Catch and Release – A Texas Case Study

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CO_2 is vented from LNG industrial hubs and because there is no incentive to monetize and store it, the resultant greenhouse gases are shared with the rest of the world. This is known in oil and gas circles as “catch and release”. Many first-generation CO_2 capture and separation technologies have been deployed commercially for decades. These are limited to applications that either have a direct use for captured CO_2, such as beverages, Enhanced Oil Recovery (EOR), or pharmaceuticals, or applications in which product standards require separation of CO_2 from the product. Because of the large footprint, high capital costs, environmental logistics associated with solvent disposal and several other challenges, CO_2 capture technologies have primarily been focused onshore. This is unlikely to change.

CO_2 is separated from natural gas, which typically contains 90% methane and hydrocarbons like ethane and propane, plus smaller amounts of nitrogen, oxygen, CO_2, sulfur compounds, and water, where the exact composition will depend on the individual site. CO_2 can be captured post-combustion from gas turbine and steam cycle emissions. Economics, space and weight constraints, and viability of other abatement strategies, such as fuel-switching or electrification, make post-combustion capture an option for new LNG clusters.

On and offshore wellhead associated gas fed into an LNG cluster will improve project economics and the environment for everyone alive on the planet. The business case for a centralized capture facility that collects, not only stripped out CO_2 from LNG natural gas processing, but associated gas from regional wellheads and gathering stations, will attract advanced country loans and grants in addition to private investment.

CO_2 can be produced from many operations in the LNG chain. Some of these are listed below:

- natural gas transportation;
- liquefaction, storage and loading of LNG;
- LNG transportation; and
- regasification.

Typical concentrations of these are reported below from two different points in the LNG operations, from scrubbers (also known as Acid Gas Removal Unit, AGRU) and from combustion.

For transport (ship, pipeline, railways, or trucks) in CCUS value chain, the CO_2 would need to be compressed to about 86-155 bar and around 13-43ºC and the associated impurities above should be lowered to conform with the recommended component concentrations seen in Table 2.

To do this, the LNG facility would have to be equipped with a carbon capture facility to treat with the additional combustion stream illustrated in Table 1.

Emissions from oilfields and offshore platforms can be collected locally, transported, and processed for sequester at the nearest centralized LNG CCUS facility. Such a system would circumvent space constraints and benefit from economies of scale for carbon capture from oilfields and LNG export gas processing. This concept and more robust low emission solutions have been proven to work in front-end engineering studies and can be further explored for large-scale feasibility, grant funding and investment secured by this author for CCUS.

Carbon capture essentially produces a concentrated stream of CO_2 at high pressure and can be readily transported for appropriate use and/or to storage sites. Although theoretically the entire combination gas streams can be transported using various transportation modes, the cost associated with doing so is impractical. Extracting the CO_2 in a more concentrated form and elevating it to the required high pressure is therefore an important component of the Carbon Capture, Utilization and Storage value chain.

During LNG processing, a relatively pure stream of CO_2 is produced in the process via scrubbing. This stream typically consists of over 98% CO_2 with mostly water vapor as the other impurity. However, further purification of these streams is needed. This often requires the subsequent removal via water vapor, of oxygen followed by pressurization. With respect to CCUS, this can be referred to as the cleaning and conditioning phase. A typical CO_2 cleaning and conditioning facility as simulated on Aspen HYSYS[1] can be seen in the Figure 1 below (comprising mainly of separators, compressors, and coolers). This system was simulated to ensure that the exiting stream from this facility would conform to the purity levels, pressures and temperatures needed for pipeline transport.

Table 1. Typical Components and Concentrations from Different CO_2 streams in LNG

Component (mol %)	Post-capture (Scrubbers)	Post-combustion from power generation
CO_2	98	3.45
H_2O	0.43	14.8
O_2	0.43	81.75
N_2O	0.43	-
CH_4	0.43	-
N_2	0.14	-
H_2	0.14	-

Table 2. Recommendations for Component Concentrations in CCUS Chain

Component	Overall Recommended Range for Requirements Level (vol% or ppmv)	Reason
CO_2	> 95%	Transport: To enable mixture to dissolve with oil Sequestration (SQ): Increase minimum miscibility pressure (MMP)
H_2O	< 50 ppmv	Transport: Corrosion and hydrate formation
H_2S	< 50 ppmv	Transport: Hydrate formation and toxicity
O_2	< 10 ppmv	Transport: Corrosion and two-phase flow SQ: Reacts with oil
N_2	< 4%	Transport: Increases MMP SQ: Increases MMP
H_2	< 4%	Transport: Two-phase flow SQ: Increase MMP
Ar	< 4%	Transport: Two-phase flow and volume efficiency SQ: Increases MMP
CO	< 2000 ppmv	Transport: Health and safety consideration (H&S)
NO_x	< 100 ppmv	Transport: H&S
SO_x	< 50 ppmv	Transport: H&S
Hydrocarbons (HCs)	< 2%	Transport: Hydrate formation and MMP SQ: Increase MMP

Figure 2. Estimating a Pipeline Diameter Based on Flow Rates

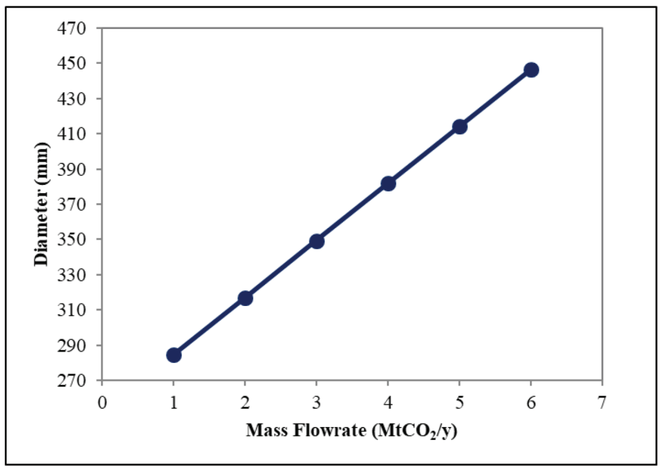

Figure 1. An Example of a Simple Process Overview of Cleaning and Conditioning of LNG CO_2 Stream for CCUS

