WORLD BANK GROUP
Energy & Extractives

GGFR
Global Gas Flaring Reduction
A Public Private Partnership

MINI-GTL TECHNOLOGY BULLETIN

Volume 1, March 2016

INTRODUCTION

For more than 5 years we have explored and evaluated the development of small scale, modular gas to liquids (GTL) technologies for the extinction and monetization of gas flares around the world. The findings were summarized in 3 reports, which were published in 2/2012, 1/2014 and 7/2015. These reports, all available on the GGFR website, www.worldbank.org/ggfr, were the 1st global assessment of this rapidly emerging business which offers great promise to help in curtailing gas flaring. Because of the rapid advances in the field, we will now provide brief, but more timely updates through a "Mini-GTL Technology Bulletin". We envision 2 to 4 issues per year.

STATE OF THE INDUSTRY

The global oil and gas industry is facing most difficult times. Oil prices have declined more than 70% to $30/bbl and below. Oversupply continues with the potential of prolonged distressed oil pricing. Companies are financially stressed and capital spending is slashed. Obviously, mini-GTL projects feel the impact of this crisis as well:

- The 1100 bpd SGC Energia GTL "Juniper" plant in Louisiana has stopped short of completion awaiting new additional financing.
- The 2500 bpd CompactGTL project in Khazakstan, aimed at converting 25MMscfd of flared gas, never got off the ground because of difficulties in raising capital for the plant.

However, the other 2 commercial projects move forward as planned:

- The ENVIA project based on Velocys GTL technology will start up in the 2nd quarter of this year close to Oklahoma City. The 200 bpd (estimated) plant will convert landfill gas (predominantly methane), augmented with pipeline gas into liquid fuels. Once successfully demonstrated, this plant size is suited for gas flares of about 2MMscfd.
- The 1st Greyrock commercial GTL plant, with a not yet announced capacity, is moving forward as well. Modular construction is underway and start-up is scheduled for later in 2016. The location of the plant was moved from Houston to another undisclosed US location.

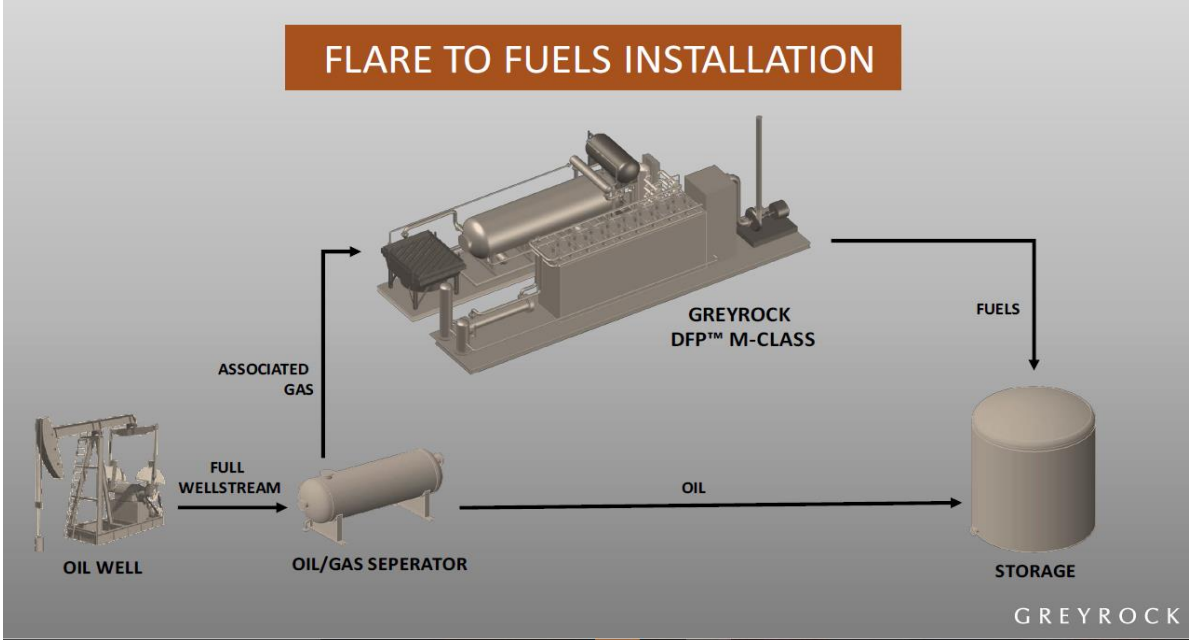
There is renewed focus on flared gas by many of the mini-GTL technology providers. The reasons are twofold. First, the announcement of the World Bank's "Zero routine gas flaring by 2030" initiative, supported by many global companies and countries, has not gone unnoticed. The 2nd reason is the cost of the feedstock, the flare gas itself, which is likely significantly lower cost than other (e.g. shale) gas. The gas feedstock is generally the single largest operating cost and has the largest impact on the economics of a mini-GTL project. Over the last few months we have seen 5 major developments in small scale GTL units specifically designed for monetizing gas flares:

- The "FLARE-TO-FUELS™ Product line" by **Greyrock**
- The FLARE BUSTER® modular plants by **Emerging Fuels Technologies (EFT)** and **Black & Veatch (B&V)**
- Two gas flaring reduction projects in Central Asia announced by **Colver Technologies**
- Construction of a 100bpd demonstration plant in Texas by **INFRA Technology**
- A mini-GTL pilot unit in Canada announced by **ME Resource Corporation (MEC)**

FLARE TO FUELS™ (GREYROCK)

On January 4, 2016, Greyrock announced the Flare-to-Fuels™ M-Class systems (M stands for "Micro"). These small and highly modular mini-GTL systems have been specifically developed for flare monetization. The plants convert about 250 or 500 Mscfd into approximately 20 and 40 bpd of clean oil or diesel, respectively. Units are delivered as modules that are remotely operated and monitored! Combinations of modules can be used to address larger flare volumes.

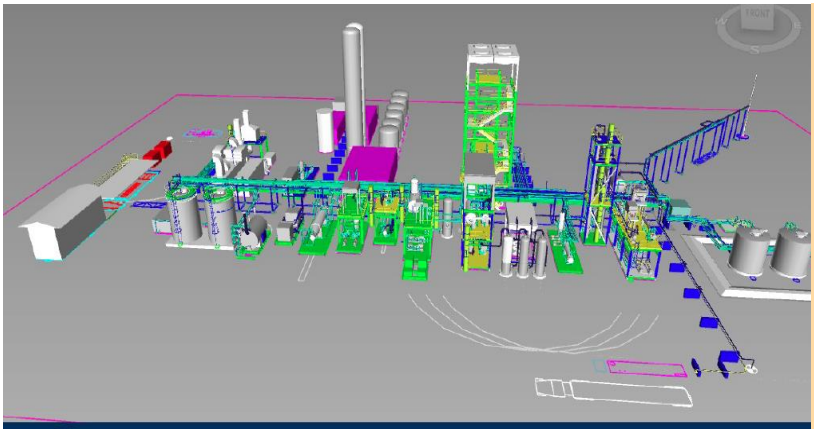
The technology is based on their DFP™ (Direct Fuel Production) process where syngas is directly converted into clean fuels (predominantly diesel) over their proprietary GreyCat™ catalyst. The technology was described in detail in an earlier report. The skid mounted M-class units will be deployed at the well site. The DFP™ plants are designed to either convert rich or lean gas flares but NGL removal is likely an economic addition in most applications. The liquid fuel blend product can be easily mixed with the produced oil at the well site eliminating the need for additional product off-take hardware (see picture below). If a local diesel market exists, a clean and high performing diesel fuel can be separated from the fuel blend with the addition of a simple distillation unit.



These highly modular systems are easily movable from well to well and convert the gas flare into more oil. A 500 Mscfd flare yields about 40bbls of oil. First plants have delivery times of about 20 months with a capital cost in the ball park of about $5 mln (remember the rule of thumb of about $100,000 per daily barrel capacity). There will be significant reductions in both areas for future plants with economies of larger scale productions. Please contact Greyrock for more information (Robert Schuetzle, rschuetzle@greyrock.com or www.greyrock.com).

