

MINI-GTL TECHNOLOGY BULLETIN

Volume 6, July 2019

INTRODUCTION

The Global Gas Flaring Reduction Partnership (GGFR) reports considerable progress and some setbacks over the last year in the commercialization of small scale gas to liquid (GTL) plants developed to monetize flared gas. The highlights are the Nigeria Gas Flare Commercialization Programme and the building of a 500 Mscfd micro-GTL and a 5 MM scfd mini-GTL plant in Colorado and Alberta, respectively.

A disappointing setback is the failure to start up the 1 MMscfd INFRA mini-GTL demonstration plant in Texas. We have pointed out years ago that this “revolutionary, 3rd generation GTL technology” came with a lot of technical risk and must be proven in a demonstration plant. INFRA built such a plant and was not able to make it operational. Many other early technology companies reviewed and categorized as “High Overall Risk” in our early reports from 2012, 2014 and 2015, (e.g. Methion, Carbon Sciences, General Methanol, R3 Sciences, Gas 2, Synfuels International and others) have not been successful. This is the norm of R&D of new technologies: from many ideas at the start, only a few will find commercial applications.

We have come to a point where currently just 5 mini-GTL technologies

1. **Greyrock (“Flare to Fuels”)**
2. **Advantage Midstream (licensing Greyrock technology)**
3. **EFT (“Flare Buster”)**
4. **Primus GE**
5. **GasTechno (“Methanol in a Box”)**

have been proven and are now available for gas flares monetization. GGFR is evaluating the benefits of an in-depth validation of these, and other small-scale gas utilization technologies, through a member supported effort. At present, the working group is in the process of being formed with representatives from GGFR Partners and possibly appropriate third parties.

NIGERIA GAS FLARE COMMERCIALISATION PROGRAMME (NGFCP)

The NGFCP was launched on December 13, 2016 with the challenging goal to eliminate all flaring in the country by 2020. It is a market driven process and follows a competitive bidding process designed to attract 3rd party investors from across the world to monetize their flared gas. The bidding process is being done in 2 stages: First, is a Request For Qualification (RFQ) which has been completed. A number of mini-GTL companies have submitted RFQs. Following a 'bidders conference' which is expected to be held in Abuja, Nigeria, this autumn, qualified applicants will be invited for the 2nd step, submission of Request for Proposals (RFP). The aggressive schedule hopes to see award of projects granted later this year, with project executions starting in 2020. www.ngfcp.gov.ng

NIGERIAN GAS FLARE COMMERCIALIZATION PROGRAMME
"HARNESSING NIGERIA'S FLARE GAS FOR SUSTAINABLE VALUE & WEALTH CREATION"

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Environmental Effect

News Highlights

- How Nigeria can save \$1b yearly from flared gas
16 Apr 2018
- FG to save \$800m as it seeks investors to commercialise flare gas
16 Apr 2018
- Global Gas Flaring Reduction Partnership (GGFR)
28 Mar 2018
- IYC, urges FG, oil firms to stop gas flaring by 2020
23 Feb 2018

CATEGORIZING SIZES OF GTL PLANTS AND PROCESSING UNITS

Here is a quick reminder of nomenclature for the range of GTL plant sizes discussed in detail in the last bulletin. We believe that the size categorization in the table below is helpful in understanding the significantly different ranges of application from small scale GTL to miniGTL and microGTL. The boundaries between the different sizes are obviously not absolute but are practical logarithmic order of magnitude steps based on the rule of thumb that 10,000 scf of gas yields 1 barrel of liquid product, 1 MM scf gas yields 100 barrels, and so on.



