



Full Length Article

Analysis of Perceptions Toward Maritime Education on Decarbonization to Support Greenhouse Gas Emission Reduction

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Abstract: The transition toward low-emission shipping requires not only technological and regulatory measures but also adequate knowledge, awareness, and competency development among maritime stakeholders. This study investigates the level of understanding, awareness, training exposure, and readiness of maritime professionals and students regarding decarbonization and evaluates the perceived role of maritime education in supporting greenhouse gas emission reduction. A cross-sectional quantitative approach was employed using a structured questionnaire distributed to 105 respondents comprising seafarers, maritime practitioners, government personnel, and maritime students. The questionnaire used a five-point Likert scale and covered key aspects of decarbonization knowledge, educational support, training implementation, curriculum integration, and skills readiness. The results indicate a relatively high level of awareness and support for maritime decarbonization. The mean score for understanding decarbonization was 3.83, while 73.3% of respondents demonstrated awareness of IMO emission-reduction targets. In addition, 78.1% perceived maritime education as an effective means of supporting emission reduction, and 79.1% supported stronger collaboration between maritime education and industry. However, 41.9% of respondents reported that they had not received formal decarbonization training, revealing a clear gap between awareness and structured competency development. The questionnaire showed high internal consistency, with Cronbach's alpha values of 0.957 and 0.978 for the two principal variables. These findings highlight the need to strengthen competency-based decarbonization education, expand access to formal training, and enhance collaboration among maritime institutions, industry, and government to better prepare the maritime workforce for the transition toward low-emission and sustainable shipping.

Keywords: Maritime education, greenhouse gas, decarbonization, seafarer

1. Introduction

The maritime world is inseparable from ports as a gateway to economic growth, which also affects the surrounding social and environmental aspects [1]. Indonesia's economic growth in 2024 still shows good and stable performance, although it has slowed down from the previous year. On the ship growth side, there is also an increasing trend in operating ships and ship visits, with ship visits in 2024 totaling approximately 70,891 ship calls,

still dominated by foreign ships. Of course, these ships use fossil fuels, which have an impact on environmental pollution. The use of these fuels must comply with the standards set by international regulations, with a maximum sulfur content of 0.5% m/m. The IMO (International Maritime Organization) has set targets to be achieved, including reducing carbon emissions (decarbonization) by 40% by 2030 and 70% by 2050 and reducing GHG emissions by 50% compared to 2008 [2][3]. Decarbonization is a major challenge for a

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modern port to become environmentally friendly and sustainable [4][5]. Indonesia supports emission reduction as stated in Law of the Republic of Indonesia Number 59 of 2024 concerning the National Long-Term Development Plan for 2025-2045, where one of the goals of the Golden Indonesia Vision 2045 is to reduce greenhouse gas emission intensity toward net-zero emissions. Community control, strengthening environmental policies, increasing the use of renewable energy, and enhancing community resilience to disasters and climate change are among the ecological policy focuses, including raising public awareness about the importance of using renewable energy through socialization and education campaigns. On the other hand, the Indonesian Chamber of Commerce and Industry (Kadin) is committed to the government to help achieve the set targets through a joint program to support decarbonization in the business and industrial sectors. The education sector is also participating in supporting decarbonization by providing training to all stakeholders in the maritime sector and delivering course materials related to decarbonization, as well as highlighting the targets that need to be considered by both the government and international organizations, in this case, the IMO.

The global education and training standard, STCW (Standards of Training, Certification, and Watchkeeping for Seafarers), and its amendments serve as a guideline for educational institutions in providing instruction. It has promoted Maritime Environmental Awareness Training, as outlined in the STCW and Manila Amendments 2010 edition 2017 book [6], and the IMO's rule to encourage energy efficiency. The first globally enforceable regulations to lower greenhouse gas emissions in the maritime sector are these rules [7]. IMO also provides guidance on monitoring, planning, and managing emission reductions, including the Energy Efficiency Design Index (EEDI), Carbon Intensity Indicator (CII), Energy Efficiency Operational Indicator (EEOI), and Ship Energy Efficiency Management Plan (SEEMP) [8][9], so that every stakeholder can understand, know concrete steps, and apply the

reduction of Greenhouse Gas (GHG) emissions more structurally. Through the training provided by the maritime education world based on IMO guidelines, it will certainly provide greater familiarization and understanding, as well as increased awareness to help reduce greenhouse gas emissions in the Indonesian maritime environment.

