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Readiness of the Philippine's domestic shipping sector for decarbonization

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ABSTRACT

This study assessed the readiness of the Philippine domestic shipping sector for decarbonization and identified the factors influencing its transition toward sustainable maritime operations. Anchored on Ecological Modernization Theory, Diffusion of Innovation Theory, and Socio-Technical Transition Theory, the study examined the sector's preparedness in terms of policy awareness and compliance, workforce knowledge and technical competence, fleet readiness and vessel technological capability, financial capacity and investment readiness, availability and adoption of alternative fuels and energy-efficient technologies, and port and operational infrastructure readiness. A quantitative-descriptive research design was employed, utilizing survey data gathered from selected stakeholders within the domestic shipping industry. Findings revealed that the Philippine domestic shipping sector is generally ready for decarbonization, with an overall grand mean of 2.94. Policy awareness and compliance obtained the highest rating, followed by workforce competence and fleet readiness, indicating strong regulatory adherence and organizational preparedness. However, financial capacity, alternative fuel adoption, and infrastructure readiness received comparatively lower ratings, highlighting critical areas requiring further development. The most commonly implemented sustainability practices included energy-efficient operations, environmental compliance programs, and waste management initiatives. Major barriers identified were high technology costs, financial constraints, limited access to alternative fuels, inadequate infrastructure, and insufficient government support. The study concludes that while the sector has established a solid foundation for decarbonization, significant investments, technological advancements, infrastructure improvements, and stronger policy interventions are necessary to achieve long-term sustainability goals. It is recommended that shipping companies, government agencies, port authorities, academic institutions, and industry stakeholders strengthen collaboration and implement the proposed Strategic Action Plan for Maritime Decarbonization Readiness to accelerate the transition toward a low-carbon and environmentally sustainable domestic shipping industry.

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INTRODUCTION

The global community has intensified efforts to address climate change through the reduction of greenhouse gas (GHG) emissions across major economic sectors, including maritime transport. The shipping industry is responsible for approximately three percent of global greenhouse gas emissions, making it a significant contributor to climate change and a critical sector for decarbonization initiatives (International Maritime Organization [IMO], 2023). Recognizing the environmental impact of maritime activities, the International Maritime Organization adopted the 2023 Revised Greenhouse Gas Strategy, which aims to achieve net-zero emissions from international shipping by or around 2050 while implementing intermediate emission reduction targets (IMO, 2023). Achieving these targets requires a combination of energy-efficiency improvements, the adoption of alternative fuels, and the development of new maritime technologies.

Recent global research emphasizes that the decarbonization of shipping will require the integration of multiple technological and policy strategies. The International Renewable Energy Agency (IRENA, 2021) highlighted that the transition toward low-carbon shipping will depend on the adoption of renewable fuels such as hydrogen, ammonia, and biofuels, along with improvements in vessel efficiency and electrification. Similarly, the International Council on Clean Transportation (ICCT, 2024) reported that zero-emission vessels powered by batteries or hydrogen fuel cells could significantly reduce maritime emissions, particularly for short-distance shipping routes. Studies conducted by DNV (2023) also indicate that hybrid propulsion systems and operational energy-efficiency measures represent the most practical near-term strategies for reducing emissions while the industry gradually transitions to alternative fuels.

In Southeast Asia, maritime decarbonization has become increasingly relevant due to the region’s heavy reliance on water transport for trade and mobility. The Asian Development Bank (ADB, 2023) documented the successful deployment of electric ferries in Thailand’s Chao Phraya River, demonstrating that electrification can be a viable solution for urban water transport systems. Singapore has also taken significant steps toward maritime decarbonization by introducing methanol bunkering standards and conducting trials for alternative fuels such as ammonia and biofuels (Maritime and Port Authority of Singapore, 2024). These regional initiatives highlight the growing momentum toward sustainable maritime transport across Southeast Asia.

For the Philippines, maritime transport plays a vital role in national development due to the country’s archipelagic geography. Domestic shipping provides essential connectivity between islands, facilitating the movement of people, goods, and services across the country. However, this heavy reliance on marine transportation also contributes to national greenhouse gas emissions. According to the Philippine national greenhouse gas inventory, emissions from water-borne navigation reached approximately 2.218 million metric tons of carbon dioxide equivalent, accounting for a notable share of the country’s transportation emissions (Climate Change Commission, 2023). These emissions underscore the importance of transitioning the domestic shipping sector toward more sustainable and energy-efficient practices.

