Port Readiness Tool for CO_2 (PRT-CO_2)

Port Readiness Level Assessment Tool for OCC Offloading and CO_2 Transport by Ship

Deliverable ID: D2.2.5

Author: Dr Erika Palfi, Richard L Stevenson, Dr Philippa J M Parmiter

Release Status: FINAL

Dissemination level: Public

Date: 09 May 2025

Filename and version: D2.2.5_Port_Readiness_Tool_PRT-CO2_v1.5_FINAL_PUBLIC

The EverLoNG project is funded through the ACT programme (Accelerating CCS Technologies, Horizon2020 Project No 691712). Financial contributions have been made by the Ministry of Economic Affairs and Climate Policy, the Netherlands; The Federal Ministry for Economic Affairs and Climate Action, Germany; the Research Council of Norway; the Department for Business, Energy & Industrial Strategy, UK; and the U.S. Department of Energy. All funders are gratefully acknowledged.

Document History

This document is stored in the following location:

Filename	D2.2.5_Port_Readiness_Tool_PRT-CO2_v1.5_FINAL_PUBLIC
Location	EverLoNG SharePoint / WP2

Revision History

This document has been through the following revisions:

Version No.	Revision Date	Filename	Brief Summary of Changes
V1.4	03/04/25	D2.2.5_Port_Readiness_Tool_PRT-CO2_v1.4	Implemented changes following ML and RS feedback, including list of abbreviations
V1.3	09/05/25	D2.2.5_Port_Readiness_Tool_PRT-CO2_v1.3	Incorporated IAPH feedback

Authorisation

This document requires the following approvals:

AUTHORISATION	Name	Signature	Date
WP Leader	Ragnhild Skagestad		09/05/25
Project Coordinator	Marco Linders		09/05/25

© EverLoNG Project, 2025

No third-party textual or artistic material is included in the publication without the copyright holder's prior consent to further dissemination by other third parties.

Reproduction is authorised provided the source is acknowledged.

Disclaimer

The information and views set out in this publication are those of the author(s) and do not necessarily reflect the official opinion of the Funders. Neither the Funders and bodies nor any person acting on their behalf may be held responsible for the use which may be made of the information contained therein.

Executive summary

The maritime sector faces increasing pressure to reduce greenhouse gas (GHG) emissions in alignment with international climate goals, such as those outlined in the Paris Agreement. Currently, shipping contributes approximately 3% of global anthropogenic CO_2 emissions; and this figure is expected to rise without effective intervention. Consequently, the sector has pledged to reach net zero emissions by 2050.

Among the measures being developed to address this challenge is Onboard Carbon Capture (OCC), a technological solution that captures CO_2 emissions directly from a ship's exhaust system during operation. This allows existing vessels to reduce their carbon footprint without requiring a shift to nascent zero-emission fuels. Additionally, CO_2 transport by ship 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 Port Readiness Tool for OCC and CO_2 Transport (PRT-CO_2) builds on the established Port Readiness Level for Marine Fuels assessment tool (PRL-MF) developed by the World Port Climate Action Program (WPCAP) in conjunction with the International Association of Ports and Harbors' (IAPH) PRL working group. 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 transport by ship while aligning with industry expectations.

The tool specifically assists port authorities and stakeholders:

- Evaluate readiness for OCC offloading and CO_2 transport by ship;
- Identify infrastructure and capability gaps;
- Align with safety and regulatory standards;
- Facilitate integration into broader CCUS networks;
- Support collaboration across port communities, operators, and policymakers.

The PRT-CO_2 is a presentation of the results of a research exercise that seeks to make a contribution to furthering progress in the area of CO_2 handling at ports. It does not claim to be comprehensive or exhaustive, but is rather intended as more of a 'live' 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 use. Indeed, IAPH is currently considering how it might be integrated into its own workstreams and activities.

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 way. 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.

Table of Contents

List of abbreviations

AI	Artificial Intelligence
CAPEX	Capital expense
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilisation
CCUS	Carbon Capture Utilisation and Storage
CFD	Computational Fluid Dynamics
CMF	International Association of Ports and Harbors' Clean Marine Fuels group
CO_2	Carbon dioxide
CSIIG	CO_2 Shipping Interoperability and Industry Group
FID	Final Investment Decision
FSU	Floating Storage Unit
GHG	Greenhouse gas
HAZID	Hazard Identification study
HAZOP	Hazard and Operability study
IAPH	International Association of Ports and Harbors
IMDG	International Maritime Dangerous Goods Code
IMO	International Maritime Organization
IT	Information Technology
$JPCO_2SO$	Joint plan of CO_2 shipping operations
JPOCCOO	Joint plan of OCC offloading operations
LCA	Life Cycle Assessment
LNG	Liquefied Natural Gas
MARPOL	The International Convention for the Prevention of Pollution from Ships
OCC	Onboard Carbon Capture
OPEX	Operating expense
PDCA	Plan, do, check, act framework
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
QRA	Quantitative Risk Assessment
SIMOPS	Simultaneous Operations
STS	Ship-to-ship
STT	Ship-to-truck
TEA	Techno-Economic Analysis
VTM	Vessel Traffic Management
VTMS	Vessel Traffic Management System
VTS	Vessel Traffic Services
WP	Work Package
WPCAP	World Ports Climate Action Program

1 The Port Readiness Tool for OCC Offloading and CO_2 Transport by Ship (PRT-CO_2)

The maritime sector faces increasing pressure to reduce greenhouse gas (GHG) emissions in alignment with international climate goals, such as those outlined in the Paris Agreement. Currently, shipping contributes approximately 3% of global anthropogenic CO_2 emissions; a figure expected to rise without effective intervention. Consequently, the sector has pledged to reach net zero emissions by 2050[1].

Among the measures being developed to address this challenge is Onboard Carbon Capture (OCC), a technological solution that captures CO_2 emissions directly from a ship's exhaust system during operation. This allows existing vessels to reduce their carbon footprint without requiring a shift to nascent zero-emission fuels. Additionally, CO_2 transport by ship 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.

In contrast, transporting captured CO_2 by ship does not contribute to reducing emissions from the shipping sector itself per se. Instead, it plays a vital role in enabling wider CCUS networks by providing a flexible and scalable method for transporting CO_2 from industrial emitters to storage sites or utilisation facilities. Ports equipped for CO_2 transport by ship are integral to this process, forming essential nodes within the infrastructure required to decarbonise other sectors.

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 Port Readiness Tool for OCC and CO_2 Transport (PRT-CO_2) was developed as part of the broader port readiness exercise conducted under Work Package (WP) 2 Task 2.2 CO_2 shipping interoperability and port readiness. The PRT-CO_2 builds on the established Port Readiness Level for Marine Fuels assessment tool (PRL-MF) developed by the World Port Climate Action Program (WPCAP) in conjunction with the International Association of Ports and Harbors' (IAPH) PRL working group[2]. 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 transport by ship while aligning with industry expectations. At the time of writing, the PRT-CO_2 was yet to be comprehensively reviewed and assessed by ports.

[1] International Maritime Organization (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

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

The primary objectives of this tool include:

- Evaluating a port's readiness to support OCC offloading and CO_2 transport by ship operations.
- Identifying gaps in infrastructure, such as offloading systems, CO_2 storage capacity, and scalability.
- Supporting adherence to safety and regulatory standards specific to CO_2 handling.
- Facilitating integration into regional and international CCUS networks.
- Providing flexibility to accommodate the diverse requirements of OCC and CO_2 transport by ship operations.

By addressing these factors, this tool aims to support ports in both decarbonising the shipping sector through OCC and enabling emission reductions across other industries by participating in the growing CO_2 transport by ship market.

1.1 PRT-CO_2 Overview

1.1.1 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. Onboard Carbon Capture (OCC) offloading, which directly addresses emissions reduction from ships by enabling the offloading and handling of captured CO_2.
2. CO_2 transport by ship, which facilitates the development of carbon capture utilisation and storage (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 not designed as a one-size-fits-all solution. Instead, it allows ports to select their area of focus - either OCC offloading, CO_2 transport by ship, or both - and to tailor the assessment to their specific needs. This dual-path structure enables ports to focus resources on the operational stream that aligns with their strategic priorities, evaluate infrastructure and planning gaps specific to OCC or CO_2 transport, and support collaborative efforts with stakeholders, regulators, and CCUS networks.

1.1.2 How was the PRT-CO_2 developed?

The structure of the PRT-CO_2 is based on the widely recognised Port Readiness Level for Marine Fuels (PRL-MF) framework developed by the World Port Climate Action Program (WPCAP) in conjunction with the International Association of Ports and Harbors' (IAPH) PRL working group. While focused on marine fuels, the overarching PRL-MF framework is also well suited to the application of CO_2 handling at ports.

Content for the PRT-CO_2 was gleaned from a combination of an extensive literature survey of publicly available material, targeted stakeholder engagement, including via the EverLoNG CO_2 Shipping Interoperability and Industry Group (CSIIG) online workshops, and work undertaken as part of other EverLoNG work packages. In order to show exactly how CO_2 has been 'mapped' onto the existing PRL-MF framework, the original PRL-MF text is retained here as standard blue font with CO_2 additions shown in green font – see Figure 1.

- **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

By adopting the existing structure of the PRL-MF in this way, the PRT-CO_2 framework ensures ease of use for ports already familiar with the PRL-MF methodology while addressing the unique technical, operational, and regulatory challenges associated with OCC and CO_2 transport.

The PRT-CO_2 is a presentation of the results of a research exercise that seeks to make a contribution to furthering progress in the area of CO_2 handling at ports. It does not claim to be comprehensive or exhaustive, but is rather intended as more of a 'live' 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 use. At the time of writing, the PRT-CO_2 was yet to be comprehensively reviewed and assessed by ports. IAPH is, however, currently considering how it might be integrated into its activities.

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 way. 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.

1.1.3 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, to assess infrastructure and operational gaps; ship operators and customers, to understand the port's capabilities for OCC offloading or CO_2 transport; regulatory authorities, to ensure compliance with safety, environmental, and operational standards; regional first responders and safety teams, to address risks associated with handling CO_2; and stakeholders in CCUS networks, to coordinate with ports for effective integration into carbon storage and transport systems.

The tool is designed to accommodate varying port sizes and configurations. Smaller ports or those with limited resources can focus on incremental improvements, while larger ports can implement advanced systems tailored to their operations. Tasks within the framework can be completed by individual entities or through collaboration among multiple stakeholders.

The PRT-CO_2 is not prescriptive, allowing for a high degree of flexibility and optionality. Ports are encouraged to document decisions about tasks or strategies deemed optional, infeasible, or irrelevant. This ensures transparency for stakeholders and allows ports to focus on areas with the most significant potential impact. By adopting this tool, ports can strategically position themselves to support the maritime industry's decarbonisation goals through OCC while also contributing to the development of CCUS networks by facilitating CO_2 transport.

The PRT-CO_2 should be used in conjunction with the accompanying report ***D2.2.6 Port Readiness for CO_2***, as well as other WP2 outputs, owing to the overlapping nature of the work undertaken across WP2.

2 PRT-CO_2 Structure and Checklist

The PRT-CO_2 is organised into three phases: Research, Development, and Deployment. These phases are further divided into nine distinct Port Readiness Levels for CO_2 (PRL-CO_2), providing a structured roadmap for ports to evaluate and improve their readiness for either OCC offloading, CO_2 transport by ship, or both. Each phase builds on the insights and progress of the previous one, ensuring a logical progression from feasibility studies to full-scale operations. The structure is designed to be adaptable to ports of varying sizes and operational capacities, allowing each port to chart a tailored pathway to CO_2 handling readiness.

The framework is a checklist that identifies key tasks, strategies, and milestones for each readiness level. This structured approach provides ports with a practical tool for assessing their current status and planning their next steps while ensuring alignment with industry standards and stakeholder expectations.

The Research Phase focuses on laying the groundwork for informed decision-making. During this phase, port communities examine the relevance of OCC and CO_2 transport to their operations and strategic goals. Feasibility studies are conducted to evaluate the technical, operational, and financial requirements of the chosen activities. Engagement with stakeholders, including shipping operators, CCUS network participants, and regulators, is a critical part of this phase to gauge interest, gather input, and identify initial opportunities and challenges.

The Development Phase builds on the research findings by moving from theoretical planning to tangible actions. This phase involves drafting detailed frameworks for OCC and/or CO_2 transport operations, including technical designs, safety protocols, and operational procedures. Pilot projects are implemented to test the feasibility and functionality of these frameworks under controlled conditions. This phase also involves establishing initial infrastructure, such as offloading systems and storage facilities, while refining strategies based on feedback and lessons learned from pilot operations.

The Deployment Phase marks the transition to fully integrated operations. Ports scale up their capabilities, transitioning from project-based approaches to routine activities embedded in the port's standard operations. This phase ensures that ports can handle OCC offloading or CO_2 transport at commercial levels, with systems in place to manage larger volumes and more frequent operations. Collaboration with industry stakeholders becomes critical to align the port's activities with broader market and policy developments, such as green corridor initiatives or expanding CCUS networks. By the end of this phase, ports will achieve full readiness, positioning themselves as key contributors to the decarbonisation of the maritime sector and the advancement of global CCUS efforts.

As ports progress through these phases, the framework supports the creation of a roadmap that outlines a clear timeline for achieving readiness. This roadmap identifies specific milestones for OCC offloading and/or CO_2 transport operations, ensuring alignment with long-term strategic goals. It also enables ports to share their readiness progress with stakeholders, fostering informed decision-

making for investments in infrastructure, ships, equipment, and planning. Beyond its practical applications, the roadmap is a communication platform that promotes transparency and collaboration among stakeholders, ensuring alignment and building confidence in the port's ambitions and capabilities.

2.1 How does the PRT-CO_2 work?

The framework consists of a structured checklist that guides port communities through the following:

- Phase 1 - Research: Ports assess the potential relevance of OCC or CO_2 transport, 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 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.

2.2 Port Readiness Levels (PRL-CO_2)

Table 1 outlines the nine Port Readiness Levels (PRL-CO_2) within the PRT-CO_2 framework. Each level is divided into tasks and objectives specific to OCC offloading and CO_2 transport by ship. This structure ensures a clear progression from foundational research to full deployment.

Levels 1–3 (Research Phase): These levels focus on foundational research, identifying feasibility, and engaging with stakeholders. OCC activities centre on understanding the technology and how it fits with port operations, while CO_2 transport tasks involve analysing market demands and proximity to CCUS networks.

Levels 4–6 (Development Phase): These levels transition from planning to action. OCC and CO_2 transport frameworks are drafted and tested through pilot projects. Infrastructure and technical systems are established and validated.

Levels 7–9 (Deployment Phase): These levels focus on scaling up operations and integrating them into regular port activities. Ports establish commercial systems, expand infrastructure, and align with industry initiatives like green corridors.

Readiness Level	Phase	OCC Offloading	CO_2 Transport
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 Transport by ship

3 Port Readiness Level Assessment Checklist (PRL-CO_2) for Ports

3.1 PRL-CO_2 for OCC Offloading

Level 1: Foundational background information on OCC offloading technologies and processes

Level 1 Objective: To gather pertinent background information that will help to form the foundation of research and inform decisions moving forward.

- Domain: Governance

Strategies, tasks and measures:

- ☐ Research present and upcoming regulations and incentives regarding shipping decarbonisation, including:
  - o International regulations and incentives, such as MARPOL Annex VI,
  - o National regulations and incentives, and
  - o Regional and local regulations and incentives.
- ☐ Research the maturity or technical readiness of the different OCC offloading approaches/ technologies.
- ☐ Identify relevant port and industry stakeholders and create an open means for communication (e.g., commercial port operators, vessel operators, port authorities, port oversight commissions, etc.).
- ☐ Investigate means to assess public opinions and perceptions from surrounding communities regarding OCC offloading implementation at the port.

Optional tasks and considerations:

- ☐ Assess (port-wide) emissions targets and how the introduction of OCC offloading could contribute to achieving those goals.
- ☐ Research the environmental attributes and the benefits of OCC offloading technology adoption.

- Domain: Safety

Strategies, tasks and measures:

- ☐ Research safety requirements necessary for ports to support OCC offloading.
- ☐ Research and understand present national/international safety regulations for CO_2 handling and cryogenic systems.

- ☐ Identify regulatory authorities involved in safety oversight at the port and create an open means for communication (e.g., local, regional, and national government authorities; port authorities, safety agencies, environmental agencies, etc.).

Optional tasks and considerations:

- ☐ Explore opportunities to collaborate with emergency response teams to enhance preparedness.
- ☐ Investigate best practices for safety in handling cryogenic CO_2.

