INTERNATIONAL MARITIME ORGANIZATION

E

MARINE ENVIRONMENT PROTECTION COMMITTEE 82nd session Agenda item 6	MEPC 82/INF.25 26 July 2024 ENGLISH ONLY Pre-session public release: ☒

ENERGY EFFICIENCY OF SHIPS

Study on the implementation of the Ship Energy Efficiency Management Plan (SEEMP) framework

Note by the Secretariat

SUMMARY

Executive summary:	This document provides the final report of a Study on the implementation of the Ship Energy Efficiency Management Plan (SEEMP) framework conducted by the World Maritime University (WMU) and funded through the Future Fuels and Technology (FFT) project.
Strategic direction, if applicable:	3
Output:	3.2
Action to be taken:	Paragraph 10
Related documents:	None

Background

1 Since the entry into force in 2013 of amendments to MARPOL Annex VI on the inclusion of regulations on energy efficiency for ships (resolution MEPC.203(62)), ships shall keep on board a Ship Energy Efficiency Management Plan (SEEMP), developed taking into account guidelines adopted by the Organization.

2 The SEEMP framework has been further developed since then, in particular with the inclusion of a Part II on the ship fuel oil consumption data collection plan in 2016 and the inclusion of a Part III on the ship operational carbon intensity plan in 2021.

3 In adopting the 2022 SEEMP Guidelines (resolution MEPC.346(78)), MEPC 78 agreed to keep the Guidelines under review in light of experience gained with their implementation, also taking into consideration that in accordance with regulations 25.3 and 28.11 of MARPOL Annex VI a review of the technical and operational measures to reduce the carbon intensity of international shipping shall be completed by 1 January 2026.

4 The *Review plan of the short-term GHG reduction measure* approved by MEPC 80 (MEPC 80/17/Add.1, annex 13) identifies that the Secretariat will make every effort in facilitating the review process, and that support from external parties (e.g. WMU) may also be required as appropriate.

5 In this context, the Secretariat, through the Future Fuels and Technology Project (FFT Project),* invited the World Maritime University (WMU) to conduct a study on the implementation of the SEEMP framework to inform and facilitate the review of the short-term measure.

Study on the implementation of the SEEMP framework

6 The WMU research plan was formulated based on three main activities:

.1 a literature review focusing on the triple parts of SEEMP

.2 online survey questionnaires designed to obtain the perspective of a wide range of stakeholders; and

.3 a series of interviews with data verifiers to provide a comprehensive picture of the data collection and verification process.

7 The report on the *Study on the implementation of the SEEMP framework* conducted by WMU is set out in the annex to this document.

8 Whilst this study has been commissioned by the IMO Secretariat, the information contained within the report represents the views of the report's authors, the online survey participants, interviewees and the authors of the literature included in the literature review only. It should not be interpreted as representing the views of IMO, or the members of the Committee.

9 This research was being undertaken solely to assist the members of the Committee in making evidence-based decisions. Any information included in the report is provided solely for analytical purposes and should not be interpreted as suggestions or recommendations for how the short-term measure (in particular triple parts of SEEMP) should be revised in the future.

Action requested of the Committee

10 The Committee is invited to note the information contained in this document.

***

* https://futurefuels.imo.org/

STUDY ON THE IMPLEMENTATION OF THE IMO SHIP ENERGY EFFICIENCY MANAGEMENT PLAN (SEEMP) FRAMEWORK

INTERNATIONAL MARITIME ORGANIZATION

WORLD MARITIME UNIVERSITY

Document Title:			
STUDY ON THE IMPLEMENTATION OF THE IMO SHIP ENERGY EFFICIENCY MANAGEMENT PLAN (SEEMP) FRAMEWORK			
Responsible Organization: **World Maritime University (WMU)** **Authors:** **Peyman Ghaforian Masodzadeh, Aykut I. Ölçer, Fabio Ballini**			
Version	Comments	Date	Authorized by
01	Draft	12 July 2024	Professor Dr. Aykut I. Ölçer; Dr. Fabio Ballini, Dr. Peyman Ghaforian Masodzadeh
02	Draft	25 July 2024	Professor Dr. Aykut I. Ölçer; Dr. Fabio Ballini, Dr. Peyman Ghaforian Masodzadeh
Sensitivity		Confidential	
Number of pages:		68	

Disclaimer

The purpose of this report is to provide relevant background information that may inform further steps in policy review to investigate the effectiveness of short-term measures implementation.

Whilst this study has been commissioned by the International Maritime Organization (IMO) Secretariat, the information contained within this report represents the views of the report's authors, the online survey participants, interviewees, and the authors of the literature included in the literature review only. It should not be interpreted as representing the views of the IMO, or the members of the Marine Environment Protection Committee.

This research is being undertaken solely to assist the members of the IMO's Marine Environment Protection Committee (MEPC) in making evidence-based decisions. Any information included in this report is provided solely for analytical purposes and should not be interpreted as suggestions or recommendations for how the short-term measures (in particular triple parts of SEEMP) should be revised in future.

Table of Contents

List of Figures

List of Tables

List of abbreviations

AER	Annual Efficiency Ratio
AHR	Average Hull Roughness
AIS	Automatic Identification System
API	Application Programming Interface
BDN	Bunker Delivery Note
CAP	Corrective Action Plan
CBT	Computer-Based Training
CoC	Certificate of Compliance
DPA	Designated Person Ashore
DCS	Data Collection System
Dwt	Dead Weight
EEDI	Energy Efficiency Design Index
EEOI	Energy Efficiency Operational Indicator
EEPI	Energy Efficiency Performance Indicator
EMS	Environmental Management System

EnMD	Energy Management Department
EnMS	Management System
EPL	Engine Power Limitation
ETS	Emission Trading System
EU	European Union
FSO	Fleet Safety Officer
GHG	Greenhouse Gas
GISIS	Global Integrated Shipping Information System
HSEEQ	Health, Safety, Environment, Energy, Quality
IACS	International Association of Classification Societies
IEEC	International Energy Efficiency Certificate
IMO	International Maritime Organization
IMS	Integrated Management System
ISM	International Safety Management
ISO	International Organization for Standardization
IT	Information Technology
KPI	Key Performance Indicator
KUP	Knowledge, Understanding, and Profession
LCV	Lower Calorific Value
MARPOL	International Convention for prevention of pollution from ships
MEPC	Marine Environment Protection Committee
MRV	Monitoring, Reporting, Verification
NGO	Non-Governmental Organization
PDCA	Plan-Do-Check-Act
PSC	Port State Control
QAR	Quality Ashore Representative
QMS	Quality Management System
RO	Recognized Organization
SEEMP	Ship Energy Efficiency Management Plan
SMS	Safety Management System
SOC	Statement of Compliance
STCW	Standards of Training, Certification and Watchkeeping
SWe	Single Window environment

EXECUTIVE SUMMARY

The main aim of this study is to provide a policy review with a focus on SEEMP implementation and effectiveness to facilitate the review of the short-term measure (EEXI, CII rating and enhanced SEEMP) expected to be completed by 1 January 2026. To shed light on various aspects of the policy review, the research plan was formulated based on three main activities including a literature review focusing on the triple parts of SEEMP, online survey questionnaires designed to obtain the perspective of a wide range of stakeholders, and a series of interviews with data verifiers to provide a comprehensive picture of the data collection and verification process.

Online survey was conducted to investigate the effectiveness of SEEMP with attention paid to its three components, namely the management plan (part I), data collection and verification (part II), and CII calculations and rating (part III). Responding stakeholders were classified into three groups (G1, G2, and G3), with questions tailored to each group. The first group (G1) consists of policy actors, including flag administrations, delegations from member states, PSC and port authorities, and classification societies. The second group (G2) consists of policy performers, including ship owners/operators and seafarers, and the third group (G3) consists of other stakeholders, including charterers, cargo owners, academia, NGOs, technology providers, training institutes, consultants, and so on.

An overview of key findings relevant to each part of SEEMP is presented below based on the results of the literature review, online survey, and interviews.

Summary of key findings on SEEMP Part I:

- By enforcement of the SEEMP Part I, the intention has been to deploy a four-steps cycle (i.e., planning, implementation, monitoring, self-evaluation and improvements) to improve the operational energy efficiency of ships. However, SEEMP Part I does not seem to utilize in the way that it was intended. Demands and goals of stakeholders, including charterers, and the managers of the commercial and operation departments in the shipping companies, in many cases, do not align with SEEMP energy efficiency goals.
- The relative SEEMP Part I ineffectiveness may be attributed to the optional nature of key elements, such as goal-setting and EEOI application, as well as a lack of emphasis on management reviews and energy audits. After a decade, still there is no regulatory requirement on supervision/auditing on the content of SEEMP Part I by the Administration.

- Shipping companies in the context of energy management could inspire from best practices and lesson learned in the ISM Code implementation such as: well-established organizational structure for safety management, the obligatory essence of the ISM Code, personnel training, and audit schemes in the safety management.
- 40% of shipping managers (G2) believe that SEEMP Part I is a "plan" and not a "system".
- 51% of policy actors (G1) believe that SEEMP's four-step cycle is operational, compared to 49% who believe it is not. The reasons cited for SEEMP's four-step cycle not being fully operational include split responsibilities among shipping stakeholders regarding energy management, a lack of monitoring tools to quantify, measure, and trace the impact of energy efficiency measures, and a lack of internal monitoring and control within companies.
- 50% of shipping managers believe that while most seafarers may know what the SEEMP is about, they may not read and follow it on every vessel.
- 40% of aggregated participants perceive a gap in the lack of coverage of shore-based energy management, while 40% believe that adding SEEMP Parts II and III has resulted in shore staff becoming more engaged with energy management.
- 46% of aggregated participants emphasized the necessity of a mandatory energy management system tailored specifically for shipping, similar to the mandatory ISM Code as a tailored safety management system (SMS) for shipping. This system may cover both ship and shore-based energy management.
- Only 21% of shipping managers (G2) stated that they have energy management department (EnMD) under HSEEQ supervision, while 35% mentioned that they have EnMD under technical directorate, and 30% highlighted that they have no EnMD and superintendents are responsible for energy management of ships under their supervision.
- 31% of shipping managers (G2) pointed out that even though they intend to provide courses and certification for their energy auditors, there is no recognized (accredited) certification course for ship internal energy auditors, similar to courses for DPA and ISM auditors. A recommendation was made that WMU and IMO establish professional licensing programs for shipping energy managers and auditors to ensure that universally accepted standards are in place. In this regard, IMO has taken important steps toward developing e-learning programs to meet the training needs of seafarers (IMO, n.d.).

- 51% of policy actors (G1) believe that SEEMP should not be enforced as a subsidiary of SMS and ISM Code anymore; rather it should be enforced under the company's EMS (environmental management system) or EnMS (energy management system).
- 52% of shipping managers (G2) stated they provide necessary energy-related training to seafarers and shore-based personnel.
- 58% of policy actors (G1) are not of the opinion that SEEMP can be a proper place (tool) for addressing the training requirements of seafarers.
- 73% of policy actors (G1) believe that the role of PSC is limited only to controlling the availability and validity of the SEEMP and IEE Certificate onboard. 35% of them voted that PSC authorities should provide special energy training for PSC officers to conduct energy inspections in more detail. 37% of them believe that PSC can cross-check the fuel consumption data reported by ships, against the actual fuel ROB (remaining onboard), BDNs, and logbooks (at least on random base).

Summary of key findings on SEEMP Part II:

- A robust and effective data collection and verification system is an essential introductory measure in order to achieve the GHG emissions reduction target by providing sufficient transparency.
- The following issues are associated with the data collection and verification system: parallel work and high administrative burden (IMO DCS and EU MRV); possibility of data manipulation; data verification quality; data disclosure and transparency; motivating effect of data collection; and role of flag states.
- According to verifiers, they encounter the following challenges in their task regarding data collection and verification: quality of the reported data (completeness of the data); data validation; lack of a unified standard (approach) in verification process; change of ownership or flag of a ship; and short verification period.
- Verifiers utilize various tools for data validation such as: experience and know-how of verifiers in primary high level logic checks; noon reports; BDNs; AIS database; voyage (arrival/departure) reports including start of sea passage and end of sea passage; copy of some pages of engine and bridge logbooks and oil record book; specialized software; theoretical model built by verifiers to estimate consumption, average speed, and some other parameters; Email conversation between ship and port; and bill of lading or cargo manifest, if operators disclose it; otherwise order document or order confirmation, or voyage cargo information signed by master.

- Verifiers confirmed that there is no unique standard, and verification bodies, in the absense of such a standard, have established their internal procedure for verification.
- The interviewees acknowledged that there is difference in the quality of verification work. In general, class verifiers believe they are performing high-quality work, primarily because they have a name and a standard to uphold.
- Most verifiers, especially those with a large number of ships, have upgraded their data platforms or created new portals (particularly from 2023) in order to receive noon reports on a daily or voyage basis. Using APIs (application programming interfaces), shipping companies are able to easily send their daily noon reports to their verifiers.
- Most of the verifiers supported EEOI as a more accurate indicator of the efficiency of transportation work which in their view is at least closer to reality.
- Most of the verifiers embraced the recommendation implying that the voyage data (required for CII calculations) to be included as part of single window environment. They stated that any record at ports could be used as valuable evidence to cross-check the reported data in the future.
- 48% of aggregated participants (G1, G2, and G3) believe that complying with both IMO DCS and EU MRV has created high administrative burden for ship operators. 32% of them believe it has resulted in ambiguity as well.
- 55% of participants from G1 and G3 believe that with a few changes it is possible that the EU MRV may to be aligned with the IMO DCS in near future to form a unified and global mechanism for data collection and verification.

Summary of key findings on SEEMP Part III:

- Several factors are beyond the control of the ship operators that have a significant impact on the CII results.
- The EEOI is seen as most accurate, as it is based on the actual tonnage of cargo and excludes the distance travelled under ballast conditions. There is, however, a significant obstacle to the use of this version of CII due to the lack of cargo data availability in the DCS at this point. The IMO's AER is the least accurate, since it assumes that vessels are loaded to full capacity in all situations, including ballast legs. The AER formula calculates the transport work based on the ship capacity (DWT) rather than the actual cargo tonnage.
- Ships with a higher payload utilization will be penalized by the AER formula, whereas those with a lower payload utilization will benefit.

- 67% of participants from G1 and G3 believe that the CII correction factors can mitigate the effects of external factors if they are carefully designed and all parties are in agreement.
- 69% of participants from G1 and G3 prefer EEOI compared to AER, due to higher accuracy and transparency of EEOI, and its encouragement to improve the ship loading factor. They believe AER demonstrates an unrealistic (more efficient) image of the ship operator. Even 46% of shipping managers from G2 also support EEOI, in contrast to 20% of this group who are in favour of AER.
- Regarding the actual cargo tonnage data, 44% of participants from G1 and G3 believe that the actual cargo tonnage without disclosing the cargo details is not commercially sensitive (e.g., 10,000 TEU or 30,000 tonnes of different grade of chemicals). Another 30% also believe that it is not sensitive because as this information is reported to the EU MRV. Only 24% believe that actual cargo tonnage is commercially sensitive data.

1. Introduction

Seaborne trade accounts for 80% to 90% of international trade (Miola & Ciuffo, 2011; ICS, 2017). Compared with other modes of transportation, sea transport has the lowest CO_2 emissions per unit of transport work (Hoffmann & Kumar, 2013). Despite this, it is important to acknowledge that the maritime sector, which contributes approximately 2.9% of global greenhouse gas (GHG) emissions (Faber et al., 2020), has a significant impact on global ecological systems (Lister et al., 2015). The *2023 IMO Strategy on reduction of GHG emissions from ships* provides the global framework to address GHG emissions from international shipping.

During the 59th meeting of the Marine Environment Protection Committee (MEPC), a package of technical and operational measures was agreed upon to improve energy efficiency and reduce GHG emissions. In this regard, a technical standard called the energy efficiency design index (EEDI) for new ships, and an operational action plan called the ship energy efficiency management plan (SEEMP) for all vessels exceeding 400 GT were adopted in MEPC 62 (July 2011) and came into effect on 1st January 2013. Accordingly, MARPOL Annex VI was amended by adding Chapter 4 to include these energy efficiency regulations. Shipping energy regulations constitute the first mandatory global GHG regime ever enacted among all international industry sectors and modes of transport.

1.1 SEEMP structure

The main body of the SEEMP, also referred to as SEEMP Part I today, enforced since 2013, is a comprehensive energy management plan tailored to each individual ship. It consists of a four-steps cycle (i.e., planning, implementation, monitoring, self-evaluation and improvements shown in Fig.1) to improve the efficiency of ship operations (IMO, 2009; IMO, 2012). This four-steps cycle in the SEEMP is supposed to act similar to the PDCA cycle (Plan-Do-Check-Act) in various management systems.

Figure 1: Four-steps cycle in the SEEMP

In 2019, the monitoring step of this cycle was separately emphasized through the introduction of SEEMP Part II, concerning ship fuel oil consumption data collection and verification. Lastly, in 2023, SEEMP Part III was introduced to support the implementation of the CII framework through a ship operational carbon intensity plan, emphasizing the self-evaluation and improvement step of the cycle. SEEMP Part III requires ships to calculate their annual energy rating (AER) as a version of carbon intensity indicator (CII). In Fig.2, we can see the evolution of the SEEMP over the last decade as well as the scope of the different parts of the SEEMP. A detailed description of SEEMP triple parts will be presented in subsequent sections of this report.

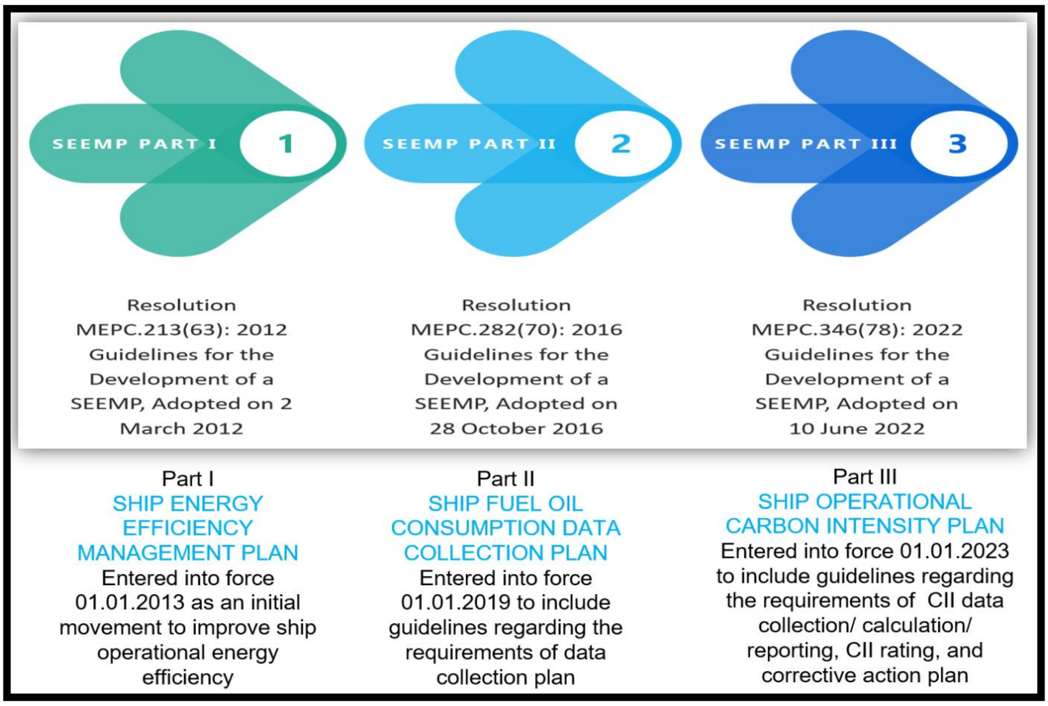


Figure 2: Emergence and evolution of the SEEMP

1.2 Research aim and objectives

The main aim of this study is to provide a policy review with a focus on SEEMP implementation and effectiveness to facilitate the review of the short-term measure (EEXI, CII rating and enhanced SEEMP) expected to be completed by 1 January 2026. As shown in Fig.3, policy review is one of the main components of the policy cycle or policy process. In this study, policy review is performed based on the results of literature review, online surveys, and interviews.

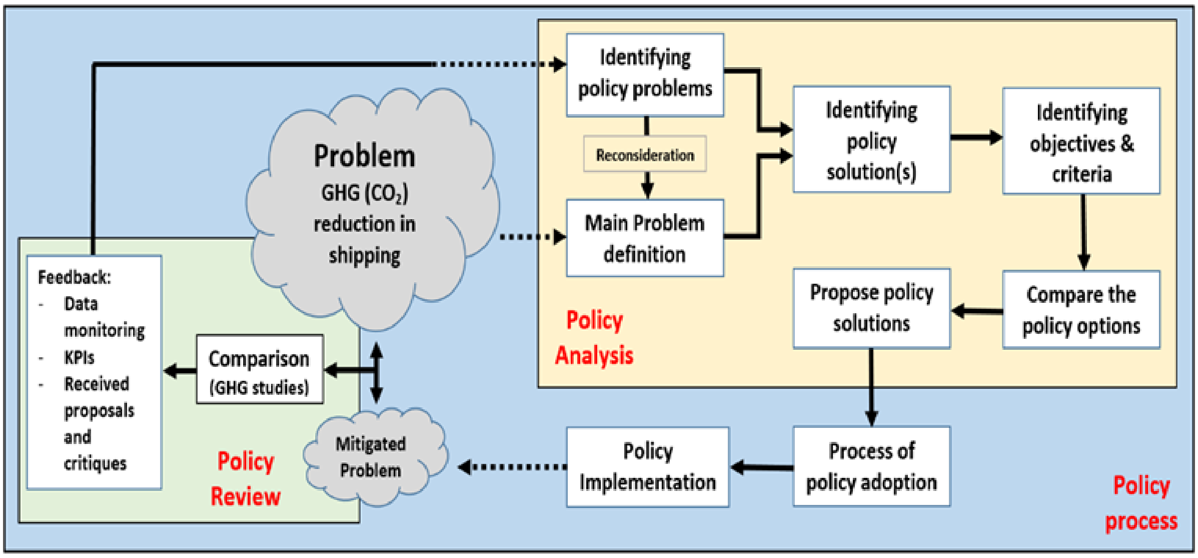


Figure 3: Role of policy review in the policy process (cycle)
Source: (Ghaforian M., 2024)

The research aim is achieved by attempting the following research objectives:

SEEMP Part I:
- To investigate the functionality of the four-steps SEEMP cycle
- To assess the status of energy management at shore and onboard and the possibility of alternative systems
- To evaluate the motivational effects of SEEMP on seafarers
- To assess the fulfilment of energy-related training needs through SEEMP
- To evaluate the role of PSC regime in implementation of ship energy regulations

SEEMP Part II:
- To assess the administrative burden imposed on ship staff and shore management in data management
- To investigate the reliability of the yearly collected data
- To investigate the issues relevant to data collection and verification that verification bodies are involved in.

SEEMP Part III:
- To assess different stakeholders’ perspective regarding the reliability of CII versions namely EEOI and AER
- To investigate the extent to which external factors can affect the attained CII

2. Methodology

To achieve the research objectives in the most efficient manner, the research plan was formulated based on three main activities in order to gather relevant information from the literature and to reflect the perspectives of various stakeholders. Specifically, the research methodology included a literature review focusing on the triple parts of SEEMP, online survey questionnaires designed to obtain the perspective of a wide range of stakeholders, and a series of interviews with data verifiers to provide a comprehensive picture of the data collection and verification process.

