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Carbon Emission Reduction via HNGLRP CC&S Technology

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Abstract

The paper objective is to present the successful achievement by Saudi Aramco gas operations to reduce the carbon emission at Hawyiah NGL Recovery Plant (HNGLRP) after successful operation & maintainability of the newly state of the art Carbon Capture & Sequestration (CC&S) technology. This is in line with the Kingdom of Saudi Arabia (KSA) 2030 vision to increase the resources sustainability for future growth and part of Saudi Aramco circular economy in action examples.

Saudi Aramco CC&S started in June 2015 at HNGLRP with main objective to capture the carbon dioxide (CO_2) from Acid Gas Removal Units (AGRUs) and then inject an annual mass of nearly 750 Kton of carbon dioxide into oil wells for sequestration and enhanced oil recovery maintainability. This is to replace the typical acid gas incineration process after AGRUs operation to reduce carbon footprint. CC&S consists of the followings: integrally geared multistage compressor, standalone dehydration system using Tri-Ethylene Glycol (TEG), CO_2 vapor recovery unit (VRU), Granulated Activated Carbon (GAC) to treat water generated from compression and dehydration systems for reuse purpose, and special dense phase pump that transfers the dehydrated CO_2 at supercritical phase through 85 km pipeline to replace the typical sea water injection methodology in enhancing oil recovery. CC&S has several new technologies and experiences represented by the compressor capacity, supercritical phase fluid pumping, using mechanical ejector application to maximize carbon recovery, and CO_2/TEG dehydration system as non-typical dehydration system. CC&S design considered the occupational health hazards generated from the compressor operation by installing engineering enclosure with proper ventilation system to minimize the noise hazard. CC&S helped HNGLRP to reduce the overall Greenhouse Gas (GHG) emission resulted from typical CO_2 incineration process (thermal oxidizing). [2]

The total GHG resulted from combustion sources at HNGLRP reduced by nearly 30% since CC&S technology in operation. The fuel gas consumption to run the thermal oxidizers in AGRUs reduced by 75% and sent as sales gas instead. The Energy Intensity Index (EII) reduced by 8% since 2015, water reuse index (WRI) increased by 12%. In conclusion, the project shows significant reduction in the carbon emission, noticeable increase in the production, and considerable water reuse.

Introduction

GHG is one of the main global challenges that requires real committment towards transition to a low carbon future. To maintain energy security and meet the needs of a rising global population hydrocarbon-based energy sources will be counted on to meet the bulk of the world's energy demand well into the future.

"For more than a century, carbon has been a primary component of energy systems that have enabled economies to prosper. But as the world seeks solutions to address the emissions challenge, the concept of a circular carbon economy has gained prominence. It encompasses the 4 Rs – Reduce, Reuse, Recycle, and Remove; restoring the human-earth balance and harmonizing the carbon cycle.

Reduce:

Energy efficient technologies can mitigate the amount of carbon entering the atmosphere, while noncarbon emitting renewables and nuclear can also play a part.

Reuse:

