As Seen In: WORLD ENERGY MAGAZINE VOL. 8 NO. 1 2005

The Economics of Gas to Liquids Compared to Liquefied Natural Gas

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Editor's note: This article is a summary of a more extensive report supervised by Professor Economides and co-authored by Michael Aguirre, Adrian Morales, Susmito Naha, Hakeem Tijani and Leonardo Vargas.

Because natural gas is rapidly emerging as the premier fuel of the world economy, its transportation from sources to markets has become an important issue. The current price of oil is only one factor in this complicated equation. You must also factor in the far larger diversity of natural gas resources and, finally, the transition to natural gas and the implicit decarbonization. All these factors carry considerable environmental, economic and political capital.

The way liquefied natural gas (LNG) or compressed natural gas (CNG) is transported becomes important when considering the volume of gas to be transported and the distance it must travel. These considerations further affect the attractiveness of natural gas reserves, often labeled as "stranded," and their monetization. The size of individual resources is important in the selection of the transportation mode. For relatively short distances (such as 2,000 km) and relatively small loads (such as 500 MMCF), CNG may be preferable to LNG. The latter is the indicated mode otherwise, subjected to individual project economics.

The conversion of natural gas to liquid (GTL) at or near the source represents another way to monetize stranded natural gas. The consumer market that this process is intended to compete in is not the market for natural gas (currently used almost exclusively in power generation). Instead, it is intended to play a role in transportation, namely as a replacement for gasoline, diesel and jet fuel.

What follows is an economic comparison between LNG and GTL from the vantage point of the natural gas producer. The study takes into account the technology and costs of conversion (liquefaction and regasification in the case of LNG; reaction and processing in the case of GTL) and respective transportation.

As an initial conclusion, the distance of transport is important. For a reasonable distance, such as Nigeria to the U.S. Gulf Coast, at a price of oil equal to $30 per barrel, a natural gas price of $4 per MCF or higher would render LNG more attractive; a lower price of gas would make GTL more attractive. At $50 per barrel, this breakdown is $6 per MCF. Conversely, if the price of natural gas is maintained below $3 per MCF, then any price of oil above $20 would render GTL more attractive.

Liquefied Natural Gas

For long-distance travel, LNG is an effective method of transporting large volumes of natural gas. Following some initial processing, the gas undergoes a liquefaction process using some variation of a cascade cycle. The gas liquefies at a temperature of approximately -256°F (-160°C) and is converted to LNG. Converting natural gas to LNG reduces the gas volume to one six-hundredth of its volume at standard conditions.

Specialized LNG tanker ships can then transport it over long distances. A typical modern LNG tanker is slated to transport about 3 billion cubic feet (BCF) of gas. Storage and regasification facilities are required to reconvert the liquid back to a gas that can then be fed into the gas distribution system.

During 2004, about 27 percent of the global natural gas trade underwent the LNG process. This trade constitutes roughly 7 percent of total world production. A large portion of the current LNG transaction occurs from Asia to Japan. The Japanese realized the immense potential of natural gas in their energy mix early on and began construction of LNG facilities in the 1970s. Today Japan imports 47 percent of the world's LNG production.

Because of rapidly increasing demand, the United States is poised to increase its natural gas import capacity – and Canada, thus far the main source of imported gas, can no longer satisfy the emerging demand. Because of this, LNG terminals are becoming an increasingly viable alternative to the United States.

Capital-intensive, highly specialized equipment is involved in the processing and transportation of liquefied natural gas:

- At almost 50 percent of the total investment, the liquefaction plant is the most expensive unit of LNG production.
- Offloading of the LNG requires a regasification terminal. Such facilities cost $500-700 million depending upon terminal capacity.
- And project-specific LNG tankers are complex and expensive. Shipping of LNG is a function of distance of transport and the discount factors. Assuming LNG transporting ships are newly built, the unit cost of shipping ranges from $0.41 to 1.5 per MMBTU for distances from 500 to 5000 miles.

