# Navigating the Gap: An Evidence-Based Assessment of Onboard Carbon Capture & Storage (OCCS) for Maritime Decarbonization


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**Made for:** Transport & Environment (T&E)

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## Executive Summary

Onboard carbon capture and storage (OCCS) is being discussed because maritime decarbonisation needs to accelerate faster than fleet turnover. Many ships operating today will still be sailing well into the 2030s, with a meaningful share remaining active into the 2040s. In that context, OCCS is being tested as a retrofit pathway that could reduce reported emissions while zero and near-zero fuel supply chains scale up and mature.

This report reviews the current OCCS project landscape and what early trials suggest it can deliver in practice. Most activity today is still at the pilot and demonstration stage, with Europe and Asia leading the early momentum and solvent-based approaches appearing most often. The main takeaway is that capturing $CO_2$ onboard is feasible, but real-world results depend on practical ship constraints: the extra energy required to run the system, the space and weight it takes up, and how reliably it can operate across normal voyages and maintenance cycles.

The analysis also shows that OCCS scalability is likely to be decided downstream. Captured $CO_2$ only becomes creditable if it can be measured, stored, offloaded, and transferred under an auditable chain of custody to a verified permanent sink. This makes offloading infrastructure, storage access, and consistent MRV rules the gating factors for deployment beyond pilots. OCCS may have a role as a bridge option in specific niches, but it is not a substitute for fuel transition and should be governed in a way that avoids lock-in (see Chapter 6 for the bridge-use conditions and guardrails).

Compliance depends on net abatement, not net capture alone: additional out-of-scope factors such as capture duty cycle (port and transient operation), $CO_2$ conditioning and storage loads, and downstream losses and custody transfer can further reduce credited abatement even when onboard net capture looks high.

### Key takeaways

- **Net abatement matters more than headline capture:** high gross capture rates can translate into materially lower net outcomes once onboard energy penalties are included.
- **Scaling is limited by the downstream chain:** offloading logistics, custody transfer, and access to storage are the main constraints, not separation performance alone.
- **Net capture is not the same as credited abatement:** duty-cycle, $CO_2$ handling/storage energy, and downstream transfer losses and MRV can materially reduce compliance-relevant abatement and are treated as boundary conditions beyond the core model.

# Table of Contents


**Executive Summary** .......... **2**

Key takeaways .......... 2

**Chapter 1: Context and scope** .......... **5**

1.1 Why OCCS is on the table now .......... 5

1.2 Regulatory landscape .......... 6

1.3 Objective and scope of this assessment .......... 6

**Chapter 2: Methodology and data integrity** .......... **7**

2.1 Evidence approach .......... 7

2.2 Analytical boundaries .......... 7

2.3 Gross vs net capture treatment .......... 8

2.4 Cost comparability .......... 8

**Chapter 3: The OCCS Project Landscape** .......... **8**

3.1 What the pipeline suggests .......... 8

3.2 Spotlight: flagship projects that are shaping expectations .......... 11

**Chapter 4: Techno-Economic Assessment** .......... **13**

4.1 Technology maturity and capture performance .......... 13

4.2 Economic feasibility .......... 15

4.3 Stakeholder evidence panel .......... 17

**Chapter 5: The Downstream Challenge** .......... **17**

5.1 Storage availability and competition .......... 17

5.2 The logistics of offloading .......... 19

**Chapter 6: Conclusion** .......... **19**

6.1 Conclusion .......... 19

6.2 Key policy conditions to capture delivered abatement .......... 20

**Works Cited** .......... **20**

**Appendix A: Assumptions and calculation methods** .......... **23**

A.1 Estimating annual CO2 emissions (main engine, tank-to-wake) .......... 23

A.2 Captured CO2 and gross capture rate .......... 23

A.3.1 Fuel-penalty method (preferred) .......... 23

A.3.2 Energy-penalty proxy method (fallback) .......... 24

A.3.3 Note on electricity-only reporting .......... 24

A.4 Exhaust CO2 concentration proxy (vol%) .......... 24

A.5 Cost boundary conventions (interpretation note) .......... 24

A.6 Converting Tank-to-Wake capture rates to Well-to-Wake abatement .......... 25

**Appendix B: Stakeholder snapshots** .......... **27**

Evidence Snapshot 1: Value Maritime ........ 27
Evidence Snapshot 2: Carbon Ridge ........ 28
Evidence Snapshot 3: CMMI ........ 29
Evidence Snapshot 4: CE-TEK Co. Ltd. ........ 30
Evidence Snapshot 5: Rotoboost ........ 30
Shipowner perspective (anonymous interview summary) ........ 32
**Appendix C: Data coverage and evidence gaps ........ 33**

# Chapter 1: Context and scope

Onboard carbon capture and storage (OCCS) is being discussed because maritime decarbonisation is accelerating faster than fleet turnover. Many ships operating today will still be sailing well into the 2030s, with a meaningful share remaining active into the 2040s. That creates a practical question: what can be done on existing assets, at retrofit pace, while zero and near-zero fuel supply chains scale up? [1][2][3]

OCCS should not be understood as a single add-on box. It is an end-to-end chain that must operate reliably at sea and remain creditable when the CO2 leaves the vessel. In practice, the value of OCCS depends less on whether CO2 can be separated from exhaust, and more on whether captured CO2 can be measured, stored, transferred, and delivered to a verified permanent sink under a robust chain of custody.

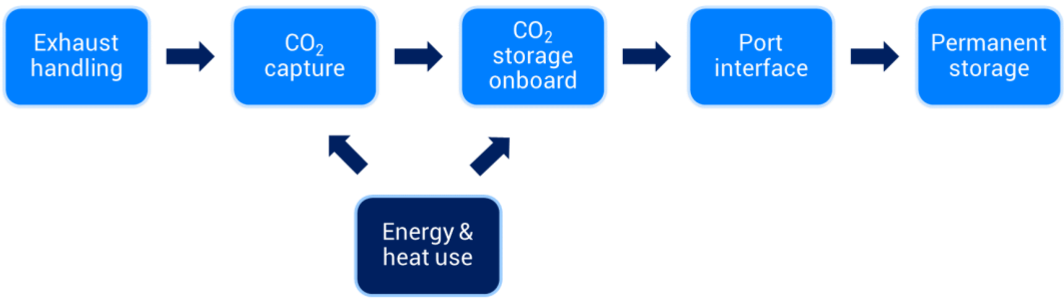


*Figure 1: OCCS is a chain, not a component: capture, conditioning, onboard storage, offloading, and verified transfer to a permanent sink.*

## 1.1 Why OCCS is on the table now

The regulatory timeline is tightening on a schedule that stresses near-term compliance options. The IMO's direction of travel points toward net-zero shipping by or around 2050, with earlier checkpoints for 2030 and 2040. In parallel, the EU is applying compliance pressure via EU ETS for maritime, creating a near-term economic cost for reported emissions on voyages linked to EU and EEA ports[3][4][5][6].

Additionally, FuelEU Maritime creates parallel compliance pressure by requiring ships on voyages linked to EU ports to progressively reduce the greenhouse gas intensity of the energy used onboard from 2025 onward. While FuelEU Maritime does not yet provide a crediting pathway for OCCS, its scheduled Commission review includes consideration of whether onboard carbon capture could be recognised, subject to a verifiable monitoring and accounting method.

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[1] https://unctad.org/publication/review-maritime-transport-2024
[2] https://www.imo.org/en/MediaCentre/PressBriefings/pages/Revised-GHG-reduction-strategy-for-global-shipping-adopted.aspx
[3] https://www.irena.org/Publications/2021/Oct/A-pathway-to-decarbonise-the-shipping-sector-by-2050
[4] https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets/ets-maritime-transport_en
[5] https://eur-lex.europa.eu/eli/dir/2023/959/oj
[6] https://www.bimco.org/news-insights/trending-topics/eu-ets/


***Figure 2****: Fleet lifetimes are long, while regulatory milestones arrive sooner, which is why retrofit pathways such as OCCS are being tested*[7].

OCCS is being explored partly because it could reduce near-term compliance exposure on existing vessels during a period of fuel-transition uncertainty. This report assesses what OCCS can realistically deliver once onboard and downstream constraints are treated as first-order requirements.

### 1.2 Regulatory landscape

For OCCS, the most important regulatory question is not whether carbon capture is allowed onboard. The practical question is: under what conditions does captured CO2 count as avoided emissions, and how is it monitored, verified, and tracked from ship to permanent storage?[8][4].

This crediting logic drives engineering requirements. If crediting depends on verified transfer to a storage site, then onboard tank design, offloading procedures, metering, sampling, and documentation become core system requirements, not peripheral add-ons.

In near-term practice, EU ETS and MRV represent the clearest compliance pull because reported emissions carry a direct cost. A central implication is that crediting depends on what happens after capture, not only capture performance. Temporary onboard storage is also not free: leakage or boil-off can create reportable emissions and operational constraints. FuelEU Maritime is important context, but it does not yet provide a crediting pathway for OCCS[4].

### 1.3 Objective and scope of this assessment

This report assesses OCCS as a decarbonisation option for maritime shipping, with emphasis on engineering realities, measurable abatement, cost drivers, and scalability constraints. It focuses on OCCS systems designed to capture CO2 from

[7] https://unctad.org/publication/review-maritime-transport-2024
[8] https://maritimeforum.org/wp-content/uploads/2025/10/Safe-Onboard-Carbon-Capture-and-Storage.pdf
[4] https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets/ets-maritime-transport_en

ship exhaust, condition it for temporary onboard storage, and transfer it to an off-ship handling chain intended to result in permanent storage or durable sequestration.