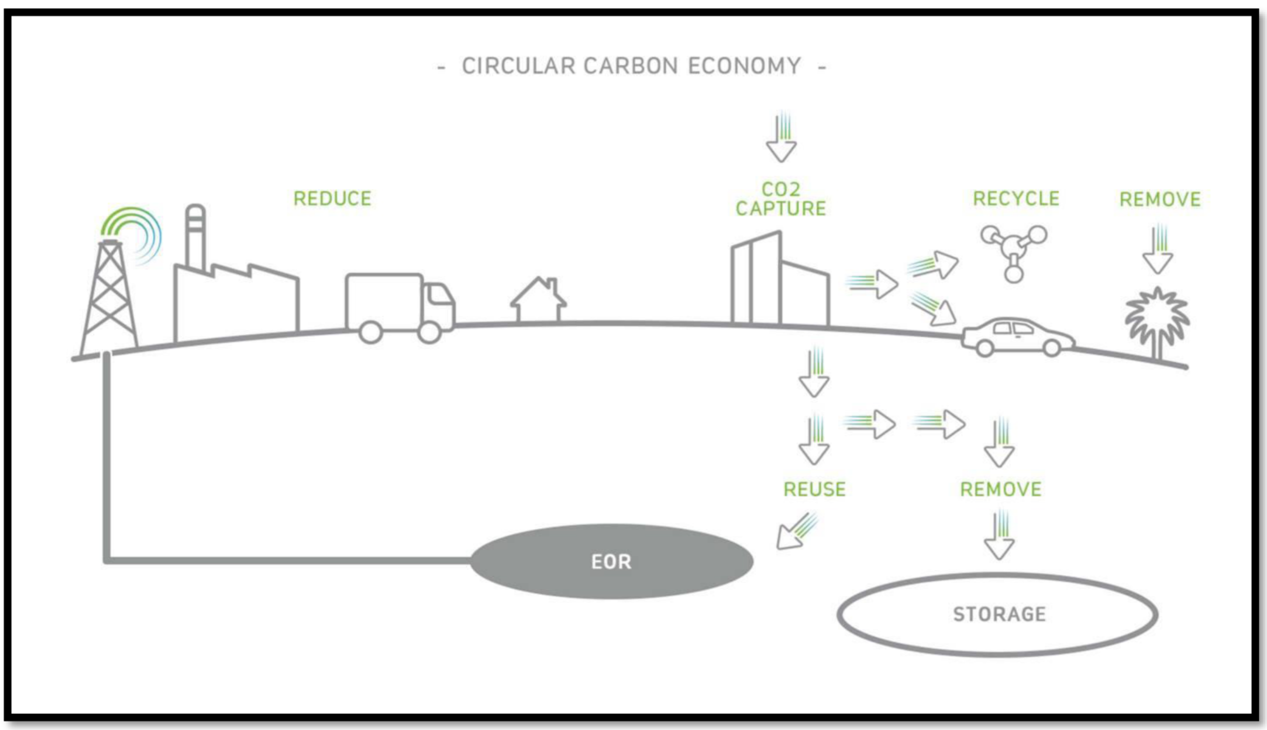
By capturing carbon through innovative technologies, it can then be used to create useful products, or be injected back into oil and gas reservoirs to increase productivity.

Recycle:

CO_2 is chemically transformed into new products such as fertilizer or cement, or other forms of energy such as synthetic fuels.

Remove:

The removal of carbon from the atmosphere can be both engineered – such as through direct air capture and sequestration – or natural, through carbon sinks such as mangrove forests."[5]



At Saudi Aramco, CC&S technology is put on stream at HNGLRP to reduce the carbon footprint and converte emissions to value to enhance oil recovery.

HNGLRP is a gas processing plant to recover ethane plus (C2+) NGL from approximately 4.0 Billion Standard Cubic Feed a day (BCFD) of sales gas. Feed gas is supplied from two main streams and both streams are sweet gas streams (free of Hydrogen Sulfide or H_2S). The NGL recovery plant process design is based on the typical cryogenic expansion process configuration. [1]

HNGLRP has two AGRUs to remove Carbon Dioxide (CO_2) from the processed gas (Fig.1); the feed is contacted in a conventional di-glycol amine (DGA) contactor to remove the CO_2 prior to NGL recovery process. Prior to CC&S, CO_2 from the stream was initially routed to an oxidizer to remove the impurities (Benzen, Toluene, and Xykene) before being vented to the atmosphere through the thermal oxidizers. [2]