World scale...Small-scale...Mini...Micro



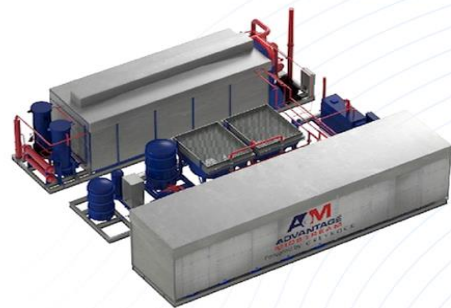
	World scale	Small-scale	Mini-GTL	Micro-GTL
Plant Picture	Atlas Methanol Trinidad	Juniper USA	INFRA Technology Texas	GasTechno M300 North Dakota
Gas Feed-rate	~>100MMscfd	~>10MMscfd	~>1MMscfd	~>0.1MMscfd
Gas Feed-rate	~>3million m ³ /d	~>300k m ³ /d	~>30k m ³ /d	~>3k m ³ /d
Capex	~> \$500MM	~> \$100MM	~> \$10MM	~> \$1MM
Product make	>10,000bpd	>1000bpd	>100bpd	>10bpd
Comments	Stationary; 20+ years	Stationary; 20+ years life	Moveable; modular	Unattended "machine"; modular

Note: 10,000scf or ~280m³ of gas yields ~1bbl of oil/diesel/gasoline

ADVANTAGE MIDSTREAM ANNOUNCES MICRO-GTL PLANT IN US: 500 MSCFD OF GAS

In the last issue we reported that Advantage Midstream, LLC, a Dallas-based, independent midstream company, announced a long-term agreement with Oklahoma City-based SandRidge Inc, to construct GTL plants to better monetize their low value associated gas. Late last year, a first venture consisting of a natural gas separation unit along with a GTL plant in the North Park basin, located in Jackson County, Colorado was announced.

The agreement provides for the installation of a natural gas refrigeration plant to process natural gas from SandRidge Energy's North Park assets. The plant will be installed adjacent to and in conjunction with Advantage's previously announced gas conversion plant that is to be installed in Jackson County. This plant is a Greyrock M-50 micro plant converting about 500 Mcf of dry gas into 50 bpd of liquids. As part of the agreement, Advantage will own and operate the integrated plants and market all liquids from the plant with



revenues shared. (Press Releases by SandRidge Energy, Oklahoma City, Mar 4, 2019 and by Advantage Midstream, Dallas, Aug 23, 2019)

“Advantage Midstream is pleased to announce another layer of processing services with SandRidge in the exciting North Park basin. The combination of traditional NGL processing and our conversion services will allow for optimal environmental and economic benefit,” said **John Stephenson, Chief Executive Officer of Advantage Midstream.**

The authors of this report have long emphasized how important the revenue stream from the NGL fraction can be for the overall economics of the dry gas GTL conversion plant.

For more information, contact: info@advantagemidstream.com; 214-396-9322

ROCKY MOUNTAIN GTL MOVES TO CONSTRUCTION: 5 MMSCFD MINI-GTL PLANT

Rocky Mountain GTL Inc. announced that it has been able to raise approximately US\$ 42 million. With the completion of the above private placement, the Board of Directors has approved the final investment decision to proceed with the construction of Canada’s first commercial GTL plant 60 kilometers east of Calgary, near Carseland, Alberta. This 500 bbl/d plant, with a price tag of about \$50 mln, is not so “Mini” at all!

The Corporation’s Carseland Enhanced GTL® (“EGTL™”) project is fully permitted and shovel ready. The proceeds of the private placements will be used to complete detailed engineering, order equipment and begin construction. The plant is designed to process up to ~5 MMscfe/d of natural gas and natural gas liquids into a nominal 500 bbl/d of paraffinic synthetic diesel and naphtha. The EGTL™ plant will be based on technology provided by affiliates of Greyrock Energy with technology enhancements by Expander Energy Inc. The GTL plant will incorporate several unique features in that it will be water neutral, self-sufficient in electric power, and will recycle significant volumes of process CO₂ to produce additional synthetic diesel. The Carseland plant forms the basis for future EGTL™ plants that are scalable from 5 MMscfe/d to 50 MMscfe/d of natural gas capacity. (FSCwire, Calgary, Alberta, Nov 28, 2018)

Rocky Mountain GTL acquired Expander Energy Inc.’s patented Enhanced GTL® technology. They also completed a technology supply agreement from Greyrock that enables the deployment of additional plants that use Greyrock’s Direct Fuel Production™ technology and GreyCat™ catalyst.