- 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.
- ☐ Identify space availability for potential OCC-related infrastructure, including solvent handling systems and temporary CO_2 storage facilities.
- ☐ Research technical requirements for connecting OCC equipment to port systems (e.g., pipelines, berths).

Optional tasks and considerations:

- ☐ Assess the availability of space in the port for future expansions or upgrades to accommodate OCC-related operations.

- Domain: Market, supply/demand

Strategies, tasks and measures:

- ☐ Asses the basic commercial potential to become a port for OCC offloading.
- ☐ Engage with shipping companies to evaluate interest and feasibility for OCC offloading services.
- ☐ Conduct a preliminary economic analysis of integrating OCC offloading infrastructure into port operations.

Optional tasks and considerations:

- ☐ Investigate anticipated trends in OCC technology adoption and its impact on shipping.
- ☐ Investigate anticipated supply and demand of OCC offloading.
- ☐ Explore funding opportunities to support OCC infrastructure development.

Level 1 objective achieved: ☐ Confirmed

Sufficient background information is gathered to be able to form the foundation of research and decisions moving forward:

- ☐ Information is gathered about OCC options and energy transition within shipping.
- ☐ OCC technology is assessed to identify aspects that might be safety-related showstoppers.
- ☐ The basic potential to become an OCC offloading port with infrastructure is assessed.
- ☐ The basic commercial potential to become an OCC offloading port is assessed.

The strategies, tasks and measures of the domains within level 2 are being prepared.

Level 2: Stakeholder interest and feasibility assessment for OCC

Level 2 Objective: to assess the eagerness of stakeholders to pursue added capabilities for OCC operations at the port and gather information on the physical and market feasibility of these operations.

The strategies, tasks and measures of the domains in level 1 have been evaluated and lessons learned are implemented.

- Domain: Governance

Strategies, tasks and measures:

- ☐ Assess the opinions and support of relevant port and industry stakeholders for shipping decarbonisation and OCC.
- ☐ Provide stakeholders with the background information gathered in Level 1 and assess their interest in investing in OCC.
- ☐ Assess stakeholders' perceived feasibility for entering the OCC market.
- ☐ Implement strategies for assessing public opinion on adding OCC capabilities at the port.

Optional task and considerations:

- ☐ Include green corridor stakeholders in discussions and assessments for OCC.
- ☐ Explore how OCC implementation aligns with international and national decarbonisation goals.

- Domain: Safety

Strategies, tasks and measures:

- ☐ Assess the budget and resources available for establishing a port-specific safety framework for OCC.
- ☐ Acquaint relevant safety and environmental authorities with market trends in OCC and make them aware of its potential growth.
- ☐ Create a network to involve all authorities and key players in the development of a safety framework.

Optional task and considerations:

- ☐ Evaluate potential partnerships with emergency services to enhance OCC safety preparedness.
- ☐ Research safety protocols from other cryogenic industries to inform OCC practices.

- Domain: Infrastructure

Strategies, tasks and measures:

- ☐ Assess the physical feasibility of facilitating vessels using OCC systems in the port.
- ☐ Identify infrastructure needs for OCC offloading, solvent storage, solvent regeneration facilities and temporary storage of captured CO_2.
- ☐ Assess currently available port infrastructure, mainly focusing on its capacity to handle CO_2 and solvent-related operations.
- ☐ Evaluate the availability and status of CO_2 and solvents as commodities within the port, considering existing supply chains and storage facilities.
- ☐ Evaluate the physical feasibility of creating designated areas for OCC operations and/or for establishing enough distance between the bunkering of the captured/ temporary stored CO_2 and solvent storage and regeneration to vulnerable areas.

Optional tasks and considerations:

- ☐ Investigate synergies between OCC infrastructure and other port decarbonisation initiatives.
- ☐ Assess spatial requirements for solvent handling and CO_2 storage.

- Domain: Market, supply/demand

Strategies, tasks and measures:

- ☐ Assess stakeholders' perceived feasibility for entering the OCC market.
- ☐ Acquaint relevant port stakeholders with the OCC value chain from well to wake and its commercial potential.
- ☐ Conduct initial financial modelling to understand costs and revenue opportunities for OCC infrastructure.

Optional tasks and considerations:

- ☐ Create a coalition of stakeholders to establish the OCC value chain.
- ☐ Ensure stakeholders in the OCC market are equipped to stay informed on the future OCC market conditions and will have the information necessary to balance demand and supply.
- ☐ Identify potential commercial partnerships related to vessels equipped with OCC systems, such as shipping companies, technology providers, and regional CCUS stakeholders.
- ☐ Identify potential incentives (e.g., reduced fees, priority berthing, or financial support for pilot projects) to attract OCC-equipped vessels.

Level 2 objective achieved: ☐ **Confirmed**

The interest of stakeholders in pursuing OCC offloading and CO_2 storage has been assessed. There is sufficient insight into the feasibility of adding OCC offloading capabilities at the port.

- ☐ The port has sufficient insight into the OCC value chain stakeholder strategies for OCC operation.
- ☐ The port has sufficient insight, budget and resources to develop a safety framework for OCC operation/ offloading.
- ☐ The port has sufficient insight into the present infrastructure and the gaps for future needed infrastructure to know if it can facilitate OCC offloading.
- ☐ The port is acquainted with the opportunities for the port's stakeholders to enter the new market.

The strategies, tasks and measures of the domains within level 3 are being prepared.

Level 3: Detailed research, analysis, and conclusions on OCC readiness

Level 3 Objective: Gather detailed information on all pertinent aspects of OCC offloading and CO_2 and solvent storage so that an informed decision on moving forward with OCC offloading operations can be made.

The strategies, tasks and measures of the domains in level 2 have been evaluated, and lessons learned are implemented.

- Domain: Governance

Strategies, tasks and measures:

- ☐ Develop an initial policy framework for OCC integration into port operations.
- ☐ Establish governance structures and assign responsibilities for regulatory compliance.
- ☐ Define legal and administrative requirements for OCC offloading operations.
- ☐ Initiate discussions with policymakers to develop clear regulatory pathways for OCC adoption.

Optional tasks and considerations:

- ☐ Consult research reports and scientific papers to supplement information gathered.
- ☐ Recruit relevant port stakeholders to participate in research programs, consortiums, and partnerships to supplement information and gather knowledge.
- ☐ Collaborate with policymakers to refine OCC regulations at national and international levels.
- ☐ Explore potential incentives to encourage shipping companies to adopt OCC solutions.
- ☐ Assess legal precedents from early adopters of OCC technologies.

- Domain: Safety

Strategies, tasks and measures:

- ☐ Develop port-specific safety guidelines for handling CO_2 offloaded from OCC systems. Conduct risk assessments focusing on cryogenic handling and solvent storage and establish emergency response protocols in collaboration with relevant authorities. The necessary aspects should be based on information previously gathered, including relevant safety standards, regulations, and industry best practices.
- ☐ Develop and distribute OCC safety manuals tailored for port staff and stakeholders.

Optional tasks and considerations:

- ☐ Design safety drills and training programmes for port personnel and emergency responders.

- ☐ Assess best practices from other industrial applications of cryogenic CO_2 handling.
- ☐ Investigate third-party safety certification requirements for OCC operations.

- Domain: Infrastructure

Strategies, tasks and measures:

- ☐ Research the exact infrastructure demand and the scale required for OCC offloading and CO_2 storage at the commercial level.
- ☐ Identify necessary modifications to existing port infrastructure to accommodate OCC operations.
- ☐ Engage with technology providers to define technical specifications for OCC offloading facilities.
- ☐ Assess long-term storage requirements for CO_2 offloaded from OCC.

Optional tasks and considerations:

- ☐ Explore flexible infrastructure solutions that allow integration with future decarbonisation technologies.
- ☐ Consider temporary or modular storage solutions for initial pilot projects.
- ☐ Investigate potential partnerships to co-develop OCC offloading infrastructure.

- Domain: Market, supply/demand

Strategies, tasks and measures:

- ☐ Research detailed costs, including capital expenses (CAPEX) and operating expenses (OPEX) for OCC offloading.
- ☐ Establish business models and cost structures for OCC offloading services.
- ☐ Identify potential customers and investors for OCC operations.
- ☐ Develop financial frameworks for revenue generation and cost recovery.
- ☐ Assess demand projections for OCC offloading services in the region.

Optional tasks and considerations:

- ☐ Investigate co-financing models involving industry and public sector stakeholders.
- ☐ Explore potential synergies with carbon credit markets.
- ☐ Provide an update to relevant green corridor projects or proposals on the research conclusions and decision to move forward.
- ☐ Develop strategies to integrate OCC into green shipping initiatives.

Level 3 objective achieved: ☐ Confirmed

Based on sufficient information about all aspects needed, the port decided whether the port can support OCC offloading and CO_2 and solvent storage or will halt progress on OCC operations.

- ☐ The port has sufficient information to develop a policy and roadmap for OCC offloading operations.
- ☐ All safety requirements and infrastructure demands can be met by the port to supply OCC offloading options.
- ☐ The port has sufficient information on the necessary infrastructure and space for OCC offloading.
- ☐ Research showed that the market availability of the target fuel meets the port's demands and that costs will not be prohibitive in moving forward.

The strategies, tasks and measures of the domains within level 4 are being prepared.

Level 4: Roadmap to proceed, framework and timeline developed

Level 4 Objective: Announce proceeding with a plan or roadmap to facilitate the offloading of CO_2 from vessels equipped with OCC systems and develop a detailed framework and timeline to serve as the guiding document for integrating OCC into port operations.

The strategies, tasks and measures of the domains in level 3 have been evaluated, and lessons learned are implemented.

- Domain: Governance

Strategies, tasks and measures:

- ☐ Draft a publicly available position or policy paper explaining the port's decision to proceed or halt with OCC offloading services.
- ☐ Create a firm PRL-CO_2 schedule, including present standing and future ambitions for OCC offloading services within the port and communicate it publicly.
- ☐ Begin drafting the foundational framework that will serve as the guiding document for proceeding with OCC offloading. The framework should include protocols for vessels and/or any of the following offloading scenarios deemed relevant at the port: ship-to-shore transfer, ship-to-ship transfer, containerised CO_2 offloading, or integration with existing port infrastructure for CO_2 handling.
- ☐ Implement the policy framework developed in Level 3 to ensure OCC integration into port operations.
- ☐ Establish regulatory reporting mechanisms for OCC offloading activities.
- ☐ Conduct legal and administrative approvals for OCC offloading trials.
- ☐ Engage stakeholders in finalising operational guidelines for pilot OCC offloading.
- ☐ Develop a collaborative working group to oversee the pilot implementation phase.
- ☐ Establish cross-border collaboration frameworks for regulatory consistency in OCC offloading if operations span multiple jurisdictions.
- ☐ Draft a thorough engagement and communication plan for stakeholders, regulatory authorities, the press, and the public. This may include:
  - o A strategy to manage the expectations of stakeholders.
  - o A plan to disseminate transparent information, including pros and cons, to the public.
  - o A frequently asked questions (FAQs) list to help inform relevant parties.
  - o A streamlined and easily accessible feedback submission tool for parties to submit comments and feedback.
  - o A robust system of communication amongst key players, including stakeholders in the offloading value chain, port authorities, regulatory authorities, etc.
  - o Relevant communication and publication tools such as a website, flyers, or one-pagers.

Optional tasks and considerations:

- ☐ Include the following in the foundational framework:
  - o A detailed strategy for monitoring the environmental impact of OCC implementation, including GHG emissions and air quality in the port. This may include tracking the volume of CO_2 captured and offloaded, as well as comparing net emissions reductions against conventional ship exhaust emissions.
  - o A strategy to set up green corridors and other coalitions that include the whole port value chain.
- ☐ Establish regular stakeholder meetings to monitor progress and address regulatory gaps.
- ☐ Explore public-private partnerships for OCC pilot funding.
- ☐ Define public engagement benchmarks to ensure that stakeholder involvement continues throughout implementation rather than being limited to early phases.

- Domain: Safety

Strategies, tasks and measures:

- ☐ Draft an in-depth safety and regulatory framework produced in concert with all relevant regulatory and safety authorities. This may include:
  - o A plan to conduct HAZID and HAZOP studies to inform risk mitigation measures and safety procedures.
  - o A review of all safety aspects and requirements researched in PRL-CO_2 1 through 3 with associated implementation plans for the necessary elements.
  - o Incident response management that includes clear delegation of responsibilities, scenarios and training of incident responders and port health organisations, and proper response equipment.
  - o An initial boundary or limitation to guide where safety frameworks, based on QRA (Quantitative Risk Assessment) and, vapour/gas dispersion studies to set control zones, need to be developed. The boundary should include any areas where OCC offloading activities could potentially take place and exclude any areas where OCC offloading activities will absolutely not take place.
  - o A plan to conduct credible spill scenarios and dispersion studies to help inform control, safety, and exclusion zones.
  - o A plan to conduct a port-specific risk assessment and spatial analysis that will guide control zoning for OCC offloading.
  - o A protocol for licensing or approval of OCC operators and activities, including an audit system for OCC operators.
  - o An overview of relevant OCC offloading scenarios and parameters to develop an OCC offloading map with designated offloading sites.
  - o Oversight and enforcement protocols and delegation of parties responsible for enforcement.
  - o Options for a 'port of refuge' for vessels equipped with OCC technology in distress, even if the port decided against accommodating-OCC offloading infrastructure.
  - o Development of reporting requirements and conditions, including:
    - ■ reporting of CO_2 capture and storage activities;
    - ■ reporting of activities and operations;
    - ■ interaction with other port stakeholders not involved in OCC operations;
    - ■ internal and external responsibilities;

        - terminals and other port users;
        - simultaneous operations (SIMOPS) involving OCC-equipped vessels;
        - signalling or marking of vessels conducting OCC offloading;
        - approval or prohibition of activities;
        - the use of standardised bunkering and offloading checklists where applicable.
    - A summary of relevant existing regulations, including an overview of regulatory gaps:
        - port bylaws or other relevant local regulations,
        - existing port safety procedures for hazardous cargo handling,
        - environmental legislation,
        - water quality and water pollution prevention regulations,
        - regional and national legislations,
        - international legislation for vessels (IMO).

- ☐ Develop a contingency plan for OCC offloading system failures, covering emergency response actions for malfunctions.

Optional tasks and considerations:

- ☐ A plan for digital support of operations, including a digital twin.
- ☐ Establish emergency response training programs specific to OCC offloading hazards.
- ☐ Develop an ongoing risk monitoring system to assess the effectiveness of safety measures, including periodic audits.
- ☐ Engage in industry collaboration to align OCC safety practices with evolving global standards.

- Domain: Infrastructure

Strategies, tasks and measures:

- ☐ Draft a detailed plan for assessing and establishing necessary infrastructure. This may include:
    - A plan to adapt present infrastructure or develop relevant infrastructure to facilitate OCC offloading based on engineering studies and other technical assessments.
        - Near-term accommodations may be achieved by modifying and adapting existing port infrastructure.
        - Long-term accommodations should focus on developing the suite of infrastructure necessary to regularly accommodate OCC offloading operations.
    - A (hands-on) timeline for infrastructure that will develop modular offloading solutions for pilot projects and scaled infrastructure for permanent operations.
    - A plan to conduct nautical safety studies to ensure that vessels equipped with OCC can enter the port safely, with designated offloading locations that mitigate the risk of collision or allision, and tidal and current surge of passing vessels is considered.
    - A consideration of the potential infrastructure requirements, including:
        - Quays to host vessels and operations.
        - Offloading infrastructure and flexible transfer systems.

        - Infrastructure for auxiliary services, including solvent handling and temporary CO_2 storage.
    - A sustainable collection system for OCC-associated waste streams, including solvents and captured CO_2.

- ☐ Introduce training programs for port staff and operators on new OCC-related infrastructure and equipment handling.

Optional tasks and considerations:

- ☐ A plan to develop or to integrate OCC processes into Vessel Traffic Services (VTS) and Vessel Traffic Management (VTM) to support offloading operations, including IT and digital support of the VTM process.
- ☐ A strategy to provide a proper level of service. E.g., maintenance, cleaning, etc.
- ☐ Conduct a long-term spatial assessment to ensure OCC offloading operations do not interfere with port capacity and vessel traffic.
- ☐ Explore modular or mobile OCC offloading solutions for ports with limited space.

