

MINI-GTL TECHNOLOGY BULLETIN

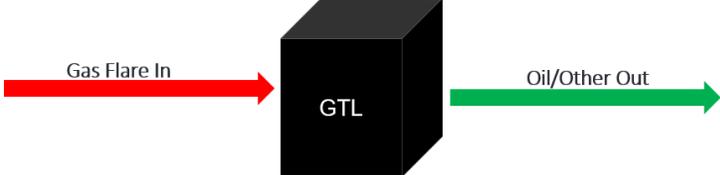
Volume 5, July 2018

INTRODUCTION

The 2018 annual GGFR Steering Committee Meeting was held in Baku, Azerbaijan, May 7-8. My presentation “Gas Flare Monetization with miniGTL and microGTL: Accelerating Adoption” met with a lot of interest but also showed ongoing concern about technology risk, operational reliability and safety. I want to emphasize again some foundational facts:



The promise of GTL for GGFR:



- **Proven chemical processes** of associated gas into liquid hydrocarbons
- **Feedstock flexibility**: wet gas, dry gas, ethane, LPG,...
- **Product flexibility**: synthetic oil, synthetic LPG (DME), diesel, gasoline, methanol,...
- **Technology provider flexibility**: commercial offers of proven systems
- **Combination NGL separation and GTL conversion**: usually economically favored

Commonly, oil producers are not comfortable with refining or chemical processes on their premises. However, most GTL processes are **established, proven and safe technologies** and should be thought of as a reliable “black box”. The **feedstock flexibility** is noteworthy: Every plant will have a built-in gas treatment system that is custom designed for the particular flare gas and will remove water and all contaminants before fractionation (optional) and gas conversion. Another great advantage is the **product flexibility** GTL will provide: in the simplest case with no local product markets, the flare gas will be converted into synthetic oil which is then blended and marketed with the crude oil. In many other cases, there will be ready markets for the GTL products such as, for example, cooking with synthetic LPG (DME) or transportation with clean diesel and gasoline. Importantly, a number of competent **technology providers** have emerged, offering a broad selection of miniGTL and microGTL solutions shown later in this Bulletin. Finally, the most economical and practical applications of GTL to raw, wet flares involves

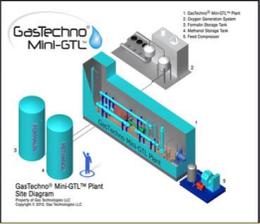
separation of condensate and NGL prior to the GTL step which converts the remaining dry gas. However, as pointed out repeatedly, the entire untreated associated gas stream can be processed through the GTL process with the help of a minor “pre-reforming” step.

There is some small risk with breakthrough technologies such as micro-channel reactors (Velocys), oxidative coupling of methane (Siluria) and methane partial oxidation (Gastechno). Velocys is no longer pursuing gas flare monetization, while GasTechno continues demonstration of their technology in the field, thereby eliminating risk concerns. The efforts of Siluria will be discussed in the next Bulletin.

CATEGORIZING SIZES OF GTL PLANTS AND PROCESSING UNITS

World scale GTL plants have been built for many decades, approaching 100 years. These plants consume large volumes of natural gas. For example, a world scale methanol plant, such as the Atlas methanol plant in Trinidad, consumes about 160MMscfd, costs about \$1 billion and is built to last decades. The world’s largest GTL-FT plant, the Shell “Pearl” plant in Qatar consumes nearly 1.5 billion scfd!

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

Smaller scale plants are targeting smaller gas volumes, significantly less than 100MMscfd. One example is the Juniper GTL-FT plant to be started up this year with a gas feed rate of 11MMscfd. The CompactGTL plant (described many times in earlier reports and currently awaiting an FID decision) was to be fed with 25MMscfd of associated gas in Kazakhstan producing 2500bpd of clean diesel. A “small scale” plant like

that would be at the upper end of our gas flare reduction focus and would likely be a stationary plant (despite extensive modularization) and be built for at least 20 years of operation.