“This landmark transaction signals a new era of natural gas processing and monetization. The patented EGTL® plants convert Natural Gas/Natural Gas Liquids/Liquid Petroleum Gas, in any combination, into a single synthetic paraffinic diesel product. Rocky Mountain GTL Inc. will eliminate price or pipeline accessibility issues for producers by providing optionality to produce natural gas (stranded or otherwise) and associated liquids by converting this resource to synthetic diesel. The unconventional oil and gas boom and global anti-flaring initiatives have created an unprecedented opportunity for Rocky Mountain

to be a world leader in the conversion of natural gas to high performance, zero sulfur, low emission and low Carbon Index synthetic liquid fuels,” stated **James H. Ross, the Corporation’s Chief Executive Officer.**

More information: www.rockymountaingtl.com; 403-452-6021



INFRA TECHNOLOGY DEMONSTRATION PLANT PROBLEM

We have followed and featured the INFRA GTL Technology for many years. Highly questionable claims of 50+% in Capex reduction and unusual operating conditions were identified as serious concerns with the need of a semi-commercial demonstration plant to substantiate the claims and prove the technology. INFRA did build a 100 bpd demonstration plant (“M100”) in Wharton, Texas in 2016, which was featured in a number of previous reports. Unfortunately, INFRA was unable to commission and start up the plant for more than 2 years. This start-up failure is a huge setback for INFRA Technology and for the emerging mini-GTL industry. It will be difficult for INFRA and their potential customers to obtain financing for early projects. The strategic path forward for INFRA is not yet known, but sale of the plant with “final phase of commercial demonstration” is one option.

Late breaking news: Greenway Technologies announced on July 23 that Mabert LLC, a major investor in Greenway, acquired the whole INFRA plant including an operating license agreement. The purpose of the acquisition is the incorporation and commercial demonstration of Greenway’s “G-Reformer” technology. We will see whether the new team will be able to make the plant with the new reformer operational. (Globe Newswire, Fort Worth, Texas, Aug 31, 2019).

Jack Haynie took on the role as Business Development Manager based in Houston. His contact information is haynie@infratechnology.com; +1 713 300 2801

EFT EXPANDS MICRO-GTL OFFERINGS AND ENTERS MINI-GTL ARENA

EFT's entry into the microGTL area with their FLARE BUSTER® 25, a nominal 25bpd mobile modular and self-sufficient microGTL plant has grown to include nominal 50 bpd, 100 bpd and 250 bpd versions. All FLARE BUSTER® sizes produce pumpable syncrude liquids that will blend directly into conventional oil. FLARE BUSTER® 25 incorporates advanced controls for satellite-linked remote monitoring/control and unmanned operation. The plant can be set up to generate its own power, and an upgrading module is available to produce fuel blendstocks (diesel/naphtha or diesel/jet naphtha).

Features:

- Primary plants consist of two to six (depending on size) trailer-mountable skids that consume 250 to 2,500 Mscfd of associated gas to produce roughly 25bpd to 250 bpd of pumpable Syncrude.
- A flexible front-end gas conditioning module to adapt to a variety of gas compositions.
- Optional capability to upgrade to transportation blendstocks (diesel, jet, naphtha).

EFT has now qualified two US Manufacturers to build these plants and expects to qualify more on a world-wide basis. The estimated cost: less than US 4 million fob US shop at 25 bpd, approx. US\$ 15 million at 250 bpd.

In addition to its FLARE BUSTER® activities, EFT continues to license its FT technology to others, recently adding Red Rock Biofuels to the list of licensees. (Personal communication from Mark Agee, VP, EFT).

