GGFR Technology Overview – Utilization of Small-Scale Associated Gas

Amazonas Station, OCP Ecuador S.A. (Photo: Wärtsilä)

April 2017

GGFR
Global Gas Flaring Reduction
A Public-Private Partnership

Contents

1 Disclaimer

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The Global Gas Flaring Reduction partnership (GGFR) is a public-private partnership that was formed in 2002 by multilateral organizations, governments, and oil companies. It is hosted and managed by the World Bank. GGFR provides a platform to support national governments and the petroleum industry in their efforts to reduce flaring and venting of gas associated with the extraction of crude oil.

2 Gas Processing

Processing of associated gas for entry into a pipeline system or where further utilization (e.g. CNG, Mini-GTL) requires heavier components and/or contaminants to be removed.

Each summary includes basic information on performance, technical requirements to implement and operate the equipment, the technology developer's business model, and existing applications currently in operation.

Aspen Engineering Services: NGL Pro

Aspen Engineering Services offers technology for flare reduction, gas conditioning and NGL recovery. The 'NGL Pro' process integrates dehydration, compression, cooling and conditioning, eliminating the need for costly glycol and refrigeration systems. Hydrate formation is precluded by a heat integration system. Consequently, no antifreeze additives are required. The 'NGL Pro' process can be coupled with the 'LNG-Pure' system to co-produce LNG and NGL, and thereby eliminate flaring.

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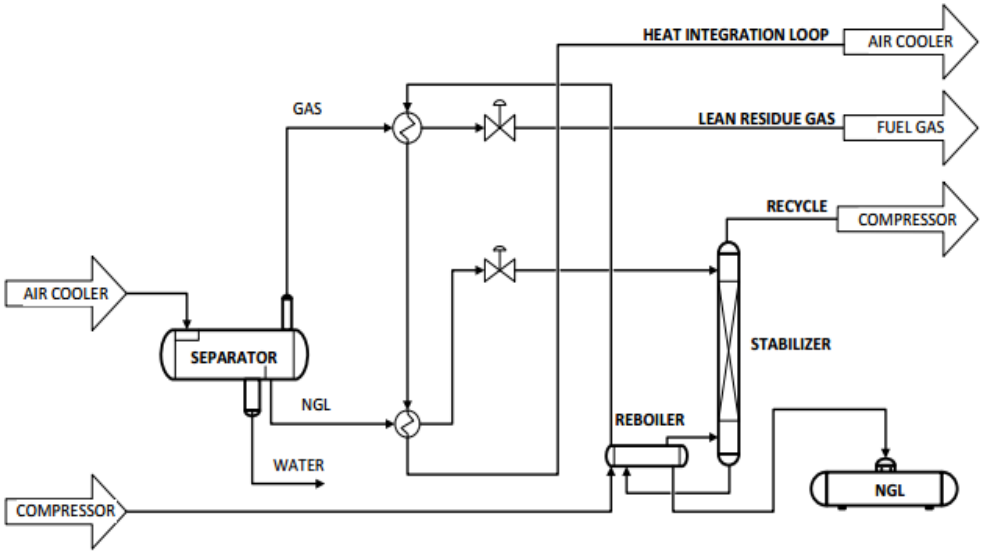

Aspen Engineering Services – Technology & operating conditions	Size range & cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
Gas processing and NGL extraction	Standard unit size is 2.5 MMSCFD. Units can be paralleled for larger capacity	Power from grid, on-site micro-grid, or gas-fired generators	Company indicated very low maintenance requirement	Company indicated suitable for offshore applications	Sale, lease or license	A commercial unit will be tested Q1 2017
Please contact company for allowable BTU variability and simulation report						
H_2S tolerance for the unit is up to 3%	Scalable & modular - 2.5 MMSCFD on an 8' x 25' skid					
Raw gas minimum inlet pressure is 20 - 75 psig		Independent compressor skid required		Footprint is 8' x 25' for 2.5 MMSCFD		
Please contact company for components separated and separation efficiency	Cost USD650K for 2.5 MMSCFD					
Handles variable flow by stabilizing compression system using recycle stream						

BINGO Interests

BINGO Interests LLC provides oil and gas operators comprehensive natural gas dual-fuel services. As a partner of Lime Instruments, an independent energy-focused controls and automation company in the United States, BINGO utilizes dual-fuel solutions to help energy companies lower frac and drilling fuel costs and eliminate the need to flare. In order to maximize savings, operators can choose from flare gas, pipeline gas, CNG, LNG, or any combination in order to optimize their dual-fuel solution. Bingo's management team has over 100 years of combined industry experience.

Contact: Nick Anderson, nanderson@bingointerests.com

Bingo Interests – Technology & operating conditions	Size range & cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
Gas processing using mechanical refrigeration (MR), Joule – Thompson (JT) skid or dehydration skid	Unit size available: 100 MCFD to 10 MMCFD	Power from grid, on-site micro-grid, or gas fired generators that uses well site-produced gas	Remotely monitored but requires periodic preventive maintenance checks and services (PMCS) on site	Company indicated suitability for offshore applications	Flexible	Unit operating in Pennsylvania is a dehydration unit due to clean gas production. Unit in North Dakota is a mechanical refrigeration unit due to heavy wet gas production
BTU manipulation technology allows for optimal substitution and minimal gas slip						
Gas with H_2S below 2500 ppm is treated using scavenger or amine unit to less than 1 ppm	Scalable & modular – footprint is 60' X 80' for 5 MMSCFD or 8' X 18' for 100MCFD			Please contact company for certification		
No inlet pressure threshold. BINGO has gas compressors and knock-down skids to handle any pressure						
Please contact the company for separation efficiency	Cost USD500/day – 6,000/day			Footprint: 60' X 80' for 5 MMSCFD, 8' X 18' for 100MCFD		
Handles variable gas flow rate						

Expansion Energy

Expansion Energy is a New York-based company focused on developing and licensing technologies for the energy, environmental and industrial sectors. Expansion Energy's technologies stem largely from the science of cryogenics and the disciplines of natural gas processing and industrial gas production.

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Expansion Energy – Technology & operating conditions	Size range & cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
Gas processing using mechanical refrigeration to separate NGLs at -150° F and 400 psia	Unit size range available: 0.5 MMCSFD to 9 MMCSFD of feed gas.	If VX Cycle LNG plant installed, power needed is produced on site by the VX Cycle, using feedstock gas. Otherwise power required from other source	Company indicated low maintenance requirements. Please contact company for more information	Small footprint allows for offshore deployment. Please contact company for more information	Sell, lease or license	10 VX Cycle LNG plants have been built and deployed over the past several years
Pre-treatment skid removes H_2S						
Minimum gas inlet pressure is 50 psia	Scalable and modular for all scales, and truck mounted for the smallest versions.					
All pre-processing, such as water and CO_2 removal, are included in the VX Cycle.						
Please contact company for component separation efficiency						
Handles rapidly varying gas flows	Please contact company for cost.					

GTUIT

GTUIT creates solutions for flare capture and associated gas conditioning challenges. Their equipment and manufacturing processes are ISO 9001:2008 compliant. GTUIT Corporate Office is located in Billings, Montana.

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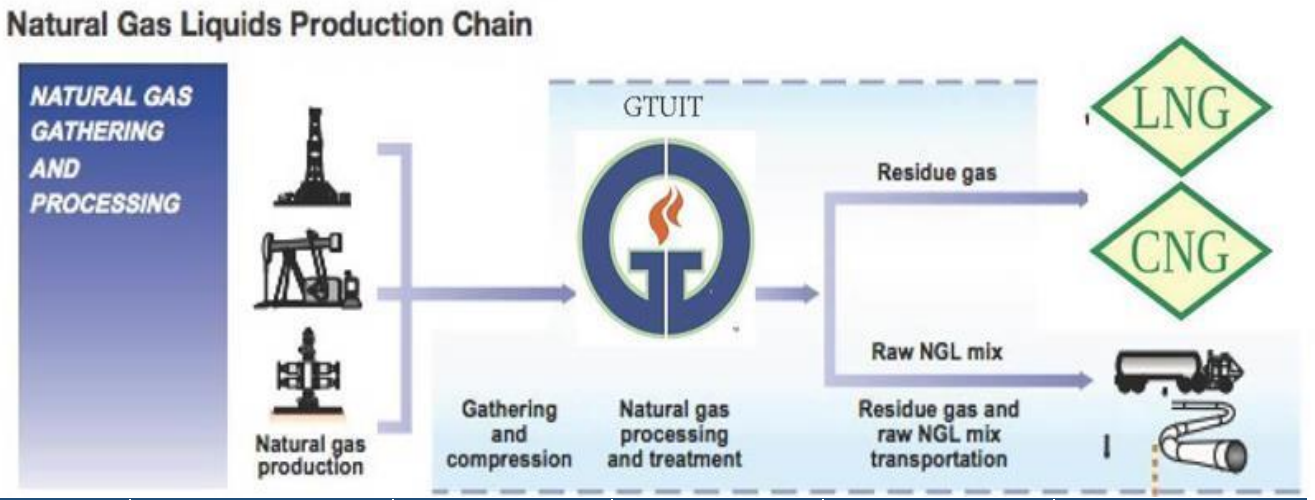

