Onboard Carbon Capture (OCC): The Everlong project

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The maritime industry must decarbonise. Onboard Carbon Capture (OCC) offers a promising solution for mitigating emissions from existing and new build vessels. Here, the EverLoNG project demonstrates the feasibility of OCC, exploring its technical, logistical, environmental and regulatory aspects, paving the way for wider adoption

OCC has emerged as a promising technology to mitigate emissions now while alternative fuels and propulsion systems are developed. The EverLoNG project, a collaborative effort involving sixteen partners from five countries, has been at the forefront of demonstrating and evaluating OCC technology.

This interview delves into the project's key findings, exploring the technical aspects of carbon capture, the logistical challenges and solutions, the impact on ship operations, and the overall environmental benefits and future potential of this crucial technology. We speak with several experts from TNO, SINTEF, Forschungszentrum Jülich, and SCCS involved in the EverLoNG project to gain a comprehensive understanding of their groundbreaking work.

Demonstrating carbon capture on ships

Jasper Ros/Juliana Monteiro (TNO):

Can you tell us about the demonstration project for carbon capture on ships? What are the main goals and objectives of this project?

The EverLoNG project designed and built a mobile CO2 capture pilot capable of capturing approximately 250 kg of CO2 per day for installation on existing ships. This pilot was deployed and operated on two distinct vessels: Heerema Marine Contractors' SSCV Sleipnir and a TotalEnergies-chartered LNG carrier, the Seapeak Arwa.

The primary objective of these demonstrations was to reduce the perceived risk of implementing carbon capture in the maritime industry.

We specifically aimed to demonstrate the feasibility of capturing CO2 from the exhaust gases of existing vessels, subsequently liquefying and storing it on board. Critically, testing with real-world exhaust gases enabled us to assess the impact of impurities, such as high NO2 concentrations, on the capture system performance. For instance, we noted that elevated NO2 levels in one vessel's exhaust gas increased the degradation rate of the capture solvent, resulting in higher ammonia emissions. We also carried out analysis of solvent quality.

What specific technologies are being used for carbon capture on the ships involved in the demonstration?

The EverLoNG pilot utilises an amine-based carbon capture system, a CO2 liquefaction system, and a liquid CO2 storage tank. We chose an amine-based system, predominantly due to its high Technology Readiness Level (TRL). This well-established and well-understood technology reduces implementation challenges, especially for onboard integration, and supports performance comparisons with land-based systems using the same technology.

For similar reasons, we chose the first-generation mono-ethanolamine (MEA) solvent. Widely used in land-based systems, MEA is well-documented and characterised in existing literature. The liquefaction system is a standard compression and cooling unit, designed to store the liquid CO2 at approximately 20 bar and -20°C within the insulated liquid CO2 storage tank.

How do you see this carbon capture technology evolving and being implemented more widely in the maritime industry in the future?

EverLoNG has significantly advanced our understanding of OCC through practical demonstrations, infrastructure analysis, safety studies, and comprehensive case studies encompassing techno-economic analysis (TEA) and life-cycle assessment (LCA).

While the project has answered many key questions, it has also revealed new challenges and areas requiring further investigation – a natural part of the process toward scaled-up implementation.
Given that “green” fuels and alternative propulsion technologies are not anticipated to achieve widespread availability and affordability within the sector in the coming decade, we expect continued investment and wider adoption of OCC as it matures.

CO2 logistics: From capture to storage

Ragnhild Skagestad, (SINTEF)/ Richard L Stevenson (SCCS):

Can you elaborate on the logistics involved in capturing, storing, and offloading CO2 captured from ships?

Capturing CO2 onboard ships generally involves post-combustion capture techniques, such as amine-based absorption. Captured CO2 is stored onboard, typically in liquid form, achieved through compression and cooling; dense phase storage (requiring only compression) is also feasible.

Offloading at port necessitates dedicated infrastructure to receive, store, and prepare the CO2 for transport to its final destination – either CO2 utilisation (CCU), ideally involving permanent sequestration, or permanent geological storage (CCS). Offloading can occur via hoses or loading arms to onshore tanks, ideally aligning with regular port operations. To minimise downtime, dedicated CO2 receiving ships or barges could gather CO2 from multiple vessels, streamlining logistics for ships and ports, particularly larger ones.

Further transport to storage or utilisation sites necessitates infrastructure such as pipelines, trucks, rail, or ships. Collaboration with existing land-based CCUS projects at port could significantly lower costs.

What are the potential challenges associated with CO2 logistics throughout the capture, storage, and offloading process?

While promising, OCC faces significant challenges.

The shipping industry’s diverse fleet, varying in size, design, cargo, engines, and fuel, makes standardisation difficult, requiring customised OCC systems for each vessel. Unpredictable shipping routes and schedules, due to short-term charters, lead to fluctuating CO2 capture volumes, complicating system optimisation.

The relatively small and variable CO2 volumes captured per ship, compared to industrial facilities, create inefficiencies in offloading and transport, especially with long intervals between port calls. Ports must adapt to offer flexible CO2 reception facilities to handle diverse ship designs and offloading schedules without disrupting operations.

EverLoNG explored a dedicated CO2 collection ship as an alternative to fixed quay facilities. Finally, broader CO2 transport and storage networks, including pipelines and intermediate storage, remain underdeveloped in many regions.

