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ENERGY EFFICIENCY OF SHIPS

Key drivers of the CII rating system

Submitted by ICS

SUMMARY

Executive summary:	This document provides a detailed examination of the factors affecting the Carbon Intensity Indicator (CII) ratings of ships within a shipping company's fleet.
Strategic direction, if applicable:	3
Output:	3.2
Action to be taken:	Paragraph 15
Related documents:	MEPC 78/17, MEPC 78/7/22; MEPC 79/7/13, MEPC 79/INF.19; MEPC 81/INF.28, MEPC 81/INF.29, MEPC 81/INF.30; ISWG-GHG 12/2/1, ISWG-GHG 12/2/2, ISWG-GHG 12/2/3 and ISWG-GHG 12/2/6

Introduction

1 This document reports information that is relevant to the ongoing review of the CII rating system. The review must be completed by 1 January 2026.

2 MEPC 78 invited interested Member States and international organizations to collect relevant data in the early years of implementation of the CII rating system and to report relevant information to the Committee (MEPC 78/17, paragraph 7.81).

Background to the Shipping Company d'Amico Società di Navigazione SpA

3 The origins of the family business date back to 1936. d'Amico Società di Navigazione SpA, the Group holding company, was incorporated in Rome in 1952. With the core business focusing both on the dry cargo and product tankers sectors, the d'Amico Group also provides international shipping services internally to its companies and to third parties. As of the end of 2023, d'Amico Group operated 36 product tankers and 37 dry bulk carriers and employed 260 personnel onshore and 2,117 personnel on board (taking into account the staff rotation on d'Amico Group ships).

4 d'Amico's fleet is relatively modern, with an average age of 8.8 years for tankers and 6.7 years for dry cargo, compared to an average in the product tankers industry of 13.5 years for MR ships and 14.8 years for LR1s, and 11.5 years for dry bulk carriers. d’Amico International Shipping S.A. (DIS) is the d'Amico Group division operating in the product tankers sector.

5 d'Amico's values are listed on their website and include:

> "Respect for the environment is a priority. Safeguarding the planet and a strong focus on future generations guide our investment choices, without compromises. At all times, we take care of our seas and promote a sustainable lifestyle for our people."

6 During 2023, d'Amico carried out a detailed study of the factors affecting the CII ratings of their fleet of product tanker carriers. The results were presented at RINA's CII Conference which was held at IMO in January 2024. A copy of d'Amico's paper is included within the annex to this document.

Comparison of sister ships

7 d'Amico's analysis included a comparison of seven oil/chemical tankers which are sister ships. The ships are all managed by d'Amico Società di Navigazione SpA and were built by Hyundai Mipo Dockyard (HMD) and Hyundai Vinashin (HVS) between 2014 and 2017 with the same engine design, propeller, hull form and nearly identical attained EEDI.

Table 1: d'Amico sister ships – principal particulars

	Ship main data
DWT	50 K
LOA	183.11 m
Breadth	32.20 m
Depth	19.40 m
Design draft	11 m
Main engine	M E 6S50 ME-B, 7,180 kW x 87.1 rpm
Diesel generator	6H21/32, 850 kW x720 rpm
Inert gas generator	4,500 m^3/h
Cargo pumps	12,600 m^3/h x 12 5MLC
Propeller	FPP, diameter 6.8 m

8 In figure 1 below, CII scores are plotted based on CO_2 emitted and miles run in the first 10 months of 2023. Despite being of the same design and being consistently operated by the same company, the ratings of the seven sister ships, varied from A to D. d'Amico concluded that the variance is due to the individual trading patterns which affect the average length of their voyages and the amount of time they are required to wait.

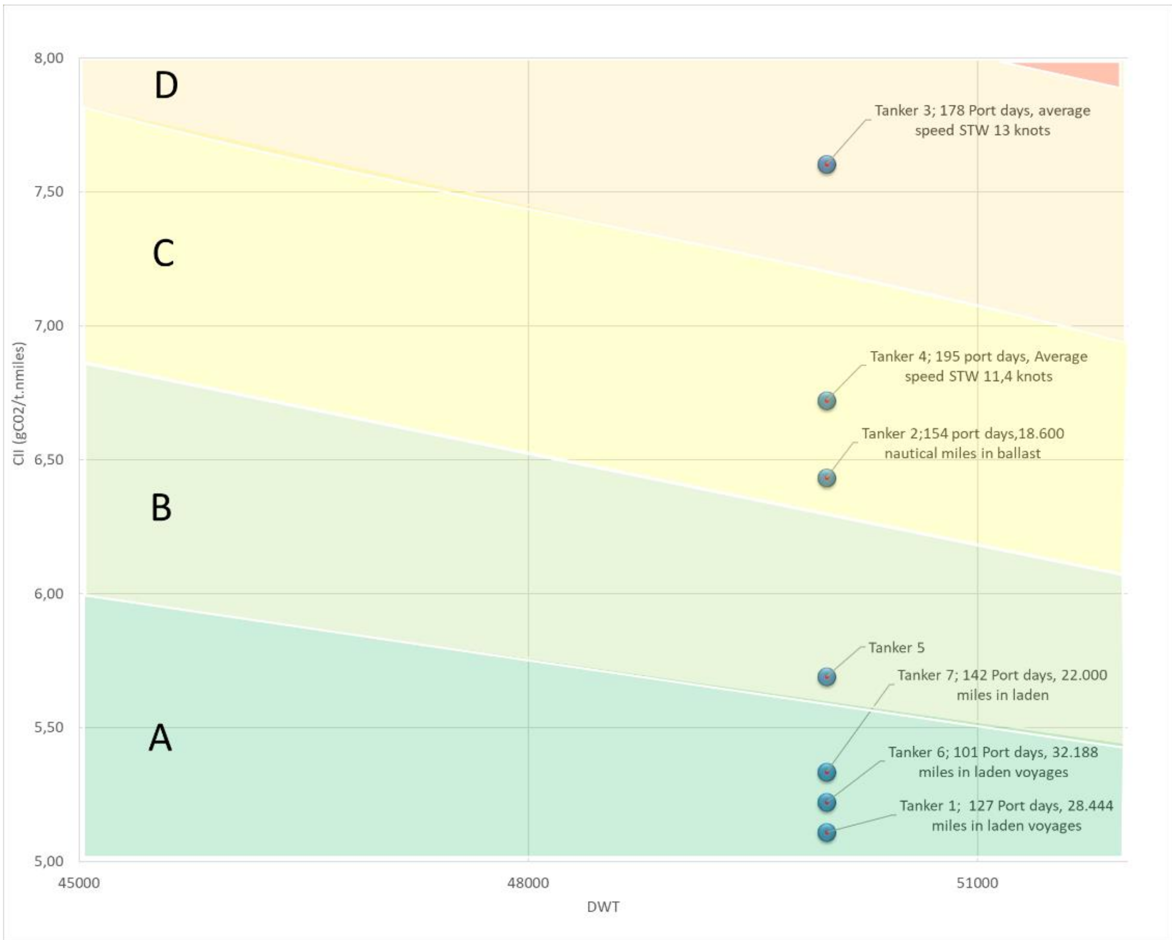

Figure 1: CII ratings for the tanker sister ships (first 10 months of 2023 data)

9 Tanker 3 achieved a poor D rating because it spent approximately half of the year (175 days) in-port/anchorage. When a ship remains for extended periods of time at anchor or in-port, and despite consuming relatively low amounts of fuel to run generators, the CII score goes to infinity. This is because distance travelled in the denominator of the equation is zero. Tanker 4 suffered similarly, having spent 195 days at/in port/anchor.

