The role of energy efficiency regulations

Mærsk Mc-Kinney Møller Center
for Zero Carbon Shipping

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Executive Summary

The International Maritime Organization (IMO) has implemented three regulatory measures to drive the short-term reduction of CO_2 emissions by improving the energy efficiency of the world fleet. The Energy Efficiency Design Index (EEDI) and the Energy Efficiency Existing Ships Index (EEXI) aim to rate the technical efficiency of ship designs by evaluating theoretical emissions from a vessel, its design characteristics, and installed equipment onboard. The Carbon Intensity Index (CII) focuses on the operational efficiency of a vessel, giving an efficiency rating based on reported fuel consumption, emissions, and transport work done throughout a calendar year. In 2013, the EEDI became the first of these regulations to enter into force and was applied to newbuilds only. Both the EEXI and the CII were introduced on 1 January 2023 and are applicable fleetwide.

A dedicated Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping (MMMCZCS) working group was established to study the drivers and enablers for onboard energy efficiency. A subgroup of this working group focused on the role of regulations as a driver to reduce emissions from the global fleet. The subgroup investigated the impact of the three IMO measures as well as their implementation challenges and potential for improvement. This investigation was supported by a range of examples provided by MMMCZCS partner organizations.

Ambitious and clearly defined regulations could significantly reduce CO_2 emissions by accelerating the adoption of energy efficiency technology (EET) and operations across the world fleet. However, while the current IMO regulations are well intended, they are not perfect and must overcome challenges to reach their full potential for impact.

With the implementation of the EEDI, the industry gained a common language on energy efficiency and standards. The measure came into force with clear and mandatory enforcement mechanisms, and its phased approach allowed for gradual preparation and uptake of different technologies over time. The first phase of the EEDI was impacted by poor market conditions and high bunker costs, which led to the introduction of slow steaming across the industry and thus significantly reduced the installed power needs on board new vessels. This reduction in installed power made it easy for new designs to comply with EEDI targets. In later phases, the EEDI has proven to be an effective mechanism for promoting the adoption of energy efficiency technical measures. The introduction of dual-fuel vessels during EEDI Phase 2 is blurring the picture on energy efficiency improvements, as a better EEDI rating can be gained using the conversion factor for the fuels the vessel is capable of consuming, thus missing the opportunity for greater energy efficiency improvements.

The EEXI has leveled the reduction of available power onboard across vessel ages in the fleet and aligned older vessels with EEDI-compliant vessels. For most vessels, shaft or engine power limitation were the main options to achieve EEXI compliance because of their low cost and high impact on EEXI. Only limited older vessels and special tonnage have generally been retrofitted with additional energy efficiency measures for EEXI compliance purposes. This reduction of available onboard power is unlikely to lead to a short-term reduction of global CO_2 emissions, since most vessels routinely operate at speeds requiring even less power than the new reduced power limits. However, in the future, the EEXI will limit the ability of vessels to speed up under favorable commercial conditions or to catch up on schedules due to port delays.

The implementation of the CII has driven an increased awareness of operational efficiency and provided a standardized framework for operational energy efficiency. Optimizing the CII rating of a vessel is challenging, requiring transparent collaboration among multiple stakeholders (shipowner, operator, charterers, technical managers, and ports and terminals). Because of this complexity, improvements in CII ratings are expected to initially come from operational measures such as speed reduction and vessel deployment changes, with the adoption of technical efficiency measures being limited. This effect is amplified by the operational nature of the CII rating, which means that two sister vessels deployed in different trades can very easily have different CII ratings.

The working group identified several areas where the CII could be strengthened. The current form of the regulations presents a risk that vessels will be able to increase their absolute CO_2 emissions while improving or maintaining a given CII rating. This could be achieved by, for example, sailing longer routes or by lowering speeds and vessel utilization. Collaboration with MMMCZCS partners also highlighted some flaws of the annual efficiency ratio (AER) used to calculate the CII. Ideally, a new metric should be more inclusive and more holistically represent how the shipping industry operates. Furthermore, the CII has a soft enforcement mechanism, creating uncertainty about the benefits and consequences of attaining or failing to attain a given rating.

While the soft enforcement of the CII has raised some questions regarding its ability to reduce global emissions, there seems to be interest from across the industry in achieving compliance and in fully understanding the complexity of this measure. In the short term, we expect that the CII could be used as a market tool to drive commercial discussions. It is in this business role, rather than purely regulatory compliance, where we expect CII to have the biggest impact on reducing short-term emissions.

The paper also recommends next steps for this regulatory framework, including the following:

– Investigate the impact of removing a carbon conversion factor from the measures and focus instead on power or energy units in order to better highlight energy efficiency improvements.

– Address overlaps between energy efficiency measures and upcoming fuel-centric regulations, such as the possible greenhouse gas (GHG) fuel standard and a possible carbon pricing mechanism currently being discussed as part of the mid-term measures.

– Investigate future reduction rates for new EEDI and CII phases.

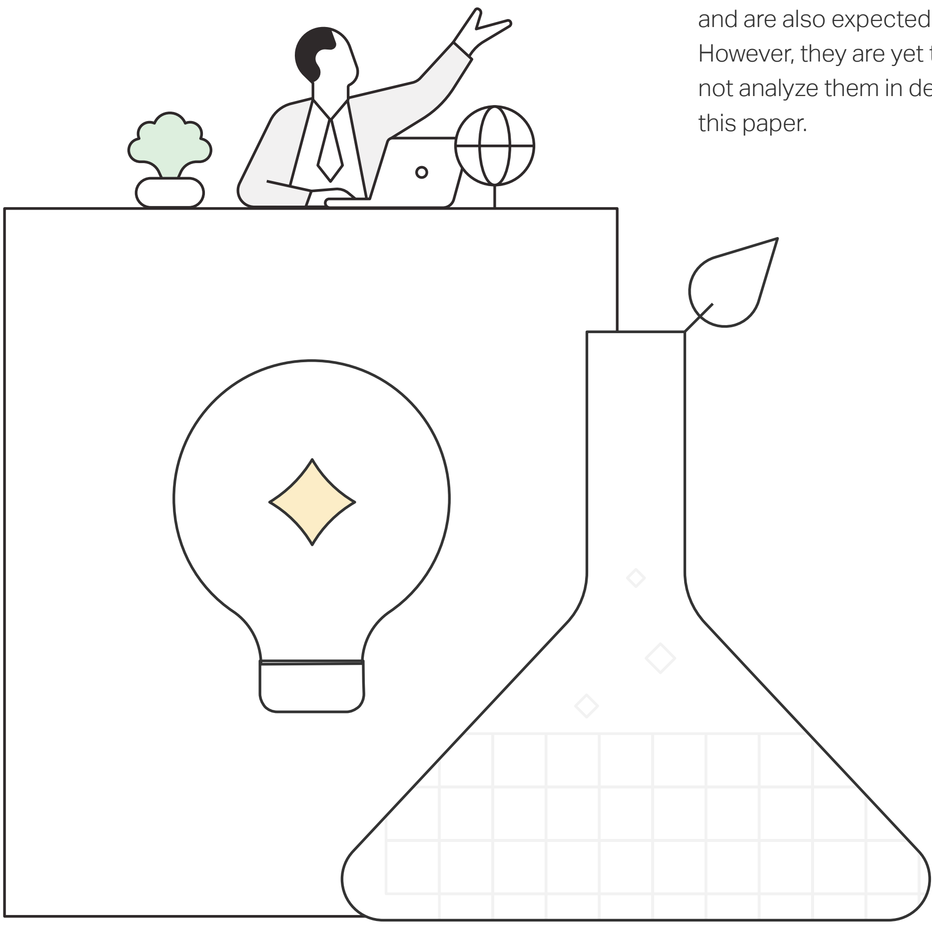
– Explore opportunities to highlight the role of ports and terminals and ways to regulate all stakeholders influencing the CII rating across the value chain.

– Recommend clear and enforceable mechanisms for CII compliance, possibly including other mechanisms such as the Ship Energy Efficiency Management Plan (SEEMP).

– Evaluate the risk of EEXI and CII compliance via power limitation and speed reduction, leading to increased overall CO_2 emissions due to the need for additional vessels to keep transport work constant.

01 Introduction

Shipping decarbonization will require both a focus on transitioning to alternative fuels and to reduce the energy consumption from ships, and regulations are a key driver for change. Current decarbonization regulations from the International Maritime Organization (IMO) focus on energy efficiency, as demonstrated by the numerous energy efficiency measures that have recently come into force, including the Energy Efficiency Design Index (EEDI), Energy Efficiency Existing Ships Index (EEXI), Carbon Intensity Indicator (CII), and the Ship Energy Efficiency Management Plan (SEEMP). Furthermore, the IMO has set targets aiming to reduce the carbon intensity of the world fleet by 40% in 2030 compared to 2008 levels.



A dedicated Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping (MMMCZCS) working group was established in 2022 to study the drivers and enablers for onboard energy efficiency. As part of the working group, a subgroup examined the impact of current and recently implemented regulations, including the EEDI, EEXI, CII, and SEEMP. This paper summarizes the conclusions from the working group, including the direct effects, indirect effects, and shortcomings of these regulations. Wherever possible, we also suggest key considerations and guidance for the industry and regulators to consider when developing future regulations to avoid unwanted cascading effects. This paper should support regulators and IMO, in their planned revisions of the EEXI and CII by 2026, and the further development of the EEDI regulation.

In addition to the energy efficiency measures listed above, the European Union (EU) has introduced a new set of regulations in the Fit for 55 package, and IMO is also discussing the introduction of additional measures such as a possible carbon pricing and a GHG fuel standard. However, these additional measures are only expected to come into force later in the decade. These measures are designed to focus on the fuel transition and are also expected to drive energy efficiency. However, they are yet to be finalized and so we could not analyze them in detail, and they are not included in this paper.

02 Existing energy efficiency regulation

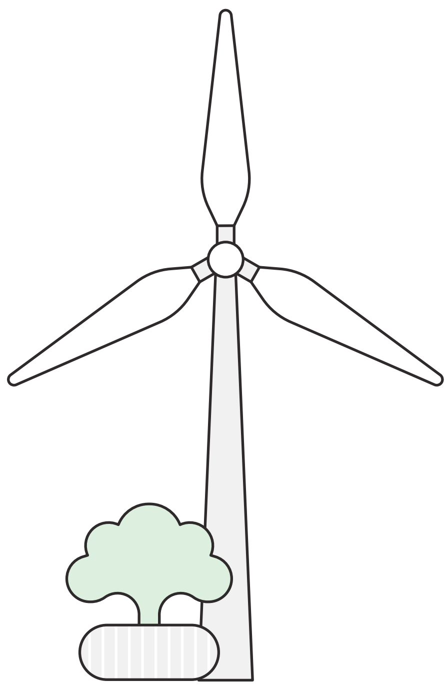
The first energy efficiency regulation adopted by the IMO was the EEDI in 2011, which applies to newbuild vessels. SEEMP (Parts I and II) was also adopted in 2011. In 2023, the EEXI also came into force, replicating the EEDI for existing ships. Both the EEDI and the EEXI are considered technical design metrics, meaning that they evaluate the vessels based on fixed design parameters without considering how the vessel is operated. Since a good efficiency design index does not necessarily mean that the vessel is operated efficiently, the IMO has also implemented the CII as a measure of vessels' operational energy efficiency in 2023. The following sections review these existing energy efficiency regulations in more detail.

2.1 EEDI: the Energy Efficiency Design Index

The EEDI was first agreed upon at the 62nd meeting of the Maritime Environmental Protection Committee (MEPC 62) and adopted by the IMO in July 2011. The EEDI came into force on 1 January 2013 and has a phased approach, meaning that it becomes stricter over time. In common with all the existing energy efficiency regulations discussed here, the EEDI measures the carbon intensity of the transported work defined as grams of CO_2 per tonne cargo-nautical miles. This metric reflects shipping as a means to transport cargo and allows for a straightforward comparison between vessels.

The EEDI is a design metric based on a vessel's design drawings, sea trials, engine shop tests, and equipment around a fixed single condition: maximum summer load line draft[1] at 75% of the installed power. The formula for the index includes terms relating to the main engine, auxiliary systems, and other technologies, such as shaft motors. Additional terms are also included for the deduction of CO_2 emissions from energy efficiency measures that the IMO classes under different categories (as in MEPC. Circ. 896).

The formula uses the installed power, specific fuel oil consumption, and primary fuel conversion factors (tank-to-wake only) to convert the expected power usage of a vessel to tonnes of CO_2 emitted. As such, the index also accounts for engines with different fuel consumption efficiencies and fuels with higher or lower conversion factors. The EEDI guidelines currently only define the conversion factor (Cf) for nine fuel types (Table 1).[2]



1 Noting that, for some ships, this may vary, e.g., for container vessels it is taken at 70% of the maximum summer load draft.
2 For dual-fuel engines, the conversion factor is defined by a formula which defined if one of the fuels can be considered and primary over the other. In such cases, then the primary fuel Cf is used in the calculation, otherwise a weighting value is used. More details are provided in MEPC 364(79).

Table 1: Standard lower calorific value, carbon content, and Cf factors as defined by the IMO.[3]

Type of fuel	Lower calorific value (kJ/kg)	Carbon content	Cf (t-CO_2/t-fuel)
Diesel/gas oil	42,700	0.8744	3.206
Light fuel oil	41,200	0.8594	3.151
Heavy fuel oil	40,200	0.8493	3.114
Liquefied petroleum gas (propane)	46,300	0.8182	3.000
Liquefied petroleum gas (butane)	45,700	0.8264	3.030
Ethane	46,400	0.7989	2.927
Liquefied natural gas	48,000	0.7500	2.750
Methanol	19,900	0.3750	1.375
Ethanol	26,800	0.5217	1.913

To comply with EEDI, shipyards and ship designers are expected to compare their attained EEDI with the required EEDI level. The required EEDI is defined by a reference line as a function of deadweight for different ship types, based on a regression of estimated values of ships built between 1999 and 2008. When the IMO decided to implement the EEDI, these reference lines were calculated alongside the definition of the reduction rates for each phase. During Phase 0, vessels were expected to be at or below the reference EEDI value. In subsequent phases, the vessel design needs to comply with the reference EEDI minus the reduction percentage for that phase. These reduction rates were set to up to 5-10% in Phase 1, up to 20% in Phase 2, and up to 30% in Phase 3. Therefore, as we move through the EEDI phases, it will become harder to comply with the EEDI requirements. Table 2 provides an overview of the phases for most ship types.

3 Resolution MEPC 364(79), IMO, 2022.

Table 2: EEDI phases for bulk carriers, gas carriers, tankers, container ships, general cargo ships, refrigerated cargo carriers, and combination carriers.[4]

	Contract date				
Delivery	Before 1 Jan 2013	1 Jan 2013–31 Dec 2014	1 Jan 2015–31 Dec 2019	1 Jan 2020–31 Dec 2024	1 Jan 2025–
Before 1 July 2015	N/A	Phase 0	Phase 1	-	-
1 July 2015–31 Dec 2018	Phase 0	Phase 0	Phase 1	-	-
1 Jan 2019–31 Dec 2023	Phase 1	Phase 1	Phase 1	Phase 2	-
1 Jan 2024–31 Dec 2028	Phase 2	Phase 2	Phase 2	Phase 2	Phase 3
1 Jan 2029–	Phase 3	Phase 3	Phase 3	Phase 3	Phase 3

Once a vessel has been constructed, the shipyard must demonstrate that the attained EEDI of the ship complies with the EEDI requirement by undertaking a sea trial to confirm the reference speed used in the calculation. Afterwards, the ship will receive its International Energy Efficiency (IEE) certificate and can be delivered to its owner. This process is an example of hard regulatory enforcement, as the vessel is not allowed to operate without a valid EEDI certificate. In Section 3 of this report, we explore how vessels are reaching EEDI compliance and the drivers for further improving EEDI ratings.

As the name suggests, the EEDI is based on design parameters rather than operational information. As such, there is a risk that a compliant vessel, or one that does not require many energy efficiency measures to be compliant, can be operated in a carbon-intense manner (for example, due to hull fouling or poor voyage planning and execution) without affecting its EEDI rating. This is also the case for the EEXI, as discussed in the next section.

Importantly, there was little to no discussion of using sustainable fuels on a lifecycle perspective to comply with IMO ambitions at the time when the EEDI framework was being discussed and agreed on by the IMO, as this was only defined in the initial IMO GHG strategy years later in 2018. Following this strategy, the IMO is now discussing the introduction of market-based measures and fuel lifecycle guidelines, and member states have expressed their ambitions to promote sustainable fuels such as those produced from green energy or biomass. As a result, the conversion factor in the EEDI formulation could be made redundant by a new IMO regulation targeting well-to-wake emissions. In this case, it could be argued that Phase 4 of the EEDI (which discussion was postponed to later in this decade) should focus purely on power instead of CO_2, thereby removing the conversion factor from the EEDI equation. Further suggestions for future considerations regarding the EEDI are covered in the conclusions of this paper.

4 MARPOL Annex VI Regulation 21.

2.2 EEXI – Energy Efficiency Existing Ships Index

The EEXI was agreed upon at MEPC 76, which took place in June 2021. The EEXI is a design metric that uses a similar formula to the EEDI but requires different documentation. The EEXI uses the same reference lines as the EEDI and is harmonized with the EEDI phases applied from 2023. Therefore, the EEXI can be seen as an extension of the EEDI mechanism to all ships, including EEDI vessels post 2013.

From 1 January 2023, compliance with the EEXI needs to be demonstrated during the first annual survey or certificate renewal. Like the EEDI, the enforcement of EEXI can be seen as a gate point: compliance dictates whether the vessel continued to operate after 2023. In contrast to the EEDI, the owner is responsible for ensuring that the vessel meets the EEXI requirements and for implementing any energy efficiency measures needed to remain compliant, rather than the shipyard or ship designers.

2.3 CII and SEEMP – Carbon Intensity Indicator and Ship Energy Efficiency Management Plan

At the same time as EEXI, the IMO agreed on the implementation of an operational energy efficiency regulation, the CII. A vessel's CII is based on its annual operational data collected and reported to IMO, typically by the holder of the Document of Compliance (DoC). Every year, the DoC holder will be required to track the vessel's fuel consumption, which is converted to CO_2 emissions using the same Cf as in the EEDI guidelines (Table 1), and any exclusions (discussed in the following paragraphs). The fuel consumption (without exclusions) is recorded in the IMO Data Collection System (DCS), reviewed by the Flag/Administration or the Recognized Organization (RO, typically the class society of the vessel), and reported to the IMO alongside the distance traveled by the vessel in the same year.

The CII came into force on 1 January 2023 and will be operational as per the current agreement at the IMO from 2023 until 2030, with revisions expected in 2026. Several exclusions and correction factors were added to the CII formula between MEPC 76 and MEPC 78. Both versions are still applicable, as both the corrected and uncorrected attained CII are to be reported to the IMO. In addition, some vessels have no applicable exclusions or corrections, and therefore only the formula from MEPC 76 is applied in practice. Both the initial (MEPC 76 and slightly amended in MEPC 78) and latest (MEPC 78) versions of the CII formula are presented in Equation 1.

Equation 1: CII formula from MEPC 76 and MEPC 78.[5]

MEPC 76	$\frac{\sum_j C_{Fj} \cdot FC_j}{Capacity \cdot D_t}$
MEPC 78	$\frac{\sum_j C_{Fj} \cdot \{FC_j - (FC_{voyage,j} + TF_j + (0.75 - 0.03y_i) \cdot (FC_{electrical,j} + FC_{boiler,j} + FC_{others,j}))\}}{f_i \cdot f_m \cdot f_{iVSE} \cdot Capacity \cdot (D_t - D_x)}$

Cf refers to the conversion factors as in Table 1; Dt stands for distance traveled; Capacity is the summer load deadweight of the vessel; Yi refers to a counter starting at zero in 2023 and progressing by one digit for every subsequent year; FC stands for fuel consumption reported in the DCS and for each exclusion; other terms refer to correction factors (fi, fm, fc and FiVSE,TFj) or distance traveled while applying for voyage exclusions.

