IEAGHG Information Paper; 2013-IP20: Maritime Carbon Capture and Storage

Background:- In January 2013 the Research & Innovation part of the ship classification society DNV, in combination with the process modeling provider PSE, published a widely reported press release describing an investigative in-house study of the feasibility of installing CCS on large maritime vessels.

The study resulted in the development of a Maritime CCS concept for a technology that captures CO_2 from the main engine exhaust gases of large seagoing vessels, liquefies and stores it on-board, until discharge to the next port with suitable offloading facilities. This announcement heralded the launch of further R&D on the concept.

The underlying feasibility study is not in the public domain, but the press release reports that it would be possible to design a Maritime CCS system to capture of about 70,000 tonne per year CO_2 from a VLCC (very large crude carrier) class of vessel with over 50% capture efficiency. The CO_2 would be stored in dedicated tanks on board the vessel to be off-loaded at a suitable port.

Rationale

Carbon capture and storage (CCS) from large stationary sources has been extensively investigated and trialed, but so far the application of CCS to the transport sector has been elusive due to the small scale of individual sources and the inability to connect a mobile source to a CO_2 disposal facility. Super-tankers are very large transport units, representing a significant percentage of the world merchant fleet. Their long voyages present a steady-state source of CO_2 and their capacity provides scope for temporary storage of captured CO_2. Therefore these vessels present a potential target for the application of CCS to the transport sector.

The scheme as proposed would require CO_2 utilisation or storage infrastructure to be available at selected ports for disposal of the collected CO_2. However, a possible off take for captured CO_2 on board oil tankers might also be offshore oil production platforms. In the short term, off-shore platforms might be purchasers of CO_2 for enhanced oil recovery, but in the long term access to depleted off-shore oil and gas fields might also be available for off-shore unloading of captured CO_2.

Technology issues

Marine diesel engines burning heavy residual fuel oil have a high excess air level, resulting in a flue gas with less than 5% CO_2 content. Chemical solvent scrubbing is a proven technology for post-combustion capture of CO_2 from dilute concentrations at atmospheric pressure, but the extent of capture achievable is constrained by the dimensions of the absorber and regeneration columns that can be accommodated.

Marine engines burn heavy residual oil, except in ports. This fuel typically has a sulphur content of about 3%, which would yield about 0.06% SO_2 in the exhaust gas. SO_2 degrades CO_2 capture solvents so the exhaust gas would have to be scrubbed to remove SO_2. The scheme proposed includes pre-scrubbing of the engine exhaust with seawater. This pre-washing process would have the added benefits of cooling the gas and removing black carbon particles from the gas, which could provide additional climate change mitigation.

The CO_2 capture process is energy intensive requiring heat for solvent regeneration and electricity for pumps, fans and CO_2 compressors. In the Maritime CCS concept, the process heat duty is met by waste heat recovery from the ship's engines supplemented by an auxiliary fuel fired steam boiler. These require a high level of integration with the infrastructure of the vessel, which makes retrofitting prohibitive for existing oil tankers.

The CO_2 captured would need to be liquefied and stored on the oil tanker in pressurised vessels, placed forward of the accommodation section, similar to the LNG tanks in the DNV Triality concept. The liquid CO_2 product would be stored temporarily on-board until discharge into transmission and storage infrastructures at the next suitable port. No change of the vessel's volumetric oil carrying capacity would be caused.

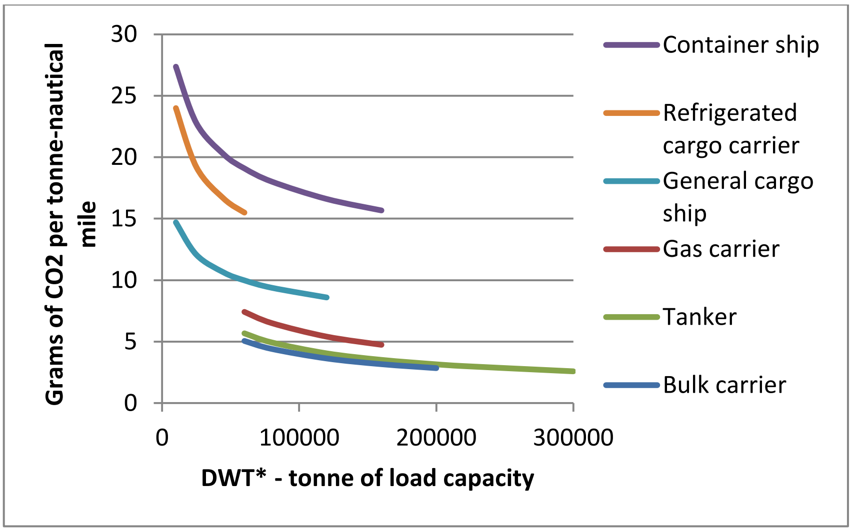
Regulatory issues

The International Marine Organisation (IMO) has established a schedule of the Energy Efficiency Design Indices (EDDI), which are emissions in terms of grams of CO_2 per tonne mile of load carried. Reference curves have been developed by the IMO for a number of ship types. The EEDI reference curves refer to statistically average EEDI data derived from fuel consumption data for existing ship types, as below.

Performance at or better than the reference EEDI curve is now mandatory for new ships under the International Convention for the Prevention of Pollution from Ships. Furthermore, a 10% improvement on that standard is required for ships built after 2015, a 20% improvement for ships built after 2020 and a 30% improvement for ships built after 2025. That sets challenging targets which might incentivise the implementation of partial CO_2 capture on very large vessels.

Size of vessels

The following chart shows that the fuel use (and the consequent CO_2 production) of marine vessels is inversely proportional to the square root of their load capacity. Therefore CO_2 capture is favoured for large ships such as super-tankers, large bulk freighters and LNG carriers. According to the Maritime CCS concept, the liquid CO2 can be temporarily stored on top of the cargo / deck area, achieving no change of the vessel's carrying capacity. The extra weight introduced by the capture, storage and liquefaction systems is at the order of 2% of the total ship weight, which can be accommodated by very large ships.



*DWT = Dead-Weight Tonnage = load carrying capacity of the ship

Extension of the concept of on-board CO_2 capture to other types of vessels such as general freighters, containerships and refrigerated vessels would result in at least 20% of the load carrying capacity being sacrificed for temporary CO_2 storage, making CCS on such vessels impractical. CO_2 capture and pressurised storage on large passenger ships would also likely be non-viable due to space and safety constraints. An advantage of very large ships is that the gas processing plant would be less affected by the turbulence of storms at sea.

Further investigation

The Maritime CCS concept study has established the technical feasibility of a CO_2 capture process suited to the exhaust from marine engines of very large ocean-going vessels, including an initial Hazard Identification (HAZID) analysis with respect to health and safety standards. Progressing the Maritime CCS concept may include consideration of the following issues:

- Investigation of the feasibility of off-loading liquid CO_2 onto off-shore oil production platforms;
- Consideration of the requirements for land-based CO_2 disposal infrastructure; and
- Examination of the real-life performance of the technology in the context of future research / prototype vessel development.

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