Literature review: Considering the lack of literature on SEEMP, we could anticipate at the early stages of the research that a systematic literature review would not be very effective. Consequently, this study employed a narrative literature review supported by follow-up search (snowballing). The literature review is presented in 3 different sections discussing triple parts of SEEMP separately.

Online survey: The primary objective of the online survey was to facilitate the review of short-term GHG reduction measures that will be initiated by the IMO in the near future. Online survey was conducted to investigate the effectiveness of SEEMP with attention paid to its three components, namely the management plan (part I), data collection and verification (part II), and CII calculations and rating (part III). Due to the fact that energy management is an area of interest for many maritime stakeholders, we intended to have the perspective of all stakeholders regarding SEEMP, to the extent possible. Therefore, stakeholders were classified into three groups (G1, G2, and G3), with questions tailored to each group.

- Group one (G1): Policy making (legislation) and policy execution (regulatory) bodies, including: Flag administrations, member state delegations, PSC, and classification societies
- Group two (G2): Policy performers, including: Ship owners, ship operators, ship owner/operator, and seafarers
- Group three (G3): Observers or other actors’ category, including: Charterers, cargo owners, academia, NGOs, technology providers, training institutes, consultants, and other stakeholders

The following table demonstrates the number of responses in each group:

	Group 1 Policy actors	Group 2 Shipping managers	Group 3 Other stakeholders	Total
Number of total responses	148	269	110	527
Number of complete responses	34	95	42	171

From June 1st to June 30th, 2024, participants had the opportunity to participate in online surveys. The overall completion rate of these three surveys was approximately 33%. Despite our best efforts, we were not able to reach seafarers in an acceptable level in group 2 due to time constraints. Therefore, more than 90% of survey participants in group 2 were shipping managers. In the future, it is imperative to reach out to seafarers in a specialized study to investigate their role in the implementation of SEEMP and to capture their perspective.

Interview: Several interviews were conducted with verification bodies from 10 classification societies in order to gain a better understanding of the issues involved in data collection and verification. Due to time constraints, it was not possible to contact verifiers from private companies. The following is a list of class verifiers participating in interviews: Det Norske Veritas (DNV), Nippon Kaiji Kyokai (ClassNK), Indian Register of Shipping (IRClass), Polish Register of Shipping (PRS), American Bureau of Shipping (ABS), Bureau Veritas (BV), Croatian Register of Shipping (CRS), China Classification Society (CCS), Lloyd's Register (LR), and Türk Loydu (TL).

Interviews were conducted online with open-ended questions. All interviews were recorded with the consent of interviewees, and the interview manuscripts were collected for further analysis. In all cases, the questionnaire was semi-structured and focused on issues related to data collection and verification. Among the themes of the questionnaire were: challenges associated with data collection and verification, knowledge and abilities of ship operators in data collection and reporting, data reliability and authentication, relevant guidelines, quality of verification work, and data manipulation possibilities. Toward the end of the interview, interviewees were asked to make recommendations on how to simplify the verification process and improve its quality.

3. SEEMP Part I: Energy Efficiency Management Plan

3.1 Background

In accordance with MARPOL Annex VI, on or after 1 January 2013, ships of 400 gross tonnage and above engaged in international voyage should retain a Ship Energy Efficiency Management Plan (SEEMP Part I) on board. Ship operators are required to develop a ship management plan to improve energy efficiency, in accordance with the latest revision of the IMO guidelines. Currently the latest revision of this guideline is Resolution MEPC.346(78) (IMO, 2022a). Over time, SEEMP Part I has been completed by the addition of SEEMP Part II (the data collection plan, which came into force in 2019), and SEEMP Part III (the ship operational carbon intensity plan, which came into force in 2023). As a result of the enhancement to the SEEMP, issues such as lack of systematic monitoring and data collection, as well as lack of decarbonization goals and measurement of carbon intensity were addressed. In this chapter, the focus is on part one of the SEEMP, the energy management plan.

This study examines the effectiveness and sufficiency of the SEEMP by shedding light on various problems associated with its implementation onboard ships. In the first instance, a review of the literature will be presented. In the following section, a summary of the results of the online survey is presented. Online survey questions were posed regarding the implementation of the SEEMP onboard and the role of shore management, the extent to which SEEMP addresses training, energy management in shipping companies, and the implementation of the SEEMP under ISM code and safety management system.

3.2 Literature review

In order to achieve energy efficiency, SEEMP aims to improve day-to-day operations (Lützen et al., 2017; Perera & Mo, 2016). According to (Hansen et al., 2020), "the SEEMP is intended by IMO to be a dynamic ship-specific document, which must be kept on board and used actively in the continuous effort to increase energy efficiency of daily operations on board". Regulations, however, only require the presence of an energy efficiency plan on board and do not specify its content. It is entirely up to the ship owner to decide about SEEMP content. It is the shipping company that formulates the SEEMP and tailor it for a particular vessel (Hansen et al., 2020). SEEMP content can include best operational practices, guideline regarding coordination between different stakeholders, methods to raise awareness and providing the necessary training for the crew, goal-setting, and monitoring approaches (Hansen et al., 2020). As a result of understanding these facts about SEEMP, it is reasonable to conclude that SEEMP is a goal-oriented regulation, in which ship operators are free to choose the best approach to achieve predetermined goals in energy efficiency and GHG reductions (Hansen et al., 2020).

By enforcement of the SEEMP Part I, the intention has been to deploy a four-steps cycle (i.e., planning, implementation, monitoring, self-evaluation and improvements) to improve the operational energy efficiency of ships (Im et al., 2019). Under the SEEMP and its four-steps cycle, vessel energy efficiency improvements should be implemented continuously (Perera & Mo, 2016; Duan et al., 2023). This four-steps cycle in the SEEMP is supposed to act similar to the PDCA cycle (plan-do-check-act) in various management systems. Therefore, one of the main objectives of this study is to investigate whether the SEEMP cycle has been operational and SEEMP has worked as a perfect system.

In an investigation by Hansen et al. (2020), it was found that although the SEEMP Part I is generally well known, some crew members remain unaware of its content. This investigation also shows that the SEEMP Part I has helped raise awareness about energy consumption and that the crew has generally become more aware of energy efficiency. There is a recommendation from Duan et al. (2023) to provide crew members with more training and education on energy efficiency management, as well as introduce a performance appraisal and reward system to improve technical proficiency and enthusiasm for effective SEEMP implementation.

A proper action during the preparation of a first draft or revision of SEEMP is to allow senior officers the opportunity to provide input on the SEEMP content (Hansen et al., 2020). As a result of their research, Hansen et al. (2020) conclude that SEEMP is not being utilized in the way that it was intended. Decisions made by the officers on board are based on goals defined by many stakeholders, including the managers of the operational department in the shipping company, the charterer, or harbour personnel. In many cases, officers will discover that these demands or goals do not align with SEEMP energy efficiency goals. Duan et al. (2023) recommend that ship technology be automated and management be computerized at a higher level, to reduce the workload of the crew members in SEEMP implementation. The use of an intelligent energy efficiency management system based on sensors and software can support the monitoring of energy consumption data, the calculation of energy efficiency levels, and the generation of energy consumption data reports (Duan et al., 2023).

3.2.1 SEEMP Part I effectiveness

While the structure and function of the SEEMP were initially intended to follow a plan, do, check, act (PDCA) cycle (IMO, 2012), shipboard operations do not follow this pattern. Even though the aim of the SEEMP is to assist the international shipping sector to achieve the goal of chapter 4 of MARPOL Annex VI, which is reducing the carbon intensity of international shipping, according to available maritime literature, the SEEMP Part I has a limited capacity to reduce emissions (Wang, 2012; Kachi et al., 2019; Maddox consulting, 2012; Johnson et al., 2013; DNV, 2015; ABS, 2013; Ghaforian M., 2018). As Wang (2012) argues, while the SEEMP Part I may slow the growth rate of total CO_2 emissions, it is unlikely to arrest or reverse the growth in absolute CO_2 emissions from shipping. It was argued by Kachi et al. (2019), Maddox consulting (2012), and Johnson et al. (2013) that the relative SEEMP Part I ineffectiveness can be attributed to the optional nature of key elements, such as goal-setting and EEOI application, as well as a lack of emphasis on management reviews and energy audits. A survey conducted in 2015 (DNV, 2015) revealed that 41% of shipping companies had not updated the original SEEMP (Part I) version of their ships, two and a half years after its enforcement. As a result, it can be concluded that the theoretically embedded PDCA cycle within the SEEMP Part I does not function as intended. Consequently, the SEEMP Part I has been demoted to the status of a guideline rather than a systematic management tool. Ghaforian M. (2018) has compared the SEEMP Part I with the ISM code in terms of managerial power and robustness, and with energy management system in terms of organisational structure in order to explain the deficiencies in the design and implementation of SEEMP Part I. It should be noted that this literature does not cover the enhanced SEEMP adopted in the context of the short-term measure.

3.2.1.1 SEEMP vs. ISM code

- *Well-established organisational structure for safety management in shipping companies*

  To strengthen the backbone of safety and quality within an organization, shipping companies establish safety management system (SMS) and create positions such as designated person ashore (DPA), quality ashore representative (QAR), fleet safety officer (FSO), and ISM auditors. In the same way, it may also prove effective to establish an energy management system (EnMS) and place it in a strategic organizational position with enough power and independence, as well as create positions such as energy managers and energy auditors. The DNV (2015) survey found that fewer than one third of shipping companies have a dedicated energy manager, and most assign the task to "everyone" which often means "no one".

- *The obligatory essence of the ISM code*

  While the SEEMP Part I includes optional elements, the ISM code contains strict rules and regulations that demonstrate the effectiveness of mandatory procedures. It is imperative that maritime energy legislation includes more mandatory elements that specifically address decarbonization and place it on par with maritime safety. According to Cullinane (2014), "it is only mandatory to have a SEEMP on board a ship, rather than to actually use it". Similarly, DNV (2015) has noted that "shipping companies have treated the SEEMP as a compliance-driven paper exercise".

- *Training quality*

  Since the implementation of the ISM Code, great emphasis has been placed on raising awareness and promoting safety procedures through mandatory training courses. In contrast, no KUP (knowledge, understanding, and profession) specifically refers to energy efficiency skills aboard ships under STCW requirements (Ölçer et al., 2023).

- *Audit scheme*

  While the ISM Code emphasizes an audit scheme that is based on a well-defined audit plan, checklists, and formulated KPIs, this is not explicitly addressed in the SEEMP. ISM audits, conducted by internal auditors of shipping companies, are currently one of the most effective methods to improve safety standards on board vessels. Likewise, internal audits focusing on energy efficiency not only increase seafarers' awareness, but can also be complemented by on-board training sessions.

3.2.1.2 SEEMP vs. EnMS (e.g., ISO 50001)

As the name implies, the SEEMP serves as an energy action plan for each individual ship rather than a management system. As shown in Fig.4, the SEEMP is one of several elements that constitute the entire PDCA cycle of the EnMS.

- *The SEEMP Part I is a management plan rather than a management system*

  Even though ship owners are required to provide SEEMP for their vessels, the effectiveness of SEEMP Part I cannot be assured without a supporting system, such as an EnMS. As an energy management plan for ships, the SEEMP Part I does not address shore-side management. A company EnMS, however, can play an important role in outlining the relationship between the energy management department (EnMD) and other departments, defining common energy objectives for different departments, and reducing the organisational split incentive in shipping companies by implementing a comprehensive action plan that covers both ship and shore management (Masodzadeh et al, 2022b).

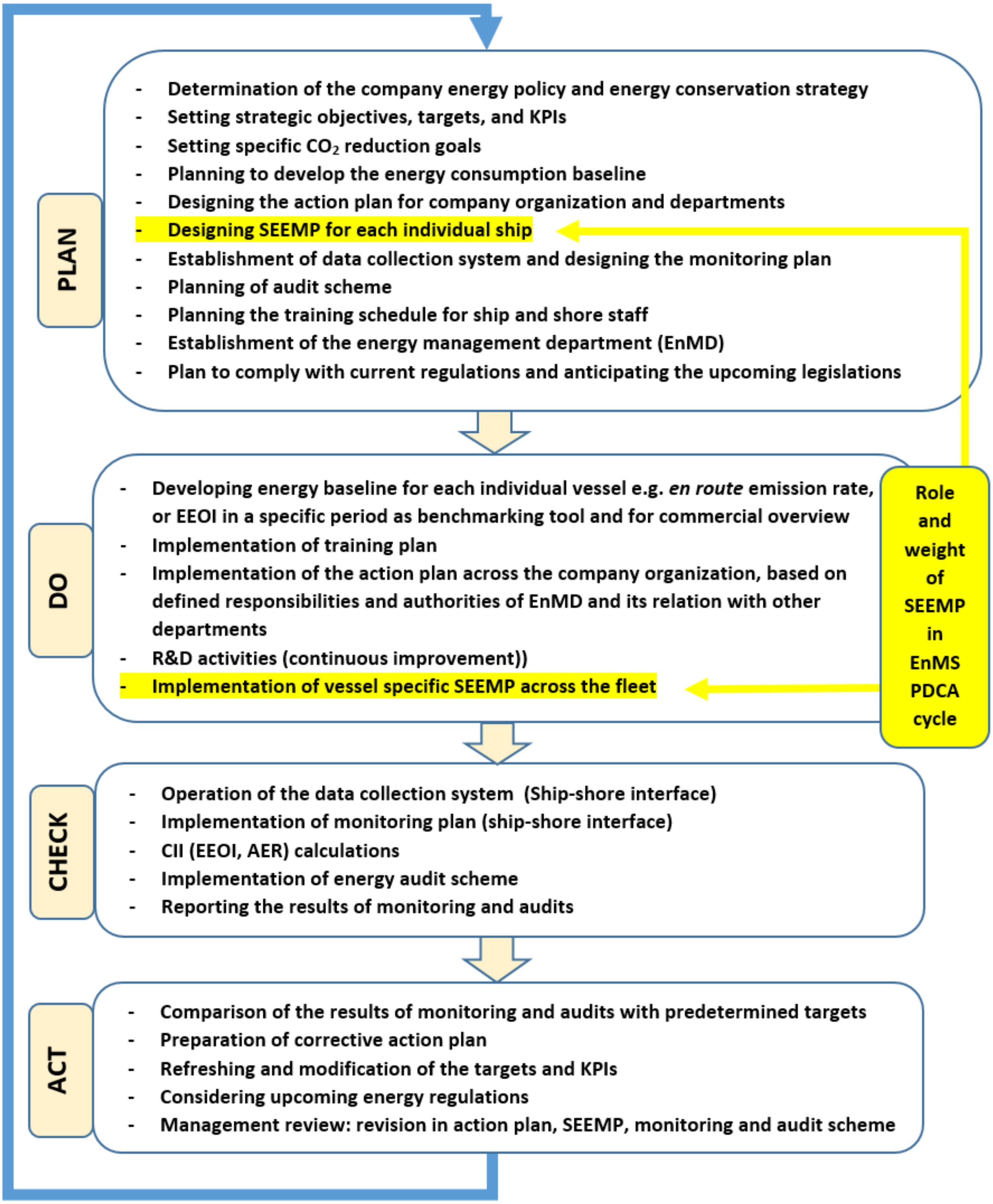


Figure 4: Structure and elements of the PDCA cycle in an EnMS for a shipping company
Source: (Ghaforian M., 2024)

It is necessary to establish an EnMS at a higher management level in order to create SEEMPs for fleet vessels, to monitor their implementation onboard vessels, and to conduct management reviews (Bazari, 2016). In addition, Bazari (2016) argues that "although aspects of planning, monitoring and self-assessment are included in the SEEMP, they are not normally the responsibility of the ship-board staff to implement".

- *Missing components in the SEEMP Part I*

  Despite the fact that standard EnMS, such as ISO 50001, contain specific requirements regarding energy reviews and baselines, the establishment of an energy management department, management reviews, identifying training requirements, and the design of proper performance indicators (PIs), most of these components are optional or less emphasized in the SEEMP Part I. Fig.5 illustrates these missing components. According to the DNV survey, "one third of participating shipping companies did not set themselves an explicit saving target" (DNV, 2015). According to Bazari and Longva (2011), due to the lack of regulatory requirements for setting and monitoring targets, the effectiveness of the SEEMP Part I needs to be boosted/incentivised by other means, for instance by mandating the use of EEOI or a similar performance indicator.

- *Energy audit*

  A successful management system relies on a monitoring system and a robust audit scheme. In order to understand the importance of audits in management systems, it is sufficient to imagine an ISM code and safety management system that are not subject to physical audits onboard ships. Energy audits are not emphasized in the SEEMP Part I, and similar practices are seldom observed in shipping companies.

With the enhancement of SEEMP by addition of SEEPM part II and III, some basic deficiencies in SEEMP Part I have been addressed, such as goal-setting, data collection and verification, CII calculation, and corrective action plans. However, as illustrated in Fig.5, other elements, such as the energy baseline, management review, seafarers' training, and energy audits, have not yet been addressed.

Scholars recommend the implementation of EnMS in shipping companies as a solution to the above-mentioned problems. It has been suggested by Cullinane (2014) that the IMO, by reviewing best practices from other industries, may be able to mandate the implementation of energy management systems in shipping companies. The implementation of ISO 50001 in shipping companies has been recommended by Cullinane (2014), Bännstrand et al. (2016), Johnson et al. (2013), and Armstrong and Banks (2015). In accordance with Maddox consulting (2012) and Nelissen and Faber (2014), SEEMP should be integrated into an environmental management system such as ISO 14001. Ghaforian M. (2024) suggests that a marine-tailored

EnMS (similar to ISM Code that is a marine-tailored safety management system) must be developed and implemented for shipping companies.

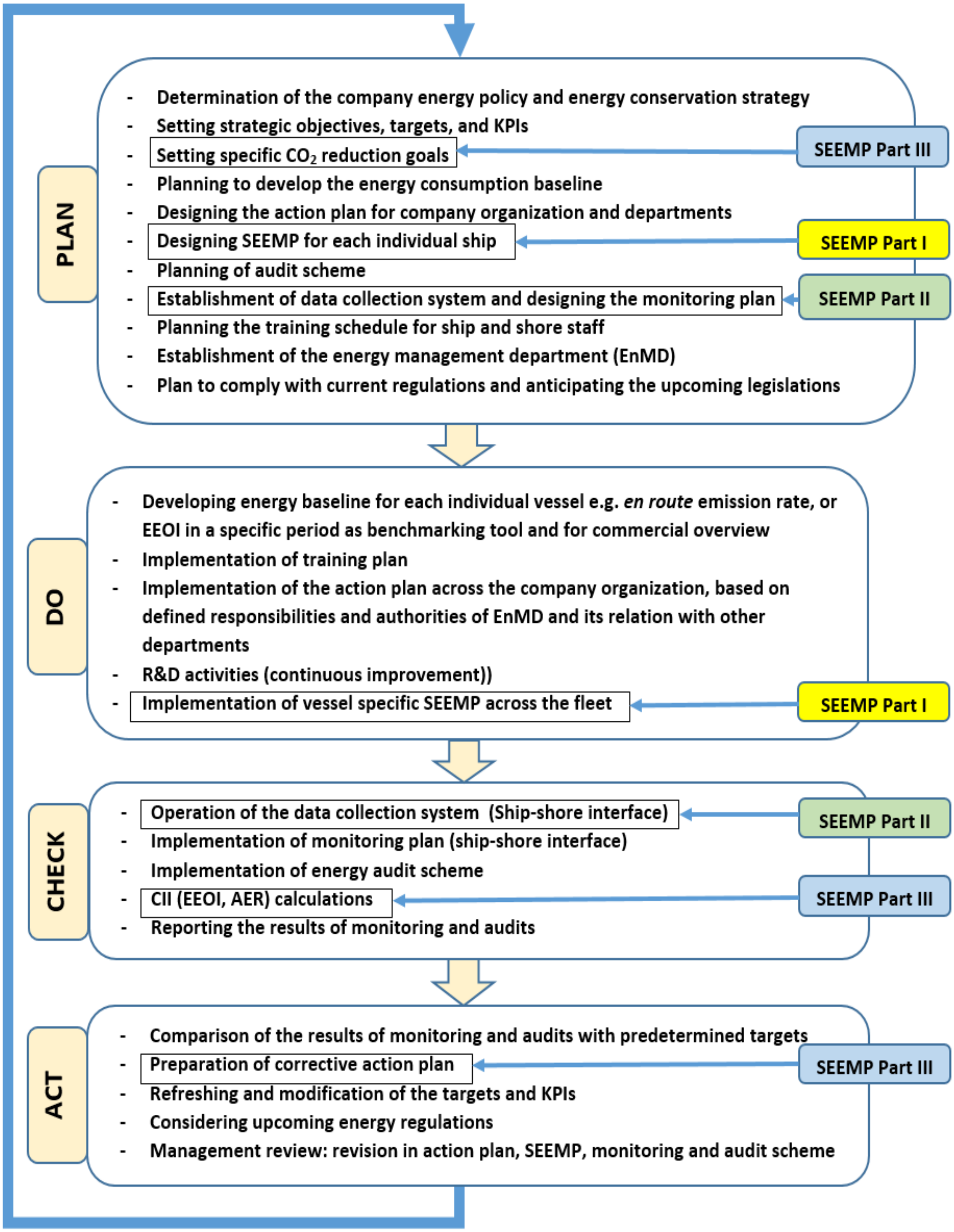


Figure 5: Share of SEEMP parts I, II, and III from the PDCA cycle of the company EnMS
Source: (Ghaforian M., 2024)

3.2.2 Shore-based energy management in shipping companies

As illustrated in Fig.5, while we assume that the goal-setting gap in part one of the SEEMP has been rectified by the obligatory emission reduction goal-setting in part III (CII reduction per year), it is important to note that goal-setting in an energy management system does not only include assigning emission reduction targets, but rather other targets must be assigned for various departments. For example, the company's energy policy should emphasize education and awareness raising goals for the training department, green procurement goals for the commercial department, and energy efficient voyage planning for the operation department (Masodzadeh et al., 2022b).

The implementation of various operational measures relies primarily on the participation of crew members on board ships and technical managers ashore. Furthermore, increasing regulatory requirements in the maritime industry present significant challenges and pressures for seafarers as they strive to achieve energy efficiency and GHG emission reduction targets. In accordance with Dewan and Godina (2023), seafarers have to cope with increased workloads, additional paperwork, heightened regulatory inspections, enhanced planned maintenance, and increased technical difficulties when implementing SEEMP. Onboard staff require sufficient training and incentives, which must be provided by shore-based management (Dewan & Godina, 2023). Ashore managers, particularly technical and marine superintendents, are crucial to implementing several energy efficiency measures onboard ships. It is the responsibility of them to supervise masters and chief engineers in implementing energy efficiency measures such as optimizing speed, monitoring hull efficiency, training and awareness of ship crews, optimizing ship power, monitoring engine performance, executing voyages, selecting the most efficient routes, and slow steaming (Dewan & Godina, 2023).

