MINI-GTL TECHNOLOGY BULLETIN

Volume 7

March 2020

INTRODUCTION

Late last year we celebrated the 5th anniversary of the annual "Gas Flare Monetization & Syngas Conversion Forum" hosted by Energy Frontiers International (EFI) in Houston and saw record attendance. As members of the GGFR Partnership you have access to all presentations from the Forum, (see instructions below) and we hope that even more members will participate in next year's Forum. Importantly, let us know of technologies, companies or specific speakers you would like to see on the program and we will do our best to accommodate your wishes. We will send you timely invitations and notices of the 6th conference, again to be held in Houston.

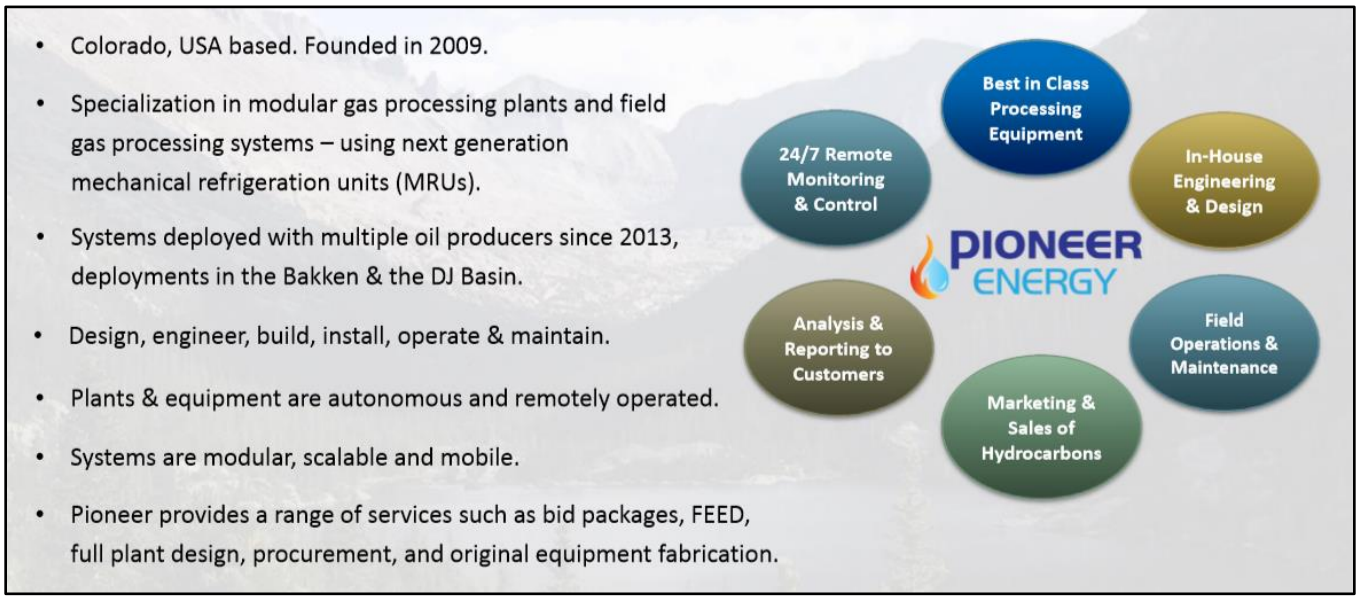
Content from the 2019 Gas Flare Monetization & Syngas Conversion Forum is available on EFI's online portal (www.energyfrontiers.org) – simply click on the EFI logo on the home page (upper left corner) and sign in with your name and Access Code "GGFR". You will have immediate access to all presentations.