Many flare gas applications require even smaller, preferably modular and movable, plants, and a variety of so-called miniGTL technologies have been developed. In order to harmonize the emerging nomenclature in this arena, we define **miniGTL as modular plants in the range from 1- 10 MMscfd (30k-300k m³/day)**. The INFRA demonstration plant in Texas is a prime example of such a plant consisting of about 12 easily moveable modules which are designed to monetize 1MMscfd of associated gas into 100bpd of diesel/gasoline or jet fuel.

The last 3 years have seen the development of **microGTL “machines”** (defined as ≤ 1 MMscf/d, ≤ 30 k m³/d) as described in previous bulletins. They are unattended, remotely controlled modules that are ideally suited for many typical gas flares around the world. Units for gas flares of as little as 0.25MMscfd (~ 8 m³/day) are now commercially available. Plants of this size were originally developed by GasTechno. Subsequently, Greyrock (“Flares to Fuels” technology, 2014) and BgtL (2017) have also developed commercial offers. In this bulletin, we will introduce a new player in this arena, the miniaturized “Flare Buster” technology by EFT.

We believe that the size categorization in the Table above is helpful in understanding the significantly different associated gas applications from small scale GTL to miniGTL and microGTL. The boundaries between the different sizes are obviously not absolute but are practical order of magnitude limits based on the rule of thumb that 10,000 scf of gas yield 1 barrel of liquid product, 1MMscf gas yield 100 barrels, and so on.

GREYROCK BUSINESS ACTIVITIES: MULTIPLE PLANTS?

Greyrock has become the leader in small-scale GTL technologies covering the range from microGTL to miniGTL and small-scale plant offerings. The picture below illustrates their global business development activities:



A “P-500” plant (5MMscfd gas, 500 bpd clean diesel) will be built in Alberta under the leadership of Expander Energy using Greyrock’s modular DFP diesel technology. A FID for this Rocky Mountain GTL plant was made earlier this year! The 2nd funded P-Class venture is the much delayed “Houston” plant which will now be built somewhere else in Texas.

A JV with Perseus, discussed in an earlier bulletin, targets gas flares in Mexico, mostly applying their microGTL “M” series. Another JV with AngloAmerican looks for small-scale GTL applications using distressed gas resources in Africa. A number of gas flares are being targeted.

Advantage Midstream, a Dallas based midstream and GTL-focused oil and gas company (www.advantagemidstream.com) has partnered with Greyrock and is exploring opportunities in many US shale gas areas. They represent the all-important link between typical technology providers and producers of associated gas or distressed gas who prefer 3rd-party leadership and ownership in the monetization of these gas resources. In May 2018, Advantage Midstream announced a long-term agreement with Sandridge Energy for GTL ventures in Colorado to assist in monetizing their low-value

gas. Financing of the projects is provided by Castlelake, L.P., a global private investment firm. Rumor has it that multiple Greyrock M units have already been funded, are being built, with some of them close to deployment on gas flares.

EMERGING FUELS TECHNOLOGIES: EFT ENTERS MICRO-GTL ARENA

EFT's entry into the microGTL area is their **FLARE BUSTER® 25**, which is a nominal 25bpd mobile modular and self-sufficient microGTL plant that produces 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 plant consists of two trailer-mountable skids that consume 250 to 300 Mscfd of associated gas to produce roughly 25bpd of pumpable Syncrude. Multiple modules can be run in parallel to match gas volumes.
- 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).



A nominal 50bpd plant is also being developed. EFT has already qualified one US Manufacturer to build these plants and expects to qualify more on a world-wide basis. Plants can be delivered in as little as 26 weeks. Cost: less than \$4 million fob US shop.

Beyond EFT's own marketing, they have also been able to license their FT technology to Juniper GTL and Fulcrum Bioenergy (Reno, Nevada).

