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DEPARTENT OF MARITIME STUDIES

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DEPARTMENT OF MARINE SCIENCE


## DEPARTMENT OF MARITIME STUDIES

## MARINE SCIENCE & TECHNOLOGY MANAGEMENT

# AN INSIGHT INTO THE NEW EEXI/CII REGULATIONS UNDER A CRITICAL EVALUATION OF THEIR CURRENT/FUTURE LIMITATIONS FOLLOWED BY THE DEVELOPMENT OF A PRACTICAL MODEL FOR CII MONITORING


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## THREE MEMBER EXAMINATION COMMITTEE

Current Thesis was unanimously approved by the Three-member Examining Committee as appointed by the in accordance with the Regulations of the Master in "Marine Science and Technology Management".

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# PREFACE

First and foremost, the author would like to address his primary thanks to Admiral (ret) George Christopoulos for being the person who inspired, motivated and referenced for undertaking this postgraduate course. Mr Christopoulos' unparallel master in marine science and the shipping business context, will be always acting like a "lighthouse for those in the search for the land of knowledge".

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Last but not least, the author is thanking all three committee members of this thesis, for the supervision, meticulous examination and necessary feedback for completing and delivering an articulate piece of work. Special thanks need to be attributed to Asst. Professor Efthimis Pariotis, whose persistence and continuous stimulus inspired the author conducting an extensive research on the subject and eventually preparing a well-documented work. Hopefully, this will be only the beginning of a promising collaboration in many fields, scientific, research and beyond.

# ABSTRACT

The recent IMO's **EEXI** (technical) and **CII** (operational) measures implementation that aim to net **zero carbon emissions** by 2050, have forced a great number of ships to adopt different **energy saving** and **power limitation technologies**, mainly **EPL** and **ShaPoLi**, for achieving but most importantly demonstrate **regulatory compliance**.

In the meantime, as this study reveals through an extensive research, the impact of the **regulations** on the global fleet is already evident on the **S&P** and **newbuilding** activity but most importantly on the **ship owner-charterers** relationship which now needs to be redefined. Also, the current lack of **alternative fuels** as the ultimate solution for the CO2 emissions problem is challenging all stakeholders to mutually invest on **transparent** ship operations. Finally, the combination of this research findings with the **CII calculation/forecasting** model developed, fused with a full year's **high frequency sensors' data**, indicate that some revision may be highly essential for improving the current form the **regulation.**

# EXECUTIVE SUMMARY

Decarbonization in shipping is not a concept or wishful thinking any more. The IMO has set specific strategies and regulations are now in place which are continuously revised to strengthen its commitment to achieving the net zero target before 2050.

Still, it seems that regulations and relevant policies are the only key drivers for decarbonization at the moment. Recent EEXI and CII regulations, have raised the bar on compliance to levels where vessels need specific plans for energy efficiency. Shipowners and operators will not only need to monitor CO2 emissions more effectively but also commit to consistently reducing emissions year on year. Literature and practice indicate that there is a significant number of ships that will not be able to make it at the end of the first reporting year (2023) for CII, reaching ratings that will force them to significantly reduce speeds (by the means of EPL or ShaPoLi or even slow steaming) eventually forcing them to be continuously investing into new technologies and energy saving devices (ESDs).

Individual research through an online questionnaire indicates that no solid strategy appears to be sufficient for achieving the absolute performance or compliance at the moment. What is more, when it comes to liability, 45,1% of the respondents believe that any penalty or reimbursement resulted by CII regulation should not entirely be covered by the charterers while 37.3% considers that the costs should be shared by both parties (owners-charterers).

The impact of the regulations on the global (and hence Greek) fleet is evident on both the S&P and newbuilding market while we notice a significant increase in old vessels selling followed by an analogous increase in newbuilds, especially those equipped with dual fuel (LNG) engines.

However, as research indicates, alternative fuels are not going to be ready for use within this decade thus different short-term options need to be considered, including operational energy-efficiency measures such as route optimization, effective weather routing, trim optimization, regular hull and propeller cleaning and others which are evidently improving fuel oil consumption hence reducing CO2 emissions.

Digital technologies will also have a key role in the monitoring of operations as they will allow situational and future awareness of the ship and they will secure the necessary transparency in communication with the charterers or other parties.

In this respect, we notice that the emergence of the regulations is practically redefining the traditionally oppositional ship owners-charterers relationship, as new commercial, legal and contractual challenges arise, compelling them to mutually invest on an improved collaboration, in order they protect the asset's deterioration thus its future efficient operation and tradability. BIMCO has already implemented specific clauses towards this direction, charterers reaction remains to be seen.

For the purpose of the study, a CII calculation and prediction model has been developed and extensively tested on a full year simulation, fused with high frequency sensors' data, collected from a LASKARIDIS MARITIME vessel. The findings of the simulation are acceptably accurate and the minimal deviation observed in the results of the forecasting process, is justified further under identifiable reasons explained in detail.

The findings of the study conclude that CII's calculation, monitoring and optimization involves much more than just a compliance process as it is severely affected by different factors (weather, port traffic, cargo, vessel's condition) as well as various entities (crew, owners/managers, charterers, regulators, terminal ports and more) with very often, conflict of interests among them.

Eventually, current CII's formula seems to be favoring the ships with the best AER that are operating in ballast or under minimum possible cargo condition. This may result in ineffective behaviors by the ship owners who will try to secure their vessels' tradability based on CII rating; consequently the formula needs to be revised.

In the end, the goal of decarbonization is not a single entity's task; it is affected by multiple parameters where different stakeholders are required to act in an absolute coordinated manner. Regulators, organizations, ship owners and operators, charterers, port authorities, renewable energy and alternative fuel developers as well as governments and authorities, they all need to jointly contribute to a common strategy's milestones for reaching at a carbon free future, on time.

## DEDICATION

In memory of my beloved mother Aikaterini, who always encouraged me to keep on learning… regardless of the time or the cost.

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# 1.0 INTRODUCTION

## 1.1 BACKGROUND AND CURRENT SITUATION

The technical measure of Efficiency Existing Ship Index (EEXI) and the most recent operational measure of Carbon Intensity Indicator (CII) which came into force on the 1st January 2023, are considered by many as the most significant initiatives imposed by International Maritime Organization (IMO) towards the decarbonization of shipping. The industry though, has not welcomed this enforcement without any skepticism, as many arguments and reactions were raised on the appropriateness and the effectiveness of the measures, even considering the actual targets for GHG emissions reduction as unrealistic. Regardless of these perspectives, the regulations are already being implemented and the global fleet is now required to comply, despite any possible lack in technical or operational readiness of the ships or the industry itself.

In this respect, a great number of ships, in order to stay competitive and hirable (even avoid imminent demolition), is challenged with selecting among a plethora of different energy saving devices and power limitation technologies for reducing their fuel consumption thus the actual carbon footprint. Equally, operators are called to revise the traditional vessel operation practices and they are coerced to rethink their usual trading patterns as they now have to consider a series of factors affecting their vessels' CII rating.

In parallel, the potential vessels' deterioration over time is also expected to influence CII, leading to limited future tradability; as a consequence the "by nature" oppositional relationship between shipowners and charterers is now once more tested. The repercussion of this new paradigm in shipping trade, is so intense that it has already been evident on the global S&P of ships and newbuilding activity. Still, IMO once again, through latest MEPC80, seems to be relentless, showing its unnegotiable intentions, insisting on reducing $CO_2$ target levels for 2030 even lower.

All these facts which are happening either concurrently or on a non-sequential but interrelated principle, create a new shipping and trading reality, a complex puzzle, where multiple stakeholders need to wisely plan their future strategy in a more multidimensional context.

## 1.2 SCOPE

This study aims to review the current EEXI and CII regulations' impact on the maritime ecosystem highlighting the existing and potential limitations of the measures towards the ultimate goal of shipping decarbonization by 2050. The scope of this thesis is focusing on identifying the key factors that affect the regulations of EEXI and CII the most, by primarily recognizing those technologies that seem to have the most effective influence and then distinguishing the practices that need to be followed for complying with the guidelines, considering the vessels' future tradability, for a potential win-win collaboration between the usual contractors (owners-charterers).

## 1.3 OBJECTIVES

The study primarily focuses on the following key objectives:

1) Review the strategy and the increasing need for decarbonization in shipping by 2050 and evaluate the performance of recent EEXI and CII regulations
2) Identify the key technical and operational factors that affect CII and investigate how these are handled by today's ship owners
3) Focus on the impact of EEXI and CII on the global and Greek fleet in particular, by highlighting their effect on vessels' S&P and newbuilding.
4) Conduct a primary survey on the current Greek and as a proportional consequence, global fleet and present the findings regarding the readiness, perception and strategy towards regulations
5) Develop a model for calculating current and forecasting future CII rating, by performing a real case simulation on a subject vessel with the use of high frequency data
6) Critically evaluate current CII regulation and propose potential practices for its improvement
7) Evaluate how the relationship of charterers and owners will be affected because of the regulations by identifying possible points for friction between them
8) Propose recommendations for a sustainable collaboration of all stakeholders involved for achieving IMO's target for complete decarbonization on time

## 1.4 METHODOLOGY AND DATA SOURCES REVIEW

For the purposes of conducting an extensive and multidisciplinary study on the subject, multiple methodologies had to be adopted. The intention to produce a robust, well-documented thesis, required apart from the literature review, the practical development (modelling) and actual implementation (simulation) of the regulatory framework (theory) into practice. The outcome of this project, although complete, it is not final because of the dynamic and continuous elaboration of the subject; all findings and conclusions should be reviewed further (even questioned) by the means of additional research and study.

Also, due to the novelty of the CII regulation, (it has been active only since January 2023) and the plethora of contradicting views over its application, a very demanding examination of all available facts and findings was essential, initiating both qualitative and quantitative methodologies in the data collection process.

While the quantitative methodology provided definitive facts and figures that were primarily used for statistical analysis, the qualitative on the other hand added a more individualized perception on the topic of the research.

The methodologies applied are outlined as:

### *1.1.1 QUANTITATIVE RESEARCH*

#### 1.1.1.1 SURVEY

During the very initial observations and data collection on the subject (early 2021 up to the second quarter of 2022), which took place prior to the systematic research (last quarter of 2022 up to June 2023), it was realized that the majority of shipping companies were considering different approaches to follow while preparing to comply with the upcoming (at that time) regulation.

Whereas some were quite proactive making some preliminary planning, others surprisingly enough, seemed to be almost convinced that the regulation would not eventually be applied, because it would “make no real sense” as they used to be claiming in cutting $CO_2$ emissions down.

This equivocal attitude, dictated the use of a primary survey (through a questionnaire) including the preparation of (10 in total) questions, posed for gathering individual responses from an indicative market sample. The questions were addressed either in-person (using direct calls or personal interviews) or virtually by the means of an online questionnaire (Google Forms).

The targeted companies (sample) were not selected completely at random since the author had the opportunity to meet with their ownership or technical/operation principals, in advance. Also, there was some prior structure/culture classification, addressing the survey mainly to companies that had previously demonstrated such willingness or preparedness to reply, increasing this way the chances of a higher response rate.  The sample used, includes the global market as a whole, although narrowing to the Greek mainly, due to easier access to principals for the purpose of a follow-up call or a potential meeting for further discussion. Also, the imperative representativity of the Greek, in relation to the global fleet (21.5%), in terms of capacity or number of vessels, was also a significant factor for this selection.

A combination of styles in questions has been applied, including open, essay-style and closed questions (multiple-choice). This fact has assisted in guiding the sample into targeted results, aiming to identify the general attitude/perception of the respondents depending on the type of the company they work for. The content of the questions was intentionally kept to quite basic and fundamental since by the time the survey was conducted there was no such familiarity with the EEXI/CII principles. The survey involved the use of Google’s Forms web tool which was followed by personal invitation to a number of 312 shipping companies in total, achieving a response of 19,2% (53 responses online and 7 through the phone). There is a copy of the survey available in the Appendix of this study (excluding the names and emails of the respondents due to confidentiality reasons).

At this point it must be noted that there was also an additional 5% who initially expressed the willingness to respond to the survey however the lack of such authority or the insufficiency in comprehension on the subject, prevented them from doing so.

The online survey was conducted over the last two months of 2022 (for a period of 60 days in total) and it was terminated just before the practical effect of CII regulation (1/1/2023).

### *1.1.2 QUALITATIVE RESEARCH*

#### 1.1.2.1 IN DEPTH INTERVIEWS AND FOCUS GROUPS

The author, within the context of his profession, had the opportunity to conduct a number of one-on-one or in groups interviews and meetings which allowed the frequent and direct interaction with technical operators, senior officers as well as ship owners. Interviews were either unstructured in content by the means of general discussion on the current regulations or structured following the designated questionnaire, including technical information regarding the method/technology were planning to be adopted for achieving EEXI/CII compliance. The sample of people directly interviewed, included shipping companies' operators, classification societies' principals, IMO's technical committee experts, ship owners and finally related technology providers.

In regards to focus groups, these were utilized similarly to the interviewing process, involving individuals from different positions or discipline, focusing this time only to the potential EEXI/CII strategy initiatives. Next section below is an indicative sample of the focus groups interviewed.

#### 1.1.2.2 FORUMS – CONFERENCES

EEXI and CII currently are at the forefront of the majority of shipping industry's forums and conferences since their announcements by IMO as the main forthcoming measures for environmental ($CO2$ footprint) compliance. During the events, different bodies from the shipping industry showcased their views along with personal judgment about the future of the regulations, either criticizing or appraising them. Some intriguing insights and beliefs were witnessed, which then were methodically recorded and subjectively interpreted to be used as catalytic material in shaping the overall conclusions expressed in this study. Indicative forums-conferences attended for the purposes of the study, include the Annual Green Shipping Event, MARTECMA, Annual Shipping Finance Event, Digital Ship, NAVIGATOR Shipping FORUM, SMART4SEA and GREEN4SEA Forum, Annual Capital Link, Greek Shipping Forum, 21st Mare Forum Greece 2023, several SNAME's events and finally Hull Performance & Insight Conference (HullPIC).

#### 1.1.2.3 MARITIME EXHIBITIONS

For the purposes of exploring by first-hand the available technologies for meeting with EEXI/CII regulations, the author selectively participated in numerous marine and shipping oriented exhibitions. During the shows, a thorough investigation on the current and future technologies was conducted, including available Mass flow/Coriolis type flow meters, ShaPoLi equipped Torque Meters, Main Engine Power Limitation (EPL) different methods along with a detailed examination and comprehensive evaluation of relevant performance monitoring software in the market. This method had as an effect the incarnation of the theoretical (regulations) framework into the pragmatic CII monitoring technologies witnessing. Also, during these events, the interaction with shipping operators and industry experts allowed a holistic view on the technology adoption and relevant market trends. Indicative exhibitions included Posidonia 2022, Europort 2022, SMM2022, Norshipping 2023, Kormarine 2023, SeaAsia2023, Seatrade Maritime 2023 and few others.

#### 1.1.2.4 OBSERVATION

All the above qualitative methods applied, included the meticulous observations by the means of keeping notes, making references, saving articles or experts' views and spotting market. Perhaps observations stand for the most important (but also subjective) methodology used while investigating the subject, which eventually contributed considerably into the critical evaluation of all findings and their association to the original model development. Also, continuous observations were combined perfectly with quantitative methods and they together played a key role in the conclusion of this study.

#### 1.1.2.5 DOCUMENTS AND RECORDS (LITERATURE REVIEW)

A number of documents and records which are properly referenced in the related section (Chapter 7 References) were critically reviewed before starting the actual writing of this thesis. Still, at the time of the primary data collection process, the number of academic documents or proven records regarding CII, was noticeably limited due to the novelty of the regulation.

Also, because of the commercial/regulatory nature of the subject no solid academic study or research was available for further review.

Likewise, no significant number of journals, books or research documents were (and still are not) available, hence the common practice of the work has been mostly based on commercial publications. Still, all references used are originating from well-established and widely accepted sources including classification societies, independent organizations, research centers and shipping industry subject matter experts (SMEs).

In the same respect, due to the fact that the shipping community had not the sufficient time to study or get prepared for the regulations (as it will be demonstrated throughout the survey), there were no officially published records on any successful methods adopted.

#### 1.1.2.6 MAGAZINES, NEWSPAPERS AND SOCIAL MEDIA POSTS

A number of different well-acknowledged publications was used for gathering information and views about the CII regulation. Publications used primarily include: Newsfront Naftiliaki, ELNAVI Magazine, Tradewinds Publications, Shipping Finance News, Naftika Chronika, Motorship.com, Hellenic Shipping News, Splash247.com, DigitalShip.com and few others. Related articles include personal or corporate views by the form of interviews, various SMEs analyses, BIMCO's principal's views, shipping market analysts' studies, Charterers' opinion expressed, ship owners remarks and future estimations regarding the future of the regulations and finally technology providers' views about the current and upcoming demand on certain expertise and hardware/software for affected vessels.

In the same context, social media posts considered, include only certain LinkedIn posts that were expressing views on the readiness, adoption rate, outcomes and potential repercussion of the CII on the market, all published by well-recognized and accredited individuals (operators or owners) or organizations (classification societies, shipping registries, shipping companies, IMO etc) who have demonstrating expertise in the field or they have the decision-making authority for approving practices for such regulatory matters.

### 1.1.2.7 CASE STUDY-MODELLING

For the needs of the practical implementation and applied study on the subject, specific sets of data have been deprived from a subject merchant vessel, named “Las Palmas” owned by Laskaridis Maritime Co. The data are collected directly from vessel’s sensors, captured by the use of PRISMA ELECTRONICS LAROS® system, under the shipping company’s continuous supervision. The sample (dataset) used, practically assisted in observing the correlation of specific measures (strategy/approach/technology) towards compliance, compared to the outcome accomplished within a full year (365 days of data). In addition, the CII calculation model has been tested based on same vessel’s data, by running a simulation on selected voyages, for proving model’s basic functionality and evaluating its accuracy in forecasting. During the simulation, the author took into consideration the different conditions applied, including the factors, processes, and consequences of events along with vessel’s individual behavior (ship, crew, operators). All these factors, contributed significantly in identifying the rationale behind the initial formation of the regulation, comprehend possible assumptions that were made while developing it and detect its (un)expected limitations in today’s complex world of shipping.

## 1.5 LIMITATIONS OF THE STUDY

At the onset of the research, it was determined that because of CII’s continuingly evolving nature, two separate but interconnected phases of research were necessary to be committed, aiming to generate a soil ground for added discussion development. The first phase was initiated before the actual implementation of the regulation (before 1/1/2023) in an attempt to examine the readiness and the overall perception about EEXI and CII at that time. The second phase was initiated only when first usable data from ships was collected (after the first quarter of 2023). During the second phase, observations were made on the reactive (rather proactive) behavior noticed by the side of the ship owners while attempting to comply with the regulations. This continuous and perhaps abrupt progression of the regulation, demanded for a meticulous investigation on its entire lifecycle, from its conception to its implementation.

Moreover, since the only feedback eventually acquired for analysis is based on those companies willing to share relevant information, this raises a considerable level of uncertainty on the findings.

Second, we need to address the lack of sufficient academic/scientific research in terms of literature available prior to this study. No textbooks relevant to the actual application or the results of CII were available during the initiation of the project thus all research made, is based on original findings and primary investigation that again may be subject further evaluation.

It is also important to mention that the majority of the information available online is usually at some point subjective, often affected by some bias as it is edited by commercially influenced parties, expressing dissimilar views on the subject. More specifically, it was noticed that there were those who defend CII's importance (mainly regulators, EU bodies, IMO ambassadors and so on) supporting and pursuing its immediate and literal use as a tool for a first level monitoring and potentially controlling CO2 emissions. These views seem to be ignoring completely about shipowners' and charterers' interests. Then, there is the latter, who claim that CII is gravely planned as another slow steaming enforcer or potentially money collecting mechanism similar to EU ETS coming in 2024, which ultimately damages seriously the industry. Finally, perhaps the most benefited ones, there are the technology providers who try to retain a neutral opinion on the ultimate effect of the CII as they mostly care about the effectives of their technology rather than the regulation's outcome in the final CO2 emissions reduction.

For the all these reasons, a critical review had to take place while evaluating all views and information publicly expressed, aiming to keep an as much impartial opinion as possible before adopting and publishing it.

Another significant limitation was the lack of reliable data on the actual performance of ships that are currently monitoring the CII. The regulation, does not (yet) require the use of high frequency data to be acquired from related ship sensors (e.g. flow meters); thus any CO2 emissions monitoring, currently derives from data based on typical noon reports. This fact, adds by default a sizable ambiguity on the quality of the data used for reference since noon reports can easily contain errors or omissions.

Also, since the regulation had been initiated only few months ago, there was no any good practice or any efficiency metrics available to be referenced in the study.

Equally, there is very limited feedback on what possible adjustments the owners or operators might have made in order to retain their vessels' CII rating within acceptable levels. This lack of proven track record, may affect the conclusions on both the impact and the effectiveness of the regulation. As a consequence, what is resolved or proved through this study may be subject to revision (perhaps in a short period of time) as more data will be available for comparison and further analysis.

Another fact to consider is that the final applicable form of the regulation was not finalized by the time the study (literature review) begun. IMO was at that time still reviewing the legibility and the applicability of the CII and several amendments in the correction factors have been announced during MEPC80 (June 2023).

Moreover, as the survey indicates, the majority of shipping companies were not definite on the strategy they are going to follow for achieving compliance. The well-known in the industry "wait and see" behavior, once more prevailed where operators showed hesitant and cautious in the beginning of the year (2023), many of them considering that there will be some extension in the deadlines (as usual) or change exemption for their vessels, as the industry was admittedly considered to unready for adopting the new regulation.

For all the above reasons, the study may have to be examined under a critical scope for its findings and the conclusions it suggests despite the authenticity of most data sources referenced and the extensive qualitative research methodology applied. The most important limitation though seems to be the timing of the actual writing as the CII regulation is currently being implemented only on its first reporting year and its first results will be available after the completion of the first or perhaps second year of operation.

## 1.6 STRUCTURE

Below there is a short description of each chapter presented in the study, highlighting the key points covered.

**CHAPTER 1 INTRODUCTION**

This is a brief presentation of the aims and objectives of the study focusing on the methodology approach used with an analysis on the qualitative and quantitative methods implemented for effective data collection. Also, the chapter classifies the problems encountered while conducting the research and the writing of the thesis, highlighting the imitations of the study.

**CHAPTER 2 THE NEED FOR ZERO CARBON SHIPPING & THE ROLE OF EEXI, CII**

This chapter includes the literature review on the goals as they have been set by IMO's current strategy on GHG emissions scheme, by categorizing the short and long terms measures for its success. The focus is mainly on EEXI and CII and the technologies currently available for achieving compliance by analyzing those factors that affect the regulations the most. The chapter concludes with the key role of digitalization and the use of alternative fuels as the ultimate goal of decarbonization in shipping.

**CHAPTER 3 CURRENT STATUS OF GLOBAL FLEET**

In this chapter, the current status, in terms of readiness, of the global (and the Greek in particular) fleet, is presented, in regards to EEXI and CII adoption by examining their potential impact in S&P and newbuilding market.

**CHAPTER 4 SURVEY'S FINDINGS AND ANALYSIS**

Chapter 4 includes the analysis of this study's survey findings, as resulted from the questionnaire and interviews, attempting to recognize and elaborate further on the attitude, perception and strategy of the ship owners regarding the regulations.

## CHAPTER 5 DEVELOPMENT OF A MODEL FOR CII CALCULATION AND FORECASTING

For the purposes of testing the CII regulation in practice, a model has been developed, capable of calculating current, and forecasting future CII. In this scope, high frequency data from a real vessel (case study) are being used for performing a simulation for a full year of operation. The accuracy of the results is examined further by investigating the potential reasons for any observed deviation.

## CHAPTER 6 CONCLUSIONS – RECOMMENDATIONS

The final chapter of this study involves the critical evaluation of current CII regulation, by identifying its limitations and proposing potential adjustments that could be applied for its improvement. It also recognizes the new status quo in ship owners-charterers relationship because of the emergence of the regulations, by proposing possible practices that need to be considered by both parties for securing their successful collaboration in the new framework of contracting. The chapter concludes with outlining the outcomes of the study and proposes specific recommendations for the way forward, towards a zero-carbon future in shipping.

## 2.0 NEED FOR ZERO CARBON SHIPPING

The shipping industry is the spine of World Trade. According to IRENA (2021) it counts for approximately 80% of the flow of the commodities transported globally, being responsible for around 11% of global carbon dioxide (CO2) emissions while the whole transportation sector counts for 24% overall. Interestingly, the same report states that 99% of the energy demand from the international shipping sector is met by fossil fuels, with fuel oil and marine gas oil (MGO) comprising as much as 95% of total demand. This fact indicates that shipping, although considered as the most efficient mean of transporting goods in terms of CO2 emissions per metric ton-mile, if no actions are taken, it will grow its Green House Gas emissions (GHG) between 50% and 250% by 2050 in comparison to 2008 levels (DNV, 2021). In this respect, in full alignment with the Paris Agreement (COP21), the majority of shipping organizations and IMO members are advocating for a net zero target for 2050. Alongside, various stakeholders within shipping community (figure 1) with either individual or common interests, despite their contradictions, have already agreed to cooperate in a shared framework/strategy for a greener shipping. Thus, we notice that there has been some serious emphasis and specific plan to primarily regulate and promptly mitigate the effect of GHG emissions (among other emissions such as NOx, SOx and particle matters (PM) that are not part of this study).


*Figure 1 Various Stakeholders within shipping Community (Source DNV, 2021)*

## 2.1 A CONTINUOUSLY EVOLVING PLAN

In the most recent revision of the International Maritime Organization's (IMO's) greenhouse gas (GHG) strategy in July 2023, MEPC 80, member states agreed to first reach net-zero GHG emissions by or around 2050 and second set "indicative checkpoints" that call for reducing total GHG emissions by 20% and striving for 30% by 2030 and 70% and striving for 80% by 2040, both relative to 2008 as reference. This is an admittedly big improvement on the initial GHG strategy as was set in 2018, which aimed to cut GHG emissions by only 50% by 2050 and contained no absolute emissions reduction targets for the intervening years.

The following figure (2) by DNV (2021) allows us to illustrate and conceive better the deviation between the "Business as usual emissions" trend compared to "Emission pathway in line with IMO's strategy", indicating the urgency and consequently the impact of the measures recently decided to be taken.

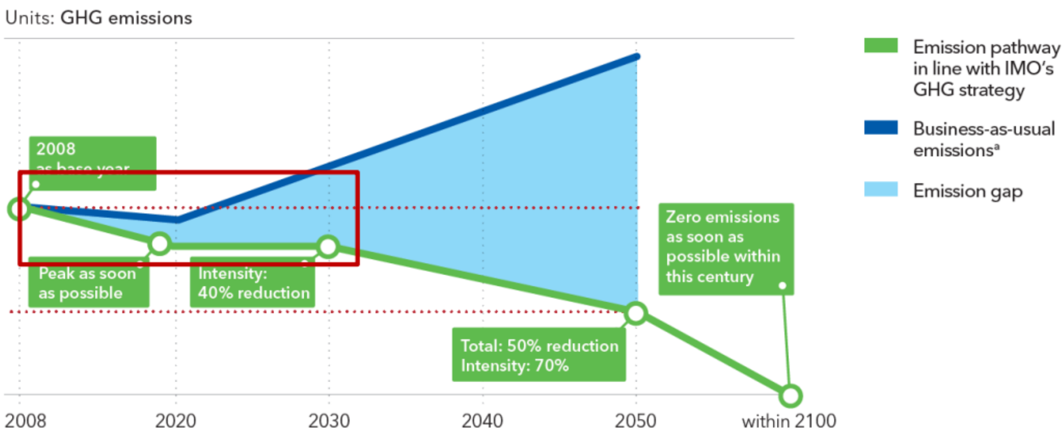



*Figure 2 IMO's initial GHG Reduction Strategy (source DNV, 2021)*

## 2.2 WHAT MEPC 80 UPDATE MEANS FOR THE INDUSTRY

The levels of ambitions agreed during the latest MEPC (80) within the revised strategy include the following:

• To peak GHG emissions as soon as possible and to reach net-zero by or around, i.e. close to 2050, mindful of different national circumstances.

• To reduce GHG emissions on a well-to-wake basis, as addressed in the Life Cycle Assessment (LCA) Guidelines.

• To reduce GHG emissions within the boundaries of the energy system of international shipping and prevent a shift of emissions to other sectors.

• A reduction in CO2 emissions per transport work (carbon intensity) by 2030 to be at least 40% as an average across international shipping compared to 2008 levels (fig.3)

• Indicative checkpoints to reach net-zero GHG emissions from international shipping of 20% striving for 30% by 2030, and 70% striving for 80% by 2040, compared to 2008

• Low-carbon and zero-carbon fuels/energy source uptake for international shipping to be at least 5%, striving for 10%, by 2030 (figure 3).

• Recognition of the need for a broad approach to regulating the safety of using zero or near-zero GHG emission technologies, fuels and/or energy sources, including addressing the human element, to ensure a safe implementation of the Strategy.

• Review, with the aim of strengthening, the energy efficiency design requirements for ships. The finalized report for the impact assessment is to be expected to be reviewed at MEPC 82. The timeline for further approval and adoption for the mid-term measures has been agreed in the 2023 strategy with an expected entry into force date in 2027. The timeline includes the completion date for the review of short-term measures i.e. 1 January 2026. (IMO, 2023)

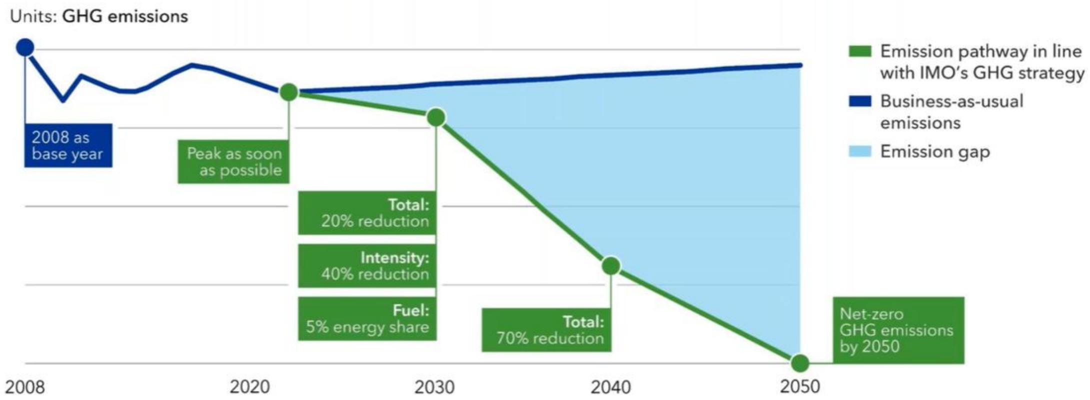



*Figure 3 Strengthened IMO Strategy on GHG measures after MEPC80 (source DNV, 2023)*

MEPC 80 suggests that the next revision of the strategy will be in 2028. A timeline for its revision is also included within the 2023 strategy. The below table (1) by IMO MEPC80, is the agreed comprehensive timeline for the milestones under the revised strategy:

| Target dates | Milestones | | |
|---|---|---|---|
| | Comprehensive impact assessment (CIA) of the basket of candidate mid-term measures | Development of candidate mid-term measures | Other milestones |
| MEPC 80 (Summer 2023) | Initiation of CIA | Initiate Phase III of the Work Plan on the development of mid- term measures | |
| MEPC 81 (Spring 2024) | Interim report | Finalisation of basket of measures | |
| MEPC 82 (Autumn 2024) | Finalised report | | |
| MEPC 83 (Spring 2025) | | Approval of measures | Review of the short- term measure to be completed by 1 January 2026 |
| Extraordinary 1 or 2-day MEPC (six months after MEPC 83 in Autumn 2025) | | Adoption of measures | |
| 16 months after adoption (2027) | | Entry into force of measures | |
| MEPC 86 (Summer 2027) | | | Initiate the review of the 2023 IMO GHG Strategy |
| MEPC 88 (Autumn 2028) | | | Finalisation of the review of the 2023 IMO GHG Strategy with a view to adoption of the 2028 IMO GHG Strategy |

*Table 1 Timeline for the milestones under the revised (MEPC 80) strategy (source IMO, 2023).*

MEPC80 agreed that further work and an impact assessment is to be carried out to select mid-term measures which should consist of both a technical and an economic element. The work scope and the timeline has been agreed in line with the 2023 GHG Strategy. A relative interim report is expected to be considered at MEPC 81.

Still, during MEPC 80 no immediate changes to CII framework were announced, including corrections factors and voyage adjustments but potential amendments for 2025 only.

## 2.3 THE URGENCY FOR STRATEGY’S REVISION

The reason for the revision and amendments was the fact that the initial strategy was not compatible with the Paris Agreement’s aim to limit global warming to well below 2°C and pursuing efforts to limit it to 1.5°C.

The new estimates of the revised strategy indicate that international shipping will exceed its current share of the world’s 1.5°C carbon budget by approximately 2032 but will not exceed the well below 2°C carbon budget (“well below” interpreted as 1.7°C) if it follows the emissions reduction pathway implied by this revised strategy (Comer and Carvalho, 2023)

### *2.1.1 EXPECTED IMPROVEMENT*

In order to visualize how things do change or are expected to change with the revised strategy we will use figure 4 as cited by Comer and Carvalho, (2023). In this chart, there is a distinctive comparison where we discern the straight-line emissions trajectory that satisfies the emissions reduction targets in the revised (2023) GHG strategy in comparison with the pathway implied by the initial GHG strategy. It is also important to notice the BAU (Business as usual) line which would dramatically impact GHC emissions over 2008’s baseline.

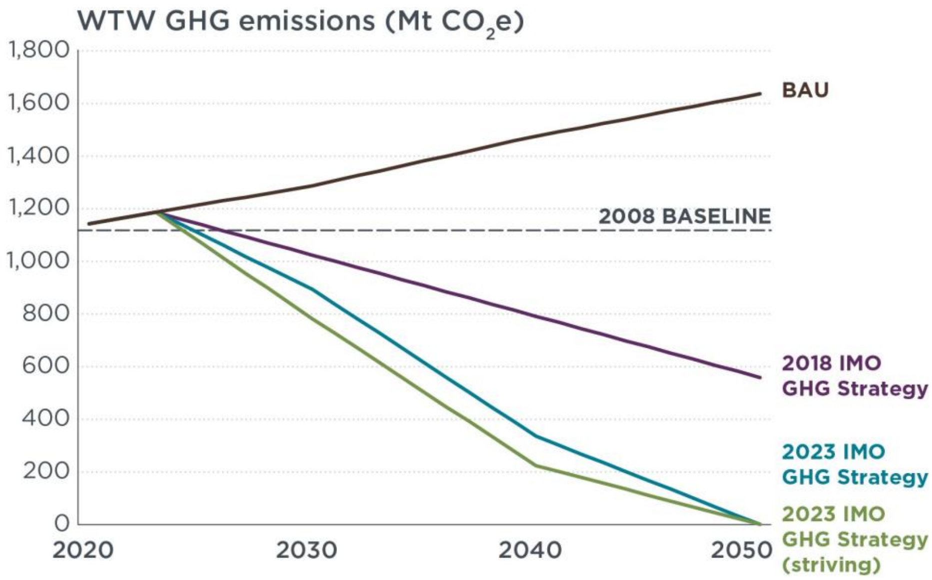



*Figure 4 Well-to-wake GHG emissions pathways implied by the revised (2023) strategy compared to the initial (2018) strategy, the emissions in 2008, and business-as-usual (BAU) emissions (source Comer and Carvalho, 2023)*

Trying to visualize the difference-anticipated improvement in terms of cumulative emissions BAC chart, (figure 5) we compare the Well To Wake (WTW) CO2e100 emissions between 2020 and 2050 under the 1.5°C and well below 2°C carbon budgets.

As we can realize, the revised strategy is not compatible with 1.5°C but is compatible with well below 2°C. As a consequence, if member states had agreed to achieve zero emissions by 2040, the strategy would have been aligned with 1.5°C.

Now, under the revised (2023) strategy, we are set to exceed the 1.5°C budget by approximately 2032 under either the 20% or 30% (striving) target; however, if shipping can get to zero WTW CO2e emissions by 2050 along this pathway, it will not exceed its well below 2°C budget. Following the "striving" trajectory results in 17.1 Gt of cumulative WTW CO2e emissions, less than the 19.2 Gt under the less ambitious 2023 targets, and that improves the probability of keeping well below 2°C (Comer and Carvalho, 2023).

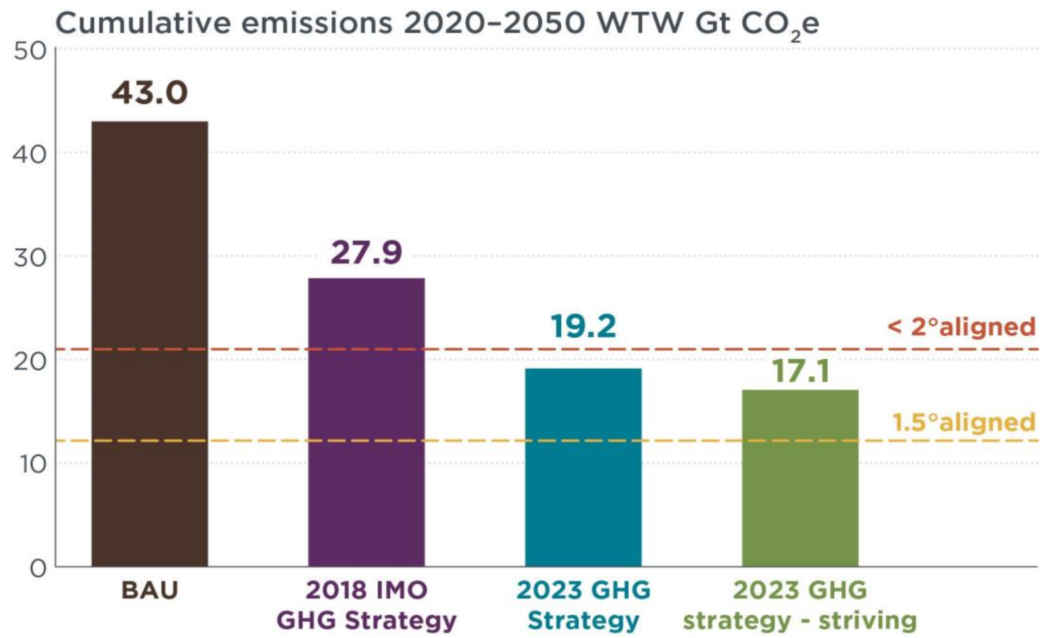



*Figure 5 Cumulative well-to-wake GHG emissions from 2020–2050 implied by straight-line emissions reduction pathways for the revised (2023) strategy, the initial (2018) strategy, and business-as-usual (BAU), compared to the 1.5°C and well below 2°C budget (source Comer and Carvalho, 2023)*

### *2.1.2 SHORT TERM MEASURES*

While IMO's strategy is not essentially legally binding for any shipping company, on the other, the related measures applied to implement it, can be. This is because they are incorporated into the International Convention for the Prevention of Pollution from Ships (MARPOL). After the initial GHG strategy, the IMO agreed on "short-term measures" to regulate GHG emissions from ships (Bureau Veritas, 2022).

Two of these entered into force in 2023: the **Energy Efficiency Existing Ship Index (EEXI)** and the **Carbon Intensity Indicator (CII)** which are the main subject of this study and greater focus will be given on these measures, in the following chapters.