The following topics are covered in this bulletin:

1. Pioneer Energy: A Fully Integrated Midstream Company
2. Primus Green Energy moves to FEED for 1st project
3. Greenway/INFRA demo plant in Texas moves ahead
4. Resurgence of world scale plants for associated gas
5. CAPTERIO: a driving force for accelerated adaption of flare gas monetization
6. New technologies:
    A. HiiROC: gas conversion to hydrogen and carbon
    B. Galores Technology: improved microGTL-FT?
    C. Dason Technology:
7. Project Update
8. Commercial small-scale GTL projects
9. Leading players contact information
10. Summary

1. PIONEER ENERGY: A FULLY INTEGRATED MIDSTREAM COMPANY

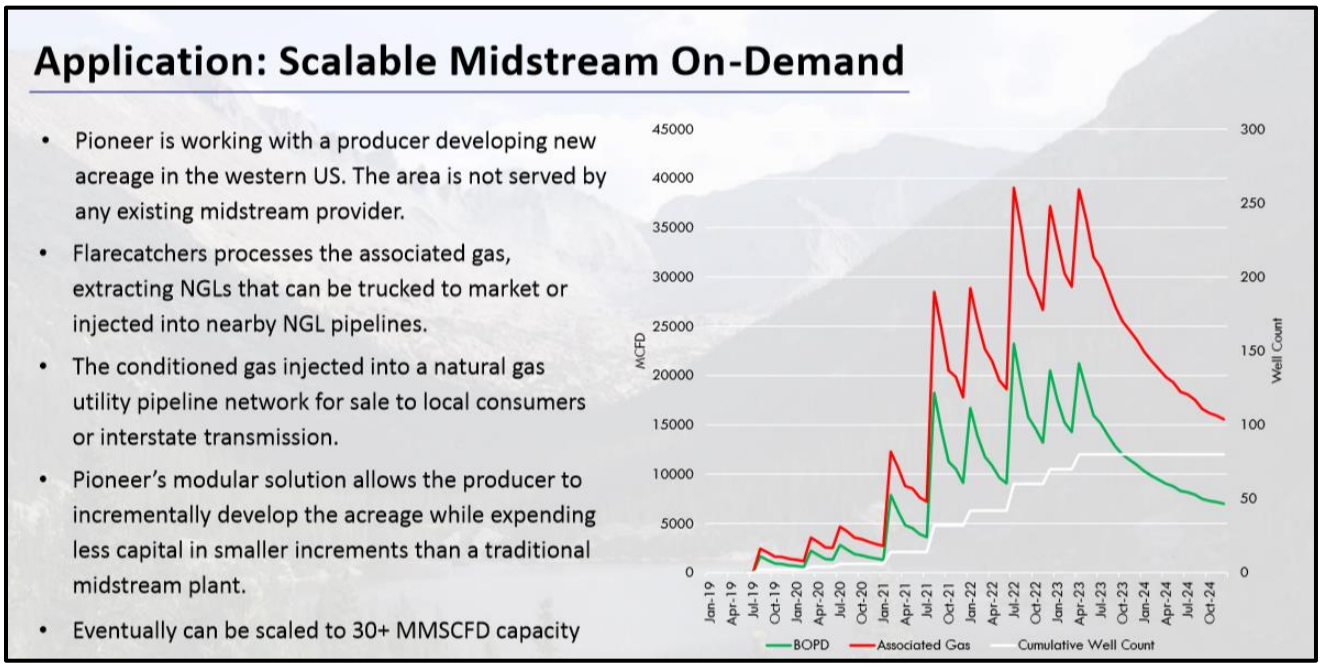
We have covered Pioneer Energy for the last 5 years and many of us have seen their flare gas processing facilities in operation in the Denver, Colorado area. They now have numerous commercial operations and have a broad, fully integrated portfolio of flare gas monetization. Originally, they processed flare gas to produce condensate and NGL's, used ethane to operate the processing units, but still had to send back the lean gas (mainly comprising of methane) to the flare. Now however, they have acquired and developed technologies to convert this lean gas into either LNG or methanol/DME, completing the monetization of all components of flare gas. The methanol/DME module is being demonstrated in a 10tpd plant at their facilities in Denver, Colorado. Furthermore, they broadened the scale of their application to range from 1 MMSCFD (mini) to 100+ MMSCFD (world-scale) using modular gas processing solutions. Their offerings and services are shown here. The complete presentation by Mr. Palaia, VP of Business Development, can be found along with the entire collection of content from the GGFR/EFI forum on EFI's online portal.