Known information gaps remain material:

- Public disclosures on OCCS' CAPEX, OPEX, and ship-specific integration costs are sparse and inconsistent.
- Few projects publicly document the intended CO2 receiving chain (custody transfer, storage route, and loss handling).
- A globally accepted MRV and chain-of-custody standard for onboard captured CO2 has not yet been finalised across jurisdictions.[2][8]

# Chapter 2: Methodology and data integrity

This report draws on a structured review of publicly disclosed OCCS initiatives and applies a small set of harmonised calculations to make key metrics comparable across projects. The approach is deliberately conservative: values stated by project stakeholders are used as reported, and calculated fields are used only to derive consistent first-order estimates where inputs allow.

## 2.1 Evidence approach

Information on OCCS projects is taken from traceable sources including technology providers, shipowners and operators, class societies, consortia and funders, and technically attributable reporting. Where multiple sources disagree, preference is given to technically accountable disclosures such as class society statements and primary project parties. Reported values are kept distinct from calculated values.

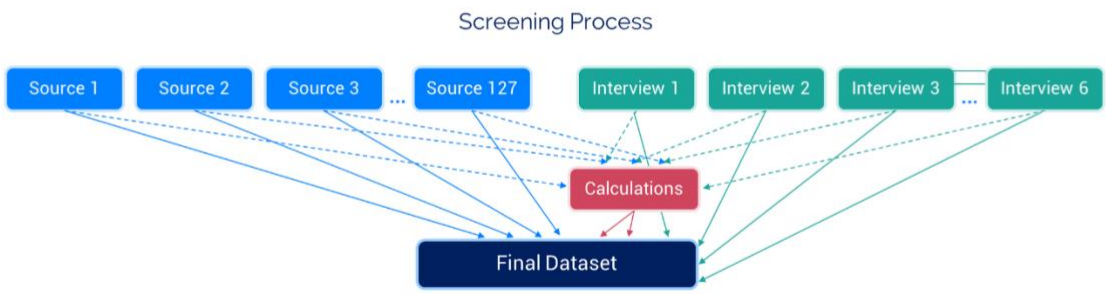


*Figure 3: Representative image of the data gathering and screening process.*

## 2.2 Analytical boundaries

The core analysis (Chapters 3 and 4) focuses on onboard capture performance and penalties, distinguishing between gross capture (engineering separation performance) and net capture (gross capture adjusted for onboard energy penalty). In this report, the onboard energy penalty refers only to the incremental energy required to run the capture process itself (primarily solvent regeneration heat plus auxiliary electrical loads for circulation, blowers, and controls), expressed as the additional fuel burn and $CO_2$ emitted to operate capture.

Energy and emissions associated with onboard $CO_2$ conditioning and storage (e.g., compression, liquefaction or refrigeration, boil-off management, and tank-related parasitics) are treated as part of the downstream chain and are therefore out of scope for the net-capture adjustment applied in Chapters 3 and 4. Downstream considerations are analysed separately (Chapter 5) because offloading and storage access determine whether captured CO2 becomes credited abatement.

### 2.3 Gross vs net capture treatment

Headline gross capture rates do not directly represent net captured CO2, because OCCS requires onboard energy (electricity and / or heat), which increases fuel consumption and therefore CO2 emissions. To avoid overstating abatement, this report treats net capture as the decision-relevant metric wherever sufficient information exists, and applies conservative adjustments based on the energy consumption where it does not (see Appendix A: Assumptions and calculation methods).

### 2.4 Cost comparability

Cost values are treated as boundary-aware. Reported CAPEX, OPEX, and levelised cost estimates vary by what is included (equipment only versus installed system; inclusion of compression and liquefaction; onboard storage; integration scope; downtime assumptions). As a result, cost results are presented as indicative and interpreted with clear scope caveats.

## Chapter 3: The OCCS Project Landscape

This section summarises the OCCS landscape based on a December 2025 snapshot, distinguishing what is actively happening (pilots and demonstrations) from what remains announced or planned. The dataset reflects a sector that is still proving operability, integration feasibility, and the practical conditions under which captured CO2 can translate into creditable emissions reduction[9].

### 3.1 What the pipeline suggests

The dataset still skews toward validation and early deployment, but it is no longer “pilots only.” Most disclosed activity sits in pilot projects, while a meaningful subset has moved into first-of-a-kind full-scale operations (often as early commercial retrofits) and feasibility studies remain a smaller share. This suggests OCCS is transitioning from trials into initial full-ship implementations[9].

[9] https://www.prescouter.com/ccus-database/


*Figure 4*: *Project pipeline by status and project scope* (December 2025 snapshot)*[9].*

Activity is concentrated regionally. Projects cluster in Europe and Asia, consistent with where supplier ecosystems and near-term compliance attention are strongest. This concentration also implies that infrastructure readiness for offloading and storage is likely to be region-dependent.

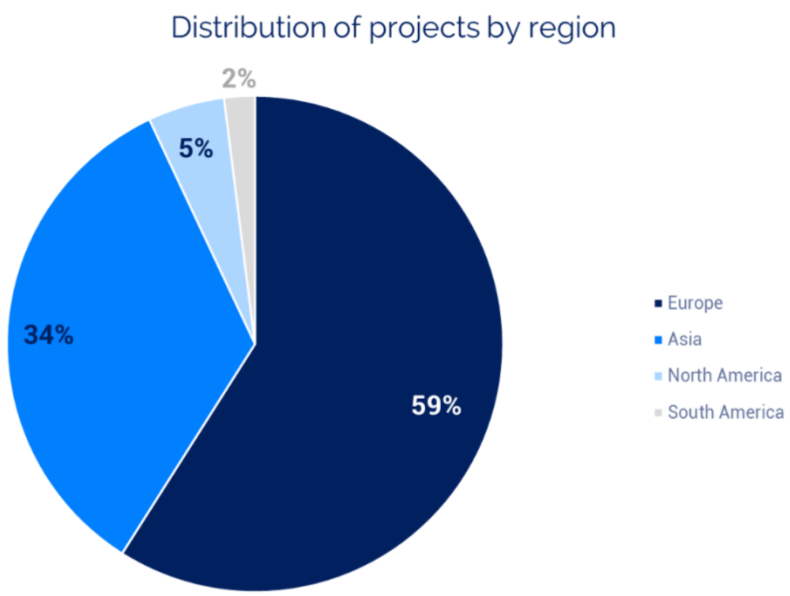


*Figure 5: Distribution of Project by geography (December 2025 snapshot)[9].*

Solvent systems dominate near-term activity. Solvent-based OCCS appears most frequently in disclosed projects, reflecting maturity and availability for shipboard

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* Feasibility = pre-deployment engineering/safety assessment with no sustained onboard capture; Pilot/Demo = time-bound real-ship capture trial to validate operability and MRV/handling; Commercial = productised, contracted installations intended for repeatable fleet rollout.

[9] https://www.prescouter.com/ccus-database/

pilots. Alternative pathways such as looping and mineralisation are present but remain early, and may depend on unresolved questions around by-products and regulatory treatment. [ (PreScouter)]

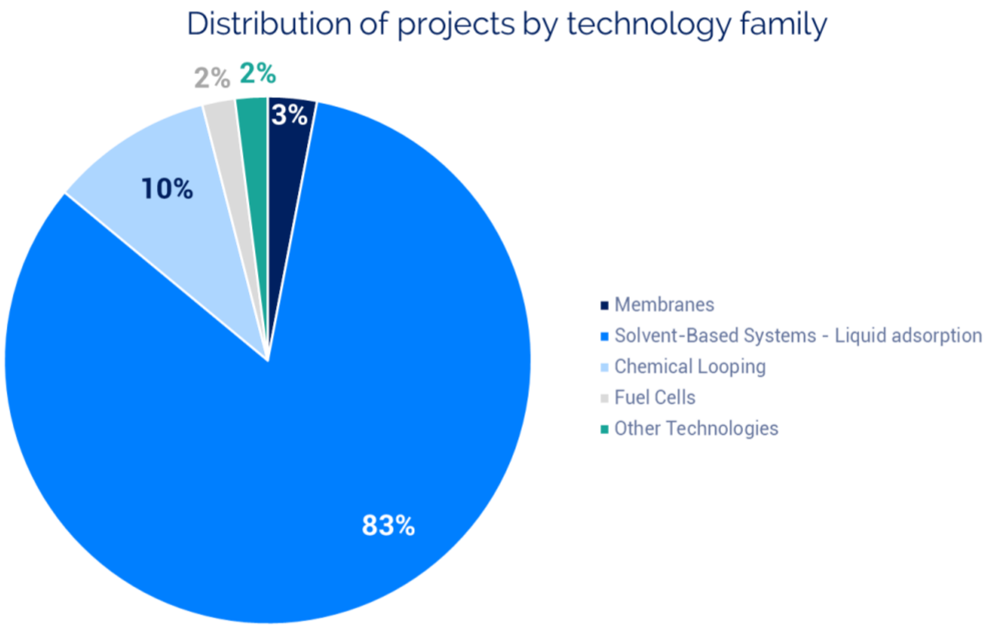


*Figure 6*: *Technology pathway split across the project snapshot (n = 49 entries)*[9].

The supplier base is still concentrated. A relatively small set of providers appears repeatedly across projects, indicating that learning curves and practical deployment credibility may be concentrated among a limited number of players.