GASTECHNO ENERGY & FUELS (GEF): MOVE FROM BAKKEN TO UTAH

GasTechno had a tremendous year as reported in previous Bulletins. On May 1, 2018, they 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. Here are some excerpts:

“In August 2017, we completed testing and third-party commercial validation of our Mini-GTL® 300 plant at a site located in New Haven, Michigan. Shortly after, we installed and operated an NGL plant, the front-end complement to our Mini-GTL facility, at an oil field in North Dakota which is in the midst of the latest oil & gas boom. During our 7 months on-site in North Dakota, we identified a significant number of associated gas flaring sites ideally suited for our Mini-GTL® plants. It was eye-opening to see all the drilling activity first-hand, and the massive potential market for GasTechno to provide associated gas capture and conversion services” commented Gas Technologies CEO Walter Breidenstein. “However, we

quickly learned that the North Dakota Industrial Commission regulations do not require 100% or “complete” associated gas capture at well sites. In practice, the NDIC regulations only require about 20% flare recovery (50% C3+ recovery) so the market demand for flare capture in the near-term can be easily satisfied by traditional refrigeration or NGL skids and does not require a Mini-GTL® unit that can capture up to 83% of the flared gas. Operators appear satisfied with 20% recovery for compliance



and are taking a “wait and see” approach with respect to the potential reversal of EPA and NDIC gas capture rules targeted for October 2018. We could not wait until October to see if there will be more stringent gas capture targets in North Dakota and operator interest for our services, so we are pressing ahead with our next installation in Utah at a much larger gas processing facility,” said Mr. Breidenstein. The picture above shows the M-300 unit on its way from North Dakota to Utah.

“GEF’s combined NGL-GTL solution converts \$9-12 BOE gas into \$70+ BOE fuels and chemicals. For producers, this creates significant incremental value compared to selling at current NGL and natural gas prices. For gas processors, the incremental value is close to \$60+ BOE via natural gas conversion to fuels and chemicals”.

The significant financial upside presented by the GasTechno solution grabbed the attention of Todd Brooks, the CEO of Paradox Resources. GEF and Paradox have reached an agreement to transfer the Mini-GTL® 300 unit from the Bakken to the Paradox Lisbon gas processing site in Utah, start it up and then scale up to GasTechno’s Mini-GTL® 750 later this year. As discussed above, these 2 units operate in what we call the microGTL arena. Later, they will scale up to the Mini-GTL® 1500 and finally the Mini-GTL® 5000 unit. Paradox has decided to become a new strategic investor into GEF operations and is also looking to support the company in its future \$50 to \$100 million capital raising efforts.

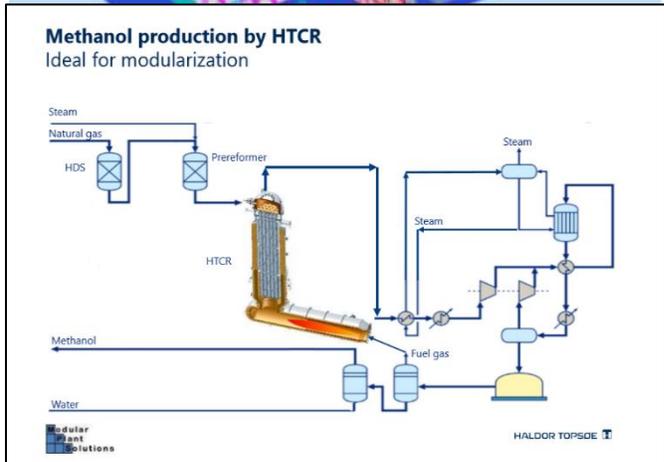
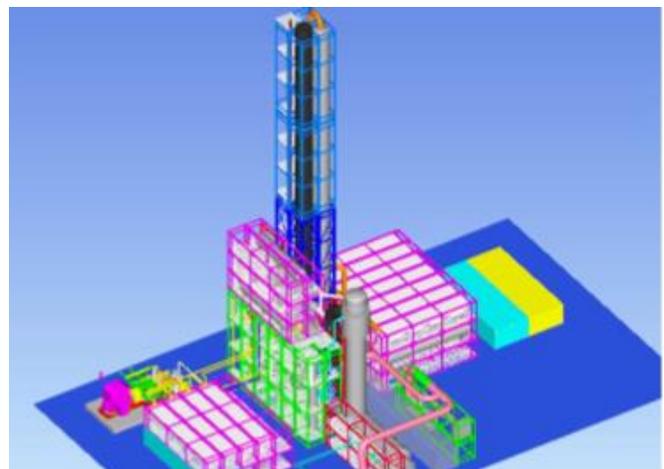
In another press release in June 2018, GasTechno offered “Exclusive Country-Level Mini-GTL Technology Licenses”. More information from the CEO Walter Breidenstein (walterb@gastechno.com).