5 MEPC.352(78), IMO, 2022 and MEPC.355 (78), IMO, 2022.

Exclusions and correction factors for the CII formula were discussed by an IMO correspondence group, in which member states considered the policy and technical justification of each factor. Many factors were considered, and not all are included in the most recent version of the formula. The exclusions and correction factors can generally be grouped as follows:

– Safety needs: correction factors and voyage exclusions related to the safety of the vessel and crew, such as voyages in ice conditions and safety and rescue operations.

– Vessel design enhancements: a correction factor can be applied to account for discrepancies between a vessel's deadweight and actual cargo capacity as a result of design enhancements for safety or cargo type.

– Level playing field for cargo or operation related fuel consumption: exclusion of some fuel consumption from the CII calculation for ship segments with a wide variety of operational modes for the same ship size, which leads to a spread in fuel consumption profiles depending on (for example, some tankers for cargo heating or container vessels on a number of reefer containers).

Once the attained CII is calculated, the vessel will receive a CII rating (A, B, C, D or E) based on a comparison to other vessels in the same segment and size, where A-rated vessels are the most efficient and E-rated vessels are the least efficient. The attained annual operational CII is compared to the required annual operational CII, which is calculated by taking the reference CII and applying a reduction factor. The reference CII is calculated based on regression lines that were developed using initial data collected for the entire world fleet of the main vessel types larger than 5,000 GT in 2019. The required annual operational CII values defining each of the ratings will be reduced year on year by applying the annual reduction rates (Table 3), making it harder for vessels to remain in the same rating over time. In this way, vessels are incentivized to implement technical or operational energy efficiency measures in order to maintain or improve their CII rating.
As of 2022, the IMO has only agreed on the CII reduction rates up to 2026, which are given in Table 3 below. Many members have requested higher reduction rates that would lead to a 50% total CII reduction by 2030 compared to the 2019 baseline. However, the discussion has been postponed to a later stage due to a lack of consensus at the IMO.

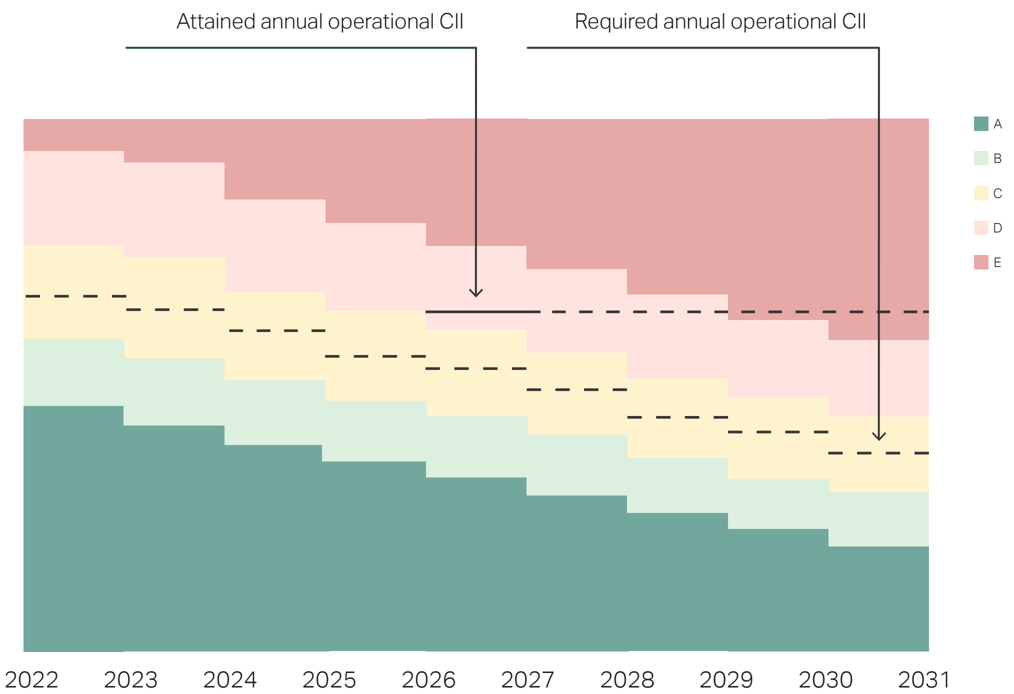
Table 3: Reduction rates for the CII.[6]

Year	Reduction factor relative to 2019
2023	5%
2024	7%
2025	9%
2026	11%
2027	-
2028	-
2029	-
2030	-

6 MEPC.338(76), IMO, 2022.

Figure 1 shows an example of how a given attained operational CII value results in different vessel ratings over time. In this case, the same attained CII value corresponds to a C rating in 2024, a D rating in 2026, and an E rating in 2029.

Figure 1: CII mechanism in a nutshell. Image reproduced with permission from ABS.[7]



In parallel to the EEDI implementation, the IMO introduced the Ship Energy Efficiency Management Plan (SEEMP) Part I, which was intended to increase operational energy efficiency measures. The SEEMP Part I, which outlines the plan of energy efficiency measures to be implemented on a specific vessel, is based on good principles. However, it has never been enforced properly. Although templates provided by class societies with generic energy efficiency measures were widely used in the industry, SEEMP Part I was not covered by auditing or verification. The IMO attempted to correct this flaw by introducing SEEMP Part III.

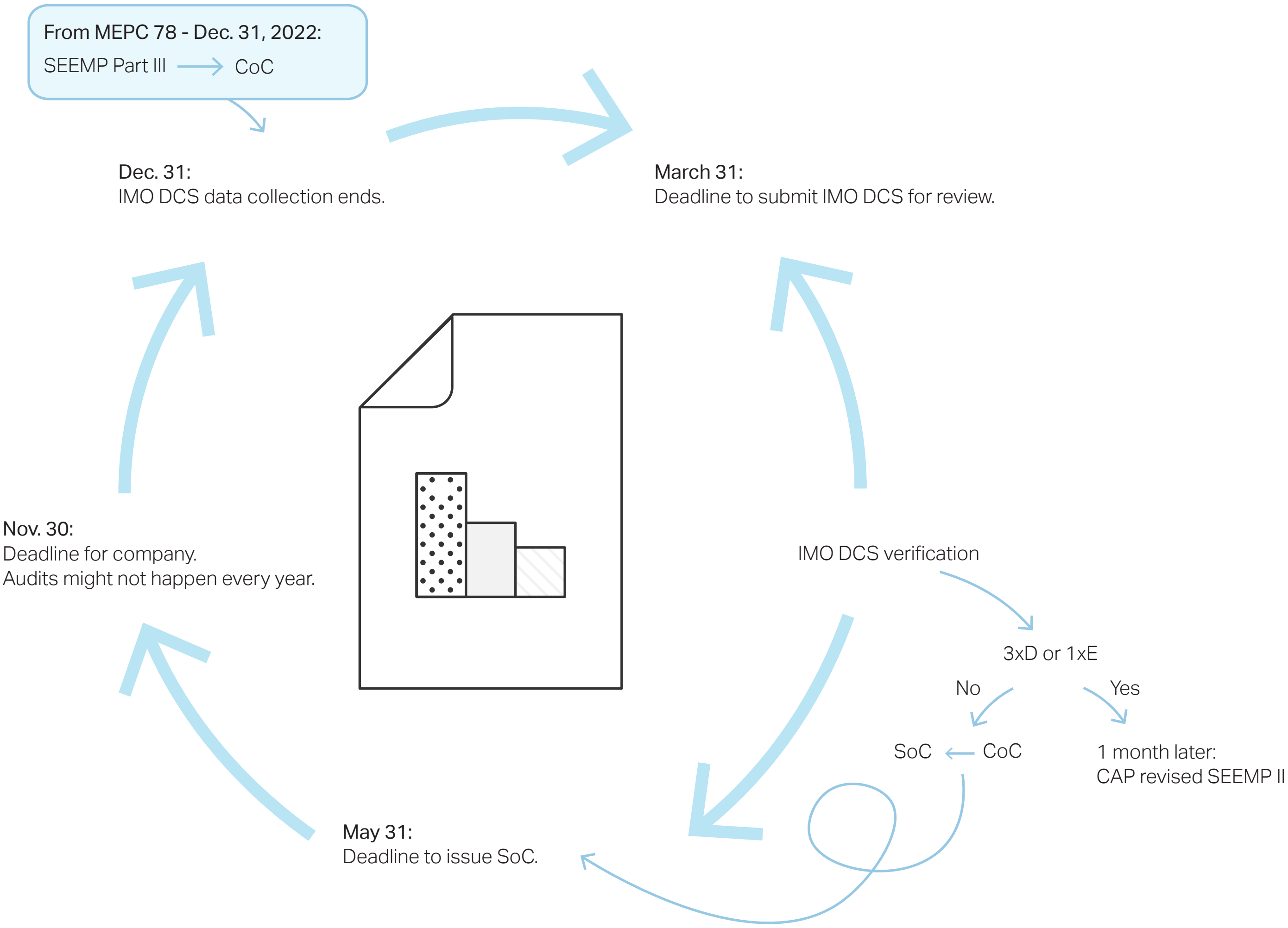
From 2023, the existing SEEMP was supplemented with a Part III, which relates to the CII and forms a key element of its implementation. Under the International Convention for the Prevention of Pollution from Ships (MARPOL), vessels need to document how the required operational CII will be reached every year in a CII implementation plan as part of their SEEMP Part III.

As such, DoC holders are required to outline their strategy for monitoring the vessel's CII rating, along with the energy efficiency measures needed to reach a specific rating. DoC holders were required to develop the SEEMP Part III for each vessel and submit it for verification and approval before the end of 2022. If accepted, the vessel is issued with a 'Confirmation of Compliance' certificate. A given vessel's SEEMP Part III will need to be re-verified regularly due to changes in the CII implementation plan, or if a corrective action plan (CAP) is required.

Once the IMO DCS data is verified for a given year, the actual CII is calculated along with the corresponding rating for that year. If a vessel has an E rating for one year or a D rating for three consecutive years, a CAP must be added to the SEEMP. The CAP must demonstrate how the required operational CII will be reached in the year following its implementation. This process is outlined in Figure 2.

7 MEPC 78 Outcomes and Industry Impacts, ABS.

Figure 2: CII and SEEMP regulations compliance flow. Image reproduced with permission from ABS.[7]
CoC - Confirmation of Compliance, SoC - Statement of Compliance.



Overall, there are three main aspects to regulatory enforcement of the CII:

– The CII implementation plan with specific measures to be outlined in the SEEMP Part III, which is to be verified by an RO (often the classification society classing the vessel). Implementation of a vessel performance monitoring system, along with a self-evaluation and improvement plan, is also required. This exercise should also increase the shipowner's and technical manager's awareness of the vessel's fuel consumption.

– Audits may be triggered during the operational lifetime of the vessel, in which the auditor will verify the actual implementation of the SEEMP Part III measures. Such audits may trigger actions to correct the implementation of the measures themselves.

– The development of a CAP in the event of the first E rating or third consecutive D rating. This would require the DoC holder to revisit the energy efficiency measures in the SEEMP Part III and specify actions to bring the vessel back to a C rating.

There is no specific guidance in IMO regulations as to what would happen to a vessel should it fail to meet the required operational CII after the implementation of a CAP. Thus, the CII is considered to have a 'soft' enforcement mechanism.

2.4 Other Regulations: market-based measures, EU ETS, FuelEU

Additional international and regional regulations, such as carbon pricing and a technical measure to promote sustainable fuels, are currently under discussion by institutions including the IMO and about to come into force in the EU. At the EU level, we will see the introduction of an Emissions Trading Scheme (EU ETS) and the FuelEU for Maritime measures in 2024 and 2025. These measures aim to increase the costs of emitting CO_2 and other GHG and to incentivize the use of sustainable fuels. Implementation of these regional regulations should also incentivize energy efficiency measures, as lower fuel consumption can also lower emissions and, therefore, the number of CO_2-equivalent allowances to be surrendered.

Given that these measures are yet to be formalized at the time of preparing this position paper, they have not been analyzed by the current working group. A final version of the EU ETS mechanism was agreed upon in December 2022, and new projects soon to be launched at the MMMCZCS will focus on this and other new regional measures.

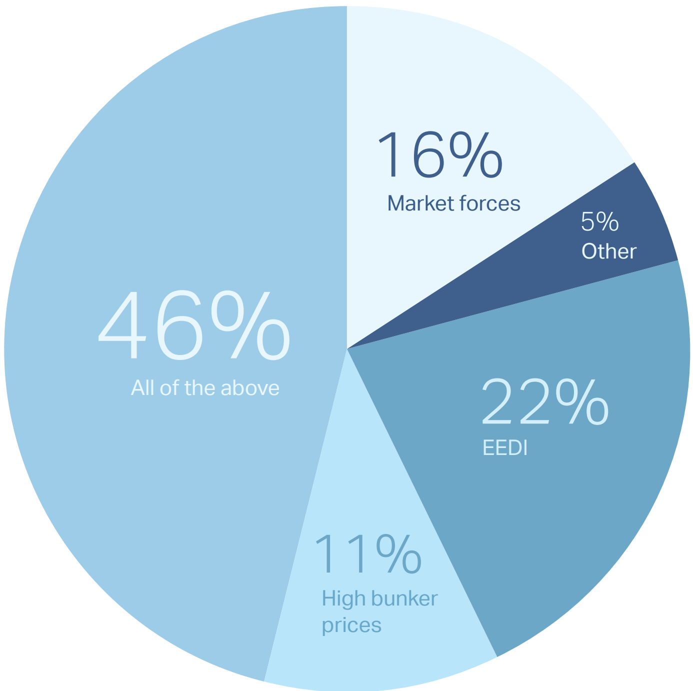
03 How is the EEDI impacting the shipping industry?

The EEDI created a single framework to establish the energy efficiency of newbuilds. All vessels engaged in international trading contracted from 2013 had to be delivered with a reviewed EEDI calculation and EEDI technical file. An EEDI vessel delivered from a shipyard in Brazil, Finland, or China needs to follow the same procedures and have the EEDI technical file calculated in the same way. The International Association of Classification Societies (IACS) has also established a uniform procedural requirement (PR38) that clarifies how the EEDI calculation and verification are to be conducted. Consequently, contracting an EEDI vessel ensures that the design complies with minimum and common standards, including for energy efficiency. Since the EEDI calculation is part of the design process, it is possible to enforce very specific and detailed calculation standards and verification processes. As such, the EEDI has created a new industry practice of creating clear, standardized documentation used to support the EEDI calculation.

Sea trials present a good example of this standardization. Prior to the EEDI, sea trials followed local standards and shipyard-specific processes. Steps from different methods were sometimes mixed, and the tests were not always documented transparently. For EEDI purposes, sea trials now use the international standard ISO 15016:2015 (or latest version).[8] All vessels follow the same procedure and the same step-by-step corrections to remove the impact of external factors, such as the added resistance from wind, waves, and currents. This standard has provided transparency and consistency for sea trials and created a level playing field across the industry.

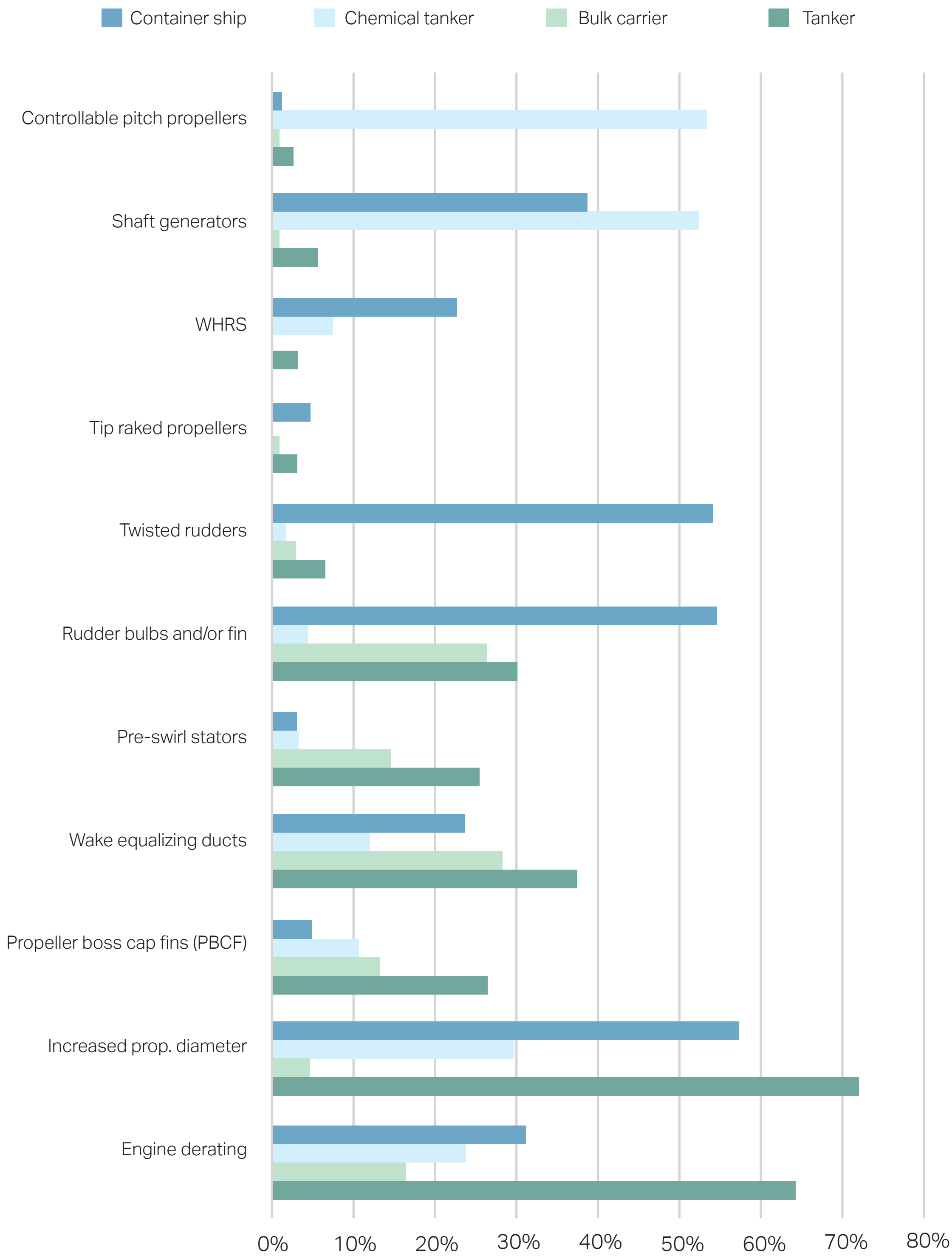
The EEDI came into force under poor market conditions (e.g., high bunker costs and low charter rates) that led to low revenues across the industry. These conditions led to the ongoing 'slow steaming' era, especially among container vessels, as well as a quest for improved energy efficiency to allow for a reduction of installed propulsion power. Therefore, while the EEDI has contributed to improvements in energy efficiency by creating a mechanism for energy efficiency indexation, the level of industry compliance with the EEDI has also benefited from poor market conditions. This conclusion is corroborated by a stakeholder consultation performed by ABS, Vessel Performance Solutions, and Arcsilea for the European Commission, the findings of which are summarized in Figure 3.

Figure 3: Summary of answers to the question 'What has been the main influence on newbuilding technical performance?' in a questionnaire performed by ABS, Vessel Performance Solutions and Arcsilea for the European Commission. Image reproduced with permission from the Publications Office of the EU.[9]



8 ISO 15016:2015 Ships and marine technology — Guidelines for the assessment of speed and power performance by analysis of speed trial data, ISO, 2015.
9 Decarbonisation of shipping, Publications Office of the European Union, 2022.

Figure 4: Usage of energy efficiency technology on EEDI vessels based on a survey with industry stakeholders.[10]



10 Decarbonisation of shipping, Publications Office of the European Union, 2022.

In order to reach compliance with the EEDI, virtually all ships built since its introduction have been delivered with derated engines (power reduction), often in combination with an increased propeller diameter. This setup is facilitated by new engines offering a lower layout power (noting that, for different segments, the weight of one factor or another is different but both are considered to be present). This measure supported EEDI compliance, since reducing the installed power directly reduces the numerator of the EEDI formula at the same ratio. Furthermore, this power reduction did not affect vessels' operability because the market favored slow steaming. The combination of derating and propeller diameter changes delivers increased efficiency by bringing the optimal operational point of the propulsive system more in line with the actual usage of the vessel. By contrast, low power usage in older ship models equates to operation in extremely low and inefficient power ranges. Feedback from working group participants indicates that compliance with the EEDI can be achieved through power reduction alone, without implementing other energy efficiency gains (through engine efficiency, retrofits, etc.). This implies that, for some vessels, the advent of the EEDI did not stimulate any major energy efficiency improvements.