GASTECHNO

On May 1, 2018, GasTechno issued a press release commenting on the experience of their Bakken gas flare monetization venture and announcing both the development of a combined NGL and GTL process and a new exciting collaboration with Paradox. However, the collaboration didn't materialize for a number of reasons but particularly because of the high cost of oxygen which made the operation of the small M-300 plant (converting only 300Mcf of gas) uneconomical.

GasTechno's new strategy forward is a global licensing effort which is underway. See the website for more information: www.gastechno.com. They also have three plants for sale: two M-300 units (US\$ 1.5mln each) and one M-700 unit (US\$2.5 mln). A distillation unit is required to separate the primary product mix into methanol, ethanol and formalin (US\$ 600k and US\$ 750k for the M-300 and M-700 respectively). (Personal communication from Walter Breidenstein, Founder and CEO)

PRIMUS GREEN ENERGY: FOCUS ON SMALL SCALE GASOLINE

Primus Green Energy had announced projects in North America converting about 6 MMscfd of gas into 160 tpd of methanol. Primus GE's business model is to build, own and operate such plants. Economy of scale considerations for the Marcellus methanol project in West Virginia (~5MMscfd to 160tpd methanol) suggested that combining 4 such plants would offer greatly improved economics. Primus' CEO Steve Murray told us that, based on this information, they re-engineered their modular plant to twice the size ("XL") and then combine 2 units, "2XL", into small scale GTL plants that convert ~21 MMscfd of gas into 2100 bpd gasoline (a more fungible product than methanol) with excellent financial returns. They continue to improve their methanol to gasoline (MTG) technology with better catalysts. Strategic focus is on building such plants in North America and licensing the technology in the Middle East. However, flare gas remains an area of interest at volumes >2MMscfd.

For more info, please contact Trent Crow, VP Strategy, tcrow@primusge.com,

GREYROCK BUSINESS ACTIVITIES: MULTIPLE PLANTS?

Greyrock issued a very interesting paper titled "Reduction of greenhouse gas and criteria pollutant emissions by direct conversion of associated flare gas to synthetic fuels at oil wellheads" in the Int. Journal of Energy and Environmental Engineering, Vol 9 (2018), 305-321. This is a must read for people interested in flare gas monetization via GTL. About $2.4 \times 10^4 \text{ m}^3/\text{day}$ of associated gas from a well in Ohio was directly converted in a Greyrock microGTL plant into about 11,000 liters/day of fuel (80/20 diesel/gasoline). For those in the USA this is ~700k scfd flare gas converted into ~70 bpd clean synthetic fuels. The thermal efficiency proved to be a remarkable 58% based on the flare feedstock into the plant. The paper was authored by Eric Tan (NREL, CO) and Dr. Dennis and Robert Schuetzle, founder and CEO of Greyrock. The abstract follows:

"This study describes the results of a "well-to-wheel" life cycle assessment (LCA) carried out to determine the potential greenhouse gas and criteria pollutant emission reductions that could be achieved by converting associated flare gas directly to synthetic fuels at oil wellheads in the US and globally. A Greyrock Flare Gas-to-Fuels™ conversion process at an Ohio oil well was used as the base case for this LCA. The liquid fuel produced directly from associated gas is comprised primarily of premium synthetic diesel with a small amount of synthetic gasoline. In this LCA scenario, the synthetic diesel and synthetic gasoline are blended at 20 and 10 vol% with petroleum diesel and gasoline, respectively. While the synthetic diesel fuel can be used as is (100%), the 20 vol% synthetic diesel blend (with petroleum diesel) was found to significantly improve engine performance, increase fuel economy, and reduce emissions. The direct conversion of associated gas to synthetic diesel fuels globally could reduce emissions of CO₂ and CH₄ by up to 356 and 5.96 million metric tons/year, respectively, resulting in the reduction of greenhouse gases (GHGs) by about 113.3 and 92.2% (20 year global warming potential) and 73.8 and

50.7% (100 year global warming potential) for synthetic diesel and gasoline fuels when compared to petroleum-derived gasoline fuels, respectively. Likewise, diesel criteria emissions could be reduced globally by up to 23.3, 0.374, 42.4, and 61.3 million metric tons/year globally for CO, particulates, NOx, and hydrocarbons, respectively. The potential economic benefit of this approach is that up to 5.30 and 71.1 billion liters of synthetic fuels could be produced each year in the US and globally from associated gas, respectively.”