A study conducted by Ghaforian M. (2018) suggests that SEEMP should be integrated into the company's energy management system. The first and most critical issue is the position of the EnMS in the organizational structure of a shipping company. In shipping companies, energy managers and energy auditors are typically marine engineers and technical professionals, thus there is a misconception that the energy management (conservation) department must be under the technical department's supervision. An EnMS lacks sufficient independence and power as a subsidiary of the technical department. Further, a department cannot control its own performance; rather, quality control should be carried out by an independent department, such as HSEQ. Based on Fig.6, Ghaforian M. (2018) recommends that the EnMS be placed under the supervision of the HSEQ department to reform it to the health, safety, environment, energy, and quality (HSEEQ) department. In this manner, energy management can be empowered and independent, freed from the dominance of SMS and the ISM code. Incorporating different management systems into a single integrated management system (IMS) may facilitate the planning and implementation process and provide an opportunity to harmonize the objectives of the various management systems. This would result in the integration of energy targets into other management systems, such as human resource management (e.g., training of seafarers), and safety and quality management (e.g., considering risks associated with alternative fuels).

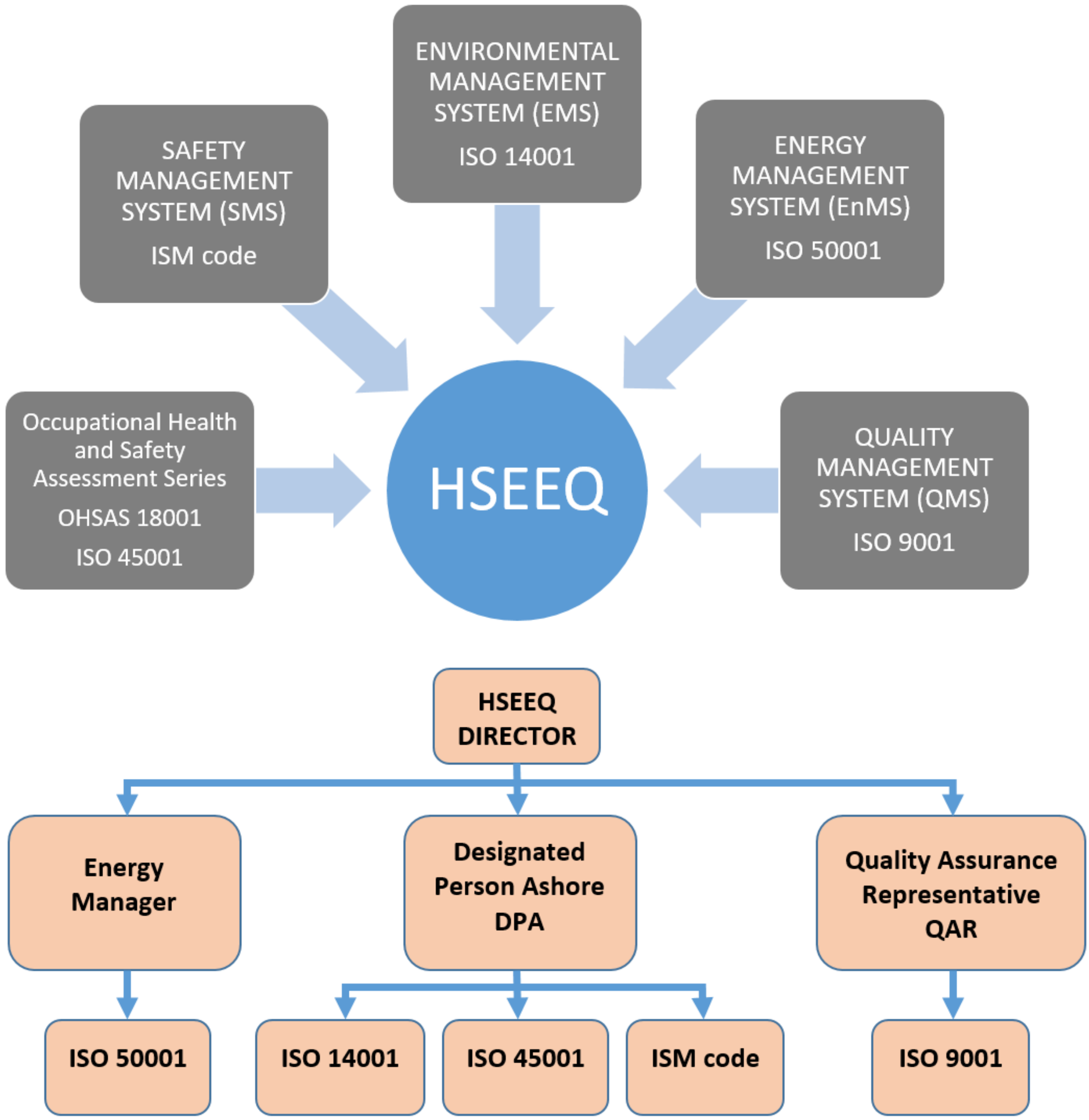
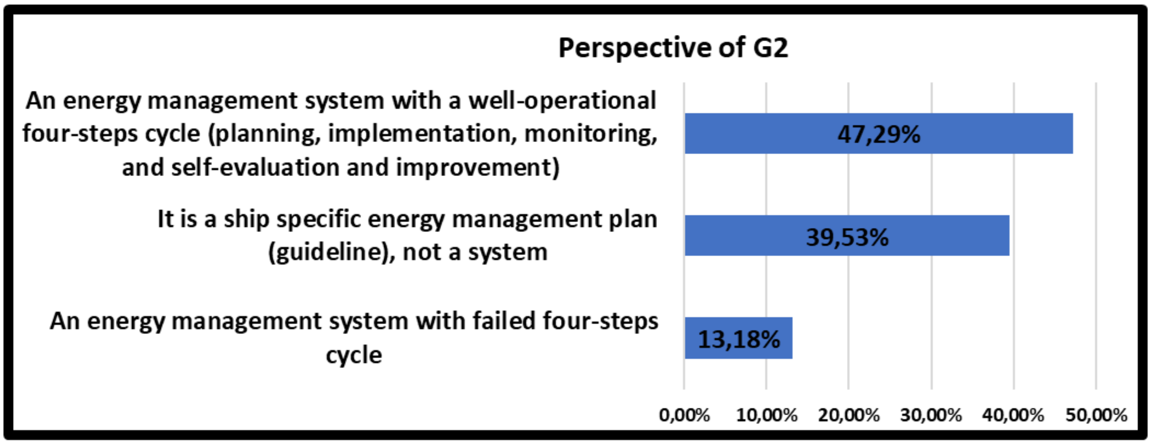


Figure 6: Organisational position of the EnMS in a shipping company
Source: (Ghaforian M., 2018)

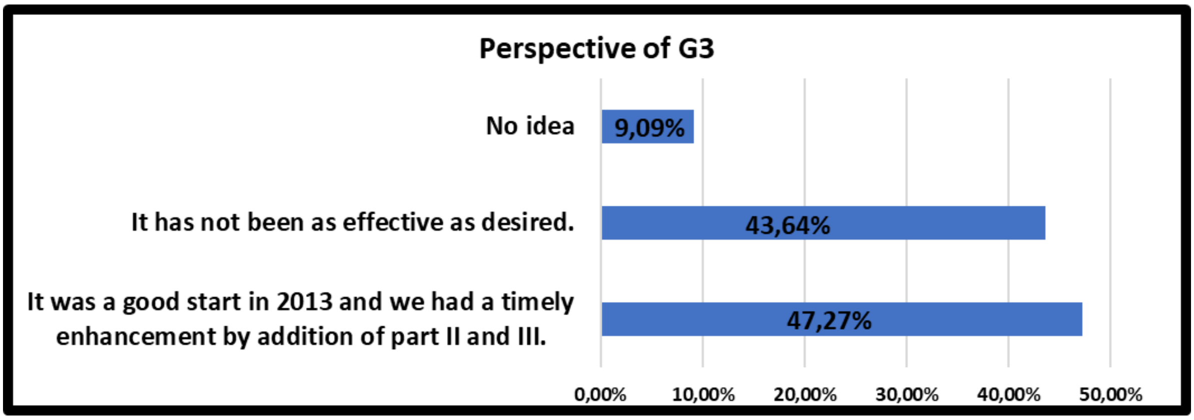
3.3 Results of online survey

3.3.1 General perspective of stakeholders regarding SEEMP Part I effectiveness

Question: What is your perception of SEEMP?

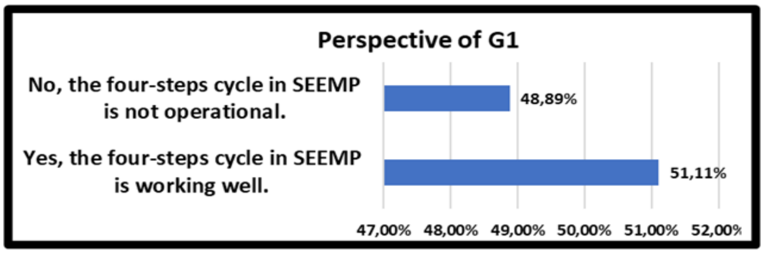


Question: What is your opinion about SEEMP effectiveness in shipping decarbonization a decade after its enforcement?

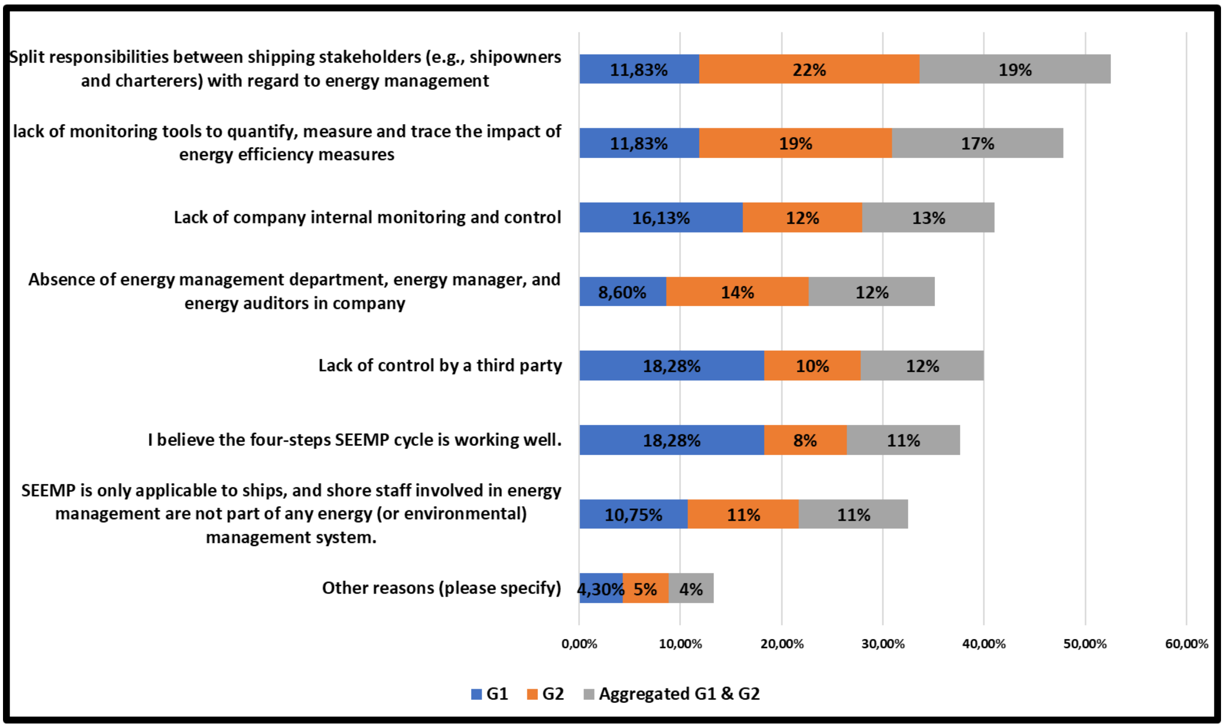


3.3.2 SEEMP implementation

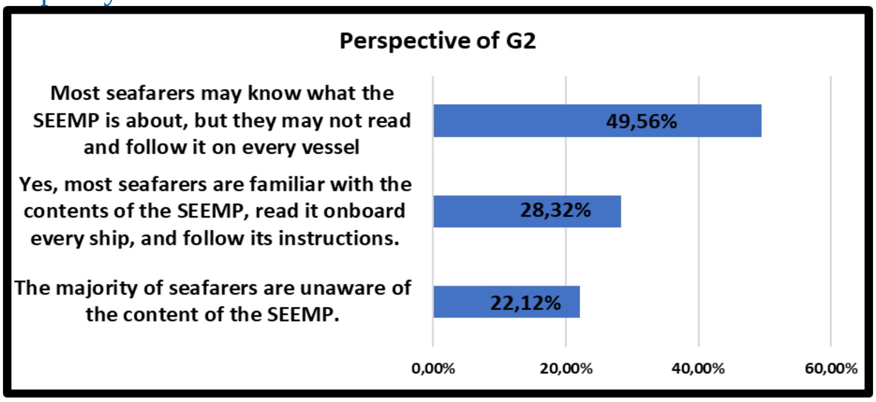
Question: In your opinion, does SEEMP's four-steps cycle (planning, implementation, monitoring, and self-evaluation and improvement), identified in SEEMP Part I, operate as intended?



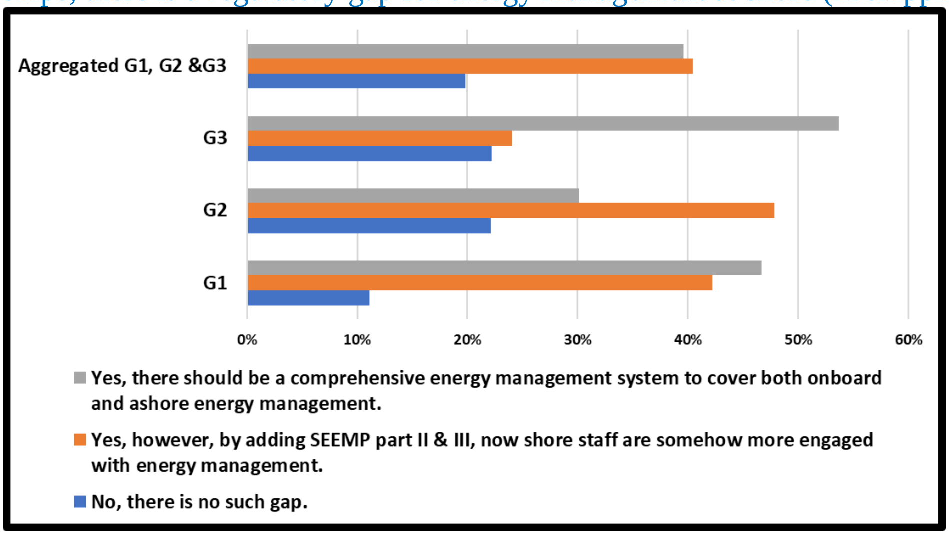
Question: If you believe that the four-steps SEEMP cycle is not operational within the context of energy efficiency management, what are your reasons?



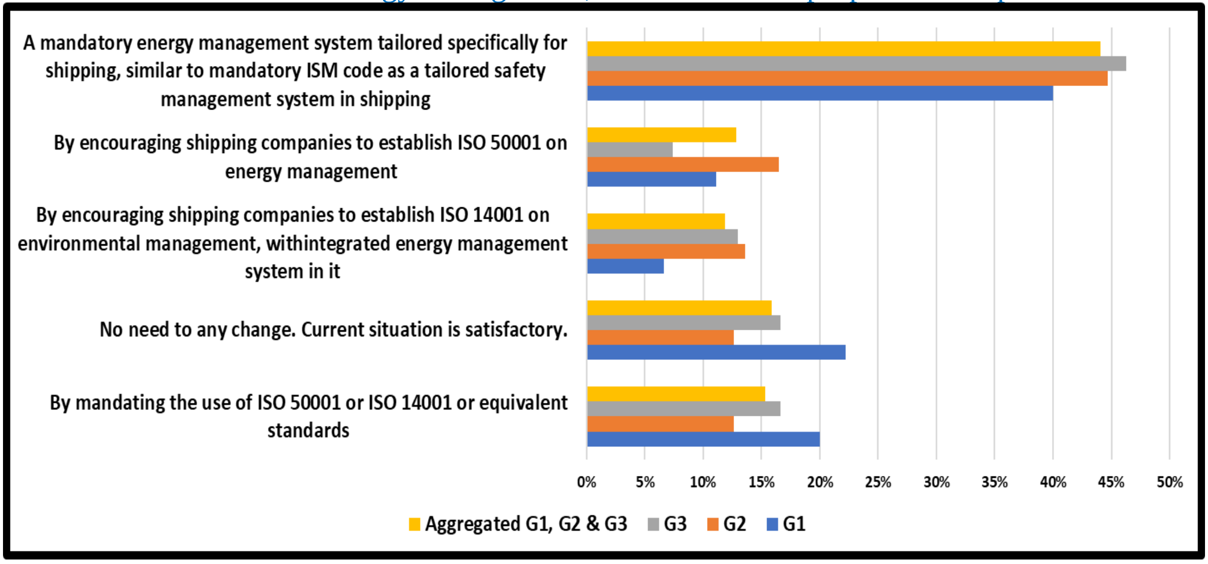
Question: In your opinion, do seafarers read and implement the SEEMP manual onboard every ship they serve?



Question: What is your opinion about this statement? Considering that SEEMP is for individual ships, there is a regulatory gap for energy management at shore (in shipping companies).

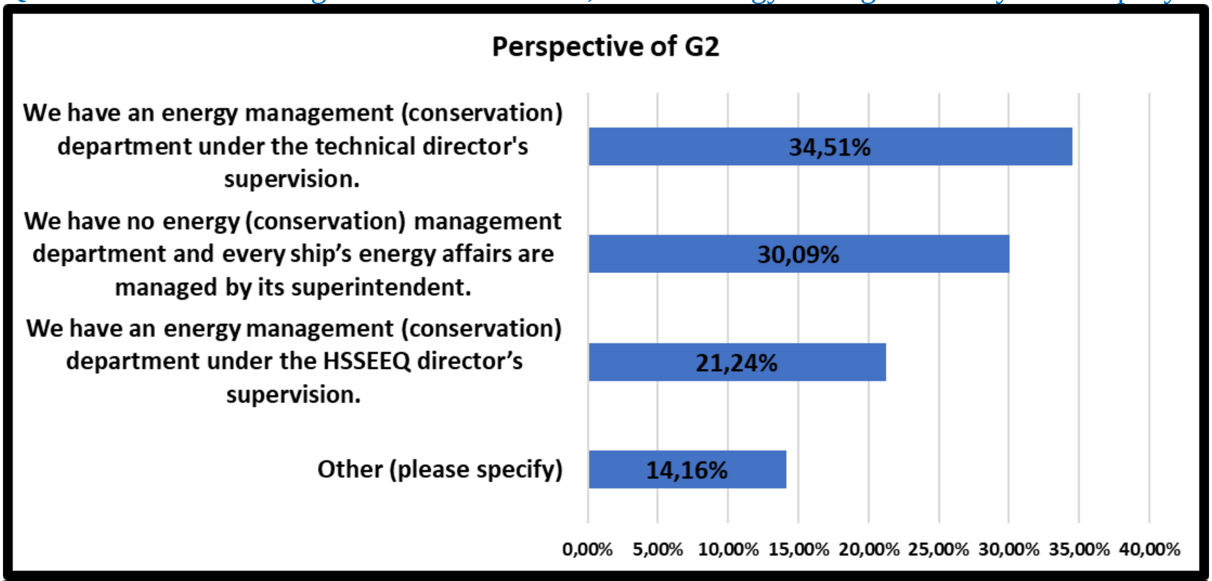


Question: If you believe that an energy management system should be implemented to cover both onboard and ashore energy management, how would this proposal be implemented?



3.3.3 Energy management in shipping companies

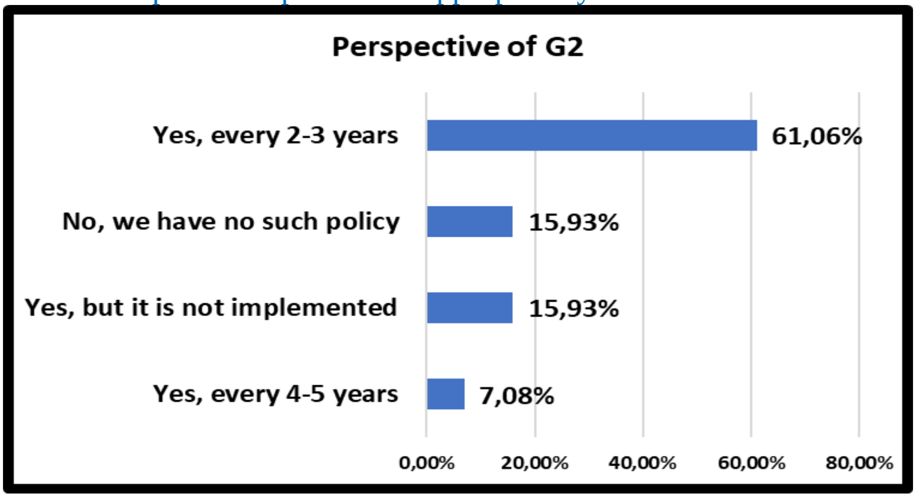
Question: In terms of organizational structure, how is energy management in your company?



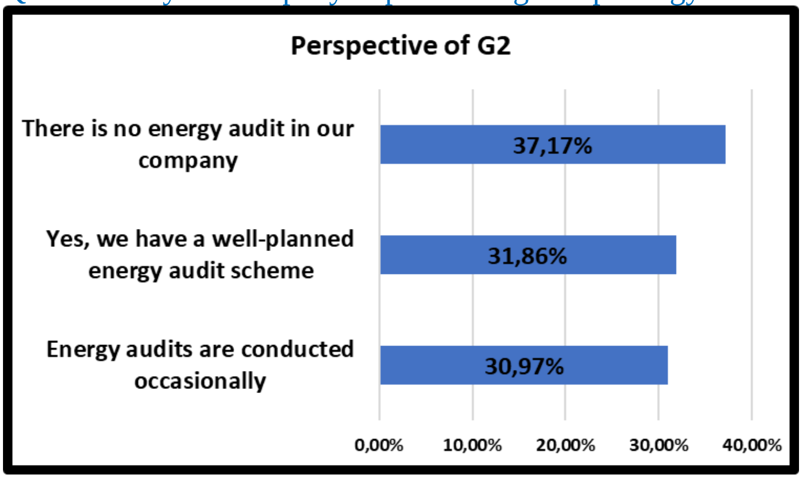
Other approaches specified by respondents:

- We have dedicated fleet performance department reporting to Group Managing Director and CEO.
- We have an energy management department under the top management supervision.
- We have energy management (conservation) department under the QC department and the technical director supervision.
- We have no energy management department but each energy action agreed has also dedicated responsible personnel.
- We have a sustainability department monitoring energy management under supervision of the chief sustainability officer.

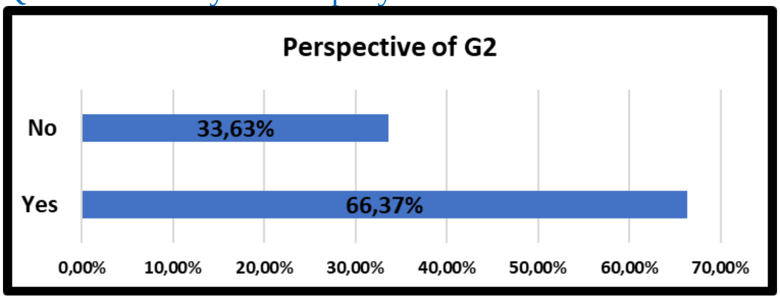
Question: In your company, is there a specific policy for reviewing and revising the SEEMP for each ship? Is it implemented appropriately?



