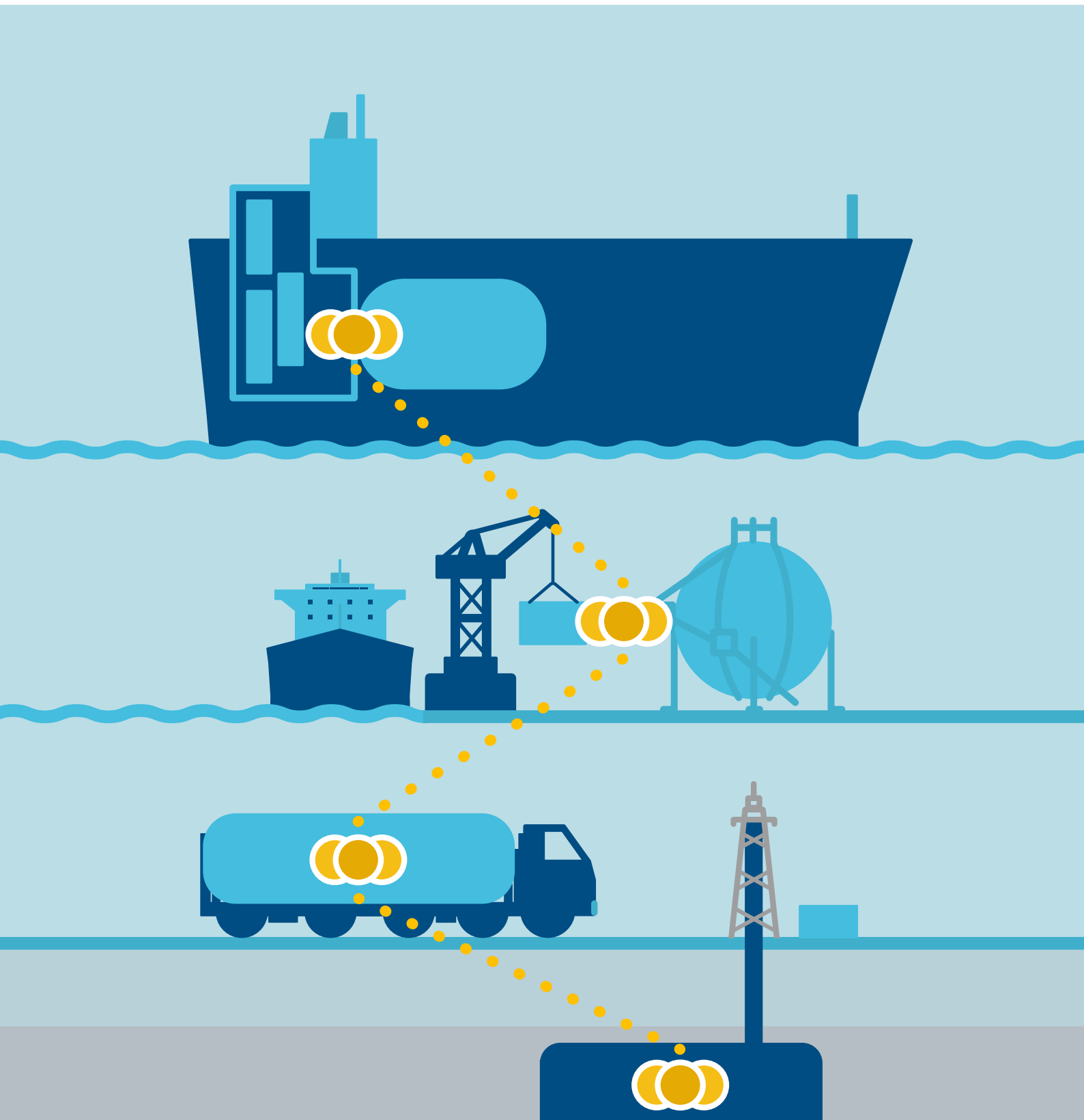


~ Handbook on Ship GHG Emissions Evaluation ~
Onboard Carbon Capture Systems Implementation Framework
(Edition. 1.0)

[English]



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Introduction

As international shipping seeks to reduce greenhouse gas (GHG) emissions, various measures have been introduced, including operational improvements, the adoption of energy-efficiency technologies, and the use of alternative fuels. Among the options receiving increasing attention is onboard CO₂ capture. Onboard Carbon Capture Systems (OCCS) are systems installed on board ships to capture CO₂ from exhaust gas, process it, and temporarily store it on board. OCCS is expected to provide one of the options for supporting GHG emission reductions in international shipping, including for existing ships.

However, the implementation and operation of OCCS extend beyond the onboard system itself. In addition to unloading, transporting, and ultimately storing, fixing, or utilizing captured CO₂, it is essential to ensure traceability throughout the entire process and to enable the quantification and verification of GHG emission reduction benefits. In this context, Monitoring, Reporting and Verification (MRV), Chain of Custody (CoC) (which provides a mechanism for transferring, tracking, and managing captured CO₂ together with its associated attribute information throughout the value chain), and independent third-party verification all play important roles. Therefore, when considering the implementation of OCCS, it is necessary to understand and assess the entire value chain, including CO₂ capture technologies, port and transportation infrastructure, CCS projects, and relevant regulatory frameworks.

ClassNK has promoted the development of safety and technical requirements for OCCS through the publication of its *Guidelines for Onboard CO₂ Capture and Storage Systems*. In addition, ClassNK has conducted technical studies on OCCS, participated in demonstration projects, and investigated and disseminated information on regulatory developments. Building on these activities, this handbook has been prepared primarily for shipowners and operators considering the implementation of OCCS. Its objective is to systematically organise the technical, infrastructural, regulatory, and GHG emission reduction assessment considerations relevant to implementation decisions and to provide information that supports informed decision-making.

The handbook is structured to provide an overview of the entire OCCS value chain, covering not only onboard capture systems but also the subsequent stages, from the unloading and transportation of captured CO₂ to its final Storage, Fixation, or Utilisation, together with the approaches used to quantify and verify the associated GHG emission reduction benefits.

This handbook has been prepared based on regulations, guidelines, and publicly available information as of the end of August 2026 (see the References section at the end of this handbook). International regulatory frameworks and methodologies for assessing GHG emission reductions associated with OCCS continue to evolve, and discussions are ongoing regarding the practical implementation of the quantification and verification of captured CO₂. It is hoped that this handbook will support the decision-making of shipowners and operators considering the implementation of OCCS and contribute to a broader understanding among stakeholders throughout the OCCS value chain, including marine equipment manufacturers, shipyards, and companies involved in CO₂ shore-side transportation and storage.

Revision Record

Version	Date	Section	Detail
1.0	2026.10	—	—

Abbreviations

AVR	Accreditation and Verification Regulation
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilisation ¹
CCUS	Carbon Capture, Utilisation and Storage
CoC	Chain of Custody
DAC	Direct Air Capture
DCS	Data Collection System
EEA	European Economic Area
EOR	Enhanced Oil Recovery
EU	European Union
EU ETS	European Union Emissions Trading System
EU MRV	European Union Monitoring, Reporting and Verification
GESAMP	Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection
GFI	Greenhouse Gas Fuel Intensity
GHG	Greenhouse Gas
HAZID	Hazard Identification Studies
IMO	International Maritime Organization
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
LCO ₂ Carrier	Liquefied Carbon Dioxide Carrier
LNG	Liquefied Natural Gas
M-AVR	Maritime Accreditation and Verification Regulation
MEPC	Marine Environment Protection Committee
MRR	Monitoring and Reporting Regulation
MRV	Monitoring, Reporting and Verification
NO _x	Nitrogen Oxides
OCCS	Onboard Carbon Capture Systems ²
SCCS-Full	Shipboard Carbon Capture and Storage (Full) ³
SO _x	Sulphur Oxides

¹ CCU pathways may be categorised as either permanent fixation or re-release utilisation and are treated differently under regulatory frameworks (see Sections 1-5 and 4-2).

² Although the term “Onboard Carbon Capture and Storage” is also used in IMO documents, the storage of captured CO₂ on board a ship is only temporary, pending unloading, and differs in nature from storage in the CCS context, which refers to permanent geological storage. In this handbook, Onboard Carbon Capture Systems (OCCS) is used in line with the Terms of Reference of the GESAMP-LCA Working Group and related documents (see Section 1-4).

³ ClassNK Notation for Onboard CO₂ Capture and Storage Systems. Following the revision of the *Guidelines for Onboard CO₂ Capture and Storage Systems*, the SCCS-Full notation has been renamed to OCCS-Full.

Overview

Understanding the Key Considerations for OCCS Adoption

Ch.	Theme	Key Content
Ch. 1	 Overview Understand the Foundations and Basic Structure of OCCS Adoption	➤ Clarify the significance of OCCS adoption and its role in the maritime industry ➤ Explain the overall value chain and the basic approach to assessment ➤ Classify the final destinations of captured CO₂
Ch. 2	 Technology Understand OCCS technology and key equipment considerations	➤ Provide an overview of onboard CO₂ capture technologies ➤ Summarise key technical considerations, including capture rate, energy penalty, and captured CO₂ quality management
Ch. 3	 Infrastructure Understand the overall infrastructure for CO ₂ transport and storage	➤ Summarise the overall OCCS-related infrastructure and its components ➤ Explain methods and characteristics of CO₂ transport, storage, permanent fixation, and utilisation ➤ Summarise key considerations for interfacing with infrastructure
Ch. 4	 Regulatory Framework Understand the rules and principles for recognising emission reductions	➤ Explain the basic principles and frameworks of the EU and IMO ➤ Summarise approaches to recognising GHG emission reductions from captured CO₂ under each framework
Ch. 5	 Verification Understand MRV, CoC, and third-party verification frameworks	➤ Explain MRV principles and key points for data collection and reporting ➤ Summarise Chain of Custody and traceability principles ➤ Explain the role of third-party verification and future regulatory developments
Ch. 6	 Implementation Decision Determine whether OCCS should be adopted based on the evaluation results	➤ Consider adoption decisions based on the elements covered in each section ➤ Present a process for making an overall adoption decision based on the evaluation criteria

Chapter 1 Basic Framework for OCCS Implementation

1-1. Role of OCCS in Maritime Decarbonisation

The international shipping industry is currently undergoing significant regulatory and technological changes aimed at decarbonisation. The 2023 IMO GHG Strategy sets out targets for reducing GHG emissions from international shipping and establishes the ambition of achieving net-zero emissions by or around 2050. In addition, the EU has introduced its own regulatory measures, including the EU ETS and FuelEU Maritime, thereby establishing frameworks that encourage shipping companies to reduce GHG emissions.

In response to these developments, various approaches to reducing GHG emissions are being considered across the maritime sector. In addition to operational improvements and energy-efficiency technologies, the transition to alternative fuels such as biofuels, methanol, ammonia, and hydrogen has attracted attention as one of the principal decarbonisation options. However, conditions vary from ship to ship, including operating patterns, ship age, and the availability of fuel supply infrastructure. As a result, the same solution may not be suitable for all ships. For existing ships, challenges related to fuel supply infrastructure, ship modifications, impacts on cargo capacity, and economic feasibility may make the transition to alternative fuels particularly difficult in some cases.

Against this backdrop, OCCS is attracting increasing attention as a potential means of reducing GHG emissions across a wide range of ship types. OCCS is an onboard system that captures CO₂ from ship exhaust gas and temporarily stores it on board. By enabling the continued use of conventional fuels while potentially contributing to GHG emission reductions, OCCS is expected to serve as one of the options supporting the decarbonisation of the maritime sector.

Furthermore, OCCS is not expected to be used solely as a stand-alone measure but also in combination with other GHG emission reduction measures. In the future, combining OCCS with low-carbon fuels and other emission reduction technologies may further enhance overall GHG reduction performance. Accordingly, OCCS can be regarded as one of the measures contributing to the decarbonisation of the maritime sector.

1-2. Overview of the OCCS Value Chain

When considering OCCS, it is necessary to look beyond the onboard capture system itself and consider the subsequent handling of captured CO₂. Discussions on OCCS often focus on onboard capture technologies. However, onboard CO₂ capture represents only one component of the overall OCCS value chain. After being captured and temporarily stored on board, CO₂ is unloaded and transported before ultimately being directed to one of three pathways: Storage, Fixation, or Utilisation.

Furthermore, whether OCCS can be recognised as a GHG emission reduction under applicable regulatory frameworks is not determined solely by the fact that CO₂ has been captured on board. What ultimately matters is how the captured CO₂ is managed after unloading and whether this process can be properly demonstrated and verified. In practice, the final destination of captured CO₂ and the establishment of traceability are among the key issues currently being discussed in the ongoing development of regulatory frameworks within both the EU and the IMO.

For this reason, it is important to understand OCCS as an integrated value chain, as illustrated in Figure 1-1, encompassing the complete process from CO₂ capture, unloading, and transportation through to final Storage, Fixation, or Utilisation. In addition, it is necessary to understand the supporting mechanisms required for these activities to be recognised as GHG emission reductions under regulatory frameworks, including MRV and CoC.