In response to environmental challenges, the Philippine government has implemented several policy measures aimed at improving environmental compliance within the maritime sector. These include the adoption of a 0.50 percent sulfur limit for marine fuels, the implementation of Ships' Energy Efficiency Management Plans (SEEMP), and the establishment of fuel-oil consumption data collection systems for domestic vessels (Maritime Industry Authority [MARINA], 2021). These initiatives represent foundational steps toward monitoring maritime energy use and reducing emissions. Nevertheless, these policies primarily address fuel quality and operational efficiency rather than establishing a comprehensive decarbonization strategy for domestic shipping. The Philippine domestic fleet also faces structural challenges, including aging vessels and limited infrastructure for alternative fuels, which complicate the transition to low-carbon maritime operations. As reported in recent maritime assessments, many domestic vessels in the Philippines exceed two decades in age, indicating the need for fleet modernization and technological upgrades (Organisation for Economic Co-operation and Development [OECD], 2023).

Furthermore, infrastructure readiness remains a major concern for maritime decarbonization in the Philippines. Studies on green shipping corridors highlight the absence of comprehensive port development plans, limited regulations governing alternative fuel bunkering, and grid integration challenges that restrict the expansion of shore power and electrified port operations (Global Maritime Forum, 2023). Without adequate port infrastructure and regulatory frameworks, the adoption of alternative fuels and electric propulsion systems will remain limited. Consequently, assessing the readiness of the Philippine domestic shipping sector for decarbonization is essential to identify existing barriers and opportunities for sustainable maritime development.

Given the global push toward low-carbon maritime transport and the strategic importance of domestic shipping in the Philippines, there is a need for a comprehensive evaluation of the sector's preparedness for decarbonization. Understanding the current state of policies, technologies, infrastructure, and institutional capacity will provide valuable insights into the country's ability to transition toward sustainable maritime operations.

The decarbonization of the maritime sector has become a critical priority in global climate governance. As countries strive to meet their climate commitments under the Paris Agreement, reducing emissions from transportation systems including maritime transport has gained increasing attention. Studies conducted between 2020 and 2025 emphasize that maritime decarbonization requires coordinated action among governments, industry stakeholders, and international organizations to develop sustainable technologies and regulatory frameworks (IMO, 2023; IRENA, 2021). These studies highlight that transitioning toward low-carbon shipping involves not only technological innovation but also investments in infrastructure, policy reforms, and capacity development.

Globally, the adoption of alternative marine fuels and zero-emission technologies is rapidly gaining momentum. According to IRENA (2021), renewable fuels such as hydrogen and ammonia have the potential to significantly reduce maritime emissions if supported by appropriate infrastructure and supply chains. Meanwhile, the ICCT (2024) emphasized that battery-electric vessels and hybrid propulsion systems provide promising solutions for short-distance shipping routes, particularly in coastal and inland waterway transport. However, these technologies require substantial investments and supportive regulatory frameworks to achieve large-scale deployment.

In the Philippine context, national climate policy has begun incorporating maritime transport within broader environmental initiatives. The country's Nationally Determined Contribution (NDC) commits to achieving a 75 percent reduction or avoidance of greenhouse

gas emissions by 2030, although a significant portion of this target is conditional upon international financial and technological support (Climate Change Commission, 2023). Despite this ambitious target, the maritime sector has not yet been fully integrated into a comprehensive national decarbonization roadmap. Existing policies primarily focus on fuel quality standards and operational efficiency measures rather than systemic transformation of the shipping industry.

At the industry level, the Philippine domestic shipping sector is characterized by a large and diverse fleet of vessels, including passenger ferries, cargo ships, fishing vessels, and service craft. Reports from MARINA indicate that the country maintains over 19,000 registered domestic vessels, reflecting the critical role of maritime transport in sustaining economic activity and connectivity across the archipelago (MARINA, 2022). However, many of these vessels rely on conventional fossil fuels and operate with aging propulsion systems, resulting in relatively high energy consumption and emissions.

