# Economic Alternative for Remote and Stranded Natural Gas and Ethane in the US

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The recent abundance of natural gas in widespread locations of the US has resulted in many resources being remote or stranded, creating the need for economical options for moving those resources to market. In many cases the gas is ethane-rich resulting in a need for new ways to monetize an otherwise low value ethane product. The current market price for ethane, in particular, is well below historical values and projections for the future indicate that this market condition will persist. Synfuels International, Inc. has developed a process for converting natural gas and light hydrocarbons to a high value, easily transportable gasoline product and, thereby, substantially increasing the value of the product. The process has great returns with payouts of about 2-3 years for ethane and about 3-4 years for natural gas streams of 15 – 20 MMSCFD and larger. The process concept and economics will be discussed.

## Introduction

The recent abundance of natural gas in widespread locations of the US has resulted in many resources being remote or stranded, creating the need for economical options for moving those resources to market. In many cases the gas is ethane-rich resulting in a need for new ways to monetize an otherwise low value ethane product. The current market price for ethane, in particular, is well below historical values and projections for the future indicate that this market condition will persist.

Natural gas production in the US has increased substantially in the last 10 years. The growth for natural gas production for the United States, along with some individual states is shown in Figure 1. The greatest contribution to these increases has been through the exploitation of shale formations. These increases have been seen not only in traditional gas production areas such as Texas and Louisiana, but also non-traditional places such as Pennsylvania and Arkansas.

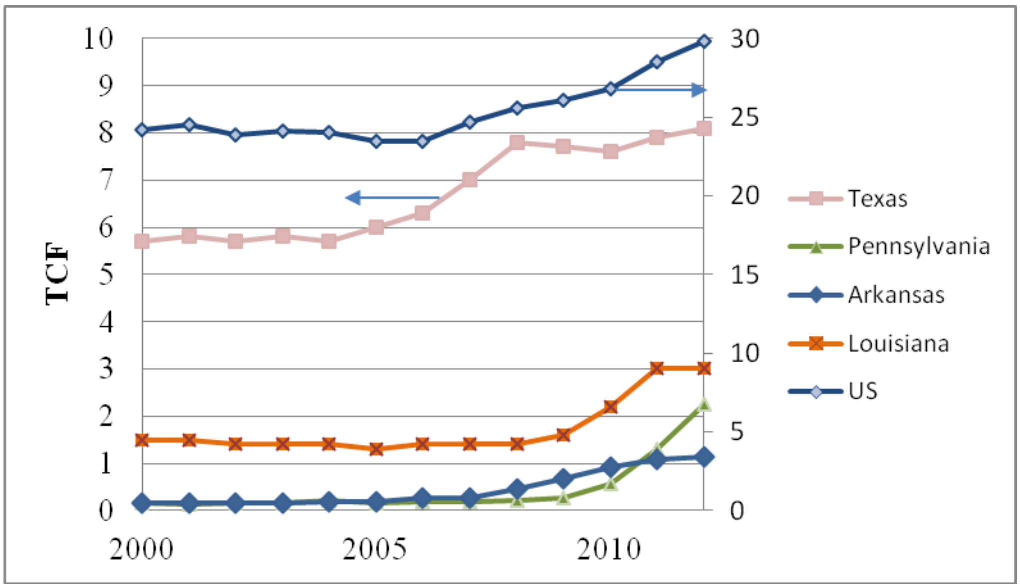


**Figure 1. US Natural Gas Production [EIA 1]**

In many areas, large quantities of natural gas is being flared due to the lack of pipeline availability. For example, as of June 2012, in N. Dakota over 200 MMSCFD was being flared. This represents about one third of the total gas production in the state [Curtis 2]. Some of these wells will be connected to a pipeline within about a year while others will continue to be flared on a longer term basis.

Along with the large increase in natural gas production in the U.S. indicated in Figure 1, there has been an even larger increase in natural gas liquids, of which ethane is the greatest volume. This increase in ethane is shown in Figure 2 [EIA 3].

From 1984 to 2008, ethane production gradually rose by approximately 40% from 500,000 BPD to 700,000 BPD. From 2008 to 2012, ethane production grew almost another 40% from 700,000 BPD to nearly 1,000,000 BPD. These production numbers do not include the more than 50,000 BPD that was either flared or rejected into the residue gas stream. In total, the US has increased available ethane by more in the last 4 years, than the previous 24 years.

