Port Readiness for CO_2

Overview of Port Readiness Tool for CO_2 (PRT-CO_2), key criteria and recommendations

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Authorisation

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Executive summary

International shipping takes care of the movement of goods and products between nations. It has the lowest carbon footprint per tonne for long-range transport but still creates around 3% of global CO_2 emissions; and this figure is projected to rise without effective intervention[1]. Consequently, the maritime sector has pledged to reach net zero emissions by 2050[2].

Among the measures being developed to address this challenge is Onboard Carbon Capture (OCC), which directly targets ship emissions. Additionally, CO_2 transport by ship (CO_2 shipping) is emerging as a critical enabler for deploying carbon capture utilisation and storage (CCUS) networks, facilitating emission reductions in other industries. Ports, and wider port communities, will be key to both endeavours in terms of providing and facilitating dedicated and specialised infrastructure, systems and processes to offload and handle this CO_2.

The EverLoNG project aims to encourage the uptake of OCC by demonstrating its application onboard LNG-fuelled ships and moving it closer to market readiness. The project focuses on technological optimisation, explores integration into existing ship and port infrastructure, supports the development of full-chain CCUS networks, conducts Life Cycle Assessment (LCA) and Techno-Economic Analysis (TEA), and contributes to the development of regulatory frameworks for the safe and effective use of OCC technology in the shipping sector.

This report summarises the activities undertaken and the key findings from the broader port readiness exercise conducted under Work Package (WP) 2 *Task 2.2 CO_2 shipping interoperability and port readiness*. The findings and recommendations presented herein directly inform the Port Readiness Tool for CO_2 (PRT-CO_2). This report is intended as an accompaniment to be used in conjunction with the PRT-CO_2.

The findings highlight a number of key criteria and considerations relevant for the successful integration of OCC and CO_2 shipping within port communities. They indicate that while some hurdles remain before ports are able to play the vital dual role of facilitating the decarbonisation of the maritime sector via OCC and of the wider economy via larger CCUS networks, it is evident that progress is being made and that none of the remaining challenges is deemed insurmountable

[1] European Commission (2025). *Reducing emissions from the shipping sector*. Available at: https://ec.europa.eu/clima/eu-action/transport-emissions/reducing-emissions-shipping-sector_en
[2] IMO (2023). *Revised GHG reduction strategy for global shipping adopted*. Available at: https://www.imo.org/en/MediaCentre/PressBriefings/pages/Revised-GHG-reduction-strategy-for-global-shipping-adopted-.aspx

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List of abbreviations

CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilisation
CCUS	Carbon Capture Utilisation and Storage
CII	Carbon Intensity Indicator
CMF	International Association of Ports and Harbors' Clean Marine Fuels group
CO_2	Carbon dioxide
CSIIG	CO_2 Shipping Interoperability and Industry Group
EEA	European Economic Area
EEDI	Energy Efficiency Design Index
EEXI	Efficiency Existing Ship Index
ETS	Emissions Trading System/Scheme
EU	European Union
GHG	Greenhouse gas
HNS Convention	International Convention on Liability and Compensation for Damage in connection with the Carriage of Hazardous and Noxious Substances by Sea
IAPH	International Association of Ports and Harbors
IMO	International Maritime Organization
LCA	Life Cycle Assessment
LLMC	Convention on Limitation of Liability for Maritime Claims
LNG	Liquefied Natural Gas
LP	Low Pressure (ca. 15 barg, -26°C)
LPG	Liquefied Petroleum Gas
MARPOL	International Convention for the Prevention of Pollution from Ships
MEA	Monoethanolamine
MEPC	Marine Environment Protection Committee
MP	Medium Pressure (ca. 5-10 barg, -40°C)
MRV	Monitoring, Reporting and Verification
OCC	Onboard Carbon Capture
PPE	Personal Protective Equipment
PRL-CO_2	Port Readiness Level for CO_2
PRL-MF	Port Readiness Level for Marine Fuels
PRT-CO_2	Port Readiness Tool for CO_2
STS	Ship-to-ship
STT	Ship-to-terminal
t / kt / Mt (pa)	tonne / kilotonne / Megatonne (per annum)
T&S	Transport & Storage
TEA	Techno-Economic Analysis
UK	United Kingdom
WP	Work Package
WPCAP	World Ports Climate Action Program

1 Introduction

International shipping takes care of the movement of goods and products between nations. It has the lowest carbon footprint per tonne for long-range transport but still creates around 3% of global CO_2 emissions; and this figure is projected to rise without effective intervention[3]. Consequently, the maritime sector has pledged to reach net zero emissions by 2050[4].

Among the measures being developed to address this challenge is Onboard Carbon Capture (OCC), which directly targets ship emissions. Additionally, CO_2 transport by ship (CO_2 shipping) is emerging as a critical enabler for deploying carbon capture utilisation and storage (CCUS) networks, facilitating emission reductions in other industries. Ports, and wider port communities, will be key to both endeavours in terms of providing and facilitating dedicated and specialised infrastructure, systems and processes to offload and handle this CO_2.

The EverLoNG project aims to encourage the uptake of OCC by demonstrating its application onboard LNG-fuelled ships and moving it closer to market readiness. The project focuses on technological optimisation, explores integration into existing ship and port infrastructure, supports the development of full-chain CCUS networks, conducts Life Cycle Assessment (LCA) and Techno-Economic Analysis (TEA), and contributes to the development of regulatory frameworks for the safe and effective use of OCC technology in the shipping sector.

1.1 Role of ports in OCC and CO_2 shipping

Ports may act as both import and export terminals for CO_2. This may include pipelines and other infrastructure as part of land-based CO_2 networks, e.g. CCUS clusters. In terms of the maritime sector specifically, they may also be required to handle liquid CO_2 (LCO_2) captured elsewhere and delivered by ship and/or captured directly from a ship's exhaust gases via OCC. In both cases, ports will need dedicated and specialised infrastructure, systems and processes in place to offload and handle this LCO_2 in ways that minimise vessel downtime and deviations from regular port and ship operations. In the case of OCC specifically, ports will also require dedicated systems to handle the solvents used in the capture process. Key aspects pertaining to governance, infrastructure, safety and market domains will likely include a combination of new systems and ones that are aligned with existing LCO_2 and other liquid cargo handling, as well as more general shipping procedures and practices.

For CO_2 handling at ports to become a central component of CCUS networks and general carbon management strategies, interoperability between ports, ships, and storage hubs will be crucial for efficient and cost-effective operations. As projects develop in different parts of the world, differences in CO_2 transport conditions and offloading infrastructure could create significant challenges for seamless operations. This would be counterproductive and requires significant levels of trust and coordination between project developers if it is to be avoided. The EverLoNG project

[3] European Commission (2025). *Reducing emissions from the shipping sector*. Available at: https://ec.europa.eu/clima/eu-action/transport-emissions/reducing-emissions-shipping-sector_en
[4] IMO (2023). *Revised GHG reduction strategy for global shipping adopted*. Available at: https://www.imo.org/en/MediaCentre/PressBriefings/pages/Revised-GHG-reduction-strategy-for-global-shipping-adopted-.aspx

underscores the need for harmonised infrastructure and handling systems to facilitate smooth CO_2 transfer between ports and storage facilities[5].

1.2 The need for a Port Readiness Tool for CO_2 (PRT-CO_2)

While OCC and CO_2 shipping are technically feasible today, numerous challenges need to be addressed before regular and widespread handling and offloading of CO_2 at ports becomes the well-established norm that it needs to be. These challenges arise from a combination of the unique characteristics of the maritime sector, including operational unpredictability, logistical complexities, and the specific demands of CO_2 handling and integration with CCUS network developments.