In addition to fleet-related challenges, port infrastructure and energy systems also present significant barriers to maritime decarbonization. Studies on green shipping corridors in the Philippines indicate that many ports lack the facilities required for alternative fuel bunkering or shore power integration (Global Maritime Forum, 2023). Furthermore, issues related to grid reliability and limited renewable energy supply constrain the potential for large-scale electrification of port operations and vessels.

Although recent initiatives such as the development of electric ferry pilots and maritime energy monitoring systems demonstrate growing interest in sustainable maritime technologies, these efforts remain limited in scope. There is currently insufficient research evaluating the overall readiness of the Philippine domestic shipping sector to transition toward low-carbon operations. Most available studies focus on specific aspects of maritime sustainability, such as ship efficiency or fuel policies, without examining the combined influence of policy frameworks, technological readiness, infrastructure capacity, and institutional support.

Therefore, this study seeks to address this gap by assessing the readiness of the Philippine domestic shipping sector for decarbonization. By analyzing the current state of regulatory policies, fleet characteristics, infrastructure capabilities, and technological options, the study aims to provide evidence-based insights that can support the development of sustainable maritime strategies in the Philippines.

Statement of the problem

This study aims to determine the readiness of the Philippines' domestic shipping sector for decarbonization among different shipping companies.

Specifically, this study seeks to answer the following questions:

1. What is the level of readiness of the Philippine domestic shipping sector for decarbonization among different shipping companies in terms of policy awareness and compliance with maritime environmental regulations, fleet readiness and vessel technological capability, availability and adoption of alternative fuels and energy-efficient technologies, port and operational infrastructure readiness, financial capacity and investment readiness for decarbonization initiatives, and workforce knowledge and technical competence in implementing sustainable maritime practices?
2. What are the current decarbonization practices implemented by different shipping companies in the Philippines?
3. What challenges or barriers are encountered by shipping companies in adopting decarbonization strategies?
4. Is there a significant difference in the level of decarbonization readiness among different shipping companies?

5. Based on the findings of the study, what strategic action plan may be proposed to enhance the readiness of the Philippine domestic shipping sector for decarbonization?

METHODOLOGY

This study employs a quantitative descriptive-comparative survey design to systematically assess the readiness of the Philippine domestic shipping sector for decarbonization. The quantitative approach was deemed appropriate because the study aims to generate measurable and objective data regarding key readiness indicators, including policy awareness and compliance, fleet readiness and technological capability, adoption of alternative fuels and energy-efficient technologies, port and operational infrastructure readiness, financial capacity, and workforce competence. These variables represent critical dimensions of maritime decarbonization readiness and reflect the current condition of shipping companies in responding to environmental regulations and sustainable maritime practices.

The descriptive component of the design is utilized to determine the overall level of readiness of shipping companies across the identified dimensions. Through this approach, the study is able to present a comprehensive assessment of the current state of the Philippine domestic shipping sector in relation to decarbonization. Specifically, it provides empirical data on how shipping companies comply with maritime environmental policies, the extent to which they have modernized their fleets, their capacity to adopt alternative fuels, and their preparedness in terms of infrastructure, financial resources, and workforce capability. This aligns with the primary objective of the study, which is to evaluate the sector's preparedness for transitioning toward low-carbon maritime operations. The descriptive design also allows the researcher to identify existing decarbonization practices being implemented by shipping companies, as well as the challenges and barriers encountered in adopting sustainable technologies and strategies. These aspects are essential in understanding not only the level of readiness but also the practical realities and constraints faced by the industry in moving toward decarbonization.

The comparative aspect of the study is employed to determine whether there are significant differences in the level of decarbonization readiness among different shipping companies. Given that the Philippine domestic shipping sector consists of diverse operators with varying levels of resources, technological capability, and operational scale, it is important to examine how readiness varies across these entities. By comparing responses from different companies, the study is able to identify disparities in readiness levels, which may be influenced by factors such as company size, type of operation covering passenger, cargo, and tanker services, and access to financial and technological resources. This directly supports one of the key research questions of the study, which seeks to determine differences in readiness among shipping companies. Furthermore, the comparative design strengthens the analytical depth of the study by enabling the identification of specific areas where certain companies may lag or excel, thereby providing a more nuanced understanding of the sector and supporting the development of targeted recommendations and strategic action plans aimed at enhancing overall decarbonization readiness.

