# Capturing the complexities

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**Shipowners and organisations in the maritime industry are considering all available options to expedite their transition towards a low-carbon operating environment while serving an ever-growing transport demand. One area identified with potential for progress – and a business case – is carbon capture and storage (CCS), but the need for scale is considerable.**

According to the United Nation's Intergovernmental Panel on Climate Change and the International Energy Agency (IEA), the annual global capacity for carbon capture will need to increase from 50 million tonnes of carbon dioxide in 2020 to 800mt of $CO_2$ per year by 2030 – and more than 5,000mt by 2050. This represents a 16-fold increase by this decade's end and a 100-fold increase by mid-century in carbon capture capacity.

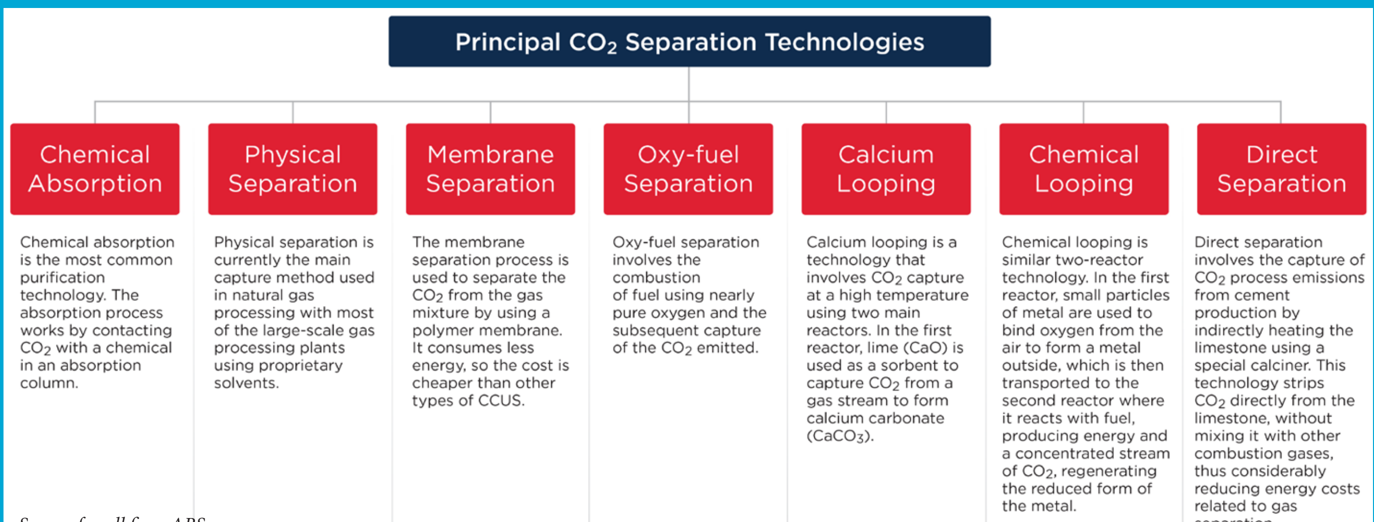
It is estimated that total global storage capacity is between 8,000 gigatonnes (gt) and 55,000gt, and even the lowest estimate far exceeds the 220gt of $CO_2$ expected to be stored from 2020 to 2070, according to the IEA's Sustainable Development Scenario. About 75% of the estimated storage is onshore in deep saline formations and depleted oil & gas fields, while the remaining quarter of capacity is offshore.

## The science behind capturing $CO_2$

For shipping to decarbonise, choosing the right pathway will be complex; but all paths will require using carbon capture technologies at scale alongside low-carbon fuels. The carbon technologies include CCS, Direct Air Capture (DAC) and bio-energy with CCS, which is the process of capturing and storing $CO_2$. Carbon can be separated using several methods, including membranes, solid sorbents and liquid sorbents, all of which have been proven effective in onshore carbon capture projects.

The capture of $CO_2$ can occur pre-combustion (syngas), post-combustion (end-of-pipe solutions) and by using oxyfuels. The captured $CO_2$ is then compressed into a liquid state and transported by pipeline, ship or truck. The post-combustion

*Fig. 1. $CO_2$ separation technologies*




*Source for all figs.: ABS*

*Fig. 2. Carbon dioxide shipping chain*


method yields a product that requires additional drying, purification and compression before transportation. This is the most mature technology, but the low partial pressure of the $CO_2$ in the flue gas is a big downside.

DAC technologies directly capture $CO_2$ from the atmosphere instead of a point source. The captured material can be stored in deep geological formations, used in food processing or combined with hydrogen to produce syn-fuels. It is an approach receiving increased focus from both private and public sectors.

## A unique business case

From the shipping industry perspective, transporting $CO_2$ by ship has a unique business case. The schematic of the $CO_2$ shipping chain from the source to storage illustrates the process of $CO_2$ capture from a power plant, liquefaction and storage. It is then loaded onto a $CO_2$ carrier, delivered to the destination port, and connected to the endpoint transmission line.

The CCS value chain is extensive and has implications well beyond the shipping industry, which will nonetheless play a crucial role in transporting $CO_2$ between the points of capture and storage/industrial utilisation.

