



# **Associated Gas Monetization via miniGTL**

## **Conversion of flared gas into liquid fuels & chemicals**

**2015: GTL is a commercial reality for flaring reduction**

**Report III**

**July 2015**



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This report was prepared for the World Bank-Global Gas Flaring Reduction Partnership

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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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# 1 GLOSSARY

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AG	Associated Gas
ATR	Autothermal Reformer
Bpd	barrels per day
CAPEX	Capital Expenditure
CNG	Compressed Natural Gas
dbc	Daily barrel capacity
dtc	Daily ton capacity
DME	Dimethyl Ether
EPC	Engineering Procurement Construction
FEED	Front End Engineering Design
FID	Final Investment Decision
FPSO	Floating Production Storage and Offloading
FT	Fischer Tropsch
GGFR	Global Gas Flaring Reduction Partnership
GTC	Gas to Chemicals
GTG	Gas to Gasoline
GTL	Gas to Liquids
GTL-FT	Gas to Liquids Fischer Tropsch
HSSE	Health, Safety, Security, Environment
kscfd	thousand standard cubic foot per day
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MMBTU	Million British Thermal Units
MMscfd	Million Standard Cubic Feet per day
MTG	Methanol to Gasoline
mtpa	Million tons per annum
OCM	Oxidative Coupling of methane
OP	Oxidative Pyrolysis
OPEX	Operating Expenditure
POX	Partial Oxidation of methane
SMR	Steam Methane Reformer
TCF	Trillion Standard Cubic Feet
Tpd	tons per day
USD	United States Dollar

## 2 EXECUTIVE SUMMARY

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Gas flaring continues around the world. The numbers are clear and well known: over 5 TCF or 140 billion m<sup>3</sup> are flared every year. Using this gas volume for power generation would generate 750 billion kWhr, more than enough to meet the current power demand of all of Africa. Converting this flared gas into liquid fuels and chemicals through Gas to Liquids (GTL) technologies, would produce 500 million barrels per year worth approximately \$35 billion.

From an environmental point of view, the extinction of these flares would avoid emitting around 350 million tons of CO<sub>2</sub> annually into the atmosphere with the additional removal of the black carbon (or soot) generated by the flares. Fortunately we have seen a 15% reduction in global flare volume over the last 10 years or so despite increasing oil production. Importantly, more and more countries are taking stronger action to reduce flaring, and the World Bank recently announced an ambitious goal of 'Zero routine gas flaring by 2030'.

More tools are becoming available to utilize the gas from flares. Mini-power can be used to generate local electricity (Gas to Wire). Mini-CNG and mini-LNG are used to consume small amounts of gas as transportation fuels in local markets in the compressed or liquefied state or as fuel for small-scale power generation.

Over the last 10 years, a number of companies have developed mini-GTL and small scale technologies that allow the conversion of small flares and large flares to synthetic oil, clean diesel and gasoline, methanol, DME (synthetic LPG), ammonia and other products. 2014 was the tipping point in the development of these technologies with the announcement of 4 (four) commercial plants. From a feedstock point of view these commercial plants consume from 2 MMscfd to 25 MMscfd, an excellent range for gas flare conversion. Specifically, CompactGTL is building a GTL in Kazakhstan which converts 25 MMscfd associated gas into 2500 bpd of high performing diesel and some other products.

In this third Report we introduce several new technology providers: SGC Energia, Maverick Synfuels, AUM Energy, Greenway Innovative Energy, Standard Alcohol Company of America and Biofuels Power. We are also reporting on the rapid progress of some of our previously reviewed companies which have advanced to the brink of commercialization.

Special attention is given to another group of companies who are developing highly mobile, truck or skid mounted units ideal for small flares below 1MMscfd.

The over-riding message is that there is a rapidly increasing choice of companies with technologies aimed at monetizing flares in all sizes. There are more tools in the tool box for the oil producers with gas flares. And most importantly, a number of commercial mini-GTL plants are now being built.

GGFR stands ready to advise on the pros and cons of these new technologies and to build bridges between potential customers and GTL solution providers.

### 3 INTRODUCTION

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This is the 3<sup>rd</sup> report in a series first commissioned just about 4 years ago in mid-2011 by the Global Gas Flaring Reduction Partnership. The objective of the study was an in-depth evaluation of the applicability of gas to liquids (GTL) technologies to the extinction of gas flares. The GTL industry is a large, worldwide endeavor, mainly comprised of methanol, ammonia/fertilizer and diesel fuel production. Typical plants consume large quantities of natural gas (~>>50MMscfd) over decades to generate attractive financial returns. Thus, the question was whether these GTL technologies could be downsized technically and economically to become viable tools for the monetization of gas flares.

The boundary conditions given by GGFR were flare sizes from sub-1MMscfd up to 25MMscfd with a wide feedstock flexibility from dry to wet gas and a good turn-down ration to accommodate fluctuations in gas supply.

The 1<sup>st</sup> report titled “*Associated Gas Utilization via miniGTL*” was issued in February 2012 and was the first study in this emerging field. Over a dozen potential technology providers were identified and evaluated. Among them, CompactGTL, Velocys, Oberon Fuels and GasTechno were the most advanced options with technology demonstrations underway and early business development efforts underway. Most importantly, small scale GTL plants had become a very exciting new field of business not just because of the worldwide gas flaring but mainly because of the new, abundant and cheap gas supply from the shale revolution in the US.