Despite this limitation, our group has observed a good uptake of EETs across different segments of the shipping industry. As shown in Figure 4, the popularity of different EETs varies across segments, but the introduction percentages have been high overall. Members of the working group consider the risk of poor sea trial results the main reason for introducing these energy efficiency measures.

The shipyard can control most of the items that affect a vessel's EEDI, such as engine power and fuel consumption. Typically, shipyards optimize these parameters as much as possible while targeting a given reference speed, which is to be determined in a sea trial. The sea trial is the last part of the EEDI calculation and provides the reference speed, which remains uncertain until the sea trial is complete. While it is now possible to predict the reference speed with good accuracy, there is always some uncertainty due to uncontrollable aspects such as the weather. Therefore, shipyards tend to accept the inclusion of energy efficiency measures that can improve the reference speed, especially if they also help to achieve the contractual speeds. These measures typically contribute to a 1-5% increase in speed at a fixed power. Increased awareness of recent phases of the EEDI for reduced fuel consumption has also increased the adoption of these technologies.

For recent EEDI phases, especially Phase 2, we have observed a trend towards using LNG fuel due to multiple concomitant factors, including low cost at the beginning of the adoption of the 2020 sulfur cap and Tier III NOX compliance. LNG fuel also provided a certain benefit in terms of EEDI compliance, as using LNG as the main fuel in the calculations provides a guaranteed ~20% reduction of the attained EEDI due to its low Cf and generally lower specific fuel consumption (SFC) compared to conventional fuel oils.

It may seem contradictory that the Cf of a fuel would need to be considered, as it can bring benefits that do not necessarily reflect the implementation of energy efficiency measures, as in the case of LNG. Also, as the IMO currently regulates only tank-to-wake CO_2 emissions, and given current knowledge of the greenhouse effect of other gases such as CH_4 and N_2O, it may seem illogical to continue to include CO_2 emissions in such a measure.

Other issues with the EEDI relate to the inclusion of different correction factors. For example, some specific vessels may be simultaneously eligible for multiple correction factors, which could, in some cases, provide a benefit of up to 8% in the EEDI calculation. The fairness of this can be questioned; however, it is very much attached to the fact that MARPOL defines very specific ship types without much granularity. For instance, there is no distinction between a chemical tanker and oil tanker when it comes to MARPOL ship type definition. However, as there are design differences between these, the correction factor is seen as an attempt to provide the granularity that originally did not exist.

3.1 Can an EEDI-compliant vessel outperform on CII?

Given the adoption of power reduction and energy efficiency measures discussed in the previous section, it is reasonable to question whether we can expect better CII ratings for EEDI-compliant ships. In other words, do EEDI-compliant vessels have a better operational carbon intensity (CII)?

Figures 5-7 show the correlation between CII and EEDI using an openly available dataset from EU MRV for 2019 in an analysis by ABS. The CII has been calculated without any correction factors or exclusions, and the vessels are grouped by delivery year. A clear trend towards more vessels performing in the CII ratings A-C appears at the beginning of the year the EEDI was enforced (2013).[11]

The main reason for a better CII rating among EEDI-compliant vessels is the use of engines with power reduction running at lower RPM with larger diameter, with improved hull forms enabling sailing speeds to be reached at lower power and having the engines operating at power settings with more efficient fuel consumption. The effect of the recent EEDI phases can also be seen, notably in the container and tanker segments, where the proportion of A- and B-rated vessels increases substantially from 2017 onwards.

11 Preference was given here to mark the contract date triggering mandatory EEDI compliance. Vessels contracted on or after 1 January 2023 were delivered by 2025; however, many vessels were demonstrating voluntary compliance with EEDI before its enforcement. Thus, in the study we marked the contract date trigger for compliance with EEDI.

Figure 5: Cross-effects of the EEDI and CII – container vessels.

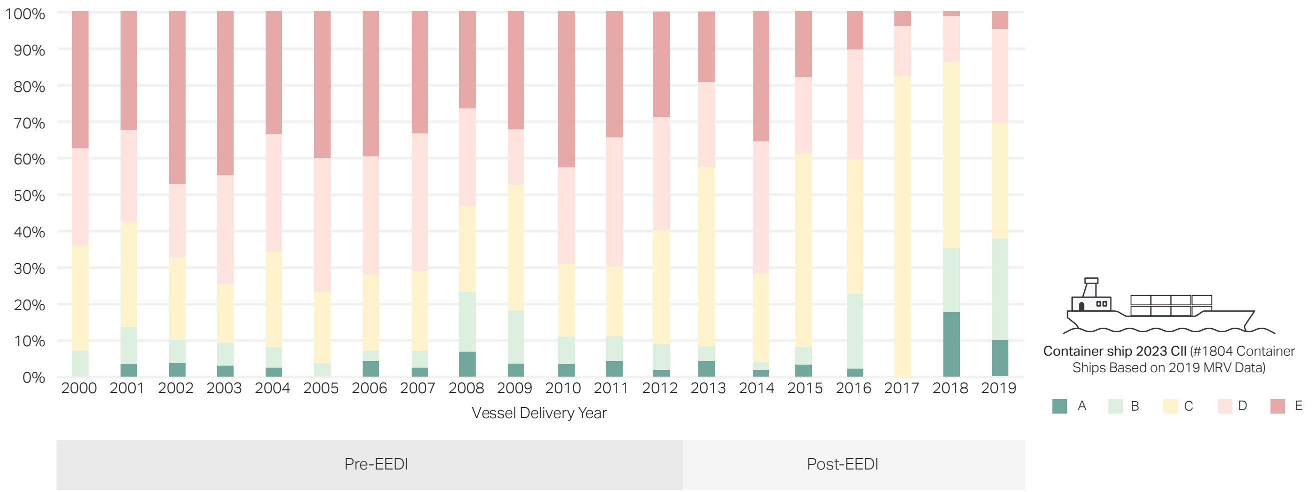


Figure 6: Cross-effects of the EEDI and CII – bulk carriers.

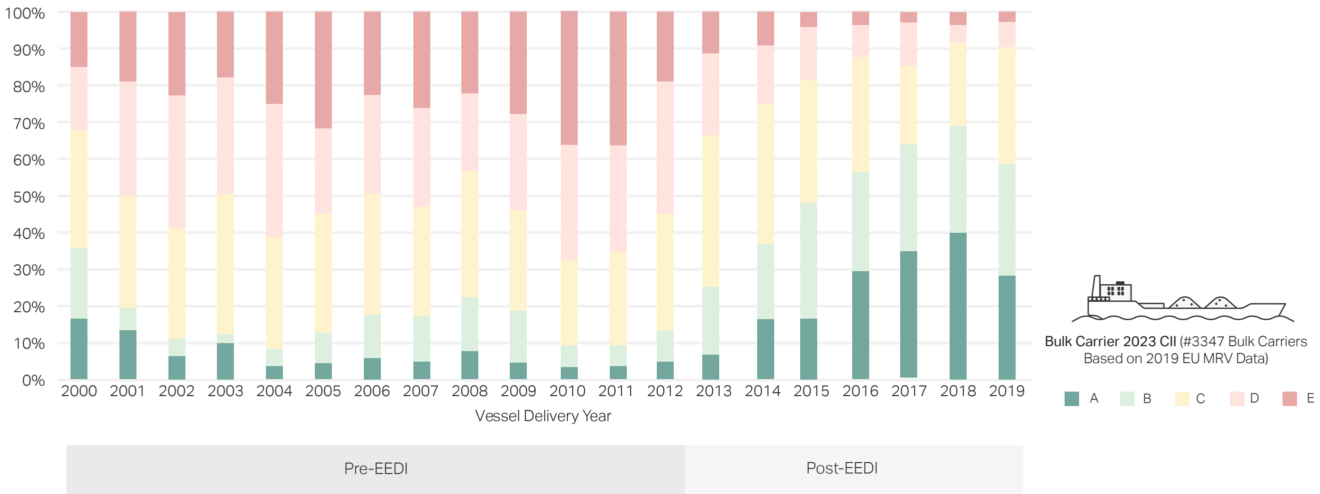
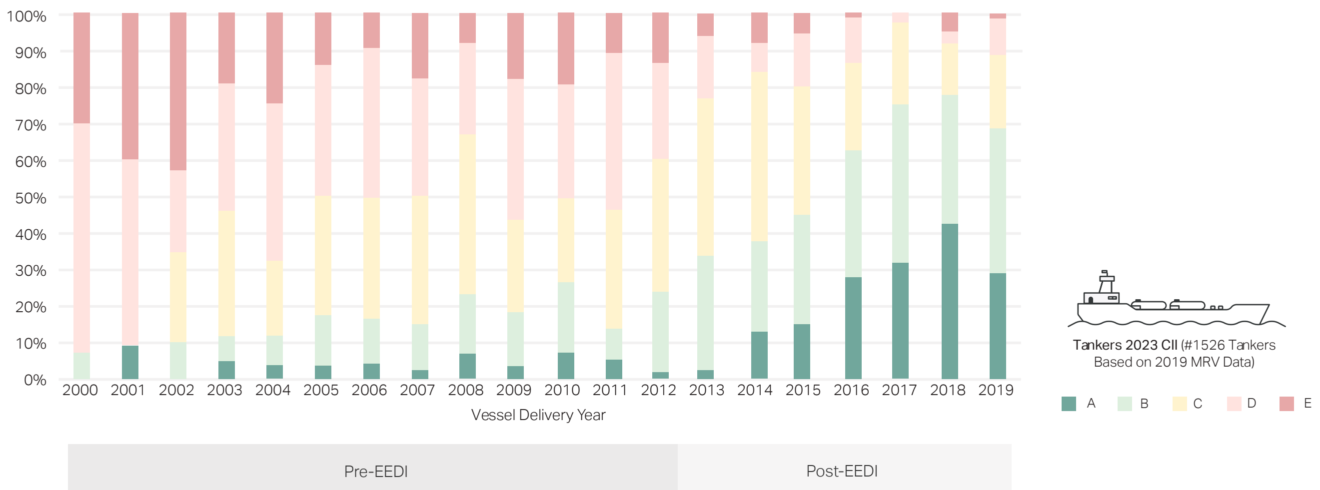


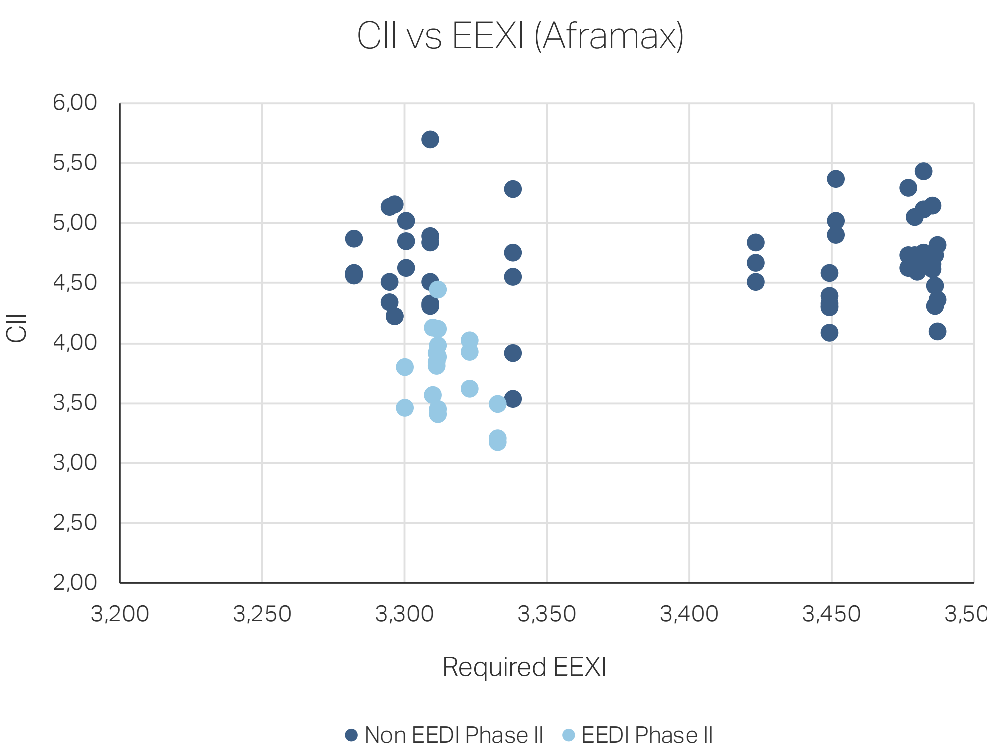
Figure 7: Cross-effects of the EEDI and CII – tankers.



Our group also examined the potential link between the EEDI and CII within specific company fleets. Figure 8 shows the CII against the required EEXI of 27 Aframax tankers from Minerva. As the figure shows, the eight EEDI Phase II-compliant vessels (red dots) have a better CII rating than the non-EEDI-compliant vessels (grey dots). There are no major differences in terms of operational energy efficiency measures between these vessels: hull and propeller cleaning, performance monitoring tools, discharge efficiency measures, and electrical load management are all similar. Therefore, the differences are considered a direct effect of the EEDI in the new building phase of the vessels.

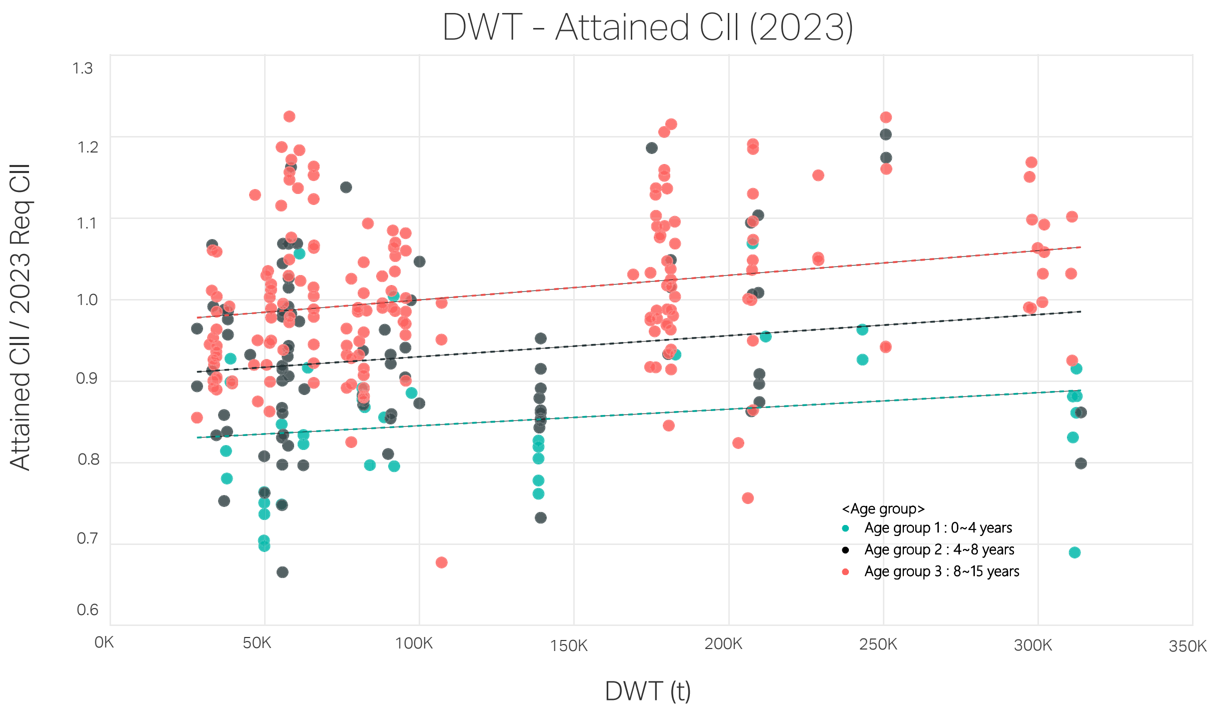
Another example provided by NYK shows similar trends. Figure 9 shows the projected CII compliance ratio (attained CII divided by required CII) in 2023 based on the 2021 DCS-reported data for NYK's entire fleet including all ship types. The fleet is divided into age groups (0-4 years, 4-8 years, and 8-15 years), with the younger vessels being mostly EEDI compliant. Overall, the younger vessels tend to have a better CII compliance ratio than the older tonnage, translating to better energy efficiency among newer vessels. A study commissioned by the European Commission on the impact of the EEDI has reported similar insights regarding the EEDI's influence on the CII based on DCS data.[12]

Figure 8: EEXI, EEDI and CII performance of the Minerva Aframax Fleet.



12 Decarbonisation of shipping, Publications Office of the European Union, 2022.

Figure 9: NYK fleet's CII compliance ratio versus age.



04 Expected impacts of the EEXI

Based on our observations of the impacts of the EEDI, what changes can we expect following the implementation of the EEXI? One key difference between the two regulations is how compliance is reached. For a newbuild vessel, there is ample time to prepare and adjust the design for EEDI compliance. In addition, the gradual increase of reduction rates under the EEDI from Phase 0 to the current Phase 3 allowed the industry to progressively adapt. Furthermore, implementation of new EETs at the newbuilding phase has a relatively lower capital expenditure (CapEx) compared to a retrofit.

By contrast, the EEXI has introduced a comparatively sudden need for compliance with the same levels as the applicable EEDI phases in 2023, without much time to allow for shipowners to fully explore ways to reach compliance by adopting new EETs. The final form of the EEXI regulations was agreed at MEPC 76 in June 2021. Although some owners started preparations ahead of this time, there were some significant changes between the draft amendments approved at MEPC 75 and the EEXI's final form. Therefore, in practice, owners were left with only 1.5 years to prepare to reach EEXI compliance.

Implementation of substantial energy efficiency changes for vessels requires planning, pre-design calculations, manufacturing with lead time, dry-docking, testing, class approval, and more. With a timeline of 1.5 years, essentially only the vessels that had already a dry-docking or energy efficiency implementation planned were able to benefit from these measures in the EEXI calculation. Therefore, the vast majority of the vessels in the fleet have adopted power limitation, which consists of reducing the maximum allowable power output of the engine, as the main measure to reach EEXI compliance. Power limitation can be achieved mechanically by setting a limiter to the vessel engine, or electronically by setting a new power limit or limiting the shaft power. Doing so changes the numerator of the EEXI formula, allowing for a reduced attained EEXI and better compliance.

In principle, limiting power limits vessel operability, as the vessel may not reach certain speed ranges for which it was designed. However, as previously mentioned, other factors have already been driving the world fleet to operate at lower speeds and consequentially at lower power ranges, than the maximum continuous rating (MCR). These conditions, together with the short implementation timeline for the EEXI, have meant that the benefits to shipowners from installing EETs are limited compared to the EEXI improvement and cost attractiveness of power limitation. In most cases, even if an EET is installed, power limitation is still required to bridge the compliance gap.

Deep-diving into the tanker segment, two datasets were provided by partners in the working group. Firstly, Minerva reported that, in the course of one year, their Aframax Tankers fleet spent only about 0.7% of time above the limited power on laden legs and 2.6% on ballast legs. Another dataset from a partner's chemical tanker fleet show that the majority of the fleet is operating within power levels below the limited MCR (Figure 10).

A similar trend can be observed for container ships. According to a partner dataset (Figure 11), a specific fleet of vessels has not exceeded the EEXI power limitation for operating power for more than 2-4% of sailing time in a year. In the rare instance where the operating power exceeded the EEXI limit, the resulting speed typically remained below 1.0 knot in excess.

