# CO2 industry standards and project economics in the biogas industry


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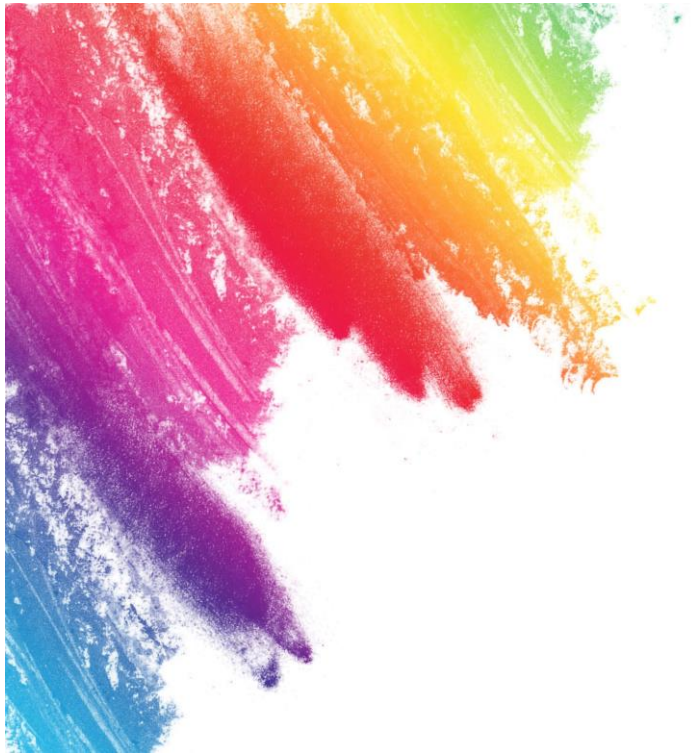


# CO2 quality standards established by trade organizations, along with input from manufacturers and major gas companies. Various grades apply to different markets served.

- - Of the approximate 49 CO2 sources from fermentation, 23 from ammonia, 19 from natural geological formations, 20 from reformers in oil refineries, numerous miscellaneous sources; practically all of these sources produce a beverage grade product.
- - The merchant industry typically sells beverage grade to all sectors, as beverage, food, and industrial, which is an overkill for industrial service; however, this has been a standard practice always.
- - Beverage grade among other grades such as food grade and industrial, would be defined by the Compressed Gas Association, and the ISBT (International Society of Beverage Technologists). Such definitions include limitations for a number of chemical compounds and elements, such as oxygen, nitrogen, carbonyl sulfide, and hydrocarbons.
- - Beverage manufacturers do not accept CO2 supplies from most biogas sources yet, particularly if the feedstocks include fecal matter.
- - Many other markets are good targets in the food and industrial sectors, with a viable refined biogas – sourced CO2 product.
- - Today, more CO2 from the ethanol sector is going to sequestration pipelines; there will be less available from this sector, and more opportunities from untapped sources, which logically include biogas.

# The merchant CO2 industry today – Minimal competition, few suppliers, followed by many price increases, leading to new significant opportunities for new sources and source types.

- - The merchant CO2 firms such as Linde do not source from biogas sources at present. These gas companies have tight controls over sources, and the majors in the industry have consolidated very significantly.
- - Most biogas CO2 sources are more likely to consider supply directly to the processor/manufacturer; with the greatest profit opportunities.
- - As more of the CO2 from ethanol plants is sequestered, which represent nearly 50% of all merchant CO2 supply feedstock, the opportunities for other CO2 sources will become more evident.
- - There should be a significant need for additional CO2 sources in the time ahead.