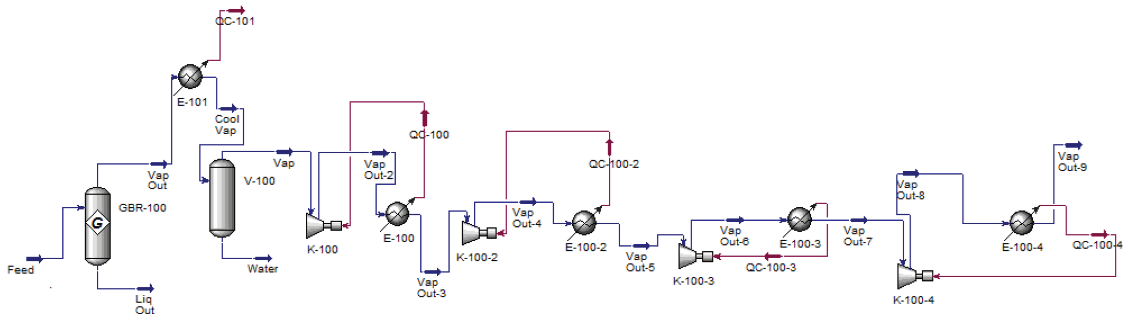

Table 3. Recommendations for Component Concentrations in CCUS Chain

CAPEX Component	Capacity/year	CAPEX (million USD)
CO_2 Cleaning and Conditioning Plant	4 million metric tonnes	2400
Pipeline Cost	4 million metric tonnes	960

Typically, the major emissions emanate from the gas turbines that drive the refrigerant cycle compressors and power generation service. About 10% of all incoming natural gas is used for these turbines, with the remaining 90% being liquefied. CO_2 emissions for LNG plants are typically 0.2 – 0.28 t of CO_2/t of LNG for industrial heavy-duty gas turbines (anticipated in the cases above).

In addition to the turbine related emissions, reservoir gas fed to liquefaction terminals typically contains around 2 mol% of CO_2 resulting in combined emissions in the approximate range of 0.3 – 0.4 t of CO_2/t of LNG for typical plants with relatively low CO_2 content in feed gas (<2 mol%). However, this can trend upwards to approximately 0.7 t of CO_2/t of LNG for plants with a high CO_2 content (14 mol%, representative) in feed gas. As no specific data on feed gas quality is yet known for these cases, we can assume a conservative 0.33 t CO_2/t LNG, and reasonably expect CO_2 available resource volumes of around 4 million metric tonnes per annum.

Though specific data for this case was not yet known, the above plant was configured in the simulation to accept typical feed compositions and conditions from the scrubbing phase in LNG processing.

Due to the nature of the LNG industry, in order to minimize disruptions to the LNG production, only established technologies should be considered for CO_2 capture in LNG plants. Of all these, post-combustion capture is considered to provide best case performance in comparison to other methods (i.e., oxyfuel and pre-combustion), with reduced technical risk and process complexity. This makes post-combustion capture appropriate for new LNG plants or as a retrofit to existing plants.

If we use reputable estimates in the literature for LNG capture plants with process CO_2 (acid gas removal unit) and post-combustion and scale up accordingly for the volumes LNG production volumes expected in this port, a CAPEX of USD2400 million and an OPEX of USD1770 million can be reflective (over a 25-year lifetime). This refers to the capture cost only and results in a specific capture cost of USD41.7/ton.

It should be noted that the OPEX can be reduced to around USD1400 million if the propane and butane streams from the process are used to generate lower cost electricity (at approximately 50% the conventional rates).

As no data on pipeline distance and right of way from a source to sink are not available for this theoretical exercise, a very high-level rough pipeline transport distance of 1.000 miles can be estimated (a sensitivity can be done around this). Based on the CO_2 resource size estimation and this distance, the pipeline cost can be roughly estimated using the series of figures below.

Based on the information outlined in the preceding section, the following design standards and associated CAPEX were estimated using the following parameters below:

- CO_2 resource – 4 million metric tons per annum
- Pipeline Diameter – 15 inches (based on CO_2 resource above and per Figure 2)
- Pipeline Length – 1,000 miles (based on estimated source-sink distance)

Accordingly, the associated CAPEX can be found in the table 3. It should be noted that the CAPEX for the cleaning and conditioning plant was estimated using the preliminary design and the Aspen HYSYS cost estimator.

Stabilizing atmospheric temperature below a 2°C increase will require halving global greenhouse gas (GHG) emissions by 2050, achieving net-zero emissions by 2055-2080, and pursuing net-negative emissions thereafter. Most credible scenarios to achieve this rate of decarbonization require widespread deployment of CCUS.

So, in the best interests of the planet and in consideration of environmental justice, catch and release must go. The best way to get rid of this arcane practice is to develop centralized carbon dioxide farms. The farms can be developed before the LNG trains are operational. Allowing for certainty of a fossil fuel path toward net zero and carbon leakage verification. It will also increase the marketability of LNG to those countries that are really concerned about climate change.

[1] Aspen HYSYS is the energy industry's leading process simulation software for process optimization in design and operations.