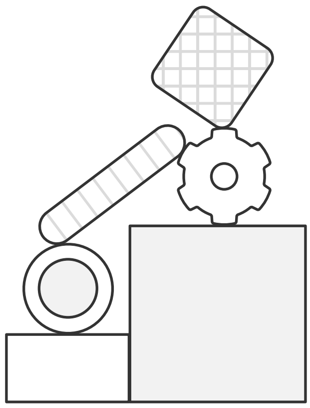


Figure 10: Average power deviation from limited MCR for a chemical tanker fleet. A negative deviation value means that the average power is lower than the limited MCR, while positive means that the average power is above the limited MCR.

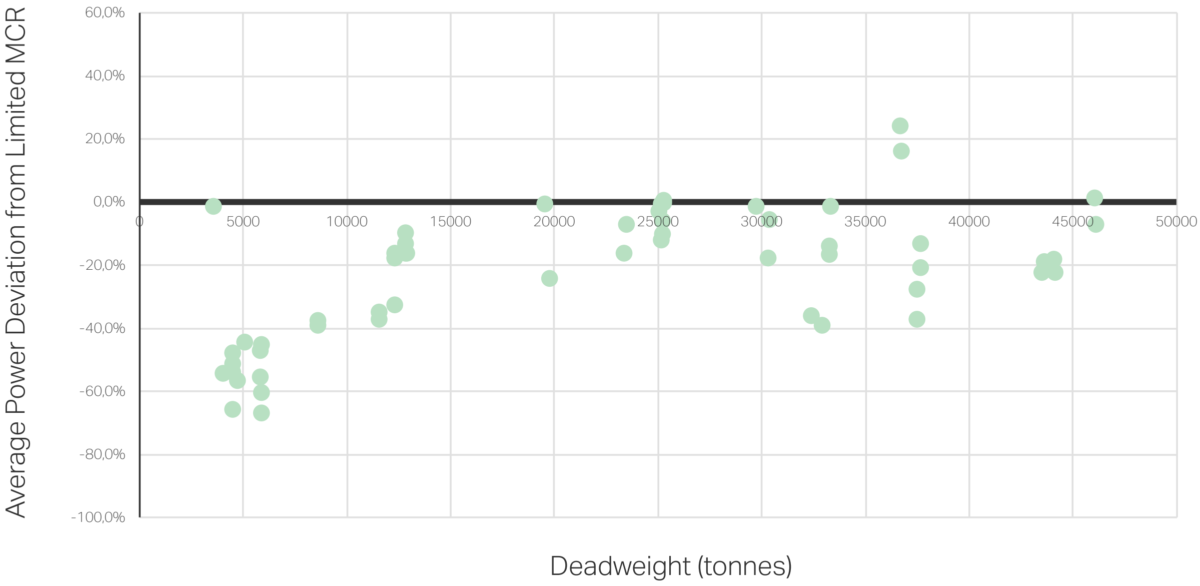


Figure 11: EEXI power limitation and effect on operational speed. Left: ratio in terms of accumulated sailing hours for a large fleet during a calendar year, where 'True' means that the vessel has sailed above the EEXI limited power. Right: the majority of hours spent over the EEXI limit are concentrated on speeds below 1.0 knot in excess of the EEXI limit.

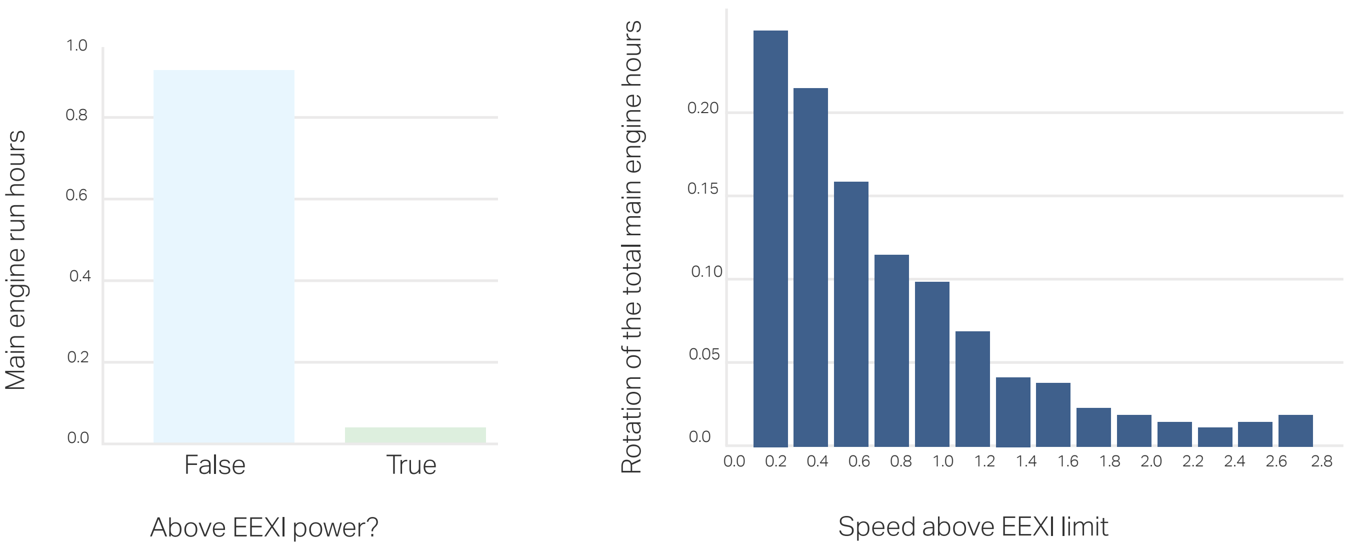
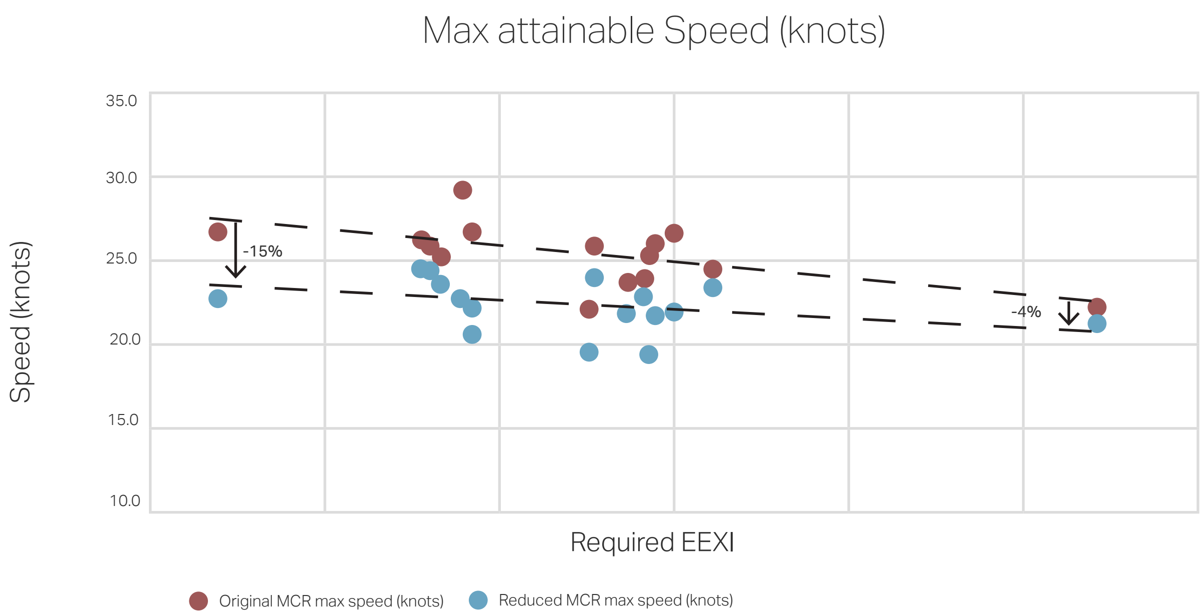


Figure 12 visualizes the reduction in maximum attainable speed driven by the EEXI for a fleet of 52 container ships with a wide range of sizes. The figure shows the maximum attainable speed both with the original power rating (red) and with the reduced MCR after EEXI-compliant power limitation (blue). We found that the top speed will be reduced on average by 15% in the low-deadweight range, by about 10% in the middle of the deadweight range, and by 4% in the higher-deadweight segment. Therefore, sudden increases in voyage speeds will be more challenging once EEXI compliance is in place.

Feedback from working group participants also indicated that it will be harder to operate at high speeds following EEXI implementation, whether to catch up on schedules from port delays and improve schedule reliability or because of good rates and favorable market conditions. From an operations perspective, this top speed limitation will introduce challenges, but it will also avoid sudden increases in CO_2 emissions.

In summary, the available data indicates that vessels can achieve EEXI compliance with a very limited impact on operating profiles. Therefore, we can conclude that the EEXI compliance process is likely to have a very limited effect on reducing the CO_2 emissions from shipping, based on current market conditions. However, should there be a change in market conditions that incentivizes higher speeds, the EEXI will act as a technical blocking point for such speeds to be achieved. Further, older tonnage would likely be impacted more by a loss of attainable commercial speed due to higher power limitations, which could then be an incentive for increased scrapping.

Figure 12: Maximum attainable speed before and after EEXI limitation for a fleet of 52 container vessels.



05 Expected impacts and limitations of the CII

The CII has provided a common language to describe operational carbon intensity. This is already a major step and highlights how international regulations imposed by the IMO can impact the industry. In addition to providing a common and standardized way to track the operational carbon intensity of a vessel, the CII is built on third-party verified data (DCS), which provides a trustworthy basis for such a mechanism. All shipowners – whether small or large, environmentally conscious or not, investment owners or operating owners – will need to annually calculate the CII and develop the SEEMP Part III with energy efficiency measures. In this way, the mechanism is expected to increase industry awareness of carbon intensity and energy efficiency. However, in its current form, it has several flaws that deserve attention from regulators, as described in the following paragraphs.

Shipping operations are complex, and many parts of the value chain can impact a vessel's CII rating, as summarized in Figure 13. As previously discussed, an owner can supply an energy-efficient vessel design with a higher chance of yielding good CII ratings. However, many operational conditions are not under the control of the vessel owner, such as sailing in bad weather or at high speed, which can lead a technically efficient vessel (e.g., EEDI Phase 3 compliant) to receive a bad CII rating. As a result, if an owner/operator focuses too much on commercial optimization, a vessel may be engaged in commercially advantageous routes but yield a bad CII rating.

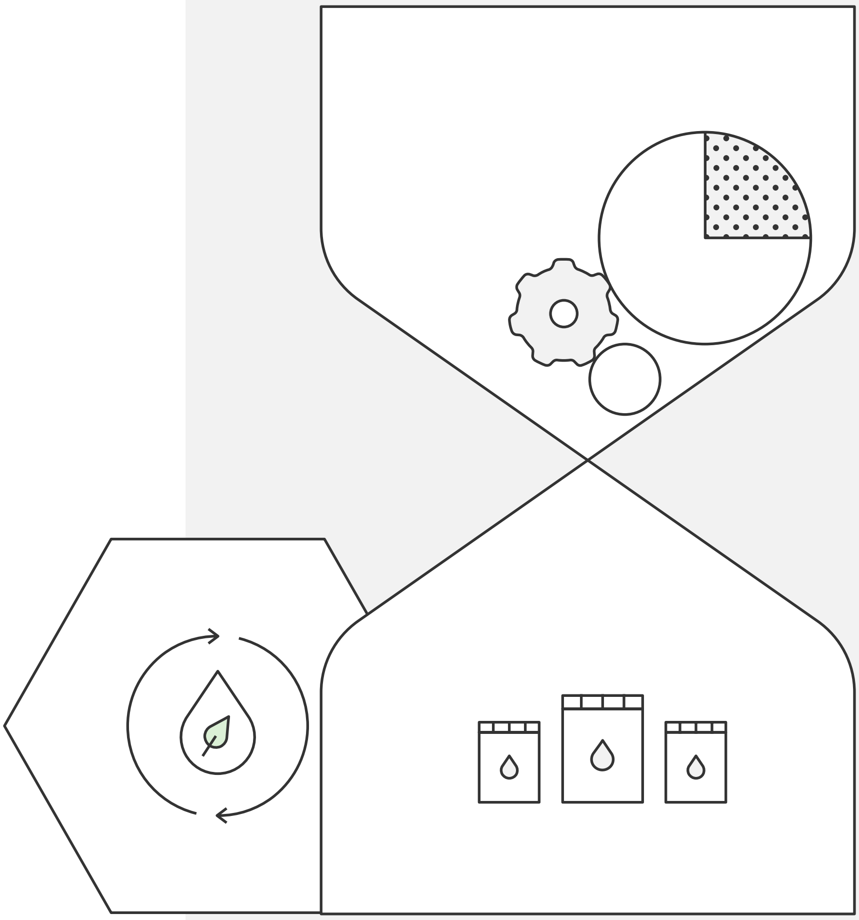
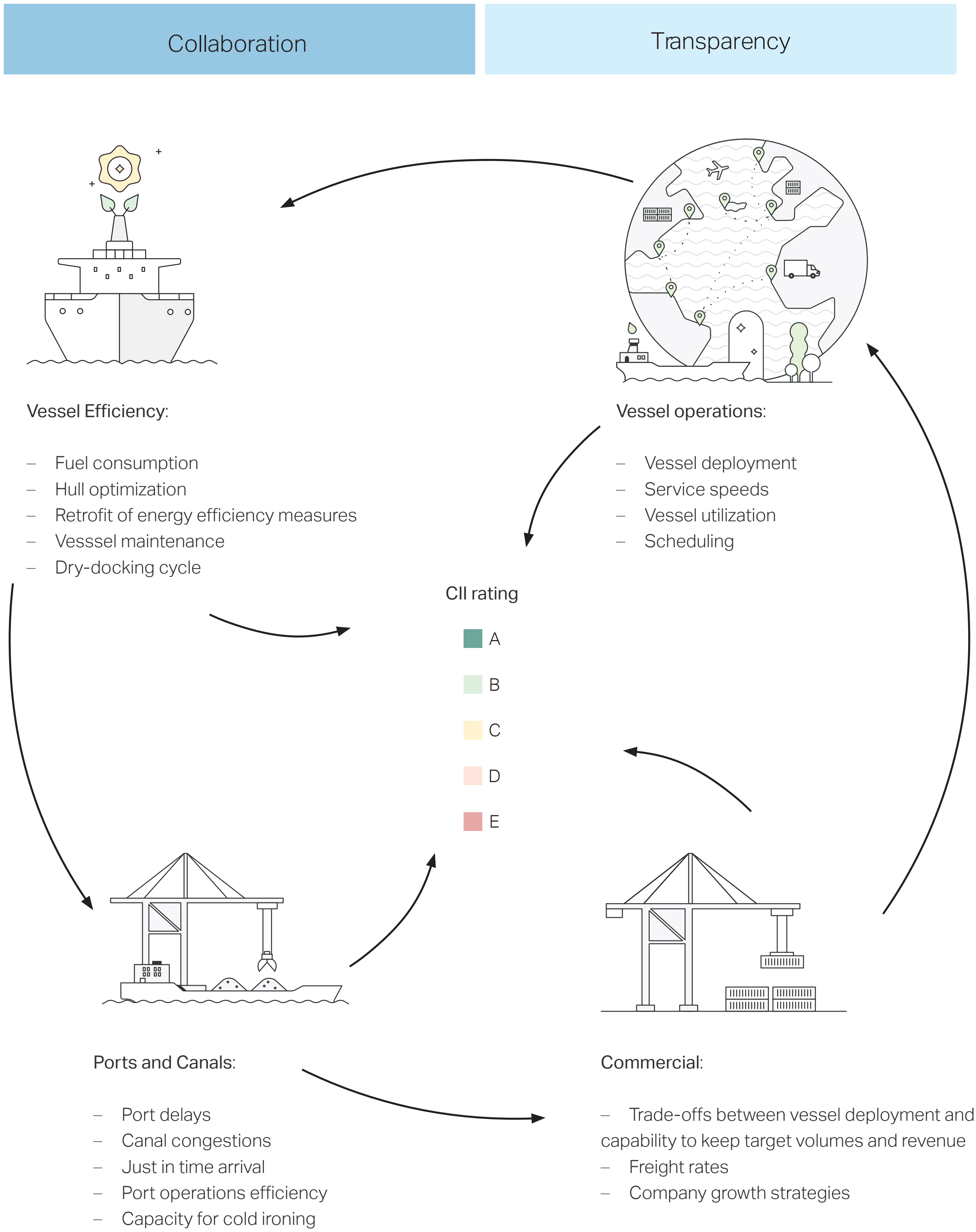


Figure 13: CII mechanism and how it is influenced by all actors in the shipping industry



Operation in more or less efficient ports or canals can lead to drastic changes in CII, and owners and operators may be unable to avoid specific ports or canals due to commercial obligations. Feedback from working group participants showed that owners are already looking into which ports are more efficient, and thus help the CII rating, and which ports have a negative effect on CII. This has yielded the concept of 'CII buffering', where vessels are deployed in such a way that they create a CII saving for part of the year to compensate for switching to a deployment with poor CII for the remainder of the year. In principle, this should be seen as a perverse incentive of the regulations, as it does not directly improve energy efficiency and may even lead to higher CO_2 emissions overall. The desired outcome in this situation would be to engage with other parts of the value chain to resolve the bottleneck that causes the E rating, instead of bringing an efficient vessel operating efficiently into inefficient operation.

Balancing all the factors that can affect CII ratings is difficult, and few shipping companies can optimize their ratings through end-to-end control. As a result, some companies may have more control over their vessels' CII ratings than others. For example, a large shipping company that both owns and operates vessels can maintain control over the profitability of the vessels, network schedule, and commercial trade-offs, allowing them to control many factors important to CII ratings. By contrast, a small company that owns and charters vessels may have limited control over a vessel's operation. However, they will still be penalized if their vessel has a series of D or E ratings. Investment funds, banks, or brokers can also impact how the CII is valued or monetized in the future.

In response to these challenges, IMO member states and non governmental organizations pledged for exclusions and corrections factors, some of which were included in the CII. The CII reduction lines are defined for the vessel types as defined in MARPOL, without specific distinction for discrepancies within that segment. For example, the tanker segment includes multiple types of vessels: shuttle tankers, tankers engaged in ship-to-ship transfers, chemical tankers, tankers operating in regions and with products requiring extensive cargo heating, etc. All these vessels are included in a single 'tanker' group. However, different stakeholders in IMO demonstrated that some correction factors and some exclusions were needed for some of these ships to create a proper level playing field, e.g., that shuttle tankers should not be directly compared to oil tankers and therefore needed a correction factor.

Correction factors for specific types of voyages, such as short voyages, have also been considered, as data show that vessels engaged in these voyages tend to have a worse CII rating. Furthermore, exclusions for fuel consumption related to excessive waiting time in port have also been discussed.[13] The argument behind these proposed exclusions is that shipowners, who are regulated by IMO and, therefore, the CII, should not be held responsible for inefficient ports or because some vessels are engaged in short sea trading. At this point, neither of these suggestions have been added to the CII mechanism, but they are expected to be proposed again in the future for consideration at IMO. However, exclusions and correction factors would be unnecessary if the CII itself could be modified to be more realistic and holistic – namely, by targeting all actors that affect operational efficiency and taking into account the specificities of how ships with different designs in different segments and different trades operate.

13 See submission MEPC 79/7/13 further detailing the issue of short voyages and waiting time.

5.1 How does the industry expect to achieve compliance with the CII?

To understand more about how companies plan to achieve compliance with the CII, working group participants were asked to participate in a SEEMP exercise, where they filled in the implementation plan in Part III. The SEEMP Part III exercises are summarized in Appendix A. Frequent inclusions for ensuring CII compliance include live CII tracking and implementing measures such as speed reduction or hull coating during dry-docking. Based on this exercise, we can offer two general observations about how shipowners intend to achieve CII compliance.

First, owners will make the best use of their vessels as they are now. This means there will be an increased focus on operational efficiency, vessel performance, fuel consumption monitoring, improved maintenance, and data-driven analytics to help track and control the CII during operation. Shipowners expect to rely on operational measures first, rather than retrofits or costly technical measures, because they do not yet understand how CII's soft enforcement mechanism will impact the market. Furthermore, operational measures alone will provide good compliance with CII (achieving a C rating or better) up until 2025.

