

GGFR Technology Overview – Utilization of Small-Scale Associated Gas



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

Contents

1	Disclaimer	4
2	Gas Processing	5
	Aspen Engineering Services: NGL Pro	6
	CleanSmart	7
	EcoVapor Recovery Systems	8
	Expansion Energy	9
	GTUIT	10
	Membrane Technology & Research Inc. (MTR, Inc.): LPG-Sep™	11
	Nacelle: Big Dog™ Flare Recovery System	12
	Pioneer Energy: Flarecatcher Titan Gas Processing & Fractionation Plants	13
	Unicorn Power Ltd. and Green Recycling Technologies	14
3	Power Generation	15
	Aggreko	16
	APR Energy: TM2500+™ Mobile Gas Turbine	17
	Capstone Turbine Corporation: C30, C65, C200, C600S, C800S and C1000S	18
	GE: Waukesha and Jenbacher	19
	LPP Combustion, LLC	20
	MESA Natural Gas Solutions LLC	21
	Moser Energy Systems	22
	OPRA Turbines: OP16 Gas Turbine	23
	Turboden – Mitsubishi Heavy Industries Group	24
	Unicorn Power Ltd. and Green Recycling Technologies	25
	Wärtsilä SG, LG and GD Flexible power plants	26

4	CNG – Compressed Natural Gas.....	27
	GE.....	28
5	Mini-LNG – Liquefied Natural Gas	29
	Beerensgroup DMCC.....	30
	Chart Industries.....	31
	Expansion Energy	32
	Galileo	33
	GE.....	34
6	Mini-GTL – Gas to Liquids.....	35
	CompactGTL.....	36
	Emerging Fuels Technology: EFT.....	37
	GasTechno Energy & Fuels (GEF)	38
	Greyrock.....	39
	Bluescape Clean Fuels (formerly Primus Green Energy).....	40
7	Innovative applications.....	41
	Crusoe Energy Systems, Inc	42
8	Multi-phase pumps.....	43
	ITT Bornemann GmbH	44

1 Disclaimer

The information contained in this website is for general information purposes only. The company and technology overviews included on this site were provided to the World Bank because of the companies' interest in the Global Gas Flaring Reduction Partnership's (GGFR) mission to advocate gas-flaring reduction and because of GGFR's interest in making information about technologies readily available to flare-out project developers. The World Bank and GGFR do not control the information provided by the companies. You acknowledge and agree that neither the World Bank nor GGFR is responsible or liable for: (i) the availability or accuracy of the company and technology information on this website or any linked sites or resources; or (ii) the content, advertising, or products on or available from linked websites or resources. The inclusion of information on this website does not imply that either the World Bank or GGFR endorses the information, technologies or companies on this website or linked sites.

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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

Company Overview

Aspen Engineering Services offers cost-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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www.aspensco.co



Technology & Operating conditions	Size range & Cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
<p>Gas treatment and NGL extraction</p> <p>Please contact company for BTU variability and simulation report</p> <p>H2S tolerance for the unit is up to 3%</p> <p>Raw gas minimum inlet pressure is 20 - 75 psig</p> <p>Separation efficiency is 80%</p> <p>Handles variable flow by stabilizing compression system using recycle stream</p>	<p>Company indicated size variability with standard unit size of 3 MMSCFD</p> <p>Scalable & Modular - 3 MMSCFD on an 8' x 25' skid</p> <p>Contact company for pricing.</p>	<p>Power from grid, on-site micro-grid, or gas fired generators</p> <p>Independent compressor skid required</p>	<p>Company indicated very low maintenance requirement</p>	<p>Company indicated suitability for offshore applications</p> <p>Footprint is 8' x 25' for 3 MMSCFD</p>	<p>Sale, lease or license</p>	<p>Nine commercial units in operation.</p>

CleanSmart

Company Overview

CleanSmart offers upstream E&P operators who are flaring gas multiple recovery opportunities to commercialize small-to-mid-scale volumes of “flared” gas into predictable streams of revenue that would otherwise be lost.

CleanSmart does this by packaging industrial scale membrane processes into a small-foot print skid-mounted chassis that operates as a micro-gas plant and/or a micro-fuel station. The mobile membrane gas recovery units (MGRUs) operate autonomously, use no moving parts and no chemicals, nor are subject to commonly encountered hydrate formation issues.

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Technology & Operating conditions	Size range & Cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
Membrane diffusion gas recovery technology for LPG and liquid recovery	400 Mscf/d to 8.5 MMscf/d. Expansion possible ~ 70 MMscf/d feedgas.	Pressurized storage tanks for storing LPGs, C3 and C3+	No moving parts, no chemicals. Each membrane element monitored by onboard sensors	Suitable for offshore operation	Revenue sharing, leasing or Rental	Wyoming, Encana, Ft. Berthold, ND: W.Africa
Modular; plug and play	Please contact company for cost					
Processing Gas Pressure C3, C3+ 225 psi. Recovery 95%	400 Mscf/d footprint 10'x10'x8'					
Processing Gas Pressure C2 800 psi	8.5 MMscf/d footprint 10' x 20' x 8'		Membrane useful life minimum 3 yr			
Can handle any turndown in feedgas volume						
No limit on H2S/CO2 content in feedgas						



EcoVapor Recovery Systems

EcoVapor's ZerO₂ technology works in conjunction with compression and vapor recovery systems to enable up to 100% gas capture on site. By removing the free oxygen from the gas stream, ZerO₂ enables flash gas from oil storage tanks to be sold instead of flared or combusted.



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Technology & Operating conditions	Size range & Cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date											
Oxygen removal units that remove 99.9% of oxygen from gas streams (e.g. oil storage tank vapors), enabling gas to be sold.	100, 300, and 1200 Mscf/d Scalable by installing multiple units in parallel. No technical maximum size	480V 3-phase power supply. Usage 45 kWh for start-up, 12 kWh during operation	Monthly oxygen sensor calibration (can be carried out by oilfield operator) Annual catalyst replacement (approx \$2,750 \$4,500 and \$13,000 for the 100, 300, and 1200 sizes respectively)	Yes	Sale or lease	85 units in operation in the USA since 2010											
Inlet pressure range: 50 - 330 psi	100 Mscf/d : 4ft x 4ft 300 Mscf/d : 4ft x 4ft 1200 Mscf/d : 6ft x 6ft																
Can handle rapid variations in gas flows, and water and CO ₂ in gas stream. Removal of H ₂ S is required	<table border="1"> <thead> <tr> <th>Size (Mscf/d)</th> <th>FOB purchase US\$</th> <th>Monthly lease US\$</th> </tr> </thead> <tbody> <tr> <td>100</td> <td>75,000</td> <td>3,500</td> </tr> <tr> <td>300</td> <td>98,000</td> <td>5,000</td> </tr> <tr> <td>1200</td> <td>265,000</td> <td>12,000</td> </tr> </tbody> </table>	Size (Mscf/d)	FOB purchase US\$	Monthly lease US\$	100	75,000	3,500	300	98,000	5,000	1200	265,000	12,000				
Size (Mscf/d)	FOB purchase US\$	Monthly lease US\$															
100	75,000	3,500															
300	98,000	5,000															
1200	265,000	12,000															

