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Synfuels "GoLoNG": Light Gas Transport

Storage and Transport of Light Gas and LNG Blends

Abstract

The Liquefied Natural Gas (LNG) industry is well established and growing. Recently depressed Natural Gas prices have slowed production and transport of LNG. Synfuels has developed a process to convert methane and other hydrocarbons to polymer grade ethylene and other high value gases. These normally gaseous high value hydrocarbons can be easily transported as a liquid blend with LNG. The blends can be separated into pure components at the receiving terminal. Conversion of low value natural gas into transportable, high value products gives the LNG owner and operator the opportunity to create and profit from saleable high value products and sell into ever changing market demands. Additional equipment is required, but the cost is relatively low compared to the additional revenue potential.

LNG summary

Supply & Demand:
Natural gas has been used for many decades as a source of heat, especially in the major cities of northern Europe and America, as well as a source of energy for producing electricity. North America has an abundance of natural gas and recent finds have added to the surplus. Other regions in the world, including China and Europe, have limited natural gas supplies but a significant demand for inexpensive energy. In Africa and Southeast Asia, natural gas is plentiful. Moving gas by pipeline under oceans is impractical, but moving it as a liquid on a ship has proven to be practical and often economical.

Transport Capacity:
The Liquefied Natural Gas (LNG) industry has been around for only 40 years. Early ship designs had capacities of 50,000 cubic meters or less, but modern ship designs have capacities ranging up to 260,000 cubic meters. The current fleet is about 300 ships with an average capacity of 140,000 cubic meters. The current carrying capacity of all of the existing ships is about 48 million cubic

meters. The annual capacity of these ships is approximately 800 million cubic meters. In contrast, in 2008 about 390 million cubic meters of LNG was shipped, representing about half of the potential carrying capacity of the existing fleet.

Cost to Transport 1 MSCF:
When gas prices were $10 to $15 per MSCF a few years ago, several contracts for LNG liquefaction facilities and concomitant ship orders were placed. Some of these liquefaction facilities may not be built, but Qatar, notably, is proceeding with completing their liquefaction facilities as well as construction of some of the largest capacity LNG ships ever built. Current prices for delivered natural gas are in the range of $4 to $5. The cost to manufacture and transport LNG from source to destination is approximately $3.50/MSCF, assuming a travel distance of about 5000 km (3100 miles). Shipping costs alone are $0.50/MSCF. Costs include:

Processing Costs include:

- LNG plant capital and construction
- LNG processing fee,
- shipping fee,
- boil off losses,
- regasification costs
- regasification margin.

Variable costs include:

- ➢ exploration and production costs
- ➢ national and local government origination margin
- ➢ pipeline fees
- ➢ local gas merchant margin
- ➢ receiving terminal fees
- ➢ local government's taxes and tariffs.

Variable fees, taxes and tariffs can completely eliminate the slim potential profit of $0.50 to $1.50 on this non-renewable natural/national resource.

Size Matters:
The bigger the LNG carrying or storage container, the lower the ratio of surface to volume. LNG is stored and shipped at -163C (-261 F), which is approximately the boiling point. The huge temperature difference between the storage/shipping container and the environment means LNG is boiled off easily. The less surface area there is with respect to the volume contained means a smaller percentage of LNG is lost to boil off. The lower the boil off, the more delivered cargo that can be sold. Boiloff has been reduced from about 15% to less than 3% by better insulation technology and bigger ships. The largest ships being built today cannot

be accommodated by all receiving terminals, so these must remain dedicated to a few larger receiving terminals until the cost of upgrading smaller receiving terminals is justified by higher gas costs or market needs. Ships smaller than about 150,000 cubic meters can be accommodated by most receiving terminals.

The general technique of producing and distributing LNG is straightforward. Gas is gathered from one or more well sites and transferred by pipeline to a gas processing facility. Contaminants such as sulfur, water, CO2 and mercury are removed and the gas is passed on to a liquefaction facility. There, the gas is refrigerated and liquefied to below its boiling point. The cold liquid gas is then transferred to a large storage tank that operates at or near atmospheric pressure and is typically blanketed with nitrogen. The LNG is then transferred to ship via an insulated pipeline until the ship is filled to capacity. The LNG laden ship sails to the receiving port in several days. At the receiving port, the LNG can be pumped as a liquid to an LNG storage tank and regassified later or it can be regassified immediately using seawater. The gas can then be charged directly to a natural gas pipeline and sent to customers or stored in caverns for later distribution.

Most of the LNG that is produced in Australasia, Africa and South America is heading north to Northeast Asia, Europe and North America. The greatest growth for LNG receiving is in Northeast Asia. Because of increasing natural gas supply within North America and the global recession, the peak prices of natural gas near $15/MSCF have dropped into the $4 to $5 range and are not expected to climb above $6/MSCF for several years.

