CO2 purity considerations for CO2 capture, transport & storage

A common international industry standard for CO2 purity that project developers could design CO2 value chains around is long overdue, argues Stephen B. Harrison, sbh4 consulting.

Carbon capture, transportation and storage (CCTS) recovers carbon dioxide (CO2) from industrial process gas emissions, transports the CO2 as compressed gas or liquid, and injects the CO2 deep into the ground for long term storage.

Many nations in Europe will need to participate in cross-border CCTS schemes because they do not have the appropriate subsurface geology to store CO2. The future of CCTS will require multi-faceted collaboration at international and regional levels. This is a driver to develop standards for CO2 purity to ensure a harmonised approach across borders and along each value chain.

Cross-border transfers

Denmark, the Netherlands, Norway and the UK are at the forefront of developing subsurface geological CO2 storage sites.

Some CCTS schemes will be within national borders. For example, two CCTS schemes are proposed in the west of England. HyNet North West will decarbonise England's Liverpool Bay industrial cluster, including blue hydrogen production at the Essar refinery. The Peak Cluster focuses on capturing, transporting and storing CO2 from lime and cement making in the Peak District.

On the other hand, in many North Sea CCTS schemes, waste CO2 will be captured in one country and transported across borders to the storage location. In the case of Norway and the UK, there will be transportation of 'waste' CO2 across the EU border.

Yara operates an ammonia and fertilizer plant at Sluiskil in the Netherlands. It is a major source of merchant liquid CO2 for commercial utilisation. From 2026, an additional 800,000 tonnes per year of CO2 will be liquefied, transported by ship and stored underground as part of the Northern Lights CCTS scheme.



At Yara's Sluiskil plant in the Netherlands an additional 800,000 tonnes per year of CO2 will be liquefied, transported by ship and stored underground as part of the Northern Lights CCTS scheme

At Sluiskil, Yara will implement 15,000 tonnes of liquid CO2 storage. This terminal will feed a fleet of two ships, each capable of carrying 7,500 tonnes of CO2. Each week, both ships will be loaded at Sluiskil and make the round trip to the offshore storage facility in the Norwegian sector of the North Sea.

Despite CCTS value chains often crossing borders, involving multiple hand-offs and utilising high-value infrastructure there is no regulatory standard to define the quality of the CO2. In the absence of an international standard, many operators refer to the 'Northern Lights' project liquid CO2 purity standard: at present, it serves to fill this policy vacuum.

CCTS first movers

Ammonia production must capture CO2 from the process gas leaving the steam methane reformer (SMR). The ammonia synthesis catalyst is iron and if it is exposed to oxygen from water or CO2, it oxidises and loses its efficacy.

Diammonium phosphate (DAP) fertilizer is produced from ammonia and phosphoric acid. To make the phosphoric acid, a mineral ore rich in phosphate rock is dissolved in sulphuric acid. However, most ores contain limestone in addition to phosphate and when the acid reacts with the limestone, CO2 is released. This CO2 is an unavoidable process emission which can be conditioned for storage.

Ethylene oxide production similarly captures CO2 within the process to avoid accumulation of CO2 in the reactor recycle gas stream. As with ammonia production, CO2 drying and purification represent only small incremental costs. In the Middle East, ethylene oxide plants on petrochemical facilities are used as commercial CO2 sources.

Since CO2 is captured for process reasons in each of the above three industries, the capital and energy costs for CO2 capture are absorbed into the production cost. The only additional costs to capture and condition CO2 from these processes are drying, purification and liquefaction.

Since the incremental cost of capturing CO2 from these cases is small, compared to investment in on-purpose equipment to capture CO2 from other processes, industrial gases distributors have historically relied on ammonia and ethylene oxide plants as their main sources of liquid CO2. DAP is now also being targeted as a commercial CO2 source in Morocco.

Biogenic CO2 and CDR

Ammonia plants have been closing down in Europe due to high natural gas prices. As a response, industrial gases distributors have begun to source biogenic CO2 from biogas plants. However, they may need to pivot to fossil fuel-derived CO2 sources because the price for biogenic CO2 is likely to be high be elevated by the voluntary carbon market (VCM).

Storage of biogenic CO2 results in negative CO2 emissions because plants remove CO2 from the air and this CO2 permanently stored underground. This process is referred to as Carbon Dioxide Removal, or CDR. CDR certificates can be sold via the VCM to companies which wish to offset their CO2 emissions, rather than physically capture them.