### *2.1.3 MID-TERM MEASURES*

Beyond the short-term measures, there are also mid-term measures currently being developed by the IMO that could enter into force as soon as 2027.

This "basket of measures," as IMO delegates are calling it, will include a technical element and an economic element. The technical element is expected to be a GHG fuel standard (GFS) that will gradually reduce the allowable WTW CO2e intensity of marine fuels. The economic element on the other, is less-well-defined for the moment; there are several things being considered, including a GHG fuel levy, a feebate program, and a cap-and-trade scheme. With regard to the GFS in specific, Comer and Carvalho, (2023), recently presented a work which is based on ICCT's Polaris energy use and emissions projection model at an IMO expert workshop which demonstrated that aligning with 1.5°C would require a 38% reduction in the WTW GHG intensity of marine fuels by 2030, 97% by 2040, and 100% by 2050 (ABS, 2022).

Figure 6 below depicts IMO's GHG reduction targets in relation to short, mid-and long-term measures

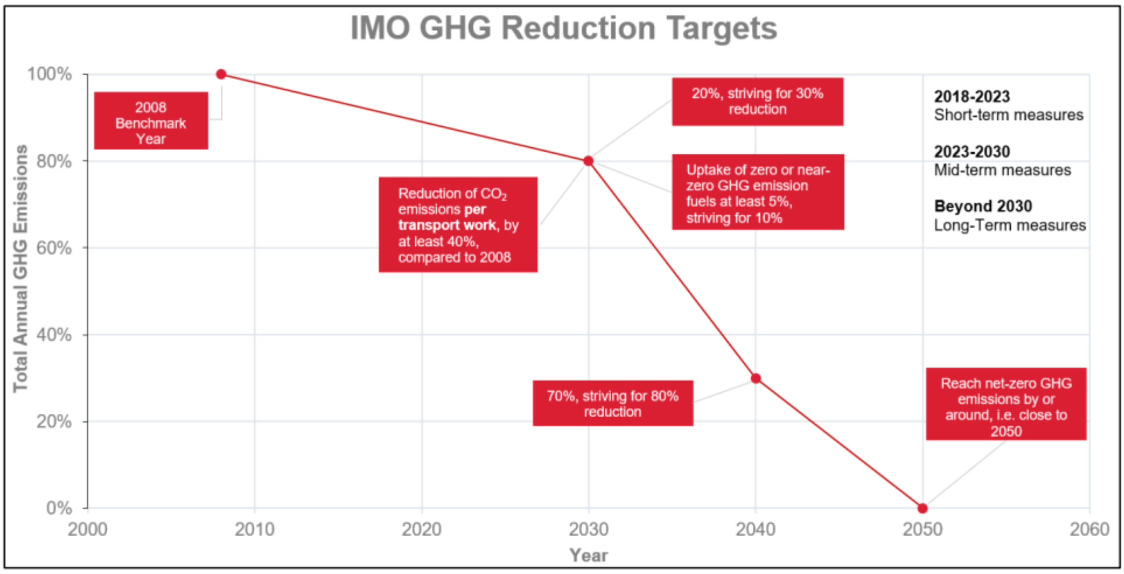



*Figure 6 Timeline of candidate Short-,Mid-and Long-Term GHG Reduction Measures (Source ABS, 2022).*

### *2.1.4 OTHER MEASURES TO CONSIDER*

Finally, countries and regions are also setting their own requirements for ships that call on their ports. For example EU has imposed Monitoring, Reporting and Verification regulation (MRV) since 2018. Also, a most recent, FuelEU Maritime, is similar to the proposed IMO GFS, which is incorporating shipping into its Emissions Trading System.

Perhaps the most interesting and awaited measure in the industry is EU ETS (Emissions Trade System) which is expected to start being implemented from January 2024, while shipping companies must surrender (use) their first ETS allowances by 30 September 2025 (European Commission, 2023). The ETS, has already proven to be an effective tool in helping drive emissions reductions cost-effectively in other industries. According to European Commission, (2023) installations covered by the ETS reduced emissions by about 35% between 2005 and 2021. The new system is designed to operate in an orderly, smooth and efficient manner from 2027. Its cap is set to achieve 42% emission reductions in 2030 compared to 2005 levels, in line with the contribution of the sectors covered to the 2030 climate target (European Commission, 2023).

As mentioned, the EU ETS works on the 'cap and trade' principle. A cap is set on the total amount of certain greenhouse gases that can be emitted by the operators covered by the system. The cap is reduced over time so that total emissions fall.

Within the cap, operators buy or receive emissions allowances, which they can trade with one another as needed. The limit on the total number of allowances available ensures that they have a value. The price signal incentivizes emission reductions and promotes investment in innovative, low-carbon technologies, whilst trading brings flexibility that ensures emissions are cut where it costs least to do so.

After each year, an operator must surrender enough allowances to cover fully its emissions, otherwise heavy fines are imposed. If an installation reduces its emissions, it can keep the spare allowances to cover its future needs or else sell them to another operator that is short of allowances.

Revenues from the sale of allowances in the EU ETS mostly feed into Member States' budgets. Allowances are also auctioned to supply the funds supporting innovation in low-carbon technologies and the energy transition: the Innovation Fund and the Modernization. (European Commission, 2023).

ABS (2022) reports that some of the basket's (mid-term) measures for GHG reduction involve a variation of technical and economical practices to be followed such as:

- Technical measure, a goal-based marine fuel standard regulating the reduction of the marine fuel's GHG intensity. There is broad support for the Greenhouse Gas Fuel Standard (GFS) as proposed initially by Austria et al.
- An economic measure, on the basis of a maritime GHG emissions pricing mechanism. On the contrary to universal support of GFS, there are divergent views on the economic elements, where the following seem to stand out:
    - IMO Maritime Sustainability Fund and Reward (F&R) by International Chamber of Shipping (ICS);
    - Zero-Emission Shipping Incentive Scheme (ZESIS) by Japan;
    - International Maritime Sustainability Funding and Reward (IMSF&R) by Argentina et al;
    - International Maritime Sustainable Fuels and Fund (IMSF&F) by China;
    - GHG Levy (GHGL) by Marshall and Solomon Islands.

### 2.1.5 IN SEARCH OF THE PERFECT MATCH

Achieving the goals of IMO's GHG Strategy will require a mix of technical, operational and innovative solutions applicable to ships. Some of them, along with the indication of their approximate GHG reduction potential, are highlighted by IMO's (2022) infographic as below figure (7):

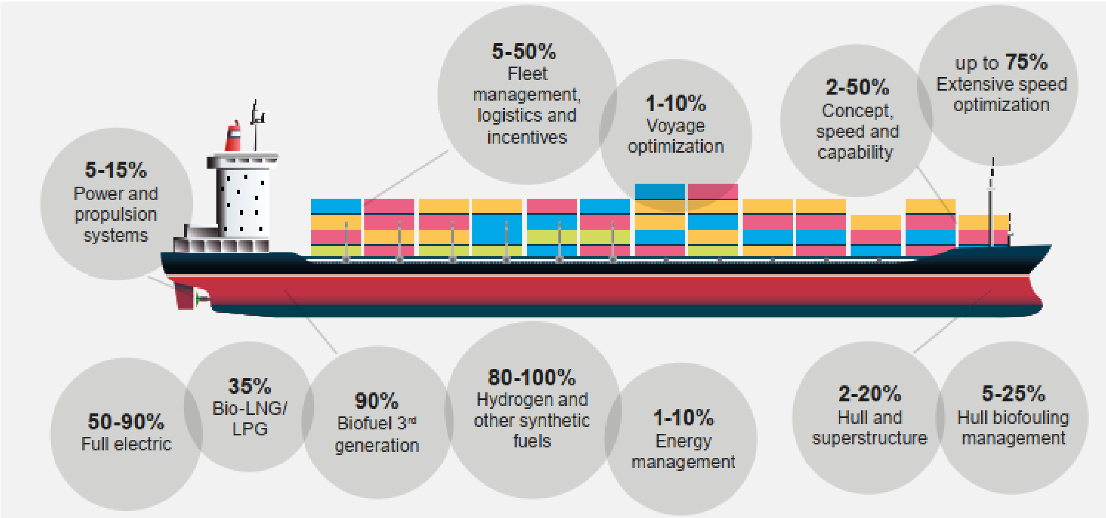



*Figure 7 Technical, operational and innovative solutions for GHG Reduction (source IMO, 2022)*

There are many parallel studies performed by classification societies, academic institutions, shipping companies and technology solution providers, either individually or jointly, on the above referenced practices. The main focus is always to reduce FOC (thus CO2 emissions) along with improving vessels 'overall performance.

What is important to mention though is that while applying more than one of available methods (or technologies) combined, their impact may not be positive as they do not always act in an absolute cumulative manner. The perfect match or combination seems to be the key element for achieving the optimum performance and CO2 minimization.

Particularly, this tends to be the norm when implementing technical solutions as any modification to any part of the vessel needs to be compatible to the rest, obeying to the laws of fluid dynamics, marine science and so on. A vessel's smooth sailing capability can be affected by many unpredicted factors when making modifications on the hull, the propeller or anywhere else, thus a "fine tuning" process needs to take place for every combination of possible modifications.

The situation is slightly different when adopting operational practices though, where the majority of performance improvement initiatives often conclude in aggregated results.

Ultimately, considering the regulations framework cited in the above paragraphs in combination to the multidisciplinary initiatives available for the shipping operators, despite how distant 2050 may seem, they indicate that shipping industry is already undertaking the sizable challenge of significantly decarbonizing its operations.

The initiative towards this direction is currently being materialized primarily by the application of short-term measures, including EEXI and CII which seem to be the foundation for monitoring first, and taking explicit action for improvement, later. In the following paragraphs we will examine what these two current measures mean, how they are formulated and the level of their effectiveness/impact in today's shipping, starting with EEXI and then focusing mainly on CII which is the main subject of this thesis.

## 2.4 ENERGY EFFICIENCY EXISTING SHIP INDEX (EEXI)


*Figure 8 IMOs Infographic on EEXI (source IMO, 2023)*

Energy Efficiency Existing Ship Index (EEXI), which has come into effect from January 1, 2023, is a framework for assessing the energy efficiency of in-service vessels as designed and built (IMO, 2023).

To determine this, the EEXI accounts for a vessel's engine and auxiliary engine power, transport capacity and given reference speed.

Emissions are calculated using the installed power of the main and auxiliary engines, the engine's specific fuel oil consumption (SFOC) and a conversion factor of the fuel's mass into CO2 mass (Bureau Veritas, 2023). Figure 8 above by IMO illustrates the basic principles of EEXI.

We easily discover that the EEXI is not introducing much of a novelty as it can be described as a variant of the well-known Energy Efficiency Design Index (EEDI), which used to apply to new ships built after 2013.
All EEXI calculations must be conducted in accordance with MARPOL Annex VI.

Calculation requirements for the EEXI are based on those used for the EEDI. Existing ships will be required to assess their energy efficiency index, known as "attained EEXI". All ships must individually calculate and receive approval of attained EEXI by their first annual, intermediate or renewal International Air Pollution Prevention (IAPP) survey of 2023. Attained EEXI will then be compared with required EEXI, a performance level set by the IMO regulations (IMO, 2023)

Required EEXI values are determined based on fleet statistics per ship type, cargo capacity, and propulsion method. Below there is a detailed formula (figure 9) displaying the method of calculating EEXI as described by Bureau Veritas, (2023).

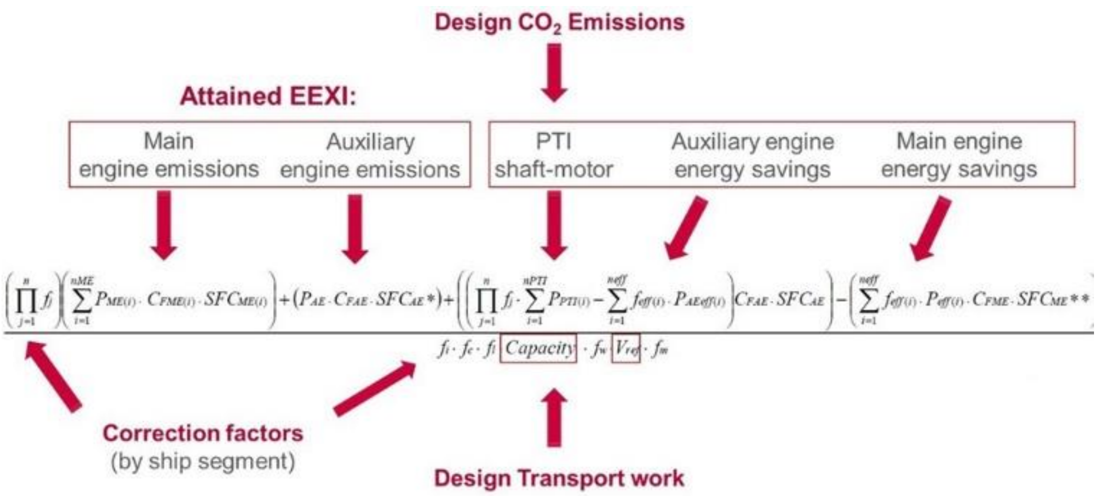



*Figure 9 EEXI Calculation formula (source Bureau Veritas,2023)*

In general terms, while compliant ships will be issued an International Energy Efficiency Certificate (IEEC), non-compliant will need to find ways to comply with the required EEXI values. Technical modifications such as Engine Power Limitation (EPL) and Shaft Power Limitation (ShaPoLi) can reduce the calculated emissions and currently seem to be the predominant methods as they are already referred in EEXI's transition clause for charter parties effective since November 2022. EPL in particular is expected to be mainly adopted as this is a relatively simple and cost-effective solution and should cause minimal disruption to the vessel's operation (DNV, 2021). MCR is a key component of the EEXI equation, and decreasing the value used in the equation will decrease the outputted EEXI value, making EPL a vital tool in limiting vessel emissions. Alongside the addition of ESDs, vessels can be made more efficient and compliant with EEXI regulation. Before elaborating further on EPL and ShaPoLi methods, it interesting to have a look on different methods identified by DNV (2021) in the below figure (10) which summarizes the process of compliance in relation to various practices to be followed for achieving such:

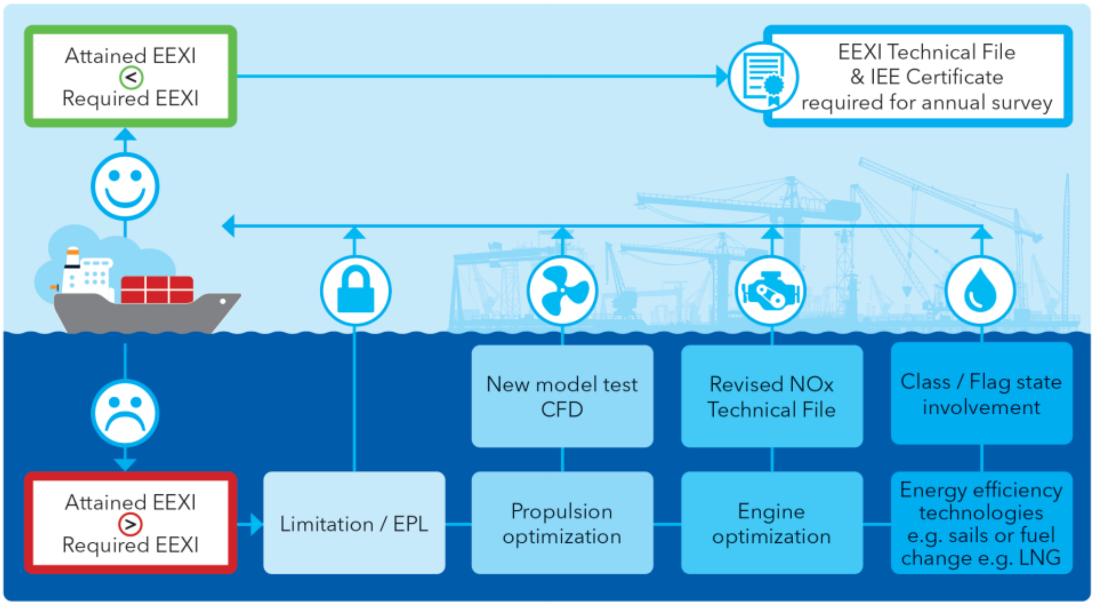



*Figure 10 Typical Pathways options and pathways to compliance (source DNV, 2021)*

It is important to note that those ships with particularly poor EEXI performance may require retrofitting, ESDs, propeller modifications or green solutions like wind-assisted propulsion (Bureau Veritas, 2023).

### 2.1.6 ENGINE POWER LIMITATION (EPL)

According to Mahajan et al (2022), power limitation or EPL in short is a semi-permanent, overridable limit on a ship's maximum power that could reduce fuel use and CO2 emissions if it reduces the operational speeds of affected vessels. It is a method of limiting the engine power during normal operation regardless of the power train combination and control system arrangements.

The set limits of the solution can all be overridden from the bridge as this is a mandatory feature stipulated by the IMO / MEPC guidelines (MEPC.335(76), 2021). There are two methods of accomplishing this, the mechanical (manually) and the electronic way. Either way, all system data must be stored in accordance with the regulations for inspection purposes any time this is required. In the below figure (11) we observe an indicative EPL application (electronic) for a 2-stroke engine, as illustrated by one of the largest engine manufacturers in shipping, Wartsila. It is worth mentioning that in terms of commissioning time onboard, a typical installation of such system usually requires no more than one day in duration.

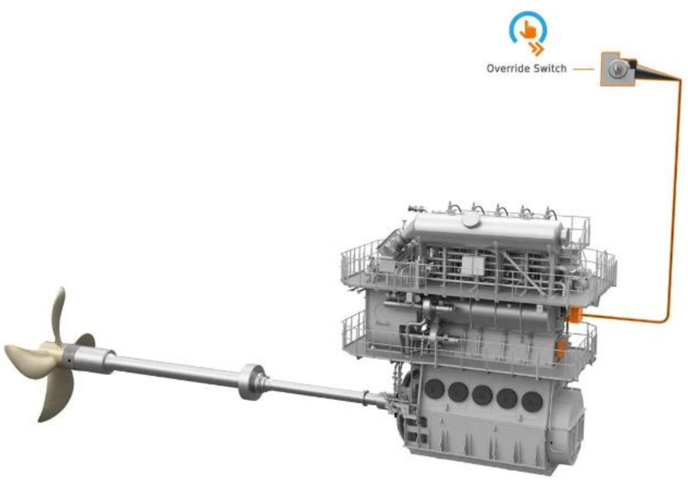



*Figure 11 Wartsila's 2-stroke engine power limitation (source Wartsila,2023)*

### 2.1.7 SHAFT POWER LIMITER (ShaPoLi)

While EPL limits the power of the M/E, on the other hand, ShaPoLi limits shaft generator. A ShaPoLi system is designed to practically limit the power output of a ship's propulsion system to a maximum level that is determined by its EEXI value. Like EPL, it is a semi-permanent solution and crew will be able to use the unlimited or reserve shaft power when needed for safety purposes (Mahajan et al. 2022).

What is more, in modern ShaPoLi systems, there is a graphical interface module onboard (usually next to the shaft power or torque meter) that provides the ships Master or the officer in charge, with real time shaft power readings, produced by the vessel, and represented in relation to power reserve threshold, as determined by vessel type.

The system can be supplied with or without an override function, depending on the case. However, it is needs to be pointed out that although literature indicates that ShaPoLi systems are supposed to be limiting the power automatically, the percentage of shipping companies that have virtually enabled such a function are minimal, thus the override function does not seem to be practically used (at least for the moment).

We also need to consider that ShaPoLi requires a shaft power/torque meter to be already installed onboard the vessel prior to its installation. Again, similar to EPL, most ShaPoLi systems can be also installed within one day of attendance on board.

A typical ShaPoLi system looks is illustrated by Wartsila below (figure 12):

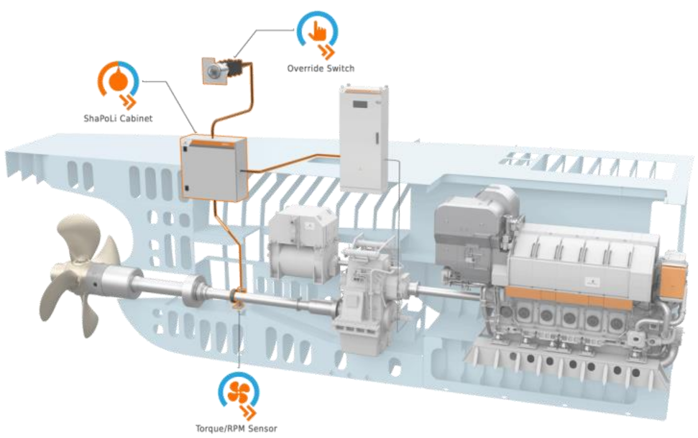



*Figure 12 Wartsila's Shaft Power Limiter (source Wartsila, 2023)*

Between the two technologies described, EPL seems to be prevailing as most preferred (this is what they verbally confirm) by the majority of the shipping companies. Wartsila (2023) reports that EPL is fully possible for many bulkers and tankers because it seems that the typical operative load is rather low, between 50% and 70%, mainly due to higher design speeds versus typical operating speeds required in today's operations. Similarly, Loizos (2021), evoking a research by DNV, is also projecting that the main means for owners to achieve compliance of the majority of their vessels will be EPL.

For determining better into this matter, deciding which method of the two is most preferred, another more practical comparison is performed, this time derived from primary evidence. This is presented in chapter 4 (Strategy towards regulations, paragraph 4.1.5)

## 2.5 THE CARBON INTENSITY INDEX (CII)

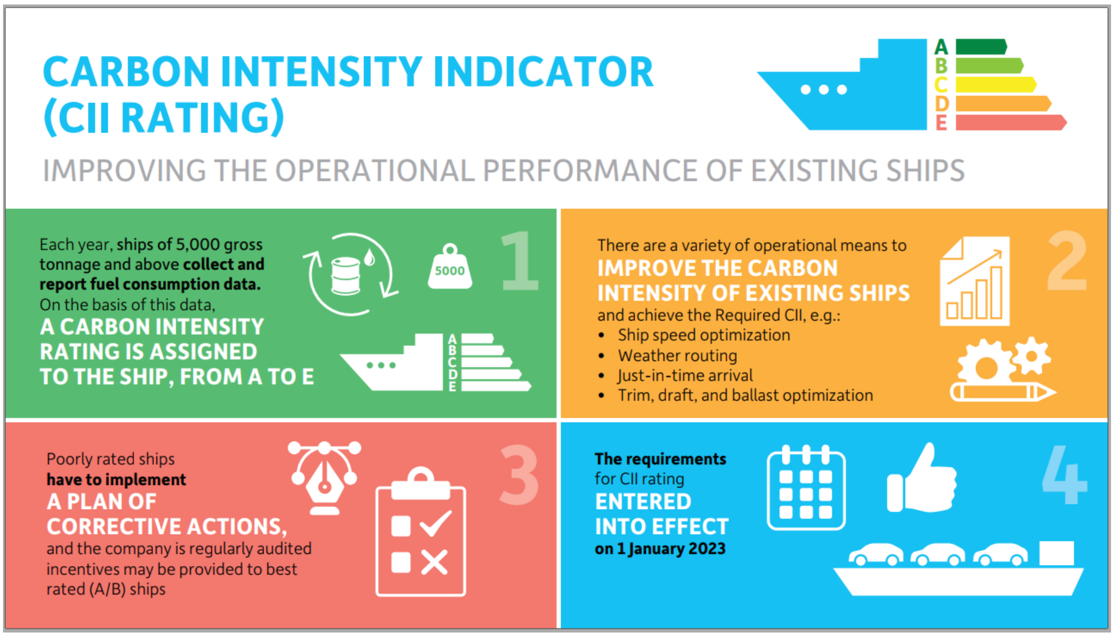



*Figure 13 IMO's Infographic on CII (source IMO, 2023)*

While the EEXI is a one-off certification targeting design parameters mainly, the CII (figure 13) is an annual review of a ship's actual carbon emission performance over the past year (AER) with such monitoring started also from January 1, 2023 (IMO, 2023).

In other words, CII, addresses emissions in operation and has been devised to measure how efficiently a ship transports goods or passengers, in grams of CO2 emitted per cargo-carrying capacity and nautical mile terms (figure 14).

$$\mathbf{CII} = \frac{[\text{AnnualFuelConsumtion}] \times [\text{CO2emissionsfactor}]}{\text{TransportWork} : [\text{DistSailed}] \times [\text{Capacity}]}$$

*Figure 14 CII's Calculation Formula (source IMO, 2023)*

The CII unit is measured in "grams of CO2 emitted per cargo-carrying capacity and nautical mile", whereby cargo capacity is either deadweight or gross tonnage depending on the ship type. In addition, to cater for special design and operational circumstances, there are certain correction factors and voyage adjustments that can be applied to the basic CII calculations for the purposes of determining the actual rating as referred below:

### *2.1.8 CORRECTION FACTORS*

**Voyage adjustments - $FC_{voyage,j}$:**

- Securing the safety of a ship or saving life at sea – all vessels
- Sailing in ice conditions – ice-classed vessels

**Correction factors:**

- $AF_{TankerSTS}$ – oil tankers engaged in STS voyages
- $AF_{TankerShuttle}$ – shuttle tankers equipped with dynamic positioning
- $FC_{electrical}$ – ships carrying refrigerated containers/gas carriers/LNG carriers/tankers
- $FC_{boiler}$ – tankers
- $FC_{others}$ – tankers

**EEDI & EEXI correction factors:**

- $fi$ - capacity correction factor for ice-classed ships
- $fm$ - ships having ice classes 1A Super and 1A

- $fc$ - cubic capacity correction factors for chemical tankers
- $fi,VSE$ represents the correction factor for ship-specific voluntary structural enhancement (source IMO, 2023).

Also, there are certain annual reduction factors that have been defined by the IMO (2023) until 2026 (Figure 15). Factors for 2027 onwards will be defined further to revision of the IMO GHG strategy and analysis of upcoming data.

| Year | Reduction factor relative to 2019 reference line |
|---|---|
| 2023 | 5% |
| 2024 | 7% |
| 2025 | 9% |
| 2026 | 11% |
| 2027 | - |
| ... | - |
| 2030 | - |

*Figure 15 IMO's Annual Reduction Factors for CII's calculation (source IMO, 2023)*

CII, is based on the fuel Data Collection System (DCS), introduced by the IMO during MEPC70, which requires all ships above 5,000GT to collect and report their FOC for each calendar year (IMO, 2023). Data to be reported to flag administrations includes:

• The technical characteristics of the ship

• EEDI

• Fuel oil consumption by fuel type in metric tons

• Distance travelled

• Hours underway

The attained CII value is then calculated from these IMO DCS reported data. Using the CII attained that year, the operational carbon intensity rating of a given ship in a given year is determined, following MEPC.354 (78) guidelines.

Ships are given an operational carbon intensity rating of A, B, C, D or E, indicating a major superior, minor superior, moderate, minor inferior or inferior performance level respectively as indicated in figure 16 (DNV, 2023).

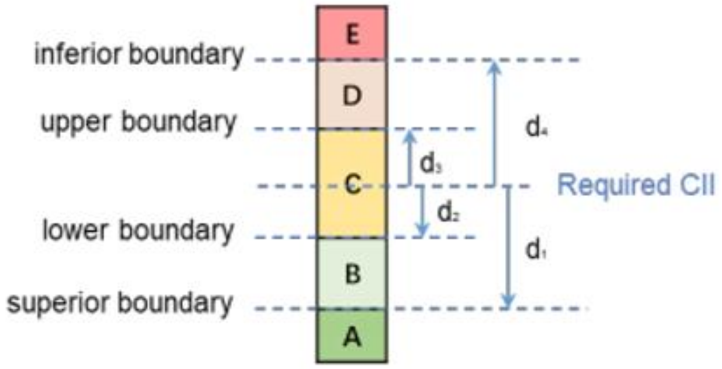



*Figure 16 The boundaries for the CII classification (source DNV, 2023)*

A ship rated D for three consecutive years, or rated E, must develop a corrective action plan to achieve the required annual operational CII (as part of the SEEMP). An impact assessment of CII is expected from the IMO in 2026, and modifications are likely to occur by then. The first year of the attained annual operational CII verification will be 2024 for the operation in calendar year 2023. Also, by 2024, CII must be calculated and reported to DCS verifier together with the aggregated DCS data for the previous year, including any correction factors and voyage adjustments. Deadline for DCS and CII submission remains unchanged - no later than 31 March each year (DNV, 2023).

The attained annual operational CII and the environmental rating (A to E) will be noted on the DCS Statement of Compliance (SoC), which will be required to be kept on board for five years (DNV, 2023).

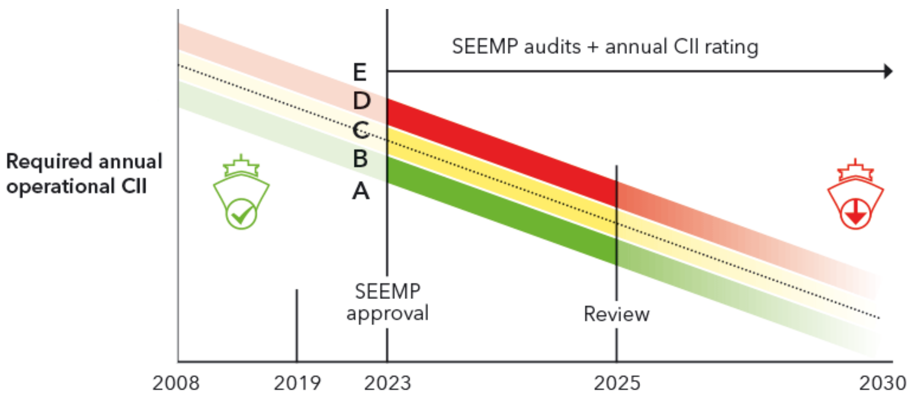



*Figure 17 CII's Classification monitoring and correction plan (Source DNV, 2023)*

Thus, as it can be concluded, unlike EEXI, which is primarily based on the technical characteristics of a vessel as designed and built, CII addresses the way the vessels are operated so it corresponds to an operational measure instead.

## 2.6 (MAJOR) FACTORS AFFECTING CII

On the surface, CII's formula can be described as quite straightforward and very easy to comprehend, not demanding any special expertise in shipping. Clearly, there are those factors that directly affect CII and they can be easily identified by just looking at the formula but there are also some others that need some more profound investigation, combined with some related experience in shipping operations, in order to be spotted.

At first, before examining the actual CII formula, we need to point out that the calculation of carbon intensity is based on the consumption of fuel and its fixed carbon factor, not on direct emissions measurements captured at some engine exhaust part. This practically means that data from flow meters must be always valid and accurate. Probably, the more accurate the flow meter readings, the better (in terms of accuracy) the results to be obtained. However, IMO does not oblige shipping companies to use data directly from the vessels' sensors and most measurements are based on noon reporting no matter the level of uncertainty entailed. Tank-to-wake CO2 emissions are obtained by applying emission factors to fuel oil data from DCS (manual) reporting. Thus we begin our CII's evaluation with a spotted technical limitation that may be significantly affecting the regulation's accuracy.

Then, looking at the formula itself, we observe that CII is related to the Annual Efficiency Ratio (AER), because it is based on vessel's (fixed) deadweight and not on the actual cargo carried. Obviously, in case it was the latter, the metric would correspond to EEOI instead. But this time, the regulation is formulated to serve a different, wider scope, considering any vessel's operation condition a reportable, regarding CO2 emissions, task.

Back to the formula, we observe that in order to lower the total CII, we need to either lower its numerator (total CO2 produced) or increase its denominator (distance sailed) provided that all other parameters remain constant.

Let's examine the first case, where the following factors, strongly related to Fuel Oil Consumption (FOC) can have a positive (or in some cases, negative) impact on the CII:

### *2.1.9 SPEED REDUCTION*

A potential reduction in vessel's speed will result in lower fuel consumption thus lower $CO_2$ Emissions. Specifically, according to a recent study focusing on the impact of operational and technological factors on the development of CII by RINA's Nikolaos Daremas (2023), a speed reduction on a Handymax bulk carrier on laden condition results in a +15% on the annual effect of vessel's CII rating. The study concludes that the vessel's operational speed is expected to significantly affect the calculated level of CII while the calculated operational CII, does not exhibit a monotonic decrease at decreasing vessel speeds. Below figure (18) is part of the study where it illustrates how CII rating is being affected on different operational speeds:

| *Handy* | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Speed 12 kn | C | C | D | D | D | D | E | E | E | E | E | E | E |
| Speed 11 kn | C | C | C | C | C | D | D | D | D | E | E | E | E |
| Speed 10 kn | B | B | C | C | C | C | C | D | D | D | D | E | E |
| Speed 9 kn | B | B | B | B | C | C | C | C | C | D | D | D | D |
| Speed 8 kn | B | B | B | B | C | C | C | C | C | D | D | D | D |
| Speed 7 kn | B | B | B | B | C | C | C | C | C | D | D | D | D |

*Figure 18 Vessel Sailing Speeds impact on CII (weather margin 15%, 5000 running hours (source Daremas,2022)*

It has to be noted though, that in order for the speed reduction to serve as an acceptable solution, it needs to be reduced at levels that are acceptable in terms of both safety and commercial aspects. Also, we should not neglect that by reducing speeds (e.g. slow steaming) we need to continuously increase global tonnage capacity for covering this "loss" which means we need more vessels at sea for transporting the available cargo.

Moreover, as it has been reported, very low speeds affect vessel's engines or may cause other damages to the machinery of the ship (this will be analyzed further in paragraph 6.1.2).

Thus, reducing speed in the principle of "slow steaming' as it is commonly referred, despite how straightforward may appear in its practice, should not be taken as a panacea for achieving lower CII ratings as there are several important elements to be considered before fully applying it.

### *2.1.10 FOC REDUCTION*

According to Stopford (2018), FOC remains the higher expenditure on a vessel operation, counting 66% of a voyage expense. Fortunately, highly related to the previous paragraph, speed reduction is not the only method for reducing FOC. There are multiple methods that can be applied by today's operators, who are challenged to select the suitable combination for better results. There are technical, operational and innovative solutions applicable to the majority of ships such as regular engine and related asset maintenance, trim optimization, weather routing, cargo loading/handling optimization, hull/propeller polishing and many others.

In the same context, there are plenty of available energy saving devices (ESDs), some of which can take advantage of the wind (rotors) or solar power while others may reduce frictional resistance (using ducts and stators, propulsion improving devices, pre-swirl fins, fin on hulls, rudders, high performance paints, air lubrications systems, etc).

What seems to be the most effective method though is the actual operation of the vessel. Operators need to apply effective weather routing, voyage/trim optimization and the appropriate management of ballast/laden voyages, while trying to achieve the optimum "just in time" arrivals and discharging.

A very relevant study conducted by DNV (2021), demonstrates specific numerical findings, where speed reduction along with improved logistics incurs >20% improvement in vessel's total FOC, hydrodynamics (cleaning, coating, hull form optimization) about 5-15% and finally machinery optimization (improvements, waste heat recovery, de-rating and battery hybridization) counts for 5-20%.

Of course, the use of alternative fuels such biofuels and LNG will most probably have a serious impact on FOC reduction also, however what seems to be of much more interest at this point is the actual CO2 emission from today's common fuels (fossil fuels) rather than the actual consumption (in metric tons) of the fuel itself (any fuel). Since there has been much discussion recently about the use of alternative fuels as the ultimate solution to decarbonization, this very matter will be described in a separate paragraph in the following sections (2.9).

### *2.1.11 THE WEATHER EFFECT IN CII*

Weather, although not easily evident in CII's calculation formula, does seriously affect the metric. In general, this is because bad weather causes increased FOC however it is very interesting to elaborate more on the weather's effect in order to estimate the actual degree of this impact.

Referring to Daremas (2023) study, this indicates a 20% increase on annual, average M/E consumption on laden condition compared to its related "good weather" consumption (on a Supramax vessel). The study suggests that the adjustment of voyages where the vessel encountered very adverse conditions, seemed a reasonable and justified option that can be considered in the annual calculation of the actual CII. An exhibit of the study is shown on the below figure (19) where different weather margins applied ranging from 0% to 20%. Noticeably, while vessel's rating (for 2023) remains under a margin up to 4% results in a C level, when applying weather margin above 16%, by the end of year has it has reached level E.

| Supramax | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weather Margin 0% | C | C | D | D | D | D | D | E | E | E | E | E | E |
| Weather Margin 4% | C | D | D | D | D | D | E | E | E | E | E | E | E |
| Weather Margin 8% | D | D | D | D | E | E | E | E | E | E | E | E | E |
| Weather Margin 12% | D | D | D | E | E | E | E | E | E | E | E | E | E |
| Weather Margin 16% | D | D | E | E | E | E | E | E | E | E | E | E | E |
| Weather Margin 20% | E | E | E | E | E | E | E | E | E | E | E | E | E |

*Figure 19 The weather effect in CII (source RINA)*

It is finally concluded that the impact of ambient conditions being encountered in a global trade is so huge, that the CII does not really reflect only how efficiently a ship transports the cargo but incorporates "unbalanced elements that may shape its value in a manner more pronounced than many other single parameters".

Therefore, we realize that those who are able to better "predict" and plan their voyages based on weather conditions, will most probably be able to demonstrate better CII at the end of the year. Perhaps this is the reason why many innovative software providers are implementing AI technologies for advising on vessel's weather routing in combination with identifying the optimum speed for reducing FOC and thus the related CII.

### 2.1.12 LOWER CARBON EMISSION FACTOR FUELS

Concluding with CII’s formula numerator, the use of a lower carbon emission factor fuel will certainly result in a lower CII rating however this impact does not seem to be very important compared to the rest described above, so it will not be examined further.

### 2.1.13 DISTANCE SAILED

Looking at the denominator of our fraction, the deadweight (DWT) of a vessel cannot be changed hence the only variable factor here, is the distance sailed.

Obviously, greater idling time by the means of port staying or anchorage will have a negative impact on the CII. Also, possible machinery breakdowns will have a similar effect. Remarkably, one of the consequences of having a DWT in the denominator is that any reduction in cargo carried and/or an increase in ballast voyages will help the vessel achieve a better CII rating (by reducing related fuel consumption of course). This seems to favor vessels that execute more ballast than laden legs. In other words, a vessel may occasionally have to sail some more miles in order to “fix” the CII if current rating is not the favorable one. We will explain thoroughly what this means not only for the relationship of ship owners and charters but for the whole industry too, in Chapter 6.

### 2.1.14 CREW’S PERFORMANCE

Apart from the “obvious” factors that are visible in the formula of CII explained in the previous paragraphs, there are also some others that cannot be traced so easily when examining how to improve CII rating. One of much importance, appears to be crew’s performance. It is not only how capable they are to operate the vessel or how consistently they maintain it but also how successfully they collect the required data for accurate CII reporting. Therefore, there is an urgency for continuous support, guidance and training for the crew who are in a great degree responsible for a ship’s CII. There have been reported several cases where different crew has handled the same vessel much better, achieving to reduce ship’s FOC and breakdowns also. As a result, a crew’s performance plays a very important role in ship’s overall performance.

## 2.7 UPCOMING REVISIONS OF THE CII REGULATION

Regulation 28.11 of MARPOL Annex VI (IMO, 2023) specifies that a review of the CII regulations and associated guidelines shall be completed by 1 January 2026, including an assessment of the need for reinforced corrective actions or other means of remedy and the need for enhancement of the data collection system.