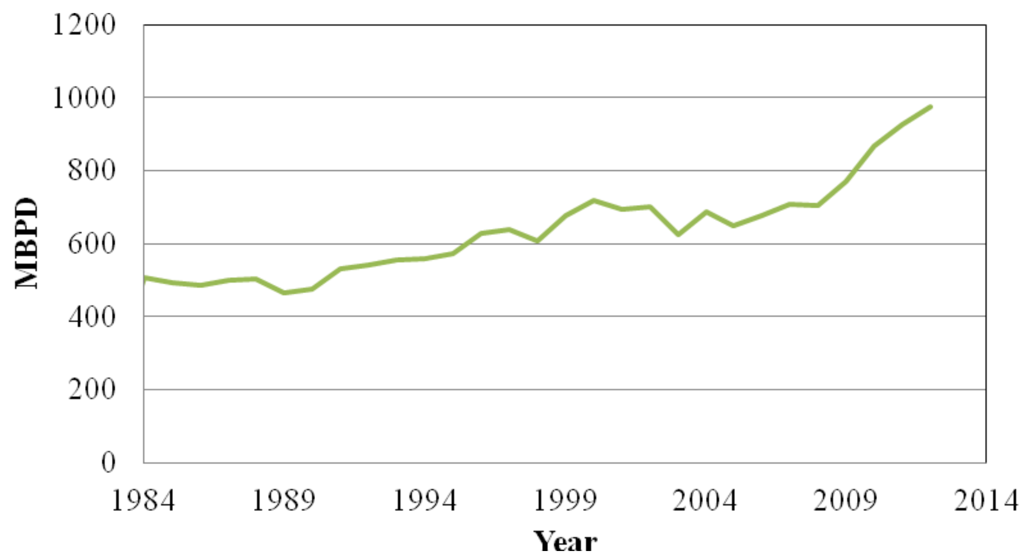


**Figure 2. US Ethane Production [EIA 3]**

By far, the dominant use of ethane is as a feedstock to Gulf Coast steam crackers to make ethylene, [Fasullo 4]. However, ethylene is not a finished product, nor one that is easily transported outside of the limited ethylene pipeline networks along the Gulf Coast. The only other significant use for ethane is in natural gas sales for its fuel value, which sets the ‘floor’ price [Fasullo 4].

Due to ethane’s limited value in the overall hydrocarbon production, shale plays are frequently developed without significant effort towards disposition of the ethane as a standalone product, [Curtis 2]. For example, in a typical Bakken gas with 12.2 GPM, the ethane content can represent about 44% of the total natural gas liquids by volume, but only 14% of the value. If the gas is produced in association with oil from a well with a Gas-Oil Ratio of 1.1 MSCF/bbl, the ethane represents a meager 1% of the value of the hydrocarbons, despite being 10% of the total hydrocarbon liquids produced.

The prices for Henry Hub natural gas, Mont Belvieu purity ethane, and West Texas Intermediate crude (WTI), all in terms of $/MMBTU are shown in Figure 3, [EIA 5, EIA 6, Midstream Monitor 7]. Historically, ethane has tracked near WTI, based on their respective heating values. This was true until about 2008, when ethane began to drop relative to crude. The primary reason for this drop was that newly available ethane began flowing, much of it from Texas shale. As can also be seen from Figure 3, the market separation in terms of $/MMBTU between gas and ethane prices and crude prices is currently the highest over the last seven years at least. Furthermore, this trend is expected to continue for many years.

