Introduction of the ZR-iLNG process

An increasing interest in commercial small-scale gas liquefaction facilities has resulted in the development of many different process schemes. Downscaling of proven but complex technologies, like amine gas treating and C3-MR liquefaction, although efficiently applied at large scale, is generally considered not cost-effective at small and medium scale.

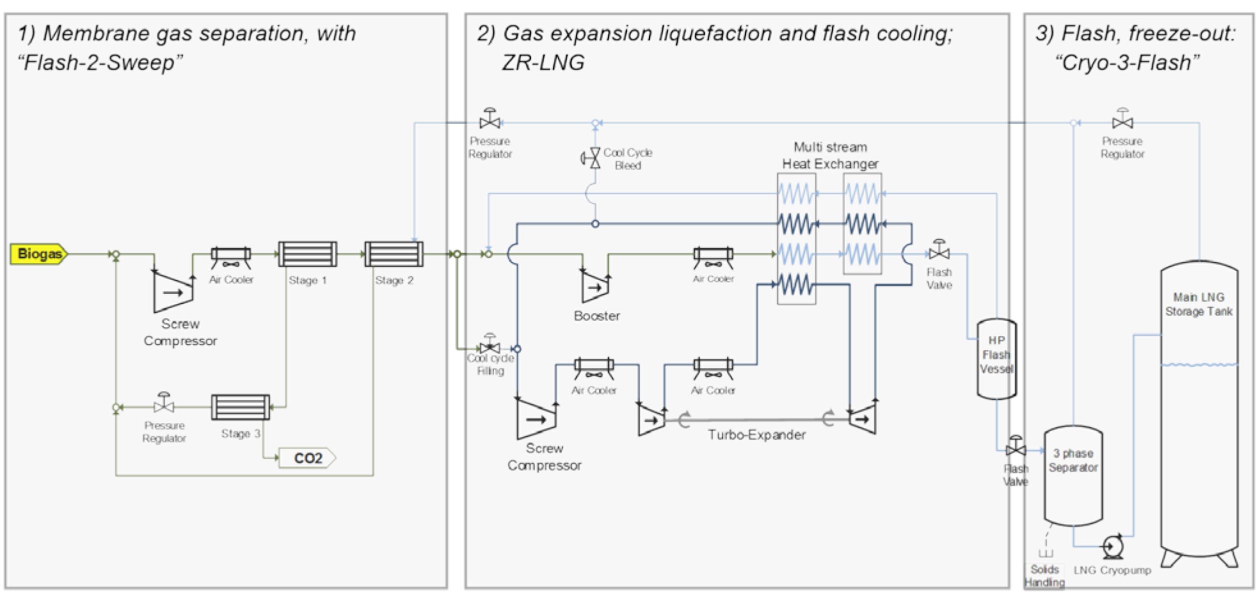
During the last 5 years, Gasconsult and Osomo have independently developed proprietary LNG process schemes with the primary objective to reduce Capex by minimizing equipment count. Besides, the standard design has to be capable to process a wide feedgas composition range and has to be relatively simple to operate and maintain.

Osomo has designed, built and operated a pilot unit, converting raw biogas to Bio LNG. The pilot unit is based on improved membrane gas separation, combined with contaminant freeze-out in a 3-phase end-flash separator, patented as iLNG technology.

Gasconsult have developed a gas-expansion, Zero Refrigerant liquefaction scheme, patented as ZR-LNG technology. The concept shows a liquefaction efficiency approaching base-load Mixed Refrigerant and cascade processes.

In October 2016, both companies identified several synergies between the 2 concepts and decided to develop jointly the ZR – iLNG process for Bio LNG and small-scale LNG with capacities up to 70,000 tonnes/y. This proved to be possible with only minor modifications of the independent process schemes. It confirmed that the technologies are complementary, with limited overlap.

Figure below shows the integrated Hysys / Unisim flow scheme of a 5 tpd Bio LNG demo project, based on ZR – iLNG. All process equipment is shown, as currently being designed in detail. The operational feedback of the Osomo 0.25 tpd pilot unit proves to be valuable. Scale-up with a factor of 20 is considered to be realistic and involves limited technical as well as commercial risks.



Figuur 1; ZR-iLNG process scheme for biogas applications

Fundamental differences between ZR-iLNG and traditional gas treating & liquefaction.

	ZR – iLNG Membrane gas separation, Gas expansion with "LNG flash" contaminant freeze-out	**Traditional** Amine and molsieve gas treating, Heavy hydrocarbons removal SMR or N2 expansion cycle with LNG subcooling
Gas treating	One unit; combined CO_2 & water removal	Several gas treatment units in series
	Simple, continuous process	Batch-wise, regenerative processes
	No chemicals, nor heat	Chemicals with heat demand
	Dry gas systems	Wet vapor and liquid streams; risk of corrosion
	Relaxed gas spec, acceptable for liquefaction	Tight gas specification; "over-treating"
Liquefaction	No refrigerant production nor import	Refrigerant; fractionation, storage and make-up
	No liquids in exchangers (dense phase)	Liquids; maldistribution, thermal stress, fatigue
	Relatively high HX temperature: -100°C	Low HX outlet temperature -150°C; risk of freeze-out
Heavy HC's	C5+ removal post-liquefaction in 3-phase sep.	High co-absorption of C2-C5 in separator or scrubber
	No issues with lean pipeline gas	Difficult to meet C5+ specification in separator
	C2-C5 fraction completely soluble in LNG	C2-C5 partly extracted; fractionation and reinjection
BOG	No BOG compressor; but recycle compressor	Dedicated BOG compressor
Utilities	No heat demand	High and low temperature heat requirement
	No aqueous waste streams	Waste water streams
HSE	No heaters	Fired heaters, furnaces, reboilers,heat transfer fluids
	Low hydrocarbon inventory	More HC's in equipment; liquids / refrigerants

