The Definitive Guide to

Monetizing North Slope Natural Gas as a Strategic Energy Resource

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Abstract

Currently in Alaska, 8 Billion Cubic Feet of Natural Gas per Day (BCFD) are produced then re-injected into the earth and lost because there is no transportation to market. This huge quantity of rich gas is a natural by-product of all oil production. Synfuels' GTL technology is available today and can reduce and eventually eliminate this waste of natural gas. Synfuels GTL is an American technology developed in association with Texas A&M University and can be deployed in Alaska long before any pipeline can be built to the lower 48. Utilizing the Synfuels technology now, Alaska could produce approximately 200,000,000 barrels of clean burning gasoline per year by processing this wasted natural gas.

When natural gas does not have immediate transport to market such as in the absence of a natural gas pipeline, the Synfuels process can convert that gas to clean liquid fuel, characterized as sulfur free premium gasoline blendstock, jet fuel or diesel. The low pressure process is much less costly to build than other gas to fuel methods or even major pipelines and can be operated economically upstream at the source of the gas and at much smaller scale. This flexibility dramatically reduces potential environmental impact. By-product emissions are only clean water and carbon dioxide. Half of the carbon dioxide can be easily sequestered.

For the Alaska North Slope operations, important aspects of the technology include:

- A small process footprint minimizing environmental impact and enclosure costs
- The liquid product can be combined with oil in existing, underused liquid pipelines. It is more fluid than crude oil and can assist cold crude to flow.
- The liquid product can be slugged in existing pipeline and then directly enter the gasoline distribution system.
- The liquid product does not contain waxes which can plug pipelines
- The process neither uses nor produces toxic chemicals or catalysts
- Equipment is small/simple enough to truck to location or assemble on-site
- By-products are only clean water and CO_2.
- CO_2 by-product can be re-injected into oil wells for reservoir maintenance. The CO_2 assists extraction of oil far better than associated natural gas.

The Need for Synfuels GTL Technology

The world needs easily transportable liquid fuels and demand is only projected to increase. Oil is becoming increasingly hard to find and expensive to produce. Age-old Gas to Liquids technology first developed in the 1920's has proven economical only at huge scale and if the gas resource is priced well below market price. Meanwhile, small sources of gas are either flared or remain undeveloped because building a pipeline to them is economically impractical. Around the world and even in the United States, gas that is associated with oil production is flared, increasing green house gas emissions while providing no useful benefit to the producer or the populace.

Synfuels GTL can succeed where traditional methods fail because it is a simple, low pressure process that produces a liquid fuel which is essentially gasoline. The most competitive technology operates expensively at high pressure and produces major amounts of non-fuel waxes. The Synfuels energy requirements are satisfied by utilizing combustible reaction byproducts to generate all the heat and electricity needed for plant operations. In other words, a Synfuels plant can be energy self sufficient. The process can be built on skids and assembled in prefabricated units at site, making it highly suitable for application to upstream oil production facilities and stranded gas fields that produce high volumes of gas for a relatively short time. Although Synfuels plants can be built economically on gas fields as small as 50 billion cubic feet or less (0.05 TCF), they benefit from economy of scale and can be economically applied to fields containing more than 1 trillion cubic feet of gas. The strategy of the Synfuels GTL process is to make as much liquid fuel with as little pressure, equipment or process complexity as possible. The maximum pressure is below 300 psig. The equipment is mostly carbon steel with only a little stainless steel applied to the internal surfaces of catalytic reactors. The entire process is 4 steps with the only significant recycle stream taking combustible byproduct gases to the first reactor to be used as fuel. Above all, the process is safe, automated and easy to operate and control.

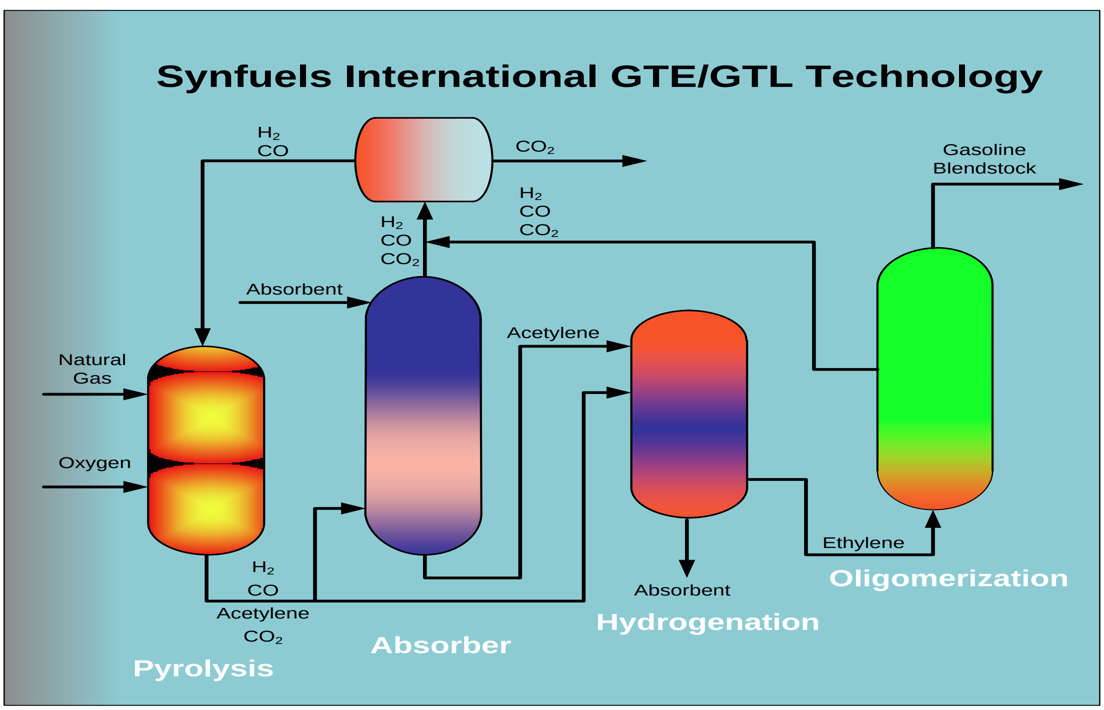
The History of the Synfuels Process

In the late 1990's, while searching for a different way to dispose of organic wastes, professors at Texas A&M, including Dr. Ken Hall, former Head of the Chemical Engineering Department, applied their technique for the conversion of methane to more valuable products. When they realized that methane could be converted to ethylene and gasoline both very valuable hydrocarbons, they decided they needed to prove their theory in practice. In the late 1990's, Texas A&M licensed their technology to Synfuels International, Inc. which raised the funds and brought together the right team to give life to the idea through a demonstration scale pilot plant located near to the university in College Station, Texas. In 2002, after the pilot plant was running, S&B Engineering and Construction, a Houston area company, was hired to evaluate the results. S&B was intrigued by the results of the TAMU team, but the S&B evaluation indicated economic success required further innovation. S&B attracted former Phillips Chief Scientist, Marvin Johnson, to the project in 2004. Dr. Johnson realized that the gas phase acetylene hydrogenation step would not achieve the desired economic results, and urged Synfuels to investigate liquid phase hydrogenation, an idea he had tried many times in his career without success. After only a few weeks of testing, liquid phase hydrogenation succeeded in the lab with excellent results. Installed in the pilot plant a few months later, it worked as well as it did in the lab at a scale 10,000 times greater. Based on these results and projected results for the remainder of the process, S&B completed a Phase II engineering package for Synfuels in 2005. Unfortunately, the final step of the process, oligomerization of ethylene into gasoline blendstock, still proved inadequate. Only about 40% of the ethylene was becoming product. The first step, methane pyrolysis to acetylene, was deemed to be too poorly understood to be scaled up to commercial scale. A well respected engineering consulting firm based in Dallas, identified these as technology hurdles that had to be overcome for the Synfuels technology to supplant existing gas to liquid technology.