This study's uniqueness comes from its targeted assessment of students' and marine professionals' knowledge, understanding, and preparedness with reference to decarbonization tactics in the shipping industry, a crucial but little-studied topic in maritime education. In contrast to earlier research that might have focused on environmental issues more broadly, this study evaluates existing preparation in a unique way and finds a major gap: 41.9% of respondents had not undergone official decarbonization training. This research fills the gap by assessing students (the future), instructors (the mentors), and practitioners (the existing industry leaders) all at once, in contrast to studies that just concentrate on mariners or curriculum writers [10]. This research examines the extent of understanding and training on decarbonization among sailors, maritime stakeholders, and students to further evaluate awareness and information dissemination regarding emissions in Indonesia. The results of this research will be useful in the future to enhance the role of the education sector in conveying the importance of reducing environmental pollution, considering the targets that must be achieved by both the IMO and Indonesia to ensure that all stakeholders in the maritime sector are more aware and increase their respective roles. The results of this research can serve as a recommendation in developing an integrated education and training program for decarbonization in the maritime environment, particularly in Indonesia.

2. Materials and Methods

2.1 Research Design

This study employed a cross-sectional quantitative research design to assess stakeholders' knowledge, awareness, perceptions, and readiness regarding maritime

decarbonization and the role of maritime education in supporting greenhouse gas emission reduction. A deductive approach was adopted to develop the research instrument based on the objectives of the study. The research focused on three principal stakeholder groups, namely active mariners, maritime professionals and stakeholders, and maritime students, representing operational, managerial, policy, and future-workforce perspectives within the maritime sector.

The study used a descriptive quantitative approach to characterize respondents' perceptions toward decarbonization and maritime education. The questionnaire was distributed digitally through professional maritime networks using WhatsApp. A non-probability purposive sampling approach, supported by snowball-style digital dissemination, was applied to reach respondents considered relevant to the research objectives. This approach was intended to ensure that participants had sufficient familiarity with maritime operations, education, training, or policy to provide informed responses.

2.2 Questionnaire Design and Measurement

Data were collected using a structured questionnaire developed around seven thematic constructs. These constructs included knowledge, referring to respondents' general understanding of maritime decarbonization; confidence, representing perceptions regarding the role and effectiveness of maritime education; training gaps, referring to variations in access to and implementation of decarbonization-related training; curriculum integration, concerning the incorporation of decarbonization topics into existing maritime education and training; organizational support, referring to institutional support for environmentally sustainable initiatives; expectations, representing respondents' views on future developments in the maritime industry; and recommendations, containing stakeholder suggestions for improving maritime decarbonization education and training.

Most perception items were measured using a five-point Likert scale, ranging from 1

(strongly disagree) to 5 (strongly agree). The Likert scale was used to quantify respondents' attitudes and levels of agreement and to facilitate descriptive statistical analysis, including frequency distributions, percentages, and mean scores [11]. In addition to Likert-scale items, the questionnaire collected information on respondents' educational background, occupation, age, work experience, and previous participation in decarbonization-related training.

2.3 Respondents and Sampling Procedure

A total of 105 respondents participated in the study. The sample included active seafarers, maritime practitioners and stakeholders, government personnel, and maritime students. The inclusion of these groups was intended to represent different levels of involvement within the maritime sector, ranging from operational practice and institutional decision-making to maritime education and future workforce preparation.

The questionnaire was disseminated electronically through professional WhatsApp networks. Active mariners were included to represent current operational conditions in the shipping industry, maritime professionals and stakeholders were included to provide managerial and policy perspectives, while maritime students represented the future workforce. Detailed demographic characteristics of the respondents, including gender, education, occupation, age, and work experience, are presented in the Results section to avoid duplication between the methodological description and respondent-profile findings.

2.4 Data Analysis

The collected data were analyzed using descriptive quantitative methods. Frequencies and percentages were calculated to describe the distribution of responses and respondent characteristics, while mean Likert scores were used to determine the overall level of agreement for the assessed questionnaire items and thematic constructs. The findings were subsequently grouped according to the principal analytical themes, including understanding and

awareness of decarbonization, the role of maritime education, implementation of training, perceived effects of training integration, and stakeholder recommendations.

