Non-Traditional Sources and Uses of LNG

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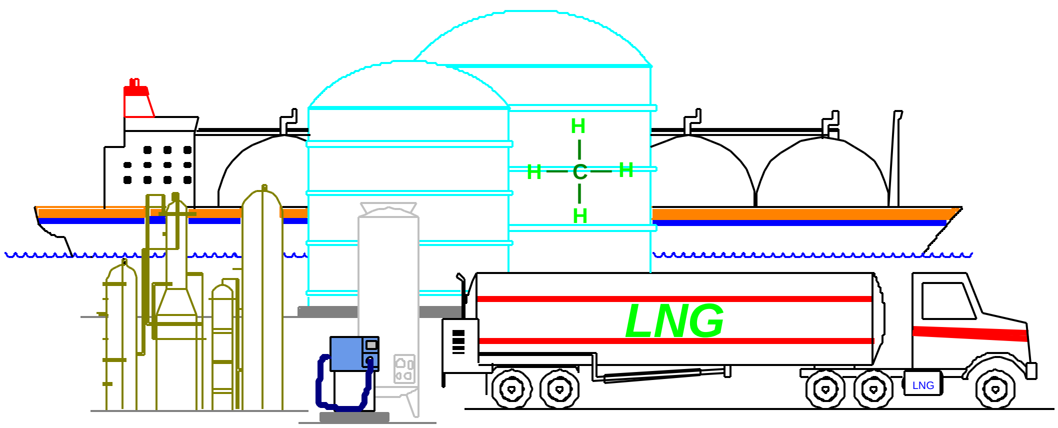

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INTRODUCTION

When one thinks about LNG the immediate thought is generally about the large international export/import projects or the traditional gas company peak shaver. As implied in the title, this paper explores LNG from different perspectives, such as, how else might LNG be produced and what other commercial uses might there be. This paper attempts to stimulate thought about other ways of thinking about LNG.

Non-traditional sourcing of LNG includes a review of all of the aspects of the process from the gas production, transportation (both as gas and liquid), and, particularly, the liquefaction process. The primary goal of non-traditional LNG sourcing is non-traditional pricing, i.e., how to make small LNG project economics perform as much larger scaled programs.

Non-traditional uses include, of course, some discussion of LNG as a vehicle fuel, but the discussion also touches on some of the increasing interest world-wide in energy distribution (fuel and electricity) in rapidly developing countries.

NON-TRADITIONAL SOURCING OF LNG

Gas Source:
The purchase (commodity) cost of gas can vary over a great range. Some gas, because of its location, pressure, and/or composition may have a very low inherent marketability, hence, purchase cost. One of the beauties of LNG is that most of these deficiencies can be overcome in its production and distribution. There is some gas "sitting" in the ground today, not being marketed, or not marketable, for a variety of reasons. Accessing these sources can help deliver the economics necessary for small LNG projects. Some of these sources include:

Distressed and small remote gas fields that are not viable for the traditional production and collection can serve as the supply for small liquefiers. If there is a road servicing the wells then there is a way to get the gas to market.

Abandoned and sealed coal mines provide low cost supplies of high levels of methane. Many of these sources also provide Section 29 tax credits which can yield upwards to $1/mmbtu to the mine owners.

Landfill gas at first blush offers a unique combination of highly desirable attributes - low cost, renewable, easily separable methane and carbon dioxide that is located close to large urban areas. That's the good news. The liquefaction process requires that all components that solidify at liquefaction temperatures must be removed prior to liquefaction. That may require a substantial capital investment. That's the bad news. Landfill gas exists at near atmospheric pressure requiring the gas to be pulled from the landfill under vacuum conditions.

This permits the potential of air 'break through.' Liquefying methane in the presence of oxygen can result in spontaneous combustion. That's the ugly news. Attention to the bad and ugly news can result in a low cost LNG supply very close to the desired market, however.

Gas Transportation:
Small LNG facilities offer a twist on the normal gas transportation thinking. It may be best to place the liquefaction plant near the gas source and/or remote from the LNG need and transport the LNG by truck (or maybe barge). Any feasibility study on a new plant should consider this option and variations on it.