Therefore, a standardised framework is needed to help ports, port communities, and other key stakeholders collectively plot a trajectory towards the safe and effective handling of CO_2. This was the rationale behind the development of the EverLoNG Port Readiness Tool for CO_2 (PRT-CO_2), which is focused on the role of ports as an interface for and facilitator of both OCC and CO_2 shipping.

1.3 Scope and structure of this report

This report summarises the activities undertaken and the key findings from the broader port readiness exercise conducted under WP2 *Task 2.2 CO_2 shipping interoperability and port readiness*. The findings and recommendations presented herein directly inform the PRT-CO_2. This report serves as an accompaniment to be used alongside and in conjunction with the PRT-CO_2.

The findings highlight a number of key criteria and considerations relevant to the successful integration of OCC and CO_2 shipping within port communities. They indicate that while some hurdles remain before ports are able to play the vital dual role of facilitating the decarbonisation of the maritime sector via OCC and of the wider economy via larger CCUS networks, it is evident that progress is being made and that none of the remaining challenges is deemed insurmountable.

Section 2 of this report provides an overview of the wider port readiness exercise. Section 3 presents the range of key criteria and issues that were identified for OCC and CO_2 shipping. Conclusions and recommendations are summarised in section 4.

2 Overview of the port readiness exercise

This section describes the two main activities undertaken as part of the broader port readiness exercise: the CO_2 Shipping Interoperability and Industry Group (CSIIG) and the PRT-CO_2.

2.1 CO_2 Shipping Interoperability and Industry Group (CSIIG)

The CSIIG forum was established to bring together experts and key stakeholders from across OCC and CCUS spectra to discuss and help efforts to develop offloading strategies and establish guidelines and recommendations for CO_2 shipping interoperability, port readiness, port infrastructure, CO_2 specifications, solvent handling, and other relevant concerns. Three online workshops were held in November 2022, September 2023 and February 2025, bringing together

[5] Parmiter, P J M (2022). *D2.2.1 CO_2 Shipping Interoperability Briefing Report*. Available at: https://everlongccus.eu/index.php/about-the-project/results

over 130 individuals from 69 organisations. These were recorded for internal purposes only and not made public. They included presentations from invited external partners as well as from the EverLoNG consortium, and these and the surrounding discussions helped to feed into various parts of the project, including the PRT-CO_2. The speakers and presentations from each of the CSIIG workshops are summarised briefly below, with a link to the corresponding review articles and slide packs on the EverLoNG project website.

2.1.1 CSIIG#1 (01/11/22)

The EverLoNG project & WP2 overview

1. Introduction to the EverLoNG project – Jurrit Bergsma (TNO)
2. Summary of work to be undertaken in WP2: Ship-based carbon capture in the full CCUS chain – Ragnhild Skagestad (SINTEF)

CO_2 shipping and interoperability

3. Summary of ZEP CO_2 Shipping Guidance - Alistair Tucker (Shell)
4. Update on progress towards development of ISO Standard for shipping – Erik Mathias Sørhaug (DNV)
5. CO_2 Shipping Interoperability discussion – Philippa Parmiter (SCCS)

CSIIG#1 review and presentation slides: *Shipping Interoperability Industry Group gets underway*

2.1.2 CSIIG#2 (20/09/23)

The EverLoNG project & full CCUS chain overview

1. Welcome & project overview: Richard L Stevenson, Project & Research Analyst, SCCS/The University of Edinburgh
2. WP2: Ship-based carbon capture in the full CCUS chain overview: Ragnhild Skagestad, Senior Research Scientist, SINTEF

Port perspective

3. Port of Antwerp & Bruges: Arne Strybos, Program Manager Fuel Transition
4. Port of Rotterdam: Françoise Van den Brink, Senior Advisor Energy Transition

Shipping/CO2 handling perspective

5. Moss Maritime: Tor Skogan, Vice President Gas
6. Altera Infrastructure: Frank Wettland, Project Manager - New Venture CCS

CSIIG#2 review and presentation slides: *Exploring the Future of Sustainable Shipping: Insights from the 2nd CSIIG Workshop*

2.1.3 CSIIG#3 (12/02/25)

The EverLoNG project & WP2 overview

1. Welcome: Richard L Stevenson, Project & Research Analyst, SCCS/The University of Edinburgh
2. EverLoNG project & WP2 OCC in the full CCUS chain: Ragnhild Skagestad, Senior Research Scientist, SINTEF

Ports and OCC

3. Port of Rotterdam: Onboard Carbon Capture: Steven Jan van Hengel, Sr. Business Development Manager Sustainable Transport, Port of Rotterdam
4. Port of Antwerp-Bruges: CCUS hub in Europe: Arne Strybos, Program Manager Fuel Transition, Port of Antwerp-Bruges
5. Greenhouse gas emissions of OCC under the FuelEU Maritime regulation: Donghoi Kim, Research Scientist, SINTEF

EverLoNG CO_2 Offloading Roadmap & Port Readiness Tool

6. Roadmap of a European offloading network: Ragnhild Skagestad, Senior Researcher, SINTEF
7. Port Readiness Tool for CO_2 (PRT-CO_2): Richard L Stevenson, Project & Research Analyst, SCCS

CSIIG#3 review and presentation slides: *Charting a course towards CO_2 port readiness: Insights from the 3rd CSIIG workshop*

2.2 PRT-CO_2

2.2.1 What is the PRT-CO_2?

The PRT-CO_2 is a dual-path framework designed to support ports and their communities in evaluating their readiness for two distinct yet complementary operations:

1. OCC offloading, which directly addresses emissions reduction from ships by enabling the offloading and handling of captured CO_2.
2. CO_2 shipping (also referred to as CO_2 transport), which facilitates the development of CCUS networks by providing a flexible and scalable method for transporting CO_2 from industrial emitters to geological storage sites or utilisation facilities.

The PRT-CO_2 is designed to provide a starting point for ports and other key industry stakeholders to review and consider from their perspective, and to generally use as a resource to take forward for further development and sectoral application. Considering the differences among ports and the dynamic nature of port activities, the tool is not designed as a one-size-fits-all solution. Instead, it allows ports to select their area(s) of focus and to tailor the assessment to their specific needs. The dual-path structure also enables ports to focus resources on the operational stream(s) that align with their strategic priorities, evaluate infrastructure and planning gaps specific to OCC or CO_2 shipping, and support collaborative efforts with stakeholders, regulators, and CCUS networks. At the time of writing, the PRT-CO_2 was yet to be comprehensively reviewed and assessed by ports.

2.2.2 How was the PRT-CO_2 developed?

The PRT-CO_2 builds on the established ***Port Readiness Level for Marine Fuels assessment tool (PRL-MF)***, developed by the World Ports Climate Action Program (WPCAP) in conjunction with the International Association of Ports and Harbors' (IAPH) PRL working group[6]. The PRL-MF itself is based

[6] World Ports Sustainability Program (WPSP) (2024). *Port Readiness Level for Marine Fuels self-assessment tool*. Available at: https://sustainableworldports.org/wpcap/wg-4/

in part on NASA's Technical Readiness Levels (TRLs)[7] and the OGSM strategic planning framework[8]. While focused on marine fuels, the overarching PRL-MF framework is also well suited to the application of CO_2 handling at ports[9].