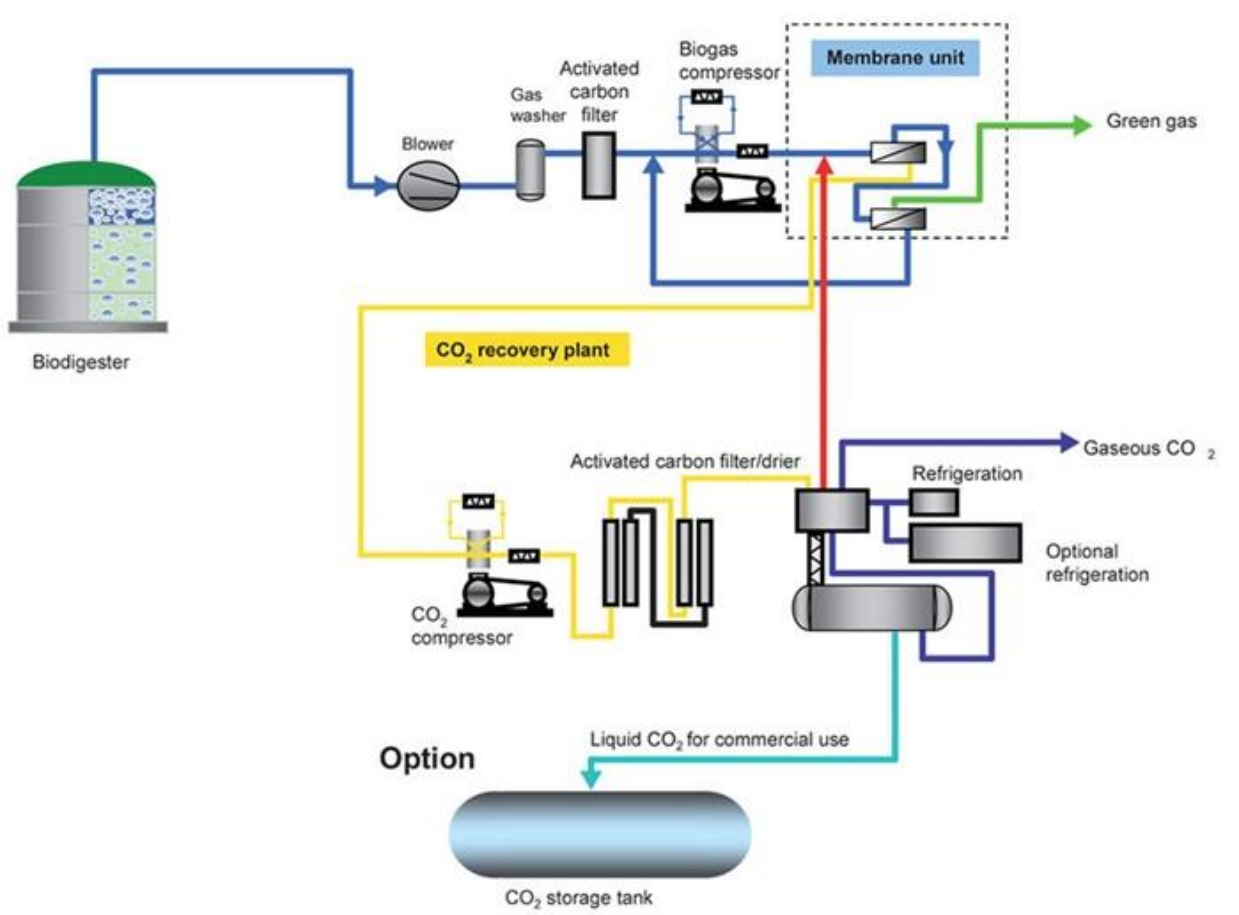
# Beverage specification – CGA & ISBT

| | | |
|---|---|---|
| • $CO_2$ Purity | 99.9% | (all ppm v, unless otherwise stated) |
| • $H_2O$ | 20 ppm | |
| • Non-Volatile Residues | 10 ppm (w) | |
| • Non-volatile organic residue | 5 ppm | |
| • Total hydrocarbons (as $CH_4$) | 50 w/ 20 max of non-$CH_4$ HCs | |
| • Methanol | 10 | |
| • $O_2$ | 30 | |
| • CO | 10 | |
| • NO Nitric Oxide | 2.5 | |
| • $NO_2$ Nitrogen Dioxide | 2.5 | |
| • $Ph_3$ Phosphine | 0.3 | |

- Further limitations on carbonyl sulfide, and hydrogen sulfide

CO2 recovery from biogas streams can involve membrane systems; along with compression, refrigeration, purification and sulfur removal. The most profitable means toward monetizing the stream is marketing directly to the processor/manufacturer. On the other hand, there can be sequestration opportunities, which could be an option. All of this is a function of the size of the CO2 stream, chemical composition, and location. Further should the CO2 be dedicated to the CO2 pipeline system, there is a CO2 specification defined by Kinder Morgan which calls for maximum temps, 95% minimum CO2, and limitations on H2O, H2S, O2, N2, Sulfur, Glycol.

# DIAGRAM BELOW – SIMPLE CO2 REFINING SYSTEM



# Plant estimated costs & requirements, cost per ton, laid in cost estimate

- -The CO2 plants are built to fit specific project requirements, as a feedstock type, and CO2 digester gas characteristics.
- - The example below would be a recent evaluation covering an 80 TPD plant from a chemical process, with one plant vendor providing a budgetary estimate.
- Capital Cost $3million 15-year amortization, 6%, interest
- Delivery, installation $1.2million
- Total estimate $4.2 million
- Power @ $0.068/Kwh, Labor $3/ton, cooling water/chemicals $2/ton
- Grand Total production cost $32.01, FOB spigot
- -Second example is from another plant vendor, $6.27 million, plus LoCat sulfur removal, plus utilities, labor, the estimated cost of production is $53.10
- Estimate cost of freight per ton is around $32.00; plus, either end of the spectrum from two suppliers, therefore:
- First option estimated laid in cost: $64/ton
- Second option estimated laid in cost: $85/ton

# Possible margins available for direct supply using the prior example

- -For each CO2 plant, the cost will likely vary depending upon variance in feedstock, raw gas quality, size, and plant supplier.
- -With the prior estimated laid in cost from two suppliers of CO2 from the source which used as an example, with costs of about $64 and $85/ton laid in; and selling prices ranging from $70 to $300/ton, the margins vary greatly.
- - As to sequestration value, this is another avenue toward monetizing CO2.
- -Large food processors which are often a reliable target have the lower selling prices often between $70-100/ton; and the smaller customers of food and industrial service can be prices in the $100s-$300/ton range, depending upon market
- -Bottom line, the biogas project developer should understand markets, costs requirements, and other factors to yield the best possible margin for their projects.