GTUIT – Technology & operating conditions	Size range & cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
On-Site gas processing using mechanical refrigeration and gas compression	Unit sizes available: 250, 500, 1000 MCSFD	Power from grid, on-site micro-grid, or gas fired generators that uses system's produced gas	GTUIT is a gas processing partner with Caterpillar Oil & Gas and uses Caterpillar dealers worldwide	Company indicated suitable for offshore applications	Sale, train, and support	20 MMCFSD of processing capacity in North America
High BTU gas processing units for NGL recovery and fuel conditioning						
H_2S treatment for concentrations as high as 20,000 PPM	Scalable & modular - up to 5000 MCFSD per site. Mobile - 48 hour deployment time	NGL/produced liquids storage		Please contact company for certification		20 million gallons of NGL's produced and sold
Raw gas minimum inlet pressure ≈ 1 psig			Comprehensive service training and documentation provided by GTUIT		Trouble shooting, parts, and remote/onsite technical support available	
Recovers up to 75% of the propane and heavier components	Cost USD1000-2000 per MCFD configuration dependent	Water is removed from typical raw gas streams – requires disposal on-site		Please contact company for footprint		Over 250,000 operational hours
Proprietary flow control equipment						

Membrane Technology & Research Inc. (MTR, Inc.): LPG-Sep™

Since its beginnings in 1982, MTR has grown continuously as industry embraced membranes as an effective gas separation technology. MTR now provides a full range of gas separation solutions for petrochemical plants, refineries, and gas processing facilities. MTR's administrative, research, and manufacturing facilities are located in Newark, California. The company has sales offices in Houston, Texas and Brussels, Belgium, and sales agents worldwide.

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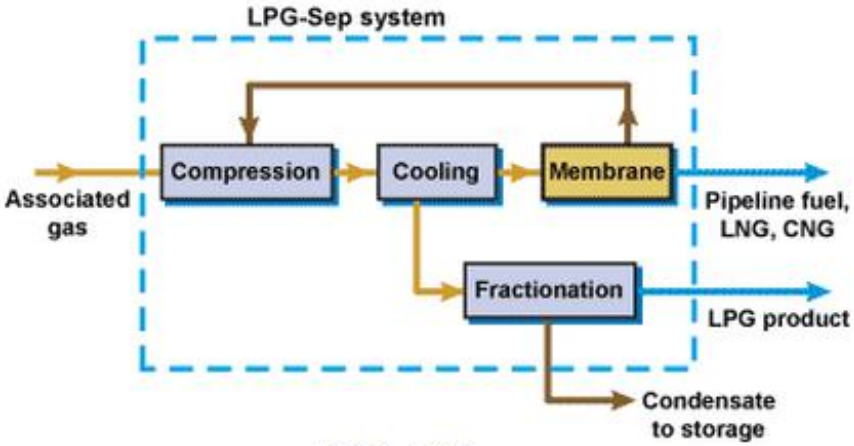

LPG-Sep™ Process

Membrane Tech & Res. – Technology & operating conditions	Size range & cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
Gas processing using hybrid combination of membrane & chiller	Unit sizes available: 1, 5, 10 and 15 MMSCFD. Higher flowrates can also be designed if required	Power from grid, on-site micro-grid, or gas-fired generators that use system's produced gas	Maintenance required on feed compressor. Compression equipment is standard oilfield compression	Company indicated suitability for offshore applications	Sale	MTR has been building hydrocarbon recovery systems for 20+ years for various applications. More than 100 units are in operation worldwide. MTR supplied complete skid-mounted scope excluding NGL/LPG storage
Feed BTU Content can vary between 1000 BTU/SCF – 400 BTU/SCF LHV						
H_2S pretreatment required upstream to produce sulfur-free LPG and condensate	Scalable & modular. Containerized and truck mounted up to 5 MMSCFD	NGL/produced liquids storage		MTR can build to required offshore/FPSO specifications		
Feed gas pressure as low as 1 psig			Membranes need to be replaced every 3-5 years			
Recovers up to 90% of C3+ hydrocarbons	Cost USD7-8 million for 5-7 MMSCFD, USD10-15 million for 10-15 MMSCFD			Compact footprints possible with hybrid approach		
Handles variable gas flow rates						

Nacelle: Big Dog™ Flare Recovery System

Founded in 2014, Nacelle offers proprietary solutions in natural gas fueling, BTU reduction, and NGL capture & extraction.

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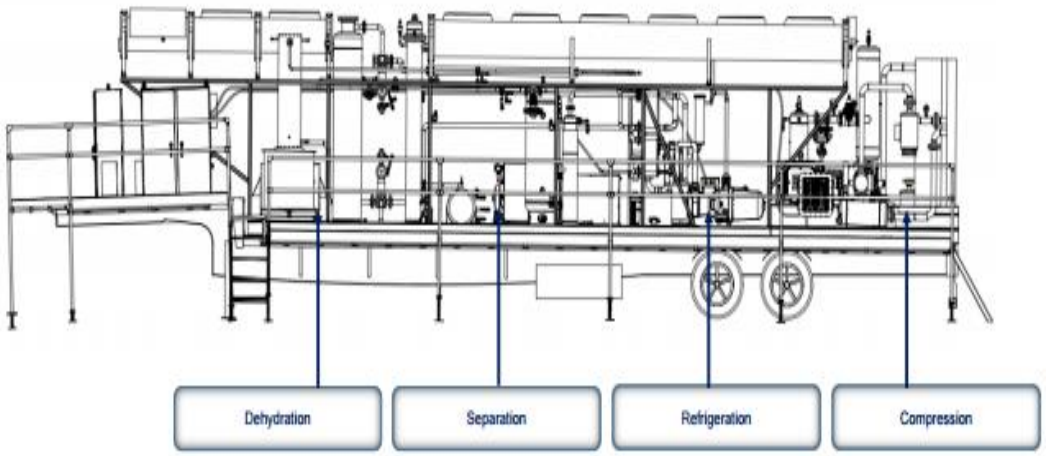
Nacelle – Technology & operating conditions	Size range & cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
Gas processing. **NGL extraction based on membrane separation**	Unit sizes available: 200 MCFD to 20 MMCFD	NGL/produced liquids storage. Depending on equipment utilized for application, additional operational requirements may apply. Please contact Nacelle for specifics related to client's situation	Dependent upon region of operation, Nacelle offers turn-key O&M. Skilled operators required. Regular scheduled preventative maintenance. On-stream factor above 92%	Equipment is suitable for offshore service	Business model varies by region. Please contact Nacelle for specifics related to client's situation	Nacelle has worked for various operators in the United States. Commercial units are in operation since March 2016.
Handles variable gas composition (wide range of BTU variability handling)						
Please contact Nacelle for H_2S treatment requirement	The systems are truck mounted, and scalable. The standard size is two 48' flat deck trailers					
Feed gas pressure varies between 50 and 1200 psi						
Please contact company for component separation and efficiency	Cost dependent on type of service agreement and scope of work					
System is able to handle fluctuating gas flows						

Pioneer Energy: Flarecatcher and NGL Distillation Systems

Pioneer Energy's Flarecatcher extracts NGLs from associated gas at the well site, using its Deep Refrigeration™ technology. The company is a Lakewood, Colorado-based service provider and original equipment manufacturer.

Contact: Joseph Palaia, jpalaia@pioneerenergy.com



Pioneer Energy – Technology & operating conditions	Size range & cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
Flarecatcher – Gas processing plant using mechanical refrigeration to chill to -65 °C	Unit sizes available: 400, 1000, 2000, 3000, 4000 MSCFD	External electrical input – can be generated by natural gas generator run off ethane separated by Flarecatcher	Basic mechanic or technician level staff is required for operations and maintenance	System can be barge or boat mounted to service off-shore application	Sale. Complete turn-key service is available for domestic clients. Remote control, O&M training is available for international clients	6 Pioneer Energy's Flarecatcher units currently operate in DJ Basin, Colorado, since 2014 – temperature variations between -40 °C and +40 °C. 15 MMScf/day of gas processed and 35,000 gallons of NGL produced (by 2016)
NGL distillation system – modular distillation systems to separate produced NGLs into propane, butane, and NG condensate streams						
Handles H_2S concentration up to 20 ppm, H_2S removal required above	Units available in trailer or skid-mounted configuration and can be in parallel					
Raw gas with minimum inlet pressure of 20 psig		NGL/produced liquid can be stored in propane tanks, typically 18,000 gallon bullet tanks rated 250 psi would fit			Value added services such as on-site installation and training, remote monitoring and operation	
Separation efficiency >70% for propane; >95% for C4+	Cost varies since every project is different. Interested parties should contact provider					
Handles variable gas composition and flows using variable speed compressor						

Unicorn Power Ltd. and Green Recycling Technologies

Unicorn Power Solutions Private Ltd. offers facility power solutions and services, with presence across India and in the Middle East. Unicorn's business portfolio of standby power solutions and facility services comprises diesel generators, UPS Systems, specialized batteries, DC power systems, facility management, power quality and energy management solutions.