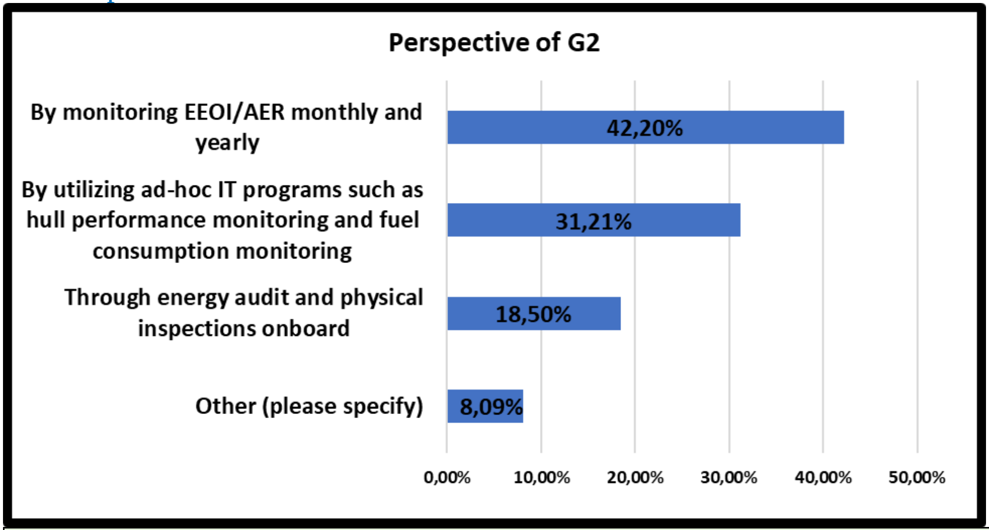
Question: Is your company implementing a ship energy audit scheme based on a time schedule?



Question: Does your company conduct an annual review of its energy management system?



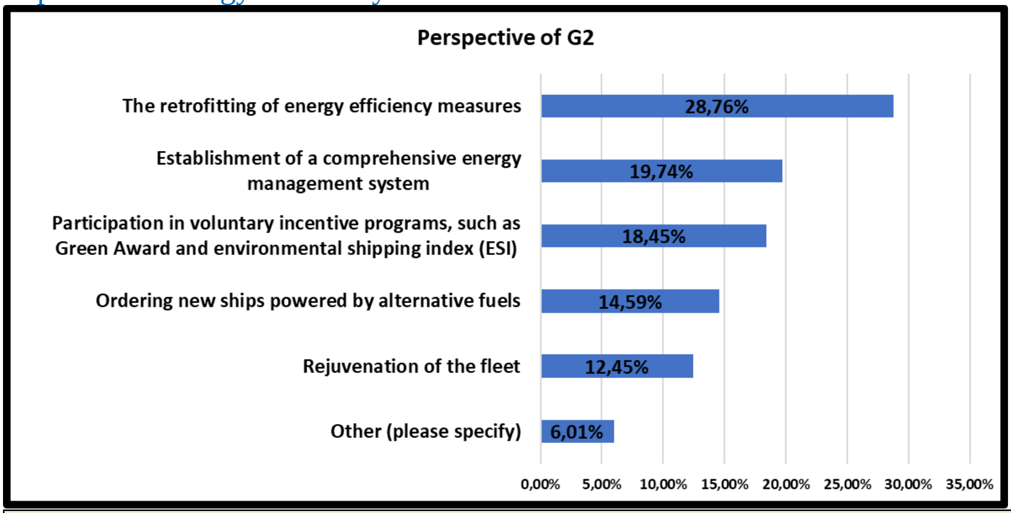
Question: How does your company evaluate the effectiveness of SEEMP implementation for each ship?



Other approaches specified by respondents:

- Comparing with the results of similar vessels in our fleet and trying to benchmark the vessel's performance against equivalent vessels of the global fleet.
- Real time engine room and navigation monitoring Software
- Own indicator and uniform monitoring dashboard

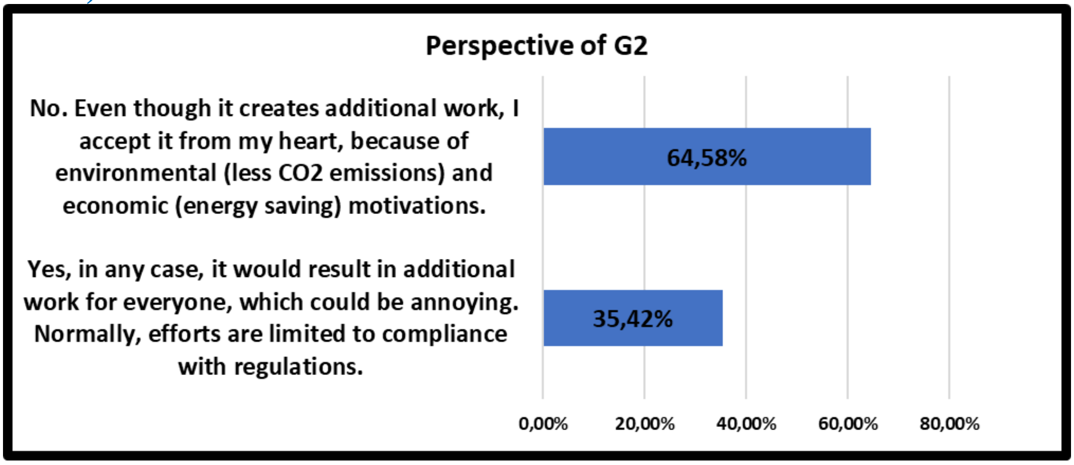
Question: Apart from compliance, what policies does your company follow in order to improve the energy efficiency of its fleet?



Other approaches specified by respondents:

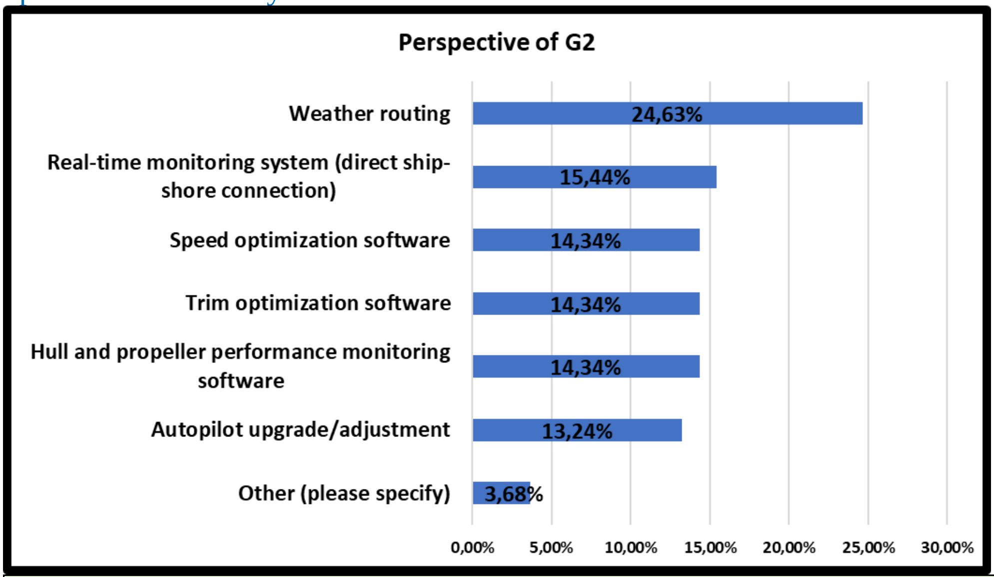
- Participation in green corridor projects
- ISO 50001 and 140001 certifications
- Running tests with biofuel across our fleet

Question: Do you consider energy management and its associated workload (onboard and ashore) as an additional burden?



3.3.4 Energy efficiency measures

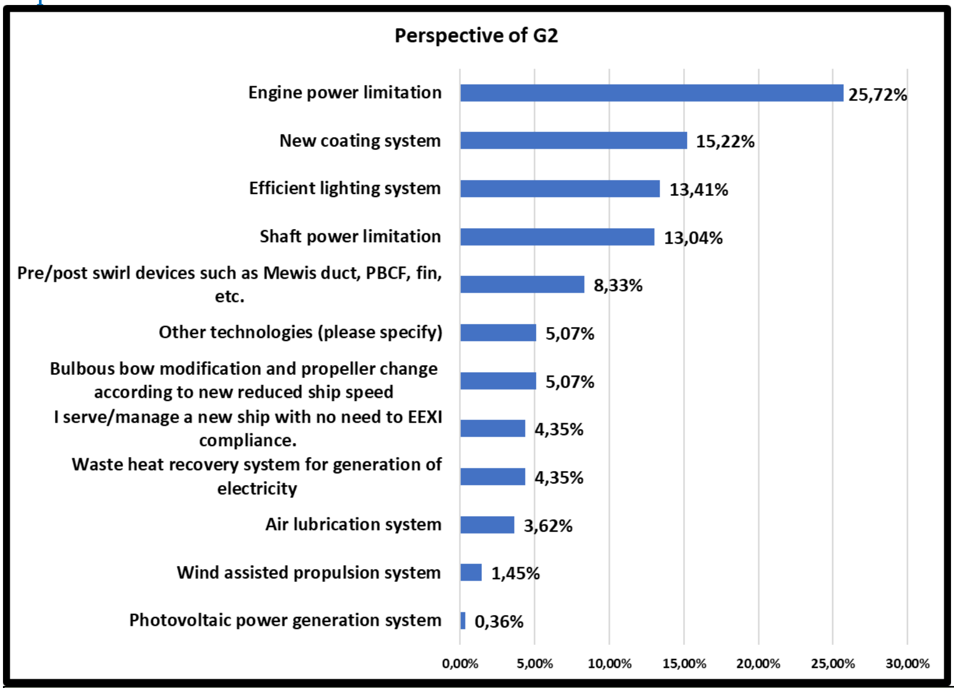
Question: What operational software do you use onboard your ship(s) and at shore to improve operational efficiency?



Other software used specified by respondents:

- Realtime engine performance monitoring and guidance
- In house Shore Power Management System
- Speed /Consumption trend graphs, warning and alert system against set baselines
- Machinery Health Monitoring
- Torque measurement

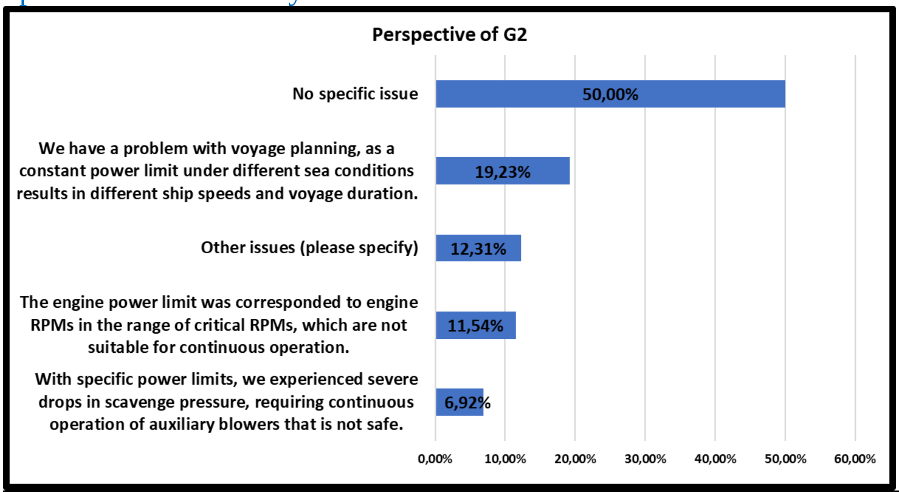
Question: Which measures were implemented on your ship to comply with the EEXI requirements?



Other technologies specified by respondents:

- Shaft generator retrofit
- Battery power
- Economizer on auxiliary engines

Question: When implementing engine power limit (EPL) on your engine, what technical or operational issues did you encounter?

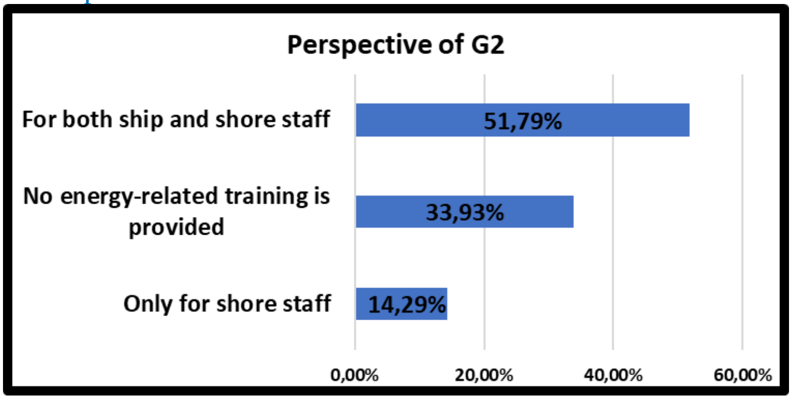


Other issues specified by respondents:

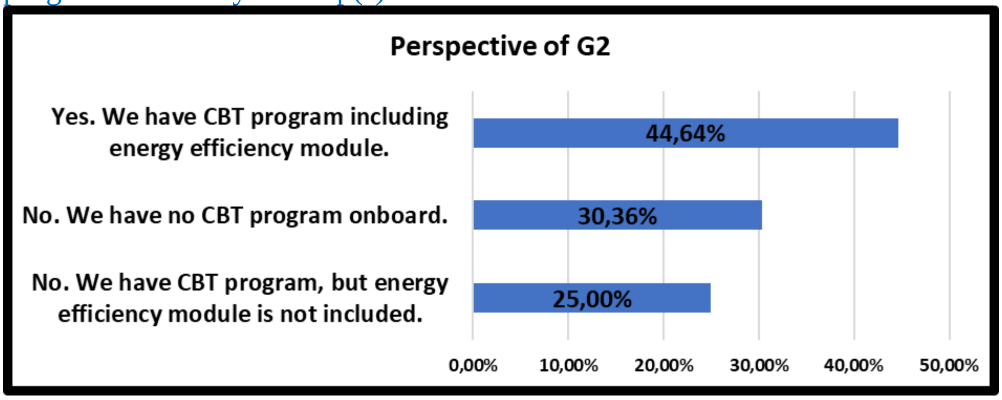
- Slow acceleration and limitation in manoeuvring characteristics: The acceleration is needed in the harbour manoeuvring that must be instantly achieved. With EEXI limits sometimes it is not possible.
- Difficulties in performing the routine cleaning of compressors, which has led to increased carbon build-up in the main engine cylinders.
- Manoeuvring in shallow water passages (e.g., rivers) requires a high level of power, sometimes exceeding the EPL.
- As a result of rough weather, the vessel is unable to meet the charterer's speed requirements due to power limitations

3.3.5 Human element and training

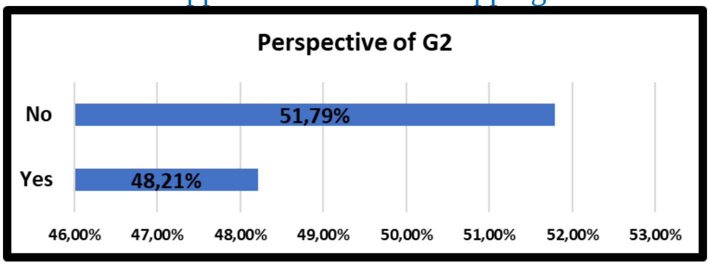
Question: Does your company provide necessary energy-related training to seafarers and shore-based personnel?



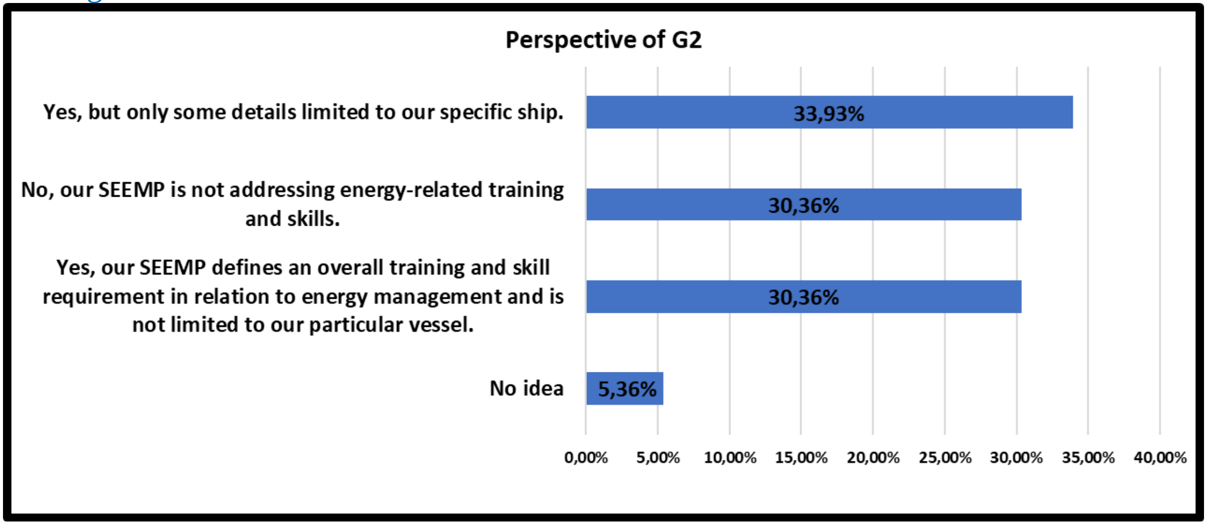
Question: Is an energy efficiency module included in the CBT (computer-based training) program onboard your ship(s)?



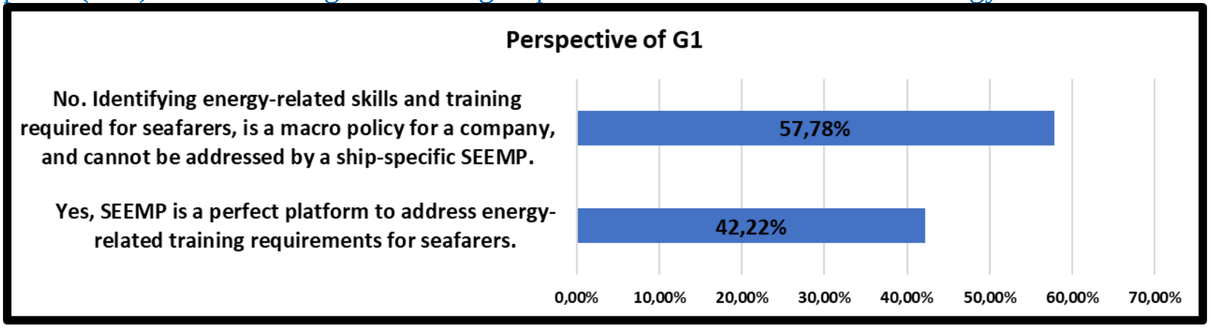
Question: Do you believe seafarers in your company are familiar with e-learning courses on energy efficiency management on board, such as those developed by IMO's Global Industry Alliance to Support Low Carbon Shipping?



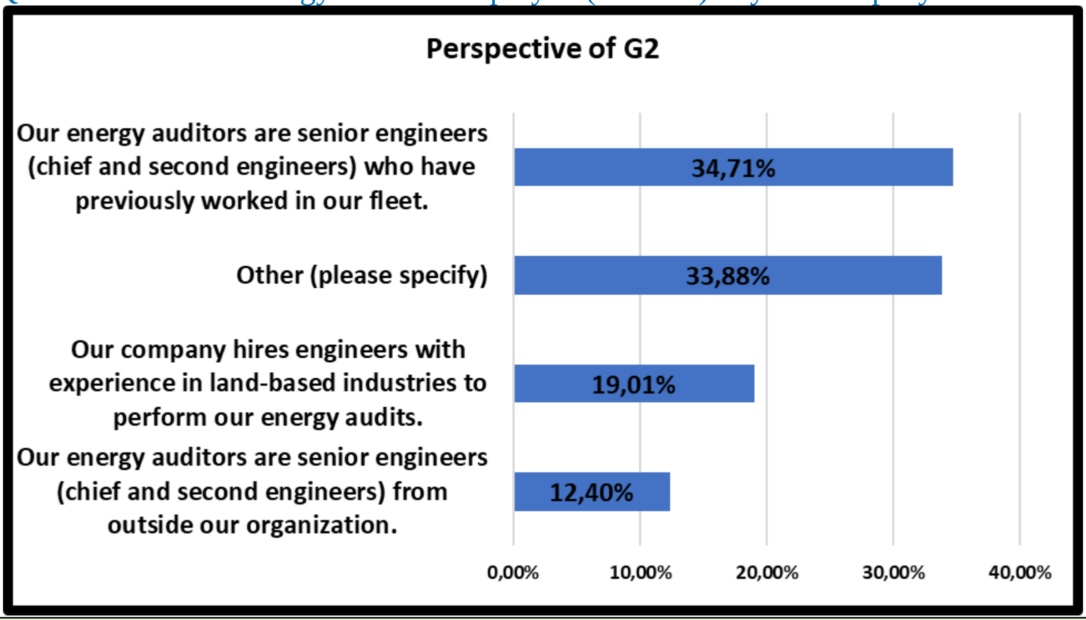
Question: Does the SEEMP manual of your ship place enough emphasis on energy-related training and skills?



Question: Are you of the opinion that SEEMP, which is a ship-specific plan, can be a proper place (tool) for addressing the training requirements of seafarers in the energy eld?



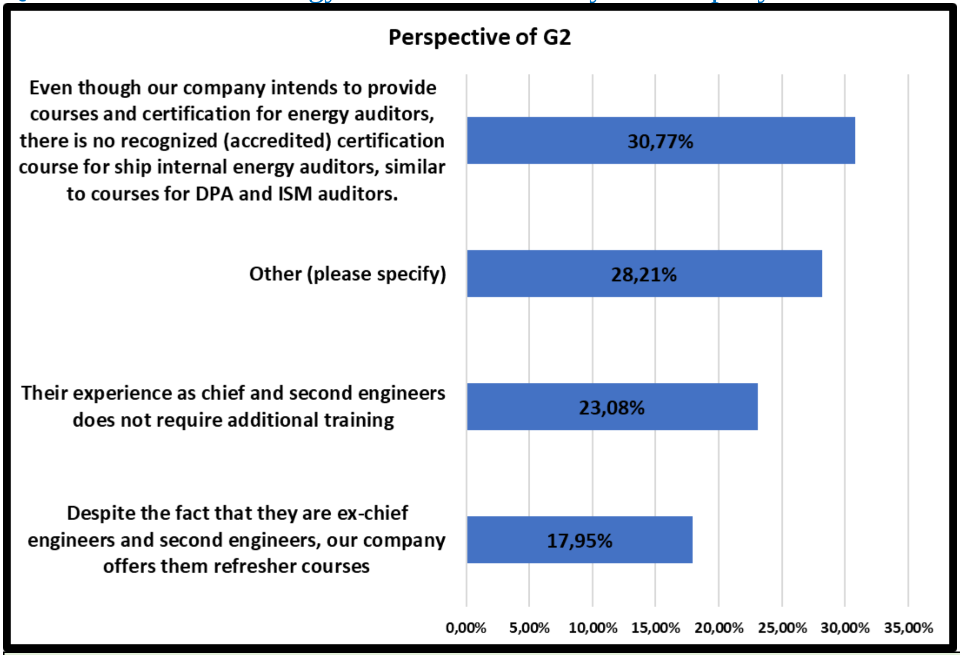
Question: How are energy auditors employed (selected) in your company?