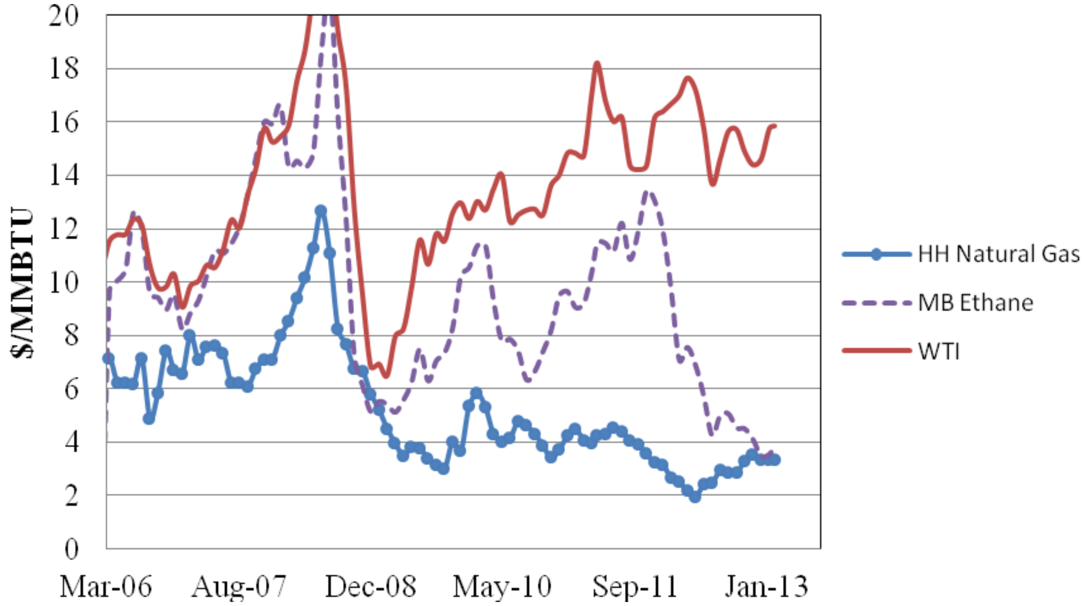


**Figure 3. Historic Oil, Residue, Gas and Ethane Prices [EIA 5, EIA 6, Midstream Monitor 7]**

The ethane production for the U.S. and the Texas Inland refinery district which includes the Eagle Ford, Barnett, and Permian Basins is shown in Figure 4 [EIA 8]. Figure 4 also shows estimated ethane production for the Appalachia 1 and MN, WI, ND, SD (Midwest) refinery districts which include the Marcellus/Utica and Bakken, respectively. While the Marcellus/Utica and Bakken districts had no significant ethane production reported, the chart shows the estimated ethane amounts produced from the fields and sold with the residue gas, based on other NGL's produced.

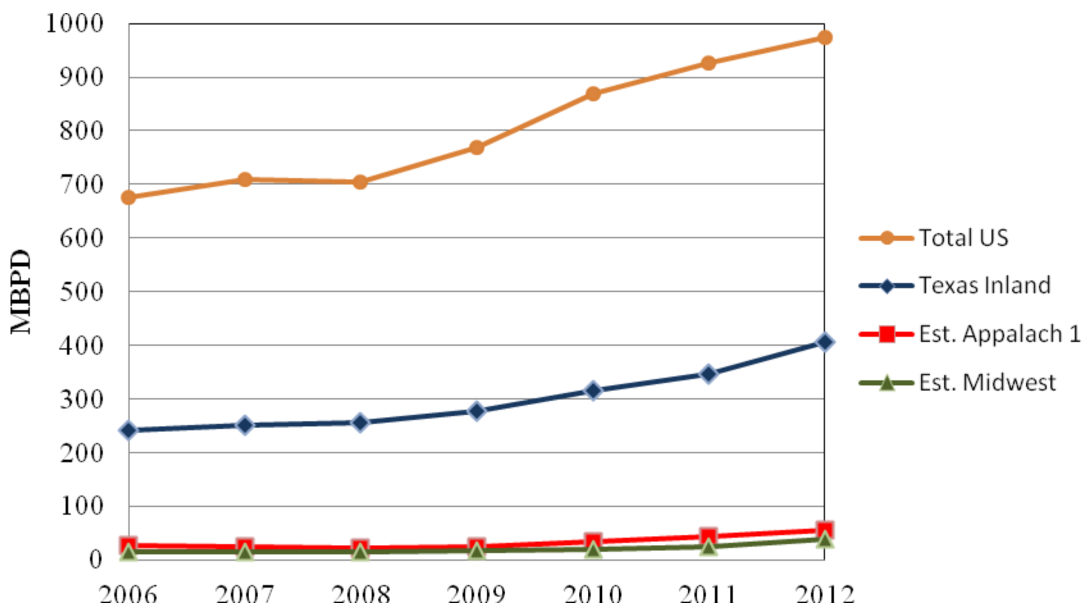


**Figure 4. US Ethane Production [EIA 8]**

From 2008 to 2011, ethane maintained a significant cost premium over natural gas, despite the rising supply shown in Figure 3. With the increasing price separation between oil and ethane, ethylene crackers that used heavier, oil price-dependent feeds such as naphtha, butane, and propane began shifting their feedstock to cheaper ethane, [Fasullo 4, Ordemann 9].