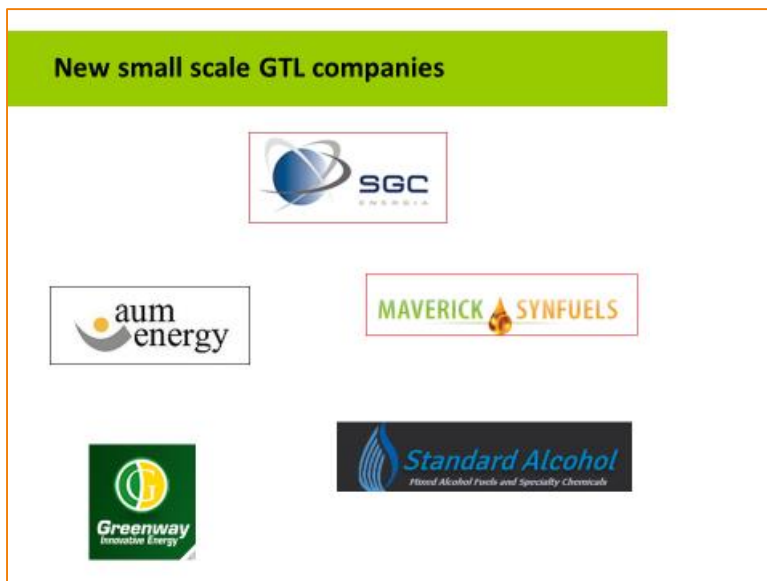
Many new players were entering this field and the pace of technology development increased tremendously. Nearly a dozen new companies were evaluated and compared to the early entrants in 2013 and a 2<sup>nd</sup> report was issued in January of 2014. The title of the 2<sup>nd</sup> report was “*Associated Gas Monetization via miniGTL; Conversion of flared gas into liquid fuels and chemicals; Update report January 2014*”. Both reports are posted on the GGFR website: [www.worldbank.org/GGFR](http://www.worldbank.org/GGFR). Among the new entrants, Greyrock was identified as the company with the most advanced technology, with Primus Green Energy, TIGAS and Siluria on fast development paths.

2014 has been a historic year for the small scale GTL business with the announcements of the first few commercial plants! It also has become abundantly clear to most experts in the GTL arena that the future of the GTL business are smaller scale plants and not the large, 100,000bpd plants built and pursued by companies like Shell and Sasol. Price tags exceeding \$10 billions coupled with 5+years project development times make such projects increasingly difficult to finance and risky to execute.

## 4 NEW TECHNOLOGY PROVIDERS

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Five new companies are being added to our portfolio, namely SGC Energia (Houston, Texas), Maverick Synfuels (Research Triangle Park, North Carolina), AUM Energy (Singapore) and Greenway Innovative Energy (Fort Worth, Texas) and Standard Alcohol Company of America, SACA (Denver, Colorado).



**SGC Energia** has been very active in GTL for a number of years but had focused on plant sizes outside the GGFR volume target range. This has changed: SGC Energia is building a 1,100bpd GTL FT plant in Louisiana, called “Juniper”. The price tag is about \$100 million. With a gas feed rate of about 12 MMscfd the plant is right in the middle of the 1 to 25 MMscfd target range. However, the major focus of SGC Energia remains mid-scale plants above 5000 bpd. Currently, there is no particular interest in small modular plants suitable for typical flares. They have a proprietary but simple FT technology called “XTLH” reflecting their interest in converting any appropriate carbonaceous feedstock to liquid hydrocarbons such as diesel, jet fuel and chemicals.

**Maverick Synfuels**, recently renamed from Maverick Biofuels, has been pursuing small scale plants converting biomass, municipal solid waste (MSW) and methane rich streams such as flares into methanol and its derivatives (olefins, DME, gasoline, etc) since 2007. Their name change reflects their shift in focus from biomass to gas flares. They use conventional methanol technology and pursue commercial opportunities. Their main offerings are called “Maverick Oasis” which are modular, factory built, movable methanol plants with capacities of about 3000 to 10,000 gpd methanol. The required gas feed rates are about 300 kscfd to about 1 MMscfd. Oberon Fuels and R3Sciences offer similarly sized methanol plants. Maverick Synfuels envisions a “spoke and hub” business model where a few such plants are the spokes delivering the methanol to hubs where the methanol is further upgraded into other products such as olefins or gasoline. The larger hubs provide economy of scale for the methanol conversion steps.

**AUM Energy** focuses on the commercialization of proven Unitel DME technology in Africa and Asia Pacific. This is the same DME technology as demonstrated by Oberon Fuels but scaled up by about a factor of 10, consuming about 10 MMscfd of gas. The target market is the proven LPG blending with DME for cooking and heating. In areas where a gas processing plant separates LPG from the associated gas, this technology would allow the conversion of the dry gas (methane/ethane) into DME which could then be exported and consumed using the existing LPG infrastructure. The modular plants will be factory built in India by AUM's EPC partner Praj and then delivered and installed at the gas flare site.

**Greenway Innovative Energy (GIE)** is a wholly owned subsidiary of UMED Holdings which continues the work initiated by the 1<sup>st</sup> Resource Group (1RG) described in the earlier reports. 1RG no longer exists. The focus remains on mobile GTL-FT units with a target range from 600 to 2000 bpd (6 to 20 MMscfd) according to their new website. GIE formed an exclusive partnership with a "large, multinational company" according to a press release in late 2014. Multiple attempts to garner further information have failed, possibly indicating technical or financial issues.