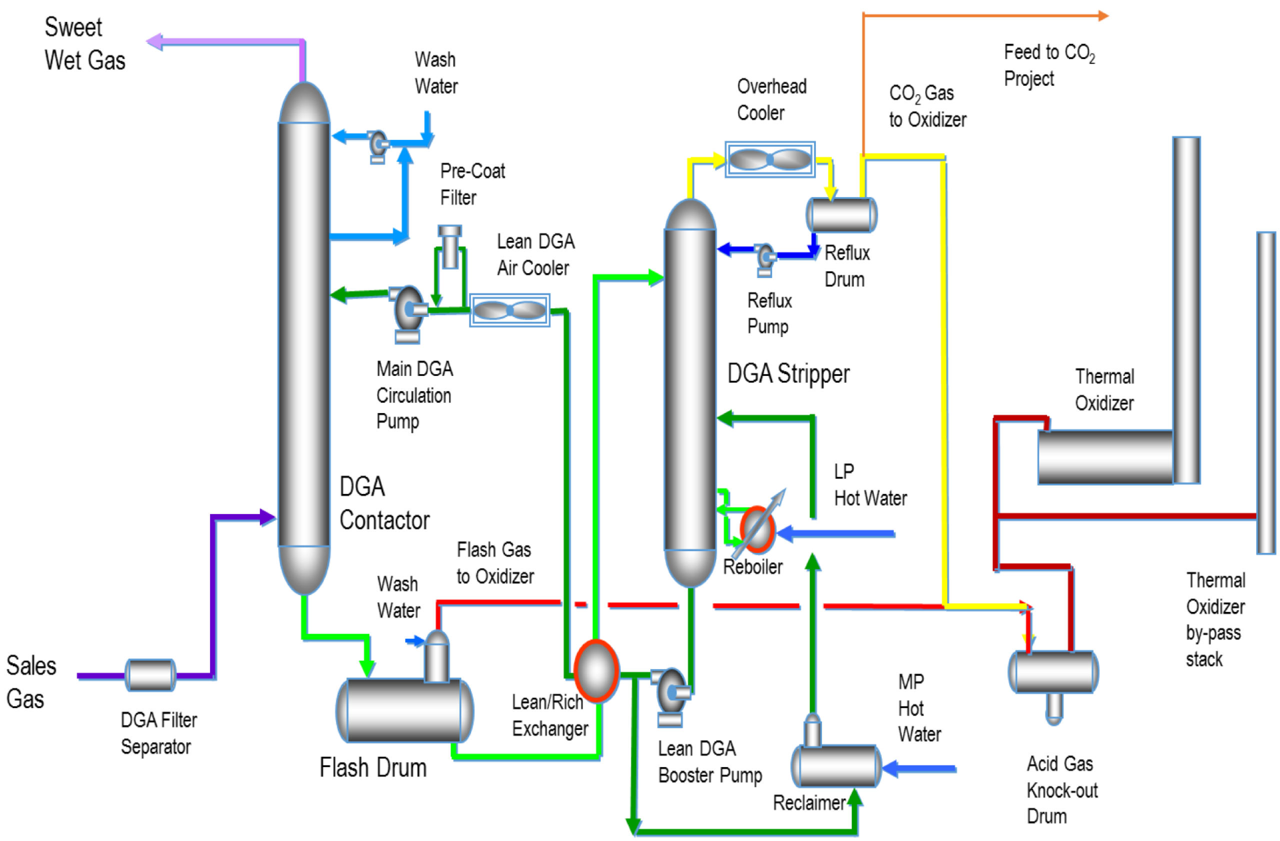


Figure 1—(Acid Gas Removal Unit Process Flow Diagram) [2]

The CO_2 is relatively pure and saturated with water. The main purpose of the CC&S, Fig. 2, is to compress nearly 45 MMSCF a day of wet CO_2 to the required transfer pressure by using a water-cooled integrally geared compressor with an intermediate TEG dehydration unit, an after cooler and a dense phase pump with suction and discharge coolers (Figure 2). Figure 2 demonstrates CC&S major equipment and streams (details are provided in the statement of theory section). [2] [3]