Their product lines include:

1. Flarecatchers: flare gas processing (typically 10MMSCFD/process train)
2. NGL Fractionators: producing condensate and LPG
3. Pioneer LNG 5000: modular LNG plant (5MMSCFD yields ~ 50,000 gpd LNG)
4. Methanol & DME: modular GTL plants (yielding transportation and cooking fuels)
5. Custom systems

As previously discusssed, meeting the challenge of cost-effectively matching changing flare gas volumes with flare gas monetization equipment can best be accomplished with modular plant solutions. Shown below is a great example of a custom flare gas monetization plan developed by Pioneer for a potential customer. Future wells with increasing flare volumes combined with the well known flare volume decreases of existing wells are matched with appropriate additional modular hardware and capacity.



Pioneer Energy is poised to become a global player in gas flare reduction. They are a preferred partner in multiple consortia proposed for Nigeria where they have been active for many years. Feed packages have been and are being prepared and multiple projects may go forward in 2020.

In Mexico, they are developing small "Well2LNG" projects in the 1-3MMSCFD range with partners Ewen Energy and Cawen Energy.

In Oman, they are working with PDO, the majority state owned oil company, and other partners on monetization of 44 flare sites. Stay tuned.

2. PRIMUS GREEN ENERGY MOVES TO FEED

Primus Green Energy is among the leaders in offering a gas conversion option to methanol and its derivatives (DME, gasoline). They have demonstrated their proprietary "STG+ technology" in their Hillsborough, NJ, pilot plant for over 10,000 hours over the last few years. In December 2019 they announced a FEED (Front End Engineering and Design) study for a plant in Texas using 28MMSCFD of gas and producing 2,800bpd of gasoline. The study is being done by IHI E&C in conjunction with a "global petrochemical company JV partner" and will be completed by the middle of 2020. Earlier project proposals had centered around 5MMSCFD gas volumes converted to 160tpd methanol. This new plant, more than 4 times larger, combined with the fungible gasoline end product makes for better financial returns and easier financiability according to the CEO Steven Murray.

3. GREENWAY/INFRA DEMO PLANT MOVES AHEAD IN TEXAS

The INFRA M100 demonstration plant in Wharton, Texas, is well known and has been visited by many of us over the last 3 years. INFRA was unable to start up the plant, a huge disappointment to all. Jack Haynie, VP Business Development, summarized the situation at the EFI GGFR conference as follows.

INFRA could never test their FT technology because of problems with their front end, in particular the hydrogen membrane system. They were unable to obtain a syngas with the correct H2/CO ratio suitable for their FT technology. The plant was put up for sale and Greenway, another small scale GTL company described multiple times in our bulletins, purchased the plant. Greenway GTL has a proprietary, advanced partial oxidation reformer, the "G-Reformer", that needs a final demonstration in an integrated plant but they do not have their own FT technology. Thus, the purchase of the INFRA plant by Greenway combines a promising "front end" and "back end" of the 2 step FT process. A successful operation will enable both technologies to be tested and hopefully validated, and will offer new technology options for both the reforming step and the FT process. We wish them success in 2020.

4. WORLD-SCALE PLANTS FOR MAG (MONETIZING ASSOCIATED GAS)

Haldor Topsoe announced the successful completion and start-up of the 1st G2G (Gas to Gasoline) plant in Ashgabat, Turkmenistan based on their TIGAS technology. It converts about 160MMSCFD of associated gas into 15,500bpd of high octane gasoline. We learned at the GGFR/EFI forum that a 2nd identical plant is being planned for Turkmenistan and other G2G plants for Russia and the US. Haldor Topsoe recently announced that they have indeed sold 5 (!) technology licenses so far. Process and catalyst optimizations in these world scale plants should enhance the performance of their small scale "Methanol To Go" technology desribed in previous bulletins. See more detail below and on EFI's online portal (www.energyfrontiers.org).