The recent MEPC 80 in July 2023, initiated the review of the short-term measures, including CII, EEXI and SEEMP, by approving the plan for reviewing among other things, experiences with enforcement of short-term measures by Flag States and Port State Control (PSC), the CII metrics (currently AER), as well as correction factors and voyage adjustments for CII.

The review will be carried out in three phases:

- From July 2023 until MEPC 82 (to be held in autumn of 2024) the focus will be on data gathering
- MEPC 82 will initiate a data analysis, which will be continued by a correspondence group until MEPC 83 (to be held in spring of 2025)
- A working group scheduled to meet in late 2024 or early 2025 will begin the review of the regulations in MARPOL Annex VI and the associated guidelines.

## 2.8 THE DIFFERENCES OF EEXI TO CII

As already identified, apart from the evident differences to the type of vessels they apply to, EEXI is a framework for determining the efficiency of the design of in-service vessels, while CII on the other side is an operational measure with different scope focusing on how efficiently a ship transports cargo.

A very interesting and easy-to-use table that highlights the main difference points while explaining some of the key issues that owners and charterers need to consider for both regulations is illustrated at the following table (2) by Tang et al. (2021).

| | EEXI | CII |
|---|---|---|
| **What do the regulations apply to?** | All new build vessels/ existing vessels above 400 GT falling within the scope of MARPOL Annex VI. | All vessels above 5,000 GT falling within the scope of MARPOL Annex VI. |
| **When will they apply?** | Expected to enter into force on 1 November 2022 with certification requirements coming into effect from 1 January 2023. | Expected to enter into force on 1 November 2022 with certification requirements coming into effect from 1 January 2023. |
| **Type of measure** | A technical measure focused on a vessel's **design** and subject to a one time-certification. | An **operational** measure focused on a vessel's operating efficiency and subject to annual assessment. |
| **Purpose** | The certification will show the energy efficiency of the vessel's design. | Will regulate the operational carbon intensity of a vessel by measuring how efficiently a vessel transports goods or passengers. |
| **How do the regulations achieve their stated purpose?** | A vessel falling under the EEXI regime will be given an Attained EEXI, which will indicate a vessel's estimated energy efficiency compared to the Energy Efficiency Design Index[1] baseline. The Attained EEXI will then be compared to a Required EEXI (which will depend on the vessel's type and size).<br><br>A vessel will be required to take steps to meet the Required EEXI if its Attained EEXI is less efficient than the Required EEXI. | The annual CII will be given in grams of CO2 emitted by cargo-carrying capacity and nautical mile.<br><br>Each vessel will be given an Attained Annual Operational CII rating (A, B, C, D, or E), with A indicating a "major superior". Ratings will be determined by comparing the Required Annual Operational CII against the Actual Attained Annual Operational CII.<br><br>Each rating threshold will become increasingly stringent towards 2030. All emissions data must be reported via the IMO Data Collection System (DCS) and the CII will be calculated based on the DCS.<br><br>C is the minimum rating required for compliance, but administrations, port authorities and other stakeholders will be encouraged to provide incentives to vessels rated A or B. |

*Table 2 Differences between EEXI and CII (source Tang et al. 2021)*

| | | |
|---|---|---|
| **What does compliance look like?** | An Attained EEXI will need to be verified unless the Attained EEDI of the vessel satisfies the Required EEXI. To do this, an application for a survey and an EEXI technical file[2] will need to be submitted to flag administration or Class for approval.<br><br>Compliance with EEXI will be shown in a vessel's International Energy Efficiency Certificate. | Vessels will need an enhanced Ship Energy Efficiency Management Plan (SEEMP). The SEEMP will need to be approved and kept on board the vessel. It will need to contain:<br><br>a. A description of the methodology used to calculate the vessel's Attained Annual Operational CII<br><br>b. The Required Annual Operational CII for the next three years and a plan to show how it will be achieved within that time<br><br>c. A procedure for self-evaluation and improvement |
| **What actions can be taken to ensure compliance?** | Actions that might make a vessel EEXI compliant:<br><br>a. Propulsion optimization<br><br>b. Using alternative fuels (e.g., ammonia, methanol and synthetic fuels)<br><br>c. Modifications to shaft power limitation (applies a limit to maximum shaft power)<br><br>d. Modifications to engine power limitation<br><br>e. Installation of energy-saving devices<br><br>f. Engine de-rating<br><br>g. Overridable power limitation to reduce a vessel's Attained EEXI | Actions that might make a vessel CII compliant:<br><br>a. Improving voyage planning (e.g., proceeding less directly but more efficiently, reducing speed or slow steaming)<br><br>b. Using alternative fuels (e.g., ammonia, methanol and synthetic fuels)<br><br>c. Installation of energy-saving devices<br><br>d. Improving the condition of the vessel (e.g., cleaning fouling and marine growth)<br><br>e. Fitting a more efficient propeller<br><br>f. Reducing cargo volume intake<br><br>g. Using an overridable power limitation to reduce CII |

*Table 2 (cont) Differences between EEXI and CII (source Tang et al. 2021)*

In addition to the key differences identified in the previous paragraphs, Tang et al (2021) identify some very interesting commercial wise points, worth mentioning:

- For EEXI, owners are primarily responsible for ensuring a vessel's compliance with MARPOL (assuming its flag state is a MARPOL contracting nation). The terms of most charter parties will say, or at least imply, that technical modifications required to comply with industry regulations lie with owners as part and parcel of their seaworthiness obligations.

- Regarding CII, owners of time-chartered vessels must comply with charterers' lawful employment orders. However, these orders could affect the vessel's CII rating, which owners must still comply with. Also, decisions by owners to slow steam, reduce cargo-carrying capacity or deviate to maintain their CII rating could put them in breach of charter, and potentially liable for damages.

- Disputes under spot fixtures could arise if owners take operational measures to maintain a CII rating which result in, for example, delays to the voyage. Again, this could put them at risk of breaching their obligations to proceed with due or utmost dispatch. In the related section of this study, chapter 6 a more extensive analysis will be made on each party's obligations and responsibilities. At this point though, we can prematurely conclude that EEXI and CII despite different in nature and context, they have a lot in common when it comes to achieving compliance, especially concerning the actions a ship company (owner) needs to take. This is quite reasonable as the regulations coming into effect are targeting the ship's overall energy consumption which can be measured in multiple manners under different scope.

Also, another very important element to keep in mind is that for any ship in question, a good performance in EEXI doesn't necessarily guarantee an acceptable result in CII despite their interrelation. This is because the relationship between EEXI versus CII related to actual energy efficiency is not strictly linear. EEXI, which is a technical measure may have an effect into vessel's overall performance when it comes to FOC, but if for instance the operators of the vessel manage it in an ineffective way (prolonged port staying, imbalanced ports rotation, long legs selection etc) then the CII rating of this vessel will be practically doomed to fail.

## 2.9 THE USE OF ALTERNATIVE FUELS

At the time of writing this study, no consensus has been reached about the next fuel that will replace (fossil) marine gas oil in global shipping. As a matter of fact, despite the literature or the noted hype about the use of alternative fuels as the optimum solution for reducing CO2 in shipping, we notice that neither the fuels are ready nor the market either (price, availability, infrastructure). There are so many arguments about what is the ideal future fuel because reasons such cost, production, extraction, processing, filtration, storage, transportation, supply and others, make it difficult to end up into a single solution. Literature reports that currently no proven source of zero-carbon fuel is capable of fully accounting for the entire shipping industry's energy needs, at least within this decade (Bureau Veritas, 20220). As a result, up to this moment, the vast majority of world's fleet is using conventional fuel, despite the fact that there is a considerable shift in newbuild vessels to be operated either by duel fuel or single LNG. The below figure (20) by DNV (2023) is depicting this slow pace, but changing reality in numbers:

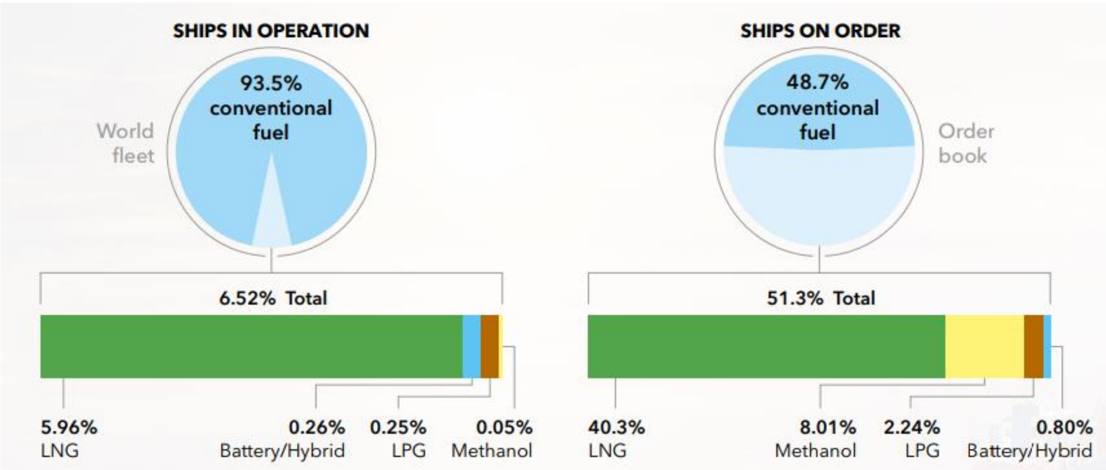



*Figure 20 Alternative fuel uptake in the global fleet as of July 2023 (source DNV, 2023)*

What seems to be not taken into account when referring to future fuels, is the fact that CII is based on a tank-to-wake perspective, so using blended carbon-based biofuels or electro fuels would not help to improve a vessel's rating, at least at this stage.

This is another pending ongoing IMO work considering the life-cycle analysis of fuels.

Finally, the use of onboard CCS systems to reduce the release of emissions is not currently being accounted for. An impact assessment of CII is expected from the IMO in 2026, and modifications are likely to occur by then.

Since the scope of this study is not focusing on the evaluation of available fuel types, no further reference or analysis will be made but only a highlight of the most common concerns in the context of using alternative fuels  in reducing CII.

## 2.10 THE KEY ROLE OF DIGITALIZATION

The shipping industry is known to be traditionally a "follower" in the utilization of disruptive technologies. However, it seems that the GHG (among other) regulations are acting as a catalyst for a faster adoption of numerous digital tools that have been developed in the recent years. Most of these tools can produce the desired results of either directly reducing carbon emissions and hence having a decarbonization effect in CII and EEXI while other digital technologies such advanced monitoring systems can provide all the information required for monitoring vessels' performance and perform maintenance more efficiently. Also, today's modern systems for high frequency data collection directly from ships' sensors allow the  continuous data interchange between the ship and the charterers. Hence, digitalization can assist significantly in keeping the relationship of the contractors (ship owners-charterers) aligned, by securing the essential transparency required.

In addition, shipping companies have to always seek for and identify the most fuel-efficient routes for their vessels. Such decisions need high volume of both historical and Big Data, related to weather, sea conditions, port congestion, speed and other parameters all to be analyzed further in order to predict the optimum route (route planning). For this reason, sophisticated software is often employed, which nowadays incorporates AI, enabling the simulation of unlimited scenarios for predicting weather patterns and finally providing the necessary insights for optimizing vessels' performance. On a wider scale, the effective collection and methodical analysis of the data allows all stakeholders, to check on a real time basis the current performance of the ship and predict any possible deviation from potential ratings set by the regulations, leading to less GHG emissions and increased level of compliance.

The latest emergence of the digital twin, consisted of Internet of Things (IoT) sensors which also involves machine learning algorithms, enables advanced remote monitoring of critical ship systems, reducing the need for physical inspections and maintenance time. This has ultimately an effect in mitigating fuel consumption and emissions from ships' auxiliary engines, preventing breakdowns and delays to decrease costly idle time.

Thus we realize that digitalization is an integral part of the decarbonization process as it facilitates its fastest implementation by practically providing all the necessary tools for conducing to fuel oil and thus CO2 reduction. In addition, digitalization is ultimately promoting better collaboration between stakeholders in shipping as it prepares the ground for translucent interactions allowing valuable data to be shared. Finally, it is through technology, that both ship owners and charterers are obtaining the advantage of being able to predict and foresee conditions in order to be operating in a more proactive than reactive principle towards a greener shipping.

## 2.11 IN CONCLUSION

At the hand of the above paragraphs we realize that more ballast voyages, slow speeding and hull/machinery optimization will end up in better CII while continuous staying at ports will have a negative impact. Still, operational optimization seems to be the prevailing method for reducing FOC and hence ship's related CII values. Undoubtedly first thing comes to operators' mind is to lower speeds where possible in order to reduce fuel consumption. Finally, access to data will be a vital factor for success as those with digital maturity and the ability to collect and analyze data, will be better in adapt to evolving regulations.

As we will examine in the next chapter, CII is actually impacting the average ship's lifespan, forcing some ships to the scrap yards earlier than it was initially planned. Thus, ship owners need to take specific mitigation measures if they wish to retain their vessels tradable for the challenging years to come.

# 3.0 HOW EEXI AND CII AFFECT CURRENT STATUS OF GLOBAL FLEET

The following paragraphs aim to describe the current world's fleet in terms of EEXI and CII readiness and how the new measures are essentially affecting ships' value, intensively reflected by the S&P or newbuilding market. The first part of this analysis is based on collecting and presenting data from published references and literature while the second part which stands as an individual chapter (4) is based on primary, "first-tier" data, acquired though a methodical survey by the means of questionnaire and other complimentary documentation process explained in paragraph 1.4.

## 3.1 CURRENT STATUS OF GLOBAL FLEET

In brief, as research indicates, the fleet of vessels that fall under EEXI and CII ratings, as it was expected, was not ready for the measures that came into effect since 1st January, 2023. This fact is actually justifying in a sense the reasons why such regulations were imposed in the first place, and as an effect, the continuous revisions on a frequent basis towards a stricter environmental policy.

To begin with, an analysis of the sailing activities of 15,372 ships published by Shipping Watch (2022), showed that more than half of the global merchant fleet was to receive one of the two worst CII ratings (D and E). Talking more about numbers, according to Offshore Energy (Prevljak, 2022), 75% of global fleet was not EEXI compliant by the beginning of the measure (January 2023). In similar context, UNCTAD (2022) reported that 30 to 40% of containerships and dry bulk carriers were considered non-compliant for CII during 2021, unless serious measures were to be taken. The same report cited that around 65% of the fleet capacity of tankers and bulk carriers were already compliant with the EEXI although some needed to undergo engine power limitation. Regarding the containers, they were CII-compliant at the time, while 31 % would be rated D or E. For dry bulk carriers, the share of rate D or E vessels was estimated at 36%. Other vessels would be required to slow down or fit new technologies. Similarly, Clarkson's Research (2022) concluded that 42% of the existing tanker, bulk carrier and container fleets would be rated D or E in 2026 if they had not modified their speeds or specifications.

To present the potential impact of EEXI and CII regulation in an illustrative manner, ABS (2021) conducted a related research back in 2021, demonstrating very high percentages of incompliant vessels (if no improvement was to be made) as shown on figure 21.

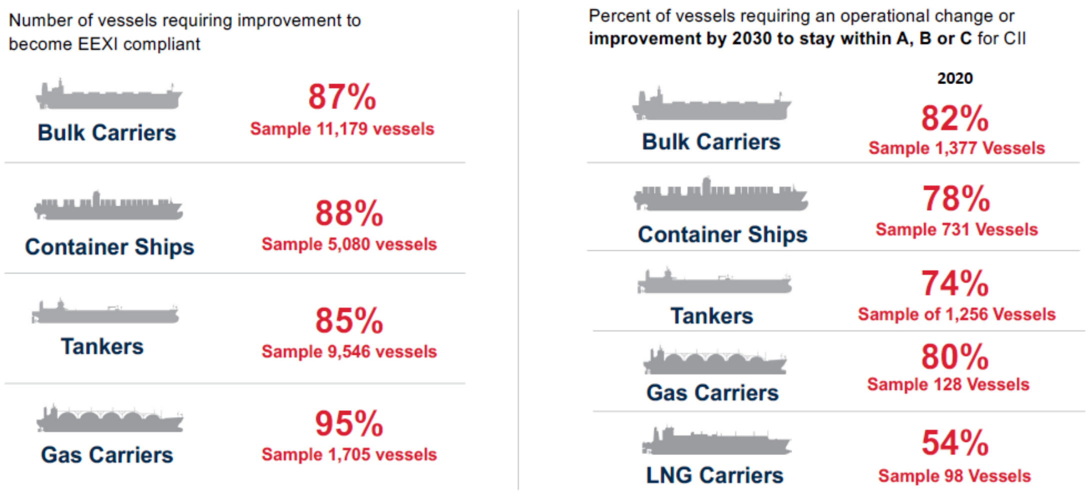



*Figure 21 Potential Impact of EEXI and CII on Global Fleet (source ABS, 2021)*

In the same context, DNV Maritime vice president and global business director for bulk carriers, Morten Løvstad (Wingrove, 2023) claimed that more than 60% of the global bulk carrier fleet will require measures to improve the CII rating to remain compliant and competitive through to 2030. As Løvstad stated, "*When CII is calculated for this year (2023) and 2024, 40-60% of the worldwide fleet of bulk carriers will have ratings of D or E, meaning owners would need to change their operations to improve this to C rating or better*" (Wingrove, 2023).

Wartsila (2023), a leading marine machinery equipment maker, claims that currently 45% of merchant vessels will need an upgrade to comply with CII and if we try to talk about the future, more than 80% of bulk carriers and container ships will be in the lowest CII category by 2030 if no action is taken.

Finally, in a recent LR report, Panos Mitrou, Global Gas Segment Director (2023), explicitly remarks that since CII assessments will become progressively stricter from 2027 until the end of the decade, ships which are adapted to meet CII requirements by 2024/5 may subsequently fall into categories D and E later in the decade.

Consequently, there seems to be a strong consensus over current fleet status in terms of EEXI and CII overall performance, as market experts, analysts and classification societies are determined that if no drastic measures are to be taken, a significant percentage of today's global fleet will not be able to cope with the regulations.

### *3.1.1 NON-COMPLIANT VESSELS CLASSIFICATION*

As we understand from the above reports, there will be a large number of vessels that will end up being non-compliant by the end of the first reporting year of the CII regulation, if no measures are to be taken promptly. These vessels are not going to be scrapped right away, as this would create a chaos in the market from one moment to the next, with unprecedented outcomes. Instead, the industry will have some (perhaps short) period for catching up with the measures after having evaluated the extent of the imminent impact.

Prevljak (2022) divides and practically categorizes non-compliant vessels into three main groupings (categories). These groupings are based on the difference between the attained and required index, as well as the efficacy of technological improvements:

a) The first of these groupings contains vessels that can be made compliant using energy-saving devices retrofitted to the main structure

b) The second category contains vessels for which an engine power limitation (or ShaPoLi) procedure is the most likely option

c) The third category includes those vessels that will struggle to remain compliant without drastically reducing speed and fuel consumption and may be the prime candidates for a one-way journey to the breaking yard (demolition).

What is for certain though is the fact that none of the above categories is to remain constant as CII is primarily affected by many parameters that may dynamically influence current and future rating. Most probably, those vessels currently compliant (category a and b) will have to invest for staying in this condition while category c vessels will be the first to be withdrawn from the market, no matter how many changes or improvements they are going to make. So the groupings have a temporary form which needs continuous effort in order to be maintained.

## 3.2 THE IMPACT OF MEASURES ON GLOBAL SHIPPING

As a consequence of the facts and findings identified above, it can be argued that global fleet will (as a matter of fact is already facing) severe repercussions unless shipping operators act promptly.

At first glance, EEXI and CII seem to severely damage vessels' employability as negative ratings will push owners to strive for performing better while charterers on their side are expected to prefer "greener" ships.

An article by Hellenic Shipping News (2022) claims that low-rated vessels would face loss of their International Energy Efficiency Certificate (IEEC), so banks may refuse to finance or refinance vessels with design indices above a certain limit, and port authorities may impose penalties on non-compliant vessels entering their waters.

Also, negative/low rating can have a direct effect on the vessel's commercial value, in terms of fuel efficiency, charter value, insurance cost, port fees, and depreciation.

LR reports (2022) that because of EEXI and CII, owners of non-compliant older vessels will be faced with the decision over whether to invest in expensive sustainability measures, sell them for conversion to floating LNG plants, or dispose them for recycling.

There are also other, quite pessimistic, views expressing that vessels' demolition is the most evident option ahead. According to Dr Anil Sharma, founder and CEO of Global Marketing Systems Inc (GMS) (Bartlett, 2023) for Seatrade Maritime News, there will be significant increase in the number of container ships and bulk carriers heading for recycling yards as result of the IMO's CII carbon intensity regulation. He forecasts that more than 80% of these ships will be in the lowest C, D, and E categories of CII. In order to support this view, Dr Sharma is citing the firm orderbook for containers and the large volume of deliveries in 2023 and next as some of the reasons for higher recycling volumes.

Moreover, as LR notices (Mitrou, 2023), the supply squeeze will be inevitable as we are likely to have a shortage of ships (reduced capacity) that comply with CII from 2025 onwards.

As a result, this could limit charterers' options, propel rates for compliant ships to new highs, and ultimately put a brake on the world's decarbonization process to the extent that this is driven from the coal to gas transition.

Equally, UNCTAD (2022) agrees that EEXI and CII will likely reduce shipping capacity as they stipulate slower sailing speeds to save fuel and will require some vessels to be retrofitted or recycled. However, it must be noted that reduction in speeds will inevitably reduce owners' profits and competitiveness, and they could quickly find themselves losing business to more efficient vessels unconstrained by slow steaming. Especially, when it comes to potential reduction in capacity, MSC warns that CII compliance could absorb up to 10% of capacity across global container fleet (Boonzaier, 2022).

### 3.3 THE IMPACT ON S&P MARKET

Arguably, that the most evident and easily measurable impact of the measures impact is traceable on the Sale and Purchase (S&P) market. According to a recent article seen in Naftika Chronika (2023), CII is seriously affecting the investment decisions for S&P of every shipping company. More specifically, the article is evoking facts from a Vessels Value survey which reports that only in 2022, 9.9% of cargo fleet (bulk carriers, tankers, containerships) were sold to second hand market. Vessels Value via Hellenic Shipping News (2023) classified the fleet in three categories (bulkers, tankers, containers) according to their current CII's ranking, spotting that of those vessels that achieved B ranking, 12,8% changed ownership while of those ships with C ranking, 11,6% changed hands. At the same time, there was less trading (transactions) for the vessels ranked with D and E (8.6% and 4.2%) which is obviously reasonable because these categories fail to meet CII's requirements (figure 22).

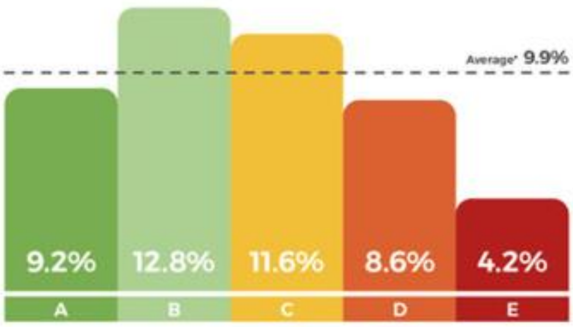



*Figure 22 2022 S&P Activity as a % Fleet sold by Estimated CII Rating and Ship Type (All Cargo) (source Hellenic Shipping News, 2023)*

On the other hand, the percentage of A rating ships that changed ownership was lower (compared to B and C rating ones), which may initially look surprising, but this can be explained by the reluctance of shipowners to part with their most energy efficient ships without getting in return, a reasonable price that reflects their current value.

In parallel, according to the same report, it is worth mentioning that CII played a particularly important role in the buying and selling of tankers and bulk carriers, but less than those of containerships.

Those tankers falling into categories A, B, C, 12.2%, 16.7% and 15.7% changed hands. On the other hand, in containerships the corresponding percentages were 5.5%, 7% and 6.7% respectively. Figure 23 below illustrates the vessels that were sold (by category):

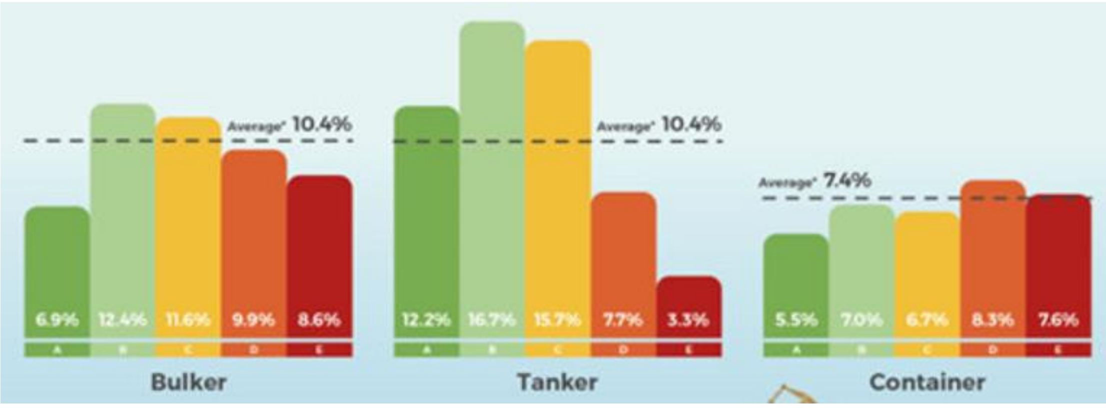



*Figure 23 2022 S&P Activity for bulker, Tankers and Containers (source Hellenic Shipping News, 2023)*

Looking into each sector, Bulker and Tanker liquidity is, on average, very similar with approximately 10% (10.4%) of each fleet being traded in 2022. However, we see that the differentiation by CII band is far more pronounced in the Tanker market. Liquidity in the Tanker market is highly concentrated in vessels operating in bands A, B and C. Just 3.3% of Tankers operating in band E were traded in 2022, three times lower than average and almost five times lower than Tankers in band B. Certainly, this may be a result of current market factors such as earnings, since Tanker rates during this period and sometime prior have been low, placing more importance on the efficiency of operations and minimizing operating costs.

What is more, the study by Vessels Value, reports that liquidity in relation to CII performance is changing over time. While band E vessels have had the lowest levels of liquidity, we see that the gap has widened substantially. It is worth noting that liquidity of band E vessels decreased during 2021, when liquidity of vessels operating in other bands increased substantially. On average, liquidity decreased slightly in 2022.

It is also notable that the liquidity of band B vessels increased during 2022, and that the gap between average liquidity and band E liquidity persists. The below figure (24) graphically summarizes the liquidity and the estimated % of value change per category:

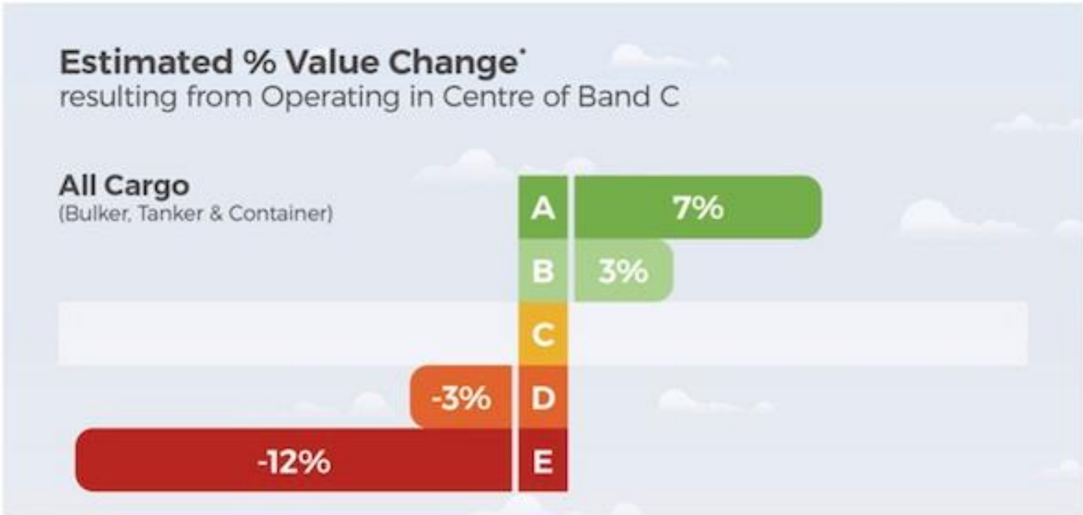



*Figure 24 Estimated % Value Change for all Cargo (source Hellenic Shipping News, 2023)*

## 3.4 NEWBUILDING ORDERS

Equally, the orders for newbuild vessels in the first three quarters of 2023, appear to be demonstrating a slightly reduced rate compared to the flourishing year of 2022, but still is at considerably high levels (table 3 below):

| | Quarter | Units | Total DWT |
|---|---|---|---|
| 2022 | Q1 | 987 | 26,966,014 |
| | Q2 | 715 | 23,606,426 |
| | Q3 | 514 | 15,116,858 |
| | Q4 | 355 | 19,017,875 |
| Total | | 2,571 | 84,707,173 |
| 2023 | Q1 | 676 | 24,097,656 |
| | Q2 | 318 | 16,263,350 |
| | Q3 | 82 | 6,422,040 |
| | Q4 | - | - |
| Total | | 1,076 | 46,783,046 |

*Table 3 Vessels ordered per quarter for 2022-2023 (source Allied's Weekly Market Review, 2023)*

Perhaps the below graph (figure 25) is more explanatory in terms of depicting the trend, as it compares the number of vessels ordered in 2022 and 2023 in comparison to 2018 but in cumulative activity. In this graph, it is pretty obvious that over the last, not only two but four years, there is a steady increasing rate of orders for newbuilds, validating the fact of global fleet renewal.

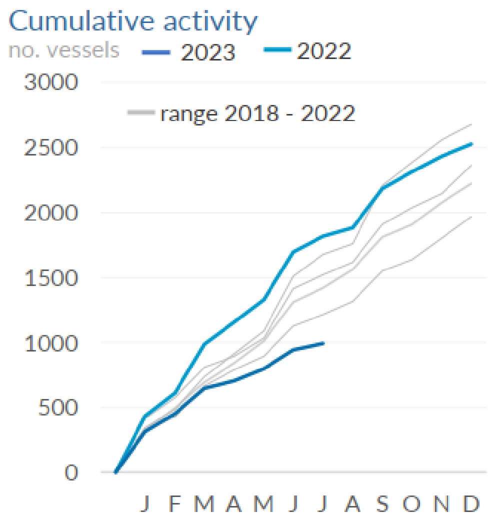



*Figure 25 Cumulative Activity in Newbuilding for 2022-2023 compared to 2018 (source: Allied Weekly Market Review, 2023)*

The slight decrease observed over year 2023 (which seems to be on a declining trajectory since the second quarter of 2022) can be attributed to multiple factors.

According to Naftemporiki (2023), the market continues to be characterized by increased prices, depletion of berth availability in shipyards, which now offer deliveries for the first half of 2027 on certain ship types (gas carriers, containerships), and uncertainty surrounding available alternative fuel technologies. These are factors that continue to bear a negative impact on attracting investment.

In the end, Clarksons Research (2022) is projecting an overall ~2% fleet growth in 2023 (and only ~1% in 2024); while they are expecting the impact of emissions regulation to reduce “effective supply” even further through slow steaming (although we also expect congestion levels to be lower).

It is noteworthy that investment interest is mainly focused on tanker orders, compared to the corresponding period of 2022, following the increase of demand for petroleum products.

This fact is also evident on the S&P activity of the Greek ship owning community as we will examine below, who appear to order or buy tankers more than any other category of vessels.

### 3.5 GREEK FLEET STANDING

The Greek owned fleet is very interrelated with the (global) facts described in the previous paragraphs. The reason the Greek fleet is used (or preferred over other top nation fleets) as a reference lies to the following three factors:

a) Greek shipping owns a weighty proportion of the total global fleet. In fact, the Greek fleet ranks steadily first in terms of DWT (table 4) and third, both in number of vessels and total value. It is comprised of 4,709 vessels ships with a total value of USD 152.69 bil.

Overall, Japan tops the total value list with a fleet worth USD 193.64 bil, and China ranks first in terms of vessel numbers with a fleet of 7,114 ships. (Vessel Value, 2023).

| Year | China | Greece | Japan | S. Korea | USA |
|---|---|---|---|---|---|
| 2012 | 174,10 | 246,70 | 225,59 | 69,73 | 57,57 |
| 2013 | 193,12 | 261,45 | 240,33 | 80,38 | 58,37 |
| 2014 | 201,88 | 283,04 | 245,56 | 83,41 | 61,10 |
| 2015 | 205,29 | 308,80 | 250,03 | 84,92 | 70,74 |
| 2016 | 219,11 | 326,37 | 249,43 | 83,27 | 71,45 |
| 2017 | 234,37 | 344,21 | 247,01 | 85,39 | 77,67 |
| 2018 | 254,81 | 367,25 | 247,25 | 81,43 | 79,60 |
| 2019 | 287,51 | 380,37 | 247,47 | 80,97 | 71,27 |
| 2020 | 309,66 | 396,77 | 256,12 | 85,44 | 72,00 |
| 2021 | 326,70 | 405,33 | 265,29 | 89,93 | 69,72 |
| 2022 | 358,23 | 418,62 | 259,72 | 95,37 | 71,79 |

*Table 4 The fleet of the top five shipping countries in million DWT (source Clarksons 2022)*

**Top Owning Nations**
by Value (USD Bn)

| Owner Nation | Number of Vessels | Total Value |
|---|---|---|
| Japan | 5,974 | $193.64 |
| China | 7,114 | $182.49 |
| Greece | 4,709 | $152.69 |
| USA | 2,404 | $97.89 |
| Singapore | 2,860 | $71.92 |
| South Korea | 1,728 | $62.99 |
| Norway | 1,731 | $58.81 |
| Germany | 2,224 | $52.03 |
| United Kingdom | 1,317 | $49.32 |

*Table 5 Top Owning Nations by Value (USD Bn) (source Vessels Value, 2023)*

b) the "Greeks", play a very significant role in the global S&P market.

In terms of S&P, Greece was the second top seller of secondhand vessels in 2022, with 428 vessels sold and a total value of USD 11.7 bil.

Also, Greece was the second biggest spender in 2022, spending USD 9.77 bil on a total of 376 vessels (Vessels Value, 2023) as displayed in figure 26 below:

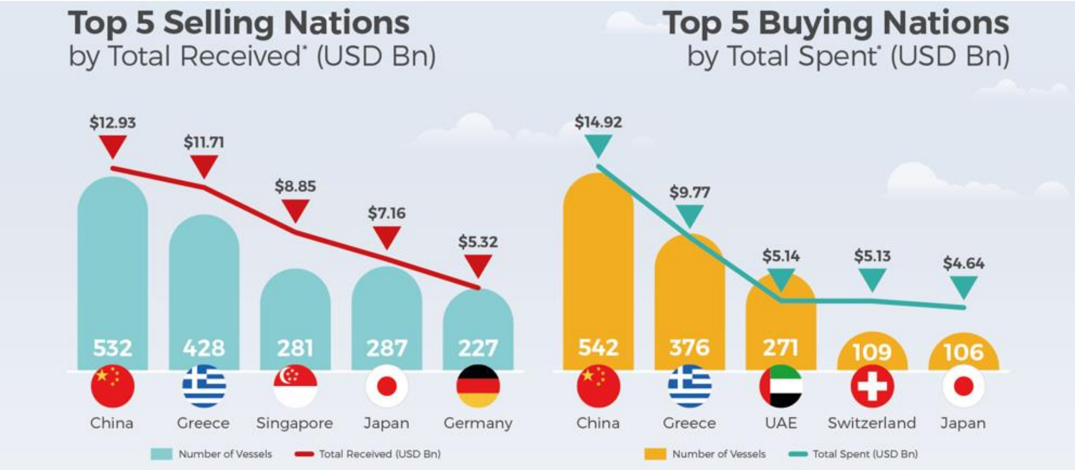



*Figure 26 How Greeks stood out in S&P market in 2022 (Vessels Value, 2023)*

c) Information is more easily accessible to Greek market since the actual survey conducted via the questionnaire and the related interviews, apply to the Greek market mainly, which literally represents the global, up to a certain respectable degree.

### *3.1.2 GREEK FLEET'S CII RATING*

Decarbonization is an increasing high priority to the Greek shipping community and this has been proved by all the initiatives already taken towards this direction. Also, reducing the GHG emissions has dominated as a topic (and still is) to the majority of recent years' shipping forums and conferences, signposting the seriousness of the matter. Last but not least, as the survey findings indicate, the majority of the Greek shipping companies are not only considering but they are also getting prepared for the measures, acting in a very proactive manner.

Recently, according to an article by Glass of Seatrade Maritime News (2023), Melina Travlou (President of Greek Shipowners Union) claimed that there is an estimation that over a quarter of the Greek fleet have achieved an estimated CII rating of 'A' and 64% of the fleet have received an estimated rating between A-C" (figure 27).

In this respect, the individual survey conducted for the purposes of this study, indicates quite similar numbers while responses from the sample are almost equally divided with a 47,1% claiming being not ready and 45,1% feeling confident they have taken all necessary measures to be ready for CII (and EEXI).

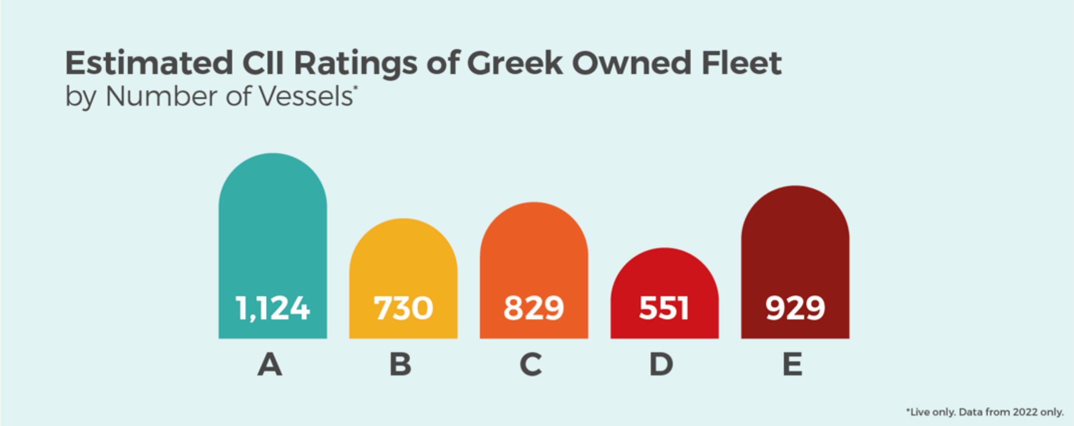


*Figure 27 Estimated CII Distribution of Greek Fleet in number of vessels (source Vessels Value, 2023)*

### *3.1.3 GREEKS STAGE DYNAMIC COME BACK TO SHIPYARDS*

According to George Georgiou (Naftemporiki, p.201, 2023), orders by Greek shipowners for newbuilds in the first four months of 2023 recorded a spectacular increase. In Q1 of 2023, Greek shipowners ordered 69 ships, including 47 tankers (165,38% increase compared to 2022, accounting for an astonishing 40.1% of the international tankers orders) with a total capacity of 5.4 million dwt and a value more than $3 billion. This very investment accounts for 18.7% of the orders placed worldwide and 19.5% of the total value.