By mapping CO_2 handling requirements onto the existing structure of this recognised industry standard, the PRT-CO_2 aims to provide a familiar and practical framework for assessing port preparedness. This approach is designed to ensure that ports are equipped to address the distinct challenges posed by OCC and CO_2 shipping while aligning with industry expectations. Figure 1 below shows how CO_2 has been 'mapped' onto the existing PRL-MF framework. The original PRL-MF text is retained in standard blue font with CO_2 additions shown in green font.

- Domain: Infrastructure
Strategies, tasks and measures:

- ☐ Research the requirements necessary to serve as a port of call for vessels to offload on board captured CO_2 and regenerate/ reload the solvent used for onboard capture.
- ☐ Conduct high-level assessments of existing infrastructure to determine compatibility with OCC offloading systems.

Figure 1: Example showing how CO_2 additions (in green) have been 'mapped' onto the existing text (in blue) and structure of the PRL-MF

Content for the PRT-CO_2 was gleaned from a combination of a literature survey of publicly available material, targeted stakeholder engagement, including via the aforementioned CSIIG online workshop series, and work undertaken as part of other EverLoNG WPs, particularly WP2. The PRT-CO_2 is intended to be used in conjunction with this report.

The authors and the EverLoNG project would like to extend their heartfelt thanks to the WPCAP and IAPH partners for agreeing to the use of the PRL-MF in this manner. However, it should also be noted that the agreement of WPCAP and IAPH does not in any way represent their endorsement or approval of the PRT-CO_2, its contents, or OCC in general.

2.2.3 Who can use the PRT-CO_2?

The PRT-CO_2 is intended for use by all members of a port community, including port authorities, ship operators and customers, regulatory authorities, regional first responders and safety teams, and stakeholders in CCUS networks. The tool is designed to accommodate varying port sizes and configurations. Tasks within the framework can be completed by individual entities or through

[7] NASA (2023). *Technology Readiness Levels*. Available at: https://www.nasa.gov/directorates/somd/space-communications-navigation-program/technology-readiness-levels/
[8] Smart Insights (2021). *Introducing the OGSM model framework*. Available at: https://www.smartinsights.com/marketing-planning/marketing-models/ogsm-model-framework/#:~:text=OGSM%20stands%20for%20objective%2C%20goals,way%20of%20monitoring%20your%20progress
[9] EverLoNG (2023). *Exploring the Future of Sustainable Shipping: Insights from the 2nd CSIIG Workshop*. Available at: https://everlongccus.eu/index.php/ships-log/exploring-future-sustainable-shipping-insights-2nd-csiig-workshop

collaboration among multiple stakeholders. The tool is not prescriptive and allows for a high degree of flexibility and optionality.

2.2.4 How does the PRT-CO_2 work?

The framework consists of a checklist-based structure that guides port communities through nine Port Readiness Levels (PRL-CO_2) within the following three phases:

- Phase 1 - Research: Ports assess the potential relevance of OCC or CO_2 shipping, conduct feasibility studies, and evaluate stakeholder interest.
- Phase 2 - Development: Ports develop and test frameworks for the chosen operations, create initial infrastructure and run pilot tests.
- Phase 3 - Deployment Phase: Ports scale up operations, transitioning from project-based approaches to fully integrated, routine operations.

Each readiness level includes specific tasks and strategies across four central 'domains' - Governance, Safety, Infrastructure and Market - to guide ports through the process of self-assessment and preparation. The checklist format ensures that ports can identify readiness gaps and develop action plans to address them, monitor progress across the readiness levels, and engage stakeholders in a structured and transparent manner. Table 1 below outlines the nine PRL-CO_2 levels and the 3-phase structure as they apply to OCC offloading and CO_2 shipping.

Readiness Level	Phase	OCC Offloading	CO_2 Shipping
PRL-CO_2 9	Deployment Phase	Integration of OCC operations into routine port activities and growth.	Integration of CO_2 transport into routine port activities and growth
PRL-CO_2 8		Full OCC offloading capabilities for commercial operations.	Full CO_2 transport capabilities for commercial operations.
PRL-CO_2 7		Project-based establishment of OCC offloading operations.	Project-based establishment of CO_2 transport operations.
PRL-CO_2 6	Development Phase	Pilot-scale demonstration of OCC offloading systems.	Pilot-scale demonstration of CO_2 unloading and handling systems.
PRL-CO_2 5		Framework validation and testing under operational conditions.	Validation of CO_2 transport systems under operational conditions.
PRL-CO_2 4		Drafting OCC frameworks and developing an implementation timeline.	Drafting frameworks and timelines for CO_2 transport operations.
PRL-CO_2 3	Research Phase	Detailed research, analysis, and conclusions on OCC readiness.	Detailed research, analysis, and conclusions on CO_2 transport.
PRL-CO_2 2		Stakeholder engagement and feasibility assessment for OCC.	Stakeholder engagement and feasibility assessment for CO_2 transport by ship.
PRL-CO_2 1		Foundational background information on OCC offloading technologies and processes.	Foundational background information on CO_2 transport by ship technologies.

Table 1: Overview of the nine Port Readiness Levels (PRL-CO_2) for OCC and CO_2 shipping

3 Findings from the Port Readiness exercise

This section presents the range of key criteria and considerations that were identified for the successful integration of OCC and CO_2 shipping within port communities. OCC is dealt with separately first (see section 3.1), followed by a cross-cutting section covering issues applicable to both (see section 3.2).

As mentioned, these findings were taken from a combination of a literature survey of publicly available material, targeted stakeholder engagement, the CSIIG online workshop series, and other work undertaken across the project, particularly WP2. Given the nascency of both OCC and CO_2 shipping, and the overlapping nature of the work undertaken across WP2, these findings are mirrored to some degree across other WP2 outputs[10].

3.1 OCC-specific issues

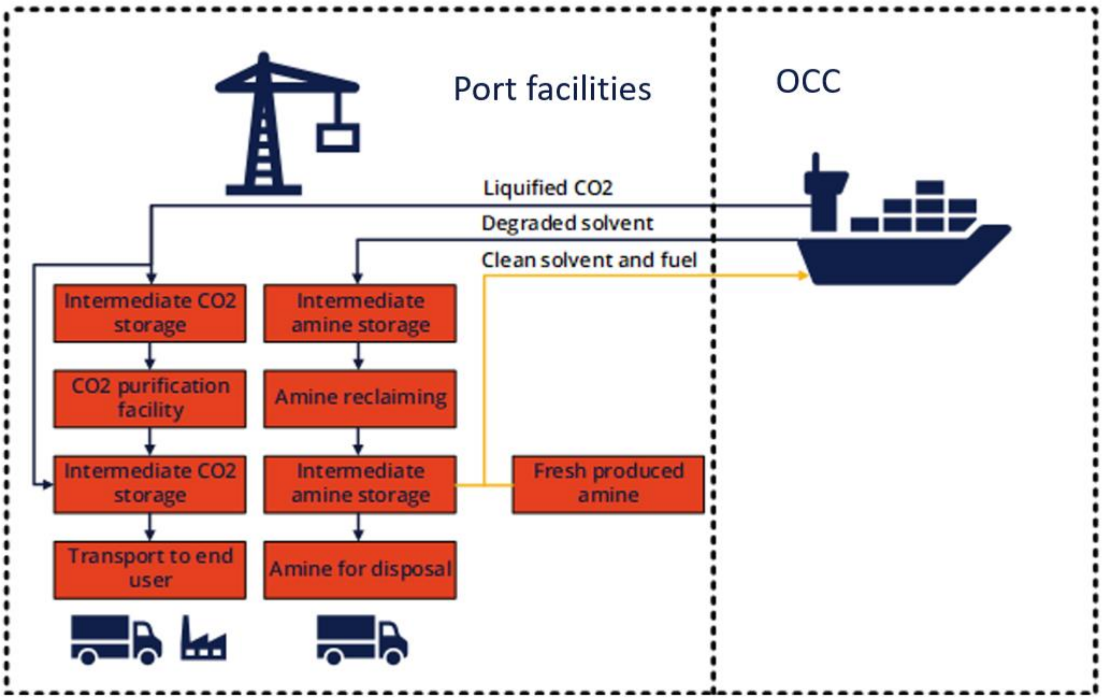

Figure 2: Schematic showing the infrastructure, systems and processes that will likely be needed for successful integration of OCC within port communities

There are three key concerns specific to OCC facilities and services at port: the amount of CO_2 to be handled, the legal classification of that CO_2, and the integration of solvent-handling processes.