Overall, the total investment can range from $1.5 to $2.5 billion, depending on the market needs and number of ships required.

Worldwide, about 17 LNG liquefaction plants and 40 regasification plants are operating today, and several new plants are under construction.

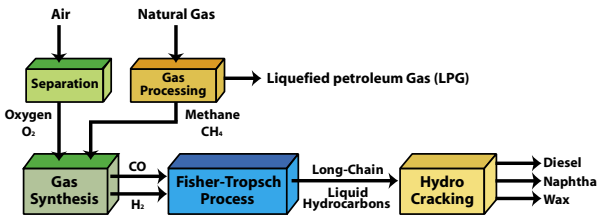

Figure 1: GTL simplified plant schematic

Gas to Liquid

The Fisher-Tropsch GTL (FT-GTL) process, illustrated in Figure 1, is by far the most popular technology for production of synthetic fuels. Beyond the technology, the economics of the GTL process remains the major element in the application of this process. The major factors affecting the economics of the GTL process are the gas price and the capital cost.

An analysis by Hart Energy's *World Refining* magazine suggests that FT-GTL will provide about 600,000 barrels per day (bbl/day) of diesel product by 2015, or somewhere around 3 percent of global diesel demand. More important, fuel produced from the FT-GTL process is practically free of sulfur and aromatics, making GTL fuels a significant player in the "clean" fuels market as the cost to meet future quality requirements of crude oil processing continue to escalate. Ultimately, GTL diesel product will represent about 7 percent of the North American and European ultra-low-sulfur diesel market.

Using GTL fuels is also carbon efficient. A study co-sponsored by ConocoPhillips and the U.S. Department of Energy shows that the carbon dioxide advantages of diesel vehicles burning gas-to-liquids (GTL) diesel fuel overcomes most of the CO_2 "greenhouse gas" penalties of GTL plants, compared to crude-based ultra-low-sulfur diesel.

Economics for GTL plants

To examine the economics of GTL operations we consider the operation of a world-class (65,000 bbl/day) FT-GTL plant at three different prospective geographic locations: Trinidad, Nigeria and Qatar. Each location intends to ship to the United States.

Feedstock. A 65,000 bbl/day GTL plant will consume around 5 TCF of gas during a 20-year life cycle. Availability of large volumes of low-priced natural gas feedstock is critical to the economics of GTL plants. Feedstock prices can vary greatly based on actual production costs and the financial structure of the project. For the purpose of this analysis we will consider natural gas feedstock prices at $0.5, $1.0 and $1.5 per MCF.

- Qatar, with estimated reserves of 900 TCF, holds the world's second largest reserves of gas (after Russia). It has already invested in large LNG facilities. Thus, the marginal cost of gas production in Qatar is very low. Freight on board (FOB) LNG prices of $2.5/MCF indicate feedstock prices of around $1.5/MCF in Qatar.
- Nigeria has fewer reserves of 125 trillion cubic feet but flares 75 per cent of the associated gas produced with its oil, which amounts to an estimated 1.5 BCF per day. Because of new government edicts to stop the practice, flared gas may be available for nearly free in Nigeria, but drilling for natural gas will produce gas at significantly higher prices.
- Trinidad and Tobago has been aggressively developing its natural gas resources. It has the advantage of close proximity to U.S. markets.

Capital costs and operating expenses. A capital cost of $25,000/daily barrel is assumed for this study. For a 65,000 bbl/day plant, this translates into a capital cost of $1.625 billion. This represents a conservative value for a large-scale GTL plant today. Operating costs (excluding feedstock and transportation) is assumed to be $5/bbl.