- Domain: Market, supply/demand

Strategies, tasks and measures:

- ☐ Draft a management plan to support and guide OCC offloading at the port. This may include:
    - A plan to facilitate and support OCC through policies and incentives such as:
        - Funding and support for demonstration projects or short-term or long-term funding for CAPEX or OPEX expenses.
        - A pricing strategy for vessels utilising OCC, including incentives or port dues adjustments.
    - A strategy to form a coalition of stakeholders involved in the OCC offloading supply and value chain.
- ☐ Develop demand forecasting models to anticipate future OCC offloading needs and required capacity.
- ☐ Ensure harmonisation of port fees and incentives across jurisdictions to enhance OCC's commercial attractiveness.

Optional tasks and considerations:

- ☐ A market licensing scheme with permits for working in assigned areas to regulate the market (if allowed).
- ☐ Include the following in the foundational framework:
    - A strategy to measure the socio-economic impacts of OCC at the port.
    - A strategy to support innovations and start-ups in the area of OCC technologies.
- ☐ Draft a commercial management plan to support and guide OCC offloading at the port. This may include:
    - A plan for marketing, acquisition, and market communication
    - A detailed allocation of resources, work hours, and budget.
    - A plan to explore market niches and funding opportunities

Level 4 objective achieved: ☐ **Confirmed**

A plan or roadmap to facilitate OCC offloading services is developed. A detailed framework has been created that will guide the remainder of activities involving OCC services.

- ☐ The port established a governance policy that reflects the decision to proceed or not proceed with OCC offloading services in the port.
- ☐ The port developed a safety policy and roadmap for the call of vessels equipped with OCC systems and the offloading of captured CO_2.
- ☐ The port established an infrastructure policy and roadmap to develop sufficient infrastructure for OCC offloading, temporary CO_2 storage, and solvent handling.
- ☐ The port developed a commercial policy and strategy, and a roadmap for OCC offloading services.

The strategies, tasks and measures of the domains within level 5 are being prepared.

Level 5: Framework implementation, testing, and training under operational conditions

Level 5 Objective: The framework drafted in PRL-CO_2 4 for OCC offloading should be tested and implemented. Testing and implementation should inform any necessary revisions to the framework. The framework should be finalised and approved by all required entities.

The strategies, tasks and measures of the domains in level 2 have been evaluated, and lessons learned are implemented.

- Domain: Governance

Strategies, tasks and measures:

- ☐ Implement engagement and communication plan with stakeholders, regulatory authorities, the press, and the public. Share relevant pieces of the framework with each entity and request feedback where necessary.
- ☐ Obtain approval of the framework from all required entities.
- ☐ Create and open a submission system for fuel providers to request licensing/ audit of their anticipated OCC offloading operation operations.
- ☐ Disperse a public guidance with the new reporting protocol and changing procedures for vessels entering the port with OCC capabilities.
- ☐ Update the Port Information Guide or website based on the guiding framework established.
- ☐ Continue implementing the communication and engagement plan by updating stakeholders,
  regulatory authorities, the press, and the public on progress following finalisation of the framework.

Optional tasks and considerations:

- ☐ Establish a 'management of change' program to address and manage required changes based on the guiding framework for OCC offloading at the port.

- Domain: Safety

Strategies, tasks and measures:

- ☐ Conduct a port specific risk assessment and spatial analysis. From the assessment, draft zoning for OCC offloading activities with an emphasis on maintaining a safe distance between OCC offloading, storage, and surrounding port operations and vulnerable or populated areas as well as a minimum distance required for passing vessels.
- ☐ Conduct credible CO_2 and solvent spill scenarios and gas dispersion studies. From the results, add defined control, safety, and exclusion zones to the framework.

- ☐ Establish a 'CO_2 offloading map' that defines and communicates where OCC offloading operations can take place to the framework.
- ☐ Conduct HAZID and HAZOP studies. From the studies, define proper risk mitigation measures and safety procedures in the safety framework.
- ☐ Conduct a nautical safety study. From the study, make any changes or additions for vessels entering the port, OCC offloading locations, or vessel passing distance.

Optional tasks and considerations:

- ☐ Simulate in a test environment all relevant planning and procedures using computational fluid dynamics (CFD)

- Domain: Infrastructure

Strategies, tasks and measures:

- ☐ Begin adapting present infrastructure to facilitate pilot-scale demonstrations of OCC offloading:
  - Identify the necessary modifications for CO_2 offloading terminals and transfer systems.
  - Assess the need for temporary storage facilities before transport to permanent sequestration or utilisation sites.
- ☐ Establish operational guidelines for OCC offloading vessels, including vessel compatibility requirements.

Optional tasks and considerations:

- ☐ Simulate OCC offloading processes with IT supported digital twinning.

- Domain: Market, supply/demand

Strategies, tasks and measures:

- ☐ Release an open call for applications from fuel ship operators and port service providers to deploy the first OCC offloading pilot projects.
- ☐ Identify potential business models for port involvement in OCC offloading.
- ☐ Develop a financial roadmap, including the assessment of funding and investment mechanisms for OCC infrastructure and operations.

Optional tasks and considerations:

- ☐ Evaluate potential incentive programs to encourage the adoption of OCC offloading services.
- ☐ Establish commercial partnerships with carbon market actors to ensure that captured CO_2 has viable transport and storage pathways.

Level 5 objective achieved: ☐ Confirmed

The framework for OCC offloading services, was tested by simulation, implemented, and revised to create a final version that was approved by the required entities.

- ☐ The port implemented the roadmap of level 4.
- ☐ The port created proper governance for OCC offloading services.
- ☐ The port developed a safety framework, regulatory framework and spatial planning for specific OCC offloading services, the framework was successfully simulated.
- ☐ The port developed infrastructure for OCC offloading services.
- ☐ The port developed commercial support to explore and accelerate the new opportunities for the intended OCC offloading services.

The strategies, tasks and measures of the domains within level 6 are being prepared.

Level 6: Pilot-scale demonstration of OCC offloading systems

Level 6 Objective: To perform a pilot-scale demonstration within a designated area of the port under tightly controlled conditions for a vessel utilising an OCC system and offloading captured CO_2.

The strategies, tasks and measures of the domains in level 5 have been evaluated, and lessons learned are implemented.

- Domain: Governance

Strategies, tasks and measures:

- ☐ Select an appropriate, small-scale pilot project for OCC offloading from the submitted applications.
- ☐ Disseminate the news of the selected pilot project(s) and timeline through the established communication channels.
- ☐ Assemble a project team responsible for overseeing the pilot project(s). This should include members to manage safety and infrastructure issues, as well as messaging and communication and regulatory compliance. Possible team members include:
  - The Harbour Master or representative
  - Competent authorities
  - CO_2 handling operators
  - Vessel operator
  - Terminal or site owner
  - Vessel services
  - Port authority representative
  - Consultant or other specialists
  - Other agency or stakeholder representatives
- ☐ Once established, the project team should:
  - Review the results of all simulations conducted during Level 5, as well as the final OCC offloading framework.
  - Determine what parts of the framework are applicable to the pilot project(s) and define the necessary requirements.
  - Execute the project plan(s) for the pilot project(s).
  - Perform an in-depth analysis and review of the completed project(s), assessing strengths, weaknesses, successes, and failures. Provide recommended revisions to the framework based on the outcomes of the analysis.
- ☐ The recommendations provided by the project team should be assessed by the greater port community and the guiding framework modified accordingly.
- ☐ Disseminate the guiding framework.
- ☐ Share the news of the successful pilot(s).
- ☐ Develop a post-pilot stakeholder consultation plan: Organise structured stakeholder engagement sessions after the pilot to collect feedback from participating regulatory agencies, vessel operators, and port authorities aiming to enhance governance mechanisms.

- ☐ Establish a Legal & Contractual Framework: Develop standardised contractual agreements for port service providers handling OCC offloading, including liability clauses, operational responsibilities, and insurance requirements for CO_2 handling.
- ☐ Define Expansion Criteria for OCC Offloading: Establish key performance indicators (KPIs) to assess whether OCC offloading can scale up based on pilot outcomes (e.g., operational efficiency, safety compliance, and environmental benefits).
- ☐ Integrate OCC Offloading into Long-Term Port Decarbonisation Strategy: If successful, outline a pathway to formally integrate OCC infrastructure into the port's long-term decarbonisation strategy and regulatory planning.

Optional tasks and considerations:

- ☐ Implement and test the monitoring system to measure the effect of OCC operation and offloading on GHG emissions and air quality at the port.
- ☐ Provide an update to relevant green corridor projects or proposals on the pilot project outcomes and decision to move forward.
- ☐ Conduct a comparative study of various regulatory approaches at ports managing CO_2 offloading and integrate the best practices.
- ☐ Explore opportunities to collaborate with global port authorities for knowledge sharing on OCC regulatory best practices.

- Domain: Safety

Strategies, tasks and measures:

- ☐ Implement training of all required personnel involved in the safety framework, including site personnel, incident responders, and port health organisations, among others.
- ☐ Implement training of all other personnel involved in handling or transferring captured CO_2 and solvent from OCC systems. This may include utilising industry, schools, or training institutes to develop and implement training courses or other training materials.
- ☐ Implement training of auditors or hire an outside agency to audit OCC offloading operators for compliance with established protocols.
- ☐ Conduct any further simulation, testing, training, or due diligence required by the port authority or regulatory agencies to validate protocols and prepare for the deployment of OCC offloading operations.
- ☐ Revise and finalise the framework based on feedback received and results from testing and implementation.
- ☐ Once established, the project team should:
    - Draft a joint plan of OCC Offloading Operations (JPOCCOO), the plan of approach for the specific OCC operation, with guidance for all parties involved, based on the OCC offloading management plan of the involved vessel(s) and local specific information. The JPOCCOO should:
        - Meet the safety and regulatory requirements in the guiding framework.
        - Reflect best practices of the industry, guidance from branch organisations, and standards.

        - Include a compatibility assessment for OCC offloading systems.
        - Include control zones for OCC offloading.
        - Include safety requirements specific to CO_2 handling, including leak prevention and emergency shut-off systems.
        - Include SIMOPS (Simultaneous Operations) safety measures.
        - Include port-specific risk mitigation.
        - Include operational safety checklists.
    - Develop a full project plan to offload captured CO_2 and spent solvent from a vessel that includes:
        - Confirmation that OCC offloading will be performed in accordance with the developed JPOCCOO.
        - Defined spatial planning for pilot operations to ensure sufficient distance between operations and vulnerable areas or the public.
        - Confirmation of the involved vessel, terminal, and CO_2 and solvent handling operator's state of preparedness.
        - A compatibility check between vessel and port infrastructure.
        - Supervision, if necessary, by relevant authorities during the offloading process.
        - Use of the proper mandatory operational checklist (IAPH).
        - Enforcement by safety specialists.
    - Submit a request for approval from the competent authorities.

- ☐ Execute the project plan and perform the pilot with the supervision of the safety experts of the project team.
- ☐ Monitor, evaluate and make a report of the pilot, including lessons learned and validation of the safety framework.
- ☐ Evaluate the readiness of emergency response after the pilot by conducting an after-action review of drills related to CO_2 leak response, cryogenic handling risks, and gas dispersion control.
- ☐ Refine risk mitigation strategies using pilot data, adjusting safety protocols based on any recurring issues or operational challenges encountered during the demonstration.
- ☐ Standardise CO_2 detection and leak prevention measures, ensuring a consistent approach to sensor placement, ventilation strategies, and pressure management for future operations.
- ☐ Establish certification and audit procedures for OCC offloading operators to ensure compliance before granting full operational licenses.

Optional tasks and considerations:

- ☐ Implement a digital monitoring system to track real-time safety parameters during offloading.
- ☐ Develop a digital safety dashboard integrating real-time risk monitoring and automated alerts for CO_2 handling operations.
- ☐ Engage in knowledge sharing across industries with LNG and ammonia port operators to compare cryogenic handling safety measures.

- Domain: Infrastructure

Strategies, tasks and measures:

- ☐ Once established, the project team should:
  - Develop a full project plan for a vessel using OCC systems to enter the port that includes:
    - The admission policy for vessels equipped with OCC technology.
    - An approach and mooring plan.
    - Defined spatial planning for OCC offloading locations where vessels equipped with OCC technology can berth.
    - Confirmation of the suitability of the berth for OCC operations.
    - Confirmation of the terminal or site operators' preparedness.
    - Informing VTM (Vessel Traffic Management) and VTS (Vessel Traffic Service) on the particulars of the vessel.
    - Implementation and testing of STS (ship-to-ship), and/or STT (ship-to-truck) or pipeline transfer checklists.
- ☐ Inform relevant parties about the entry of the pilot vessel into the port and/ or of the OCC offloading operation.
- ☐ Execute the project plan and perform the pilot with the supervision of the experts of the project team.
- ☐ Monitor, evaluate and make a report of the pilot, including lessons learned and validation of the safety framework.
- ☐ Evaluate temporary and permanent infrastructure needs to determine if initial demand can be satisfied with mobile buffer tanks or if long-term infrastructure investments are necessary.
- ☐ Test alternative CO_2 offloading scenarios, including ship-to-truck (STT), ship-to-ship (STS), and pipeline transfer for flexible offloading solutions.
- ☐ Address port capacity for scaling OCC offloading by assessing berthing constraints and operational flow to determine whether multiple OCC offloading sites are necessary.
- ☐ Investigate the energy requirements for CO_2 processing at the port, including shore power availability and integration with low-carbon energy solutions for CO_2 compression.

Optional tasks and considerations:

- ☐ Investigate temporary or modular CO_2 storage solutions to accommodate offloaded CO_2.
- ☐ Conduct a feasibility study on multi-user CO_2 handling infrastructure to determine if OCC offloading can be integrated with other CO_2 supply chains.

- Domain: Market, supply/demand

Strategies, tasks and measures:

- ☐ Release an open call for additional projects utilising OCC offloading technologies.
- ☐ Evaluate the commercial feasibility post-pilot by performing a cost-benefit analysis of OCC offloading, emphasising operational costs, carbon credit opportunities, and pricing models.
- ☐ Define business models for long-term OCC offloading operations, outlining potential revenue streams such as service fees, port dues adjustments, and integration with carbon markets.

- ☐ Explore offtake agreements with carbon market players and engage with CO_2 storage operators, and work with industrial partners to establish long-term CO_2 transport pathways.
- ☐ Assess future incentives and funding mechanisms, identifying potential public and private sources for OCC infrastructure expansion.

Optional tasks and considerations:

- ☐ Engage with shipping operators and industrial partners to explore scaling OCC offloading beyond the pilot phase.
- ☐ Conduct a competitor analysis, identifying other ports investing in OCC offloading and positioning the port as a leader in the sector.
- ☐ Explore potential cross-industry collaborations with cement, steel, and hydrogen sectors to integrate OCC offloading with broader CCUS value chains.

Level 6 objective achieved: ☐ **Confirmed**

It is demonstrated by pilot-scale project(s) that the established framework and infrastructure for offloading captured CO_2 and solvent from vessels using OCC systems in the port are sufficient and effective.

- ☐ The port tested the governance arrangements for OCC offloading and processed feedback in the arrangements.
- ☐ The port performed a practical test of the developed safety arrangements and infrastructure for OCC offloading within a designated area of the port under tightly controlled conditions to examine and improve the safety preparation for more frequent activities in OCC offloading operations.
- ☐ The port performed a practical test of the developed infrastructure, or roadmap for the further development of infrastructure, within a designated area of the port under tightly controlled conditions to examine and improve the infrastructural preparation for more frequent OCC offloading activities.
- ☐ To create market confidence, a pilot is performed to prove the port is ready for OCC offloading operations and is prepared to host larger or more frequent OCC offloading activities.

The strategies, tasks and measures of the domains within level 7 are being prepared.

Level 7: Project-based establishment of OCC offloading operations

Level 7 Objective: To facilitate project-based OCC offloading operations, allowing vessels equipped with OCC systems to offload captured CO_2 at the port, controlled by safety protocols and project teams.

The strategies, tasks and measures of the domains in level 6 have been evaluated, and lessons learned are implemented.