As for bulkers, the “Greeks” ordered 59 new vessels, accounting for the astonishing 21% of the global activity (Naftemporiki, p.61, 2023).

In order to better realize the extent of “Greeks” newbuilding orders, we need to compare it to that of China’s. In the related table below (6) identified by Petropoulos (Head of Research in Petrofin Research (2023)) we notice the distribution of committed newbuilding orders, where although Chinese shipowners have a much larger order book for 2023 and 2024, the “Greeks” tend to acquire significant advantage for the years 2025 and 2026 (Naftemporiki, p.189, 2023)

| Year | China | Greece |
|---|---|---|
| 2023 | 11,04 | 7,06 |
| 2024 | 9,95 | 5,92 |
| 2025 | 4,87 | 5,02 |
| 2026 | 0,64 | 1,46 |
| 2027 | 0,87 | 0,00 |
| 2028 | 0,74 | 0,00 |
| Grand Total | 28,11 | 19,46 |

*Table 6 Order book China vs Greece in mil DWT (source Petropoulos T. 2023)*

However, it needs to be noted that this increased S&P is not exclusively associated to IMO's environmental regulations despite the fact that 70% of the vessels sold in the first two quarters of 2023 were more than 16 years old. If we look at the tables of S&Ps in more detail, considering the price and the type of the vessels sold, we realize that driving factors for the S&P activity were the fundamentals of the market itself. In other words, the increased S&P appeared because the conditions were ideal following the related demand. The ships that were actually sold (tankers mainly), were valued near their brand-new cost, even after ten years of operation (near USD 50 mil.). On the other hand, new orders were placed as a result of attractive pricing by the shipyards (especially Chinese) in combination to a convenient time for delivery (Petropoulos T. 2023). Thus, it would be an exaggeration to merely correlate the increased S&P activity to the age (or aging) of the vessels which is certainly expected to have an immediate effect in their performance towards environmental requirements.

Interestingly, in regards to the use of alternative fuels, the vast majority of 2023 orders, in fact 49 out of 69 vessels in total, concern ships using conventional fuels. At the same time, 15 of the ships currently under construction, will be equipped with dual-fuel engines, using LNG in most cases as an alternative fuel (Petropoulos T. 2023).

It can be argued that the conditions of uncertainty (explained in detail in chapter 2) currently surrounding the right choice of fuel and the lack of infrastructure to support it, in combination with current high costs, are preventing the "Greeks" (and most probably the rest of ship owning nations) from ordering double fuel ships.

## 4.0 ONLINE SURVEY REVIEW

In this chapter, in high relation with the previous one, a specifically planned and targeted survey is presented which has been conducted for the purposes of the study. The survey has been carried out through personal email invitations, addressed to a number of 312 shipping companies in total, achieving a response rate of 19,2% (53 responses online and 7 through phone survey). The questions were set with main focus the current status, attitude towards and the opinion of the (Greek mainly) ship owners about the EEXI and CII measures. This survey, which can be considered as the actual "voice of the shipping community", is aimed to identify and potentially validate (even perhaps contradict) all those points discussed in the previous chapters by establishing a firsthand view on the regulations under consideration.

### 4.1 <u>FINDINGS ANALYSIS</u>

The first (1 to 3) questions are practically identifying the composition of the sample in order to collect some information regarding the identity of the fleets we are examining, in terms of size, type and the age of vessels, either owned or managed.

#### *4.1.1 NUMBER OF VESSELS OWNED/MANAGED*

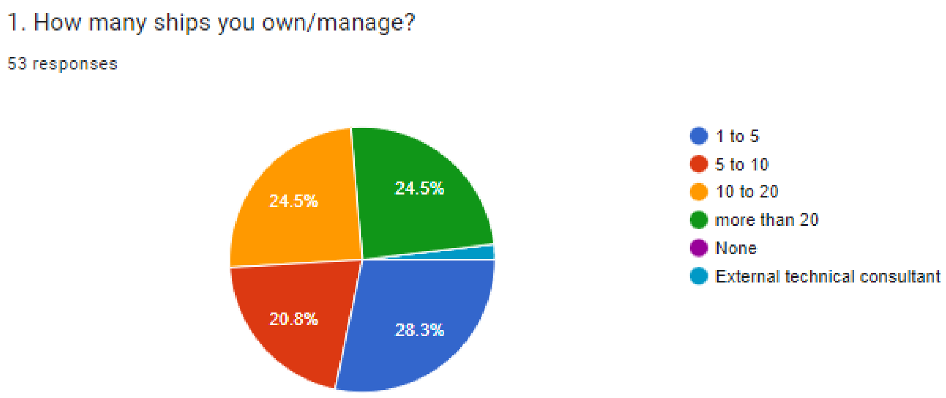



*Figure 28 Number of vessels owned/managed*

To begin with, the responses of question 1 (figure 28), create the (quite anticipated) demographics of today's owning/managing shipping companies, where their size is divided almost in four (equal) parts, as the majority (29.4%) owns/manages 1 to 5 vessels.

Interestingly, if the percentage of 29.4% is combined with the second predominant response (5 to 10 vessels) which gets 19.6%, we notice that nearly half of the sample (49%) belongs to the category of "1 to 10 owing/managing vessels".

Taking into account that the majority of the companies contacted were Greek owned, these facts once more confirm the current condition that has been shaped over the last decade in Greek shipping, where almost half of the companies own/manage from 1 to 10 vessels. Moreover, we observe a significant percentage (25.5%) that owns/manages more than 20 vessels.

### *4.1.2 TYPE OF VESSELS OWNED/MANAGED*

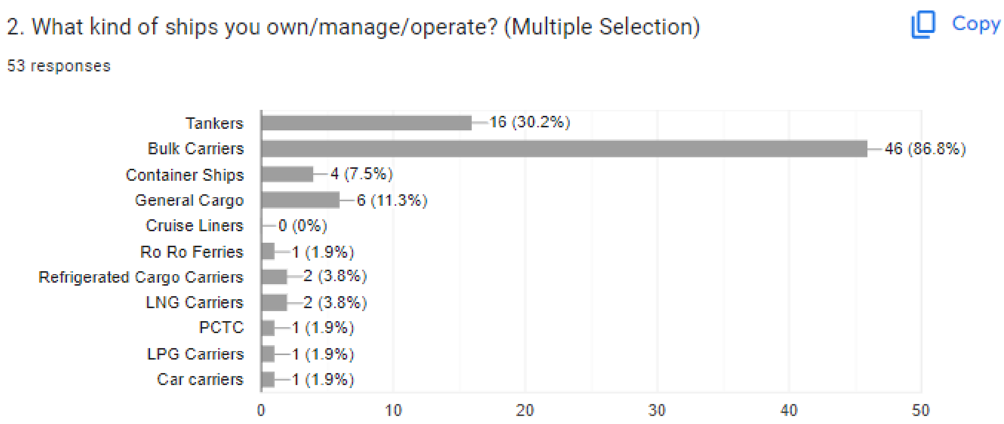



*Figure 29 Type of vessels owned/managed*

Moving to vessels' type demographics (question 2) (figure 29), we again detect a reasonable outcome to our sample where an overwhelming majority of bulk carriers (86.3%) dominate, and tankers category is following in second place. Again, we are able to discern how realistic and representative of the actual market our sample is, knowing the demographics of the Greek fleet identified in the previous chapter, which can be used as a typical representation for the global market, too.

### 4.1.3 VESSELS AGE

Next question (3) is depicting the age of the fleet (figure 30).

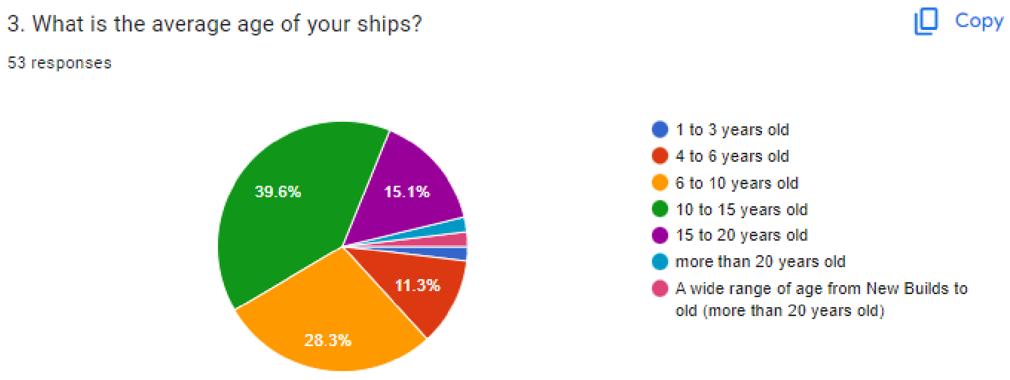



*Figure 30 Vessels Age*

As the sample's responses indicate, there is only a small fragment (11.3%) of vessels being from 4 to 6 years old, which are considered relatively new, able to cope with the demanding CII's ratings effectively (often called full-eco ships). The vast majority (37.3%) is consisted of vessels being from 10 to 15 years old, which when correlated to 29.4% aging from 6 to 10 years, creates the today's global "reality", verifying that most vessels will have to strive in order to be efficient against the new regulations.

### 4.1.4 EEXI/CII READINESS

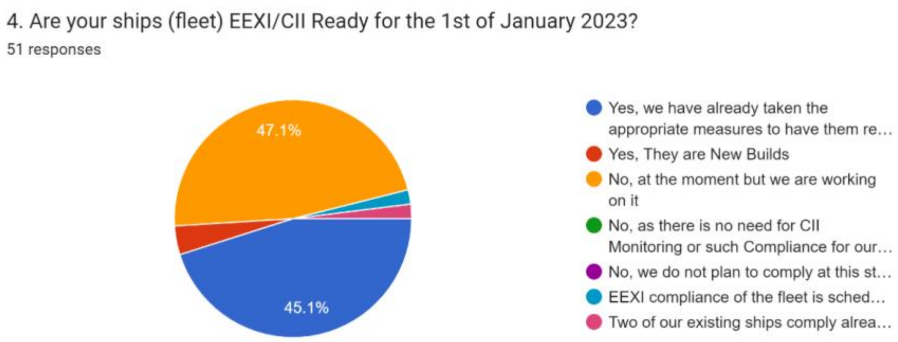



*Figure 31 EEXI/CII readiness*

Luckily, the responses resulted in the question (4) (figure 31) about fleets' readiness in respect to EEXI/CII before its actual enforcement (1st of January, 2023) seem to be very explicit, demonstrating almost a binary answer. In more detail, the sample shows almost equally divided percentages, while 47,1% claiming being not ready and 45,1% feeling confident they have taken all necessary measures for coping with the regulation.

Interestingly, these findings appear to be significantly different several months after the time the survey was conducted. A relative feedback extracted through continuous interaction with a great number of respondents, by the means of interviews and general observations, indicates that the proclaimed, but tactical technologies such EPL and ShaPoLi, are now (second half of 2023) progressing significantly in their installation progress. Although the majority of the companies appear to have opted for ShaPoLi over EPL, because of the abrupt demand and market's unreadiness, they appear to be still struggling to complete their installation due to the lack of equipment available.

Other reasons for this delay include project's complexity since it requires multiple parties to coordinate efficiently, difficulty in scheduling necessary actions in accordance to scheduled dry dockings and finally the uncertainty about the future of the vessels (meaning what vessels will be kept or may be sold). However, as we notice, almost half of the respondents, have prematurely declared that they comply with the measures regardless if the additional equipment has been installed on board or not. So, where is this proclaimed readiness attributed to? Why did the respondents declared being ready if they were practically not? Is the percentage of those claiming to be ready attributed to the companies that have already managed to install EPL or ShaPoLi onboard? Were they aware of the different methods to be followed in order to achieve compliance?

As later interviews prove, many of the respondents considered (and some still do) EPL, ShaPoLi and slow steaming equally effective or just sufficient for being compliant with the EEXI and CII. This argument, is indeed supported by next question's answers (question 5) which concerns the specific strategy options each company was considering to follow for achieving and most importantly, proving compliance.

### 4.1.5 STRATEGY TOWARDS CII REGULATION

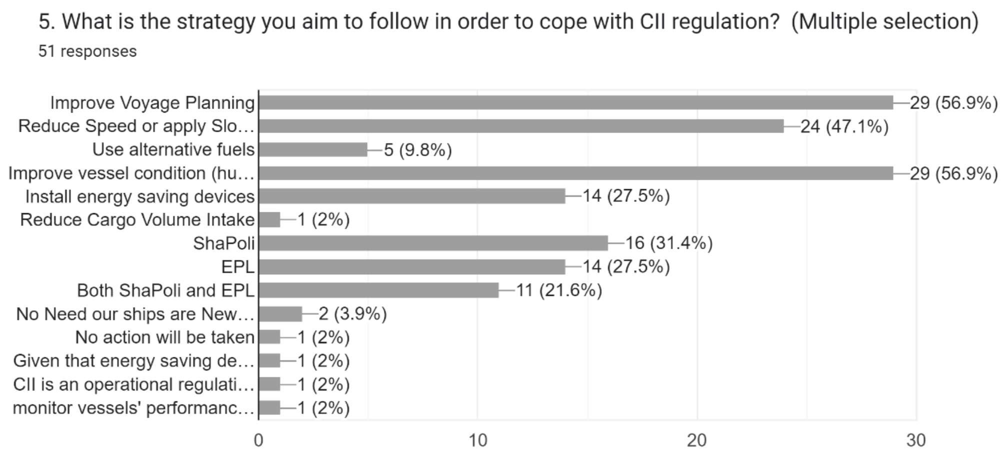



*Figure 32 Strategies being adopted for CII compliance*

In this question (5) (figure 32), we intentionally allowed multiple selection in responding, reflecting the fact that no solid strategy seems to be sufficient for achieving the absolute performance or compliance; and the majority of the shipping companies seemed to be very well aware of that.

Noticeably, we witness a positive response on combined methods such as "improving voyage planning", "reducing speed (slow steaming)" and "improving vessel's condition by hull/propeller cleaning" that substantially outnumber the most "obvious" or expected responses of merely selecting technologies such EPL or ShaPoLli. Surprisingly, 21.6% claimed that both technologies will be applied proving that some respondents were either not familiar with what each technology entails (since no company is applying both on the same ship) or perhaps they were not sure which one to select at that time.

Still, one of the most interesting points to examine here is the similar selection between ShaPoLi and EPL. These two methods seem to acquire comparable percentage in preferences, despite their differences in their complexity in operation, installation and the cost. As it was concluded via follow-up calls, a non-minor number of respondents had no clear perception on each solution's effectiveness, being not able to differentiate the results between the two.

For instance, when a typical question about how the captain/crew will react when bad weather conditions apply, most interviewees responded that EPL is the optimum choice as it allows the manual intervention on engine's governor. (no matter the reaction time or any other repercussion involved in such case).

This statement, which seems to follow the general speed reduction or slow steaming principle as the dominant way forward, seemed to sufficient at the time of the survey, probably neglecting the fact that even in slow steaming or in the case of an emergency, regulatory authorities will still need specific and accurate reporting of the incident and the reasons why such intervention occurred.

On the other hand, ShaPoLi, has been considered equally efficient, intended to be a system which will be automatically identifying power "violation" and it will be cutting the power accordingly. What seems to be important here though, is that up to this moment, no company has activated such automatic functionality onboard. The vast majority of ShaPoLi systems are by default on "monitoring only" mode and if any interventions are to be made, this remains with the captain or the operators. So again, the manual intervention on an ad-hoc basis, seems to be the key for not exceeding "normal" power/consumption which would result in excessive CO2 emissions. Still, as practice shows, ShaPoLi has massively prevailed over EPL in the end.

In a similar perspective, we notice that the use of energy saving devices (ESDs) is considered by many respondents (27.5%) as a logical approach for reducing the impact of CII. However, a list of these devices was not provided for selection as it would make the answering process more difficult.

We also spot a very hesitant response (only 9.8%) on alternative fuels as a strategy for CII, most probably because no mature research was conducted yet, confirming our argument identified in the paragraph 2 about the readiness of the market.

Interestingly, the option of "reducing Cargo Volume Intake" although in theory has been discussed as an option, in our survey it seems to be out of question, even though our sample is addressed exclusively to ship owners-operators. This fact proves that shipping companies do not seem to be willing (yet) to compromise for the sake of any regulation as they keep being driven by sheer professionalism in transferring cargo operations effectively, "no matter the cost".

### 4.1.6 THE EFFECT OF EEXI/CII IN GHG EMISSIONS

Moving to the next question's responses (figure 33), it is interesting to observe the expressed perception of owners/operators towards the effect of CII in the general context of reducing emissions by 2030. The responses of question 6, indicate a quite optimistic rather than skeptical view on the matter, while there is a positive awareness about the CII as a measure for monitoring and controlling the excessive emissions. In fact, almost 75% of the respondents consider that the final impact (reduction) will range from 5 to 20%. Certainly, the forecasted IMO 40% reduction, does not seem to be realistic or achievable as only 1.9% of the respondents have declared such answer, while a 3.8% believes that there will be no effect at all. In other words, although the majority of owners initially reacted in a negative manner to the measure because they considered it ineffective or rushed and not properly planned, they eventually seem to express some trust in the importance of the measure, provided that this will be properly planned before its actual implementation.

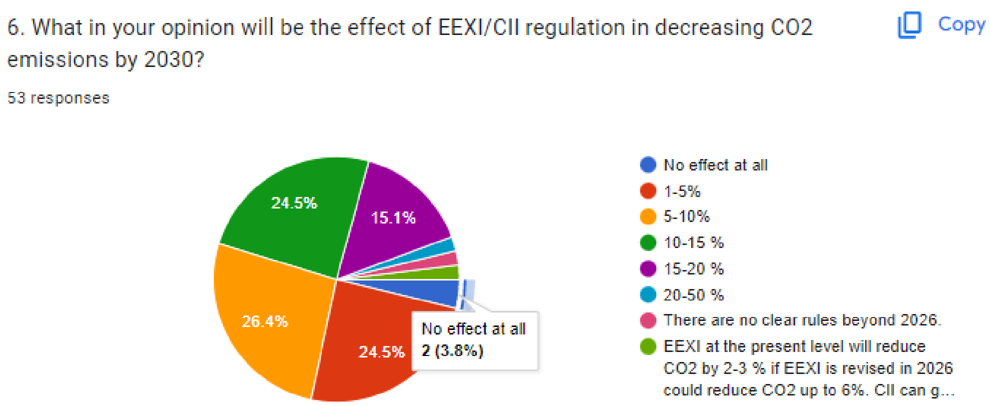



*Figure 33 Opinion on the effect of EEXI/CII Emissions reduction till 2030*

### 4.1.7 WILLINGNESS TO PAY

However, admitting CII's value may be one thing, being willing to pay for it, is another. Again the question has been set in such a way to identify correspondent's perception on the real (one-off vs perpetual) expenses of CII's adoption and conformance.

As the pie chart of answers reveals (question 7) (figure 34), when the question on what is considered reasonable or affordable to be paid for compliance, a dominant 39.6% states that this should range from $15 to $50K, over a slightly lower percentage (34%) claiming that even $5 to $15K would be enough for compliance.

These figures dictate that most of operators probably had already “taken the exercise” of calculating such budgets, since both numbers stated above are considered very realistic when related to the dominant technologies/methods of EPL and ShaPoLi. For the purposes of the study, a relative market research had to be conducted. Specifically, the research revealed that for the replacement of mechanical flow meters with mass flow/Coriolis type, for a typical Supramax (it typically requires 1xM/E, 1xD/G, 1xBoiler or 1xCommon for M/E and D/G Consumption, DG in/DG out depending on the pipeline arrangement) with the parallel installation of a Shaft/Torque Meter equipped with ShaPoLi module, the cost ranges from $30K to $45K (when adopting the ShaPoLi method) or from $9K to $13K (if EPL is to be implemented). In order to understand these figures better, we need to correlate them with the responses of the next question (8) also, where we notice that respondents seem to focus more on the hardware/equipment part of the CII requirement rather on the change or the continuous investment it actually requires, since they appear to be unable to foresee what additional costs may be incurred because of this change.

At this point, it is worth noting that these answers about recognizing the monetary value and bearing the relative costs, come into accordance to the existing (EEXI’s) agreed framework as formed by BIMCO (2022). The active agreement in place (since November 2022) describes that owners shall be responsible for and pay the cost of technical modifications including procurement, purchase, payment, installation and any trials associated therewith. Equally, this clause has immediate effect in CII too, where we witness an acknowledgment by the side of the respondents about the cost of investing into energy-related modifications.

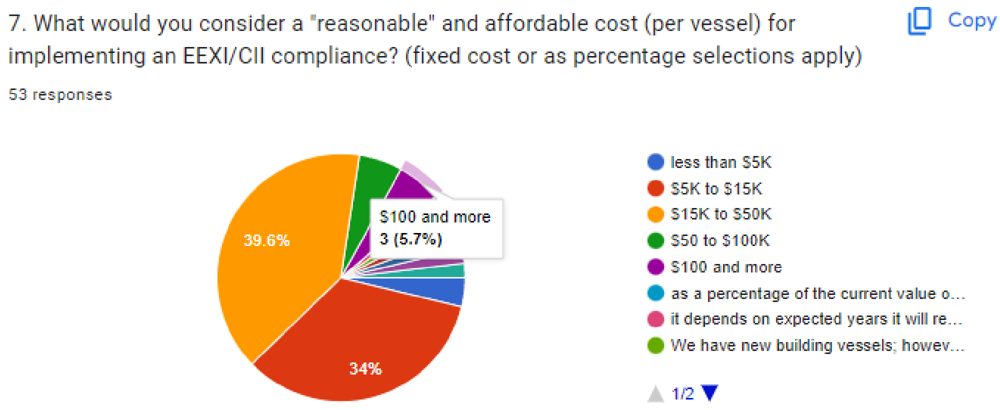



*Figure 34 EEXI/CII Compliance cost estimation*

### *4.1.8 HOW EEXI/CII IS AFFECTING THE ORGANIZATION*

Regarding the EEXI's/CII's impact/effect on the organization, the sample reveals that 60% of the responses are relating CII with investing in new technologies, while only 43.1% considers the investment in people and resources essential (figure 35). Possibly, there seems to be a "hidden" or difficult to estimate cost that not all the respondents are able to foresee, hence this difference in the responses. Those (5.7%) that have responded that $100K or more reasonable in the previous question (7), most probably have already included both costs this in their budgeting as they were able to realize that EEXI/CII is not only about replacing flow meters and installing measuring/controlling devices on board. Just to mention a few, there are extra costs that might be attributed to possible recurring fees related with a software or other associated services for monitoring the actual CII and providing guidance on how to reduce it (consulting). This means hiring new people or just outsourcing this operation entirely.

Still, we may assume that the combination of these two responses, prove the fact that the majority of the respondents, although aware of the organizational change and the potential investment required for meeting the regulation, they are not able to estimate the actual cost this change incurs in terms of new processes or predict the real impact in plain monetary terms. Certainly, it is much easier to calculate the costs for tangible materials based on specific equipment and installation services, rather than estimating any collateral expenses that may sustained in the long term.

Besides, according to additional interviews that followed the matter, the majority of the companies were primarily getting prepared to cope with the regulation based on the existing personnel. This trend can also be supported by the 17% of respondents who have supported that no "real change is taking place at the moment" as this clearly statement could mean they will continue on the current organizational status, not planning to invest further on supplementary staff.

Also, another considerable percentage (28.3%) in the responses is convinced that perhaps replacing the old fleet may be the only solution for complying with the new measures. Arguably, this does not necessarily mean that they do not feel that any investment should take place at the moment; but looking at the current age of the global fleet, it can be concluded that investing on too old (especially on a more than 15 years or older) vessels, may not worth it. As a matter of fact, there are several indications where the survey clearly gives prominence to very critical selection while evaluating any technology to be adopted for improving compliance, as a vessel's age is a decisive factor for any investment in the future, severely affected by the nature of the measures.

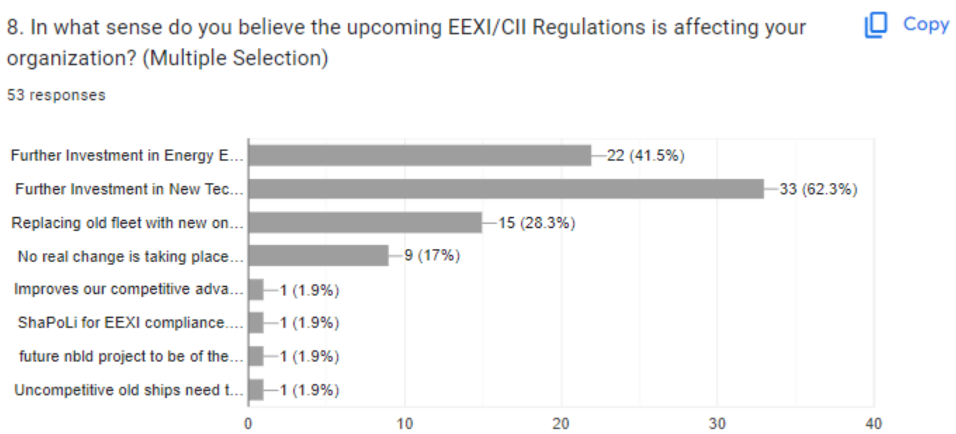



*Figure 35 EEXI/CII effect on organization*

### *4.1.9 WHO SHOULD PAY THE BILL?*

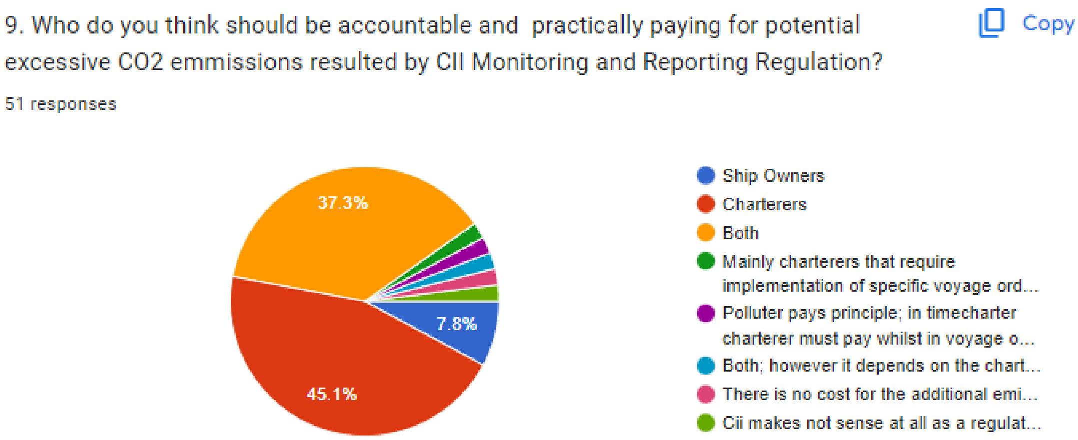



*Figure 36 CO2 emissions accountable*

Perhaps the most fundamental question of the survey (which will be also extensively discussed over the next chapter is the question (9) (figure 36), which reflects the latest argument recently surfaced in the shipping market, about who is to pay for CII's compliance. Many authors and market experts are reviewing this matter over and over again, as CII seems to be igniting another controversy between the charterers and the owners/operators.

So, who is to take the responsibility for the vessel's current and future condition and its ability to comply effectively with the latest and future regulations?

Before taking the responses for granted, we again need to mention that the survey has been carried out based on owners' opinion only, so some bias would be expected in the first place in these answers.

Still, unpredictably enough, there seems to be a fair balance in the findings. In contrast to what anyone would expect, the respondents feel that any penalty or reimbursement resulted by CII regulation should not entirely be covered by the charterers (despite the strong 45,1% defending this argument) but should be shared between the two (37.3%) whereas only a fraction (7.8%) is claiming that this should be a cost totally covered by ship owners.

Also, it is quite stimulating to cite some of the various opinions, exactly as they have been recorded trough the responses. There is an interesting view proposing the "polluter pays" principle, where in the condition of a time-charter the charterer should be paying whilst in per voyage agreement the owner should be in charge of any additional costs.

On the contrary, another view claims that CII makes no sense at all as a regulation as it is not efficient for a vessel less than 70.000 dwt.

It seems that the subject of who is to finally pay for the bill or how this should be split when it is issued, is an increasingly interesting matter that will occupy the discussions over the relationship of owners/charterers for the next years. Currently, there are no monetary penalties to be attributed or shared, but the intentions of the regulators, considering FuelEU and the forthcoming EU ETS in 2024, is very clear, making both parties look worried about what the immediate future brings.

A more extensive reference on the above matter will be made in the final chapter (6) (Conclusions-Recommendations) where there is a combination of views, literature findings and author's conclusions on the matter trying to keep a critical but also impartial attitude on who should be accountable for any penalties or even for the actual cost of the compliance.

Finally, the fact that 84.3% of the respondents requested for a copy of the survey's findings (figure 37) proves the high interest in the matter of CII and its importance for the majority of shipping companies participating in the survey.

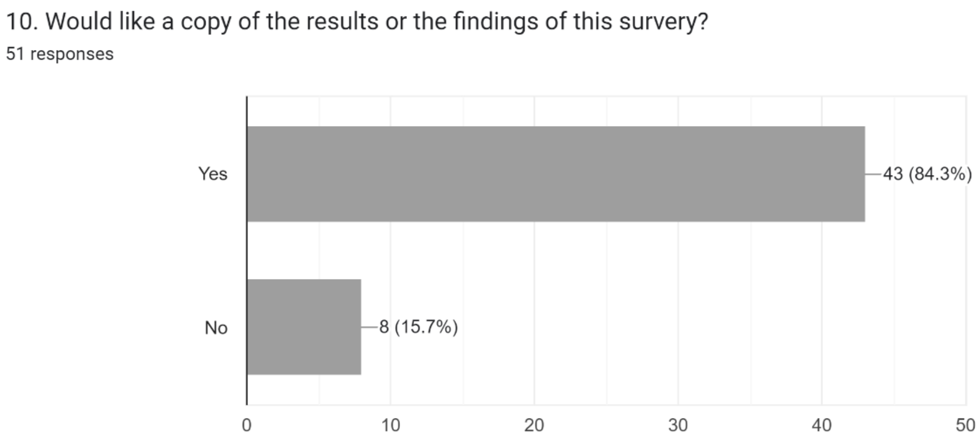



*Figure 37 Request on survey's copy*

# 5.0 CII CALCULATION AND FORECASTING MODEL DEVELOPMENT

For the purposes of a hands-on experimentation with the CII formula and further investigation on the potential of forecasting its rating that is dynamically affected by different operational profiles, an original model has been developed.

The software tool used for constructing the model is MS-EXCEL, mainly due to its compatibility with most software in the market and its flexibility in data which may allow potential users to develop the model further. The current model encompasses all theoretical functions and formulas as regulated by IMO, following the latest updates released up to the date of this thesis completion (31/08/2023). The model can be operated on two main different modes, namely one fed by manual data, as they are collected through a vessel's noon reports; or by the means of automatically created datasets, fused by high frequency data (HF) collection systems. It also can be used as an effective forecasting tool, when fed with (pre)planned routes, provided that the related fuel consumption is known (or better, well-estimated) in advance. During the functionality testing process, all methods were applied using data from a LASKARIDIS MARITIME Co vessel, named "Las Palmas". The subject vessel used is a 63,576 tons Panamax Bulk Carrier (IMO 9916290) currently operated by the owning company.

In terms of the technology applied for acquiring and feeding the model with high frequency data, the PRISMA ELECTRONICS LAROS® data collection system has been selected, also under both PRISMA ELECTRONICS and LASKARIDIS MARITIME Co approval and continuous support. The system is installed onboard the subject vessel since 7/11/2021, interfacing with onboard sensors for acquiring signals/data on a per minute time intervals. The points of interfacing onboard include all five (Coriolis) flow meters (M/E in/out, D/G in/out and Boiler), a ShaPoLi equipped Torque Meter, ECDIS and Anemometer.

The access on all these (structured) data, enabled not only a comprehensive view of the vessel's operational conditions but also allowed the further analysis of various critical parameters that constitute vessel's actual performance highly related to CII rating.

As a result, the study has combined both theoretical (sea trials, M/E's shop tests) and actual (readings from the sensors) vessel's data, in an attempt to ultimately transcend from the hypothetically ideal conditions that apply on a new build vessel, into the most realistic performance the vessel maybe demonstrating after been trading for some time.

This way, the extent of the actual aging of the asset is also considered, based on pragmatic measurements, allowing the correlation of this aging to the real performance of the vessel which can potentially lead to the development of a vessel specific “speed/consumption mapping”.

## 5.1 CII MODEL DESCRIPTION - DECOMPOSITION

The model is consisted of three main interconnected tabs, namely “CII Rating”, “Speed_Cons Table” and “BackCalc” which contain macro commands for making it operate as a single interface entity. The first tab, described as “CII Rating” shown in the following table (7), acts as the main user’s interface (mask) that is used for entering key data. It also provides the required visualization, relative to CII ratings incurred, along with color coded tables, illustrating the “allowable speeds” in accordance to their CII rating. The second tab, “Speed_Cons Table” (table 8) is a fixed values table that allows no modifications to the user; it has been created for providing all necessary (but fixed) valuable data concerning the relation between speed and consumption in different loading conditions. The last tab, “BackCalc” is the core of all calculations and it can be described as the “back office” of the model. This is also where vessel’s particulars are entered for the CII rating calculation. Finally, this tab accommodates the forecasting functionality tables, as they will be elaborated further in the related section.

As it can be realized, this model is designed to be vessel specific, meaning that since all fixed parameters of the vessel are set (e.g. DWT), the only interaction required by the user, will be the data input regarding distance travelled, distance to be sailed (in ballast or laden condition) and the CO2 Emissions produced (in relation to the actual FOC measured). The rest of information to be displayed will be automatically calculated based on the above inserted values.

**CII Calculation and Rating Prediction Tool**

CII Report
FROM: (dd/MM/yyyy HH:mm)
TO: (dd/MM/yyyy HH:mm)

| Distance Travelled (Over Groud) | nm |
|---|---|
| | |

| CII Rating | -- |
|---|---|
| | |

| CO2 Emissions | mt |
|---|---|
| | |

| CII Coeff | % |
|---|---|
| | |

| Allowed CO2 Emissions | mt |
|---|---|
| | |

| Available CO2 Emissiosn | mt |
|---|---|
| | |

| Scale | From | To |
|---|---|---|
| A | < | 3,99 |
| B | 3,99 | 4,36 |
| C | 4,36 | 4,92 |
| D | 4,92 | 5,47 |
| E | 5,47 | < |

| AER Limit |
|---|
| 4,64 |

| Distance to go Ballast (nm) | Diastance to go Laden (nm) |
|---|---|
| | |

<table>
<tr><th></th><th colspan="13">Laden</th></tr>
<tr><th>Ballast</th><th>10.0</th><th>10,5</th><th>11.0</th><th>11,5</th><th>12.0</th><th>12,5</th><th>13.0</th><th>13,5</th><th>14.0</th><th>14,5</th><th>15.0</th><th>15,5</th><th>16.0</th></tr>
<tr><td>10.0</td><td>10.0 | 10.0</td><td>10.0 | 10,5</td><td>10.0 | 11.0</td><td>10.0 | 11,5</td><td>10.0 | 12.0</td><td>10.0 | 12,5</td><td>10.0 | 13.0</td><td>10.0 | 13,5</td><td>10.0 | 14.0</td><td>10.0 | 14,5</td><td>10.0 | 15.0</td><td>10.0 | 15,5</td><td>10.0 | 16.0</td></tr>
<tr><td>10,5</td><td>10,5 | 10.0</td><td>10,5 | 10,5</td><td>10,5 | 11.0</td><td>10,5 | 11,5</td><td>10,5 | 12.0</td><td>10,5 | 12,5</td><td>10,5 | 13.0</td><td>10,5 | 13,5</td><td>10,5 | 14.0</td><td>10,5 | 14,5</td><td>10,5 | 15.0</td><td>10,5 | 15,5</td><td>10,5 | 16.0</td></tr>
<tr><td>11.0</td><td>11.0 | 10.0</td><td>11.0 | 10,5</td><td>11.0 | 11.0</td><td>11.0 | 11,5</td><td>11.0 | 12.0</td><td>11.0 | 12,5</td><td>11.0 | 13.0</td><td>11.0 | 13,5</td><td>11.0 | 14.0</td><td>11.0 | 14,5</td><td>11.0 | 15.0</td><td>11.0 | 15,5</td><td>11.0 | 16.0</td></tr>
<tr><td>11,5</td><td>11,5 | 10.0</td><td>11,5 | 10,5</td><td>11,5 | 11.0</td><td>11,5 | 11,5</td><td>11,5 | 12.0</td><td>11,5 | 12,5</td><td>11,5 | 13.0</td><td>11,5 | 13,5</td><td>11,5 | 14.0</td><td>11,5 | 14,5</td><td>11,5 | 15.0</td><td>11,5 | 15,5</td><td>11,5 | 16.0</td></tr>
<tr><td>12.0</td><td>12.0 | 10.0</td><td>12.0 | 10,5</td><td>12.0 | 11.0</td><td>12.0 | 11,5</td><td>12.0 | 12.0</td><td>12.0 | 12,5</td><td>12.0 | 13.0</td><td>12.0 | 13,5</td><td>12.0 | 14.0</td><td>12.0 | 14,5</td><td>12.0 | 15.0</td><td>12.0 | 15,5</td><td>12.0 | 16.0</td></tr>
<tr><td>12,5</td><td>12,5 | 10.0</td><td>12,5 | 10,5</td><td>12,5 | 11.0</td><td>12,5 | 11,5</td><td>12,5 | 12.0</td><td>12,5 | 12,5</td><td>12,5 | 13.0</td><td>12,5 | 13,5</td><td>12,5 | 14.0</td><td>12,5 | 14,5</td><td>12,5 | 15.0</td><td>12,5 | 15,5</td><td>12,5 | 16.0</td></tr>
<tr><td>13.0</td><td>13.0 | 10.0</td><td>13.0 | 10,5</td><td>13.0 | 11.0</td><td>13.0 | 11,5</td><td>13.0 | 12.0</td><td>13.0 | 12,5</td><td>13.0 | 13.0</td><td>13.0 | 13,5</td><td>13.0 | 14.0</td><td>13.0 | 14,5</td><td>13.0 | 15.0</td><td>13.0 | 15,5</td><td>13.0 | 16.0</td></tr>
<tr><td>13,5</td><td>13,5 | 10.0</td><td>13,5 | 10,5</td><td>13,5 | 11.0</td><td>13,5 | 11,5</td><td>13,5 | 12.0</td><td>13,5 | 12,5</td><td>13,5 | 13.0</td><td>13,5 | 13,5</td><td>13,5 | 14.0</td><td>13,5 | 14,5</td><td>13,5 | 15.0</td><td>13,5 | 15,5</td><td>13,5 | 16.0</td></tr>
<tr><td>14.0</td><td>14.0 | 10.0</td><td>14.0 | 10,5</td><td>14.0 | 11.0</td><td>14.0 | 11,5</td><td>14.0 | 12.0</td><td>14.0 | 12,5</td><td>14.0 | 13.0</td><td>14.0 | 13,5</td><td>14.0 | 14.0</td><td>14.0 | 14,5</td><td>14.0 | 15.0</td><td>14.0 | 15,5</td><td>14.0 | 16.0</td></tr>
</table>

CII rating | Speed_Cons Table | BackCalc

*Table 7 CII Rating Tab*

| Speed/Consumption in tn per day | | |
|---|---|---|
| **Speed** | **Ballast** | **Laden** |
| 10,0 | 8,50 | 10,04 |
| 10,5 | 9,82 | 11,60 |
| 11,0 | 11,27 | 13,31 |
| 11,5 | 12,86 | 15,18 |
| 12,0 | 14,58 | 17,22 |
| 12,5 | 16,45 | 19,43 |
| 13,0 | 18,47 | 21,82 |
| 13,5 | 20,66 | 24,40 |
| 14,0 | 23,00 | 27,17 |
| 14,5 | 25,52 | 30,15 |
| 15,0 | 28,21 | 33,33 |
| 15,5 | 31,08 | 36,72 |
| 16,0 | 34,14 | 40,34 |
| | | |
| **DWT** | **63576** | |

1

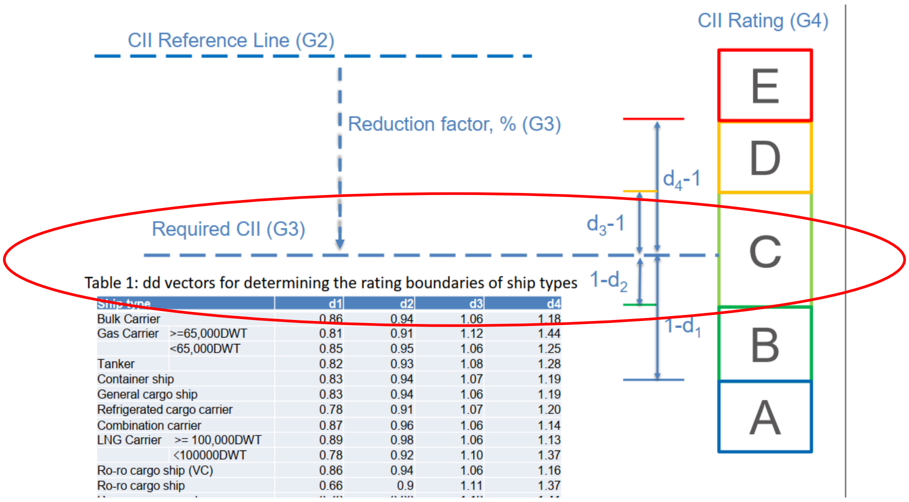
| Vessel Type | |
|---|---|
| Bulker | 1 |
| Tanker | 0 |
| Container | 2 |
| Year | 2023 |

2

*Table 8 Speed_Cons Table*

### 5.1.1 *CII RATING FUNCTION (TAB)*

The first tab, “CII rating” (figure 39) acts as the main CII information dashboard the user is viewing when start using the model. The optimum purpose of this “mask” is to indicate the current CII rating, based on the vessel’s data provided, following the CII formula. It also informs the user about “Allowed CO2 Emissions” (point 6, figure 39) and “Available CO2 Emissions” (point 9,figure 39). “Allowed CO2 Emissions” represents the limit of CO2 emissions the vessel can emit for a designated distance so as the CII equals to vessel’s AER before starting having an impact on CII Rating. Literature describes this as “Required CII” as shown (circled in red) in the below figure (38) as identified by IMO (2021).