The founders of Synfuels knew they were close to success and convinced others, such as AREF Investment Group of Kuwait, that methane to gasoline technology was practical and would be economical. In 2008, AREF brought sufficient funding to Synfuels to build the intermediate scale pyrolysis reactor and continue oligomerization research. At the end of 2008, the multi-million dollar mid-scale pyrolysis reactor was built and tested. In early 2009, the results were in and exceeded the 2007 estimates of the third party engineering firm. The Mid-Scale Reactor, capable of processing 1 Million cubic feet of gas per day worked effectively and efficiently, cutting combustion heat losses in half compared to the pilot scale reactor. Finally, oligomerization catalysts were identified that produced gasoline blendstock yields in excess of 88%. In 2008, a Dallas based process engineering firm was asked to compile an independent review of the Synfuels GTL process for release in May 2009. That report unveils Synfuels' GTL as an unqualified success.

Process Description

The advantages of the Synfuels International GTL natural gas conversion process are simplicity of process design and flexibility of product. Figure 1 depicts the Synfuels process.



Although practiced commercially for long periods in the past, Synfuels has further developed and perfected the thermal reaction which converts natural gas into acetylene, the first isolatable product which is made in the pyrolysis reactor. Internally generated fuel and oxygen are combined in the combustion section of the pyrolysis reactor to produce high temperature in the range of 3000 F to 5000F. Natural gas is injected into the high temperature gas stream wherein it rapidly pyrolizes. The products of this reaction include acetylene and ethylene, as well as hydrogen, carbon monoxide (which are recycled as fuel), carbon dioxide and water (used for cooling or local drinking water). High temperature acetylene is chemically stablized, with a coolant quench to stop further reaction.

<u>The 1-2-3 Synfuels Process</u>

Synfuels Step #1; Acetylene production through pyrolysis

Following reconstitution of natural gas into acetylene and several other gasses using a Synfuels developed thermal reaction, the acetylene is separated from the gas mixture with one of many safe, commercially available acetylene absorbents that retains the acetylene in the liquid absorbent, dissipates heat and releases the remaining gases for further use. At this point the acetylene can be purified using existing purification technology. Acetylene is used for welding throughout the world, but has recently resurged as a chemical feedstock for making vinyl chloride, especially in China.

Synfuels Step #2; Ethylene production via Synfuels technology

Drs. Marvin Johnson (voted Chemical Engineer of the Last Century) and Edward Peterson (the author) invented and developed the patented Liquid Phase Hydrogenation process to convert acetylene into high value ethylene. This had never before been accomplished and at 97% conversion, produces a near perfect result. The ethylene is produced by pumping the acetylene enriched absorbent to the proprietary liquid phase hydrogenation (LPH) reactor which employs a unique catalyst that generates a sustained yield of 96% ethylene. The source of hydrogen is a slipstream of the gas generated in the first reactor. The gas and liquid are forced down through the hydrogenation reactor in the fashion of a trickle bed reactor, promoting good gas-liquid mixing and high conversion with excellent selectivity. Acetylene hydrogenation is a very exothermic operation. Employing the chemical absorber also as a heat absorber in the Synfuels LPH reactor beneficially dampens the severe temperature swings normally seen in the alternative method; gas phase hydrogenation of acetylene. The patented liquid phase hydrogenation process step operates at about 250F and 250 psig, which are considered moderate, safe process conditions.

Ethylene is used widely throughout the world for making polymers, commodity chemicals, medicines, resins, fabrics and many household products. Ethylene has minimal absorptivity in the acetylene absorbent, so it separates readily from the absorbent after being formed. Ethylene is traditionally manufactured from cracking ethane or heavier hydrocarbons, but heavier hydrocarbons have alternate uses and ethane resources are dwindling worldwide. The Synfuels Gas to Ethylene (GTE) process, Step #1 and Step #2 combined, can produce ethylene from natural gas that contains only methane as well as natural gas that contains heavier hydrocarbon components. The patented Synfuels GTE process is an excellent choice for making ethylene when the source of natural gas is more than 95% methane or the gas field is too small to support a traditional ethane steam cracker.

Synfuels Step #3; Gasoline Blendstock through catalytic oligomerization

Fuels such as premium gasoline blendstock and jet fuel are produced by passing the ethylene rich stream coming from the LPH reactor through an oligomerization reactor. The ethylene reacts within the pores of the catalyst to form molecules as large as tridecane (C13), but do not grow larger. Therefore, no waxes or multi-ringed aromatics form. The product normally has an average carbon number of 7 to 9, but this can be modified to meet customer needs. Aromatic content normally ranges between 10 and 45 vol% which can be fine tuned by catalyst selection or reactor operating conditions. The oligomerization reactor operates close to 800F and 100 psig, but the choice of catalyst can change the preferred operating pressure and temperature significantly. The patented Synfuels Gas to Liquid (GTL) process which is Step #1 plus Step #2 plus Step #3, is an excellent choice for making liquid fuels when the source of natural gas is far from a pipeline, associated with oil and flared or re-injected, or stranded due to geological, geographical, political or economic considerations.

Synfuels GTL process, when applied at the North Slope of Alaska, can turn wasted, re-injected natural gas into strategically important easily transportable sulfur free and wax free liquid fuel. This fuel can be transported in existing oil pipelines. The CO2 captured by Synfuels can easily be sequestered through re-injection.

Design Development

The Synfuels design and patented processes have been demonstrated at its fully operational demonstration plant in Texas. The Synfuels GTL and GTE designs were developed from pilot plant data by S&B Engineers and Constructors in Houston (S&B) between 2002 and 2005. The original design developed by Texas A&M University (TAMU) with assistance from Bryan Research and Engineering (BRE) of Bryan Texas, was refined by S&B during this period. Partial oxidation was replaced with pyrolysis to enhance conversion and simplify reactor design and lower cost. The unique and proprietary LPH catalyst and process was developed through S&B by Marvin Johnson, former Chief Scientist for Phillips Petroleum at Phillips' labs in Bartlesville, OK. This replaced the gas phase hydrogenation process that had been used for several years at the pilot plant. In 2005, S&B completed work on a stage 2 (FEL2) engineering package for both a 50 MMSCFD GTL and GTE plant, providing Synfuels with a detailed construction estimate for each plant. Each package includes a heat and mass balance, process simulation, flow diagrams, P&ID's, equipment list, utility estimates, construction estimates, material selection diagram and three dimensional drawings of the complete facility plot plan. S&B also provided a detailed worksheet for estimating construction and operating costs of a plant built on the US Gulf Coast.