- Domain: Governance

Strategies, tasks and measures:

- ☐ Encourage operators and CO_2 handling providers to continue to submit requests for OCC offloading operations.
- ☐ Vet proposals and projects as they are received.
- ☐ Assemble project team(s) to lead and or support each project, as in PRL-CO_2 level 6.
- ☐ Apply the OCC offloading framework to multiple project scenarios as listed above and incorporate reviews and learnings from each project.
- ☐ Continue to support schooling and training institutes to prepare port staff and operators for more regular, larger-scale OCC offloading operations.
- ☐ Update the port information guide.
- ☐ Engage in communication to share knowledge and experience with other ports regarding OCC offloading.
- ☐ Provide public communications announcing the initiation of more regular OCC offloading operations at the port.
- ☐ Project-based operations are monitored and evaluated, and lessons learned are used for further adjustment of the frameworks for governance, safety and infrastructure.
- ☐ Establish a long-term governance framework for OCC offloading to shift from a project-based approach to a standardised operational process within the port's regulatory structure.
- ☐ Establish standardised permitting and licensing procedures for OCC offloading, moving beyond project-specific approvals to create an efficient, recurring process for vessel operators.
- ☐ Strengthen the regulatory alignment between OCC offloading and broader CCUS networks, ensuring compatibility with national and international CO_2 transport and storage regulations.
- ☐ Establish data-sharing agreements with other ports involved in OCC offloading to develop a global knowledge base and repository of best practices.

- ☐ Conduct a comprehensive review process involving multiple stakeholders after project implementation, collecting insights from port operators, shipowners, regulatory bodies, and industry groups to enhance OCC governance policies.

Optional tasks and considerations:

- ☐ Monitor the effect of OCC offloading operations on CO_2 reductions within the port and its contribution to overall emission reductions.
- ☐ Monitor and publish the quantities of CO_2 offloaded from vessels with OCC systems.
- ☐ Host an international summit or workshop on OCC offloading to establish the port as a leader in OCC integration and knowledge sharing.
- ☐ Engage policymakers to investigate incentives for adopting long-term OCC offloading, such as regulatory support, tax benefits, or integration into carbon markets.

- Domain: Safety

Strategies, tasks and measures:

- ☐ Project teams should plan and execute each new OCC offloading operation as was done in PRL-CO_2 6, including receiving approval from relevant competent authorities and ensuring safety protocols for every project.
- ☐ Competent authority is granting project-based licences or exemptions for OCC offloading operations.
- ☐ Establish an OCC Offloading Safety Audit process to ensure ongoing improvement informed by lessons learned from project-based operations.
- ☐ Develop standardised emergency response plans for OCC offloading, ensuring that first responders, port authorities, and vessel operators are united in CO_2 leak and incident mitigation protocols.
- ☐ Develop a port-wide OCC safety culture training program for the entire port, incorporating regular refresher courses for all personnel involved in CO_2 offloading operations.
- ☐ Integrate OCC offloading into comprehensive port safety drills and crisis management exercises, ensuring compatibility with other port operations (e.g., LNG, ammonia, and hydrogen handling).

Optional tasks and considerations:

- ☐ Develop a risk assessment protocol for simultaneous offloading of OCC and other port activities (SIMOPS).
- ☐ Assess the necessity of dedicated OCC safety teams at the port to supervise operations continuously rather than on a project-by-project basis.
- ☐ Explore AI-powered safety monitoring tools that automatically identify CO_2 leaks or irregularities during OCC offloading operations.

- Domain: Infrastructure

Strategies, tasks and measures:

- ☐ Implement the admission procedure for vessels equipped with OCC systems that intend to offload captured CO_2 at the port.
- ☐ Ensure necessary infrastructure to execute OCC offloading operations exists or is developed for (if applicable) ship-to-ship (STS), ship-to-truck (STT), or direct pipeline offloading, depending on project relevancy; and "spin-off" infrastructure, such as mobile CO_2 storage or auxiliary gas-handling services.
- ☐ Aid port operations with strong IT support that is adapted to CO_2 handling operations.
- ☐ Evaluate the requirement for dedicated OCC offloading infrastructure, shifting from adaptable project-based configurations to permanent or semi-permanent offloading stations.
- ☐ Develop guidelines for selecting OCC offloading sites to optimise locations for minimal disruption to other port operations.
- ☐ Explore the standardisation of CO_2 offloading connection interfaces to enable seamless offloading across various vessel types and storage solutions.
- ☐ Conduct a port-wide CO_2 pipeline feasibility study across the port to evaluate the viability of a dedicated pipeline connection between OCC offloading points and storage/utilisation facilities.

Optional tasks and considerations:

- ☐ Develop procedures or integrate OCC offloading into procedures for Vessel Traffic Services (VTS) and Vessel Traffic Management (VTM).
- ☐ Investigate the potential for OCC offloading hubs, where multiple vessels can discharge CO_2 at a centralised facility instead of depending on individual berth setups.
- ☐ Evaluate the feasibility of mobile CO_2 buffer storage, which would allow greater flexibility in scaling OCC offloading capacity as demand increases.

- Domain: Market, supply/demand

Strategies, tasks and measures:

- ☐ Implement a market strategy that identifies new opportunities and supports the uptake of OCC offloading through:
  - Funding and support for demonstration projects,
  - Short-term or long-term funding of CAPEX or OPEX,
  - A pricing incentive for vessels utilising OCC technology vs conventional vessels.
- ☐ Monitor funding and pricing opportunities.
- ☐ Establish financial models for long-term OCC offloading services, ensuring that port fees, service charges, and potential carbon credit monetisation align with industry requirements.

- ☐ Expand OCC offloading services, including optional CO_2 purification, compression, or direct pipeline transport to storage and utilisation sites.
- ☐ Create a transparent CO_2 offloading pricing model that ensures predictability for shipowners and encourages further OCC adoption.
- ☐ Identify potential cross-sector partnerships, especially with carbon utilisation industries (such as synthetic fuel production and cement manufacturing), to establish a stable demand for offloaded CO_2.

Optional tasks and considerations:

- ☐ Explore market niches for OCC offloading and potential integration into existing CCUS value chains.
- ☐ Connect stakeholders within the CO_2 transport and utilisation supply chain with potential customers.
- ☐ Evaluate global OCC offloading market trends to ensure the port remains competitive in pricing, infrastructure, and regulatory alignment.
- ☐ Explore possible funding sources to shift OCC offloading from project-based operations to fully commercialised services.

Level 7 objective achieved: ☐ **Confirmed**

Offloading of captured CO_2 from vessels equipped with OCC systems can take place in the port on a project basis and is controlled by safety protocols and project teams.

- ☐ The port's formal policy on how to facilitate vessels offloading captured CO_2 from OCC systems on a project basis, has been accepted by relevant stakeholders. The port governance is able to support regular OCC offloading operations.
- ☐ Port safety and regulatory framework are project-based fit for facilitating OCC offloading operations, controlled by safety protocols and project teams.
- ☐ Port infrastructure is project-based fit for facilitating OCC offloading operations, controlled by safety protocols and project teams.
- ☐ A starting OCC offloading market is developed, the port is exploring business opportunities for CO_2 handling and is prepared to host larger and more frequent OCC offloading operations.

The strategies, tasks and measures of the domains within level 8 are being prepared.

Level 8: Full OCC offloading capabilities for commercial operations

Level 8 Objective: To facilitate full capabilities for OCC offloading operations at the port, where operations are system-based and managed by audits, licensing, and continuous monitoring.

The strategies, tasks and measures of the domains in level 7 have been evaluated, and lessons learned are implemented.

Domain: Governance

Strategies, tasks and measures:

- ☐ Perform a full audit and assessment to fully license operators who conducted OCC offloading in PRL-CO_2 6 or 7.
- ☐ Initiate the system of auditing and licensing determined in the guiding framework for any additional operators seeking to offload captured CO_2 from onboard carbon capture systems.
- ☐ Create a long-term governance framework for OCC offloading to ensure full integration into standard port operations, accompanied by structured permitting and regulatory oversight. (Shifts from project-based to permanent systems.)
- ☐ Standardise OCC offloading permits and licensing to establish a clear process for operators to obtain long-term approvals instead of case-by-case project approvals. (from temporary permits to a structured regulatory process)
- ☐ Establish cross-border compliance frameworks to ensure that OCC offloading is in accordance with international maritime emissions regulations, carbon markets, and CO_2 transport laws.
- ☐ Establish regulatory enforcement mechanisms to identify vessels that do not comply with OCC offloading standards and to implement corrective actions. (Shifts from voluntary compliance to enforceable measures.)
- ☐ Implement data-sharing agreements with regulatory bodies to ensure that the real-time monitoring of OCC offloading performance is reported to oversight agencies.

Optional tasks and considerations:

- ☐ Measure and report the effect of OCC offloading on CO_2 emission reductions at the port and its contribution to overall climate objectives.
- ☐ Report and publish the quantity of CO_2 offloaded from OCC-equipped vessels.
- ☐ Continue to share experiences and lessons learned with other ports integrating OCC offloading.
- ☐ Host OCC offloading regulatory workshops with international policymakers to ensure standardisation of CO_2 handling, reporting, and compliance mechanisms across ports.

- ☐ Establish a mechanism for grievance and dispute resolution that enables stakeholders, such as ship operators, CO_2 buyers, and regulators, to address operational issues promptly.

- Domain: Safety

Strategies, tasks and measures:

- ☐ Scale-up operations according to the guiding framework to facilitate OCC offloading as part of normal port operations, ensuring all safety and regulatory requirements are met and port-wide organisational oversight is in place.
- ☐ Arrange ongoing training and drills for the port's emergency response organisation in collaboration with OCC vessel operators, CO_2 storage operators, and regulatory agencies.
- ☐ Continuously monitor OCC offloading operations and operators to ensure compliance with the safety and regulatory framework.
- ☐ Competent authority is granting system-based licenses or exemptions for OCC offloading operations.
- ☐ Establish a port-wide OCC offloading safety audit system that mandates regular audits for vessels, operators, and port facilities to ensure safety compliance. (Transitions from ad-hoc safety checks to mandatory, scheduled audits.)
- ☐ Create an automated risk assessment tool that integrates real-time data from OCC offloading operations to proactively identify potential safety issues. (Data-driven risk management is essential at scale.)
- ☐ Ensure all OCC offloading personnel complete certified training programs, making compliance mandatory for all port staff and third-party operators by changing recommended training to required training.
- ☐ Expand emergency response plans for large-scale OCC offloading incidents, ensuring that fire, spill, and gas dispersion response measures are appropriately scaled to accommodate increasing volumes of CO_2. (This expands the level 7 emergency response to include higher-risk scenarios.)
- ☐ Establish clear liability and insurance policies for OCC offloading operations, ensuring all parties understand their financial and legal responsibilities in the event of accidents. (Permanent services require structured liability coverage.)

Optional tasks and considerations:

- ☐ Implement AI-driven safety monitoring to enable real-time anomaly detection in OCC offloading operations, thereby preventing system failures.
- ☐ Conduct regular OCC emergency response drills with vessel operators and CO_2 storage providers to ensure coordinated incident management across sectors.

- Domain: Infrastructure

Strategies, tasks and measures:

- ☐ Ensure that dedicated infrastructure is in place for OCC offloading, including buffer tanks, temporary storage solutions, and CO_2 transfer systems to pipelines or transport hubs and sufficient services.
- ☐ Transition OCC offloading from temporary to dedicated infrastructure, ensuring that permanent storage, pipeline connections, or direct CO_2 transport to industrial partners are available.
- ☐ Expand OCC offloading capacity based on projected demand, determining whether additional berths, storage tanks, or offloading stations are required. (This move will transition from flexible project-based capacity to long-term infrastructure planning.)
- ☐ Implement standardised CO_2 transfer systems, ensuring compatibility between different ship designs and OCC offloading terminals. (This will ensure interoperability across multiple OCC-equipped vessel types.)
- ☐ Digitise port logistics for OCC offloading by integrating scheduling, tracking, and reporting into the port's digital management system.

Optional tasks and considerations:

- ☐ Evaluate the infrastructure needs for scaling OCC offloading capacity to meet increased demand.
- ☐ Explore the feasibility of shared CO_2 offloading hubs, where multiple OCC vessels can offload CO_2 at a single, centralised location. Shared hubs could enhance efficiency.
- ☐ Explore options for floating CO_2 storage facilities, offering flexibility for ports facing space limitations.

- Domain: Market, supply/demand

Strategies, tasks and measures:

- ☐ Define long-term commercial contracts for OCC offloading to ensure stable revenue streams for port operators and predictable costs for vessel owners. (Moves from pilot project pricing to structured, long-term pricing agreements.
- ☐ Create a CO_2 pricing model for OCC offloading, ensuring clear pricing structures that align with carbon markets and regulatory frameworks.
- ☐ Integrate OCC offloading into voluntary and compliance carbon markets, enabling ship operators to generate revenue from the captured and offloaded CO_2. (Establishing financial incentives for OCC adoption.)
- ☐ Expand partnerships with industrial CO_2 buyers to ensure that captured CO_2 has end-users in carbon utilisation sectors (e.g., synthetic fuels, cement, chemicals). (Builds on level 7 while formalising end-user agreements.
- ☐ Develop financial incentives for early adopters of OCC offloading to ensure that vessels utilising OCC enjoy cost benefits compared to conventional operations.

Optional tasks and considerations:

- ☐ Customers may set ambitions and clear timelines for decarbonisation that align with OCC offloading adoption.
- ☐ Evaluate the potential of CO_2 shipping by determining if OCC offloading sites can be integrated with larger CO_2 transport networks.
- ☐ Examine public-private funding strategies for OCC offloading expansion, ensuring sustainable investment in OCC infrastructure.

Level 8 objective achieved: ☐ **Confirmed**

The port supports full OCC offloading capabilities, and operations are successfully system-based and managed through audits, licensing, and monitoring.

- ☐ The port governance is able to support regular OCC offloading operations controlled by safety management.
- ☐ Port's safety and regulatory framework is system-based fit for facilitating OCC offloading operations, controlled by safety management and compliance checks.
- ☐ Port's infrastructure is system-based fit for facilitating OCC offloading operations.
- ☐ A growing OCC market is developed, and the port is exploring business opportunities for CO_2 offloading, storage and utilisation.

The strategies, tasks and measures of the domains within level 9 are being prepared.

Level 9: Integration of OCC operations into routine port activities and growth

Level 9 Objective: To expand the market and demand for OCC offloading services, ensuring a competitive environment for vessel operators, offloading service providers, and CO_2 buyers while establishing OCC offloading as a standardised and scalable operation.

The strategies, tasks and measures of the domains in level 8 have been evaluated, and lessons learned are implemented.

- Domain: Governance

Strategies, tasks and measures:

- ☐ Licensed CO_2 handling operators provide OCC offloading services to vessels on a regular basis.
- ☐ A plan, do, check, act (PDCA) cycle and evaluation-based system is in place for all aspects of the safety framework and OCC offloading operations.
- ☐ Develop a network strategy to remain up to date with innovations and new trends in OCC offloading infrastructure, carbon markets, and technical improvements for CO_2 capture and transport.
- ☐ Develop a regulatory roadmap for long-term OCC offloading operations, ensuring it aligns with international maritime regulations, carbon markets, and environmental policies.
- ☐ Develop a standardised compliance framework for OCC offloading across various ports, promoting the harmonisation of regulations and best practices worldwide.
- ☐ Establish a stakeholder advisory board for OCC offloading to promote regular engagement with vessel operators, CO_2 buyers, port authorities, and regulatory bodies. (Market-driven expansion necessitates multi-stakeholder input.)
- ☐ Expand cooperation agreements for cross-border OCC offloading, ensuring that vessels using OCC can offload CO_2 at multiple ports with aligned regulations.

Optional tasks and considerations:

- ☐ Develop key performance indicators (KPIs) for port's environmental performance related to OCC offloading.
- ☐ Develop and implement a system to track all CO_2 offloading operations at the port to support GHG reporting and integration with carbon markets.
- ☐ Organise an international OCC offloading forum to promote knowledge-sharing, technology standardisation, and regulatory alignment among ports.
- ☐ Work with international organisations (IMO, IAPH, and climate bodies) to establish OCC offloading certification programs.

- Domain: Safety

Strategies, tasks and measures:

- ☐ Incorporate a plan, do, check, act (PDCA) cycle in the port's safety management system to check and improve OCC offloading safety framework regularly.
- ☐ Establish an international OCC safety code to guarantee that all vessels and port facilities adhere to standardised operational and safety procedures.
- ☐ Integrate OCC offloading safety standards into existing port-wide hazard management frameworks, ensuring seamless alignment with other hazardous materials handling protocols.
- ☐ Require independent safety audits for OCC offloading service providers to ensure third-party verification of safety compliance. Safety oversight extends beyond the port authority.

Optional tasks and considerations:

- ☐ Enhance safety best practices by collaborating with other ports and industry groups to refine OCC offloading risk mitigation strategies.
- ☐ Utilise AI-powered safety analytics to forecast and reduce potential risks in OCC offloading operations.
- ☐ Explore blockchain or digital twin technologies to enhance OCC offloading safety monitoring and compliance tracking.