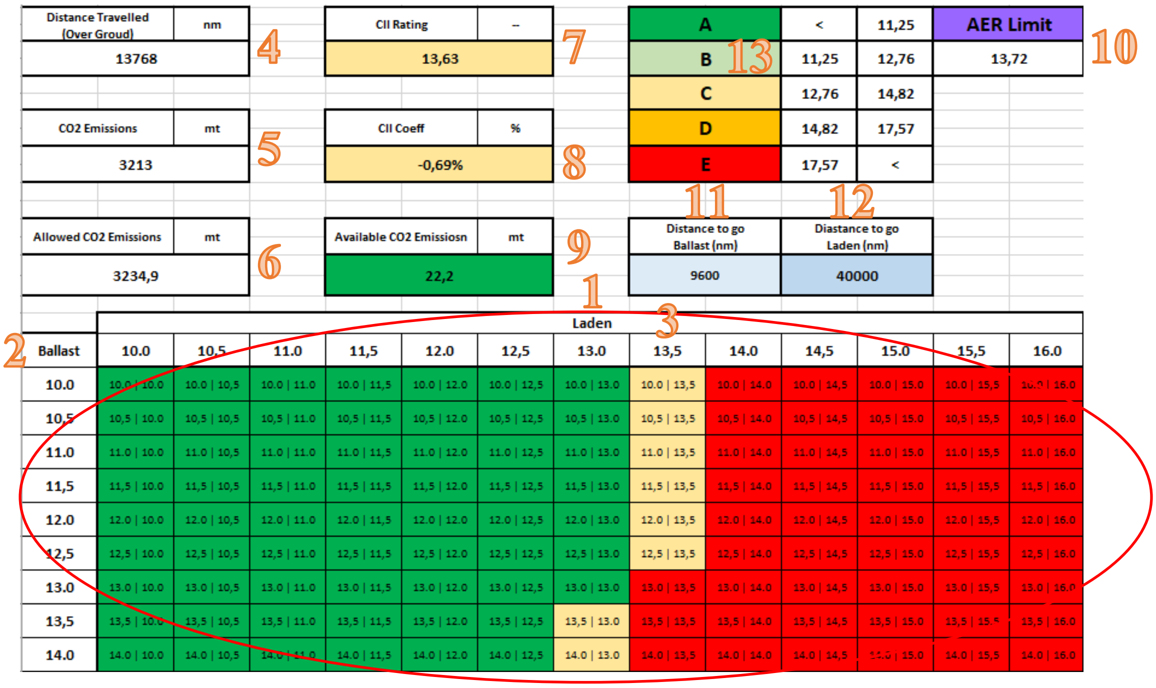

| Ship type | | d1 | d2 | d3 | d4 |
|---|---|---|---|---|---|
| Bulk Carrier | | 0.86 | 0.94 | 1.06 | 1.18 |
| Gas Carrier | >=65,000DWT | 0.81 | 0.91 | 1.12 | 1.44 |
| | <65,000DWT | 0.85 | 0.95 | 1.06 | 1.25 |
| Tanker | | 0.82 | 0.93 | 1.08 | 1.28 |
| Container ship | | 0.83 | 0.94 | 1.07 | 1.19 |
| General cargo ship | | 0.83 | 0.94 | 1.06 | 1.19 |
| Refrigerated cargo carrier | | 0.78 | 0.91 | 1.07 | 1.20 |
| Combination carrier | | 0.87 | 0.96 | 1.06 | 1.14 |
| LNG Carrier | >= 100,000DWT | 0.89 | 0.98 | 1.06 | 1.13 |
| | <100000DWT | 0.78 | 0.92 | 1.10 | 1.37 |
| Ro-ro cargo ship (VC) | | 0.86 | 0.94 | 1.06 | 1.16 |
| Ro-ro cargo ship | | 0.66 | 0.9 | 1.11 | 1.37 |

*Figure 38 CII's Rating boundaries (source IMO, 2021)*

In other words, “Allowed CO2 Emissions” refer to the mean of rating “C”, which is directly related with the AER. Next, “Available CO2 Emissions” stands for the remaining CO2 that can be emitted in future before the CII rating practically changes. This can get negative or positive values, shifting the ranking “upwards or downwards” accordingly. These two indicators can be described as the main “traffic lights” that are assisting in monitoring the performance of the vessel. They allow the user to be easily aware of the current and future status of the vessel, depending on the operational profile selected.

In addition, the tool has been designed in such a manner that it offers all those necessary calculations for allowing the forecasting of CII's potential shift in rating, also indicating the "speed limits" the vessel needs to retain for remaining within current rating.

In favor of practicality, the related table of speeds in laden and ballast condition (points 1 and 2 respectively), displays all the "within limits" speeds (in green) for maintaining the CII Rating intact, by dynamically adjusting the relative coloring on the correlated cells, according to CII's rating color code (point 3) as displayed in the below indicative example (marked in red circle) (figure 39).




| | Laden | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ballast | 10.0 | 10,5 | 11.0 | 11,5 | 12.0 | 12,5 | 13.0 | 13,5 | 14.0 | 14,5 | 15.0 | 15,5 | 16.0 |
| 10.0 | 10.0 \| 10.0 | 10.0 \| 10,5 | 10.0 \| 11.0 | 10.0 \| 11,5 | 10.0 \| 12.0 | 10.0 \| 12,5 | 10.0 \| 13.0 | 10.0 \| 13,5 | 10.0 \| 14.0 | 10.0 \| 14,5 | 10.0 \| 15.0 | 10.0 \| 15,5 | 10.0 \| 16.0 |
| 10,5 | 10,5 \| 10.0 | 10,5 \| 10,5 | 10,5 \| 11.0 | 10,5 \| 11,5 | 10,5 \| 12.0 | 10,5 \| 12,5 | 10,5 \| 13.0 | 10,5 \| 13,5 | 10,5 \| 14.0 | 10,5 \| 14,5 | 10,5 \| 15.0 | 10,5 \| 15,5 | 10,5 \| 16.0 |
| 11.0 | 11.0 \| 10.0 | 11.0 \| 10,5 | 11.0 \| 11.0 | 11.0 \| 11,5 | 11.0 \| 12.0 | 11.0 \| 12,5 | 11.0 \| 13.0 | 11.0 \| 13,5 | 11.0 \| 14.0 | 11.0 \| 14,5 | 11.0 \| 15.0 | 11.0 \| 15,5 | 11.0 \| 16.0 |
| 11,5 | 11,5 \| 10.0 | 11,5 \| 10,5 | 11,5 \| 11.0 | 11,5 \| 11,5 | 11,5 \| 12.0 | 11,5 \| 12,5 | 11,5 \| 13.0 | 11,5 \| 13,5 | 11,5 \| 14.0 | 11,5 \| 14,5 | 11,5 \| 15.0 | 11,5 \| 15,5 | 11,5 \| 16.0 |
| 12.0 | 12.0 \| 10.0 | 12.0 \| 10,5 | 12.0 \| 11.0 | 12.0 \| 11,5 | 12.0 \| 12.0 | 12.0 \| 12,5 | 12.0 \| 13.0 | 12.0 \| 13,5 | 12.0 \| 14.0 | 12.0 \| 14,5 | 12.0 \| 15.0 | 12.0 \| 15,5 | 12.0 \| 16.0 |
| 12,5 | 12,5 \| 10.0 | 12,5 \| 10,5 | 12,5 \| 11.0 | 12,5 \| 11,5 | 12,5 \| 12.0 | 12,5 \| 12,5 | 12,5 \| 13.0 | 12,5 \| 13,5 | 12,5 \| 14.0 | 12,5 \| 14,5 | 12,5 \| 15.0 | 12,5 \| 15,5 | 12,5 \| 16.0 |
| 13.0 | 13.0 \| 10.0 | 13.0 \| 10,5 | 13.0 \| 11.0 | 13.0 \| 11,5 | 13.0 \| 12.0 | 13.0 \| 12,5 | 13.0 \| 13.0 | 13.0 \| 13,5 | 13.0 \| 14.0 | 13.0 \| 14,5 | 13.0 \| 15.0 | 13.0 \| 15,5 | 13.0 \| 16.0 |
| 13,5 | 13,5 \| 10.0 | 13,5 \| 10,5 | 13,5 \| 11.0 | 13,5 \| 11,5 | 13,5 \| 12.0 | 13,5 \| 12,5 | 13,5 \| 13.0 | 13,5 \| 13,5 | 13,5 \| 14.0 | 13,5 \| 14,5 | 13,5 \| 15.0 | 13,5 \| 15,5 | 13,5 \| 16.0 |
| 14.0 | 14.0 \| 10.0 | 14.0 \| 10,5 | 14.0 \| 11.0 | 14.0 \| 11,5 | 14.0 \| 12.0 | 14.0 \| 12,5 | 14.0 \| 13.0 | 14.0 \| 13,5 | 14.0 \| 14.0 | 14.0 \| 14,5 | 14.0 \| 15.0 | 14.0 \| 15,5 | 14.0 \| 16.0 |

*Figure 39 Dynamic adjustment of color code depending on CII's rating*

Since the first tab is designed to merely act as a simple monitoring "mask", most of its data are being automatically calculated or received by the other two tabs (Speed_Cons Table and BackCalc).

As previously explained, "Distance Travelled" and "CO2 Emissions" data (pointed 4 and 5 in figure 39, respectively) need to be inserted (either manually entered or automatically fed by a data collection system). All next remaining fields such "CII Rating" and "CII Coefficient" (points 7 and 8 in figure 39) are being fed or calculated by the related fields in the "BackCalc" as they will be individually explained in the related section.

The “distance to go” greyed fields (pointed with 11 and 12 respectively) need to be manually entered by the user in order to activate the forecasting functionality, displayed in the related tables of tab “BackCalc” as it will be presented on the related section.

Finally, on the right-hand side of the figure (39) there is the related rating scaling indication (point 13) as defined by IMO, illustrating all different levels of CII applicable to the related subject vessel.

### *5.1.2 SPEED_CONS TABLE*

For the purpose of the forecasting functionality/feature, the construction of a vessel specific speed/consumption table is necessary (table 8, point 1). This table provides the appropriate variables that need to be taken into account while calculating the CII rating under specific conditions whether in ballast or laden. The table represents a mapping of different consumptions resulted from different speeds calculated, using a straightforward and robust methodology based on real measurements. In more detail, there has been use of the theoretical Speed/Power curves of the vessel as they are derived from sea trials in combination to M/E’s shop test curves, by the simultaneous use of real time measurements (data) collected with LAROS® system. Noon report data could be used also as a reference; however this would possibly incur significant uncertainty, compared to a certified high frequency signals acquisition system. As a result, Speed_Cons Table contains fixed values (constants) that are to be inserted once, depending on the vessel’s type and they should be not altered unless the subject vessel is changed.

The “vessel type” table presented on the right (table 8, point 2) is used a reference table for associating the appropriate boundaries (factors), linked to “BackCalc” tab where the related table exists and it will be explained further in the “BackCalc” section below.

### 5.1.2.1 CONSTRUCTING THE SPEED/CONSUMPTION TABLE

The construction of the speed/consumption table is of vital importance in the process of developing the forecasting feature of the model. In order to prepare this table, specific information regarding the vessel's performance is required, provided as supplementary documentation by the yard, usually being available to the technical department of a shipping company.

Primarily, the methodology followed for constructing the relevant table, involves the identification of different power that is required at certain speeds depending on different loading conditions, Ballast (Draft) and Laden (Scantling Draft). Because as practice shows sea trials are usually performed in ideal weather conditions (0 to 4bf), in high speeds, usually higher than 12 knots and since there are no real data available from the shaft power for low speeds (point 5, table 9), some assumptions needed to be made. In order to estimate the "missing" low power/speeds (below 12 knots) we use specific polynomial (cubic) approximation (data filled in point 6) and approximate (low) power values (point 7). Then all data from points 5,6,7, are calculated for providing the required final column of power (point 8). [1]

The relative table below (table 9) summarizes all subject vessel's sea trials data (Speed vs Power) as provided by the subject vessel's company.

| Vessel's Sea Trials Graphs (Speed vs Power Curves) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (fill all dark yellow highlighted cells and as much as possible form the highlighted light yellow cells) | | | | | | | | | | | | |
| | Ballast Draft | | | | Design Draft | | | | Scantling Draft | | | |
| | 6.50 | | | | 11.00 | | | | 13.30 | | | |
| Speed | Shaft Power | Poly | Power | Final | Shaft Power | Poly | Power | Final | Shaft Power | Poly | Power | Final |
| 10.0 | | 1225 | 1145 | 1185 | | 2122 | 1460 | 1791 | | | | 2100 |
| 10.5 | | 1426 | 1365 | 1396 | | 2232 | 1713 | 1972 | | | | 2266 |
| 11.0 | | 1659 | 1615 | 1637 | | 2377 | 1994 | 2185 | | | | 2465 |
| 11.5 | | 1925 | 1897 | 1911 | | 2562 | 2306 | 2434 | | | | 2701 |
| 12.0 | 2198 | 2227 | 2212 | 2198 | 2761 | 2791 | 2650 | 2761 | | | | 3049 |
| 12.5 | 2577 | 2569 | 2564 | 2577 | 3079 | 3071 | 3028 | 3079 | | | | 3335 |
| 13.0 | 2963 | 2952 | 2955 | 2963 | 3426 | 3404 | 3442 | 3426 | | | | 3662 |
| 13.5 | 3388 | 3379 | 3386 | 3388 | 3853 | 3796 | 3893 | 3853 | | | | 4090 |
| 14.0 | 3880 | 3852 | 3862 | 3880 | 4241 | 4253 | 4385 | 4241 | | | | 4425 |
| 14.5 | 4365 | 4374 | 4384 | 4365 | 4737 | 4777 | 4918 | 4737 | | | | 4927 |
| 15.0 | 4949 | 4948 | 4956 | 4949 | 5333 | 5375 | 5494 | 5333 | | | | 5529 |
| 15.5 | 5616 | 5575 | 5579 | 5616 | 6068 | 6050 | 6115 | 6068 | | | | 6299 |
| 16.0 | 6217 | 6259 | 6257 | 6217 | 6803 | 6809 | 6783 | 6803 | | | | 7102 |
| 16.5 | 6903 | 7001 | 6994 | 6903 | 7707 | 7655 | 7501 | 7707 | | | | 8118 |
| 17.0 | 7886 | 7805 | 7790 | 7886 | 8566 | 8593 | 8270 | 8566 | | | | 8913 |

*Table 9 Sea Speed vs Power based on sea trials (property of Laskaridis Maritime Co)*

[1] The actual polynomial and factors for these calculations are property of LASKARIDIS SHIPPING Co hence they cannot be shared further. The shipping company has provided the values instead, exclusively for the purposes of the model development, without disclosing the actual calculation formulas.

The table is consisted of three different loading conditions (profiles indicated 1,2,3 on table 9) including Ballast, Design and Scantling drafts modes with indications of their related depths (point 5). On the left of the table (point 4) there is the speed column ranging from 10 to 17 knots, which is associated to different power measured or calculated. For speeds ranging from 12 to 17 knots (point 5,9), we observe that there are actual measurements completed according to measurements of the shaft power meter onboard. The same applies to design drafts (point 2).

The rest three columns (present on each loading condition), represent the polynomial (6), theoretical (7) and shaft power resulted values, all different power results, constituting the final power for each loading condition. (point 8)

In the next phase, we attempt to identify and then apply the outcome of the relation of M/E's SFOC to engine load (%) using the data available from M/E's shop tests (figure 40). Shop tests are always performed using Marine Diesel Oil (MDO).

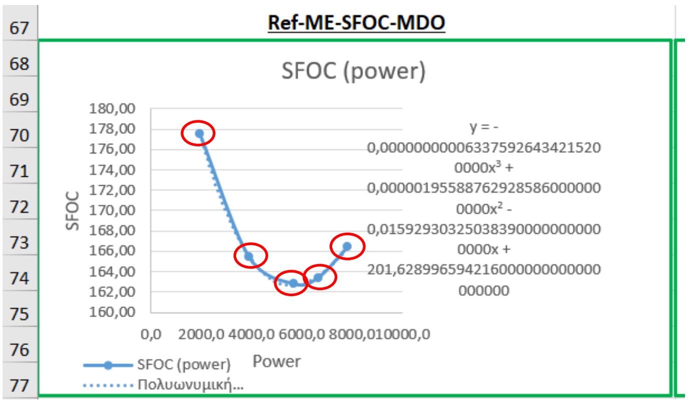



*Figure 40 Reference Curve of M/E to SFOC relation using MDO (property of Laskaridis Maritime Co)*

The five different points identified in the above (circled in red) diagram (figure 40), essentially describe the normal five different testing modes of operation used during sea trials, namely at 25%, 50%, 75%, 100% and at nominal % power, (which usually varies depending on the engine type). Then, using the data from the above SFOC to power relationship, we apply a 3rd degree (cubic spline) interpolation which results in the necessary polynomial function that will be eventually used for the actual calculation of the actual M/E's consumption on given power(s). In the last stage of this process, we need to multiply each individual power identified in the previous table (figure 40) to its related SFOC which results in fairly accurate estimation of the actual consumption on different speeds for different drafts (table 10).

Data in this table are corresponding to measurements taken under weather conditions of 4 bf wind, using Heavy Fuel Oil (HFO). The consumptions are irrelevant to the actual duration of the measurements and probably independent to the distance travelled as they represent mean values. The same type of calculations is usually performed for different weather conditions (the use of different fuel type is not important at this stage) for constructing the different mapping of speeds for each vessel.

| M/E Consumptions - BF4 - HFO | | | |
|---|---|---|---|
| SPEED (kn) | Ballast | Design | Scantling |
| 10 | 6.40 | 9.40 | 10.87 |
| 10.5 | 7.47 | 10.26 | 11.63 |
| 11 | 8.66 | 11.26 | 12.54 |
| 11.5 | 9.98 | 12.40 | 13.60 |
| 12 | 11.32 | 13.87 | 15.14 |
| 12.5 | 13.04 | 15.28 | 16.42 |
| 13 | 14.77 | 16.82 | 17.89 |
| 13.5 | 16.65 | 18.76 | 19.85 |
| 14 | 18.88 | 20.56 | 21.43 |
| 14.5 | 21.14 | 22.91 | 23.83 |
| 15 | 23.94 | 25.81 | 26.78 |
| 15.5 | 27.22 | 29.57 | 30.82 |
| 16 | 30.38 | 33.63 | 35.33 |
| 16.5 | 34.20 | 38.74 | 40.94 |
| 17 | 39.71 | 43.15 | 44.64 |

*Table 10 M/E Consumption per different speeds for 4 BFs using HFO*

The outcome of the above calculations, is a (vessel specific) table that contains different operational profile speeds (marked as 1) in respect to their related fuel oil consumption (FOC) for different drafts (marked as 2,3) as shown in the below table (11) which is then placed in the second tab of our model, "Speed_Cons Table":

| Speed/Consumption in tn per day | | |
|---|---|---|
| 1<br>Speed | 2<br>Ballast | 3<br>Laden |
| 10,0 | 8,50 | 10,04 |
| 10,5 | 9,82 | 11,60 |
| 11,0 | 11,27 | 13,31 |
| 11,5 | 12,86 | 15,18 |
| 12,0 | 14,58 | 17,22 |
| 12,5 | 16,45 | 19,43 |
| 13,0 | 18,47 | 21,82 |
| 13,5 | 20,66 | 24,40 |
| 14,0 | 23,00 | 27,17 |
| 14,5 | 25,52 | 30,15 |
| 15,0 | 28,21 | 33,33 |
| 15,5 | 31,08 | 36,72 |
| 16,0 | 34,14 | 40,34 |
| DWT | 63576 | |

*Table 11 Speed/Consumption for different drafts*

Certainly, the more (validated) data available during the construction process, the better the relative speed/consumption table (thus the final model) will be.

Although this method demands for specific vessel's data to be available before starting estimating the relationship between speed and consumption, it also requires meticulous study of the quality of these data before feeding them in our model. Vessel's aging, in terms of engine, hull, propeller and weather conditions seem to have a serious impact when attempting to identify the current speed/consumption association, as the "default" data from sea trials and shop tests do not usually provide the same level of accuracy, compared to the conditions at the time the vessel was new. In the simulation part of the study (paragraph 5.4) that follows, we will witness how important these attributes can be in our potential CII projections.

### *5.1.3 BACKCALC(ULATIONS) TAB*

For the normal operation of the "CII Rating" front interface, there are multiple calculations occurring in the "background" each time the model is requested to provide either current ranking or forecasting of the CII. All calculations for such tasks are taking place in the "BackCalc" Tab.

This tab is consisted mainly of four different tables, some for data input (either manually or automatically through LAROS® system), and others for just displaying results or as reference tables (such as speed vs consumption comparison) contributing to the calculation of the forecasted results.

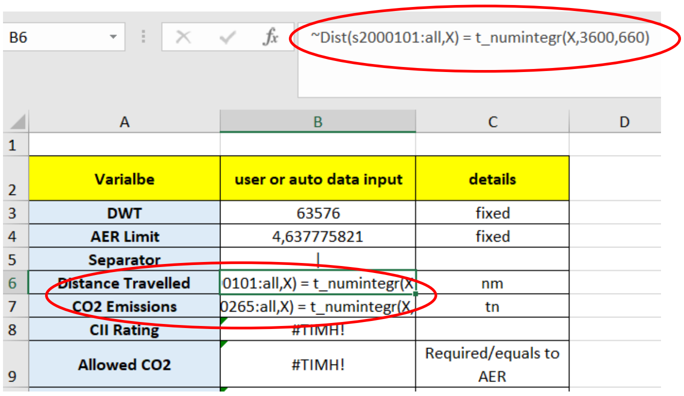
We start our presentation of the "BackCalc" with the main data input table (12).

| | Varialbe | user or auto data input | details |
|---|---|---|---|
| 1 | DWT | 63576 | fixed |
| 2 | AER Limit | 4,637775821 | fixed |
| 15 | Separator | \| | |
| 3 | Distance Travelled | 55000 | nm |
| 4 | CO2 Emissions | 16000 | tn |
| 5 | CII Rating | 4,575740226 | |
| 6 | Allowed CO2 | 16216,91999 | Required/equals to AER |
| 7 | Available CO2 | 216,9199896 | Remaining to be emitted from required |
| 8 | CII Percentage | -1% | (Deviation from Theoritical) |
| 9 | Dist. Ballast | 0 | user defined |
| 10 | Dist.Laden | 0 | user defined |
| 11 | Total Dist | 55000 | |
| | CO2 Coeff. | | |
| 12 | MGO | 3,206 | factors |
| 13 | LSFO | 3,151 | factors |
| 14 | HFO | 3,114 | factors |

*Table 12 Back Calc Interface*

“DWT” and “AER Limit” (pointed as 1 and 2) are defined by the user before starting using the model, as they are vessel specific, fixed values and they only change when the subject vessel changes. The concept of this table, is to ask the user to enter only “Distance Travelled” (point 3) and “CO2 Emissions” (point 4) on the easiest way possible, before all related results will show up. In regards to “CO2 Emissions” in particular, LAROS® system is receiving the related fuel density thus it can automatically read the fuel type (since Coriolis flow meters are onboard the vessel) and provide the related factor for the required calculations as set by IMO.  These values can be either entered manually based on the noon reports or automatically via LAROS® system.

It is interesting to elaborate a little but further on the formula used when enabling a macro command which describes the automatic process for data input from LAROS® (circled with red in table 13).  “Dist” stands for a normal nonspecific variable, while the “s2000101” is the variable that provides vessel’s speed in knots (from vessels GPS data) of which the integration results in the distance sailed (equally for “CO2 Emissions”, parameter “20000265” integral provides the overall CO2 production in mt/day in relation to the consumption as there is no other way (yet) of calculating the actual CO2 production. “t_numintegr” is the integral of the mean speed calculated using a time period of 1-hour (3600 sec) or 1-day (86400) sec.


B6 ~Dist(s2000101:all,X) = t_numintegr(X,3600,660)

| Varialbe | user or auto data input | details |
|---|---|---|
| DWT | 63576 | fixed |
| AER Limit | 4,637775821 | fixed |
| Separator | \| | |
| Distance Travelled | 0101:all,X) = t_numintegr(X | nm |
| CO2 Emissions | 0265:all,X) = t_numintegr(X | tn |
| CII Rating | #TIMH! | |
| Allowed CO2 | #TIMH! | Required/equals to AER |

*Table 13 Macro command used for importing Distance Travel using LAROS® system*

As for “660”, it stands as a polygonal chain for preventing possible data gaps which has been set on purpose for reassuring data quality in our measurements. To explain further, if there is a data gap of more than 660 sec or else around 10 min (gap>600 sec), then this “disputable” time period will be ignored in our data sample, being “too long”.

In case the gap is less than 660 sec (gap<600 sec), then two last data set of measurements will be perceived as one, assuming that there was no difference in the values during this interval. This is a normal process for data normalization, usually adopted for dealing with potential data gaps, provided that the high frequency data sampling allows it. Next, “CII Rating” (point 5 in table 14) practically corresponds to the results that will be ensued by the typical formula of CII, that equals to the fraction showing the production of CO2 divided by DWT and then multiplied by the distance travelled. The multiplication with 1000000 is applied in order the calculations result in more normal values, as required by the regulation. This specific “CII Rating” can be described as the “reference CII” which is typically a mean value of the CII calculated as referenced in table (13).

SUM | =B7*1000000/B6/B3

| | A | B | C |
|---|---|---|---|
| 1 | | | |
| 2 | Varialbe | user or auto data input | details |
| 3 | DWT | 63576 | fixed |
| 4 | AER Limit | 4,637775821 | fixed |
| 5 | Separator | \| | |
| 6 | Distance Travelled | 0101:all,X) = t_numintegr(X | nm |
| 7 | CO2 Emissions | 0265:all,X) = t_numintegr(X, | tn |
| 8 | 5 CII Rating | =B7*1000000/B6/B3 | |

*Table 14 CII Rating calculation formula*

Equally important, is the information of the “Allowed CO2” and the “Available CO2” (both circled in red below) and the calculation of their potential discrepancy.

SUM | =B4*B3*B14/1000000

| | A | B | C |
|---|---|---|---|
| 1 | | | |
| 2 | Varialbe | user or auto data input | details |
| 3 | DWT | 63576 | fixed |
| 4 | AER Limit | 4,637775821 | fixed |
| 5 | Separator | 15 \| | |
| 6 | Distance Travelled | 0101:all,X) = t_numintegr(X | nm |
| 7 | CO2 Emissions | 0265:all,X) = t_numintegr(X, | tn |
| 8 | CII Rating | #TIMH! | |
| 9 | Allowed CO2 | =B4*B3*B14/1000000 | Required/equals to AER |
| 10 | Available CO2 | #TIMH! | Remaining to be emitted from required |
| 11 | CII Percentage | #TIMH! | (Deviation from Theoritical) |

*Table 15 Calculation of Allowed CO2*

“Allowed CO2” follows the typical formula of CII and it practically corresponds to AER limit, as indicated on the table above (15) while “Available CO2” is just the subtraction of the “Allowed CO2” minus the actual “CO2 Emissions”, table (16).

The “separator” (point 15 of the table) is used for defining a standard symbol for separating the different speeds that will be displayed in ballast and laden condition respectively when the forecasting functionality will be activated and it makes no difference to our calculations at all.

SUM | =B9-B7

| | A | B | C |
|---|---|---|---|
| 1 | | | |
| 2 | **Varialbe** | **user or auto data input** | **details** |
| 3 | **DWT** | 63576 | fixed |
| 4 | **AER Limit** | 4,637775821 | fixed |
| 5 | **Separator** | \| | |
| 6 | **Distance Travelled** | )0101:all,X) = t_numintegr(X, | nm |
| 7 | **CO2 Emissions** | )265:all,X) = t_numintegr(X, | tn |
| 8 | **CII Rating** | #TIMH! | |
| 9 | **Allowed CO2** | #TIMH! | Required/equals to AER |
| 10 | **Available CO2** | =B9-B7 | Remaining to be emitted from required |

*Table 16 Calculation f Available CO2*

Thus, “Available CO2” actually represents the CO2 available to be emitted which can be used for planning or optimizing vessel’s next voyages.

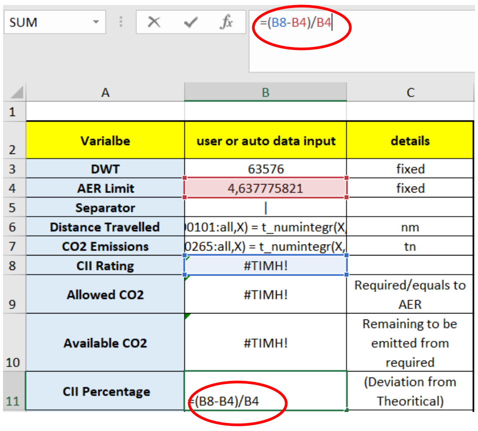
“Dist. Ballast” and “Dist. Laden” (table 17) are related to manual data entry process described in the first tab “CII Rating” section. These fields are expected to be manually entered from the user in order to activate the forecasting function of the model.

| | | | |
|---|---|---|---|
| 12 | **Dist. Ballast** | 0 | user defined |
| 13 | **Dist.Laden** | 0 | user defined |

*Table 17 Manual Data Entry for Distance in Ballas or Laden condition*

Another very useful indicator in our model, is the “CII Percentage” (marked with red circle and its related calculation formula in table 18) which represents the deviation of CII’s rating to AER Limit.

This indicator, which can receive negative or positive values, allows us to evaluate the potential inconsistency or discrepancy of our current rating to what the vessel "should" perform in order to keep CII's rating intact. This is a very useful tool that can be used by ship operators when planning/negotiating vessel's future operations. (table 18).


SUM =(B8-B4)/B4

| | A | B | C |
|---|---|---|---|
| 1 | | | |
| 2 | Varialbe | user or auto data input | details |
| 3 | DWT | 63576 | fixed |
| 4 | AER Limit | 4,637775821 | fixed |
| 5 | Separator | \| | |
| 6 | Distance Travelled | )0101:all,X) = t_numintegr(X | nm |
| 7 | CO2 Emissions | )265:all,X) = t_numintegr(X, | tn |
| 8 | CII Rating | #TIMH! | |
| 9 | Allowed CO2 | #TIMH! | Required/equals to AER |
| 10 | Available CO2 | #TIMH! | Remaining to be emitted from required |
| 11 | CII Percentage | =(B8-B4)/B4 | (Deviation from Theoritical) |

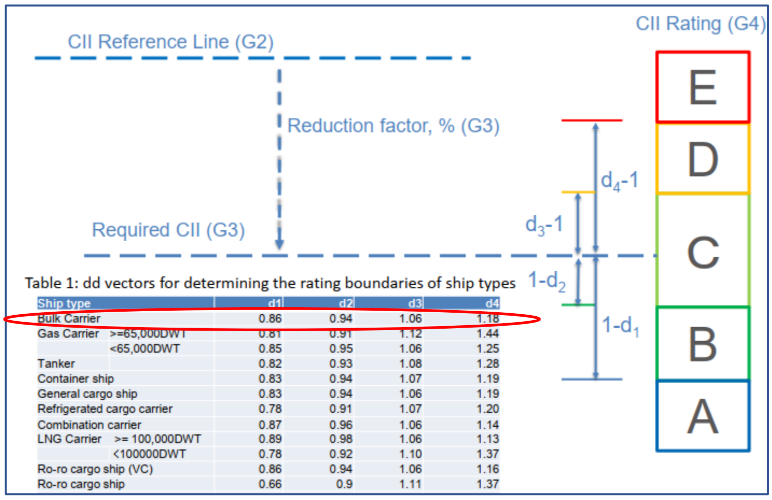
*Table 18 CII's Rating Calculation formula*

Next, there is the "CO2 Coefficient" table (19) which also needs to be inserted (just once) by the user depending on the type of the fuel used because different fuels have their individual factors, necessary for our calculations. This table is used only when manual data are entered into the model since LAROS® is automatically calculating these factors provided that Coriolis flow meters are available onboard.

| CO2 Coeff. | | |
|---|---|---|
| MGO | 3,206 | factors |
| LSFO | 3,151 | factors |
| HFO | 3,114 | factors |

*Table 19 CO2 Coefficient for different types of fuel*

Finally, before starting using the final CII calculator developed, we also need to define the limits of each CII scale (category) so as the proper coloring is applied. For this reason we use the "DD vectors" as identified by IMO in accordance to the following figure (41).




| Ship type | | d1 | d2 | d3 | d4 |
|---|---|---|---|---|---|
| Bulk Carrier | | 0.86 | 0.94 | 1.06 | 1.18 |
| Gas Carrier | >=65,000DWT | 0.81 | 0.91 | 1.12 | 1.44 |
| | <65,000DWT | 0.85 | 0.95 | 1.06 | 1.25 |
| Tanker | | 0.82 | 0.93 | 1.08 | 1.28 |
| Container ship | | 0.83 | 0.94 | 1.07 | 1.19 |
| General cargo ship | | 0.83 | 0.94 | 1.06 | 1.19 |
| Refrigerated cargo carrier | | 0.78 | 0.91 | 1.07 | 1.20 |
| Combination carrier | | 0.87 | 0.96 | 1.06 | 1.14 |
| LNG Carrier | >= 100,000DWT | 0.89 | 0.98 | 1.06 | 1.13 |
| | <100000DWT | 0.78 | 0.92 | 1.10 | 1.37 |
| Ro-ro cargo ship (VC) | | 0.86 | 0.94 | 1.06 | 1.16 |
| Ro-ro cargo ship | | 0.66 | 0.9 | 1.11 | 1.37 |

*Figure 41 DD vectors for rating according to ship type (source IMO, 2023)*

The data from the above figure are inserted in our model in the related table below (20); in our case, since the data used for testing and demonstrating the model are corresponding to a bulk carrier, the circled in red data are used. The columns referring to years from 2022 (point 1) up to 2026 refer to CII's limits (in relation to AER limit) as they are defined by IMO. The limits are planned to be diminishing on annual basis. The regulation has provided the (decreasing) factors for each year up to 2026, when the committee will then consider and decide how to proceed onwards.

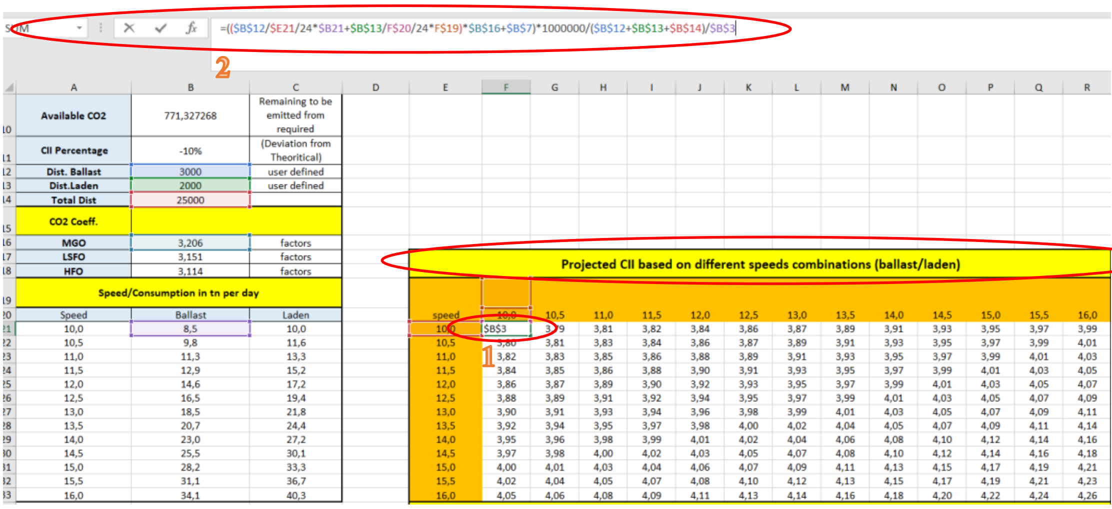
| dd vectors for determining the rating boundaries of different ship types | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Type | d1 | d2 | d3 | d4 | a | c | **2022** | 2023 | 2024 | 2025 | 2026 |
| Bulker | 0,86 | 0,94 | 1,06 | 1,18 | 2 4745 | 0,622 | **4,881869** | 4,637776 | 4,540138 | 4,442501 | 4,344864 |
| Tanker | 0,82 | 0,93 | 1,08 | 1,28 | 5247 | 0,61 | **6,164538** | 5,856311 | 5,73302 | 5,60973 | 5,486439 |
| Bulker | 3,988487206 | 4,359509272 | 4,91604237 | 5,472575469 | | | 1 | | | | |
| Tanker | 3,802976173 | 4,313131514 | 5,008797887 | 5,936353051 | | | | | | | |
| Vessel | 3,988487206 | 4,359509272 | 4,91604237 | 5,472575469 | | | | | | | |
| | | | | | | | | 3 -5% | -7% | -9% | -11% |

*Table 20 DD vectors initiated in the model for Bulkers/Tankers*

The actual formula for its calculation (point 1) refers to the multiplication of the related factor (point 2) with vessel's DWT, and then applying the diminishing percentage (point 3) (outcome) of each previous year on the result of the next, until 2026.