If market pressure demands vessels with a C rating or better, owners who have already implemented tools for optimal operations will be able to adapt faster to these market demands. As a result, owners who have been investing heavily in energy efficiency over the last decade could have a commercial advantage over owners with off-the-shelf designs. However, market pressure for vessels with C ratings or better may also encourage speed reduction. As an illustration, Table 4 shows an example of a container ship that must operate at low-end speeds of 16-19 knots or below to maintain at least a C rating and 12-16 knots for an A rating. While small changes in vessel speed can be accommodated without major consequences for vessel operations, reducing the speed from 18 to 12-13 knots may necessitate schedule changes or skipping port calls. This would reduce the vessel's overall capacity for transport work, and could incentivize the industry to employ extra vessels, larger ships with lower utilization, or even shift transportation to more carbon-intense options such as road transportation.

Second, once the vessel's operational efficiency is exhausted or insufficient for CII compliance, owners will consider retrofits or other more cost-intensive solutions for increasing energy efficiency, such as adoption of biofuels.

At this stage, the IMO has not defined CII reduction rates beyond 2026, making it difficult for the industry to plan for energy efficiency measures beyond this date. However, discussions in the working group suggest that there is still space for more advanced technologies to be implemented in the industry, leaving room for additional CII reduction rates. Examples of technologies that can be further deployed in the global fleet include wind-assisted propulsion, air lubrication, waste heat recovery systems, shaft generators, and hybridization of the engine room (e.g., using batteries or fuel cells).

Table 4: Estimated CII compliance map – speed and draft.

(gCO_2/nm)	Draft (m)					
Speed (kn)	9	10	11	12	13	13.5
12	0.35	0.35	0.34	0.35	0.39	0.41
13	0.38	0.37	0.37	0.38	0.41	0.43
14	0.40	0.40	0.39	0.40	0.42	0.44
15	0.41	0.40	0.40	0.41	0.46	0.48
16	0.44	0.44	0.44	0.44	0.51	0.52
17	0.48	0.47	0.47	0.48	0.56	0.57
18	0.52	0.51	0.52	0.53	0.60	0.61
19	0.55	0.55	0.55	0.57	0.66	0.67
20	0.59	0.60	0.61	0.62	0.72	0.73
21	0.64	0.65	0.66	0.68	0.78	0.79
22	0.68	0.70	0.73	0.75	0.85	0.87

A B C D E

5.2 How will the CII be enforced?

As mentioned in Section 2.3, the CII is subject to a soft enforcement mechanism. Based on discussions at recent IMO meetings, some member states believe that this soft enforcement is appropriate, given the annual variability in fuel consumption and distance traveled. However, the current soft enforcement means that it is unclear what benefits shipowners can expect if their vessels attain good CII ratings. From a regulatory standpoint, there are none. In theory, owners of such vessels are expected to gain some market benefits, as vessels that can demonstrate good CII ratings are expected to:

– Benefit from better charter rates from sustainability-conscious companies.

– Receive preference for inclusion in green or sustainable investment portfolios.

– See better financing conditions than vessels with higher ratings.

– Be a preferred option for long-term charters.

– Potentially have a better capability to demonstrate higher speed and flexibility, because of either better design or a CII buffer strategy, as described in Section 5.

It is also unclear what the ultimate consequence of non-compliance with the CII will be. It has been established that owners need to report the CII rating, and that vessels with one E or three consecutive D ratings will be subject to a CAP that details the actions to be taken to achieve the required operational CII in the following years. However, it is unclear what consequences will be activated if the CAP is ineffective (i.e., if the vessel continues to demonstrate poor CII ratings). As these points are yet to be clarified, the expectation is that CII enforcement will mostly be driven by the market, via mechanisms such as charter rates, financing, and GHG reporting.

Implementation of the SEEMP Part III also forms an important aspect of CII enforcement. Current SEEMP Part III Development and Verification guidelines[14] comprise some wording that may lead to multiple interpretations (i.e., it is said that the implementation plan is to be robust without a proper definition for robustness), complicating the evaluation and verification of the impact of different energy efficiency measures on the CII rating by the RO. The SEEMP Part III will also be subject to auditing in order to verify that the implementation plan as outlined is being followed. The auditor should also verify whether the CII is being monitored and check the efficacy of individual energy efficiency measures being tracked. However, the actual consequences of not conforming to these standards and associated follow-up actions are not defined. Also, the SEEMP Part III audit may in principle be performed at the same time as International Safety Management (ISM) audits. However, the latter relates to safety, while SEEMP Part III relates to energy efficiency. As such, it is not logical for the ISM auditor to also perform the SEEMP Part III audit, as the two require different technical qualifications.

14 MEPC.346(78), IMO, 2022 and MEPC.347(78), IMO, 2022.

5.3 How could the CII be improved?

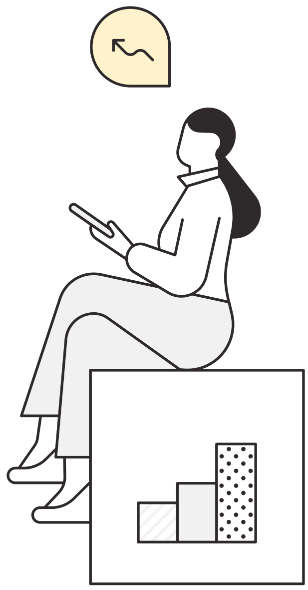
Despite the good intentions of CII and the additional correction factors and exclusions that have been added to create a fairer playing field, there are several ways this regulation could be further improved.

In the group, there have been suggestions that the CII could be improved by changing its performance metric from the current AER to the energy efficiency operational index (EEOI). The AER measures all carbon emissions from all ballast and laden voyages, anchorage, and port stays, divided by the deadweight capacity (DWT) of the vessel and distance sailed in the year (in grams of CO_2 per DWT mile). The numerator of the AER, which reflects the amount of fuel consumed and thus CO_2 emitted, can be reduced by carrying less weight or less cargo, while the denominator uses the maximum carrying capacity of the vessel and remains the same irrespective of how much cargo the vessel is carrying. As a result, the AER penalizes laden legs and incentivizes ballast legs. Furthermore, increasing the distance of the legs positively influences the AER calculation. In some segments of the shipping industry, ballast legs are unavoidable and part of common practice, while others generally avoid ballast legs. Some owners' business models aim to engage vessels in as few ballast legs as possible so as to maximize the vessel's profitability. Other owners have engagements where there are as many ballast legs as laden legs.

By contrast, the EEOI measures the carbon emissions from all ballast and laden voyages, anchorage, port stays, divided by the cargo transported in tonnes and distance sailed in the year.

Despite the AER's shortcomings, switching to the EEOI may create other perverse incentives that should be analyzed before any transition. For example, using the EEOI could disincentivize carrying low-density cargo. Also, those vessels on the spot market that can triangulate voyages may have an advantage compared to others that cannot change trade patterns and are engaged in agreements requiring 50% of voyages to be carried out in ballast. In addition, the EEOI will not fix issues related to port waiting times and port fuel consumption.

Another way to provide more level playing field would be to create new ship categories split into specific segments. For example, tankers could be split into chemical tankers, shuttle tankers, and so on. This would allow vessels to be compared against their true peers in the rating mechanism, potentially negating the need for correction factors and exclusions. An illustrative example is Bulker Carrier 1 profiled in Appendix A. This vessel is a cement carrier, which is defined as a bulk carrier. The vessel (as demonstrated in the Appendix A) is energy efficient, but has been designed for a very particular trade in New Zealand and has energy-intensive port operations. One of the only ways for the vessel to reach a C rating is by implementing cold ironing (connecting the vessel to shore electrical power), but the owner is highly dependent on local government investment in such technologies to make this possible. This is a vessel segment that could benefit from a different vessel type, such as cement carrier. However, splitting ship types into new categories would not change the fact that operational patterns could still differ within those segments, creating CII disparities. The creation of new ship categories might also lead to ship type segments containing a very limited number of vessels, which would render the calculation of a reference line uncertain and complicated.



A working group member and operator of chemical tankers performed a deep-dive into the impact on CII ratings when cargo heating is required. They found that despite the fact that the fuel consumption related to cargo heating can be deducted from the CII calculation (75% of the total cargo heating fuel consumption and reduced by 3% every subsequent year), the added power consumption due to heating can still lead to undesirable CII ratings for some vessels and routes, even with corrections. Furthermore, some vessels may not be capable of achieving better efficiencies for the cargo heating boilers, and therefore the solution would be to find alternative measures such as sailing with less cargo or transporting cargo that does not require heating. In such cases, reducing the vessel speed may increase the CII, as the number of days at sea increases and, hence, so does fuel consumption. It is feared that this will create imbalances in the market, as some sectors may see an increased offer of tonnage as others will see a shortage of tonnage.

As the CII connects so many stakeholders, it has the potential to unite all the moving parts of this complex industry. However, for this to happen, the shipping industry will need to find ways to encourage more cooperation and transparency. Increasing transparency would require data-sharing between shipowners, charterers, ports, and service providers to understand how operational decisions from each stakeholder impact CII ratings. Creating an environment where information about vessels (e.g., actual fuel consumption, cargo transported, waiting times in ports, delays in canal passages) can be shared responsibly and transparently will facilitate the identification of bottlenecks and bring industry focus to all aspects driving the carbon intensity performance of the world fleet. In the last MEPC 80 meeting in July, IMO has agreed to the inclusion of more data in the DCS. This should provide a better basis for the development of better regulations. However, this will not happen in time for the CII review which is due 1st January 2026.

Increasing cooperation with a focus on climate leadership would enable a joint effort towards more efficient operations and CII excellence. Under current regulations, only the shipowner is responsible for a bad CII rating, unless the time charter contract pushes the responsibility to the charterer by including a clause that the vessel is to be returned to the owner at a given CII rating. This is, of course, not trivial, given the traditional balance of responsibilities in charter contracts and the fact that some routes will always yield poor CII ratings. In addition, it is important to recognize that shipowners and operators are not the only stakeholders responsible for carbon intensity. In an ideal situation, all stakeholders should take ownership of their effect on a vessel's CII rating. In other words, a charterer is as responsible for the emissions of a vessel as an owner, and a port is as responsible for the delays in ports as shipping companies fixing the schedules of the vessels in the network.

06 The unseen consequences of energy efficiency regulations

Despite the intention of the regulations to increase energy efficiency across the industry, they may also create additional or originally unseen effects. In this section, we highlight some of these unintended impacts using examples provided by the members of the working group.

6.1 The risk of increased emissions

There is a non-negligible risk that some of the energy efficiency regulations discussed in this report will lead to increased GHG emissions. This may seem counter-intuitive: however, it is important to highlight that the metrics underlying the regulations focus on carbon intensity (i.e., grams of CO_2 per tonne-nautical miles), and that it is possible to decrease carbon intensity while increasing actual CO_2 emissions. To give an extreme example, emissions from a vessel that stays in port for most of a given year will have no nautical miles attached to them, leading to an excessively high attained CII. On the other hand, a vessel that sails for most of the year will simultaneously increase its emissions and its nautical miles sailed, yielding a good CII rating. Perversely, the latter situation leads to much higher CO_2 emissions but a better CII rating.

Therefore, the CII does not penalize all CO_2 emissions equally. For the purposes of attaining a good CII rating, there is a greater benefit from reducing the 'non-sailing' (i.e., not leading to motion) CO_2 emissions, even if smaller in quantity, than in reducing the 'sailing' (i.e., leading to motion) CO_2 emissions. In fact, the process of reducing the 'non-sailing' CO_2 emissions may see them replaced by more carbon-intense 'sailing' emissions.

As a theoretical example, let us take a modern 7,000-TEU container vessel which has sailed for 10,000 nautical miles. This vessel will have accumulated 3,340 tonnes of CO_2 emissions, assuming a constant sailing speed of 16 knots. The accumulated AER of this vessel is 3.90 gCO_2/t-nm. This vessel is approaching a port and is facing a port congestion, leading to a potential waiting time of two days before being allocated a place. The vessel has a choice between (1) waiting two days for an upcoming port stay, or (2) avoiding the port stay by taking two extra sailing days on a longer route. These options would have the following impacts:

1. Two days of idling represents consumption of about 26 tonnes of fuel and emission of 83.0 tonnes of CO_2. As this option does not contribute to increasing the nautical miles traveled, the AER is increased from 3.9 to 4.0, or an increase of 2.6%.

2. Adding two more days of continuous sailing at 16 knots represents about 80 tonnes of fuel consumption or 256 tonnes of CO_2 emissions. The AER remains unchanged.

While this example is simplistic, it shows that not all emissions are equal. Sailing for two more days does not increase the CII in the same way as waiting for two days, yet it induces three times more CO_2 emissions and the same cargo is transported. Therefore, a good CII is not necessarily a confirmation of low CO_2 emissions.

One case shared by partners of the working group is that, due to expected charter rate costs, some operators are investigating the possibility of avoiding delays at the Suez Canal by taking a longer route around the Cape of Good Hope. In an example discussed with partners, a calculation was performed on a 15,000-TEU container vessel sailing from Asia to Europe. The difference in distance between the Cape and the Suez routes is 3,500 nautical miles. Assuming a vessel consumption profile on 17 knots, choosing to sail around the Cape leads to 8.3 more days' sailing, but also represents a cost saving of 165,000 USD (using as basis a bunker price of 600 USD/tonne and Suez Canal passage fees of 650,000 USD).[15] At the same time, the effect on the CII is negligible – in fact, a slight reduction of 0.2%.

Given the potential market conditions of low charter rates and the addition of more container vessels to the global fleet, taking this longer route to optimize operational costs may be an option, especially as it does not affect the CII rating. However, for a single voyage, the increase in CO_2 emissions from taking the Cape route is 42%, or approximately 2,600 tonnes, compared to the Suez Canal route.

Of course, the previous examples assume higher bunker fuel costs. However, should there be market pressures (charter rates, charter clauses, penalties, etc.) that promote low CII ratings, actions such as the ones described previously may become common practice. In addition, a SEEMP Part III exercise performed with the working group identified that the first measure activated by owners is likely to be speed reduction, which might have unwanted consequences as well.

Let us take as another example an Aframax tanker sailing at an average yearly speed of 12.0 knots. The vessel spends about 60% of the year sailing between Brazil and Europe. In a given year, the vessel will carry approximately 530,000 tonnes of oil and will receive a D rating under the CII.

Should this vessel reduce its speed by 1.0 knot in order to reach a C rating, the amount of cargo transported in a year will be reduced by 40,000 tonnes of cargo transported, assuming all other variables are constant. Therefore, should there be 12 vessels of similar size all reducing their speed by 1.0 knot, the reduced tonnage transported is equivalent to one new vessel. Adding a new vessel to the fleet would result in an increase of 8,500 tonnes of CO_2 emissions, while the CO_2 savings due to reduced speed of the other 12 vessels amounts to 12,900 tonnes. In other words, the net effect of the CII in this example is not 12,900 tonnes of reduced CO_2 emissions, but rather only 4,400 tonnes.

Should the effects detailed previously be combined with economic growth creating further demand for ships, the CII may not be able to fulfill its full CO_2 reduction impact potential. Rather, its effect may be dampened by the market making unintended use of CII ratings. This problem will be further explored in future and ongoing MMMCZCS projects to be or that have been launched as a spin-off of this working group's activities. One of the already ongoing project focused on the effect of speed reduction. Its findings may be shared in the future.

15 Suez Toll Calculator, Wilhelmsen.

6.2 The role of ports and canals

The IMO regulates shipowners and linked entities[16] but has limited jurisdiction over ports. Despite this, ports and canals can significantly impact a vessel's CII. Inefficient port operations and delays can bring a B- or C-rated vessel to an E rating. On the other hand, efficient port operations, minimizing waiting time, or measures such as the implementation of cold ironing, can bring an E-rated vessel to B/C levels. Even known or expected port congestion can often drive CO_2/CII-increasing behavior by owners. For example, ships may increase their speed (increasing CO_2 emissions and CII) in order to arrive first in the queue and lay anchor (also increasing the CO_2 and CII due to continued use of auxiliary power).

A similar point applies to canals (e.g., Panama, Suez, Kiel, St Lawrence Seaway), where unforeseen closures or congestion can lead to substantial delays in the supply chain. Such delays force vessels to lay anchor and increase their fuel consumption from auxiliary engines without increasing the nautical miles the vessel sails, thereby leading to poor CII ratings. Attempts to avoid such delays, such as taking the Cape route instead of the Suez, may even improve CII at the expense of increased fuel consumption and emissions.

Engaging ports and canals in energy efficiency regulations is a necessary step to accelerate the decarbonization of the shipping industry. The current exclusion of these important actors, together with overlap and interactions between regulations, can create perverse effects. This is illustrated by several examples highlighted by partners of the working group:

Example 1:

If the operator tracks the CII on the basis of the sailing period only (i.e., not including port stays), the CII (AER) could be improved by 8% or from rating C to B. In this scenario, the underlying reference lines include the port stays' fuel consumption. The transit periods are those that can be fully controlled by ship operators, in that they can dictate the operating speed, fuel consumption, route, etc., while, as highlighted in previous sections, the port stays are outside their full control. Of course, this would leave the CII covering a smaller portion of the fuel consumption from ships, but the IMO could develop new mechanisms better suited to promoting energy efficiency in port. This example is further backed up by Example 2.

Example 2:

As the owners and operators cannot fully control waiting time, one solution to avoid the worsening effect of having a vessel idle for many days would be to have the vessel sail at very low speed on longer routes (possibly in circles), replacing the waiting time with sailing time. In a calculation provided by a partner, this would increase the total fuel consumption and distance traveled and reduce the fuel consumption without distance sailed, leading to a CII reduction of 9% (C to B) and increasing the absolute CO_2 emissions by 19%. Reducing idle time also reduces the amount of fouling, which is an added benefit of maintaining the vessel sailing.

Example 3:

This example highlights a case of a vessel that, while operating on the same route, every so often encounters port delays which lead to a need to increase the speed from 13-14 knots to 18-19 knots in order to compensate for the delay and arrive on time at the next port. Following EEXI implementation and the consequent installation of engine power limitation, such an increase in speed will no longer be fully possible. Also, due to enforcement of CII, the higher speeds would no longer be desired. Therefore, the practical solution for the vessel is to skip the next port and replace this port leg with alternative means of transport such as a new vessel or road transportation. Thus, the risk of less-utilized vessels and more CO_2 emissions increases, along with the possibility of replacing CO_2 emissions in shipping with emissions in other, less efficient segments.

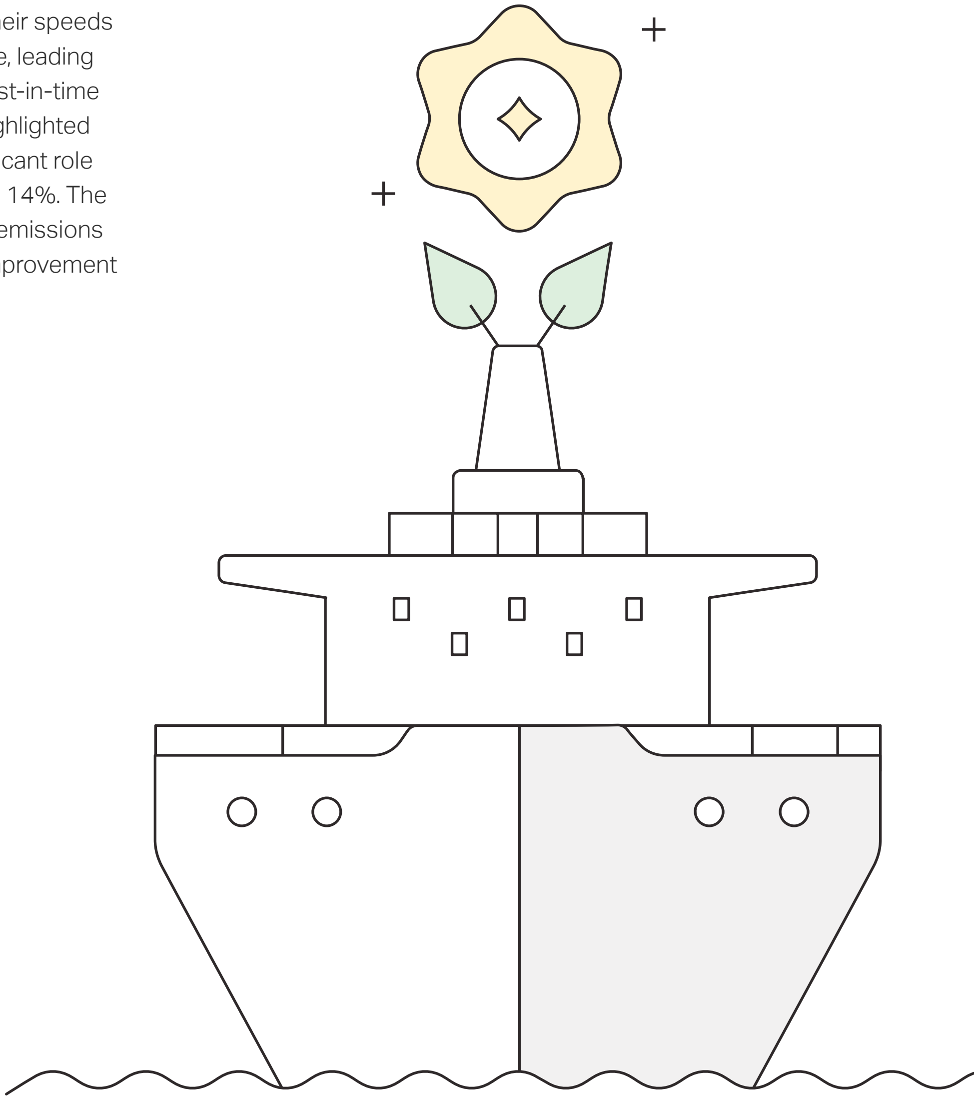
16 A DoC holder is typically a regulated entity by IMO who is not necessarily the shipowner and possibly the operator, charterer or the manager of the vessel.