3.1.1 CO_2 volumes and intermittency

Compared to large-scale industrial facilities and CCUS networks, which can aggregate larger quantities of CO_2 to produce consistent and reliable streams, an OCC-equipped ship will produce and deliver much smaller and intermittent volumes. This is partly due to the size of vessels but also because shipping routes and schedules can be highly dynamic due to short-term charter

[10] EverLoNG (2025). Various. Available at: https://everlongccus.eu/about-the-project/results

agreements, leading to unpredictability around routes, cargo, and CO_2 volumes. For example, an LNG carrier operating between Houston and Rotterdam is expected to produce approximately 4,900 tCO_2 per 22-day round trip[11], which equates to around 81 $ktCO_2$pa. For comparison, the Hafslund Oslo Celsio energy-from-waste plant in Oslo is expected to send up to 350 $ktCO_2$pa to the Northern Lights project[12], more than four times the volume of CO_2 from this single source. This presents logistical challenges for ports regarding onward transport and storage that will need to be managed. It will also have an impact on cost. Long intervals between port calls, e.g. 11 days, exacerbate this issue, making efficient collection and storage infrastructure essential.

There is another cost implication related to the interplay between the ultimate fate of the CO_2 and how that is influenced and impacted by emissions reduction mechanisms such as the EU ETS, for example. CSIIG workshop discussions suggested that the relatively smaller and intermittent volumes of OCC CO_2 could be more readily, and economically, directed to utilisation (CCU) rather than storage (CCS), e.g. as part of circular carbon economy developments such as the NextGen District Project[13] at the Port of Antwerp-Bruges, where a power-to-methanol project was already underway. This would need to be considered carefully, however, as emissions reduction under the EU ETS can only be realised via geological storage or utilisation where the CO_2 is stored in a manner intended to be permanent[14]. This is likely to significantly narrow the range of potential economically viable CCU options. As with larger emitters producing more reliable streams of CO_2, however, it may also be possible for smaller volumes from OCC to be aggregated before being sent to permanent storage.

3.1.2 CO_2 classification

The CSIIG workshops identified the classification of OCC CO_2 as a key concern. Where CO_2 transported under the terms of the London Protocol for the purposes of geological storage is classified as 'cargo', it appears likely that OCC CO_2, irrespective of its fate, will be classified as ship-based waste at the point of offloading. This was raised by ports as an issue of extreme importance, with the general consensus being that a waste classification would be best avoided, noting that it has the potential to dictate (and complicate) everything downstream in terms of handling permits, processes and procedures, commercial attractiveness, and therefore utilisation potential. To that end, it was suggested that OCC CO_2 may be eligible for an exemption, but this is (at the time of writing) unclear and far from certain. Either way, clarity on the legal status under both maritime policy and land-based policies is vital, as it will shape the entire value chain, including efforts to design the right tax incentives and customs requirements.

3.1.3 Integration of solvent processing

Among the many different capture technologies that might be utilised for OCC, solvent-based technologies are the most mature. The field is characterised by a wide range of options, each with

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[11] Aas, K et al. (2024). *D2.1.2 Full chain cases for SBCC*. Available at : https://everlongccus.eu/index.php/about-the-project/results

[12] NTB Kommunikasjon (2025). *Carbon capture in Oslo becomes a reality!*. Available at: https://kommunikasjon.ntb.no/pressemelding/18397537/carbon-capture-in-oslo-becomes-a-reality?publisherId=17848223&lang=en

[13] Vlaanderen Circulair (2025). *NextGen District Antwerp*. Available at: https://circularports.vlaanderen-circulair.be/cases/nextgent-district-antwerp/

[14] European Commission (2024). *Emissions trading system (ETS) – permanent emissions storage through carbon capture and utilisation*. Available at: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/14135-Emissions-trading-system-ETS-permanent-emissions-storage-through-carbon-capture-and-utilisation_en

distinct properties and operational implications. The EverLoNG project used a first-generation mono-ethanolamine (MEA) solvent. MEA is commonly used in land-based systems and is consequently well-documented and characterised in existing literature. However, as OCC technologies continue to advance, one potential issue that may arise is that different systems could employ different solvents, each with distinct requirements for regeneration, disposal, and maintenance. This variance could affect infrastructure and interoperability, potentially decreasing the number of ports available for vessels to replenish spent solvent.

Solvent handling will be a new activity for ports, and it will bring uncertainty. In the pursuit of more effective and efficient solutions, the selection and management of solvents is a key factor. From a technology development perspective, imposing a 'standard' solvent would be counterproductive and very difficult to implement. On the one hand, giving developers the freedom to select the solvent that best aligns with their specific CCS system requirements and operational contexts is beneficial; on the other hand, it introduces complexity when considering the logistical and infrastructural nuances of solvent handling that would need to take place at ports. Here, the distinction between ships with a consistent home port and those without becomes particularly significant. The former may establish bespoke solvent management systems, enhancing the efficiency and sustainability of their CCS processes. Meanwhile, those without a designated home port may face additional challenges, requiring flexible and resilient solvent handling strategies that accommodate varying port facilities and regulations.