10 With a CII rating of A, tankers 1, 6 and 7 were kept very busy and employed on long voyages. Despite resulting in higher quantities of fuel consumed, long voyages are highly favourable in the CII calculation because they result in fewer voyages in a given year and therefore less time in-port where the ship emits CO_2 from diesel generators and cargo equipment, but does not accumulate miles run in the denominator of the CII equation.

11 In terms of the impact of short voyages and port waiting time, these findings closely align with those presented in documents ISWG-GHG 12/2/1 (BIMCO et al.), ISWG-GHG 12/2/2 (IPTA et al.), ISWG-GHG 12/2/3 (Malaysia et al.), ISWG-GHG 12/2/6 (Liberia), MEPC 78/7/22 (India), MEPC 79/7/13 (Bahamas et al.), MEPC 79/INF.19 (INTERCARGO) and MEPC 81/INF.28 through MEPC 81/INF.30 (INTERCARGO).

Study conclusions

12 The study concludes that the present CII metric is more prone to reflect a "trade" rather than the "efficiency" of the transportation. In effect, the operational profiles can overwhelm a ship's technical attributes, even for the most advanced, energy-efficient ship.

13 More specifically, the inclusion of fuel consumption when the ship is not under way in the calculation of the attained CII poses challenges for a functioning CII framework because:

.1 ships are penalized for time spent at ports, despite the fact that the length of port calls is completely outside the control of the ship. The duration of port calls depends on the efficiency and limitations of the port or terminal;

.2 ships engaged in short sea shipping are penalized because the nature of the trade includes significantly more port calls compared to long haul trades;

.3 in periods of reduced demand and consequential oversupply of ships, some ships will wait at anchorage for long periods until new orders are received. This waiting time at anchorage results in a deterioration of the ship's attained CII; and

.4 some ports and terminals are notorious for congestion, meaning that ships have to wait at anchorage for prolonged periods of time before being able to load or unload their cargo. This leads to some trades being disproportionally impacted by the CII framework, to such a degree that they could be characterized as inferior trades.

14 The ships with the best Annual Efficiency Ratio (AER) are also those always trading in ballast condition without any cargo on board. As a result, the current metric penalizes efficiently operated ships carrying cargo, while favouring inefficiently utilized empty ships. Whereas the metric AER favours ships in ballast condition, the voluntary metric currently used for trial purposes – the Energy Efficiency Operational Indicator (EEOI) severely penalizes them. Neither is appropriate. Ballast condition is an integral part of a ship's normal operation and should neither be favoured nor severely penalized.

Action requested of the Committee

15 The Committee is invited to consider the report as set out in the annex to this document, and to ensure that all such identified anomalies are fully addressed during the ongoing review of the CII rating system.

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ANNEX

AT THE DISCOVERY OF CII BEHAVIOUR

C D'Apì, d'Amico Società di Navigazione SpA, IT

SUMMARY

CII and EEXI are two complementary indicators for measuring ship efficiency. Understanding the practical implication of adopting the CII requires an analysis of the differences in formula between the two indicators. Among the various factors that rapidly deteriorate the CII ranking, the most important factors are: many short voyages and port waiting times.

The CII is strongly dependent on the "size" of the ships, and thus, the ship's operational profile and use of commercial plants influence its value. Moving from the Handy size to the Cape size, we observe how the size effect has a benefit on staying in a "good" ranking for multiple years. CII shows a wide variance among sister ships. Certainly "slow steaming" gives a positive effect on remaining in the same class ranking, hardly on making a jump in class. "Technical retrofits" unless draconian measures are adopted, have a very limited effect on the CII.

The use of "biofuel blends" from renewable sources as established at the recent MEPC 80 certainly gives a benefit for ranking improvement.

However, there are contradictions to how the CII formula has been designed, such as the benefit that ships get by doing more miles in ballast than laden, and this makes the CII in some respects an index of inefficiency. The adoption of additional correction factors such as waiting time, dry dock days, and short voyages can make the formula more robust.

In this context, "real-time monitoring" of the CII is a strategic element to catch changes in the ranking in time and take corrective actions mainly operational before the ship ends up in a ranking that requires SEEMP amendments.

NOMENCLATURE

Cf	Carbon factor
CII	Carbon Intensity Indicator (gCO_2/tons-nautical miles)
CO2	Carbon dioxide
CPP	Clean Petroleum Product
DPP	Dirty Petroleum Product
DWT_{max}	Deadweight at scantling draft
EEDI	Energy Efficiency Design Index (gCO_2/tons-nautical miles)
EEXI	Energy Efficiency Existing Ship Index (gCO_2/tons-nautical miles)
GHG	Greenhouse gas
IAEET	Innovative Auxiliary Engine Efficiency Technologies emissions saving
IPEET	Innovative Propulsion Energy Efficiency Technologies emissions saving
ISCC	International Sustainability and Carbon Certification
JIP	Joint Industry Project
LR 1	Long Range tanker
MCR	Maximum continuous rating
MR	Medium Range tanker
PBCF	Propeller Boss Cap Fin
POME	Palm oil Mill effluent
PTI	PTI shaft motor emissions
Rpm	Revolutions per minute
STS	Ship to Ship
TTW	Tank to wake
WTW	Well to Wake

1 INTRODUCTION

The International Maritime Organization (IMO) has set ambitious decarbonization targets for the shipping industry, and the key dates for compliance are edging closer. By 2030, IMO aims to reduce ships' carbon emissions per transport work by at least 40% compared to 2008. This should be done in parallel with an overall reduction of greenhouse gas (GHG) emissions on well-to-wake by 100% by 2050 as established during MEPC 80.

To accomplish this, the Marine Environment Protection Committee (MEPC) is increasingly passing regulations devoted to minimizing the marine sector's carbon emissions and environmental impact.

In June 2021, MEPC put forward two new regulations as practical short-term measures to deploy the levels of ambition into the decarbonization path: the Energy Efficiency Existing Ship Index (EEXI) and the Carbon Intensity Indicator (CII)[1].

The EEXI measures CO_2 emissions per transport work, purely considering the ship's design parameters EEXI does not require any measurement or reporting of true CO_2 emissions while the ship is in operation. EEXI is the sister to EEDI, Energy Efficiency Design Index, which has been in force since 2013[9]. These indexes measure the same in practice; however, EEDI is applied to new ships while EEXI applies to existing ships.