Gas Pretreatment:
Simply stated, gas pretreatment relates to what needs to be "done" to the feed gas to make it liquefiable. This may include compression, filtering of solids, removal of liquids and gases that would solidify under liquefaction, and purification (removal of non-methane gases). Non-traditional gas sources may have much higher (45%) carbon dioxide content than normal pipeline gas (≈ 1%). Landfill gas will need multiple stages of compression, this, interestingly enough, can be used in the gas clean up and purification process. It is easier to purify high nitrogen natural gases in the liquefaction stage, however. Pretreatment is where any oxygen present must be detected and removed.

Gas Liquefaction:
Liquefying natural gas is easy . . . liquefying natural gas cost effectively is the challenge. Liquefaction requires energy. The source of that energy, along with installed capital costs, set the liquefaction cost. Low cost gas means low cost fuel which may mean low cost liquefaction. Low capital recovering may mean low cost LNG. Included in these potential low cost scenarios are:

<ins>"Piggy-Back" plants</ins> are those that overlay on existing cryogenic natural gas processing plants. Most favorable are those that liquefy large quantities of methane as part of normal operation. These would include nitrogen rejection units (see at right) and helium extraction plants. A small side stream of LNG can often be taken from these plants without upsetting the thermodynamic balance, particularly in the evening hours. These also require fairly small capital investments. Cryogenic hydrocarbon extraction and petro-chemical processes also pose opportunities, but one must be very careful when looking at these facilities to assure the process gas is liquefiable.

Nitrogen Rejection Unit

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Stand-alone liquefaction plants[1] (such as the one below) are relatively capital intensive when compared to the other options. There is a vast number of natural gas liquefaction "cycles" (combination of heat exchange and refrigeration) on which to base a design. The U.S. Patent Office is filled with different cycles and variations on themes. The gas being liquefied, however, pretty much takes the same liquefaction path independent of the refrigeration cycle. The dry, clean gas enters a heat exchanger and exits as LNG. Increasing the methane content is accomplished by incorporating a distillation tower and dividing the heat exchange into a series of heat exchanger cores. The design of the refrigeration cycle drives the capital and operating costs of the liquefaction plant. Three basic refrigeration techniques are discussed below: 1) gas compression-expansion, 2) turbo-expansion, and 3) Stirling cycle.

Modular LNG Production Facility

1) *Gas expansion-compression*. This is the basic cycle that cools the household refrig-erator and air-conditions your car. A refrigerant gas is compressed to high pressure and then cooled with air or water causing complete or partial con-densation of the refrig-erant. The refrigerant is then expanded across a restriction causing a sub-stantial drop in pressure and in temperature. The cold refrigerant stream is ex-changed against the process stream liquefying the natural gas. The refrig-erant (now a gas) is then returned to the compressor completing the cycle.

2) *Turbo-expansion*. Pressure let-down locations, such as city gate stations, offer a thermodynamic answer to low-cost liquefaction. Before discussing turbo-expanders a brief review of gas pipeline operations is in order. Gas is moved from the gas field to the gas utility in high pressure transmission pipelines (600 to 1,200 psig). Before the gas can be distributed its pressure must be reduced to typically less than 100 psig at so-called "city gates" or take station. The city gate is an ideal location to

[1] The standards for design and construction of LNG plants may also be changing. See the box at top of Page 5.

utilize a turbo-expander liquefaction cycle because it takes advantage of the wasted refrigeration associated with the pressure drop very efficiently.

A turbo-expander is essentially a centrifugal compressor running backwards. What does that mean? A centrifugal compressor is rotated by a motor (requiring energy). The gas entering the compressor is (relatively) low pressure and ambient temperature. The gas leaving the compressor is (relatively) high pressure and high temperature. What if the unit was run backwards, i.e., expanded, not compressed? High pressure gas (as from a gas transmission line) at ambient temperature enters the expander. As the high pressure gas moves through the expander two very significant things happen: the blades of the expander are forced to rotate because of the flow (generating power and dropping the pressure), and as the pressure drops so does the temperature. The end result is a low pressure, low temperature gas stream (refrigeration) and a rotating shaft (usable horse power). The refrigeration can be used to liquefy a side stream of the high pressure gas. The warmed-up, expanded, gas stream can now be sent into the gas distribution system. The rotating shaft is available to perform any other "work" necessary in the operation.