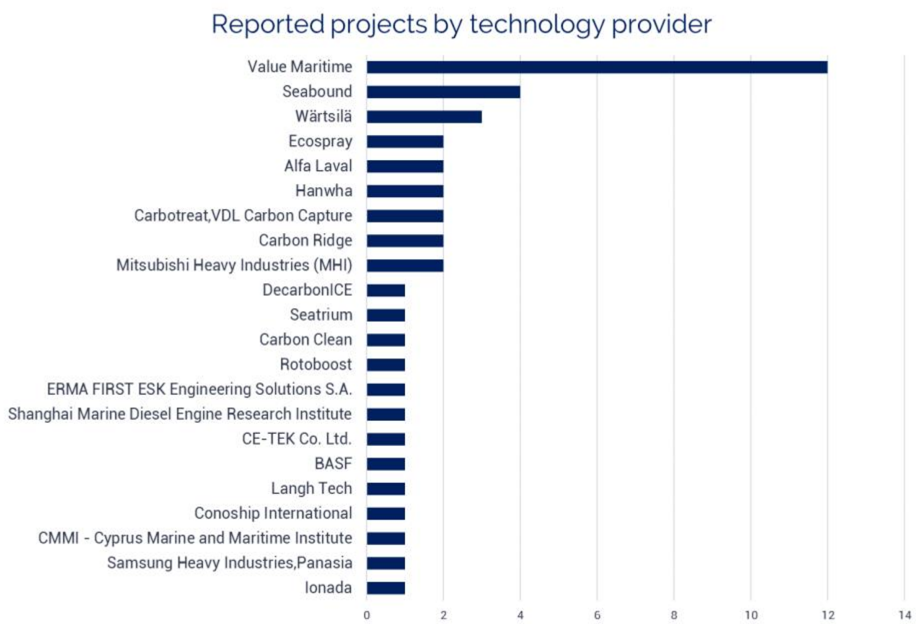


*Figure 7*: *Most frequently referenced technology providers (count of project entries)* [9].

Overall, OCCS is being trialed actively, and the emergence of first-of-a-kind full-scale installations shows that ship-side integration can move beyond pilots in selected

[9] https://www.prescouter.com/ccus-database/

cases. However, fleet-scale deployment remains unproven, because it is not yet clear that these systems can be replicated across vessel classes and operating profiles while maintaining meaningful net abatement and a credible, repeatable offloading and custody chain. The next question is therefore not how many projects exist, but whether they deliver meaningful net abatement and a credible offloading chain[9].

### 3.2 Spotlight: flagship projects that are shaping expectations

A small set of initiatives matters disproportionately because they test what will ultimately decide OCCS scalability: full-ship integration, repeatable operation at sea, and proof that captured $CO_2$ can be transferred off the vessel under an auditable chain of custody. In this report, "full ship integration" means the capture unit plus the supporting ship systems it depends on, including waste-heat or steam integration for solvent regeneration, power supply and redundancy, control and automation interfaces with engine load, and the physical impacts of $CO_2$ conditioning and storage (footprint, weight, stability, and hazardous-area and safety case requirements). "Repeatable operation at sea" means the system can run through real voyage conditions (load swings, weather, vibration and motion, maintenance cycles, and port manoeuvring) without sustained performance loss, unacceptable downtime, or degradation of MRV data quality. By contrast, many early tests validate separation under steady conditions or short trials, but do not yet demonstrate robust operation across duty cycles, port constraints, and the operational decision of when capture is paused or throttled.

One of the clearest "end-to-end" demonstrations is the MV Ever Top pilot, which validated not only capture onboard, but also transfer and offloading logistics. In the trial, 25.44 tonnes of captured $CO_2$ were transferred ship-to-ship and then offloaded onward via shore logistics, which makes it one of the most concrete examples of what "captured" needs to look like in practice to become "handled" $CO_2$[9][10][11].

*Figure 8: Evergreen from the Ever Top Pilot*

[9] https://www.prescouter.com/ccus-database/
[10] https://www.motorship.com/equipment/evergreen-container-vessel-trials-carbon-capture/1504650.article
[11] https://safety4sea.com/first-full-chain-onboard-carbon-capture-pilot-completed-in-china

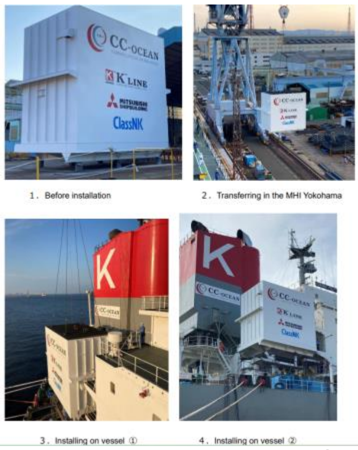


*Figure 9: Installation steps for the K Line's Corona Utility project*

A second reference point is K Line's Corona Utility (CC-Ocean project demonstration), which has been repeatedly cited as an early "real ship" implementation signal. The value of this project is less the headline capture concept and more the operational reality it forces into view: how to run capture onboard within marine constraints, and what $CO_2$ quality and handling requirements look like when integrated into a vessel context. Public technical reporting highlights very high $CO_2$ purity in the captured stream (reported at >99.9% $CO_2$), reinforcing that capture itself can be engineered to a high standard, even if the downstream chain remains the scaling bottleneck[12].

A third flagship signal comes from Scorpio Tankers' pilot with Carbon Ridge on STI SPIGA. This project reflects the "retrofit-first" pathway that many shipowners are likely to follow: start with a manageable demonstration on an existing vessel, learn quickly on operability and integration constraints, and only then consider whether replication is commercially and operationally feasible. It also reinforces a key theme of this report: the deployment question is not only capture performance, but whether the full onboard-and-offboard system can operate repeatedly without creating unacceptable penalties in space, energy, and port-side complexity[13].


*Figure 10: Schematics of the Scorpio Tankers' pilot*

Taken together, these flagship initiatives reinforce a consistent pattern: OCCS is technically achievable, but scaling depends on whether projects can deliver net abatement, operate reliably under real trading conditions, and connect to a downstream chain that is viable for custody transfer and regulatory crediting. Net abatement is linked directly to commercial scalability because it determines the number of credited tonnes delivered per unit of shipboard cost and disruption. If energy penalties, duty-cycle limits, or MRV constraints reduce net abatement, then the effective cost per tonne avoided rises and the business case weakens. In practice, OCCS only scales if the credited abatement is large enough to be

[12] https://www.classnk.or.jp/hp/pdf/research/rd/2022/05_e0.pdf
[13] https://www.imarest.org/resource/mp-what-is-a-centrifugal-carbon-capture-system.html

economically meaningful versus alternative compliance routes (for example paying for EU ETS allowances, using eligible fuels to improve compliance scores, or pursuing other operational measures). In other words, "can capture" is not sufficient; the system must produce enough credited abatement to lower total compliance cost under the applicable rules.

# Chapter 4: Techno-Economic Assessment

## 4.1 Technology maturity and capture performance

Many disclosed initiatives reference gross capture rates in the 70-95% range, particularly for solvent-based systems. In practice, gross capture is not the metric that determines whether OCCS is a creditable compliance pathway. What matters is the effective annual reduction, after accounting for (i) the onboard energy penalty and (ii) the fact that capture systems do not operate at full performance continuously across real voyage conditions. A solvent OCCS system requires heat for regeneration and electricity for pumps, blowers, controls, and often $CO_2$ conditioning. That energy demand is supplied by the ship's onboard system and typically translates into additional fuel consumption, and therefore additional $CO_2$ emissions. The result is a structural gap between gross capture (separation performance) and net capture (gross capture adjusted for the penalty). In the project dataset used for this report, projects with high headline gross capture translate into net capture outcomes that commonly fall in the mid-range once consistent penalty treatment is applied[9].

A further real-world effect is operating profile. A subject matter expert noted that while 90-95% capture can be technically achievable during steady sailing conditions, dynamic loads, manoeuvring, and practical operating constraints reduce performance on an annual basis. Capture may be throttled down or turned off during port operations or transient conditions, and overall availability can reduce the annual capture outcome by roughly 10-20% relative to "steady-state" sailing capture. In other words, even if net capture appears to sit around ~50-60% after energy penalty adjustment, the effective annual net abatement can plausibly land closer to ~40-55% once operational duty-cycle constraints are included. This is not a failure mode. It is the reality of deploying a complex energy-consuming process on a moving asset with variable load profiles and tight space, power, and operational limits[8][14].