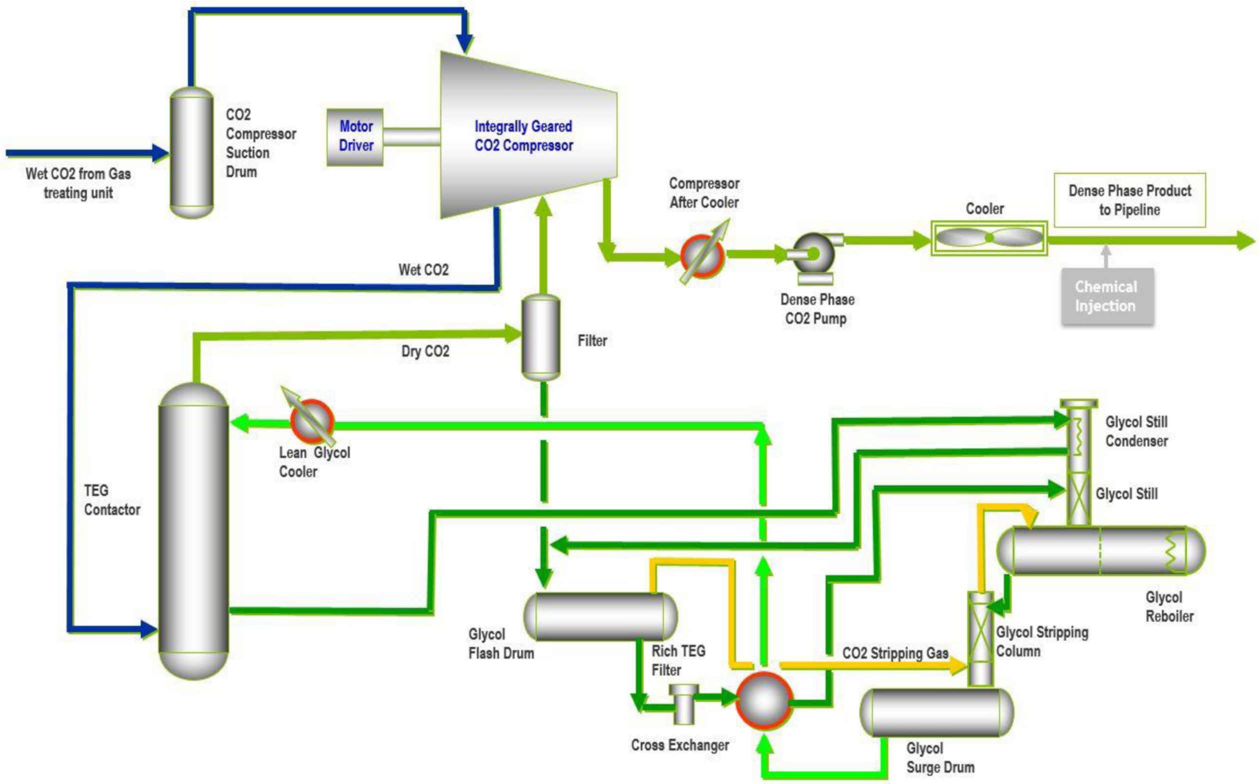


Figure 2—(CC&S Process Flow Diagram) [2]

CC&S is a set of technologies that capture carbon dioxide (CO_2) emissions at source, preventing them from entering the atmosphere, or else directly from the air. The CO_2 emissions are then transported away and either stored deep underground or turned into useful products.

CC&S captures 45 Milion Standard Cubic Feet per day (MMSCFD) from AGRUs, Fig.1, removes water and hydrocarbons through dehydration system, and finally pumpes nearly 2 Kton per day of supercritical CO_2 via 85 km pipeline for sequestration & enhanced oil recovery purposes. [2]

CC&S has been used for long period decades to help improve the quality of natural gas considering environmental protection, but by pioneering CC&S technology at HNGLRP, Saudi Aramco currently removes and sequesters CO_2 indefinitely since 2015. Moreover, it can now add value to what has always been considered a waste product, via turning the CO_2 into marketable industrial and commercial products. CO_2 can be recycled by chemically transforming it into new products. For example, polypropylene carbonate polyols product is currently produced from recycled CO_2. [5]

Statement of Theory and Definitions

CO_2 Compression. CO_2 compressor is constant speed-centrifugal type compressor with multiple stages including inter-stage coolers and K.O drums. To compress feed gas from around 5.3 psig to 1607 psig, seven stages are required. Compressor suction pressure is controlled by opening of inlet guide vanes (IGV).