CURRENT CONTACT LIST

1. The current leading GTL technology providers with commercial offers for gas flares are:

Greyrock: Robert Schuetzle, rschuetzle@greyrock.com; +1 415 939 9904

Advantage Midstream : John Stephenson, info@advantgemidstream.com; +1 214-396-9322

EFT: Mark Agee at magee@emergingfuels.com; +1 918 605 5456

GasTechno: Walter Breidenstein at walterb@gastechno.com; +1 231 535 2914

Primus GE: Trent Crow, tcrow@primusge.com, +1 908-281-6000

2. GTL technology providers no longer interested in flare gas monetization:

Velocys

Oberon Fuels

Topsoe/MPS

3. GTL technology providers with unknown status:

Maverick Synfuels: Sam Yenne at syenne@mavericksynfuels.com; +1 919 749 8717

BgtL: Dr. Zhijun Jia at zhijunjia@bgtl-llc.com; +1 608 461 1356

Verdis: Rob Ayasse at rob.ayasse@verdisfuels.com; +47 469 59 309

IN OTHER NEWS

A number of potential mini-GTL projects reported in the last issue seem not to have materialized. One was a Maverick technology methanol project at Prudhoe Bay by Prudhoe Bay Chemicals, the others were GTL-FT plants in Texas and Kentucky by Extiel inc.

On June 28, 2019 the world's only Gas to Gasoline plant was opened in Ashgabat, Turkmenistan. It is a world scale plant, converting about 150MMscfd of gas into 15,500bpd of gasoline, using Haldor Topsoe TIGAS technology. We have described the technology and reported on the construction of this plant. Congratulations to all parties involved. We will see whether this successful world scale GTL project will lead to interest in smaller scale projects monetizing flares.



Photo: Haldor Topsoe

IN SUMMARY

- Over 200 companies have filed for the RFQ (Request for Qualification) in Nigeria to participate in the commercialization of Nigeria's flared gas.
- A micro-GTL plant (500 Mscfd) will come on-line this year in Colorado (Advantage Midstream/Greyrock/Sandridge)
- A mini-GTL plant, "Rocky Mountain GTL", (5 MMscfd) is being built in Alberta, Canada (Rocky Mountain GTL Inc/EGTL/Greyrock).
- A Greyrock micro-plant was used at an Ohio oil well for flare gas conversion and the test results are reported in a detailed publication.
- A world scale gas to gasoline plant (Topsoe TIGAS technology) was started up and dedicated in Turkmenistan in June 2019. Capacity: 15,500bpd of products
- EFT is building on their GTL-FT technology with multiple licenses and a new expanded micro-GTL offer.
- Gastechno is pursuing global licensing of its technology portfolio and has its 3 micro-GTL plants on sale.
- Primus GE is now focusing on a number of "small scale" GTL plants in North America (21 MMscfd into 2100 bpd gasoline), while continuing to evaluate "mini" GTL opportunities.
- The INFRA Technology demonstration plant in Texas (M-100, 1 MMscfd) has been sold. It was never operational. A sale to Mabert/Greenway was announced in late July with the intent to make the plant operational with a new reformer technology.
- The ENVIA/Velocys demonstration plant in Oklahoma (250 bpd, 2.5 MMscfd) is for sale. It was a successful demonstration with production of renewable fuels from landfill gas. However, future Velocys projects will all be based on bio-feedstocks to earn renewable fuel credits in the USA which are critical for attractive economics.

We hope you enjoy the reading! Feel free to contact either of us. If you know of any interesting developments, please let us know.

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Martyn Howells: hhowells@worldbank.org

For more information on GGFR, please visit: <https://www.worldbank.org/en/programs/gasflaringreduction> and follow us on Twitter @WBG_Energy.