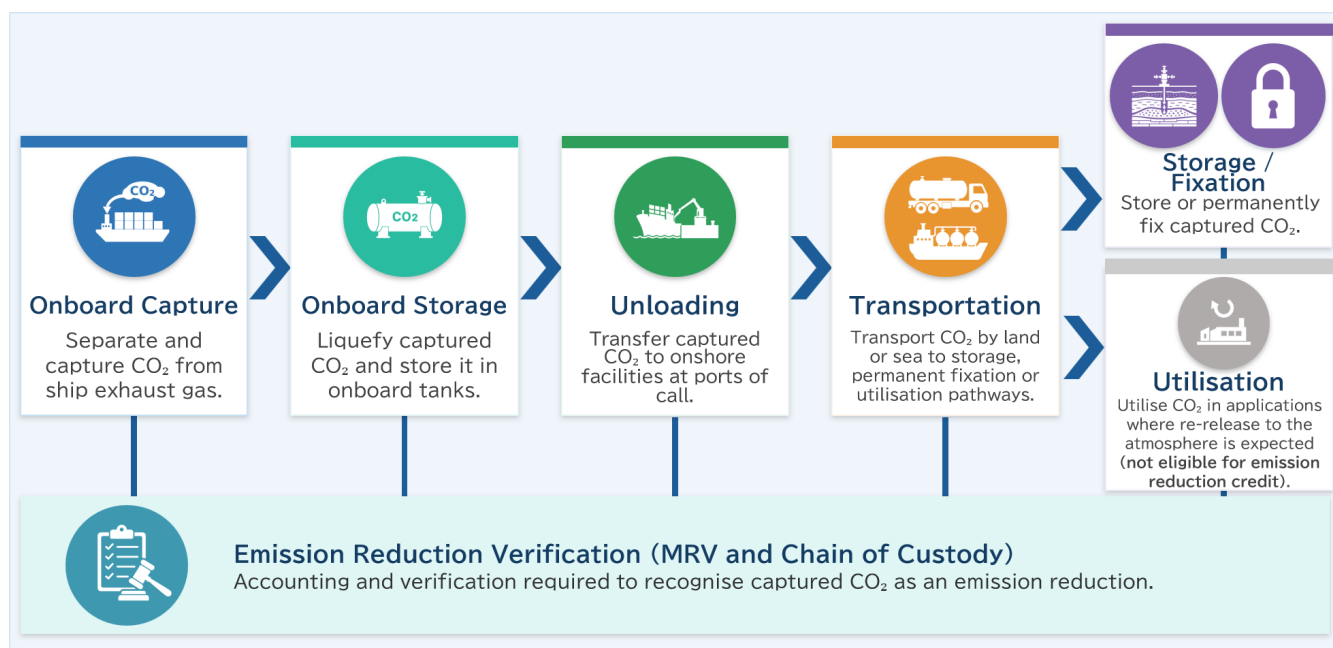


Figure 1-1 Overview of the OCCS Value Chain

1-3. Key Stakeholders in the OCCS Value Chain

As discussed above, OCCS extends beyond the capture of CO₂ on board and encompasses an entire value chain leading to its final destination. Accordingly, a wide range of stakeholders are involved, including shipowners and operators, equipment manufacturers, shipyards and engineering companies, port operators, transportation providers, entities responsible for the final treatment of captured CO₂, and independent third-party verification bodies.

No single stakeholder can typically deliver the entire OCCS value chain on their own. Effective implementation, therefore, requires coordination and cooperation among all stakeholders involved.

At the centre of the value chain are shipowners and operators. As the primary decision-makers for OCCS implementation, they determine the candidate ships, operating profiles, and implementation strategies, while also assessing investment requirements and commercial feasibility.

Equipment manufacturers are responsible for developing and supplying onboard capture systems, compression and liquefaction equipment, and storage systems. Shipyards and engineering companies are responsible for integrating these systems into ships. Particularly in retrofit projects, their involvement from the early planning stage is essential to address issues such as engine room arrangement, tank layout, weight distribution, and impact on safety.

Port operators are responsible for establishing and operating facilities for the reception and unloading of captured CO₂, while transportation providers transport the unloaded CO₂ to its final destination. In addition, entities responsible for the Storage, Fixation, or Utilisation of captured CO₂ play a critical role in enabling the GHG emission reduction benefits associated with OCCS.

Where regulatory quantification and verification are required, independent third-party verification bodies are also involved. Such verification plays an important role in ensuring the reliability of captured CO₂ quantities and related data, while objectively demonstrating the associated GHG emission reduction benefits.

As described above, OCCS involves a diverse range of stakeholders across the value chain. Therefore, when considering OCCS implementation, it is important not only to evaluate individual technologies but also to identify, coordinate, and manage the roles and relationships of the stakeholders involved.

1-4. Basic Approach for OCCS Implementation

Since the feasibility of OCCS implementation cannot be determined solely by the performance of the onboard system, what is important is whether the value chain required to appropriately manage captured CO₂ can be established.

For example, even if a high-performance OCCS is installed on board, continuous operation may not be feasible unless unloading facilities, transportation networks, and suitable pathways for the Storage, Fixation, or Utilisation of captured CO₂ are available. In addition, to assess the GHG emission reduction benefits associated with captured CO₂, mechanisms must be established to enable its post-capture pathway to be tracked and verified.

Accordingly, the viability of OCCS depends on a range of factors, including technology, infrastructure, regulatory frameworks, and the mechanisms supporting quantification and verification. Therefore, when considering OCCS implementation, a comprehensive assessment should be conducted from the following perspectives:

- Whether an unloading and transportation infrastructure capable of accepting captured CO₂ is available;
- Whether suitable Storage, Fixation or Utilisation pathways are available;
- Whether the selected destination or pathway may be recognised as an emission reduction under applicable regulatory frameworks;
- Whether compliance with applicable regulations and alignment with future regulatory developments can be ensured; and
- Whether supporting mechanisms, including MRV and CoC, can be established to support quantification and verification.

Based on this approach, the following chapters explain, in sequence, CO₂ capture technologies, transportation and storage infrastructure, regulatory frameworks, and the mechanisms supporting quantification and verification. Chapter 6 presents assessment criteria and key considerations for implementation decisions based on these elements. Information on OCCS implementation cases and related projects is provided in Appendices A and B.

1-5. Three Categories of Final Destinations for Captured CO₂

For the purposes of this handbook, the final destination of captured CO₂ is classified into three categories: geological storage (Storage), permanent chemical incorporation into products (Fixation), and utilisation involving the subsequent re-release of CO₂ (Utilisation). These categories differ fundamentally in the way they are treated under regulatory frameworks for the recognition of GHG emission reductions. It is therefore important to

distinguish between them and understand their respective characteristics. Regulatory treatment is discussed further in Chapter 4. The definitions used in this handbook are presented in Table 1-1.

Table 1-1 Definitions of Categories of Final Destinations for Captured CO₂

Category	Definition Used in this Handbook	Typical Examples
Storage	Injection of captured CO ₂ into deep geological formations for long-term isolation from the atmosphere. Within the EU, this includes injection into storage sites permitted under the CCS Directive (Directive 2009/31/EC).	Saline aquifer storage, depleted oil and gas field storage (e.g. Northern Lights (Norway), Greensand (Denmark) and Porthos (Netherlands))
Fixation	Permanent chemical incorporation of captured CO ₂ into a product in a manner that prevents its release to the atmosphere during normal use and after the end of the product's life under normal conditions.	Carbonated concrete, carbonated aggregates and products based on mineralisation (carbonate formation)
Utilisation	Use of captured CO ₂ as a feedstock or product where release back to the atmosphere is expected during use or following the end of the product's life.	Feedstock for synthetic fuels (e-fuels) and methanol, food and beverage applications, welding applications and agricultural applications
(Reference) Enhanced Oil Recovery (EOR)	A technique involving the injection of CO ₂ into oil reservoirs to improve crude oil recovery. Although a portion of the injected CO ₂ may remain underground, the primary purpose of EOR is to enhance oil recovery. It should therefore be distinguished from dedicated geological storage.	MOL Szank Field (Hungary), Zutica and Ivanic Grad Storage (Croatia)

In general, Carbon Capture and Storage (CCS) corresponds to the Storage category, whereas Carbon Capture and Utilisation (CCU) is an umbrella term encompassing both Fixation and Utilisation. As CCU does not distinguish between Fixation and Utilisation pathways involving the eventual re-release of CO₂, this handbook treats Fixation and Utilisation as separate categories.

Chapter Summary

- When considering OCCS implementation, it is important to assess not only the onboard system itself but also the viability of the entire value chain, including CO₂ unloading, transportation, final treatment pathways, and the mechanisms supporting quantification and verification.
- The OCCS value chain involves a wide range of stakeholders, including shipowners and operators, equipment manufacturers, shipyards and engineering companies, port operators, transportation providers, entities responsible for the Storage, Fixation or Utilisation of captured CO₂, and independent third-party verification bodies.
- The final destinations of captured CO₂ can be classified into three categories: Storage, Fixation, or Utilisation. Each category is subject to different regulatory treatment and approaches to the assessment of GHG emission reduction benefits.

Chapter 2 Onboard CO₂ Capture Technologies

2-1. Components of OCCS

The previous chapter explained that OCCS should be considered not merely as an onboard system but as an entire value chain extending to the final destination of captured CO₂. This chapter focuses on onboard CO₂ capture technologies, which form the starting point of that value chain. For detailed safety and technical requirements for OCCS, reference should be made to the *Guidelines for Onboard CO₂ Capture and Storage Systems* published by ClassNK.

An important aspect of understanding OCCS is recognising that it is not a single piece of equipment but an integrated system comprising multiple components, as illustrated in Figure 2-1. Exhaust gas from a ship is first directed to a CO₂ capture unit, where CO₂ is separated from the exhaust stream. The captured CO₂ is then processed through compression, liquefaction, or other treatment processes before being temporarily stored in onboard storage tanks. Instrumentation, monitoring equipment, and control systems are also required to ensure the safe and reliable operation of the overall system. In addition, some OCCS designs store captured CO₂ in combination with other substances rather than as pure CO₂.

At shore-based CCS facilities, relatively large sites are often available, allowing individual equipment and facilities to be arranged and optimised separately. By contrast, ships must accommodate the entire system within strict space and weight constraints. Consequently, it is important to evaluate not only the performance of individual components but also whether the overall system can be practically integrated on board, considering equipment arrangement, energy supply, piping systems, and control systems.

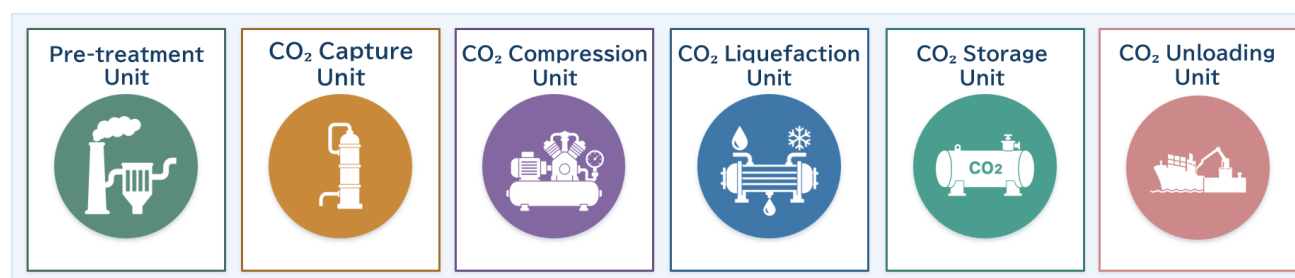


Figure 2-1 Typical Components of an OCCS

2-2. Overview of Onboard CO₂ Capture Technologies

When considering the implementation of OCCS, the selection of an appropriate CO₂ capture technology is one of the key decisions. Several CO₂ capture technologies are currently being considered for onboard applications. This section provides an overview of the principal post-

combustion capture technologies applicable to OCCS, which separate and capture CO₂ from exhaust gas generated by fuel combustion.

Among publicly announced OCCS demonstration and development projects, the chemical absorption method has been adopted in many cases. The chemical absorption method uses an absorbent solution, such as amines, to absorb CO₂ from exhaust gas, followed by the separation and recovery of CO₂ through a heating process. This technology has extensive operational experience in shore-based CO₂ capture facilities and is, therefore, regarded as one of the leading candidates for maritime applications.

However, the chemical absorption method generally requires thermal energy to regenerate the absorbent solution and recover the absorbed CO₂. Consequently, securing a suitable onboard heat source is an important consideration. The utilisation of waste heat from the main engine has been proposed as one potential solution, although the amount of heat available may vary depending on operating conditions. Furthermore, as exhaust gas composition and onboard operating conditions differ from those of shore-based facilities, experience gained from shore-based applications cannot necessarily be transferred directly to the onboard environment.

In recent years, the membrane separation method has also attracted considerable attention. The membrane separation method employs specialised membranes that selectively permeate CO₂, enabling its separation from exhaust gas streams. This approach is expected to facilitate modularisation and simplify system configuration. As no absorbent solution is required, it also offers the advantage of eliminating the need for solvent replenishment and management. However, challenges remain with respect to membrane performance and the energy consumption associated with generating the pressure differentials required to achieve high CO₂ capture rates.

In addition, research and development activities are being pursued for other technologies, including the physical absorption method and the cryogenic separation method. Each of these technologies has its own advantages and challenges, and further technological development and demonstration experience are expected to expand understanding of their suitability for shipboard applications.