**Standard Alcohol Company of America (SACA)** is a well-funded, well-managed company based in Denver. They have a patented, much improved mixed alcohol process that produces C1 (methanol) to C10 (decanol) alcohols. This alcohol mix is a high octane, clean burning gasoline blendstock and many of the alcohols are valuable chemicals. SACA just announced the construction of a 500 bpd (!) demonstration/commercial plant in the Denver area. It will be at least 2 years before the technology can be declared as demonstrated. Their interest in developing smaller, modular plants for flaring reduction is not yet known.

There are a few other potential entrants:

**ME Resource Corp (MEC)** is a publicly traded Canadian company who is developing a highly mobile "microrefinery unit" (MRU) for flare reduction. The system is based on FT technology with a catalytic partial oxidation as syngas front end with a daily gas consumption rate of only 100 to 500 Mscfd producing between 10 and 50 bpd of liquid hydrocarbons. R&D continues along with fund raising efforts for a demonstration plant.

**Biofuels Power Corporation (BFLS)** is a Houston based company with plans to build a 30 bpd GTL-FT demonstration plant. The goal is modular 500bpd plants. Partners are ThyssenKrupp and Liberty GTL.

**Petro River Oil** acquired the **Havelide System** technology which is claimed to be able to convert gas into liquid products at much lower cost than typical GTL processes.

**GTC** is now licensing the "old" GRT technology described in earlier reports using bromine to convert gas into gasoline and aromatics. The "GT-G2A" technology looks for early investors.



