Onboard Carbon Capture Systems

in Deep Sea Shipping

Regulatory Barriers and Policy Sequencing Requirements

Executive White Paper

May 24, 2026

Reference No: REF 2026 001

This white paper analyses the fragmented regulatory landscape constraining OCCS deployment in international shipping and identifies the policy sequencing required to enable commercial scale adoption.

Executive Summary

Onboard Carbon Capture Systems (OCCS) can reduce vessel level carbon emissions by 20 to 30% without changing fuel. This makes OCCS a practical transition option for deep sea shipping while zero carbon fuels remain supply constrained, expensive, and unevenly available across trade routes.

The barrier to deployment is not only technical performance or retrofit cost. It is regulatory fragmentation across four domains: IMO instruments, EU climate law, EU sustainable finance frameworks, and international CO_2 transport law. The result is a bankability gap. Captured CO_2 may be physically removed from exhaust gas, but it is not yet treated consistently as avoided emissions across compliance, finance, disclosure, and chain of custody systems.

The timing issue is now central. EU ETS obligations apply to maritime emissions from 2024, and FuelEU Maritime applies from 2025. By contrast, the IMO Net Zero Framework remains pending after the adjournment of its 2025 adoption session and the continuation of negotiations at MEPC 84 in 2026. IMO GFI exposure should therefore be treated as envisaged carbon pricing exposure, not as a current charge, but it is sufficiently material to affect fleet planning, vessel valuation, and retrofit decisions.

Causal analysis shows a clear hierarchy:

- **Timing misalignment** is the dominant root cause. EU carbon costs are active, while IMO operational recognition for OCCS is still under development.
- **Legal uncertainty** is the second root cause. Cross border CO_2 transfer, port reception, custody, and liability remain insufficiently harmonized.
- **Accounting gaps** and **finance asymmetry** are downstream effects. They become easier to solve once timing and legal uncertainty are addressed.

The relevant window is now 2026 to 2028. This is not the start of the transition. It is the period in which regulators, ports, financiers, and shipowners can turn OCCS from a technical option into a bankable compliance pathway before 2030 capital decisions harden.

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Nomenclature

EEDI	Energy Efficiency Design Index	**EEXI**	Energy Efficiency Existing Ship Index
CII	Carbon Intensity Indicator	**MRV**	Monitoring, Reporting and Verification
DCS	IMO Data Collection System	**OCCS**	Onboard Carbon Capture Systems
ETS	Emissions Trading System	**GFI**	Greenhouse Gas Fuel Intensity
NZF	Net Zero Framework	**LP**	London Protocol
CSRD	Corporate Sustainability Reporting Directive	**SFDR**	Sustainable Finance Disclosure Regulation
ESRS	European Sustainability Reporting Standards	**EUA**	EU Allowance

1 Why OCCS Matters Now

The maritime sector faces a compliance squeeze with no easy exit. Decarbonization is mandatory under EU climate law, and the IMO remains committed to net zero GHG emissions by or around 2050. Yet zero carbon fuels are still constrained by cost, supply, safety infrastructure, and port availability. For many deep sea vessels, especially existing ships with long remaining economic life, waiting for fuel availability is not a viable compliance strategy.

Deep sea cargo vessels above 5,000 GT are particularly exposed. They operate across multiple jurisdictions, face EU ETS costs when calling at EU ports, and are likely to face IMO GFI based obligations if the NZF is adopted. OCCS offers a transitional route because it can reduce reported exhaust carbon at vessel level while preserving fuel flexibility.

The strategic issue is not whether OCCS can help. The issue is whether the policy system will recognize, verify, finance, and reward the captured carbon quickly enough.

For HHX clients, this creates a practical decision problem. Shipowners, lenders, ports, and public authorities need to know which vessels are credible candidates, which regulatory assumptions are bankable, which contracts must be in place, and which policy dependencies can derail the business case. This is where structured technical, regulatory, and financial alignment becomes decisive.

2 Four Regulatory Barriers and Key Facts

OCCS encounters overlapping constraints across four regulatory domains. The key facts are summarized below.

Barrier	Decision relevance
A. Accounting and crediting	CII, EEXI, IMO DCS, EEDI, and EU MRV do not yet provide a complete operational pathway to treat captured CO_2 as compliance relevant avoided emissions. A vessel may capture carbon but still lack full recognition in the regulatory calculation.
B. Legal and logistical uncertainty	Cross border CO_2 transfer, port reception, storage access, custody documentation, and liability allocation remain incomplete. The London Protocol provides a route for export for geological storage through provisional application, but the wider operational chain remains fragmented.
C. Finance and disclosure asymmetry	Land based carbon capture has clearer sustainable finance recognition than maritime OCCS. Without recognized accounting and custody rules, early adopters may not receive lower cost capital, taxonomy eligibility, or ESG recognition.
D. Timing misalignment	EU ETS obligations started with 2024 emissions and FuelEU Maritime applies from 2025. IMO NZF and GFI mechanisms remain pending after the 2025 adjournment and the renewed 2026 work programme. This gap weakens retrofit economics.