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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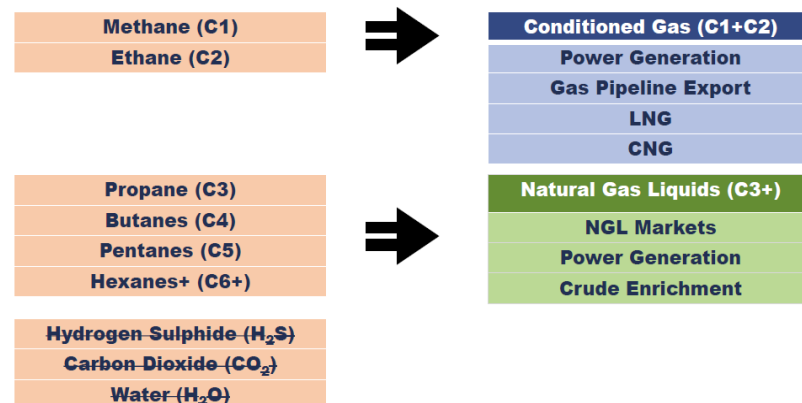
Technology & operating conditions	Size range & cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
<p>Gas processing using mechanical refrigeration to separate NGLs at -150° F and 400 psia</p> <p>Pre-treatment skid removes H₂S</p>	<p>Unit size range available: 0.5 MMCSFD to 9 MMCSFD of feed gas.</p>	<p>If VX Cycle LNG plant installed, power needed is produced on site by the VX Cycle, using feedstock gas.</p> <p>Otherwise power required from other source</p>	<p>Company indicated low maintenance requirements.</p> <p>Please contact company for more information</p>	<p>Small footprint allows for offshore deployment.</p> <p>Please contact company for more information</p>	<p>Sell, lease or license</p>	<p>10 VX Cycle LNG plants have been built and deployed over the past several years</p>
<p>Minimum gas inlet pressure is 50 psia</p> <p>All pre-processing, such as water and CO₂ removal, are included in the VX Cycle.</p> <p>Please contact company for component separation efficiency</p>						
<p>Handles rapidly varying gas flows</p>	<p>Please contact company for cost.</p>					



GAS TREATMENT USING INTELLIGENT TECHNOLOGY

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.

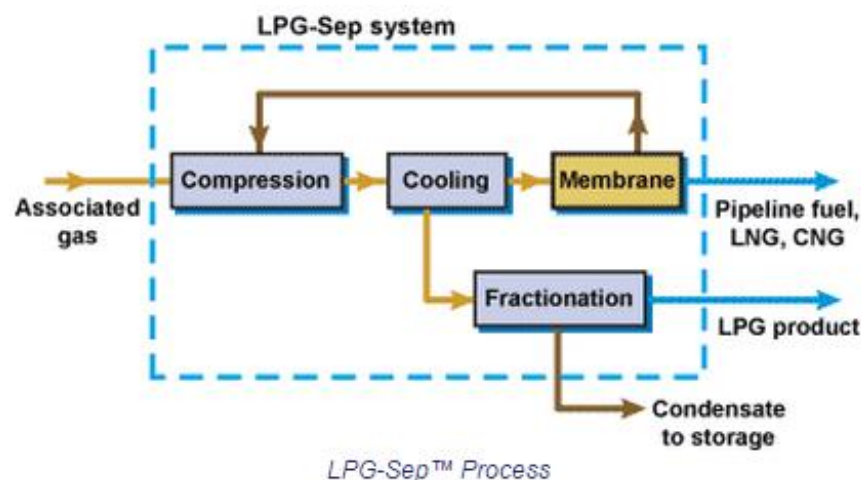
Contact: Martin Oakley, moakley@gtuit.com
 Brian Cebull, bcebull@gtuit.com



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 High BTU gas processing units for NGL recovery and fuel conditioning	Unit sizes available: 250, 500, 1000, 3000, 5000 MCSFD Scalable & modular - +20,000 MCFSD per site.	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	Suitable for offshore applications	Sale, train, and support	68 MMCFSD of processing capacity in North America
H ₂ S treatment for concentrations as high as 20,000 PPM Raw gas minimum inlet pressure ≈ 1 psig	Mobile - 48 hour deployment time for trailer mounted, 5 days for skid mounted	NGL/produced liquids storage	Comprehensive service training and documentation provided by GTUIT	Please contact company for certification	Trouble shooting, parts, and remote/onsite technical support available	90 million gallons of NGL's produced and sold
Recovers up to 75% of the propane and heavier components Proprietary flow control equipment	Cost USD 1000-2000 per MCFD configuration dependent	Water is removed from typical raw gas streams – requires disposal on-site		Please contact company for footprint		Over 800,000 operational hours

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.



Contact: Kaaeid Lokhandwala, kaaeid.lokhandwala@mtrinc.com

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.	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	Higher flowrates can also be designed if required					
H ₂ S pretreatment required upstream to produce sulfur-free LPG and condensate	Scalable & modular. Containerized and truck mounted up to 5 MMSCFD	NGL/produced liquids storage	Membranes need to be replaced every 3-5 years	MTR can build to required offshore/FPSO specifications		
Feed gas pressure as low as 1 psig				Compact footprints possible with hybrid approach		
Recovers up to 90% of C3+ hydrocarbons	Cost USD7-8 million for 5-7 MMSCFD, USD10-15 million for 10-15 MMSCFD					
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.

