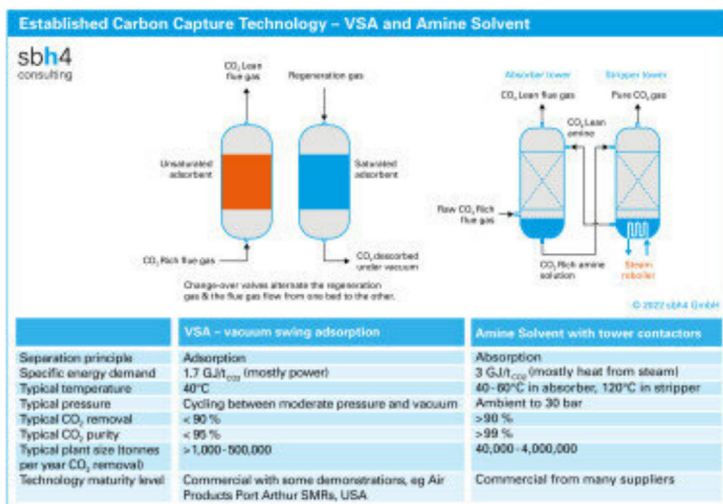


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Cryogenics for CO₂ emissions reduction

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Author credit: Stephen B. Harrison, sbh4 consulting

CCTUS refers to carbon dioxide (CO₂) capture, transportation, utilisation, and storage. Moving large amounts of CO₂ cost effectively can be achieved through liquefaction of the CO₂. 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 also 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. Ships will transport liquid CO₂ from the capture locations to the underground injection location, offshore in the North Sea.

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. The potential solution would be to vent nitrogen gas from the system, but the vent gas would also contain CO₂. Much of the CO₂ would be vented and lost, meaning this is rarely a viable solution.

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.

Hundreds of small-scale direct CO₂ capture and liquefaction installations exist worldwide, mostly at breweries. Similar technology is used to remove CO₂ during upgrading of biogas to biomethane. But, in this case separation of the methane and CO₂ is required prior to liquefaction. This is often achieved using a membrane or amine solvent CO₂ capture process.

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 does not actually use direct liquefaction of CO₂, rather it 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. There is no heat input required. The implication is that it is aligned to operation with renewable electricity, meaning that no CO₂ emissions are created from capturing the CO₂.

A further advantage of the CCC technology is that it is 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 CO₂ from emissions generated from burning coal, waste, or heavy fuel oil. In contrast, amine-based absorption and molecular sieve adsorption processes for CO₂ capture are very sensitive to sulphur impurities, meaning that a pre-purification stage would be required.

CO₂ liquefaction relies on mechanical refrigeration and heat exchange. It is different to the cryogenic liquefaction process used on air separation units, where expansion of the air itself on a turbine is used to generate the cold energy required for liquefaction of the air.

Liquid CO₂ storage tanks are constructed of carbon steel and insulated with polyurethane foam. This also differs from cryogenic storage of liquid oxygen, argon and nitrogen which are much colder. They require an austenitic grade of stainless steel for the tank and vacuum insulation to prevent vaporisation of the cryogenic liquid.

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