Simplified, EEXI estimates CO_2 emissions per transport work (grams of CO_2 per ton-miles), although the equation is more complex, accounting for possible reduction factors, energy-saving equipment, etc. [5].

$$EEXI = \frac{C02\ emissions}{Trasportation\ work}$$

$$EEXI\left[\frac{gC02}{tons - nmiles}\right] = \frac{ME\ emissions + Aux\ engine\ emissions + (\ PTI - IAEET) - IPEET}{Capacity\ *\ Reference\ speed * Reduction\ Factors}$$

As EEXI and EEDI aim to improve the global fleet's energy efficiency, there is a maximum threshold level that the index must fall below. The reference line forming the requirement level was implemented in 2013, with the requirement getting stricter every five years (from 2015). The baselines were created for every ship type separately using regression analysis of operation data. Currently, any new ships operating in international waters, with a gross tonnage over 400, must meet EEDI Phase 2 requirements. In most ship types and sizes, this is 20% below the original EEDI reference line[2].

The required EEXI is expressed as a reduction percentage to the EEDI Phase 0 reference line. In general, the required EEXI will be in line with the reduction factors required for Phase 2 of the EEDI with a few exceptions.

The CII instead measures the "*actual*" CO_2 emissions calculated by the following simplified formula, where the numerator is total CO_2 emitted from the ship during the calendar year, regardless of whether the ship was sailing at loaded or ballast draft, discharging cargo in-port, waiting at anchor, sustaining cargo during transit (refrigeration, heating or special services), or any other typical activity. The denominator is the official deadweight capacity of the vessel (at scantling draft) multiplied by the total miles travelled during the year, again regardless of the activity or the condition of the vessel. Some correction factors have been approved for specific type of ships for certain activities[4]. As can be seen from the formula, a vessel that sits at anchor all year running her generators could theoretically achieve a CII of infinity[3].

$$CII\left[\frac{gC02}{tons - nmiles}\right] = \frac{Actual\ C02\ emissions}{Dwt_{max}\ x\ Actual\ Miles\ traveled} * correction\ factors$$

Based on the result of the above equation, the ship is assigned a ranking in letter grade format (A, B, C, D, or E)[6]. An "A" ranking results from a CII value that is well below the maximum allowable value for that type of vessel, and an "E" ranking results from a CII value that is well above the maximum allowable value. A ship that receives a "D" ranking for three consecutive years, or an "E" ranking for one year, will be required to develop a plan for corrective action.

The problem many owners have with CII is that they are often not in control of whether the ship makes short trips or long trips, or even how fast the ship needs to transit between ports in order to be in position for when the third-party terminal is ready to transfer the cargo to or from the ship. Those decisions rest primarily with the charterers of the ship, the operators of the terminals, and are affected by market dynamics in general. But currently, it is solely the shipowner who will bear the consequences (commercial or otherwise) if those operational decisions result in a poor CII grade. Another shortcoming with CII is that it does not take into account the actual weight of cargo carried by the ship during the course of the year. Instead, it assumes the ship is carrying its full rated DWT capacity all of the time. This makes it impossible to differentiate and reward ships that are operated more efficiently by their owners and/or charterers on a ton-mile basis. A ship that carries more cargo longer distances throughout the year provides a greater benefit to society per unit emission than a ship that sails around empty most of the year.

2 CII VS EEXI IN A NUTSHELL

Although CII uses the same unit as EEXI (gCO_2/ton-nautical miles), the two are not comparable.

EEXI calculation is one off (some call it a "ticket-to-game") while the CII is on a yearly basis. It is also a technical regulatory measure, whereas CII is an operational measure.

CII is a yearly average based on what the ship actually fuel burns, whereas EEXI uses the theoretical amount of fuel needed for the part of the ship's power plant contributing to propulsion. CII thus includes fuel used for cargo operations, heating, refrigeration, inerting, cargo transfer, tank washing, cargo hold ventilation, ballast water exchange, which EEXI does not.

While ships are never operated according to their design (EEXI is based on 75% or 83% MCR if a power limitation is deemed necessary be applied[5]), CII is a direct reflection of their actual operation, even if it allows for some exemptions (e.g. ice conditions, STS operations, scenarios specified in regulation 3.1 of MARPOL Annex VI, which may endanger safe navigation of a ship).

CII is ship specific as opposed to fleet specific. It applies to ships larger than 5,000 GT, which itself prevents comparison with EEXI/EEDI, since those regimes categorize ships (except for cruise ships) by DWT. Generally speaking, there are more ships that need to report CII than ships that need to comply with EEXI.

CII makes use of reference lines to which ships must relate their yearly reduction factors as agreed at MEPC 76: 1% per year reduction rate from 2020-2022 (3% in total), and 2% per year from 2023-2026 (8% in total) to make up the 11% by 2026[7]. However, CII reduction factors were only set until 2026, rather than 2030 as was anticipated. This means that the 2026 review, in addition to evaluating the implementation experience, will need to re-examine the reference lines in order to complete and finalize the reduction factor table with the years from 2026 until 2030. The reference line for the EEXI instead has been fixed as well as the reduction factor corresponding generally to 20%.

A final important thing to touch on is the rating system used with CII. This system illustrates the level of compliance by means of different zones or bandwidths – A being the best, E being the worst. At a minimum, a ship must be within bandwidth C. However, the ship is given no direct incentive to be in A or B, and the current level of enforcement creates almost no incentive to leave D and E.

3 CII BEHAVIOUR

d'Amico Società di Navigazione SpA, manages a large fleet of tankers and bulk carriers in a variety of trades worldwide, ranging in size from 40k dwt to 75k dwt for the tankers and from 37k dwt to 117k dwt on bulkers. The fleet is among the youngest in the industry with an average age of 7.6 years for tankers and 5.9 years for dry cargo.

In 2022, 88.2% of the bulk carriers are already compliant with EEDI Phase 2, thus with EEXI requirements.

As regards the tankers, 60.7% of the ships are compliant with EEDI Phase 2 and 17.9% with Phase 3 in 2022. The percentage of tankers compliant with the EEXI is therefore 89.3%.

3.1 SIZE EFFECT

A sensitivity study for the size effect has been done among three classes of tankers: LR1, MR and Handy size.

For the scope, we assumed three different operational profiles related to the years 2021, 2022 and the first 10 months of 2023 (table 1) predicting the CII ranking for the period 2023-2026.

LR1 is mainly operated in long hauls, spending fewer port days and more time in laden. LR1 is mainly employed in CPP mode which does not require cargo conditioning.

Handy tankers are mainly operated in short voyages, spending less time in ballast and more port days. Handy tankers are mainly employed in DPP mode which does require cargo conditioning. In addition, many short voyages lead to many cargo operations (loading/unloading).

Table 1: Operational profile related to the first 10 months of 2023

Ship size	Average total nautical miles	Average ballast miles	Average laden miles	Average anchorage/port days	Average speed STW
Handy	35,095	14,456	19,839	160	12.5
MR	40,301	14,617	24,800	141	12.6
LR1	45,506	14,779	29,761	123	12.7

The graphs in figure 1.2.3, show how the size and thus the operational profile allows the LR 1 to be more resilient in remaining in good class rating mainly between "A" to "C". MR tankers between "B" and "D". While handy tankers mainly between "D" and "E".