TOPSOE/MPS: MEOH-TO-GO

MeOH-To-Go™ is a small-scale modular methanol plant designed for field operations anywhere in the world. These plants enable users to use associated or stranded gas with variable gas quality to produce methanol or its derivatives DME, gasoline, etc. The plant (Topsoe/MPS only offer this one size) needs 7.1MMscfd of gas and produces 215tpd of methanol. With potential add-ons, it could produce 150tpd DME (equivalent to about 95tpd of LPG) or about 700bpd of high octane gasoline.

MeOH-To-Go™ is a partnership between Haldor Topsoe, known for their methanol process technology with over 40 licensed methanol units around the world, and Modular Plant Solutions. The MeOH-To-Go™ design utilizes modular construction methods, making it moveable if needed, thus also reducing the risks in field construction. The plant can be self-supporting and can even be remotely operated and monitored! Thus, this miniGTL plant has some features typical for microGTL units.

The plant uses a Haldor Topsoe Convection Reformer (HTCR) and not a 2-step reformer as erroneously reported in the last Bulletin (Volume 4). The simple Process Flow Diagram (PFD) is shown above. The HTCR is a heat exchange type steam reformer where a furnace provides the heat for the endothermic steam reforming reaction and a convection type heat exchange reformer. The



company claims that this reformer scheme is well suited for small scale plants because it is steam neutral and lower cost than more conventional reformers.

Haldor Topsoe/ Modular Plant Solutions partnership's business focus is on this one plant size with first commercialization in the US. Apparently, customers for the first 5 plants have been "lined up"!

INFRA TECHNOLOGY

INFRA's 100bpd demonstration plant in Texas is still not operational. First product is now expected later in 2018. David Loeschner is the new Business Development Manager. His contact information: loeschner@infratechnology.com; +1 832 839 1111

MAVERICK SYNFUELS: MODULAR METHANOL PROJECT IN ALASKA

Maverick Synfuels has been discussed in some detail in earlier reports/bulletins. They provide skid-mounted modular natural gas and biogas-to-methanol plants in sizes ranging from 25 metric tons per day (800Mscfd natural gas equivalent) to 100 metric tons per day (3MMscfd equivalent) covering the microGTL and miniGTL range. The plants are designed around simple and proven methanol production technology thus minimizing technical and economic risks. Using advanced manufacturing processes, the various sections of the methanol plant are skid-mounted at a central facility for truck transport and rapid assembly at the plant site. Accordingly, from start of engineering to plant commissioning, the schedule can be reduced to 12-15 months. The simplicity of design also affords the capability of fully automated operation resulting in a significant reduction in operating costs. At this scale, plant air emissions are usually well under those required for special permitting. With proper protection from the environment, the company claims that the plant can operate in the harshest environment, including the North Slope of Alaska where Maverick (in partnership with Prudhoe Bay Chemical) is progressing with a NG100 plant. This plant will produce (some of) the methanol needed for oil and gas operations on-site from associated gas and replaces previously imported methanol. More information on this miniGTL plant in North America will be provided in the next bulletin.

This application demonstrates the innovative use of associated gas for local upstream oil production ventures. www.mavericksynfuels.com; Contact is Sam Yenne at syenne@mavericksynfuels.com; +1 919 749 8717

COMPACT-GTL

CompactGTL continues to pursue opportunities in the former CIS and Asia with 2 projects in the pre-FEED and feasibility stage. Their offer is in the small-scale GTL segment between 1000 and 4000bpd consuming 10 to 40MMscfd of gas and producing syncrude or diesel. Recently they have started to work on waste to fuels projects in Europe as well. Their new Chief Commercial Officer is Anar Asgarov. Anar.asgarov@compactgtl.com; +44 (0) 203 6450536

PRIMUS GREEN ENERGY: MANAGEMENT CHANGE

Primus GE was a leader in miniGTL process development with a novel STG⁺ (syngas-to-gasoline) and syngas-to-methanol technology. Two commercial methanol projects were announced in the US and in Canada (see earlier bulletins). However, after another management shake-up (5th CEO in 6 years) things have gone quiet. Thus, there is a question mark on the availability of their technology solution at this time. Steven Murray is their new CEO and the source of update information. smurray@primusge.com; +1 281 639 5954

VERDIS FUELS: FLOATING GTL IN NIGERIA?