### Limits on Ethane Price/Demand Growth

Several new ethylene plants are being contemplated along with some expansions to consume some of the expected production, [Fasullo 4]. To integrate these plants with existing infrastructure for feedstock delivery and product off-take, they are almost exclusively built on the US Gulf Coast, [Fasullo 4]. This relative proximity to other ethylene producers requires world-class economies of scale to compete. As such, these plants represent very large ethane commitments, typically on the order of 95,000 BPD (149 MMSCFD) of ethane for the life of the plant. They also involve very large capital commitments, in the range of $1.7 to 3 billion [Kaskey 10, Marais 11] depending on the sophistication and product slate. Because recent shale resources are located far from the Gulf Coast, extensive pipelines are required to bring the ethane to the cracker. The overall risks of constructing new ethylene capacity, including feedstock, transportation, competition, and capital are sizeable, on top of the normal risk of price and demand for the final product.

As mentioned above, transporting ethane from new production areas such as the Bakken and Marcellus fields is not a trivial matter. Even if a pipeline exists and capacity is available, transportation cost impacts ethane value to the producer significantly. The estimated transportation fees associated with moving ethane from some of the major shale basins to Mont Belvieu are shown in Table 1. In most instances, a purity ethane pipeline was not available, so pricing for a Y-grade product is used in the table. Data is from FERC non-incentive tariffs, [FERC 12].

**Table 1. Transportation Fees to Mont Belvieu**

| Basin | Transport Fee to Gulf Coast | | Value to Producer (GC – transportation) | |
|---|---|---|---|---|
| | ($/gal) | $/MMBTU | ($/gal) | $/MMBTU |
| Marcellus | $0.15 | $2.28 | $0.106 | $1.53 |
| Bakken | $0.21 | $3.20 | $0.046 | $0.61 |
| Eagle Ford | $0.07 | $1.07 | $0.186 | $2.74 |
| Permian Basin | $0.05 | $0.76 | $0.206 | $3.05 |

February 2013 Gulf Coast ethane price - $0.256/gal or $3.9/MMBTU [EIA 6, Midstream Monitor 7]

## The Opportunity

The problem of residue gas and ethane oversupply and, particularly, localized oversupply in remote and stranded locations is in need of a solution that can convert moderate quantities (15 to 50 MMSCFD and up) of residue gas and ethane to a higher value and more easily transported product. These small volumes put it far outside of the reasonable scale of a 'local' ethylene plant. In many cases, pipelines may be at capacity or not available at all. Furthermore, even if pipeline capacity is available, high transportation fees may result in very low prices for natural gas and ethane in the field. In addition, the current trend of very large differences in gas and ethane prices relative to crude prices is expected to continue for many years.

Synfuels International, Inc. has developed a process for converting natural gas and light hydrocarbons to a high value, easily transportable gasoline product and, thereby, substantially increasing the value of the product. Synfuels has a relatively small construction time of about two years, short payback period, so projects can payout quickly. The small plant size allows the plants to be distributed to production sites. In addition, a pipeline is not necessary since the product can be easily transported by truck or rail.

## Synfuels GTL Process Description

The Synfuels GTL Process is an integrated conversion process to transform light hydrocarbons into a gasoline product. A general process flow diagram is shown in Figure 5.

The cracking reactor, or thermal cracker, operates by combusting fuel gas with oxygen to generate a very high temperature flame. The feed hydrocarbon to be cracked, typically preheated in a heat exchanger, is then injected into the stream of combustion products to raise the temperature of the feed to the cracking temperature.

The cracking of the feed takes place almost instantly. The yield to ethylene and acetylene ranges between 40-80%, depending on the composition of the feed. The reaction is quenched with water to inhibit byproduct reactions that generate carbon monoxide and coke. Due to the nature of thermal reactions, some coke will be produced. At these conditions, coking is typically 2-3% of the inlet carbon.

The largest size cracking reactor currently available is suitable for approximately 5 MMSCFD of natural gas feed. Thus, in a commercial plant, the appropriate number of Thermal Reactors would be operated in parallel.

The cracked gas is further cooled by cross-exchange to recover heat. The cracked gas is then introduced to the Spray Tower, where it is washed with circulating water to cool the gas, condense the combustion water, and remove any coke particles. Once the cracked gas has been cleaned and cooled, it is compressed to approximately 150 psig with a multi-stage rotary screw compressor. The cracked gas then flows to the Ethylene Reactor where the acetylene is converted to ethylene.