To ensure the validity of the findings, the study tests the null hypotheses at the 0.05 level of significance. This statistical threshold is used to determine whether the observed differences in readiness among shipping companies are statistically significant or merely attributable to chance. Through the application of inferential statistical tools, specifically analysis of variance or ANOVA, the study is able to objectively evaluate the presence of significant differences across groups. This aligns with the study's hypothesis, which states that there is no significant difference in the level of decarbonization readiness among different

shipping companies. Overall, the use of a quantitative descriptive-comparative survey design is appropriate and effective for this study as it enables the systematic collection, measurement, and analysis of data related to decarbonization readiness. It provides both a detailed description of the current state of the Philippine domestic shipping sector and a comparative evaluation of differences among companies, thereby generating evidence-based insights that can inform policy development, industry practices, and future research on sustainable maritime transport.

The study is conducted within the Philippine domestic shipping sector, which plays a vital role in the country's economic development and inter-island connectivity. As an archipelagic nation composed of more than 7,000 islands, the Philippines relies heavily on maritime transport for the movement of passengers, goods, and essential services (Maritime Industry Authority [MARINA], 2022). The research environment includes selected shipping and maritime-related companies operating in the Philippines, engaged in passenger transport, cargo shipping, tanker operations, ferry services, and logistics support.

The selected companies are primarily situated in major maritime and economic hubs across the country. 2GO Group, Inc. maintains its main office in Pasay City, Metro Manila, Philippines, located near major ports and logistics hubs such as Manila South Harbor, making it well-positioned for coordinating nationwide shipping, freight, and distribution operations. Chelsea Logistics and Infrastructure Holdings Corp. has its main office in Taguig City, Metro Manila, Philippines, situated within the Bonifacio Global City area, which affords the company strategic advantages for management, logistics coordination, and corporate operations. FastCat Ferries, operated by Archipelago Philippine Ferries Corporation or APFC, is based in the Philippines with operations and offices primarily located in Luzon port areas such as Batangas. FastCat Ferries is recognized for its modern roll-on/roll-off vessels, commonly referred to as RoRo vessels, which are designed to transport passengers, vehicles, and cargo across major inter-island routes efficiently and safely. Its location near key ferry terminals and RoRo ports enables effective inter-island connectivity, making it a vital component of domestic maritime transportation and a relevant subject in assessing decarbonization readiness within the ferry segment of the industry.

Petrolift, Inc. is based in the Philippines, primarily in coastal and port areas that are strategically positioned near fuel terminals and oil distribution hubs, allowing the company to effectively manage tanker operations and marine fuel logistics. Carlos A. Gothong Lines, Inc. has its main office in Mandaue City, Cebu, Philippines, situated near Cebu Port, one of the busiest domestic shipping hubs in the country, enabling the company to support cargo movement and distribution across the Visayas and Mindanao. Metro Ferries and IMP operate within the Philippines, particularly in regional and coastal port areas where their offices are typically located near ferry terminals to support localized passenger ferry services and regional mobility. The American Bureau of Shipping, or ABS, although headquartered in Houston, Texas, USA, maintains a Philippine office in Manila, where it provides classification, certification, and compliance services to ships operating within the country. These companies are primarily located in major maritime and economic hubs such as Metro Manila, Cebu, and other strategic port areas across the Philippines. These locations were selected because of their direct involvement in domestic shipping operations, their accessibility to major ports, and their importance in maritime logistics and regulatory support, rendering them suitable and relevant environments for assessing the readiness of the Philippine domestic shipping sector for decarbonization.

