

EXECUTIVE SUMMARY

Maritime CO₂ Shipping Technoeconomic Assessment

Global Review of the State-of-the-Shipping Industry

PRIMARY AUDIENCE

Power generators, industrial CO₂ emitters, shipping companies, and Carbon Capture and Storage (CCS) project developers with limited access to onshore CO₂ storage.

SECONDARY AUDIENCE

Stakeholders with a general interest in CCS.

KEY RESEARCH QUESTION

Constructing a pipeline through a highly urbanized area to transport captured CO₂ to the underground storage facility can be very challenging because of public safety concerns, space, and right-of-way constraints. Industrial facilities that emit CO₂ where capture would take place are often located along waterfronts to provide access for fuel delivery and water for cooling/process water. Maritime shipping ports may be co-located with these facilities providing an alternative, less expensive and safer mode of CO₂ transport out of urban areas. In addition, offshore CO₂ storage opportunities may exist nearby, allowing the CO₂ to be shipped from an onshore terminal to an offshore platform where it is injected below the seabed. Alternatively, the CO₂ may be shipped from an onshore terminal to a distant coastal terminal where it is offloaded to a pipeline leading to an onshore underground storage complex.

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Before contemplating such a maritime CO₂ shipping project, four key questions need to be addressed:

- What are the technical, legal, and social challenges associated with shipping captured CO₂ out of highly urbanized areas?
- Is transporting CO₂ by ship a cost-effective alternative compared to pipelines when shipping ports are readily available?
- What are the differences in costs between transporting captured CO₂ by ship to an offshore or onshore storage terminal? What are the economies of scale?

RESEARCH OVERVIEW

The study provides an overview of global CO₂ shipping operating, legal, and regulatory constraints, and a detailed assessment of potential costs for large-scale CO₂ maritime operations. Capturing CO₂ emissions from industrial sources and transporting the CO₂ to a geologic storage facility where it is injected deep underground and permanently stored is considered a key technology for limiting global warming. Various transport modes can be used to move CO₂ from the capture plant to the storage facility, including truck, rail, pipeline, maritime shipping, and combinations thereof. This report focuses on CO₂ shipping. It provides a review of the technologies used to ship CO₂ under three pressure and temperature regimes including low, medium, and elevated conditions. A review of maritime shipping regulations and global CO₂ shipping experience is provided, along with a summary of proposed CO₂ shipping projects and projects currently under development. Lastly, an economic assessment was performed to illustrate the capital expenditures and operating expenses for various CO₂ shipping scenarios focused on Japan and the United States.

KEY FINDINGS

- Liquid CO₂ has been transported by small ships at medium pressure for the food and beverage industry since the 1980s. Medium-pressure CO₂ shipping is a mature technology. There are two additional pressure/temperature (P/T) regimes that are currently being considered for CO₂ ship transport: Low pressure (LP) and Elevated pressure (EP). The three P/T regimes all have different advantages and disadvantages related to ship design, operation, and liquefaction requirements.

- To determine the most cost-effective shipping solution, it is crucial to consider the entire value chain. The optimal solution depends on the distance, volume, pressure, CO₂ composition and specification, and injection method.
- The maturity of offshore injection from ship-shaped units is still unproven and thus may have a higher operating risk compared with port-to-port trade. However, some of the offshore unloading technologies have been used in the oil and gas industry for many years. For Floating Storage Injection (FSI) designs, the onboard storage capacity is limited, implying that injection operations are subject to disruption during prolonged harsh weather conditions, when supply ship access is limited.
- The London Protocol applies to offshore CO₂ storage and cross-border maritime CO₂ shipping. Cross-border transportation represents a significant challenge that must be addressed early during project development.
- There are currently no existing facilities for importing liquid CO₂ within either Japan or Australia. The technical suitability of future shipping projects is based on the premise that import infrastructure would be established to enable liquid CO₂ export and import.
- CO₂ ship transport within the United States (US) is regulated by the Jones Act, which requires that gas carriers be constructed/assembled in the US. US ship building capacity is limited and expensive compared to offshore suppliers, creating a potential financial and supply chain challenge. Using barges and tugs or utilizing an intermediate port outside of the US in the logistic network, are not subject to the Jones Act. This is an alternative shipping approach that could be evaluated early during project development.
- Mitigation actions like physical barriers, leakage simulations/analyses, early community engagement, and alternatives like offshore intermediate storage are needed to address safety concerns related to unexpected releases of CO₂ from onshore storage facilities supporting shipping.
- The cost difference between low and medium-pressure vessels is minimal for distances less than 2,500 km (1,550 miles) but tends to increase beyond this threshold due to the limited capacity of medium pressure vessels (assumed to be capped at 20-30 ktonne), necessitating a larger fleet for longer distances.
- Economic analysis shows that the shore-to-shore scenario is the most favorable for the US case. For the Japan/Korea case, there are minor differences in levelized costs between shore-to-shore and shore-to-offshore direct injection, with shore-to-shore being slightly less expensive but involving a less comprehensive value chain. However, it should be noted that the shore-to-shore scenario does not include the added costs associated with piping the CO₂ to the onshore or offshore storage facility, which increase the total costs. In addition, the levelized cost for liquefaction must be added to the shipping costs to obtain a total cost for the entire transport value chain.

WHY THIS MATTERS

Sedimentary basins that contain permeable, high-capacity storage formations are not distributed equally across the globe. Some geographic regions may lack adequate on- or off-shore storage that cannot be accessed by CO₂ pipeline. Maritime CO₂ shipping provides an alternative mode of transport that allows these regions to access CO₂ storage facilities that would not be available otherwise.



THE LOW-CARBON RESOURCES INITIATIVE

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