3.2 OCC and CO_2 shipping - cross-cutting issues

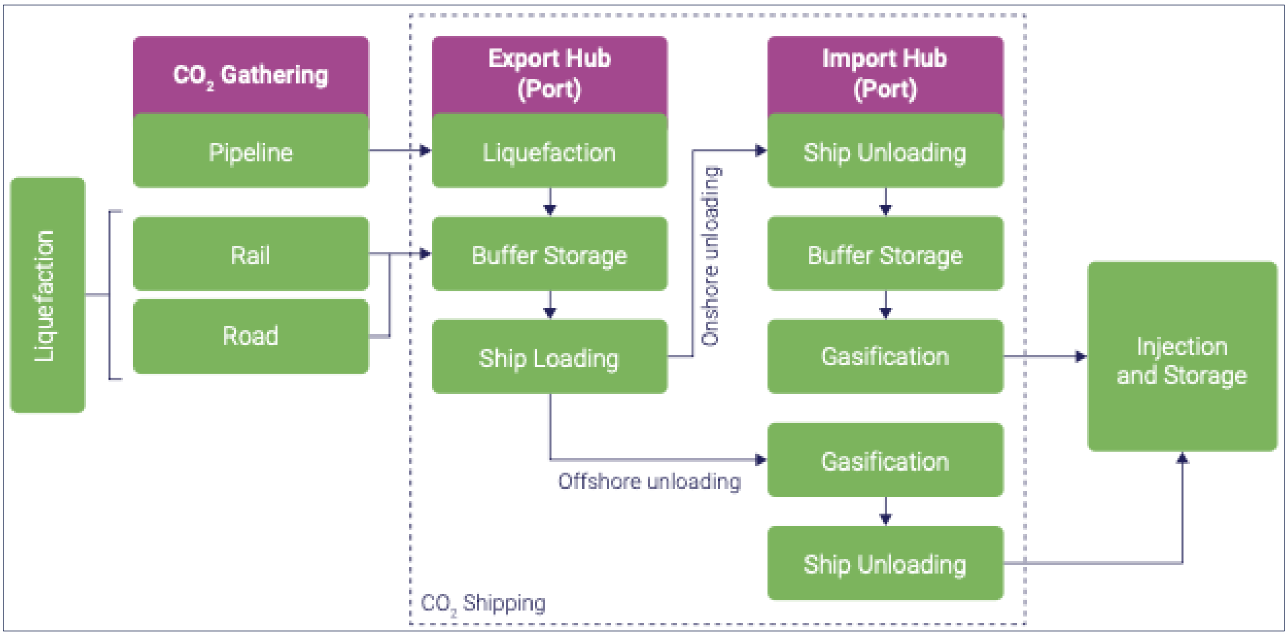

Figure 3: Schematic showing a full CCS value chain and highlighting the infrastructure, systems and processes that will likely be needed for successful integration of CO_2 shipping within port communities (source: *Industrial decarbonisation: getting ready for non-pipeline transport*[15])

3.2.1 Port suitability

The ports most likely to undertake CO_2 handling operations are larger ports aiming to become global CO_2 hubs and those associated with existing or planned CCUS networks. Whether for OCC or CO_2 shipping and whether for export or import operations, such ports will generally require the following:

- Quayside infrastructure/facilities
  - Space available for key infrastructure for loading/offloading, buffer storage, and perhaps CO_2 conditioning (liquefaction)
  - Bunkering facilities
  - Utilities: water and electricity supply, waste removal facilities
- Be able to accommodate suitably sized vessels, and in sufficient numbers, so as to be able to cope with demand

Access to CO_2 infrastructure, such as pipelines, intermediate storage, or transport facilities, is critical for seamless supply chain operations and the successful deployment of OCC. Currently, only a select few ports connected to the food and drink sector[16] or CCUS projects have some of the necessary infrastructure and/or systems already in place, such as the Ports of Sluiskil and Øygarden (Northern Lights) and the Port of Esbjerg (Greensand), though none are currently configured for OCC. Further

[15] UKRI (2024). *Industrial decarbonisation: getting ready for non-pipeline transport*. Available at: https://www.ukri.org/publications/industrial-decarbonisation-getting-ready-for-non-pipeline-transport/
[16] Global Centre for Maritime Decarbonisation (2024). *Concept study to offload onboard captured CO_2*. Available at: https://www.gcformd.org/projects/lco2-offloading-concept-study/

development is required for full OCC deployment. While this is expected to change as large-scale CCUS networks develop, the significant expansion of port facilities and downstream handling networks needed for widespread OCC deployment will necessitate considerable time, planning, and coordination between port authorities, shipping companies, and CO_2 transport and storage operators.

In addition to those ports associated with specific CCUS projects, it is expected that larger ports[17] will take the lead where OCC is concerned. This is predominantly due to their higher throughput and existing facilities and expertise. Large ports are quite simply busier places, seeing more throughput than smaller ones. They are also typically very diverse, with multiple terminals catering to different vessel types and cargo operations. Developing flexible CO_2 reception facilities capable of handling various ship designs, volumes, and offloading intervals that do not disrupt existing operations will be challenging, but these same characteristics offer the opportunity to utilise or adapt existing facilities and expertise, and to develop economies of scale. In particular, larger ports are more likely to have experience and facilities in place for the handling of other liquefied gases, such as LPG and LNG, that share some similarities with LCO_2[18,19], and can thereby provide somewhat of a blueprint for LCO_2 handling operations. As the field then develops, it is expected that smaller ports will also begin to offer OCC services.

3.2.2 CO_2 specification

CO_2 specification is critical to the entire CCUS value chain. Specification standards are currently dictated by large-scale CCUS projects based on the purity requirements for transport infrastructure and geological storage sites. These standards are typically in the public domain[20,21]. They also pose a significant challenge to achieving cost-effective CCUS solutions. The implication for ports is that they may need to consider providing CO_2 conditioning facilities.

3.2.2.1 Standard composition

The composition of CO_2 pertains to the temperature and pressure at which it is transported and the level of impurities that it might contain.

Temperature and pressure are dictated by the amount of CO_2 being transported, the distance being travelled, and to some extent, the cost of construction materials. It is generally accepted that at least two temperature and pressure 'standards' will be suitable - low pressure (LP; approx. 15 barg, -26^{o}C) and medium pressure (MP; approx. 5-10 barg, -55^{o}C to -40^{o}C) - for operations in and around the North Sea region. LP will likely be preferred for transporting over longer distances due to its lower capital (tanks) and operating (energy) costs. With both LP and MP needed, it will not be feasible or advisable for ports to offer facilities or services operating at a single standardised temperature and pressure regime.

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[17] Such as the Port of Rotterdam and Port of Antwerp-Bruges
[18] Global Centre for Maritime Decarbonisation (2024). *Concept study to offload onboard captured CO_2*. Available at: https://www.gcformd.org/projects/lco2-offloading-concept-study/
[19] European Commission JRC Publications Repository (2024). *Shaping the future CO2 transport network for Europe*. Available at: https://publications.jrc.ec.europa.eu/repository/handle/JRC136709
[20] Northern Lights (2024). *Liquid CO_2 (LCO2) Quality Specifications*. Available at: https://norlights.com/wp-content/uploads/2024/06/NorthernLights-GS-co2-spec2024.pdf
[21] Porthos (2021). *Porthos CO_2 Specifications*. Available at: https://www.porthosco2.nl/wp-content/uploads/2021/09/CO2-specifications.pdf

In terms of the chemical composition of the CO_2, or the types and levels of impurities present, however, an agreed standard may indeed be desirable. This is because of the potential for corrosion of infrastructure and handling equipment caused by impurities. CO_2 offloading systems – both OCC and CO_2 shipping – will include vapour equilibrium return lines, critical to balancing mass flows during cargo transfer. These return lines, as well as storage infrastructure, are sensitive to impurities in the CO_2 stream, which differ depending on the specific capture technologies and purification processes employed. These impurities can lead to contamination and corrosion, both of which will be extremely costly[22]. Ports may, therefore, need to consider CO_2 conditioning and purification systems/services. In the case of OCC, this is likely particularly relevant for ports handling multiple ships with different capture technologies and/or fuel types where the co-mingling of different 'flavours' of CO_2 is likely.

Contrary to the above, some companies intend to operate at high pressure, adjusting their operations on a case-by-case basis depending on the specific requirements of a given value chain[23]. This shows that there is likely to be a degree of fluidity across and within operators.

Aiming for a single standard for high-purity CO_2 is generally considered to be unnecessary and counterproductive, incurring higher costs. Still, while some variation is likely and even desirable, that too will have to be within a defined envelope. Costs for ports are likely to be incurred from either the remediation of damage caused by impurities, the extent of which would be unplanned and unknown, or from additional conditioning facilities, which would be both planned and known, i.e. predictable while ensuring seamless operations. Efforts are ongoing to establish CO_2 stream specifications and standardisation through collaboration between the EU and the UK[24].