Regarding technical feasibility, the long-distance transportation of $CO_2$ poses no more risk than natural gas transmission since the asset technology is mature and many $CO_2$ pipeline networks already exist. However, pipeline transportation costs depend on distance. As such, shipping can be considered for specific applications.

It is estimated that the $CO_2$ as a commodity market could increase by 1-7gt of $CO_2$ per year by 2030 as new routes to $CO_2$ utilisation are unlocked, such as usage in fuels, chemicals and building materials.

The transformation of $CO_2$ into low-carbon fuels could be the earliest large-scale application of CCS technology, overcoming the challenge of electrifying industrial heat and creating a roadmap towards producing low-carbon fuels in volume.

## Projects in development

Studies have shown that vessel shipment is economically preferable to pipelines for distances greater than 700 km and quantities exceeding 6.0mt of $CO_2$ per year. As of April 2022, four liquid carbon dioxide ($LCO_2$) carriers are in operation (mostly in service for the food and beverage industry). Three others are currently on order by various operators, including for Equinor's Northern Lights project, built specifically to service the burgeoning need for transporting liquid $CO_2$ for offshore sequestration.

The Northern Lights project involves developing infrastructure to transport $CO_2$ from capture sites by ship to a terminal in western Norway for intermediate storage before being transported by pipeline for permanent storage in a reservoir 2.6 km under the seabed. This project is one component of the Norwegian government's Longship CCS project and is expected to have a capacity of 1.5mt of $CO_2$ per year as part of phase one. Once the $CO_2$ is captured, it is expected to be transported by newly delivered ships, injected and permanently stored underneath the North Sea. The plan is to expand capacity by an additional 3.5mt based on the market demand.

There are many other initiatives in the pipeline, such as the Acorn $CO_2$ SAPLING project in the UK. Additionally, offshore storage capacity has been identified off the coast of Japan (considered a fit case for source-to-sink matching due to the presence of concentrated $CO_2$ emitters near the coastline).

## Vessel demand

According to a 2018 study by the European Zero Emission Technology and Innovation Platform, it is estimated that 600 vessels will be required to support $CO_2$ transport for the burgeoning CCS sector in Europe. Although the study was EU-specific, the $CO_2$ carriers will support the development of the carbon value chain worldwide.

As of April 2022, three vessels have been ordered for offshore sequestration purposes, and if the market follows the IEA estimate of needing a 16-fold increase in CCS capacity by 2030 and a 100-fold increase by the middle of the century, it is estimated that the number of vessels required will be 48 and 300, respectively.

In response to the growing demand, Hyundai Heavy Industry and Korea Shipbuilding & Offshore Engineering have developed a design for a new 40,000 $m^3$ $LCO_2$ carrier. ABS and Daewoo Shipbuilding & Marine Engineering are developing designs for a 70,000 $m^3$ very large $LCO_2$ carrier and have recently obtained design approval. The 853 by 145 ft vessel will be one of the largest $LCO_2$ carriers certified by a classification society.

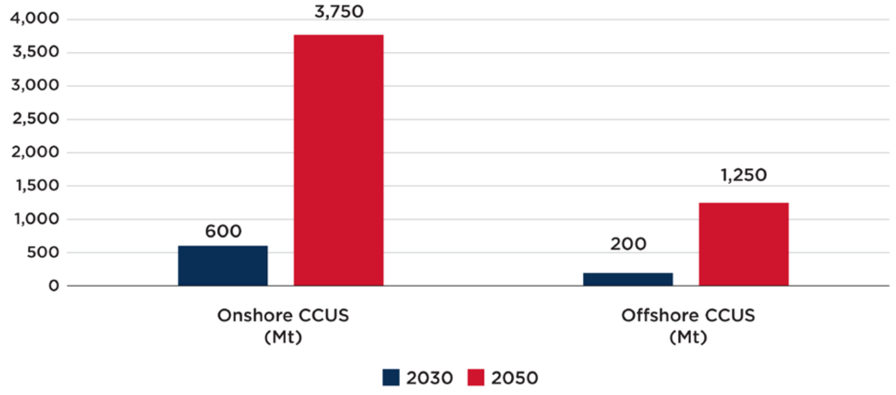
The offshore sequestration market may take off more quickly than the onshore market due to permitting complexities near population centres and the need for pipelines to transport the $CO_2$. Although onshore storage capacity is extensive, it may not convert into viable projects. Depending on the momentum of initial project successes, offshore projects may provide a path for accelerating the deployment of $LCO_2$ vessels.

## Impact on alternative fuels

As an end-of-pipe solution to reduce vessel emissions, CCS is still in its infancy; current land-based CCS equipment cannot be used on ships because its power consumption and space requirements present huge challenges. Also, the system's capture efficiencies are not proven, and storage on board can be difficult.