In 2005, S&B concluded engineering development for Synfuels. The 50 MSCFD pilot scale process required some further development. The pilot scale pyrolysis reactor was a unique design that had little precedent in US industry. Several parties that showed interest in the

Synfuels process indicated that a larger pyrolysis reactor that scaled up from the small reactor would be necessary to prove the value of the Synfuels overall process. Also, the pilot plant had not been fully integrated such that the hydrogen and carbon monoxide produced by the pyrolysis reactor were not used as planned as a fuel in the pyrolysis reactor. The pilot plant corrected these deficiencies and was successfully integrated in 2007. The results were evaluated by a process consultant firm, which found the integration to be successful following a long term operational run of the pilot plant. In 2008, a 20 times larger version of the pyrolysis reactor was constructed and tested at the pilot plant site. A full scale reactor capable of processing 5 MMSCFD was not practical due to the large quantity of gas required, so a mid-scale reactor was the first commercial scale reactor built by Synfuels and operated at 1 MMSCFD, approximately 20 times the process rate of the small scale reactor. Tested from October 2008 through April 2009, the scale up proved a definite success. The reactor operated at good conversion. A lifetime of thermal cycles have also been conducted safely and without problem. Nominal carbon conversion for lean gas increased from 33% for the small reactor to over 40% for the mid scale rector. Rich gas, characteristic of associated gas, showed conversion above 46%. Work on the mid-scale reactor was completed in April of 2009 as all of the design data necessary for designing a full scale plant was obtained.

The design advantages of the Synfuels technology include:

1) Near zero recycle for efficiency

Most GTL processes such as Fischer-Tropsch, have per pass conversions in the range of 15 to 33%. Those processes must compress the reactant, separate reacted product from mostly un-reacted feed, then recompress once more. A process that gives 15% conversion per pass must process more than 6 times more gas than a process that has no recycle. Gas compression equipment is expensive and a major user of capital and power. The Synfuels design is nearly free of recycle. The four stages in Synfuels GTL of 1) pyrolysis, 2) absorption, 3) hydrogenation and 4) oligomerization yield only about 3% light products that are re-circulated to the pyrolysis reactor. The oligomerization step produces about 5% olefins that are returned to the oligomerization reactor. The Synfuels GTE (Step #1 plus Step #2) and GTA (Step #1 only) processes produce no recycle. Components such as hydrogen and carbon monoxide that are produced in the process are used to generate the heat and power required to operate the process. Eliminating recycle reduces capital and operating costs as well as equipment size, making the Synfuels GTA, GTE and GTL processes more affordable with less environmental impact compared to comparable technologies. Figure 2 represents a typical multi-step F-T process.

In contrast to Synfuels' technology, the Fischer-Tropsch process is complex and energy and capital intensive. It is calculated to be 3.6X the capital cost of a Synfuels plant per barrel of finished fuel product produced.

2) Synfuels low pressure operation for low cost and safety

The maximum operating pressure in the Synfuels process is about 300 psig. Parts of the Fischer-Tropsch (FT) process operate in the 800 psig to 1200 psig range (i.e. reformer). High pressure equipment requires more stringent design and often thicker walls and/or expensive alloys to achieve adequate strength. High pressure operation increases the cost and resource requirements of the standard FT process.

3) Synfuels safe hydrogenation – inherently safe

Synfuels' unique and proprietary liquid phase hydrogenation process establishes the safety of the hydrogenation step by utilizing the acetylene absorbent as a heat sink. Acetylene hydrogenation is highly exothermic. Using the absorbent as a heat sink strongly moderates the temperature increase through the bed. Instead of varying hundreds of degrees as in a typical gas phase hydrogenator, the Synfuels LPH reactor temperature rise is normally about 60F. Run under comparable conditions, temperature increase for a gas phase reactor would be more than 400F and as much as 800F. As the reaction rate increases with temperature, such high reaction temperatures would lead to run away heating that damage the catalyst and could damage the reactor as well. Run away heating cannot occur in the Synfuels liquid phase reactor.

4) Synfuels static catalyst beds for simplicity

Some FT processes use fluidized catalyst beds or moving catalyst beds. Fluidized beds generally lead to improved homogeneity in product composition, but are more difficult to design, build and operate. Typical problems include: catalyst agglomeration due to waxy deposits, narrow range of particle sizes required for proper bed fluidization, difficulty in obtaining even fluidization and reactivity across fluid bed, catalyst attrition and carry over into product, and narrow operating range limiting turndown or turnup.

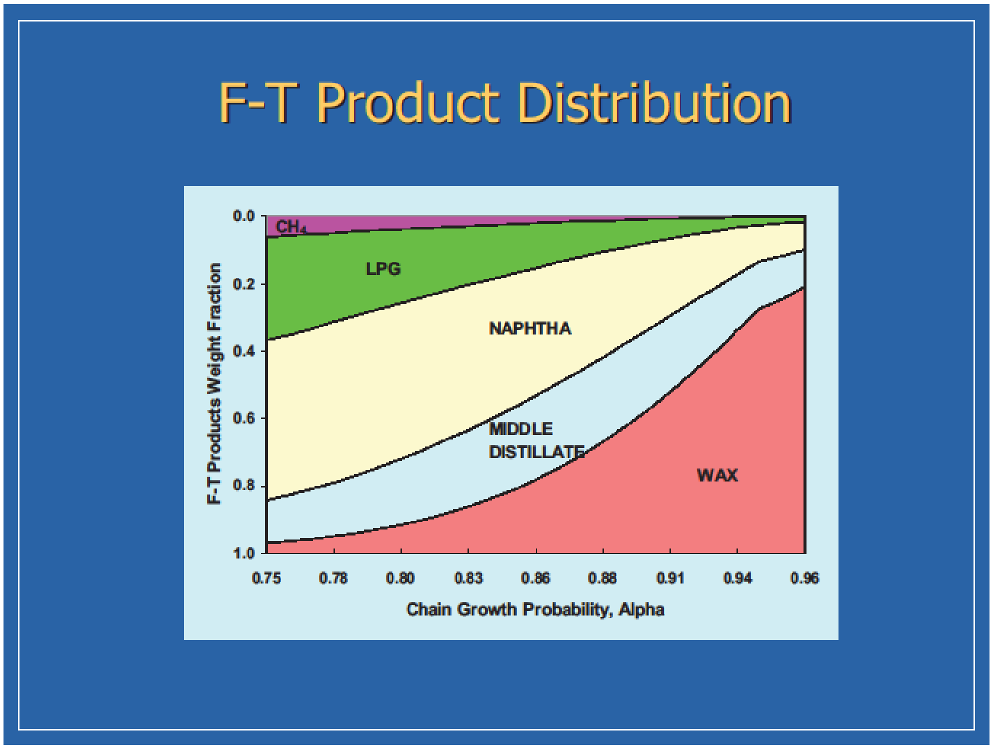
The oligomerization reactor can benefit from being a fluidized design, but our goal of simplicity in operation and lower costs have led us to choose a multiple section fixed bed design. Moving catalyst in pipes and other process equipment leads to catalyst attrition. The powdery catalyst that results can be very difficult to separate from products and can lead to catalyst infiltration into downstream process equipment followed by equipment damage as occurred at the ORYX Fischer Tropsch GTL plant in Qatar. At the very least, catalyst attrition and loss requires replacement of the catalyst more often. Synfuels does not utilize moving or fluidized catalyst beds in any part of its process.