## 5.2 THE FORECASTING FUNCTIONALITY

In the next phase, we need to check how the interconnected tables are working together for producing forecasts that can be used from the shipping company when planning next vessel's voyages.




| | |
|---|---|
| Available CO2 | 771,327268 | Remaining to be emitted from required |
| CII Percentage | -10% | (Deviation from Theoritical) |
| Dist. Ballast | 3000 | user defined |
| Dist.Laden | 2000 | user defined |
| Total Dist | 25000 | |
| CO2 Coeff. | | |
| MGO | 3,206 | factors |
| LSFO | 3,151 | factors |
| HFO | 3,114 | factors |
| Speed/Consumption in tn per day | | |
| Speed | Ballast | Laden |
| 10,0 | 8,5 | 10,0 |
| 10,5 | 9,8 | 11,6 |
| 11,0 | 11,3 | 13,3 |
| 11,5 | 12,9 | 15,2 |
| 12,0 | 14,6 | 17,2 |
| 12,5 | 16,5 | 19,4 |
| 13,0 | 18,5 | 21,8 |
| 13,5 | 20,7 | 24,4 |
| 14,0 | 23,0 | 27,2 |
| 14,5 | 25,5 | 30,1 |
| 15,0 | 28,2 | 33,3 |
| 15,5 | 31,1 | 36,7 |
| 16,0 | 34,1 | 40,3 |

| Projected CII based on different speeds combinations (ballast/laden) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| speed | 10,0 | 10,5 | 11,0 | 11,5 | 12,0 | 12,5 | 13,0 | 13,5 | 14,0 | 14,5 | 15,0 | 15,5 | 16,0 |
| 10,0 | $B$3 | 3,79 | 3,81 | 3,82 | 3,84 | 3,86 | 3,87 | 3,89 | 3,91 | 3,93 | 3,95 | 3,97 | 3,99 |
| 10,5 | 3,80 | 3,81 | 3,83 | 3,84 | 3,86 | 3,87 | 3,89 | 3,91 | 3,93 | 3,95 | 3,97 | 3,99 | 4,01 |
| 11,0 | 3,82 | 3,83 | 3,85 | 3,86 | 3,88 | 3,89 | 3,91 | 3,93 | 3,95 | 3,97 | 3,99 | 4,01 | 4,03 |
| 11,5 | 3,84 | 3,85 | 3,86 | 3,88 | 3,90 | 3,91 | 3,93 | 3,95 | 3,97 | 3,99 | 4,01 | 4,03 | 4,05 |
| 12,0 | 3,86 | 3,87 | 3,89 | 3,90 | 3,92 | 3,93 | 3,95 | 3,97 | 3,99 | 4,01 | 4,03 | 4,05 | 4,07 |
| 12,5 | 3,88 | 3,89 | 3,91 | 3,92 | 3,94 | 3,95 | 3,97 | 3,99 | 4,01 | 4,03 | 4,05 | 4,07 | 4,09 |
| 13,0 | 3,90 | 3,91 | 3,93 | 3,94 | 3,96 | 3,98 | 3,99 | 4,01 | 4,03 | 4,05 | 4,07 | 4,09 | 4,11 |
| 13,5 | 3,92 | 3,94 | 3,95 | 3,97 | 3,98 | 4,00 | 4,02 | 4,04 | 4,05 | 4,07 | 4,09 | 4,11 | 4,14 |
| 14,0 | 3,95 | 3,96 | 3,98 | 3,99 | 4,01 | 4,02 | 4,04 | 4,06 | 4,08 | 4,10 | 4,12 | 4,14 | 4,16 |
| 14,5 | 3,97 | 3,98 | 4,00 | 4,02 | 4,03 | 4,05 | 4,07 | 4,08 | 4,10 | 4,12 | 4,14 | 4,16 | 4,18 |
| 15,0 | 4,00 | 4,01 | 4,03 | 4,04 | 4,06 | 4,07 | 4,09 | 4,11 | 4,13 | 4,15 | 4,17 | 4,19 | 4,21 |
| 15,5 | 4,02 | 4,04 | 4,05 | 4,07 | 4,08 | 4,10 | 4,12 | 4,13 | 4,15 | 4,17 | 4,19 | 4,21 | 4,23 |
| 16,0 | 4,05 | 4,06 | 4,08 | 4,09 | 4,11 | 4,13 | 4,14 | 4,16 | 4,18 | 4,20 | 4,22 | 4,24 | 4,26 |

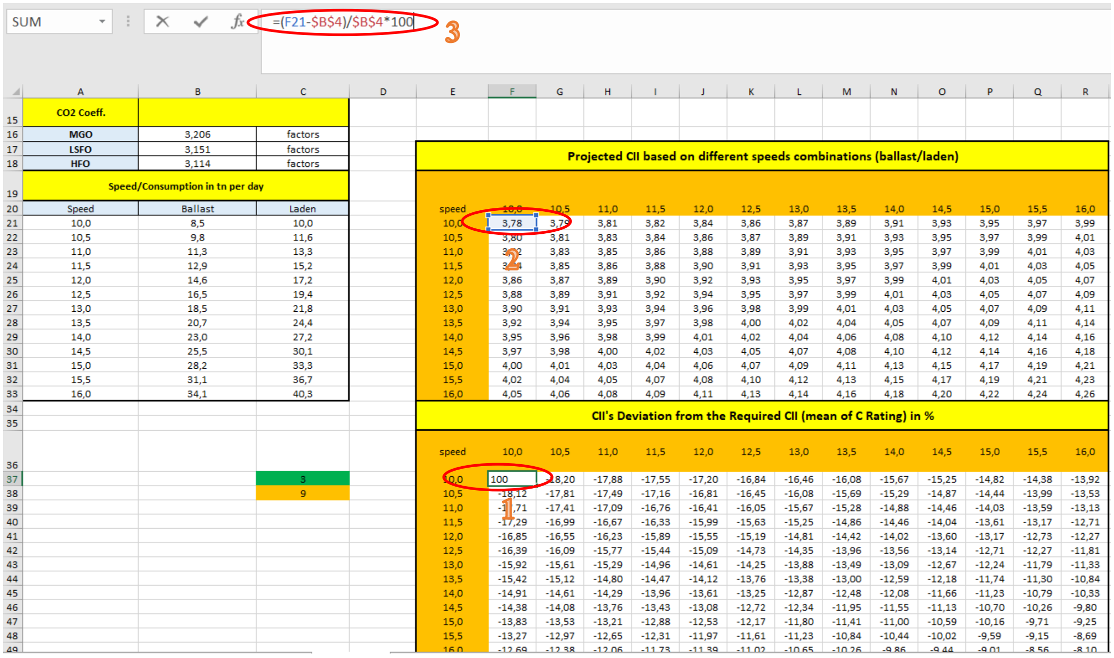
*Figure 42 Projection of CII for different speeds/drafts calculation*

For this purpose, we have to decompose all the necessary calculations occurring for each combination of speeds in the related table. Let's, for example, examine the formula in cell F21, circled in red (point 1, figure 42). During this process, we practically calculate the variables of CO2 Emissions with the distance travelled (as DWT remains stable) but in a cumulative manner throughout the year (as this is required by the regulation). This means that we always need to consider the existing values from the beginning of the year for both CO2 Emissions and distance travelled to our calculations. Then we apply the calculations by adding the new values resulted, taking into account the speed impact on the results, according to different operational profiles and conditions. As a result, the formula applied, is allowing the dynamic combination of existing (stored) data in combination to the new (automatically acquired) data, following the manual input (requested by the user) for the planned distance to be sailed.

Consequently, the subject formula (point 2, figure 49) is practically calculating the product of the sum of previously measured (stored) CO2 and new input/received CO2 Emissions with the fixed deadweight (DWT) multiplied by the sum of the past distance travelled up to that point with the new (remaining) miles to sail for covering the (planned) distance the user has entered.

Time attribute used in our formula simply results from the typical equation of speed (speed=distance/time solved for t) and then we multiply time to the consumption and its related CO2 Coefficient with its fuel type in order to estimate the overall CO2 Emissions.

While table "Projected CII based on different speed combinations (ballast/laden)" refers to CII calculations, the next table (displayed in figure 43) is identifying the differential percentage of CII to AER limit (points 1 and 3) on different speeds (in reference to what has been projected through previous table of projections, point 2, figure 43). Both tables, have been constructed for combining theoretical functions and equations as defined by IMO's formula with the use of real data from the subject vessel.



SUM =(F21-$B$4)/$B$4*100 3

| CO2 Coeff. | | |
|---|---|---|
| MGO | 3,206 | factors |
| LSFO | 3,151 | factors |
| HFO | 3,114 | factors |

| Speed/Consumption in tn per day | | |
|---|---|---|
| Speed | Ballast | Laden |
| 10,0 | 8,5 | 10,0 |
| 10,5 | 9,8 | 11,6 |
| 11,0 | 11,3 | 13,3 |
| 11,5 | 12,9 | 15,2 |
| 12,0 | 14,6 | 17,2 |
| 12,5 | 16,5 | 19,4 |
| 13,0 | 18,5 | 21,8 |
| 13,5 | 20,7 | 24,4 |
| 14,0 | 23,0 | 27,2 |
| 14,5 | 25,5 | 30,1 |
| 15,0 | 28,2 | 33,3 |
| 15,5 | 31,1 | 36,7 |
| 16,0 | 34,1 | 40,3 |
| | | 3 |
| | | 9 |

Projected CII based on different speeds combinations (ballast/laden)

| speed | 10,0 | 10,5 | 11,0 | 11,5 | 12,0 | 12,5 | 13,0 | 13,5 | 14,0 | 14,5 | 15,0 | 15,5 | 16,0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10,0 | 3,78 | 3,79 | 3,81 | 3,82 | 3,84 | 3,86 | 3,87 | 3,89 | 3,91 | 3,93 | 3,95 | 3,97 | 3,99 |
| 10,5 | 3,80 | 3,81 | 3,83 | 3,84 | 3,86 | 3,87 | 3,89 | 3,91 | 3,93 | 3,95 | 3,97 | 3,99 | 4,01 |
| 11,0 | [illegible] | 3,83 | 3,85 | 3,86 | 3,88 | 3,89 | 3,91 | 3,93 | 3,95 | 3,97 | 3,99 | 4,01 | 4,03 |
| 11,5 | [illegible] | 3,85 | 3,86 | 3,88 | 3,90 | 3,91 | 3,93 | 3,95 | 3,97 | 3,99 | 4,01 | 4,03 | 4,05 |
| 12,0 | 3,86 | 3,87 | 3,89 | 3,90 | 3,92 | 3,93 | 3,95 | 3,97 | 3,99 | 4,01 | 4,03 | 4,05 | 4,07 |
| 12,5 | 3,88 | 3,89 | 3,91 | 3,92 | 3,94 | 3,95 | 3,97 | 3,99 | 4,01 | 4,03 | 4,05 | 4,07 | 4,09 |
| 13,0 | 3,90 | 3,91 | 3,93 | 3,94 | 3,96 | 3,98 | 3,99 | 4,01 | 4,03 | 4,05 | 4,07 | 4,09 | 4,11 |
| 13,5 | 3,92 | 3,94 | 3,95 | 3,97 | 3,98 | 4,00 | 4,02 | 4,04 | 4,05 | 4,07 | 4,09 | 4,11 | 4,14 |
| 14,0 | 3,95 | 3,96 | 3,98 | 3,99 | 4,01 | 4,02 | 4,04 | 4,06 | 4,08 | 4,10 | 4,12 | 4,14 | 4,16 |
| 14,5 | 3,97 | 3,98 | 4,00 | 4,02 | 4,03 | 4,05 | 4,07 | 4,08 | 4,10 | 4,12 | 4,14 | 4,16 | 4,18 |
| 15,0 | 4,00 | 4,01 | 4,03 | 4,04 | 4,06 | 4,07 | 4,09 | 4,11 | 4,13 | 4,15 | 4,17 | 4,19 | 4,21 |
| 15,5 | 4,02 | 4,04 | 4,05 | 4,07 | 4,08 | 4,10 | 4,12 | 4,13 | 4,15 | 4,17 | 4,19 | 4,21 | 4,23 |
| 16,0 | 4,05 | 4,06 | 4,08 | 4,09 | 4,11 | 4,13 | 4,14 | 4,16 | 4,18 | 4,20 | 4,22 | 4,24 | 4,26 |

CII's Deviation from the Required CII (mean of C Rating) in %

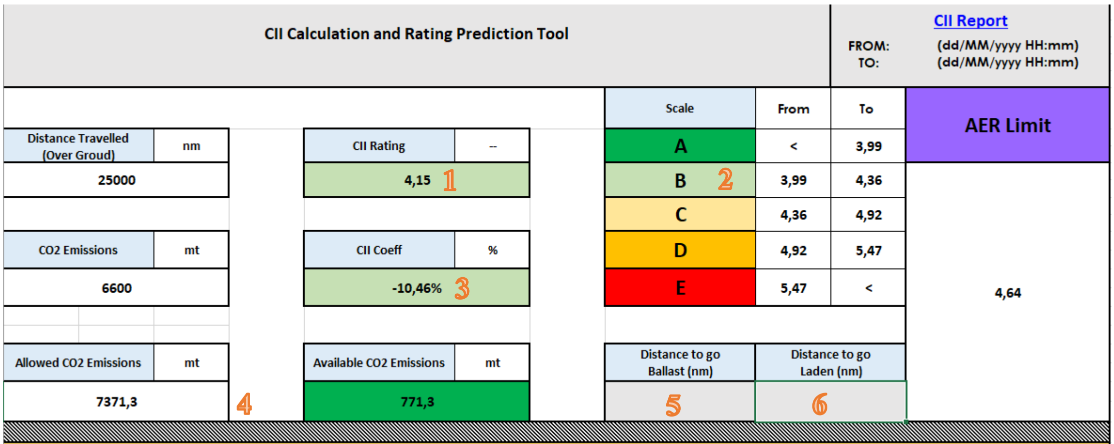
| speed | 10,0 | 10,5 | 11,0 | 11,5 | 12,0 | 12,5 | 13,0 | 13,5 | 14,0 | 14,5 | 15,0 | 15,5 | 16,0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10,0 | 100 | -18,20 | -17,88 | -17,55 | -17,20 | -16,84 | -16,46 | -16,08 | -15,67 | -15,25 | -14,82 | -14,38 | -13,92 |
| 10,5 | -18,12 | -17,81 | -17,49 | -17,16 | -16,81 | -16,45 | -16,08 | -15,69 | -15,29 | -14,87 | -14,44 | -13,99 | -13,53 |
| 11,0 | [illegible] | -17,41 | -17,09 | -16,76 | -16,41 | -16,05 | -15,67 | -15,28 | -14,88 | -14,46 | -14,03 | -13,59 | -13,13 |
| 11,5 | -17,29 | -16,99 | -16,67 | -16,33 | -15,99 | -15,63 | -15,25 | -14,86 | -14,46 | -14,04 | -13,61 | -13,17 | -12,71 |
| 12,0 | -16,85 | -16,55 | -16,23 | -15,89 | -15,55 | -15,19 | -14,81 | -14,42 | -14,02 | -13,60 | -13,17 | -12,73 | -12,27 |
| 12,5 | -16,39 | -16,09 | -15,77 | -15,44 | -15,09 | -14,73 | -14,35 | -13,96 | -13,56 | -13,14 | -12,71 | -12,27 | -11,81 |
| 13,0 | -15,92 | -15,61 | -15,29 | -14,96 | -14,61 | -14,25 | -13,88 | -13,49 | -13,09 | -12,67 | -12,24 | -11,79 | -11,33 |
| 13,5 | -15,42 | -15,12 | -14,80 | -14,47 | -14,12 | -13,76 | -13,38 | -13,00 | -12,59 | -12,18 | -11,74 | -11,30 | -10,84 |
| 14,0 | -14,91 | -14,61 | -14,29 | -13,96 | -13,61 | -13,25 | -12,87 | -12,48 | -12,08 | -11,66 | -11,23 | -10,79 | -10,33 |
| 14,5 | -14,38 | -14,08 | -13,76 | -13,43 | -13,08 | -12,72 | -12,34 | -11,95 | -11,55 | -11,13 | -10,70 | -10,26 | -9,80 |
| 15,0 | -13,83 | -13,53 | -13,21 | -12,88 | -12,53 | -12,17 | -11,80 | -11,41 | -11,00 | -10,59 | -10,16 | -9,71 | -9,25 |
| 15,5 | -13,27 | -12,97 | -12,65 | -12,31 | -11,97 | -11,61 | -11,23 | -10,84 | -10,44 | -10,02 | -9,59 | -9,15 | -8,69 |
| 16,0 | -12,69 | -12,38 | -12,06 | -11,73 | -11,39 | -11,02 | -10,65 | -10,26 | -9,86 | -9,44 | -9,01 | -8,56 | -8,10 |

*Figure 43 Percentage of CII's Deviation from the Required (Projection)*

### 5.1.4 CII CALCULATION FUNCTIONALITY TEST

Testing the functionality of CII's calculation, involves a straightforward process. The user needs to only enter the required data regarding the distance travelled and the related CO2 Emissions for the related distance (when in manual data entry mode). Assumingly, for testing and demonstration purposes we enter (through "BackCalc" Tab and not on the "CII rating" Tab as these are supposed to be validated data coming the vessel through official noon reports or an automated system) an indicative distance of 25000 miles and the related CO2 Emissions at 6600 mt (figure 44, points 5 and 6). We immediately observe a CII Rating of 4.15 (point 1) which classifies the vessel to second scale (Rating B) (point 2). We also notice that the color code matching functionality works perfectly. Also, CII Coefficient (or else Deviation Percentage) (point 3) is getting a negative value meaning that the vessel has hypothetically performed better than "allowed", allowing some 771,3 mt of emissions (point 4) to be emitted as "spare".

We can further conclude that the subject vessel is a very efficient vessel, performing well as CII's future rating allow the vessel to either increase speed if required, or handle more next port calls with more flexibility. This kind of scenarios, act like options for the operators when using the model.




| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Laden | | | | | | | | | | | | |
| Ballast | 10.0 | 10,5 | 11.0 | 11,5 | 12.0 | 12,5 | 13.0 | 13,5 | 14.0 | 14,5 | 15.0 | 15,5 | 16.0 |
| 10.0 | 10.0 \| 10.0 | 10.0 \| 10,5 | 10.0 \| 11.0 | 10.0 \| 11,5 | 10.0 \| 12.0 | 10.0 \| 12,5 | 10.0 \| 13.0 | 10.0 \| 13,5 | 10.0 \| 14.0 | 10.0 \| 14,5 | 10.0 \| 15.0 | 10.0 \| 15,5 | 10.0 \| 16.0 |
| 10,5 | 10,5 \| 10.0 | 10,5 \| 10,5 | 10,5 \| 11.0 | 10,5 \| 11,5 | 10,5 \| 12.0 | 10,5 \| 12,5 | 10,5 \| 13.0 | 10,5 \| 13,5 | 10,5 \| 14.0 | 10,5 \| 14,5 | 10,5 \| 15.0 | 10,5 \| 15,5 | 10,5 \| 16.0 |
| 11.0 | 11.0 \| 10.0 | 11.0 \| 10,5 | 11.0 \| 11.0 | 11.0 \| 11,5 | 11.0 \| 12.0 | 11.0 \| 12,5 | 11.0 \| 13.0 | 11.0 \| 13,5 | 11.0 \| 14.0 | 11.0 \| 14,5 | 11.0 \| 15.0 | 11.0 \| 15,5 | 11.0 \| 16.0 |

*Figure 44 CII Calculation Functionality testing*

### 5.1.5 CII FORECASTING FUNCTIONALITY TESTING

Apart from the very simple functionality of calculating and displaying the CII with parallel information regarding the available CO2 Emissions remaining with no effect on CII rating, our model is designed to forecast CII's rating, illustrating the limit of speeds that need to be maintained for keeping it steady or how this will be affected when different speeds applied on different drafts.

In our previous test, the data manually entered, indicated a very effective vessel; thus we need to modify this now, in order to observe the forecasting in a more well distinguishing and illustrative manner. So, for demonstration purposes, we manually change the initial data on “Distance travelled” and “CO2 Emissions”, by entering 52000 nm for distance with a total of CO2 Emissions of 18000mt (points 1 and 2, figure 45).

Once entered, we witness the new CII’s rating which equals to 5,44 (point 7, figure 45) now indicating a vessel close to “E” ranking (point 10). Next, if we assume that we plan to operate the vessel for a distance of 3000 miles in ballast and 20000 miles in laden (points 5 and 6), we manually enter these values in the “CII Rating” Tab and we observe how the related speeds table (point 3) in Ballast/Laden table is shifting, also indicating what speeds (combinations) need to be maintained in each loading condition or else how the CII rating will be affected under those speeds.

According to the results, if the vessel maintains a steady speed of 10 knots in ballast or 12.5 knots in laden (point 4), by the end of the trip, her rating will be shifted to “A”. Similarly, for speeds from 13 up to 14.5 knots in laden the CII rating will be modified and remain to “C” but if she reaches the speed of 15knots (in laden) (point 7) or use a combination of 12,5 in ballast and 14,5 in laden, then she will enter “the red zone” of “E” rating (point 8) (practically that would mean that the vessel will remain in rating “E” no matter the ballast and laden miles to sail, as this is the current ranking of 5.44 previously calculated in the previous paragraph).

The way the model is constructed, it offers many ways to read and interpret its calculations, as the result table allows operators to foresee either the combination of speeds in order to remain within limits of the current CII, or when using the color matching appropriately, to have an approximate insight on the vessel’s proneness to shift rating/category, either upwards or downwards. This, easy to read functionality, allows operators to plan the next voyages with much more effectiveness when it comes to how the CII will be affected.

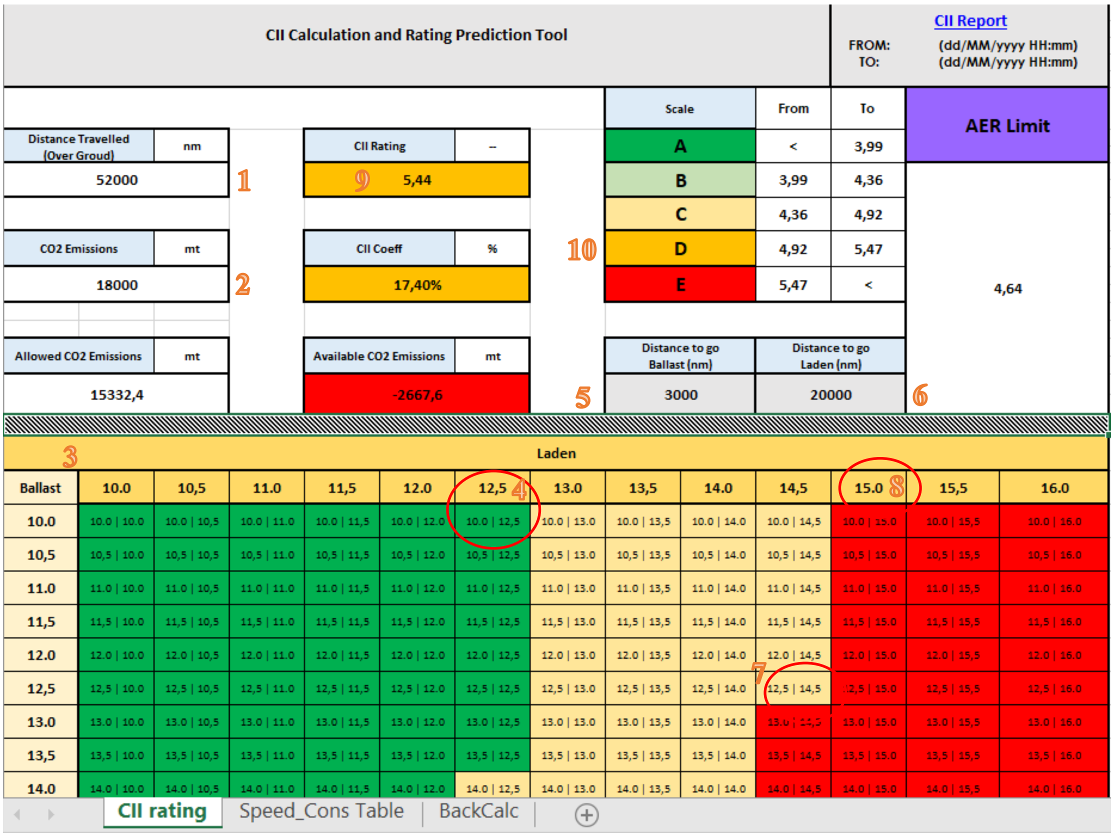



*Figure 45 Forecasting different speeds effect into CII's Rating*

## 5.3 SIMULATION

Next, we will attempt to “run” the forecasting model, this time fed with high frequency data, collected using LAROS® system onboard subject vessel “Las Palmas”.

The ideal time period required for such a simulation is to use a full year’s data (365 days) in order to check the performance of our model and at the same time assess how it corresponds to realistic CII’s annual regulation requirements. Because of thesis submission date set at the (01/07/2023), instead of using a calendar’s data beginning from the 1st of January, we will be using related measurements for an equal period of time (365 days in total) but this time starting from 1/7/2022 ending on 1/07/2023 instead. The results are expected to be equally effective for our conclusions.

The fact that there are available data for the subject vessel for a period of almost two years’ time (hindcast/historical data), allows us to check multiple scenarios for evaluating how accurate the model is, by selecting certain operational data and observing their impact on the CII.

However, although a time period referring to a calendar year from 1/1/2022 to 31/12/2022 would seem more realistic and closer to what the regulation dictates, the fact that the vessel's operators and crew were not (hypothetically) considering CII at that time (since the regulation was not active), would perhaps result in more vague measurements. In order to avoid this, we may select the period from 1/1/2023 up to 1/7/2023 instead.

During our trials, we will examine CII's rating results occurred within six first months of measurements (beginning from 1/7/2022 ending on the 1/1/2023) and then by setting the end of that period as the beginning of our forecast, will try to evaluate how accurate the forecasting model will be for the following six months (up to 1/7/2023) since we already have the actual CII rating data for that period.

Before starting feeding data, we need to make sure that there is continuity in the measurements. Figure (46) evidences this data consistency, necessary for all related calculations. Parameters indicated (in order of appearance) are drafts (for defining loading condition) (point 1), speed over ground (for measuring distance travelled) (point 2) and total consumption (for calculating $CO_2$ emissions) (point 3). The measurements are collected on a per minute sampling frequency.

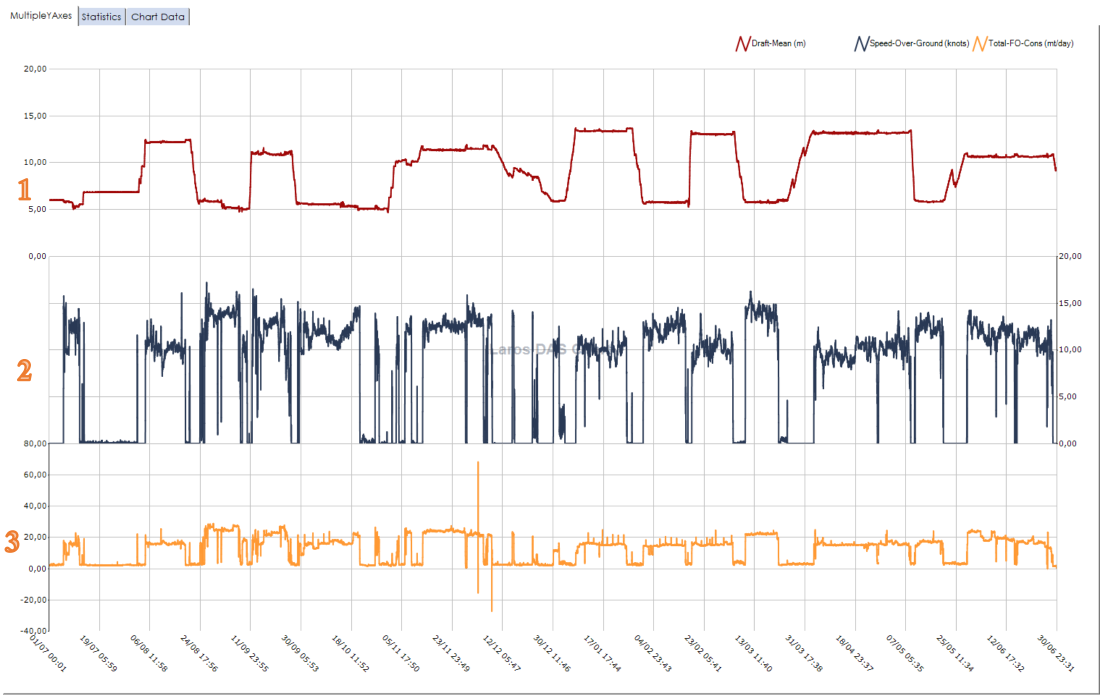



*Figure 46 LAROS® data continuity check for the parameters examined*

Next, we will feed our model with all the measurements illustrated above in order to identify the first six months' CII (1/7/2022 to 1/1/2023). Then we will attempt to forecast how this CII will be affected (projection) based on the distance to be sailed in different loading conditions (since we already know the actual distance sailed and the $CO_2$ produced) which will be finally compared to the actual CII occurred, taking into account the different speeds (and consumptions) achieved within the target period (1/1/2023 to 1/7/2023). For this analysis we use the reference data as recorded by LAROS® system as illustrated below (figure 47):

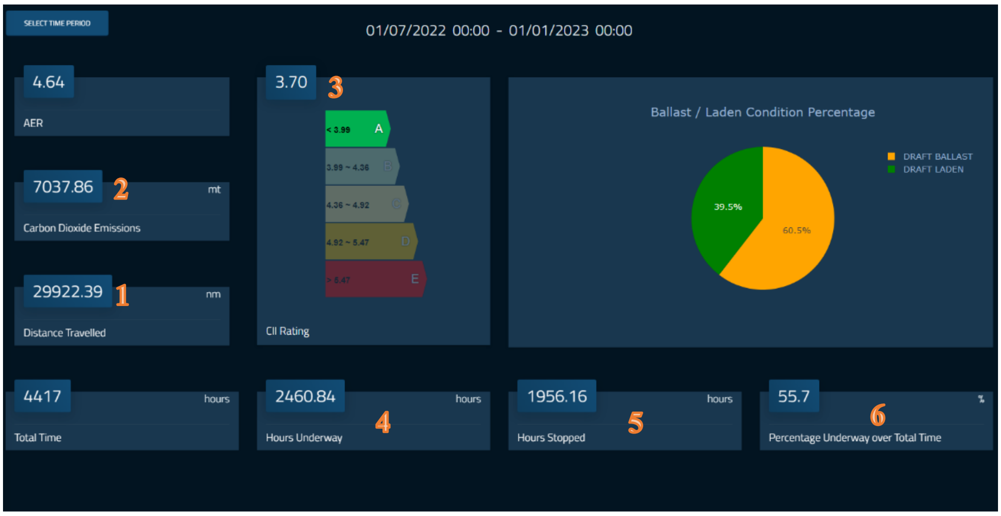



*Figure 47 LAROS® actual data on "Las Palmas" from 1/7/2022 to 1/1/2023*

We observe that for a period of time from 1/07/2022 to 1/1/2023 the vessel has sailed a distance of 29922 nautical miles (point 1) with a total production of 7037 (point 2) metric tons of $CO_2$ resulting in a CII of 3.70 (point 3), classified its ranking with A. Interestingly, the vessel spent 2460 hours underway (point 4) while 1956 hours (point 5) was stopped (at anchorage or other non-underway condition) achieving a percentage of 55.7% (point 6) of time being underway.

By feeding our model with distance travelled and $CO_2$ emissions data from above, we get identical CII results (as expected since the reference database is common). Below figure (48) displays the results by our model (circled in red):

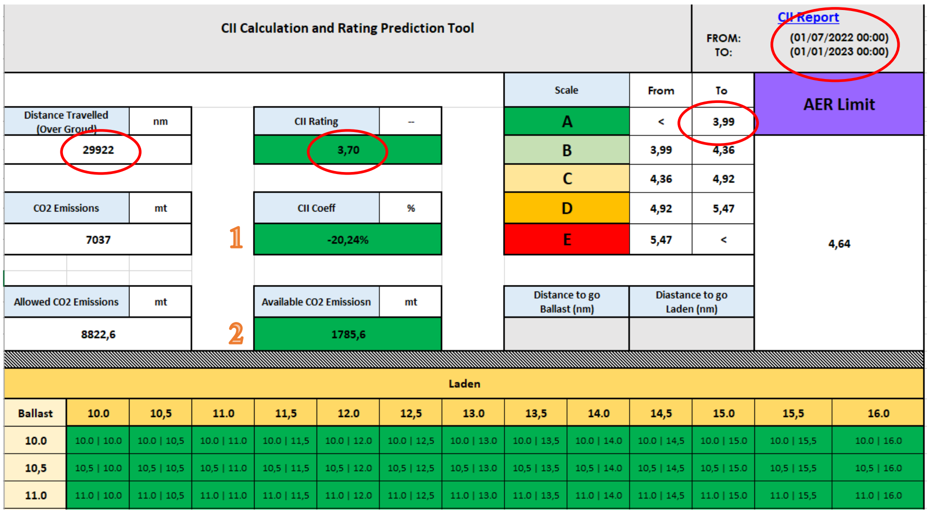



*Figure 48 CII Calculation model fed with LAROS® data results*

Evidently, this is truly a very efficient (super eco) vessel as she is delivering an astonishing -20,2% CII Coefficient (point 1) within 6 months of normal operation by having sailed almost 30000 miles, which practically means she has covered above the average of "normal trading" miles. Still, the vessel is allowed to produce (or consume) plenty amounts of CO2 (point 2) without practically affecting the current CII Rating.

In the next phase, as we will use the available data concerning vessel's operation for the next six months (up to 1/07/2023) which will allow us to test the forecasting functionality of our model.

Figure 49 below displays LAROS® data regarding the period of time we are applying our forecast model on, examining the period from 1/1/2023 up to 1/07/2023. Based on our records available, during this period the vessel has sailed 11.919 miles in ballast condition and 26.546 miles in laden condition.

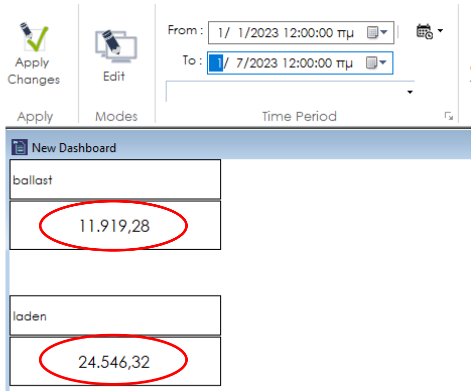



*Figure 49 LAROS® data regarding miles sailed for ballast and laden conditions*

Again, by inserting these two values in our model (distance to go in ballast and laden fields as displayed in figure 50) we should be able to have theoretical forecasting on CII's potential shifting based on different speed combinations for different drafts (ballast/laden).

| Distance to go Ballast (nm) | Diastance to go Laden (nm) |
|---|---|
| **11919** | **24546** |

*Figure 50 Distance to sail input fields*

Table (21) below demonstrates how the related table available in "BackCalc" Tab is formed after the "distance to go" values have been inserted, illustrating all possible speeds in different loading conditions and their related "Projected CII".[2]

| Projected CII based on different speed combinations (ballast/laden) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| speed | 10,0 | 10,5 | 11,0 | 11,5 | 12,0 | 12,5 | 13,0 | 13,5 | 14,0 | 14,5 | 15,0 | 15,5 | 16,0 |
| 10,0 | 2,77 | 2,85 | 2,93 | 3,01 | 3,10 | 3,20 | 3,29 | 3,39 | 3,50 | 3,60 | 3,71 | 3,83 | 3,95 |
| 10,5 | 2,80 | 2,88 | 2,96 | 3,05 | 3,14 | 3,23 | 3,32 | 3,42 | 3,53 | 3,64 | 3,75 | 3,86 | 3,98 |
| 11,0 | 2,83 | 2,91 | 2,99 | 3,08 | 3,17 | 3,26 | 3,36 | 3,46 | 3,56 | 3,67 | 3,78 | 3,89 | 4,01 |
| 11,5 | 2,87 | 2,95 | 3,03 | 3,11 | 3,20 | 3,30 | 3,39 | 3,49 | 3,60 | 3,70 | 3,82 | 3,93 | 4,05 |
| 12,0 | 2,91 | 2,98 | 3,07 | 3,15 | 3,24 | 3,33 | 3,43 | 3,53 | 3,63 | 3,74 | 3,85 | 3,97 | 4,08 |
| 12,5 | 2,94 | 3,02 | 3,10 | 3,19 | 3,28 | 3,37 | 3,47 | 3,57 | 3,67 | 3,78 | 3,89 | 4,00 | 4,12 |
| 13,0 | 2,98 | 3,06 | 3,14 | 3,23 | 3,32 | 3,41 | 3,51 | 3,61 | 3,71 | 3,82 | 3,93 | 4,04 | 4,16 |
| 13,5 | 3,02 | 3,10 | 3,18 | 3,27 | 3,36 | 3,45 | 3,55 | 3,65 | 3,75 | 3,86 | 3,97 | 4,08 | 4,20 |
| 14,0 | 3,07 | 3,15 | 3,23 | 3,31 | 3,40 | 3,49 | 3,59 | 3,69 | 3,79 | 3,90 | 4,01 | 4,13 | 4,25 |
| 14,5 | 3,11 | 3,19 | 3,27 | 3,36 | 3,45 | 3,54 | 3,64 | 3,74 | 3,84 | 3,95 | 4,06 | 4,17 | 4,29 |
| 15,0 | 3,16 | 3,23 | 3,32 | 3,40 | 3,49 | 3,58 | 3,68 | 3,78 | 3,88 | 3,99 | 4,10 | 4,22 | 4,34 |
| 15,5 | 3,20 | 3,28 | 3,36 | 3,45 | 3,54 | 3,63 | 3,73 | 3,83 | 3,93 | 4,04 | 4,15 | 4,26 | 4,38 |
| 16,0 | 3,25 | 3,33 | 3,41 | 3,50 | 3,59 | 3,68 | 3,78 | 3,88 | 3,98 | 4,09 | 4,20 | 4,31 | 4,43 |

*Table 21 Projected CII for 1/1/2023 to 1/7/2023*

[2] Vertical speed values on the table represent ballast while horizontal represent laden conditions

In the above table, we spot that current CII (approximately 3.70) (point 1) can be maintained for a limit combination of speeds consisted of either 15.5 in ballast or 13 knots in laden condition. What seems to be quite intriguing is the fact that the vessel will start to be shifting into rating B (CII 3.99 or more) (point 2) only by a speed of 15 in ballast or 14.5 knots in laden. Despite how non-realistic this may appear because these are quite high speeds for a normal merchant vessel's operation, still it acts as an useful indication on how the CII will be modified if the vessel keeps operating at certain speeds. If for example we consider a normal speed (slow steaming) of 11 knots in average (for both conditions) then we notice that CII will be reduced further reaching a value of 2.99 (point 3) by the end the year. This functionality provides a helpful tool for planning next voyages and related operations.