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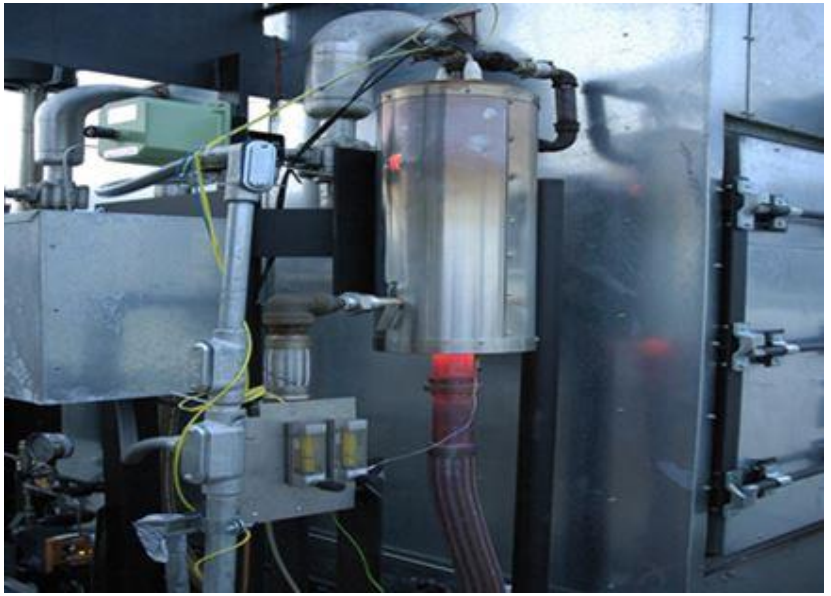

Unicorn – Technology & operating conditions	Size range & cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
Cold-plasma gas scrubber conversion of associated gas into syngas, which can be used for power generation or fuel production	200 and 500 kW units (ca. 60-150 m3/h raw methane)	Please contact company for additional operational requirements	Company indicated that O&M is comparable to a diesel generator. Please contact company for O&M	Offshore suitable depending on power/gas receiver availability	Sale	New technology. Pending installations at several international and domestic gas well sites
Please contact company for tolerance to BTU variability						
H_2S tolerance up to 200 ppm	Scalable & modular – multiple of 200 and 500 kW units			Please contact company for certification		
Minimum gas intake pressure 0.4 psi						
Handles flow variability (<50% change in 15 minutes)	Cost USD2.5 million/MW for gas scrubber and generation set; USD0.8 million/MW for gas scrubber alone			Please contact company for footprint		

3 Power Generation

Technologies suitable to generate electricity from associated gas.

Each summary includes basic information on performance, technical requirements to implement and operate the equipment, the technology developer's business model, and existing applications currently in operation.

Aggreko

With 10 GW of global generation capacity and operations in more than 100 countries, Aggreko is a supplier of mobile, modular power generation. Aggreko supplies large-scale, supplementary generation capacity to state utilities, powering off-grid mines and oil and gas facilities, and a wide array of heavy industries. Aggreko has developed a fully integrated, mobile generation system running on APG and coalbed methane to exploit smaller, isolated gas reserves where the construction of permanent infrastructure is unviable. Much needed electricity is produced through previously wasted fuel, and customers avoid possible financial penalties imposed on flaring.

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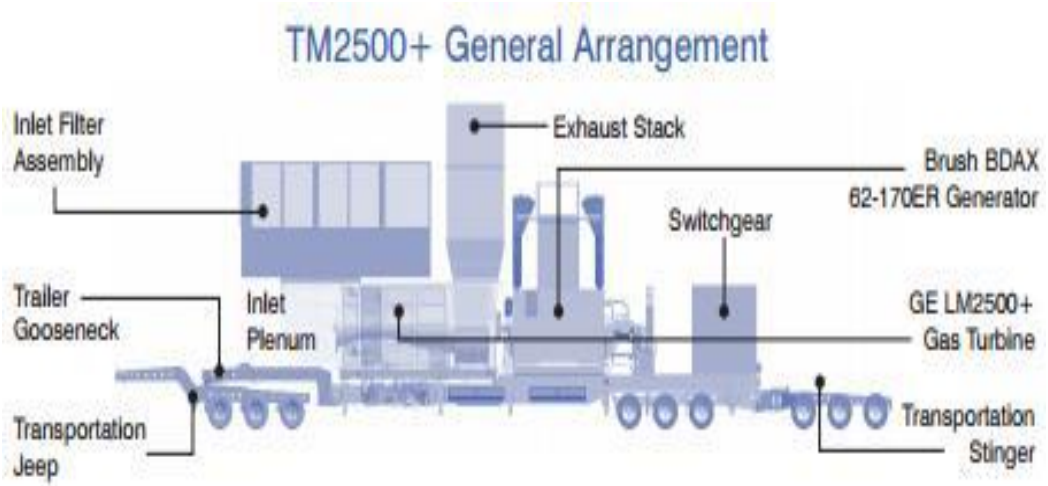
Aggreko – Technology & operating conditions	Size range & cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
Power generation using gas reciprocating engines.	Aggreko operates a fleet of generators ranging from 30kW to 2MW	Each project has its own bespoke requirements, which are managed and built into the project design	Aggreko manages all O&M activities, as part of its fully integrated, end-to-end rental package	Extensive power generation experience in offshore environments. While APG packages are currently all onshore, adapting for offshore is entirely feasible	Rental model whereby all project elements are managed by Aggreko. Minimizes capital outlay and offers complete flexibility. Contact Aggreko for BOT opportunities.	Flare gas-to-power sites have been successfully operating since 2008. Aggreko currently generates 200 MW at sites in Russia, Romania and South Africa
Gas volume requirements 340 Mscfd/MW						
Handles standard inlet gas pressure ranges 5-6 bar; and up to 100 bar with gas pressure reduction and filtration equipment. Technology covers a range of gas specs	Scalable, modular and truck mounted. Gensets are containerized in 20 ft containers.					
No pre-processing required (subject to gas specification) H_2S content up to 10 ppm. Multi-fueling available (gas and propane)	Pricing is dependent on each specific project. Contact Aggreko for details					

APR Energy: TM2500+™ Mobile Gas Turbine

APR Energy became an independent company in March 2004, when co-founders John Campion and Laurence Anderson bought the ALSTOM Power Rentals division from ALSTOM Power. They continued to operate with a licensing agreement under the ALSTOM brand until June 2008, when it was rebranded as APR Energy. In June 2011, Horizon Acquisition Company acquired APR Energy, and in September 2011 re-listed it on the London Stock Exchange. APR Energy headquarter is in Jacksonville, Florida.

Contact: Eric Toumayan, eric.toumayan@aprenergy.com



APR – Technology & operating conditions	Size range & cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
Turnkey power generation solutions using gas turbines	TM2500+ ISO rating is 26-30MW (will increase to 30 – 35MW in 2017)	The turbine fleet is designed for rapid deployment and reliable ongoing operation in any environment	APR provides comprehensive operation and maintenance services, plus supply of all necessary spare parts and consumables for the turbines and balance of plant	APR standard turbine products are not configured for offshore service. Customized options are available. Please contact APR Energy for further details	APR typically structures its deals as Power Purchase Agreements, but for longer term contracts BOOT options are available. IPP solutions inclusive of fuel supply also possible. Please contact APR Energy for further details	APR has a fleet of in excess of 2000MW and has completed over 3GW over 30 countries. Please contact APR Energy for further details
Please contact APR Energy for gas-pressure/volume requirements and customized performance data						
Please contact APR Energy for sensitivity to gas composition and flow rate	Turbine solutions are scalable and modular, ranging from 20 to 500 MW					
Multi-fuel configurations (diesel, gas, LPG, naphtha)	Please contact APR Energy for cost					

BINGO Interests

BINGO Interests LLC provides oil and gas operators natural gas dual-fuel services. As a partner of Lime Instruments, an independent energy-focused controls and automation company in the United States, BINGO utilizes dual-fuel solutions to help energy companies lower frac and drilling fuel costs and eliminate the need to flare. In order to maximize savings, operators can choose from flare gas, pipeline gas, CNG, LNG, or any combination in order to optimize their dual-fuel solution. BINGO's management team has over 100 years of combined industry experience.