5) Standard materials of construction for simplicity

High pressures and temperatures for process equipment often require high strength steel alloys for construction. The Synfuels process equipment is mostly made from carbon steel except for the small pyrolysis reactor, which is made from a common grade of stainless steel and the hydrogenation reactor, which is internally lined with stainless steel.

6) Minimum byproducts for reduced environmental impact

Traditional Fischer Tropsch (F-T) processes produce as much as 70% and normally about 50% soft and hard waxes. A typical product distribution published by Technip at the 2008 International Gas to Liquids Conference in London is shown in Figure 2. These waxes are converted to useful fuels by thermal cracking, isomerization and other additional process steps that reduce the cost effectiveness and increase the environmental impact of the F-T process while increasing its complexity. The Synfuels process does not produce by-products other than water and CO2.



7) Proven scalability for multiple applications

Recent successful tests of the first Synfuels commercial scale pyrolysis reactor have shown that the overall process can be scaled up to any full size configuration. The pilot scale tests were scaled up from lab scale information and known scaling parameters. The pyrolysis reactor, with little published scaling data, scaled up from the pilot plant to commercial size without incident or surprise, other than it performed better than anticipated.

<u>Consistent Performance</u>

Pyrolysis Reactor Scale-up

Operation of the one million standard cubic feet of gas per day (1 MMscf/D) mid-scale pyrolysis reactor (MSR) and the original pilot scale reactor (50 Mscf/D) using the same pipeline quality lean natural gas allowed the third party engineers to compare results and the effect of heat conservation on methane conversion to acetylene. Both reactors were run with richer gas to compare the effect of richer gas on conversion. These results were reviewed and assessed by the third party engineering firm who concluded that:

1) The mid-scale reactor (MSR) operated for 7 days continuously on lean gas

2) During that run, the average carbon based conversion was 39.9%
3) Operated on other occasions, the MSR conversion held at 41.2%
4) Richer feeds lead to higher conversion
5) Conversion of carbon increases linearly with increasing richness

The results and the duration of operational testing were deemed sufficient for commercial viability conclusions. The Synfuels GTE & GTL testing phase has continued for several years. Test duration is governed first by the time required to draw clear conclusions from test data and second by the cost of plant operations. The verified test results are shown in the following graphs and figures and are taken directly from the third party engineering report.

The following graph shows the effective, consistent, continuous conversion of natural gas made essentially of methane with a carbon number of 1.0.

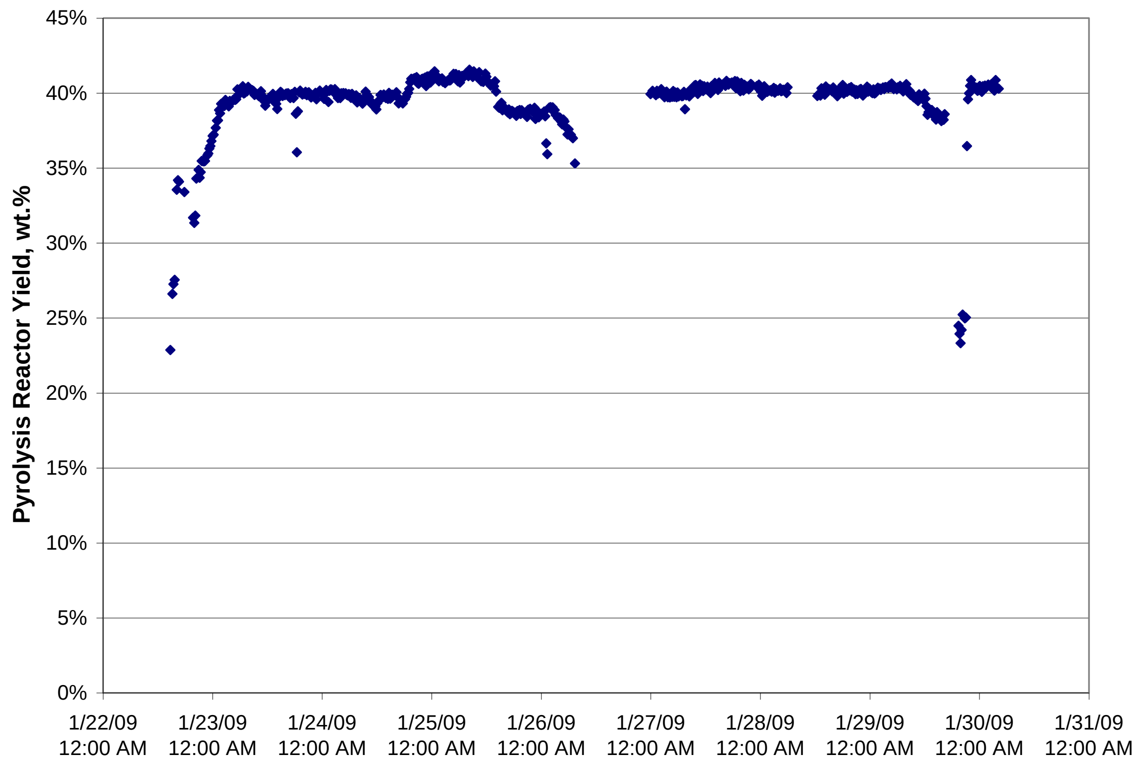
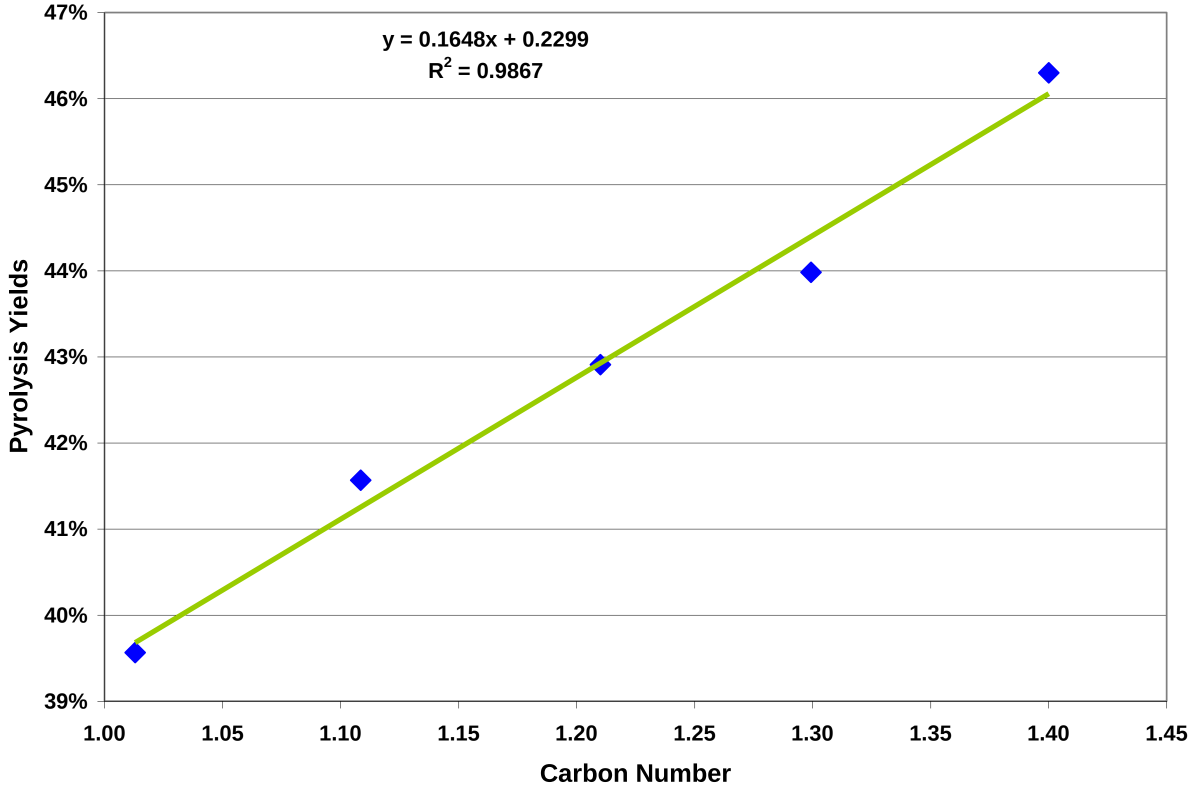