The use of adjustable IGV is the most efficient method of controlling a constant speed compressor. The vanes are built into the inlet of the 1st stage, or succeeding stages, and can be controlled through the linkage mechanism either automatically or manually. In CO_2 compressor, it is controlled automatically to keep compressor inlet pressure at constant. The vanes adjust the capacity with a minimum of efficiency loss and increase the stable operating range at design pressure.

Compressor surge is a large pressure and volume fluctuation that takes place when attempting to operate at a higher pressure ratio than design maximum. However, surge phenomenon is characteristic of centrifugal compressors and can cause mechanical damage to the compressor itself. Although surge cannot be eliminated, but it can be avoided by installation and proper operation of anti-surge controller. An anti-surge system is provided which senses conditions approaching surge, and maintains the unit pressure ratio below the surge limit by recycling some flow to the compressor suction. The final element is anti-surge valve which releases pressure build up from the discharge of the compressor to the suction side.

Multistage compressors rely on inter-stage cooling whenever the inlet temperature of the gas and the required compression ratio are such that the discharge temperature of the gas exceeds a certain limit.

Gas Dehydration. Recovered CO_2 gas contains water contents from upstream system. This water content, if present in CO_2 gas, may form carbonic acid (H_2CO_3) and cause corrosion in pipeline. In order to avoid this sever corrosion in CO_2 pipeline, water content of CO_2 is removed by Gas dehydration unit (GDU). Tri-Ethylene Glycol (TEG) is used in GDU to remove water from gas phase and maximum allowable water content in CO_2 pipeline is 7 lb/MMSCF.

The glycol removes water from CO_2 gas by physical absorption and is carried out in absorption column called TEG contactor. After absorbing water content, TEG is often referred to as "rich glycol" and leaves from bottom of absorption column. The dry CO_2 gas leaves the top of the absorption column. Rich glycol is then regenerated in regeneration system and then recycled back to absorption column top.

Gas dehydration process is favorable at high pressure and low temperature. However, higher the operating pressure, higher will be equipment rating and hence higher will be the equipment cost. Keeping in mind above two factors, GDU is installed between 5^{th} and 6^{th} stage.

The gas enters the scrubber section in the bottom of the TEG Contactor where most of the condensed hydrocarbon liquids or free water is removed from the gas, if such liquids are carried with the feed.

The gas from the scrubber section flows into the top part of the vessel, the glycol contactor section, where the gas is dehydrated against a counter current flow of lean glycol. The dry gas leaves the top of the contactor section and is passed through a Dehydration Outlet Gas Filter Coalescer to remove any entrained glycol droplets.

The lean glycol to the TEG Contactor is kept at a temperature of 12 °F above the temperature of the gas to the Contactor. This is done to prevent excessive loss of glycol with the gas from the Contactor.

Rich glycol from the TEG Contactor is then reduced in pressure in the level control valve on the liquid outlet before it is routed to the Glycol Still Condenser where the rich glycol is heated against the hot vapour product from the Still Column. Part of the rich glycol stream can be routed around the condenser to maintain a correct temperature in the top of the Glycol Still column.

The heated rich glycol from the Still Condenser flows to the Glycol Flash Drum where CO_2 gas is flashed off. Any light hydrocarbons collected in this vessel may be skimmed off and routed to the off skid Separated Water Drum. The gas from the Glycol Flash drum is used as stripping gas, or routed to the vapour recovery system (VRU).

The rich glycol from the Glycol Flash Drum flows through the Rich Glycol Filter to the Lean/Rich Glycol Exchanger where it is heated against hot lean glycol from the Glycol Surge Drum.

The heated rich glycol is then reduced in pressure through a control valve before it enters the Glycol Re-boiler. In the re-boiler, the glycol is heated by means of hot water, to a temperature of 370 °F.

The vapour from the Glycol Re-boiler enters the Glycol Still Column. At the top of the Glycol Still Column, the vapour enters the Glycol Still Condenser where it is cooled to condense a reflux to the still column. The purpose of the still column is to recover valuable glycol that would otherwise be lost with the vapour product from the Glycol Re-boiler.