FLARE BUSTER[R] (EFT AND B&V)

We have reported earlier (Report III) that EFT has developed and thoroughly tested an outstanding GTL FT catalyst and an Advanced Fixed Bed GTL reactor. This proprietary reactor/catalyst system is at the center of the Flare Buster[R] technology which was developed in partnership with Black and Veatch by engineering and packaging the technology into standardized plant designs. One focus has been on highly modular, skid mounted plants aimed at monetizing gas flares, appropriately termed FLARE BUSTERS[R]. A current base model is a 500 bpd unit which uses a gas volume of about 5.4 MMscfd. The plot space required is about 250 ft by 350 ft. The pictures below show a complete 3D model view of such a plant and the core FT reactor. Again, using the rule of thumb for estimating the capital cost of GTL plants, this 500 bpd plant should cost about $50 mln or less. We have learned that smaller plants are under development based on customer interest.



3D MODEL VIEW OF FLARE BUSTER® PROCESS

The plants come on a series of truckable skids and can be quickly installed in remote locations. Obviously, relocations of plants are possible. Barge mounting is offered when water access is an option. The plants operate self-sufficiently without the need for power and water. They offer 2 product options: the simplest case is clean syncrude (all liquid at room temperature) that can be blended with the produced crude oil. If finished products such as diesel and jet fuel are desired, product finishing modules can be added.

EFT has the most advanced GTL testing R&D lab. Customer's gas feedstocks can be tested and GTL samples can be produced. Black and Veatch offers a full spectrum of FEED to EPC services including facilitating project financing.

Visit: www.bv.com; www.emergingfuels.com

FLARE REDUCTION IN CENTRAL ASIA: COLVER, A "NEW" SMALL SCALE GTL PLAYER

Colver Technologies is a Shenyang, China, based GTL company with conventional but modular GTL-FT plants with a gas feedstock range of 5-100 MMscfd (500-10,000 bpd). They offer both onshore and offshore solutions. They are an independently operated company that benefits from state-endorsed public/private sector collaborative funding arrangements. With more than 100 employees, they have a very sizable operation. Mr. Lim Wu is the CEO and Gus Stuyvesant is their new COO. Until recently, Colver was very much under the radar and impossible to contact. However, starting just last fall they issued a number of press releases announcing commercial ventures in Central Asia (Kyrgyzstan, Turkmenistan) for the monetization of gas flares. Specifically, on September 23, 2015 they announced a successful small pilot plant at a Kyrgyzneft production site. Plans for 2 more gas flare reduction plants on adjacent sites were announced on Nov. 21, 2015.

Moreover, a MOU with Turkmengaz was announced on Oct. 4, 2015, looking at 2 more flare reduction projects on sites close to Ashgabat!

Another recent Colver press release (Nov 4, 2015) mentions that they are "in late stage talks with an unnamed major oil company aimed at deploying their GTL technology at more than 30 offshore drilling platforms around the world". We reported earlier that Petronas was looking for such technology and had evaluated a number of potential technology providers. It is possible that Colver Technologies is among the finalists or is the finalist in this competitive evaluation process. Stay tuned.

HOME

Gas-to-liquids (GTL) Onshore

Our onshore solutions provide a cost-effective, flexible and scalable means for converting stranded shale and gas associated with conventional crude oil extraction processes into premium synthetic liquids at the production source. The modular plant design makes use of mass-produced reactors sequentially linked and makes for a highly-adaptable solution.

The above image is taken from their website (www.colvertech.com). It shows a highly modular GTL module of unknown capacity and function. Efforts continue to learn more about them.