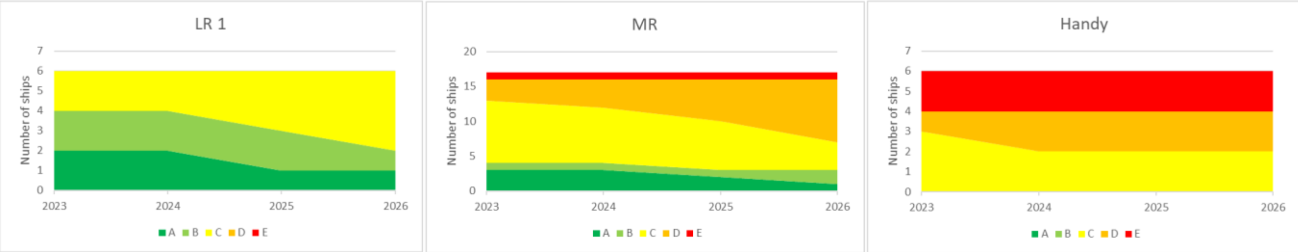

Figure 1: CII prediction basis on the 2023 operational profile

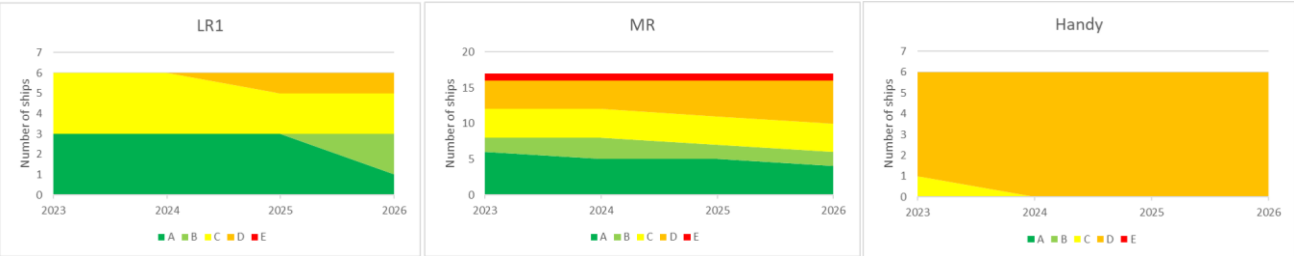

Figure 2: CII prediction basis on the 2022 operational profile

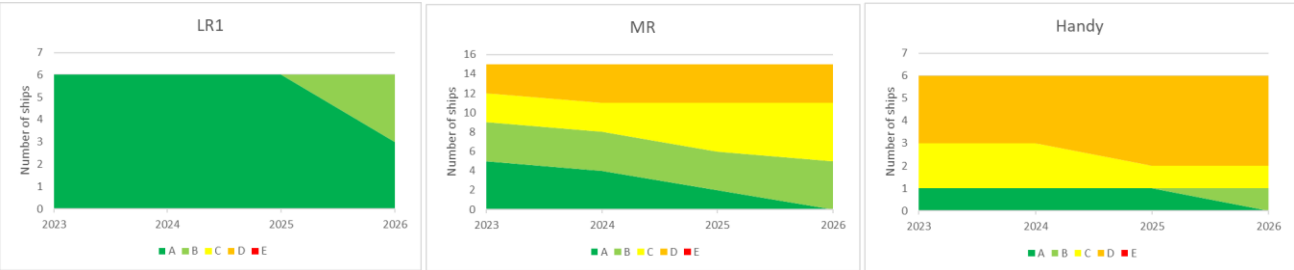

Figure 3: CII prediction basis on the 2021 operational profile

3.2 WIDE VARIANCE AMONG SISTER SHIPS

No correlation exists between a good ship design and the CII attained values. Ships with the same EEXI/EEDI values can achieve anywhere from "A" to "E" score.

A case study has been done among seven sisterships oil/chemical tankers managed by d'Amico Società di Navigazione SpA and delivered in Hyundai Mipo Dockyard (HMD) and Hyundai Vinashin (HVS) between 2014 and 2017 with the same engine design, propeller, hull form and nearly identical attained EEDI very close to the phase 3 (see table 2). A similar study has been commissioned by the Blue Sky maritime coalition.

Table 2: Sister ship principal characteristics

	Ship main data
DWT	50 K
LOA	183.11 m
Breadth	32.20 m
Depth	19.40 m
Design draft	11 m
Main engine	ME 6S50 ME-B, 7,180 kW x 87.1 rpm

	Ship main data
Diesel generator	6H21/32, 850 kW x720 rpm
Inert gas generator	4,500 m^3/h
Cargo pumps	12, 600 m^3/h x 125MLC
Propeller	FPP, diameter 6.8 metres

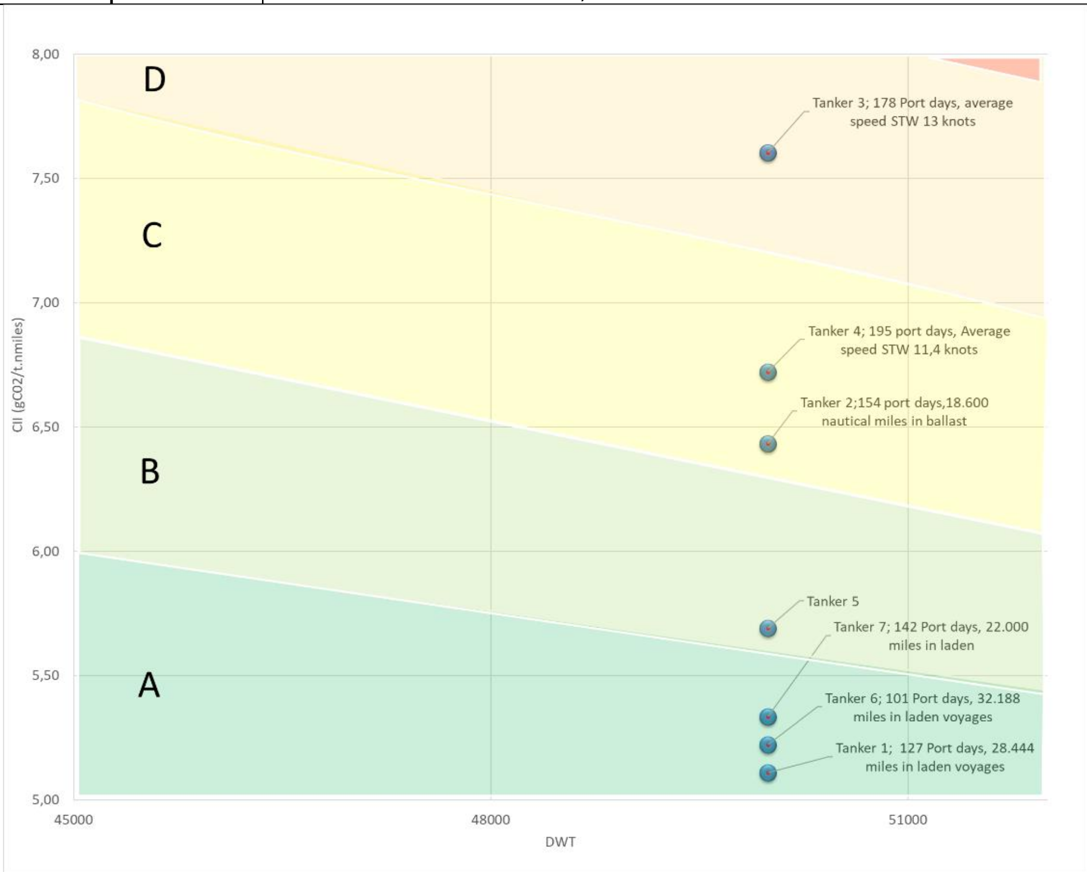

Figure 4: CII rating for tanker sister ships (first 10 months of 2023 data)

CII scores are plotted based on CO_2 emitted and miles run in the first 10 months of 2023. The seven sisterships, shown in blue in figure 4, fall on a vertical line on the graph because they have identical deadweight capacities. Tanker 3 is at the top of the graph and Tanker 1 is at the bottom. While Tanker 1 achieved "A" grade in 2023, tanker 3 achieved a "D" grade. The remaining five ships of the class are distributed evenly between those two extremes. The variance has nothing to do with their highest design and everything to do with the individual trades they are in and their respective commercial requirements (including ordered speed) which affect the average length of their voyages and the amount of time they are required to wait.