Topsoe also disclosed that their small scale methanol venture (partner with Modular Plant Solutions) is progressing well. The plant size was optimized from 215tpd methanol to 300tpd, needing about 9MMSCFD of gas. A 1st commercial project in the US will be announced "soon".

G2G-1 – First Commercial TIGAS™ Facility

- Location: Akhal Region, Ashgabat, Ovadandepe Settlement, Turkmenistan
- Owner: Government of Turkmenistan/State concern - Turkmengaz
- Technology: Topsøe (all core units)
- EPC: Kawasaki Heavy Industries Ltd, in JV with Rönesans Construction and Sojitz Corporation
- Feed: 175,000 Nm^3/h natural gas
- Products: 15,500 bpd (1800 ton/day) RON 92 Gasoline
- Financing: JBIC
- Total EPC contract value: approx. 1.7 billion USD
- Topsøe Catalysts: GSK-10 & GIK-10
- The official inauguration of the facility took place on the 28th of June 2019 and was presided over by the President of Turkmenistan

HALDOR TOPSØE

Kawasaki

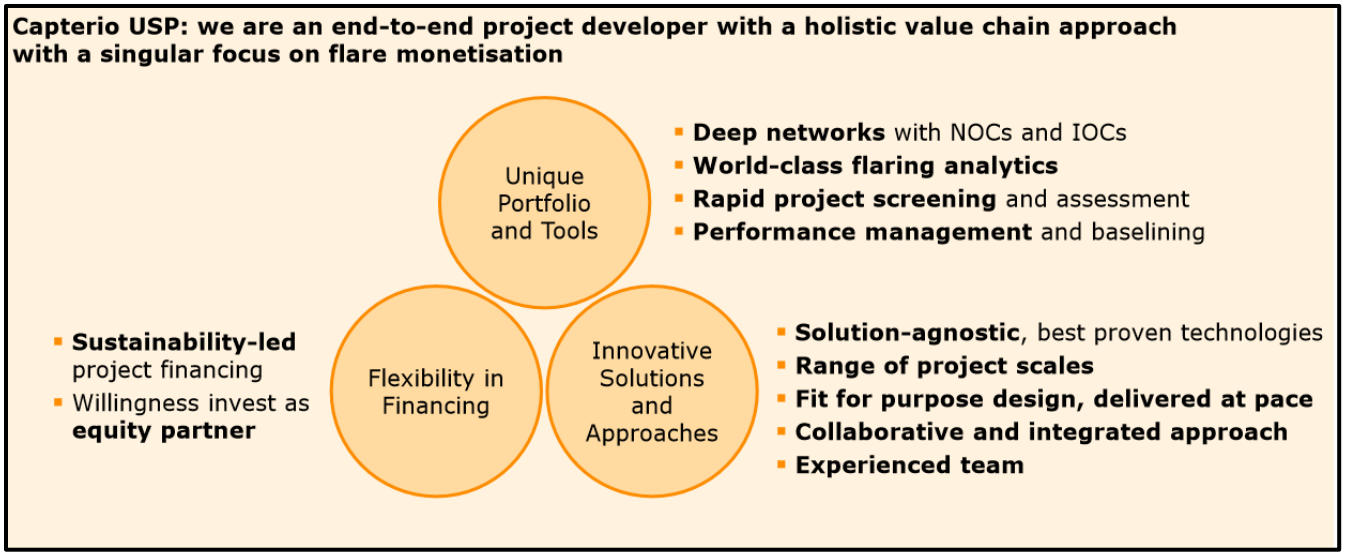
TÜRKMENGAZ

RÖNESANS TÜRKMEN

sojitz

5. CAPTERIO

Capterio is a project developer that brings together flare gas assets, proven technologies and financing with a singular focus on flare monetization (www.capterio.com). Dr. Mark Davis, founder and CEO of Capterio, delivered a presentation "Monetizing flared gas through new applications of proven technology" at the GGFR/EFI forum, available along with the entire content from the forum on EFI's online portal (see page 1 for access instructions). Companies like Capterio support the remit of GGFR and can supplement GGFR's activities in developing flare gas solutions projects around the globe.