Verdis Fuels was an early pioneer in small-scale GTL but has been quiet the last few years. Rob Ayasse, President and CEO based in Norway, informed us of some exciting developments. First, Verdis has partnered with Suez Oil and Gas Systems, a global engineering, fabrication and project management company. They have just completed a full pre-FEED study of a 1000bpd GTL-FT plant to be deployed offshore Nigeria! Rob stated that “an aggressive push shall be made to target onshore and offshore flares”.

Verdis is also developing a microGTL (250kscfd, 25bpd product) unit employing their proprietary reforming and FT technology. Initially developed for biogas resources, such a system is ideally suited for small gas flares as well.

Verdis is in a rapid technology demonstration phase and could have commercial offerings soon, both in the microGTL and small-scale GTL areas.

CURRENT LEADING TECHNOLOGY PROVIDERS WITH COMMERCIAL OFFERS

PRODUCT	COMPANY	MICRO-GTL	MINI-GTL	SMALL-SCALE
Methanol blend	GasTechno	x		
Methanol	Maverick Synfuels	x	x	
Methanol	Topsoe/MPS		x	
Methanol, gasoline	Primus GE ¹		x	
Oil, diesel, methanol	BgtL	x		
FT: diesel	Greyrock	x	x	x
FT: oil, diesel	EFT	x	x	
FT: diesel, gasoline, jet	INFRA		x	
FT: diesel, oil	CompactGTL			x

¹ Status unclear

CURRENT CONTACT LIST

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

Greyrock: Robert Schuetzle, rschuetzle@greyrock.com; +1 (916) 290 9350

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

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

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

INFRA: David Loeschner at loeschner@infratechnology.com; ; +1 832 839 1111

Topsoe/MPS: David Townsend at david.townsend@modularplantsolutions.com; +1 281 450 3679

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

Primus GE: Steven Murray at smurray@primusge.com; +1 281 639 5954

CompactGTL: Edmund Buckley at edmund.buckley@compactgtl.com; +44 020 3645 0536

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

IN OTHER NEWS

Expander Energy announced the Final Investment Decision (FID) for the 1st **miniGTL plant in Alberta**. We reported this was imminent in the last bulletin. The plant will be fed with 5MMscfd of pipeline gas and will produce about 500bpd Fischer Tropsch products, pre-dominantly clean diesel. As already mentioned, the core of the technology comes from Greyrock. www.expanderenergy.com

Extiel GPG, LLC, a new miniGTL company based in Texas, announced plans to build **2 miniGTL plants in Somerset, TX**, the 1st train at 250bpd (2.5MMscfd gas) and the 2nd at more than 500bpd (5MMscfd gas). The feedstock is shale gas. The product focus is on high-value waxes and base oils rather than diesel to improve overall project economics. www.extielgpg1.com More information and their interest in flare gas will be provided in the next Bulletin.



SUMMARY

Greyrock has taken the lead in establishing commercial uptake of their technologies in conjunction with powerful partnerships. Advantage Midstream is a new key player in the commercialization of small-scale GTL technologies.

A miniGTL plant will be built in Canada (Expander Energy and Greyrock).

EFT is building on their GTL-FT technology with multiple licenses and a new microGTL offer.

Gastechno is making progress: they have a low-cost, breakthrough technology and continue to overcome concerns about technology risks and product portfolio. Their partnership with Paradox Energy could be transformative.

Topsoe and MPS are now offering competition for Primus GE with modular methanol plants in the same size range.

“Quiet” technology providers continue to pursue their technologies with new financial injections: Verdis Fuels and Maverick Fuels are good examples. Maverick Synfuels is now working on a commercial plant in Alaska for local methanol production for Prudhoe Bay.

We hope you enjoy the reading! Feel free to contact either of us:

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