GTUIT

Innovation Leader – White Paper

September 2020

Conditioning of Associated Gas to Power a Dual Fuel Frac Fleet

Transforming wellsite operations through innovation

Brian Cebull James Haider Mark Peterson Jeff Richey Austin VanDelinder

Associated Gas to Power a Frac - Overview

Historically, pressure pumpers and the producers they work for have powered their frac pumps with diesel engines. More recently, a push to use cleaner burning and less expensive natural gas has moved the industry to develop frac fleets which can run mostly on natural gas. This newer Tier 4 "dual fuel" engine technology has the ability to substitute upwards of 85% of natural gas in place of diesel and still achieve the engine performance required for frac pumping, all while meeting the EPA's stringent Tier 4 emissions standards. Retrofit kits have also been developed to convert earlier Tier 2 diesel engines to substitute some portion of gas for diesel, but at a lower replacement efficiency than the newer Tier 4 engines.

To power these new frac fleets with gas, pressure pumpers and producers have relied on gas sources trucked to frac sites from regional processing facilities in the form of compressed natural gas (CNG) or liquified natural gas (LNG). Many frac sites have gas gathering pipelines either at the location or very close to them. Unfortunately, raw associated gas in these pipelines is generally too "rich" or too "hot" to be used directly for substitution in a Tier 2 or Tier 4 engine - until now. Starting in July 2020, GTUIT processed raw associated gas adjacent to a frac site near Midland, Texas and delivered the gas directly to both Tier 2 and Tier 4 frac engines on site. The raw gas was taken from a nearby gathering pipeline, processed at the frac site using GTUIT's patent pending gas processing equipment, and then piped directly to the Tier 2 and Tier 4 engines which powered the frac. The results speak for themselves. Over 8 days completing this frac on a site just outside Midland, TX, the Tier 4 engines averaged 77% natural gas-for-diesel substitution with peaks reaching 85%.

The implications of this successful demonstration cannot be overstated. Tier 4 engines designed specifically for gas substitution of diesel can achieve approximately 80% gas substitution during frac pumping (Tier 2 engines typically achieve 55%-70% substitution). On their own, these Tier 4 diesel engines that are capable of gas substitution are a tremendous step forward for the industry by virtue of the price savings of gas over diesel and the significant reduction in site emissions. With the added savings of creating engine-quality gas right at the frac site by utilizing the raw associated gas the producer already owns, producers have yet another option to improve their completions efficiency, reduce their environmental impact, enhance their Environmental-Social-Governance (ESG) value, and strengthen their bottom line.

Associated Gas – The Curse…and the Blessing

The advent of the shale revolution has created an abundance of oil supply in the United States. Along with the abundance of oil has come an increase in natural gas known as "associated gas" since it is produced in association with the production of crude oil. As producing basins are developed and become more mature, their produced gas-oil ratios (GORs) tend to increase, which means incrementally more associated gas is produced with each barrel of oil production. The challenges of associated gas are not going away as long as industry continues to develop and produce shale and other unconventional oil resources. Since its inception, GTUIT has built its business around finding innovative distributed solutions to condition and repurpose associated gas for the benefit of industry, communities, and the environment.

The characteristics of associated gas have changed over time as industry has shifted from conventional reservoirs to production directly from tight oil source rocks or the adjoining strata. While an energy content of 1,200 Btu/scf was considered "rich" or "hot" by industry standards a decade ago, today's

associated gas can have an energy content of more than 1,700 Btu/scf thanks to the presence of heavy or longer chain hydrocarbons such as propane, butane, pentane, hexane, and more. While centralized gas plants can process this gas down to a level of 1,000 Btu or less, the presence of these heavy hydrocarbons in the gas phase makes it nearly impossible to use the gas beneficially on site. One might think that more energy per cubic foot would be a positive for fueling dual fuel engines, but the higher energy content is typically detrimental to engine performance. To maximize efficiency and minimize emissions, today's modern engines are designed to run optimally within a relatively narrow fuel composition band. Outside of this band, de-rated engine performance will result in any number of issues like pre-ignition and detonation which can significantly damage the engine and/or cause more frequent engine maintenance. The heavier hydrocarbons of associated gas are the culprits if present in sufficient amounts, hence the need for GTUIT's gas processing technology that removes these components and makes the gas usable.