The ethylene-rich product from the Ethylene Reactor is then preheated and fed to the Product Reactor to yield gasoline blend stock. The product gasoline blend stock consists primarily of C6-C8 with some lighter components down to C4 and some heavier components up to C11. The product contains about 30 wt% aromatics, usually toluene and xylene, as well as a small quantity of naphthenes (5-10 wt%). The remainder of the product is a mixture of mostly branched paraffins. Olefins are typically less than 3 wt%. The gravity falls in the range of 50-60 degrees API with a Research Octane Number of 93-95. A refrigerated lean-oil absorption system is used to efficiently recover the product from the gas stream. A product stabilizer may be used to yield a gasoline blend stock to meet a particular Reid Vapor Pressure (RVP).

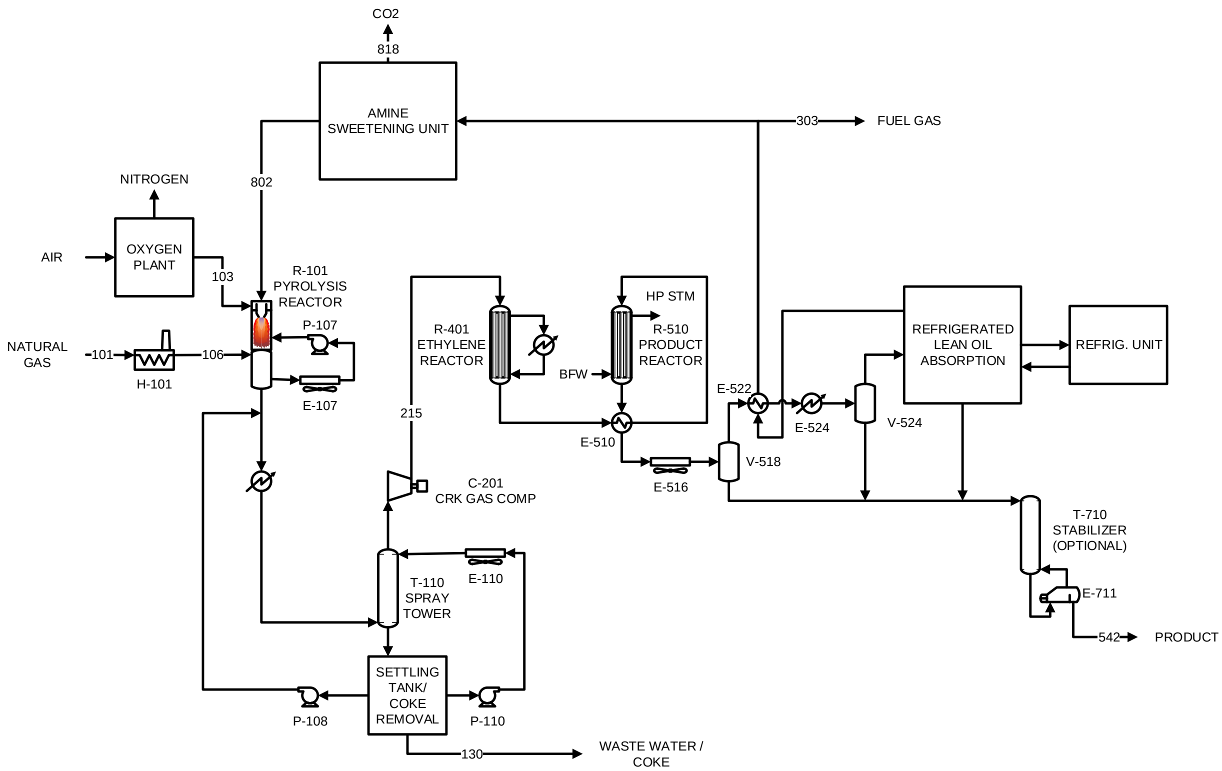


**Figure 5. Synfuels GTL Process Flow Diagram**

The residue gas is available for use as fuel. To reduce the buildup of inerts in the recycle loop, an Amine Sweetening Unit removes the carbon dioxide from the fuel gas returning to the burner. The remainder of the fuel is available for heating or power production.