The reliability of the questionnaire was evaluated using Cronbach's alpha. The manuscript reports Cronbach's alpha values of 0.957 for the decarbonization-understanding variable (X) and 0.978 for the training-implementation variable (Y), indicating high internal consistency of the questionnaire items. The relationship between the two main variables was also examined using correlation analysis, resulting in a reported correlation coefficient of 0.935. In addition, the coefficient of determination was reported as $R^2 = 0.762$, indicating the proportion of variation associated with the relationship between the two variables.

3. Results

Table 1. Respondent profile by education and occupation

No.	Education	Percentage	Occupation	Percentage
1	Diploma	53.1%	Seafarer	67.6%
2	Bachelor's degree	39.5%	Maritime practitioner	22.9%
3	Master's degree	7.4%	Government officer	4.7%
4	Doctoral degree	0.0%	Student	4.8%

The respondents also varied in age and professional experience. The largest age group consisted of respondents younger than 30 years (37%), followed by those aged 30–39 years (35%), 40–49 years (22%), and 50 years or older (6%). The work-experience profile also showed variation, with the largest group having between 5 and 10 years of experience (37%), followed by respondents with 15 years or more of experience (25%) and those with 10–15 years of experience (20%).

Table 2. Respondent profile by age and work experience

No.	Age Group	n	%	Work Experience	n	%
1	<30 years	39	37	<5 years	19	18
2	30–39 years	37	35	5–<10 years	39	37
3	40–49 years	23	22	10–<15 years	21	20
4	≥50 years	6	6	≥15 years	26	25

3.1 Respondent Characteristics

A total of 105 respondents participated in the study. Of these, 97 respondents (92.4%) were male, and 8 respondents (7.6%) were female. The respondents represented a range of educational and occupational backgrounds within the maritime sector. Most respondents held a diploma qualification (53.1%), followed by bachelor's degree holders (39.5%) and master's degree holders (7.4%). No respondent reported holding a doctoral degree. In terms of occupation, seafarers constituted the largest group (67.6%), followed by maritime practitioners (22.9%), students (4.8%), and government officers (4.7%). These characteristics indicate that the sample was dominated by respondents with direct operational or professional involvement in the maritime sector.

Main Variables

The internal consistency of the questionnaire was assessed using Cronbach's alpha. The decarbonization-understanding variable (X) produced a Cronbach's alpha value of 0.957, while the training-implementation variable (Y) produced a value of 0.978. Both values exceed the reliability threshold used in this study, indicating that the items within each variable demonstrated high internal consistency.

The manuscript also reports a correlation coefficient of 0.935 between Variables X and Y, indicating a strong positive relationship between respondents' understanding of decarbonization and the implementation of decarbonization-related training. In addition, the reported coefficient of determination was $R^2 = 0.762$. These findings suggest that the two variables are closely associated; however, the statistical relationship should be interpreted carefully and should not be presented as

3.2 Reliability and Relationship Between the

evidence of causality because the study employed a cross-sectional design.

3.3 Level of Understanding and Awareness

Respondents generally demonstrated a relatively high level of understanding of maritime decarbonization. For the item measuring understanding of decarbonization in the context of shipping, 40.0% of respondents selected a score of 4 and **33.3%** selected a score of 5. The mean score was 3.83, indicating that most respondents tended to agree that they understood the concept of maritime decarbonization.

Awareness of the shipping sector's contribution to greenhouse gas emissions was also relatively high. A total of 66.7% of respondents selected scores of 4 or 5, with an average Likert score of 3.60. This result indicates that most participants recognized the environmental implications of maritime operations and the relevance of emission reduction within the shipping sector.

Respondents also demonstrated awareness of international emission-reduction targets established by the IMO. Approximately 73.3% selected scores of 4 or 5 for the item assessing knowledge of IMO emission-reduction targets. This finding suggests that most respondents were familiar with the existence of international decarbonization policies and regulatory objectives.

3.4 Perceived Role of Maritime Education

Respondents expressed strong confidence in the role of maritime education in supporting decarbonization. A total of 78.1% selected scores of 4 or 5 when assessing whether maritime education could effectively contribute to greenhouse gas emission reduction. This indicates broad support for the inclusion of decarbonization-related knowledge and competencies within maritime education and training.

The respondents also showed a high willingness to participate in programs or activities related to emission reduction. Approximately 70.4% selected scores of 4 or 5 for willingness to participate. These findings show that positive perceptions toward maritime

education were accompanied by a relatively high level of personal readiness to participate in decarbonization initiatives.