In addition to removing the heavy hydrocarbons to reduce the energy content, modern dual fuel engines also require treatment that delivers a fuel that has steady composition and energy content with no fluctuations due to ambient conditions or changing inlet compositions. Sudden changes in the energy content of the gas typically cause the engine to shut down gas fuel substitution. As shown in Figure 1 below, the measured Btu value of raw associated gas at the wellsite can vary wildly during normal production.

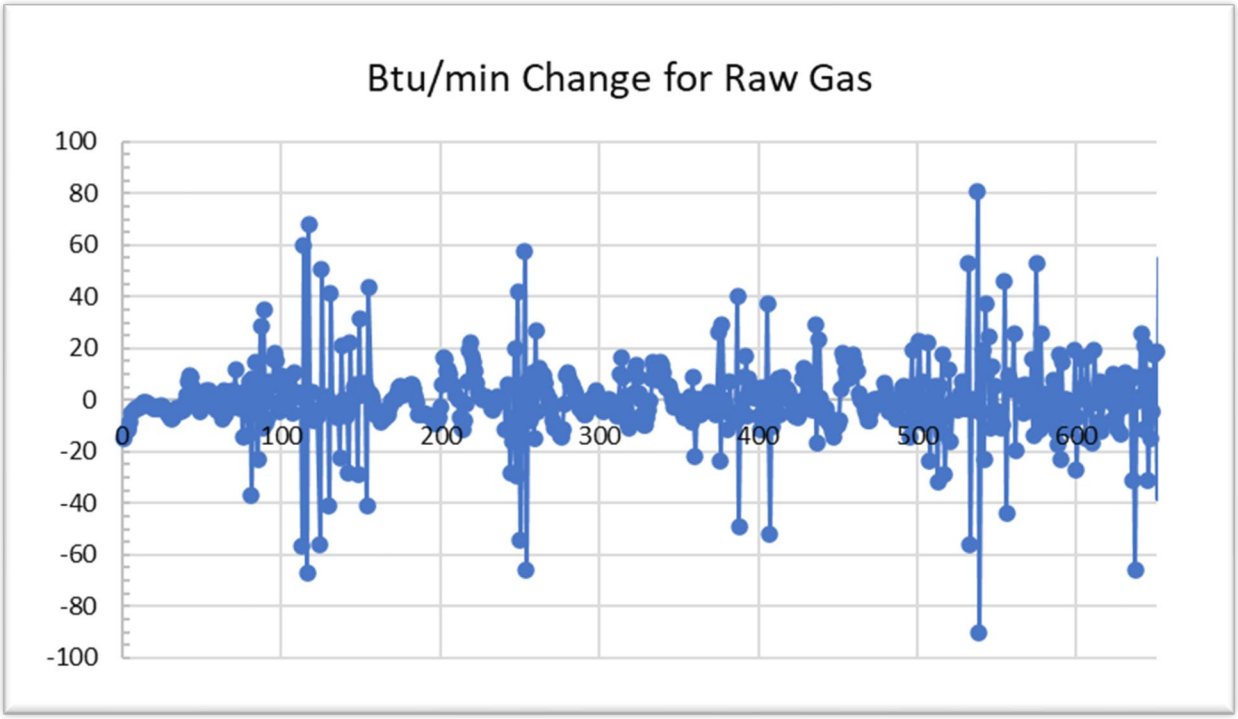

Figure 1: Measured rate of change of gas energy content <u>BEFORE</u> GTUIT treatment

Figure 2 below demonstrates the consistency of composition and energy content (Btu) in that same raw associated gas after having been treated using GTUIT's gas processing technology. GTUIT achieves this consistency across extreme environmental conditions ranging from the Permian basin in August to the

Bakken in January. Other common gas processing technologies such as JT or direct refrigeration are very sensitive to environmental conditions and cannot achieve sufficient processed gas quality and consistency as ambient or inlet conditions change. It is this consistency of gas quality delivered by GTUIT technology that is essential to maximizing efficiency and minimizing maintenance in dual fuel engines.