## 5 THE STATE OF THE BUSINESS

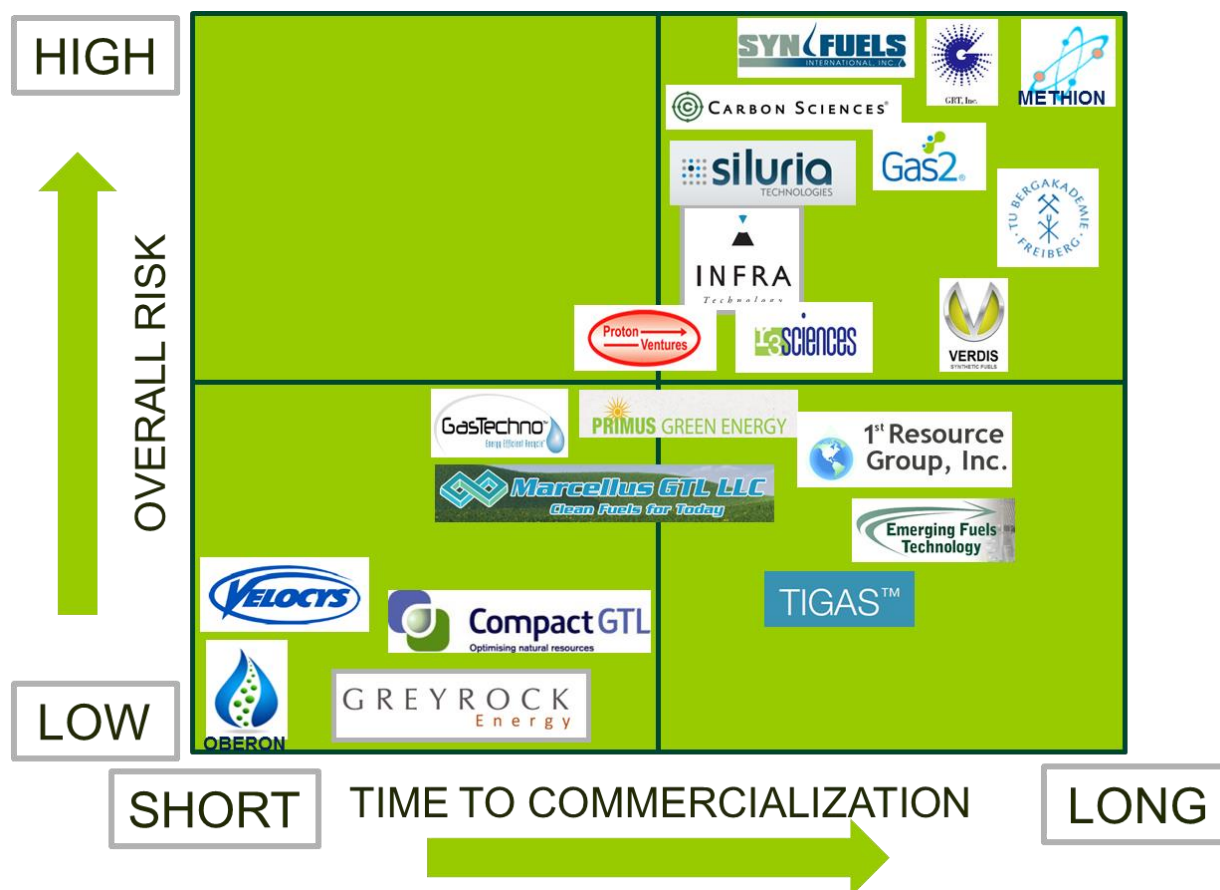


Figure 1: Positioning from report 2, January 2014

The above Figure 1 shows the qualitative positioning of the major players with respect to remaining overall risks and time to commercialization from report 2 dating to late 2013/early 2014. Velocys, Greyrock, CompactGTL and Oberon Fuels were deemed to be closest to a first commercial plant. Other technologies faced technical challenges, still needed pilot plant demonstrations and/or required additional investment capital. In this fast moving business, there have been some significant changes over the last year or so. Carbon Sciences have given up on their GTL technology, and 1stResource Group seems to be no longer in the business either. The same is true for MarcellusGTL. Technology problems, lack of financing, stiff competition and the lower oil prices are likely reasons. Clearly, Synfuels, GRT, Methion, Gas2 and TU Freiberg are not ready for commercial gas flaring reduction projects. Little, if any, progress has been reported by them. The greatest progress has been made by Primus Green Energy and Siluria as discussed in more detail later. Velocys, Greyrock and CompactGTL have announced their 1<sup>st</sup> commercial projects! A first TIGAS plant is being built though at large scale. Then there are the five “newcomers” just described.

# Updated Assessment: 2015 Technology Options

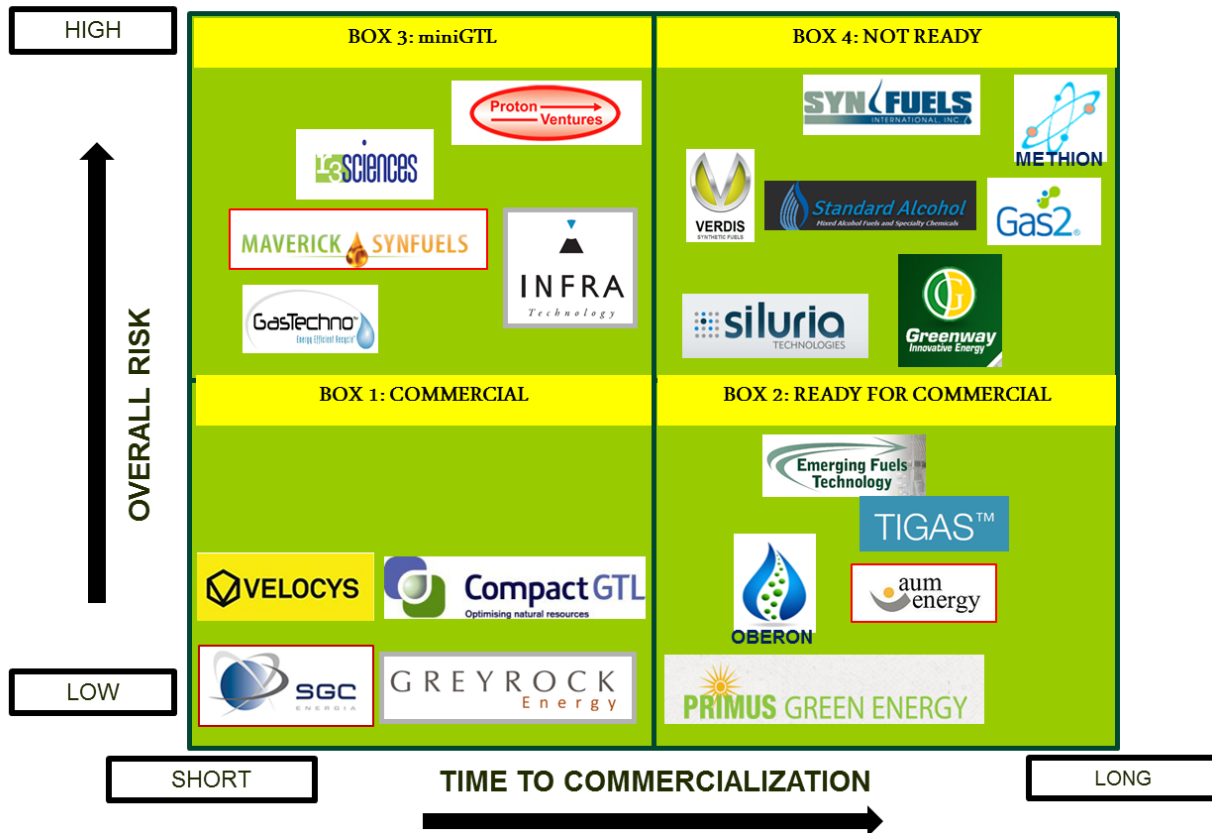


Figure 2: Current (June 2015) state of the technology options

Figure 2 shows the current (June 2015) state of the technology options for the small scale GTL business in general and the gas flaring reduction application in particular. Based on the transition of some technologies into the commercial world, the great progress by others and the increasing number of companies, we elected to regroup the options.

In Box 1, titled “Commercial”, we group the companies that are building the first commercial project. Congratulations to them! New customers will have the benefit from the learnings of these 1<sup>st</sup> plants. A list of all commercial plants is shown in Figure 3.

In the lower right hand Box 2, titled “Ready for Commercial”, are companies with viable technologies and integrated, engineered plants ready for commercial offers. Some of them are expected to move to the left into the Commercial box within 12 to 24 months. **Primus Green Energy** is the clear front runner with multiple projects being explored. They offer simple, robust modular units from about 4 to 20 MMscfd feed rate which can deliver either methanol or gasoline. Their STG+ technology is clearly superior to conventional MTG technologies for these smaller scale plants.