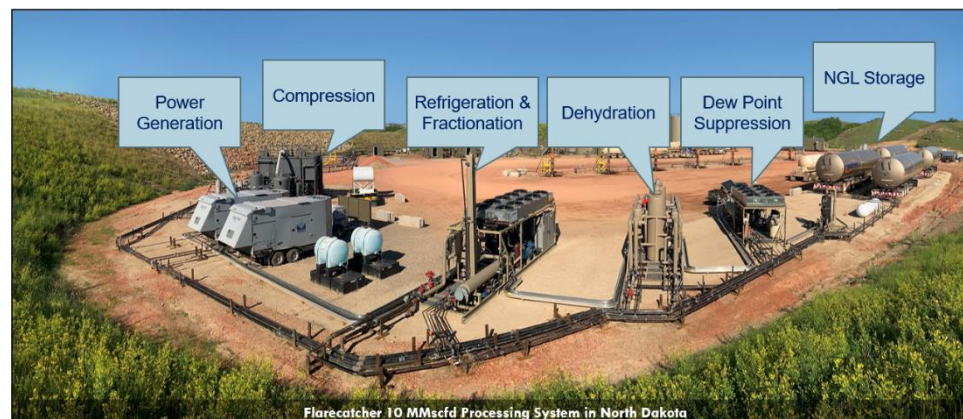


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Technology & operating conditions	Size range & cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
<p>Gas processing. NGL extraction based on membrane separation</p> <p>Handles variable gas composition (wide range of BTU variability handling)</p> <p>Please contact Nacelle for H₂S treatment requirement</p> <p>Feed gas pressure varies between 50 and 1200 psi</p> <p>Please contact company for component separation and efficiency</p> <p>System is able to handle fluctuating gas flows</p>	<p>Unit sizes available: 200 MCFD to 20 MMCFD</p> <p>The systems are truck mounted, and scalable. The standard size is two 48' flat deck trailers</p> <p>Cost dependent on type of service agreement and scope of work</p>	<p>NGL/produced liquids storage.</p> <p>Depending on equipment utilized for application, additional operational requirements may apply. Please contact Nacelle for specifics related to client's situation</p>	<p>Dependent upon region of operation, Nacelle offers turn-key O&M.</p> <p>Skilled operators required. Regular scheduled preventative maintenance. On-stream factor above 92%</p>	<p>Equipment is suitable for offshore service</p>	<p>Business model varies by region. Please contact Nacelle for specifics related to client's situation</p>	<p>Nacelle has worked for various operators in the United States. Commercial units are in operation since March 2016.</p>

Pioneer Energy: Flarecatcher Titan Gas Processing & Fractionation Plants

Pioneer Energy’s Flarecatchers are modular, skid-mounted mechanical refrigeration-based plants (MRUs) that are used to monetize stranded and flared gas streams, including associated gas, non-associated gas, and oil tank vapors. The units produce spec products like LPG, condensate, light naphtha, and lean conditioned gas and are highly automated, which decreases field installation and recurring labor costs and enables extremely high uptime. The company is based in Lakewood, CO, USA.

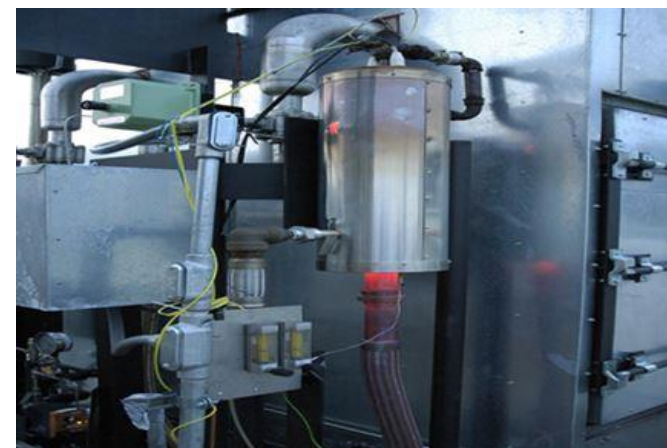


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Technology & operating conditions	Size range & cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
Flarecatcher – Gas processing plant using mechanical refrigeration to chill to as cold as -65 °C	Unit sizes available: 1,000 – 30,000 MSCFD	External electrical input – can be generated by natural gas generator run off residue gas or dry gas from the Flarecatcher	Basic mechanic or technician level staff is required for operations and maintenance. Units are autonomous and remotely monitored, decreasing field labor requirements.	System can be barge, boat, or platform mounted to service off-shore applications. Systems can be containerized to protect against harsh environments.	Direct sale internationally. Partner with EPC to provide complete turnkey installation, commissioning, and training of ops team.	Pioneer Energy has completed more than 20 installations 45,000 sq ft manufacturing facility enables construction of large orders
Optional fractionation modules to separate produced NGLs into LPG and condensate. Propane, butane, and naphtha optional outputs	Units have infinite turndown and can be easily paralleled to accommodate any size plant					
Integrate with 3 rd party equipment for H ₂ S removal	Units are skid-mounted and designed for rapid deployment and redeployment	NGL/produced liquid can be stored in propane tanks, typically bullet tanks rated at 250 psi	Turnkey service may be available though local representative		Value added services: FEED studies, custom engineering, remote monitoring and operation	
Gas accepted at any pressure; Processing pressures between 150 and 450 psig depending on application						
High separation efficiency. High lean gas fuel quality	Cost varies since every project is different. Interested parties should contact Pioneer					
Remotely monitored and operated via cellular or satellite network						

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.



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

Technology & operating conditions	Size range & cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
<p>Cold-plasma gas scrubber conversion of associated gas into syngas, which can be used for power generation or fuel production</p> <p>Please contact company for tolerance to BTU variability</p>	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.	Offshore suitable depending on power/gas receiver availability	Sale	New technology. Pending installations at several international and domestic gas well sites
<p>H₂S tolerance up to 200 ppm</p> <p>Minimum gas intake pressure 0.4 psi</p> <p>Handles flow variability (<50% change in 15 minutes)</p>						
	Scalable & modular – multiple of 200 and 500 kW units		Please contact company for O&M	Please contact company for certification		
	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 the world's leading supplier of mobile, modular power generation, temperature control, energy storage and hybrid projects incl. renewables. Aggreko supports a diverse range of customers including supplying large-scale, supplementary generation capacity to state utilities, powering off-grid mines, oil & gas facilities, and a wide array of heavy industries.

Aggreko have developed a fully integrated, mobile generation system running on APG or any alternative gas, to exploit gas reserves of any size where the construction of permanent infrastructure is economically unattractive, in particular due to volume changes in time. Much needed electricity is produced through previously wasted fuel and customers avoid excess carbon and air pollutant emissions as well as possible financial penalties imposed on flaring.