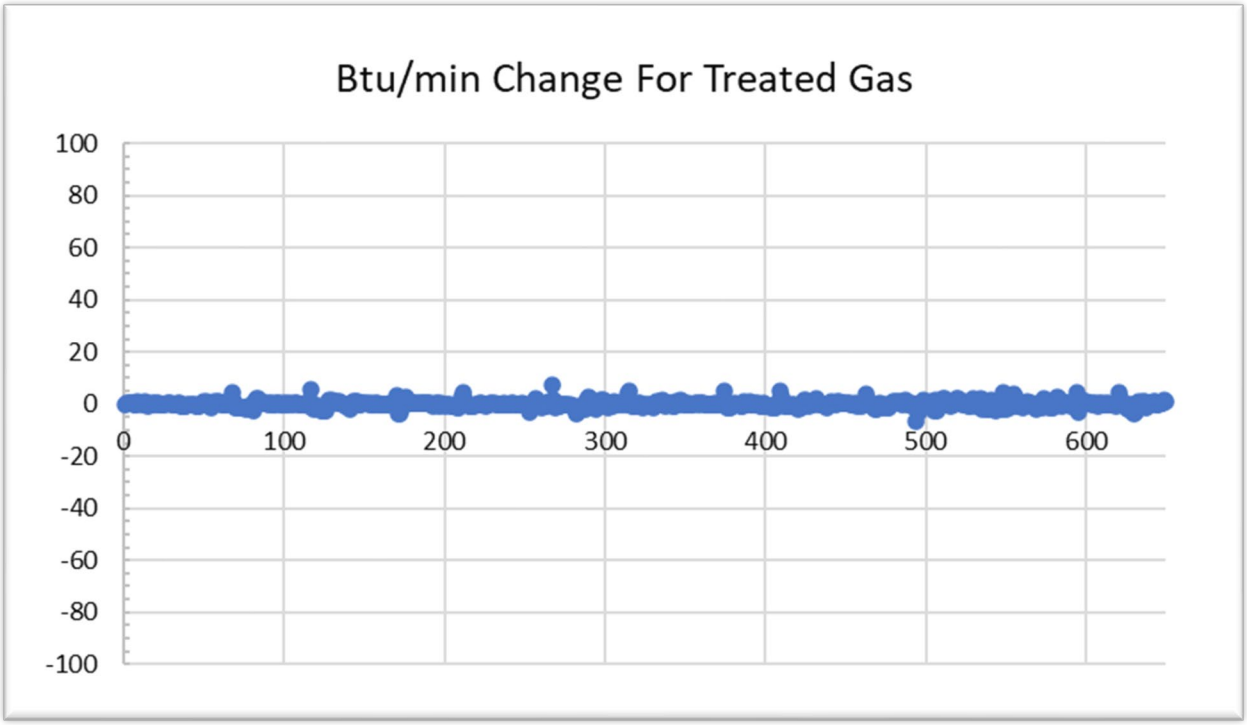

Figure 2: Measured rate of change of gas energy content AFTER GTUIT treatment

GTUIT Direct Fueling – The Solution

As the use of dual fuel engines has grown in oilfield applications (including frac and drilling), so too has the demand for refined gas that meets the specifications for those engines. However, the infrastructure, costs, and logistics to complete the life cycle thru traditional processing of a single molecule of gas to be burned in a dual fuel engine are extensive and expensive.

Traditional Process Steps to Deliver Gas to Dual Fuel Engines with CNG/LNG

1. Associated gas released during oil extraction and surface processing
2. Associated gas inserted into a raw gas pipeline
3. Associated gas compressed to high pressures and moved down raw gas transmission pipeline to processing facility
4. Associated gas processed/refined at regional gas processing facility
5. Refined gas reinserted into refined/processed gas pipeline or:
    a. Compressed further into Compressed Natural Gas (CNG)
    b. Compressed and cooled to create Liquified Natural Gas (LNG)
6. CNG or LNG loaded onto a specialty trailer and trucked from processing facility to frac site

7. CNG or LNG routed through let-down equipment to achieve dual fuel gas inlet temp and pressure specifications
8. Gas delivered to dual fuel engines

As an alternative, GTUIT's technology allows operators to process the associated gas right on the same site as their dual fuel engines, vastly reducing the complexity and costs of the gas processing.