3.5 Decarbonization Training Implementation

Despite the relatively high level of awareness and understanding, access to formal decarbonization training remained uneven. When respondents were asked whether they had previously received material or training related to decarbonization, 58.1% answered "Yes," while 41.9% answered "No."

The proportion of respondents who had not received formal training reveals a clear difference between awareness and formal competency development. Although many respondents understood the importance of decarbonization and recognized international emission-reduction targets, a substantial proportion had not yet participated in structured decarbonization education or training. This gap indicates that the dissemination of decarbonization knowledge has not been accompanied by equally broad access to formal training.

3.6 Perceived Impact of Training Integration

Respondents strongly supported closer integration between maritime education and the maritime industry. A total of 79.1% selected scores of 4 or 5 for the statement that collaboration between industry and educational institutions could enrich the curriculum. This indicates that respondents considered industry–education cooperation an important mechanism for ensuring that educational content remains relevant to emerging decarbonization practices.

A similar proportion (79.1%) agreed that training could improve knowledge related to exhaust-gas emissions. In addition, 77.1% of respondents selected scores of 4 or 5 for the view that decarbonization training could encourage behavioral changes supporting environmental sustainability. These findings indicate that respondents perceived decarbonization training as relevant not only to technical knowledge but also to environmental awareness and professional behavior.

Regarding competency development, 75.2% of respondents selected scores of 4 or 5 for the statement that training could prepare the skills required to support renewable-energy transitions and energy-efficiency implementation in accordance with IMO programs. Overall, the results indicate broad stakeholder support for strengthening the integration of decarbonization competencies within maritime education and training.

3.7 Stakeholder Recommendations

Three principal themes emerged from respondents' recommendations. First, respondents emphasized curriculum integration, particularly the inclusion of decarbonization topics within formal maritime curricula and basic training programs. Second, respondents highlighted the importance of practical applications and technological development, including environmentally friendly technologies, alternative-fuel infrastructure, and specialized competencies or certification for green shipping operations. Third, respondents emphasized the need for broader and continuous dissemination, indicating that decarbonization education and training should be expanded across Indonesia rather than being limited to specific institutions or stakeholder groups.

4. Discussion

4.1 Awareness of Maritime Decarbonization

The findings indicate that respondents generally possessed a relatively strong awareness of maritime decarbonization. The mean score of 3.83 for understanding decarbonization, combined with the finding that 73.3% of respondents were aware of IMO emission-reduction targets, suggests that decarbonization is no longer an unfamiliar concept among the maritime stakeholders represented in this study. This level of awareness is important because international shipping regulations increasingly require maritime professionals to understand environmental performance, energy efficiency, and greenhouse gas reduction.

The introduction of IMO energy-efficiency instruments such as the Energy Efficiency Design Index, Carbon Intensity Indicator, Energy Efficiency Operational Indicator, and Ship Energy Efficiency Management Plan has increased the need for maritime personnel to understand both regulatory requirements and operational implications. The manuscript identifies these mechanisms as part of the broader IMO framework for improving energy efficiency and reducing greenhouse gas emissions.

However, awareness alone does not necessarily indicate operational competence. Respondents may recognize decarbonization concepts and policy targets without necessarily possessing the technical knowledge or practical skills required to implement them onboard ships or within maritime organizations. This distinction becomes particularly important when the awareness findings are considered together with the training results.

4.2 The Gap Between Awareness and Formal Training

One of the most important findings is that 41.9% of respondents had never received formal material or training related to decarbonization, despite the generally high levels of awareness reported in the survey. This indicates an awareness–training gap within the sampled maritime community.

The result suggests that a portion of respondents may have acquired their understanding of decarbonization through professional experience, informal information channels, organizational communication, or exposure to maritime regulations rather than through structured Maritime Education and Training (MET). The existence of this gap is significant because knowledge obtained informally may not provide the systematic technical competencies required to respond to rapidly changing decarbonization technologies and regulatory requirements.

This result is consistent with the rationale already presented in the manuscript that maritime education and training need to evolve alongside technological and regulatory developments [12]. Therefore, expanding

formal decarbonization training should not simply focus on increasing awareness but should emphasize practical competencies, regulatory application, and operational decision-making.