Accordingly, when considering OCCS implementation, it is important to select a capture technology suited to the ship and trading route under consideration, considering factors such as available space and weight capacity, trading patterns, availability of heat and electrical power, CO₂ storage capacity, the frequency of CO₂ unloading, and acceptance conditions at receiving facilities.

For example, where chemical absorption technology is adopted, particular attention should be given to absorbent supply requirements and replenishment frequency, the availability of

heat for solvent regeneration, and the space required for installation of the capture system. As these considerations vary depending on the technology employed, the selection of an appropriate capture method should be based on the specific characteristics of the ship and its intended trading route.

2-3. Capture Rate and Energy Penalty

Capture rate and energy penalty are key parameters in the technical assessment of OCCS. In general, higher capture rates are associated with greater energy penalties. Energy penalty refers to the additional thermal energy and electrical power required to operate an OCCS and influences operating costs, fuel consumption, and overall system performance.

When evaluating OCCS technologies for implementation, it is not necessarily appropriate to assess them solely based on capture rate. Achieving higher levels of CO₂ capture generally requires greater energy input and larger equipment capacity, which in turn increases the associated energy penalty; for example, in chemical absorption systems, increasing the capture rate typically increases the heat required for solvent regeneration, resulting in additional energy demand. Similarly, increasing equipment capacity to improve capture performance usually leads to greater space and weight requirements. Furthermore, a higher energy penalty may result in increased fuel consumption and consequently higher GHG emissions.

In particular, recent discussions at the IMO have increasingly focused not only on the amount of CO₂ captured but also on the overall impact on GHG emissions across the entire OCCS value chain, including the energy required for the capture process; for example, even when a high capture rate is achieved, the net GHG emission reduction benefit may be limited if significant additional energy is required to achieve that performance.

Accordingly, when considering the implementation of OCCS, it is important to not just evaluate capture technologies based on capture rate but also consider energy requirements, equipment size implications, and the resulting overall GHG reduction benefits.

For a detailed evaluation, the balance between capture rate and energy penalty should be assessed in light of ship operating conditions and the availability of heat and electrical power. Reference should also be made to the approach to GHG emission reduction assessment described in Chapter 4.

2-4. Quality and Management of Captured CO₂

In addition to the quantity of captured CO₂, it is necessary to understand and appropriately manage its quality. This is because the quality of captured CO₂ may affect its subsequent transportation and integration into Storage, Fixation, or Utilisation pathways.

Ship exhaust gas contains impurities such as water vapour, sulphur oxides (SO_x), and nitrogen oxides (NO_x). If these impurities are not adequately removed, they may lead to solvent degradation, corrosion (e.g. of compressors, piping systems, and storage tanks), or otherwise adversely affect system performance. Furthermore, the type and concentration of impurities may influence liquefaction conditions and the design of pre-treatment systems.

In addition, transport operators and entities responsible for Storage, Fixation, or Utilisation may each establish their own acceptance criteria for captured CO₂. Consequently, it is necessary to manage not only CO₂ purity, water content, and impurity concentrations, but also pressure and temperature. The required quality specifications may also vary depending on the final destination, such as storage, fixation, or utilisation.

Such requirements may influence the specification and design of CO₂ capture and pre-treatment systems; for example, where higher CO₂ purity or stricter impurity control is required, additional treatment equipment or operational measures may be necessary. Furthermore, from the perspective of future quantification and verification, it is desirable to identify the applicable requirements during the OCCS planning stage and to appropriately monitor and record the actual quality of captured CO₂ during operation.

At present, no harmonised standards covering the entire OCCS value chain, from onboard capture through transportation to Storage, Fixation, or Utilisation, have been established. Accordingly, when considering OCCS implementation, it is necessary to confirm in advance the specific requirements of transport operators and Storage, Fixation, or Utilisation operators and to ensure that the OCCS design and operational arrangements can satisfy them. As the CCS market continues to develop and value chains become increasingly complex, further progress in standardisation and the harmonisation of captured CO₂ quality specifications is also expected.

2-5. Key Factors Affecting OCCS Implementation

Based on the technical characteristics discussed above, the feasibility of OCCS implementation can be evaluated from three principle perspectives: onboard integration, energy supply, and operation and maintenance.

The first, onboard integration of OCCS, requires not only the installation of the CO₂ capture unit itself but also compression equipment, liquefaction equipment, and storage tanks.

Particularly in retrofit projects, the arrangement of these components often becomes a key technical constraint. In addition, captured CO₂ must be stored on board until it can be unloaded at a suitable port. Consequently, storage capacity requirements may vary significantly depending on the amount of CO₂ captured, voyage duration, port call frequency, and the availability of ports capable of receiving captured CO₂. Furthermore, the weight of both the equipment and the stored CO₂ may affect cargo-carrying capacity and ship stability. Accordingly, the feasibility of installation should be assessed by considering available onboard space and weight margins, equipment arrangement, required CO₂ storage capacity, and potential impacts on cargo capacity and stability.

The second, energy supply of OCCS requires additional thermal energy and electrical power, energy management considerations such as power generation capacity and waste heat utilisation are important. Therefore, the heat and power requirements of the selected capture technology should be identified, and it should be confirmed that the required energy can be supplied reliably under the ship's expected operating conditions.

The third, operation and maintenance of OCCS increases the scope of onboard operational and maintenance activities; for example, capture equipment, compression and liquefaction systems, storage facilities, measuring instruments, and control systems all require monitoring, inspection, and maintenance. Accordingly, implementation planning should include an assessment of the required operational and maintenance activities, considering the workload of the crew, the frequency of maintenance, the replenishment arrangements of consumables, and the availability of shore-side support, to determine whether these activities can be accommodated within the ship's operational framework.

These factors are closely interrelated; for example, increasing the capture rate may increase the quantity of CO₂ captured, which in turn may require greater energy consumption and larger storage capacity. Therefore, when considering OCCS implementation, it is important not to evaluate individual elements in isolation but to assess whether the overall system is feasible under the specific conditions of the ship and its intended trading pattern, considering onboard integration, energy supply, and operation and maintenance requirements.

Chapter Summary

- OCCS comprises CO₂ capture equipment, compression and liquefaction systems, storage facilities, and associated instrumentation and control systems. A variety of capture technologies are available, including chemical absorption and other approaches.
- Higher capture rates may be accompanied by increased energy consumption and larger equipment requirements. Therefore, when evaluating OCCS performance, it is important to consider not only the capture rate but also the associated energy penalty and its impact on overall GHG emission reductions.
- The quality of captured CO₂ affects its compatibility with unloading, transportation, and subsequent Storage, Fixation, or Utilisation pathways. Accordingly, relevant quality requirements should be identified with due consideration of the entire value chain through to the final destination of the captured CO₂.
- The suitability of OCCS depends not only on capture performance but also on factors such as available onboard space, additional weight, energy penalty, captured CO₂ quality management, and operational conditions. Therefore, implementation should be assessed with due consideration of the technical constraints specific to the ship concerned.

Chapter 3 CO₂ Transportation and Storage Infrastructure

3-1. Overview of OCCS Infrastructure

When implementing OCCS, it is necessary not only to determine which CO₂ capture technology will be installed but also to identify in advance where the captured CO₂ will be transported and how it will ultimately be managed. This is because, even if CO₂ is successfully captured on board, its continuous management cannot be ensured unless downstream transportation routes and final destination pathways are available.

The infrastructure supporting the OCCS value chain can be broadly divided into three components: unloading facilities, transportation systems, and Storage, Fixation, or Utilisation facilities. Figure 3-1 illustrates an example of a CO₂ transportation system: captured CO₂ is unloaded at port facilities, transported through the relevant transportation network, and ultimately delivered to its final destination for Storage, Fixation, or Utilisation. Accordingly, the feasibility of OCCS implementation depends not only on the performance of the onboard system but also on its connectivity with these downstream infrastructure elements.

This chapter provides an overview of CO₂ transportation systems, Storage, Fixation or Utilisation pathways, and their associated infrastructure.

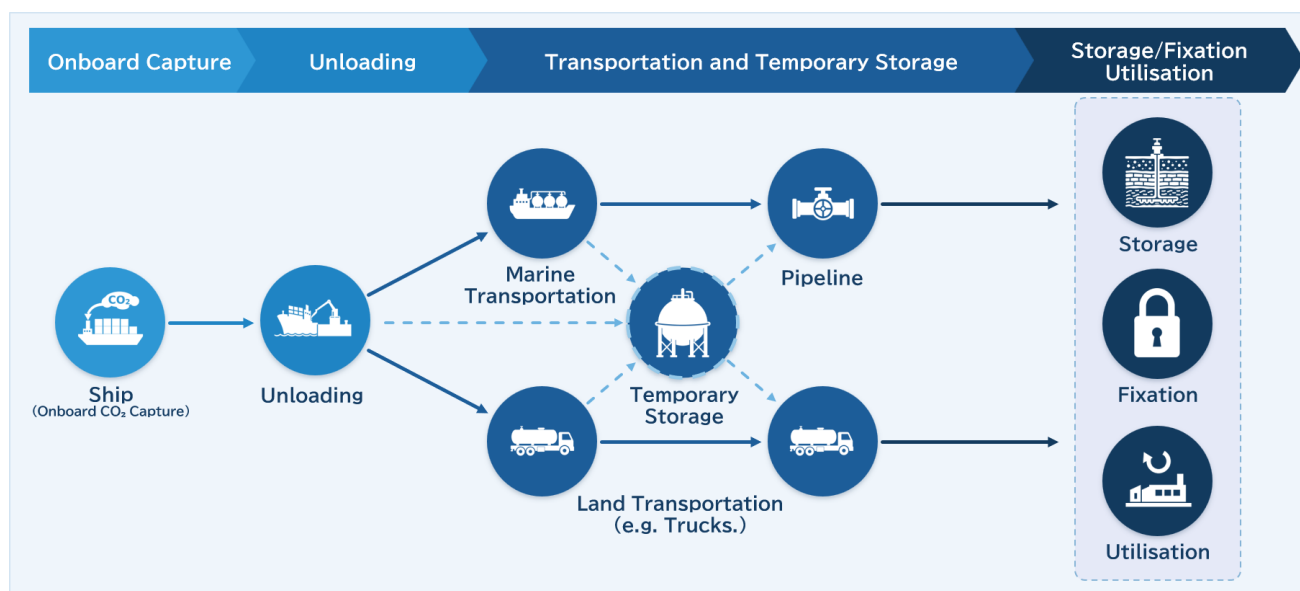


Figure 3-1 Example of a CO₂ Transportation System

3-2. CO₂ Transportation Systems

Captured CO₂ is processed into a condition suitable for transportation and subsequent Storage, Fixation, or Utilisation, and is then temporarily stored in onboard tanks. After a ship calls at a port, the captured CO₂ is transferred to shore-side facilities through unloading

infrastructure. The method of transportation used thereafter depends on factors such as project scale, geographical conditions, and the infrastructure availability. Since relatively small quantities of CO₂ are typically handled at the demonstration stage, transportation by road tankers or ISO tank containers (standardised tank containers designed for the transport of liquids and gases) has been considered and adopted by a number of projects.

For future commercial applications involving larger volumes of CO₂, more efficient transportation methods will become increasingly important. One such option is pipeline transportation. In land-based CCS projects, where CO₂ sources and storage sites are located relatively close to one another, pipelines are regarded as an effective means of transporting large volumes of CO₂. However, in the case of OCCS, ships may call at multiple ports and unloading locations may therefore be geographically dispersed. As a result, there may be situations in which pipeline transportation alone is not a practical solution.

Accordingly, the development of transportation networks utilising liquefied CO₂ carriers (LCO₂ carriers) has attracted increasing attention in recent years. Such networks may aggregate captured CO₂ from multiple ports and transport it to large-scale CCS sites. These concepts envisage the establishment of value chains centred on CO₂ collection hubs and dedicated transportation networks.

When considering the implementation of OCCS, it is therefore important to confirm in advance the available infrastructure and transportation options, taking into account the ship's trading pattern and ports of call, the quantity of captured CO₂, the frequency of CO₂ unloading, and the distance to the final Storage, Fixation, or Utilisation destination.

3-3. Storage, Fixation and Utilisation of CO₂

As described in Chapter 1, captured CO₂ must ultimately be directed to a final destination. For the purposes of this handbook, final destinations are classified into three categories: Storage, Fixation, or Utilisation. These categories differ not only in terms of the infrastructure required and the associated CO₂ quality requirements but also in how GHG emission reduction benefits may be treated under applicable regulatory frameworks.

At present, CCS, corresponding to the Storage category used in this handbook, is being considered as one of the leading options for the final management of CO₂ captured by OCCS. In geological storage, CO₂ is injected into deep geological formations and isolated from the atmosphere over the long term. Geological storage is widely adopted in large-scale CCS projects currently being developed around the world. In particular, major projects utilising depleted oil and gas fields and saline aquifers are being developed in the North Sea region, and their potential role as final destinations for CO₂ captured from shipping is also being explored.

It should also be noted that storage operators may establish acceptance requirements for captured CO₂ from the perspectives of injection facilities, reservoir integrity, safety, and operational considerations. Therefore, it is important to confirm in advance that the quality of the CO₂ produced by the OCCS is compatible with the requirements of the intended storage site.