GTUIT's Direct Fuel Conditioning Process

1. Associated gas released during oil extraction and surface processing
2. GTUIT pulls associated gas from raw gas line at line pressures as low as 10 PSIG and processes it to engine specifications
3. GTUIT delivers processed gas to dual fuel engines

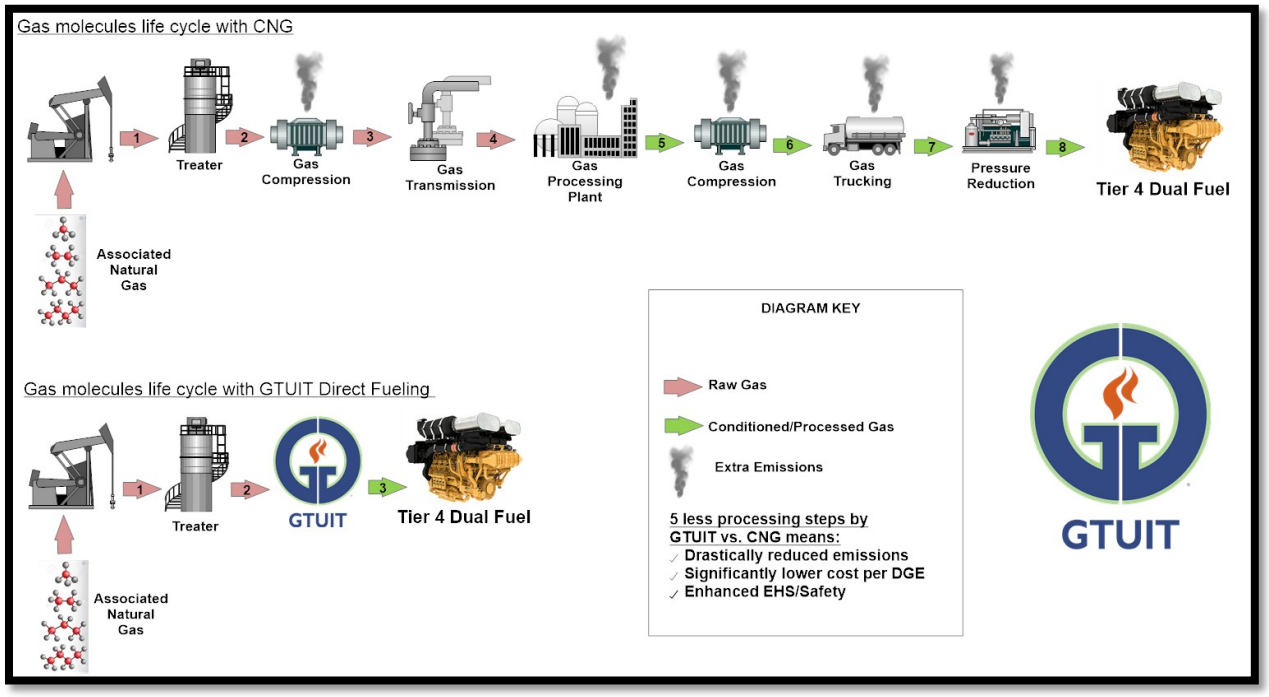

Figure 3: Life cycle of a dual fuel gas molecule with traditional CNG processing versus GTUIT processing

Based on the process assumptions shown in Figure 3 above, the following table shows the estimated total annual CO_2 emissions from a single dual fuel fleet using GTUIT direct fueling versus trucked CNG.

	Estimated Annual CO_2 Emissions
GTUIT Direct Fueling	1,580 tons
Trucked CNG	6,140 tons

By reducing the number of "touches" the gas receives before it reaches a dual fuel engine, associated gas treated by GTUIT produces almost four times less CO_2 emissions versus CNG as well as dramatically less truck traffic compared to CNG or LNG as transport trailers are not added and removed from the site daily. This reduction in truck traffic results in less particulate matter, NO_X, and CO emissions, and greatly reduces the safety hazards associated with truck activity on an active frac site.

Direct associated gas fueling greatly reduces CO_2 emissions versus using trucked CNG to power a dual fuel frac spread and provides operators and pressure pumpers the greatest economic and ESG value for hydraulic fracturing.

Figure 4: GTUIT's mobile & modular fuel gas processing system

Fueling a Frac Using GTUIT Processed Gas - Performance Data

Since 2011, GTUIT has led an industry movement to find beneficial uses for associated gas. To date, GTUIT has processed over 30 BCF of associated gas and produced over 2 million barrels of natural gas liquids (NGLs) which has prevented over 600,000 tons of CO_2 emissions. GTUIT has deployed fuel gas processing equipment designed specifically to take raw associated gas at the wellsite and process that gas for use in a variety of engines. GTUIT has successfully deployed its gas processing technology in multiple basins throughout North America as well as in South America and a new deployment to North Africa is scheduled for the fall of 2020.