3) *Stirling Cycle.* The Stirling refrigeration cycle is not new to cryogenics, but it only recently has been getting attention relative to natural gas liquefaction. The Stirling Cycle could easily take a technical paper to describe its operation adequately. It, however, is being viewed by many as the cost-effective solution to small liquefaction plants, less than 10,000 gallons per day. A small Stirling machine would combine the refrigeration and the heat exchanger into a single unit. Stirling liquefiers, once commercialized, are expected to have low capital costs and maintenance costs due to the very few moving parts. The Stirling machine may fit a very important niche in making small quantities of LNG available in many areas of the country.

<u>Local gas company (LDC) peakshavers</u> are feeling the impact of the changing winds of the natural gas industry. What historically was inconceivable, may now be very doable. LDCs are beginning to realize that they are sitting on an underutilized asset. Typically the entire storage has been reserved for the gas company, but experience shows that rarely is more than 50% is needed. Furthermore, the plants were designed for 200 days a year liquefier operation, when in fact, many more days of operation are possible.

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Update on NFPA 59A and DOT Part 193

NFPA 59A, *"Standard for the Production, Storage and Handling of LNG,"* was originally developed in the mid-1960s. It has been routinely reviewed and kept current through the volunteer LNG Technical Committee, of which this author is a member. 59A has published revised editions 8 times in the 36 intervening years.

DOT 49 CFR Part 193, *"Liquefied Natural Gas Facilities; Federal Safety Standards,"* was promulgated in early 1980. Part 193 undergoes a much less intensive review process. By the time of this presentation the first major modification to it may well have been approved. Part 193 is often the "standard of choice" of the Authority Having Jurisdiction.

For the first time since these standards have co-existed there is serious discussion pertaining to the DOT adopting NFPA 59A sections on siting, design, construction, equipment, and fire protection. If adopted, siting of shop-fabricated based LNG facilities would become considerably simpler. Part 193 would also be a more up to date document due to the rigorous and routine review by the LNG Technical Committee.

Reference: *"A Progress Review of the NFPA Petition to the US DOT Regarding the Integration of NFPA 59A into 49CFR193,"* presented at the 1997 AGA Operations Conference, Nashville.

LNG Storage:

A major deviation in thinking in terms of design basis for "base-loaded" small LNG plants is in the storage. Instead of needing 200 days of storage, depending on the storage at the various end-use points, only 5 or 10 days of storage may be needed. This may result in the installation a few shop-fabricated LNG tanks instead of a large field-erected LNG tank (such as the ones below). Since many of these programs will be based on a certain growth over a certain period of time, the program managers can also manage the growth of their storage. It may not be necessary to have all of the storage installed at the beginning of the program.

Shop-Fabricated Tank

Field-Erected Tank

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LNG Distribution:
This dimension of the LNG program, at least, is fairly straight forward. How much is it going to cost to transport LNG from the source to the end-use? Typically 11,000 gallon trailers like the one below carry the LNG. A simple phone call to any of the LNG trucking operations yields a quick answer. The cost is determined by the distance covered and the gallons transported. A key factor in any program is load factor. In the case of LNG trucking, as the load factor on LNG trailer(s) increases the program would probably be best served by owning and operating the LNG trailers independent of commercial truckers. Larger scale programs may begin looking to rail and barge shipments of LNG.

LNG Transport Trailer Leaving LNG to CNG Fueling Station

NON-TRADITIONAL USES OF LNG

Hub & Spoke:
Imagine a developing country, state, territory seeking the ability to rapidly expand its electric grid into the "wilderness" just like rural electrification in the United States earlier in this century. The problem is, oil is expensive (and imported) and/or the closest refinery is extremely far away. Coal is out of the question for a variety of reasons. Hydro, wind, solar, geo-thermal power are impractical or uneconomical. Yet the country has substantial, indigenous natural gas reserves. That's the good news - the bad news is that gas pipeline infrastructure is non-existent, not economically viable, or environmentally destructive. What do you do?

This is the basis of the “Hub & Spoke” concept, where a new natural gas liquefaction plant is built (the hub), over-the-road LNG transportation is provided to support the (new) remote gas-fired power plants (the spokes). The program can be extended to vehicle fuel and satellite gas distribution with the same impact. However, satellite gas distribution with a low load factor can have a detrimental impact on the overall program economics.