Table 1: Regulatory barriers and their commercial relevance

Question	Answer
What is OCCS?	A shipboard system that captures CO_2 from exhaust gas and transfers it ashore for permanent geological storage or verified downstream use, subject to custody and legal rules.
Why is 2024 still relevant?	2024 is the reference year because maritime EU ETS exposure began with 2024 emissions. It should no longer be written as the start of a future window. The analysis is now about managing the 2026 to 2028 decision period.
What is the core commercial risk?	Investment can fail if captured CO_2 reduces physical emissions but is not recognized in ETS, FuelEU, CII, DCS, finance, or disclosure systems.
What can unlock bankability?	A verified MRV pathway, clear port reception and storage arrangements, interim recognition logic, and finance criteria that lenders can apply before full IMO implementation.

Table 2: Key facts for decision makers

3 Causal Structure: Which Barriers Drive Which?

Not all barriers carry equal weight. A structured causal analysis, mapping pairwise influence relationships among the four barriers on a 0 to 4 scale, identifies which barriers are root causes and which are effects. Two measures drive the classification: *prominence*, meaning total influence sent and received, and *relation*, meaning net influence sent minus received. Positive relation identifies a driver. Negative relation identifies an effect.

Barrier	Prominence	Relation	Classification	Rank
D. Timing misalignment	5.29	+1.23	Root cause	**Dominant**
B. Legal uncertainty	4.09	+0.20	Root cause	Secondary
A. Accounting gap	4.18	-0.56	Effect	Tertiary
C. Finance asymmetry	3.97	-0.67	Effect	Downstream

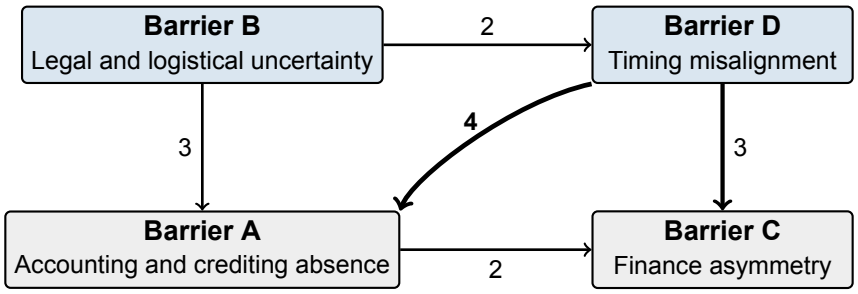
Table 3: Causal analysis results

Interpretation: Timing misalignment drives the system because it converts policy uncertainty directly into failed investment returns. Legal uncertainty is the second root cause because it prevents custody, port reception, insurance, and offtake commitments. Accounting and finance issues are important, but they are largely downstream of timing and legal clarity.

4 Governance Gaps and Policy Priorities

The policy sequence must reflect the 2026 position. The issue is no longer how to start action in 2024. That date is now historical and remains relevant mainly as the first EU ETS reference year. The practical window is 2026 to 2028.

The highest leverage policy action remains a verified reporting route for captured CO_2. Without it, OCCS remains technically useful but commercially discounted. With it, shipowners can



Legend: Blue = root causes. Grey = effects. Arrow width shows influence strength.

Figure 1: Causal influence structure

connect retrofit decisions to carbon cost avoidance, lenders can underwrite repayment assumptions, and port authorities can justify reception infrastructure.

5 Quantifying Exposure and the Cost of Delay

OCCS deployment must be evaluated as a portfolio decision, not as a single vessel technology choice. The same equipment can be bankable or unbankable depending on route exposure, EU port calls, expected NZF timing, CO_2 custody arrangements, storage access, and finance treatment.

For a shipowner or financier, the decisive question is therefore not simply: "Does OCCS work?" The better question is: "For which vessels, routes, contracts, ports, and policy assumptions does OCCS become bankable?" This is the practical screening problem that HHX is positioned to support through carbon cost modelling, technical alignment audits, policy risk mapping, and financing readiness review.

6 Recommendations for Stakeholders

6.1 For EU Policymakers

- Prioritize the MRV route for captured CO_2. This is the fastest way to connect physical capture with ETS relevance.
- Coordinate EU MRV treatment with the IMO work programme so that regional action does not create a second accounting logic that later conflicts with IMO DCS or CII.
- Clarify how verified OCCS can be treated in sustainable finance and disclosure frameworks once custody and storage evidence are available.