Early in 2020, GTUIT began laying the groundwork to prove out yet another use of associated gas; powering a dual fuel frac fleet using GTUIT conditioned fuel created from the producer's own associated gas instead of trucked CNG. The economic and logistics benefits of powering a frac fleet in this way became even more compelling following the COVID-19 outbreak and the resulting drop in oil production and prices. In July this year, a combined effort by GTUIT and its partners culminated in the deployment of three of GTUIT's mobile gas processing units and GTUIT's veteran operations team to a completion site outside of Midland, in the Permian Basin of West Texas.

Figure 5: Three GTUIT processing systems on a Permian frac site

The site chosen was well-suited for this deployment in part because of nearby access to a raw gas gathering pipeline. As shown in Figure 6 below, laboratory analysis of this specific gas before and after treatment showed a large and consistent reduction in the energy content of the fuel gas from a source with varying energy content.

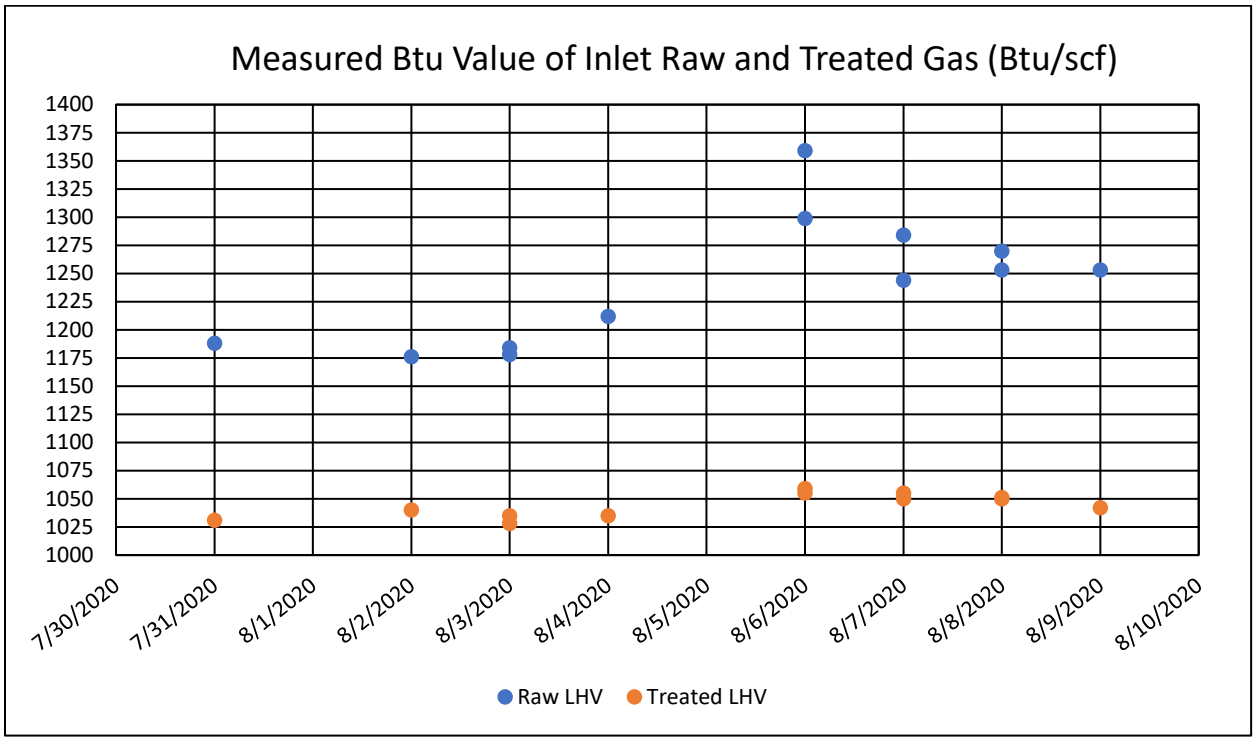

Figure 6: Measured Btu value before and after GTUIT treatment

As a general rule, the higher the energy content of the fuel, the lower the Methane Number (MN). Methane Number is a term used by engine manufacturers as a relative measurement of a fuel gas mixture's resistance to engine knock, or detonation, in a natural gas engine. In general, lower MN's will cause engines to knock which will de-rate the engine power output, cause engine damage, and increase maintenance costs.