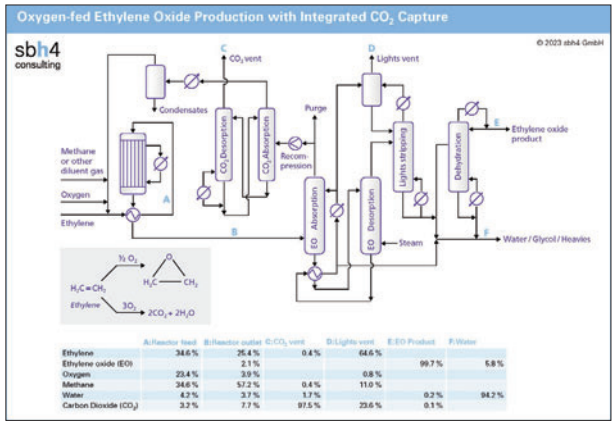
One of the main sources of biogenic CO2 is the upgrading of biogas to biomethane. In Denmark, the biogas sector is highly consolidated with several large plants dominating production. The implication is that CO2 capture on these large biomethane facilities is cost-effective.

INEOS Energy has capitalised on this opportunity. They will aggregate liquefied biogenic CO2 in Denmark and transport it by ship to the Greensand Future CO2 storage site west of Esbjerg. This is a depleted oil field in the Danish sector of the North Sea which is being repurposed for CCTS.

Protecting infrastructure investments

Due to the high CO2 intensity of their products, the high costs of electrification and geogenic CO2 emissions, cement, iron and steel, glass, and lime making are all prime candidates for CCTS. However, the contaminant impurities in each of these flue gas streams differ.

As CCTS scales, CO2 emissions from these industries will be aggregated into shared infrastructure to reduce unit costs of CO2 sequestration. Pipelines, ships, trains and geological storage sites will be operated to serve multiple emitters from a range of industries. The implication is that the CO2 from each of these sources must be compatible with the grades of steel being used in the common infrastructure. Additionally, the CO2 must address environmental and safety concerns during transportation and storage.



The only additional costs to capture and condition CO2 from the process are drying, purification and liquefaction

Contaminant concerns

In some CCTS schemes, CO2 will be liquefied to enable its transportation by ship to an offshore platform where it will be injected into the CO2 reservoir. Non-condensable gases such as nitrogen or methane increase the required energy input during CO2 compression and liquefaction. Furthermore, these gases do not behave in the same way as CO2 when injected underground at high pressure: they take up disproportionately large amounts of valuable space in the storage site.

Some captured CO2 will also be routed to utilisation for e-fuels production. E-methanol and e-SAF are built from green hydrogen and CO2. During the synthesis of methanol and SAF inert gases such as nitrogen accumulate in the process recycle streams. Therefore, these inert gases must be vented, with the consequence that valuable feedstock and product is vented with them. Therefore, the CO2 purity requirement for these CO2 utilisation applications is very high.

Other CCTS schemes will compress CO2 to a high pressure so that it can be cost effectively transported in pipelines before being injected into geological storage sites. If corrosive gases such as ammonia, hydrogen sulphide and moisture are present in the CO2, they may damage to the compressors and pipeline. Corrosion is expensive to repair and poses a safety risk.

The safety of personnel and the general public are also of paramount importance. CO2 which is intended for CCTS may contain chemicals such as mercury or hydrogen cyanide. Specifying and monitoring the concentrations of these toxins ensures that they exist only in trace quantities which neither damage processing equipment nor pose a health risk.

CO2 condition harmonisation

Commercial merchant liquid CO2 supply chains operate at around 15 barg and -20 °C. The industrial gases sector has converged to this condition over decades. It is a cost-effective balance of safety, minimum liquefaction energy, boil off minimisation and affordable capital equipment.

With the onset of CCTS higher and lower pressures of liquid CO2 have been considered, with the traditional standard now having the 'medium-pressure' classification. Operators and researchers have investigated the merits of operating at other pressure and temperature conditions. However, up to now, CCTS projects have all honoured the 'medium-pressure' standard.

International confirmation of standard CO2 purity, impurities, temperature and pressure would lock in parameters that companies involved in the CCTS value chain can design around. A common standard will ensure optimal performance, safety and efficiency. It will allow the industry to scale up cost-effectively and internationally. And, It is long overdue.

More information

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