

Carbon Capture and Transportation with Cryogenic Technologies

Moving large amounts of CO₂ cost effectively can be achieved through liquefaction of the CO₂. Cryogenic CO₂ capture is ideally suited to capture post-combustion CO₂ emissions generated from burning coal, waste, or heavy fuel oil.

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Cryogenic liquid CO₂ storage tanks

Cryogenics makes CO₂ compact for transportation and storage. Gaseous CO₂ at atmospheric pressure and ambient temperature requires 588 times more volume than liquid CO₂.

Cryogenic CO₂ capture technologies are ideal where liquid CO₂ distribution will be re-

quired to the utilisation or sequestration location. This will be the case where the CO₂ is destined to be used in food, beverage, or other industrial gases applications.

It is likely that liquid CO₂ distribution for carbon capture and sequestration (CCS) projects will be required for many years, since al-

most no CO₂ pipeline infrastructure exists today. For example, the Northern Lights CCS project (which will permanently store CO₂ emissions from a waste to energy plant and Norcem's Brevik cement plant in Norway) will use liquid CO₂ distribution.

Gas-phase CO₂ capture technologies may be

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more suitable if CO₂ compression and pipeline transmission is required, or if onsite gaseous CO₂ utilisation is possible.

CO₂ liquefaction

CO₂ can be captured in the gas phase using conventional technologies such as amine solvent absorption. CO₂ liquefaction is achieved using a cryogenic heat exchanger to condense CO₂ gas. Electrical power is required to operate the refrigeration equipment, so the process can be decarbonised using renewable electricity.

As an alternative to mechanical refrigeration, ammonia absorption refrigeration can be used. This process avoids the mechanical compression of a refrigerant gas and derives the cold energy instead from the absorption and desorption of ammonia in water. If waste heat is available, this process can be more efficient than mechanical refrigeration.

After liquefaction, CO₂ is stored and transported in tanks which are insulated to minimise boil off. Typically, liquid CO₂ storage tanks are constructed of carbon steel and insulated with polyurethane foam. Often, a refrigeration unit is used to re-liquefy boiled off CO₂. This avoids CO₂ losses and over-pressurisation of the CO₂ storage tank.

CO₂ capture through direct liquefaction

Direct liquefaction of mixed gases is difficult. For example, when CO₂ is present in a mixture with nitrogen, the nitrogen is incondensable at the temperature at which the CO₂ can be liquefied. This means that the CO₂ liquefier heat exchanger becomes shrouded with nitrogen gas and there is no longer any contact with the CO₂ gas to be liquefied.

On the other hand, direct liquefaction of very pure CO₂ is viable. In this context, 'very pure' would typically a purity greater than 98%. Biogenic CO₂ released from bioethanol fermentation or brewing produces CO₂ at this purity.

Direct liquefaction of CO₂ from fermentation broths requires drying of the CO₂ prior to liquefaction. This is essential to avoid formation of solid ice particles within the CO₂ liquefier. It also ensures that the CO₂ product is suitable for commercial applications in the food and beverage sector or for metallurgical welding applications.



Cryogenic CO₂ distribution by road

Cryogenic Carbon Capture

It is only recently that technology has been developed for the direct liquefaction of CO₂ from lower concentration CO₂ streams.

The US start-up Sustainable Energy Solutions, now part of Chart Industries, has developed the Cryogenic Carbon Capture (CCC) process during the past decade.

CCC relies on direct sublimation of CO₂ gas to solid CO₂. Hence it can capture CO₂ from dilute flue gas streams. After the solid CO₂ has been formed, it is dissolved into liquid CO₂. The product is high purity liquid CO₂.

The CCC process relies only on electrical power for gas blowers and compressors for its operation. The implication is that it is aligned to operation with renewable electricity, meaning that no CO₂ emissions are created from capturing the CO₂.

The CCC technology is that it sufficiently robust to treat 'dirty' post-combustion flue gases that contain oxides of sulphur or nitrogen.

This means that it is ideally suited to capture post-combustion CO₂ emissions generated from burning coal, waste, or heavy fuel oil. In contrast, amine solvent processes for CO₂ capture are sensitive to sulphur impurities.

Cryogenic CO₂ capture from SMRs

CO₂ capture from steam methane reformers (SMRs) is often regarded as a 'quick-win' in the decarbonisation of industrial processes. The CO₂ concentration, pressure, and partial pressure in the SMR process gas is high. This leads to cost-effective CO₂ capture. CO₂ has been captured from SMRs for decades so that the CO₂ can be used to make urea fertilizer.

The use of cryogenics to capture and purify CO₂ from SMRs is likely to be the next milestone in the development of CO₂ capture from these units. The Cryocap™ H2 process from Air Liquide combines cryogenic separation of CO₂ from the SMR process gas stream with membrane separation of hydrogen.

A demonstration project at an SMR in Port Jérôme, on the river Seine in France, showed that an additional 12% hydrogen yield from the SMR is achievable using the Cryocap™ H2 process. This can have a tremendous positive impact on operational economics and can help to fund the investment in the Cryocap™ H2 equipment.

More information

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