Example 4:

This example provides a visualization of the effect of a port delay. For this case, the vessel was capable of operating in good CII ratings for most of the time. However, as soon as the vessel visits an inefficient port, the CII deteriorates to E level. This continues until the end of the year. Figure 14 shows a visual representation of this case for 2023, where the arrow marks the port visit.

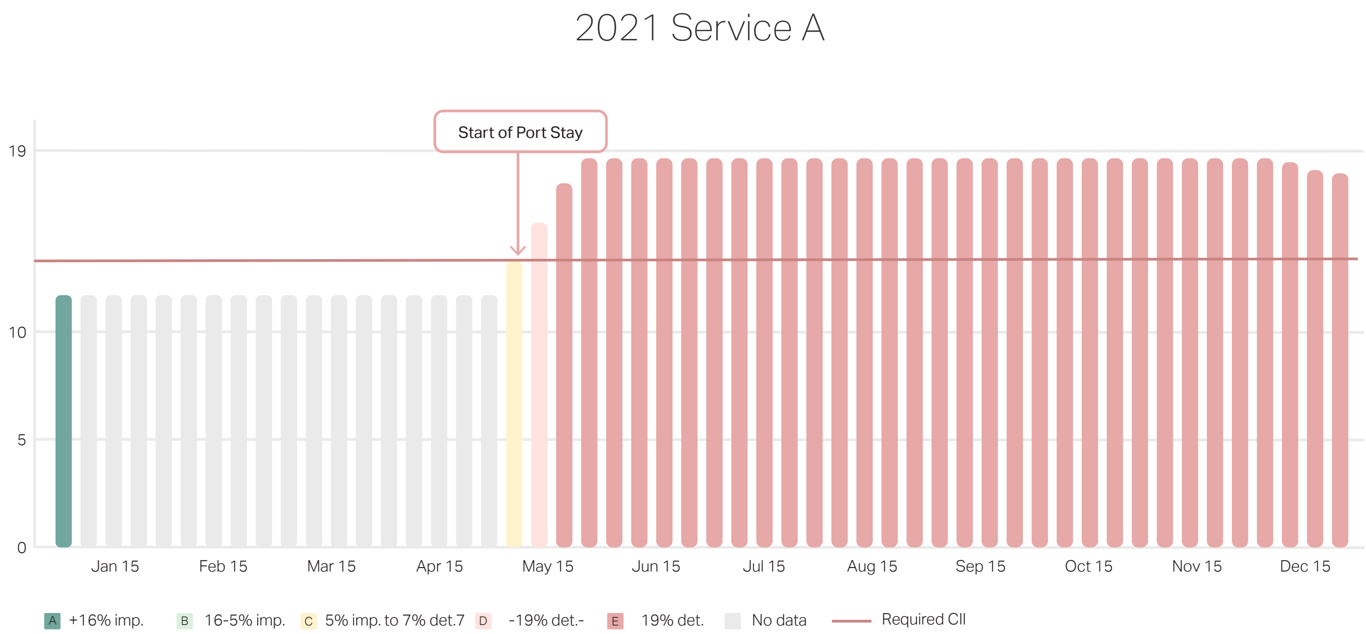
Improving communications between ports, canals, and ships could enable better CII results and reduced CO_2 emissions. One way to achieve this would be to borrow the concept of airport control towers, making ports responsible for directing ships in terms of their speeds in view of avoiding or minimizing waiting time, leading to an 'estimated time of arrival' priority, or 'just-in-time shipping'. A project[18] shared by a partner highlighted that just-in-time shipping could play a significant role in lowering absolute CO_2 emissions by up to 14%. The calculation for this project targets absolute emissions rather than CII, but we can expect that CII improvement could be of the same order of magnitude.

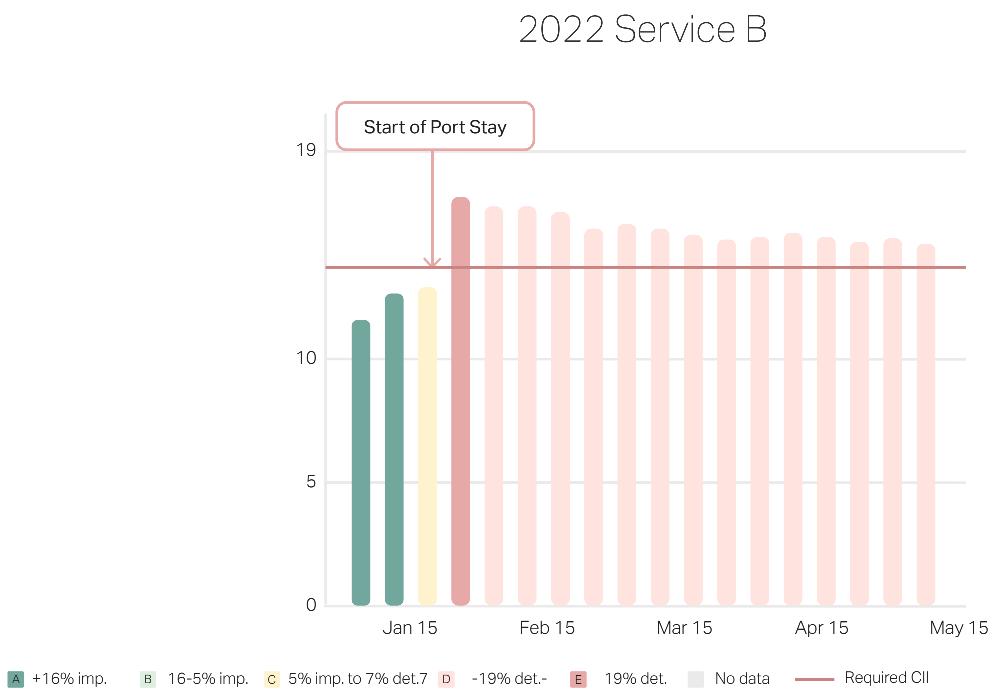
In adopting the initial GHG strategy in 2018,[19] the IMO encouraged the development of ways to include ports in the process of GHG emissions reduction. However, this encouragement has remained voluntary, and no actual regulation has been introduced to promote such cooperation. In this position paper, the intent is to demonstrate by examples how ports can play a significant role. Rather than excluding ports from the CII mechanism, finding ways to include them in the regulatory framework would add accountability and help reduce GHG emissions. Future working groups at the MMMCZCS will investigate how ports and canals can take a more active role in the decarbonization of the shipping industry.



17 Unifeeder data.

Figure 14: Example operational profile for a vessel operating in inefficient ports for 2021 (left) and 2022 (right).[17]





18 Just In Time Arrival, MarineTraffic, 2022.
19 MEPC.304(72), IMO, 2018.

6.3 Interactions between regulations and the market

One specific challenge lies on how the shipping industry operates. An owner is not necessarily the operator of the vessel as the same may be chartered out to many charterers along the years. As such, on many occasions the owners do not have control over the operation (speed, schedule, amount of cargo transported, etc.), which has a major influence on the vessel CII. Many (and, possibly by time of publication, most) recent charter agreements have seen the inclusion of a CII clause, which aims to ensure that the chartered vessel is delivered back to the owner at a given rating. Some charter agreements also include clauses allowing for revised operating conditions in case undesired ratings are observed. It remains to be seen if this trend will expand to the whole industry. Recently, a CII clause was released by BIMCO[20] as an attempt to define an acceptable clause to serve the legal agreement of vessel charter counterparties. This clause has received some criticism; however, as this paper shows, certain weaknesses in the CII mechanism, as outlined in previous sections, make design of this type of clause challenging.

Sailing speeds are driven by market conditions: when bunker prices are cheaper and/or freight rates are higher, it is more economical to sail at higher speeds, and vice versa. However, the CII (and, to a lesser extent, the EEXI) will impose limits on sailing speed. In addition, as previously highlighted, delays at ports and canals have substantial impacts both on vessels' schedules and CII ratings. Vessels that can speed up in order to counterbalance delays while maintaining good CII ratings will be seen as less risky alternatives and are likely to get better charter agreements.

Feedback from participants shows that CII ratings, in conjunction with the equivalent sailing speed, are beginning to factor as a way to identify both economically and environmentally performant vessels. The CII has also appeared in ESG reports and is being used as a way for companies to demonstrate environmentally friendly behavior. However, it should be noted that since Scope 3 emissions are absolute emissions and the CII is an efficiency metric, there is no direct correlation between the two.

20 CII Operations Clause for Time Charter Parties 2022, BIMCO, 2022.

Due to the lack of clear regulatory enforcement highlighted in previous sections, the partners of this working group expect that market forces take the role of a 'regulating' force for the CII. This is not necessarily a negative trend; however, the effect of market 'regulation' is less predictable and less universal than actual regulatory enforcement. Should market conditions suddenly change, the pressure to promote vessels with A-C CII ratings will change. Under competitive market conditions (high charter rates and bunker prices), A- to C-rated vessels may benefit from preferential rates. However, vessels with D and E ratings will still be able to find charter conditions and operate. As the reduction rates in the CII calculation increase, the number of vessels falling into the D and E categories will also increase over time, unless energy efficiency is adequately addressed. As such, the market will need to be able to find ways to factor in D- and E-rated vessels by revising operating conditions, commercial deployment, and so on. This highlights that although market enforcement can be taken as a positive trend that could fill the gaps left by current official regulations, the best way to drive enforcement is through clear regulations.

Furthermore, if regulations are to be used as a market tool, it could be more efficient to directly link energy efficiency with actual market-based measures and regulations, such as carbon pricing and fuel levies. It also seems worthwhile to consider whether introducing a global carbon tax or fuel levy would render the CII obsolete, as high bunker costs would incentivize the adoption of more CapEx-intensive technical measures. However, before rushing to conclusions, it is important to analyze the effectiveness of these potential market-based measures in delivering energy efficiency. MMMC ZCS will launch studies focusing on these regulations after MEPC 80 when more clarity will be provided by IMO on the topic.

Arguably, energy efficiency regulations should factor in the role of the market. In a way, market enforcement is much more agile and flexible than regulations. A good combination of sound regulatory text and market enforcement could lead to more efficient decarbonization than solely relying on hard regulatory enforcement.

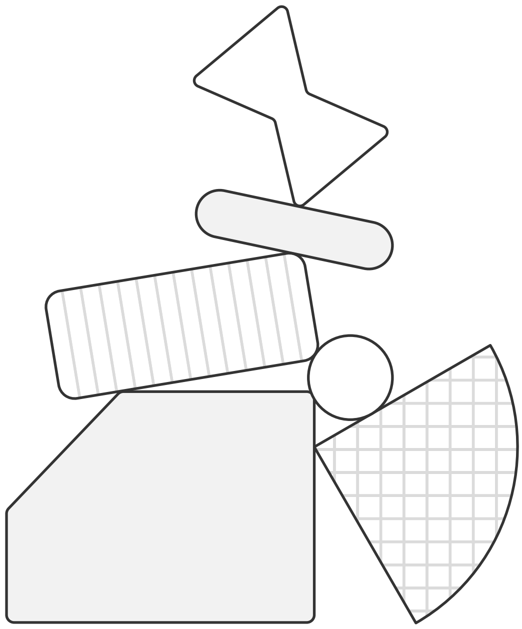
07 Conclusions

Supported by the partners of MMMCZCS, the working group investigated the current and potential future effects of three key energy efficiency regulations, namely the EEDI, EEXI, and CII (supported by the SEEMP). This section outlines our conclusions, while the next section offers recommendations for the way forward.

Implementing the EEDI, in conjunction with favorable market conditions, has led to more efficient ship designs and reduced installed power onboard. Phases 2 and 3 of the EEDI have created an increased focus on energy efficiency, with more new vessels, including hydro- and aerodynamic improvements to the hull, propeller, appendages, and superstructure, as well as optimized onboard power generation.

Implementing the EEXI is leading to a level playing field in the industry, as the installed power on vessels is becoming uniform among old and new tonnage. However, a lack of sufficient implementation time for this measure has led to only a small number of vessels undergoing comprehensive EET retrofits.
Instead, shaft or engine power limitation has been chosen as the main option for most vessels to attain EEXI compliance. This was spurred by power limitation's commercial attractiveness as a rather inexpensive solution relative to its high effect in yielding EEXI compliance compared to many other technologies. Furthermore, in most cases, these EETs only provide marginal improvements to the EEXI, so power limitation is still required. In the future, more EETs are expected to be retrofitted on old tonnage or for specific segments, such as some types of LNG carriers, where the power limitation required to reach EEXI compliance is too high and, therefore, other means to improve energy efficiency are needed.

Despite the widespread implementation of power limitation, the EEXI is not expected to affect vessels' average sailing speed based on pre-COVID numbers and, therefore, will not lead to a direct reduction of total CO_2 emissions compared to pre-COVID market conditions. However, vessels with reduced installed power will no longer be able to speed up to compensate for delays due to ports, bad weather, or logistics, nor to benefit from good market conditions such as high demand and high freight rates. As such, the EEXI is likely to act as a commercial limit for vessels rather than promoting CO_2 emissions reductions or driving wider adoption of EET. We conclude that the EEXI will act as a safety net to prevent increased emissions in future market conditions.



Like the EEXI, the CII had a rather short implementation timeline: both measures were agreed on by the IMO at MEPC 76 and came into force in 2023. In addition, the CII exclusions and correction factors were confirmed at MEPC 78 in June 2022, which delayed the final shape of the CII. In addition to this short timeline, energy efficiency retrofits are CapEx-intensive and often require dry-docking. For these reasons, owners are expected to achieve the necessary operational CII by using operational efficiency measures first. These measures typically deal with speed reduction, overhauling of engines, fuel consumption optimization for different non-propulsion consumers, choosing different routes, and omitting certain ports, or swapping vessels between routes to target a fleetwide average CII rating around C rating. The current uncertainty as to how the CII will be enforced is another reason driving owners to focus on operational measures to attain CII compliance. Working group participants indicated that biofuels also appeal to owners as a potential pathway for CII compliance. In summary, CapEx-intensive EET retrofits are expected to be implemented only when operational measures cannot yield sufficient energy efficiency improvements or if there are difficulties about sourcing biofuels.

On a positive note, the CII is creating a uniform and standardized way to track operational carbon intensity. All vessels will need to document their CII rating, and the simple fact of calculating the rating should create increased awareness of energy efficiency across the industry. The CII is also starting to be adopted as a commercial benchmarking tool, incorporated in ESG strategies, or used when applying for green financing options. That said, a good CII rating does not guarantee that a vessel is energy efficient.

The reasons for this include the following:

– Since the CII rating is based on maximum deadweight, it does not directly show if a vessel is more efficient in terms of its capability to actually transport cargo. As the CII does not account for cargo transported, a vessel may improve its rating by sailing a larger portion of the year in ballast. Two vessels that are similar in terms of deadweight, dimensions, and installed equipment may have the same CII rating and AER, but very different amounts of cargo transported in a given year.

– A vessel operator may opt for a longer route to avoid waiting times at ports or canals, thus avoiding an increased CII rating. Such a choice would paradoxically yield higher CO_2 emissions and a lower CII value compared to leaving the vessel idling at anchor.

– The CII does not distinguish between different types of fuels or CO_2 emissions: some emissions, although small, as they are not linked to increasing distance traveled (e.g., waiting time, auxiliary power usage, etc.) are more penalized than others (e.g., propulsive-related power usage). This leads to a pressure towards potentially alternative ways of operating a vessel that might result in a higher CO_2 emission while not negatively impacting the CII.

These and other examples show that the CII rating mechanism needs to be modified or supplemented by additional information if it is to accurately measure whether a vessel's operations are carbon efficient.

CII ratings are impacted by external factors not directly controlled by the owner and operators of the vessel, such as port stays and weather conditions. Perhaps, for this reason, the CII has been designed with a soft enforcement mechanism. However, this soft enforcement also creates uncertainty for the industry. As time goes on, it will be important to track the implementation of the CII mechanism across the industry and understand what behaviors it is driving.

08 The way forward

Based on the findings of the working group, we have identified several clear steps for increasing the effectiveness of the existing and recently implemented energy efficiency regulations to drive a more energy-efficient global fleet. This section outlines important takeaways for further consideration for energy efficiency regulations in shipping in general, as well as specific recommendations for the EEDI, CII, and SEEMP.

Systemic regulatory considerations:

– *Improving vessel data collection and availability*:
In the last MEPC 80, IMO has agreed to include more data in the the DCS mechanism. Such decision is welcomed as it will allow for better regulations to be developped. Further development can be done on the granularity of data and we recommend efforts in this direction to be pursued. Feedback from working group participants and experience with similar mechanisms, such as EU MRV, show that the industry is positive towards more data-sharing and transparency. Therefore, we also recommend that DCS data be made publicly available so that more industry experts can analyze the data and provide recommendations for further development of these regulations.

– *Recognizing the role of ports and canals*:
As previously outlined, ports and canals have a large impact on the operational efficiency of the vessels and are not currently directly regulated by the IMO. New regulations could be designed that allow responsibilities for emissions from shipping to be shared among different stakeholders rather than penalizing only one actor. One option could be multiple energy efficiency regulations, with one only looking at fuel consumption when the vessel is sailing, another for fuel consumption during port stays, and so on.

– *Shifting focus from CO_2 to energy*:
The entire unit system of the energy efficiency measures should be revisited to avoid overlap between regulations targeting energy efficiency and those targeting change towards sustainable low-emissions fuel. As market-based measures are being discussed by the IMO as a possible means to regulate emissions on a well-to-wake basis, a change of metric for EEDI and EEXI from a CO_2-centric to a power- or energy-centric calculation could be considered. This would allow the industry to put more focus on reducing the energy demand of the fleet. Alternatively, updating these mechanisms to include non-CO_2 GHG emissions could also be considered in order to allow a better level playing field among fuels.

Future directions for the EEDI:

– *Extending and strengthening the EEDI*:
The EEDI mechanism should be further strengthened, as it is being shown to promote the installation of energy-efficient technologies on newbuilds. This could be done by enlarging the scope of emissions covered by the EEDI, increasing the reduction rates, or usage of alternative metrics as highlighted above, in additional phases.

Future directions for the CII:

– *CII monitoring*:
The implementation of the CII mechanism needs to be monitored to track whether the industry is taking measures that efficiently improve the carbon intensity of the fleet without leading to higher CO_2 emissions. For example, there may be unintended consequences of 'quick fixes' for CII compliance, such as speed reduction measures creating a lack of tonnage that leads to the introduction of more vessels and risks, thus increasing absolute emissions from the fleet.

