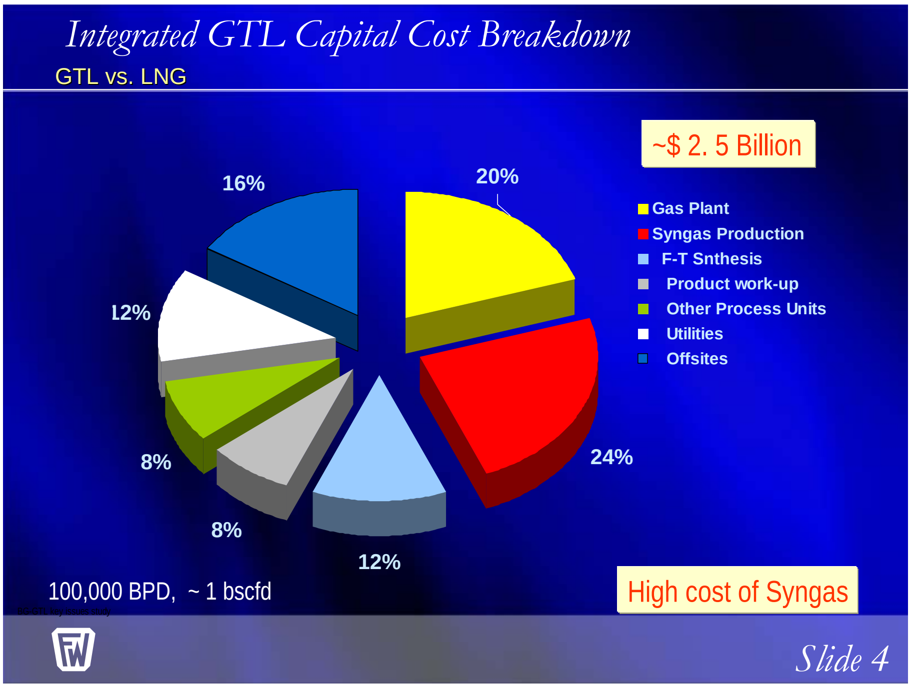
Slide 3

Similarly a typical GTL facility processing 1 BSCFD will product approximately 100,000 BPD of GTL products. Depending upon the technology employed the facility may include about 5-6 trains. The indicative capital cost for such a facility is estimated at around $ 2.5 Billion. Significant developments in GTL technology are currently ongoing and it very likely to see a downtrend in the number of trains and the overall capital expenditure in the near future.

The capital costs of a GTL facility can conveniently be divided into the following units:

- gas plant
- synthesis unit including the air separation unit
- Fischer-Tropsch unit
- product upgrading unit
- other processing units
- utilities
- offsites

The typical capital cost breakdown of a GTL facility processing 1 BSCFD is shown in Slide 4.



Integrated GTL Capital Cost Breakdown

GTL vs. LNG

~$ 2. 5 Billion

🟨 Gas Plant
🟥 Syngas Production
🟦 F-T Snthesis
⬜ Product work-up
🟩 Other Process Units
⬜ Utilities
🟦 Offsites