FIGURE 8

RELATIONSHIP BETWEEN PYROLYSIS YIELD AND FEED CARBON NUMBER



Taken together, independent experts considered the effect of reduced heat loses and calculated the following improvement from mid-scale reactor results shown in Figure 8 above at 1 million scf/D to expected results below in Table 5 for a commercial reactor operating at 5 MMSCf/D.

TABLE 5

PYROLYSIS YIELD IMPROVEMENT POTENTIAL

	Pilot Plant	***Mid-Scale***	***Commercial***
Design Pyrolysis Gas Flow Rate(1) (Mscf/D)	50	1,000	50,000
Actual Pyrolysis Gas Flow Rate(1) (Mscf/D)	24.7	454.8	50,000
Short-Term Pyrolysis Yield (Wt.% Carbon)	34.0	41.2	45.3
Long-Term Pyrolysis Yield (Wt.% Carbon)	N/A	39.9	44.0(2)
Scale-Up Ratio	1	18.5	202.8
Short-Term Conversion Increase (Wt.% Carbon)	--	7.2	4.1
Heat Loss (% of nominal burner duty)	42.7	17.7	8.4

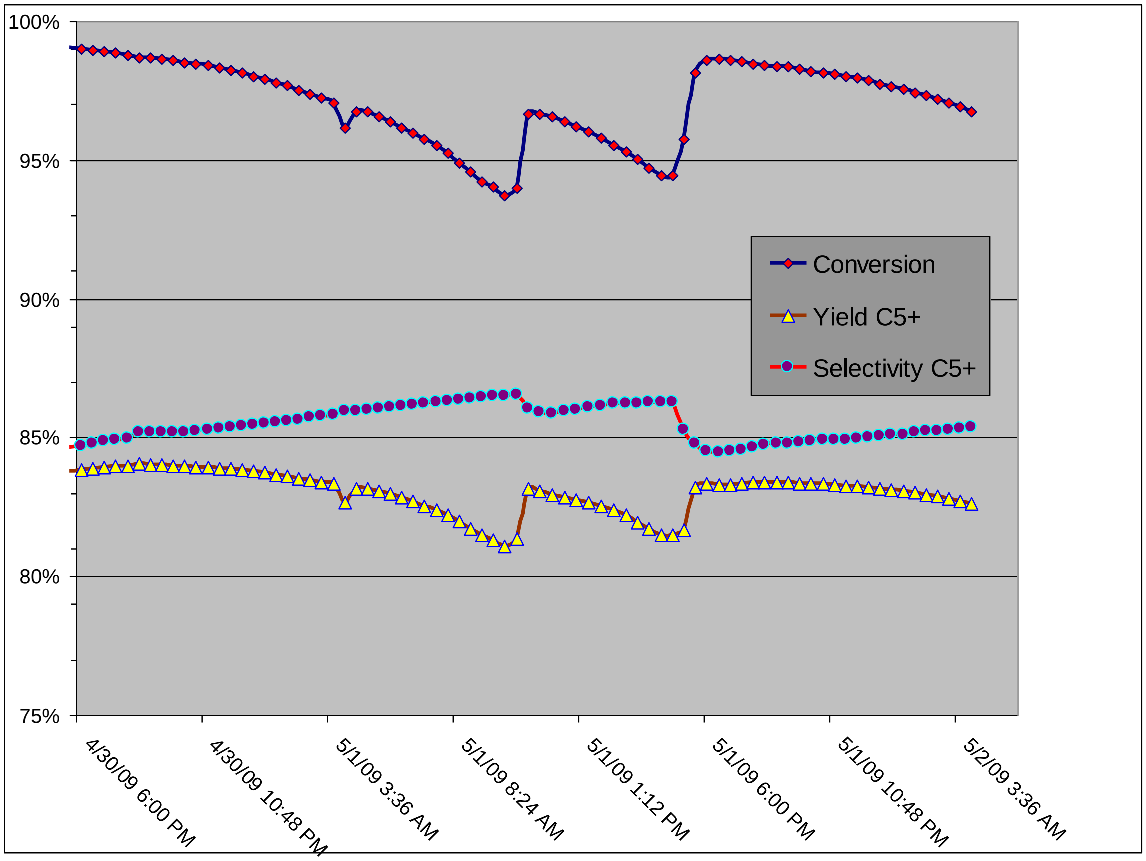
Notes:

1. Pyrolysis gas carbon number of 1.0.
2. Long-term commercial yield obtained by de-rating the short-term yield by 1.3 Wt.%.