– *Evaluating exclusions and correction factors*:
Revision of the CII mechanism should include a thorough assessment of how the exclusions and correction factors currently agreed on by the IMO are influencing the mechanism's effectiveness, in order to determine whether such factors are necessary.

– *Evaluating the potential impact of switching from AER to EEOI*:
Because the EEOI includes actual transported cargo, this change could in principle allow the CII to more holistically capture a vessel's actual carbon intensity and efficiency. However, in case of an upcoming recession, leading to less cargo to be transported, the EEOI may worsen due to lower vessel utilization. Therefore, such change of metric should be carefully examined and evaluated based on data and potentially modeling.

– *Promoting transparency and cooperation*:
Owners, operators, ports, charterers, financial institutions, and other stakeholders will need to increase transparency and cooperation in order to optimize the CII. Without a regulatory push for this cooperation to happen, there is a risk that the full potential of this measure will not be reached.

Future directions for the SEEMP:

– *Strengthening the SEEMP mechanism*:
Part III of the SEEMP, which highlights the measures to be undertaken by vessels to continuously comply with the CII, is based on very vague and subjective requirements. These requirements should be revised to be clearer and more specific.

– *Clarifying auditing processes:*
The SEEMP Part III and the CII will be subject to auditing, which could play a major role in ensuring that energy efficiency measures are continuously implemented, and that the CII mechanism is effective. However, the exact role of the audit is not clear in the regulatory text. In addition, there are no specific requirements for the technical qualifications of this auditor, who in principle could be the same auditor as for the ISM audits. However, auditors for the ISM and SEEMP Part III should have different qualifications and thus should not be the same, unless appropriate training is considered.
Many of these topics are and will be the subject of future MMMCZCS projects. In April, we kicked off the first spin-off project from the group 'The Future of Energy Efficiency Regulations', where 30 partners of MMMC ZCS will aim to have a recommendation ready for IMO on energy efficiency regulations, ahead of the IMO CII review due before 2026, which is expected to begin in the third quarter of 2024. The objective of the project is to investigate and propose an improved regulatory framework increasing the adoption of technical and operational energy efficiency measures across the fleet. The project will also evaluate the interaction with other existing and future GHG regulations to ensure that the combination yields the desired effect of accelerating the decarbonization of the industry.

09 The project team

This report was prepared by the Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping (MMMCZCS) with assistance from our partners.

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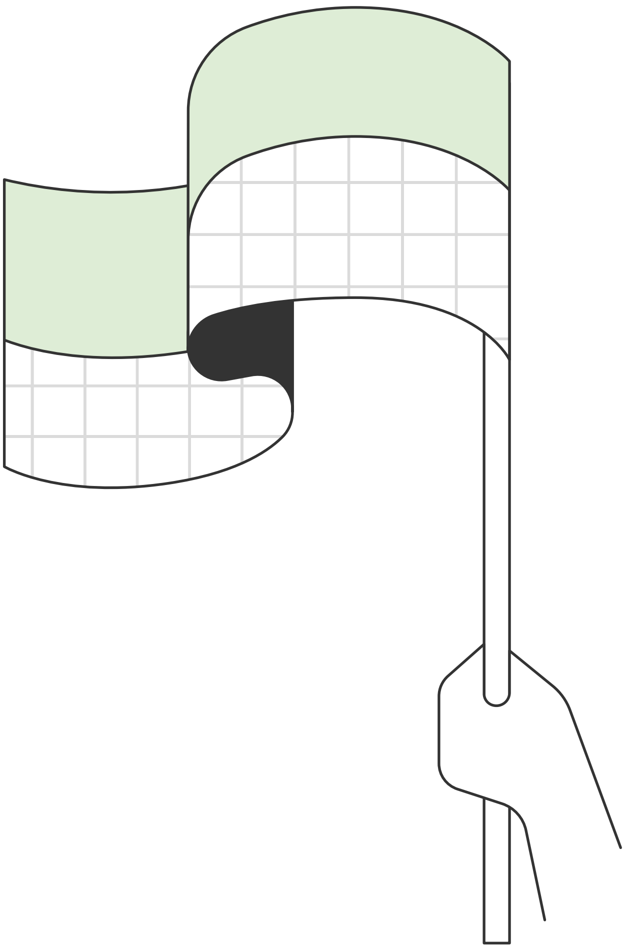


Appendix A – SEEMP Part III Examples

Bulk Carrier 1

Vessel particulars

Name	-
Vessel type	Bulker- cement carrier
Year built	2016
DWT[21]	-
GT[22]	-

Information on the CII (One table per DCS year, meaning that 'projections' based on multiple DCS years can be provided.)

DCS year 2021	Attained CII (AER) before correction factors	Attained CII After correction factors	Required CII	Rating
2023	27.16	27.16	15.92	E
2024	27.16	27.16	15.59	E
2025	27.16	27.16	15.25	E
2026	27.16	27.16	14.92	E

1. Calculation methodology of the ship's attained annual CII, including required data and how to obtain these data as far as not addressed in Part II.

Attained CII

The attained CII of the vessel is obtained by calculating the Annual Efficiency Ratio (AER) from the vessel's class verified IMO DCS data:

Annual Efficiency Ratio (AER) = Annual CO_2 / DWT x Distance traveled (emissions per dwt-miles)

Where:
Annual CO_2 emissions can be calculated by multiplying annual fuel oil consumption and CF for the type of fuel consumed on board.

21 As per IEEC.
22 As per IEEC.

	Type of fuel	Referrence	C_F = t-CO_2 / t-Fuel
1	Diesel/gas oil	ISO 8217 Grades DMX through DMB	3.206
2	Light fuel oil (LFO)	ISO 8217 Grades RMA through RMD	3.151
3	Heavy fuel oil (HFO)	ISO 8217 Grades RME through RMK	3.114

DWT: The capacity of the vessel. In this case, it is 9578 MT

Distance traveled: Annual Sailed Distance in Nautical Miles

Main engine, auxiliary engines and boiler consumption: The daily fuel consumptions are measured through flow meters and are reported by the Chief Engineer to the office via an enterprise performance reporting data platform. All the fuel tanks are also manually sounded each month to reconcile the reported consumptions with the actual tank consumptions. The BDNs are kept on board and in office for cross-verification. Annualized IMO DCS data gets verified from the class.

2. Three-year implementation plan.

The vessel is way deep inside the 'E' CII rating. To improve to a 'C' rating in 2024, the vessel will have to reduce its emissions by around 43%, which is a highly challenging task unless radical steps are undertaken.

The vessel is a specialized cement carrier and falls under the bulk carrier category. The vessel is in a New Zealand coastal trade and spends more time in ports than sailing. Typically, the vessel spends 60% of the time in ports, 34% at sea and 6% of the time maneuvering in/out of the ports. In terms of fuel consumption, the vessel consumes 60% at sea, 34% in ports and 6% during maneuvering.

The vessel's average sailing speed is 12-12.5 knots. The graphs in Figure 15-18 highlight the performance and operating profile of the vessel.

Figure 15: CII performance and projection.

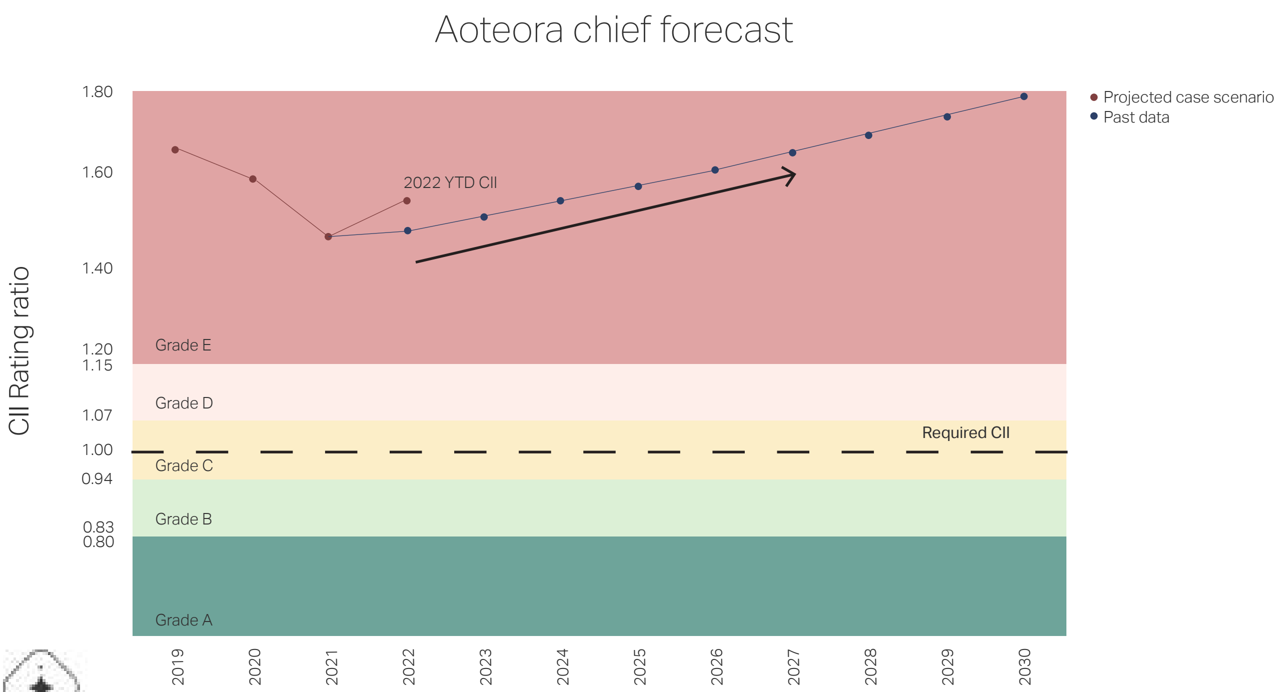
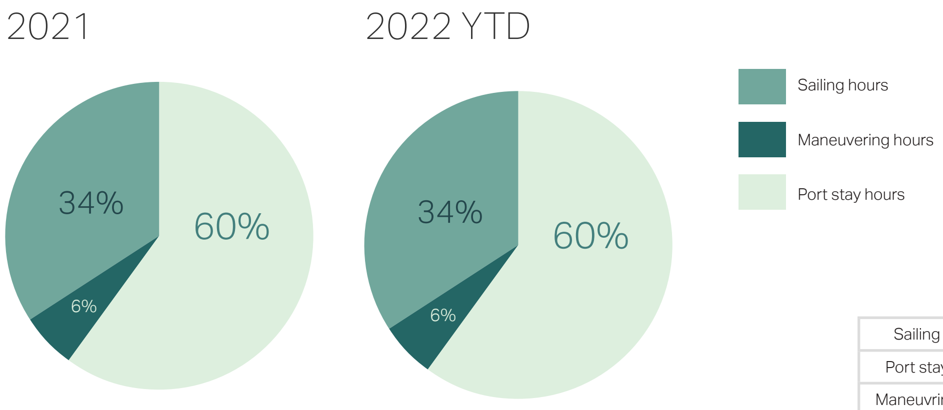


Figure 16: Sailing, maneuvering & port days.



	2021	2022 YTD
Sailing days	123	54
Port stay days	220	97
Maneuvring days	21	10

Figure 17: Fuel consumption profile (in MT).

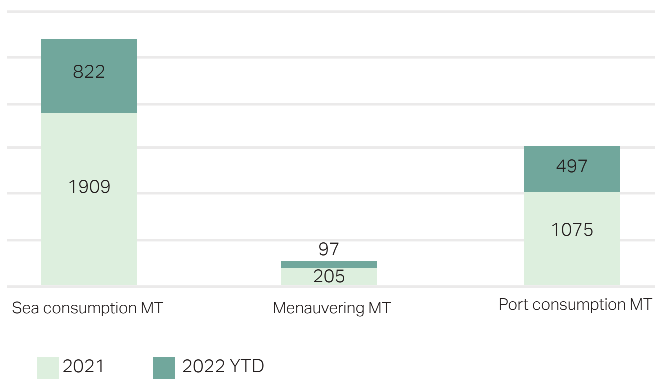
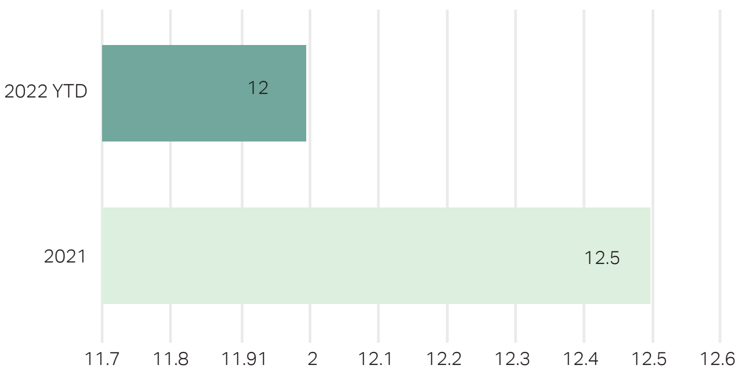


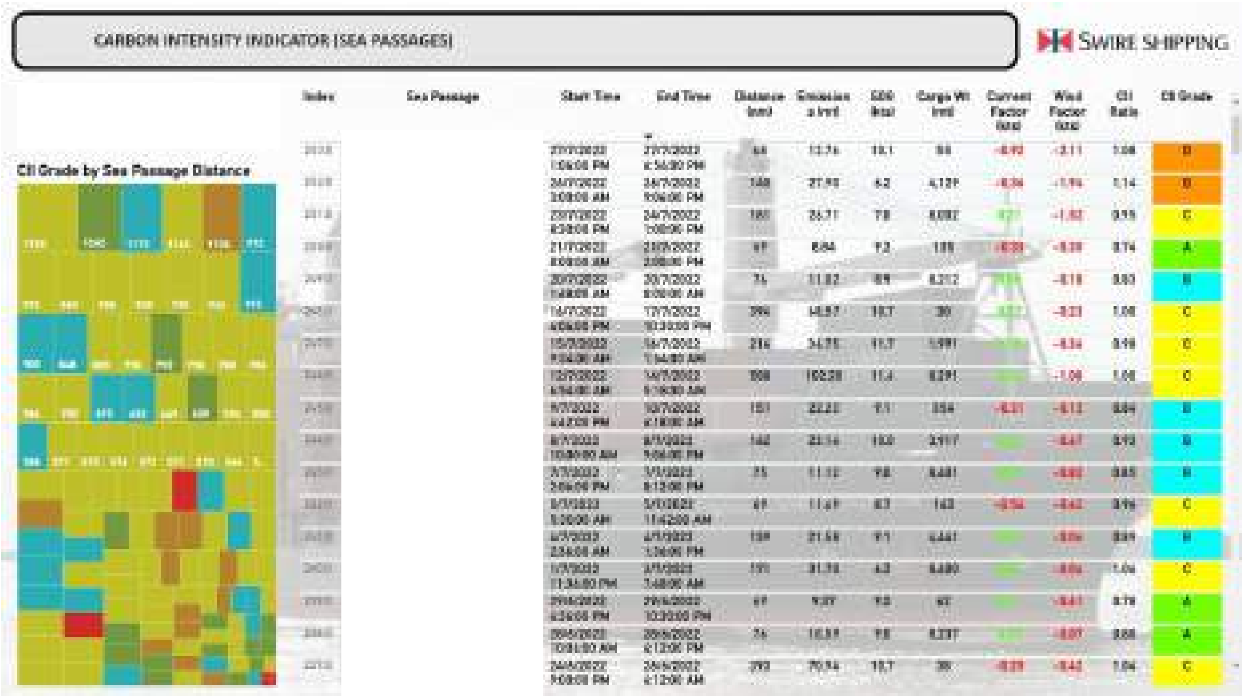
Figure 18: Average sailing speed in knots.



Sea CII

If CII were calculated just for the sea passages, it would be at a satisfactory level. Figures 19 and 20 show the sea CII ratings for latest passages:

Figure 19: CII (passages).



As the port consumption gets added to the sea consumption, the overall CII (AER) is adversely affected, as shown by Figure 20.

Figure 20: Vessel CII.

To improve the vessel's CII performance, it is imperative to address the vessel's port fuel consumption due to its special trade requirements.

Main measures to achieve the required annual operational CII

1. Alternative marine power (AMP or cold ironing)

The company shall achieve the objective mainly by upgrading the vessel's power management system (PMS) to allow the vessel to switch over to the shore power (cold ironing) during the port stays. All the stakeholders viz. Swire Shipping, Charterer (Cement Company) and Maritime New Zealand are in discussion to upgrade the shore infrastructure for cold ironing purposes across New Zealand ports. This will reduce the overall annual fuel consumption by over 1000 MT.

2. Speed reduction

From 1 January 2024, the average sea speed shall be reduced from 12.5 to 10 knots. This will result in annual fuel savings of around 170 MT.

The aforementioned measures combined will result in a total fuel reduction of 1170 MT from the vessel's total annual fuel consumption. It will improve the annual operational CII to a 'C' rating with an AER value of 14.6 gCO_2/tonne-mile.

Other measures to improve the operational CII:

– Half-yearly hull inspection and propeller polishing to maintain the propulsion performance of the ships. Where required, hull cleaning shall be carried out.

– Voyage performance shall be improved by enrolling with a third-party service provider to ensure weather routing is being carried out, and that constant power voyages are executed with active monitoring from office side.

– Specialized crew training shall be provided to TOP4 officers to ensure they understand the importance of the CII and endeavor to optimize the energy consumption onboard.

2.1 List of measures to be considered and implemented

Measure	Impact on CII	Time and method of implementation and responsible personnel	Impediments and contingency measures
Alternative marine power – Cold Ironing	35% reduction	**Milestone:** Vessel and NZ port infrastructure ready for the cold ironing. **Due:** 1 Jan 2024. **Responsible:** Maritime New Zealand, Swire Shipping & Cement Company (Charterer).	**Impediment:** Policy decision at MNZ, project delay due to assorted reasons. **Contingencies:** Alternative fuels like the bio-diesel to be explored. **Responsible:** Swire Shipping & Cement Company (Charterer).
Speed reduction – deployment plan	3.3% reduction	**Milestone:** Change in the vessel's deployment and vessel's speed from 1 Jan 2024. The speed is to be changed from 12.5 to 10 knots. **Due:** 1 Jan 2023 **Responsible:** Swire Shipping & Cement Company (Charterer).	**Impediment:** Port delays, congestion, weather conditions, casualty. **Contingencies:** Monthly monitoring of the CII performance by Swire Shipping. If a significant impact on CII performance is observed, an emergency meeting to be held with all stakeholders to address the underlying issues and improve the CII performance. **Responsible:** Swire Shipping.

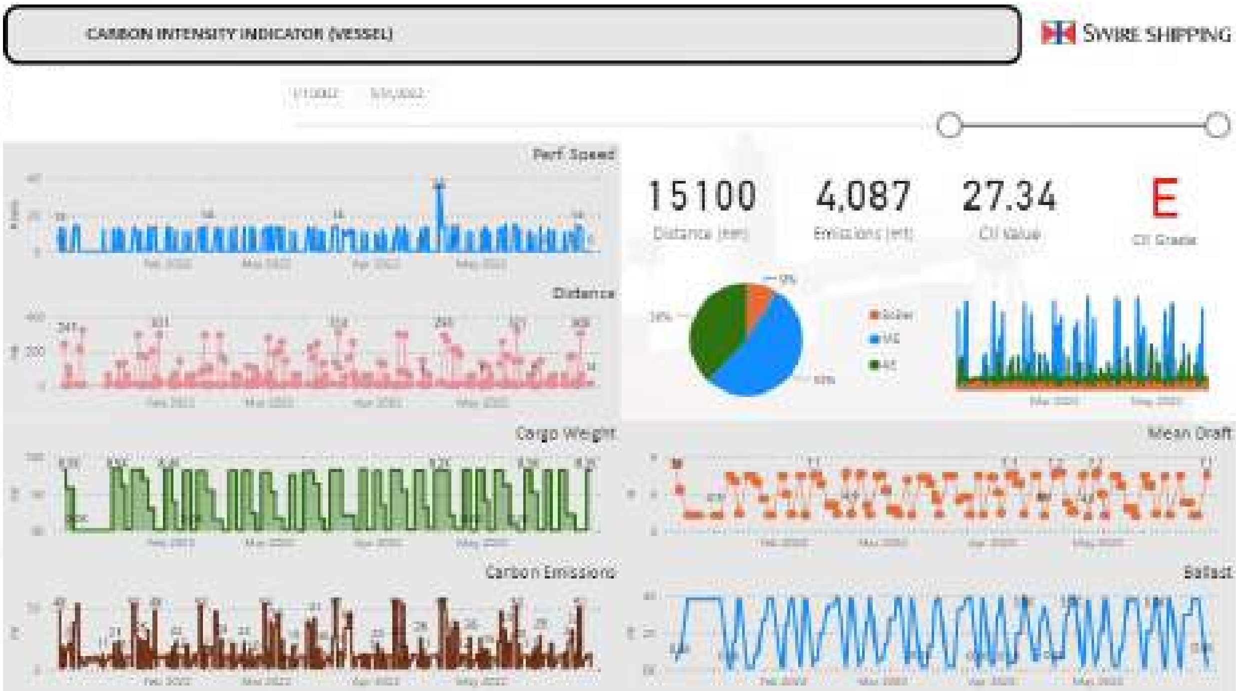
2.2 Calculation showing the combined effect of the measures and that the required operational CII will be achieved.

