Carbon Capture and Transportation with Cryogenic Technologies

Moving large amounts of CO_2 cost effectively can be achieved through liquefaction of the CO_2. Cryogenic CO_2 capture is ideally suited to capture post-combustion CO_2 emissions generated from burning coal, waste, or heavy fuel oil.
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Cryogenic liquid CO2 storage tanks

Cryogenics makes CO_2 compact for transportation and storage. Gaseous CO_2 at atmospheric pressure and ambient temperature requires 588 times more volume than liquid CO_2.

Cryogenic CO_2 capture technologies are ideal where liquid CO_2 distribution will be required to the utilisation or sequestration location. This will be the case where the CO_2 is destined to be used in food, beverage, or other industrial gases applications.

It is likely that liquid CO_2 distribution for carbon capture and sequestration (CCS) projects will be required for many years, since almost no CO_2 pipeline infrastructure exists today. For example, the Northern Lights CCS project (which will permanently store CO_2 emissions from a waste to energy plant and Norcem's Brevik cement plant in Norway) will use liquid CO_2 distribution.

Gas-phase CO_2 capture technologies may be 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.

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