The consistent reduction in energy content after processing shown in Figure 6 delivered a highly consistent MN that exceeded the minimum requirement for the Tier 4 DGB engines that were being fueled, as shown in Figure 7 below.

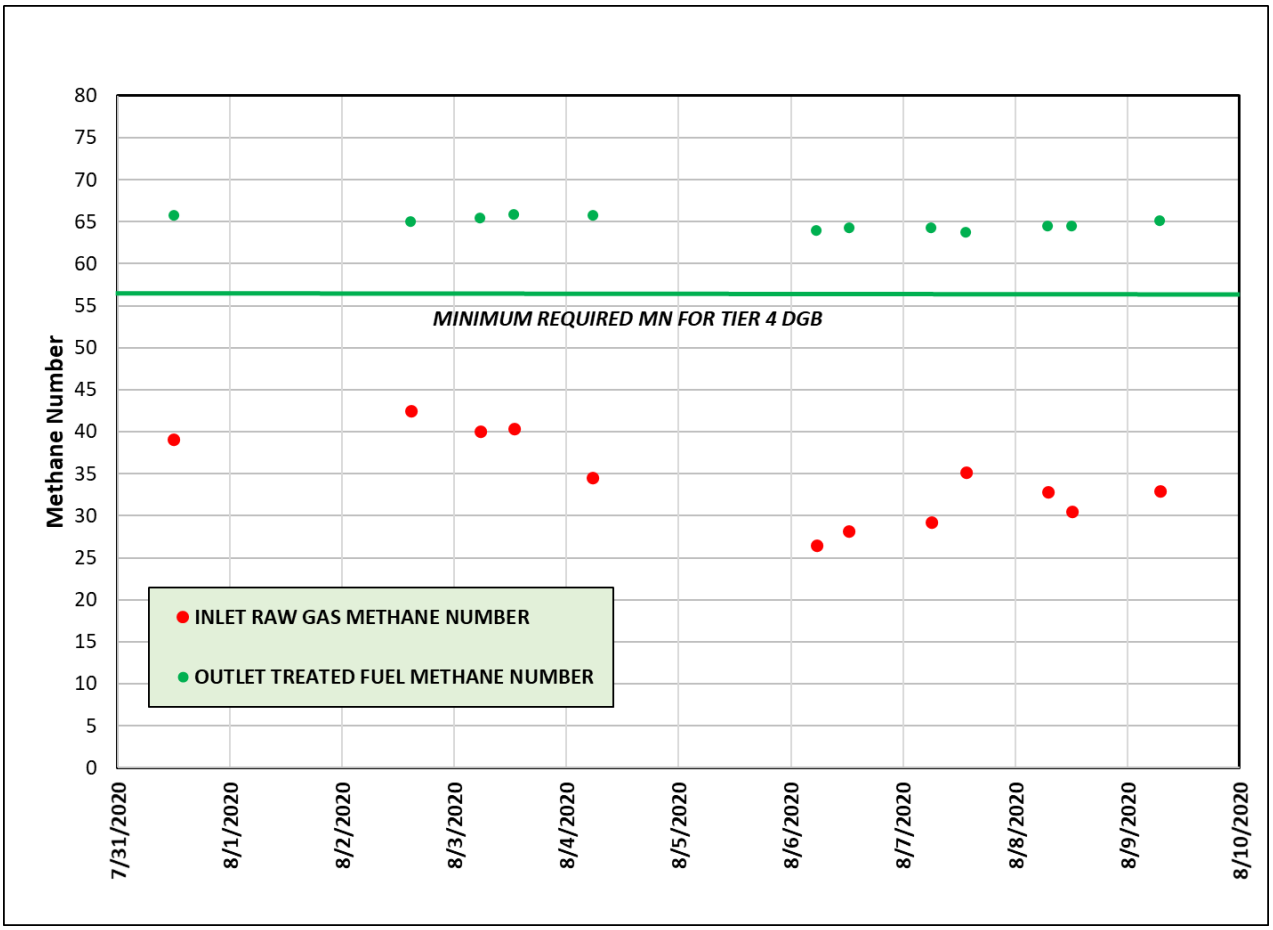

Figure 7: Methane number before and after treatment

By achieving a consistently high methane number, substitution rates as high as 85% at lower loads and over 70% at greater engine loads were common for the duration of the frac (Figure 8). This resulted in substantial diesel savings to both the producer and the pressure pumper. As substitution is controlled by both engine speed and load, greater savings can be achieved by optimizing both variables for a given frac fleet.