**Oberon Fuels** did build a methanol to DME plant in California in 2012 to demonstrate a novel proprietary technology. However, a fully integrated plant starting with natural gas and using conventional methanol technology has been delayed. The integrated design will offer small plants with a gas consumption rate of about 1.3MMscfd. These “NG10” plants produce 10,000 gpd DME (or 11,300gpd methanol). Slightly larger plants with 2 or 3 times the capacity are also under consideration. Oberon Fuels further envisions plants fed by biogas or a combination of natural gas and biogas.

**Emerging Fuels Technology (EFT)** has stepped up its business development efforts. It has partnered with Black and Veatch as their EPC arm and has signed an MOU with Airbus to develop sustainable synthetic jet fuel via the GTL-FT process. They offer design packages of their patented advanced fixed bed Fischer Tropsch reactor/catalyst system. Their basic module has a capacity of 250 bpd (2.5 MMscfd) with multiple configurations up to 10,000 bpd.

Haldor Topsoe’s **TIGAS** technology is being commercialized at a very large scale (15,500 bpd). Much smaller plants are under development, but a recent report claimed that a size of about 2500 bpd is their smallest economic plant. If true, this would put TIGAS at the upper end of the GGFR volume range. Topsoe is a leader in small scale, modular reformers down to about 0.5 MMscfd. Their Russia business unit is working hard to modularize TIGAS for Russian flaring mitigation.

In the “Mini-GTL” Box 3 we have grouped technology providers offering novel approaches at a very small scale of less than 1 MMscfd. Despite a higher technology risk for some, these companies could quickly move into the Commercial box since the capital cost hurdle for one plant is small at a few million dollars per project.

**Maverick Synfuels** offers very small (5000 sqft), factory built and rapidly deployable methanol plants using a proprietary technology. These plants can be readily moved and are ideal for small flares. A first commercial plant using biogas from a dairy farm is being pursued. The feed rate is not known but is less than 1MMscfd.

**GasTechno** is developing a simple breakthrough technology where natural gas and oxygen react to form predominantly methanol without the use of catalysts and syngas. This so-called POX (partial oxidation of methane) technology has been pursued by many without success. Thus, GasTechno faces great skepticism about the validity of their technology. In order to mitigate these concerns, GasTechno has commissioned an independent verification and qualification of their technology by DNV. The final report will be issued later this summer and will cover plant sizes from a few hundred thousand cfd to 10 MMscfd. Furthermore, GasTechno has been filing for patents addressing the work-up of the methanol/formalin product mix into a clean diesel additive. Currently, they are building a much improved pilot methanol plant which is intended to be the 1<sup>st</sup> commercial plant in the field.

**R3Sciences** is building their 2000 gpd methanol prototype plant this year with the goal of commercial units available in 2016. The size of the modular, transportable plants will be in the same range as the Maverick Synfuels plants, roughly 2,000 to 10,000 gpd of methanol.

**INFRA Technology** has succeeded to raise the money for their 100 bpd demonstration plant which is being built in Houston. Their modular, easily transportable plants are aimed at remote gas flares. Their direct syngas to products process requires high temperature operation outside the typical operating window.

High yields of methane production will cut into hydrocarbon production levels which in turn will decrease the capex savings touted by INFRA. The demo plant will allow the determination of true performance and cost data.

The very small size of the **ProtonVentures** ammonia plant of 3 tons per day with a gas feed rate of 200 kscfd poses economic challenges and no news has been reported recently.

The companies in Box 4, the “Not Ready” box, have no small scale commercial offerings at this time. Moreover, the companies are at very different trajectories. The status of Standard Alcohol and Greenway Innovative Energy has been described in chapter 4. There is no news from Methion and Gas2. There was a sign of life from Synfuels International with a licensing agreement with Sabic Global technologies.

Great progress has been made by **Siluria**. Their novel OCM technology is now demonstrated in a 1 tpd plant in LaPorte, Texas which came on line on April 1, 2015. The plant is owned and operated by Braskem. The back-end to this plant, the conversion of ethylene to liquids (gasoline), ETL, is being piloted in California but is based on rather conventional technology. Siluria now projects commercial offers in 2017/2018. At this time, it is not known what the plant size range will be.

**Verdis** also reports great progress. They have a completely redesigned unit with excellent conversion efficiency for their syngas to diesel direct technology. Their catalyst yields a very impressive 90% diesel. Funding is required to build a 25 bpd demo plant. They are also developing a novel syngas technology based on catalytic partial oxidation and are designing a 100 bpd plant. Bench testing is being done in their R&D facility in Calgary. An office was opened in Tromsø, Norway concentrating on developing a GTD (gas to diesel) plant fully optimized for offshore use.

## 6 FIRST COMMERCIAL PROJECTS

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It is a long, arduous and expensive path from technology invention to technology development, piloting and demonstration followed by business development of fully engineered plant solutions and FEED expenses. Thus, the Final Investment Decision (FID) by customers, partners and finance institutions to actually build the plant is a major accomplishment. 2014 was a pivotal year for the small scale GTL business with a number of companies crossing this hurdle, and a number of other projects moving very close to it.