100,000 BPD, ~ 1 bscfd

High cost of Syngas

Slide 4

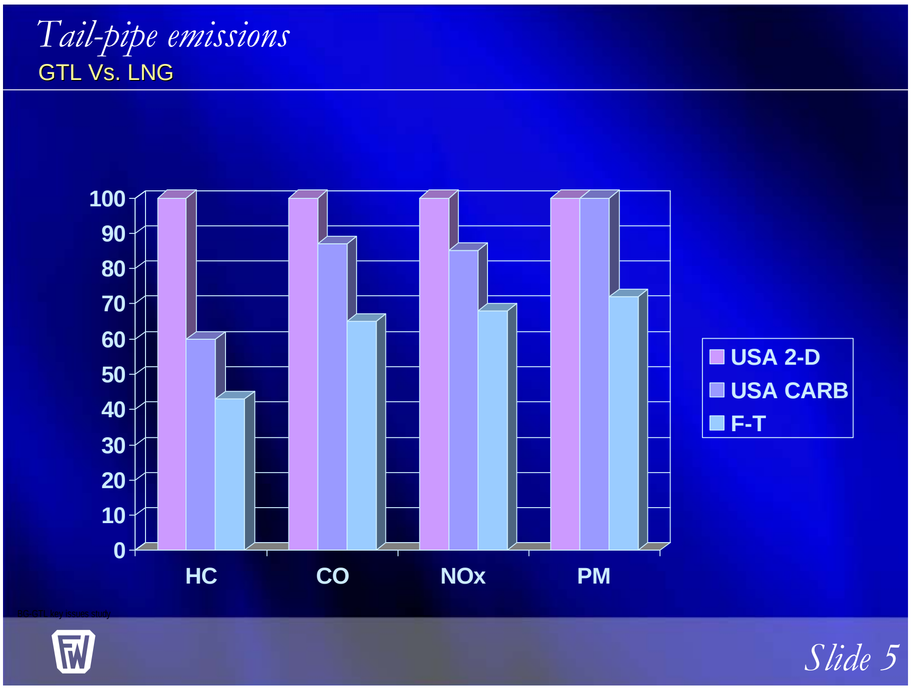
Both GTL and LNG require similar magnitude of capital investment while processing equal amount of natural gas feed. The capital costs of the LNG production facility are considerable less than those for the GTL. However, a significant CAPEX is also required for LNG ships and regasification terminals which are not incurred in a GTL full chain costs.

6.0 ASSESSMENT OF GTL VS LNG

6.1 Product Valuation

It is clear that LNG and GTL products are destined for different energy markets. LNG predominantly caters for power generation, industrial fuel and for domestic and commercial heating and air-conditioning. LNG demand is consequently prone to seasonal changes. The GTL products are destined for use as transportation fuel and petrochemical industry. The pricing mechanism for LNG is based on long term commitment by the supplier and consumer and is linked to crude oil price with a floor and a ceiling. These pricing mechanisms for LNG should, over the long term, result in a flatter and less volatile price regime.

GTL diesel however, is a commodity and will be marketed along with diesel produced from refineries, the price of which is directly affected by the crude oil price. GTL products consequently compete with products from the refinery. The GTL naphtha due to its high paraffin content is an excellent feedstock for petrochemical plants. F-T diesel is characterised by low sulphur (~3 ppm), low aromatics (~1 %), a high Cetane number (~70), and excellent cold flow properties (CFPP <-10 OC). These properties result in improved engine performance and reduced exhaust emissions. This makes the diesel significantly different from diesel derived from crude oil, which is under increasing environmental pressure to reduce its sulphur, nitrogen, olefins, aromatics and metals content. Emissions of unburned hydrocarbons, carbon monoxide, nitrous oxides and particulate matter of F-T diesel are much lower than the USA 2-D and USA CARB diesels. These reductions in emissions are shown in Slide 5. These characteristics of GTL Naphtha and diesel could potentially commend some price premium in certain market locations. These environmental benefits of the GTL products make the GTL technology important for the supply of low sulphur, low aromatic diesel fuels.