The above results are for lean gas only and conversions were reduced by 1.3% from actual measurements to reflect what the third party engineering firm expects can be obtained in the first plant design before short term test results can be realized in long term operations. Normal design and operating improvements, achieving what has already been shown in the mid-scale reactor, will lead to conversions of methane to acetylene starting at 45%, increasing to more than 50% with richer natural gas typical of associated gas.

Liquids Production

The Synfuels liquid product is made in the oligomerization step, where ethylene and small amounts of other olefins are linked together to make gasoline molecules containing 5 to 13 carbon atoms. Prior to 2008, the catalysts and conditions we employed produced only about 40% of the desired product. The rest was lost to production of ethane, propane and other small molecules. In 2008 we obtained and tested newer commercial grade oligomerization catalysts that worked well with non-ethylene molecules. Immediately, conversion jumped to 70% from 40%. Currently, in our manually operated test rig we have achieved 88 percent conversion of ethylene to C5+ in a single pass. Small olefins such as propylene and butene make up from 4 to 10% of the product. Recycling these small olefins through the reactor will boost C5+ production to between 87 and 93%. Results of a recent, industry standard 4 day run is shown in the figure below. Conversion to C4+ is already above an average of 95%.



Product quality information

The nature of the Synfuels liquids product depends upon the oligomerization operation. The product composition depends principally on the catalyst chosen, but also on operating conditions such as pressure, temperature and reactant flow rate. Having achieved high rates of conversion to liquids, we continue to study the effect of system perturbations on the chemical quality of our products. In addition to complete chromatographic analyses, we are running D86, Reid Vapor Pressure (RVP) and specific gravity analyses for each unique sample at established and certified external petroleum labs. To date, we find that we can produce products with average carbon numbers of 7 to 9, with aromatic content of 10% to 45% and with RVP's of about 2 to more than 10. It is important to Synfuels that we are able to alter product composition to meet the product quality and specification needs of our clients.

Comparative Technologies

A large quantity of natural gas can be moved in the gas state from a gas production facility to the user by multiple means. The Alaska oil pipeline, between the North Slope and the southern Alaska distribution site, is designed to transport 2.2 million barrels a day of crude oil. Currently, the pipeline is operating at about ¼ capacity, so additional liquid load is not a concern. Some have postulated that gas and liquid could be moved through the same line. That is impractical, because moving gas and liquid in the same line causes liquid surging and rapid pressure swings in a chaotic manner through the length of the pipeline that would lead to pipeline tears and breaks. The only safe and effective way to move gas from the source in far northern Alaska to the south coast is by pipeline. Moving it as a gas requires a new pipeline be constructed. Moving it as a liquid allows the current pipeline to be used, with substantial cost and environmental savings.

Gas Pipeline

Despite their simplicity, pipelines are highly capital intensive. Laying a pipeline is costly, with a cost split roughly evenly between materials and labor. In addition provision for compression stations, which are necessary for mass transport over long distances, can contribute 40% of final installed capital cost. Once established, the operations of a pipeline system can cost 5% of the fixed capital per year. As a rule of thumb, capital cost of $1 million per kilometer can be expected for new land-based pipelines. The capital cost is about $2 million per kilometer for new undersea pipelines including compressor stations. When built, the annual operating cost is typically about 5% of the installed capital. Laying pipelines through difficult terrain will cost substantially more than this. The 800 mile, 48 inch diameter Alaska oil pipeline cost $8 billion to build in 1968, or $10 million per mile. Based on the consumer price index in 1968=34.1 and in April of 2009 = 211, the cost to build a second Alaska liquid pipeline would be approximately 50 billion dollars, or $62 million per mile.

The cost of constructing gas pipelines in easily accessible locations in the US is represented by the formula:[1]

$/mile = 563,000 + 35,600*D, where D is the diameter of the line in inches

According to this formula, the cost of a new 800 mile gas pipeline in the continental US would be 1.8 billon dollars. Adding in compressors increases this to 2.1 billion dollars or more, depending on the pipeline pressure. For Alaska, construction costs can be 5 times or more than they are in the lower 48. This does not include cost of delays due to exceptional construction conditions, environmental regulations and environmental terrorism. The actual cost of building this pipeline could range up to 32 billion dollars according to recent published estimates. On January 5, 2008, Governor Palin announced that the Canadian company TransCanada Corp., was the sole AGIA-compliant applicant.[8][9] On August 27, 2008, Governor Palin signed a bill into law giving the state of Alaska authority to award TransCanada Corp. 500 million dollars in seed money and a license to build and operate the pipeline to transport natural gas from the North Slope to the Lower 48, through Canada. With strategic employment of Synfuels GTL technology, this pipeline may be an unnecessary capital expense which would also carry enormous environmental impact.

LNG

Liquification of gas at the source eliminates the need for a pipeline. Large terminals have been built around the world. Colder temperatures in northern Alaska would make heat conservation and gas liquification easier. The colder temperatures also make navigation of the waters risky. Although the waters near Prudhoe are considered ice-free about 70 days a year, typically from August through September, there are years when the bay stays filled with ice. Getting LNG

[1] Gas Usage and Value, Duncan Seddon, PennWell CO,2006

barges into and out of Prudhoe Bay would never be guaranteed. Building an LNG terminal in the marshy, unstable ground near Prudhoe Bay has never been seriously considered.

CNG

Compressed natural gas can be stored in long cylinders at pressures near 4500 psi, or 300 times atmospheric pressure. Although not a liquid, the gas is shipped by ocean going craft that would require clear water ways. Therefore, CNG is also impractical for monetizing gas produced in northern Alaska.

LIQUID PRODUCTION (GTL)

Fischer Tropsch Technology

Fischer-Tropsch technology dates from the 1920's. Carbon containing feedstocks are reacted with oxygen to form first carbon monoxide and hydrogen, and then reacted over catalyst to form primarily linear alkanes that share many characteristics with crude oil. It is very waxy and is solid at room temperature. The gasoline fraction of syncrude has a RON (Research Octane Number) of approximately 20 and is improved by isomerizing and reforming this fraction. The diesel fraction has a density that is below the minimum for most specs, and the high acid number, indicating significant presence of carboxylic acids, warns of higher than normal corrosivity.[1]

Fischer Tropsch Economics

Robertson[2] completed a work that was commissioned in order to analyze the GTL options for Alaska's undeveloped gas fields in the North Slope, which are estimated to contain 38 TCF of gas. The complexities in this analysis (such as location factors and location options) make a direct comparison with the analyses presented for Synfuels process difficult. The salient points of the analysis are given in Robertson's figure 10 - 10. This chart compares the capital charges to operating charges for several variants, including Syntroleum's air based FT technology. The operating charges are high as a result of the extreme environment. The results shown in his figure indicate that there is little difference between the various options studied apart from the controlling technology. Robertson believes that Syntroleum significantly lower costs as a consequence of the use of air enhanced nitrogen- diluted synthesis gas. However it is Seddon's[1] opinion that Robertson's analysis does not take full account of the extraction costs from FT product streams diluted with nitrogen from the use of an air based process. Seddon states his experience the consequence of high nitrogen content is to require downstream vessels to be considerably larger. The products are more difficult to fully extract from abundant diluent in streams. This increases the overall costs and Seddon states little if any cost savings results.