## Process Economics

Based on the market conditions discussed previously, two options for processing remote and stranded natural gas and ethane with the Synfuels technology are presented below. The first option reviewed is for 20 MMSCFD of stranded or remote natural gas of approximately 1,250 BTU/SCF Gross Heating Value. For natural gas with limited possibilities for a pipeline or gas that is currently being flared, the producer should consider all available alternatives to create additional revenue. The Synfuels process produces approximately 1,710 bbl/d of liquid product with estimated gross revenue of $60 MM per year. As expected, the net revenue from the process is directly tied to the cost of the natural gas feedstock price.

As shown in Table 2, the estimated payout for natural gas ranges from 2.8 years for $0/MMBTU gas to 4.3 years for $2/MMBTU gas.

**Table 2. Economics of the Synfuels GTL Process for Natural Gas (1250 BTU/SCF)**

| | | | |
|---|---|---|---|
| **Residue Gas Feedstock** | | | |
| Gas Flow | 20 | MMSCF/D | |
| | | | |
| **Product** | | | |
| Liquid Volume | 1,710 | bbl/d | |
| Product Value | 100 | $/bbl | |
| Gross Revenue | $60 MM | $/yr | |
| | | | |
| **Costs** | | | |
| Estimated Capital Cost | $135 MM | | |
| | | | |
| Plant Feed ($/MMBTU) | $0.00 | 1.00 | 2.00 |
| Feed Annual Cost ($/yr) | $0 MM | $8.75 MM | $17.5 MM |
| Estimated Operating Cost ($/yr) | $11 MM | $11 MM | $11 MM |
| | | | |
| **Estimated Net Revenue ($/yr)** | **$49 MM** | **$41 MM** | **$32 MM** |
| **Return on Investment** | **36%** | **30%** | **23%** |
| **Estimated Payout (years)** | **2.8** | **3.4** | **4.3** |

Gas feeds with heating values higher than 1250 BTU/SCF would produce larger amounts of liquids and would have corresponding shorter payout times.

The second option reviewed is for 20 MMSCFD ethane feed of approximately 1,770 BTU/SCF Gross Heating Value. The Synfuels process converts this potentially low value gas stream into a saleable liquid product of approximately 3,660 bbl/d. In economic terms, the $4/MMBTU or less feed stream is now worth $16/MMBTU as a liquid product based on current market prices as shown in Figure 3. In addition, with payout times less than 3 years the process is very attractive in terms of capital investment and future profits. Upon payout, the process continues to yield substantial profits even if ethane prices increase.

**Table 3. Economics of the Synfuels GTL Technology for Ethane**

| | | | |
|---|---|---|---|
| **Ethane Feedstock** | | | |
| Gas Flow | 20 | MMSCF/D | |
| | | | |
| **Product** | | | |
| Liquid Volume | 3,660 | bbl/d | |
| Product Value | 100 | $/bbl | |
| Gross Revenue | 128 MM | $/yr | |
| | | | |
| **Costs** | | | |
| Estimated Capital Cost | $190 MM | | |
| | | | |
| Plant Feed ($/MMBTU) | $2.00 | $4 | $6 |
| $/gal | $0.131 | $0.263 | $0.394 |
| Feed Annual Cost ($/yr) | $25 MM | $50 MM | $74 MM |
| Estimated Operating Cost ($/yr) | $12 MM | $12 MM | $12 MM |
| | | | |
| **Estimated Net Revenue ($/yr)** | **$91 MM** | **$67 MM** | **$42 MM** |
| **Return on Investment** | **48%** | **35%** | **22%** |
| **Estimated Payout (years)** | **2.1** | **2.9** | **4.6** |

Since these units can be located in the fields in close proximity to the natural gas or ethane, the cost of the feed stocks would continue to be lower due to the fact that long distance transportation cost are removed.

**Summary and Conclusions**

The recent abundance of natural gas and ethane in widespread locations of the US has resulted in many resources being remote or stranded, creating the need for economical options for moving those resources to market. In many cases the residue gas or ethane is being sold at or below the fuel value and thus creating an immediate need for an alternative to monetize a low value resource. The current market price for ethane, in particular, is well below historical values and projections for the future indicate that this market condition will persist. Synfuels International, Inc. has developed a process for converting natural gas and light hydrocarbons to a high value, easily transportable gasoline product and, thereby, substantially increasing the value of the product. The processing unit can be installed near the remote or stranded source and thereby remove the transportation costs that currently limit the current product value to the producers. The process has great returns with payouts of about 2-3 years for ethane and about 3-4 years for natural gas streams of 15 – 20 MMSCFD and larger.

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