[9] https://www.prescouter.com/ccus-database/
[8] https://maritimeforum.org/wp-content/uploads/2025/10/Safe-Onboard-Carbon-Capture-and-Storage.pdf
[14] https://futurefuels.imo.org/wp-content/uploads/2025/09/08.-The-potential-role-of-onboard-carbon-capture-in-decarbonization-of-shipping-DNV.pdf

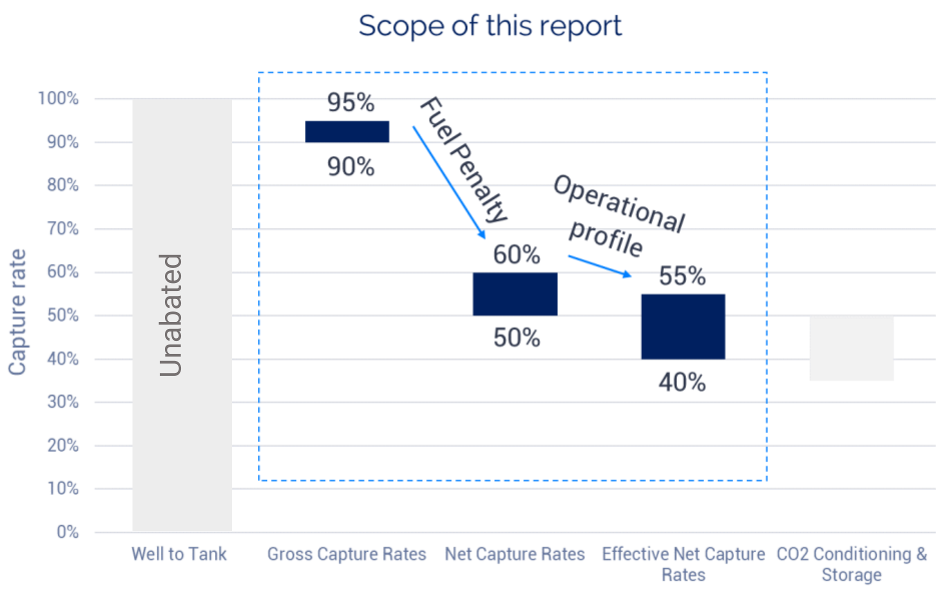


***Figure 11**: Gross vs net capture rate after applying consistent onboard penalty treatment (illustrative).*

This assessment reports capture outcomes on a Tank-to-Wake (TtW) basis, meaning it treats OCCS as reducing only the $CO_2$ emitted during onboard fuel combustion. If results were expressed on a Well-to-Wake (WtW) basis, the effective capture rate would be lower because upstream Well-to-Tank (WtT) emissions (fuel production, processing, and transport) are not affected by onboard capture. In other words, OCCS can reduce the combustion portion of emissions, but it does not change the upstream emissions intensity of the fuel itself; therefore, adding WtT emissions increases the denominator in a WtW metric and mechanically reduces the apparent percentage reduction.

**Example (Marine Gas Oil, FuelEU default values):**

Assumptions:

- WtT = 14.40 $gCO_2e/MJ$
- TtW = 76.23 $gCO_2e/MJ$
- WtW = 90.63.

Logic:

1. A 90% TtW capture rate leaves 10% of TtW emissions (7.623 $gCO_2e/MJ$) while WtT remains 14.40, so post-capture WtW = 14.40 + 7.623 = 22.023 $gCO_2e/MJ$.
2. The WtW reduction is therefore 1 − 22.023/90.63 = 75.7%,
3. meaning a 90% TtW capture rate becomes ~75% on a WtW basis because WtT remains unchanged.

More details of the calculation in the section “A.6 Converting Tank-to-Wake capture rates to Well-to-Wake abatement”

## 4.2 Economic feasibility

For shipowners, OCCS is a compliance decision that competes with other compliance options for both retrofits and newbuilds. The economic case is highly sensitive to boundaries, because what is included in an OCCS cost number varies widely across public disclosures (equipment-only versus installed system; inclusion of liquefaction and storage; integration scope; downtime assumptions). In this section, reported costs are interpreted as capture-system costs (LCOC, €/t$CO_2$ captured) unless explicitly stated otherwise, not full "€/t$CO_2$ avoided" including downstream transport and storage[9].

Where sufficient inputs exist, indicative levelised costs span a wide range. This spread is not primarily driven by capture chemistry. It is driven by integration assumptions and the "full ship" cost context. Three drivers dominate: the energy penalty (fuel cost and reduced credited abatement), the space and weight shadow cost (tanks and conditioning competing with cargo or operability), and retrofit complexity and downtime (installation scope and yard time). Unless otherwise stated, LCOC is expressed per tonne captured; translating to cost per tonne avoided requires dividing by net abatement (net capture after onboard penalty and duty-cycle).

Figure 8 helps explain why this cost range is structural rather than anecdotal. In this report, Figure 8 expresses an indicative capture-system LCOC (USD per t$CO_2$ captured) as a function of (i) exhaust $CO_2$ concentration and (ii) capture capacity, using the same boundary conventions across cases. Capture cost tends to rise sharply as $CO_2$ concentration falls and as systems move toward smaller, modular capacities, which is directionally consistent with the economics of dilute exhaust capture and the loss of scale benefits. This figure should therefore be read as "cost of capturing $CO_2$ on the ship" rather than "all-in cost per t$CO_2$ avoided." Converting to cost per t$CO_2$ avoided requires (a) adjusting for net abatement after onboard energy penalty and duty-cycle effects (Section 4.1) and (b) adding downstream costs such as port handling, transport, and permanent storage fees where applicable (Chapter 5). For OCCS, this means the cost challenge is often not only the capture unit, but the combined effect of dilute exhaust conditions, onboard integration constraints, and the additional equipment required to make captured $CO_2$ transferable under an auditable chain of custody.

[9] https://www.prescouter.com/ccus-database/

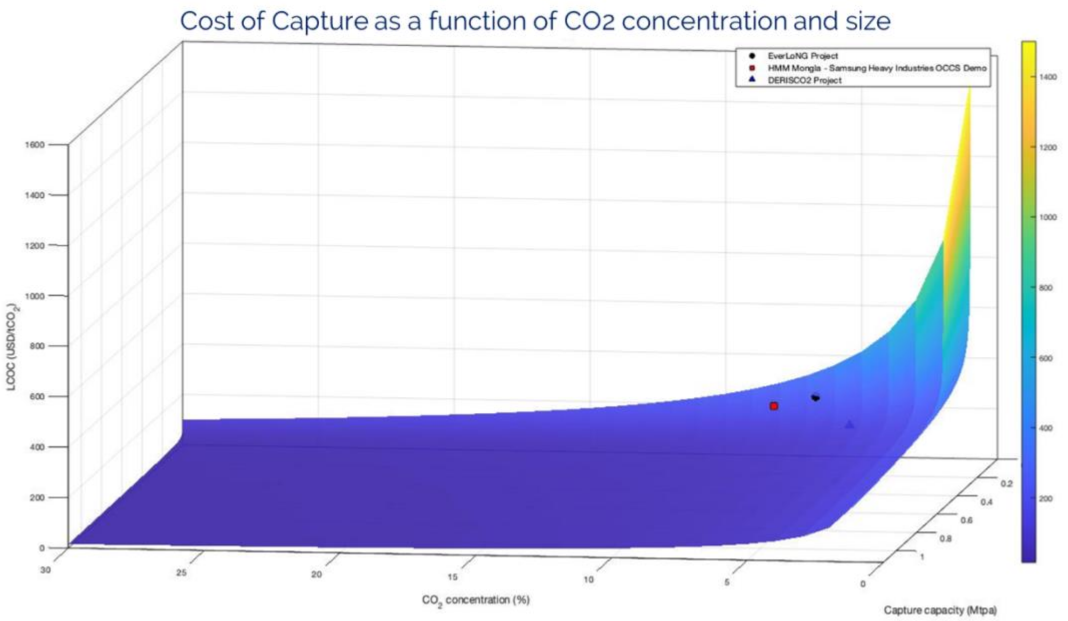


*Figure 12: Indicative capture-system LCOC (USD/t$CO_2$ captured) as a function of exhaust $CO_2$ concentration and capture capacity, with representative project markers mapped to the same axes. Boundary covers onboard capture and $CO_2$ conditioning to a transferable form as defined in the model; it excludes port reception infrastructure, port time and handling fees, onward transport, and permanent storage charges unless explicitly stated.*

To improve interpretability, the same cost surface is also presented as a 2D heatmap that allows direct read-off of values and clearer comparison to the reference projects. Highlighted cells indicate the closest matching combinations of concentration and capacity for the projects used as reference points, so readers can see where each case sits in the modelled cost space without relying on 3D interpretation.

| CO2 Concentration in flue gas (%) | Capture Capacity (tpa) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 90 | 1,481 | 2,872 | 4,263 | 5,654 | 7,045 | 8,436 | 9,827 | 11,218 | 14,000 |
| 5 | $ 417 | $ 239 | $ 209 | $ 193 | $ 183 | $ 175 | $ 169 | $ 164 | $ 160 | $ 153 |
| 5.2 | $ 405 | $ 231 | $ 203 | $ 188 | $ 177 | $ 170 | $ 164 | $ 159 | $ 155 | $ 148 |
| 5.4 | $ 393 | $ 225 | $ 197 | $ 182 | $ 172 | $ 165 | $ 159 | $ 154 | $ 150 | $ 144 |
| 5.6 | $ 381 | $ 218 | $ 191 | $ 177 | $ 167 | $ 160 | $ 154 | $ 150 | $ 146 | $ 140 |
| 5.8 | $ 371 | $ 212 | $ 186 | $ 172 | $ 163 | $ 156 | $ 150 | $ 146 | $ 142 | $ 136 |
| 6 | $ 361 | $ 207 | $ 181 | $ 167 | $ 158 | $ 151 | $ 146 | $ 142 | $ 138 | $ 132 |
| 6.2 | $ 352 | $ 201 | $ 176 | $ 163 | $ 154 | $ 148 | $ 142 | $ 138 | $ 135 | $ 129 |
| 6.4 | $ 343 | $ 196 | $ 172 | $ 159 | $ 150 | $ 144 | $ 139 | $ 135 | $ 131 | $ 126 |
| 6.6 | $ 335 | $ 191 | $ 168 | $ 155 | $ 147 | $ 140 | $ 135 | $ 131 | $ 128 | $ 123 |
| 6.8 | $ 327 | $ 187 | $ 164 | $ 151 | $ 143 | $ 137 | $ 132 | $ 128 | $ 125 | $ 120 |
| 7 | $ 319 | $ 183 | $ 160 | $ 148 | $ 140 | $ 134 | $ 129 | $ 125 | $ 122 | $ 117 |
| 7.2 | $ 312 | $ 179 | $ 157 | $ 145 | $ 137 | $ 131 | $ 126 | $ 123 | $ 119 | $ 114 |
| 7.4 | $ 306 | $ 175 | $ 153 | $ 142 | $ 134 | $ 128 | $ 124 | $ 120 | $ 117 | $ 112 |
| 7.6 | $ 299 | $ 171 | $ 150 | $ 139 | $ 131 | $ 126 | $ 121 | $ 117 | $ 114 | $ 110 |
| 7.8 | $ 293 | $ 168 | $ 147 | $ 136 | $ 128 | $ 123 | $ 119 | $ 115 | $ 112 | $ 107 |
| 8 | $ 287 | $ 164 | $ 144 | $ 133 | $ 126 | $ 120 | $ 116 | $ 113 | $ 110 | $ 105 |
| 8.2 | $ 282 | $ 161 | $ 141 | $ 131 | $ 123 | $ 118 | $ 114 | $ 111 | $ 108 | $ 103 |
| 8.4 | $ 276 | $ 158 | $ 139 | $ 128 | $ 121 | $ 116 | $ 112 | $ 108 | $ 106 | $ 101 |
| 8.6 | $ 271 | $ 155 | $ 136 | $ 126 | $ 119 | $ 114 | $ 110 | $ 106 | $ 104 | $ 99 |