It should be mentioned that Capterio is technology agnostic, and miniGTL technology is only one of the various utilization technologies they might propose for a particular project. Importantly, they will also provide project financing solutions.

6. NEW TECHNOLOGIES:

A: HiiROC Gas Conversion to Hydrogen and Carbon

HiiROC Ltd was incorporated in the UK in 2019 (www.hiiroc.com). They apply plasma technology (developed initially in Russia and Bulgaria) to disassociate methane and other hydrocarbons into hydrogen and carbon black. Operating at very high temperature (>6000 deg K) and high pressure (50 bar), nearly complete conversions of methane have been observed. While all hydrocarbons can be disassociated in this process, contaminants such as nitrogen, sulfur and oxygen must be removed from the feedgas as they reduce the hydrogen yield by forming ammonia, hydrogen sulfide and water.

Potential use of the hydrogen could be the generation of electricity via a fuel cell. According to HiiROC, with 1200kWh energy going into the process (100m3 of natural gas at 1000kWh potential energy and 200kWh energy for the plasma process), 325kWh of electricity are generated in the fuel cell by reacting 600kWh energy equivalent of hydrogen (18kg H2). The "end to end efficiency" is therefore only about

27%. There are nearly 500kWh of additional potential energy in the 54kg of carbon black produced, but combusting this carbon would generate CO2, negating a major advantage of this process, namely CO2 free hydrogen production.

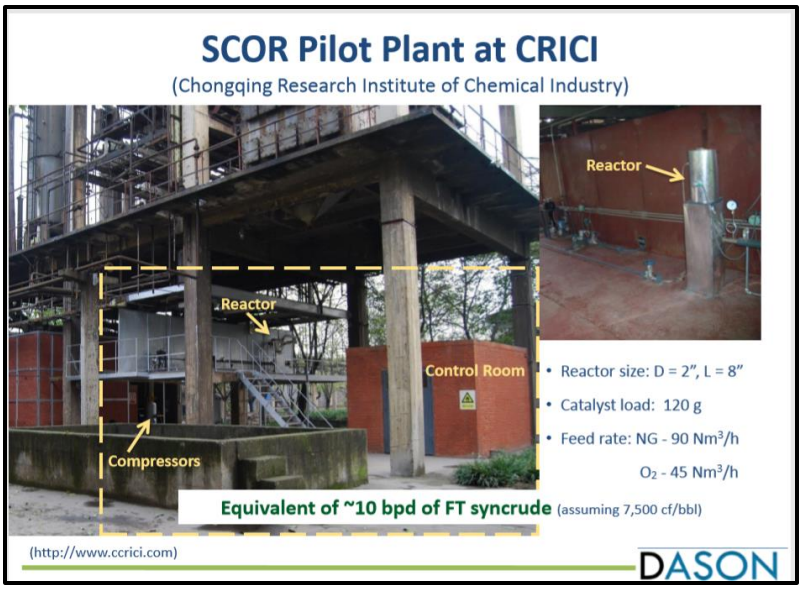
Significant progress has been made in plasma technology over the last 50 years. HiiROC claims that they have successfully resolved the critical issues of erosion and degradation of the plasma electrodes, as well as the efficiency of separation and capture of sub-micron/nano carbon particles. They are now raising money for a first demonstration unit and are in advanced discussions with a number of companies. For more information, please contact Simon Morris at s.morris@hiiroc.com.