Also, by inserting the desired distance to travel in the required fields, there is another useful table being produced. This table is illustrating "CII's Deviation from the Required CII"[3] (table 22):

| CII's Deviation from the Required CII (mean of C Rating) in % | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| speed | 10,0 | 10,5 | 11,0 | 11,5 | 12,0 | 12,5 | 13,0 | 13,5 | 14,0 | 14,5 | 15,0 | 15,5 | 16,0 |
| 10,0 | -40,31 | -38,63 | -36,86 | -35,02 | -33,09 | -31,09 | -29,01 | -26,86 | -24,62 | -22,31 | -19,92 | -17,45 | -14,90 |
| 10,5 | -39,62 | -37,93 | -36,17 | -34,32 | -32,40 | -30,40 | -28,32 | -26,16 | -23,93 | -21,62 | -19,22 | -16,76 | -14,21 |
| 11,0 | -38,90 | -37,21 | -35,44 | -33,60 | -31,68 | -29,67 | -27,60 | -25,44 | -23,20 | -20,89 | -18,50 | -16,03 | -13,48 |
| 11,5 | -38,14 | -36,45 | -34,69 | -32,84 | -30,92 | -28,92 | -26,84 | -24,68 | -22,45 | -20,13 | -17,74 | -15,27 | -12,73 |
| 12,0 | -37,35 | -35,66 | -33,90 | -32,05 | -30,13 | -28,13 | -26,05 | -23,89 | -21,66 | -19,34 | -16,95 | -14,48 | -11,94 |
| 12,5 | -36,53 | -34,84 | -33,07 | -31,23 | -29,31 | -27,31 | -25,23 | -23,07 | -20,83 | -18,52 | -16,13 | -13,66 | -11,11 |
| 13,0 | -35,67 | -33,98 | -32,22 | -30,37 | -28,45 | -26,45 | -24,37 | -22,21 | -19,98 | -17,67 | -15,27 | -12,81 | -10,26 |
| 13,5 | -34,78 | -33,10 | -31,33 | -29,49 | -27,57 | -25,56 | -23,49 | -21,33 | -19,09 | -16,78 | -14,39 | -11,92 | -9,37 |
| 14,0 | -33,87 | -32,18 | -30,41 | -28,57 | -26,65 | -24,65 | -22,57 | -20,41 | -18,17 | -15,86 | -13,47 | -11,00 | -8,45 |
| 14,5 | -32,92 | -31,23 | -29,46 | -27,62 | -25,70 | -23,70 | -21,62 | -19,46 | -17,22 | -14,91 | -12,52 | -10,05 | -7,50 |
| 15,0 | -31,93 | -30,25 | -28,48 | -26,64 | -24,71 | -22,71 | -20,63 | -18,48 | -16,24 | -13,93 | -11,54 | -9,07 | -6,52 |
| 15,5 | -30,92 | -29,23 | -27,47 | -25,62 | -23,70 | -21,70 | -19,62 | -17,46 | -15,23 | -12,91 | -10,52 | -8,05 | -5,51 |
| 16,0 | -29,87 | -28,19 | -26,42 | -24,58 | -22,65 | -20,65 | -18,57 | -16,42 | -14,18 | -11,87 | -9,48 | -7,01 | -4,46 |

*Table 22 CII's Deviation from the Required in %*

In our example, negative values mean that the vessel is actually performing in a very positive way, delivering such negative deviation that allows it to be retaining the desired CII with minimum effort, even at very high speeds. Even if these high speeds are not going to be reached, high (negative) deviation from the required CII, allows vessel's operators to handle port staying or other high FOC conditions with much more flexibility.

[3] Vertical speed values on the table represent ballast while horizontal represent laden conditions

Furthermore, as we do have the real data regarding the actual speed profiles eventually applied during the period of our projections (1/1/2023 to 1/7/2023) we are able to verify our forecasting model even further by examining its accuracy, comparing LAROS® measured data to our model's hypothetical projections.

According to LAROS® data, the vessel for the given period has sailed on the below average speed profiles (figure 51):

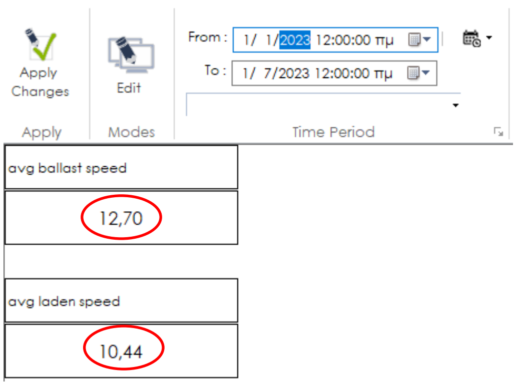



*Figure 51 Average speeds maintained from 1/1/2023 to 1/07/2023*

Spotting the speeds of 12,7 in ballast and 10,44 in laden in our table (circled in red), according to our CII projections table (ideally) this is expected to be approximately 3.02 (table 23).

| Projected CII based on different speed combinations (ballast/laden) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| speed | 10,0 | 10,5 | 11,0 | 11,5 | 12,0 | 12,5 | 13,0 | 13,5 | 14,0 | 14,5 | 15,0 | 15,5 | 16,0 |
| 10,0 | 2,77 | 2,85 | 2,93 | 3,01 | 3,10 | 3,20 | 3,29 | 3,39 | 3,50 | 3,60 | 3,71 | 3,83 | 3,95 |
| 10,5 | 2,80 | 2,88 | 2,96 | 3,05 | 3,14 | 3,23 | 3,32 | 3,42 | 3,53 | 3,64 | 3,75 | 3,86 | 3,98 |
| 11,0 | 2,83 | 2,91 | 2,99 | 3,08 | 3,17 | 3,26 | 3,36 | 3,46 | 3,56 | 3,67 | 3,78 | 3,89 | 4,01 |
| 11,5 | 2,87 | 2,95 | 3,03 | 3,11 | 3,20 | 3,30 | 3,39 | 3,49 | 3,60 | 3,70 | 3,82 | 3,93 | 4,05 |
| 12,0 | 2,91 | 2,98 | 3,07 | 3,15 | 3,24 | 3,33 | 3,43 | 3,53 | 3,63 | 3,74 | 3,85 | 3,97 | 4,08 |
| 12,5 | 2,94 | 3,02 | 3,10 | 3,19 | 3,28 | 3,37 | 3,47 | 3,57 | 3,67 | 3,78 | 3,89 | 4,00 | 4,12 |
| 13,0 | 2,98 | 3,06 | 3,14 | 3,23 | 3,32 | 3,41 | 3,51 | 3,61 | 3,71 | 3,82 | 3,93 | 4,04 | 4,16 |
| 13,5 | 3,02 | 3,10 | 3,18 | 3,27 | 3,36 | 3,45 | 3,55 | 3,65 | 3,75 | 3,86 | 3,97 | 4,08 | 4,20 |
| 14,0 | 3,07 | 3,15 | 3,23 | 3,31 | 3,40 | 3,49 | 3,59 | 3,69 | 3,79 | 3,90 | 4,01 | 4,13 | 4,25 |
| 14,5 | 3,11 | 3,19 | 3,27 | 3,36 | 3,45 | 3,54 | 3,64 | 3,74 | 3,84 | 3,95 | 4,06 | 4,17 | 4,29 |
| 15,0 | 3,16 | 3,23 | 3,32 | 3,40 | 3,49 | 3,58 | 3,68 | 3,78 | 3,88 | 3,99 | 4,10 | 4,22 | 4,34 |
| 15,5 | 3,20 | 3,28 | 3,36 | 3,45 | 3,54 | 3,63 | 3,73 | 3,83 | 3,93 | 4,04 | 4,15 | 4,26 | 4,38 |
| 16,0 | 3,25 | 3,33 | 3,41 | 3,50 | 3,59 | 3,68 | 3,78 | 3,88 | 3,98 | 4,09 | 4,20 | 4,31 | 4,43 |

*Table 23 Projected CII for speeds (avg) 12,7 in ballast and 10,44 in laden*

At the end of the period though, after having sailed 36589 nautical miles in total, the actual CII appears to be slightly different, with a value of 3,29 (figure 52 below) which although different to the expected, still is considered to be normal (a lower value than the expected would definitely mean problematic calculations).

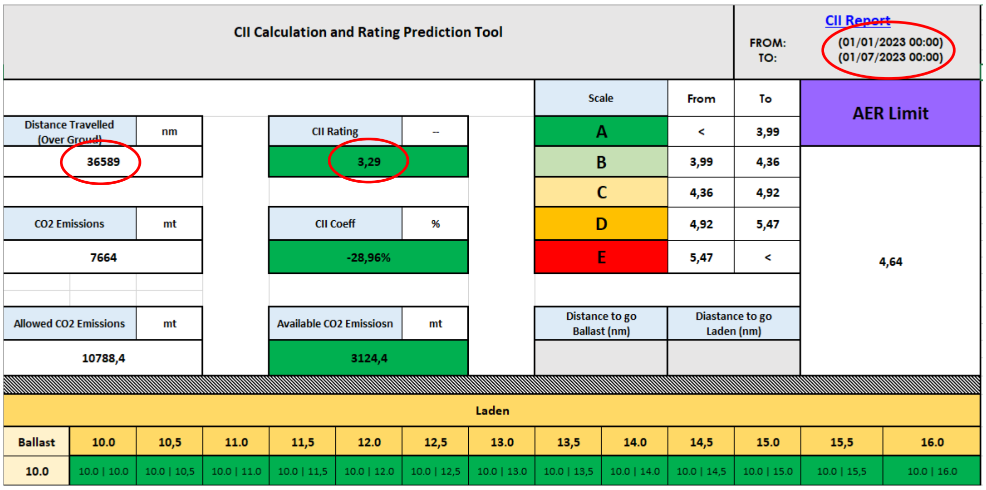



*Figure 52 CII rating for speeds (avg) 12,7 in ballast and 10,44 in laden*

### 5.1.6 POTENTIAL REASONS FOR FORECAST'S DEVIATION

The deviation observed can be attributed to multiple factors, each having different level of impact on our results, including the most obvious, being the "idle days" where the vessel was not underway, as indicated on the data available through LAROS measurements (figure 53 in the next page).

Specifically the vessel has operated on a 75.2% (point 3) underway over her total time of sailing (although this performance commercially-wise could be considered very efficient) but still there is a substantial 15% of time being idle which is seriously affecting our CIIs' deviation. Moreover, LAROS® system cannot automatically detect and differentiate (since such a factor or exemption rule in the formula it is not properly regulated from IMO yet) when the vessel is actually sailing with the minimum cargo (ballast condition). Still, there is fuel consumption even when the vessel is at anchor (idle) which is seriously affecting the CII. This condition, although spotted by LAROS®, does not automatically subtract those emissions corresponding to anchor state. All these factors affecting CII but not currently taken into account when calculating its exact rating, will be evaluated further in chapter 6.1 (CII's critical evaluation).

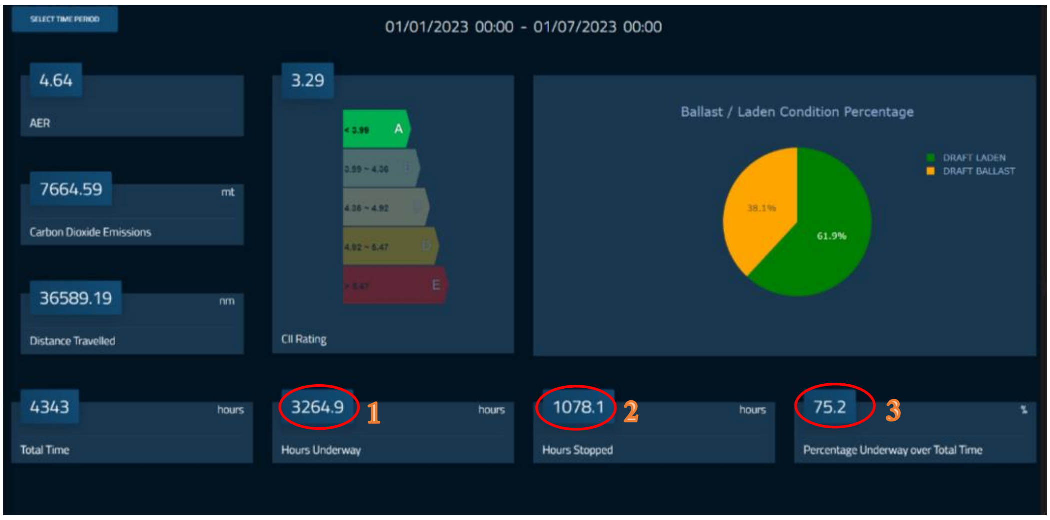



*Figure 53 LAROS® data regarding actual percentage underway*

In our case, apart from the idle time noticed though, there are other distinguished factors that may affect CII and hence the noticed deviation:

Pointedly, the observed higher CII, can be attributed to vessel's aging through time (hull/propeller fouling mainly), adverse weather conditions (speed/power curves inserted into our equations refer to weather up to 4 bf only as previously mentioned) and potential speed fluctuations (speed/ consumption relation is not proportional but cubic proportional). Fortunately, there is plenty of data to assist us further in determining the impact of the above for such deviation.

To begin with, performing a basic statistical analysis for the factors mentioned above, we observe that there are values that seem to be ranging considerably out of the expected limits, often distant from the reference values entered in our model. Specifically, in figure 54, wind speed has an average value of 3.7 (very close to the limit of 4bf) with a standard deviation of 1,33 (point 1). What seems to be surprising though is the maximum value of 9.1bf (point 2). Equally, when looking into the speeds recorded, when compared to the data initially used for our calculations (12,7 and 10,4 for ballast and laden conditions respectively) (point 3 and 4) there seems to be a substantial digression. We observe maximum ballast speed of 16.2 and 14,2 knots (points 5 and 6) while the standard deviation is at 1,3 and 1,2 respectively (points 7 and 8).

| Type | True-Wind-Speed-(Beaufort) (bft) | Speed-Over-Ground-Ballast-Underway (knots) | Speed-Over-Ground-Laden-Underway (knots) |
|---|---|---|---|
| Number of data points | 8665 | 1844 | 4682 |
| Average value | 3,738 | 12,746 | 10,45 |
| Standard deviation | 1,338 | 1,306 | 1,283 |
| Maximum value | 9,1 | 16,277 | 14,252 |
| Minimum value | 0 | 4,856 | 2,989 |
| Value range | 9,1 | 11,421 | 11,263 |

*Figure 54 LAROS® data ranges and deviations recorded*

In order to realize how often these values are appeared in our data sample within the six months period examined, we need to plot the measurements in a time graph. This will allow us to detect these outliers' frequency with their duration in time, in order to better realize the possible effect they have in the final CII rating observed.

Figure 55 below displays all three critical factors compared, in a synchronized (with a common time stamp) manner for the period examined.

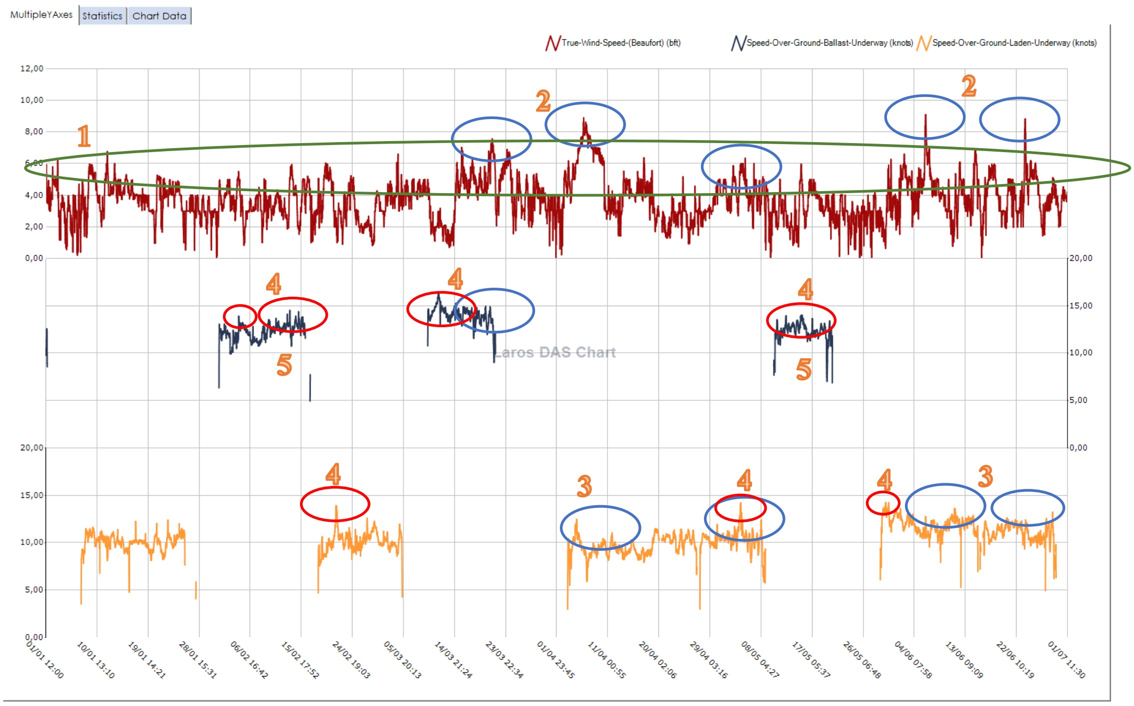



*Figure 55 LAROS® time series of data for identifying outliers and events*

First, we examine the time series available for the weather conditions encountered where wind exceeded 4bf. Seemingly, we can easily observe that almost half of the period (circled in green) (point 1), the vessel is experiencing weather above 4bf. There are also certain obvious peaks in our measurements (circles in blue) (points 2) that weather reaches 8 to 9 bf, occasionally lasting for several days.

If we correlate these exceedances with their related speed in both ballast and laden condition (circles in blue) (points 3) we practically identify potential excessive consumptions that have significant impact to CII's initial estimations.

Certainly, adverse weather conditions such swell, currents and other sea state or meteorological data which are usually available through a weather provider would provide more accurate results however this level of detail (considering the low level of deviation noticed), is considered unnecessary at this stage.

Having spotted the weather conditions and its potential effect in the examined deviation we move on to the excessive speed documented.

In the same figure (55), we may discern multiple occasions where the speed is much higher than the average speed used for identifying the projected CII.

There are speeds close to 15 knots (circled in red) (points 4) that manifest serious aberration to the mean values used in the model (12.7 and 10.4knots) that evidence higher consumption which leads to increased CO2 production. What is more, many of the high-speed incidents identified, have distinguishable duration. Indicatively there are certain points where the vessel was speeding near 15 knots for a period of almost a week (13/03/2023 to 23/03/2023 and from 09/05/2023 to 17/05/2023) (points 5).

In conclusion we realize that the deviation between projected and actual CII noticed, can be considered normal as it can be justified by several factors, some of them identified above. However, since each operator may set different limits for considering the projected vs actual (CII rating) acceptable, further analysis could be conducted for identifying the root cause for such deviations further.

Perhaps, the most important outcome of this analysis is that CII's rating calculation or even forecasting can be quite precise (but not definite), since there are several (some easy to identify while others not) factors that affect it. In the following chapter, an extensive evaluation of the CII regulation is presented, highlighting the factors that although seriously influence it, still they are not currently taken into consideration.

## 6.0 CONCLUSIONS - RECOMMENDATIONS

In the following concluding paragraphs, the outcomes of the study in conjunction with pertinent views of industry's experts are deductively presented. The chapter starts with a critical evaluation of CII regarding its effectiveness and recommendations for its improvement; it then depicts the new status quo between ship owners/operators and charterers and it finally concludes with the author's critical views and recommendations about the future of the regulation in regards to current and forthcoming developments in shipping.

### 6.1 CRITICAL EVALUATION OF CURRENT CII REGULATION

The extensive review on the current literature in combination with the precious feedback gained from the shipping community through the methodical survey and the real data testing (simulation) using the original model developed, have all contributed to shaping a holistic view on the CII operation. The findings of the above methodologies applied, have proved that CII's calculation, monitoring and ultimate optimization, involves much more than simply complying with a mathematical formula. On the contrary, it has been demonstrated that the regulation's monitoring is a much more complex procedure, severely affected by different factors (weather, port traffic, cargo, vessel's condition) as well as various entities (crew, owners/managers, charterers, regulators, terminal ports) with quite often conflicting interests. In final analysis, it has been revealed that a vessel's CII rating is extended far from pure emissions monitoring as it is mostly related to the nautical miles the vessel sails under specific loading conditions, which in fact means that it is seriously affected by the vessel's operational trade patterns. Respectively, it has been demonstrated, that the current CII formula, favors the ships with the best AER, that are operating in ballast or minimum possible cargo carrying condition. Thus, current CII is practically penalizing efficiently carrying cargo ships, while supporting inefficiently utilized empty ships (the opposite to EEOI which is by default penalizing ships operating in ballast condition).

In the bigger picture, we conclude that although AER aims to reduce the carbon intensity of each ship individually, it does not manage to reduce the intensity of each cargo on the same basis, where the focus of efficiency should be on.

Indeed, if EEOI was used instead, the variance in the metric would be much higher provided that EEOI takes into consideration whether a ship is transporting cargo or not. In this case, the carbon intensity of different cargoes would vary dramatically, depending on any ballast legs prior to loading. As a result, owners would be able to improve their performance by focusing on the most optimal cargoes; while on the other hand, they would avoid long ballast legs as this would seriously affect their CII rating.

As Andrea Olivi (2023) head of wet freight at Trafigura underlines, AER is a mathematical expression of the carbon intensity of vessel operations, assuming an employment profile that cannot be influenced. As an effect, if owners were responsible only for the consumption of their ships (on a per nautical mile principle) and had no control or agency over the voyages or ballast legs their vessels perform, then this would be the correct metric to use. However, this is not an expression of the carbon intensity of commercial operations - and by using the AER instead of EEOI, the IMO seems to have removed all incentives for shipowners to optimize laden/ballast ratios.

In the same respect, a more intense criticism has been expressed by Panos Zachariadis, Technical Manager of Atlantic Bulk Carriers and senior advisor of IMO (2022), who claims that CII is too complicated and, in some cases, absurd. Zachariadis, points out that because the regulation is based on AER, it does not reflect the reality in terms of a vessel's performance, as it is seriously affected by exogenous factors such weather or ports delays. This "disconnection", as he characteristically calls it, of the "operational" indexes from the design of the vessel, makes even the operational indexes (AER, EEOI) and even the design (EEDI), deficient and unreliable. Still, Zachariadis concludes, despite these facts, the regulation was finally approved by IMO, without the physical presence of IMO's technical experts and perhaps this is a fact that should not be neglected.

Philippos Philis, President of ECSA and CEO of Cyprus-based bulker company Lemissoler Navigation, highlights that in real life, the measures of AER and EEOI can bring about completely different results (Glass,2023). He uses an example taken from a Lemissoler's ship on which they have noticed that producing the best rating under the AER, has generated the worst one under the EEOI.

From the above, it can be argued that since ballast condition is an integral part of ships' routine operation under any trading scheme, there should be no difference on how this condition is being treated by the regulation. The above statements indicate though, in contrast to the responses collected through our survey (paragraph 4.1.5), that there could be a quite common case that some owners may decide to reduce cargo intake in order to consume less fuel and, therefore, achieve better CII ratings. However, this behavior could put them at risk of being found in breach of their contract obligations (charter party agreement).

Also, the inclusion of FOC when the vessel is not underway in the calculation of the attained CII seems to be problematic, too. With the current regulation (the way is it currently formed), ships are penalized for the time spent at ports although this provisional condition is usually out of their control. As a result, the fact that there are many (well-known) ports with higher traffic than others will most probably force operators to select their voyages distinctively for their future trading. This means that while planning, they will need to take into consideration all possible ports delays in conjunction to traffic handling capabilities of each port, before agreeing/selecting their charter party agreements (CPAs). Equally, this behavior may be followed by a comparable selection of trades for charterers too, who will now negotiate the voyages for assignment under a different scope. Consequently, we realize that both sides, mainly owners operating in the spot market, will need to achieve as much optimized port rotation as possible.

In the same respect, we need to make a reference for the periods of reduced or minimal transporting demand (idling) which unavoidably will lead to oversupply of ships; all those "redundant" ships that remain at ports for prolonged periods of time will be challenged with significant deterioration in their attained CII. Current regulation does not take into account these conditions at all. An amendment to the regulation in regards to the vessels being considerably idle in those recession times could potentially assist owners improve their obligations against CII.

Last but not least, there are those ships that are engaged in short sea shipping also to be considered. These ships, will be practically penalized because of the nature of their trading, as short sea shipping involves pointedly more port calls compared to those who trade in longer (deep sea going) voyages.

This effectively results in a less trading- more waiting condition which will be seriously affected by the current regulation. So, a different categorization or treatment for these vessels by the regulation, would be beneficial and definitely more reasonable in the future.

Without a doubt, vessels not being underway due to anchorage, port congestion or other “nonproductive” state seems to be the main issue at the moment and most probably, this will potentially cause an additional point of friction between charterers and owners unless explicit clauses are in place. The next chapter focuses on the most evident reasons for potential arguments between the two parties and suggests measures that could alleviate any rising conflicts.

## 6.2 THE NEW STATUS QUO

It is common knowledge that the incentives and interests between owners and charterers have traditionally been contradictory, while the first are worrying about sharing too much information during trading thus risking to meet various claims, while charterers on the other side, are usually forced to abide with predefined speed limits and strict deadlines on the delivery time, often reflecting this responsibility back to the owners. This cycle of continuous pressure has arguably not promoted the ideal win-win collaboration as very often one must lose for the other to win and vice versa. By the emergence of the new regulations, especially CII (and EEXI), owners-charterers’ oppositional in nature relationship, is to be tested again, this time under more adverse conditions, since CO2 emissions related to FOC, is a fairly measurable parameter that may set new metrics for performance monitoring and compliance between the two parties.

### *6.1.1 COMMERCIAL, LEGAL AND CONTRACTUAL CHALLENGES*

The new regulations are bringing new commercial, legal and contractual challenges for both sides to consider, that perhaps require for a re-mapping in the way these contractors will continue to cooperate from now and on.

According to a recent article by Mononews.gr (2023) large shipping groups are pressuring companies (charterers) that charter their ships, such as oil majors and freight companies, to cover the losses they will suffer if their ships are downgraded under the new regulations of CII. Major freight groups, on the other hand, oppose efforts to impose legal obligations on charterers. Jan Dieleman, Cargill's president, (Cargill is chartering over 700 ships) points out that shipping industry seeks to apply "something that is black and white (to an issue) that is not black and white" (Mononews.gr, 2023).

Another executive member of a company that charters more than 300 vessels, the same article continues, also has reacted similarly, aiming to exonerate (shipowners) from responsibility, adding that such proposals were "not fit for purpose". There is an explicit claim that shipowners should also be held accountable for ensuring the efficient operation of their ships. It seems that the row over who should pay for shipping emissions is intensifying a long-running struggle which unless they set explicit and official contractual clauses, it won't be terminated any time soon.

As it has been already discussed in the previous chapters, any initial modification to meet with EEXI/CII requirements is likely to fall on the shipowner, as the owner (in fact the ship) is the one practically obliged to comply with MARPOL. This argument is pretty straightforward as it describes owners' predetermined obligations to be followed for ensuring compliance with the regulation which is not expected to be altered regardless the vessel is fully chartered or not. No matter how explicit this fact may appear, it still causes some disproportion in the relationship of the contractors.

In order to better understand the potential points of friction that may arise between the two parties, let's examine some ordinary examples of their routine interaction under the new regulations in the next paragraphs:

### *6.1.2 INDICATIVE EXAMPLES THAT MAY RAISE ARGUMENTS*

To begin with, the most common type of these two parties collaboration is through a common time-charter. Because of the new regulations, owners and charterers will have to examine their options very carefully before signing the charter party agreement (CPA). Especially, shipowners will have to make sure that the agreement does not affect their right to deal with all those technical matters arising due to new requirements for compliance, allowing them to perform any necessary amendment on their vessels (retrofit), such the installation of power limitation technologies or ESDs. This certainly involves the liberty to schedule dry-docking while the vessel is chartered but without any impact on the active charter. Indeed, BIMCO's latest clauses (November 2022) do describe this kind of rights and obligations for both sides, however the actual abiding and application of the clauses remain to be proved.

But this is not the end of the story. The compliance with CII's requirements by the side of the owners is not a one-off process. CII, is continuously being affected throughout the year(s) and despite its "resetting" nature on an annual basis, the vessel on the other side is being deteriorated day by day, following a negative energy performance trend that is constantly demanding maintenance or efficiency improvement efforts. The vessel though, is being practically operated by the charterers and not the owners as they dictate the operational profile, voyages selection and so on. Thus, both sides need to ensure that a sufficient CII rating will "remain" after each voyage or charter party agreement completion, allowing the vessel to be in a "good" state, allowing her to be hired over and over again. If not, it will be the owners who will end up with increased CO2 emissions compliance obligations, literally striving to secure the next charter. In this sense, we may expect the actual vessel's tradability to be a key point for future arguments, provided this (tradability) cannot be proved easily; (perhaps CII presently stands as the only comprehensive index for verifying a vessel's efficiency standing) so possible conflicts while a charter is active will be expected.

In order to make this example more explicit, we may examine a case of reduced speed, versus inconsistent speed and its performance warranties as required by a charter party.

It will not be a surprise if a situation may arise where the vessel has to be operated at a certain speed in order to comply with CII, but in parallel having to face potential underperformance claims from charterers. Every time this happens, there must be a clause in place to protect both sides interests, by defining the speed of the vessel speed depending on certain priority or to be set under explicit approval of the charter, regardless the effect on FOC or CII rating. Of course, charterers will have to reimburse for the potential losses of the ship in such cases. Without a doubt, the key element for this speed/CII rating management is solid transparency during ship's operations.

Similarly, owners ordinarily have the obligation to be sailing and operating the vessels with all due dispatch, no matter the type of the charter agreement. It is for a fact that the way current CII metrics are formulated, the fastest route to a loading or discharging port, is not the most efficient (since FOC has the greatest effect on the index). Hence, owners need to make sure that they are not to be found in any breach of their contractual "ASAP" discharging obligations, while they are merely doing their best to offer their services while at the same time trying to merely comply with the CII requirements. In this respect, for the owners' sake, the charter party clauses need to be extended, including such charterers' provisions in the CPA that will eventually protect them for any losses arising due to potential claimed dispatch breaches.

On the other side, from a charterers' perspective, they will always need to ensure that their orders regarding vessel's speed, in spite of this being low or high, are lawful and legitimate, not causing any further consequences; or else they will have to accept the risk of having to compensate up to the agreed rate of hire for a vessel that has become less commercially efficient, in terms of CII rating, thus is lowering her potential earnings.

Also, a quite significant point to mention is the potential deterioration of the vessel because of slower speeds (slow steaming) or engine power limitation which may cause another debate between the two parties. There is a series of reported effects on any vessel that is operating on slow speed (running the M/E below normal operating range of 70 to 85% MCR). As C/E Sanguri (2019) points out in a Marine Insight report, the turbocharger is selected for the normal running load range of 70 to 85 %. Low load operations of the main engine lead to lower running RPM of the turbocharger and less generation of scavenge air.

This leads to ineffective and incomplete combustion, increased fouling and also makes the cleaning measures like dry grit cleaning of the turbine ineffective. Other identified issues resulting from slow speeds regard the waste heat recovery, fuel injectors and fuel pumps, SFOC optimization, propeller's efficiency, shaft generators deterioration, fouling and contamination of tubes and others (Sanguri, 2019). Thus there is a serious impact on the vessel because of slow speeds that will definitely lead to increased costs of maintenance. At this very moment, there is no any provision on how these damages will be reimbursed or who should be liable for them. Perhaps this is because it is quite early since the regulation is less than a year mature, but as time goes by and more data on the actual deterioration come up, this will incur more discussions very shortly. Undoubtedly, from a technical perspective, it will be very difficult to define the actual level of such deterioration because of slow speeds operations, and most probably an extensive research on the matter should be performed before applying any factors or other method for calculating the monetary value of the damages.

Another instance to consider is the case (while on a voyage charter) that the owner is potentially pursuing  the demurrage agreed in the CPA, by intentionally sailing as fast as possible towards the port (especially when there is reported congestion) in order to claim demurrage once the vessel arrives and then waits at anchorage. Of course, in this case, the owner will come across with increased costs due to high speed applied (provided that the owner is in charge of the fuel) and as consequence, increased CO2 emissions which cannot be reimbursed later (this would depend on the nature of the CPA). This leads us to the conclusion that because of CII, a possible reconsideration of the existing demurrage models under voyage charters may be essential, in order to secure all contractual parties' interests.

Finally, we need to identify and analyze further the option of reducing cargo intake, in contrast to the general reluctancy witnessed through our survey for such behavior. Again, such practice could put owners at risk of being found in breach of their obligations under the charter party; for example in case owners are "tightened" through a cargo total capacity warranty. In this respect, we take it for granted that most owners will demand to have the final saying when it comes to the volume of cargo to be loaded but this definitely opposes to charterers' will, who as practice dictates, do not usually accept any compromise when it comes to sign the contract, as they know that less capacity is translated into more itineraries for the same amount of goods delivery.

So again, a reconsideration on the existing clauses may be required for securing that no further debates arise when negotiating the cargo intakes.

In relation to the points identified from the above instances, Tang et al. (2021) identify the challenges and obligations for both, owners and charterers:

a) For EEXI, owners are primarily responsible for ensuring a vessel's compliance with MARPOL (assuming its flag state is a MARPOL contracting nation). The terms of most charter parties will say, or at least imply, that technical modifications required to comply with industry regulations lie with owners as part and parcel of their seaworthiness obligations.

b) For CII, owners of time-chartered vessels must comply with charterers' lawful employment orders. However, these orders could affect the vessel's CII rating, which owners must still comply with. Also, decisions by owners to slow steam, reduce cargo-carrying capacity or deviate to maintain their CII rating could put them in breach of charter, and potentially liable in damages.

c) Disputes under spot fixtures could arise if owners take operational measures to maintain a CII rating which result in, for example, delays to the voyage.

   Again, this could put them at risk of breaching their obligations to proceed with due or utmost dispatch.

In this exact respect, BIMCO's recent clauses recently voted, (November 2022) are pushing the parties to "force" cooperation before invoking any "penalties" for default. It remains to be seen if BIMCO's clauses are sufficient for the moment or further clauses need to be initiated for both sides.

### *6.1.3 THE NEED FOR EXPLICIT CLAUSES FROM BOTH SIDES*

As it can be concluded from previous paragraph's points, in order to avoid possible disputes, both owners and charterers need to carefully consider multiple contractual obligations in advance. The initiation or modification of current clauses cannot be one-sided as there are conflicting interests that need to be harmonized for a sustainable future collaboration.

A related article on the matter cited in Naftika Chronika (2022), mentions that the task to define appropriate charter clauses is now very difficult since EEXI and CII have made the commercial management very important. According to the same source, the actual evaluation of a ship weighs on the ship itself and, by extension, on its owner. Based on this, it is important that charterers realize the responsibility they bring to the CII rating of a ship since they act as its commercial managers in many cases.

Interestingly, Panos Zachariadis, Atlantic Bulk Carriers Technical Manager, (2022) makes a clear discrimination between the two regulations and the clauses identified as he believes they should not be treated equally. Zachiariadis states that ship owners are in charge of EEXI (even of ETS) regulation compliance since this is a technical measure, by performing a prior study for vessels' limit where the power will need to be cut off and also to install the equipment that will not allow the power to exceed this limit. However, when it comes to CII, the situation is different. CII, as Zachariadis continues, is an operational measure, which is addressed to the operator/charterer of the ship. But charterers are not used to be meeting IMO regulations. It is therefore the first time that charterers are required to comply with a regulation that is primarily addressed and concerns them. Therefore, the references and obligations in the BIMCO clause are primarily addressed to the charterer, who initially perceived them as discriminatory.

Indeed, BIMCO Documentary Committee (2022) recently adopted the CII Operations Clause for Time Charter Parties (Chambers, 2022), which assumes that a time charterer should take responsibility for a ship's emissions because the charterer makes the relevant decisions on the operation of the ship. Moreover, BIMCO explained further in a release that when entering into the charter party, or incorporating the clause into an existing charter party, the parties are to agree on a specific CII to be achieved each year.

BIMCO, also took the initiative to clarify many points where potential misunderstandings started to arise such as the guarantees of the original charter agreement regarding the guaranteed speed and consumption of the ship and the obligations of the shipowner for proper maintenance of the ship and so on.

In relation to this, we should expect to see the rapid emergence of template clauses (including BIMCO's) for use in time and voyage charter parties.

These standard provisions should cover the key points and deal with the allocation of risk and cost between owners and charterers.

To sum up, it is apparent that the industry will have to meet more regulations from the IMO (and the EU or other regions/bodies) aimed at reducing shipping's CO2 emissions in the near future, consequently the need for new contracts and clauses is expected to be increased. Both parties will certainly have to make some compromises but most importantly they need to communicate towards a better cooperation that will respect their common interests. CII, despite its absolute nature in terms of reporting requirements, may be the perfect opportunity for bringing contractors at the same place to jointly set common goals and plan the next steps ahead. If not, the damage will unquestionably affect both parties and this will make their currently oppositional relationship, worse.

### 6.3 EPILOGUE - THE WAY FORWARD

In closing, despite the points for argument, identified insufficiencies and the potential uncertainty that surrounds the CII regulation, the latter is finally "up and running". Ready or not, all candidate vessels will have to report their performance by the end of year (2023) and depending on their rating, possible further action will be required for the ships to stay competitive for future hires. However there are some conclusive points worth mentioning that can accelerate or improve both the effect of the regulations and the ultimate success of the net zero carbon shipping strategy.

To begin with, CII regulation itself needs to be revised to become more reasonable and fairer for all affected parties as in its current form, does not actually serve the cause for which it has been initiated, at least by its "definition". Unless the CO2 emission levels is the only attribute under examination, regardless the actual (transport) work being carried, the current formula has to be redefined or else the criticism over its application will most probably be continued.

Currently, CII is practically penalizing the efficiently carrying ships and this may have significant repercussions not only on owners-charterers relationship but on the entire world trade, too. Using EEOI instead of AER or a better formulated combination of the two, could be a good start.

Moreover, the actual state of the vessel in relation to the weather and other conditional factors in combination with the nature of vessel's trade should be also considered while calculating the CO2 emissions. Otherwise, owners and operators are expected to do their best in "manipulating" the regulation every time this is feasible, putting their interests over what is best for the environment.

In this regard, the regulation should do what is possible to incentivize operators to undertake the most efficient (in respect to shipping's ecosystem not just the CII's metric) voyages discouraging them to be selecting those that will end up with the lowest CII rating; and this attitude could be significantly ignited by relative amendments on the metric.