First commercial “miniGTL” projects					
Name	Location	Technology	Capacity	CAPEX	Remarks
Juniper GTL	Westlake, LA	XTLH	1100bpd	\$100MM	1 <sup>st</sup> SGC Energia project
Envia Energy	Oklahoma	Velocys	200bpd?	NA	1 <sup>st</sup> Velocys project; Landfill Gas
CompactGTL 1	Kazakhstan	CompactGTL	2500bpd	\$275MM	1 <sup>st</sup> commercial CompactGTL plant Associated flared gas
Greyrock 1	Houston area	Greyrock	1000bpd?	NA	1 <sup>st</sup> commercial Greyrock plant
Ashgabat	Turkmenistan	TIGAS	15,500bpd	\$1.7B	1 <sup>st</sup> commercial TIGAS plant Large scale, AG? Pursuit of smaller plants

Pinto Energy	Ashtabula, OH	Velocys	3000bpd	\$300MM	Velocys acquired Pinto; FID 2015
Red Rock Biofuels	Oregon	Velocys	1100bpd	\$70MM DOD	Forest wastes; \$80MM grant; FID 2015
Primus GE	multiple				FID 2015

Figure 3 (Light green background = FID'd plant; Dark green background = Plants pending FID)

The honor of the 1<sup>st</sup> commercial small scale GTL plant belongs to SGC Energia with their 1,100 bpd Juniper GTL plant in Westlake, Louisiana. Commissioning and start-up is scheduled for 1Q 2016. The feedstock is natural gas. A number of other plants are being pursued in North America, all named after trees, with plant sizes likely larger and outside the GGFR volume range of interest.

Envia Energy, a JV of Waste Management, NRG Energy, Ventech Engineers International and Velocys, is building a small scale GTL-FT plant on a landfill in Oklahoma City fed by landfill gas with back-up from natural gas. The capacity has not been announced but the author believes it to be about 200 bpd. The plant will come on-line 2Q 2016. If technically and economically successful, dozens of such plants can be built around the US. This plant size is also ideal for small flares of about 2 MMscfd.

**CompactGTL is the 1<sup>st</sup> company to build a plant fed by associated, flared gas.** Their 2500 bpd GTL-FT plant in Kazakhstan is fed with about 25 MMscfd of essentially free gas. The gas is free because of the flaring limitations and penalties in Kazakhstan. The Capex has been announced at \$275 million or \$110,000/dbc.

Greyrock has announced its first commercial plant to be erected in the Houston area. Capacity and capex have not been announced, but we speculate that the size will be their 1000 bpd offering. Greyrock is aggressive in project development with new partnerships such as with Expander Energy to deploy GTL facilities in Canada, and with Nerd Gas for plants in Wyoming and the Rocky Mountain region.

Topsoe's TIGAS technology, though proven and available for 20+ years, is now being commercialized at large scale. An international team led by Japanese entities will build a 15,500 bpd TIGAS gasoline plant in

Ashgabat, Turkmenistan at a cost of \$1.7 billion! Obviously, this is a world scale plant, but it may help pave the way for the marketing of smaller scale TIGAS plants suitable for flare reduction.

Velocys expects 2 more FIDs in 2015 for both a 3,000 bpd plant in Ashtabula, Ohio and a 1,100 bpd Red Rock Biofuels plant in Oregon. The latter plant has received an \$80 million grant from the DOE for renewable diesel and jet.

Primus Green Energy is also getting close to FIDs for projects ranging from Kazakhstan to the US. In general, the author expects that 3 to 5 new commercial projects, with FIDs from Primus and others, will be added to this list in 2015.

## 7 FLARE SIZE APPLICABILITY

Company	Website	Technology/	Status	Small	Medium	Large
	<a href="http://www.xxx.com">www.xxx.com</a>	Product	Box #	~<1MMSCFD	>1-10MMscfd	>10MMscfd
Proton Ventures	protonventures	Ammonia	3	target	maybe	no
GasTechno	gastechno	POX/MeOH+	3	target	good	no
R3Sciences	r3sciences	MeOH	3	target	no	no
Verdis	verdisfuels	direct FT/diesel+	4	target	good	no
Oberon Fuels	oberonfuels	DME, MeOH	2	target	good	no
Maverick Synfuels	mavericksynfuels	MeOH+	3	target	good	no
Biofuels Power	biofuelspower	FT/diesel+	4	no	target	no
Aum Energy	aumenergy	DME	2	no	target	maybe
Infra Technology	infratechnology.ru	direct FT/diesel+	3	target	target	no
Greyrock	greyrock	direct FT/diesel+	1	maybe	target	good
EFT	emfueltech	FT/diesel+	2	no	target	good
Velocys	velocys	FT/diesel+	1	good	target	good
Greenway IE	greenwaygtl	FT/diesel+	4	no	target	good
Primus Green Energy	primusge	MeOH, gasoline	2	maybe	target	target
CompactGTL	compactgtl	FT/diesel+	1	no	maybe	target
SGC Energia	sgcenergia	FT/diesel+	1	no	good	target
TIGAS	topsoe	gasoline	2	no	good	target
Siluria	siluria	OCM/ethylene, gasoline	4	?	?	?
Gas2	gas-2	FT/diesel+	4	?	?	?
Methion	methion	MSA/methanol+	4	target	target	target
Synfuels	synfuels	OP/ethylene, gasoline	4	no	no	target

In this Table we list all the technologies evaluated in this and the past two reports with the websites, the technologies and the products as well as their box status in the risk/readiness assessment. Please note

that we have also listed the technologies in Box 4 that do not yet have commercially viable options. Most importantly, we have sorted them with respect to their flare size applicability from small to large:

**Small:** highly mobile, skid mounted plants for flare size below 1 MMscfd

**Medium:** for flares above 1 MMscfd up to 10 MMscfd; mobility decreases with size

**Large:** for flare monetization above 10 MMscfd; stick built plants with 20+ year life

The descriptions are as follows:

**Target:** business focus of company

**No:** stated non focus area (for technical or business reasons)

**Good:** company could easily move into this area

**Maybe:** potential interest

This Table will be useful in a first pass decision analysis of the appropriate technologies for different flare situations. How large a gas volume needs to be converted? For how long? Do I have a preference for the product made and the technology used? What risk tolerance do I have? If people need more information on a particular technology, they can go the website and get into contact with the company. GGFR is also willing to facilitate contact.

Another way to choose a technology in these early days of commercialization is a competition among some of the leading candidates. Petronas, the Malaysian national oil company, invited about half a dozen potential providers late last year. Among the invitees were Greyrock, Velocys, Verdis, GasTechno, Infra and CompactGTL. Petronas talked about their need for flare gas utilizations with a capacity of 20 MMscfd in both offshore and onshore applications. The companies were invited/challenged to provide an integrated design for such plants. It has been reported that the winning proposal will be carried forward by Petronas through feasibility study and FEED to potential commercial applications.

## 8 FLARE TO GTL PLANT: GAS SUPPLY AND TREATMENT CONSIDERATIONS

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The feedstock for world scale GTL-FT and methanol plants is “pipeline quality” natural gas, rich in methane and ethane, the least valuable components of gas. Nearly without exception it is always a clear economic choice to separate and sell condensates and LPG from the raw gas. For example, the Shell Pearl plant in Qatar converts about 1.4 bcf/d of dry gas into 140,000 bpd of diesel and other hydrocarbons while the upstream gas processing plant separates 160,000 bpd of valuable liquids (LPG, condensates) from the produced wet gas.

The feedstock flexibility of GTL plants been touted as a huge advantage in these times of lower oil prices where lower gas feedstock prices are increasingly important. GTL plants can convert heavier hydrocarbons than methane with ease: an inexpensive pre-reformer is needed to handle ethane and higher hydrocarbons. Thus, if ethane or propane have the lowest value or are the lowest cost, use them. On the

other hand, if it is uneconomic to separate the gas into liquid and gaseous fractions, the whole flare gas volume can be sent to the GTL plant.

Most GTL plants use catalysts that are sensitive to poisoning by sulfur which needs to be removed by conventional means. Inerts such as N<sub>2</sub> or CO<sub>2</sub> just pass through the GTL plant, while CO<sub>2</sub> may be partially converted in methanol plants.

The production profiles of individual flares are well known and pose two challenges. First, short term variations need to be accommodated. All the plants have some significant turn-down ratio, i.e. ability to run at less than full capacity. Second, flare volumes typical decline over time making a GTL plant underutilized and eventually uneconomic. In many (most) flare applications, a small gas gathering system combining the gas from a number of flares is the solution to deliver a relatively constant gas stream to the GTL plant. This becomes increasingly important with larger and larger plants. The plants of “miniGTL” providers listed in Box 3 with flare capacities below 1MMscfd can however easily be moved to another flare site.

Importantly, all companies offer gas treatment solutions that can be customized for the composition of the flare gas to be monetized. Truck mounted, modular gas treatment plants are offered by companies such as Denver based Pioneer Energy which could be the “connector” between the raw flare and the GTL plant.

## 9 ECONOMICS OF GAS FLARE GTL PROJECTS

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The economic driver for small scale GTL projects was the recent large oil/gas arbitrage. Gas feedstock prices of \$4/MMBTU combined with a diesel value price of \$20/MMBTU (\$120/bbl in a \$100/bbl oil world) made for some attractive economics. With the oil price dropping to about \$60/bbl, the value of the GTL products (diesel, gasoline, etc) dropped to about \$12/MMBTU. Even though the gas price also decreased to less than \$3/MMBTU, the overall economic return is smaller. There is also some concern that oil prices will increase only slowly which is not helpful in financing such projects.

Forecasting the price of oil is very difficult for many reasons. However, longer term, the production cost of the highest cost producer of the last few million barrels of oil consumed sets the price. With global demand of about 95 Million barrels of oil per day, the high cost producer is North American shale oil with an average breakeven cost of about \$65/bbl according to a recent study by Morgan Stanley. This should set a lower limit in IRR calculations for GTL plants. For comparison, the average breakeven cost in the Middle East is \$27/bbl.