- Domain: Infrastructure

Strategies, tasks and measures:

- ☐ Ensure the port is capable of regular OCC offloading operations and has the necessary infrastructure and capacity to handle growing demand.
- ☐ Create a roadmap for OCC offloading infrastructure expansion by identifying future capacity needs based on projected adoption rates.
- ☐ Establish dedicated OCC offloading berths and optimise port logistics to ensure efficient vessel turnaround times.
- ☐ Ensure that OCC offloading facilities are integrated into the broader CO_2 transport infrastructure, facilitating the seamless movement of offloaded CO_2 to storage or utilisation sites.

Optional tasks and considerations:

- ☐ Evaluate the feasibility of expanding OCC offloading infrastructure to accommodate multiple vessels at the same time or to support new industry demands.
- ☐ Evaluate modular OCC offloading infrastructure solutions to enable scalable and flexible expansion as demand grows.

- ☐ Explore the co-location of OCC offloading sites with industrial CO_2 users to enable direct CO_2 utilisation where feasible. This integrates OCC into industrial decarbonisation efforts.

- Domain: Market, supply/demand

Strategies, tasks and measures:

- ☐ Assess the quality and effectiveness of the OCC offloading market arrangements, including the market strategy and supply chain arrangements, port incentives for supporting OCC offloading, the port pricing strategy, and market communication. The market should support:
  - Multiple suppliers supply OCC offloading,
  - Multiple CO_2 buyers securing offloaded CO_2 for utilisation or permanent storage,
  - A balanced supply and demand to ensure sustainable growth.
- ☐ Contracts or agreements between CO_2 suppliers, vessel operators, and offloading service providers.
- ☐ Ensure the port is capable of allowing stakeholders to make final investment decisions (FID) on OCC offloading infrastructure projects.
- ☐ Create a financial roadmap to expand the OCC offloading market, ensuring clear investment pathways for new service providers and infrastructure development. (OCC offloading goes beyond pilot-scale markets.)
- ☐ Create a pricing structure for OCC offloading that ensures transparent costs for vessel operators, CO_2 storage providers, and carbon credit generators. Market-based pricing is essential for industry growth.
- ☐ Broaden collaborations with carbon utilisation sectors, ensuring a steady demand for offloaded CO_2 in addition to sequestration.
- ☐ Integrate OCC offloading into voluntary and compliance carbon markets, enabling vessel operators to monetise CO_2 captured and offloaded.

Optional tasks and considerations:

- ☐ Develop a strategy to integrate OCC offloading with broader CCUS markets and CO_2 transport networks, ensuring long-term sustainability.
- ☐ Provide an update to relevant green corridor projects or proposals on the new status of the port as an OCC offloading hub.
- ☐ Assess incentives for early adopters of OCC offloading, such as tax benefits, reduced port fees, or emissions-based credits.
- ☐ Analyse regional and global OCC offloading demand, ensuring that infrastructure and service models align with projected growth.
- ☐ Explore financing options for OCC offloading expansion, including public-private partnerships and green investment funds.

☐ **Confirmed**

Level 9 objective achieved:

The port offers a competitive environment for utilising OCC and offloading captured CO_2. OCC offloading capabilities are incorporated into regular port processes to ensure the commercial success of the port.

- ☐ The port is future-proof for vessels equipped with OCC systems and the offloading of captured CO_2.
- ☐ The port's quality and safety management is future-proof and prepared for facilitating OCC offloading operations with a robust compliance and monitoring framework.
- ☐ The port's infrastructure is future-proof and prepared for facilitating OCC offloading operations and integrating with long-term CO_2 transport and storage solutions.
- ☐ The port contains a mature for OCC offloading, supporting multiple service providers and CO_2 buyers.

3.2 PRL-CO_2 for CO_2 Transport by Ship

Level 1: Foundational background information on CO_2 transport by ship technologies and processes

Level 1 Objective: To gather pertinent background information that will help to form the foundation of research and inform decisions moving forward.

- Domain: Governance

Strategies, tasks and measures:

- ☐ Research present and upcoming regulations and incentives on CO_2 transport integration into CCUS networks, including:
  - o International regulations and incentives, such as the London Protocol and IMDG Code,
  - o National regulations and incentives, and
  - o Regional and local regulations and incentives.
- ☐ Research the maturity or technical readiness of the different CO_2 transport by ship approaches/ technologies.
- ☐ Develop an initial governance framework outlining roles and responsibilities for CO_2 shipping operations.
- ☐ Identify relevant port and industry stakeholders and create an open means for communication (e.g., commercial port operators, vessel operators, port authorities, port oversight commissions, etc.).
- ☐ Investigate means to assess public opinions and perceptions from surrounding communities regarding CO_2 transport operations at the port.

Optional tasks and considerations:

- ☐ Research the environmental and logistical benefits of CO_2 transport by ship.
- ☐ Assess the port's contribution to regional and international CCUS network goals.

- Domain: Safety

Strategies, tasks and measures:

- ☐ Research safety requirements for handling liquefied CO_2 during offloading, storage, and transfer.
- ☐ Research and understand present national/international safety regulations for CO_2 handling and cryogenic systems and identify potential safety risks specific to CO_2 transport by ship, including cryogenic leaks and system failures.

- ☐ Identify regulatory authorities involved in safety oversight at the port and create an open means for communication to identify initial training and equipment needs (e.g., local, regional, and national government authorities; port authorities, safety agencies, environmental agencies, etc.)

Optional tasks and considerations:

- ☐ Explore opportunities to collaborate with emergency response teams to enhance preparedness.
- ☐ Explore collaborations to establish best practices for CO_2 transport safety.
- ☐ Investigate mitigation strategies for CO_2 leakage risks.

- Domain: Infrastructure

Strategies, tasks and measures:

- ☐ Research the requirements necessary to serve as a port of call for vessels to load and/or offload transported CO_2.
- ☐ Map existing infrastructure capabilities for CO_2 transport by ship, including berths, storage, and pipelines.
- ☐ Identify space availability for potential CO_2 transport by ship infrastructure, including temporary CO_2 storage facilities.
- ☐ Research technical requirements for connecting ship equipment to port systems (e.g., pipelines, berths).
- ☐ Identify potential upgrades needed to accommodate CO_2 vessels and associated systems.
- ☐ Assess geographical and logistical advantages for integrating the port into CCUS supply chains.

Optional tasks and considerations:

- ☐ Evaluate opportunities for infrastructure co-development with CCUS partners.
- ☐ Explore temporary storage solutions for CO_2 awaiting onward transport.
- ☐ Assess the availability of space in the port for future expansions or upgrades to accommodate CO_2 transport by ship-related operations.

- Domain: Market, supply/demand

Strategies, tasks and measures:

- ☐ Asses the basic commercial potential of becoming a CO_2 transport hub, focusing on demand from emitters and storage facilities.
- ☐ Analyse the economic feasibility of integrating CO_2 shipping into port operations.
- ☐ Engage with CCUS stakeholders to explore collaboration opportunities.

☐ Conduct a preliminary economic analysis of integrating CO_2 transport infrastructure into port operations.

Optional tasks and considerations:

☐ Investigate anticipated supply and demand trends for CO_2 shipping.

☐ Explore green corridor initiatives that could increase demand for CO_2 transport services.

Level 1 objective achieved: ☐ **Confirmed**

Sufficient background information is gathered to be able to form the foundation of research and decisions moving forward.

☐ Information is gathered about CO_2 transport by ship and CO_2 capture projects.

☐ CO_2 transport by ship is assessed to identify aspects that might be safety-related showstoppers.

☐ The basic potential to become a CO_2 transport hub port with infrastructure is assessed.

☐ The basic commercial potential to become a CO_2 transport hub port is assessed.

The strategies, tasks and measures of the domains within level 2 are being prepared.

Level 2: Stakeholder interest and feasibility assessment for CO_2 transport by Ship

Level 2 Objective: To assess the eagerness of stakeholders to pursue added capabilities for CO_2 transport by ship at the port and gather information on the physical and market feasibility of these operations.

The strategies, tasks and measures of the domains in level 1 have been evaluated, and lessons learned are implemented.

- Domain: Governance

Strategies, tasks and measures:

- ☐ Assess the opinions and support of relevant port and industry stakeholders for CO_2 transport readiness.
- ☐ Provide stakeholders with the background information gathered in Level 1 and assess their interest to invest in CO_2 shipping operations.
- ☐ Assess stakeholders' perceived feasibility for entering the market for CO_2 transport by ship.
- ☐ Implement strategies for assessing public opinion on adding capabilities for CO_2 transport at the port.
- ☐ Develop frameworks for stakeholder collaboration within regional CCUS networks.

Optional task and considerations:

- ☐ Include green corridor stakeholders in discussions and assessments for CO_2 transport by ship.
- ☐ Include CCUS network operators in feasibility discussions.
- ☐ Assess alignment with national and international carbon management strategies.

- Domain: Safety

Strategies, tasks and measures:

- ☐ Assess the budget and resources available for establishing a port-specific safety framework for CO_2 transport.
- ☐ Acquaint relevant safety and environmental authorities with market trends and make them aware of the growing or future use of CO_2 transport by ship.
- ☐ Create a network to involve all authorities and key players in the development of a safety framework.
- ☐ Create communication channels with safety and environmental authorities to ensure alignment on CO_2 shipping protocols.

- ☐ Develop partnerships with storage site operators to integrate safety planning.

Optional task and considerations:

- ☐ Propose safety workshops with regulators and industry representatives.
- ☐ Perform preliminary risk assessments for CO_2 leaks and transfer hazards.

- Domain: Infrastructure

Strategies, tasks and measures:

- ☐ Assess the physical feasibility of accommodating vessels dedicated to CO_2 transport at the port.
- ☐ Identify whether CO_2 transport requires additional infrastructure beyond current port capabilities.
- ☐ Assess currently available port infrastructure, including existing CO_2 storage facilities and transport pipelines.
- ☐ Evaluate existing port handling capabilities and determine gaps in CO_2-specific infrastructure.
- ☐ Assess the physical feasibility of creating or utilising a specific port area for CO_2 transfer, ensuring separation from vulnerable areas such as other hazardous cargo and residential

Optional tasks and considerations:

- ☐ Investigate potential upgrades to loading/unloading arms, berth designs, and port handling systems.
- ☐ Explore the potential to co-develop CO_2 storage infrastructure with industrial partners or CCUS stakeholders.
- ☐ Assess the scalability of CO_2 transport facilities to support future demand growth.

- Domain: Market, supply/demand

Strategies, tasks and measures:

- ☐ Conduct market research to identify demand for CO_2 transport by ship.
- ☐ Assess stakeholders' (emitters, shipping operators, and storage facilities) perceived feasibility for entering the market for CO_2 transport.
- ☐ Engage with emitters, shipping operators, and storage facilities to evaluate collaboration potential.
- ☐ Create preliminary economic models to assess the viability of CO_2 shipping operations.
- ☐ Acquaint relevant port stakeholders with the CO_2 transport value chain and its commercial potential.

Optional tasks and considerations:

- ☐ Ensure stakeholders in the CO_2 transport and storage market are equipped to stay informed on the future market conditions of CO_2 transport and storage and will have the information necessary to balance demand and supply.
- ☐ Identify potential commercial partnerships as they relate to CO_2 transport.
- ☐ Explore partnerships with industrial emitters to establish long-term CO_2 transport agreements.
- ☐ Investigate synergies with other regional decarbonisation projects.
- ☐ Consider incentives to encourage the adoption of CO_2 transport services (e.g., reduced port fee, priority berthing, incentive programs, etc.).
- ☐ Develop strategic plans to position the port as a key player in global CO_2 shipping networks.

Level 2 objective achieved: ☐ **Confirmed**

The interest of stakeholders to pursue CO_2 transport by ship capabilities has been assessed. There is sufficient insight into the feasibility of adding CO_2 transport capabilities at the port.

- ☐ The port has sufficient insight into the CO_2 transport value chain and stakeholder strategies for CO_2 transport.
- ☐ The port has sufficient insight, budget and resources to develop a safety framework for CO_2 transport by ship.
- ☐ The port has sufficient insight into the present infrastructure and the gaps for future needed infrastructure to know if it can facilitate CO_2 transport by ship.
- ☐ The port is acquainted with the opportunities for the port's stakeholders to enter the new market.

The strategies, tasks and measures of the domains within level 3 are being prepared.

Level 3: Detailed research, analysis, and conclusions on CO_2 transport by Ship readiness

Level 3 Objective: Gather detailed information on all pertinent aspects of CO_2 transport by ship so that an informed decision on moving forward with CO_2 transport by ship operations can be made.

The strategies, tasks and measures of the domains in level 2 have been evaluated, and lessons learned are implemented.

- Domain: Governance

Strategies, tasks and measures:

- ☐ Establish a regulatory roadmap for integrating CO_2 transport into port operations.
- ☐ Define compliance measures and reporting obligations for CO_2 shipping activities.
- ☐ Develop collaborative agreements with government agencies and CCUS stakeholders.
- ☐ Work with legal experts to outline liability and contractual considerations for CO_2 transport.

Optional tasks and considerations:

- ☐ Consult research reports and scientific papers to supplement information gathered.
- ☐ Recruit relevant port stakeholders to participate in research programs, consortiums, and partnerships to supplement information and gather knowledge.
- ☐ Advocate for consistent regulatory standards across national and international jurisdictions.
- ☐ Assess potential tax or financial incentives for CO_2 transport investments.
- ☐ Explore the creation of regional regulatory working groups for CO_2 shipping.

- Domain: Safety

Strategies, tasks and measures:

- ☐ Develop a safety framework for CO_2 transport infrastructure, including loading and unloading procedures, conduct hazard and operability studies specific to CO_2 handling and implement emergency response strategies in cooperation with relevant authorities. The necessary aspects should be based on information previously gathered, including relevant safety standards, regulations, and industry best practices.
- ☐ Standardise CO_2 transport risk assessments across participating ports.

Optional tasks and considerations:

- ☐ Design industry-wide safety workshops for CO_2 transport and handling.
- ☐ Establish monitoring systems for early leak detection and risk mitigation.
- ☐ Engage international safety organisations for cross-border CO_2 transport alignment.

- Domain: Infrastructure

Strategies, tasks and measures:

- ☐ Research the exact infrastructure demand and the scale required for CO_2 transport services at the commercial level.
- ☐ Identify key technical requirements for ship-to-shore CO_2 handling systems.
- ☐ Engage with industry stakeholders to align infrastructure development with transport demand.
- ☐ Consider shared infrastructure models to distribute investment risks.

Optional tasks and considerations:

- ☐ Assess multi-use infrastructure options to integrate CO_2 handling with other port activities.
- ☐ Explore scalability solutions to accommodate future CO_2 volumes.
- ☐ Investigate offshore CO_2 transfer options to reduce port congestion.

- Domain: Market, supply/demand

Strategies, tasks and measures:

- ☐ Research detailed costs, including capital expenses (CAPEX) and operating expenses (OPEX) for CO_2 transport services.
- ☐ Define commercial models for CO_2 transport services, including pricing structures.
- ☐ Establish partnerships with industrial emitters and storage sites to secure transport demand.
- ☐ Develop long-term investment plans for CO_2 transport infrastructure and operational sustainability.
- ☐ Conduct stakeholder engagement to align CO_2 transport services with market needs.

Optional tasks and considerations:

- ☐ Investigate opportunities to integrate CO_2 transport into broader CCUS initiatives.
- ☐ Assess the feasibility of government-backed financial support for CO_2 transport projects.
- ☐ Explore export opportunities for CO_2 transport services.
- ☐ Provide an update to relevant green corridor projects or proposals on the research conclusions and decision to move forward.

Level 3 objective achieved: ☐ **Confirmed**

Based on sufficient information about all aspects needed, the port decided whether it could support CO_2 transport infrastructure and services or would halt progress on these services.

- ☐ The port has sufficient information to develop a policy and roadmap for CO_2 transport infrastructure and services.
- ☐ All safety requirements and infrastructure demands can be met by the port to supply CO_2 transport infrastructure and services.
- ☐ The port has sufficient information on the necessary infrastructure and space for CO_2 transport services.
- ☐ Research indicates that the market availability of CO_2 transport infrastructure and services aligns with the port's needs and that associated costs will not present a prohibitive barrier to implementation.

The strategies, tasks and measures of the domains within level 4 are being prepared.

Level 4: Roadmap to proceed, framework and timeline developed

Level 4 Objective: Announce proceeding with a plan or roadmap for integrating CO_2 transport by ship into port operations and develop a detailed framework and timeline to serve as the guiding document for the implementation process.