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Propane Replacement

Propane replacement is exactly that, whether speaking about local gas distribution (see below) or industrial fuel. This is also a program that allows for fairly straight forward economical analysis. Not every propane program is ripe for LNG. Assuming the economics bear out, LNG programs are simpler to operate and more reliable, especially in the very cold winter climates.

Large Propane-Air Peakshaving Facility

Highly Dedicated, Captive End-User:

There are a variety of potential natural gas users that due to special circumstances could benefit from a small baseload supply of LNG.

A paper mill that is experiencing boiler stack emission excursions from its heavy fuel oil during the middle of the day and must reduce output to stay below allowable emission levels. With the introduction of natural gas in a co-burn role the boiler can maintain 100% plant capacity. Unfortunately the closest gas pipeline is too far away to justify installation of a lateral. Enter LNG.

A synthetic woolen mill burns about 1 mmbtu of gas per day to generate electricity. Historically the plant has been on a fully interruptible gas contract with propane back-up. A review of annual operating costs showed that trucking in LNG to provide year-round fuel was the best choice. The facility, owned by the LNG supplier, not the mill owner, now receives an average of over one LNG truck per day.

Mine haul trucks offer one of the most exciting opportunities for LNG growth. These monster fuel users operate 24-hours per day, operate in a very fixed geography and pay no highway taxes. This is one market in need of new technology, however. As big as these rigs are, there is very little room to support non-conforming LNG tanks. Similarly, there are no 2,200 to 2,500 HP engines to power the rigs. This, too, shall change.

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Vehicular Fuel:

Anyone that has heard me speak or read any of my other papers knows that I will not let a chance to talk about LNG as vehicle fuel pass. Having said that, this paper will focus only on "real" natural gas vehicle (NGV) programs. What is meant by "real"? Real as opposed to tests, pilots, demonstrations, etc., etc. A real program stands on its own economics; it does not require government incentives or environmental mandates to make it work. In other words, it means a lot of vehicles burning a lot of natural gas. What that means is we're not talking about fueling vehicles with compressors . . . we're talking about fueling them with pumps. So what are the "real" programs?

Dedicated long haul is the term used when the same tractors run the same routes week after week. Many Class 8 tractors consume 80 gallons of diesel a day (or more). Quickly thinking about that at 5½ days per week that's about 23,000 gallons of diesel per year. How many cents per gallon saving are needed to justify running on an alternative fuel? This information has been published in a number of places; suffice to say, dedicated long haul can offer opportunities.

Centralized fleet fueling is commonplace in many areas. Different vehicles from different fleets can use these fueling stations be it a "no frills" station like the one at left or like the one at right that is part of a mini-mart.


Card-Access Fleet Fueling Station


Public-Access LNG Fueling Station

The LNG Corridor is an evolving concept where a network of LNG fueling stations is developed over specific high frequency routes such that over-the-road trucks can move with a high level of confidence that fuel will be available to them.

SuperCNG station is the name CH·IV International has given to a new approach to fueling a large quantity of CNG continuously to either a high population of light duty vehicles (taxis and vans) or a large fleet of transit buses. Anyone who has tried to make a large CNG program operate with compressors is well aware of the difficulties realized with continuous capacity, energy consumption during peak hours and inability to fully fill CNG tanks due to the heat of compression. The SuperCNG station has eliminated all of these problems and more. The SuperCNG station is an optimum way of using LNG to produce CNG.

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SUMMARY

There is more activity (at least discussion and conceptualizing) in small tank LNG projects than there has been since the early 1970s; just ask any tank manufacturer. As stated at the beginning, one purpose of this paper was to stimulate thought about other ways of thinking about LNG. A number of topics were touched upon in this paper and probably many inadvertently missed. When one takes into account the completely depreciated LNG peakshavers, Order 636, new utility thinking, new players, new markets, the partnering of gas companies and electric producers, and so on and so on . . . LNG could be a fun place to be over the next decade.

Jeff Beale is the president of **CH·IV International. CH·IV International** specializes in LNG . . . all aspects of LNG. **CH·IV International** has offices in Millersville, MD and Houston, TX. Why **CH·IV? . . . CH·IV** is intended to be read as "CH" Roman numeral "4", or simply **CH_4**; the chemical formula for methane (primary natural gas constituent).

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