*Table 1: 2D heatmap view of the same cost model outputs (USD/t$CO_2$ captured) across $CO_2$ concentration and capture capacity. Highlighted cells show the parameter combinations closest to disclosed project cases used as reference points[9].*

OCCS becomes economically credible only when three elements align: the retrofit package is repeatable, net capture remains relevant for policy compliance after onboard penalties, and the downstream chain exists in a form regulators and verifiers can accept.

### 4.3 Stakeholder evidence panel

The quantitative results in Sections 4.1 and 4.2 describe what OCCS could deliver under consistent assumptions. In practice, feasibility is shaped by constraints that are often missing from public project announcements: retrofit disruption, footprint and stability limits, waste-heat availability, solvent and maintenance handling at sea, and the chain-of-custody requirements implied by evolving MRV expectations.

To anchor the numbers in real deployment conditions, this report draws on stakeholder evidence from technology providers and ship operators. These snapshots are not endorsements. They are included because they reflect recurring integration bottlenecks behind the performance and cost ranges, and they help explain why reported boundaries differ so widely between projects. The full set of stakeholder snapshots is provided in "Appendix B: Stakeholder snapshots".

## Chapter 5: The Downstream Challenge

OCCS can only be credited if captured CO2 leaves the ship and reaches a verified permanent sink. This makes the downstream chain - offloading, logistics, and access to storage - a limiting factor for scale. Even when onboard capture works, the ability to move and store CO2 reliably at predictable cost determines whether OCCS can move beyond pilots[15][16][17][18].

### 5.1 Storage availability and competition

Near-term open-access storage capacity remains scarce relative to cross-sector demand. Flagship European storage hubs are expanding, but they are shared resources serving multiple industries. As OCCS scales, shipping will compete for storage access with sectors that often have stronger infrastructure alignment such as cement, waste-to-energy, refineries, hydrogen, and steel. For OCCS, downstream access cannot be treated as an add-on. It is part of the feasibility case. $CO_2$ Hub Infrastructure (Sites for loading, unloading, and storage of $CO_2$) are currently being planned globally, with major concentration seen in Europe, while active storage sites are limited in their spread[18].

[9] https://www.prescouter.com/ccus-database/
[15] https://www.globalccsinstitute.com/resources/global-status-of-ccs-report/
[16] https://www.iea.org/reports/co2-transport-and-storage-tracking-report-2024
[17] https://eto.dnv.com/2024/co2-storage-demand-from-shipping
[18] https://www.lr.org/en/knowledge/research-reports/offloading-of-captured-co2-from-ships/

*Figure 13:* *Global $CO_2$ Hub Infrastructure Under Development as of 2025 (Source PS CCUS Database)*[9]

*Figure 14: Active $CO_2$ Storage (Stored/ On Injection Sites) as of 2025 (Source PS CCUS Database)*[9]

When assessing future storage capacity potential, multiple sources diverge sharply due to diverging assumptions, scope, and scenarios. Figure 11 deliberately places these three different data types side-by-side. The dark-blue bars represent potential storage capacity (how much $CO_2$ could be injected annually under a given build-out), the grey bar represents an emissions proxy for shipping (a practical upper bound for “possible demand” if OCCS were applied very broadly), and the orange bar represents a demand estimate for shipping (how much $CO_2$ storage shipping might actually require under a specific uptake scenario).

Within each category, values still vary because of different scenario framings (realistic pipeline versus net-zero pathways), whether numbers reflect announced projects or capacity expected to be operating by 2030, and differences in scope and methodology. We interpret this figure as a comparison of categories, not a single forecast: storage can become a

[9] https://www.prescouter.com/ccus-database/

bottleneck mainly in high-uptake net-zero pathways, while in more conservative pathways the nearer-term constraint is often port-side offloading and handling capacity rather than geology.

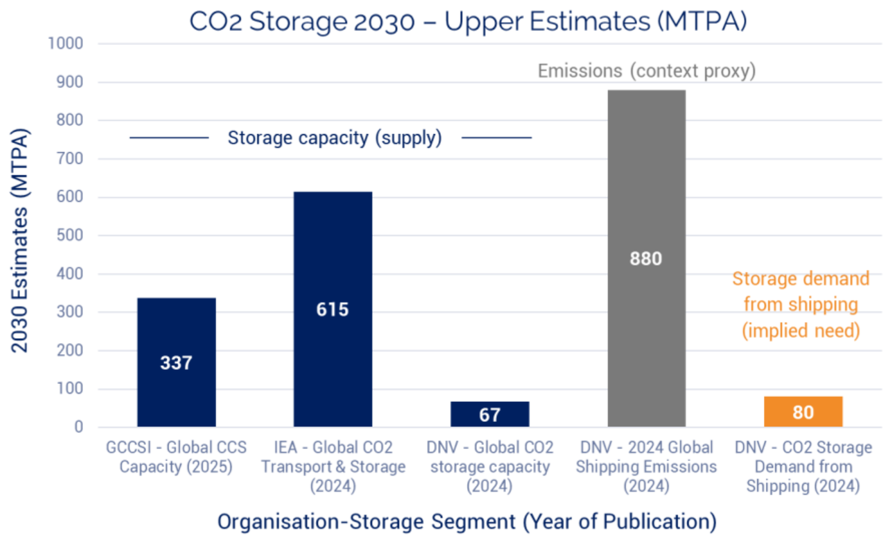


***Figure 15**: 2030 upper-bound comparisons from selected sources, grouped by data type: storage capacity, storage demand, and shipping emissions (context proxy). Values are not directly comparable across categories; they are shown together to illustrate the order-of-magnitude spread and the different underlying questions each source answers.*

### 5.2 The logistics of offloading

Offloading is the operational bridge between captured and stored. In most configurations, CO2 is conditioned and held onboard, often as liquid CO2, then transferred at port to a receiving system. This requires infrastructure that most ports do not have today: compatible transfer equipment, storage, metering for custody transfer, and an onward route to storage.

Three practical issues dominate: infrastructure readiness, CO2 specification and acceptance criteria (including impurity handling), and route predictability. Many ships do not operate fixed loops, which makes offloading reliability a binding constraint. Even where technically feasible, offloading introduces cost and operational friction through port time, procedures, documentation, and contracting. These factors are often invisible in pilot announcements but decisive for real deployment.

## Chapter 6: Conclusion

### 6.1 Conclusion

OCCS is being pursued because shipping’s decarbonisation timeline is tightening faster than fleets can turn over. The project landscape remains pilot-led, but already shows a consistent pattern: gross capture can look high on paper, while the decision-relevant outcome is net abatement once onboard energy penalties, storage footprint, and downstream handling are treated as first-order constraints.

OCCS is not a substitute for fuel transition. It may become a bridge option in specific niches where retrofit space exists, offloading logistics are credible, and net abatement remains meaningful. OCCS only makes sense as a *time-limited* compliance bridge where it can (i) deliver material net abatement, (ii) be installed and operated repeatably with tolerable space/weight impacts, and (iii) connect to a credible offloading + permanent storage chain. Where those conditions are not met, OCCS risks becoming high-cost complexity that does not materially reduce the cost of compliance versus alternative levers (and increases the risk of delaying fuel transition).

### 6.2 Key policy conditions to capture delivered abatement

1. Standardise what counts towards compliance (net capture by default): crediting should account for onboard penalties and leakage
2. Certified abatements should require verified transfer to a permanent sink.
3. Treat MRV and chain-of-custody as compliance hardware: specify minimum instrumentation, calibration, data integrity, and custody documentation.
4. Close the downstream gap explicitly: accelerate port reception readiness and clarify safety and liability interfaces for CO2 handling and transport.
5. Avoid incentive fragmentation: align regimes so investment does not optimise for narrow compliance while ignoring durable abatement logic.
6. Make “no lock-in” a design principle: allow bridge use where credible, but reduce the risk OCCS delays fuel transition through conservative crediting and clear eligibility rules.