4.3 Role of Maritime Education and Industry Collaboration

The strong level of confidence in maritime education provides an important basis for strengthening decarbonization capacity. In this study, 78.1% of respondents believed that maritime education could contribute to greenhouse gas emission reduction, while 79.1% supported stronger collaboration between maritime educational institutions and industry.

These findings indicate that respondents do not view decarbonization solely as a technological or regulatory issue. Instead, they recognize education and competency development as important components of the transition toward lower-emission maritime operations. Industry collaboration is particularly relevant because maritime decarbonization involves practical measures related to vessel operation, energy efficiency, fuel management, alternative fuels, and emerging technologies.

The manuscript also notes that shipowners need to adopt technical and operational energy-efficiency measures to reduce fuel consumption and emissions [13]. From an educational perspective, this implies that maritime training should connect theoretical knowledge with practical operational applications. Collaborative curriculum development, industry-based case studies, simulator exercises, and professional training could therefore help reduce the gap between policy awareness and operational competence.

4.4 Training, Behavioral Change, and Skills Readiness

The results show that respondents perceived training as having effects beyond knowledge acquisition. Approximately 77.1% believed that decarbonization training could encourage environmentally responsible behavioral change, while 75.2% believed that such training could improve readiness for

renewable-energy transition and energy-efficiency implementation.

This finding is important because maritime decarbonization depends not only on the availability of new technologies but also on the ability and willingness of maritime personnel to use them effectively. The manuscript emphasizes that technological development alone is insufficient, and that behavioral change, institutional support, and stakeholder participation are also required [14]. Accordingly, maritime decarbonization education should integrate technical competencies with environmental awareness, decision-making, and operational behavior.

These findings also suggest that training programs should be designed around measurable competencies rather than limited to general awareness sessions. Such programs could include energy-efficient ship operation, emission monitoring, application of IMO energy-efficiency measures, alternative-fuel safety, and environmental management.

4.5 Implications for Maritime Education and Training

The combined findings support the need for stronger integration of decarbonization into maritime education and training. Respondents specifically recommended curriculum integration, practical applications, technological exposure, specialized certification, and continuous dissemination of decarbonization knowledge.

For maritime education institutions, these findings indicate that decarbonization should be treated as a competency-development issue rather than only as an environmental-awareness topic. Curriculum development should therefore connect regulatory knowledge with practical skills related to vessel energy efficiency, emission reduction, alternative fuels, and environmentally responsible operations.

At the same time, the recommendations suggest that implementation should involve collaboration among educational institutions, shipping companies, regulators, and maritime professionals. Such collaboration could help ensure that training content remains aligned

with industry needs and evolving IMO requirements.

4.6 Overall Interpretation

Overall, the findings reveal a generally positive environment for strengthening maritime decarbonization education in Indonesia. Respondents showed relatively high awareness of decarbonization, confidence in the role of maritime education, willingness to participate in emission-reduction activities, and support for curriculum and training development. At the same time, the proportion of respondents who had not received formal training demonstrates that awareness has not yet been fully translated into structured competency development.

Therefore, the principal issue identified in this study is not simply a lack of awareness but a gap between awareness and formal preparation. Closing this gap will require more systematic integration of decarbonization into maritime curricula, stronger industry and education collaboration and expanded access to competency-based training.

5. Conclusions

This study demonstrates that maritime professionals, seafarers, and students generally have a high level of awareness of maritime decarbonization and show strong support for the role of maritime education in reducing greenhouse gas emissions. Respondents also expressed a high willingness to participate in emission-reduction initiatives and supported stronger integration of decarbonization topics into maritime education and training. These findings indicate that the maritime community represented in this study is receptive to further development of decarbonization-related competencies.

However, an important gap remains between awareness and formal preparation. A total of 41.9% of respondents reported that they had not received formal decarbonization training, indicating that knowledge and awareness have not yet been fully supported by structured competency development. This finding highlights the need to expand access to

formal training and to strengthen the integration of decarbonization topics within maritime curricula, professional development programs, and industry-based training. 8. Simanjuntak

The study therefore suggests that maritime education institutions, industry stakeholders, and relevant government agencies should strengthen cooperation in developing practical and competency-based decarbonization training. Priority areas should include energy-efficient ship operation, emission-reduction practices, alternative fuels, environmental awareness, and compliance with evolving IMO requirements. Such efforts can help bridge the gap between policy awareness and operational readiness and support the development of a maritime workforce that is better prepared for the transition toward low-emission and more sustainable shipping.

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