INFRA TECHNOLOGY BUILDS 100BPD DEMONSTRATION PLANT

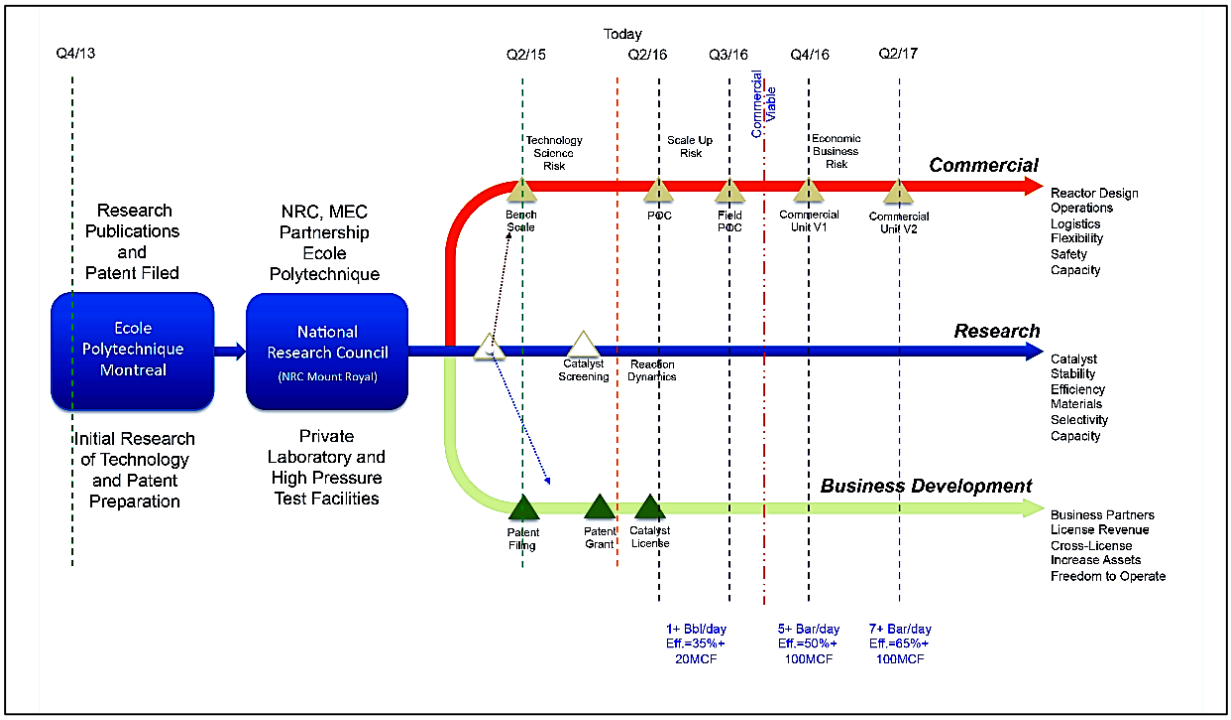
Another exciting development is the construction of a 100 bpd INFRA technology plant, built to demonstrate their modular, transportable syngas to fuel direct GTL technology. Land outside Houston in Wharton County, Texas, has been acquired, reactors, modules and catalysts have been manufactured and shipped and start-up is scheduled for later this year. "The plant is designed to eliminate gas flaring in an economically feasible manner", according to a recent press release. Once technically and commercially proven, INFRA will be ready to ship commercial plants. In their February newsletter, they report a completed Pre-FEED study for a customer for the construction of a 1,200 bpd plant.

Modular GTL-FT reactors are shipped to the 100 bpd plant in Texas.

www.infratechnology.com

PILOT MICRO REFINERY UNIT BY MEC

ME Resource Corporation (MEC) is a Canadian exploration company headquartered in Vancouver. MEC has acquired, developed and patented a mini-GTL technology starting in 2013 and we briefly introduced the company in an earlier report. Mr. Singh is Chairman and CEO, Dr. Patience the CTO. MEC is on an aggressive development path. After technology optimization and bench scale testing in the lab in 2015, they have announced (March 2, 2016) a 1 bpd field test with Carson Petroleum on one of their Alberta based test wells. MEC's development plan then shows 2 commercial units, each consuming 100 Mscfd, over the next 12 months! (www.meresourcecorp.com)



MEC's technology is based on FT technology like most others. However, they use an unusual front end (CPOX, catalytic partial oxidation) to make syngas and run the FT reaction in a fluidized bed rather than a fixed bed reactor. Their products are Engineered Fuels™ in the typical FT range from syncrude to diesel, naphtha and diluents. Unreacted syngas can be converted into power. However, they have driven miniaturization to the extreme with a product line designed for flares or other waste gas streams from only 100 Mscfd to 500 Mscfd. They call their mini-GTL plants "MRU"s (Micro Refinery Units).