Tanker 3 achieved a poor CII score in the first 10 months of 2023 because it spent approximately half of the year (175 days) in-port/anchorage. When a ship remains for extended periods of time at anchor or in-port, running her generators the CII score goes to infinity. With no accumulation of miles transited, the denominator of the equation is zero. This has a significant negative impact on the CII score and resulting ranking. Tanker 4 suffered similarly, having spent 195 days in-port/anchor however it was operated at 11.4 knots against tanker 1 which was operated at an average speed of 13 knots resulting in less main engine consumption and better rating.

Tankers 1 and 6 were kept very busy and employed in long hauls (48,674 total miles/127 port days and 53,316 total miles/101 port days respectively). Long voyages are highly favourable in the CII calculation because they result in fewer voyages in a given year and therefore less time in-port where the ship emits CO_2 from diesel generator and cargo equipment (inert gas generator, water ballast treatment system, etc.) but does not accumulate miles run in the denominator of the CII equation. A little bit better performance for tanker 6 because it did fewer miles in laden condition.

Tanker 7 was also rated "A" despite 145 days in-port/anchor. Against tankers 1 and 6 it was the favourite by fewer miles in laden voyage and thus less consumption.

3.3 ECO STEAMING EFFECT

To assess the effect of "ECO steaming" for the CII rating, a case study has been done with tanker 3 selected among the seven sisterships (see table 2) calculating the CII rating at 14 knots and at 13 knots in normal seagoing condition with the following assumptions:

.1 ME power spent at sea calculated as average between design draft and ballast draft;

.2 15% of sea margin;

.3 5% of hull margin;

.4 electric load calculated in normal seagoing condition;

.5 electric load in-port as average between loading and discharging operation including the use of water ballast treatment system;

.6 CPP mode (no heating);

.7 no product change (no tank washing, only inerting);

.8 no correction factors or voyage adjustment; and

.9 no adverse weather conditions.

Tanker 3 has a daily consumption of 25.7 tons of fuel in normal seagoing conditions at 14 knots and 5.9 tons of fuel per day while in-port with the above assumptions. The only parameter that changes is the sailing days with a higher figure corresponding to a ship with long voyages and relatively little time in-port. Conversely, a low figure for sailing days corresponds to a ship with short voyages and a higher percentage of time in-port over the course of a year (see figure 5).

Sailing days	85	105	125	145	165	185	205	225	245	265	285
Port days	280	260	240	220	200	180	160	140	120	100	80
Sailing speed (knots)	14	14	14	14	14	14	14	14	14	14	14
Average sailing consumption (t/days)*	25,7	25,7	25,7	25,7	25,7	25,7	25,7	25,7	25,7	25,7	25,7
Average port consumption (t/days)**	5,9	5,9	5,9	5,9	5,9	5,9	5,9	5,9	5,9	5,9	5,9
Total consumption (tons)	3830	4227	4624	5021	5419	5816	6213	6610	7007	7404	7801
Miles travelled	28560	35280	42000	48720	55440	62160	68880	75600	82320	89040	95760
CII (gco2/t nmiles) @14 knots	8,35	7,46	6,86	6,42	6,09	5,83	5,62	5,45	5,30	5,18	5,07
Rating	D	D	C	C	B	B	B	A	A	A	A
CO2 emission (tons) @14 knots	11927	13164	14400	15637	16873	18110	19346	20583	21819	23056	24292

Figure 5: CII and total CO_2 emitted vs transiting days at 14 knots

At 13 knots, tanker 3 has a daily consumption of 21 tons of fuel in normal seagoing and 5,9 tons of fuel per days while in-port with the above assumptions (see figure 6).

Sailing days	85	105	125	145	165	185	205	225	245	265	285
Port days	280	260	240	220	200	180	160	140	120	100	80
Sailing speed (knots)	13	13	13	13	13	13	13	13	13	13	13
Average sailing consumption (t/days)*	21,0	21,0	21,0	21,0	21,0	21,0	21,0	21,0	21,0	21,0	21,0
Average port consumption (t/days)**	5,9	5,9	5,9	5,9	5,9	5,9	5,9	5,9	5,9	5,9	5,9
Total consumption (tons)	3431	3734	4037	4340	4643	4946	5249	5552	5855	6158	6461
Miles travelled	26520	32760	39000	45240	51480	57720	63960	70200	76440	82680	88920
CII (gco2/t nmiles) @13 knots	8,06	7,10	6,45	5,98	5,62	5,34	5,11	4,93	4,77	4,64	4,53
Rating	D	D	C	B	B	A	A	A	A	A	A
CO2 emission (tons) @13 knots	10683	11627	12571	13515	14458	15402	16346	17290	18233	19177	20121

Figure 6: CII and total CO_2 emitted vs transiting days at 13 knots

Certainly "slow steaming" gives a positive effect to remain in the same class ranking, hardly on making a jump in class which happens only within relatively narrow ranges of annual sailing days.

Reducing the overall average speed from 14 knots to 13 knots would have improved the ship's grade only in these cases:

.1 from "D" to "C", if the sailing days fell within approximately 110 and 125 annually;

.2 from "C" to "B" if the sailing days fell within approximately 137 and 162 annually; and

.3 from "B" to an "A" if the sailing days fell within approximately 173 and 215 annually.

But in most other cases the ship's grade would not have improved if the ship's speed were reduced from 14 knots to 13 knots.

