SHIP TRANSPORT

map-it CCU

CO_2 ship transport is an established method for moving liquefied CO_2 (LCO_2) using specialized vessels. Originally developed for transporting small volumes of food-grade CO_2, this method has evolved to support larger-scale transportation of industrial CO_2 as part of carbon capture, utilization, and storage (CCUS) initiatives. LCO_2 is transported in semi-refrigerated vessels designed to maintain temperatures between -50°C and -20°C under medium to low pressure, ensuring safety and stability during transit. These vessels are equipped to handle the unique properties of CO_2, including its precise temperature and pressure requirements. Ship transport is particularly suited for linking CO_2 capture facilities with storage locations or utilization hubs, where CO_2 can be used as a feedstock for fuels, chemicals, or building materials. CO_2 transport pressure depends on scale and application. Currently, the food and beverage industry ships CO_2 at medium pressure (13–18 bar, -30°C to -28°C) using small vessels.[1] High-pressure transport (35–45 bar) allows liquefaction at ambient temperatures (0–10°C), reducing energy needs and easing loading/unloading. [1] Low-pressure transport (6.5–8.7 bar, -45°C to -41°C) requires larger tank volumes and very pure CO_2, as the conditions approach the triple point. However, at these pressures, vessels can be constructed in rectangular shapes, allowing for more efficient use of ship volume and higher CO_2 payload per trip. Large carriers (up to 80,000 m^3) offer scalability without high-volume needs. CO_2 shipping shares similarities with LNG and LPG transport, enabling knowledge transfer, though it operates at significantly higher temperatures than LNG (−162 °C). **The information in this infosheet also applies to CO_2 transport by truck and rail.**

Large scale liquified CO_2 carrier

FUNCTION IN CCU VALUE CHAIN

- Transporting large volumes of CO_2.
- Linking the capture phase with storage or utilization sites.

LIMITATIONS

- **Lower capacity compared to pipelines**: Ships are less efficient than pipelines for transporting high-volume CO_2 over short distances or for long-term continuous operations. However, ships become more competitive as transport distance increases.
- **Higher operating costs** for long-term use, while flexible for smaller or shorter-term projects.
- **Batch transport (non-continuous):** Ships operate in batches, making them less suitable for applications requiring continuous CO_2 transport.
- **Distance and weather limitations:** Ship transport can be affected by weather conditions and operational delays, particularly in adverse climates or over long distances.
- **Port infrastructure requirements:** Many ports lack the specialized infrastructure needed to handle, store, and transfer liquefied CO_2.

ENERGY

- Marine fuel is used to power the ship's propulsion system.
- Electricity is primarily used for compressing and cooling (see the infosheet about liquefaction).

CONSUMABLES

- Marine fuel

Energy & Consumables

Parameter	Value
Fuel ($g/tCO_2/km$)[2]	**Y** = -0.0396***X** + 7.1684

*Y – Fuel consumption and X – Ship capacity in **$ktCO_2$***

COSTS

Shipping costs consist of costs for ships, loading and unloading facilities, intermediate storage, and liquefaction. Further, it also consists of operation and maintenance costs (labor, fuel, electricity, harbor fees). Shipping costs are independent of the scale of transport and distance. The cost can vary widely depending on vessel type and size, route, and scenario.

CAPEX: Capital investment costs can be estimated as a function of the desired ship capacity ($ktCO_2$/ship)[2]

Transport pressure 7 barg

$\mathbf{Y} = -0.0064*\mathbf{X}^2 + 1.613*\mathbf{X} + 17.408$

Transport pressure 15 barg

$\mathbf{Y} = -0.0128*\mathbf{X}^2 + 3.0649*\mathbf{X} + 38.734$

Where **Y** is the ship CAPEX in M€/ship and **X** is the ship capacity in $ktCO_2$.

OPEX: **Fixed OPEX** can be estimated as a function of the desired ship capacity ($ktCO_2$/ship)[2]

Transport pressure 7 barg

$\mathbf{Y} = -0.0003*\mathbf{X}^2 + 0.0807*\mathbf{X} + 0.8721$

Transport pressure 15 barg

$\mathbf{Y} = -0.0006*\mathbf{X}^2 + 0.1534*\mathbf{X} + 1.9363$

Where **Y** is the ship fixed OPEX in M€/ship/yr, and **X** is the ship capacity in $ktCO_2$.

Variable OPEX are the costs associated with marine fuel use at a fuel price of 325 €/t.

Buffer storage costs 550 and 920 €/m^3 for 7 and 15 barg options, respectively.

Loading and Unloading facilities cost 7.9 M€ for a 3 $MtCO_2$/yr capacity for each facility. Annual operating costs are 2% of the investment cost.

Harbor fees amount to 1.1 €/tCO_2 at each harbor.

[2]*2017 euros; discount rate – 8%; project lifetime – 25 yrs; operating rate – 85%.*

More detailed information on shipping costs is given in the Clarksons/CCSA report 2024.[3]

Total CO_2 transportation costs:

Costs are given for transporting pure CO_2 between two harbors at 7 and 15 barg pressures for CO_2 capacities in the range 1 – 20 $MtCO_2$/yr.[2] Lower capacities have higher transport costs.

Distance	Transport cost (7 barg)	Transport cost (15 barg)
km	€/tCO_2	€/tCO_2
100	25 – 18	30 – 20
500	29 – 21	37 – 29
1000	33 – 23	44 – 36
1500	37 – 26	49 – 43
2000	40 – 29	64 – 48

TECHNOLOGY PROVIDERS

- CO_2 carrier by **Exmar**, Belgium
- CO_2 shipping by **Clarksons**, United Kingdom
- CO_2 shipping by **Knutsen NYK Carbon Carriers**, Norway
- CO_2 transport ships by **Northern Lights**, Norway
- CO_2 transport ships by **Nippon Gases**, UK & Ireland *(Operates four CO_2 transport ships, each with a capacity of 1,000 m^3, primarily used for short-distance transport along coastal routes.)*

ALTERNATIVE TECHNOLOGIES

- **Truck**: Flexible for short distances, but higher operational costs. Alternative pressures may also be used for truck transport, particularly for last-mile delivery in the CCU value chain (e.g., for beverage applications and similar uses).
- **Rail**: Offers a flexible and lower-capital option for smaller volumes, but higher OPEX.

  Truck/Rail CO_2 conditions:

  - *Liquid at -18 °C and 14-20 bar, water <30 ppmv, and oxygen <10 ppmv.*[4]
  - *Liquid at -50 °C and 7 bar (medium pressure) and -30 °C and 19 bar (high pressure).*[5]
- **Pipeline**: More cost-effective for large volumes over shorter distances (see infosheet).

  CO_2 conditions: *Liquid (supercritical) at 20 °C and 100-150 bar, water 100-400 ppmv, and oxygen <10 ppmv.*[4]

CONTACT INFO

Mohammed Khan (mohammednazeer.khan@vito.be)
Miet Van Dael (miet.vandael@vito.be)

ACKNOWLEDGEMENT

This infosheet was prepared as part of the MAP-IT CCU project funded by VLAIO (grant no. HBC.2023.0544).

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