## Works Cited


PreScouter. (n.d.). *PreScouter’s CCUS Database (project repository)*. Retrieved from https://www.prescouter.com/ccus-database/

UNCTAD. (2024). *Review of Maritime Transport 2024*. Retrieved from https://unctad.org/publication/review-maritime-transport-2024

IMO. (2023). *Revised GHG Strategy for global shipping (MEPC 80)*. Retrieved from https://www.imo.org/en/MediaCentre/PressBriefings/pages/Revised-GHG-reduction-strategy-for-global-shipping-adopted.aspx

IRENA. (2021). *A pathway to decarbonise the shipping sector by 2050*. Retrieved from https://www.irena.org/Publications/2021/Oct/A-pathway-to-decarbonise-the-shipping-sector-by-2050

European Commission. (2025). *FAQ: Maritime transport in the EU Emissions Trading System (ETS)*. Retrieved from https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets/ets-maritime-transport_en

(2023). *Directive (EU) 2023/959 (EU ETS reform incl. maritime)*. European Parliament and of the Council. Retrieved from https://eur-lex.europa.eu/eli/dir/2023/959/oj

BIMCO. (2025). *EU ETS guidance*. Retrieved from https://www.bimco.org/news-insights/trending-topics/eu-ets/

European Parliament and of the Council. (2023). *Regulation (EU) 2023/1805 (FuelEU Maritime)*. Retrieved from https://eur-lex.europa.eu/eli/reg/2023/1805/oj

Maritime Technologies Forum. (2025). *Safe Onboard Carbon Capture and Storage*. Retrieved from https://maritimeforum.org/wp-content/uploads/2025/10/Safe-Onboard-Carbon-Capture-and-Storage.pdf

European Commission. (2025). *FuelEU Maritime Q&A (Regulation (EU) 2023/1805)*. Retrieved from https://transport.ec.europa.eu/transport-modes/maritime/decarbonising-maritime-transport-fueleu-maritime/questions-and-answers-regulation-eu-20231805-use-renewable-and-low-carbon-

IMO. (2025). *Carbon Capture and Storage topic page (incl. work plan)*. Retrieved from https://www.imo.org/en/MediaCentre/HotTopics/Pages/Carbon-capture-and-storage-(CCS).aspx

DNV. (2025). *The potential role of onboard carbon capture in decarbonization of shipping (presentation by Georgopoulou)*. Retrieved from https://futurefuels.imo.org/wp-content/uploads/2025/09/08.-The-potential-role-of-onboard-carbon-capture-in-decarbonization-of-shipping-DNV.pdf

Global CCS Institute. (2025). *Global Status of CCS / global capacity overview*. Retrieved from https://www.globalccsinstitute.com/resources/global-status-of-ccs-report/

IEA. (2024). *CO2 transport and storage tracking / capacity outlook*. Retrieved from https://www.iea.org/reports/co2-transport-and-storage-tracking-report-2024

DNV. (2024). *CO2 storage capacity and demand from shipping (global estimates)*. Retrieved from https://eto.dnv.com/2024/co2-storage-demand-from-shipping

Lloyd's Register & Lloyd's Register & GCMD. (2024). *Concept study: offloading captured CO2 from ships*. Retrieved from https://www.lr.org/en/knowledge/research-reports/offloading-of-captured-co2-from-ships/

The Motorship. (2025, September 9). *Evergreen container vessel trials carbon capture*. Retrieved from The Motorship: https://www.motorship.com/equipment/evergreen-container-vessel-trials-carbon-capture/1504650.article

The Editorial Team. (2025, June 30). *First full-chain onboard carbon capture pilot completed in China*. Retrieved from SAFETY4SEA: https://safety4sea.com/first-full-chain-onboard-carbon-capture-pilot-completed-in-china

ClassNK (Nippon Kaiji Kyokai). (2022). *ClassNK Technical Journal No. 5 2022 (I): Zero-Emission Ships*. Retrieved from https://www.classnk.or.jp/hp/pdf/research/rd/2022/05_e0.pdf

McLellan, A. (2025, October 8). *What is a centrifugal carbon capture system?* Retrieved from The Institute of Marine Engineering, Science & Technology (IMarEST): https://www.imarest.org/resource/mp-what-is-a-centrifugal-carbon-capture-system.html

Value Maritime. (n.d.). *Services / FILTREE System*. Retrieved from Value Maritime: https://valuemaritime.com/products-services/

The Maritime Executive. (2024). *Scorpio Tankers Partners with Carbon Ridge for Onboard Carbon Capture*. Retrieved from The Maritime Executive: https://maritime-executive.com/article/scorpio-tankers-joins-efforts-to-develop-shipboard-carbon-capture

Cyprus Marine and Maritime Institute (CMMI). (n.d.). *OCCS*. Retrieved from CMMI: https://www.cmmi.blue/

Prevljak, N. H. (2024, February 27). *New South Korean project eyes development of onboard CCS*. Retrieved from Offshore Energy: https://www.offshore-energy.biz/new-south-korean-project-eyes-development-of-onboard-ccs/

Rotoboost. (n.d.). *Technology*. Retrieved from Rotoboost: https://www.rotoboost.com/solutions/marine

Sustainable Ships. (n.d.). *FuelEU Maritime emission factors: where to find them (incl. WtT/TtW values)*. Retrieved from https://sustainable-ships.org/fueleu-maritime-emission-factors-etc-where-to-find-them/

International Council on Clean Transportation (ICCT). (2021). *Well-to-wake $CO_2$ emissions of marine fuels (briefing)*. Retrieved from https://theicct.org/wp-content/uploads/2021/06/Well-to-wake-co2-mar2021-2.pdf

## Appendix A: Assumptions and calculation methods

This appendix documents the fixed assumptions and calculation steps used to derive harmonised fields when project disclosures do not provide complete inputs. These calculations are applied consistently to support cross-project comparison. Reported project values are kept distinct from calculated values in the dataset.

### A.1 Estimating annual CO2 emissions (main engine, tank-to-wake)

Where annual CO2 emissions are not disclosed, this report estimates main-engine tank-to-wake emissions using a standard power-based method:

$$Annual\ CO2\ emissions\ \left(\frac{tCO2}{year}\right) = \frac{main\ engine\ installed\ power\ (kW) \times SFOC\ \left(\frac{kg}{kWh}\right) \times emission\ factor\ \left(\frac{kgCO2}{kg\ fuel}\right) \times load\ factor\ \times operating\ hours}{1000}$$

Default operating hours (hours/year):

- 5,000 hours for short-sea and feeder operations (<25,000 DWT).
- 6,500 hours for deep-sea ships (>25,000 DWT).

Default load factor: 0.65 (main engine).

Specific fuel oil consumption, SFOC (kg/kWh): HFO/VLSFO 0.184; MGO/MDO 0.180; LNG 0.158.

Tank-to-wake CO2 emission factors (kg CO2/kg fuel): HFO/VLSFO 3.114; MGO/MDO 3.206; LNG 2.750.

### A.2 Captured CO2 and gross capture rate

Where a project discloses captured CO2 directly (tCO2/year), that value is recorded as reported. Where only gross capture rate is disclosed, captured volume is estimated as:

$$Captured\ CO2\ \left(\frac{tCO2}{year}\right) = annual\ CO2\ emissions\ \times gross\ capture\ rate$$

Gross capture is treated as an engineering separation metric. Climate relevance and crediting depend on net abatement after onboard penalties.

A.3 Net capture rate adjustment (gross capture adjusted for onboard penalty)

Headline gross capture rates do not represent net abatement, because OCCS requires onboard energy (electricity and or thermal duty) that increases fuel consumption and therefore CO2 emissions. Net capture is calculated by adjusting gross capture using one of two methods.

### A.3.1 Fuel-penalty method (preferred)

Where incremental fuel consumption attributable to OCCS is disclosed (kg fuel per tCO2 captured), it is converted into a CO2 penalty per ton captured:

$$E_{pen}\left(\frac{kgCO2}{tCO2\ captured}\right) = F_{pen} \times EF_{fuel}$$

$$\text{Net capture rate: } \mathrm{R_{net}} = \mathrm{R_{gross}} \times \frac{1-E_{pen}}{1000}$$

This approach treats reported incremental fuel as a system-level penalty, including onboard electricity generation and heat provision where applicable, and avoids double counting.

### A.3.2 Energy-penalty proxy method (fallback)

When no energy or fuel penalty data are available, a simplified proxy penalty EP (percentage points) is applied depending on vessel size class:

- ≥50,000 DWT: 5 percentage points.
- 25,000 to 50,000 DWT: 7.5 percentage points.
- <25,000 DWT: 10 percentage points.

$R_{net} = R_{gross} - EP$. This method is used only to avoid overstating abatement when project-specific penalty data are not disclosed.

Using the project dataset, we compared this fallback proxy (5, 7.5, or 10 percentage points depending on DWT) against projects where a fuel-penalty-derived net capture rate could be calculated from reported penalty inputs. In that subset (n = 19), the proxy typically produces a *higher* net capture than the fuel-penalty method, by about +13 percentage points on average (median +10 pp, range roughly +5 to +31 pp). This indicates the proxy can be biased toward optimistic net abatement when real penalties are driven by limited recoverable waste heat, onboard power constraints, partial-load operation, and conservative auxiliary assumptions embedded in reported incremental fuel use. The proxy can still be pessimistic in specific designs that strongly exploit waste heat or have unusually low incremental fuel per $tCO_2$ captured, but the observed comparisons suggest that, in practice, the proxy more often understates the true penalty (and therefore overstates net capture) relative to project-reported penalty cases in the current dataset.

### A.3.3 Note on electricity-only reporting

Some sources disclose electricity demand (kWh/tCO2) and thermal duty separately. Where a source provides total incremental fuel consumption per tCO2 captured, it is treated as inclusive of onboard electricity generation and steam provision, and electricity is not added as a separate penalty term.