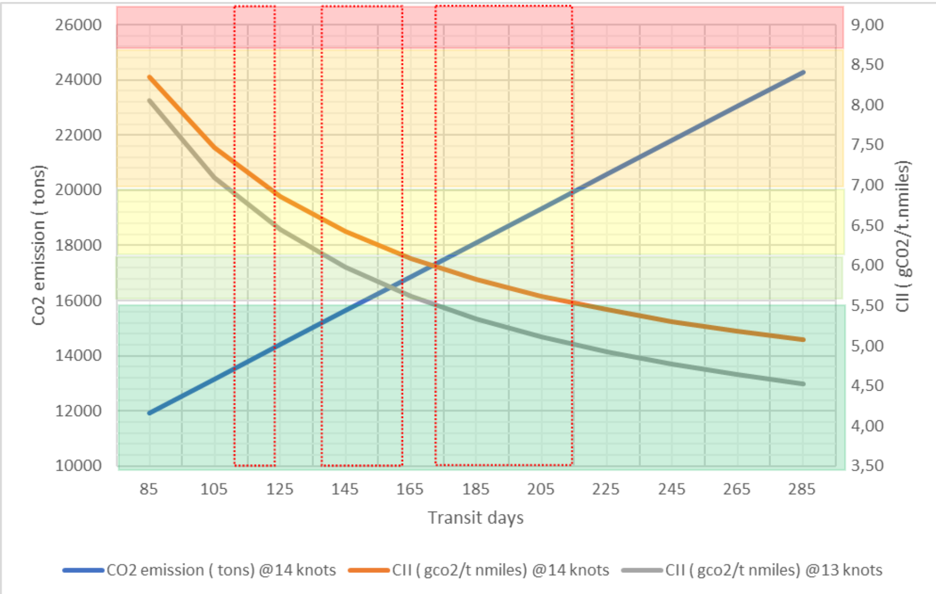

Figure 7: CII rating vs days transiting at 14 and 13 knots

If the goal is to reduce absolute carbon emissions, the above analysis points directly to the inherent flaws of the formula as constructed. The higher the number of sailing days, the higher the absolute level of carbon emissions. Yet, the highest absolute level of carbon emissions perversely corresponds with the best CII rating.

3.4 PORT DAYS EFFECT

Analysing the same graphs in figure 7, it can be concluded that port days/waiting time alone has a profound impact on the CII score. The same vessel with the same fuel efficiency can achieve anywhere from an "A" grade to a "D" grade depending on the number of sailing days, all else being equal.

Data gathered by the whole tanker fleet managed by d'Amico Società di Navigazione allows to further confirm that the CII is mirroring the port/anchor days (see figure 8).

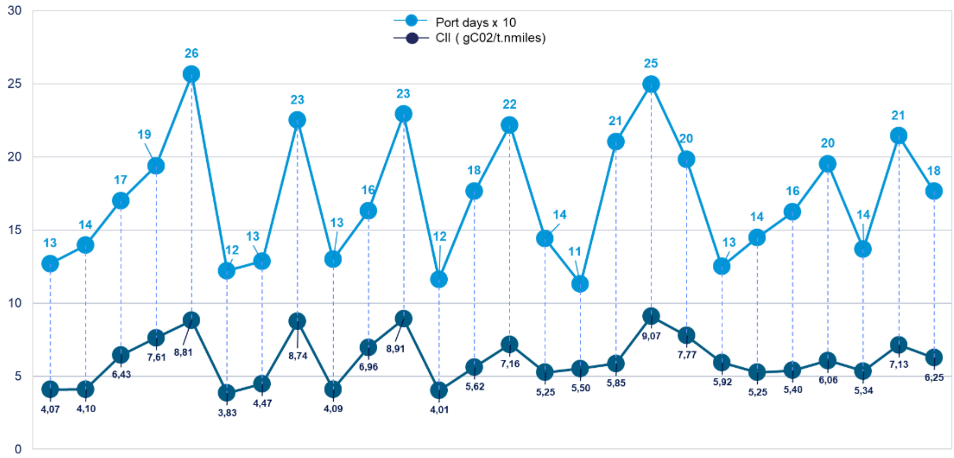

Figure 8: CII mirroring port days (data 2021)

4 BIOFUEL BLENDS AND CII

In June 2021, d'Amico Società di Navigazione launched a Joint industry Project (JIP) to test the biofuel blends (B30) derived from advanced second-generation feedstock. The composition of biofuel blend was:

.1 POME (Palm oil mill effluent): 30%; and

.2 VLSFO (Very low sulphur fuel oil 0,5% Sulphur max): 70%.

The development of POME oil is in keeping with the sustainability principles of ISCC and is qualified as waste under ISCC. Advanced Biofuel Renewable Energy Directives RED II Annex IX of 2018 now includes Palm Oil Mill Effluent (POME) as a suitable feedstock for Biofuels, to be reviewed again in 2030.

The ultimate objective of the project was to certify the possible reduction of CO_2 emissions using the so called well-to-wake (WTW) analysis confirming that the use of biofuel B30 does not affect the Tier II certification of the engines for the NO_x compliance and to test the effect on the CII.

Trials were conducted from 19 June 2021 up to 6 July 2021 on board one of its managed LR1 product tanker already in EEDI phase 2.

Both main engine and diesel generators were tested under the Administration flag deviation till the result of NO_x emissions.

The outcomes of the project are summarized below:

.1 drop in solution which means that the biofuel blends can be used without modifications or specific engine settings;

.2 NO_x emissions within the allowable limit for both main engine and diesel generators considering the expected variability in measurement and calculation allowed by the NO_x technical code;

.3 positive effect on the CO_2 reduction on well-to-wake basis, marginal on tank to propeller basis; and

.4 positive effect of the CII and class rating on well to wake basis.

Learn more @ Articles: Our Decarbonisation Journey: d'Amico International Shipping (nepia.com)

4.1 BIOFUEL BLENDS EFFECT

To assess the biofuel blends effect for the CII, a case study has been done on a Handy size tanker starting from the result of the JIP and applying the latest interim guidance (MEPC.1/Circ.905) which addresses how to calculate the relevant Cf for marine biofuel blends[8].

As per circular MEPC.1/Circ.905, biofuels will be considered "sustainable" that have been certified by a sustainability certification scheme (e.g. ISCC or RSB), and providing a well-to-wake GHG emissions reduction of at least 65% compared to the well-to-wake emissions of fossil MGO of 94 gCO_2eq/MJ (i.e. achieving an emissions intensity not exceeding 33 gCO_2eq/MJ).

The well-to-wake GHG emissions value of the fuel mentioned on the sustainability certificate (expressed in gCO_2eq/MJ) is multiplied by its lower calorific value (LCV, expressed in MJ/g) for the purpose of regulations 26, 27 and 28 of MARPOL Annex VI to determine a CF value.

For blends, the CF should be based on the weighted average of the CF for the respective amount of fuels by energy.

Biofuels not certified as "sustainable" or not fulfilling the well-to-wake emission factor criteria should be assigned a CF equal to the CF of the equivalent fossil fuel type.

The Handy size tanker under consideration is rated "D" at the end of October 2023 having accumulated 32,180 miles and burned 2,327 tons of LSFO and 986 tons of MGO.

The sensitive study as reported in table 5 has been performed with the following assumptions:

.1 energy intensity of feedstock varying fm 33 to 9 gCO_2/MJ;

.2 adjustment in fuel consumption due to low calorific value of blending vs the LSFO;

.3 no correction factors applied for the CII calculation; and

.4 replaced the quantity of LSFO with the sustainable biofuel blend keeping the original quantity of MGO and miles.