The strategies, tasks and measures of the domains in level 3 have been evaluated, and lessons learned are implemented.

- Domain: Governance

Strategies, tasks and measures:

- ☐ Draft a publicly available position or policy paper explaining the port's decision to proceed or halt with CO_2 shipping operations.
- ☐ Create a firm PRL-CO_2 schedule, including present standing and future ambitions for CO_2 shipping within the port and communicate it publicly.
- ☐ Begin drafting the foundational framework that will serve as the guiding document for proceeding with CO_2 transport operations. The framework should include protocols for CO_2 handling, key considerations for CO_2 carrier compatibility with port facilities and operational procedures for CO_2 offloading from ships and/or any of the following offloading scenarios deemed relevant at the port: ship-to-shore transfer, ship-to-ship transfer, or integration with storage infrastructure for CO_2 handling.
- ☐ Draft a thorough engagement and communication plan for stakeholders, regulatory authorities, the press, and the public. This may include:
  - o A strategy to manage the expectations of stakeholders.
  - o A plan to disseminate transparent information, including pros and cons, to the public.
  - o A frequently asked questions (FAQs) list to help inform relevant parties.
  - o A streamlined and easily accessible feedback submission tool for parties to submit comments and feedback.
  - o A robust system of communication amongst key players, including CCUS value chain participants, port authorities and terminal operators handling CO_2, regulatory bodies overseeing CO_2 transport safety and compliance, etc.
  - o Relevant communication and publication tools such as a website, flyers, or one-pagers.

Optional tasks and considerations:

- ☐ Include the following in the foundational framework:
  - o A detailed strategy for monitoring the environmental impact of CO_2 transport, ensuring compliance with emissions and safety regulations. This may include tracking CO_2 shipment volumes and offloading activities to ensure transparency and efficiency.

- A strategy to set up green corridors and other coalitions that include the whole port value chain to facilitate long-term CO_2 transport and storage developments.
- A roadmap for integrating CO_2 transport into regional or international CCUS hubs and value chains.

☐ Define public engagement benchmarks to ensure that stakeholder involvement continues throughout implementation rather than being limited to early phases.

- Domain: Safety

Strategies, tasks and measures:

☐ Draft an in-depth safety and regulatory framework produced in concert with all relevant regulatory and safety authorities. This may include:

- A plan to conduct HAZID and HAZOP studies to inform risk mitigation measures and safety procedures, to assess potential risks in CO_2 handling, offloading, and storage operations.
- A review of all safety aspects and requirements researched in PRL-CO_2 1 through 3 with associated implementation plans for the necessary elements.
- Incident response management that includes clear delegation of responsibilities, scenarios and training of incident responders and port health organisations and storage facility operators, and proper response equipment, including CO_2 leak detectors, ventilation systems, and protective gear.
- Establishing control zones for CO_2 operations, informed by QRA and dispersion modelling of CO_2 behaviour. The boundary should include any areas where CO_2 handling is allowed or restricted, considering population density, nearby industrial activities, and environmental concerns.
- A plan to conduct credible spill scenarios to assess the impact of a CO_2 leak on port areas and surrounding communities and inform the development of control, safety, and exclusion zones for CO_2 handling and transport.
- A plan to conduct a port-specific risk assessment and spatial analysis that will guide control zoning for CO_2 transport operations.
- A protocol for licensing or approval for CO_2 operators and offloading activities, ensuring operators comply with port safety standards and environmental regulations and international CO_2 transport guidelines, including those outlined by the International Maritime Organization (IMO).
- Development of a CO_2 handling and transport map, indicating permitted areas for CO_2 offloading and transfer and safety zones for CO_2 storage and transport vessels.
- Oversight and enforcement protocols and delegation of parties responsible for enforcement.
- Options for a 'port of refuge' for CO_2 transport vessels in distress, even if the port is not designated for large-scale CO_2 offloading.
- Requirements and conditions for:
  - the volume, purity, and condition of CO_2 being transported;
  - details of offloading operations, including time, location, and equipment used;

        - interaction with other port stakeholders not involved in CO_2 transport operations;
        - internal and external responsibilities;
        - terminals and other port users;
        - simultaneous operations (SIMOPS) involving CO_2 transport, ensuring safe separation of CO_2 handling activities from other port operations and clear procedures for loading, unloading, and temporary storage of CO_2;
        - signalling or marking of vessels transporting CO_2;
        - approval or prohibition of activities, in strict compliance with regional, national, and international safety standards and pre-approved contingency plans in case of equipment failure or safety breaches.
    - A summary of relevant existing regulations, including an overview of regulatory GAPS:
        - port bylaws or other relevant local regulations,
        - existing port safety procedures for handling pressurised gases at the port,
        - environmental legislation,
        - water quality and water pollution prevention regulations,
        - regional and national legislations,
        - international legislation for vessels (IMO)

Optional tasks and considerations:

- ☐ A plan for digital support of operations, including a digital twin.
- ☐ Develop a digital risk management system to monitor CO_2 transport and offloading activities in real time and integrate CO_2 transport safety measures into the port's Vessel Traffic Management System (VTMS), including periodic audits.
- ☐ Establish a periodic safety review process to ensure the ongoing assessment of CO_2 transport safety measures and the updating of risk assessments based on emerging regulations and best practices.
- ☐ Collaborate with industry stakeholders to align CO_2 transport safety frameworks with international CCUS initiatives and CO_2 shipping standardisation efforts and to share best practices on CO_2 transport safety.
- ☐ Engage in stakeholder workshops to address concerns and refine safety frameworks.

- Domain: Infrastructure

Strategies, tasks and measures:

- ☐ Draft a detailed plan for assessing and establishing the necessary infrastructure for CO_2 handling, storage, and transfer at the port. This may include:
    - Assessment of existing port infrastructure to determine its suitability for CO_2 reception, temporary storage, and further transportation.
        - Near-term accommodations may be achieved by modifying and adapting existing port infrastructure.
        - Long-term accommodations should focus on developing the suite of

infrastructure necessary to regularly accommodate large-scale CO_2 shipping operations.

- Consideration of CO_2 ship offloading methods, including:
  - Direct pipeline transfer from ship to permanent storage or further transport.
  - Temporary storage facilities, including insulated tanks or geological storage.
  - Ship-to-ship transfer, if applicable.
- A plan to conduct nautical safety studies to ensure CO_2 transport vessels can enter and manoeuvre in the port safely-and that risk factors such as potential collisions and tidal and current surge of passing vessels are considered.
- A consideration of the potential infrastructure requirements, including:
  - Quayside maintenance and inspection facilities.
  - CO_2 quality monitoring and conditioning units.
  - Safety zones for offloading operations.

Optional tasks and considerations:

- ☐ A plan to develop or to integrate CO_2 transport operations for Vessel Traffic Services (VTS) and Vessel Traffic Management (VTM) to coordinate CO_2 shipping activities, including digital tools for real-time tracking.
- ☐ A strategy to provide a proper level of service. E.g., maintenance, cleaning, etc.
- ☐ Exploration of shared CO_2 transport infrastructure that may serve multiple industrial emitters.
- ☐ Consideration of mobile or modular CO_2 storage units to provide additional flexibility in offloading operations.
- ☐ Review of potential funding and investment opportunities for infrastructure expansion and integration with CCUS networks.

- Domain: Market, supply/demand

Strategies, tasks and measures:

- ☐ Draft a management plan to support and guide CO_2 transport operations at the port. This may include:
  - A plan to facilitate and support CO_2 transport through policies and incentives such as:
    - Funding and support for demonstration projects or short-term or long-term funding for CAPEX or OPEX expenses related to CO_2-handling infrastructure.
    - A pricing strategy for CO_2 shipping operations, including incentive schemes for early adopters and regulatory alignment.
  - A strategy to form a coalition of stakeholders involved in the CO_2 shipping and storage value chain, ensuring seamless integration between industrial emitters, shipping companies, and storage operators.

- Engage with carbon market entities and regulatory bodies to align CO_2 transport operations with emission trading systems and carbon offset frameworks.

Optional tasks and considerations:

- ☐ A market licensing scheme with permits for working in assigned areas to regulate the market (if allowed).
- ☐ Include the following in the foundational framework:
  - A strategy to measure the socio-economic impacts of establishing CO_2 transport operations at the port, including potential job creation, regional economic benefits, and policy incentives.
  - A strategy to support innovations and start-ups focused on CO_2 shipping logistics, handling technologies, and carbon utilisation pathways.
- ☐ Draft a commercial management plan to support and guide CO_2 transport at the port. This may include:
  - A plan for marketing, acquisition, and market communication
  - A detailed allocation of resources, work hours, and budget.
  - A plan to explore market niches and funding opportunities

Level 4 objective achieved: ☐ **Confirmed**

A plan or roadmap to facilitate CO_2 transport operations is developed. A detailed framework has been created that will guide the remainder of the activities involving CO_2 transport services.

- ☐ The port established a governance policy that reflects the decision to proceed or not proceed with CO_2 transport operations in the port.
- ☐ The port developed a safety policy and roadmap for handling CO_2 transport by ship, including offloading, temporary storage, and regulatory compliance.
- ☐ The port established an infrastructure policy and roadmap to develop sufficient CO_2 handling, offloading, and storage infrastructure to support maritime transport.
- ☐ The port developed a commercial policy and strategy and a roadmap for CO_2 shipping services, pricing structures, and integration into carbon markets.

The strategies, tasks and measures of the domains within level 5 are being prepared.

Level 5: Framework implementation, testing, and training under operational conditions.

Level 5 Objective: The framework drafted in PRL-CO_2 4 for CO_2 transport by ship should be tested and implemented. Testing and implementation should inform any necessary revisions to the framework. The framework should be finalised and approved by all required entities.

The strategies, tasks and measures of the domains in level 4 have been evaluated, and lessons learned are implemented.

- Domain: Governance

Strategies, tasks and measures:

- ☐ Implement engagement and communication plan with stakeholders, regulatory authorities, the press, and the public. Share relevant pieces of the framework with each entity and request feedback where necessary.
- ☐ Obtain approval of the framework from all required entities for CO_2 shipping operations, including handling, offloading, and transport protocols.
- ☐ Create and open a submission system for CO_2 transport operators to request licensing/ audit of their anticipated operation.
- ☐ Disperse a public guidance with the new reporting protocol and updated procedures for vessels entering the port for CO_2 transport capabilities.
- ☐ Update the Port Information Guide or website based on the guiding framework established.
- ☐ Continue implementing the communication and engagement plan by updating stakeholders, regulatory authorities, the press, and the public on progress following finalisation of the framework.

Optional tasks and considerations:

- ☐ Establish a 'management of change' program to address and manage required changes based on the guiding framework for CO_2 transport by ship operations at the port.

- Domain: Safety

Strategies, tasks and measures:

- ☐ Conduct a port-specific risk assessment and spatial analysis. From the assessment, draft zoning for CO_2 loading and offloading operations emphasises maintaining a safe distance between CO_2 handling activities, vulnerable or populated areas, and other port operations, as well as a minimum distance required for passing vessels.

- ☐ Conduct credible CO_2 spill scenarios and gas dispersion studies. From the results, add defined control, safety, and exclusion zones to the framework.
- ☐ Establish a 'CO_2 Handling map' that defines and communicates where CO_2 loading and offloading operations can take place in the framework.
- ☐ Conduct HAZID and HAZOP studies for CO_2 handling and transport. From the studies, define proper risk mitigation measures and safety procedures in the safety framework.
- ☐ Conduct a nautical safety study. From the study, make any changes or additions for vessels entering the port, CO_2 loading/offloading locations, or vessel passing distance.

Optional tasks and considerations:

- ☐ Simulate in a test environment all relevant planning and procedures using computational fluid dynamics (CFD).

- Domain: Infrastructure

Strategies, tasks and measures:

- ☐ Begin adapting present infrastructure to facilitate pilot-scale demonstrations of CO_2 loading and offloading operations, including:
  - Berth modifications for CO_2 transport vessels.
  - Installation of CO_2 loading/unloading arms or pipelines for direct transfer to storage or further transport.
  - Development of temporary CO_2 storage solutions, ensuring compliance with safety and environmental regulations.
  - Defining and implementing ship-to-shore CO_2 transfer protocols, ensuring compatibility between vessel equipment and port infrastructure.
- ☐ Establish operational guidelines for CO_2 transport vessels, including vessel compatibility requirements.

Optional tasks and considerations:

- ☐ Simulate CO_2 loading and offloading processes with IT-supported digital twinning.

- Domain: Market, supply/demand

Strategies, tasks and measures:

- ☐ Release an open call for applications from CO_2 transport providers, vessel operators, and CCUS stakeholders to deploy the first pilot projects for CO_2 loading/offloading operations.
- ☐ Identify potential business models for port involvement in CO_2 transport by ship, including handling fees, service contracts, and integration with CCUS networks.
- ☐ Develop a financial roadmap, including the assessment of funding and investment mechanisms for CO_2 transport infrastructure, offloading systems, and temporary storage solutions.

Optional tasks and considerations:

- ☐ Evaluate potential incentive programs to encourage the adoption of CO_2 transport services, such as fee reductions for early adopters, port dues adjustments, or infrastructure funding support.
- ☐ Establish commercial partnerships with carbon market actors and CCUS stakeholders to ensure transported CO_2 has viable storage or utilisation pathways.

Level 5 objective achieved: ☐ **Confirmed**

The framework for CO_2 transport operation was tested by simulation, implemented, and revised to create a final version approved by the required entities.

- ☐ The port implemented the roadmap of level 4.
- ☐ The port created proper governance for CO_2 transport operations, including regulatory compliance, reporting procedures, and coordination with relevant authorities.
- ☐ The port developed a safety framework, regulatory framework and spatial planning for CO_2 loading and offloading operations. The framework was successfully simulated.
- ☐ The port developed infrastructure to support CO_2 transport by ship.
- ☐ The port developed commercial support to explore and accelerate the new opportunities for CO_2 transport.

The strategies, tasks and measures of the domains within level 6 are being prepared.

Level 6: Pilot-scale demonstration of CO_2 shipping operations and handling systems

Level 6 Objective: To perform a pilot-scale demonstration within a designated area of the port under tightly controlled conditions for a vessel engaged in CO_2 transport, either loading or offloading CO_2.

The strategies, tasks and measures of the domains in level 5 have been evaluated, and lessons learned are implemented.

- Domain: Governance

Strategies, tasks and measures:

- ☐ Select an appropriate, small-scale pilot project for CO_2 loading and/or offloading from the submitted applications.
- ☐ Disseminate the news of the selected pilot project(s) and timeline through the established communication channels.
- ☐ Assemble a project team responsible for overseeing the pilot project(s). This should include members to manage safety and infrastructure issues, as well as messaging and communication and regulatory compliance. Possible team members include:
    - The Harbour Master or representative
    - Competent authorities
    - CO_2 handling operators
    - Vessel operator
    - Terminal or site owner
    - Vessel services
    - Port authority representative
    - Consultant or other specialists
    - Other agency or stakeholder representatives
- ☐ Once established, the project team should:
    - Review the results of all simulations conducted during Level 5, as well as the final CO_2 shipping operations framework.
    - Determine what parts of the framework are applicable to the pilot project(s) and define the necessary requirements.
    - Execute the project plan(s) for the pilot project(s).
    - Perform an in-depth analysis and review of the completed project(s), assessing strengths, weaknesses, successes, and failures. Provide recommended revisions to the framework based on the outcomes of the analysis.
- ☐ The recommendations provided by the project team should be assessed by the greater port community, and the guiding framework modified accordingly.

- ☐ Disseminate the guiding framework.
- ☐ Share the news of the successful pilot(s).
- ☐ Develop a post-pilot stakeholder consultation plan to systematically gather feedback from regulatory agencies, vessel operators, and port authorities to enhance governance mechanisms.
- ☐ Establish a legal and contractual framework for CO_2 shipping operations by defining liability clauses, operational responsibilities, and insurance requirements for CO_2 handling. This includes long-term agreements for CO_2 transport and compliance with maritime regulations such as MARPOL and the London Protocol.
- ☐ Define the expansion criteria for CO_2 transport by ship, establishing key performance indicators (KPIs) to enhance operational efficiency, ensure safety compliance, and promote environmental benefits while ensuring scalability.
- ☐ Integrate CO_2 shipping into the port's long-term decarbonisation strategy, ensuring alignment with future sustainability goals, international CCUS networks, and emissions reduction mandates.
- ☐ Harmonise CO_2 transport regulations across jurisdictions by collaborating with international maritime organisations and regulatory bodies to ensure seamless cross-border transport of CO_2.