One aspect of the studies done into the use of GTL on Alaska's North Slope is the question of transporting the product to market. Crude oil from Prudhoe Bay oil field is moved by pipeline facilities. The crude oil is heavy, so the question arises as to the suitability of using the existing pipeline to move the much lighter and waxy GTL products.

[2] Robertson, E.P., INEEL (Bechtel), available on the Web site of Alaska Dept. of revenue and summarized in "North Slope GTL Opinions Analyzed, OGJ, January 31, 2000, p.74.

Another report that originated in 1996 from Bechtel[3], indicating that 8820 bpd of syncrude could be produced from 100 MMSCF/D. This does not include the further processing (cracking, reforming, hydrogenation) to convert the syncrude to useful products, where 55% of the original product volume is retained (4850 bpd). The capital cost was $415 million and produced product at $23/barrel when the CIP was 154. In today's prices, the plant cost and product cost to manufacture would be $568 million and $31.5/barrel syncrude. This cost does not include the cost of the finishing, which according to Ratan[4], is approximately a third of the capital cost. That would bring the manufacturing price of finished product to $48. Ratan also presented an economy of scale assessment [5] for FT production from 10K to 150K bpd that shows below 20K bpd, the total cost of producing a barrel of FT product can exceed $100, although break even costs are approximately $47 for a 50K bpd plant. The data suggest a $20/bbl increase in product cost of FT finished product for a 20 K bpd plant over a 50K bpd plant.

This is much more in line with the cost per barrel presented by Shell and Synthol, both large projects, where at zero gas cost; the finished product cost manufacture is $42 to $49 per barrel in 2004 prices. [6]

Recent evidence supports the lower production estimates and higher cost of Fischer-Tropsch. During the six months to December 31, Oryx [A Sasol / Qatar partnership] achieved an average production rate of 9 000 bbl/d, and operated stably at 16 000 bbl/d for December. On single days, the plant was also able to achieve production rates of up to 20 000 bbl/d. The design capacity is 34,000 bpd but this is not thought by Sasol to be unachievable after spending an estimated $250 million beyond the original budget.

A typical cost scale factor for building plants of different sizes is 0.7. That means that a plant that is built to produce twice as much product as another will cost only 62% more to build. This is the result of the equation:

$$\text{Cost factor} = (\text{production increase})^{0.7}$$

On the other hand, a plant that produces half as much will cost 62% of the full size plant. Therefore, an FT plant that costs $3.55 billion and produces 50,000 bpd[7] will have a 2,000 bpd scale down cost of $373 million.

Synfuels Process Economics

The Synfuels technology is described earlier in this paper, but it is important to repeat that it produces no waxes and requires little or no recycle. The Synfuels economics are based on a very complete phase II engineering design and its technology has received third party due diligence verification in May of 2009.

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[3] Choi, Gerald N., Design/Economics of a Once Through Natural Gas Fischer-Tropsch Plant with Power Co-Production

[4] Technip, Executive Briefing, 2004 International GTL Conference.

[5] Technip, Executive Briefing, 2004 International GTL Conference, p.18-19.

[6] Gas Usage and Value, Duncan Seddon, PennWell CO,2006, p. 231.

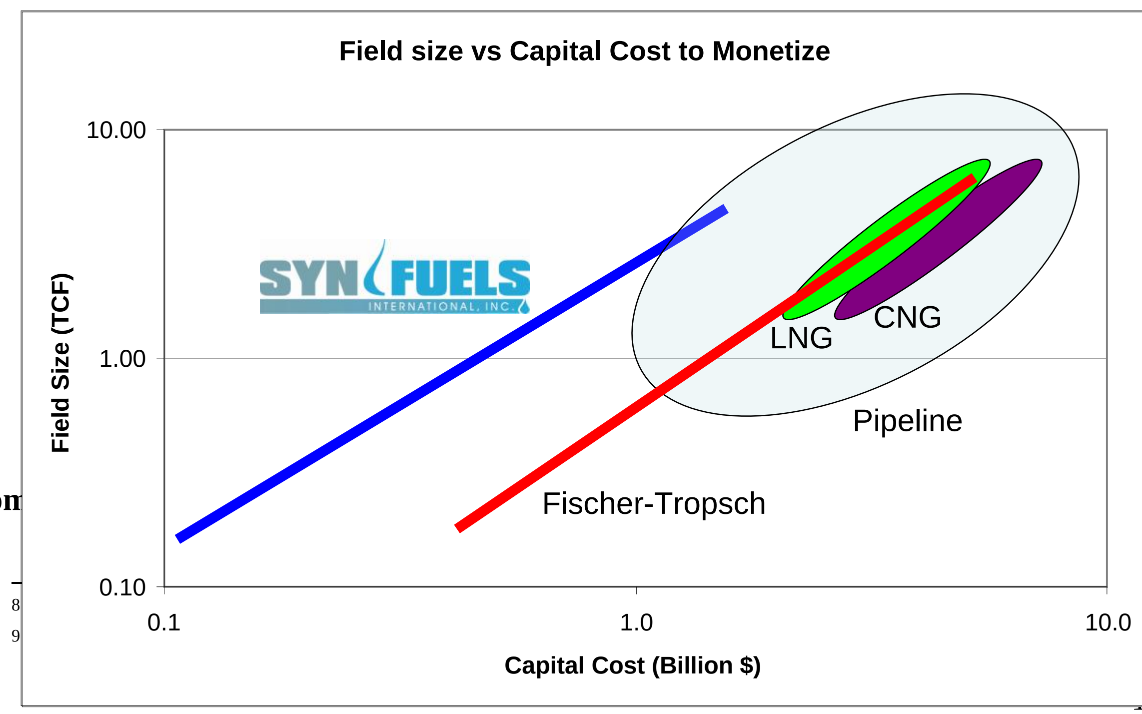
[7] Technip, Executive Briefing, 2004 International GTL Conference, p.14.

A 100 MMSCF/D Synfuels plant will produce 6440 bpd of gasoline blendstock starting with a gas that is typical of many reservoirs, having a carbon number of 1.2. The break even cost for this plant, excluding royalty, is $22.33 per barrel. Plant cost will be $224 million. Estimates are that C4+ product, which represents about 95% of the product, will be transportable. The product will be a stable liquid at crude transmission operating conditions. The top end of this product composition is a C13 hydrocarbon which represents the light end of diesel material.