Table 5: CII sensitivity study for B30 varying energy intensity

Feedstock Energy Intensity (gC02e/MJ)	33	33	30	27	24	21	18	15	12	9
Feedstock LCV (MJ/g)	0.0395	0.0395	0.0395	0.0395	0.0395	0.0395	0.0395	0.0395	0.0395	0.0395
HFO LCV (MJ/g)	0.0405	0.0405	0.0405	0.0405	0.0405	0.0405	0.0405	0.0405	0.0405	0.0405
blending %	0	30	30	30	30	30	30	30	30	30
Feedstock Cf (According provisional guidelines adopted by MEPC 80)	1.304	1.304	1.185	1.067	0.948	0.830	0.711	0.593	0.474	0.356
HFO Cf	3.114	3.114	3.114	3.114	3.114	3.114	3.114	3.114	3.114	3.114
MGO Cf	3.206	3.206	3.206	3.206	3.206	3.206	3.206	3.206	3.206	3.206
Blending LCV (MJ/g)	0.0405	0.0402	0.0402	0.0402	0.0402	0.0402	0.0402	0.0402	0.0402	0.0402
Fraction of energy related to the feedstock	0.000	0.295	0.295	0.295	0.295	0.295	0.295	0.295	0.295	0.295
Fraction of energy related to the HFO	1.000	0.705	0.705	0.705	0.705	0.705	0.705	0.705	0.705	0.705
Blending Cf	3.114	2.580	2.545	2.510	2.476	2.441	2.406	2.371	2.336	2.301
Dwt	39,309	39,309	39,309	39,309	39,309	39,309	39,309	39,309	39,309	39,309
HFO consumption (tons) *first 10 months of 2023*	2,327	2,327	2,327	2,327	2,327	2,327	2,327	2,327	2,327	2,327
MGO consumption (tons) *first 10 months of 2023*	986	986	986	986	986	986	986	986	986	986
Total Nautical miles(Nmiles*) first 10 months of 2023*	32,180	32,180	32,180	32,180	32,180	32,180	32,180	32,180	32,180	32,180
HFO consumption adjustment due to lower calorific value	2,327.0	2,344.2	2,344.2	2,344.2	2,344.2	2,344.2	2,344.2	2,344.2	2,344.2	2,344.2

of blending tons)										
CII (gCO_2/t.nmiles)using biofuel	8.23	7.28	7.22	7.15	7.09	7.02	6.96	6.89	6.83	6.76
Improvement %	0.0%	11.5%	12.3%	13.1%	13.9%	14.7%	15.5%	16.3%	17.0%	17.8%
CII rating using biofuel blends	D	C	C	C	C	B	B	B	B	B
CO_2 emission increasing %	0.00%	0.74%	0.74%	0.74%	0.74%	0.74%	0.74%	0.74%	0.74%	0.74%

According to the graph in figure 10, in dropping the energy intensity of the feedstock, the Handy size can achieve a better rating from "D" to "B" with an improvement in ranking up to 18%.

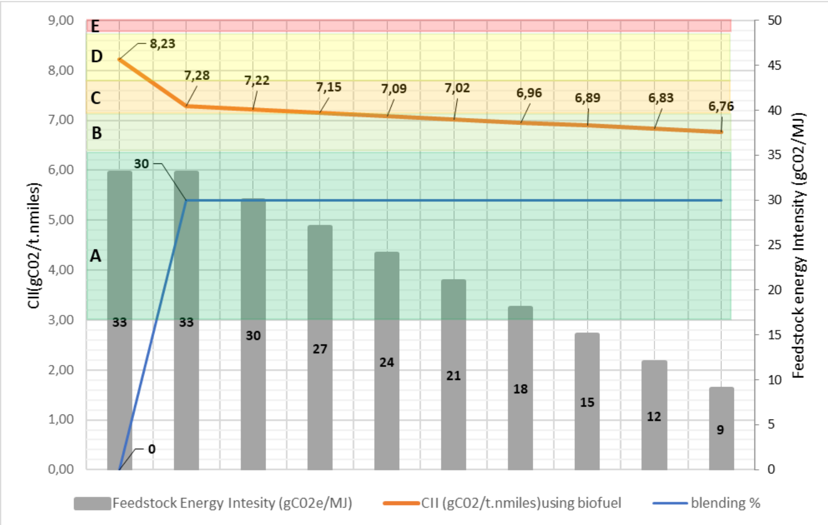

Figure 9: CII Biofuel blends effect varying the energy intensity (data: first 10 months of 2023)

A further sensitivity study has been made keeping the Energy intensity of feedstock and varying the blending ratio from 0 to 100% with the following assumptions:

.1 energy intensity of feedstock of 33 gCO_2eq/MJ;

.2 adjustment in fuel consumption due to low calorific value of blending vs the LSFO;

.3 no correction factors applied for the CII calculation; and

.4 replaced the quantity of LSFO with the sustainable biofuel blend keeping the original quantity of MGO and miles.

The improvement in CII value is about 40%, with a very little increase of total CO_2 emitted of about 2.4% using B100 (see table 6).

Table 6: CII Sensitivity study for different blending %

Feedstock Energy Intensity (gC02e/MJ)	33	33	33	33	33	33	33	33	33	33	33
Feedstock LCV (MJ/g)	0.0395	0.0395	0.0395	0.0395	0.0395	0.0395	0.0395	0.0395	0.0395	0.0395	0.0395
HFO LCV (MJ/g)	0.0405	0.0405	0.0405	0.0405	0.0405	0.0405	0.0405	0.0405	0.0405	0.0405	0.0405
blending %	0	10	20	30	40	50	60	70	80	90	100
Feedstock Cf (According provisional guidelines adoped by MEPC 80)	1.304	1.304	1.304	1.304	1.304	1.304	1.304	1.304	1.304	1.304	1.304
HFO Cf	3.114	3.114	3.114	3.114	3.114	3.114	3.114	3.114	3.114	3.114	3.114
MGO Cf	3.206	3.206	3.206	3.206	3.206	3.206	3.206	3.206	3.206	3.206	3.206
Blending LCV (MJ/g)	0.0405	0.0404	0.0403	0.0402	0.0401	0.0400	0.0399	0.0398	0.0397	0.0396	0.0395
Fraction of energy related to the feedstock	0.000	0.098	0.196	0.295	0.394	0.494	0.594	0.695	0.796	0.898	1.000
Fraction of energy related to the HFO	1.000	0.902	0.804	0.705	0.606	0.506	0.406	0.305	0.204	0.102	0.000
Blending Cf	3.114	2.937	2.759	2.580	2.401	2.220	2.039	1.856	1.673	1.489	1.304
Dwt	39309	39309	39309	39309	39309	39309	39309	39309	39309	39309	39309
HFO consumption (tons) *first 10 months of 2023*	2327	2327	2327	2327	2327	2327	2327	2327	2327	2327	2327
MGO consumption (tons) *first 10 months of 2023*	986	986	986	986	986	986	986	986	986	986	986
Total Nautical miles(Nmiles) *first 10 months of 2023*	32180	32180	32180	32180	32180	32180	32180	32180	32180	32180	32180
HFO consumption adjustement due to lower calorific value of blending (tons)	2327.0	2332.7	2338.5	2344.2	2350.0	2355.7	2361.5	2367.2	2373.0	2378.7	2384.5
CII (gC02/t.n miles)using biofuel	8.23	7.92	7.60	7.28	6.96	6.63	6.30	5.97	5.64	5.30	4.96
Improvement%	0.0%	3.8%	7.7%	11.5%	15.4%	19.4%	23.4%	27.4%	31.5%	35.6%	39.8%
CO_2 emission increasing %	0.0%	0.2%	0.5%	0.7%	1.0%	1.2%	1.5%	1.7%	1.9%	2.2%	2.4%

The use of biofuel allows to lower the CII from 8.23 gCO_2/ton.miles up to 4.96 gCO_2/ton.miles using B100 (see the graph in figure 10).

