# 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 required 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 almost 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 more suitable if $CO_2$ compression and pipeline transmission is required, or if onsite gaseous $CO_2$ utilisation is possible.

## CO2 liquefaction

$CO_2$ can be captured in the gas phase using conventional technologies such as amine solvent absorption. $CO_2$ liquefaction is achieved using a cryogenic heat exchanger to condense $CO_2$ 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, $CO_2$ is stored and transported in tanks which are insulated to minimise boil off. Typically, liquid $CO_2$ storage tanks are constructed of carbon steel and insulated with polyurethane foam. Often, a refrigeration unit is used to re-liquefy boiled off $CO_2$. This avoids $CO_2$ losses and over-pressurisation of the $CO_2$ storage tank.

## CO2 capture through direct liquefaction

Direct liquefaction of mixed gases is difficult. For example, when $CO_2$ is present in a mixture with nitrogen, the nitrogen is incondensable at the temperature at which the $CO_2$ can be liquefied. This means that the $CO_2$ liquefier heat exchanger becomes shrouded with nitrogen gas and there is no longer any contact with the $CO_2$ gas to be liquefied.

On the other hand, direct liquefaction of very pure $CO_2$ is viable. In this context, 'very pure' would typically a purity greater than 98%. Biogenic $CO_2$ released from bioethanol fermentation or brewing produces $CO_2$ at this purity.

Direct liquefaction of $CO_2$ from fermentation broths requires drying of the $CO_2$ prior to liquefaction. This is essential to avoid formation of solid ice particles within the $CO_2$ liquefier. It also ensures that the $CO_2$ 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 $CO_2$ from lower concentration $CO_2$ 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 $CO_2$ gas to solid $CO_2$. Hence it can capture $CO_2$ from dilute flue gas streams. After the solid $CO_2$ has been formed, it is dissolved into liquid $CO_2$. The product is high purity liquid $CO_2$.

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 $CO_2$ emissions are created from capturing the $CO_2$.

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 $CO_2$ emissions generated from burning coal, waste, or heavy fuel oil. In contrast, amine solvent processes for $CO_2$ capture are sensitive to sulphur impurities.

## Cryogenic CO2 capture from SMRs

$CO_2$ capture from steam methane reformers (SMRs) is often regarded as a 'quick-win' in the decarbonisation of industrial processes. The $CO_2$ concentration, pressure, and partial pressure in the SMR process gas is high. This leads to cost-effective $CO_2$ capture. $CO_2$ has been captured from SMRs for decades so that the $CO_2$ can be used to make urea fertilizer.

The use of cryogenics to capture and purify $CO_2$ from SMRs is likely to be the next milestone in the development of $CO_2$ capture from these units. The Cryocap™ H2 process from Air Liquide combines cryogenic separation of $CO_2$ 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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