3.2.2.2 Conditioning

The question as to where CO_2 conditioning should take place is three-fold: where will the facilities be located physically, where in the value chain will this occur, i.e. who will do it, and how will it be done?

In terms of value chain, current T&S projects, e.g. Northern Lights[25], Greensand, and Prinos CO_2[26], place the final conditioning step outside of their business models, thereby placing the responsibility and cost onto emitters. This can be done using fixed facilities at the quayside, as is currently the case for several projects. Alternatively, it can be done via floating CCS infrastructure that includes a final

[22] Riviera (2025). *CO_2 vapour-return strategies face cost and regulatory hurdles*. Available at: https://www.rivieramm.com/news-content-hub/co2-vapor-return-strategies-face-cost-and-regulatory-hurdles-84146

[23] Carbon Collectors will operate a barge system at high pressure and is not aiming for a uniform CO_2 standard. As presented during UKCCSRC public webinar (18/03/25) *European CCUS webinar series - CCUS in the Netherlands*. Available at: https://ukccsrc.ac.uk/european-ccus-webinar-series-2025/

[24] CCSA/ZEP (2024). *Achieving a European market for CO2 transport by ship*. Available at https://zeroemissionsplatform.eu/wp-content/uploads/ZEP_report_HD.pdf

[25] Northern Lights (2025). *How to store CO_2 with Northern Lights*. Available at: https://norlights.com/how-to-store-co2-with-northern-lights/

[26] As presented by Greensand and Prinos CO_2 during Carbon Capture European Summit public webinar (20/03/25) *CCES First Look: Spotlight on Europe's Groundbreaking CCUS Projects*. Available at: https://www.carboncaptureeuropesummit.com/webinar-europe-s-leading-ccus-projects

onboard CO_2 conditioning phase prior to storage, as is the case for the Stella Maris CCS project[27]. In both cases, it is expected that differences in CO_2 quality and/or composition – for post-combustion CO_2 at least; pre-combustion separated CO_2 may present additional challenges – will be dealt with relatively easily using established technologies. For the same reason, it is not necessarily anticipated that separate facilities will be needed for OCC CO_2 and CO_2 from other sources.

While conditioning can, in principle, be done onboard vessels, it is unlikely to be feasible on OCC-equipped ships. This is due to a combination of space restrictions and cost implications for treating the relatively small amounts of CO_2 captured.

Either way, ports will play a crucial role in facilitating these services. This makes sense for several reasons: ports will constitute the last upstream point before the CO_2 enters the final downstream transport and storage (T&S), or utilisation, phase; some ports will become aggregators of CO_2 from various sources and offer temporary buffer storage; and the aforementioned issues related to impurities and co-mingling.

3.2.3 Loading/Offloading[28]

CO_2 can be loaded/offloaded using flexible hoses or fixed loading arms, both of which are well-understood technologies in operation today for handling liquified gases, including CO_2. Individual ISO tanks can also be used, but the use of flexible hoses is the conventional method of conveying liquids from ship-to-terminal (STT) or ship-to-ship (STS), or vice versa. To connect the hoses from the port to the vessel, a system to carry the hoses to the vessel is needed. For this, a crane or derrick is usually used. The connection hoses-manifold requires manpower. A fixed loading arm, as currently used for LPG and LNG, is a mechanical arm of articulated steel pieces that connects to the ship while following the movements of the ship due to changing draft, tide, and wind. A return vent is required to maintain the pressure equilibrium between the ship and quayside storage[29].

3.2.4 CO_2 Liquefaction

For larger ports operating as CCUS hubs, CO_2 is likely to arrive from different sources and via different transport modes. If imported via pipeline, CO_2 is likely to arrive as a gas and will, therefore, need to be liquefied for temporary buffer storage before onward transportation via ship (or road/rail) if it is being exported. Liquefaction facilities will also be required to recover CO_2 boil-off gas from storage and loading operations.

Boil-off recovery will also be needed for CO_2 offloading operations, where, in the case of OCC, LCO_2 is offloaded and temporarily stored before onward transport for either storage or utilisation as part of a larger CCUS network.

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[27] EverLoNG (2023). *Exploring the Future of Sustainable Shipping: Insights from the 2nd CSIIG Workshop*. Available at: https://everlongccus.eu/index.php/ships-log/exploring-future-sustainable-shipping-insights-2nd-csiig-workshop

[28] Skagestad, R. et al. (2024). *CO_2 offloading alternatives and guidelines*. Available at: https://everlongccus.eu/about-the-project/results

[29] Global Centre for Maritime Decarbonisation (2024). *Concept study to offload onboard captured CO_2*. Available at: https://www.gcformd.org/projects/lco2-offloading-concept-study/

3.2.5 Intermediate buffer storage

The amount of buffer storage required will depend on a range of project/site-specific variables, including but not limited to berthing capacity, expected CO_2 volumes, ship capacities, routes, schedules, travel times, and quayside land availability – see Figure 4 below.

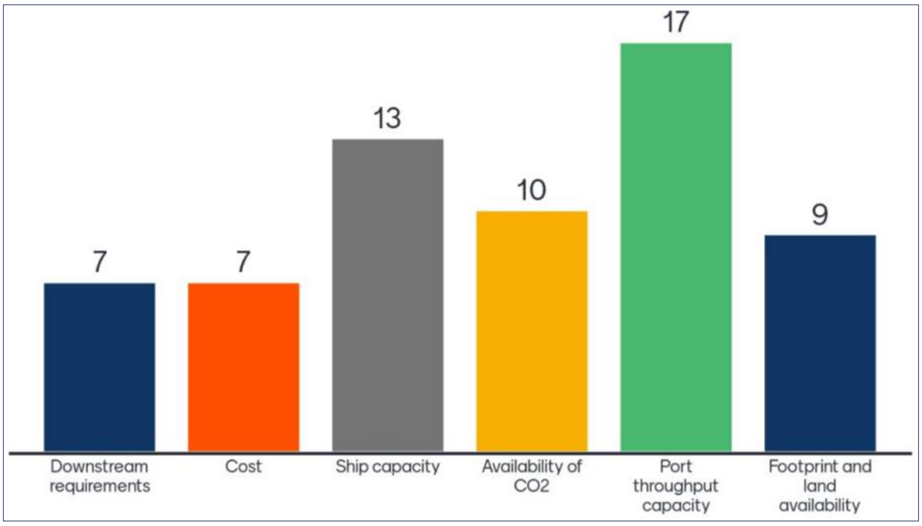

Figure 4: CSIIG#1[30] participant responses to the question *"What do you perceive to be the key criteria that will drive the size of dockside storage? (select up to 3)"*

While estimates vary, a minimum quayside storage capacity of at least 140% of ship capacity has been proposed, with additional capacity recommended where further uncertainties are concerned, and upper estimates suggesting capacities capable of accommodating as much as 3-5 ship cargoes, potentially amounting to as much as 100 kt of buffer storage, will be needed[31].

One way to circumvent space restrictions is to utilise floating storage barges[32], which can be replaced once full, in the same way that skips are used for land-based waste. The Port of Antwerp-Bruges already has a framework in place for STS bunkering of LNG that could, depending on infrastructure deployed, be readily applied to LCO_2. Other LNG-handling ports are very likely to have similar frameworks in place that could also be adapted.

3.2.6 Market and supply chain

While market and supply chain factors are not entirely within the control of port communities seeking to develop CO_2 handling services, ports can play an obvious and important role in forming partnerships with other key stakeholders from across the maritime sector, CCUS, wider industrial sector, and government to shape a way forward. This is particularly true for larger ports with significant industrial bases, given their importance to national economies and their need to decarbonise.