The ZR liquefaction and iLNG technology have in common that both are based on evaporative / 'end-flash' cooling. In other words; cooling to a low temperature is achieved by pressure reduction and consequently part of the liquid evaporates. The advantage is that there is no heat exchange colder than -100°C and therefore a much higher concentration of contaminants can be allowed without the risk of freeze-out in the exchanger. Traces of contaminants will eventually freeze-out in a controlled way, during flash cooling in the 3-phase separator.

Traditional liquefaction technologies condense the gas, followed by significant sub-cooling of the liquid to low temperatures (-150°C). The purpose is to suppress the flash flowrate at the pressure reduction to storage conditions. However, the lower temperature requires a significantly lower concentration of contaminants and therefore more intense gas treating, which requires more process equipment and utilities.

ZR-iLNG process recycles the significant flow of flash gas without a dedicated end-flash or BOG compressor. This function is taken by the recycle gas compressor, which also provides the compression in the gas expansion cooling scheme. Besides, the clean and dry flash gas is used to improve the performance of standard membrane gas separation by sweeping the low pressure side of the membrane, the so-called 'flash-to-sweep' concept.

Comparison of Biogas-to-LBM treating & liquefaction technologies

Table below lists several pros and cons of 4 integrated Biogas-to-LBM schemes. More permutations of gas treating and liquefaction technologies are possible. However, the 'most logical fit' between treating & liquefaction technology has been selected.

Gas treating technology	1 Membranes	2 Water scrubber	3 Amine scrubber	4 Cryo – Freeze-out
CO_2 removal	3-stage membrane separation, improved by 'flash-2-sweep'	Biogas water scrubber with 1-2 mol% CO_2 water saturated gas at outlet	Amine unit - acid gas removal	3 temperature steps of impurity freeze-out
Polishing	Post-liquefaction	TPSA - Molsieve dehydration & CO_2 removal	TSA – molsieve dehydration	Required for LNG at < 5 bar
Treated gas spec. CO_2	0.1 mol% (1000 ppm)	< 0.04 mol% (400 ppm)	< 0.04 mol% (400 ppm)	> 2 mol% (without polishing)
H_2O	< 1 ppm	< 1 ppm	< 1 ppm	< 1 ppm
Aromatics	< 100 ppm	< 10 ppm	< 10 ppm	<10 ppm
Liquefaction technology	Gas expansion (Zero Refrigerant)	N2 single expander	Single Mixed Refrigerant (SMR)	Cascade refrigerant system
	End flash cooling	Sub-cooling	Sub-cooling	Sub-cooling
Heat exchanger temperature	-100 °C	-150 °C	-150 °C	-150 °C
Continuous or Batch process	+ Continuous	- Batch TPSA, high regen flow	- Batch TSA	- Batch; parallel exchangers
Utilities; Heat demand	+ No heat	- High heat demand	- - Very high heat demand	+ No heat
Waste water streams	+ No	- Yes	- Yes	+ No
Methane content in CO_2 vent to atmosphere	+ < 0.6%	- 0.5 – 1.5%	+ < 0.5%	+ 0%
Tolerance to high H_2S in feed	- - No	+ Yes	+ Yes	- No
Refrigerant handling, need for storage, make-up and bleed	+ No	- Yes	- Yes	- Yes
Complexity High equipment count	+ No	- Yes	- Yes	- Yes
Process performance – efficiency	+ Avg	- Low	+ High	- Low

Conclusion

More demanding gas specifications require more complex gas treating units, with more equipment, chemicals, waste streams and high heat demand. Option 1, the ZR-iLNG process is an exception because of a much higher temperature in the cryogenic heat exchanger, which is made possible by the gas expansion and end-flash process. Therefore, the liquefaction process becomes significantly more tolerant towards higher concentration of (trace-) impurities, like CO_2, water and aromatics. And this allows the unique application of simple, scalable and improved membrane gas separation in the LNG scheme.

The gas expansion process is the logical match with the 'freeze-out' process as well as the 'flash-to-sweep' concept to improve the separation performance of standard biogas membranes.

The result is an integrated gas treating & liquefaction scheme with minimum equipment count and based on a continuous process. Because of the excellent scalability it's a one-scheme-fits-all solution.

Way forward

Gasconsult and Osomo believe that a 5 tpd Bio LNG demo unit will 'provide proof of concept'. The process flow diagram is shown in figure 1. An operational commercial-demo project, based on the integrated ZR-iLNG technologies, will demonstrate the considerable advantages in real life.

The same principles apply to a small to midscale LNG unit supplied with pipeline gas, although some modifications of the scheme are required. Renewable biogas and Bio LNG will significantly increase the exposure of a demo unit. A demo unit will emphasize that promising applications can be realised in the field of small scale, local production of LNG as a renewable transport fuel in the future.

References

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