Captured CO₂ may also be directed to utilisation pathways, commonly referred to as CCU. However, CCU encompasses two forms with fundamentally different characteristics and regulatory treatment.

The first involves applications in which CO₂ is chemically and permanently incorporated into a product and is not released to the atmosphere during normal use or following disposal, such as carbonated concrete and carbonated aggregates produced through mineralisation (carbonate formation). This category is referred to as “Fixation” in this handbook.

The second involves applications in which captured CO₂ is used as a feedstock for products such as synthetic fuels and methanol, where the CO₂ is expected to be released back into the atmosphere during use. This category is referred to as “Utilisation” in this handbook.

Under certain conditions, the former may be eligible for recognition as a GHG emission reduction, whereas the latter is not currently recognised for this purpose under the regulatory frameworks discussed in this handbook. In both cases, it is necessary to confirm in advance that the quality of the CO₂ produced by the OCCS satisfies the requirements of the intended Fixation and Utilisation destination.

In addition, the regulatory treatment of GHG emission reduction benefits may differ depending on whether the final destination is categorised as Storage, Fixation, or Utilisation. This topic is discussed further in Chapter 4. Therefore, when considering the implementation of OCCS, it is important to identify potential final destinations for captured CO₂ at an early stage of the evaluation process.

3-4. Key Considerations for Infrastructure Connectivity

As described above, the implementation of OCCS requires the establishment of an integrated value chain extending from onboard CO₂ capture through unloading facilities and transportation systems to the final destination for Storage, Fixation, or Utilisation.

However, the availability of infrastructure varies significantly by region. Even where the same OCCS is installed, the feasibility of implementation may vary considerably depending on the ship's trading area and port call patterns; for example, ships that regularly call at specific ports may have access to CO₂ reception and unloading facilities, whereas ships operating on irregular routes may face challenges in securing suitable CO₂ reception and unloading

facilities along their trading routes.

In addition, it is important to confirm not only the existence of infrastructure but also whether captured CO₂ can be accepted in practice. The practical arrangements for the reception and unloading of captured CO₂ at ports currently largely depend on national regulatory frameworks and port operating practices. Accordingly, it is necessary to verify not only the availability of infrastructure but also the operational arrangements and conditions for accepting captured CO₂; for example, matters such as the legal classification of captured CO₂ in the unloading country and its treatment for customs purposes should be confirmed during the early stages of project planning.

Furthermore, international shipping may involve value chains in which captured CO₂ is transported across national borders and subsequently stored, fixed, or utilised in another country. In such cases, the legal status of captured CO₂ and the regulatory treatment of cross-border transportation may become significant considerations. In addition to the applicability of relevant international treaties, including the London Protocol, it is necessary to confirm the compatibility of arrangements between the countries concerned and their respective regulatory frameworks.

Accordingly, implementation decisions should not be based on the ship alone. Rather, it is necessary to assess whether a viable value chain can be established from capture through to final treatment by considering the combination of Ship × Route × Port × Destination (Storage, Fixation, or Utilisation). Examples of major CO₂ storage projects and associated unloading infrastructure in the EU/EEA are provided in Appendix C.

Chapter Summary

- The feasibility of OCCS implementation depends on the ability to establish a viable value chain connecting onboard CO₂ capture with subsequent unloading, transportation, and final destinations for captured CO₂, namely Storage, Fixation, or Utilisation.
- Following unloading, captured CO₂ is transported by land-based or maritime transport systems before being delivered to facilities for Storage, Fixation, or Utilisation. Accordingly, transportation methods and infrastructure should be considered in relation to the ship's trading route, ports of call, quantity of captured CO₂, and unloading frequency.
- Storage, Fixation, and Utilisation each have different infrastructure requirements, CO₂ acceptance criteria, and regulatory treatment. It is therefore important to identify the intended final destination of captured CO₂ at an early stage and confirm the applicable requirements.
- When considering OCCS implementation, it is important to assess not only the availability

of infrastructure but also factors such as the legal status of captured CO₂ in the unloading country, reception arrangements, and regulatory frameworks applicable to cross-border transportation. The viability of the entire value chain should therefore be evaluated by considering the combination of ship, trading route, port, and final destination from capture to final treatment.

Chapter 4 Regulatory Frameworks and the Approach to Emission Reductions

4-1. Fundamental Principles of Regulatory Treatment for OCCS

One of the objectives of implementing OCCS is to reduce GHG emissions. However, under regulatory frameworks, the quantity of CO₂ captured on board is not necessarily recognised directly as an equivalent amount of GHG emission reductions.

A common principle underlying both EU and IMO frameworks is that assessment does not depend solely on how much CO₂ has been captured, but also on how the captured CO₂ is ultimately managed. For example, the regulatory treatment of captured CO₂ may differ depending on whether it is permanently stored in geological formations or subsequently released back into the atmosphere following utilisation.

To be recognised as a GHG emission reduction under regulatory frameworks, it is important not only to quantify the amount of CO₂ captured but also to demonstrate and verify how the captured CO₂ is subsequently transported, stored, fixed, or utilised. In other words, OCCS is not assessed solely based on the onboard system itself but rather across the entire post-capture value chain.

That said, there are differences between the EU and the IMO in terms of regulatory maturity and approaches to assessment. Within the EU, regulatory mechanisms have already been established that allow captured CO₂, under certain conditions, to be deducted from the amount of emissions subject to allowance surrender under the EU ETS. By contrast, discussions at the IMO are currently focused on developing methodologies for accounting and verifying the GHG emission reduction benefits associated with OCCS.

This chapter explains how captured CO₂ from OCCS is currently treated, and how it may be treated in the future in the context of GHG emission reduction assessment under EU and IMO frameworks. An overview of the main milestones in ongoing regulatory developments is provided in Appendix D.

4-2. Treatment of Captured CO₂ within the EU Framework

Within the EU, regulatory frameworks have already been established to recognise captured CO₂ from ships under the EU ETS, subject to certain conditions. This represents one of the most developed regulatory approaches currently available. However, the deductible quantity is not simply the amount of CO₂ captured on board. Rather, deductions are permitted only for captured CO₂ that has either been transferred in accordance with specified requirements or permanently fixed.

Several regulatory frameworks are relevant to the treatment of captured CO₂ from OCCS. To understand how GHG emission reductions associated with captured CO₂ are recognised, it is necessary to consider these frameworks in an integrated manner:

- Frameworks for the monitoring, reporting, and verification of ship emissions (EU MRV);
- Frameworks requiring the surrender of emission allowances for ship emissions (EU ETS); and
- Frameworks governing CO₂ transportation, geological storage, and fixation (including the CCS Directive and related legislation).

Under the EU ETS, shipping companies are required to surrender emission allowances corresponding to GHG emissions from relevant voyages. Within this framework, captured CO₂ may, subject to the following conditions, be considered for compliance under the EU ETS.

- (1) **Storage:** In the case of geological storage, the quantity of CO₂ transferred to an eligible CO₂ transportation and storage chain may be deducted from emissions subject to allowance surrender requirements under Article 12(3a) of the EU ETS Directive. Any leakage occurring during transportation or storage after transfer becomes the responsibility of the transport operator or storage operator under the applicable regulatory framework.
- (2) **Fixation:** In the case of fixation, deduction is permitted not on the basis of the amount of CO₂ captured on board, but on the basis of the quantity of CO₂ permanently fixed within products that satisfy the requirements established by the EU. This treatment is provided for under Article 12(3b) of the EU ETS Directive and Delegated Regulation (EU) 2024/2620. To qualify as permanent fixation, the CO₂ must remain stably fixed over the long term in accordance with the applicable requirements; for example, CO₂ permanently fixed in products such as concrete or aggregates in which CO₂ is permanently incorporated through carbonation may qualify for deduction where the requirements of that Delegated Regulation are met.
- (3) **Utilisation:** Where captured CO₂ is used as a feedstock for synthetic fuels or other applications in which the carbon is expected to be released back into the atmosphere during use or following the end of the product's life, deduction from emissions subject to allowance surrender is not currently permitted. In such cases, the carbon is instead considered within the life cycle assessment of the fuel or product concerned.

Figure 4-1 illustrates the quantity of captured CO₂ that may be recognised as deductible depending on the final destination of the captured CO₂.

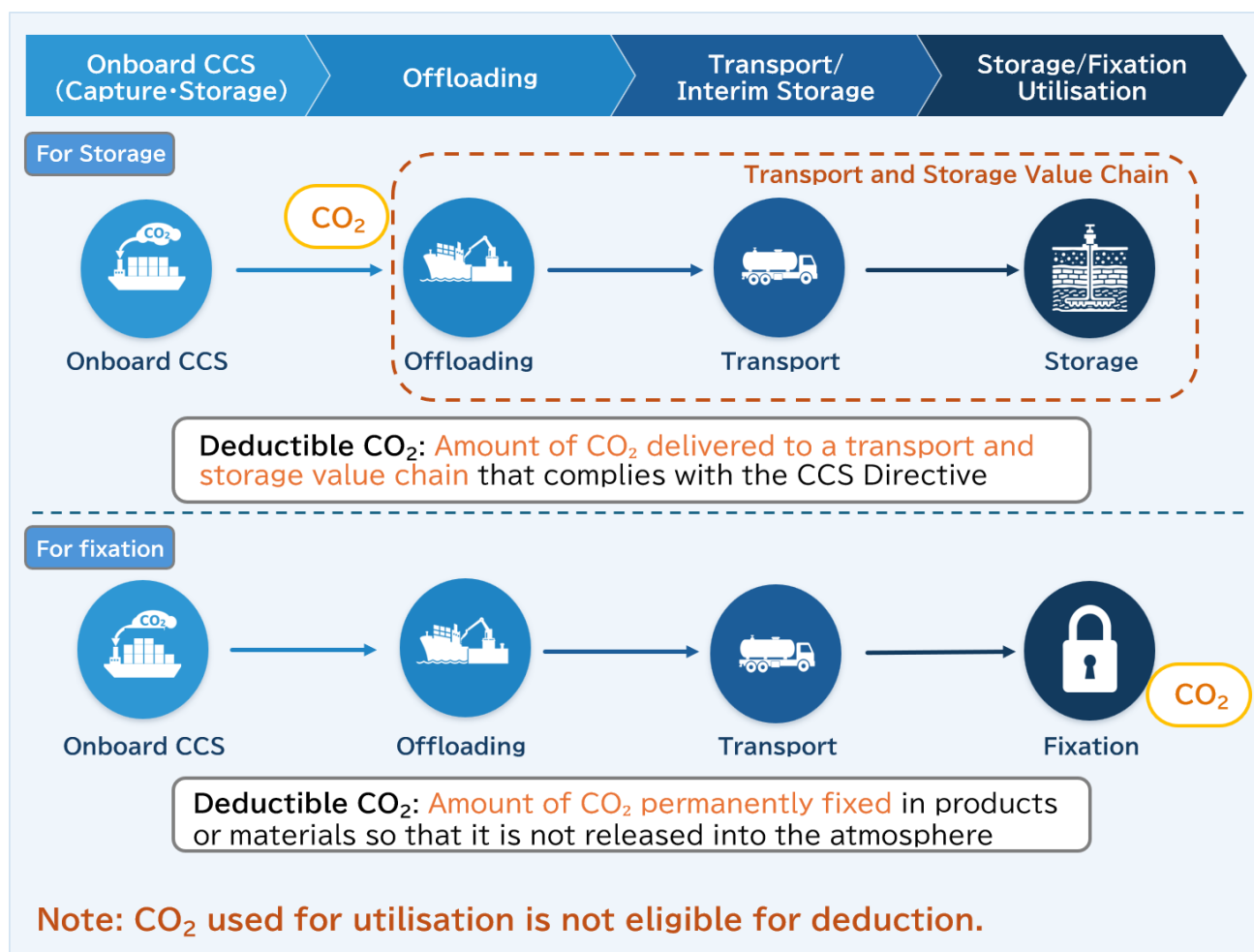


Figure 4-1 Deductible Quantities of Captured CO₂ under the EU ETS

As described above, even where captured CO₂ is fixed in products, it is not automatically recognised as a GHG emission reduction. The manner in which the CO₂ is fixed and its ultimate fate are important considerations. Accordingly, management and verification of the entire value chain, including transportation, Storage, or Fixation following capture (excluding utilisation pathways involving re-release), are required.

At the same time, several regulatory challenges remain. One of the most significant challenges is the absence of a dedicated mechanism for demonstrating and verifying that OCCS-derived CO₂ has been transferred to an eligible value chain. Although frameworks such as the EU ETS, EU MRV, and the CCS Directive already exist, no dedicated CoC framework has yet been established to manage the entire process from onboard capture through to final treatment.

As a result, an important practical challenge remains how to demonstrate and verify that

captured CO₂ has either been transferred to an eligible CO₂ transportation and storage value chain or permanently fixed within products in accordance with applicable requirements.

A further challenge will be the development of integrated frameworks for MRV, CoC, and third-party verification covering the entire value chain from onboard capture through to final treatment.

It should also be noted that, although FuelEU Maritime became applicable in 2025, captured CO₂ from onboard capture systems is not currently considered under that regulation. However, its future regulatory treatment is expected to be assessed in light of technological developments and operational experience.