Other approach specified by respondents:

- The majority of responses indicate that they do not have an energy auditor

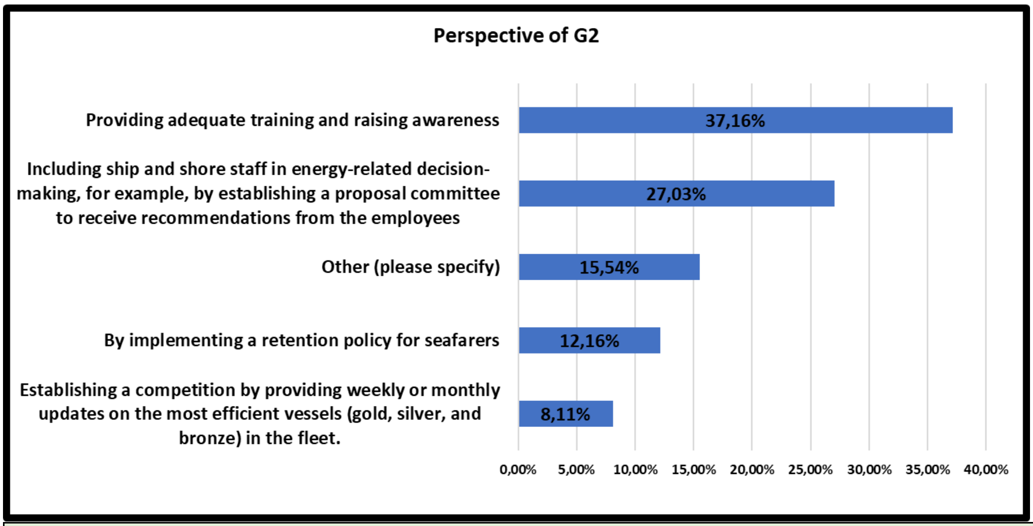
Question: How are energy auditors trained in your company?



Other approaches specified by respondents:

- Training in ISO14001 and ISO50001
- Training is provided by third party shipping experts
- External training provided by class societies and other training institutions
- We use external auditors
- We recommend WMU & IMO to provide professional licensing programs to certify the marine energy auditors in order to have universal accepted standards

Question: What are your company's actions to motivate seafarers to operate in a more energy-efficient manner?



Other actions specified by respondents:

- There are no such motivating actions
- Updating senior officers on their vessel's energy/environmental performance by way of weekly CII-related reports.
- End of contract bonus
- Sharing of best fuel saving practices, and quarterly performance review
- Raising awareness during crew seminars

3.3.6 Role of other stakeholders

Question: What is the significance of the following roles in shipping's energy transition?

Perspective of G3:

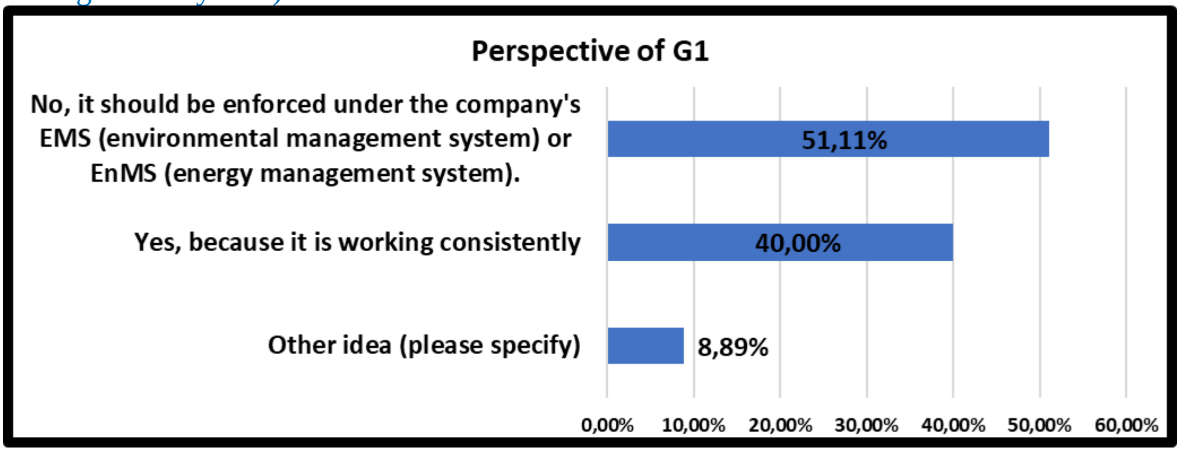
Statement	Not at all important	Slightly important	Moderately important	Very important	Extremely important	Overall
Role of cargo-owners in collaboration with charterers through platforms like "Clean Cargo Working Group" to reflect the vessels' carbon footprint in the tendering process	1 1.85%	10 18.52%	16 29.63%	19 35.19%	8 14.81%	54 100%
Role of charterers in adoption of smart contracts and longer charter parties to resolve the split incentive problem between shipowners and themselves	0 0%	8 14.81%	14 25.93%	23 42.59%	9 16.67%	54 100%
Role of NGOs in promoting green shipping and smart contracts	5 9.26%	15 27.78%	20 37.04%	10 18.52%	4 7.41%	54 100%
Role of maritime education and training institutes (METIs) in training and preparing seafarers to handle new technologies and alternative fuels	2 3.7%	5 9.26%	12 22.22%	12 22.22%	23 42.59%	54 100%
Role of technology providers in improving the reliability and maturity of advanced technologies at a reasonable and competitive price	2 3.7%	1 1.85%	7 12.96%	24 44.44%	20 37.04%	54 100%

Min Max

Question	Count	Score	Not at all important	Slightly important	Moderately important	Very important	Extremely important
Role of cargo-owners in collaboration with charterers through platforms like "Clean Cargo Working Group" to reflect the vessels' carbon footprint in the tendering process	54	3.43					
Role of charterers in adoption of smart contracts and longer charter parties to resolve the split incentive problem between shipowners and themselves	54	3.61					
Role of NGOs in promoting green shipping and smart contracts	54	2.87					
Role of maritime education and training institutes (METIs) in training and preparing seafarers to handle new technologies and alternative fuels	54	3.91					
Role of technology providers in improving the reliability and maturity of advanced technologies at a reasonable and competitive price	54	4.09					
Average		3.58					

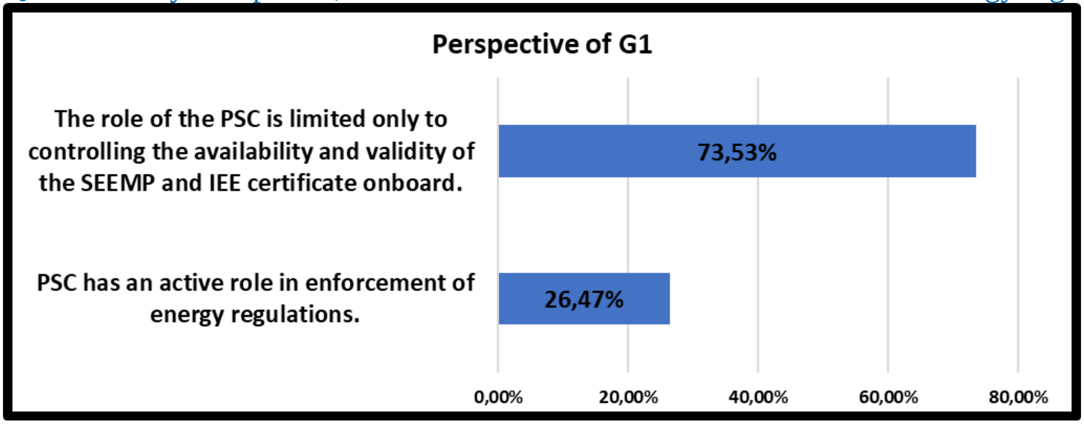
3.3.7 SEEMP enforcement

Question: In your opinion, should SEEMP still be enforced as a subsidiary of SMS (Safety Management System) and ISM code?

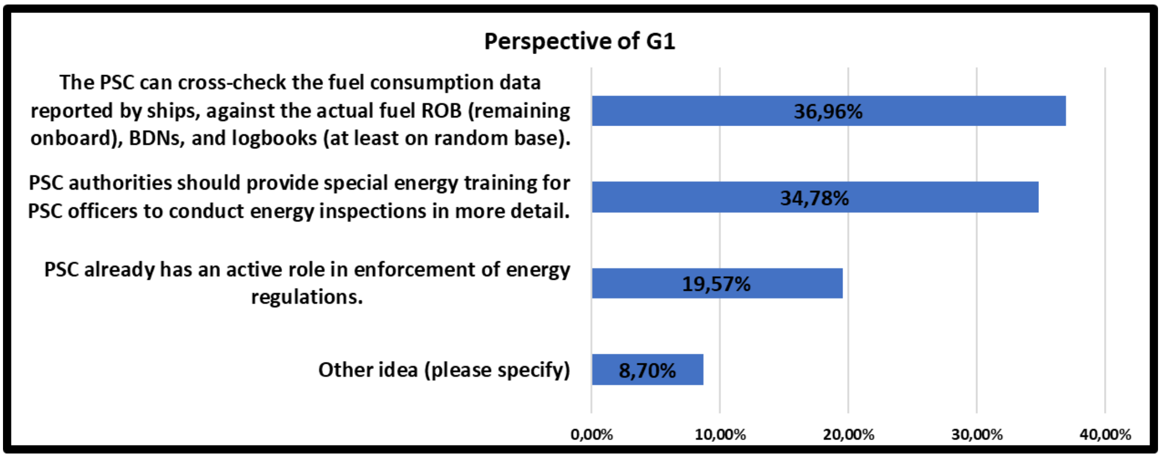


Other idea:
- Most shipping companies implement Integrated Management Systems combining SMS, EMS, QMS, etc. SEEMP should be part of company IMS.
- It should be enforced under a mandatory Code from MARPOL (ship energy efficiency Code)
- Obligatory enforcement of ISO 50001, considering the SEEMP as part of its procedures, not subsidiary of ISM.

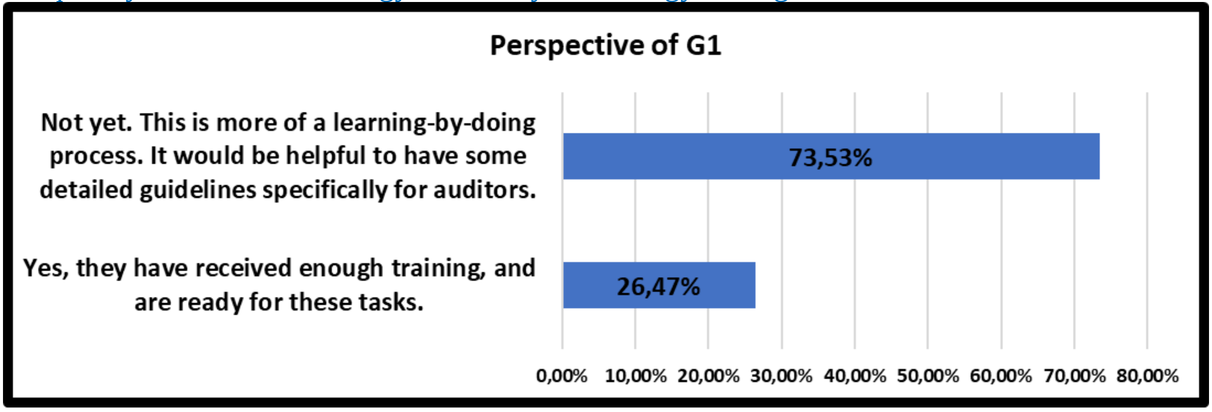
Question: In your opinion, how is the role of the PSC in enforcement of energy regulations?



Question: If you believe that the PSC's role is limited only to controlling the availability and validity of the SEEMP and IEE certificate onboard, what is your recommendation to entrust a more active role to the PSC?



Question: Do you believe that the auditors/surveyors working for ag administrations/ROs who are responsible for implementing and auditing SEEMP (and hereinafter correction plans) are adequately familiar with energy efficiency and energy management?



4. SEEMP Part II: Data Collection and Verification Mechanism

4.1 Background

As of 2019, in accordance with IMO DCS requirements, ships of 5,000 GT and above must carry SEEMP Part II onboard in conjunction with a certificate of compliance (CoC). The ships subject to the IMO DCS are required to develop a ship fuel oil consumption data collection plan (SEEMP Part II) and the plan should be confirmed by the Administration or an RO. Throughout this research, we aim to shed light on different aspects of the data collection and verification process in order to provide insight into issues that shipboard and shoreside personnel, as well as data verifiers, encounter. As a first step, a brief literature review will be presented. A summary of the results of the online survey is then provided. In the online survey, questions were asked concerning the reliability of the data collected, the methods for monitoring and reporting onboard, and the administrative burden on both shore and ship staff. Finally, we will present the aggregated results of our interviews with verifiers. In order to gain a deeper understanding of the data collection and verification process, verification teams from 10 classification societies were interviewed.

4.2 Literature review

The monitoring process is an integral part of any management system. Despite being a subsidiary of the control stage in a plan-do-control-act (PDCA) cycle, monitoring can be regarded as the eye of a management system. In addition to providing greater transparency, effective monitoring can also result in a greater sense of responsibility for the relevant stakeholders, which will encourage them to improve their performance (Masodzadeh et al., 2024). In the context of shipping industry, every individual ship must report their annual fuel consumption and/or carbon emissions to the legal authorities. The results are then verified to determine whether the ship is in compliance with regulations or if some action needs to be taken in the future (Castells-Sanabra et al., 2020). Four methods have been proposed for monitoring on board: (1) using bunker fuel delivery note (BDN), (2) bunker fuel tank monitoring, (3) Flow meters for applicable combustion processes and (4) Direct CO_2 emissions measurements (Deane et al., 2019). It is noteworthy that the latter is currently not required by MARPOL Annex VI and is not recognized as a valid method for collecting data on annual fuel oil consumption in the SEEMP Guidelines.

MRV requirements are set by two regulatory bodies, the European Union (EU MRV) and the International Maritime Organization (IMO DCS). The IMO DCS is a global MRV scheme and the collected data is stored in the IMO ship fuel oil consumption database. The collected data are analysed and used to develop future regulations and policies (Castells-Sanabra et al., 2020). EU MRV, however, is a regional data collection mechanism for voyages to and from EU ports and between EU ports. Establishment of EU MRV has been a prerequisite for the inclusion of the shipping industry in the EU ETS (Adamowicz, 2022). A comparison between the IMO DCS and the EU MRV is provided in Table 1.

Table 1: A comparison between IMO DCS and EU MRV
Source: Consolidated results of (LR, 2017), (Castells-Sanabra et al., 2020), and (IMO, 2022c)

	EU MRV for CO_2 emissions	IMO DCS for fuel oil consumption
Entry into force	1 July 2015	1 March 2018
First monitoring period	Calendar year 2018	Calendar year 2019
Applies to	Ships of 5,000 GT and above on commercial voyages to/from EU ports, and between EU ports	Ships of 5,000 GT and above on international voyages
Procedure	Monitoring plan	Data collection plan (SEEMP Part II)
To be included in the reported data[1]	- Fuel consumption (port/sea) - Cargo monitoring - Distance travelled - Time at sea and in port - Transport work (actual cargo carried) - CO_2 emissions calculated/tabulated - Port of departure/arrival	- Fuel consumption - Design deadweight used as cargo proxy - Distance travelled - Hours underway
Reports to	European Commission (EC)	Flag state (or authorized organization)
Verification	Third-party independent accredited verifier materiality level of 5%	Flag state (or authorized organization) materiality level of 5% (2022 resolution)
Disclosure	Public	Parties to MARPOL Annex VI
Reporting platform	EU THETIS MRV	No unique reporting platform for shipowners. Data is reported by administrations on the GISIS platform

[1] It is noteworthy that additional reporting parameters for DCS were adopted by resolutions MEPC.362(79) and MEPC.385(81). Reporting parameters are described in appendix IX of MARPOL Annex VI.

Disclosure of ship energy consumption and performance through a transparent mechanism can exert responsibility, commitment, and regulatory pressure on ship operators to mitigate their carbon footprint. According to Deane et al. (2019), “a robust and effective data collection system is an essential introductory measure in order to achieve the GHG emissions reduction target established by the Initial IMO Strategy and in framing a more ambitious emissions reduction target subsequently”. In their study, Deane et al. (2019) relate transparency to accountability and explore how IMO DCS and EU MRV have been successful in raising accountability levels through increased transparency. They conclude that “while the EU MRV system facilitates both internal and external transparency, and facilitates answerability, the IMO DCS primarily promotes internal transparency, with limited opportunities for external transparency, and ultimately lacks the arrangements needed to promote meaningful answerability”. It is noteworthy that MEPC 81 adopted amendments to regulation 27 of MARPOL Annex VI entering into force in August 2025 allowing the Secretary-General of IMO, on an ad-hoc basis, to share data with analytical consultancies and research entities, under strict confidentiality rules, and allowing shipping companies to choose to disclose the fuel oil consumption reports of their ships in a non-anonymized form to the general public.

Considering the accountability created by sufficient transparency, the role of monitoring, reporting, and verification of ship emissions has been proposed as a measure to reduce GHG emissions in the shipping industry (Castells-Sanabra et al., 2020). Therefore, the importance of the accuracy and discernment of the energy performance indicator, in this case the CII, becomes evident. It is critical to note that the accuracy of this indicator (CII) is primarily dependent on the quality of the data fed into it. But how reliable are the yearly reported data, and what are the challenges associated with the collection and verification of such data? In order to answer this question, we consider the following list of issues related to data collection and verification.

a) Parallel work and high administrative burden
   There are two systems of data collection, namely IMO DCS and EU MRV[2], operating in parallel. Even though both systems adhere to similar objectives and requirements, they have posed some confusion and administrative challenges to ship owners (Boviatsis & Tselentis, 2019; ICOMIA, 2019). Additionally, due to the lack of a unified and strict standard in the verification process, different verifiers have different requirements.

[2] Also the UK MRV

On pre-arrival, ports require ship staff to transmit voyage data to the port authorities. Furthermore, ship staff must report voyage data to shore management. In addition, various logbooks are required to be filled out on board. Together with shore management and the IT department, the crew of the ship should identify and correct any data gaps before submitting the annual dataset to the verifiers. As a final step, the ship and shore staff should correct any data errors observed by their verifier (Masodzadeh et al., 2024).

b) Possibility of data manipulation

Various reasons may lead to the ship's operational data being reported incorrectly at different levels. Often, ship crews report higher fuel consumption in noon reports in order to maintain a reserve of fuel onboard for unforeseen circumstances, or to sell it on the black market (Faber et al., 2012; Poulsen & Johnson, 2016). In order to avoid the charterer's performance claims, it is possible for the manager of a time-chartered vessel to instruct ship staff to underreport fuel consumption on a daily basis (Poulsen & Johnson, 2016). Additionally, data collected at shipping companies could be manipulated before being sent to the flag state and verifiers.

In both the IMO DCS and the EU MRV, ship operators are required to report their operational data annually. A data collection period of one year is a relatively long timeframe, which may provide sufficient time for data cleaning and adjustment. In this long period of time, carbon leakage could increase as a result of fuel smuggling and unreported or underreported bunkering operations. When this occurs, ship fuel consumption may be higher than what is reported annually. With the implementation of the current CII calculation and rating, as well as the inclusion of shipping in the EU ETS, this risk may be exacerbated. Because, the fuel consumption and CII rating of ships may have implications on the hiring status of vessels and charter parties, as well as the additional allowances ship operators must purchase under the EU ETS (Ghaforian M., 2024). It is noteworthy that MEPC 81 requested the IMO Secretariat to conduct a review of the suitability of the IMO DCS for the implementation and enforcement of current and future IMO GHG reduction measures.

c) Data verification quality

Statistical noise and errors are unavoidable in yearly reported data, which require extensive efforts to filter, verify, and process these data (Masodzadeh et al., 2022a). All this manpower should be utilized by the verifiers only during the verification season, which lasts for two months only (April to the end of May). Furthermore, due to the lack of a unified and strict standard in the verification process (Deane et al., 2019), the quality of data verification by different verifiers is not equal. As a result, ship operators switch between verifiers to choose the one that is most convenient for them. Since literature referring to these issues are scarce, this subject was discussed in detail during interviews with verifiers.

d) Data disclosure and transparency

A significant difference between the two data collection systems, the IMO DCS and the EU MRV, is the level of detail required, particularly in the definition of transport work. The IMO DCS does not recognize the efforts of ship operators in improving their cargo and voyage management since it takes into account the vessel's dead weight (Dwt) when calculating work done. Nevertheless, the EU MRV discloses actual cargo tonnage to the public. The non-disclosure of actual cargo tonnage removes any incentive to improve the loading factor of ships and to increase the overall efficiency of the transportation process. In the IMO DCS and its indicator AER, ships are considered fully loaded at all times, even when they are fully ballasted (Zhang et al., 2019). According to (ICOMIA, 2019) “the use of nominal deadweight tonnage as a proxy for the cargo carried will remove the incentives to reduce emission and improve the energy efficiency of vessels”. This issue will be discussed in detail in the next Chapter focused on SEEMP Part III.

The other issue is referring to the balance between confidentiality and transparency. It has been argued by Deane et al. (2019) that since the data in the IMO DCS is anonymized to maintain confidentiality, there is minimal external transparency, undermining opportunities for answerability associated with the data. The anonymized data could only be used for statistical purposes, and not for revising best practices in emissions reductions to raise stakeholders' awareness (Deane et al., 2019).

e) Motivating effect of data collection

In view of the fact that the ship crew changes constantly, and CII ratings are announced annually, it is not feasible to attribute verification results to individual crew members. This means that the verification results and annual CII number (rating) cannot send a meaningful signal to ship staff and operators, and stimulate them to improve their energy efficiency (Masodzadeh et al., 2022a).

f) Role of flag states

Flag states act as a link between shipping companies and verifiers. Flag states play an essential role in the quality of the verification work, whether they verify the annual data themselves or entrust it to their recognized organizations (ROs). In light of this fact, the detrimental role flag states play in data collection and verification should not be overlooked

(Masodzadeh et al., 2022a). In contrast to the EU MRV system, the IMO DCS gives flag states the authority to set data verification standards. Although the IMO has produced guidelines and suggestions for the verification standards, they are not mandatory. A result of this risk is a reduction in the transparency of the data, which raises questions about how much confidence can be placed in the data quality, either externally, by the general public, or internally by the organization itself (Deane et al., 2019).

There has always been some discussion about merging two data collection systems, the IMO DCS and the EU MRV, in order to reduce administrative burdens as well as improve data quality and transparency. For instance, according to (ICOMIA, 2019), "the IACS suggested aligning the requirements of the EU MRV regulation with the IMO DCS". Due to the absence of adequate international legal arrangements, the EU MRV entered into force in 2018. The EU was expected to phase out its MRV after the IMO DCS was implemented the following year. Nevertheless, the significant differences between the EU MRV and the IMO DCS, allow both systems to continue to operate independently (Christodoulou et al., 2021). In the future, the introduction of the mid-term IMO measures could lead to the integration of EU MRV with the IMO DCS and the maximization of uniformity in the data collection and verification process.