[30] EverLoNG (2023). *Shipping Interoperability Industry Group gets underway*. Available at: https://everlongccus.eu/index.php/ships-log/shipping-interoperability-industry-group-gets-underway

[31] CCSA/ZEP (2024). *Achieving a European market for CO2 transport by ship*. Available at https://zeroemissionsplatform.eu/wp-content/uploads/ZEP_report_HD.pdf

[32] Carbon Collectors (2025). *CO_2 transport and storage: This is how it is done*. Available at: https://carboncollectors.nl/co2-transport-storage/

3.2.6.1 Business models and finance

As is the case with wider CCUS networks, business cases for commercial OCC and CO_2 shipping operations are yet to materialise. The cost of change remains stubbornly high, while the cost of carbon remains too low to incentivise owners and operators into action and so government subsidy is needed to stimulate the market and encourage private (co-)investment. Early investment should be encouraged in order to develop supply chains so that projects will be better able to hit the ground running once the various other facilitating mechanisms are in place.

3.2.6.2 Ship type and availability

Transporting LCO_2 via ship is a proven technology deployed in food-grade and other industrial applications, typically at low or medium pressure (6-15 barg). Some degree of standardisation is desirable for dedicated CO_2 carriers serving large CCUS networks. The Northern Lights project, for example, has already taken delivery of the first of four carriers designed to operate at medium pressure of 15 barg (max. 19 barg) and -26^{o}C (min. -35^{o}C)[33]. It is anticipated that medium pressure will become the norm for vessels of up to 25,000m^3 capacity operating in/around the North Sea region. However, lower pressures (5-10 barg, -55 to -40^{o}C) may be more suitable for longer distances.

The fleet of CO_2 carriers that will be required to service the North Sea region is, of course, yet to be built - a process that can take up to 30 months per ship with current build start waiting times of between 3-4 years. Estimates place the number of ships that will likely be required by 2030 for EU and UK CO_2 shipping operations at between 10-20 purpose-built vessels. Such uncertainty and long lead times present clear challenges for ports in terms of planning for initial CO_2 capacities in a way that also facilitates further expansion once projects become operational and need these services at port.

3.2.7 Safety

The main safety concerns pertain to CO_2 and, specifically for OCC, any hazardous chemicals used in the capturing process, e.g. solvents, which in the case of the EverLoNG project was MEA. CO_2 is an asphyxiating gas processed under pressure and utilises storage systems with high potential energy that can be released in a damage scenario. Solvents may have toxic, flammable, and corrosive properties, to which personnel could be exposed during replenishing work, maintenance, or system leaks. Leakages, either during offloading or replenishing operations, pose a significant safety concern, exacerbated by the fact that such operations can occur near populated areas. In very general terms, there is, therefore, a strong emphasis on appropriate emergency systems, the necessity for port communities to ensure competency and training standards for personnel involved in LCO_2 handling through, for example, structured classroom training sessions, and effective public engagement strategies.

These safety concerns are discussed more fully in the EverLoNG WP5 report *D5.2.3 Risks and safeguards*[34]. For ease of reference, the list of preventative and mitigating measures relevant to CO_2 offloading and hazardous chemicals from that report is repeated here.

[33] Northern Lights (2024). Northern Lights' first CO2 transport ship ready for delivery. Available at: https://norlights.com/news/northern-lights-first-co2-transport-ship-ready-for-delivery/

[34] Leisner, M. (2025). *Risks and safeguards*. Available at: https://everlongccus.eu/about-the-project/results

3.2.7.1 CO_2 preventative measures

- Piping systems used for offloading CO_2 should be designed to minimise the probability of leakages, contain leakages if they occur, and avoid cold surfaces.
- The construction and support of the offloading manifold should be strong enough to prevent damage to the offloading system in a drift-off, where the offloading hose is the only point connecting the ship to the bunkering facility.

3.2.7.2 CO_2 mitigating measures

- The ship's CO_2 offloading station should be arranged to reduce the consequences of a release event as far as possible. This implies preferably locating the offloading station on the open deck. If an open deck arrangement is not possible, the offloading system should be arranged to minimise the need for manned operations and possibly be fitted with additional forced ventilation to dilute minor leakages.
- The CO_2 offloading station should be arranged to withstand the consequences of cold leakages from the offloading arrangements.
- Personnel involved in offloading operations should be outfitted with appropriate personal protective equipment.
- The offloading hose should be arranged to separate the ship and the bunkering facility without releasing CO_2 or overloading the ship or reception facility manifolds.
- The offloading system should be arranged with means to detect leakage and systems to stop the offloading process automatically.
- The offloading system should have a shut-down valve in the offloading station to facilitate the emergency closing of the CO_2 discharge.
- An emergency shut-down communication system should be arranged between the ship and the reception facility.

3.2.7.3 Hazardous chemicals preventative measures

- Piping systems should be designed and arranged to minimise the probability of leakages. This implies using materials that will not be deteriorated by the fluid (e.g. resistant to corrosion, compatible with the chemical), are suitable for the system's design temperature, are arranged and supported to ensure that operational conditions do not cause undue stresses and are connected by welding as far as possible. Where welding is not possible, joining methods are chosen to minimise the probability of leakage.

3.2.7.4 Hazardous chemicals mitigating measures

- Piping systems should be designed to ensure that operational releases from purging, gas freeing and pressure relief are managed safely. This is also applicable for emergency releases due to system leaks and loss of vacuum insulation on tanks and systems.
- Any leaks from tanks and piping systems should be detectable, and it should be possible to isolate the leak point from large reservoirs of the hazardous fluid in question.
- The chemical containment and piping systems should be arranged to contain and drain any leakage.
- Ignition sources should be controlled, leak sources should be adequately shielded, and suitable passive and active fire safety measures should be arranged if the process fluid constitutes a fire risk.
- Spaces containing chemical storage tanks should be arranged with ventilation systems able to dilute chemical leakages and transfer them to a safe discharge in the open air.

- Suitable PPE, operating and maintenance procedures and training should be available to relevant personnel. Eyewash and safety showers should be provided at the appropriate location(s).

3.2.8 Regulation

Regulation and policy surrounding OCC, CO_2 shipping, and wider CCUS networks are still under development. Several of these have already been discussed above: CO_2 composition, solvent requirements, training, and safety. Additionally, there are several important overarching regulatory gaps that are key to influencing how and how quickly OCC as a maritime decarbonisation option and wider CCUS networks and CO_2 markets develop. Bridging these gaps will be vital in providing confidence and certainty to project developers regarding issues such as cross-border movement of CO_2, accountability, liability, and ownership.

3.2.8.1 OCC regulatory gaps[35]

Regulations covering OCC remain limited, but efforts are underway within the IMO and EU towards developing a suitable OCC regulatory framework.

Currently, there are no IMO standards or technical requirements in place, e.g. under MARPOL or other related frameworks. Following the Marine Environment Protection Committee 81 (MEPC 81) in March 2024, however, the IMO is now working to establish an OCC regulatory framework for GHG emissions reduction.

Maritime transport has only recently been included in the EU ETS, beginning in January 2024. The EU ETS also includes provisions under which OCC could be eligible, provided robust MRV processes are in place for both CCS and CCU options. Another relevant aspect of the EU ETS pertains to the vapour equilibrium return process, as discussed in section 3.2.2.1, and boil-off recovery, as discussed in section 3.2.4. The economic implications of any losses incurred combined with issues surrounding ownership of CO_2 under the EU ETS could be significant if not properly accounted for. The EU ETS is likely to require some sort of compensation mechanism to ensure that these do not unduly impede progress[36,37]. Alignment of other ETSs in these regards, i.e. the UK ETS, will also be key.