B: Galores Micro-GTL FT Technology

Galores B.V., a newly formed Netherlands based company, is a new entry in the development of modular micro-GTL units. Their technology is based on proven processes for reforming and Fischer Tropsch syngas conversion. The innovative aspect is the significantly reduced CO2 emission and self-sufficiency in energy and water according to Dr. Qi Chen, inventor and CEO. They target a 1st unit for 2021 with a gas feed rate of 200MSCFD producing about 20bpd of liquid hydrocarbons. The units will be highly modular and moveable with remote monitoring. Galores would join Greyrock and EFT who already offer such systems. The company is looking for investors to accelerate the demonstration phase and commercial roll-out. The contact is Dr. Carl van der Grift, Commercial Director, at vandergrift@catalyst-intelligence.com, +31 6 8235 2452

C: Dason Technology

The Dason technology tackles the energy intensive and costly reforming processes currently used in all GTL technologies. Their technology uses the direct oxidation of methane to syngas ($CH_4 + 1/2O_2 = CO$ and $2H_2$) using a dual catalyst system. This elegant reaction has been researched for many decades but exhibited many hurdles. Dr. Bang Xu, CEO and CTO, seems to have developed a functioning system where this partial oxidation occurs very rapidly over a small catalyst bed. The technology is called “Short Contact Time Oxidation Reactor” (SCOR). The advantages could be numerous, especially lower Capex and much improved efficiency. With SCOR, only 7500SCFD of gas are needed to produce 1 bbl of liquid product compared to the typical 10,000SCFD in today’s processes! The process is autothermal (no furnace required), yields the correct H_2/CO ratio of 2 (no syngas conditioning needed) and neither needs nor produces water.



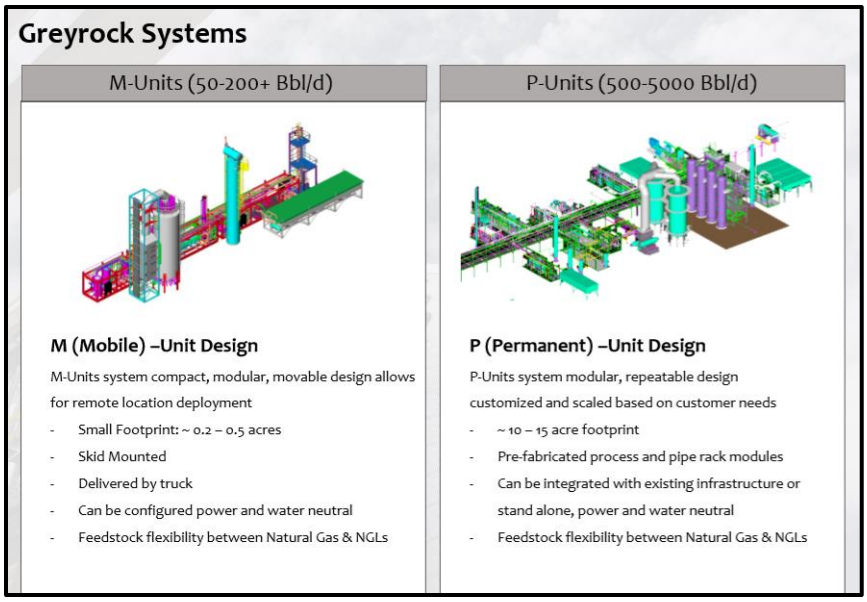
The SCOR process has been pilot tested up to about 200MSCFD of gas. Shown at the left is a 1st test in China where a small SCOR unit of 2 inches diameter and 8 inches of length converted 90m3/h of gas (~70,000SCFD), enough to produce about 10bpd of FT products. Dason Technology now wants to move on to an integrated 1st micro-GTL plant demonstration project and is searching for partners and investors. Please contact Dr. Zbigniew Ring, Chief Engineer at zbigniew.ring@gmail.com; telephone +1 630 815 1564