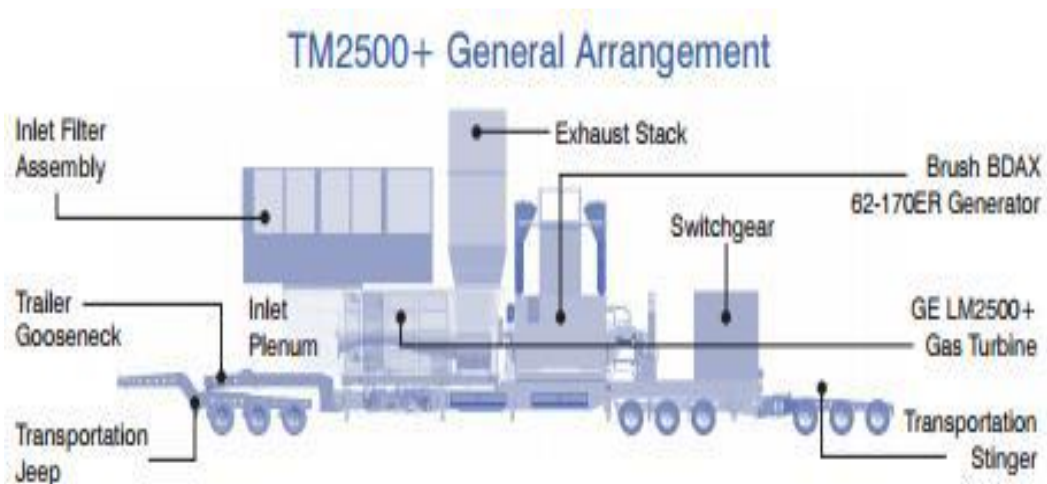
Contact: AggrekoFlareToPower@aggreko.com



Technology & Operating conditions	Size range & Cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
<p>Power generation using gas reciprocating engines. Co-generation can be added.</p> <p>Gas volume requirements 9.5 Mcf (270 m³)/ MW.</p>	<p>Aggreko operates a fleet of generators ranging from 36kW to 10MW.</p>	<p>Each project has bespoke requirements, which are managed and built into the project design. Aggreko provides the design, engineering, commissioning of the projects and can operate them upon need.</p>	<p>Aggreko manages all O&M activities, as part of its fully integrated, end-to-end turnkey solution. All maintenance & refurb are performed by Aggreko.</p>	<p>Extensive power generation experience in offshore environments. Aggreko's APG references are mostly on-shore, with the first reference for off-shore in the North Sea.</p>	<p>Simple rental available. Turnkey service provision model with all project elements managed by Aggreko. Minimizes capital outlay and offers complete flexibility & scalability. Contact Aggreko for BOT opportunities.</p>	<p>Flare gas-to-power sites have been successfully operating since 2008. Aggreko currently generates ~500 MW at sites in Africa, the Americas, Asia and Europe. The company's APG portfolio continues to grow thanks to a combination of positive economic and environmental impact.</p>
<p>Handles standard inlet gas pressure ranges 5-6 bar; and up to 190 bar with gas pressure reduction and scrubbing equipment. Technology covers a range of gas specs.</p>	<p>Scalable, modular. Truck mounted optional. Typical 1 MW gensets are containerized in 20 ft containers.</p>					
<p>H₂S content up to 10 ppm and more under certain conditions. Multi-fueling available (gas and propane).</p>	<p>Pricing is dependent on each specific project. Contact Aggreko for details.</p>					

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.



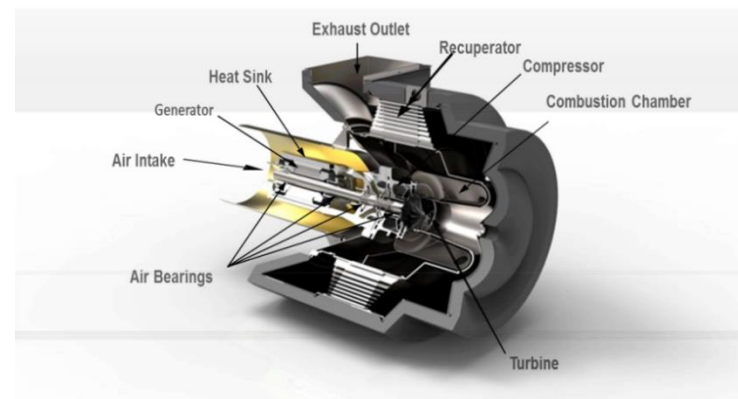
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Technology & operating conditions	Size range & cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
Turnkey power generation solutions using gas turbines	TM2500+ ISO rating is 26-30MW (will increase to 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					

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.

Contact: Dorian Alloatti: dalloatti@CGRNenergy.com



Technology & operating conditions	Size range & cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
<p>Micro-turbine power generation</p> <p>Gas volume requirement: 10 Mcf/day for 30 kW; 20 Mcf/day for 65 kW; 54 Mcf/day for 200 kW</p> <p>Gas inlet pressure is 55-60 psig for C3 model, 75-80 psig for C65 to C1000 models</p> <p>Handles variable gas composition (up to 70% CO₂, 22% N₂, 30,000 ppm H₂S) and flow</p> <p>Pre-processing is not expected to be required</p> <p>Multi-fueling is possible using diesel, propane and kerosene</p>	<p>Unit sizes available: 30, 65, 200, 600, 800, 1000 kW</p> <p>Units are scalable and modular. Can be put in parallel. All models can be skid or trailer mounted, or containerized</p> <p>Cost USD1,000 - 1,700/kW depending on model, configuration and options</p>	<p>Beside gas flare, air and fuel free of liquids and filtered for particulates are required for off-grid application.</p>	<p>Includes the first 8,000 hours and then the 40,000 hours overhauls. Air and fuel filters change (site dependent).</p> <p>No lubricants of refrigerant required</p>	<p>Available configuration suitable for offshore.</p> <p>Compliant for explosive environments (ATEX Directive 94/9/EC)</p>	<p>Sale through international distributors’ network. Lease and financing options also available</p>	<p>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 % H₂S</p>

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.

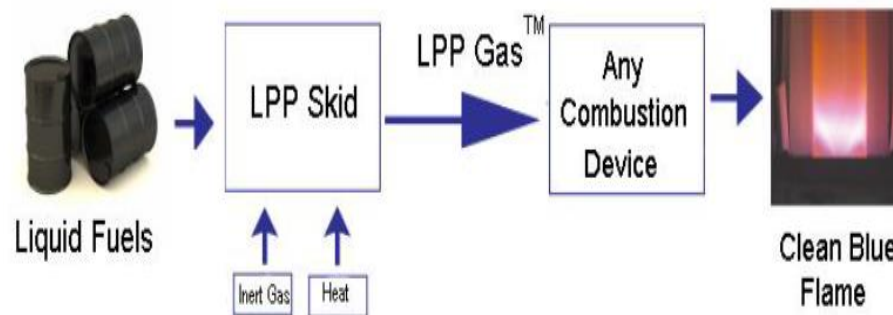


Contact: Larissa Shaaked, larissa.shaaked@ge.com

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

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.