Contact: Nick Anderson, nanderson@bingointerests.com

BINGO – Technology & Operating conditions	Size range & Cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
Power generation using radial gas turbines	Turbines typically scaled to 250 kW – 30 MW	-	Preventive maintenance checks and services monthly.	Company indicated suitability for offshore	Sale or lease	-
Gas volume requirement of 360 Mcfd/MW						
Minimum gas inlet pressure is 70 psi	Turbines are scalable, modular and containerized. Footprint is 6' x 10' for 35kw genset, 8' X 55' for 5MW genset			Please contact company for certification		
Handles variable gas flow rate.						
Proprietary BTU manipulation technology allows for optimal efficiency burn and minimal gas slip	Cost depends on scale and operation. Contact BINGO for a quote			Footprint is 6' x 10' for 35kw genset, 8' X 55' for 5MW genset		
Multi-fueling possible with diesel or natural gas by rapid switching						

Capstone Turbine Corporation: C30, C65, C200, C600S, C800S and C1000S

Capstone is a member of the U.S. Environmental Protection Agency's Combined Heat and Power Partnership, which is committed to improving the efficiency of the nation's energy infrastructure and reducing emissions of pollutants and greenhouse gases. A UL-Certified ISO 9001:2008 and ISO 14001:2004 company, Capstone is headquartered in the Los Angeles area with sales and/or service centers in the United States, Latin America, Europe, Middle East, China and Singapore.

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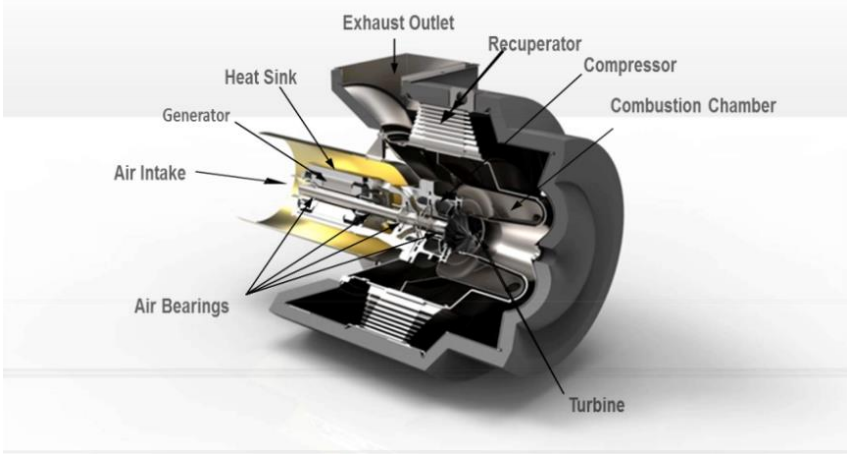

Capstone – Technology & operating conditions	Size range & cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
Micro-turbine power generation	Unit sizes available: 30, 65, 200, 600, 800, 1000 kW	Beside gas flare, air and fuel free of liquids and filtered for particulates are required for off-grid application.	Includes the first 8,000 hours and then the 40,000 hours overhauls. Air and fuel filters change (site dependent). No lubricants of refrigerant required	Available configuration suitable for offshore. Compliant for explosive environments (ATEX Directive 94/9/EC)	Sells through international distributors' network. Lease and financing options also available	Several units C30s, C65, C800s C1000s operating on wet flare gas in Germany, the U.S. (Wyoming, California) and Russia. The units in Russia operate on flare gas containing up to 3.5 % H_2S
Gas volume requirement: 10 Mcf/day for 30 kW; 20 Mcf/day for 65 kW; 54 Mcf/day for 200 kW						
Gas inlet pressure is 55-60 psig for C3 model, 75-80 psig for C65 to C1000 models	Units are scalable and modular. Can be put in parallel. All models can be skid or trailer mounted, or containerized					
Handles variable gas composition (up to 70% CO_2, 22% N_2, 30,000 ppm H_2S) and flow						
Pre-processing is not expected to be required	Cost USD1,000 - 1,700/kW depending on model, configuration and options					
Multi-fueling is possible using diesel, propane and kerosene						

GE: Waukesha and Jenbacher

For more than 80 years, GE has been recognized as a manufacturer in the development and production of gas engines for the efficient generation of power and heat. Essential components necessary for reliable engine operation – such as spark plugs, gas mixer, and engine controls – are developed directly in Jenbach and Waukesha. This allows GE to control the development and construction, system integration, and testing of the complete units.

Contact: Chris Maslak, chris.maslak@ge.com
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GE – Technology & operating conditions	Size range & cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
Power generation using reciprocating gas engines.	Unit size range for Waukesha engines: 200KW – 3.7MW; Jenbacher engines: 250KW – 9.5MW	Please contact company for additional operational requirements	O&M is carried out by authorized distributors and service providers. Please contact company for detailed O&M	Waukesha engines are suitable for offshore	Sale through authorized distributors & service providers	~30 years of experience in remote areas. 3 applications using associated gas supply in middle East
Depend on engine type, application – island, standby or continuous and power rating						
Gas inlet pressure is 60 – 115 psi. Allowable gas pressure variation: ±10%	Units are scalable, modular and containerized. Practical size: 200KW – 2.5MW			Please contact company for certification		
Handles variable gas composition and flow but not below engine nominal threshold						
Gas pre-processing provided by company but can be outsourced depending on application	Please contact company for cost			Please contact company for footprint		
Multi-fueling possible with some units						

 Costs are indicative only; FOB in country of origin unless indicated otherwise
See World Bank and GGFR Disclaimer

LPP Combustion, LLC

LPP Combustion, LLC (LPP), a Maryland, USA-based company, has developed a technology for lean, pre-mixed, pre-vaporized combustion of liquid fuels, allowing these fuels to burn cleanly in natural gas-fired power turbines and other combustion devices.

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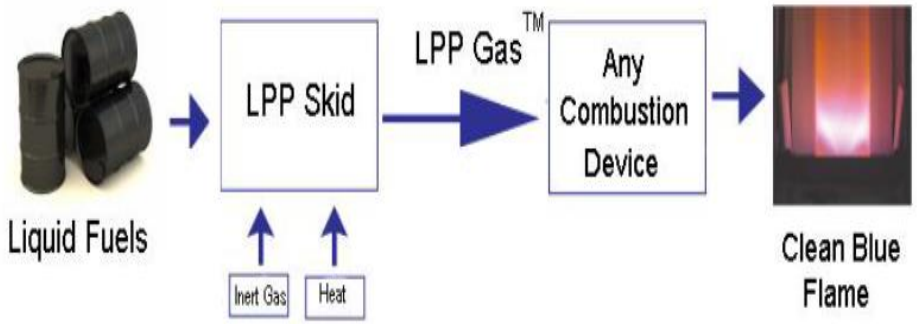

LPP – Technology & operating conditions	Size range & cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
Fuel preparation skid for making flare gas usable in turbines or engines	Unit size range from 30 kW to 300 MW Genset can be supplied upon request	-	Oil and gas plant technician can learn to operate the skid	Company indicated suitability for offshore	Sale, lease	A mobile 30 kW commercial unit running on flare gas. Currently installing a 65 kW skid in Canada to operate on vaporized waste petroleum products
Gas volume requirement of 186 – 280 Mcf/day/MW for simple-cycle turbines						
Compresses the fuel to turbine inlet pressure	Skids are inherently modular in design, and containerized and truck mounted up to 30 MW			Please contact company for certification		
Handles variable gas composition and flow			Annual maintenance outage of few days is anticipated			
Pre-processing of gas not required	Cost USD1200/kW for systems under 200 kW and USD150 – 300/kW for multi-MW			Please contact company for footprint		
Multi-fueling simultaneously and by rapid switching						

Moser Energy Systems

Moser Energy Systems was founded in 1973 by Jim and Kathy Moser. Moser Energy Systems began manufacturing associated gas-powered generators in 2009, changing the way oil and gas operators make use of unwanted associated gas from oil wells, a resource often burned off (flared). Moser Energy Systems is headquartered in Wyoming, USA.