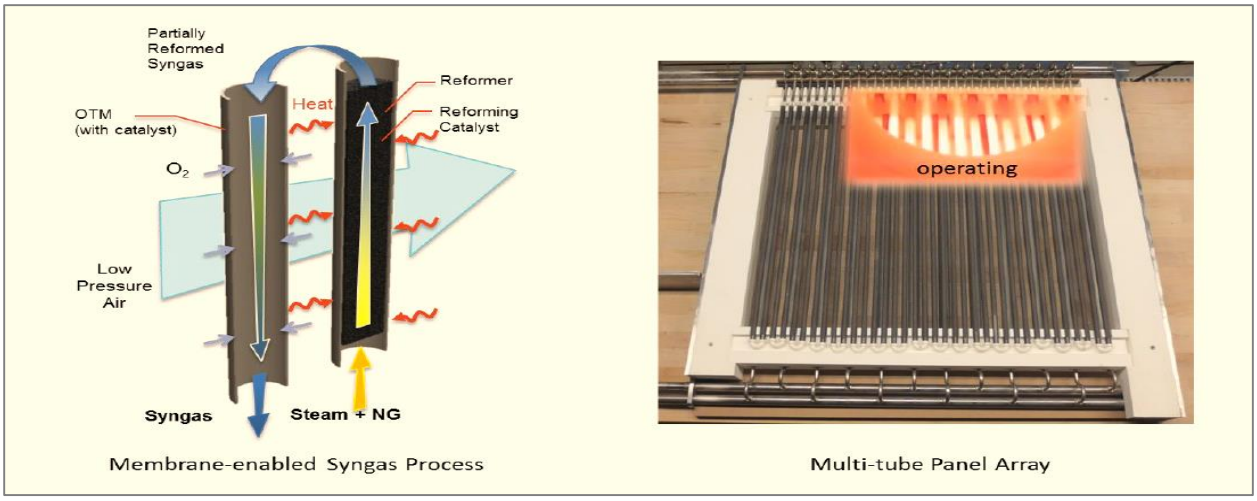
NOVEL OTM SYNGAS TECHNOLOGY (PRAXAIR)

Nearly all mini-GTL technologies are syngas based. Natural gas must be reformed to syngas which is then converted to syncrude, diesel, methanol, gasoline, etc. Most of the research has focused on this 2nd reaction step and the technology providers use miniaturized conventional reforming technologies such as steam methane reformers (SMR), autothermal reformers (ATR) or partial oxidation units (POx). Considering that more than 50% of the total capital cost is spent on the reformer, there is considerable room for improvement in overall cost, size and carbon footprint.

Praxair's OTM (Oxygen Transport Membrane) Combined Reforming technology, which combines the functionality of an oxygen supply system, steam methane reformer and autothermal reformer, is a step-change process intensification of the front end of a GTL system. This OTM system is modular and scales down to small sizes without losing its capital cost and operating efficiency advantages. Capital cost savings of 10-20% are shown. When combined with a suitable synthesis process

unit, the OTM based GTL system can produce liquid fuels with a 30% lower greenhouse gas footprint compared to conventional reforming technologies.

After 20+ years of R&D with many partners and DOE support, Praxair has installed and operated pilot plant and demonstration scale systems for a number of years. They have increased their membrane manufacturing capacity to supply the requirements of the first commercial systems. Praxair is now ready to demonstrate the OTM technology in a 200 bpd GTL project and they are seeking government or industry collaboration partners.



Membrane-enabled Syngas Process

Multi-tube Panel Array

Information: Omar Vargas, omar.vargas@praxair.com

PRIMUS/JEREH PARTNERSHIP

In October, 2015, Primus Green Energy announced that it has partnered with Chinese company Jereh for marketing and deploying their modular gas-to-gasoline and gas-to-methanol systems. Jereh has world class engineering, fabrication and delivery capabilities to support the world wide deployment of the Primus GE GTL systems.

SUMMARY

In a little bit more than half a year we have seen many new developments and a lot of progress in the use of mini-GTL technologies for gas flaring reduction. The development of true mini-GTL units, highly modular and transportable, remotely controlled and relatively inexpensive, are very exciting for the gas flaring reduction community. 2016 is poised to be another step change for mini-GTL technologies.

This report was prepared for the World Bank-Global Gas Flaring Reduction Partnership by Dr. Theo H Fleisch. The opinions and conclusions expressed in this report are those of Dr. Fleisch and do not represent recommendations or endorsements by the Global Gas Flaring Reduction Partnership or the World Bank

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