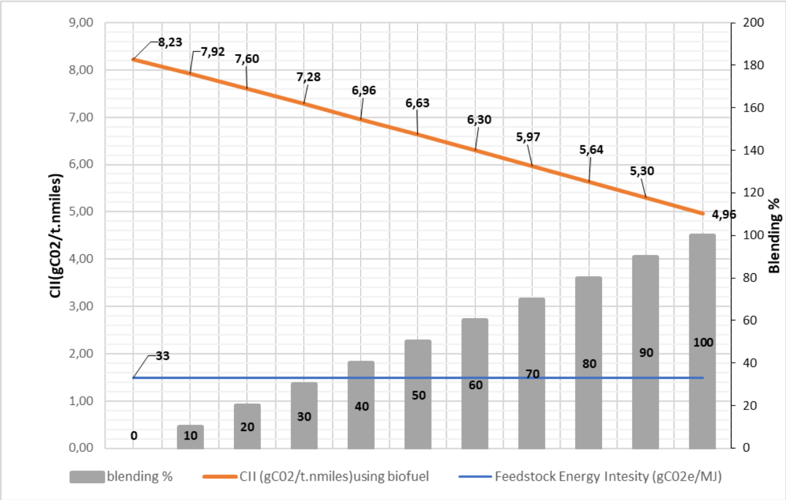

Figure 10: CII Biofuel blends effect varying the blending%
(data: first 10 months of 2023)

5 TECHNICAL RETROFITS AND CII

D'Amico Società di Navigazione Spa has set five pillars to guide, implement and develop the environmental strategy of managed ships in short midterm, focusing on both technical and operational measures. Learn more at en.damicoship.com/media/9873/damico-group-2022-sustainability-report.pdf.

The pillars are:

.1 efficiency;

.2 digitalization;

.3 carbon capture;

.4 biofuel blends; and

.5 derating (only for those ships in EEDI phase 1 or pre EEDI).

As regards the efficiency and digitalization, the following have been adopted so far:

.1 the installation of a main engine Eco Nozzle to boost propulsion efficiency by reducing the SFOC up to 7 g/kWh;

.2 the installation of Propeller Boss Cap Fins (PBCF) and Mewis duct to improve propeller efficiency up to 3%;

.3 the application of very low friction paints to improve hull efficiency up to 2%;

.4 the soft cleaning of hull and propeller to keep the hull efficient;

.5 the application of silicon paint on the propeller;

.6 the replacement of traditional neon with LED lights to increase electric load efficiency (up to 35 tons of fuel saving per ship per year);

.7 the cutting of non-essential consumers in the different operational profiles to improve electric load efficiency;

.8 the application of Condition Based Maintenance;

.9 the monitoring in real time of the CII; and

.10 optimum ship routeing.

The aim is to improve the fleet EEXI of 10% in 2026 against 2019 and the fleet CII of 11% in 2026 against 2019.

5.1 TECHNICAL RETROFITS OUTCOME EFFECT

To assess the effect of "Technical retrofits" on the CII rating, a case study has been done with Tanker 3 selected among the seven sisterships (see table 2) calculating the CII rating with and without PBCF and Eco Nozzles in two operational profiles:

.1 Operational profile [a]: Speed 14 knots, 165 days of sailing time and 200 port days; and

.2 Operational profile [b]:Speed 14 Knots; 200 days of sailing time and 165 of port days.

The following assumptions have been introduced in the case modelling:

.1 Me power spent at sea calculated as average between design draft and ballast draft;

.2 15% of sea margin;

.3 5% of hull margin:

.4 PBCF power saving 3%;

.5 ECO nozzles SFOC average saving: 4 g/kWh;

.6 electric load calculate in normal seagoing condition;

.7 electric load in-port as average between loading and discharging operation including the use of water ballast treatment system;

.8 CPP mode (no heating);

.9 no product change (no tank washing, only inerting);

.10 no correction factors or voyage adjustment; and

.11 no adverse weather condition.

For each operational profile, the CII has been calculated with PBCF fitted and with PBCF combined with ECO Cam fitted evaluating the rating between 2023 and 2026.

Table 7: CII effect due to technical retrofits in the operational profile [a]

	CII (gCO_2/ton.nmiles)	2023	2024	2025	2026
Rating with PBCF	5.97	B	B	B	C
Rating with PBCF+ ECO Nozzles	5.87	B	B	B	B
Rating without PBCF+ ECO Nozzles	6.09	B	B	C	C

Table 8: CII effect due to technical retrofits in the operational profile [b]

Operational profile [b]	CII (gCO_2/ton.nmiles)	2023	2024	2025	2026
Rating with PBCF	5.32	A	A	A	B
Rating with PBCF+ ECO Nozzles	5.23	A	A	A	B
Rating without PBCF+ ECO Nozzles	5.45	A	B	B	B

In both cases, the effect of the technical retrofits is limited to keep the same rating without retrofit for one up to maximum of two years, hardly to make a jump in superior class unless draconian measures are adopted (see tables 7 and 8).

6 CONCLUSIONS

The present CII metric is more prone to reflect a "**trade**" rather than the "**efficiency**" of the transportation.

The cases presented in this paper demonstrate how the operational profiles dictated by the charterers can overwhelm technical ship attributes even for the most advanced energy-efficient ship.

The inclusion of fuel consumption when the ship is not under way in the calculation of the attained CII poses challenges for a functioning CII framework because:

.1 ships are penalized for time spent at ports despite the fact that the length of port calls is completely outside the control of the ship. The duration of port calls depends on the efficiency and limitations of the port or terminal;

.2 ships engaged in short sea shipping are penalized because the nature of the trade includes significantly more port calls compared to long haul trades;

.3 in periods of reduced demand and consequential oversupply of ships, some ships will wait at anchorage for long periods until new orders are received. This waiting time at anchorage results in a deterioration of the ship's attained CII; and

.4 some ports and terminals are notorious for congestion, meaning that ships have to wait at anchorage for prolonged periods of time before being able to load or unload their cargo. This leads to some trades being disproportionally impacted by the CII framework to such a degree that they could be characterized as inferior trades.

The ship with the best AER would be also the ship always trading in ballast condition without any cargo on board. As a result, the current metric penalizes efficiently operated ships carrying cargo, while favouring inefficiently utilized empty ships. Whereas the metric AER favours ships in ballast condition, the voluntary metric currently used for trial purposes – the Energy Efficiency Operational Indicator (EEOI) severely penalizes them. Neither is appropriate. Ballast condition is an integral part of a ships' normal operation and should neither be favoured nor severely penalized.

The challenge is to transform the CII from a "**trade**" metric to a "**performance**" metric.

7 ACKNOWLEDGEMENTS

The participants in the JIP for the testing of biofuel blends and relevant effects on CII were: TRAFIGURA, FOBAS, ABS, RINA, LIBERIAN ADMINISTRATION and MAN ES whose contributions were invaluable.

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9 AUTHOR'S BIOGRAPHY

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