In reviewing literature, it is apparent that there is a lack of academic discussion focused on improving data quality, minimizing administrative burden, and increasing transparency. A mechanism of voyage-based data collection and verification has been proposed by Masodzadeh et al. (2024). In this mechanism, ship staff would report their latest voyage data to their verifiers before entering the port. Verifiers would receive voyage data, verify it, and link it to the chain of data from previous voyages. At any time, interval, the collected and verified data could be sent to the IMO database for archiving. Meanwhile, verifiers would calculate the average cumulative CII from January 1st until that point in time, which may be viewed as a live CII.

4.3 Results of interviews with data verifiers

As mentioned in the methodology section, a series of interviews were conducted with verification bodies from 10 classification societies in order to gain a better understanding of the issues involved in data collection and verification. Among the themes of the questionnaire were: challenges associated with data collection and verification, knowledge and abilities of ship operators in data collection and reporting, data reliability and authentication, relevant guidelines, quality of verification work, and data manipulation possibilities. Toward the end of the interview, interviewees were asked to make recommendations on how to simplify the verification process and improve its quality.

Below is the list of questions along with the aggregated answers of interviewees, without any reference to specific class verifiers.

- **What are the main challenges in your work (data collection and verification)?**

- Quality of the reported data (completeness of the data)

  There are still some ship operators who are not very proficient at collecting and reporting data and miss out on key information, even though many ship operators (especially those with large fleets) are equipped with vessel management systems and have a very good understanding of GHG regulations. Larger fleets generally report higher quality data than smaller fleets. According to a verifier, clients with fleets of five to seven vessels are not concerned about reporting, as it is only a small part of their daily activities.

- Data validation

  Most verifiers (interviewees) do not verify 100% of the data. Online visit of ship operators' IT system (or in person visit if possible) is recommended by the EU, however, it is not included in the IMO guidelines. It is important to note that the sampling size of data differs between various verifiers, ranging from 5% (by some verifiers for high quality reports) to 30% (by most verifiers), and even higher for more strict verifiers. According to the verifiers, the IMO does not provide clear instructions regarding sample size. Regarding authentication of data, while EU MRV encourages verifiers to crosscheck received data with AIS data, IMO does not have such a request, and hence, according to one of the interviewees, verifiers do not feel confident about voyages where EU ports are not involved (the majority (9 out of 10) of verifiers work with both EU MRV and IMO DCS). In addition, most verifiers complain about the supporting documents they request from ship operators, and too much back-and-forth conversation despite time constraints during the verification season (1st April to end of May).

- Lack of a unified standard (approach) in verification process

  There is no requirement or clarification as to how the sampling size should be selected, the key parameters to be verified, or the supporting documentation that ship operators should provide. According to a verifier, based on the quality of the data, they request details of five to ten entries from the dataset from ship operators. The need for a unified standard for data verification was unanimously agreed upon by all verifiers.

- Change of ownership or flag of a ship

  Usually, the process of handing over and retrieving data from the previous owner does not proceed smoothly, and then there is a delay in getting that data or the company has closed. There have been instances in which ships have been recycled. It takes a considerable amount of time to resolve these challenges. In particular, since CII came into force, verifiers are required to calculate CII for the full year, which is challenging without a dataset for the full year (part of the data is in the possession of the previous owner).

- Short verification period

  Although companies are required to report their annual data between January and March, the majority of the data is received towards the end of March or even later. In some cases, data reporting even occurs just before the deadline for receiving the SOC (statement of compliance). Therefore, verifiers will have a very short period of time to perform their verification.

- **What is your perception about the ship operators' knowledge relevant to data collection regulations, definitions (e.g., port of call, voyage, etc), and parameters to be reported?**

There are some operators who do an excellent bookkeeping because they have a dedicated environmental (or energy management) department to deal with reporting requirements. However, there are still some operators who are unaware of requirements. If the data collection and reporting tasks are assigned to experts within shipping companies, the results are generally much better than when ship staff perform this task with the perception that this task is an additional burden on top of their workload. In the latter case, they are not interested in understanding the regulatory requirements regarding the collection and reporting of data. As an example, in accordance with the definition, operators are expected to report fuel consumption and distance once the vessel leaves the berth and once the vessel returns to the berth. However, what the clients typically record is from the start of the sea passage until the end of the sea passage, and they fail to record a few distances from the berth to the start of the sea passage and then from the end of the sea passage to the berth. Before the implementation of the CII calculation in 2023, no one paid attention to such data deficiencies. However, since distance is a very key player in the CII metric, they started reporting all these missing distance data this year, even with exaggeration. In general, although there is still a lack of knowledge, operators' understanding of data collection and reporting is improving. Another verifier correlated the growth of knowledge in operators with monetary motivations and regulatory pressure with the emergence of CII rating and its effect on charter parties and vessel hiring.

In an effort to enhance the knowledge and understanding of ship operators, one of the class verifiers explained the online training programs they have been offering since 2019. In this course, more than 400 ship and shore staff have been trained, but their main challenge is the continual change of personnel in companies, which forces them to conduct such courses repeatedly.

According to some verifiers, ship operators engaged in trade with EU ports and, as a result, involved in EU MRV, have a better understanding of the regulations than other operators. However, an interviewee also pointed out the confusion created for some ship operators due to compliance with both EU MRV and IMO DCS.

- **Are ship operators able to do the needful corrections in dataset after you find and report the data gap to them?**

According to verifiers, it differs among ship operators, and there is a correlation between the knowledge of the ship operators and the time it takes to resolve the data gap. In some cases, they are able to solve the issue in a timely manner, but in many cases, it requires a great deal of back-and-forth communication. The majority of errors that occur in the case of manual entry of data are typos that can be easily detected and corrected, however, there are also systematic errors, for example, across several vessels of a fleet. It is here that verifiers encounter challenges due to time constraints, in particular when ship operators report their data close to the end of March, when there is a deadline for reporting.

In addition, there is a great deal of discussion regarding some operational modes such as drifting and very slow streaming, whereby verifiers see distances reported by operators while AIS shows speeds that are close to zero. In order to avoid such discussions, some verifiers accept reports of drift mode.

Meanwhile, some verifiers have developed a system that allows operators to upload their data continuously throughout the year. In this way, operators don't have to upload the data to verifiers on the year end; as a result, they can benefit from automatic data checks. It is possible that the majority of data errors have already been detected automatically, and operators will be able to follow up on it. Due to this, operators receive quite good feedback continuously and are able to take action on it throughout the year.

- **Are you receiving data in different format or it is a unique and standard format?**

It is typical for verifiers to develop their own format based on the IMO template provided in resolutions MEPC.346(78) and MEPC.348(78), and then share it with their clients and request them to use the same format for data reporting. Some operators follow this format, but others have their own format and ask if it is acceptable to verifiers. It is noteworthy that most verifiers do not (cannot) force ship operators to follow the verifier's format, and since the operators' format contains all the data required, verifiers accept it. However, some verifiers insist on their own format and force their clients to adhere to it. This problem has diminished over time, but it can still be observed particularly for clients switching from one verifier to another.

- **How is the level of noise and bugs in the data collected?**

It depends on the amount of effort ship operators devote to the generation of data. In the opinion of a verifier, the reported data, the output of an advanced IT system in a specialized department of a shipping company, is clearly distinguishable from data reported directly and manually from ships. Human error can be observed when a chief engineer or first mate is responsible for filling out forms. Obviously, they are also very busy and may not have the time to carefully record and submit the data. Some verifiers may request two decimals for some parameters and request ship operators to report the actual numbers without rounding.

Generally, verifiers desire to receive data from automated IT systems with the least amount of human input. Consequently, before the report is sent to the vessel's verifiers, it is passed through the quality office for pre-checking. Therefore, the quality of those reports is very high. This method of reporting saves time and makes it easier for staff to prevent errors. Obviously, this depends on the knowledge of the crew on board and staff on shore.

There are some cases in which crew members have difficulty defining the fuel oil type in their reports. In general, bunker suppliers do not provide sufficient information in the issued BDN regarding the fuel grade in accordance with ISO 8217. As an example, different grades of low sulphur fuel have different carbon emission factors, which are not known to ship operators.

- **What percentage of tolerance limit do you set in your verification work, in terms of "feasibility concept of materiality"? (How much data gap (%) is acceptable compared to total aggregated data?)**

Verifiers generally stated that the IMO does not provide instructions regarding the feasibility concept of materiality, and that they follow the EU recommendation, which suggests a materiality of 5%. Only two verifiers stated that recently IMO also has aligned its guideline with the EU in this matter, and highlighted a materiality of 5% in resolution MEPC.348(78) paragraph 6.3. One of the verifiers emphasized that they consider a materiality of 5% for uncorrectable data errors, and if they find correctable data issues, they will attempt to rectify it and reduce the materiality even less than 5%.

- **What tools you have in hand to authenticate the validity of the reported data?**

A number of verification tools were highlighted by various verifiers as a means of authenticating the validity of the data reported. Below is a list of these tools:

- Experience and knowhow of verifiers in primary high level logic checks
- Noon reports
- BDNs
- AIS database
- Voyage (arrival/departure) reports including start of sea passage and end of sea passage
- Copy of some pages of engine and bridge logbooks and oil record book
- Specialized software (e.g., Storm Geo)
- Theoretical model built by verifiers to estimate consumption, average speed, and some other parameters
- Email conversation between ship and port
- Bill of lading or cargo manifest, if operators disclose it; otherwise order document or order confirmation, or voyage cargo information signed by Master

The best way to obtain a true representation of the overall fuel consumption is to refer to the longest voyages, the longest distances travelled, or the longest time spent en route. Additionally, verifiers control sample BDNs to assess fuel consumption. They can also cross-check the distance, position, and speed data submitted by the client against the AIS data. When discrepancies are discovered, clients are requested to provide their supporting documents or some explanation. According to the verifiers, the IMO does not recommend a sample size, whereas the EU recommends 30%, but that also is not strictly followed, and the final decision is based on the verifiers' experience. A verifier, for instance, suggests that they collect samples from long, medium, and short voyages in order to obtain an overall assessment of ship performance.

- **What could be the number of verified ships per verifier in verification season? How much is the annual verification cost per ship?**

There were some verifiers who did not disclose these data. However, for those verifiers who disclosed these data, the number of verified ships is very variable from 25 to 75, 100, 320, and 400 ships per verifier. It is noteworthy that a verification body with more than 400 reports (ships) per verifier performs verification for more than half of its clients continuously throughout the year rather than just during the verification season of two months. A verifier, however, stated they do not count ships, but rather reports, since one ship may have two or even three reports after being transferred from one owner to another.

An annual IMO DCS verification may cost between US$ 1,000 and 1,300 per ship (report). The cost per ship could be increased by an additional fee for EU MRV verification. Several verifiers offer packages encompassing IMO DCS, EU MRV, and UK MRV with negotiable costs.

- **Is there any unified standard for verification process? Do you think such standard is necessary?**

Verifiers confirmed that there is no unique standard, and verification bodies, in the absense of such a standard, have established their internal procedure for verification. To develop their internal procedures, verification bodies usually consider ISO 14065:2020, recommended by the EU commission, recommendation No.175 suggested by IACS, and resolutions MEPC.346(78) and MEPC.348(78). In the opinion of the verifiers, implementing a global standard could improve data quality. As stated by a verifier, the absence of a standard has resulted in uncertainties regarding the sample size and the content and rigidity of the CAP (corrective action plan). Another verifier stated that the absence of such a standard has led ship operators to switch between verifiers easily, and to ask why many supporting documents were required by that verifier, but not by other verifiers. The other interviewee described cases in which data was reported to a different verifier or flag and a statement of compliance was issued within an hour, which is physically impossible.

- **Do you see any difference in the quality of verification work performed by different verification bodies (in terms of strictness in verification process)?**

The interviewees acknowledged that there is difference in the quality of verification work. In general, class verifiers believe they are performing high-quality work, primarily because they have a name and a standard to uphold. An interviewee argued that exposure to private verifiers (non-classification societies) has become limited, and most ship operators prefer an IACS verifier, mainly because ship operators believe class certification holds more value. Another possible explanation is the good relationship shipping managers have with their own classes.

According to an interviewee, the quality of verification differs even among class verifiers. In his opinion, it is all about the effort and time verification bodies invest in establishing a robust and precise verification procedure, as well as investing in their verification department by developing the necessary tools and software, and employing enough personnel.

- **Can somebody reach to a perception that a specific verification body is less strict with a motivation to be able to work with more flags and ship operators?**

The overall response of the verifiers was positive. According to interviewees, ship operators always prefer ROs that require the least supporting documents. It is one of the points they check when they make a service agreement with a verifier. As a result of linking the verification cost with the verification quality, an interviewee highlighted that those verifiers that attempt to reduce the price do not (cannot) hold high standards and quality. He added "I assume there are also some parties (verifiers) that see this as a nice way to create revenue". According to another interviewee, all verifiers desire to work with and attract more clients, however, the quality of verification should not be compromised.

- **Have you ever offered a voyage-based or daily data collection to ship operators? Has any volunteer ship operator requested for a voyage-based or daily data collection service instead of yearly data reporting?**

Most verifiers, especially those with a large number of ships, have upgraded their data platforms or created new portals (particularly from 2023) in order to receive noon reports on a daily or voyage basis. Using APIs (application programming interfaces), shipping companies are able to easily send their daily noon reports to their verifiers. A number of clients have appreciated this option, and the number of ships using this service is on the increase, particularly from 2023 when CII calculations were enforced, and from 2024 when shipping are included in the EU ETS.

Among the verifiers providing this service, some already offer a live CII to ships immediately following the submission of their latest voyage. Others only control data continuously, but provide annual CII results at the end of the year. There are others who have just begun to offer this service. These verifiers stated that with continuous data collection, ship owners will benefit from automatic data checks, and further, the verification load could be spread over a 12-month period instead of a two-month period. As well, a verifier reported that some of their clients have requested CII updates on a monthly or voyage-based basis in order to use it in charter parties (BIMCO contracts). Another interviewee suggested that data reporting could be split into two parts, for example two 6-month periods, or 9 months (April till December) and 3 months (January till March), in order to meet the deadline for the end of March.

- **EEOI or AER? What is your preference? Is actual cargo tonnage a commercially sensitive data?**

In the opinion of a verifier, the calculation and verification of AER is easier. Most of the verifiers, however, supported EEOI as a more accurate indicator of the efficiency of transportation work which is at least closer to reality.

Concerning the disclosure of cargo tonnage, verifiers pointed out that this data is already reported to the EU Thetis website for many ships. The actual cargo tonnage is disclosed only to ROs with strict confidentiality clauses, and the public has access only to cumulative and aggregated data, not voyage-specific data. Most verifiers believe that if the cargo tonnage is treated similarly to how it is treated under the EU MRV mechanism, it cannot constitute a commercially sensitive data. As per a verifier, the IMO DCS system will include voluntary reporting of actual cargo tonnage starting in January 2025, an important step toward merging IMO DCS with EU MRV to develop a unified data collection system.

- **In your opinion, is there any possibility for data manipulation by ship operators? If yes, can you raise some examples?**

In the opinion of the verifiers, ship operators did not care much about data reports prior to 2023. However, after the enforcement of CII calculations and its impact on charter parties, as well as regulatory pressure, they are striving to improve their CII rating by focusing on the CII formula. “This year they have woken up and start to look what they are really reporting” stated by a verifier. In order to increase the distance travelled in the denominator of the CII formula, ship operators attempt to report each and every movement. The overreporting of distances by 5% cannot be easily verified, according to a verifier. Even some efforts to change the ship deadweight also have been observed by a verifier. In addition, the possibility of underreporting of fuel consumption and missing or underreported BDNs was not ruled out by the verifiers. In general, interviewees argue that there is always the possibility of data manipulation. “If someone is cheating really well, then most probably he can cheat any verifier" stated by a verifier.

By referring to CII correction factors, which are associated with emergency, some verifiers highlight the possibility of data manipulation. Specifically, a verifier emphasized that in emergency situations involving safety issues, where correction factors are considered, regulators must provide detailed clarification to answer such questions as: how much fuel consumption should be deducted during emergency situations? What is the duration of the emergency? Does the deduction also apply to repairs made after an emergency? And how do other verifiers handle these situations?

- **Can you imagine the voyage data (required for CII calculations) to be included as part of single window environment?**

First, the concept of a single window environment was explained to interviewees, and then they were asked about the feasibility of incorporating voyage data into this mechanism. According to this recommendation, ships at prearrival ports are required to report the required data in a standard format under a single window environment. Voyage data required for CII calculation could be part of this report, including time en route, distance en route, consumption en route, cargo tonnage, and probably fuel ROB on arrival and departure ports.

Most of the verifiers who embraced this recommendation stated that any record at ports could be used as valuable evidence to cross-check the reported data in the future. However, this data must be archived in a well-established IT platform in ports, it should become part of regulations, and ports must be convinced to disclose this data in the request of verifiers. It is expected that this proposal will have a very high deterrent effect against data manipulation. While noon report is evidence for 24 hours, this record at ports through single window environment could be good evidence for a voyage.

- **What are your recommendations for improving the data collection and verification process?**

- It is difficult and sometimes impossible to retrieve data from a previous owner. Despite the fact that all ROs have access to the IMO database, an interviewee was unsure whether they could use previous data from the previous RO to calculate the yearly CII for a ship whose owner or flag had recently changed. The verifier requested clarification regarding such regulatory details. The other verifier emphasized that if data exchange between verifiers in

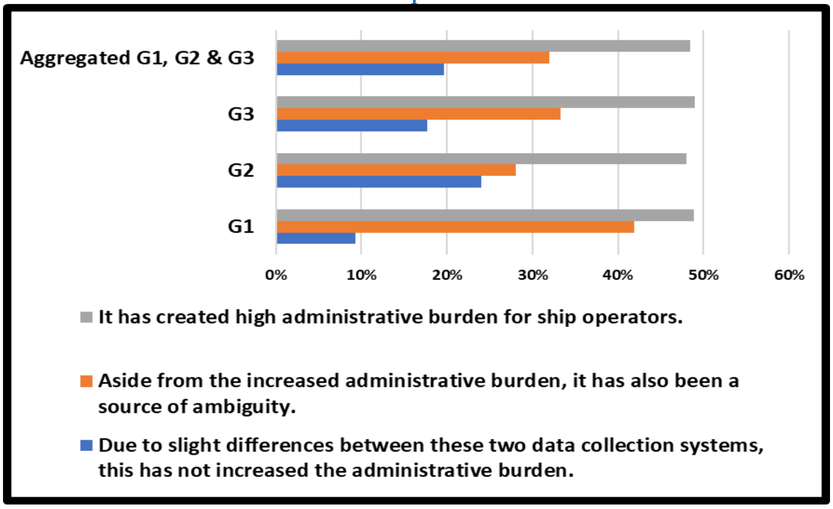
GISIS becomes legalized and facilitated, in the end it will be beneficial for clients as well, because they will not have to worry about taking this data from the other manager or looking for a data gap and so on.

- A recommendation was that in the GISIS platform enough details demonstrating the history of attained CII and CII rating of vessels to be provided. When ships switch between verifiers, these data are extremely important.
- A recommendation was to increase the level of automation and digitalization in data collection, transfer, and processing in order to minimize errors and administrative burdens.
- In order to avoid confusion among ship operators and minimize administrative burden on ship and shore staff, as well as verifiers, it was recommended that current data collection mechanisms (EU MRV and IMO DCS) be merged to create a global and unified data collection system.
- According to some verifiers, the current CII formula is not a fair indicator for certain types of vessels, such as bunker vessels, as well as for vessels engaged in short voyages. They recommended that the CII formula be modified in the appropriate manner and that useful correction factors be taken into consideration for these ships.
- There were some verifiers who advocated continuous voyage-based data collection throughout the year, rather than reporting data for a year at a time.
- As a result of concerns regarding a very short verification period, it has been recommended that the verification period be extended to at least three months.
- It was recommended that ISO 8217 should clearly assign carbon emission factors to different fuel grades, especially low sulphur fuels.
- There was a recommendation to improve and equalize the quality of verification among various verifiers. An interviewee argued that verification quality is more equal in the case of MRV, because each verifier has to be accredited by accreditation bodies controlled by the EU, and EU can push accreditation bodies to ensure that the qualities is equal. According to this verifier, this mechanism does not work in the same manner at the level of the IMO.
- The majority of verifiers recommended that the verification process be made more uniform. They advocated a unified and more rigid standard that included clear instructions for various verification procedures.
- There was a recommendation to consider a penalty for ships that fail to submit by 31 March, the regulatory deadline.

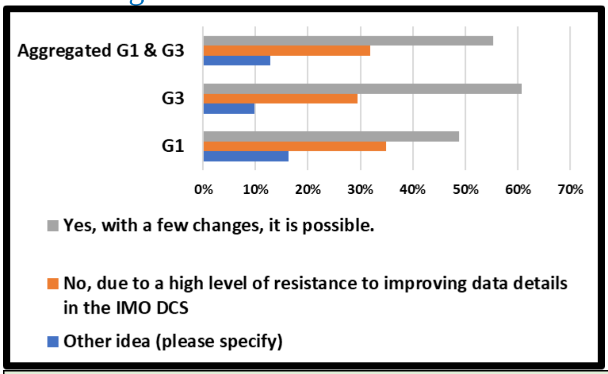
4.4 Results of online survey

4.4.1 Data collection mechanism, administrative burden, and reliability of data

Question: What is your idea regarding ship operators' compliance with both the IMO DCS and the EU MRV data collection requirements at the same time?



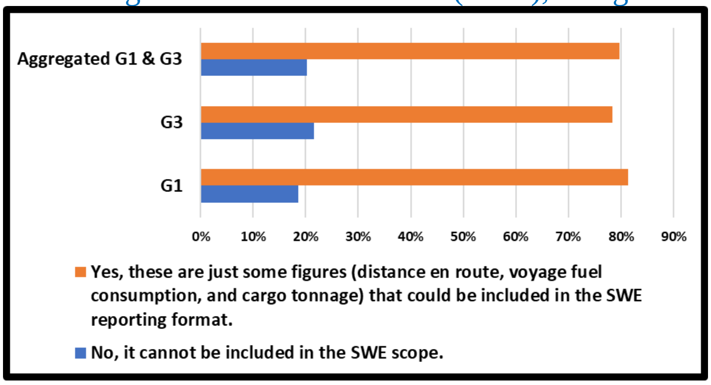
Question: Can you imagine that the EU MRV will be aligned with the IMO DCS in near future to form a global standard mechanism for data collection?