Transportation costs. The shipping cost for the products of the GTL plants (LNG, diesel and naphtha) is assumed to be the same as for tankers that transport crude oil. Shipping costs in our study are determined from various sources that highlight the high case scenario of transportation from one region to another. The use of high-transportation cost scenarios may have influenced the economic calculations, but due to GTL competing with crude oil for tanker ships, this economic model may account for a competitive atmosphere in the shipping industry. Shipping costs and distances are shown in the following table:

Route	$M/day	$/bbl	$MM/journey	Distance (km)
West Africa to U.S.				
	140	1.20	2.33	10,400
Middle East to Asia				
	162	1.61	3.14	12,000
Persian Gulf to U.S. Gulf Coast				
	216	3.32	6.47	18,700
Persian Gulf to Japan (high)				
	135	1.34	2.61	12,000
Persian Gulf to Japan (low)				
	70	0.69	1.35	12,000

We used a floor cost of $0.50/bbl for a shipping distance shorter than 9,000 km to account for smaller ships used from countries geographically located near the United States and large tankers used when crossing the Atlantic Ocean. This assumption is based on the production capabilities of current GTL plants and the carrying capacity of a tanker ship.

Because of the large cargo capacity of the tankers, which hold some 2 million barrels, the time required to produce this volume with a 70,000-barrels-a-day GTL plant would be roughly 28 days or one month.

Product distribution and prices. The GTL plant is assumed to produce the following products:

- Diesel oil: 44,000 bbl/day
- Naphtha: 17,000 bbl/day
- LPG: 4,000 bbl/day

This product distribution is typical of a middle-distillate process.

GTL products are assumed to be sold at the U.S. Gulf Coast. Product prices in this analysis are a differential based on New York Mercantile Exchange (NYMEX) light sweet crude prices. The diesel price differential is assumed to be similar to that of unleaded gasoline. The price differential between light, sweet crude and unleaded gasoline is about $5/bbl. We assume a $1/bbl price premium for superior quality GTL diesel. Hence, diesel price = crude price + $6/bbl.

The three-year average differential of Gulf Coast naphtha prices vs. West Texas intermediate (WTI) is about $3/bbl. WTI prices are generally $4/bbl below NYMEX light sweet. Assuming a $1/bbl price premium for quality, we can assume naphtha prices as the same as NYMEX light sweet crude prices. Similarly, no differential is assumed for LPG prices. Product prices are maintained as constant throughout the project.

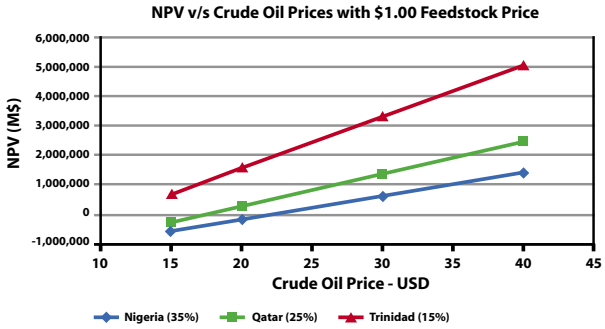

Figure 2: NPV vs. crude oil prices ($1.0/MCF feedstock price)

Results of Economic Analysis

For our analysis, the net present value, or NPV, was calculated for plants at different locations. The feedstock cost and crude oil prices (and hence product prices) varied. The discount factor for NPV analysis and product transportation costs varied by country:

- Nigeria: 35 percent
- Qatar: 25 percent
- Trinidad: 15 percent

The results for $1/MCF of feedstock price are summarized in Figure 2.

At crude oil prices greater than $22/bbl, a positive NPV can be obtained even at a discount factor of 35 percent. For a feedstock price of $1.5/MCF, the required crude price is $25/bbl; for low feedstock prices ($0.5/MCF) a GTL project may be viable at crude oil prices as low as $20/bbl.