Optional tasks and considerations:

- ☐ Implement and test the monitoring system to measure the effect of CO_2 loading/offloading operations on GHG emissions and air quality at the port.
- ☐ Provide an update on relevant green corridor projects or proposals on the pilot project outcomes and decision to move forward.
- ☐ Conduct a comparative study on different regulatory approaches across ports handling CO_2 shipping operations and integrate best practices.
- ☐ Explore opportunities to collaborate with international port authorities to standardise permitting and operational frameworks for CO_2 transport.

- Domain: Safety

Strategies, tasks and measures:

- ☐ Implement training of all required personnel involved in the safety framework, including site personnel, incident responders, and port health organisations, among others.
- ☐ Implement training of all other personnel involved in handling or transferring CO_2 during loading/offloading operations. This may include utilising industry, schools, or training institutes to develop and implement training courses or other training materials.
- ☐ Implement training of auditors or hire an outside agency to audit CO_2 handling operators for compliance with established protocols.

- ☐ Conduct any further simulation, testing, training, or due diligence required by the port authority or regulatory agencies to validate protocols and prepare for full deployment of CO_2 shipping operations.
- ☐ Revise and finalise the framework based on feedback received and results from testing and implementation.
- ☐ Once established, the project team should:
    - Draft a joint plan of CO_2 shipping operation ($JPCO_2SO$), the plan of approach for the specific CO_2 operation with guidance for all parties involved, based on the loading/offloading management plan of the involved vessel(s) and local specific information. The $JPCO_2SO$ should:
        - Meet the safety and regulatory requirements in the guiding framework.
        - Reflect on best practices of the industry, guidance from branch organisations, and standards.
        - Include a compatibility assessment for CO_2 loading/offloading systems.
        - Include control zones for CO_2 handling operations.
        - Include safety requirements specific to CO_2 cryogenic handling and pressure management.
        - Include SIMOPS safety measures.
        - Include port-specific risk mitigation.
        - Include operational safety checklists.
    - Develop a full project plan to load/offload CO_2 from a vessel that includes:
        - Confirmation that CO_2 loading/offloading will be performed in accordance with the developed $JPCO_2SO$.
        - Defined spatial planning for pilot operations to ensure sufficient distance between operations and vulnerable areas or the public.
        - Confirmation of the involved vessel, terminal, and CO_2 handling operator's state of preparedness.
        - A compatibility check between vessel and port infrastructure.
        - Supervision, if necessary, by relevant authorities during CO_2 loading/offloading.
        - Use of the proper mandatory operational checklist (IAPH or equivalent).
        - Enforcement by safety specialists.
    - Submit a request for approval from the competent authorities.
- ☐ Execute the project plan and perform the pilot CO_2 loading/offloading operation under the supervision of the safety experts of the project team.
- ☐ Monitor, evaluate and make a report of the pilot, including lessons learned and validation of the safety framework.
- ☐ Assess emergency response readiness after the pilot by performing an after-action review of emergency drills focused on CO_2 spill response, cryogenic handling risks, and gas dispersion control.
- ☐ Refine risk mitigation strategies based on pilot data, adjusting safety protocols to address any recurring issues or operational challenges identified during the demonstration.

- ☐ Standardise CO_2 detection & leak prevention measures to ensure a consistent approach to sensor placement, ventilation strategies, and pressure management for safe CO_2 transport operations.
- ☐ Establish certification and audit procedures for CO_2 shipping operators, ensuring compliance prior to granting full operational licenses.
- ☐ Conduct nautical safety reviews for CO_2 ship handling, covering ship berthing, manoeuvring risks, and interactions with other port activities *(*specific vessel types and handling complexities*).*

Optional tasks and considerations:

- ☐ Develop a digital safety dashboard that integrates real-time monitoring of CO_2 loading and offloading risks.
- ☐ Collaborate with LNG and ammonia shipping operators to exchange best practices in cryogenic transport safety.
- ☐ Investigate the risks associated with CO_2 phase changes and the potential for dry ice formation in pipeline or shipboard systems.

- Domain: Infrastructure

Strategies, tasks and measures:

- ☐ Once established, the project team should:
  - Develop a full project plan for a vessel transporting CO_2 to enter the port that includes:
    - The admission policy for vessels engaged in CO_2 transport.
    - An approach and mooring plan.
    - Defined spatial planning for locations where CO_2 transporting vessels can berth.
    - Confirmation of the suitability of the berth for CO_2 handling.
    - Confirmation of the terminal or site operators' preparedness.
    - Informing VTM and VTS on the particulars of the vessel.
    - Implementation and testing of STS and/or STT checklists.
- ☐ Inform relevant parties about the entry of the pilot vessel into the port and/ or CO_2 loading/offloading operation.
- ☐ Execute the project plan and perform the pilot with the supervision of the experts of the project team.
- ☐ Monitor, evaluate and make a report of the pilot, including lessons learned and validation of the safety framework.
- ☐ Assess the temporary and permanent infrastructure needs to determine if the initial CO_2 transport demand can be met with temporary solutions like floating storage units (FSUs), modular CO_2 storage tanks, or direct pipeline integration.

- ☐ Test alternative CO_2 offloading scenarios, including ship-to-ship (STS), ship-to-truck (STT), and direct pipeline transfer for flexible handling at various types of ports.
- ☐ Evaluate port capacity to expand CO_2 transport operations while identifying infrastructure bottlenecks for high-frequency CO_2 vessel traffic.
- ☐ Investigate energy requirements for CO_2 processing at the port, including shore power availability, cryogenic energy recovery, and extra compression needs for safe storage. (Emphasise energy demands for CO_2 liquefaction and recompression at offloading sites.)

Optional tasks and considerations:

- ☐ Investigate modular CO_2 storage solutions that adapt to changes in transport demand.
- ☐ Conduct a feasibility study on multi-user CO_2 handling infrastructure to determine if CO_2 transport can be integrated with other CCUS storage hubs.
- ☐ Assess the feasibility of offshore CO_2 offloading platforms in areas with limited port infrastructure.

- Domain: Market, supply/demand

Strategies, tasks and measures:

- ☐ Release an open call for more projects utilising CO_2 shipping operations.
- ☐ Examine the commercial feasibility after the pilot by conducting a cost-benefit analysis of CO_2 shipping, which includes operational costs, carbon credit opportunities, and pricing models.
- ☐ Define business models for long-term CO_2 transport by ship, outlining potential revenue streams such as handling fees, adjustments to port dues, and integration with carbon markets.
- ☐ Engage CO_2 storage operators and industrial partners to create long-term CO_2 transport contracts and establish offtake agreements with carbon market participants.
- ☐ Assess future incentives and funding strategies while identifying potential public and private funding sources for expanding CO_2 transport infrastructure.

Optional tasks and considerations:

- ☐ Engage shipping operators and industrial partners to explore scaling up CO_2 shipping beyond the pilot phase.
- ☐ Conduct a competitive analysis to identify other ports investing in CO_2 shipping and position the port as a leader in the industry.
- ☐ Explore cross-industry collaborations across the cement, steel, and hydrogen sectors to integrate CO_2 transport into broader CCUS networks.
- ☐ Investigate the market demand for CO_2 export through shipping to countries with permanent storage capacity.

Level 6 objective achieved: ☐ **Confirmed**

It is demonstrated by pilot-scale project(s) that the established framework and infrastructure for the arrival of vessels transporting CO_2, as well as for the loading and offloading of CO_2 in the port, are sufficient and effective.

- ☐ The port tested the governance arrangements and processed feedback in the arrangements.
- ☐ The port performed a practical test of the developed safety arrangements and infrastructure for CO_2 loading and offloading within a designated area of the port under tightly controlled conditions to examine and improve the safety preparation for more frequent CO_2 transport activities.
- ☐ The port performed a practical test of the developed infrastructure, or roadmap for the further development of infrastructure, within a designated area of the port under tightly controlled conditions to examine and improve the infrastructural preparation for more frequent activities of vessels transporting CO_2.
- ☐ To create market confidence, a pilot is performed to prove the port is ready for CO_2 shipping operations and is prepared to host larger or more frequent CO_2 loading and offloading activities.

The strategies, tasks and measures of the domains within level 7 are being prepared.

Level 7: Project-based establishment of CO_2 transport operations

Level 7 Objective: To facilitate project-based CO_2 shipping operations, allowing vessels transporting CO_2 to load and offload CO_2 at the port under controlled safety protocols and project teams.

The strategies, tasks and measures of the domains in level 6 have been evaluated, and lessons learned are implemented.

- Domain: Governance

Strategies, tasks and measures:

- ☐ Encourage vessel operators and CO_2 transport providers to continue to submit requests for CO_2 loading and offloading operations.
- ☐ Vet proposals and projects as they are received.
- ☐ Assemble project team(s) to lead and or support each project, as in PRL-CO_2 6.
- ☐ Apply the CO_2 transport-to multiple project scenarios as listed above and incorporate reviews and learnings from each project.
- ☐ Continue to support schooling and training institutes to prepare port staff and operators for more regular, larger-scale CO_2 transport operations.
- ☐ Update the port information guide to reflect evolving regulations and CO_2 handling protocols.
- ☐ Engage in communication to share knowledge and experience with other ports regarding CO_2 transport by ship.
- ☐ Provide public communications announcing the initiation of more regular CO_2 loading and offloading operations at the port.
- ☐ Project-based operations are monitored and evaluated, and lessons learned are used for further adjustment of the frameworks for governance, safety and infrastructure.
- ☐ Develop a long-term governance framework for CO_2 transport to transition from a project-based approach to a standardised operational process within the port's regulatory structure.
- ☐ Establish standardised permitting and licensing procedures for CO_2 transport by ship, progressing beyond project-specific approvals to create an efficient, recurring process for vessel operators.
- ☐ Enhance regulatory alignment between CO_2 transport and broader CCUS networks, ensuring compliance with national and international CO_2 transport and storage regulations, such as the London Protocol and MARPOL Annex VI.

- ☐ Establish agreements for data sharing with other ports involved in CO_2 transport to create a global knowledge base and repository of best practices.
- ☐ Facilitate a multi-stakeholder review process after project implementation, collecting insights from port operators, shipowners, regulatory bodies, and industry groups to enhance CO_2 transport governance policies.
- ☐ Ensure adherence to maritime regulations for CO_2 transport, especially concerning customs, taxation, leak liability, and long-term accountability for CO_2 Storage.

Optional tasks and considerations:

- ☐ Monitor the effect of the use of CO_2 transport on emissions reductions within the port and its contribution to overall climate objectives.
- ☐ Monitor and publish the quantities of CO_2 loaded and offloaded.
- ☐ Organise an international CO_2 transport summit or workshop to establish the port as a leader in CO_2 shipping integration and knowledge sharing.
- ☐ Collaborate with policymakers to investigate incentives for the long-term adoption of CO_2 transport, such as regulatory support, tax benefits, or integration into carbon markets.
- ☐ Evaluate how international CO_2 transport restrictions, such as the London Protocol amendments, affect the port's ability to export CO_2 across jurisdictions.

- Domain: Safety

Strategies, tasks and measures:

- ☐ Project teams should plan and execute each new CO_2 loading and offloading operation as was done in PRL-CO_2 6, including receiving approval from relevant competent authorities and ensuring safety protocols for every project.
- ☐ Competent authority is granting project-based licences or exemptions for CO_2 transport operations.
- ☐ Establish a CO_2 transport safety audit process to ensure ongoing improvement based on lessons learned from project operations.
- ☐ Establish standardised emergency response plans for CO_2 loading and offloading, ensuring that first responders, port authorities, and vessel operators are coordinated in CO_2 leak and incident mitigation protocols.
- ☐ Create a port-wide CO_2 safety culture training program for the port, incorporating periodic refresher courses for all personnel involved in CO_2 loading and offloading operations.
- ☐ Incorporate CO_2 transport safety into comprehensive port emergency drills, ensuring alignment with current hazardous cargo handling protocols.
- ☐ Conduct a study examining the effects of CO_2 venting and accidental releases, focusing on potential asphyxiation risks, cryogenic hazards, and environmental concerns.

- ☐ Create a risk assessment protocol for concurrent CO_2 loading/offloading and other port activities (SIMOPS).
- ☐ Conduct shipboard CO_2 handling safety audits to ensure vessels comply with international cryogenic transport safety standards.

Optional tasks and considerations:

- ☐ Create a risk assessment protocol for concurrent CO_2 loading/offloading and other port activities (SIMOPS).
- ☐ Assess the necessity of dedicated CO_2 transport safety teams at the port to manage operations on a full-time basis instead of a project-by-project approach.
- ☐ Investigate AI-driven safety monitoring tools that automatically identify CO_2 leaks or anomalies in CO_2 loading and offloading operations.
- ☐ Investigate the risks associated with CO_2 phase changes and the potential for dry ice formation in pipelines and shipboard systems.

- Domain: Infrastructure

Strategies, tasks and measures:

- ☐ Implement the admission procedure for vessels transporting CO_2 to enter the port.
- ☐ Ensure necessary infrastructure to execute CO_2 transport operations exists or is developed for (if applicable) STS, STT, or direct pipeline transfer, depending on project relevancy; and "spin-off" infrastructure, such as temporary CO_2 storage or auxiliary gas-handling services.
- ☐ Aid port operations with strong IT support that is adapted to CO_2 handling operations.
- ☐ Evaluate the necessity for dedicated CO_2 handling infrastructure, shifting from flexible project-based setups to permanent or semi-permanent CO_2 loading and offloading stations.
- ☐ Establish guidelines for CO_2 offloading site selection, ensuring that locations are optimised to minimise disruption to other port operations.
- ☐ Standardise CO_2 offloading connection interfaces to enable seamless loading and unloading across various vessel types and storage solutions.
- ☐ Conduct a port-wide CO_2 pipeline feasibility study across the port to evaluate the viability of a dedicated pipeline connection between CO_2 offloading points and storage/utilisation facilities.
- ☐ Examine the feasibility of offshore CO_2 offloading terminals, especially for ports limited by onshore storage capacity.
- ☐ Assess logistics for CO_2 transhipment hubs, determining if specific ports can function as regional CO_2 aggregation points for subsequent distribution to storage sites.

Optional tasks and considerations:

- ☐ Develop procedures or integrate CO_2 transport into the procedures for Vessel Traffic Services (VTS) and Vessel Traffic Management (VTM).
- ☐ Investigate the potential of mobile CO_2 buffer storage to enable greater flexibility in scaling CO_2 handling capacity.
- ☐ Consider scalable modular CO_2 storage solutions to adapt to variations in transport demand.
- ☐ Assess the viability of floating CO_2 storage units (FSUs) for temporary CO_2 storage at critical offloading points.

- Domain: Market, supply/demand

Strategies, tasks and measures:

- ☐ Implement a market strategy that identifies new opportunities and supports the uptake of CO_2 shipping through:
  - Funding and support for demonstration projects,
  - Short-term or long-term financing for CAPEX or OPEX,
  - A pricing incentive for vessels transporting CO_2 vs conventional cargo carriers.
- ☐ Monitor funding and pricing opportunities.
- ☐ Develop financial models for long-term CO_2 transport services, ensuring they align with industry needs concerning port fees, service charges, and potential carbon credit monetisation.
- ☐ Enhance CO_2 transport service options, including optional CO_2 purification, compression, or direct pipeline transport to storage/utilisation locations.
- ☐ Create a clear pricing model for CO_2 transport that guarantees predictability for shipowners and encourages greater adoption of CO_2 shipping.
- ☐ Identify potential cross-sector partnerships, particularly with carbon-utilisation industries (e.g., synthetic fuel production and cement manufacturing), to create a stable demand for transported CO_2.
- ☐ Assess potential long-term offtake agreements for CO_2 transport to permanent storage sites.

Optional tasks and considerations:

- ☐ Explore market niches for CO_2 transport and potential integration into existing CCUS value chains.
- ☐ Connect stakeholders within the CO_2 transport and utilisation supply chain with potential customers.
- ☐ Evaluate global CO_2 shipping market trends, ensuring the port remains competitive in pricing, infrastructure, and regulatory alignment.
- ☐ Investigate potential funding sources for transitioning CO_2 transport from project-based operations to fully commercialised services.

☐ Analyse the economic viability of CO_2 export to regions with large-scale permanent storage capacity.

Level 7 objective achieved: ☐ **Confirmed**

Loading and offloading of CO_2 from vessels transporting CO_2 can take place in the port on a project basis and are controlled by safety protocols and project teams.