The vapour from the Still Condenser enters a VRU Suction Cooler where it is partly condensed and cooled using cooling medium. The vapour / liquid mixture enters the VRU Scrubber where the liquid is removed from the gas. The gas is compressed through the VRU Ejector and routed, together with the gas from the

Glycol Flash Drum, off the skid for recovery. The liquid is pumped via the VRU Scrubber Condensate Pump to the off skid Separated Water Drum.

The hot glycol from the Glycol Re-boiler enters the Glycol Stripping Column where the glycol is stripped in a packed bed against a counter current flow of stripping gas (CO_2 from the Glycol Flash Drum). Gas stripping is necessary to increase the purity of the glycol from the 98.5 wt%, which is achievable without stripping, to 99.6-99.8 wt% which is required to meet the desired gas dew points with a reasonable margin.

The glycol from the Stripping Column flows by gravity into the Glycol Surge Drum. The surge drum acts as a reservoir of glycol for the Glycol Pumps and the entire loop.

The hot lean glycol from the surge drum flows by gravity to the Lean/Rich Glycol Exchanger where it is cooled against the colder rich glycol from the Glycol Flash Drum.

The lean glycol is further sent to the Glycol Circulation Pumps which pump the lean glycol to the Glycol Contactor via a lean Glycol Cooler where the glycol is cooled to 12°F above the temperature of the gas to the contactor.

Two injection systems are provided for injecting chemicals to control TEG pH value, if necessary, and to reduce TEG foaming.

Granulated Activated Carbon (GAC) BEDS. GAC is used to remove BTX residulas from separated water during CO_2 Compression, Dehydration, and glycol regeneration. The water leaves GAC with less than 5 PPMv of BTX residulas and reused as a makeup for AGRU in lieu of fresh water. GAC is operated in intermittent basis based on the inlet water pumps operation philosophy. GAC is followed by guard filters to capture activated carbon material slippage to the reuse streams operation.

A Special Dense Phase CO_2. Pure CO_2 is a colorless, odorless, and non-flammable substance at ambient pressure and temperature. The physical state of CO_2 varies with respect to its temperature and pressure: at normal temperature and pressure, CO_2 is a gas; at low temperatures CO_2 is a solid; at intermediate temperatures (between −56.5 C, and 31.1 C), CO_2 may be turned from a vapor into a liquid by compressing it to the corresponding liquefaction pressure. The phase diagram for pure CO_2, which contains a distinct feature i.e. critical point. The critical point is defined by the critical pressure and temperature of the fluid composition above which the substance exists as a supercritical fluid, where distinct liquid and gas phases do not exist. Thus, above critical point, CO_2 no longer exists in distinct gaseous and liquid phases, but as a dense-phase or supercritical phase with the density of a liquid but the viscosity of a gas. Increases in pressure no longer produce liquids at temperatures exceeding the critical temperature. At pressures above, but temperatures below critical, the CO_2 exists as a liquid whose density increases with decreasing temperature.

In this way, the most efficient state of CO_2 for pipeline transport is as a dense-phase liquid, allowing high density of fluids without risk of phase change, which corresponds to a lower pressure drop along the pipeline per unit mass of CO_2 when compared to the transportation of the CO_2 as a gas or as a two-phase combination of both liquid and gas. In this 'supercritical' mode, captured CO_2 has to be compressed to a pressure above the critical pressure prior to transport, which occurs at a pressure higher than 1070 psig and a temperature of more than 88 °F for pure CO_2.

It is important for operators to maintain single-phase flow in CO_2 pipelines by avoiding rapid pressure drops, from a cost and efficiency point of view. At pressures very close to the critical point, a small change in temperature or pressure yields a very large change in the density of CO_2, which could result in a change of phase and fluid velocity. Refer to the below phase diagram for CO_2.[(4)]