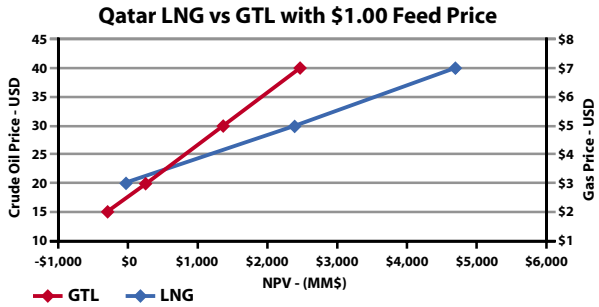

Figure 3: LNG vs GTL economic comparison ($1.0/MCF feedstock price)

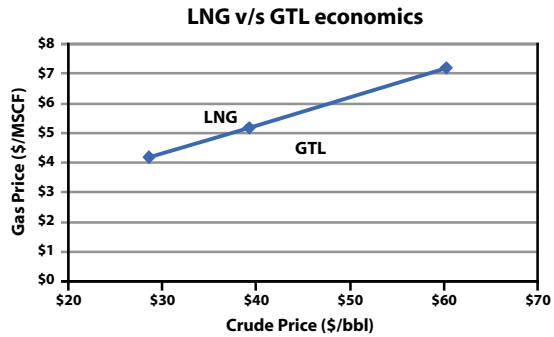

Figure 4: LNG vs GTL generalized comparison

LNG vs GTL

Liquefied natural gas is an alternative means to gas-to-liquid for gas monetization from a producer's vantage point. For example, a great advantage of GTL is the ease of product transportation. Hence the economic viability of GTL plants will be most attractive when compared with LNG projects for gas supply over long distances. We consider here the relative economics of LNG versus a GTL plant in Qatar supplying the Gulf Coast.

LNG cost basis. A world-scale LNG plant produces about 4 million metric tons per annum (MMTPA) and consumes approximately the same amount of gas as the 65,000 barrel-per-day GTL plant (650 MMCF/day). For a long-haul GTL plant, such as the Qatar-to-United States route of 18,000 km, 10 LNG carriers will be required at a capital cost of $1.4 billion. The liquefaction plant is estimated to cost $800 million and the regasification plant $240 million, representing a total capital outlay of $2.44 billion.

Feedstock gas price is assumed to be $1.0/MCF. Operating costs for a 4 MMTPA LNG plant are:

- Liquefaction plant $1.0/MCF of gas processed
- Regasification $0.3/MCF
- Shipping costs $1.0/MCF due to the larger number of ships required for transporting over long distances and the corresponding higher operating expense

Analysis results

The results of the LNG versus GTL comparison are shown in Figure 3. The analysis provides a useful tool to compare relative returns from the two projects. For example, for an NPV of $2.0 billion, a gas price of $4.7/MCF or a crude oil price of $35/bbl are required. A more interesting way to compare the results is shown in Figure 4, where the line represents the relative ratio at crude and gas prices at which two projects have the same NPV. Hence, above this line LNG projects are more attractive, and below the line GTL projects are more attractive.

At crude oil prices of ~$50/bbl and current gas prices of ~$6/MCF, the LNG and GTL projects seem to offer equal economic returns. Lower oil prices may render LNG more attractive, and higher gas prices may do the opposite. What we've observed in the last year makes the dilemma rather painful. ■

Michael J. Economides is one of the most instantly recognizable names in the petroleum and chemical engineering professions and the energy industry.

He is a professor at the Cullen College of Engineering, University of Houston, and the chief technology officer of the Texas Energy Center. Previously, he was the Samuel R. Noble Professor of Petroleum Engineering at Texas A&M University and served as chief scientist of the Global Petroleum Research Institute (GPRI). Prior to joining the faculty at Texas A&M University, Dr. Economides was the director of the Institute of Drilling and Production at the Leoben Mining University in Austria. Before that, Dr. Economides worked in a variety of senior technical and managerial positions with a major petroleum services company.

Dr. Economides has written or cowritten 11 professional textbooks and books, including *The Color Of Oil*, and almost 200 journal papers and articles. Dr. Economides does a wide range of industrial consulting, including major retainers by national oil companies at the country level and by Fortune 500 companies. He has had professional activities in more than 70 countries. He also has written extensively in wide-circulation media on a broad range of issues associated with energy, energy economics and geopolitics. He appears regularly as a guest and an expert commentator on national and international television programs.