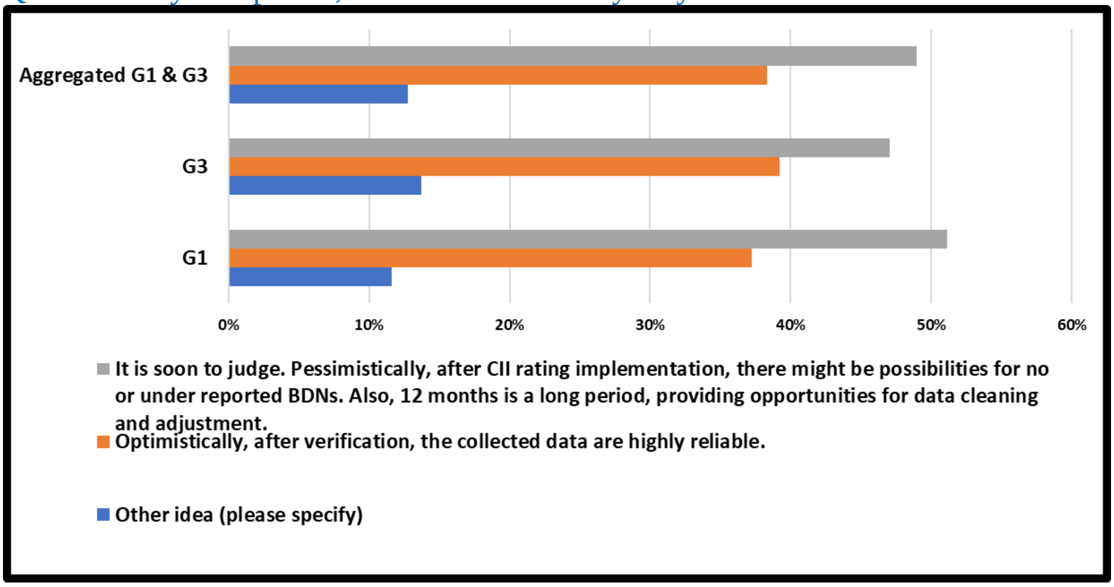
Other ideas specified by respondents:

- There should be a common reporting system (i.e., platform), not just common reporting format.
- We need global GHG regulation. If other regions/countries adopt similar GHG regs to EU/MRV, it will lead to a high level of bureaucracy.
- No, due to different political agendas.

Question: Can you imagine that voyage data required for CII calculation, to become part of the future single window environment (SWE), being collected on a voyage basis?

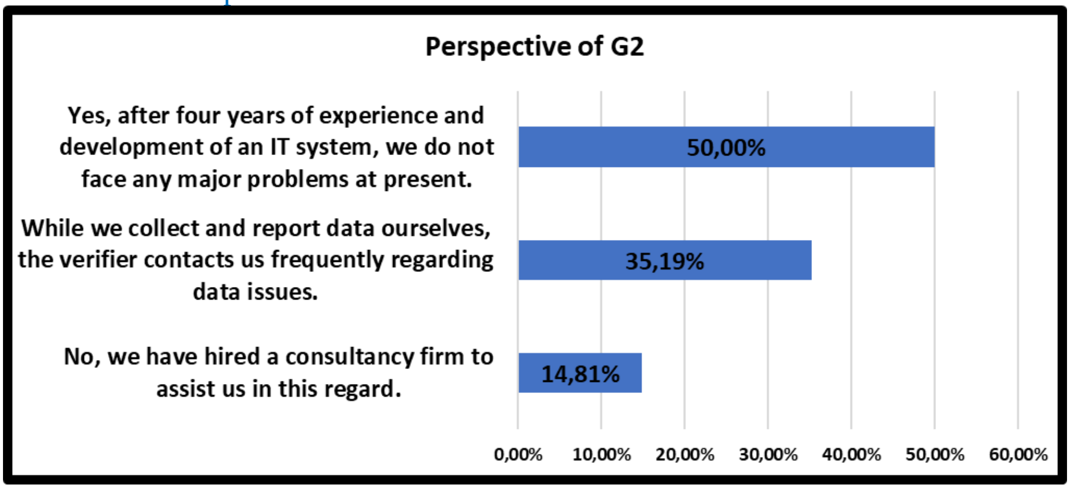


Question: In your opinion, how reliable are the yearly collected data?

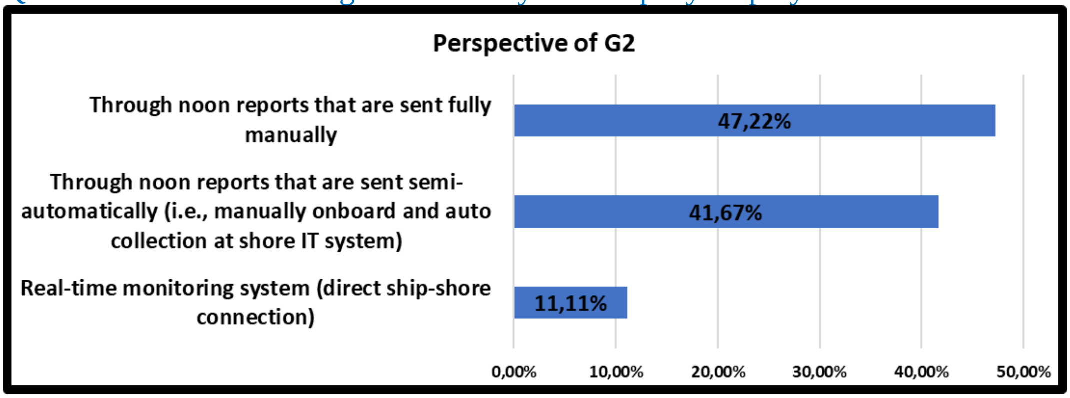


4.4.2 Data collection in shipping companies

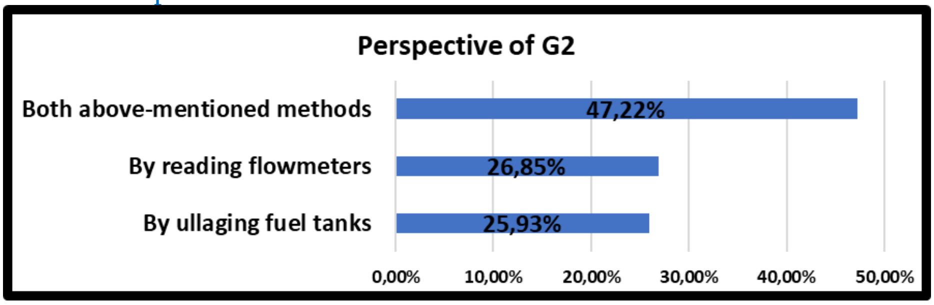
Question: Are you well-familiar with the data reporting regulations, definitions, and parameters that need to be reported?



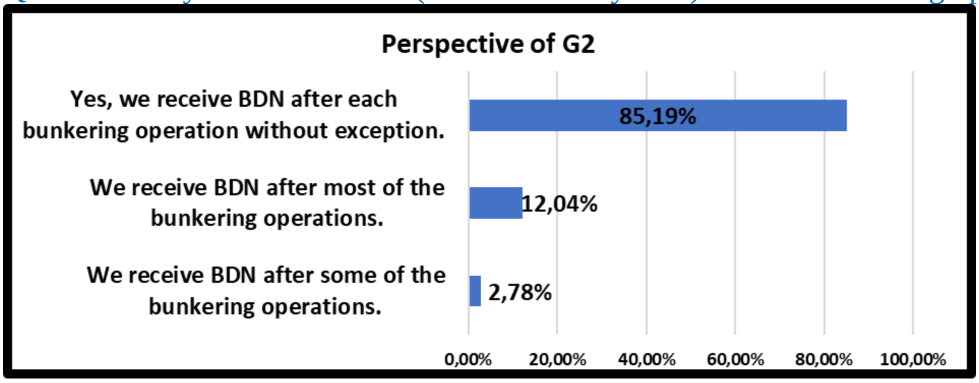
Question: What monitoring method has your company employed?



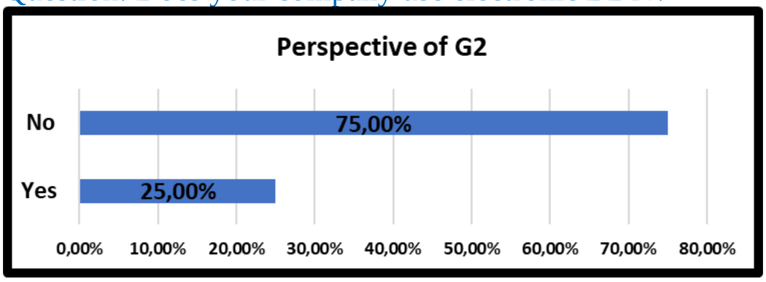
Question: How is the daily fuel consumption calculated onboard for recording in the logbook and noon report?



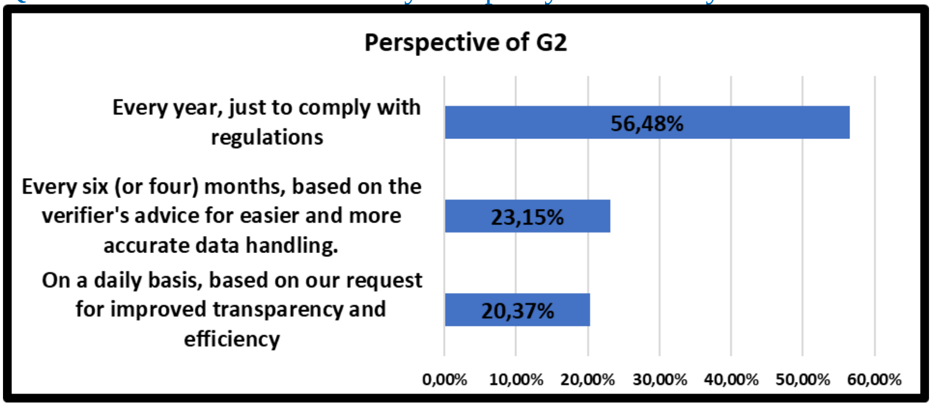
Question: Do you receive BDN (bunker delivery note) after all bunkering operations?



Question: Does your company use electronic BDN?



Question: At what intervals do you report your data to your verifier?



5. SEEMP Part III: CII Calculations and Energy Rating

5.1 Background

Since 1 January 2023, ships of 5,000 GT and above must have a verified SEEMP Part III on board together with the CoC. Beginning in 2024, the CII must be calculated and reported to the verifier in conjunction with the aggregated DCS data for the previous year. There will be a note on the DCS statement of compliance (SoC) of the CII attained as well as the environmental rating (A to E). The SoC must be kept on board for five years.

Reviewing IMO (2022a, 2022b), DNV (2023b), and LR (2023) demonstrates that SEEMP Part III should include the following document:

- the required annual operational CII for the next three years
- the target CII for the next three years
- methodology for calculating the ship's attained annual operational CII and the processes that will be used to report this value to the flag state
- an implementation plan regarding how the required annual operational CII will be achieved during the next three years with yearly targets
- a procedure for self-evaluation and improvement
- a corrective action plan in case of an inferior rating

Some classification societies provide advisory services to develop SEEMP part III (ClassNK, 2022; DNV, 2023b; LR, 2023).

This research aims to examine the uncertainty factors associated with CII calculations, as well as to investigate the acceptability of different CII versions (EEOI and AER) to various stakeholders. First, a brief literature review will be presented. Afterwards, a summary of the results of the online survey is provided.

5.2 Literature review

The monitoring system should include a perspicacious KPI with sufficient accuracy to identify poorly performing units (Lindberg et al., 2015). In the absence of such KPIs, inefficient units cannot be identified within the system, and as such, there is no motivation to improve their performance. The same is true for efficient units, which are not motivated to maintain their high performance, especially when significant investment is required. In order to accomplish a broader objective, KPIs provide detailed information on a set of variables. A ship CII, for example, is designed to measure the rate of CO_2 emissions per unit of transportation work in order to promote a greener ship operation.

An accurate ship energy efficiency indicator can have the following applications, according to Masodzadeh et al. (2022a): first, to provide feedback to ship operators in order to enable them to evaluate operational efficiency and take corrective actions where necessary. Second, charterers may use it as a reference to adjust freight rates in favour of more efficient vessels. Third, it can serve as a criterion for ship energy ratings, and could be an essential prerequisite for the implementation of the basket of IMO mid-term measures (fuel standard and economic element). Forth, incentive providers could use it to recognize more efficient vessels and encourage them through their incentive programs.

5.2.1 Uncertainties in CII calculations

The impact of highly fluctuating operational factors on CII calculations makes it an uncertain tool for assessing ship energy efficiency from a technical standpoint. In their article, Faber et al. (2009) argue that the EEOI is not a suitable basic parameter for a mandatory policy, and that it is difficult, if not impossible, to compare the EEOI between different types of ships. It is also confirmed in the EPSD report (Cullinane, 2014) that the EEOI cannot be used to compare ships, as even sister ships can have very different operational characteristics from each other. In an analysis of 11 sister tankers built by the same shipyard and operated by the same company, but with different contracts and trades, divergent annual EEOI results were calculated (IMO, 2020). In another study, Masodzadeh et al. (2022a) by considering operational uncertainties including 15% for weather condition, 9% for hull roughness, 6% for fuel quality, 15% for speed fluctuation by 5%, and other factors, conclude a 50% variation in calculations of operational efficiency. CII calculations are influenced by some operational and technical factors that could be beyond the ship operator's control. These factors, as shown in Table 2, could be divided to external factors and technical and operational restrictions (Masodzadeh et al., 2024).

Table 2: Factors influencing the results of CII calculations
source: (Masodzadeh et al., 2024)

Factors beyond the control of the ship operator	A- External factors	• Weather conditions (sea state, current, and wind) • Navigation circumstances (e.g., a war zone or piracy area and the impossibility of slow steaming)
	B- Technical and operational restrictions	• Ship's hull depreciation (beyond hull fouling) • Ship's machinery depreciation • Fuel quality (fuel specific energy) • Contractual terms and conditions (e.g., speed) • Waiting time and turnaround time at ports

Category A refers to external factors that are beyond the control of the ship operator. CII calculations are significantly affected by weather conditions. For estimating the effect of wind and sea current on fuel consumption in international shipping, the Third (Smith et al., 2015) and Fourth (Faber et al., 2020) IMO GHG studies and Olmer et al. (2017) have introduced an additional 15% sea margin. According to Taskar et al. (2016), even a larger sea margin of 15% to 25% should be considered. In addition, certain navigational conditions, such as passing through a war zone or piracy area, may prevent certain energy-saving practices, such as slow steaming. CII calculations do not take into account this condition (discussion regarding correction factors for such situations is in progress). To maintain security, ships operating in piracy areas may be instructed to operate at maximum speed, which increases fuel consumption (Jafarzadeh & Utne, 2014). As well, encountering piracy areas may adversely affect efficient routing, which Fu et al. (2010) have described as 'efficiency loss due to geographical rerouting.'

Category B comprises technical and operational limitations. With increasing age, ships' hull and machinery depreciate inevitably over time. A ship's average hull roughness (AHR) is directly related to its age. Doulgeris et al. (2012) have estimated that every 30µm of added roughness amplitude results in an increase of 2% in hull resistance. As shown in Table 3, AHR increases with ship age regardless of drydocking and hull cleaning.

Table 3: Average hull roughness and ship age
Source: (Olmer et al., 2017)

Age of ship	AHR
0–1 year	120 µm
2–5 years	150 µm
6–10 years	200 µm
11–15 years	300 µm
16–20 years	400 µm
>20 years	500 µm

In the calculation of carbon intensity, fuel quality is not taken into account. Fuel properties, such as the lower calorific value (LCV) and viscosity, have a direct effect on the amount of fuel consumed. The engine must consume more fuel with a lower LCV in order to achieve the same power produced by a fuel with a higher LCV. A higher viscosity fuel also requires more heat energy to become ready for injection.

Furthermore, a ship operator cannot directly control waiting times caused by port congestion or turnaround times in ports for cargo operations. However, these factors have an important impact on the calculation of CII. In one recommendation, the voyage definition should be redefined to exclude time spent in port and to consider the time between the departure from the origin port and the arrival at the destination port.

5.2.2 EEOI versus AER

Currently, energy efficiency indicators in ship operation are based on the CII formula. The formula has been recognized over the last decade under different names such as EEOI (formula 1) and AER (formula 2), with slight variations in formulation, but with significant differences in results. Other indicators such as ISPI (Individual Ship Performance Indicator: CO_2 emissions per distance travelled) and EESH (Energy Efficiency as per Service Hour) are less widely used than EEOI and AER (Zhang et al., 2019; EU Commission, 2020). Zhang et al. (2019) have also proposed another indicator (formula 3), the Energy Efficiency Performance Indicator (EEPI), which has not yet made its way into the shipping regulatory framework. EEOI, AER, and EEPI differ primarily in the calculations of transport work that is incorporated into the CII formula's denominator.

$$EEOI = \frac{\sum_i \sum_j (\mathrm{FC}_{\mathrm{ij}} \times CF_{\mathrm{j}})}{\sum_i (M_{\mathrm{cargo}} \times Laden\ voyage\ \ distance)} \tag{1}$$

$$AER = \frac{\sum_i \sum_j (\mathrm{FC}_{\mathrm{ij}} \times CF_{\mathrm{j}})}{\mathrm{DWT} \times Annual\ total\ distance\ traveled} \tag{2}$$

$$EEPI = \frac{\sum_i \sum_j (\mathrm{FC}_{\mathrm{ij}} \times CF_{\mathrm{j}})}{\mathrm{DWT} \times Annual\ laden\ distance\ \ traveled} \tag{3}$$

Where:

i:	Voyage number
j:	Fuel type
FC_{ij}:	Mass of consumed fuel j at voyage i
CF_j:	CO_2 emission factor for fuel j

Two versions of CII, namely EEOI and AER, are rarely compared or discussed in academic literature. In seminars and bulletins, charterers and shipping non-governmental organizations (NGOs) have expressed their concerns regarding the CII formulation. Oldendorff Carriers (2022), Intercargo (Lloyd's List, 2022a), and Trafigura (Lloyd's List, 2022b) have criticized the AER formula with notable comments that primarily highlight the incorrect method of calculating transportation work by utilizing vessels' deadweight instead of the actual cargo carried.

There is a dispute over the measurement of transport work in the CII calculations. Several variants of the CII formula are listed above; they all have the same numerator, the ship's annual CO_2 emissions, but different denominators, the ship's transport work. Based on the review of formulas (1) to (3), it is evident that even a slight change in the definition of transport work can have a dramatic impact on the CII results, accuracy, and accreditation.

EEOI is more representative of actual transport work, as it is based on the actual tonnage of cargo and excludes the distance travelled under ballast conditions. There is, however, a significant obstacle to the use of this version of CII due to the lack of cargo data disclosure. The EEPI is a theoretical indicator with a relative accuracy between the EEOI and the AER (Zhang et al., 2019). Of the three indicators, the IMO's AER is the least accurate, since it assumes that vessels are loaded to full capacity in all situations, including ballast legs. The AER formula calculates the transport work based on the ship capacity (DWT) rather than the actual cargo tonnage. Therefore, ships with a higher payload utilization will be penalized, whereas those with a lower payload utilization will benefit (Zhang et al., 2019). A review of six months of noon reports of a 38,000 DWT chemical carrier has shown that, even though the AER in the second quarter was lower than the AER in the first quarter, the EEOI calculations indicate that the vessel emitted more greenhouse gases for every unit of work performed in the second quarter (Masodzadeh et al., 2024).

5.3 Results of online survey

5.3.1 Influencing factors on CII results

Question: What is the extent to which the following factors can increase the attained CII of a ship in their worst-case scenario? (These are normally beyond the ship operator's control)

Perspective of G1:

Statement	Not at all affective	Slightly affective	Moderately affective	Very affective	Extremely affective	Overall
Weather conditions (sea state, current, and wind)	0 0%	12 30%	9 22.5%	15 37.5%	4 10%	40 100%
Impossible slow steaming due to navigation circumstances (e.g., a war zone or piracy area)	0 0%	14 35%	15 37.5%	10 25%	1 2.5%	40 100%
Impossible slow steaming due to contractual terms and conditions	1 2.5%	8 20%	16 40%	11 27.5%	4 10%	40 100%
Ship's hull and machinery depreciation	3 7.5%	13 32.5%	10 25%	11 27.5%	3 7.5%	40 100%
Fuel quality (lower calorific value of bunker fuel)	3 7.5%	9 22.5%	11 27.5%	15 37.5%	2 5%	40 100%
Waiting time and turnaround time at ports	0 0%	9 22.5%	10 25%	12 30%	9 22.5%	40 100%

Min Max

Question	Count	Score	Not at all affective	Slightly affective	Moderately affective	Very affective	Extremely affective
Weather conditions (sea state, current, and wind)	40	3.27					
Impossible slow steaming due to navigation circumstances (e.g., a war zone or piracy area)	40	2.95					
Impossible slow steaming due to contractual terms and conditions	40	3.23					
Ship's hull and machinery depreciation	40	2.95					
Fuel quality (lower calorific value of bunker fuel)	40	3.1					
Waiting time and turnaround time at ports	40	3.52					
	Average	**3.17**					

Perspective of G3:

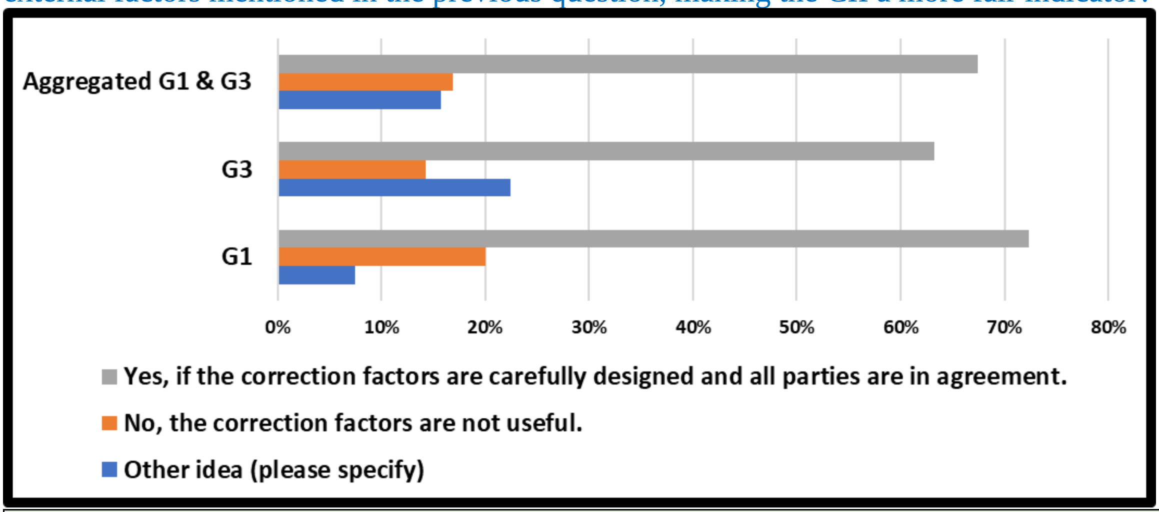
Statement	Not at all affective	Slightly affective	Moderately affective	Very affective	Extremely affective	Overall
Weather conditions (sea state, current, and wind)	3 6.12%	6 12.24%	17 34.69%	14 28.57%	9 18.37%	49 100%
Impossible slow steaming due to navigation circumstances (e.g., a war zone or piracy area)	1 2.04%	10 20.41%	15 30.61%	12 24.49%	11 22.45%	49 100%
Impossible slow steaming due to contractual terms and conditions	3 6.12%	8 16.33%	18 36.73%	12 24.49%	8 16.33%	49 100%
Ship's hull and machinery depreciation	4 8.16%	14 28.57%	14 28.57%	12 24.49%	5 10.2%	49 100%
Fuel quality (lower calorific value of bunker fuel)	3 6.12%	17 34.69%	12 24.49%	8 16.33%	9 18.37%	49 100%
Waiting time and turnaround time at ports	2 4.08%	5 10.2%	12 24.49%	11 22.45%	19 38.78%	49 100%

Min Max

Question	Count	Score
Weather conditions (sea state, current, and wind)	49	3.41
Impossible slow steaming due to navigation circumstances (e.g., a war zone or piracy area)	49	3.45
Impossible slow steaming due to contractual terms and conditions	49	3.29
Ship's hull and machinery depreciation	49	3
Fuel quality (lower calorific value of bunker fuel)	49	3.06
Waiting time and turnaround time at ports	49	3.82
Average		3.34

(Score scale: Not at all affective – Slightly affective – Moderately affective – Very affective – Extremely affective)

Question: Are you of the opinion that CII correction factors can mitigate the effects of the external factors mentioned in the previous question, making the CII a more fair indicator?