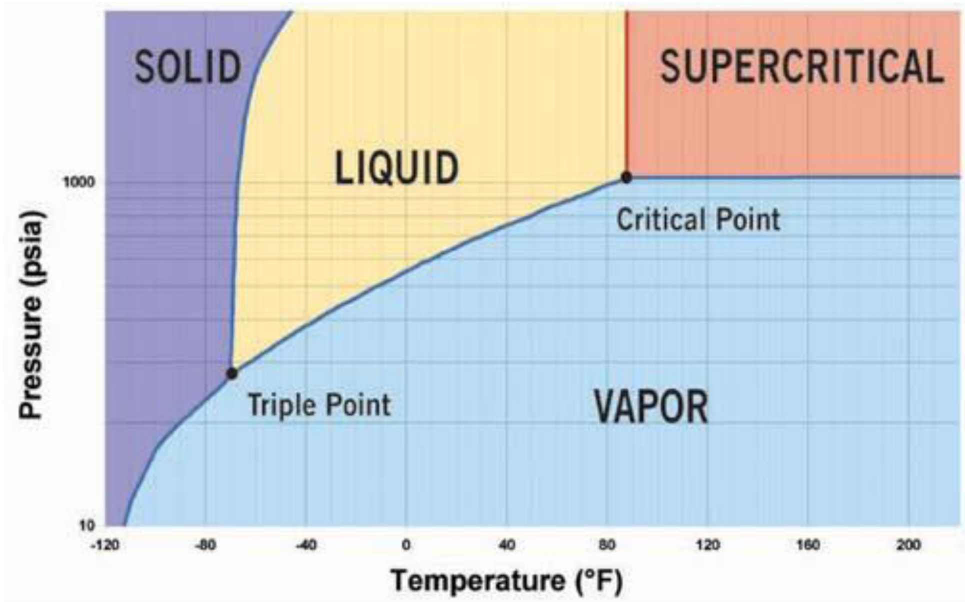


Figure 3—CO_2 Phase Diagram[(2)] [(3)]

Presentation of Data and Results

CC&S has several significant environmental improvements and revenue generation oppurtunities as shown in the below table:

Parameter	Improvement %
Greenhouse Gas Emission Reduction (Tonnes)	30
Internal Fuel Gas Consumption Reduction (MMSCFD)	75
Energy Intensity Index Reduction (EII) (Kbtu/Boe)	8
Water Reuse Index Increase (WRI) (%)	12

Conclusions

CC&S shows significant reduction in the carbon footprint, increase in the revenue, and increase in water reuse.

In November 2020, CC&S project has received the Asian Corporate Excellence & Sustainability (ACES) award in the "Green Initiative Award" category.

Acknowledgments

We want to acknowledge the great team work that the design team members have demonstrated during the different project stages till having CC&S on stream. A special appreciation goes to all Hawyiah NGL members that were heavily involved in the project design, commissioning, start-up, and safe operation. Another appreciation goes to Saudi Aramco central engineering for their commitment and dedication to provide great support. This project is not a one man job, it is truly a team well done job.

References

1. Anazi, Khalid E. 2007. Hawiyah NGL Recovery Project: Operational Considerations During Project Design. Paper IPTC 11241 presented at the International Petrolium Technology Conference (IPTC), Dubai, UAE, 4–6 December 2007.
2. Alhashboul, A.A., Mufti, A.A. and Kokal, S.L. 2017. Surface Facilities Design for the First CO_2 EOR Demonstration Project in Saudi Arabia. Paper SPE-185836-MS presented at the SPE Europec featured at 79th EAGE Conference and Exhibition, Paris, France, 12-15 June 2017.
3. Kokal, S.L., Sanni, M.L., and Alhashboul, A.A. 2016. Design and Implementation of the First CO_2-EOR Demonstration Project in Saudi Arabia. Paper SPE-181729 presented at the SPE ATCE, Dubai, UAE, 26-28 September 2016.
4. Joana Serpa, J., Morbee, J., and Tzimas, E. 2011. Technical and Economic Characteristics of a CO_2 Transmission Pipeline Infrastructure. *EUR 24731 EN Published by European Commission, Joint Research Center (JRC), Institute of Energy (IE)*.
5. The Circular Carbon Economy. [online] Aramco.com. Available at: <https://www.aramco.com/en/making-a-difference/planet>.