- ☐ The port's formal policy on how to facilitate vessels transporting CO_2 on a project basis has been accepted by relevant stakeholders. The port governance is able to support regular CO_2 loading and offloading operations.
- ☐ Port safety and regulatory framework is project-based fit for facilitating CO_2 loading and offloading operations, controlled by safety protocols and project teams.
- ☐ Port infrastructure is project-based and fit for facilitating CO_2 loading and offloading operations, controlled by safety protocols and project teams.
- ☐ A starting CO_2 shipping market is developed, and the port is exploring business opportunities for CO_2 transport and is prepared to host larger and more frequent CO_2 shipping operations.

The strategies, tasks and measures of the domains within level 8 are being prepared.

Level 8: Full CO_2 transport capabilities for commercial operations

Level 8 Objective: To facilitate full capabilities for CO_2 shipping operations at the port, where loading and offloading operations are system-based and managed by audits, licensing, and continuous monitoring.

The strategies, tasks and measures of the domains in level 7 have been evaluated, and lessons learned are implemented.

- Domain: Governance

Strategies, tasks and measures:

- ☐ Perform a full audit and assessment to fully license operators who conducted CO_2 loading and offloading in PRL-CO_2 6 or 7.
- ☐ Initiate the system of auditing and licensing determined in the guiding framework for any additional operators seeking to transport CO_2 by ship.
- ☐ Develop a comprehensive long-term CO_2 transport governance framework, ensuring that CO_2 shipping is seamlessly integrated into standard port operations with organised permitting and regulatory oversight.
- ☐ Standardise CO_2 transport permits and licenses to establish a clear process for operators to secure long-term approvals instead of requiring case-by-case project approvals.
- ☐ Strengthen regulatory alignment between CO_2 transport and broader CCUS networks, ensuring compatibility with national and international CO_2 transport and storage regulations, including the London Protocol, MARPOL Annex VI, and EU ETS shipping regulations.
- ☐ Develop mechanisms for regulatory enforcement to ensure that vessels not in compliance with CO_2 transport regulations are identified and appropriate corrective actions are taken. (Shifts from voluntary compliance to enforceable measures.)
- ☐ Establish data-sharing agreements with regulatory bodies, ensuring that real-time monitoring of CO_2 transport performance is reported to oversight agencies. Permanent monitoring must now be established.

Optional tasks and considerations:

- ☐ Measure and report the impact of CO_2 shipping operations on overall port emissions and climate objectives.
- ☐ Report and publish the quantity of CO_2 loaded and offloaded at the port.
- ☐ Continue to share experiences and lessons learned with other ports handling CO_2 transport.
- ☐ Organise CO_2 transport regulatory workshops with international policymakers to ensure the standardisation of CO_2 handling, reporting, and compliance mechanisms across ports.

- ☐ Establish a mechanism for grievance and dispute resolution, enabling stakeholders (e.g., ship operators, CO_2 buyers, and regulators) to quickly address operational issues.
- ☐ Engage with policymakers to assess possible amendments to the London Protocol, enabling greater flexibility in cross-border CO_2 transport.

- Domain: Safety

Strategies, tasks and measures:

- ☐ Scale-up operations according to the guiding framework to facilitate CO_2 transport as part of normal port operations, ensuring all safety and regulatory requirements are met and port-wide organisational oversight is in place.
- ☐ Arrange on-going training and drills for the port's emergency response organisation in collaboration with CO_2 vessel operators, CO_2 storage facilities, and regulatory agencies.
- ☐ Continuously monitor CO_2 loading and offloading operations and operators to ensure compliance with the safety and regulatory framework.
- ☐ Competent authority is granting system-based licences or exemptions for CO_2 shipping operations.
- ☐ Establish a comprehensive CO_2 transport safety audit system for the port, mandating regular audits for vessels, operators, and port facilities to ensure safety compliance.
- ☐ Develop an automated risk assessment tool that integrates real-time data from CO_2 loading and offloading operations to proactively detect potential safety concerns. Data-driven risk management is necessary at scale.
- ☐ Ensure that all CO_2 transport personnel complete certified training programs, making compliance mandatory for all port staff and third-party operators. (Shifts from recommended to required training.)
- ☐ Expand emergency response plans for large-scale CO_2 transport incidents by ensuring that fire, spill, and gas dispersion response measures are scaled appropriately to accommodate increasing CO_2 volumes. (Expands on level 7 emergency response to include higher-risk scenarios.)
- ☐ Establish clear liability and insurance policies for CO_2 transport operations to ensure all parties comprehend their financial and legal responsibilities in the event of accidents. (Permanent services necessitate structured liability coverage.)

Optional tasks and considerations:

- ☐ Create a digital monitoring system to track CO_2 loading and offloading safety performance in real time.
- ☐ Integrate AI-driven safety monitoring to enable real-time anomaly detection during CO_2 loading and offloading operations, preventing system failures.

- ☐ Conduct regular emergency response drills with vessel operators and CO_2 storage providers to ensure effective cross-sector coordination for incident management.
- ☐ Examine the risks related to CO_2 phase changes and the potential for dry ice formation in pipelines and shipboard systems.

- Domain: Infrastructure

Strategies, tasks and measures:

- ☐ Ensure that dedicated infrastructure is in place for CO_2 transport, including loading and offloading terminals, temporary storage, and transfer systems to pipelines or transport hubs and sufficient services.
- ☐ Transition CO_2 transport from temporary to dedicated infrastructure, ensuring that permanent storage, pipeline connections, or direct CO_2 transport to industrial partners are available.
- ☐ Expand CO_2 transport capacity according to projected demand by determining the necessity for additional berths, storage tanks, or offloading stations. (Transition from flexible project-based capacity to long-term infrastructure planning.)
- ☐ Implement standardised CO_2 transfer systems to ensure compatibility among various ship designs and CO_2 offloading terminals, promoting interoperability across different CO_2 vessel types.
- ☐ Digitise port logistics for CO_2 transport by integrating scheduling, tracking, and reporting into the port's digital management system.

Optional tasks and considerations:

- ☐ Assess infrastructure needs for scaling CO_2 transport capacity to meet rising demand.
- ☐ Explore the feasibility of shared CO_2 transport hubs, where multiple vessels can offload CO_2 at one centralised facility. (Shared hubs could improve efficiency.)
- ☐ Explore options for floating CO_2 storage facilities, offering flexibility for ports with spatial limitations. (For ports with restricted onshore capacity.)
- ☐ Evaluate the logistics of CO_2 transshipment hubs by identifying if specific ports can act as regional CO_2 aggregation points for subsequent distribution to storage sites.

- Domain: Market, supply/demand

Strategies, tasks and measures:

- ☐ Establish commercial frameworks for CO_2 transportation services, including pricing models, service agreements, and integration with carbon markets.
- ☐ Develop a clear and transparent service fee structure for CO_2 transport operations, ensuring predictable costs for ship operators.

- ☐ Enhance market engagement by fostering connections among vessel operators, CO_2 storage facilities, and industrial CO_2 users.
- ☐ Define long-term commercial contracts for CO_2 transport to ensure stable revenue streams for port operators and predictable costs for vessel owners. (Transition from pilot project pricing to structured, long-term pricing agreements.)
- ☐ Develop a CO_2 pricing model for shipping services that ensures transparent pricing structures aligned with carbon markets and regulatory frameworks.
- ☐ Integrate CO_2 transport into voluntary and compliance carbon markets, enabling ship operators to earn revenue from CO_2 transport activities.
- ☐ Expand partnerships with industrial CO_2 buyers, ensuring the transported CO_2 has end-users in carbon utilisation sectors (e.g., synthetic fuels, cement, chemicals). This builds on level 7 while formalising end-user agreements.
- ☐ Create financial incentives for early adopters of CO_2 shipping to ensure that vessels transporting CO_2 gain cost advantages over conventional cargo operations.

Optional tasks and considerations:

- ☐ Customers may set ambitions and clear timelines for decarbonisation that align with CO_2 transport by ship.
- ☐ Assess the potential for CO_2 export by determining if ports can be integrated into larger CO_2 transport networks that supply global sequestration projects.
- ☐ Examine public-private funding models for the expansion of CO_2 transport, ensuring sustained investment in CO_2 infrastructure.
- ☐ Evaluate the economic feasibility of CO_2 export to areas with large-scale permanent storage capacity.

Level 8 objective achieved: ☐ **Confirmed**

The port supports full CO_2 shipping capabilities, and operations are successfully system-based and managed through audits, licensing, and monitoring.

- ☐ The port governance is able to support regular CO_2 loading and offloading operations controlled by safety management.
- ☐ The port's safety and regulatory framework is system-based fit for facilitating CO_2 loading and offloading operations, controlled by safety management and compliance checks.
- ☐ The port's infrastructure is system-based, fit for facilitating CO_2 loading and offloading operations.
- ☐ A growing CO_2 shipping market is developing, and the port is exploring business opportunities for CO_2 transport and utilisation.

The strategies, tasks and measures of the domains within level 9 are being prepared.

Level 9: Integration of CO_2 transport into routine port activities and growth

Level 9 Objective: To expand the market and demand for CO_2 shipping services, ensuring a competitive environment for vessel operators, CO_2 handling service providers, and CO_2 buyers while establishing CO_2 transport as a standardised and scalable operation.

The strategies, tasks and measures of the domains in level 8 have been evaluated, and lessons learned are implemented.

- Domain: Governance

Strategies, tasks and measures:

- ☐ Licensed CO_2 handling operators provide CO_2 loading and offloading services to vessels on a regular basis.
- ☐ A plan, do, check, act (PDCA) cycle and evaluation-based system is in place for all aspects of the safety framework and CO_2 transport operations.
- ☐ Develop a network strategy to remain up to date with innovations and new trends in CO_2 transport infrastructure, carbon markets, and technical improvements for CO_2 handling and storage.
- ☐ Establish a regulatory roadmap for long-term CO_2 shipping operations that ensures alignment with international maritime regulations, carbon markets, and environmental policies.
- ☐ Establish a standardised compliance framework for CO_2 shipping at various ports, facilitating the global harmonisation of regulations and best practices.
- ☐ Establish a stakeholder advisory board for CO_2 shipping to ensure regular engagement with vessel operators, CO_2 buyers, port authorities, and regulatory bodies. (Market-driven expansion requires input from various stakeholders.)
- ☐ Enhance cross-border CO_2 shipping agreements to ensure that vessels transporting CO_2 can load or offload at multiple ports with aligned regulations. This will enable international CO_2 hubs to operate seamlessly together.

Optional tasks and considerations:

- ☐ Develop key performance indicators (KPIs) for the port's environmental performance related to CO_2 shipping.
- ☐ Develop and implement a system to track all CO_2 loading and offloading operations at the port to support GHG reporting and integration with carbon markets.
- ☐ Organise an international CO_2 shipping forum to promote knowledge sharing, standardise technology, and harmonise regulations among ports engaged in CO_2 transport.

- ☐ Collaborate with international organisations (IMO, IAPH, and climate bodies) to develop CO_2 shipping certification programs for vessels and operators.
- ☐ Engage policymakers to assess possible revisions to the London Protocol that would enable greater flexibility in cross-border CO_2 transport.

- Domain: Safety

Strategies, tasks and measures:

- ☐ Incorporate a plan, do, check, act (PDCA) cycle in the port's safety management system to check and improve its CO_2 shipping safety framework regularly.
- ☐ Develop an international CO_2 shipping safety code to ensure all vessels and port facilities adhere to standardised operational and safety procedures.
- ☐ Integrate CO_2 shipping safety standards into current port-wide hazard management frameworks, ensuring seamless alignment with other hazardous material handling protocols.
- ☐ Require independent safety audits for CO_2 shipping service providers to ensure third-party verification of safety compliance. (Oversight extends beyond the port authority.)

Optional tasks and considerations:

- ☐ Enhance safety best practices through collaboration with other ports and industry groups to refine CO_2 shipping risk mitigation strategies.
- ☐ Utilise AI-driven safety analytics to forecast and address potential risks in CO_2 shipping operations.
- ☐ Explore blockchain or digital twin technologies to enhance CO_2 shipping safety monitoring and compliance tracking.
- ☐ Investigate the risks associated with CO_2 phase changes and the potential for dry ice formation in pipelines and shipboard systems.

- Domain: Infrastructure

Strategies, tasks and measures:

- ☐ Ensure the port is capable of regular CO_2 loading and offloading operations, with the necessary infrastructure and capacity to handle growing demand.
- ☐ Create a roadmap for CO_2 shipping infrastructure expansion by identifying future capacity needs according to projected adoption rates.
- ☐ Establish dedicated CO_2 shipping berths and optimise port logistics to ensure efficient vessel turnaround times.
- ☐ Ensure that CO_2 shipping facilities are integrated into the broader CCUS infrastructure to allow seamless movement of CO_2 to storage or utilisation sites.

Optional tasks and considerations:

- ☐ Evaluate the feasibility of expanding CO_2 shipping infrastructure to support multiple vessels at the same time or to address emerging industry demands.
- ☐ Evaluate modular CO_2 storage solutions that permit scalable and flexible expansion to accommodate increasing demand.
- ☐ Investigate the co-location of CO_2 shipping terminals with industrial CO_2 users to facilitate direct CO_2 utilisation when feasible.
- ☐ Evaluate the logistics of CO_2 transshipment hubs, determining whether specific ports can serve as regional CO_2 aggregation points for further distribution to storage sites.

- Domain: Market, supply/demand

Strategies, tasks and measures:

- ☐ Assess the quality and effectiveness of the CO_2 shipping market arrangements, including the market strategy and supply chain arrangements, port incentives for supporting CO_2 transport, the port pricing strategy, and market communication. The market should support:
  - Multiple service providers offering CO_2 transport,
  - Multiple CO_2 buyers securing offloaded CO_2 for utilisation or permanent storage,
  - A balanced supply and demand.
- ☐ Contracts or agreements between CO_2 suppliers, vessel operators and offloading service providers.
- ☐ Ensure the port is capable of allowing stakeholders to make final investment decisions (FID) on CO_2 shipping infrastructure projects.
- ☐ Develop a financial roadmap for CO_2 shipping market expansion, ensuring clear investment pathways for new service providers and infrastructure development.
- ☐ Establish a transparent pricing structure for CO_2 shipping that benefits vessel operators, CO_2 storage providers, and carbon credit generators. (Market-based pricing is vital for the industry's growth.)
- ☐ Expand collaborations with carbon utilisation sectors to ensure a consistent demand for transported CO_2 beyond sequestration.
- ☐ Integrate CO_2 shipping into voluntary and compliance carbon markets, enabling vessel operators to monetise CO_2 transport and offloading services.

Optional tasks and considerations:

- ☐ Develop a strategy to integrate CO_2 shipping with broader CCUS markets and CO_2 transport networks, ensuring long-term sustainability.
- ☐ Provide an update to relevant green corridor projects or proposals on the new status of the port as a CO_2 shipping hub.
- ☐ Assess incentives for early adopters of CO_2 shipping, such as tax benefits, port fee reductions, or emissions-based credits.

- ☐ Examine both regional and global CO_2 shipping demand, ensuring that infrastructure and service models align with projected growth.
- ☐ Explore financing methods for CO_2 shipping expansion, such as public-private partnerships and green investment funds.
- ☐ Assess potential markets for CO_2 shipping exports, identifying regions with a high demand for CO_2 transporting CO_2 to storage sites or industrial users.

Level 9 objective achieved: ☐ **Confirmed**

The port offers a competitive environment for vessels transporting CO_2, with CO_2 loading and offloading capabilities fully incorporated into regular port processes to ensure the commercial success of the port.

- ☐ The port is future-proof for vessels engaged in CO_2 transport and offloading operations.
- ☐ Port quality and safety management is future-proof and prepared for facilitating CO_2 loading and offloading operations with a robust compliance and monitoring framework.
- ☐ Port infrastructure is future-proof and prepared for facilitating calls, CO_2 loading and offloading operations, ensuring compatibility with long-term CO_2 transport and storage solutions.
- ☐ The port contains a mature market for CO_2 shipping, supporting multiple service providers and integration with carbon markets and CCUS networks.

4 Acknowledgements

The EverLoNG project is funded through the ACT programme (Accelerating CCS Technologies, Horizon2020 Project No 691712). Financial contributions have been made by the Ministry of Economic Affairs and Climate Policy, the Netherlands; The Federal Ministry for Economic Affairs and Climate Action, Germany; the Research Council of Norway; the Department for Business, Energy & Industrial Strategy, UK; and the U.S. Department of Energy. All funders are gratefully acknowledged.