4-3. Treatment of Captured CO₂ within the IMO Framework

While the EU has already commenced implementation of its regulatory framework, discussions within the IMO are currently focused on how the GHG emission reduction benefits of OCCS should be assessed and reflected in future regulatory measures. A distinguishing feature of the IMO approach is its focus on evaluating the net GHG reduction effect across the entire OCCS value chain, taking into account not only the quantity of CO₂ captured on board but also the energy consumption associated with OCCS operation and the emissions arising from the subsequent transportation and Storage or Fixation of captured CO₂.

These discussions are closely linked to the development of the LCA Guidelines on the life-cycle GHG intensity of marine fuels and the IMO Net-Zero Framework, both of which are being advanced following the adoption of the 2023 IMO GHG Strategy. Within this context, the deduction term e_{OCCS} was introduced in the 2024 LCA Guidelines (resolution MEPC.391(81)) to reflect the GHG emission reduction benefits associated with OCCS.

The e_{OCCS} term is intended to account for the GHG emission reduction effect of OCCS within the calculation of fuel life-cycle GHG intensity under the LCA Guidelines. As illustrated in Figure 4-2, the calculation considers not only onboard capture but also GHG emissions associated with the entire value chain, including transportation and subsequent Storage or Fixation.

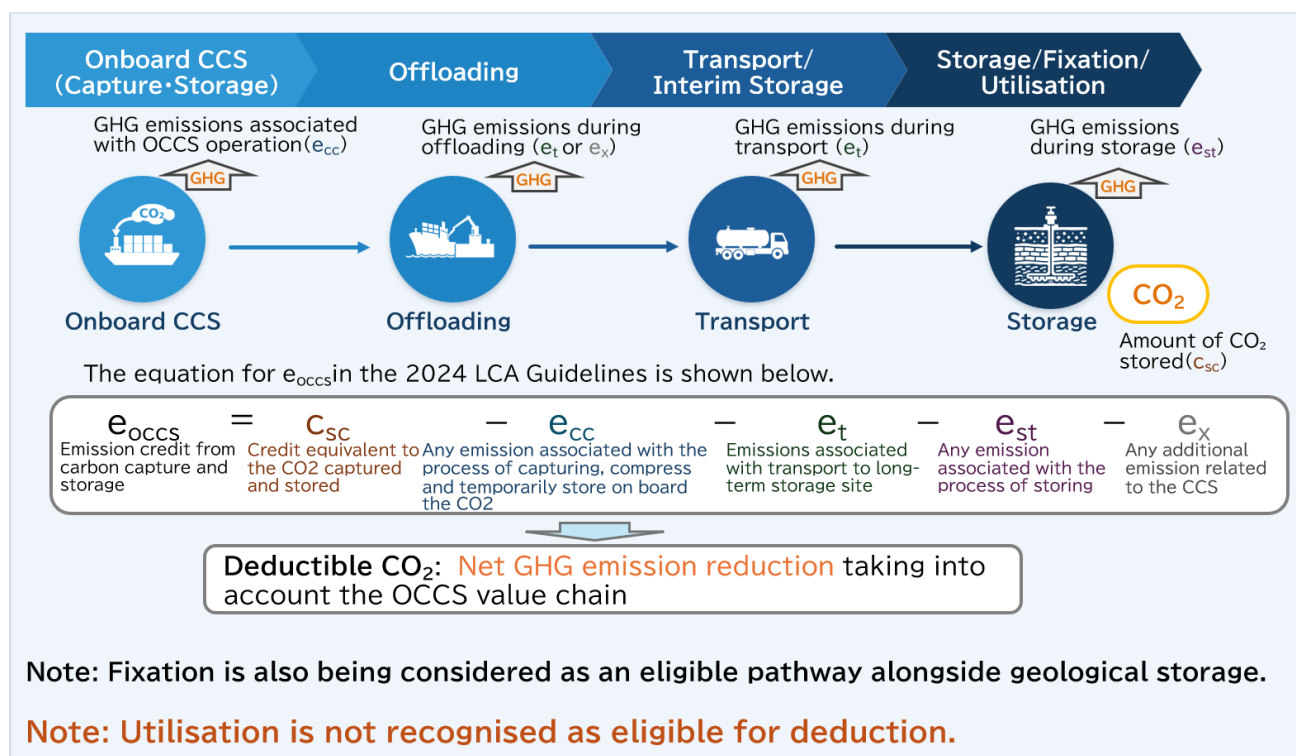


Figure 4-2 Deductible Elements for Captured CO₂ under the LCA Guidelines

For example, even where 100 tonnes of CO₂ are captured on board, the net GHG emission reduction benefit attributable to OCCS may be less than 100 tonnes after considering the energy consumption associated with OCCS operation as well as the GHG emissions arising from the transportation, Storage, or Fixation of the captured CO₂. Accordingly, under the IMO approach, emission reductions are assessed based on the overall GHG reduction achieved across the value chain rather than solely on the quantity of CO₂ captured.

However, although the e_{occs} deduction term has been introduced, detailed methodologies for accounting and verification have not yet been established. In particular, the following issues remain key topics of discussion:

- How the quantity of captured CO₂ should be measured;
- How the energy consumption associated with OCCS should be evaluated;
- How GHG emissions and CO₂ losses during transportation should be quantified; and
- How the quantity of CO₂ that has been permanently stored or fixed should be determined;

Another important challenge in the IMO discussions is the establishment of verification and certification mechanisms to support these calculations. While shipping companies can manage and record onboard CO₂ capture data and equipment operating data, it is difficult for them to directly verify the transportation, Storage, or Fixation status of CO₂ once it has been transferred beyond the ship.

Accordingly, current discussions are also considering the development of verification

frameworks involving independent third-party organisations, drawing on experience from certification schemes used in areas such as sustainable fuels. Particular attention is being paid to Chain of Custody (CoC) because GHG emission reductions cannot be properly recognised under future regulatory frameworks unless it is possible to trace and verify where captured CO₂ has ultimately been transferred and how it has been treated. Consequently, an important issue under consideration within the IMO is how to ensure traceability from onboard capture through to final Storage or Fixation.

The treatment of utilisation pathways has not yet been established within the IMO framework and remains a subject for future consideration.

In light of these developments, MEPC 84 (May 2026) agreed to continue the development of the OCCS regulatory framework and to advance work on guidance relating to the accounting, verification, and certification of GHG emission reductions achieved through OCCS.

At present, the IMO has not yet reached the stage of implementing a detailed regulatory system comparable to the EU ETS. Nevertheless, work is progressing on the development of accounting and verification rules that may form the basis of future international regulatory frameworks. The central issue is not simply how much CO₂ is captured, but rather how the resulting GHG emission reduction benefit should be assessed and how that benefit can be demonstrated and verified.

Table 4-1 Comparison of the Treatment of Captured CO₂ under EU and IMO Frameworks

Item	EU	IMO
Status of Regulatory Development	EU ETS Certain provisions have already been established. FuelEU Maritime Not yet incorporated.	The 2024 LCA Guidelines introduce a deduction term (e _{OCCS}) intended to reflect GHG emission reduction benefits. Detailed methodologies are still under development.
Underlying Principle	EU ETS Assessment is based on either the quantity of CO ₂ transferred to an eligible CO ₂ transportation and storage chain or the quantity of CO ₂ permanently fixed in products that satisfy regulatory requirements.	Assessment is based on the GHG reduction term (e _{OCCS}) across the entire value chain.
Subject of Assessment	EU ETS ✓ Storage: Deductible quantity is the amount of CO ₂ verified as having been transferred to an eligible CO ₂ transportation and storage chain (Article 12(3a) of the EU ETS Directive). ✓ Fixation: Deductible quantity is the amount of CO ₂ permanently fixed in products in accordance with the requirements of Article 12(3b) of the EU ETS Directive and Delegated Regulation (EU) 2024/2620. ✓ Utilisation: Not deductible. CO ₂ used as a feedstock for synthetic fuels or other applications involving subsequent release cannot be deducted from ship emissions.	LCA Guidelines ✓ Storage: GHG emission reductions considering the entire value chain are recognised in principle as potentially eligible for deduction. However, methodologies for quantification, verification, and certification have not yet been established and therefore are not currently reflected in deductions. ✓ Fixation: Currently under consideration to be treated in parallel with Storage. ✓ Utilisation: Not currently recognised as eligible for deduction. Methodologies, including approaches to avoid double counting, remain under consideration.
Current Eligibility for Deduction	EU ETS The quantities described above may be deducted from emissions subject to allowance surrender requirements	Under the current IMO regulatory framework, there is no established mechanism allowing the quantity of captured CO ₂ to be deducted directly from emissions. Although the LCA Guidelines include the deduction term e _{OCCS} within the GHG intensity calculation formula, the e _{OCCS} term is currently assigned a value of zero because methodologies for quantification, verification and certification have not yet been established.
CoC and Traceability	No OCCS-specific CoC framework has yet been established.	Recognised as one of the key issues in the ongoing development of the regulatory framework.
Future Outlook	FuelEU Maritime The European Commission is expected to consider the treatment of OCCS by the end of 2027.	Completion of the work on related guidelines is targeted by 2028.
Principal Regulatory Instruments	1. Directive 2003/87/EC: EU ETS Directive 2. Regulation (EU) 2015/757: MRV Maritime 3. Delegated Regulation (EU) 2023/2917: M-AVR (Maritime Accreditation and Verification Regulation) 4. Implementing Regulation (EU) 2018/2066: MRR (Monitoring and Reporting Regulation) 5. Implementing Regulation (EU) 2018/2067: AVR (Accreditation and Verification Regulation) 6. Directive 2009/31/EC: CCS Directive 7. Delegated Regulation (EU) 2024/2620 8. Regulation (EU) 2023/1805 (FuelEU Maritime)	1. 2024 LCA Guidelines (MEPC.391(81)) 2. Report of the Marine Environment Protection Committee on its Eighty-Third Session (MEPC 83/17) 3. Report of the Marine Environment Protection Committee on its Eighty-Fourth Session (MEPC 84/16)
Key Common Feature: Both frameworks place greater emphasis on demonstrating and verifying the fate of captured CO ₂ than on the quantity captured on board itself. Under the EU framework, this means demonstrating transfer to an eligible value chain or permanent fixation in products, whereas under the IMO framework the focus is on the GHG emission reduction achieved across the entire value chain.		

Chapter Summary

- To enable GHG emission reductions achieved through OCCS to be recognised under regulatory frameworks, it is important not only to quantify the amount of CO₂ captured on board but also to appropriately assess, demonstrate, and verify the resulting GHG emission reduction effect, considering subsequent transportation and final Storage or Fixation.
- Under the EU ETS, the quantity of CO₂ transferred to an eligible CO₂ transportation and storage value chain, or the quantity of CO₂ permanently fixed in products or materials in accordance with applicable requirements, may be deducted from reported GHG emissions under certain conditions. By contrast, utilisation pathways involving the subsequent re-release of CO₂ are not currently eligible for deduction.
- Within the IMO framework, a deduction term (e_{OCCS}) has been introduced in the LCA Guidelines to reflect the GHG reduction effect of OCCS. However, detailed methodologies for accounting, verification, and certification have not yet been established, and the framework is not yet capable of reflecting actual GHG emission reductions in practice. Future regulatory developments are expected to establish mechanisms that appropriately account for GHG reduction effects across the entire value chain, from CO₂ capture through transportation to final Storage or Fixation.

Chapter 5 MRV, CoC and Third-Party Verification

5-1. Role of MRV in OCCS

To enable GHG emission reductions achieved through OCCS to be recognised under regulatory frameworks, it is important to continuously monitor and record the quantity and quality of captured CO₂ and to demonstrate and explain the resulting data. The foundation for this is the MRV framework.

Conventional MRV frameworks in the maritime sector have primarily been developed to monitor fuel consumption and GHG emissions from ships. Both the EU MRV and the IMO DCS are intended to determine how much fuel a ship consumes and how much CO₂ or other GHG emissions it produces.

In the context of OCCS, however, the scope of assessment may extend beyond emissions alone to include the quantity of CO₂ captured, stored, transferred, transported, and ultimately directed to Storage, Fixation, or Utilisation, as illustrated in Figure 5-1. Accordingly, MRV in the context of OCCS should be regarded not merely as a mechanism for monitoring emissions, but as an information framework that supports data management across the captured CO₂ value chain and underpins the quantification and verification of GHG emission reduction benefits.

However, the scope of information required from shipping companies varies depending on the applicable regulatory framework. Under the EU ETS, the responsibility of the ship operator is generally considered to end when captured CO₂ is transferred to an eligible value chain. Accordingly, shipping companies are required to demonstrate the quantity transferred and the eligibility of the receiving value chain. By contrast, under the IMO framework, emissions associated with transportation and final treatment may influence the calculation of e_{OCCS} . As a result, the treatment of data relating to activities beyond the ship remains one of the key issues under discussion.

In addition to the management of captured CO₂ quantities, quality-related information, such as CO₂ purity and impurity concentrations, may also constitute important data. Therefore, it is important to continuously collect and retain data relating to both the quantity and quality of captured CO₂ as fundamental information supporting future quantification, verification, and traceability.