DCS year: 2020	Required annual operational CII	Targeted operational annual CII	Targeted rating
2023	14.88	27.16	E
2024	14.57	14.6	C
2025	14.25	14.6	C
2026	13.94	14.6	C

3. Self-evaluation and improvement

A monthly CII scorecard is published to establish the gap between the planned and actual performance of the vessel. In the case of significant divergence, a meeting with relevant stakeholders is called to address the CII underperformance.

Figure 21: Vessel CII.



Bulk Carrier 2

Vessel particulars

Name	-
Vessel type	Bulk carrier
Year built	2009
DWT[23]	179,000
GT[24]	93,000

Information on the CII (One table per DCS year, meaning that 'projections' based on multiple DCS years can be provided.)

DCS year: 2019	Attained CII (AER) before correction factors	Attained CII after correction factors	Required CII	Rating
2023	2.46	2.46	2.43	C
2024	2.46	2.46	2.38	C
2025	2.46	2.46	2.33	C
2026	2.46	2.46	2.28	D

DCS year: 2020	Attained CII (AER) before correction factors	Attained CII after correction factors	Required CII	Rating
2023	2.45	2.45	2.43	C
2024	2.45	2.45	2.38	C
2025	2.45	2.45	2.33	C
2026	2.45	2.45	2.28	D

DCS year: 2021	Attained CII (AER) before correction factors	Attained CII after correction factors	Required CII	Rating
2023	2.91	2.91	2.43	E
2024	2.91	2.91	2.38	E
2025	2.91	2.91	2.33	E
2026	2.91	2.91	2.28	E

23 As per IEEC.
24 As per IEEC.

1. Calculation methodology of the ship's attained annual CII, including required data and how to obtain these data as far as not addressed in Part II.

Voyage-based data will be used for continuous monitoring and reconciled with the bunker delivery notes and quantities remaining on board at each bunker delivery.
Voyages to be excluded will be highlighted and excluded from the final calculation.

2. Three-year implementation plan.

The fuel consumption from 2021 is discarded, as the lower miles sailed were year-specific and the ship is not expected to repeat that pattern in the future.
Specific measures to avoid class D in 2026 are:

- ME overhaul during 2024 dry dock
- Hull coating renewal during 2024 dry dock
- In-water hull and propeller cleaning every 6 months and after 20+ days' stay in port
- LO analysis for the engine room systems with continuous-based maintenance agreement to limit the ME efficiency reduction
- Voyage-based CII monitoring to alert owner, charterer and ship officers of voyage impact on annual CII

Documentation: Measure → Attribute (fuel consumption reduction) → CII reduction

2.1 List of measures to be considered and implemented

Measure	Impact on CII	Time and method of implementation and responsible personnel	Impediments and contingency measures
ME and AE overhaul	3%	**Milestone:** Dry dock. **Due:** 2024. **Responsible:** Fleet Cell	**Impediment:** NA. **Contingencies:** CBM on ER systems.
Hull coating	3%	**Milestone:** Dry dock. **Due:** 2024. **Responsible:** Fleet Cell.	**Impediment:** NA. **Contingencies:** IW hull cleaning every 6 months and following 20+ days at port.
CII live	2%	**Milestone:** continuous monitoring. **Due:** Start during 2023. **Responsible:** Fleet Cell.	**Impediment:** Cargo readiness and port delays. **Contingencies:** Just-in-time practice.

2.2 Calculation showing the combined effect of the measures and that the required operational CII will be achieved

DCS year	Required annual operational CII	Targeted operational annual CII	Targeted rating
2023	2.43	2.46	C
2024	2.38	2.33	C
2025	2.33	2.26	C
2026	2.28	2.28	C

3. Self-evaluation and improvement

The impact of the above measures is evaluated after each milestone and their effectiveness assessed during the annual SEEMP revision.

Quarterly and per-voyage CII graphs will also be used to improve the CII forecast.

Bulk Carrier 3

Vessel particulars

Name	-
Vessel type	Bulk carrier
Year built	2009
DWT[25]	179,000
GT[26]	93,000

Information on the CII (One table per DCS year, meaning that 'projections' based on multiple DCS years can be provided.)

DCS year	Attained CII (AER) before correction factors	Attained CII after correction factors	Required CII	Rating
2023	2.65	2.65	2.43	D
2024	2.65	2.65	2.38	D
2025	2.65	2.65	2.33	D
2026	2.65	2.65	2.28	D

DCS Year: 2020	Attained CII (AER) before correction factors	Attained CII after correction factors	Required CII	Rating
2023	2.55	2.55	2.43	C
2024	2.55	2.55	2.38	D
2025	2.55	2.55	2.33	D
2026	2.55	2.55	2.28	D

DCS Year: 2021	Attained CII (AER) before correction factors	Attained CII after correction factors	Required CII	Rating
2023	2.76	2.76	2.43	D
2024	2.76	2.76	2.38	D
2025	2.76	2.76	2.33	E
2026	2.76	2.76	2.28	E

25 As per IEEC.
26 As per IEEC.

1. Calculation methodology of the ship's attained annual CII, including required data and how to obtain these data as far as not addressed in Part II

Voyage-based data will be used for continuous monitoring and reconciled with the bunker delivery notes and quantities remaining on board at each bunker delivery.
Voyages to be excluded will be highlighted and excluded from the final calculation.

2. Three year implementation plan

The fuel consumption from 2021 is discarded as the lower miles sailed were year-specific and the ship is not expected to repeat that pattern in the future.
Specific measures to avoid class D in 2026 are:

– ME overhaul during 2024 dry dock.

– Hull coating renewal during 2024 dry dock.

– In-water hull and propeller cleaning every 6 months and after 20+ days' stay in port.

– LO analysis for the engine room systems with continuous-based maintenance agreement to limit the ME efficiency reduction.

– Voyage-based CII monitoring to alert owner, charterer and ship officers of voyage impact on annual CII.

2.1 List of measures to be considered and implemented

Measure	Impact on CII	Time and method of implementation and responsible personnel	Impediments and contingency measures
ME and AE overhaul	3%	**Milestone:** Dry dock. **Due:** 2024. **Responsible:** Fleet Cell.	**Impediment:** NA. **Contingencies:** CBM on ER systems.
Hull coating	3%	**Milestone:** Dry dock. **Due:** 2024. **Responsible:** Fleet Cell.	**Impediment:** NA. **Contingencies:** IW hull cleaning every 6 months and following 20+ days at port.
CII live	2%	**Milestone:** continuous monitoring. **Due:** Start during 2023. **Responsible:** Fleet Cell.	**Impediment:** Cargo readiness and port delays. **Contingencies:** Just-in-time practice.

2.2 Calculation showing the combined effect of the measures and that the required operational CII will be achieved

DCS year	Required annual operational CII	Targeted operational annual CII	Targeted rating
2023	2.43	2.55	C
2024	2.38	2.42	C
2025	2.33	2.34	C
2026	2.28	2.34	C

3. Self-evaluation and improvement

The impact of the above measures is evaluated after each milestone and their effectiveness assessed during the annual SEEMP revision.

Quarterly and per-voyage CII graphs will also be used to improve the CII forecast.

Container Vessel

Vessel particulars

Name	-
Vessel type	Container ship
Year built	2011
DWT[27]	23300
GT[28]	18300

Information on the CII (One table per DCS year, meaning that 'projections' based on multiple DCS years can be provided.)

DCS year: 2021	Attained CII (AER) before correction factors	Attained CII after correction factors	Required CII	Rating
2023	16.22	16.22	13.79	D
2024	-	-	13.50	D
2025	-	-	13.21	E
2026	-	-	12.92	E

1. Calculation methodology of the ship's attained annual CII, including required data and how to obtain these data as far as not addressed in Part II

Attained CII

The attained CII of the vessel is obtained by calculating the Annual Efficiency Ratio (AER) from the vessel's class verified IMO DCS data:

Annual Efficiency Ratio (AER) = Annual CO_2 / DWT • Distance traveled (emissions per dwt-miles)

Where:

Annual CO_2 emissions can be calculated by multiplying annual fuel oil consumption and CF for the type of fuel consumed on board.

27 As per IEEC.
28 As per IEEC.

	Type of fuel	Referrence	C_F = t-CO_2 / t-Fuel
1	Diesel/gas oil	ISO 8217 Grades DMX through DMB	3.206
2	Light fuel oil (LFO)	ISO 8217 Grades RMA through RMD	3.151
3	Heavy fuel oil (HFO)	ISO 8217 Grades RME through RMK	3.114

DWT: The capacity of the vessel. In this case, it is 9578 MT.

Distance traveled: Annual Sailed Distance in Nautical Miles.

Main engine, auxiliary engines and boiler consumption: The daily fuel consumptions are measured through flow meters and are reported by the Chief Engineer to the office via an enterprise performance reporting data platform. All the fuel tanks are also manually sounded each month to reconcile the reported consumptions with the actual tank consumptions. The BDNs are kept on board and in office for cross-verification. Annualized IMO DCS data gets verified from the class.

Reefer containers correction factor
There are no reefer KWHr meters installed on the vessel. The number of reefers and their operating hours are measured through the BAPLIE files, and reefer fuel consumption is calculated by the formula given by the IMO GHG working group.

$$FC_{electrical\_reefer,j} = Cx \cdot 24 \cdot SFOC_{avg} \left(Reefer\_days_{sea} + \sum Reefer\_days_{port} \right)$$

Where:
- Cx represents a default reefer consumption of 2.75kWHr
- SFOC represents a default SFOC of 175 g/kWhr
- Reefer days sea – From BAPLIE file

Reefer days port is calculated with the following formula:

$$Reefer\_days_{port} = \frac{N0_c Arrival + N0_c Departure}{2 \cdot Days_{port}}$$

Where:
- $Days_{port}$ represents number of days in port
- $Reefer\_days_{port}$ represents the number of in-use reefer days while at port
- $N0_c$Arrival represents number of reefer containers on arrival
- $N0_c$Departure represents number of reefer containers at departure

Correction factor for reefer containers: The reefer containers related annual fuel consumption is deducted from the vessel's total annual fuel consumption to calculate the annual operational CII of the vessel.

2. Three-year implementation plan

Main measures to achieve required annual operational CII.

The company will achieve the objective mainly through speed reduction measures. The deployment plan has been suggested and agreed on with various stakeholders viz. Commercial, Operation, and Ship Management teams. Below is how various deployment plans were suggested and the appropriate one is chosen:

Plan D:

2023 (Jan-March) – Performa Speed – 18 Knots @ Sea with 53 MT/day total consumption including margins

2023 (Apr-Dec) – Performa Speed – 16.5 Knots @ Sea with 40.5 MT/day total consumption including margins

2024 – Performa Speed – 16.5 Knots @ Sea with 40.5 MT/day total consumption, including margins

2025 – Performa Speed – 16.5 Knots @ Sea with 40.5 MT/day total consumption, including margins

2026 – Performa Speed – 14 Knots @ Sea with 32 MT/day total consumption, including margins

Other Measures to improve the Operational CII:

1. Half-yearly hull inspection and propeller polishing to maintain the propulsion performance of the ships. Where required, hull cleaning shall be carried out.
2. Voyage performance shall be improved by enrolling with a third-party service provider to ensure weather routing is being carried out and constant power voyages are executed with active monitoring from office side.
3. Specialized crew training shall be provided to TOP4 officers to ensure they understand the importance of the CII and endeavor to optimize the energy consumption onboard.

Table 5: Plan A, B, C and D

	Plan A - 2023 - 6:6	
	Jan - Jun	**Jul - Dec**
Assumed speed	**18**	**16.5**
No. of days	181	184
Sea days	99	115
Port days	83	69
Sea consumption per day (MT)	53	40.5
Port consumption per day (MT)	5	5
Fuel consumption	5633	4999
Total fuel consumption	10632	
DWT	23305	
Distance traveled	85832	
Attained EOY CII value 2023	16.55	
EOY CII rating 2023	E	
Required ‘C’ rating CII value 2023	14.76	
Projected CII rating 2024 at 16.5 knots	D	
Projected CII rating 2025 at 16.5 knots	D	

	Plan B - 2023 - 5:7	
	Jan - May	**Jul - Dec**
Assumed speed	**18**	**16.5**
No. of days	151	214
Sea days	83	134
Port days	68	80
Sea consumption per day (MT)	53	40.5
Port consumption per day (MT)	5	5
Fuel consumption	4729	5813
Total fuel consumption	10542	
DWT	23305	
Distance traveled	85832	
Attained EOY CII value 2023	16.41	
EOY CII rating 2023	E	
Required ‘C’ rating CII value 2023	14.76	
Projected CII rating 2024 at 16.5 knots	D	
Projected CII rating 2025 at 16.5 knots	D	

	Plan C - 2023 - 4:8	
	Jan - Apr	**May - Dec**
Assumed speed	**18**	**16.5**
No. of days	120	245
Sea days	65	153
Port days	55	92
Sea consumption per day (MT)	53	40.5
Port consumption per day (MT)	5	5
Fuel consumption	3734	6657
Total fuel consumption	10391	
DWT	23305	
Distance traveled	85832	
Attained EOY CII value 2023	16.18	
EOY CII rating 2023	D	
Required 'C' rating CII value 2023	14.76	
Projected CII rating 2024 at 16.5 knots	D	
Projected CII rating 2025 at 16.5 knots	D	

	Plan D - 2023 - 3:9	
	Jan - Mar	**Apr - Dec**
Assumed speed	**18**	**16.5**
No. of days	90	275
Sea days	49	172
Port days	41	103
Sea consumption per day (MT)	53	40.5
Port consumption per day (MT)	5	5
Fuel consumption	2802	7481
Total fuel consumption	10283	
DWT	23305	
Distance traveled	85832	
Attained EOY CII value 2023	16.01	
EOY CII rating 2023	D	
Required 'C' rating CII value 2023	14.76	
Projected CII rating 2024 at 16.5 knots	D	
Projected CII rating 2025 at 16.5 knots	D	

Table 6: Projected CII outcomes from Plan A, B, C and D for 2023, 2024 and 2025.

	2023	2024	2025	Remark
Plan A	E	D	D	**Not feasible.** If 'E' in 2023, we'll have to improve the CII rating to at least 'C' in 2024. That means further speed reduction to around 15 Knots in 2024.
Plan B	E	D	D	**Not feasible.** If 'E' in 2023, we'll have to improve the CII rating to at least 'C' in 2024. That means further speed reduction to around 15 Knots in 2024.
Plan C	D	D	D	**Feasible.** We'll have to improve the CII rating to at least 'C' in 2026. That means speed reduction to around 14 Knots in 2026.
Plan D	D	D	D	**Feasible.** We'll have to improve the CII rating to at least 'C' in 2026. That means speed reduction to around 14 Knots in 2026.

Other Measures to improve the Operational CII:

1. Half-yearly hull inspection and propeller polishing to maintain the propulsion performance of the ships. Where required, hull cleaning shall be carried out.

2. Voyage performance shall be improved by enrolling with a third-party service provider to ensure weather routing is being carried out and constant power voyages are executed with active monitoring from office side.

3. Specialized crew training shall be provided to TOP4 officers to ensure they understand the importance of the CII and endeavor to optimize the energy consumption onboard.

2.1 List of measures to be considered and implemented

Measure	Impact on CII	Time and method of implementation and responsible personnel	Impediments and contingency measures
Speed reduction-deployment plan	3.3% reduction	**Milestone:** Change in deployment and vessel's speed from 1 Jan 2023. Aforementioned Plan D is chosen to control and comply with the annual operational CII requirements. **Due:** Jan 2023. **Responsible:** Commercial, Operation and Ship Management Teams.	**Impediment:** Port delays, congestion, weather conditions, casualty. **Contingencies:** Monthly monitoring of the CII performance by Ship Management. If significant impact CII performance is observed, an emergency meeting to be held with all stakeholders to address the underlying issues and improve the CII performance. **Responsible:** Ship Management.

2.2 Calculation showing the combined effect of the measures and that the required operational CII will be achieved

DCS year	Required annual operational CII	Targeted operational annual CII	Targeted rating
2023	13.79	16.01	D
2024	13.50	15.4	D
2025	13.21	15.4	D
2026	12.92	13.6	C

3. Self-evaluation and improvement:

A monthly CII scorecard is published to establish the gap between the planned and the actual performance of the vessel. In case of significant divergence, a meeting with relevant stakeholders is called to address the CII underperformance.

Figure 22: Monthly CII scorecard.

ONE PAGE GUIDE

If attained EEXI is less than required EEXI,
value will be in green, meaning vessel has met requirements,
otherwise it will be in red,
and please contact fleet efficiency for more information.

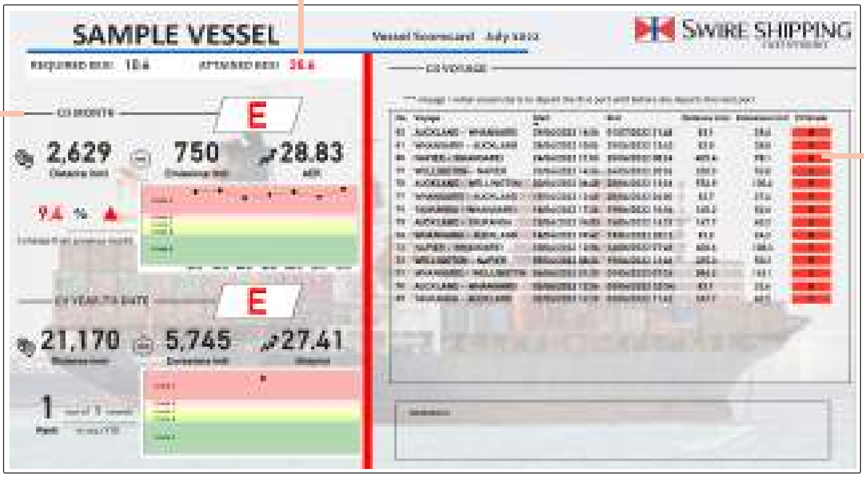
SWIRE SHIPPING
FLEET EFFICIENCY

Vessel is being given a CII rating ranging from A to E, and the ratings thresholds will become more stringent towards 2030.

- A: Excellent
- B: Good
- C: Satisfactory
- D: Below Average
- E: Poor

Vessel is recommended to achieve at least a C rating from 2023.

Annual CII is only being considered by IMO, but Monthly CII helps to improve vessel transparency from monthly performance.



Each voyage is being accessed and given a CII rating from the distance sailed and emissions produced.

Since the definition of voyage duration relates to when vessel leaves first port until before she leaves the next port, this would infer that the longer the vessel remains at port during the voyage, the higher likelihood that vessel will attain a worse rating.

* CII (Carbon Intensity Indicator) - ship's carbon emissions relative to the amount of cargo carried over a certain distance.
* CII is also called AER (Annual Efficiency Ratio), and it acts mostly as an operational lever.
* CII = Annual CO2 Emissions / (DWT x Distance Travelled)
* CII unit: gmCO2/DWT Ton-Mile

Visit our website for more

www.zerocarbonshipping.com

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for Zero Carbon Shipping