Contact: Leo Eskin, eskin@lppcombustion.com
 Chris Broemmelsiek, broemmelsiekc@lppcombustion.com
 Arthur Schatz, schatza@lppcombustion.com

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	-	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	Genset can be supplied upon request					
Compresses the fuel to turbine inlet pressure	Skids are inherently modular in design, and containerized and truck mounted up to 30 MW		Annual maintenance outage of few days is anticipated	Please contact company for certification		
Handles variable gas composition and flow						
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						

MESA Natural Gas Solutions LLC

Company Overview

Mesa is a leading power solutions company specializing in the manufacturing, sales, leasing and operations of natural gas and liquid propane-powered mobile and stationary generator sets. Mesa’s best-in-class power solutions enable customers to reduce their energy costs and capital expenditures as well as increase reliability and operational up-time, all while lowering emissions and decreasing carbon footprint.

Contact: Zachary Soukup zach.soukup@mesangs.com
 Trey Lawson trey.lawson@mesangs.com



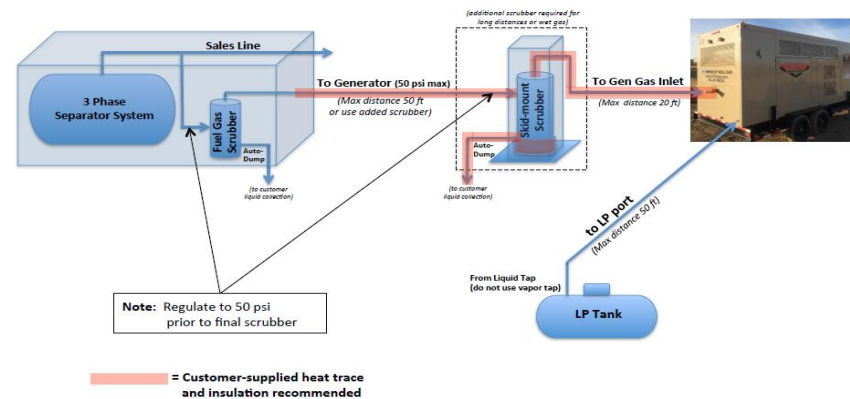
Technology & Operating conditions	Size range & Cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
Power generation	Relocatable units: 70 – 350 kW, 480V	None	Minor quarterly/semi-annual maintenance. Operation and maintenance can be carried out by trained oil company personnel. MESA offers a 4-week training program	Not currently suitable for offshore operation	Sale, lease or joint venture	450 MW powergen fleet More than 20 million runtime hours using associated gas and/or non-commercial gaseous fuels 32 MW of commercial & industrial microgrids installed since 2018
Gas inlet pressure : 6 – 90 psi.	Stationary standby units: 300 – 400 kW 480V Standard prime units: 70 kW – 350 kW 480V					
Handles variable gas composition and flow with automatic air/fuel management	Units come in an enclosed, weatherized trailer or skid. Up to 32 sets can be run in parallel					
No processing needed for < 100 ppm H2S	Power conversion efficiency: 0.25 mcf/day per kW of average load					
Automatic fuel switching to secondary source. Acceptable fuels: AG, propane, CNG, LPG (800 – 2500+ BTU/scf	Please contact company for cost data					

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.

Contact: Mark Bohon, mark@moseres.com
 Pascal Boudreau, pascal@moseres.com

NG Generator Site Prep Recommendations

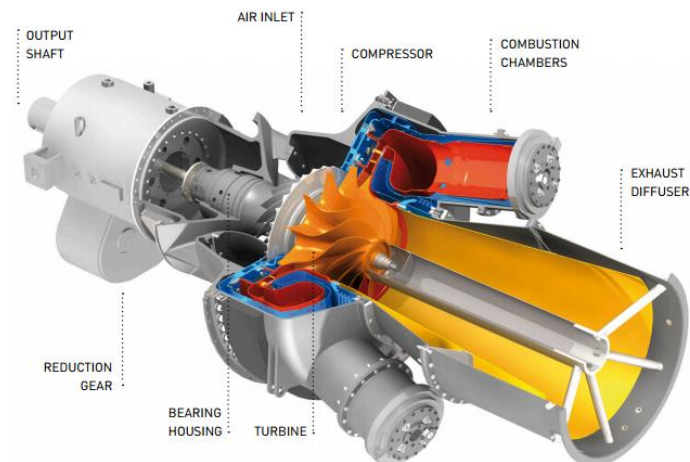


Technology & operating conditions	Size range & cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
Power generation using natural gas generator	Unit size available: 70, 125, 170, 225, 350, 1000 kW	Minimize liquids in wellhead gas	Monthly oil changes, quarterly 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.	Insulating above ground gas lines, if operations are in cold climates				
Variable inlet gas flows and heat content (800-1800 Btu)	Paralleling capable up to 32 units					
Minimal to no gas processing (up to 200 ppm H ₂ S). 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.

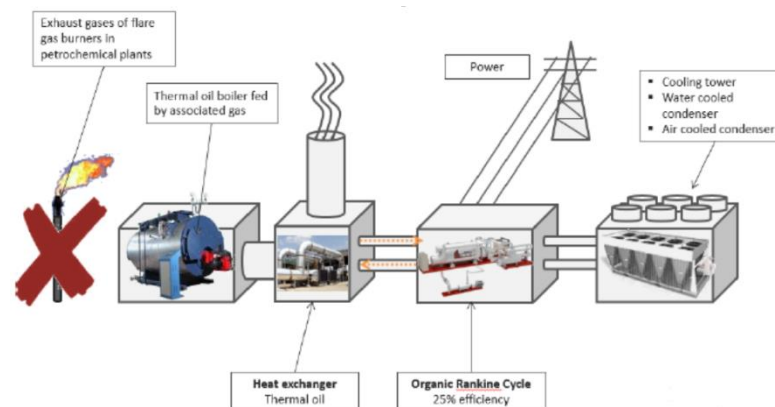
Contact: Anshuman Pandey , apa@opra.nl ; +31 6 211 540 93
sales@opra.nl



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, BOO, 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		Virtually zero lube oil consumption	20-ft container footprint		Over 1 million operating hours using associated gas
Handles variable gas composition and low heating values						
Pre-processing of gas not required (H ₂ S 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: Marco Baresi, Marco.Baresi@turboden.it

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

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 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 Miskowicz, sm1.grt@gmail.com

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%.				Please contact company for certification		
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)					
For gas composition variation, please contact company.						
Gas pre-processing not required for H ₂ S 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 SG, LG and GD Flexible 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. GD, SG and LG power plants were developed to provide a broad range of solutions suitable for demanding applications in the oil and gas industry and fluctuating fuel supply both in term of composition or flowrate.