## A.4 Exhaust CO2 concentration proxy (vol%)

Where exhaust CO2 concentration is not disclosed, representative values are used for qualitative interpretation of capture difficulty and system sizing. These proxies are not treated as measured project data.

- LNG: 5.4%.
- Liquid fuels (HFO/VLSFO/MGO/MDO), 2-stroke: 8.2%.
- Liquid fuels (HFO/VLSFO/MGO/MDO), 4-stroke: 6.7%.

## A.5 Cost boundary conventions (interpretation note)

Cost disclosures across OCCS projects vary widely in scope. Reported CAPEX and OPEX may include only the capture unit, or may include conditioning, liquefaction, storage, shipyard integration, and downtime. For that reason, cost values are treated as boundary-aware and comparisons are interpreted cautiously.

Where sufficient inputs exist, an indicative levelised cost of capture (LCOC) is computed as:

$$LCOC = \frac{annualised\ CAPEX\ +\ annual\ OPEX}{annual\ CO2\ captured}$$

Costs for port infrastructure, intermediate logistics, and storage fees are not assumed unless explicitly stated by the source.

## A.6 Converting Tank-to-Wake capture rates to Well-to-Wake abatement

This section shows how to translate a Tank-to-Wake (TtW) capture rate (applied to onboard combustion emissions) into a Well-to-Wake (WtW) abatement percentage when upstream Well-to-Tank (WtT) emissions are included.

**Key relationship.**

WtW = WtT + TtW. Onboard capture reduces only the TtW component.

**Conversion formula (WtW abatement from a TtW capture rate).**

Let R_{TtW} be the capture rate applied to TtW emissions (e.g., 0.90).

$$Post - capture\ WtW\ emissions\ = WtT\ +\ (1 - R_{TtW})\ \times TtW$$

Therefore, WtW abatement fraction:

$$A_{WtW} = 1\ -\ \frac{WtT\ +\ (1 - R_{TtW})\ \times TtW}{WtT\ + TtW}$$

**Worked example 1: Marine Gas Oil (MGO)** (FuelEU default values[19])

Assumptions

- WtT = 14.40 $gCO_2e/MJ$
- TtW = 76.23 $gCO_2e/MJ$
- WtW = 90.63 $gCO_2e/MJ$
- If $R_{TtW}$ =90% (capture rate)

Calculations:

- Remaining TtW = 0.10 × 76.23 = 7.623
- Post-capture WtW = 14.40 + 7.623 = 22.023
- WtW abatement = 1 − 22.023/90.63 = **75.7%**

[19] https://sustainable-ships.org/fueleu-maritime-emission-factors-etc-where-to-find-them/

**Worked example 2: LNG** (FuelEU default values[19])

Assumptions

- WtT = 18.50 $gCO_2e/MJ$
- TtW = 57.63 $gCO_2e/MJ$
- WtW = 76.13 $gCO_2e/MJ$
- If $R_{TtW}$=90% (capture rate):

Calculations:

  - Remaining TtW = 0.10 × 57.63 = 5.763
  - Post-capture WtW = 18.50 + 5.763 = 24.263
  - WtW abatement = 1 − 24.263/76.13 = **68.1%**

**Interpretation.** Because WtT emissions are unaffected by onboard capture, expressing results on a WtW basis always reduces the effective abatement percentage relative to the same stated TtW capture rate. [ (International Council on Clean Transportation (ICCT), 2021)]

[19] https://sustainable-ships.org/fueleu-maritime-emission-factors-etc-where-to-find-them/

# Appendix B: Stakeholder snapshots

## Evidence Snapshot 1: Value Maritime

Value Maritime's OCCS positioning reinforces what the dataset suggests about early adoption: shipowners start where retrofit disruption is manageable. The company emphasises modular, containerised "add-on" practicality over headline capture rates, which frames OCCS primarily as an integration and operability problem rather than a chemistry problem. Its reported deployments across multiple vessels are therefore most useful as a signal of repeatability (installation workflow, crew handling, maintenance cadence) rather than a definitive indicator of end-to-end abatement performance. [ (Value Maritime. (n.d.))]

*Figure 16: Filtree system deployed on a ship.*

### Carbon Capture Technology

- Optimal capture rates for standard operations are between **20% to 30%**, varying with operational factors and storage space.
- Capture rates can potentially reach up to **75%** when operating on non-sulphur fuels like LNG or methanol.
- The parasitic energy load is estimated at approximately **2% to 3%** of the ship's total power output.

### Current Deployment and Projects

- Pilot projects are underway on various ship types, including an MR tanker, an LR1 tanker, and one bulk carrier.
- Operations are largely on a test basis, for example, using only two $CO_2$ storage batteries onboard the testing vessels.
- Current deployment is hindered by the **lack of a compelling business case** for Onboard Carbon Capture and Storage (OCCS).

### Downstream $CO_2$ Management and Storage

- Captured $CO_2$ is stored in a "$CO_2$ battery" system, which can include isotank containers or retrofitted tanks (e.g., ballast tanks).
- Value Maritime is working on delivery/reuse solutions, including projects for greenhouses and agreements with the Port of Rotterdam for $CO_2$-Amine storage.
- A sister company, **Value Carbon**, is focussing on $CO_2$ reuse or long-term storage solutions.

### Challenges

- The primary hurdle is the current lack of a strong business case for OCCS, leading most vessels to opt only for simpler scrubber technology.
- A significant downside is the substantial **space requirement** for both the amine processing unit and the necessary tanks for $CO_2$/Amine storage.

## Evidence Snapshot 2: Carbon Ridge

Carbon Ridge exemplifies the “pilot as integration proof” pathway in OCCS. Its messaging focuses on modularity and real-ship deployment constraints, highlighting that the key learning curve is sustained operation under variable engine loads, limited space, and shipboard maintenance realities, not only separation efficiency. As a result, the most decision-relevant proof points for readers are practical integration metrics (uptime, footprint, power draw, operational burden) rather than headline capture percentages. [ (Maritime Technologies Forum, 2025)] [ (The Maritime Executive, 2024)]


*Figure 17: Carbon Ridge’s OCCS integrated on STI SPIGA.*

### Carbon Capture Technology

- A **60 tons of CO2 per day** unit and fits within a **40-foot** container footprint.
- Processes flue gas from a scrubber at approximately **3.5% to 4%** CO2 concentration.
- Targeted Levelized Cost of Carbon Capture (LCOC) is around **$120 per ton**.
- Limits vessel **parasitic energy load to <10%**.
- Initial trials is reported to have achieved peak CO2 capture rates of **99.8%**.

### Development Stage and Testing Timeline

- A **1 ton per day** unit was deployed on the vessel **STI SPIGA** in **July 2025**, with full DNV class certification achieved.
- Installation was done in a day and is designed to take no more time than a standard dry dock period.
- **The next pilot project is a larger system on an LR2 tanker, scheduled for mid-2027**.
- Future plans include the use of Type C tanks for CO2 storage.

### Downstream $CO_2$ Management and Storage

- The company aims to be a full-service provider, **taking on captured CO2 liability**.
- Initial CO2 storage uses ISO tank DOT certified containers for intermodal transport.
- CO2 can then be offloaded in ports or offshore stations and sequestered or utilized

### Challenges

- Major hurdles include first-of-a-kind **approval delays** from class societies.
- Regulators often compare CO2 handling to LNG (-180°C, high pressure) instead of the **different CO2 conditions** (-45°C, 10 bar).
- The market anticipates surging CO2 prices, driving compliance needs, but the paradox between innovation and regulation hinders new approvals without prior projects.

## Evidence Snapshot 3: CMMI

CMMI's mineralisation-based concept aims to change the downstream constraint by changing what leaves the ship. Instead of transferring a conditioned $CO_2$ stream for transport and storage, the pathway targets conversion of carbon into a more stable product onboard, potentially reducing reliance on specialised offloading infrastructure and storage access. However, this does not remove boundary questions, it shifts them: feasibility and crediting depend on by-product management, MRV acceptance, and regulatory treatment under real operating conditions, meaning "downstream simplicity" must be evaluated together with accounting credibility. [ (Maritime Technologies Forum, 2025)] [ (Cyprus Marine and Maritime Institute (CMMI). (n.d.))]

*Figure 18: MV Coruisk to be retrofitted with CMMI solvent technology.*

### Carbon Capture Technology

- **Primary Focus:** Chemical Absorption, utilizing an alkaline solvent to precipitate $CO_2$ as a Ca/Mg-salt for seawater discharge.
- **Secondary Focus:** Membrane separation, being tested to demonstrate $CO_2$ purity, with plans for compression, liquefaction, and port unloading of captured $CO_2$.

### Development Stage and Testing Timeline

- **Project Context:** The OCCS work is under the Green Marine initiative funded by the EU Horizon Fund.
- **Testing Stages:** Development follows a three-stage process: lab testing, land-based trials, and a future demonstration phase.
- **Key Milestones:**
  - Land-based testing for Chemical Absorption is scheduled for **January 2026**.
  - Results from the land-based chemical absorption and waste heat recovery testing are expected by **February 2026**.

### Downstream $CO_2$ Management and Storage

- Carbon Capture, Utilization, and Storage (CCUS) and Waste Heat Recovery are the primary planned end-uses for the captured $CO_2$.

### Challenges

- **Regulatory Uncertainty:** There is a lack of clear regulatory guidance for innovative $CO_2$ management pathways, such as discharging salt precipitates into seawater.
- **Vessel Integration:** Significant space constraints and energy demands make installation, especially on existing vessels, challenging.
- **Safety & Cost:** Safety risks and the associated increase in insurance costs are a major concern for operators.
- **Solvent Issues:** Certain absorption processes (e.g., ammonia-based) can introduce new harmful emissions, requiring specific regulatory guidance.