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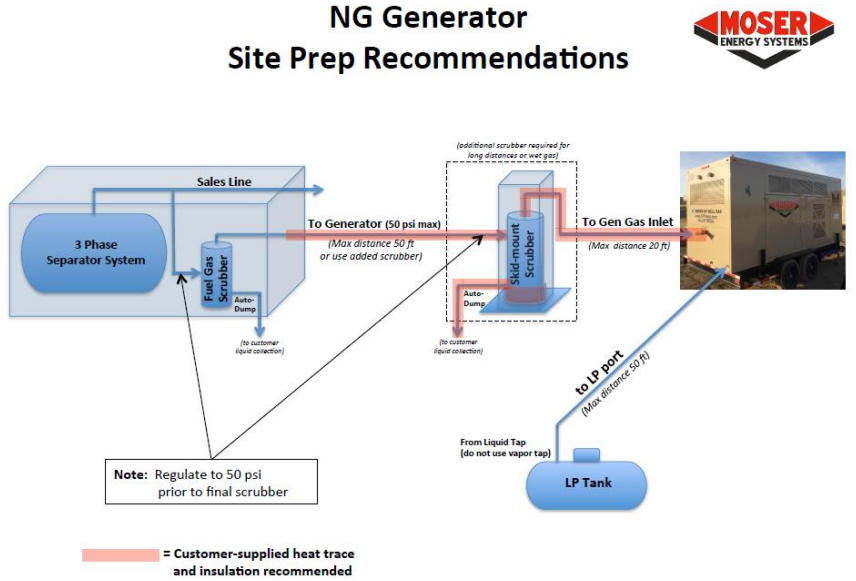
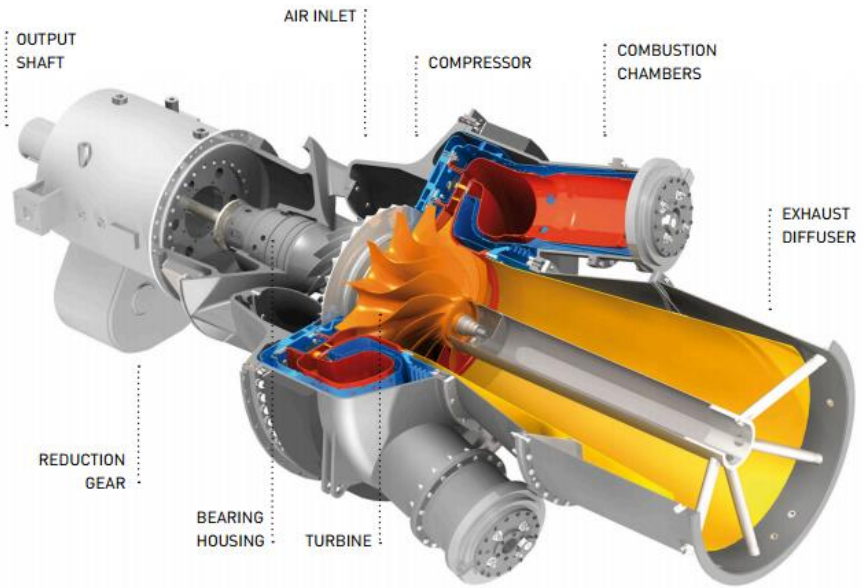


Moser – Technology & operating conditions	Size range & cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
Power generation using natural gas generator	Unit size available: 70, 125, 170, 225, 350, 1000 kW	Minimize liquids in wellhead gas	Monthly oil changes, quarterly valve adjustments, semi-annual sparkplug replacement	In progress	Sale, rental or joint venture	Moser fleet has over 10 million run -hours using associated gas
Gas volume requirement of 10 -250 Mcfd depending on unit size						
Gas inlet pressure range 5 – 50 psi	Units are enclosed on trailer or skid. Paralleling capable up to 32 units					
Variable inlet gas flows and heat content (800-1800 Btu)		Insulating above ground gas lines, if operations are in cold climates				
Minimal to no gas processing (up to 200 ppm H_2S). Generators include scrubber with auto-pump to empty accumulated liquids	Contact company for cost					
Multi-fueling using natural gas and propane						

OPRA Turbines: OP16 Gas Turbine

OPRA Turbines is a developer and manufacturer of advanced radial gas turbines and gas turbine powered generator sets in the 2MW power range. The OP16 gas turbine benefits from a simple and flexible design providing robustness, reliability, and low emissions for a variety of applications within the oil & gas industry in the 1 – 10 MW power range. OPRA Turbines was founded in 1991. Turbine package engineering, manufacturing, R&D, testing, and service activities are located in Hengelo, The Netherlands.

Contact: Camilo Contreras, c.contreras@opra.nl
cco@opra.nl; sales@opra.nl

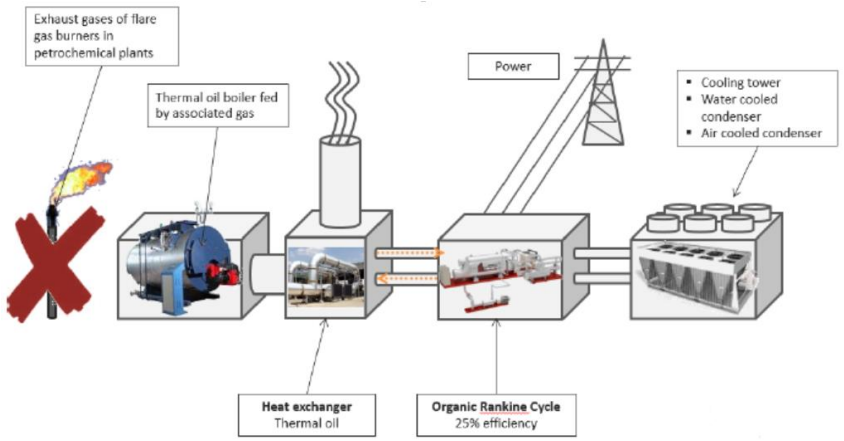


OPRA – Technology & operating conditions	Size range & cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
Power generation using radial gas turbines	Turbines typically scaled to 1 – 10 MW	Auxiliary power for black start	1 inspection per year and overhaul at 42,500 hours	Turbine has DNV - API 616 type approval for offshore applications	Sale; rental; build-own-operate (BOO); build-own-operate-transfer (BOOT)	28 turbines in offshore and onshore oil and gas fields in Russia, North Sea and Brazil
Gas volume requirement of 332 Mcfd /MW and a LHV range 5-120 MJ/kg						
Gas inlet pressure > 145 psi	Turbines are scalable, modular and containerized - 20 ft. configuration					
Handles variable gas composition and low heating values			Virtually zero lube oil consumption	20-ft container footprint		Over 1 million operating hours using associated gas
Pre-processing of gas not required (H_2S limit ≤4% vol)	Cost USD900-1000/kW					
Multi-fueling by rapid switching						

Turboden – Mitsubishi Heavy Industries Group

Turboden, part of Mitsubishi Heavy Industries group since 2013, is involved in the development and production of ORC turbogenerators, which harness heat to generate electric and thermal energy, and provide energy efficiency solutions for the oil & gas sector by recovering heat from exhaust gases. Founded in 1980 as spin-off of Politecnico of Milan, Turboden has installed more than 330 plants worldwide accounting for 8 million operating hours and 11,000 GWh of global electrical production.

Contact: Francesca Ettorre, Francesca.Ettorre@turboden.it
Marco Baresi, Marco.Baresi@turboden.it



Turboden – Technology & operating conditions	Practical size & cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
Power generation ORC system uses a thermal boiler fed by flare gas to vaporize an organic fluid used to generate electricity in a Rankine cycle	ORC unit sizes of 200 kW to 20 MW	Cooling water required in case of CHP mode	1 standard maintenance of a week/year and no overhaul	The ORC unit can be containerized in containers or shelters suitable for offshore service	Sale, Lease (through partnership with MHI)	A commercial plant (1.8 MW) is operating on flare gas in Osa-Perm, Russia since January 2015
Gas volume requirement 1.5 – 20 MMcf/day (respectively 1 – 20 MW ORC unit)						
Gas inlet minimum pressure > 1.5 psi	Turbines are scalable, modular and containerized. Truck mounted up to 300 kW					
Handles variable gas fuel composition and flow				The footprint will depend on the ORC unit size. The smallest is a 300 kW system which fits in a 40' container		
Pre-processing of gas is not expected to be required	Cost USD4000-4500/kW for 300-600 kW; USD2800-3300/kW for 1–5 MW; USD1700-2200/kW for >5 MW					
Multi-fueling simultaneously by mixing flare gas with natural gas and other fuels (e.g. Diesel)						

Unicorn Power and Green Recycling Technologies

Unicorn Power Solutions Private Ltd offers facility power solutions and services, with presence across India and in the Middle East. Unicorn's business portfolio consists of standby power solutions and facility services and comprises diesel generators, UPS Systems, specialized batteries, DC power systems, facility management and power quality & energy management solutions. Unicorn's alliances in respective product segments enable Unicorn to offer products and solutions backed with round the clock, on-site services.

Contact: Steven Miszkowicz, sm1.grt@gmail.com

Unicorn Power – Technology & operating conditions	Size range & cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
Power generation using gas turbines	Unit size range is 200 - 500 kW. (gas requirement 63 – 296 Mscft/day)	Please contact company for additional operational requirements	Company indicated that O&M is comparable to a diesel generator. Please contact company for detailed O&M	Company indicated suitability for offshore	Sale	Well-site testing scheduled 1Q2017. Plans for installations at several international and domestic gas well sites.
Company indicated electric efficiency 30-35%.						
Minimum gas intake pressure 0.4 psi	Turbines are scalable, modular (up to 20 x 500 kW) and containerized (40 ft container per 500KW unit)			Please contact company for certification		
For gas composition variation, please contact company.						
Gas pre-processing not required for H_2S conc. < 200 ppm.	Cost USD2.5 million/MW			Footprint is 40 ft container for 500 kW		
Multi-fueling performed simultaneously using diesel or gasoline						

Wärtsilä 32GD and 46 GD Multifuel power plants

Wärtsilä is over 180 years old and provides advanced technologies and lifecycle solutions for the marine and energy markets. The company has operations in over 200 locations in more than 70 countries around the world. Wärtsilä is listed on Nasdaq Helsinki. 32GD and 46GD multifuel power plants were developed to provide a solution suitable for demanding applications in the oil and gas industry and fluctuating fuel supply.