Contact: Thomas Bourliere, Thomas.bourliere@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	Wartsila engines are suitable for offshore	Equipment Supply or EPC	More than 16,000 professionals in 70 countries. A combined 60 GW delivered worldwide (including all types of power plants)
GD multifuel power plants designed to run on associated gas or crude oil. SG power plants can accommodate up to 60% CO ₂ +N ₂ in Feed gas						
Plant output: 10 – 400 MW. Efficiency: 45%	Units are modular and scalable.			Please contact company for certification	O&M: Continuous support for improving and optimizing operational efficiency through installation lifecycle available	Power plants running on Associated gas / Flare gas for the past 15 years
Tolerant against fuel quality variation. Pretreatment of gas not anticipated. For H ₂ S limit, please contact company	Please contact company for standard modular size					
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 CO₂ and H₂S. To meet gas specification, removal of N₂ 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: www.bhge.com/supplier-center

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 20x for custom CNG packages	Power generation requirements (400 kW for a 400 hp CNG In A Box system) supplied by company.	Requires operator with reciprocating equipment experience.	Storage requirements depend on desired fueling speed.	Not currently certified for offshore.	Sale	Over 70 CNG In A Box systems in operation
Suction pressures \geq 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	Requires dispensers to load the CNG into vehicles (if required)	Please contact company for O&M requirements	Please contact company for more information	Please contact company for more information		
Feedgas must be treated to remove H ₂ S. 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						

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 CO₂, H₂S and mercury. To meet gas specification, removal of N₂ 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.

Beerensgroup DMCC

Company Overview

Beerensgroup offers small scale LNG liquefaction plants in a range of sizes. We also offer LNG ISOTANKS, each holding 950 MMbtu of gas that can be used for both storage and transport.

Contact Thomas Miller, email@beerensgas.com
 UAE: +971 56 797 4500 EU +47 92 329 329
 www.beerensgas.com; www.beerenstank.com



Technology & Operating conditions	Size range & cost	Additional operational requirements	O & M	Offshore suitability	Business model	Experience to date
<p>Small Scale liquefaction plants, transport and storage of LNG. Satellite stations, storage tanks, vaporizers, cryogenic pumps, fuelling stations, dispensers and modular liquefaction plants.</p> <p>LNG ISOTANKS holding 18 ton from 8 – 10 bars. Holding time up to 110 days with no boil off.</p>	<p>Liquefaction plants from 15 tonnes/d (780 MMbtu) to 230 tonnes/d (11,960 MMbtu)</p> <p>Plants are modular and scalable.</p>	<p>Onsite storage required. Beerensgroup offers LNG storage units from 40 m3 to 4000 m3 capacities.</p>	<p>Beerensgroup are Building and operating Small Scale LNG plants. If client prefer to operate Beerensgroup will do the training with the customers operators. (15 tons/d) require minimal training; larger plants require more intensive training.</p>	<p>Small-scale LNG plants (scalable 15 tons/d units) have a small footprint and are suitable for offshore operations.</p>	<p>Liquefaction plants are offered on either an EPC or BOT basis ISOTANKS are leased out for a minimum period of 3 years.</p> <p>Beerensgroup offers a full door to door supply chain delivering LNG in ISOTANKS</p>	<p>First company in the world shipping LNG to China in Isotanks from 2 European terminals.</p> <p>1 of 2 companies distributing LNG in road tankers/isotanks in India for state oil and gas companies.</p>
<p>Liquefaction plants can handle rapid variations in gas flowrate and composition.</p>	<p>For transport of LNG, 40 ft T-75 ISOTANKS.</p> <p>Each tank holds 950 MMbtu or 18 ton at 8 bars for up to 110 days with no boil off.</p>	<p>The liquefaction plants require power from: 500 kW for 15 tons/d up to 4MW for 230 tons/d.</p>	<p>Training is provided by Beerensgroup.</p> <p>Maintenance programs are provided by Beerensgroup</p>			<p>Our isotanks are in use in UK, Netherlands, Belgium, India and China.</p>
<p>Liquefaction plants are custom built, and the design addresses any plant inlet pressure and gas feedstock composition.</p> <p>Boil off gas treatment plants</p>		<p>Beerengroup build and operate LNG fuelled (500 kW to 2 MW) generators.</p>			<p>Our Concept? A containerized 0.5-2 MW power plant based on LNG or Liquid H2 to supply electricity.</p>	<p>Liquefaction plants in Operations in a number of countries including Indonesia, China and India</p>

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: Ty Webb, ty.webb@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.		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	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	Please contact company for more information		
Chart can design and provide gas pre-processing solutions as required for cryogenic liquefaction							
Can handle changing gas flows. Capable of turndown to 50% of design capacity							

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 MMSCFD (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 ₂ S							
Handles rapidly varying gas flows	Please contact company for cost						

Galileo

Company Overview

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 -225 °F. This multi-stage compression 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



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)	Unit size is 0.7 MMscfd which produces 5000 tpa of LNG. Full boil-off recovery system.	437 kW power supply (Galileo also provide Gas driven Units when power supply is not available), compressed air and internet connection	Provides full training for customer technicians and 24x7 technical support.	Vertical / Horizontal storage tanks 300 m3 capacity	Technology is suitable for offshore applications, configured as a Cryobarge.	Sale, leasing or liquefaction services - customer provides the gas, 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 160 psi.	Scalable & modular. Each unit fits in the size of a 40 feet seacontainer, which facilitates its delivery on a single trailer. Start up in 5 mins, full production in 10 mins. Easily relocatable.		Preventive maintenance (1hr duration) recommended each 2,000 operating hours	40' Isocontainers for distribution (17 metric tonnes of LNG each) and Vertical / Horizontal storage tanks 300 m3 capacity	Please contact company for more information.	International opportunities sought	40 systems installed
Treatment system (ZPTS) can be provided to clean non-desirable components such as N2, H2O, Mercaptans, Mercury etc, and reducing the CO2 to the required <50 ppm			Units can be remotely operated				
Can adapt to changing gas composition by modifying treatment.			Liquefaction plant (including treatment) FOB cost 600 US\$/tpa.				

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						

6 Mini-GTL – Gas to Liquids

Advances in modular GTL technologies have recently enabled small-scale GTL plants (~>10MMscfd of gas), highly flexible mini-GTL units (~>1MMscfd of gas) and even remotely controlled micro-GTL “machines” (~<1MMscfd of gas), to be operationally and economically feasible. Commercial offers are available from a number of technology providers and the first few plants are being built. For the latest update, please see the latest Mini-GTL Bulletin Volume 5, issued in July of 2018.

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 chemical conversion process is obviously more expensive compared to other direct gas utilization options such as CNG or mini-LNG. However, it is the TOTAL cost from flare gas intake through processing and distribution to final use that determines the overall financial return.

