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Ship-based carbon capture – port infrastructure and implementation roadmap

Ragnhild Skagestad[a] Anette Mathisen[a], Kristian L. Aas[a], Sumudu Karunarathne[a]

[a] *SINTEF Industry, Hydrovegen 69, Porsgrunn, Norway*

Abstract

Introduction

A likely game changing EU Action for the maritime sector operating in the EU came into effect on January 1st 2024. The EU Action was the inclusion of maritime emissions into the EU-ETS (Emission Trading System) [1]. The implementation is gradual and in the initial phase ships ≥ 5 000 GT (Gross Tonnage) would need to account for 40 % of 2024 emissions in 2025, 70 % of 2025 emissions in 2026, and 100 % from 2027 onwards. It is expected that this EU Action will speed up the decarbonisation of the maritime sector. Different pathways for decarbonising the sector have been proposed; ship optimisation (e.g., engine efficiency, operational profile, wind assistance), fuel-swich (zero emission fuels), and on-board CO_2 capture.

The ongoing ACT project "EverLoNG" aims to encourage the uptake of ship-based carbon capture (SBCC) by demonstrating its use onboard LNG-fuelled ships and thereby moving the technology closer to market [2]. The present work explores how implementation of SBCC will affect existing ship - port integration and infrastructure. Further, assuming a full-scale rollout of SBCC, a possible port implementation roadmap is proposed.

Ship - port integration

The work builds on the previous article Maelum et al. [3] with the current paper focusing more on CO_2 unloading alternatives, in-port interim CO_2 storage, and the subsequent infrastructure needed for the captured CO_2 to reach a permanent storage location.

Two main assumptions have been made when assessing ship – port integration and these are;

- That the captured CO_2 will be stored onboard the vessel in liquid form
- That any unloading of CO_2 will take place at the same time as the vessel's normal operation when it comes into port (i.e., that the vessel will not visit a separate port only for unloading CO_2)

The optimal onboard CO_2 storage and unloading solutions might differ depending on the vessel and port facilities. The type of vessels that calls at the Port of Rotterdam are liquid bulk, dry bulk, roll on/roll off, and container [5]. These vessels will call the port at different and dedicated locations/quays, making a common infrastructure for CO_2 handling more challenging and potentially resulting in a complex in-port CO_2 handling infrastructure. Identifying the optimal method for unloading CO_2 will depend on type of vessel and the port layout.
CO_2 unloading alternatives are primarily tank container swap, skid mounted storage tank swap, and unloading through cryogenic, flexible hoses/loading arms (analogue to loading/unloading of CO_2 transported by dedicated CO_2 cargo

ships today). From the perspective of the vessel, unloading the CO_2 in a similar way to how it unloads its cargo is likely preferable.

If neither of the above-mentioned CO_2 unloading alternatives are feasible, the use of bunkering ships may be an option. To facilitate that, a bunkering ship could be applied, and when the ship is loading/unloading their main cargo, the bunkering ship can attach to the other side of the ship and transfer the CO_2 at the same time. After disconnecting the flexible hoses, the bunkering ship will go to another ship at their quay, and then when the bunkering ship is full, the bunkering ship will go to a special receiving quay where the CO_2 is offloaded. The CO_2 will be stored in intermediate storage tanks before the CO_2 is transported further to permanent storage or utilization, or if possible, be unloaded directly from the bunkering ship into the transferring infrastructure to further transport.

Port implementation roadmap

Several ports are already taking an active role in the developing CO_2 handling infrastructure when it comes to land-based CCS. A port that is active in developing CO_2 handling infrastructure for such an application is Port of Antwerp Bruges with the Antwerp@C project [4]. The challenge when it comes to developing a port implementation roadmap for CO_2 captured onboard ships is that the CO_2 volumes to be handled are significantly less and are potentially more unpredictable than what is expected for CCS from land-based industries, especially when looking at ports individually.

The primary focus in this work will be on ports located in Europe. It is not expected that all ports would need infrastructure for receiving CO_2 captured through SBCC. Current selection criteria are:

- Port throughput (see example Port of Rotterdam [5])
- Port's own plans for CO_2 infrastructure
- No of calls from ships that are likely to implement SBCC
- Location in relation to existing or planned infrastructure
- Other relevant criteria, e.g., strategic location, high degree of predictable routes, key import/export ports with ports outside of Europe

The key message from this work will be recommendations for how a roadmap can be developed and a key timeline for how a network of different ports with this infrastructure can be achieved.

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