Contact: Chris Whitney, chris.whitney@wartsila.com

Wärtsilä – Technology & operating conditions	Size range & cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
Power generation using gas engines.	Please contact company for unit size range	Please contact company for additional operational requirements	Please contact company for detailed O&M	Waukesha engines are suitable for offshore	Sale. Continuous support for improving and optimizing operational efficiency through installation lifecycle available	More than 11,000 professionals in 70 countries. A combined 60 GW delivered worldwide (including all types of power plants)
32 GD and 46 GD multifuel power plants designed to run on associated gas or crude oil.						
Plant output: 10 – 400 MW. Efficiency: 45%	Units are modular and scalable. Please contact company for standard modular size			Please contact company for certification		
Tolerant against fuel quality variation. Pretreatment of gas not anticipated. For H_2S limit, please contact company						
Multi-fueling without interruption (natural gas, diesel, HFO, biofuels, crude oil)	Please contact company for cost			Please contact company for footprint		

4 CNG – Compressed Natural Gas

Small-scale CNG technologies used to compress (associated) gas to increase its energy density, thereby allowing economic transport of the gas to markets.

Where a pipeline may be uneconomic or not yet constructed, CNG offers a 'virtual pipeline' to transport gas to supply power plants and industrial and domestic gas users, or for use as a fuel for cars and (small) trucks.

A CNG system requires pre-processing of the (associated) gas to remove contaminants such as CO_2 and H_2S. To meet gas specification, removal of N_2 and/or higher hydrocarbons may also be required.

CNG has a lower energy density than LNG, but the lower capital cost of CNG can make it an attractive option especially for small (<~ 5 MMscf/d) gas volumes. For larger gas volumes and/or distances to market, however, the large number of trucks needed to transport the gas can make it economically and/or operationally unattractive.

Each summary includes basic information on performance, technical requirements to implement and operate the equipment, the technology developer's business model, and existing applications currently in operation.

GE

GE's second-generation, optimized CNG In A Box technology is a modular 'plug and play' system that enables the rapid establishment of CNG fueling stations to keep pace with demand. This scalable solution helps expand fueling networks by removing the financial risk that has previously limited market development, enabling more CNG station entrepreneurs to build their own stations.

Contact: Chris Maslak, chris.maslak@ge.com
Larissa Shaaked, larissa.shaaked@ge.com

GE – Technology & operating conditions	Size range & cost	Additional operational requirements	O&M	Storage/ transportation	Offshore suitability	Business model	Experience to date
CNG In A Box™ system/custom CNG packages	Unit size ranges from 0.2-2.6 MMscfd, scalable up to 20× for custom CNG packages	Power generation requirements (400 kW for a 400 hp CNG In A Box system) supplied by company. Requires dispensers to load the CNG into vehicles (if required)	Requires operator with reciprocating equipment experience. Please contact company for O&M requirements	Storage requirements depend on desired fueling speed. Please contact company for more information	Not currently certified for offshore. Please contact company for more information	Sale	Over 70 CNG In A Box systems in operation
Suction pressures >= 30 psi.	'CNG In a Box' system is modular and transportable by a single truck. Custom CNG packages may require as many as four per package						
Feedgas must be treated to remove H_2S. Pre-processing is dependent on gas specification and can be provided by GE							
Handles rapidly varying gas flows	Cost is USD500k for a 400 hp CNG In a Box system						

 Costs are indicative only; FOB in country of origin unless indicated otherwise
See World Bank and GGFR Disclaimer

5 Mini-LNG – Liquefied Natural Gas

Small-scale LNG technologies used to liquefy (associated) gas to increase its energy density, thereby allowing economic transport of the gas to markets.

Where a pipeline may be uneconomic or not yet constructed, small-scale LNG offers a 'virtual pipeline' to transport gas to supply power plants, industrial and domestic gas users, and/or for use as a fuel for cars and trucks. LNG has a higher energy density than CNG, making it a more attractive option for transporting larger (>~ 5 MMscf/d) gas volumes and/or distances to market. Its higher capital cost, however, can make it economically unattractive for small gas volumes.

LNG liquefaction requires pre-processing of the (associated) gas to remove contaminants such as CO_2, H_2S and mercury. To meet gas specification, removal of N_2 and/or higher hydrocarbons may also be required.

LNG is used in many parts of the world to supply gas (following re-gasification) to power plants and industrial/domestic gas users. It is also being increasingly used in liquid form as a fuel for large trucks.

Each summary includes basic information on performance, technical requirements to implement and operate the equipment, the technology developer's business model, and existing applications currently in operation.

Chart Industries

Chart is involved in the design and manufacture of cryogenic equipment used from the beginning to the end in the liquid gas supply chain. For more than 40 years Chart has worked on the development and use of LNG and supplies equipment and solutions across the complete LNG value chain – liquefaction, storage, distribution, and end-use.

Contact: George Arnett, George.Arnett@chartindustries.com
Paul Shields, Paul.Shields@chartindustries.com

Chart – Technology & operating conditions	Size range & cost	Additional operational requirements	O&M	Storage/ transportation	Offshore suitability	Business model	Experience to date
Small-scale LNG liquefaction Nitrogen expansion, closed loop. Mixed refrigerant Joule Thompson, closed loop	Unit sizes available: 4.0(0.03), 8.1(0.06), 12.2(0.08), 16.2 (0.11), 20.3 (0.14), 36.5(0.25), 40.5(0.28), 71.4(0.50) and 142.8(1) MMCSFD (MTPA)	Power requirement varies. Please contact company	Chart can provide training programs to the operators	Systems are compatible with Chart designed and built storage or third-party storage	Company indicated suitability for offshore applications by optimizing footprint. Please contact company for more information		Multiple plants operating in North America and other regions
Gas inlet pressure range is 450 - 950 psig	Scalable/modular units in any size/configuration from available units						
Chart can design and provide gas pre-processing solutions as required for cryogenic liquefaction		All plants require instrument air, refrigerant supply and other standard utilities	Maintenance is generally routine and mostly associated with rotating equipment in the plant	Please contact company for transportation			
Can handle changing gas flows. Capable of turndown to 50% of design capacity	Please contact company for cost						

Expansion Energy

Expansion Energy is a New York-based company focused on developing and licensing technologies for the energy, environmental and industrial sectors. The company's technologies stem largely from the science of cryogenics and the disciplines of natural gas processing and industrial gas production.

Contact: Jeremy Dockter, jdockter@expansion-energy.com
David Vandor, dvandor@expansion-energy.com

Expansion Energy – Technology & operating conditions	Size range & cost	Additional operational requirements	O&M	Storage/ transportation	Offshore suitability	Business model	Experience to date
Mini-LNG liquefaction using patented methane expansion cycle: the "VX™ Cycle".	Unit sizes range from 0.35 to 42 MMCSFD (2,500 – 300,000 MTPA)	All required power is produced on site by the VX Cycle using the feedstock gas	Company indicated low maintenance requirements. Please contact company for more information	VX Cycle is flexible regarding storage pressure, LNG temperature and storage container configurations. VX Cycle produces a "sub-cooled" LNG product, which minimizes LNG boil-off	Small footprint allows for offshore deployment. Please contact company for more information	Sell, lease or license	10 VX Cycle LNG plants have been built and deployed over the past several years
Minimum gas inlet pressure is 50 psia. Booster compressor can be added if gas pressure is lower	Scalable and modular for all scales, and truck mounted for the smallest versions. Standard sizes are 6,000 and 100,000 GPD of production. The 100,000 GPD plant requires about 9 MMSCFD of feed gas						
All pre-processing, such as water and CO_2 removal, are included in the VX Cycle, and pre-treatment skid removes H_2S							
Handles rapidly varying gas flows	Please contact company for cost						

Galileo

Galileo's Cryobox® has an adjustable production capacity of up to 9013 gpd (gallons per day). The high-pressure, thermodynamic cycle of the Cryobox converts natural gas to the liquid state as temperatures are reduced to less than -243°F. This multi-stage compression process includes a "boil-off" recovery system which eliminates all gas-venting usually associated with LNG storage and loading facilities. This process avoids gas waste while complying with all safety and ecologic regulations.