Future MRV frameworks for OCCS are expected to support data management across the entire value chain, covering not only conventional shipboard emissions but also captured CO₂ after its transfer from the ship.

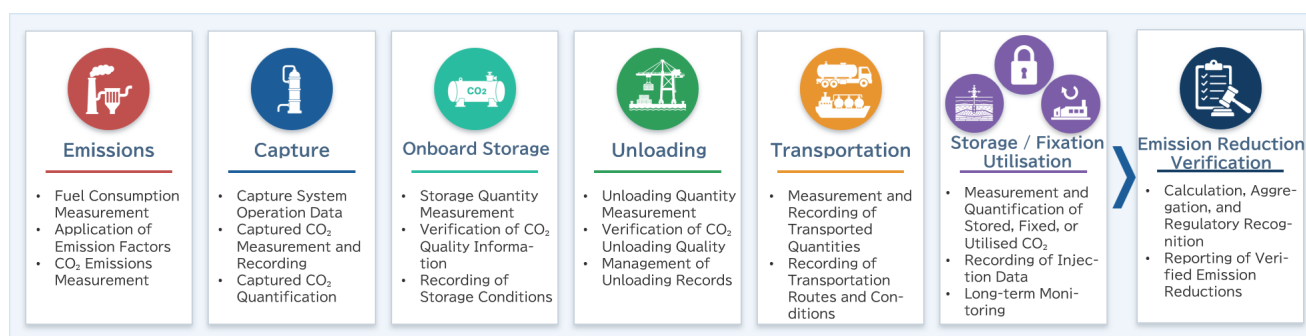


Figure 5-1 Example of the Scope of MRV in the OCCS Value Chain

5-2. CoC and Traceability

According to ISO 22095, the international standard for CoC, “CoC” refers to the process by which inputs, outputs, and associated information are transferred, monitored, and controlled as they move through each stage of a supply chain. In the context of OCCS, CoC can be understood as a mechanism for consistently managing not only the captured CO₂ itself, but also attribute information such as when, on which ship, and in what quantity the CO₂ was captured, and how it was ultimately treated, throughout the value chain.

“Traceability” refers to the ability to trace the history, location, or application of an object. Although closely related to CoC, traceability and CoC are not identical concepts. Some CoC models, such as the Book-and-Claim model, do not rely on physical traceability and should therefore be distinguished from traceability-based approaches.

Several CoC models exist and ISO 22095 defines the following five: Identity Preserved, Segregation, Controlled Blending, Mass Balance, and Book-and-Claim. In addition, ISO 22095-2 and ISO 22095-3, published in January 2026, provide further guidance on the Mass Balance and Book-and-Claim models, respectively.

Within the OCCS value chain, CO₂ unloaded from multiple ships may be mixed with CO₂ originating from other emission sources at shore-side reception facilities, collection hubs, or liquefied CO₂ carriers. Under such circumstances, maintaining the physical identity of the CO₂ captured by each individual ship throughout the entire value chain is unlikely to be practical. Consequently, the selection of an appropriate CoC model is likely to become a key factor in determining whether GHG emission reductions achieved by individual ships can be recognised under regulatory frameworks. In the sustainable fuels sector, the Mass Balance model has already been widely adopted, allowing physical mixing while maintaining the consistency of attribute information through bookkeeping systems. Developments in this area are therefore expected to attract significant attention.

In such certification schemes, mechanisms have been established to track materials and associated attributes from feedstock production through fuel manufacture, supply, and final

use. Similarly, in the context of OCCS, mechanisms capable of demonstrating and verifying the following are likely to be required:

- Who was responsible for the management of the CO₂;
- When custody was transferred between parties; and
- How the CO₂ was ultimately treated.

It should be noted that the concept of transfer of regulatory responsibility is distinct from CoC. Examples include the transfer of legal obligations from a storage operator to the competent authority following site closure under Article 18 of the CCS Directive, and the transfer of the obligation to surrender allowances following the delivery of CO₂ to an eligible value chain under Article 12(3a) of the EU ETS Directive. These concepts should therefore be understood separately from CoC.

In practice, future OCCS frameworks are likely to require not only MRV systems for obtaining and managing data such as captured CO₂ quantities but also CoC arrangements capable of managing information relating to the transportation, Storage, Fixation, or Utilisation of captured CO₂ across the entire value chain. Accordingly, in addition to MRV, the establishment of an appropriate CoC framework is expected to become an important element of future OCCS schemes.

5-3. Role of Third-Party Verification

Independent third-party verification is important for ensuring the reliability of information generated through MRV and CoC arrangements. This is because shipping companies may find it difficult to directly confirm the transportation and final treatment of captured CO₂ after its transfer from the ship, while operators responsible for final treatment are not in a position to confirm onboard capture activities.

Future regulatory frameworks may require verification of quantities captured on board, quantities stored on board, quantities transferred, quantities transported, quantities stored, fixed, or utilised as well as the net GHG emission reductions achieved across the entire value chain. Although utilisation pathways involving the subsequent re-release of CO₂ are not currently recognised as contributing to GHG emission reductions, records relating to such pathways may nevertheless be required to demonstrate how the captured CO₂ was ultimately treated. In addition to the verification of CO₂ quantities, quality-related information and records maintained under CoC systems may also form part of the verification scope.

Discussions within the IMO have likewise considered an approach under which onboard activities would be verified primarily by the responsible Administration, while activities beyond the ship would be verified through independent third-party verification arrangements. This matter remains under discussion.

Accordingly, as the GHG emission reduction benefits associated with OCCS are expected to be assessed on the basis of the entire value chain rather than onboard activities alone, third-party verification bodies are likely to play an important role in verifying not only data obtained on board but also the consistency of information recorded at each stage of the value chain.

5-4. Future Directions for Verification and Certification Frameworks

In both the EU and the IMO, verification and certification frameworks specifically designed for OCCS are still under development, and discussions on their future direction are ongoing. One of the key issues under consideration is the establishment of CoC arrangements and the traceability required to support them.

Based on the CoC concepts described above, the reliable assessment of GHG emission reductions requires not only the identification of the applicable CoC model, but also a clear understanding of the scope of records and management measures required under that model.

For OCCS, it is important that captured CO₂ is appropriately managed throughout the value chain, from capture and transportation to its final destination for Storage, Fixation, or Utilisation, and that the results can be traced and verified. Accordingly, one of the key challenges is determining how records, evidence, and other relevant information relating to capture, transfer, transportation, Storage, Fixation, or Utilisation should be managed and shared among stakeholders.

Furthermore, international shipping is expected to involve long value chains comprising a large number of stakeholders. For this reason, the use of electronic record management systems and data-sharing mechanisms is also being considered as a means of facilitating efficient traceability and CoC management.

In addition, ensuring consistency among EU frameworks, IMO frameworks, and national regulatory systems will become increasingly important. Shipping is inherently international in nature, and the capture, transportation, and final destination of captured CO₂ may span multiple countries. As a result, alignment of quantification and verification requirements, as well as approaches to data sharing across different frameworks, is likely to become an important issue in the future.

Chapter Summary

- MRV provides the foundation for data management within the OCCS value chain by enabling the continuous monitoring and recording of captured CO₂ quantities, stored quantities, transferred quantities, and quality-related information.
- CoC is a mechanism for transferring, monitoring, and managing captured CO₂ and its associated attribute information throughout the value chain and represents one of the approaches used to support traceability.
- Third-party verification plays an important role in providing assurance regarding information generated through MRV and CoC systems and in objectively demonstrating GHG emission reduction benefits.
- Future regulatory frameworks are expected to focus on the development of traceability, verification, and certification mechanisms covering the entire value chain, from CO₂ capture and transportation through to Storage, Fixation, or Utilisation.

Chapter 6 OCCS Implementation Decision Flow

6-1. Basic Approach to Implementation Decisions

This chapter is intended primarily for shipowners and operators considering the implementation of OCCS. It identifies the principal matters that should be assessed when evaluating the potential for implementing OCCS on a particular ship and trading route. It also presents a practical framework for implementation decisions from the perspectives of achieving the expected GHG emission reduction benefits and ensuring economic viability.

As described in the preceding chapters, the feasibility of OCCS implementation is not determined solely by the performance of the onboard system. In addition to establishing a value chain capable of appropriately managing captured CO₂ from onboard storage through unloading, transportation, and ultimately to Storage, Fixation, or Utilisation, it is also necessary to ensure compliance with applicable regulatory requirements and to establish mechanisms capable of supporting the appropriate quantification and verification of GHG emission reduction benefits.

Accordingly, when considering the implementation of OCCS, a comprehensive assessment should be conducted from at least the following perspectives:

- ① Regulatory Compatibility
- ② Infrastructure Connectivity
- ③ Technical Feasibility of Onboard Systems
- ④ Capability to Support MRV, CoC, and Third-Party Verification
- ⑤ Economic Viability of the Overall Value Chain

Even where a favourable assessment is obtained for a particular evaluation area, OCCS implementation may not be viable for a specific ship or trading route if significant challenges remain in other areas.

For example, although CO₂ unloading facilities may be available along the intended trading route, captured CO₂ cannot be appropriately managed unless the acceptance requirements of the final destination are also satisfied. Similarly, even where a high CO₂ capture rate can be achieved from a technical perspective, implementation may be difficult to justify if economic viability cannot be demonstrated after considering additional energy consumption, capital expenditure, and other associated costs.

6-2. Assessment Criteria for Implementation Decisions

① Assessment of Regulatory Compatibility

The first step is to determine under which regulatory frameworks, and in what manner, the GHG emission reduction benefits achieved through OCCS may be recognised for the ship and trading route concerned. For example, for EU-related routes, the relationship with the EU ETS and FuelEU Maritime should be examined. As the IMO is also considering how GHG emission reductions achieved through OCCS should be treated, it is important to consider not only the regulatory frameworks in place at the time of implementation but also future regulatory developments.

At a minimum, the following matters should be considered when assessing regulatory compatibility:

- GHG-related regulatory frameworks applicable to the ship and trading route;
- The regulatory treatment of GHG emission reduction benefits achieved through OCCS;
- Whether CO₂ unloading, transportation and final treatment arrangements satisfy applicable regulatory requirements;
- Whether the data required for GHG quantification can be obtained and recorded;
- Whether third-party verification and certification requirements can be satisfied; and
- The potential impact of future regulatory developments on the expected benefits of implementation.

As regulatory frameworks relating to OCCS are still under development, a degree of regulatory uncertainty should be considered in relation to matters that have not been determined at the time of implementation.

② Assessment of Infrastructure Connectivity

For OCCS, GHG emission reduction cannot be completed simply by storing captured CO₂ on board. It is necessary to secure suitable facilities for unloading the captured CO₂ and receiving facilities for its subsequent transportation, Storage, Fixation, or Utilisation.

Accordingly, considering the ship's ports of call and operating profile, it should be confirmed whether infrastructure capable of continuously receiving captured CO₂ is available.

The following matters should be considered:

- The availability of CO₂ unloading facilities that can be used by OCCS-equipped ships;
- The location of unloading facilities and their compatibility with the ship's ports of call;
- Processing capacity and acceptance requirements of unloading facilities;
- Available transportation methods and transportation networks after unloading;
- The availability of Storage, Fixation, or Utilisation pathways;

- CO₂ acceptance requirements at the final destination;
- Whether captured CO₂ quality satisfies acceptance requirements throughout the value chain; and
- Contractual arrangements and procedural requirements associated with unloading, transportation, and final treatment.

In particular, even where existing CO₂ unloading facilities are available, facilities intended for serving food and beverage, or similar applications may not necessarily be suitable for receiving captured CO₂ or for connecting it to subsequent storage or other treatment pathways. It is, therefore, necessary to confirm not only the existence of such facilities but also their intended use, acceptance requirements, and handling capacity.

③ Assessment of Technical Feasibility of OCCS

It should be assessed whether OCCS can be installed on the ship and achieve the required capture performance while maintaining normal ship operations.

The principal assessment criteria are as follows:

- CO₂ capture rate;
- Energy penalty, including the required electrical power and heat supply;
- Space required for equipment installation;
- Additional weight associated with OCCS equipment and related systems;
- CO₂ storage capacity;
- Impact on fuel consumption and operational performance;
- Maintenance and operational workload;
- Onboard safety and compatibility with existing equipment; and
- The ability to achieve the required captured CO₂ quality.

Particularly in retrofit projects for existing ships, installation space, weight, and interference with existing equipment may become significant constraints. Furthermore, securing the electrical power and heat required to operate the OCCS may increase fuel consumption. It is therefore necessary to assess the net GHG emission reduction benefits after accounting for the energy penalty, rather than considering the capture rate alone.

It is also necessary to confirm that the quality of the CO₂ captured on board satisfies the acceptance requirements for subsequent transportation, Storage, Fixation, or Utilisation. Accordingly, when selecting an onboard system, it is important to select an appropriate capture method by considering not only its capture performance, but also the downstream value chain.

④ Readiness for MRV, CoC and Third-Party Verification

As described in Chapters 4 and 5, depending on the applicable regulatory framework, assessing the benefits of OCCS implementation may require consideration not only of the quantity of CO₂ captured on board but also of the energy consumed in operating the OCCS, the unloading and transportation of captured CO₂, and its final Storage, Fixation, or Utilisation. It is therefore important to ensure from the implementation planning stage that the proposed system configuration enables the collection and management of the data required for future quantification and verification.