There are 3 key parameters for attractive economics for miniGTL and small scale GTL:

1. Find lowest cost feedstock
  2. Produce most valuable product
  3. Ongoing reductions in capex and opex
1. **Find lowest cost feedstock:** These new developments should further steer the companies towards flared gas, which is likely the lowest cost feedstock in many applications. CompactGTL has been able to secure essentially free flared gas in Kazakhstan, partly because of the high penalties for flaring in that country. Flaring restrictions and penalties are rapidly becoming more prevalent and stringent around the world. Recent North Dakota regulations limit flaring levels to 35% of total gas production in 2012, down to 23% in 2015 and to 15% in 2016 requiring oil production reductions to meet these limits. The recent World Bank goal of routine flare elimination by 2030 is a strong impetus for implementing flare reduction measures. A GTL plant consuming flared gas saves the flaring penalty and allows full production of the oil in addition to producing a valuable liquid product such as more oil or a high performing transportation fuel.
- The impact of the cost of the gas feedstock on overall economics is, as expected, large. For example, Primus Green Energy showed for their 500 gpd gasoline plant that a \$1/MMBTU lower feedstock cost added more than 4% to the IRR.
2. **Produce most valuable product:** In the simplest case, a GTL plant could produce synthetic oil to be blended and exported with the crude oil. Likely, this will be the lowest value product but also the lowest plant and product transport cost. The production of clean, high cetane diesel or clean, high octane gasoline will generate more revenue from these more valuable products. In addition to the refinery value uplift of about 20% over crude oil, there could be locally higher value for these products because remoteness of the flare location may require import of such fuels. The local requirement for and value of other products (such as methanol, DME, olefins, ammonia) needs to be studied. For example, Primus Green Energy showed that the IRR of a methanol plant (160 tons/day) of similar size to their 500 gpd gasoline plant was more than twice as high at the current methanol price of about \$1.35/gallon. The higher value of methanol versus gasoline, combined with the lower capex of the methanol plant, are the cause of this difference.
3. **Ongoing reductions in capex and opex:** Economy of scale is the name of the game if one wants to drive down production costs. For example, the size of world scale methanol plants has increased from about 500 tpd to 5000 tpd over the last 40 years or so. The corresponding methanol production costs (capex and opex) have decreased from about \$220/ton to \$140/ton, an economy of scale gain of about 35%. In developing small scale GTL plants, engineers have worked hard to minimize the loss of economy of scale. They have simplified flow sheets, reduced or eliminated recycle streams (Primus GE and CompactGTL), invented new technologies (such as microchannel reactors) and sacrificed some energy efficiencies for more cost savings. Further savings are obtained from factory built base units which are multiplied for larger plants.

The end result of all these efforts is that today's small scale plants have similar costs to world scale plants! For instance, small scale GTL-FT plants making synthetic diesel can be built at a capex of

around \$100,000/dbc, the same as seen for world scale plants. There are further claims that this capex cost can be lowered by 10 to 30% over the next few years for these small scale GTL plants. There are similar data for methanol plants. World scale plants have a capex with a cost of about \$200,000/daily ton capacity or about \$570 per annual ton capacity. There are no firm capex numbers yet for small scale methanol plants. However, early estimates show higher capex numbers up to \$900 per annual ton. A number of studies have shown that despite this higher capex such plants can be quite attractive because of the lower feedstock costs and the absence of methanol transportation cost to the market. When a methanol to gasoline unit is added (MTG, STG+), obviously the capex further and becomes quite similar to the capex of GTL-FT plants. In other words, production of diesel via GTL-FT or gasoline via MTG/STG+ have roughly similar costs today for same size plants as seen in world scale plants. Let me refer again to the 2 commercial plants of CompactGTL and TIGAS which both have a capex of \$110,000/daily barrel diesel and gasoline.

As more and more small scale commercial plants are being built, lower unit cost will become available. It is expected that costs will come down because of “mass fabrication” of factory built sub-units as well as because of learnings and of continued value engineering.

The verdict is still out on the cost of breakthrough technologies such as the direct POX of feedstock to methanol without the need for syngas production as pursued by GasTechno. Capex cost reductions of more than 50% are predicted.

## 10 CONCLUSIONS

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2014 was the tipping point for the emerging small scale GTL business with four commercial projects passing through the final investment decision point. The four companies behind these projects, SGC Energia, Greyrock, Velocys, and CompactGTL will now focus on safe project delivery, on-time and on-budget. The projects will come on-line in 2016 and 2017 (CompactGTL).

These projects cover a broad range of daily gas volumes from about 2 MMscfd (200 bpd Velocys) to about 25 MMscfd (2500 bpd CompactGTL). Highly mobile miniGTL plants (<1MMscfd) are expected to find first customers within 12 to 18 months.

Only one of the first 4 commercial plants uses associated flared gas as feedstock (CompactGTL). It is expected that flared gas will become a preferred feedstock for 2 reasons: one, the need for low cost feedstocks in the new, lower oil price world and two, the increasing local and global pressures to minimize and eliminate gas flaring.

2014 was just the beginning. It is possible that another 3 to 5 projects will pass the FID hurdle before the end of 2015. Importantly, other companies will join the 4 front runners. Thus, there will be a choice for the gas flaring customer and good competition among the technology providers.

Five new companies have been added and reviewed in this latest Report III: SGC Energia, Maverick Synfuels, AUM Energy, Greenway Innovative Energy and Standard Alcohol.

A very positive trend for the GGFR community is the relentless trend to smaller and smaller plants. Primus Green Energy is offering a 500 bpd gasoline plant consuming less than 5 MMscfd. This plant has a footprint of only about 80 feet by 80 feet (26m by 26m). This plant is still mobile: it takes less than a month to disassemble, move, re-assemble and start-up the plant.

All technology providers understand the remoteness of most flare gas applications and have developed robust systems with easy and safe controls.

**The message to the GGFR community is clear: there are now multiple choices of companies that can monetize flared gas from a few hundred thousand scfd to 25 MMscfd and beyond.**