However, the way forward should not be focusing on CII rating only or how to effectively comply with it, but it should look at a greater perspective on how to reduce emissions overall. In relation to future initiatives to be taken, there seems to be a relative consensus that alternative carbon neutral fuels will be the predominate strategy that will lead faster to the desired decarbonization path. As already discussed in this study, in spite of the fact the industry has not concluded on the ideal fuel for the future (yet), we still witness a serious fuel use transition in 2023, with half the ordered tonnage capable of using LNG, LPG, or methanol in dual-fuel engines, compared to one third of the tonnage on orders of the previous year (DNV, 2023).

Now it is the industry' turn to demonstrate commitment, by investing in producing efficient and abundant supply of renewable fuels. In parallel, there needs to be immediate identification of key ports and instant planning for global infrastructure development, able to serve the global network of shipping trade. Obviously, such a venture will demand the collaboration of various stakeholders including fuel producers, bunkering companies, port authorities and others, so it is expected to take some considerable time before we practically witness this supply chain to be fully operational. Strategic partnerships may be the only way forward into this direction, as any future fuel supply investments, require collective decisions and efforts.

In the meantime, as we will start to be efficiently observing through EU ETS from 2024 onwards, a realistic carbon levy should be established for each fuel. This practice would definitely favor the renewable energy fuels, by limiting at the same time any future investments in fossil fuels.

Certainly, the upcoming EU ETS is expected to be a real game changer, as the shipping industry will be required to shift from just monitoring and correcting, to be actually paying for the $CO_2$ Emissions of the ships. EU ETS is an emission cap-and-trade system where only a limited amount of emission allowances – the cap – is to be available in the market and this can also be traded. This novel regulatory scheme, which has already been very successful in the industry of the aviation and others, will practically price the emissions, compelling shipping companies or ship operators to be more conservative when negotiating their next charters, as they will be enforced to budget the pollutants contributed to EU ETS.

From a technological perspective, proven innovative technologies and ESDs, are increasingly important and they should be adopted on a much larger scale. According to a latest report (Marine Forecast 2050) by DNV (2023), at this moment, there are only 28 installed wind assisted propulsion systems onboard large vessels while air lubrication systems are installed or ordered for more than 250 vessels in total. This number needs to be seriously increased, not only for these two technologies but for all those that evidently manage to improve a vessel's flotation under lower fuel consumption, no matter the fuel. Regulating some of these technologies as "standard equipment" for all future new build vessels would most probably be a very good practice to begin with.

Similarly, we have seen that carbon capture and storage (CCS) systems are currently not accounted for CII's rating (or against any other IMO's regulation). This should be amended very shortly as the technology for completing this process is mature and sufficiently proved for its results. Certainly, this adoption needs to be accompanied by the appropriate land infrastructure for the purposes of unloading the $CO_2$ captured, but considering the significance of the GHG targets and the increasing pressures for achieving it, establishing such installations in a short period of time should not be a problem for the industry to handle.

Also, reliable high frequency data captured directly from the vessels' sensors must be a mandate for any vessel that needs to be monitoring and reporting its emissions. The regulation is too sensitive to tolerate human errors or data with high uncertainty, currently available in traditional noon reports.

In this respect, the regulators need to establish a suitable standard required for all data collection systems or define the method to be applied for installing such, by setting the minimum requirements for their certification and then enforce the adoption of such systems onboard any accountable vessel. What is more, these systems could be directly connected to ports' databases, by automatically sharing all environmental data before allowing the vessels entering the ports. This would enhance the communication among all involved parties providing the necessary transparency that is currently missing.

In regards to collaboration and transparency, CII has opened a new chapter in the relationship between shipowners and charterers. Key element for the continuation of future successful transactions between them is the absolute transparent cooperation with as much honesty possible. Both sides need to focus and equally try on complying with all legislation and regulations, both at the IMO and regional levels.

Definitely, this collective effort comes with significant costs that cannot be absorbed by ship owners (or even charterers) only. In fact, we should not expect this to happen, at least not visibly enough, as practice shows us a cost rollover. Most likely, if no specific measures (clauses) are set in place, the new contractual arrangements to be made, will practically allocate all related costs all over the value chain, reaching the extent of the end consumer. So, there must be a fair distribution on costs based not only on who owns but also on who dictates, operates and even selects the vessel.

At last, perhaps the ultimate challenge in a net zero carbon future is the optimum convergence and harmonization of any regional with international regulations. Without a doubt, the energy transition of shipping must be perceived as a global matter which needs international framework of regulations to be adapted to the characteristics of the sector in order to finally create resources for clean fuels and new technologies. The existing situation where different regions are trying to impose their individual rules cannot be for much longer as it creates imbalance and unfairness in the global market. Ship owners should focus only on how to be efficient in a unified and fair context rather worrying about how to comply, from a regional regulation to the next. In this sense, perhaps the introduction of a universal levy, would be decisive.

Besides, if this practice is implemented, it will not only result in an immediate reduction of carbon emissions, but it will also have an impact on fuel savings and thus increase monetary revenue for all parties involved.

In conclusion, the goal of decarbonization is not a single entity's task; on the contrary it is affected by multiple parameters where different stakeholders need to act in an absolute coordinated manner, operating like a perfectly tuned machine. Regulators, organizations, ship owners and operators, charterers, port authorities, renewable energy and alternative fuel developers as well as governments and authorities, they all need to jointly contribute to strategy's milestones. Unfortunately, it seems that at the moment, regulations and relevant policies are the only key drivers for decarbonization while shipowners are asked to be navigating in rather "uncharted waters", as they are currently being offered many but quite uncertain options for compliance.

As this study has indicated, this decade will most likely be critical for setting the whole shipping industry on course for the target net zero CO2 emissions, no matter how realistic these goals may be. Timing is a key factor here, as the industry is challenged to promptly balance the short and long-term objectives, primarily accomplishing fast CO2 emissions reduction from the existing fleet, while moving toward more substantial emissions objectives in the (not too) long-term future.

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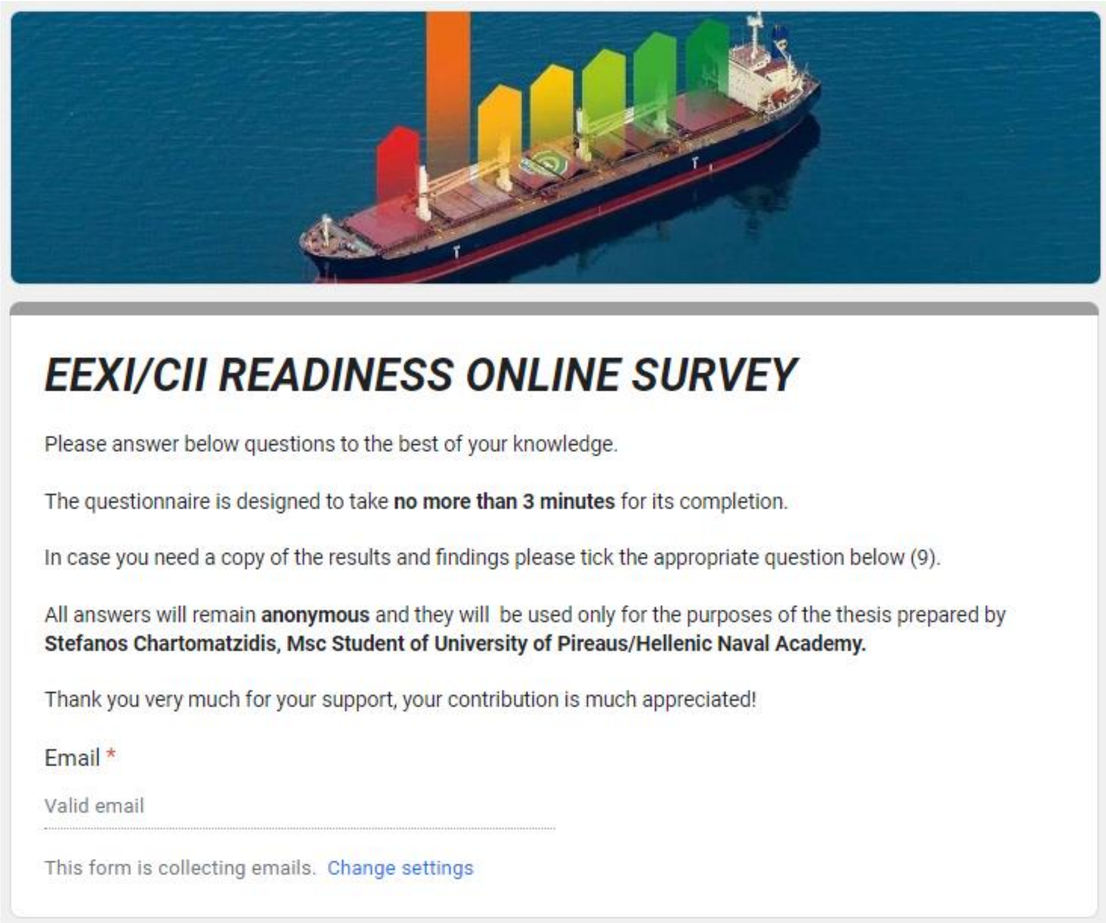
# 8.0 APPENDIX

## 8.1 ONLINE QUESTIONNAIRE TEMPLATE AND RESPONSES



**EEXI/CII READINESS ONLINE SURVEY**

Please answer below questions to the best of your knowledge.

The questionnaire is designed to take **no more than 3 minutes** for its completion.

In case you need a copy of the results and findings please tick the appropriate question below (9).

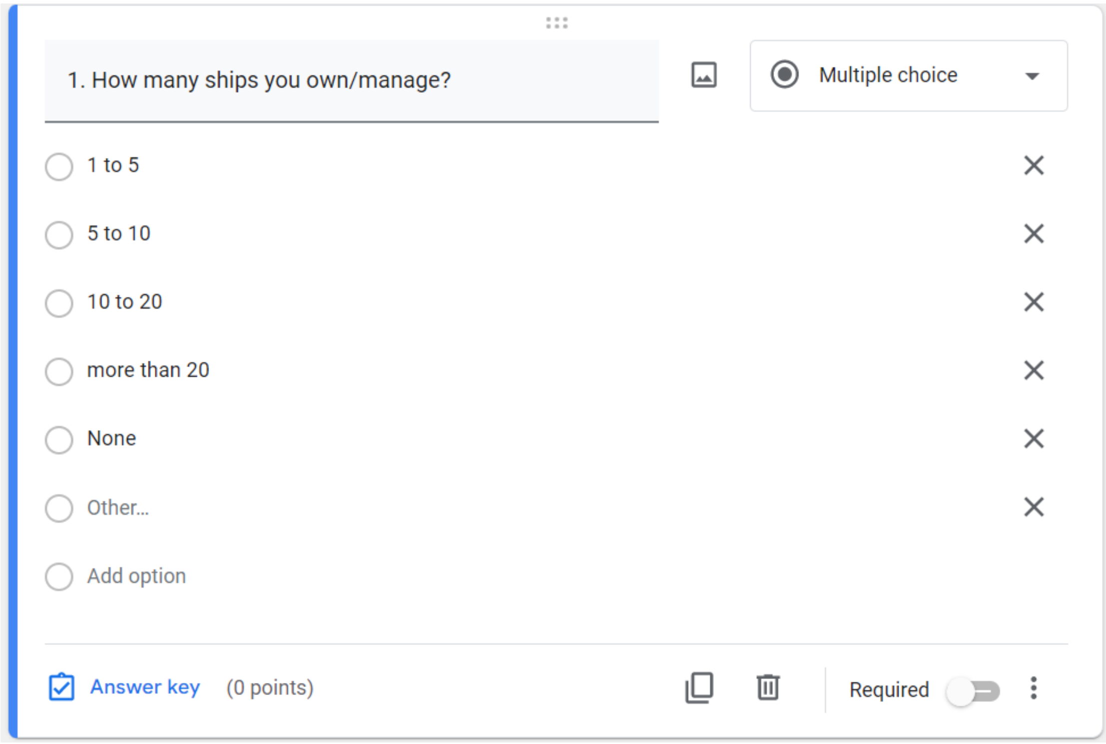
All answers will remain **anonymous** and they will be used only for the purposes of the thesis prepared by **Stefanos Chartomatzidis, Msc Student of University of Pireaus/Hellenic Naval Academy.**

Thank you very much for your support, your contribution is much appreciated!

Email *

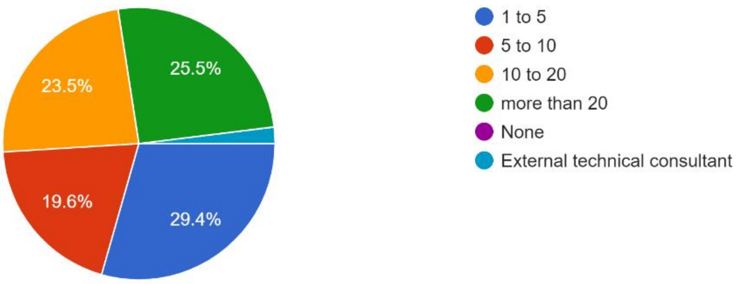
Valid email

This form is collecting emails. Change settings




1. How many ships you own/manage?

51 responses

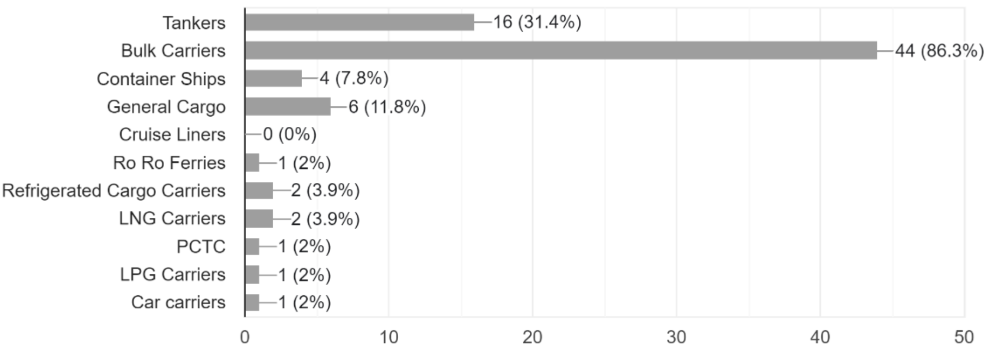


2. What kind of ships you own/manage/operate? (Multiple Selection)

- [ ] Tankers
- [ ] Bulk Carriers
- [ ] Container Ships
- [ ] General Cargo
- [ ] Cruise Liners
- [ ] Ro Ro Ferries
- [ ] Refrigerated Cargo Carriers
- [ ] LNG Carriers
- [ ] Other...

2. What kind of ships you own/manage/operate? (Multiple Selection)

51 responses



3. What is the average age of your ships?

- ◯ 1 to 3 years old
- ◯ 4 to 6 years old
- ◯ 6 to 10 years old
- ◯ 10 to 15 years old
- ◯ 15 to 20 years old
- ◯ more than 20 years old
- ◯ A wide range of age from New Builds to old (more than 20 years old)
- ◯ Other...

3. What is the average age of your ships?

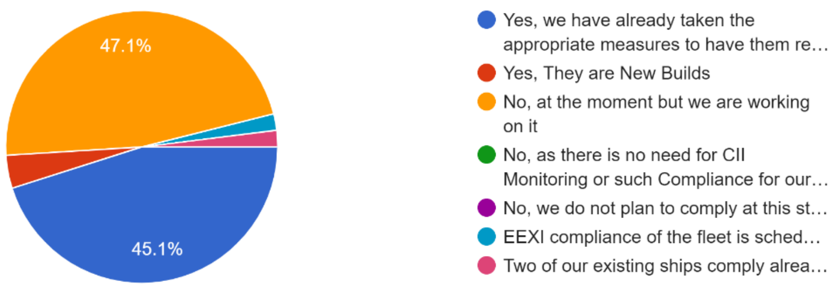
51 responses

4. Are your ships (fleet) EEXI/CII Ready for the 1st of January 2023?

- Yes, we have already taken the appropriate measures to have them ready
- Yes, They are New Builds
- No, at the moment but we are working on it
- No, as there is no need for CII Monitoring or such Compliance for our ships
- No, we do not plan to comply at this stage
- Other...

4. Are your ships (fleet) EEXI/CII Ready for the 1st of January 2023?

51 responses

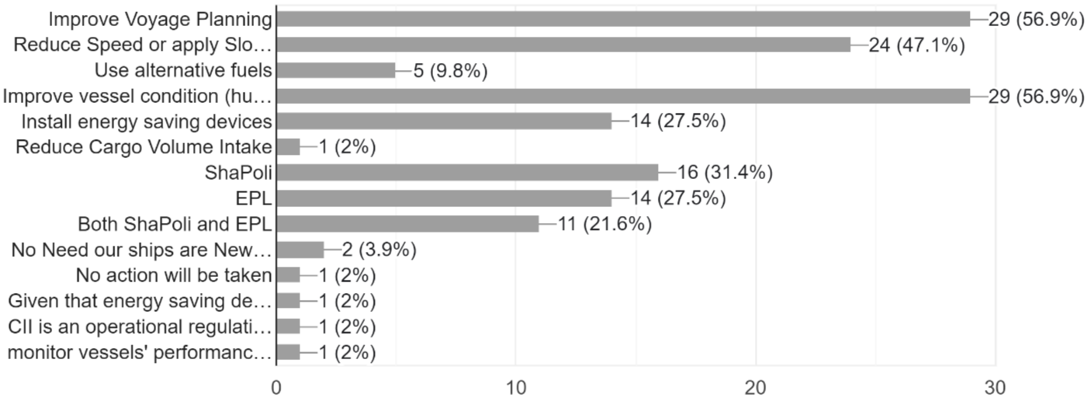


5. What is the strategy you aim to follow in order to cope with CII regulation? (Multiple selection) *


- [ ] Improve Voyage Planning
- [ ] Reduce Speed or apply Slow Steaming
- [ ] Use alternative fuels
- [ ] Improve vessel condition (hull/propeller cleaning)
- [ ] Install energy saving devices
- [ ] Reduce Cargo Volume Intake
- [ ] ShaPoli
- [ ] EPL
- [ ] Both ShaPoli and EPL
- [ ] No Need our ships are New Builds
- [ ] No action will be taken
- [ ] Other...

5. What is the strategy you aim to follow in order to cope with CII regulation? (Multiple selection)

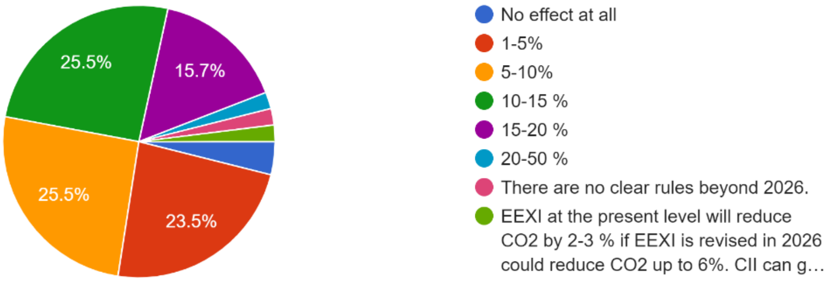
51 responses




6. What in your opinion will be the effect of EEXI/CII regulation in decreasing CO2 emissions by 2030?


- No effect at all
- 1-5%
- 5-10%
- 10-15 %
- 15-20 %
- 20-50 %
- Other...

6. What in your opinion will be the effect of EEXI/CII regulation in decreasing CO2 emissions by 2030?
51 responses




7. What would you consider a "reasonable" and affordable cost (per vessel) for implementing an EEXI/CII compliance? (fixed cost or as percentage selections apply)

- less than $5K
- $5K to $15K
- $15K to $50K
- $50 to $100K
- $100 and more
- as a percentage of the current value of the vessel (please state percentage on "other" button below)
- Other...

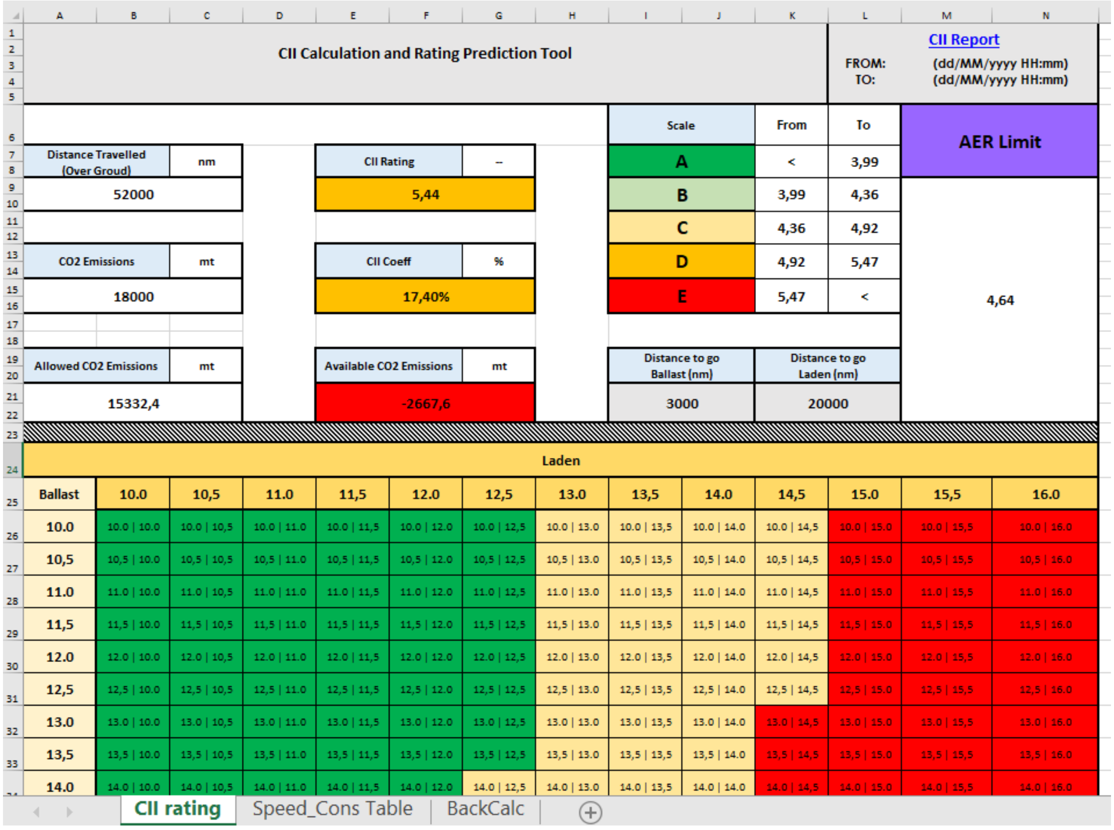
7. What would you consider a "reasonable" and affordable cost (per vessel) for implementing an EEXI/CII compliance? (fixed cost or as percentage selections apply)

51 responses


8. In what sense do you believe the upcoming EEXI/CII Regulations is affecting your organization? (Multiple Selection)

- [ ] Further Investment in Energy Efficiency (people and resources) department is required
- [ ] Further Investment in New Technologies (e.g. Condition Monitoring, Torque Meters, Mass Flow Meters et...
- [ ] Replacing old fleet with new one seems to be the only way forward
- [ ] No real change is taking place at the moment
- [ ] Other...

# 8.2 CII's CALCULATION AND FORECASTING MODEL INDICATIVE SCREENSHOTS



CII Calculation and Rating Prediction Tool

CII Report

FROM: (dd/MM/yyyy HH:mm)
TO: (dd/MM/yyyy HH:mm)

| Distance Travelled (Over Groud) | nm | CII Rating | -- | Scale | From | To | AER Limit |
|---|---|---|---|---|---|---|---|
| 52000 | | 5,44 | | A | < | 3,99 | |
| | | | | B | 3,99 | 4,36 | |
| CO2 Emissions | mt | CII Coeff | % | C | 4,36 | 4,92 | |
| 18000 | | 17,40% | | D | 4,92 | 5,47 | |
| | | | | E | 5,47 | < | 4,64 |
| Allowed CO2 Emissions | mt | Available CO2 Emissions | mt | Distance to go Ballast (nm) | Distance to go Laden (nm) | | |
| 15332,4 | | -2667,6 | | 3000 | 20000 | | |

| Ballast \ Laden | 10.0 | 10,5 | 11.0 | 11,5 | 12.0 | 12,5 | 13.0 | 13,5 | 14.0 | 14,5 | 15.0 | 15,5 | 16.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10.0 | 10.0 \| 10.0 | 10.0 \| 10,5 | 10.0 \| 11.0 | 10.0 \| 11,5 | 10.0 \| 12.0 | 10.0 \| 12,5 | 10.0 \| 13.0 | 10.0 \| 13,5 | 10.0 \| 14.0 | 10.0 \| 14,5 | 10.0 \| 15.0 | 10.0 \| 15,5 | 10.0 \| 16.0 |
| 10,5 | 10,5 \| 10.0 | 10,5 \| 10,5 | 10,5 \| 11.0 | 10,5 \| 11,5 | 10,5 \| 12.0 | 10,5 \| 12,5 | 10,5 \| 13.0 | 10,5 \| 13,5 | 10,5 \| 14.0 | 10,5 \| 14,5 | 10,5 \| 15.0 | 10,5 \| 15,5 | 10,5 \| 16.0 |
| 11.0 | 11.0 \| 10.0 | 11.0 \| 10,5 | 11.0 \| 11.0 | 11.0 \| 11,5 | 11.0 \| 12.0 | 11.0 \| 12,5 | 11.0 \| 13.0 | 11.0 \| 13,5 | 11.0 \| 14.0 | 11.0 \| 14,5 | 11.0 \| 15.0 | 11.0 \| 15,5 | 11.0 \| 16.0 |
| 11,5 | 11,5 \| 10.0 | 11,5 \| 10,5 | 11,5 \| 11.0 | 11,5 \| 11,5 | 11,5 \| 12.0 | 11,5 \| 12,5 | 11,5 \| 13.0 | 11,5 \| 13,5 | 11,5 \| 14.0 | 11,5 \| 14,5 | 11,5 \| 15.0 | 11,5 \| 15,5 | 11,5 \| 16.0 |
| 12.0 | 12.0 \| 10.0 | 12.0 \| 10,5 | 12.0 \| 11.0 | 12.0 \| 11,5 | 12.0 \| 12.0 | 12.0 \| 12,5 | 12.0 \| 13.0 | 12.0 \| 13,5 | 12.0 \| 14.0 | 12.0 \| 14,5 | 12.0 \| 15.0 | 12.0 \| 15,5 | 12.0 \| 16.0 |
| 12,5 | 12,5 \| 10.0 | 12,5 \| 10,5 | 12,5 \| 11.0 | 12,5 \| 11,5 | 12,5 \| 12.0 | 12,5 \| 12,5 | 12,5 \| 13.0 | 12,5 \| 13,5 | 12,5 \| 14.0 | 12,5 \| 14,5 | 12,5 \| 15.0 | 12,5 \| 15,5 | 12,5 \| 16.0 |
| 13.0 | 13.0 \| 10.0 | 13.0 \| 10,5 | 13.0 \| 11.0 | 13.0 \| 11,5 | 13.0 \| 12.0 | 13.0 \| 12,5 | 13.0 \| 13.0 | 13.0 \| 13,5 | 13.0 \| 14.0 | 13.0 \| 14,5 | 13.0 \| 15.0 | 13.0 \| 15,5 | 13.0 \| 16.0 |
| 13,5 | 13,5 \| 10.0 | 13,5 \| 10,5 | 13,5 \| 11.0 | 13,5 \| 11,5 | 13,5 \| 12.0 | 13,5 \| 12,5 | 13,5 \| 13.0 | 13,5 \| 13,5 | 13,5 \| 14.0 | 13,5 \| 14,5 | 13,5 \| 15.0 | 13,5 \| 15,5 | 13,5 \| 16.0 |
| 14.0 | 14.0 \| 10.0 | 14.0 \| 10,5 | 14.0 \| 11.0 | 14.0 \| 11,5 | 14.0 \| 12.0 | 14.0 \| 12,5 | 14.0 \| 13.0 | 14.0 \| 13,5 | 14.0 \| 14.0 | 14.0 \| 14,5 | 14.0 \| 15.0 | 14.0 \| 15,5 | 14.0 \| 16.0 |

CII rating | Speed_Cons Table | BackCalc

*Figure 56 CII Rating Tab Illustration*

| Varialbe | user or auto data input | details |
|---|---|---|
| DWT | 63576 | fixed |
| AER Limit | 4,637775821 | fixed |
| Separator | \| | |
| Distance Travelled | 52000 | nm |
| CO2 Emissions | 18000 | tn |
| CII Rating | 5,444690894 | |
| Allowed CO2 | 15332,36072 | Required/equals to AER |
| Available CO2 | -2667,639283 | Remaining to be emitted from required |
| CII Percentage | 17% | (Deviation from Theoritical) |
| Dist. Ballast | 3000 | user defined |
| Dist.Laden | 20000 | user defined |
| Total Dist | 52000 | |
| CO2 Coeff. | | |
| MGO | 3,206 | factors |
| LSFO | 3,151 | factors |
| HFO | 3,114 | factors |
| Speed/Consumption in tn per day | | |
| Speed | Ballast | Laden |
| 10,0 | 8,5 | 10,0 |
| 10,5 | 9,8 | 11,6 |
| 11,0 | 11,3 | 13,3 |
| 11,5 | 12,9 | 15,2 |
| 12,0 | 14,6 | 17,2 |
| 12,5 | 16,5 | 19,4 |
| 13,0 | 18,5 | 21,8 |
| 13,5 | 20,7 | 24,4 |
| 14,0 | 23,0 | 27,2 |
| 14,5 | 25,5 | 30,1 |
| 15,0 | 28,2 | 33,3 |
| 15,5 | 31,1 | 36,7 |
| 16,0 | 34,1 | 40,3 |

CII rating | Speed_Cons Table | BackCalc

*Figure 57 BackCalculations Tab information*

| E | F | G | H | I | J | K | L | M | N | O | P | Q | R |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Projected CII based on different speeds combinations (ballast/laden)** | | | | | | | | | | | | | |
| speed | 10,0 | 10,5 | 11,0 | 11,5 | 12,0 | 12,5 | 13,0 | 13,5 | 14,0 | 14,5 | 15,0 | 15,5 | 16,0 |
| 10,0 | 4,41 | 4,47 | 4,52 | 4,59 | 4,65 | 4,72 | 4,79 | 4,86 | 4,93 | 5,01 | 5,09 | 5,17 | 5,26 |
| 10,5 | 4,42 | 4,47 | 4,53 | 4,59 | 4,66 | 4,72 | 4,79 | 4,87 | 4,94 | 5,02 | 5,10 | 5,18 | 5,27 |
| 11,0 | 4,42 | 4,48 | 4,54 | 4,60 | 4,67 | 4,73 | 4,80 | 4,87 | 4,95 | 5,03 | 5,11 | 5,19 | 5,27 |
| 11,5 | 4,43 | 4,49 | 4,55 | 4,61 | 4,67 | 4,74 | 4,81 | 4,88 | 4,96 | 5,03 | 5,11 | 5,20 | 5,28 |
| 12,0 | 4,44 | 4,50 | 4,56 | 4,62 | 4,68 | 4,75 | 4,82 | 4,89 | 4,96 | 5,04 | 5,12 | 5,20 | 5,29 |
| 12,5 | 4,45 | 4,50 | 4,56 | 4,63 | 4,69 | 4,76 | 4,83 | 4,90 | 4,97 | 5,05 | 5,13 | 5,21 | 5,30 |
| 13,0 | 4,46 | 4,51 | 4,57 | 4,63 | 4,70 | 4,77 | 4,83 | 4,91 | 4,98 | 5,06 | 5,14 | 5,22 | 5,31 |
| 13,5 | 4,47 | 4,52 | 4,58 | 4,64 | 4,71 | 4,77 | 4,84 | 4,92 | 4,99 | 5,07 | 5,15 | 5,23 | 5,32 |
| 14,0 | 4,48 | 4,53 | 4,59 | 4,65 | 4,72 | 4,78 | 4,85 | 4,93 | 5,00 | 5,08 | 5,16 | 5,24 | 5,33 |
| 14,5 | 4,49 | 4,54 | 4,60 | 4,66 | 4,73 | 4,79 | 4,86 | 4,94 | 5,01 | 5,09 | 5,17 | 5,25 | 5,34 |
| 15,0 | 4,50 | 4,55 | 4,61 | 4,67 | 4,74 | 4,80 | 4,87 | 4,95 | 5,02 | 5,10 | 5,18 | 5,26 | 5,35 |
| 15,5 | 4,51 | 4,56 | 4,62 | 4,68 | 4,75 | 4,81 | 4,88 | 4,96 | 5,03 | 5,11 | 5,19 | 5,27 | 5,36 |
| 16,0 | 4,52 | 4,57 | 4,63 | 4,69 | 4,76 | 4,83 | 4,89 | 4,97 | 5,04 | 5,12 | 5,20 | 5,28 | 5,37 |
| **CII's Deviation from the Required CII (mean of C Rating) in %** | | | | | | | | | | | | | |
| speed | 10,0 | 10,5 | 11,0 | 11,5 | 12,0 | 12,5 | 13,0 | 13,5 | 14,0 | 14,5 | 15,0 | 15,5 | 16,0 |
| 10,0 | -4,93 | -3,72 | -2,44 | -1,11 | 0,27 | 1,72 | 3,22 | 4,77 | 6,39 | 8,05 | 9,78 | 11,56 | 13,40 |
| 10,5 | -4,78 | -3,56 | -2,29 | -0,96 | 0,43 | 1,87 | 3,37 | 4,93 | 6,54 | 8,21 | 9,93 | 11,71 | 13,55 |
| 11,0 | -4,62 | -3,40 | -2,13 | -0,80 | 0,59 | 2,03 | 3,53 | 5,09 | 6,70 | 8,37 | 10,09 | 11,88 | 13,71 |
| 11,5 | -4,45 | -3,23 | -1,96 | -0,63 | 0,76 | 2,20 | 3,70 | 5,26 | 6,87 | 8,54 | 10,26 | 12,04 | 13,88 |
| 12,0 | -4,27 | -3,05 | -1,78 | -0,45 | 0,94 | 2,38 | 3,88 | 5,43 | 7,05 | 8,72 | 10,44 | 12,22 | 14,06 |
| 12,5 | -4,09 | -2,87 | -1,60 | -0,27 | 1,12 | 2,56 | 4,06 | 5,62 | 7,23 | 8,90 | 10,62 | 12,40 | 14,24 |
| 13,0 | -3,90 | -2,68 | -1,41 | -0,08 | 1,31 | 2,75 | 4,25 | 5,81 | 7,42 | 9,09 | 10,81 | 12,59 | 14,43 |
| 13,5 | -3,70 | -2,48 | -1,21 | 0,12 | 1,51 | 2,95 | 4,45 | 6,01 | 7,62 | 9,29 | 11,01 | 12,79 | 14,63 |
| 14,0 | -3,50 | -2,28 | -1,01 | 0,32 | 1,71 | 3,15 | 4,65 | 6,21 | 7,82 | 9,49 | 11,22 | 13,00 | 14,83 |
| 14,5 | -3,28 | -2,07 | -0,79 | 0,54 | 1,92 | 3,37 | 4,87 | 6,42 | 8,03 | 9,70 | 11,43 | 13,21 | 15,04 |
| 15,0 | -3,06 | -1,85 | -0,58 | 0,76 | 2,14 | 3,58 | 5,08 | 6,64 | 8,25 | 9,92 | 11,65 | 13,43 | 15,26 |
| 15,5 | -2,84 | -1,62 | -0,35 | 0,98 | 2,37 | 3,81 | 5,31 | 6,87 | 8,48 | 10,15 | 11,87 | 13,65 | 15,49 |
| 16,0 | -2,61 | -1,39 | -0,12 | 1,21 | 2,60 | 4,04 | 5,54 | 7,10 | 8,71 | 10,38 | 12,10 | 13,89 | 15,72 |

*Figure 58 Projected CII and its deviation from the required tables*

| **dd vectors for determining the rating boundaries of different ship types** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Type | d1 | d2 | d3 | d4 | a | c | **2022** | 2023 | 2024 | 2025 | 2026 |
| Bulker | 0,86 | 0,94 | 1,06 | 1,18 | 4745 | 0,622 | **4,88187** | 4,63778 | 4,54014 | 4,4425 | 4,34486 |
| Tanker | 0,82 | 0,93 | 1,08 | 1,28 | 5247 | 0,61 | **6,16454** | 5,85631 | 5,73302 | 5,60973 | 5,48644 |
| Bulker | 3,988487206 | 4,359509272 | 4,91604237 | 5,472575469 | | | | | | | |
| Tanker | 3,802976173 | 4,313131514 | 5,00879789 | 5,936353051 | | | | | | | |
| Vessel | 3,988487206 | 4,359509272 | 4,91604237 | 5,472575469 | | | | | | | |
| | | | | | | | | -5% | -7% | -9% | -11% |
| Year | 2023 | | | | | | | | | | |
| Type | | | | | | | | | | | |
| Bulker | 1 | | | | | | | | | | |
| Tanker | 0 | | | | | | | | | | |
| | | | | | | | | | | | |
| Alert | 4,637775821 | | | | | | | | | | |

CII rating | Speed_Cons Table | **BackCalc**

*Figure 59 DD Vectors or rating boundaries according to the ship type*

## 8.3 LIST OF ABBREVIATIONS

| ABBREVIAITON | DEFINITION |
|---|---|
| AI | Artificial Intelligence |
| AER | Annual Efficiency Ratio |
| BAU | Business as usual |
| BIMCO | Baltic and International Maritime Council |
| CCS | Carbon Capture and Storage |
| CII | Carbon Intensity Indicator |
| COP | Conference of the Parties |
| CPA | Charter Party Agreement |
| DCS | Data Collection System |
| DWT | Deadweight tonnage |
| ECDIS | Electronic Chart Display and Information System |
| EEDI | Energy Efficiency Design Index |
| EEOI | Energy Efficiency Operational Indicator |
| EEXI | Efficiency Existing Ship Index |
| EPL | Engine Power Limitation |
| ESD | Energy Savind Device |
| ETS | Emissions Trading System |
| f&R | Fund and Reward |
| FOC | Fuel Oil Consumption |
| GHG | Green House Gases |
| GFS | Greenhouse Gas Fuel Standard |
| HF | High Frequency |
| GHGL | GHG Levy |
| IMO | International Maritime Organization |
| IAPP | International Air Pollution Prevention |
| IEEC | International Energy Efficiency Certificate |
| ICCT | International Council on Clean Transportation |
| ICS | Chamber of Shipping |
| IoT | Internet of Things |
| IMSF&R | International Maritime Sustainability Funding and Reward |
| IMSF&F | International Maritime Sustainable Fuels and Fund |
| IRENA | International Renewable Energy Agency |
| LCA | Life Cycle Assessment |
| LNG | Liquefield Natural Gas |
| MARPOL | International Convention for the Prevention of Pollution |
| M/E | Main Engine |
| MEPC | Marine Environment Protection Committee |
| MCR | Maximum Continuous Rating |
| MGO | Marine Gas Oil |
| MRV | Monitoring, Reporting and Verification |
| PSC | Port State Control |
| SEEMP | Ship Energy Efficiency Management Plan |
| S&P | Sale and Purchase |
| SFOC | Specific Fuel Oil Consumption |
| ShaPoLi | Shaft Power Limitation |

| | |
|---|---|
| SoC | Statement of Compliance |
| SME | Subject Matter Expert |
| STS | Ship to Ship |
| TTW | Tank to Wake |
| UNCTAD | United Nations Conference on Trade and Development |
| WTW | Well to Wake |
| ZESIS | Zero-Emission Shipping Incentive Scheme |