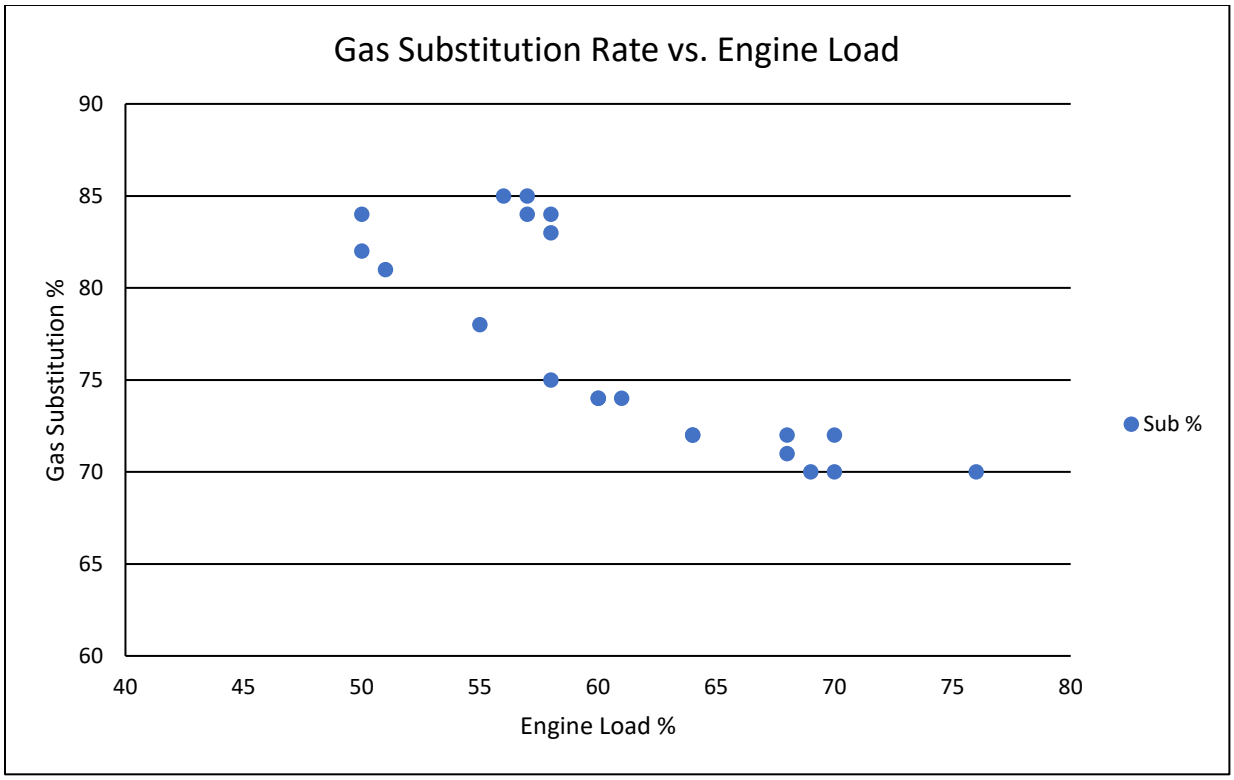

Figure 8: Substitution of diesel by engine load percentage at various RPM settings

During the 8-day test, GTUIT equipment and operations proved to be reliable through the Texas summer heat and conditioned gas was available instantly whenever fuel was required by the fleet. This availability and instant input of high-quality treated gas ensures that the dual fuel engines were able to maximize diesel substitution from the beginning to the end of each fracturing stage, minimizing the cost per stage.

Powering a Frac Using GTUIT Processed Gas – Economics

The use of associated gas in drilling and completions operations can also lead to significant net cost savings versus diesel and CNG. When selecting their source of gas for dual fuel applications, operators should use a methodic approach that is ranked based on both potential cost savings and emissions reductions. In nearly all cases, if there is associated gas being flared as a waste product on or near the location, this gas will be the first choice for enhanced economics and emissions reduction. This choice is followed closely by the option to pull raw associated gas from a nearby gas gathering line. Both scenarios involve turning raw, unprocessed gas into a valuable commodity right on the wellsite - this is where GTUIT's proven technology really stands out. The next choice for a gas supply is tapping a processed gas line where the gas has already been processed in a gas plant. This gas has been "touched" many times already and is typically greater in both cost and emissions than previous options. The last and final choice is to source gas via trucked CNG or LNG. These later options offer some savings over diesel but have significantly lower overall emissions reductions than the other choices.