## Evidence Snapshot 4: CE-TEK Co. Ltd.

CE-TEK's relevance is less about disclosed performance numbers and more about how the market is trying to de-risk OCCS: structured development programmes involving shipbuilders, technology suppliers, and class societies. This pattern signals that bankability in early-stage maritime capture will be driven by engineering assurance, safety cases, and qualification pathways at least as much as capture claims. For readers, CE-TEK-type initiatives are best interpreted as evidence that standards, certification, and marine operability requirements will shape the pace of deployment. [ (Maritime Technologies Forum, 2025)] [ (Prevljak, 2024)]

### Carbon Capture Technology

- The technology is designed to achieve a solvent regeneration heat duty of **2.5 GJ per ton of $CO_2$**.
- The onboard solvent will achieve a **90% $CO_2$ capture rate** even at low exhaust concentrations of around **6 vol%**.
- The solvent circulation volume is **reduced by approximately 50%** compared to conventional MEA solvents, offering CAPEX and OPEX advantages.

### Development Stage and Testing Timeline

- A pilot-scale OCCS system, capable of capturing **0.7 tons of $CO_2$ per day**, is currently under construction at KSOE's Ulsan shipyard.
- The project is a partnership among CE-TEK, Heavy Industries Power Systems (HPS), and HD Korea Shipbuilding & Offshore Engineering (KSOE).
- System completion is scheduled for **February 2026**, after which demonstration testing will validate performance.

### Other Remarks

- The OCCS market is expected to accelerate commercial-scale development with strengthening IMO regulations and the introduction of a **global carbon tax in 2027**.
- Early OCCS adoption is most viable for **large vessels**, such as container ships, tankers, and LNG carriers, due to the substantial scale of the capture and storage equipment.
- Ships powered by **natural gas engines** are particularly well-suited for OCCS because their exhaust contains significantly fewer impurities.

### Challenges

- **Technical challenges** include the integrated development of ship-specific process design and real-time monitoring technologies.
- **Operational challenges** involve strict ship space/load constraints and frequent engine load fluctuations that disrupt stable operation.
- **Regulatory hurdles** exist as dedicated OCCS certification standards, $CO_2$ storage/transport infrastructure, and vessel-specific $CO_2$ safety criteria are not fully established.

## Evidence Snapshot 5: Rotoboost

Rotoboost's narrative highlights a recurring driver across OCCS economics: the onboard energy penalty. It reinforces that the decision-relevant outcome is net abatement once added energy demand is reflected in fuel burn and utilities integration, and that feasibility can hinge on how effectively waste heat and onboard power are managed. For readers assessing OCCS credibility, the key takeaway is that energy integration is not a secondary detail; it directly governs net capture and operating cost, and often dominates over incremental improvements in separation performance. [ (Maritime Technologies Forum, 2025)] [ (Rotoboost, n.d.)]

*Figure 19: Rotoboost TCD Layout for a marine Ship.*

### Carbon Capture Technology

- **Core Concept:** Converts C1-C6 feedstocks into hydrogen and solid carbon (graphene/graphite) via a pre-combustion process.
- **Engine Integration:** Supports up to **25% hydrogen blending** in main engines without requiring modifications to existing instrumentation.
- **LCA Performance:** Achieves a lifecycle assessment of 1.2–2 kg $CO_2$/kg $H_2$, significantly lower than Steam Methane Reforming.

### Current Deployment and Projects

- **Current Status:** Feasibility studies for onboard application were finalized late last year; currently evaluating with shipowners.
- **Deployment:** Technology has been successfully installed on land, with marine pilots planned following completed assessments.
- **Validation:** Technical findings and integration studies are actively being presented at industry forums like Gastech.

### Downstream $CO_2$ Management and Storage

- **Form Factor:** Captures carbon in a solid state (graphene), eliminating the need for complex liquefaction storage.
- **Revenue Stream:** Solid carbon can be a valuable commodity for steelmaking or chemicals, generating revenue for operators.
- **Economic Impact:** The project projects negative abatement costs due to the commercial value of the captured graphene.
- **Usage:** The hydrogen produced serves as a clean feedstock, while solid carbon is permanently sequestered/sold.

### Challenges

- **Regulatory Uncertainty:** Current regulations lack clarity on "avoided emissions," disadvantaging pre-combustion technologies compared to standard capture.
- **Incentives:** It remains unclear if shipowners will receive specific emission reduction credits for solid carbon capture.
- **Technical Limits:** Hydrogen blending above 25% requires further lab testing and 100% H2-ready engine availability.
- **Market Alignment:** Regulations often focus on "$CO_2$" specifically rather than "Carbon," creating hurdles for non-$CO_2$ capture.

### Shipowner perspective (anonymous interview summary)

This summary reflects a single anonymised interview with a shipowner representative (commercial operator), captured to provide a practitioner view; the source is kept anonymous to enable candid discussion of operational and commercial constraints

A shipowner perspective adds a critical filter to the technical story: even if OCCS works as a prototype, scalable adoption is constrained by space, weight, and operational logistics. In this interview, OCCS was described as potentially workable in narrow niches such as short-sea operations, predictable loops, or cases where captured $CO_2$ can be handled locally and reliably. In deep-sea or transatlantic contexts, the system footprint and storage demand were seen as prohibitive, especially when it reduces cargo capacity or complicates vessel operations.

The interview also challenged a common assumption about owner behaviour. The view was that shipowners are not inherently resistant to change, and that many are already willing to adopt alternative fuels and new engine platforms. The binding constraint is not willingness to invest; it is fuel availability and supply-chain readiness. Against that backdrop, OCCS was seen primarily as a technology-provider learning exercise rather than an obvious compliance solution at scale, unless downstream handling becomes simple, predictable, and widely available.

## Appendix C: Data coverage and evidence gaps

This assessment is grounded in a structured project dataset, but the evidence base remains uneven across the metrics that matter most for decision-making and regulatory crediting. PreScouter explicitly tracked the share of missing or low-quality values across primary fields, including performance, cost, and downstream chain descriptors. The resulting gap analysis shows a consistent pattern: the most decision-relevant parameters are also among the least consistently disclosed.

Across the dataset, net capture rate, OPEX, and key ship-level integration descriptors are frequently missing or not reported in a comparable way, while some basic descriptive fields (such as technology family and general status) are more consistently available. For example, the Table 1 indicates persistent gaps across "Amount of $CO_2$ captured", "Net capture rates", "Energy consumption", and cost fields such as CAPEX and levelized cost, even as some ship-level identifiers improved versus earlier iterations.

The downstream chain is a particularly important blind spot. While OCCS is often framed as a capture performance problem, creditable abatement depends on what happens after capture, including conditioning, temporary storage, offloading, custody transfer, and verified permanent storage. Yet the dataset gap analysis indicates that fields tied to downstream management and storage attributes remain among the most incomplete and lowest-granularity categories, limiting how confidently public announcements can be interpreted as scalable decarbonisation pathways.

*Table 2: Data gaps per metric.*

| Project Metric | Datagap (%) |
|---|---|
| Status | 0 |
| Operational Year | 25 |
| Technology | 4.5 |
| Technology Family | 4.5 |
| Amount of $CO_2$ Captured (Million Metric Tons per Year) | 31 |
| Gross Capture Rate (%) | 32 |
| Net Capture Rates (calculated) | 32 |
| Energy Consumption | 66 |
| Levelized CC cost ($$/t of $CO_2$ captured) | 48 |
| Project Cost (USD) or CAPEX | 45 |
| OPEX | 45 |
| Downstream management of $CO_2$ | 23 |
| Type of formation | 73 |
| Announcement date of project | 13.6 |
| Calculated Total Emissions (calculated) | 46 |
| Ship Name | 45 |
| IMO Number | 50 |
| Ship Size (DWT) | 48 |
| Fuel Type | 43 |
| Main Engine Size (MW) | 57 |
| Engine Type | 66 |

**Implication for interpretation:** the quantitative ranges in Chapters 3 to 5 should be read as “best-available evidence under sparse disclosure,” not as precise forecasts. This is also why the report prioritizes conservative harmonised calculations and treats downstream logistics and MRV as gating factors for scale.

In order to provide to fill gaps in the dataset, PreScouter calculated different values based on the methodology described in “Appendix A: Assumptions and calculation methods”. The following pie chart shows the origin of the datapoints:

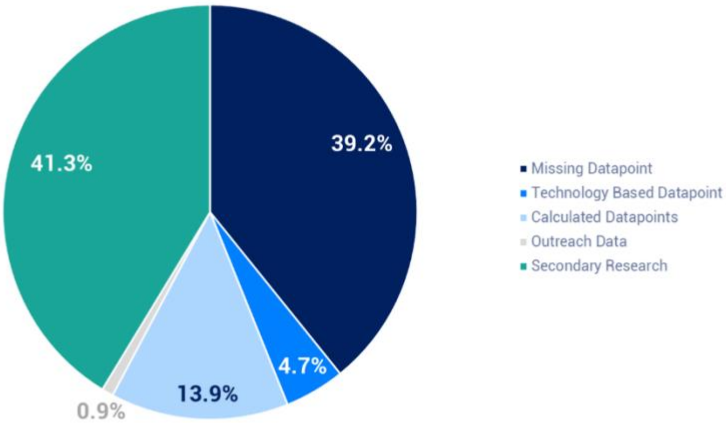


*Figure 20: Data Granularity based on Type of Data for the Shortlisted Metrics.*