A New Method to Transport High Value Gases

Synfuels GTX technology produces high value acetylene and ethylene from low value methane. With naphtha as a feedstock, the Synfuels GTX process can produce propylene as well. The chart below shows that the value of natural gas is much less than the value of acetylene, ethylene and propylene. Ethylene and propylene are more than 4 times as valuable as methane based on mass and acetylene is more than 11 times more valuable as methane. The added value of ethylene and propylene derives from the useful and varied products that they can be made into, including polymers, solvents, industrial chemicals, consumer products, detergents, medications and much, much more. Acetylene is widely used in China as a feedstock for production of polyvinyl chloride and used worldwide as a welding gas. Like natural gas, these high value gases (HVGs) cannot be conveyed by pipeline under water. Currently, these HVGs are made from ethane and heavier hydrocarbons, such as propane, butane and naphtha (C2+). HVG manufacturing plants are generally built close to an HVG specific pipeline for distribution or near a chemical conversion plant that can immediately convert HVGs into a liquid or solid product. These HVG production plants are often located in developed countries where the cost of C2+ is much higher than in developing countries, where most of the LNG liquification plants are or will be located. If these HVGs could be manufactured where feedstock prices are low and economically transported in a high value/density state to locations where HVG prices are high, there would be substantial added value for the manufacturer.

Destination Value of Select Gases

Gas	Product Value ($/tonne)
Methane	262
Propylene	1084
Ethylene	1184
Acetylene	3067

The Synfuels GoLoNG Process

Synfuels has a new process that can bring substantial added value to the existing supplier of LNG.

Step 1: Synfuels GTX technology can convert natural gas to acetylene and ethylene. Uniquely, Synfuels can convert methane alone to acetylene or ethylene. There is no competitive process for converting methane to ethylene. Synfuels converts natural gas mixtures or pure components to HVG's without need for purification or separation. Synfuels GTX can use virtually any gas or liquid hydrocarbon mixture to make HVG. For simplicity in this example, we can assume that the HVG is ethylene. Ethylene is a high value commodity gas that is converted to many different chemicals and polymers throughout the world. Low cost methane is upgraded to high value ethylene in the Synfuels GTX process.

Step 2: Ethylene is transported by pipeline to an LNG facility. If the Synfuels GTX facility is sited at the LNG facility, the cost of ethylene transport is minimized.

Step 3: The ethylene is refrigerated and mixed with the LNG. The refrigeration for ethylene may be supplied by the LNG refrigeration system through the addition of a cold box heat exchanger and a low pressure ethylene compressor. The mixture is stored in an LNG storage tank.

Step 4: The mixture is loaded onto a standard LNG transport ship. Synfuels has demonstrated that liquid ethylene is fully miscible with liquid methane. Because liquid ethylene is more dense than methane, a full load of cargo is reached before the storage tanks are full.

Step 5: The mixture is offloaded to a liquid storage tank at the receiving terminal.

Step 6: The liquid mixture is cryogenically separated at the receiving terminal into pure ethylene and pure methane. The liquid mixture at -163C supplies the majority of the cryogenic driving force of the separation. Heat for separation is supplied by ambient water or air. For a 75 vol% ethylene mixture, a 99.9% purity separation can be made for both components using a relatively short 10 stage (theoretical) tower.

Step 7: The ethylene is sent to an ethylene user and the natural gas is added to the natural gas pipeline. In many places around the world an ethylene distribution system will be nearby. In that case, connecting to the ethylene distribution system will be a minor expense.

Steps 1 through 7 also apply to other Synfuels HVG production such as acetylene.

The Economics of G/LNG

At the beginning of 2009, global ethylene production was 126.7 million tones (279 billion pounds) per year. In 2008, 7 million tones per year (tpy) were added. Ethylene production capacity in North America was about 36 million tpy (Mtpy) at the beginning of 2009. By 2013, this number is expected to decrease by 4 Mtpy. In the Mid-East, the supply of ethylene will grow from 17 Mtpy in 2008 to 28 Mtpy by the end of 2012. Between 2009 and 2013, ethylene capacity in China will expand by over 8 Mtpy.

A complicating factor is ethylene oversupply. In 2010, with 145 Mtpy worldwide capacity, demand is less than capacity by about 17 Mtpy or about 15% of capacity. Oversupply places price pressure on ethylene. With an additional 20 Mtpy ethylene capacity by 2013, the oversupply is expected to decrease to 7%. With an increase in total capacity and a decrease in surplus, it is reasonable to assume ethylene prices will increase between 2010 and 2013.

Surplus ethylene puts greatest pressure on high cost producers. With higher manufacturing costs in North America and Europe, the profit from making ethylene is lower. Even so, high cost ethylene continues to be made because ethylene is a gas and is made locally to be used locally.

High Value/Density Cargo:
With Synfuels G/LNG process, low cost methane can be converted to high value ethylene that can be shipped as a mixture with LNG using existing equipment

and facilities. For example, with a destination value of $5/MSCF, the liquid methane on an LNG ship with a standard capacity of 138,000 cubic meters is worth $15.3 million. A mixture of 75% ethylene/25% methane by volume, having the same mass, is worth $58.4 million at destination.