Tail-pipe emissions

GTL Vs. LNG

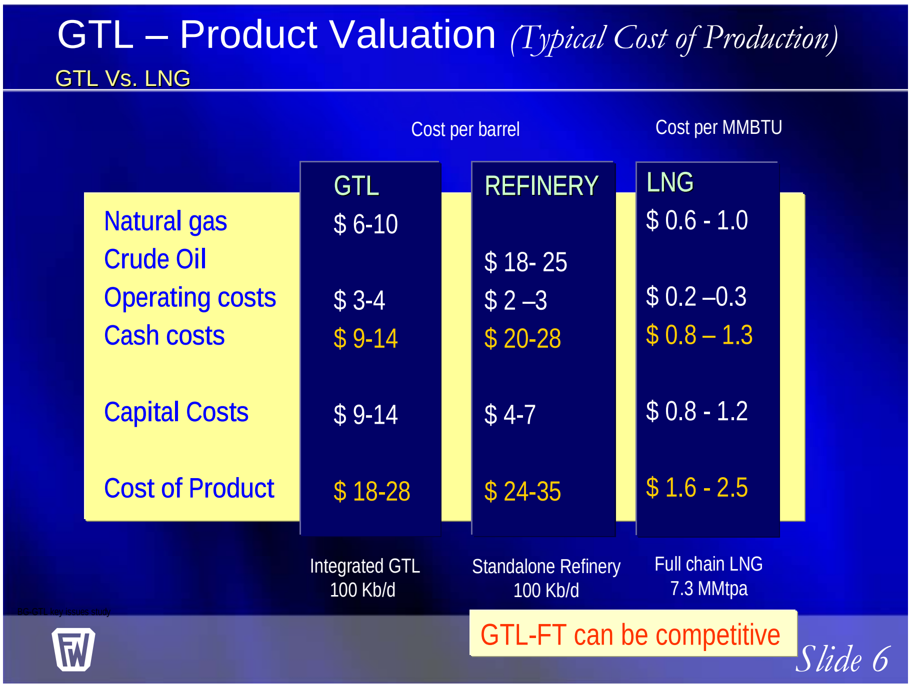
BG-GTL key issues study

Slide 5

6.2 Economic Assessment

Foster Wheeler, in advising their clients, has utilized two methods for assessment of GTL versus LNG as a route to monetisation of stranded gas.

One method for assessing is the cost of producing GTL and LNG products. Slide 6 below compares the cost of producing GTL transportation fuels and LNG at a natural gas price of $0.6-1.0/ MMbtu and refinery fuels at crude oil price of $18-25/ BBL. Since one barrel of GTL product requires approximately 10,000 SCF (10 MMbtu) of natural gas the feedstock cost for GTL corresponds to $ 6-10/ Barrel. Although the operating and capital repayments costs are higher for GTL than for refinery products the overall cost of producing diesel from gas is slightly less than that produced from crude oil. On a similar basis the cost of LNG production is estimated to be between $1.6 – 2.5 per MMbtu.



GTL – Product Valuation *(Typical Cost of Production)*

GTL Vs. LNG

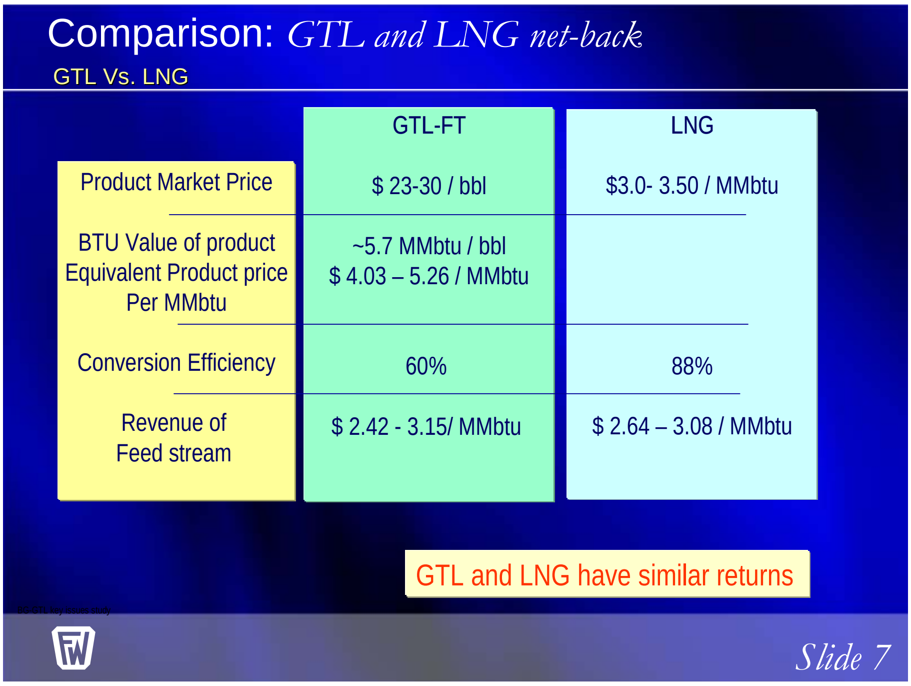
	Cost per barrel		Cost per MMBTU
	GTL	REFINERY	LNG
Natural gas	$ 6-10		$ 0.6 - 1.0
Crude Oil		$ 18- 25	
Operating costs	$ 3-4	$ 2 –3	$ 0.2 –0.3
Cash costs	$ 9-14	$ 20-28	$ 0.8 – 1.3
Capital Costs	$ 9-14	$ 4-7	$ 0.8 - 1.2
Cost of Product	$ 18-28	$ 24-35	$ 1.6 - 2.5
	Integrated GTL 100 Kb/d	Standalone Refinery 100 Kb/d	Full chain LNG 7.3 MMtpa