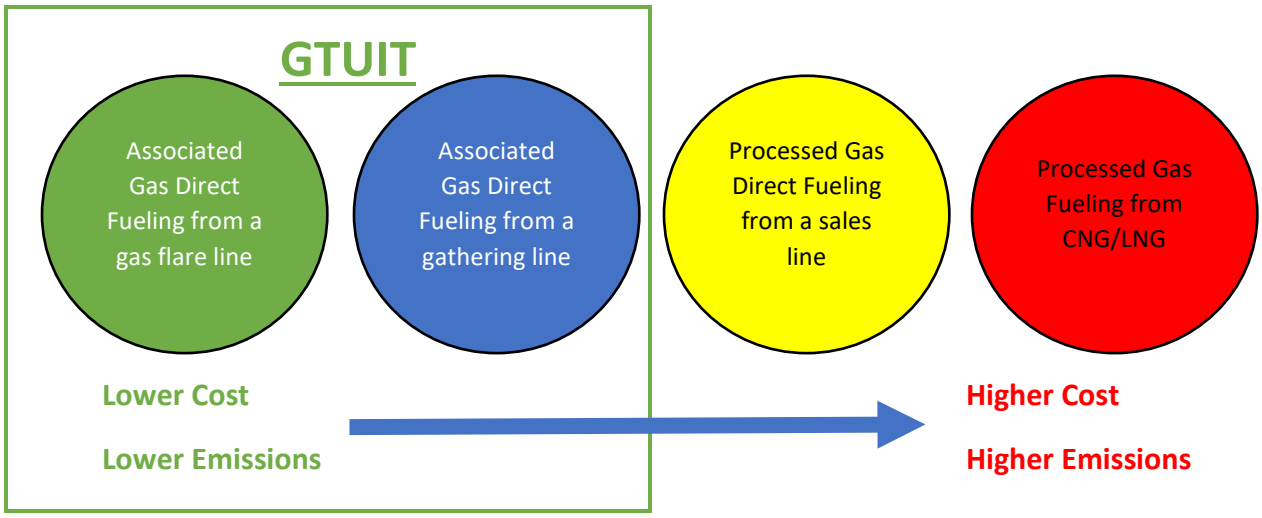

Figure 9: Selection chart for gas fuel sources for dual fuel applications

The estimated net cost savings to operators for using associated gas direct fueling versus CNG and diesel are very compelling.

Economic assumptions:

Delivered Diesel Price	$1.50/gallon
Delivered CNG Price	$1.05/DGE
Tolling Fee for Raw Associated Natural Gas	$1.91/mmbtu
Gallons NGLs produced per MCF processed	2.5 GPM
Net NGL Price	$0.44/gallon
DGE Gallons Consumed Per Day	12,500 gallons/day
Total Stages per Month	276
Base Cost per DGE for Associated Gas Processing	$0.65/DGE

**DGE = Diesel Gallon Equivalent*

Estimated monthly savings for a single frac fleet using direct gas fueling:

Operator Monthly Cost Savings VS. **CNG**	Operator Monthly Cost Savings VS. **Diesel**
$62,393	$177,393

As the price of natural gas, oil, and diesel increases, the savings become more amplified. For example, the estimated monthly savings for an operator when the price of delivered diesel hits $2.50 per gallon is estimated to be $464,893!

The Next Phase

E&P operators are searching continuously for solutions to reduce their drilling and completion costs while creating added value for their companies. Dual fuel engines offer an opportunity for operators to significantly reduce their diesel consumption during drilling and fracturing operations by replacing diesel with natural gas. Using associated gas from existing oil production provides the best value for gas substitution due to its reduced cost and lower emissions compared to trucking in costly outside fuel. GTUIT's conditioning technology provides optimal value and reliability for treating and supplying this inexpensive gas to power hydraulic fracturing operations or any other dual fuel application. If your operations require power and you have access to associated natural gas that requires treatment, please email the GTUIT team at info@GTUIT.com to learn more about how GTUIT can bring even greater value to your dual fuel fleet.