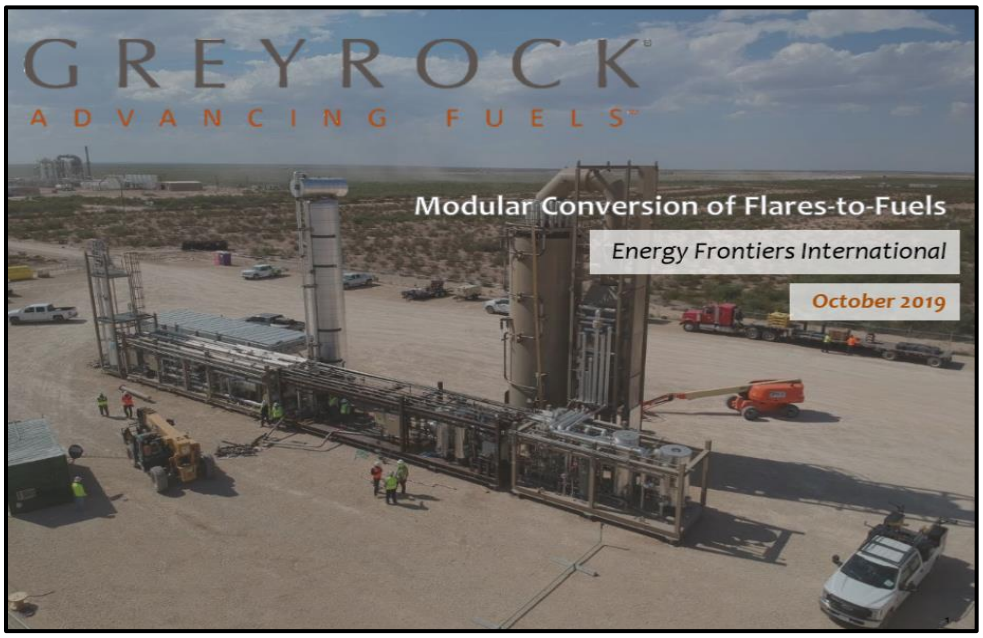
7. PROJECT UPDATES

A: Rocky Mountain GTL: The Rocky Mountain GTL #1 plant is rising from the Alberta flatlands in Carseland, 60km southeast of Calgary (see 1st official picture). Construction commenced in May 2019 and commissioning/start-up should take place before the end of 2020, but no official start-up date has yet been announced.

This 500bpd miniGTL-FT plant, to be fueled by natural gas and NGLs, is the 1st of its kind in Canada, with more plants on the horizon. Affiliate in the project, Expander Energy, recently announced a 2nd plant of the same capacity but using woody biomass as feedstock. This 1st Biomass/Gas to Liquids (BGTL) plant in Canada will be built in 2 phases and will produce 500bpd of renewable bio-diesel and bio-jet fuels.

B: Greyrock Energy: Over the last few years, Greyrock had "announced" numerous plants in both the P-Class (Permanent units; 500-5000 bpd) and M-Class (Mobile units; 50-200+bpd) category. However, actual plants and locations remain to a large extent a mystery, often apparently due to customer wishes. Mikhail Tretyak, the new Senior Vice President Engineering & Construction, showed a slide (see below) with 2 plants in Texas: a M-Class plant in the foreground, and a larger P-Class plant in the background left. He also showed a time-lapse video showing how construction of the M-Class plant was achieved in just a few days. In February of this year, Greyrock announced that this plant is used for "Carbon Recycling" where CO2 and renewable H2 is converted to renewable FT diesel.





C: NiQuan Energy: From 2006 to 2009, WorldGTL developed and built a 2500bpd small scale GTL plant in Trinidad. The plant went into receivership and was never completed. NiQuan who acquired the plant in 2017, is finishing construction and is planning commissioning and start-up the middle of this year. They plan to build similar other plants in other parts of the world, and might become a player in flare gas monetization.

D: EFT Flarebuster technology: Mark Agee reported the development of an improved technology, FLAREBUSTER 2.0 with an even more compact, patented and lower cost design. The capex of these plants is reportedly close to a low $60,000/daily barrel! Their FT technology and FT catalyst have become the most licensed FT process.