6.2 For IMO Member States

- Keep the NZF process moving, but avoid presenting GFI exposure as already adopted while the adoption process remains pending.
- Develop interim guidance for OCCS measurement, verification, custody, and port reception so that early projects produce usable regulatory evidence.
- Advance London Protocol coordination and bilateral CO_2 transfer arrangements for geological storage corridors.

Gap	2026 priority	2027 to 2028 target
Timing	Treat EU ETS and FuelEU as live cost regimes. Treat IMO GFI as pending or envisaged exposure. Build retrofit cases with scenarios rather than single point forecasts.	Align EU MRV, interim CII logic, and IMO NZF guidance so that verified capture has a recognized compliance pathway.
Legal status	Use bilateral or regional CO_2 transfer arrangements where geological storage routes are available. Clarify port reception, custody, and liability before retrofit contracts are signed.	Move from project level arrangements to repeatable port and storage corridors with standard reception receipts and custody documents.
Accounting	Define measured capture, purity, energy penalty, discharge, custody, and storage evidence in vessel level MRV plans.	Revise EU MRV and IMO DCS templates so captured and emitted quantities are distinguished consistently.
Finance	Require lenders to model carbon exposure, residual technology risk, custody risk, and policy timing risk explicitly.	Recognize OCCS retrofits in green lending, taxonomy linked finance, and sustainability linked instruments once verification pathways are credible.

Table 4: Updated implementation logic for the 2026 to 2028 window

6.3 For Shipowners

- Commission fleet level carbon exposure audits using 2024 emissions as the EU ETS reference point and 2026 to 2028 as the decision window.
- Screen vessels by route, remaining life, engine profile, space, energy penalty, port access, storage access, charterer expectations, and financing constraints.
- Treat OCCS as a portfolio option. Some vessels may justify immediate preparation, while others should wait for policy clarity or fuel alternatives.

6.4 For Financial Institutions

- Price carbon risk explicitly in vessel valuation, loan covenants, and refinancing assumptions.
- Distinguish current EU ETS exposure from pending IMO GFI exposure, and require scenario based sensitivity analysis.
- Build finance structures around milestones: verified MRV method, port reception contract, storage or offtake evidence, and policy recognition.

6.5 Where HHX Adds Value

HHX.blue can support this transition without asking clients to wait for perfect regulatory clarity. The practical work is to convert uncertainty into structured decisions: vessel screening, OCCS readiness assessment, regulatory gap mapping, MRV design, carbon cost scenarios, financing narratives, and stakeholder alignment with ports, class, lenders, and public authorities.

This makes the white paper's conclusion operational. OCCS is not only a technology question. It is a sequencing, evidence, and bankability question. That is exactly where integrated

Metric	Commercial implication
Fleet exposure	Large ocean going ships above 5,000 GT are the main policy target and the most relevant retrofit population. Exposure depends on age, route, fuel, cargo profile, and EU port intensity.
EU ETS cost	Maritime EU ETS is already active. The phase in means cash impact grows through 2027, so 2026 planning must treat carbon cost as an operational credit variable.
IMO GFI exposure	Not a current charge. It is pending or envisaged carbon pricing exposure under the NZF process. It should be used in scenarios, not presented as an adopted penalty.
OCCS adoption without policy clarity	Limited to pilots, high exposure vessels, strategic first movers, and publicly supported projects.
OCCS adoption with aligned policy	Wider deployment becomes possible if capture is verifiable, custody is legally secure, and finance frameworks recognize the emissions benefit.
Capital implication	The policy prize is not only avoided carbon cost. It is access to cheaper capital, reduced stranded asset risk, and stronger negotiating position with charterers, lenders, and regulators.

Table 5: Exposure and investment implications

maritime policy, finance, and technical advisory work creates value.

7 Conclusion

OCCS can provide a credible transition pathway for deep sea shipping, especially where existing vessels face rising carbon costs before zero carbon fuels are available at scale. The core barrier is not a single missing rule. It is a sequence problem across timing, legal status, accounting, and finance.

The revised causal hierarchy is clear. Timing misalignment and legal uncertainty must be addressed first. Accounting and finance can then follow with greater speed and less contradiction. The EU can move fastest through MRV recognition. IMO can provide global consistency through the NZF, DCS, CII, and OCCS workstreams. London Protocol coordination can make cross border CO_2 transfer credible for storage corridors. Financial institutions can convert these signals into lending criteria.

The relevant period is now 2026 to 2028. Decisions in this period will determine whether OCCS remains a small pilot activity or becomes a bankable compliance option before 2030. Stakeholders who prepare early, with verified data, clear custody logic, and finance ready scenarios, will have a stronger position than those who wait for the final rulebook.

The opportunity is to turn regulatory uncertainty into structured advantage. HHX.blue supports that work.

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Contact us for a private consultation, carbon exposure review, or technical alignment audit.

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