Carbon carriage: Risks and opportunities

Carbon capture and storage (CCS) is a long-established technology but its profile has grown as a potentially significant solution to achieve rapid decarbonisation. What are the associated risks and opportunities for the shipping industry?

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Traditionally, CCS has most often been used for the enhanced recovery of oil from depleted reservoirs. More recently, its profile has grown as a necessary solution to decarbonise hard-to-abate industries such as energy, cement and steel production. Shipping can be added to this, as onboard carbon capture is likely to be required as alternative zero emission fuels are unlikely to be available in the necessary quantities and prices to achieve the IMO's 2050 and interim targets. That captured CO_2 will need transporting from the capture site (whether that be an industrial installation or onboard a vessel) to the injection site, where it will be permanently stored in a subterranean or subsea geological formation.

The scale of the opportunity

It is estimated that global CCS capacity must increase 120 times from current levels by 2050, rising to at least 4.2 gigatonnes per annum, for countries to achieve their net-zero commitments. Whilst pipelines will generally offer a more cost-efficient option where there is sufficient scale and regularity of supply of CO_2, carriage by sea is more appropriate for longer distance transport (over approximately 350km), flexibility of quantity, source and injection locations. Estimates of global offshore storage capacity range from 2,000 to 13,000 gigatonnes of CO_2. Regions such as Korea, Japan and the North Sea, which have subsea storage locations and coastal-based emissions, are likely to be suitable for seaborne carriage of CO_2. If onboard carbon capture is widely adopted, this will require carriage by sea from temporary port-based to permanent storage locations.

One of the leading CCS schemes is the Norwegian government-sponsored Longship project. This includes capturing CO_2 from industrial sources in the Oslo-fjord region (from cement, chemicals and energy) and shipping liquid CO_2 from these industrial capture sites to an onshore terminal. From there, the CO_2 will be transported by pipeline to an offshore subsea storage location in the North Sea. It has recently signed contracts to receive about 1.2 million tonnes CO_2 annually from the Netherlands (Yara Sluiskil) and Denmark (Orsted power stations). Northern Lights is responsible for developing and operating the CO_2 transport and storage facilities for the project. Phase one is due to be operational in 2024 with an annual storage capacity of up to 1.5 million tonnes of CO_2.

The limited size of the CO_2 fleet

Although CO_2 has been carried by sea since the late 1980s, there are currently only four CO_2 vessels. All are operated by Larvik Shipping, a Norwegian company. These vessels trade on short-haul routes within Europe, carrying food-grade CO_2. The quantities carried are modest; the largest vessel can carry only 3,600 cubic metres (cbm), approximately 1,770 tonnes.

Globally, there are reported to be five vessels on order. Three ships, each of 7,500 cbm, are being built at Dalian shipyard, PRC, for the Northern Lights project. Capital Gas Ship Management has speculatively ordered two far larger 22,000 cbm CO_2 carriers which are also designed to be able to carry LPG and ammonia. These are being built at the Hyundai Mipo shipyard, South Korea with anticipated delivery in 2025-2026. Since they have no specific CCS project to fulfil, their multi-capability means they will have the flexibility to undertake carriage of other liquified gases.

Practical issues and risks of CO_2 carriage

CO_2 has unusual characteristics which make it a challenging cargo to carry. It requires both pressure and refrigeration to be carried in liquid form. The higher the temperature, the higher the pressure required, and vice versa. The most efficient option, in terms of technology and cost, for transport is in a compressed liquid state, close to the so-called 'triple point' (-56.6^{o}C, 5.18bar): the temperature and pressure at which solid, liquid, and gaseous forms of CO_2 coexist in thermodynamic equilibrium. This brings with it the risk of freezing during operations, and so safer handling may dictate a slightly higher temperature and pressure.

Carriage of the larger-scale quantities of CO_2 for CCS will draw upon knowledge acquired from the shipment of LPG, LNG and the smaller quantities of food-grade CO_2. But there are material differences. Larger quantities of the gas will likely be carried at lower pressures, requiring correspondingly lower temperatures. Unlike food-grade CO_2, industrial CO_2 emissions may contain impurities which can give rise to complications. Sampling and testing protocols to minimize contamination have not yet been fully developed. Free water is an unwanted impurity capable of producing operational and technical challenges such as hydrate formation and subsequent blockages. Impurities in the form of NOx, SOx and oxygen pose risks of corrosion to equipment.

Boil-off is another issue to manage. This occurs during handling, and by motion and ambient heat during carriage. The rate of boil-off, affected by the distance travelled, level of impurities, and tank pressure, is predicted to be 0.15%/day based on LNG carrier rates. Boil-off can be managed through re-liquification, similarly to LNG and LPG carriers.

Despite being non-flammable, the risks associated with a leakage of CO_2 are not insignificant. A 2005 report by the Intergovernmental Panel on Climate Change stated that as well as the possibility of hydrates and ice forming in the seawater, if not rapidly dispersed gaseous CO_2 might lead to asphyxiation of the crew and stop a vessel's engines. If the leakage were to occur in port, the risk to the local population would be serious: in 2008 approximately 15 tonnes (8,200cbm) of CO_2 leaked from a fire extinguishing installation in Mönchengladbach, Germany, causing the intoxication of 107 and hospitalisation of 19 people. The UK Health and Safety Executive found that the hazard distance for an unplanned discharge from a vessel could be up to 400 metres.

Potential losses and liabilities

Marine insurers are already providing cover for the carriage of CO_2, but the limited nature and scope of its carriage to date means that there is little direct claims data upon which to assess and price the risks.

Leakage of CO_2 gives rise to several issues. The escaped CO_2 will have a financial value which may be linked to the market price of CO_2 credits or allowances; or be contractually designated by the CCS project. State-run CCS projects may give rise to differing risk profiles to purely commercial projects. The CO_2 may also be treated as a pollutant, with corresponding penalties or fines; there are unlikely to be clean-up costs as there are with oil and other non-gaseous pollutants. Depending upon the nature and extent of the leakage there may also be personal injury and property damage claims.

There is the potential risk of contamination claims caused by impurities in previous CO_2 cargoes. Impurities could also result in claims for corrosion damage to a vessel's equipment. There may be difficulties identifying the source of the contamination for any recourse action.

Liquified CO_2 is classified as a dangerous cargo under the International Maritime Dangerous Goods Code (IMDG Code). It also falls under the International Code for the Construction and

Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code). At present, a shipowner will have strict liability for environmental damage resulting from the carriage of CO_2 under the EU's Environmental Liability Directive (ELD) if this occurs within the territorial jurisdiction of an EU state. Otherwise, liability is governed by national regulation and tort law. A shipowner's right to limit liability will be governed by the LLMC, which may or may not encompass all environmental claims, depending upon the particular national interpretation of the convention.

If, as expected, the 2010 International Convention on Liability and Compensation for Damage in Connection with the Carriage of Hazardous and Noxious Substances by Sea (2010 HNS Convention) comes into force within the next couple of years, this will provide a liability and compensation framework for the carriage of bulk CO_2. The convention channels liability and imposes strict liability on the shipowner, who in turn has the right to limit liability according to the size of the vessel. The shipowner is required to maintain insurance up to that limit, and there is a right of direction action against insurers in the event of the shipowner's insolvency. The convention provides for a two-tier fund: the first tier comprises the vessel limitation amount; the second tier provides additional compensation up to 250 million SDR (approximately $330 million), which is funded by contributions from receivers of HNS cargoes.

A version of this article is also available in the Marine Insurer, January 2024 edition.