Competitive Economics

The following chart depicts the capital cost required to monetize gas fields of various sizes. For very large fields, Fischer-Tropsch and LNG are competitive.[4,8] CNG costs more based on transporting the product 5000 km. For shorter transport distances, about 2000 km, CNG could be competitive with LNG for smaller fields. However, taking into account the various markets that LNG can be sold into, gas sources in Sub-Saharan Africa, Australia and the majority of South America could not utilize CNG transport.[9]

Because of its simplicity, few process steps and low to zero recycle, the Synfuels capital cost is much lower than the FT capital cost for the same size field. The FT basis plant is a 50,000 barrel per day plant and the Synfuels basis plant is a 3,000 bpd plant. A scale adjustment factor of 0.7 was applied to each base design in order to make each comparable over the range of natural gas field sizes. The cost for pipelines included only major pipelines under construction or under consideration, including: Turkmenistan-China (Central Asia), Russia-China, Rockies Express, Bronco, GulfCrossing, Kakinada, Nabucco, Gasducto del Noresta Argentina, and Iran-Pakistan-India. Because pipelines are surface structures that cross various borders and terrain between source and service, their costs and risk factors vary widely vs. field size. It is anticipated that the Alaskan pipeline would tend to be one of the more expensive pipelines built, on a dollar per kilometer basis due to cold weather, terrain, environmental opposition, native peoples' claims and permitting and high cost of labor.



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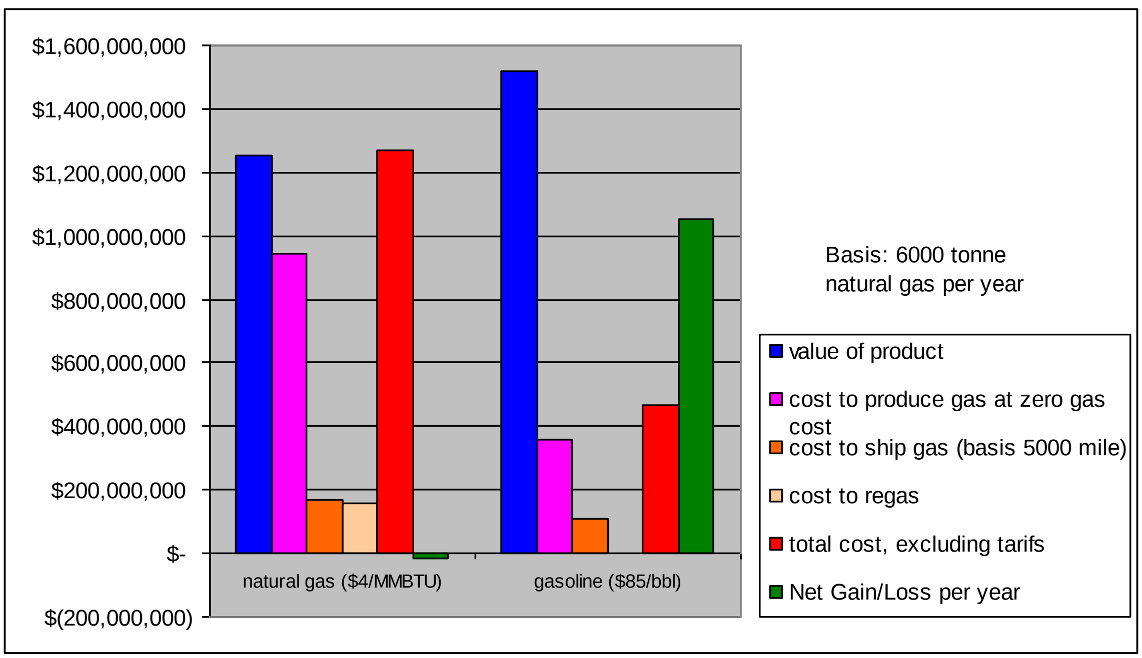
Natural gas and liquid fuels are both excellent sources of energy world-wide, but their value per BTU is very different. The energy available from a barrel of gasoline is about 5.2MMBTU. At $85 per barrel, the gasoline energy based value is $16.3/MMBTU. On the other hand, natural gas is selling today for approximately $4/MMBTU. The ratio of energy value of gasoline to natural gas is currently about 4.1. Gasoline demands a significant premium, worldwide, for its energy content because it is easily transportable and storable.

This disparity in energy based value can produce a situation where the best economic alternative is to convert the gas to a saleable liquid rather than sell it as a gas without conversion. The following chart compares the value of processing 6000 tons per year of natural gas sold as LNG vs. the value of converting it to by-product and wax free gasoline blendstock by the Synfuels process. Although one could expect that even associated or stranded gas would be valued in a range from -$0.50 (nuisance & processing cost) to $1.00 by the owner, the following cases are evaluated at zero gas cost for simplicity.[10]

One sees immediately that at $4/MMBTU gas, LNG will not make money, even if the gas costs nothing. On the other hand, Synfuels GTL Gasoline will return excellent value, even though more than half of the energy available from the natural gas is utilized to process the natural gas into a liquid fuel. In the Synfuels GTL case, virtually all of the native value of the gas is returned. Projections of the future value of natural gas in the gas state versus stable liquid fuels, strongly favor the higher value of liquid fuels.

Realizable Value from LNG Compared to SYNFUELS GTL Gasoline



[10] Gas Usage and Value, Seddon, pp249-259

Summary

For the Alaskan north slope, gas transmission by a separate new pipeline is one alternative to get the gas to a location such as Valdez. Once in Southern Alaska, the gas could be piped to the Continental US at further cost or transformed to LNG, incurring well known but large costs. Construction of the original liquid pipeline was dangerous and difficult, but well received by the lower 48 states. Today, environmentalist groups, many members of congress and a large part of the US population want more energy but not at the capital and environmental price of a mega-pipeline. It is understood that the Valdez LNG option is no longer being considered due to cost, safety and the environment and this leaves only the very long distance TransCanada pipeline option.

The Potential Gas Committee, a group of academics and industry specialists supported by the Colorado School of Mines, reports the largest increase in natural-gas reserves in its 44-year history. Estimated reserves rose to 2,074 trillion cubic feet (TCF) in 2008 from 1,532 TCF in its 2006 report. Current U.S. usage is about 25 TCF per year, thus new reserve figures suggest at least 83 years at current usage. But this figure is certainly low. While this recent report relates to the latest biennial survey, reserve increases of a lesser amount are commonplace even with continuous increases in production. Given these estimates it may never be necessary or practical to transport Alaska's North Slope associated gas to the lower 48 states by gas pipeline.

LNG and CNG are impractical for Alaska's North Slope. Synfuels GTL permits use of the existing crude pipeline for gas monetization through transformation of the gas to higher-value liquid. GTL by way of Fischer-Tropsch technology has been evaluated for North Slope operations. The environmental impact may be unacceptable. The capital and operating cost per barrel can be shown to be much greater than projection. Unless the FT product is upgraded to high value liquids like diesel, then waxes contained in the syncrude may cause pipeline flow issues that could shut down the pipeline. GTL by way of Synfuels technology offers a cheaper solution and superior product. Finally, it recovers the economic value of the natural gas better than any of the other methods.

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