Customer Flexibility:
LNG contracts are generally long term contracts that in bad times, such as now, can lose money for the provider. The ability to ship ethylene with the LNG allows the LNG provider to meet LNG delivery obligations while benefitting from greater profits from ethylene delivery can turn losses into profits. The HVG/LNG mixtures can be varied to meet changing customer demands. If more HVG is needed, the concentration of HVG can be increased (up to about 90 vol% for ethylene or propylene). If less HVG is needed at the delivery point, less is added to the shipment. Ship size can be varied along with HVG concentration, offering greater flexibility to customers. HVG blends can be stored in dedicated tanks and only moved to ship when needed, such as during peak customer needs or when existing HVG production plants shutdown or fail, creating local shortages.

Synfuels GoLoNG technology for Today

Low Cost Advantage:
There are several locations in the Middle East and North Africa where LNG facilities are located nearby ethylene manufacturers. These are generally low cost ethylene manufacturers. In the current market, there is significant excess capacity of ethylene. Loading local excess ethylene supply onto an LNG ship and transporting it to markets where ethylene is more expensively manufactured has the potential of capturing that manufacturing cost difference as additional value to the low cost manufacturer.

There are many locations throughout the world, especially in the Far East, where gas is in short supply. There are several locations in the Far East where LNG receiving terminals are located near ethylene manufacturing sites. Building ethylene production facilities in those locations is expensive, but the need for the chemicals produced from ethylene in those places is great and growing. The value of the Synfuels G/LNG process is to bring the raw material directly to the market where it is needed, at a lower cost than it can be produced locally, and reduce or eliminate the need to construct ethylene manufacturing facilities that manufacture ethylene from imported raw materials.

CASE EXAMPLES

Synfuels GTE and G/LNG for the Near Future

Synfuels GTE produces ethylene from gas and liquid hydrocarbons, but most notably from methane, the compound that comprises the majority of LNG. The Synfuels GoLoNG process demonstrates the practicality and competitiveness of moving that ethylene from low cost production sites to high value destinations with a minimum of new equipment and cost.

Case 1: Synfuels GTE applied to Methane Only

A 215 MMSCFD Synfuels GTE facility will produce approximately 500,000 tpy of ethylene using only methane as feedstock. This is enough ethylene to fill one LNG tanker of 138,000 cubic meter capacity per month with a 75 vol% ethylene blend of LNG. The projected cost of the Synfuels GTE facility is $620 million. Shipping costs at about $50,000 per day (which is higher than average) amounts to $18.3 million per year. The methane is assumed to cost $1 per MSCF. The delivered value of the ethylene, at $1184 per tonne, is $592 million. Thus, ethylene transport costs are 3% or less of the value of the delivered ethylene. This analysis does not allot any of the cost to the methane transport.

The receiving terminal additional costs have been roughly estimated at $50 million to $100 million. These costs include a small storage facility for LNG mixture, a cryogenic separation tower, short term gas storage for ethylene and methane (to establish purity and smooth transfer) and an ethylene pipeline. Assuming $100 million for origination and destination additional capital charges, the project IRR amounts to 49.5%. If the destination capital charge is twice that, the IRR remains high at 43.5%. On top of that, if the cost of delivered ethylene drops to 75% of the expected value or $888/tonne (40.2 cents per pound), the IRR remains 27%.

Ethylene Value ($/tonne)	Added Capital ($MM)	IRR (%)
1184	100	49.5
1184	200	43.5
888	200	27

Case 2**: **Synfuels GTE and G/LNG applied to Methane and Ethane feed

Significant Yield Improvements Developed at Synfuels GTX Plant in Texas: Synfuels recently discovered and has applied for a patent on multiport injection of feed into its pyrolysis reactor. The new design allows for separation of a feed into 2 or more components so that better yields can be achieved. With a feed that contains 28 vol% ethane and 72 vol% methane, the projected yield increases from 42% to 52.2% due to the improved cracking efficiency of ethane for a single feed pyrolysis reactor for a commercial scale reactor (CSR). This results in a yield of 788,500 tpy and is thus an increase of 57.7% for the same volumetric feed rate. If these components are fed to separate feed locations into the pyrolysis reactor, the projected yield increases from 52.2% to 57.4%. The CSR projected yields include a 2% total yield increase over observed mid-scale reactor (MSR) due to improved heat conservation. The new reactor design provides a projected yield of 867,080 tpy of ethylene or an improvement over the single port field design of 10.0%. The following table shows the effect of gas price for the methane/ethane feed, added capital, single vs dual port feed and value of product.

CASE	Single/Dual Port (S or D)	Gas Price ($/MSCF)	Ethylene Value ($/tonne)	Added Capital ($MM)	IRR (%)
A	S	1	1184	200	80.9
B	S	1	1184	300	72.1
C	S	1.5	1184	200	76.4
D	S	1	888	200	55.3
E	D	1	1184	200	91.1
F	D	1	1184	300	81.2
G	D	1.5	1184	200	86.6
H	D	1	888	200	62.7
I	**D**	**1**	**1184**	**100**	**103.8**
J	**S**	**1.5**	**888**	**300**	**45.2**

Case I and J represent probable best and worst cases. Even the worst case presents intriguing opportunity.

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