8. COMMERCIAL SMALL-SCALE GTL PROJECTS

Four years ago (Bulletin 2, 2016) we started a list of "commercial" small scale GTL projects that had or were close to FID (Final Investment Decision) or were in construction. Out of 6 projects, only one was built, namely the ENVIA Velocys plant on a landfill in Oklahoma. Based on feedback from the GGFR membership, we now start a new compilation of small scale GTL that are at a minimum in the FEED stage, have a FID, are in construction or are operational. Please let us know of projects that we have missed. We will continuously update this list in upcoming Bulletins.

Commercial small-scale GTL plants 3/2020						
Name	**Location**	**Technology**	**Capacity**	**Gas Feed Stock**	**Status**	**Remarks**
ENVIA Energy	Oklahoma	Velocys FT	160bpd?	Landfill gas	For sale	Operation 2016-2018
INFRA 1	Texas	Greenway/INFRA FT	100bpd	Shale gas, 1MMSCFD	Start-up phase	2 year delay in start-up New reformer from Greenway
Rocky Mountain GTL	Alberta	Greyrock/Expander	500bpd	Gas, 5MMSCFD	Construction	Start-up 2Q 2020
Greyrock 1	Texas	Greyrock FT	P class (500bpd)	Shale gas	Construction complete	No information on operation
Greyrock 2	Texas	Greyrock CO2 recycling	M class (50bpd)	CO2 and H2	Construction complete	Demo of CO2 recycling to FT liquids (diesel)
Primus GE 1	Texas	STG+ gasoline	2800bpd gasoline	Shale gas 28MMSCFD	FEED	FID expected in 2020

9. LEADING PLAYERS CONTACT INFORMATION

Current leading small scale GTL technology providers and project developers pursuing commercial flare gas monetization projects with small scale GTL.

COMPANY	WEBSITE	TECHNOLOGY	CONTACT	E-MAIL
EFT	www.emergingfuels.com	FT process	Mark Agee	magee@emergingfuels.com
GASTECHNO	www.gastechno.com	Methanol	Walter Breidenstein	walterb@gastechno.com
GREYROCK	www.greyrock.com	FT process	Mike Tretyak	mtretyak@greyrock.com
INFRA	www.infratechnology.com	FT process	Jack Haynie	haynie@infratechnology.com
PIONEER	www.pioneerenergy.com	Gas processing, Methanol	Joe Palaia	jpalaia@pioneerenergy.com
PRIMUS GE	www.primusge.com	Methanol, gasoline	Trent Crow	tcrow@primusge.com

TOPSOE/MPS	www.modularplantsolutions.com	Methanol	David Townsend	David.townsend@modularplantsolutions.com
ADVANTAGE MIDSTREAM	www.advantagemidsteam.com	Gas Processing Greyrock FT		info@advantagemidstream.com
CAPTERIO	www.capterio.com	Project Developer	Mark Davis	mark.davis@capterio.com
MAVERICK SYNFUELS	www.mavericksynfuels.com	Methanol	Sam Yenne	syenne@mavericksynfuels.com
VERDIS	www.verdisfuels.com	FT process	Rob Ayasse	Rob.ayasse@verdisfuels.com
PROTON VENTURES	www.protonventures.com	Ammonia Fertilizer	Bob Weehuizen	

10. SUMMARY

- 2 Greyrock plants operational in Texas (50 and 500bpd? FT liquids)
- Rocky Mountain GTL #1 construction nears completion (500bpd FT liquids)
- Primus Green Energy moves to FEED for 1st GTG plant in Texas (2800bpd gasoline)
- Topsoe's 1st G2G plant in Turkmenistan fully operational (15,500bpd gasoline)
- Topsoe's small scale methanol venture ("Methanol To Go") is close to a 1st project
- INFRA and Greenway will finish 100bpd demo plant in Texas
- Pioneer Energy develops small scale methanol plant to become fully integrated midstream company
- Emergence of MAG project developers such as Capterio, Advantage Midstream
- Development of new technologies (HiiROC, Galores, Dason)

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