The matters to be considered include, for example, the following:

- Whether captured CO₂ quantities can be measured appropriately;
- Whether energy consumption associated with OCCS operation can be quantified;
- Whether captured CO₂ quality can be measured and recorded;
- Whether unloading quantities and transfer records can be obtained;
- Whether information relating to transportation and final treatment can be obtained;
- Whether the origin and handling history of captured CO₂ can be linked and managed; and
- Whether records required for third-party verification can be retained.

It is particularly important to establish appropriate links between data obtained on board and data held by transportation providers and entities responsible for Storage, Fixation, or Utilisation after unloading. Information management mechanisms such as CoC should therefore be considered from the early stages of implementation planning.

As methodologies for OCCS quantification and verification within the IMO and other regulatory frameworks are expected to undergo further development, it is desirable to retain sufficient flexibility to accommodate future regulatory changes in relation to requirements that have not yet been finalised.

⑤ Assessment of Economic Viability Across the Entire Value Chain

When deciding whether to implement OCCS, it is necessary to assess not only the cost of installing the onboard system, but also the costs associated with the entire value chain from CO₂ capture through to final treatment.

The principle cost items include the following:

- Capital expenditure for OCCS equipment and associated systems;
- Retrofit and installation costs;
- OCCS operating and maintenance costs;
- Additional fuel and energy costs;
- CO₂ unloading costs;
- CO₂ transportation costs;

- Intermediate storage costs;
- Costs associated with Storage, Fixation or Utilisation;
- Costs associated with MRV, verification and traceability arrangements; and
- Costs associated with contractual and procedural requirements.

When evaluating the benefits of implementation, it is important to consider not only equipment costs but also the GHG emission reduction benefits achieved through OCCS and the economic value arising under the applicable regulatory frameworks.

Accordingly, for the ship and trading route concerned, it is desirable to compare OCCS implementation with the measures that would be required if OCCS were not implemented, as well as with other GHG emission reduction measures, and to assess whether the expected emission reduction benefits justify the required investment and operating costs.

6-3. Assessment of OCCS Feasibility

When assessing the feasibility of OCCS implementation, it is useful to evaluate the target ship and trading route as a single project and to consider the assessment criteria described in the previous section in an integrated manner, recognising the relationships between them.

As a first step, it should be determined whether the GHG emission reduction benefits achieved through OCCS may be recognised under the regulatory frameworks applicable to the trading route concerned. Next, consideration should be given to whether infrastructure is available for the unloading, transportation, and final treatment of captured CO₂. Where a positive outlook exists for both regulatory recognition and infrastructure availability, it should then be assessed whether the necessary equipment can be installed on the ship, whether the required capture performance can be achieved, and whether any operational impacts can be accommodated.

In addition, it should be confirmed whether the proposed system configuration enables the collection and management of the data required for the quantification and verification of GHG emission reduction benefits. Finally, the economic viability of the entire value chain should be evaluated, considering capital expenditure, additional fuel and energy costs, and the costs associated with CO₂ unloading, transportation, and final treatment.

Based on the results of these assessments, the feasibility of OCCS implementation may, for example, be categorised as follows.

High Feasibility for Implementation

Implementation feasibility may be considered high where the regulatory treatment of OCCS is sufficiently clear, infrastructure for CO₂ unloading, transportation, and final treatment is available, the required equipment can be installed on the target ship and the required capture

performance can be achieved, the data necessary for quantification and verification can be obtained and managed, and economic viability can be demonstrated across the value chain.

Conditionally Feasible for Implementation

Implementation may be considered conditionally feasible where the project is technically viable, but certain conditions remain relating to CO₂ unloading and transportation infrastructure, final treatment pathways, regulatory treatment, or economic viability. In such cases, the relevant conditions should be clearly identified, and developments relating to regulatory frameworks, infrastructure, and other relevant factors should continue to be monitored.

Difficult to Implement at Present

Implementation may be considered difficult at present where no suitable CO₂ infrastructure is available along the target trading route, the required equipment cannot be installed on the target ship, there is no clear prospect of regulatory recognition of GHG emission reduction benefits, or economic viability cannot be achieved across the value chain as a whole.

However, regulatory frameworks, infrastructure, and technologies relating to OCCS are expected to continue evolving. Accordingly, even where implementation is considered difficult at present, reassessment is desirable as regulatory development, infrastructure deployment, and technological advancement progress.

The OCCS implementation decision-making flow described above is illustrated in Figure 6-1.

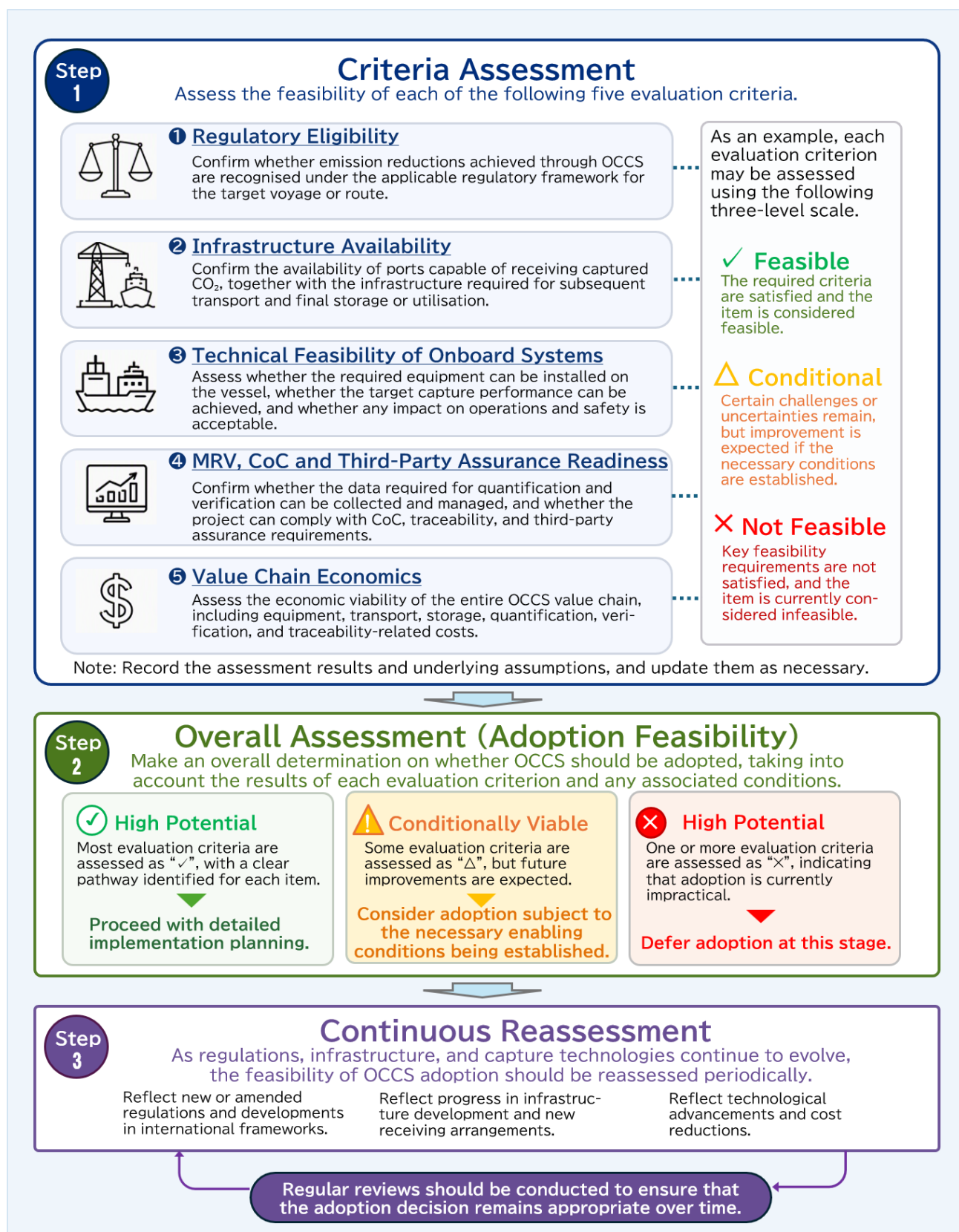


Figure 6-1 OCCS Implementation Decision-Making Flow

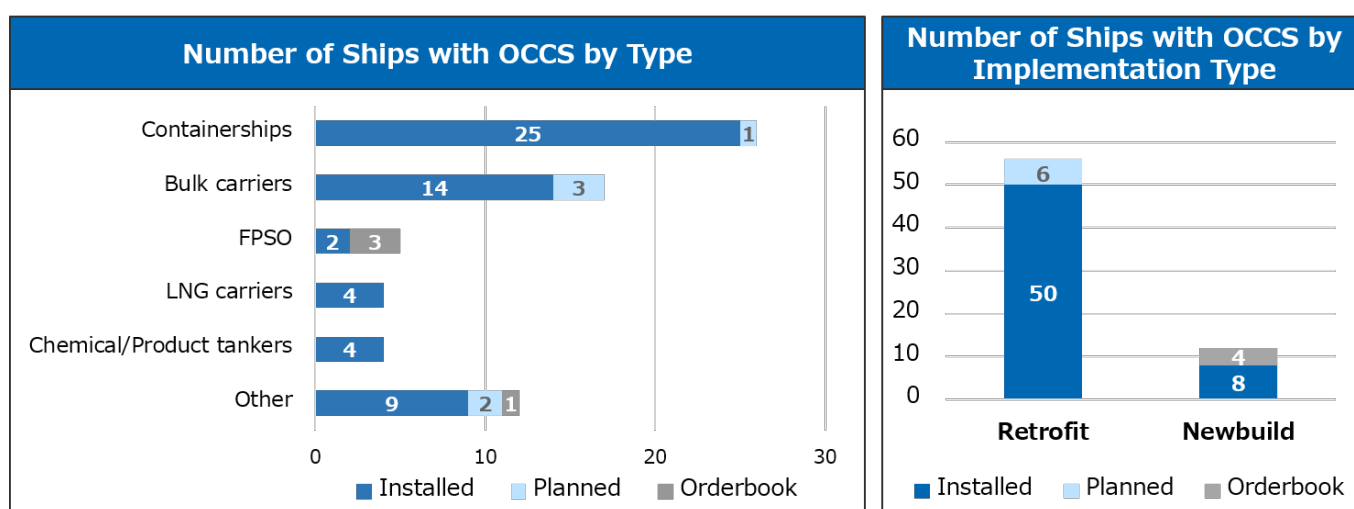
Chapter Summary

- Implementation decisions for OCCS should be based on a comprehensive assessment of regulatory compatibility, infrastructure connectivity, technical feasibility of onboard systems, capability to support MRV, CoC, and third-party verification, and the economic viability of the entire value chain.
- In addition to ensuring that GHG emission reduction benefits can be appropriately quantified and verified, it is important to identify in advance the data, records, and allocation of responsibilities among stakeholders required throughout the value chain, from CO₂ capture through to final treatment.
- As regulatory frameworks, infrastructure, and technologies relating to OCCS are expected to continue evolving, it is important to periodically reassess implementation feasibility in light of developments in regulations, infrastructure, technology, and economic viability, even where implementation is currently considered difficult.

Appendices

Appendix A. OCCS Deployment Status

Demonstration projects related to OCCS are underway in various parts of the world, and examples of OCCS installations on commercial ships are gradually increasing. As shown in Figure A-1, according to information available from Clarksons Research, as of the end of May 2026, 58 ships of 5,000 GT and above were reported to be equipped with OCCS, while a further 11 ships were identified as having OCCS installations planned. The 58 ships equipped with OCCS correspond to approximately 0.14 % of the fleet of ships in service with a gross tonnage of 5,000 GT and above at that time.



Source: Compiled based on Clarksons Research data (ships of 5,000 GT and above, as of the end of May 2026).

Figure A-1 OCCS Deployment Status

Appendix B. Major OCCS Demonstration and Shipboard Implementation Projects

OCCS-related projects are being undertaken worldwide. In addition to verifying the performance of OCCS technologies, projects focusing on shipboard implementation have emerged, including engineering design and safety assessments for onboard installation as well as initiatives covering the unloading, transportation, utilisation, or storage of captured CO₂. Representative projects are summarised in Table B-1.