While solidification has been proposed to minimise the impact of wave movement, integrating a CCS system on board would

*Fig. 3. IEA's estimates for onshore vs offshore CCS market – in million tonnes of $CO_2$ (2030 and 2050)*



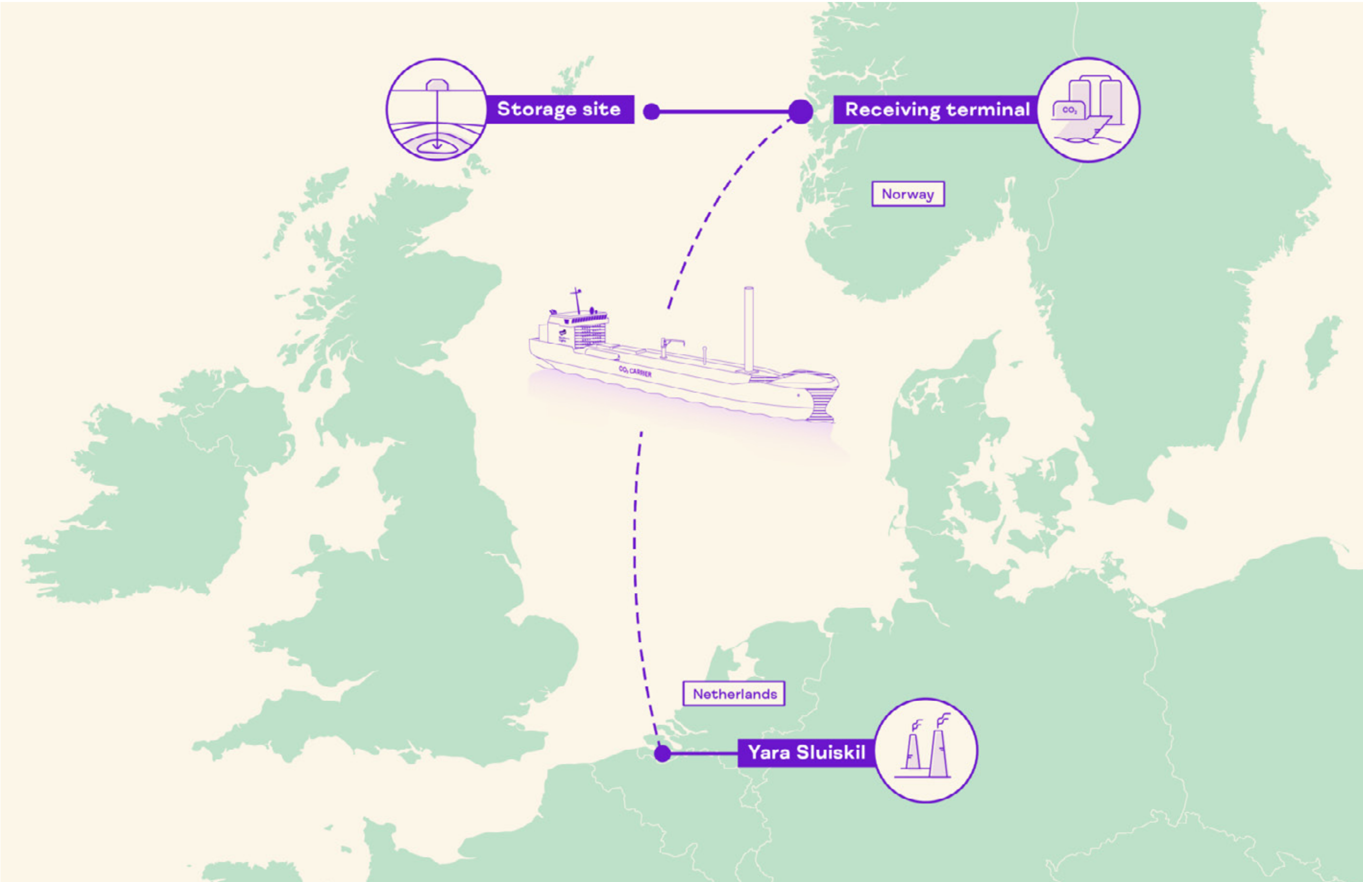




Photo: Northern Lights

involve additional capital and operational costs from retrofitting. There would need to be a clear value chain for captured carbon to be economically viable. Nonetheless, the carbon value chain presents a massive opportunity for the oil & gas, maritime and shipping industries, as well as for engine and turbine manufacturers.

Control system manufacturers that design onboard CCS devices will need to find ways to make their products cost-competitive and resolve the $CO_2$ storage, power consumption and space issues on vessels. Once proven technically feasible, end-of-pipe solutions can be rapidly deployed to support decarbonisation.

## Maritime carbon economics

Driven by the need for decarbonisation, carbon economics is emerging as a major new force in the maritime industry. Though still in the early phases of their development in offshore applications – in particular, the DAC technology is at a very early developmental stage and there remain significant efficiency challenges related to its implementation – carbon capture technologies will nevertheless provide a proven and realistic solution to lowering emissions during the transition phase away from the use of fossil fuels.

Transporting captured carbon onboard ships requires efficiency improvements for the technology to provide a sustainable long-term solution. Significant uptake of CCS technologies will be realised when a set of enablers – primarily the maturity of onboard CCS storage technologies and the further development of liquid $CO_2$ carrier designs – is in place and can facilitate the development of the broader ecosystem.

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