Fuel EU Maritime does not currently include OCC as an emissions reduction option, though this is expected to change when it is reviewed in 2027; again, MRV processes pending.

Regulatory requirements for OCC should be incorporated consistently into existing relevant regulations, e.g. Energy Efficiency Design Index (EEDI), Efficiency Existing Ship Index (EEXI), Carbon Intensity Indicator (CII), as well as the EU ETS and Fuel EU Maritime.

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[35] DNV (2024). *The potential of onboard carbon capture in shipping*. Available at: https://www.dnv.com/maritime/publications/the-potential-of-onboard-carbon-capture-in-shipping-download/

[36] CCSA/ZEP (2024). *Achieving a European market for CO2 transport by ship*. Available at https://zeroemissionsplatform.eu/wp-content/uploads/ZEP_report_HD.pdf

[37] Riviera (2025). *CO_2 vapour-return strategies face cost and regulatory hurdles*. Available at: https://www.rivieramm.com/news-content-hub/co2-vapor-return-strategies-face-cost-and-regulatory-hurdles-84146

3.2.8.2 CO_2 shipping regulatory gaps[38]

CCUS is a key part of climate policy across the EU, EEA, and the UK, with developments and projects advancing across the region. If CCUS is to reach its full potential, however, a multi-user, cross-border, flexible EU-wide CO_2 T&S network will be essential, and CO_2 shipping will play a key role in making that happen. There is currently no comprehensive legal framework covering all stages of the CCUS value chain, and among those that are relevant to the transportation of CO_2 by ship, there remain a number of important challenges. The major regulatory hurdles are the London Protocol and the UK and EU ETSs, with other potential concerns of liability in the event of accidents.

3.2.8.2.1 London Protocol

The London Protocol prohibits the cross-border transport of waste, including CO_2. However, an amendment to Article 6 was adopted in 2009 that allows for the transboundary export of captured CO_2 for the purposes of permanent storage under the seabed. While this has not yet entered into force due to not having acquired the requisite level of ratification from contracting parties, an interim solution under EU Directive 2009/31/EC (the CCS Directive) encourages bilateral agreements for CCS, but this does not cover CO_2 shipping. This amendment has considerably smoothed the path for CCS in general, to the point where it is generally now considered a purely administrative hurdle. However, work remains to be done to fully include CO_2 shipping.

3.2.8.2.2 EU ETS and UK ETS alignment

Nevertheless, there remains some uncertainty around how the London Protocol will be managed in the event that captured CO_2 is actually transported across borders for geological storage. In terms of CO_2 transported between the EU and the UK, the EU ETS and UK ETS are expected to play an important facilitating role. Alignment between the two systems will be necessary to ensure that CO_2 captured under one regime can be legitimately stored under the other, thereby avoiding the need to surrender allowances in either direction. Given that both systems share a common heritage, it is hoped that this will not prove unduly difficult[39].

3.2.8.2.3 HNS Convention and Limitation of Liability for Maritime Claims

The International Convention on Liability and Compensation for Damage in connection with the Carriage of Hazardous and Noxious Substances by Sea (HNS Convention) was adopted in 2010. It governs liability and compensation in the event of an incident at sea involving hazardous or noxious substances, modelled on the international legal regime applicable to the carriage of oil and gas. Yet to enter into force, due to a low number of ratifications, it will apply to CO_2 carriers, imposing liability on ship owners in the event of an incident at sea. While it applies to CO_2 transport, it remains unclear whether it will prove suitable for the specific purpose of CO_2 shipping in the context of CCUS. Therefore, further amendments may be needed, and stakeholders should be aware of this. Until the HNS Convention enters into force, the Convention on Limitation of Liability for Maritime Claims (LLMC) is expected to apply, implying that progress should continue.

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[38] Argüello, G. et al. (2024). *Transboundary transportation of CO_2 streams by ships: regulatory barriers for scaling up carbon capture and sub-seabed storage.* Frontiers in Marine Science. ORIGINAL RESEARCH article. Front. Mar. Sci., 01 October 2024. Sec. Global Change and the Future Ocean. Volume 11 – 2024. Available at: https://doi.org/10.3389/fmars.2024.1423962

[39] CCSA (2024). *Accelerating a Europe-wide CO2 storage market*. Available at: https://www.xodusgroup.com/media/o2mjjood/ccsa-accelerating-a-europe-wide-co2-storage-market.pdf

4 Conclusions and recommendations

Ports and wider port communities will be key to both OCC and CO_2 shipping in terms of providing and facilitating dedicated and specialised infrastructure, systems and processes to offload and handle CO_2.

The findings presented here highlight a number of key criteria and considerations relevant to the successful integration of OCC and CO_2 shipping within port communities. The challenges described pertain to various aspects under the broad categories of governance, infrastructure, safety, and market, and while some hurdles still need to be overcome, none of them is deemed insurmountable.

For CO_2 handling at ports to become a central component of CCUS networks and general carbon management strategies, significant levels of trust and cooperation between ports, ship owners, technology developers, storage hubs, governments, and regulators will be crucial. This high degree of collaboration is reflected in the recommendations below.

The overarching recommendation is to collaborate with as many key stakeholders as possible, including (but not limited to) shipbuilders, ship owners/operators, technology providers, third-party CO_2 handling providers, OCC demonstration/pilot projects, CCUS developers and wider networks, regulatory bodies and flag states. This collaboration should focus on monitoring OCC and CO_2 shipping deployment to plan and develop appropriate infrastructure and/or associated services.

This will likely include forming groups or consortia for the purpose of assessing port readiness levels for CO_2. The EverLoNG PRT-CO_2 is specifically designed for this purpose. Recommended activities to be undertaken include (but are not limited to) the following:

4.1 OCC

- Engage with potential OCC CO_2 off-takers, including both CCS and CCU.
- Engage with third-party CO_2 handling providers on the potential to centrally aggregate OCC CO_2.
- Engage with the IMO and other relevant national regulatory bodies, including tax and customs, regarding OCC CO_2 classification.
- Engage with land-based CCUS projects and developers on solvent handling/processing for knowledge/expertise sharing.

4.2 OCC & CO_2 shipping

- Engage with other ports looking into OCC and CO_2 shipping to pool resources and share knowledge.
- Bring in smaller ports to build a knowledge/expertise-sharing network and pipeline of potential OCC/CO_2 shipping hubs.
- Engage with land-based CCUS projects and developers to monitor developments and identify CO_2 shipping opportunities.
- Engage with existing LCO_2 handling providers.

- Engage with regulatory processes to influence and monitor developments and advocate for consistent integration into existing regulatory frameworks and indices.
- Engage with financial mechanisms, such as EU ETS, UK ETS and insurance to ensure secure and timely development and scale-up.
- Explore funding mechanisms established by the EU, e.g. Innovation Fund, Connecting Europe Facility, Projects of Common Interest) and national government schemes.

This report summarises the activities undertaken and the key findings from the broader port readiness exercise conducted under Work Package (WP) 2 *Task 2.2 CO_2 shipping interoperability and port readiness*.

The findings and recommendations presented herein directly informed the Port Readiness Tool for CO_2 (PRT-CO_2).

This report is intended as an accompaniment to be used in conjunction with the PRT-CO_2.

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