How can collaboration between shipping companies, port authorities, and other stakeholders ensure efficient and sustainable CO2 logistics for captured emissions?

Collaboration is crucial. To adopt OCC technologies, shipping companies must integrate them into vessel designs, invest in efficient capture systems and optimise ship layouts for CO2 storage.

They also need to work with policymakers on financial incentives. Port authorities must develop the necessary infrastructure for CO2 offloading and storage, including pipelines, storage tanks, and transportation networks. Interoperability and coordination between ports are vital.

Integrating carbon capture into ship operations

Jasper Ros (TNO):

How does integrating carbon capture technology impact ship operations and engine management?

Ideally, the carbon capture system should have minimal impact on ship operations and engines. Exhaust gas bypasses are essential to prevent vessel blackouts. The capture system needs to be integrated with existing energy systems. For instance, waste heat can be used to strip CO2 from the solvent, but the system should be optimised to minimise additional fuel consumption.

OCC also increases the demand for cooling water and electricity, potentially requiring system upgrades. We haven't observed any indications of OCC affecting engine management.

What adjustments need to be made to shipboard systems and crew training to accommodate carbon capture?

Integrating a carbon capture system requires connecting it to the vessel's exhaust gas lines, energy (steam), electrical, and cooling water systems. For existing ships, space must be allocated for the equipment, and integration studies, including stability analysis, are necessary.

Crews will need training on the new system, which will be integrated into control room operations and maintenance schedules. While the system is largely automated, crew training on basic troubleshooting is crucial for minimising downtime, maximising CO_2 capture, and improving the system's economic viability. Expert support, though not necessarily onboard, is recommended.

How do you envision future ship designs incorporating carbon capture technology seamlessly into their operations?

Historically, ship engines have been optimised for propulsion efficiency, resulting in ever-lower exhaust gas temperatures. However, these reduced temperatures are less suitable for carbon capture systems, which depend on exhaust gas heat. Future ship designs should adopt a more holistic approach, re-optimising engine design with the integrated OCC plant in mind.

The EverLoNG analysis, using two years of operational data from a TotalEnergies-chartered LNG carrier, compared various engine types and their heat provision potential for carbon capture. We discovered that engines with slightly lower propulsion efficiency but higher exhaust gas temperatures can actually provide better overall CO_2 avoidance potential when considering the combined performance of the engine and the onboard capture system.

Life cycle assessment of carbon capture

Petra Zapp (Forschungszentrum Jülich):

Can you explain what Life Cycle Assessment (LCA) is and how it is used to evaluate the environmental impact of carbon capture on ships?

To accurately assess the overall emissions reduction potential of onboard CO_2 capture and prevent shifting emissions or increasing other environmental impacts, a holistic, life-cycle approach is essential. Only if the additional efforts required for capture, transport, and storage or utilisation of the CO_2 are less than the amount of CO_2 captured onboard can this technology truly contribute to maritime decarbonisation. LCA provides this holistic framework.

Using a "cradle-to-grave" approach, LCA identifies all material and energy inputs and emissions associated with the process, from fuel provision for vessel operation (including additional fuel and electricity for the capture system) and the supply of MEA solvent, through CO2 capture and liquefaction, transport, and finally, geological storage or utilisation.

LCA then assigns these inputs and outputs to various environmental impact categories, providing a comprehensive picture of the environmental consequences of OCC.

What are the key findings from the LCA study on CO2 emissions associated with carbon capture technology on ships?

Our LCA study projects substantial CO2 reductions during ship operations with large-scale carbon capture: 72% for the Sleipnir and up to 82% for the LNG carrier, exceeding EverLoNG's initial targets. However, considering the entire process chain (capture, transport, and storage), effective CO2 reductions are 51% and 55%, respectively.

Critically, the analysis extends beyond CO2, accounting for other greenhouse gases (GHG) like methane (which has a significantly higher global warming potential). Including all GHGs, such as additional methane from increased fuel consumption and methane slip, overall mitigation potential is reduced to 36% and 42%. While OCC could contribute to achieving the IMO's 2030 targets, it won't be sufficient for the more ambitious 2040 and 2050 goals.

This underscores the need for further efficiency improvements, like optimised heat integration (reducing additional fuel use) and measures to minimise methane slip, to maximise GHG reduction.

The future of carbon capture in shipping

Marco Linders (TNO):

What are the maritime industry's biggest challenges in achieving its decarbonization goals?

Beyond technology, the maritime industry's decarbonisation faces key challenges in regulation and logistics.

A robust regulatory framework is crucial to incentivise action. The entire CO2 logistics chain, from onboard storage to transport and final storage/utilisation, must be established. Cost remains a barrier, requiring incentives to bridge the gap between OCC costs and current ETS prices.

In your view, what are the key areas for further research and development to advance carbon capture technologies for ships?

Further research should focus on larger-scale, long-term OCC demonstrations to better understand solvent degradation and emissions. Beyond onboard technology, CO2 logistics, especially offloading and transport infrastructure, need development.

EverLoNG has proven OCC's viability, with our findings on processes, integration, and safety advancing the technology toward market readiness. Future research should prioritise amine emissions and efficiency improvements. We believe OCC is a valuable tool for maritime decarbonisation.

EverLoNG data and findings are accessible to the public, supporting our aim to educate the maritime industry and other stakeholders about this promising technology.

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