Most of the conversion technologies require no pre-processing of the gas other than to remove contaminants. In many cases, separation of higher hydrocarbons (LPG and condensate) creates valuable income streams in addition to the GTL product revenue.

The individual company overviews include 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 was an early leader in the development of small scale GTL technologies. In collaboration with Petrobras, their modular innovative GLT-FT technology was demonstrated in a large pilot plant in Brazil. They then focused on building their first commercial plant in Kazakhstan using 25MMscfd of associated gas to make clean diesel and other products. Global political and economic developments stopped the commercial process. Today, 2 projects are in the feasibility and pre-FEED stage.

Contact: Elchin Salmanov elchin.salmanov@compactgtl.com
 +44 0 203 971 2330



Technology & operating conditions	CompactGTL – Size range & cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
Small scale GTL via a patented two-stage Fischer-Tropsch process Product: Synthetic crude or diesel Compact GTL is also working on Waste to Liquid projects	Unit sizes available from 1,000 to 15,000 barrels of synthetic crude/diesel per day; required gas supply 10 – 150 MMscf/d	Plant can be designed on a completely stand-alone basis	Company provides operator training	Company indicated suitability for offshore applications	License, design as well as build/own/operate for smaller capacities	Integrated gas feed to liquid products Commercial Demonstration Plant operated successfully for 3 years with Petrobras in Brazil. Technology approved for use within Petrobras. Over 8 years of testing in multiple rigs in CGTL pilot plant in Wilton, UK
	FT reactors modularized with module dimensions of a 40 feet container					
	Please contact company for costs					

Emerging Fuels Technology: EFT

EFT emerged from Syntroleum, a leading GTL company in the nineties. Ken and Mark Agee are leading EFT. They have developed a modular Flare Buster™ GTL-FT platform together with Black & Veatch. Recently they have announced the FLARE BUSTER 25, which is a nominal 25 bpd mobile, remotely controlled and self-sufficient micro-GTL plant that produces syncrude. 50 and 250 bpd versions are being developed.

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



EFT Technology & operating conditions	Size range & cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
Advanced GTL-FT catalyst and reactor. Catalyst has high activity and long life.	MiniGTL: 500bpd (and up) 5MMscfd gas, Fob cost <\$50 mln	Can be self-supporting!	Highly automated operation;	Currently under evaluation	Licensing Build and sale	Decades of experience of world scale GTL plants.
Modules for gas treatment for high feedstock flexibility; Modules for syncrude upgrading to diesel, jet fuel, etc	MicroGTL: 25bpd (and up) M 25 (see Picture) Delivery: 26 weeks, FOB cost <US\$ 4mln M50 (50 bpd) and M250 (250 bpd) are being developed	Power and water supply, wastewater treatment. Additional requirements, site dependent	Low maintenance cost			Large laboratory for R&D and training; License of GTL technology to Juniper GTL, and Fulcrum and Red Rock Biofuels.

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® Micro-GTL® plants convert associated flare gas and stranded natural gas into high-value fuels and chemicals (predominantly methanol, ethanol) The unit capital cost of the plants is approximately 70% lower than traditional methanol production facilities and they require relatively limited operation & maintenance costs. However, long term performance of this breakthrough technology is not yet known.



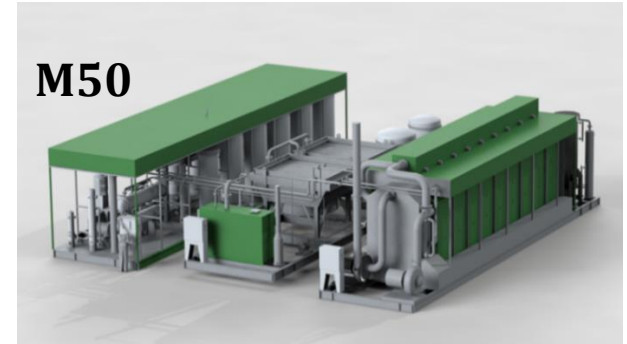
Contact: Walter Breidenstein, walterb@gastechno.com

Technology & Operating conditions	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.	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.	Power can be generated on-site from off-spec gas or purge gas from the GTL process.				
One-step conversion. No catalyst, no syngas. Add-on technologies can be used to produce DME, gasoline, etc.produce DME, gasoline, etc.	300 Mscfd plant installed in a 40' ISO container Cost for 300 Mscfd is USD1,300/tpy capacity. Cost for 5,000 Mscfd is USD450/tpy capacity	Oxygen generated on-site for scales exceeding 1,000 Mscfd of natural gas	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/off-takers may be possible	The same 300 Mscfd unit was run on Bakken flare gas in 2018

Greyrock

Greyrock Energy was founded in 2006 as Pacific Renewable Fuels by Robert Schuetzle 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 commercial offers of P class plants (>500bpd) and M class “Micro-GTL” units (>5bpd).

Contact: Robert Schuetzle; rschuetzle@greyrock.com



Technology & operating conditions	Size range & cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
<p>Gas-to-liquid Fischer Tropsch conversion.</p> <p>Proprietary catalyst that directly converts syngas into diesel.</p>	<p>Uses a modular, integrated architecture with an adaptive control system to deliver robust performance;</p> <p>P Class plants M Class units for flare gas (remote controlled); M 50: uses 500Mscfd</p>	<p>Power would be required for operations.</p> <p>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)</p>	<p>Typical O&M that would be associated with oil and gas equipment such as pumps, compressors, etc.</p> <p>Please contact company for more information</p>	<p>Company indicated that smaller unit can be suitable for offshore applications.</p> <p>Please contact company for more information</p>	<p>Licensing. Greyrock’s JV partners (Advantage Midstream in North America, AngloAmerican in Africa, and Perseus in Mexico) will build/own/operate plants</p>	<p>Successfully demonstrated the technology at the 30 bpd level in a plant in Toledo, Ohio in 2011-2014.</p> <p>A Greyrock M-50 is part of a plant under construction by Advantage Midstream in Colorado.</p> <p>A project using a Greyrock M-500, modified by Expander Energy Inc, is under construction in Alberta, Canada</p>
	<p>Cost ranges from US\$ 65,000/bbl to US\$ 100,000/bbl</p>					

Bluescape Clean Fuels (formerly Primus Green Energy)

Bluescape Clean Fuels, headquartered in Houston, TX, has developed its multi-patented GTL technology called STG+™ (syngas-to-gasoline+) which economically produces high value liquids such as gasoline, methanol, and syncrude directly from renewable syngas or natural gas. BCF's flagship office and state-of-the-art demonstration facility in Hillsborough, NJ serve as the hub of its operations and technical development programs.