Contact: Gabriel Lorenzi, glorenzi@galileoar.com

Galileo – Technology & operating conditions	Size range & cost	Additional operational requirements	O&M	Storage/ transportation	Offshore suitability	Business model	Experience to date
Mini-LNG liquefaction. Joule Thomson plus a closed-loop single refrigerant (propane); no boil-off	Unit size is 0.7 MMscfd, which produces 500 tpa of LNG	Power supply (Galileo also provides gas-driven units when power supply is not available) and compressed air	Provides full training for customer technicians and 24x7 technical support	Please contact company for storage	Technology is suitable for offshore applications, configured as a Cryobarge. Please contact company for more information	Sale, leasing or liquefaction services (customer provides the gas and land, Galileo operates and charges a fixed fee per MMbtu liquefied)	5 years producing LNG, with equipment in Argentina, USA, Australia, and Colombia
Gas inlet pressure range 101 – 159 psi.	Scalable & modular - Each unit fits in the size of a 40 feet sea container, which facilitates its delivery on a single trailer						
Treatment system (ZPTS) can be provided to clean non-desirable components such as N_2, H_2O, mercaptans, mercury etc., and reducing the CO_2 to the required <50 ppm			Preventive maintenance routine is recommended each 2,000 operating hours	Please contact company for transportation			
Can adapt to changing gas composition by modifying treatment system	Liquefaction plant (including treatment) FOB cost USD5 MM						

GE

From design to engineering and manufacturing, GE offers skid-mounted small-scale solutions to provide a cleaner, abundant fuel source. Available with four distinct refrigeration cycles, the plant's design and equipment selection can be customized to meet your production requirements. GE's fully-modular design applies standardized components and a simplified, proprietary plant control system to reduce plant commissioning time, maintenance needs and installation costs, while enhancing plant operability and efficiency. Designed for a variety of remote power, utility, and transportation applications, this fully integrated, plug-and-play natural gas liquefaction plant can produce between 25k and 1,200k gallons of LNG per day.

Contact: Chris Maslak, chris.maslak@ge.com
Larissa Shaaked, larissa.shaaked@ge.com

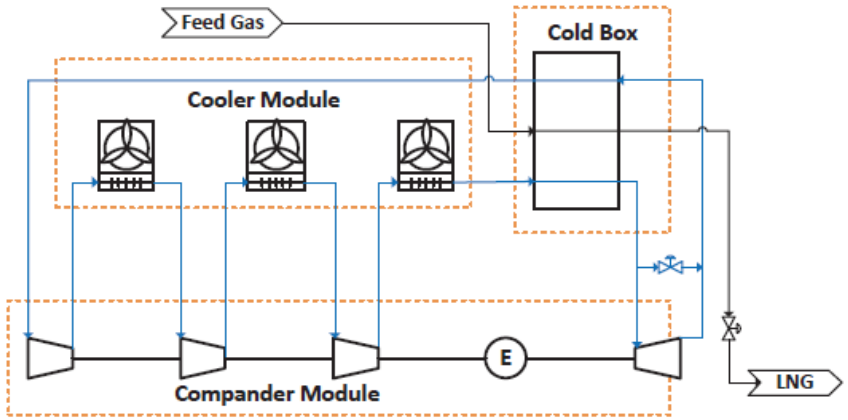
GE – Technology & operating conditions	Size range & cost	Additional operational requirements	O&M	Storage/ transportation	Offshore suitability	Business model	Experience to date
Mini-LNG liquefaction. Nitrogen expansion, methane open loop, pre-cooled mixed refrigerant (MR and single-cycle MR	Unit sizes range from 0.25 - 1.2MM GPD	Power generation requirements supplied by company	Please contact company for O&M requirements	Company indicated additional requirement of logistics of moving gas to final destination and storage. Please contact company for more information	Footprint is dependent on volume of flaring but can be modularized suitable for offshore. Please contact company for more information	Sale, lease	Two applications using stranded or associated gas supply – ~10 years of experience in remote areas
GE also provides pre-treatment to handle off-specification gas	Transportable and capable to be truck mounted						
Pre-processing of gas can be outsourced depending on application							
Solutions are available to handle fluctuation in gas supply	Please contact company for cost						

Linde Cryostar - StarLiteLNG™

Cryostar is an engineering and manufacturing company created in 1966. It is headquartered in France with offices world-wide. Cryostar and Linde merged in 2006. Based on its experience with the boil-off gas re-liquefaction system onboard LNG carriers, Cryostar offers a range of small-scale LNG or LBG plants for on-shore natural gas or biogas liquefaction application.

Contact: cryostarcustomerservice@cryostar.com

Mini-LNG



Linde Cryostar – Technology & operating conditions	Size range & cost	Additional operational requirements	O&M	Storage/ transportation	Offshore suitability	Business model	Experience to date
Mini-LNG Closed cycle, nitrogen expansion technology. Gas is liquefied by a nitrogen refrigeration cycle driven by a combination of compressors and expander	Typical unit sizes are 28, 50, 88, 125, 200 tpd of LNG	Power (1.5-6 MW depending on unit). Requires instrument air, cryogenic quality nitrogen and water.	Preventative maintenance is 2 days per year and 14 days every 35,000 hours. High level of automation provided for start/stop/ operation and turndown to be used by non-expert personnel	Please contact company for storage and transportation details	Yes – the design is used on methane tankers to re-liquefy the boil-off gas	Sale	Technology is used on-board tankers to re-liquefy the boil-off gas (18 tankers since 2007)
Minimum gas inlet pressure is 73 psi	Modular in skids for easy installation on site. 5 standard sizes to cover a range from 20 to 200 tpd, scalable by adding units in parallel						
Pretreatment required with CO_2 content <= 50ppm, H_2O content< 1ppm and H_2S<=4ppm					Compliant with PED 97/23/ EC EN, BS, NFPA ASME, AS1200 API, IEC, ANSI ASTM NEC, NEMA ATEX, IECEx.		
Handles gas flow rate variation with operation possible from 25% to 100%	Please contact company for cost						

6 Mini-GTL – Gas to Liquids

Technologies to convert (associated) gas into synthetic crude or other liquid hydrocarbons, e.g. gasoline, diesel, naphtha, methanol.

Advances in GTL technologies have recently enabled small-scale GTL, and even micro-scale GTL, to be operationally and potentially economically feasible.

The final GTL product may be syncrude, which can be injected into an oil pipeline, thereby avoiding the need to transport another product to market, or higher-value fuels or chemical feedstocks such as gasoline, diesel, naphtha, methanol or di-methyl ether (DME).

Conversion of (associated) gas to a liquid significantly increases the gas' value and its ease of transport, but the conversion process is relatively complex and expensive compared to other direct gas utilization options such as CNG or mini-LNG.

Many of the conversion technologies used require no pre-processing of the gas other than to remove contaminants.

Each summary includes basic information on performance, technical requirements to implement and operate the equipment, the technology developer's business model, and existing applications currently in operation.

CompactGTL

CompactGTL's modular unit offers a small-scale gas-to-liquid (GTL) solution for small- and medium-sized oil field assets where no viable gas monetization option exists so that the associated gas is either flared or reinjected. CompactGTL's modular small-scale GTL solution can become a project enabler, allowing the oil company to proceed with development and unlock oil field value.

Contact: Alina Ussenko, Alina.Ussenko@compactgtl.com

Technology & operating conditions	CompactGTL – Size range & cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
Mini-GTL via a patented two-stage Fischer-Tropsch that provides 3 – 5 years lifetime for the catalyst	Unit sizes available from 1,500 to 15,000 barrels of synthetic crude per day; required gas supply 15 – 150 MMscf/d	Plant can be designed on a completely stand-alone basis	Company provides operator training	Company indicated suitability for offshore applications	Sale	First commercial-scale plant in Kazakhstan in progress; commercial demonstration plant fully funded by Petrobras - over 3 years of operation; pilot plant in the U.K – over 8 years of testing
Requires gas pre-treatment	Modular and containerized within a 40 feet container					
Product: Synthetic crude, which can be upgraded to diesel and naphtha streams using 3rd-party upgrading technologies	Please contact company for cost			Please contact company for certification and footprint		

GasTechno Energy & Fuels (GEF)

Gas Technologies LLC manufactures, installs and operates modular gas-to-liquids plants that utilize the patented GasTechno® single-step GTL conversion process. GasTechno® Mini-GTL® plants convert associated flare gas and stranded natural gas into high-value fuels and chemicals including methanol, ethanol and gasoline/diesel oxygenated fuel blends while serving to reduce greenhouse gas emissions. The unit capital cost of the plants is approximately 70% lower than traditional methanol production facilities and they require relatively limited operation & maintenance costs.