Table B-1 Major OCCS Demonstration and Shipboard Implementation Projects

Project	Project Summary
CC-Ocean (2021)	A joint project undertaken by Kawasaki Kisen Kaisha, Ltd. (K Line), Mitsubishi Shipbuilding Co., Ltd., and ClassNK to demonstrate onboard CO ₂ capture under actual operating conditions. The project was conducted for approximately six months from August 2021 aboard the coal carrier CORONA UTILITY and successfully achieved CO ₂ capture with a purity exceeding 99.9 %. ClassNK conducted evaluations and verification activities throughout the project from a safety perspective. (1)
REMARCCABLE (2024)	A project focused on the design and safety assessment of an OCCS retrofit solution for an MR tanker. The project included Front-End Engineering Design (FEED), safety assessments such as Hazard Identification (HAZID) studies, and economic evaluations, providing engineering insights relevant to the large-scale adoption of OCCS on commercial ships. For the reference ship STENA IMPERO (MR tanker), the study concluded that a net annual CO ₂ reduction of approximately 19.7 % could potentially be achieved with a fuel penalty of 9.2 %. Capital expenditure (CapEx) was estimated at USD 13.6 million, while the CO ₂ abatement cost was estimated at USD 769/tCO ₂ . (2)
EverLoNG (2025)	A project involving the installation of OCCS systems on an LNG carrier and a semi-submersible crane ship to demonstrate the application of OCCS on LNG-fuelled ships under actual operating conditions. The project also examined the broader CCUS value chain, including CO ₂ unloading, transportation, and storage, as well as regulatory and certification frameworks necessary for the implementation of OCCS. (3)
Project CAPTURED (2024 and 2025)	A demonstration project involving the retrofit installation of OCCS on the Evergreen container ship EVER TOP. In 2024, ClassNK assigned the SCCS-Full notation (now OCCS-Full) to EVER TOP. In addition, the quantity of unloaded captured CO ₂ was verified and, under instructions from the Panama Administration, deducted from the ship's annual CO ₂ emissions for the purposes of the IMO Carbon Intensity Indicator (CII) rating scheme. This represented a case-specific determination made at the discretion of the Administration under the CII framework applicable at that time. As discussed in Chapter 4 of this handbook, methodologies for the quantification and verification of onboard captured CO ₂ within the IMO framework remain under development, and this case should not be regarded as representative of the current general regulatory approach. In 2025, the project expanded beyond onboard CO ₂ capture to demonstrate a post-capture value chain covering CO ₂ unloading, transportation, and subsequent onshore treatment (fixation or utilisation). ClassNK was involved in coordinating the handling of captured CO ₂ with the Administration and other relevant authorities. (4)
Clipper Eris (2025)	The world's first project to demonstrate a full-scale OCCS system under commercial operating conditions. The system was installed on the ethylene carrier CLIPPER ERIS, owned by Solvang ASA, using OCCS technology supplied by Wärtsilä. The system captures CO ₂ from post-combustion exhaust gas, liquefies the captured CO ₂ , and stores it in dedicated liquefied CO ₂ tanks installed on deck. The process comprises five stages: pre-treatment, absorption, desorption, liquefaction, and storage. The project reportedly achieved CO ₂ capture rates of up to approximately 70 %, corresponding to around 50 tonnes of CO ₂ per day under actual operating conditions. Captured CO ₂ is intended to be unloaded at ports of call and subsequently directed to permanent storage or utilisation pathways within a verified CCUS value chain. As of July 2026, the specific downstream destination had not been publicly disclosed. (5)

Source

(1) ClassNK, *CC-Ocean Project Conducted with K Line and Mitsubishi Shipbuilding for Verification of Marine CO₂ Capture Systems*

(2) Global Centre for Maritime Decarbonisation (GCMD), *Project REMARCCABLE: Realising maritime carbon capture to demonstrate the ability to lower emissions*

(3) EverLoNG, *Demonstrating carbon capture on LNG-fuelled ships*

(4) ClassNK, *Notation Assigned to Onboard CCS System on EVERGREEN Neo-Panamax Container Ship*; GCMD, *GCMD Details How Onboard Captured CO₂ Was Successfully Offloaded, Transported and Utilised*

(5) Solvang ASA, *World-first full-scale onboard carbon capture on Clipper Eris, Wärtsilä, Onboard carbon capture solution (CCS) for ships*

Appendix C. CO₂ Storage Facilities and Unloading Infrastructure in EU/EEA and UK

The European Union has established a permitting framework for geological CO₂ storage facilities under the CCS Directive (Directive 2009/31/EC), which regulates the storage of CO₂ in geological formations.

The principal CO₂ storage sites identified within the EU/EEA as of May 2026 are summarised in Table C-1.

As shown in Table C-1, several CO₂ storage sites are already in operation within the EU/EEA. In addition, projects such as Longship (Northern Lights) in Norway, Greensand in Denmark, and Porthos in the Netherlands are being developed not only for specific CO₂ sources but also to accept CO₂ captured from multiple emission sources.

The CCS Directive includes provisions concerning third-party access to storage sites and transportation infrastructure (Article 21). Accordingly, parties other than the storage site operator may, in principle, be able to access existing infrastructure. However, CCS projects generally involve pre-arranged contractual commitments regarding the sources of captured CO₂, and priority is often given to specific contracted users. As a result, separate contractual arrangements with the storage operator may be required for third parties wishing to utilise storage capacity.

Table C-1 Principal CO₂ Storage Facilities in the EU/EEA

Status	Country	Facility	Description	CO ₂ Storage Capacity	Start-up Year	Storage Permit
Operational	Hungary	MOL Szank Field	Capture, transportation and storage of CO ₂ from a gas processing plant, including EOR (Note 1)	0.16 MtCO ₂ /year	1992	Unknown
	Norway	Equinor Sleipner	Separation and storage of CO ₂ generated during natural gas production	1.0 MtCO ₂ /year	1996	Granted
	Norway	Equinor Snøhvit	Separation and storage of CO ₂ generated during natural gas production	0.7 MtCO ₂ /year	2008	Granted
	Croatia	Zutica and Ivanic Grad Storage	Capture, transportation and storage of CO ₂ from a gas processing plant, including EOR (Note 1)	0.65 MtCO ₂ /year	2014	Unknown
	Iceland	Climeworks Orca	Storage of CO ₂ captured through Direct Air Capture (DAC)	0.004 MtCO ₂ /year	2021	Granted
	Iceland	Climeworks Mammoth	Storage of CO ₂ captured through Direct Air Capture (DAC)	0.036 MtCO ₂ /year	2024	Granted
	Italy	Eni Ravenna	Capture, transportation and storage of CO ₂ from a gas processing facility. Storage capacity planned to expand in Phase 2.	(Phase 1) 0.025 MtCO ₂ /year (Phase 2) 4.0 MtCO ₂ /year	2024	Granted
	Iceland	Silverstone	Capture and storage of CO ₂ emitted from a geothermal power plant	0.037 MtCO ₂ /year	2025	Granted
Planned	Norway	Longship (Northern Lights)	Ship transport of CO ₂ captured from industrial facilities to an onshore receiving terminal, followed by offshore storage via subsea pipeline. Storage capacity planned to expand in Phase 2.	(Phase 1) 1.5 MtCO ₂ /year (Phase 2) >5.0 MtCO ₂ /year (planned from the second half of 2028)	2025	Granted
	Denmark	Greensand	Transport and storage of CO ₂ from the oil and chemical industries by ship	(Initial) 0.4 MtCO ₂ /year (Planned) 4-8 MtCO ₂ /year by 2030	Planned for mid-2026	Granted
	Netherlands	Porthos	Transportation and storage of CO ₂ captured from multiple emission sources	2.5 MtCO ₂ /year	Planned for the second half of 2027	Granted

Source

Compiled based on information from the Global CCS Institute, Global Status of CCS 2025; IOGP, CO₂ Storage Projects in Europe; European Commission Reports on the Implementation of the CCS Directive; and other publicly available sources (The table includes planned capacities and projects, which are subject to change in the future).

Note 1: Storage projects involving Enhanced Oil Recovery (EOR) should be distinguished from dedicated geological storage, as their primary purpose is the enhancement of oil recovery. Regulatory treatment may differ depending on whether the project has obtained a storage permit under the EU CCS Directive. Individual confirmation is therefore recommended (see Section 1-4).

Permanent geological storage of CO₂ also requires suitable CO₂ Unloading facilities. In recent years, facilities capable of handling liquefied CO₂ have entered operation in certain regions, while additional infrastructure linked to large-scale CCS projects is being developed, particularly in Europe.

The principal CO₂ Unloading facilities identified within the EU/EEA and the United Kingdom as of May 2026 are summarised in Table C-2.

Table C-2 Principal CO₂ Unloading Facilities in the EU/EEA and the UK

Status	Country	Facility / Port	Description	CO ₂ Unloading Capacity	Start-up Year
Operational	United Kingdom	Nippon Gases Tilbury, Warrenpoint & Teesside Ports	Liquefied CO ₂ unloading terminals (used for food and beverage applications)	Unknown	2019
	Finland	Loviisa Port	Liquefied CO ₂ export terminal (used for food and beverage applications)	Unknown	Unknown
	Germany	Port of Hamburg	Liquefied CO ₂ unloading terminal (used for food and beverage applications)	Unknown	Unknown
	Norway	Øygarden	Liquefied CO ₂ unloading facility at the Øygarden receiving terminal	Unknown	2025
Planned	Poland	Port of Gdansk	Open-access liquefied CO ₂ import/export terminal	2.7–8.7 MtCO ₂ /year	From 2027
	Netherlands	CO ₂ next Terminal, Port of Rotterdam	Open-access liquefied CO ₂ import/export terminal	5.4 MtCO ₂ /year	2028
	Netherlands	Project Aramis, Maasvlakte, Port of Rotterdam	Liquefied CO ₂ unloading and transfer facilities	22 MtCO ₂ /year	2030
	Sweden	Port of Gothenburg	Development of a CO ₂ transportation chain	4 MtCO ₂ /year	Unknown

Source

Compiled based on information from the *Global Centre for Maritime Decarbonisation (GCMD), Concept Study to Offload Onboard Captured CO₂*, and other publicly available sources.

Many of the facilities currently in operation listed in Table C-2 were originally developed to handle liquefied CO₂ for food, beverage, and similar applications, rather than for onboard captured CO₂ destined for permanent storage. It should also be noted that food and beverage applications fall within the category of Utilisation as defined in this handbook and involve the eventual re-release of CO₂ into the atmosphere. Consequently, such applications are not currently recognised as GHG emission reductions under applicable regulatory frameworks.

By contrast, projects such as Øygarden, CO₂next Terminal, and Project Aramis are being developed as part of CCS value chains and include facilities for CO₂ reception, temporary storage, and transportation. Although these facilities are primarily intended for industrial CO₂ sources, they may also have the potential to accept CO₂ captured onboard ships.

Appendix D. OCCS-Related Work Programme at the IMO and the EU

- Within the IMO, work relating to OCCS is progressing from the following three perspectives. These activities are being carried out in parallel within the Marine Environment Protection Committee (MEPC), the GESAMP-LCA Working Group (Working Group on the Assessment of Life Cycle GHG Intensity of Marine Fuels under the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection), and the Maritime Safety Committee (MSC) / Sub-Committee on Carriage of Cargoes and Containers (CCC).

(1) Development of a Regulatory Framework for OCCS

Under the work plan approved at MEPC 83, development is underway of a regulatory framework to enable GHG emission reductions achieved through OCCS to be reflected within IMO measures. Key areas under consideration include the following:

- Guidelines for the testing, survey, and certification of OCCS systems
- Methodologies for accounting for OCCS within IMO GHG measures
- Addressing legal and regulatory barriers
- Connection to certified reception facilities
- Data recording and reporting requirements

(2) Development of Methodologies for Accounting GHG deduction term (e_{OCCS})

The 2024 LCA Guidelines introduced e_{OCCS} as a concept for evaluating life cycle GHG intensity. The GESAMP-LCA Working Group is currently considering methodologies for accounting of GHG emissions associated with the capture, transportation, Storage, Fixation or Utilisation of CO₂, together with approaches for preventing double counting.

(3) Development of Safety Requirements for OCCS Systems

At MSC 110, safety-related issues and regulatory gaps associated with OCCS were identified. Detailed consideration is expected to begin at CCC 12, with the following issues identified as key topics:

- Classification of captured CO₂ (e.g. cargo, waste and overboard discharge)
- Requirements for the storage and transportation of captured CO₂
- Need for amendments to the IMDG Code

- Within the EU, the European Commission is expected to evaluate the potential inclusion of emerging GHG reduction technologies, including onboard CCS systems, within GHG intensity calculation methodologies and related regulatory frameworks.

Table D-1 Major OCCS-Related Work Programme at the IMO and the EU

Year	Major Meeting / Activity	Description
2026 (September)	CCC 12	Commencement of detailed consideration of OCCS safety requirements and related regulatory issues
2026 to 2027	OCCS Correspondence Group (CG)	Discussions conducted in accordance with the work plan approved by MEPC
2027 (around summer)	MEPC 86 (expected)	Submission and consideration of the Correspondence Group report
End of 2027	FuelEU Maritime Review Report	European Commission review of GHG reduction technologies, including OCCS, and assessment of the need for regulatory amendments
2028 (around September)	CCC 14	Target completion of work on OCCS safety requirements
2028 (around autumn)	MEPC 88 (expected)	Target completion of the OCCS regulatory framework and related guidelines

Source

Compiled based on IMO Secretariat, IMO's Ongoing Work on Onboard Carbon Capture and Storage (OCCS) Systems and FuelEU Maritime Regulation, Article 30(2)(i).

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5. Global Centre for Maritime Decarbonisation (GCMD), *Project REMARCCABLE*.
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NIPPON KAIJI KYOKAI

Business Assurance Division
Green Certification Department

4-7 Kioi-cho, Chiyoda-ku, Tokyo 102-8567, JAPAN
Tel : +81-3-5226-3025
Email : dcs@classnk.or.jp

www.classnk.com

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