BCF has increased its project development efforts in the renewables space, working with various waste gasification technologies to produce a 'zero fossil fuel' gasoline that requires no further refining. Beyond renewables, BCF continues to work around the globe with governments and private companies alike on flare reduction and stranded natural gas monetization opportunities.

Contact: info@bluescapecleanfuels.com



Technology & Operating conditions	Size range & Cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
<p>Small scale GTL via multi-patented technology. (NOT a Fischer-Tropsch process)</p> <p>Products: gasoline, methanol, or syncrude</p> <p>With gasified biofeedstocks, all products are renewable</p>	<p>All units are modular design and scalable</p> <p>Size range from 100 bbl/day – 5000 bbl/day</p> <p>Competitive capital cost. Please contact BCF for details.</p>	<p>STG+™ can fully integrate with most gasification technologies</p> <p>Requires standard utilities; option to locate at operating facilities or remote locations.</p>	<p>STG+™ plants have minimal labor requirements.</p> <p>Requires a single operator during normal plant operation.</p> <p>Shut down for maintenance is only 10 days per year.</p>	<p>Feasibility studies indicate suitability for offshore application due to STG+™ flexible layout options and small footprint.</p> <p>Please contact BCF for additional details.</p>	<p>Flexible structures, from system supply to build/ own/ operate</p>	<p>Operating demonstration plant (7 bpd gasoline or 14 bpd methanol) with > 11,000 hrs successful operation</p> <p>FEED programs completed for methanol and gasoline commercial facilities</p>

7 Innovative applications

Applications where combinations of technologies are used to offer innovative ways in which associated gas can be used.

Crusoe Energy Systems, Inc

Company Overview

Crusoe Energy Systems, Inc. is on a mission to eliminate the routine flaring of natural gas by providing oil and gas companies with a fast, low cost and simple solution to stranded gas. Our Digital Flare Mitigation® (DFM) systems convert otherwise wasted natural gas into electricity to power energy-intensive computing right at the well site. We are passionate about creating solutions that benefit the environment, local communities and energy producers. Based in Denver, Colorado, Crusoe was founded in 2018 and has deployed over 40 DFM data centers across some of North America's most prolific oil and gas basins including the Bakken, the Powder River, and the Denver-Julesburg. In 2021, Crusoe closed \$128 million in Series B equity financing from leading technology and climate-focused investors. Crusoe plans to expand its operational footprint with projects in the Permian Basin in 2021.

Contacts: Anna Pierini apierini@crusoeenergy.com



Technology & Operating conditions	Size range & Cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
<p>Digital Flare Mitigation®: On-site electricity generation using gas reciprocating engines and turbines to power modular and mobile advanced computing systems.</p> <p>9.9 mcf/MWh at 1000 BTU/scf Gas inlet pressure: 30-150 psi</p>	<p>Highly scalable, modular solution: 1.7MW to 40+MW:</p> <p>The smallest single module consists of one 2 MW generator capable of consuming up to 300 mcf/d of rich (~1,500 BTU) gas and two 40'x9' modular data centers. Scalable up to 40+MW with turbine generators.</p> <p>Modules are skidmounted.</p>	<p>Flexible BTU range from 900-2500 btu/scf.</p> <p>No processing required besides basic separation of liquids using the operator's existing on-site separator</p> <p>Max allowable H2S >20pp without treatment</p>	<p>Crusoe operates the equipment.</p> <p>O&M carried out by Crusoe's in-house mechanics, electricians and technicians as well as authorized service providers</p>	<p>Suitable for offshore deployment</p>	<p>Crusoe provides a total solution to flare gas mitigation and capture at little to no cost to producers. Crusoe provides, installs, and operates all equipment for Digital Flare Mitigation. In many cases, Crusoe is able to purchase the gas from the producer.</p>	<p>Crusoe has been in business since 2018. In that time, Crusoe has deployed 40+ Digital Flare Mitigation® systems throughout the United States and mitigated over 1 billion cubic feet of flare gas. Crusoe's clients have included a range of public and private operators, ranging from small, private-equity backed producers to large International Oil Companies.</p>
<p>If gas flow rates are unstable, Crusoe can install a CNG vessel to act as a "gas battery" to smooth flow rates.</p>	<p>Offered as a service at little to no cost to the producer</p>					

8 Multi-phase pumps

Multi-phase pumps offer a potentially attractive way to combine oil, gas and water production from multiple (small) production sites so that the fluids can be processed centrally, thereby benefitting from economies of scale.

ITT Bornemann GmbH

Company Overview

ITT Bornemann GmbH, established in 1853 in Germany, offers Multiphase Boosting Systems which are used to eliminate flaring and field separation. Bornemann pumps simply boost the whole untreated flow coming from the wells to a Central Processing Facility which can be 100 km away from the production site(s). In this way the environmental impact is reduced to a minimum, no flaring and no need for smaller facilities close to the oil wells. With only one pipeline the untreated flow is transported to be processed in a larger central unit. In this way all the gas can be more efficiently separated on a bigger scale and can, for example, be used to run a turbine and produce electricity or the gas can be used for domestic use and make use of the value of the gas.

Contact : René van Schöll, rene.vanschoell@itt.com



Capacity: 40,302 BPD (267 m³/h)
GVF: 50 to 99 %

Technology & Operating conditions	Size range & Cost	Additional operational requirements	O&M	Offshore suitability	Business model	Experience to date
The Bornemann pump can transport the untreated- flow coming from the wells, including crude/water/gas to a CPF tens of kms from the wells. No need for oil/water/gas separation, compression or flaring at the wellsite. The gas is simply moved forward with the crude/water to the CPF where it can be used to generate electricity or sell for domestic use.	The systems are flexible. The flow can go from 20 m ³ /hr up to 5500 m ³ /hr. The total investment can vary from 100k USD up to 20 mIn USD, depending on the capacity.	The pumps are situated very close to the wells. Power is needed to operate the pumps, this can be 50kW up to 4 MW. In some cases Bornemann can supply a gas-turbine to generate electricity from the gas coming from the wells. The rest of the gas will be transported, together with the water/crude to the CPF. Only one pipeline is needed to to send the untreated flow to the CPF. No need for 3 (water, gas & crude) pipelines	Low Capex - The pumps can operate as stand-alone, with no need for on-site personnel. The systems are very robust and do not need lot of attention. Up time >99%	Bornemann pumps can be used on an offshore platform and boost the whole flow to a Central Processing Platform or to an onshore location for further treatment/separation of the gas.	Bornemann will supply turn-key systems, with more than 650 systems globally we have the invaluable experience to meet the end-user specifications and requirements.	Since the 1990's Bornemann has installed over 650 systems worldwide, onshore & offshore