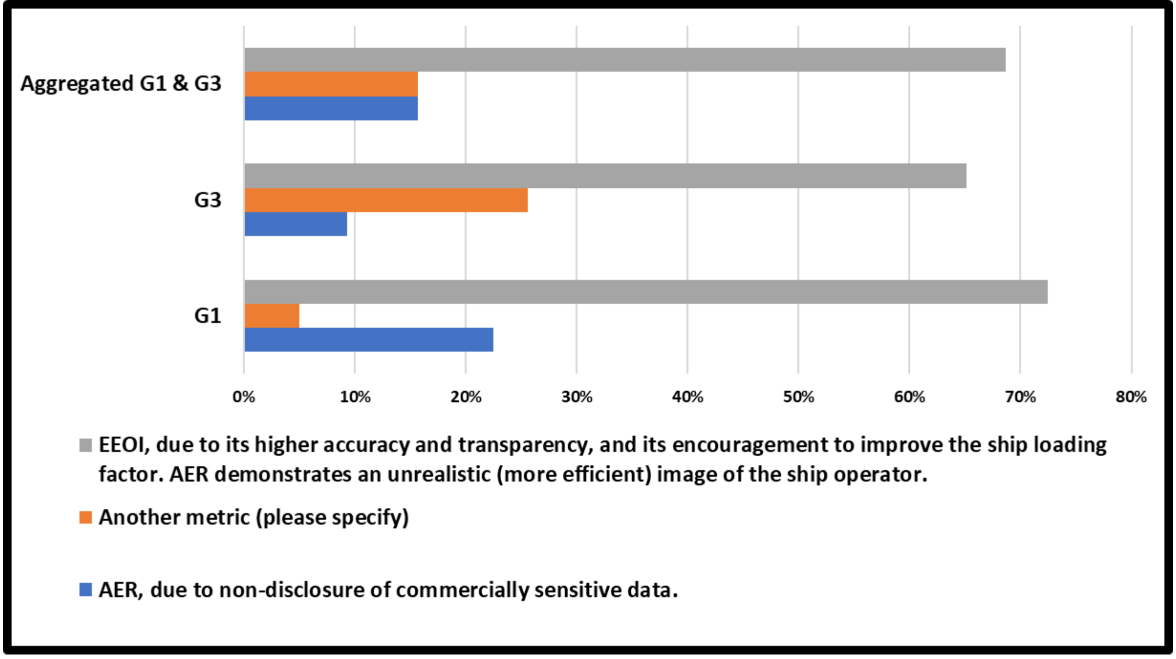


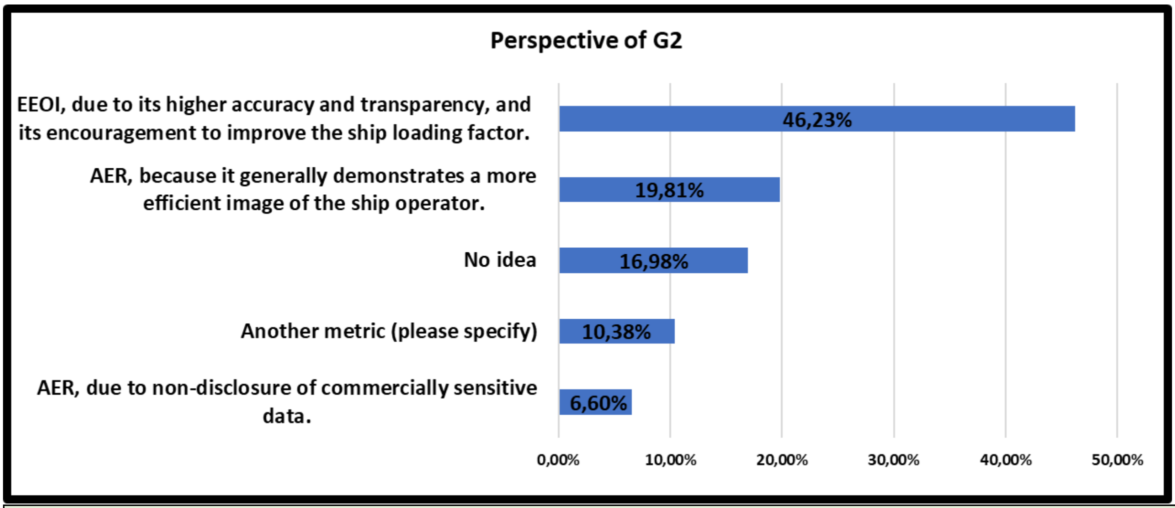
Other ideas specified by respondents:

- To exclude the periods at anchorage/port/berth/drydock
- Alternate reference lines for specific trades such a short sea shipping
- Splitting CII into a propulsion related part (at sea), and a base load related part (auxiliary engines, boiler) can reduce the number of correction factors.
- Some types of vessels are falling out of the score. For instance, bunker vessels which has close to zero NM; thus, not able to reach "C" rating by any mean.

5.3.2 EEOI versus AER

Question: Which version of CII do you prefer: AER/cgDIST, EEOI or another metric? (EEOI formula considers actual cargo tonnage, and AER/cgDIST formula considers vessels capacity)

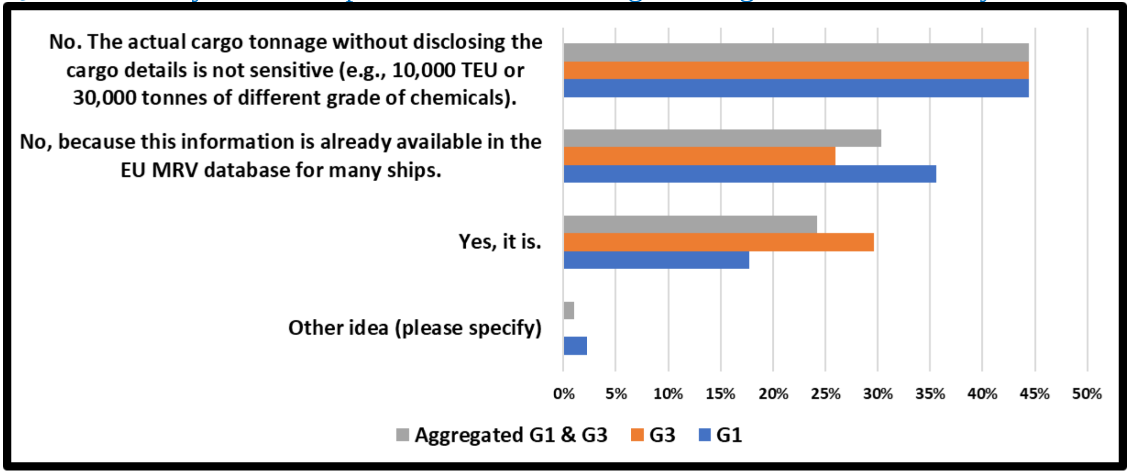




Other ideas specified by respondents:

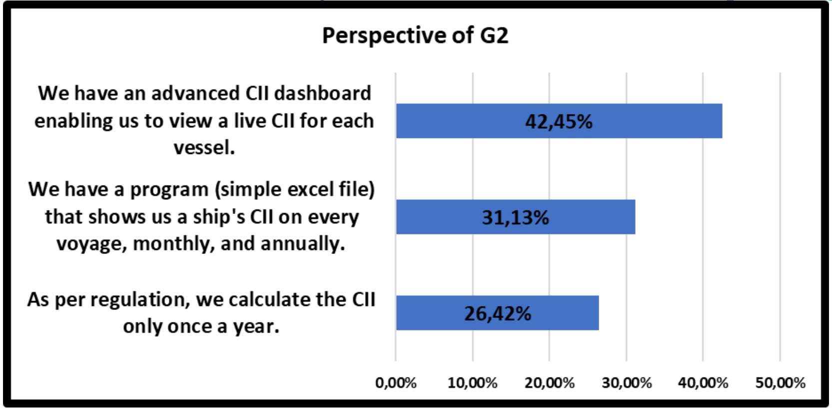
- EEOI excluding the periods in anchorage/port/berth/drydock
- EEOI for the sea passage part related to main engine (propulsion), and a separate metric for onboard energy consumption (related to auxiliaries and boiler) in port and at sea

Question: Are you of the opinion that "actual cargo tonnage" is commercially sensitive data?

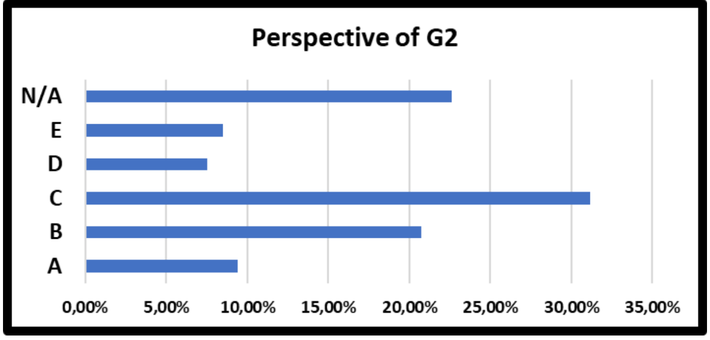


5.3.3 CII rating in shipping companies

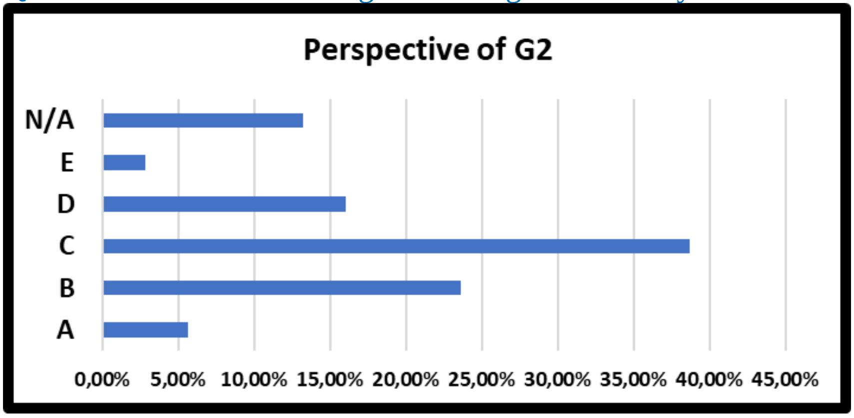
Question: How often do you calculate CII to assess a ship's energy performance?



Question: What is the CII rating in 2023 for the ship you serve or manage?



Question: What is the average CII rating of the fleet you work for in 2023?



References

- ABS. (2013). Ship energy efficiency measures: status and guidance. https://ww2.eagle.org/content/dam/eagle/advisories-and-debriefs/ABS_Energy_Efficiency_Advisory.pdf
- Adamowicz, M. (2022). Decarbonisation of maritime transport–European Union measures as an inspiration for global solutions? Marine Policy, 145, 105085.
- Armstrong, V. N., & Banks, C. (2015). Integrated approach to vessel energy efficiency. Ocean Engineering, 110, 39-48.
- Bännstrand, M., Jönsson, A., Johnson, H., & Karlsson, R. (2016). Study on the optimization of energy consumption as part of implementation of a Ship Energy Efficiency Management Plan (SEEMP). International Maritime Organisation (IMO): London, UK.
- Bazari Z. (2016). IMO Train the Trainer (TTT) Course on Energy Efficient Ship Operation. Module 6 – Energy Management Plans and Systems.
- Bazari, Z., & Longva, T. (2011). Assessment of IMO mandated energy efficiency measures for international shipping. International Maritime Organization, 10.
- Boviatsis, M., & Tselentis, B. (2019). A comparative analysis between EU MRV and IMO DCS—the need to adopt a harmonised regulatory system. In 16th international conference on environmental science and technology (pp. 2018-2019).
- Buhaug, Ø., Corbett, J., Endresen, Ø., Eyring, V., Faber, J., Hanayama, S., ... & Yoshida, K. (2009). Second IMO GHG study 2009. https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/SecondIMOGHGStudy2009.pdf

- Castells-Sanabra, M., Borén, C., van der Meer, R., Torralbo, J., & Ordás, S. (2020). Existing emission calculation methods applied to monitoring, reporting and verification (MRV) on board. NAŠE MORE: znanstveni časopis za more i pomorstvo, 67(2), 163-171.
- Chircop, A. (2019). The IMO Initial Strategy for the Reduction of GHGs from International Shipping: A Commentary. The International Journal of Marine and Coastal Law, 34(3), 482–512. https://doi.org/10.1163/15718085-13431093
- Christodoulou, A., Dalaklis, D., Ölçer, A. I., & Ghaforian Masodzadeh, P. (2021). Inclusion of shipping in the EU-ETS: Assessing the direct costs for the maritime sector using the MRV data. Energies, 14(13), 3915.
- ClassNK (2022). Implementation of SEEMP PART III and submission for approval. retrieved from: https://www.classnk.or.jp/hp/pdf/tech_info/tech_img/T1271e.pdf
- Cullinane, K. (2014). Targeting the environmental sustainability of European shipping: The need for innovation in policy and technology (No. 6). Report.
- Deane, F., Huggins, A., & Karim, M. S. (2019). Measuring, monitoring, reporting and verification of shipping emissions: Evaluating transparency and answerability. Review of European, Comparative & International Environmental Law, 28(3), 258-267.
- Dewan, M. H., & Godina, R. (2023). Roles and challenges of seafarers for implementation of energy efficiency operational measures onboard ships. Marine Policy, 155, 105746.
- DNV (2023a). DNV launches real-time emissions data verification solution for trusted collaboration across maritime value chain. (19 April 2023). Retrieved from: https://www.dnv.com/news/dnv-launches-real-time-emissions-data-verification-solution-for-trusted-collaboration-across-maritime-value-chain-242396
- DNV (2023b). SEEMP PART III. Retrieved from: https://www.dnv.com/maritime/insights/topics/seemp-part-iii/index.html
- DNV (2015). Energy Management Study 2014. Technical report. www.dnvgl.com/maritime/energy-management-study-2015.html
- Doulgeris, G., Korakianitis, T., Pilidis, P., & Tsoudis, E. (2012). Techno-economic and environmental risk analysis for advanced marine propulsion systems. Applied energy, 99, 1-12.
- Duan, M., Wang, Y., Fan, A., Yang, J., & Fan, X. (2023). Comprehensive analysis and evaluation of ship energy efficiency practices. Ocean & Coastal Management, 231, 106397.
- EU Commission (2020). 2019 Annual Report on CO2 Emissions from Maritime Transport.
- Faber, J., Hanayama, S., Zhang, S., Pereda, P., Comer, B., Hauerhof, E., ... & Xing, H. (2020). Fourth IMO GHG Study. London, UK.
- Faber, J., Markowska, A., Nelissen, D., Davidson, M., Eyring, V., Cionni, I., ... & Schwarz, W. (2009). Technical support for European action to reducing Greenhouse Gas Emissions from international maritime transport.

- Faber, J., Nelissen, D., Smit, M., Behrends, B., & Lee, D. S. (2012). The fuel Efficiency of maritime transport. Potential for improvement and analysis of barriers.
- Fu, X., Ng, A. K., & Lau, Y. Y. (2010). The impacts of maritime piracy on global economic development: the case of Somalia. Maritime Policy & Management, 37(7), 677-697.
- Ghaforian M., P. (2024). Policy Innovation as the Cornerstone of Energy Transition: An Analysis of Energy Policy in the Shipping Economy and Operations. PhD thesis under publication.
- Ghaforian Masodzadeh, P. (2018). Ship energy management self-assessment (SEMSA) an introduction to new set of rules and standards in operation mode.
- Hansen, E. K., Rasmussen, H. B., & Lützen, M. (2020). Making shipping more carbon-friendly? Exploring ship energy efficiency management plans in legislation and practice. Energy Research & Social Science, 65, 101459.
- Hoffmann, J., & Kumar, S. (2013). Globalisation–the maritime nexus. In The handbook of maritime economics and business (pp. 65-94). Informa Law from Routledge.
- ICOMIA (2019). Quarterly EU Report. May 2019. Retrieved from: https://www.nmma.org/assets/cabinets/Cabinet55/ICOMIA%20Quarterly%20Report%20-%20May%202019.pdf
- ICS (2017). International Chamber of Shipping website. http://www.ics-shipping.org/shipping-facts/shipping-and-world-trade
- Im, N. K., Choe, B., & Park, C. H. (2019). Developing and applying a ship operation energy efficiency evaluation index using SEEMP: A case study of South Korea. Journal of Marine Science and Application, 18, 185-194.
- IMO (2009). Guidelines for the development of a ship energy efficiency management plan (SEEMP). Resolution MEPC.1/Cric.683.
- IMO (2012). 2012 Guidelines for the development of a ship energy efficiency management plan (SEEMP). Resolution MEPC.213(63).
- IMO (2020). Comments on Compromise Solutions for Short-Term-Measures Including Both Proposals of EEXI for Use of CIIs. Submitted by INTERTANKO. IMO doc. ISWGGHG 7/2/32.
- IMO (2022a). 2022 GUIDELINES FOR THE DEVELOPMENT OF A SHIP ENERGY EFFICIENCY MANAGEMENT PLAN (SEEMP). RESOLUTION MEPC.346(78).
- IMO (2022b). GUIDELINES FOR THE VERIFICATION AND COMPANY AUDITS BY THE ADMINISTRATION OF PART III OF THE SHIP ENERGY EFFICIENCY MANAGEMENT PLAN (SEEMP). RESOLUTION MEPC.347(78)
- IMO (2022c). 2022 GUIDELINES FOR ADMINISTRATION VERIFICATION OF SHIP FUEL OIL CONSUMPTION DATA AND OPERATIONAL CARBON INTENSITY. RESOLUTION MEPC.348(78)

- IMO (n.d.). E-Learning and Training Packages. https://futurefuels.imo.org/home/training-and-cooperation/e-learning-training-packages/
- Jafarzadeh, S., & Utne, I. B. (2014). A framework to bridge the energy efficiency gap in shipping. Energy, 69, 603-612.
- Johnson, H., Johansson, M., Andersson, K., & Södahl, B. (2013). Will the ship energy efficiency management plan reduce CO2 emissions? A comparison with ISO 50001 and the ISM code. Maritime Policy & Management, 40(2), 177-190.
- Kachi, A., Mooldijk, S., Warnecke, C., & BMU, N. S. (2019). Carbon pricing options for international maritime emissions. New climate-institute for climate policy and global sustainability gGmbH: Berlin, Germany.
- Lindberg, C. F., Tan, S., Yan, J., & Starfelt, F. (2015). Key performance indicators improve industrial performance. Energy procedia, 75, 1785-1790.
- Lister, J., Poulsen, R. T., & Ponte, S. (2015). Orchestrating transnational environmental governance in maritime shipping. Global Environmental Change, 34, 185-195.
- Lloyd's List. (2022a). Intercargo says CII 'flaws' must be fixed (07 Dec 2022). Retrieved from: https://lloydslist.maritimeintelligence.informa.com/LL1143281/Intercargo-says-CII-flaws-must-be-fixed
- Lloyd's List. (2022b). Trafigura implores IMO to change CII rule (09 Dec 2022). Retrieved from: https://lloydslist.maritimeintelligence.informa.com/LL1143300/Trafigura-implores-IMO-to-change-CII-rule
- LR (2017). Guidance on the EU MRV Regulation and the IMO DCS for Shipowners and Operators. Retrieved from: https://maritime.lr.org/l/941163/2021-12-09/2pvfb/941163/16390595727phzs5hs/mo_guidance_on_the_eu_mrv_regulation_and_the_imo_dcs_for_shipowners_an.pdf
- LR (2023). SEEMP PART III - SHIP ENERGY EFFICIENCY. retrieved from: https://www.lr.org/en/seemp-part-iii-ship-energy-efficiency/
- Lützen, M., Mikkelsen, L. L., Jensen, S., & Rasmussen, H. B. (2017). Energy efficiency of working vessels–A framework. Journal of Cleaner Production, 143, 90-99.
- Maddox consulting (2012). Analysis of market barriers to cost effective GHG emission reductions in the maritime transport sector. Reference: CLIMA.B.3/SER/2011/0014
- Masodzadeh, P. G., Ölçer, A. I., Ballini, F., & Celis, J. G. (2024). Live carbon-tracking mechanism for ships, a methodology to mitigate uncertainties in the carbon intensity calculations. Transportation Research Interdisciplinary Perspectives, 23, 101004.
- Masodzadeh, P. G., Ölçer, A. I., Ballini, F., & Christodoulou, A. (2022a). How to bridge the short-term measures to the Market Based Measure? Proposal of a new hybrid MBM based on a new standard in ship operation. Transport Policy, 118, 123-142.

- Masodzadeh, P. G., Ölçer, A. I., Ballini, F., & Christodoulou, A. (2022b). A review on barriers to and solutions for shipping decarbonization: What could be the best policy approach for shipping decarbonization? Marine Pollution Bulletin, 184, 114008.
- Miola, A., & Ciuffo, B. (2011). Estimating air emissions from ships: Meta-analysis of modelling approaches and available data sources. Atmospheric environment, 45(13), 2242-2251.
- Nelissen, D., & Faber, J. F. (2014). Economic impacts of MRV of fuel and emissions in maritime transport. CE Delft.
- Ölçer A.I., Kitada M., Lagdami K., Ballini F., Alamoush A.S., Masodzadeh P.G. (Eds.). (2023). Transport 2040: Impact of Technology on Seafarers - The Future of Work. World Maritime University.
- Oldendorff Carriers (2022). CII IS NOT THE ANSWER. Retrieved from: https://oldendorff-website-assets.s3.amazonaws.com/assets/downloads/Oldendorff-EMISSIONS.pdf
- Olmer, N., Comer, B., Roy, B., Mao, X., & Rutherford, D. (2017). Greenhouse gas emissions from global shipping, 2013–2015 Detailed Methodology. International Council on Clean Transportation: Washington, DC, USA, 1-38.
- Perera, L. P., & Mo, B. (2016). Emission control based energy efficiency measures in ship operations. Applied Ocean Research, 60, 29-46.
- Poulsen, R. T., & Johnson, H. (2016). The logic of business vs. the logic of energy management practice: understanding the choices and effects of energy consumption monitoring systems in shipping companies. Journal of Cleaner Production, 112, 3785-3797.
- Smith, T. W., Jalkanen, J. P., Anderson, B. A., Corbett, J. J., Faber, J., Hanayama, S., ... & Pandey, A. (2015). Third IMO greenhouse gas study 2014.
- Taskar, B., Yum, K. K., Steen, S., & Pedersen, E. (2016). The effect of waves on engine-propeller dynamics and propulsion performance of ships. Ocean Engineering, 122, 262-277.
- Wang, H. (2012). Cutting Carbon from Ships. International Council on Clean Transportation, ICCT Blog.
- Zhang, S., Li, Y., Yuan, H., & Sun, D. (2019). An alternative benchmarking tool for operational energy efficiency of ships and its policy implications. Journal of Cleaner Production, 240, 118223.