GTL-FT can be competitive

Slide 6

Since the full chain capital cost and to some extent the operating costs of LNG and the integrated GTL project are considered to be similar the difference in the profitability of the two gas monetizing options is essentially governed by the final value of the products.

A second method for assessing which option to adopt is illustrated by the revenue generated from the same quantity of gas. This is illustrated in slide 7.



Comparison: *GTL and LNG net-back*

GTL Vs. LNG

	GTL-FT	LNG
Product Market Price	$ 23-30 / bbl	$3.0- 3.50 / MMbtu
BTU Value of product Equivalent Product price Per MMbtu	~5.7 MMbtu / bbl $ 4.03 – 5.26 / MMbtu	
Conversion Efficiency	60%	88%
Revenue of Feed stream	$ 2.42 - 3.15/ MMbtu	$ 2.64 – 3.08 / MMbtu

GTL and LNG have similar returns

Slide 7

If a typical current market price of the GTL Diesel and LNG are assumed as $28-30/bbl and $3.0-3.5/MMbtu respectively, and understanding of the amount of feed gas necessary to produce each of the products, the ultimate value of the resource can be calculated to be $2.42-3.15 per MMbtu for GTL and $2.64–3.08 per MMbtu for LNG. Assuming that cash and capital costs for both the systems are comparable, the ultimate value of the resource appears to be very similar based on the above pricing assumptions.

The above product valuations suggest comparable investments for both GTL and LNG. However, the long term pricing mechanism for LNG is not conducive to maximizing resource revenue. The GTL product on the other hand is vulnerable to crude oil prices. However, under the ‘normal’ crude oil pricing range GTL appears to offers better revenue for the resources as GTL products are considered high value products.

6.3 Assessment of LNG and GTL Integration

Compared to standalone facilities, a combined GTL-LNG integrated facility would benefit from reductions in both capex and opex. However, there is very little scope for integration within the process units, and most of the integration options reside in the offsites and utilities area. The most significant integration would be in the selection of machinery drives, and in the optimisation of the power and steam systems between the two plants.

Some of the key integration advantages are outlined below:

- LNG Product Increased: The LPG product from the GTL facility can be routed to final LNG product thereby eliminating separate LPG handling facilities for GTL LPGs. This also enhances the LNG product quality by increasing the heating value of the LNG.
- Steam/Power Utility Synergies: Integration of steam/power systems (where applicable) can be expected to create significant capital savings. Depending upon the overall project definitions Foster Wheeler studies have shown a reduction of $30-50 million.
- General Utilities: Some utility systems such as Instrument Air, Nitrogen and Cooling Water can be supplied with minimal additional cost from the GTL plant to the LNG plant. These allow certain systems to be removed from the LNG plant scope reducing capital cost.

The integration also provides obvious infrastructure, labour and synergies in general facilities such as common administrative and control buildings, fire-fighting, waste disposal etc.

In summary GTL F-T technology is beginning to show commercial viability where as LNG has been well established. GTL facility is more complex, has lower plant efficiencies and is more capex intensive than LNG facility. However the full chain capex of both GTL and LNG are comparative. Due the similar capital outlay the decision to invest in LNG or GTL from a resource owner’s perspective can be challenging. Besides the capital, other factors such as technology risks, plant availability and overall company strategy are also important consideration in the decision.

GTL and LNG serve different energy markets and both are attractive for monetization of stranded gas reserves. GTL products, dependent upon the crude oil price, exhibit slightly higher value per MMbtu than LNG. GTL, offers opportunities for diversification of the product portfolio of organizations needing to monetise their stranded gas reserves.