Contact: Walter Breidenstein, walterb@gastechno.com
Evan Visser, evan@gastechno.com

Technology & Operating conditions	GasTechno – Size range & cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
Direct partial oxidation of natural gas to produce methanol, ethanol and formaldehyde	Unit sizes available: 300 to 10,000 Mscfd; the potential exists to scale up to 30,000 Mscfd	Power and oxygen are the only inputs other than the gas supply. Power can be generated on-site from off-spec gas or purge gas from the GTL process. Oxygen generated on-site for scales exceeding 1,000 Mscfd of natural gas	Requirements for preventive and corrective maintenance teams depend on plant scale	Company indicated suitability for offshore applications based upon a DNV GL Pre-Feed Study in 2015	Design, build and operate plants, purchasing the feedstock gas from the field operator	In November 2016 the first commercial-GasTechno® Mini-GTL® plant was successfully commissioned on a natural gas field in Michigan, USA
	Modular and containerized. 300 Mscfd plant installed in a 40' ISO container					
One-step conversion. No catalyst, no syngas. Add-on technologies can be used to produce DME, gasoline, etc.	Cost for 300 Mscfd is USD1,300/tpy capacity, while at 5,000 Mscfd the cost is USD450/tpy capacity		Small-scale plants are designed to be operated remotely and may not require full time presence of operators	Process evaluated by DNV as technically viable for offshore installation. Process has compact footprint – 40 foot ISO container for 300 Mscfd	Other project structures including joint ventures with producers/operators as well as tolling agreements with producers/offtakers may be possible	

Greyrock

Greyrock Energy was founded in 2006 as Pacific Renewable Fuels by Robert Schuetle and Dr. Dennis Schuetzle. The company is headquartered in Sacramento, California, with offices and a demonstration plant in Toledo, Ohio. Its sole focus is small-scale GTL Fischer-Tropsch plants for Distributed Fuel Production®, and it has a commercial offer of both a fully integrated 2000 bpd plant consuming about 20 MMscfd and smaller "MicroGTL" plants.

Contact: Robert Schuetzle; rschuetzle@greyrock.com

Technology & operating conditions	Greyrock – Size range & cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
Gas-to-liquid (GTL) conversion. Proprietary catalyst that directly converts syngas into fuels, eliminating the 3rd GTL-FT reaction step. It's a "Direct To Diesel™" GTL technology.	Uses a modular, integrated architecture with an adaptive control system to deliver robust performance Cost ranges from USD65,000/bbl to USD100,000/bbl	Power would be required for operations. Power generation is an optional package (Greyrock systems have excess steam that can generate enough power to run the system and in some cases export power)	Typical O&M that would be associated with oil and gas equipment such as pumps, compressors, etc. Please contact company for more information	Company indicated that smaller unit can be suitable for offshore applications. Please contact company for more information		Successfully demonstrated the technology at the 30 bpd level in a plant in Toledo, Ohio in 2011-2014.

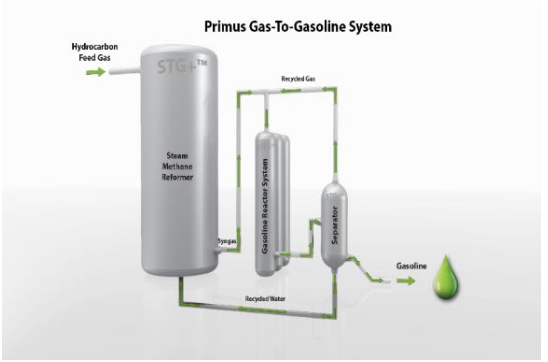
Metgas Processing Technologies S.p.A

METGAS PROCESSING TECHNOLOGIES S.p.A., a subsidiary of MAIRE TECNIMONT GROUP, in June 2016 became one of the major shareholders in Siluria Technologies. Siluria has developed industrial technologies for the production of chemicals and fuels starting from gas. The technologies are based on proprietary Oxidative Coupling of Methane ("OCM") process. The OCM technology is based on Siluria's catalyst platform. METGAS PROCESSING TECHNOLOGIES and Siluria have combined their respective technologies and expertise to commercialize the GAS TO PROPYLENE Technology to convert gas directly into one of the most important base chemical products, Propylene.

Contact: Valerio Coppini; v.coppini@met-gas.com

Metgas – Technology & Operating conditions	Size range & Cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
Small-scale GTL converting associated gas to propylene	Plant sizes from 8 MMscf/d to > 150 MMscf/d	For a stand-alone plant, some of the feed- gas is used to generate the utilities required. These are: ▪ Cooling water ▪ Instrument air ▪ Nitrogen ▪ Plant air ▪ Electricity ▪ Steam These must otherwise be supplied by a 3rd party	Opex ~ 220 USD/t of propylene for a stand-alone plant. This Includes utilities, typical operation and maintenance costs, and catalyst replacement (lifetime 2 yrs). Excludes purchase of feed-gas	Currently under evaluation	Provision of: - License - Basic engineering package - Training - Detail design Engineering review - Commissioning and performance tests assistance - Proprietary equipment. Tecnimont, sister company of METGAS, could provide EPC-LSTK services for project implementation	A 1 ton/d demonstration plant has been operating in La Porte, Texas, since 2015
Propylene shipment can be by road, tanks, rail tanks or ship without refrigeration						
Process can accept lean to very rich associated gas. Contaminants in the gas can be tolerated	For 15 MMscf/d plant the footprint is between 5 and 7 acres					
~10% of the product mass is in the form of C4/C5+ which can be transported by road/rail tanks	EPC cost for a stand-alone (i.e. self-sufficient) plant is estimated to about USD200-250 mln for 80 kt/year of polymer-grade propylene, depending on the location of the plant					
Plant turndown is 70-110%. Process can operate outside this range, but product yield and product selectivity would suffer						

Primus Green Energy



Primus Green Energy is based in Hillsborough, New Jersey, USA. The company is backed by Kenon Holdings, a NYSE-listed company with offices in the United Kingdom and Singapore that operates dynamic, primarily growth-oriented, businesses. Sam Golan is the CEO of Primus Green Energy and Dr. George Boyajian is the Chief Commercial Officer. Primus Green Energy™ has developed Gas-to-Liquids technology that produces high-value liquids such as gasoline, diluent and methanol directly from natural gas or other carbon-rich feed gas.

Contact: George Boyajian, gboyajian@primusge.com
Desirae Haluk, dhaluk@primusge.com

Technology & operating conditions	Primus – Size range & cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
Gas-to-liquid (GTL) technology Proprietary STG+™ process is a single-loop process that converts natural gas feedstock directly into gasoline or methanol	Unit sizes available: 5MMscfd feed gas = 500bbd gasoline or 160MTd methanol. 20MMscf/d feed gas = 2000bbd gasoline or 640MT/d methanol	Cooling water, process water, electricity, standard utilities	STG+™ plants have minimal labor requirements. Requires a single operator during normal plant operation, and shut down for maintenance is only 10 days per year	Company indicated suitability for offshore applications due to STG+™ systems' flexible layout options and small footprint.	Sales, licensing, tolling	Primus has announced two 160 MTD methanol projects in North America slated to come online in 2018 (West Virginia, Alberta). In October 2013, it commissioned a 7 bpd (100,000 gallons per year) demonstration gasoline plant using pipeline gas
Product: methanol and gasoline	STG+™ Systems are modular and scalable					
Can handle variable gas volume and composition; up to 10 ppm H_2S	Cost USD~50 MM for a 5MMscf/d plant. Does not include the cost of outside battery unit					

 Costs are indicative only; FOB in country of origin unless indicated otherwise
See World Bank and GGFR Disclaimer

Velocys

Velocys is a smaller-scale GTL company that provides a bridge connecting stranded and low-value feedstocks, such as associated gas and landfill gas, with markets for premium products, such as renewable diesel, jet fuel and waxes. The company was formed in 2001, a spin-out of Battelle, an independent science and technology organization. In 2008, it merged with Oxford Catalysts, a product of the University of Oxford. Velocys aims to deliver economically compelling conversion solutions. It is traded on the London Stock Exchange, with offices in Houston, Texas; Columbus, Ohio; and Oxford, UK.

Contact: Philipp Stratmann, philipp.stratmann@velocys.com
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Velocys – Technology & operating conditions	Size range & cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
Small-scale single-stage Fischer-Tropsch (FT) converting associated gas to diesel, jet fuel and naphtha**.** Combines micro channels reactors and super-active catalysts to provide high conversions to desired products	Plant sizes available 1,400 and 5,000 bpd (about 14 and 50 MMscfd of gas) using reactor sizes of 175 and 700 bpd	Power and water supply, wastewater treatment. Additional requirements, site dependent	Opex ~ 25-35 USD/bbl for a stand-alone plant in the US Gulf Coast. Includes utilities, typical operation and maintenance costs, and catalyst replacement. Excludes purchase of feed-gas	Currently under evaluation	License or sale of FT reactors and FT catalyst. Building integrated solutions in its focus markets with strategic partners including technical solution, route to financing, engineering, feedstock and offtaker	First product produced at commercial reference plant: ENVIA Energy's Oklahoma City GTL plant. 26,000 hours of testing at demonstration scale including one test at Petrobras' facility. 1.3 million hours testing of catalyst in laboratory
Conversion rate efficiency > 91%	FT island is modularized, scalable and containerized					
	EPC cost for a 5,000 bpd unit around USD500 mln, depending on the location of the plant. Smaller plants have higher CAPEX per barrel					