The respondents of the study consist of selected personnel from the aforementioned domestic shipping companies operating in the Philippines. These respondents are purposively chosen based on their direct involvement, knowledge, and experience in maritime operations, environmental compliance, and strategic decision-making within their respective organizations. Specifically, the respondents include company executives and managers,

operations and logistics personnel, marine engineers and technical staff, environmental compliance officers, and port and maritime support personnel. These individuals are considered appropriate respondents because they possess relevant insights regarding their company's level of readiness for decarbonization, particularly in terms of policy compliance, fleet modernization, adoption of alternative fuels and energy-efficient technologies, infrastructure capability, financial preparedness, and workforce competence. The inclusion of respondents from different functional roles ensures a comprehensive and multi-dimensional perspective of decarbonization readiness across the shipping sector. Moreover, gathering data from multiple companies allows for meaningful comparison of readiness levels, which is essential in addressing the study's objective of determining significant differences among shipping companies.

The instrument used in this study is a researcher-developed adaptive survey questionnaire adapted from validated environmental readiness, sustainability, and maritime-related survey instruments. The questionnaire is designed to measure the level of decarbonization readiness of the Philippine domestic shipping sector across multiple dimensions. It follows a multi-dimensional framework consistent with established studies on environmental readiness and sustainability assessment, incorporating key constructs such as policy compliance, technological capability, infrastructure readiness, financial preparedness, and workforce competence. These constructs are recognized as critical determinants of readiness in environmental transition and decarbonization initiatives.

The questionnaire consists of two main parts. The first part, which focuses on Decarbonization Readiness as the Core Scale, measures the level of readiness across six dimensions: policy awareness and compliance, fleet readiness and technological capability, adoption of alternative fuels and energy-efficient technologies, infrastructure readiness, financial capacity, and workforce competence. This section utilizes a four-point Likert scale, where a score of 4 corresponds to Highly Ready, 3 corresponds to Ready, 2 corresponds to Less Ready, and 1 corresponds to Not Ready, in order to obtain quantifiable and interpretable data. The second part of the instrument identifies the existing decarbonization practices implemented by shipping companies as well as the barriers and constraints encountered in adopting sustainable maritime strategies. The instrument is considered adaptive because it integrates multiple validated constructs from existing environmental and sustainability-related studies while being contextualized specifically to maritime decarbonization. Furthermore, it allows flexible interpretation across different types of shipping companies, making it suitable for capturing the varying levels of readiness, operational capacities, and challenges within the Philippine domestic shipping sector.

The data gathered in this study are analyzed using appropriate descriptive and inferential statistical tools to ensure accurate interpretation and to address the research questions and hypotheses. Frequency and percentage are used to describe the distribution of respondents and to summarize categorical data, providing a clear overview of respondent characteristics and general trends in their responses. The weighted mean is utilized to determine the level of decarbonization readiness of the Philippine domestic shipping sector across the six identified dimensions, namely policy awareness and compliance, fleet readiness and technological capability, adoption of alternative fuels and energy-efficient technologies, infrastructure readiness, financial capacity, and workforce competence. The weighted mean allows for the measurement of the extent to which each indicator is practiced or observed. Ranking is applied to identify the highest and lowest indicators in terms of readiness, as well as to determine the most common practices and the most significant challenges encountered by shipping companies in adopting decarbonization strategies. Analysis of variance, or ANOVA,

is used to determine whether there is a significant difference in the level of decarbonization readiness among different shipping companies. This statistical test is appropriate for comparing the mean responses of multiple groups and identifying whether variations are statistically significant. All hypotheses in the study are tested at the 0.05 level of significance. If the computed p-value is less than 0.05, the null hypothesis is rejected, indicating a significant difference among groups. Otherwise, the null hypothesis is accepted. Through the application of these statistical tools, the study ensures that the findings are objective, reliable, and suitable for drawing valid conclusions regarding the decarbonization readiness of the Philippine domestic shipping sector.

RESULTS AND DISCUSSION

This chapter presents the results and discussion of a quantitative and mixed-methods study examining the level of readiness of the Philippine domestic shipping sector for decarbonization, the current decarbonization practices being implemented by shipping companies, and the barriers encountered in adopting decarbonization strategies. The study employed a descriptive survey research design using a structured questionnaire as the primary data collection instrument. Respondents were drawn from domestic shipping companies operating in the Philippines through purposive sampling, and their responses were analyzed using weighted means and standard deviations to determine the level of readiness across six key dimensions. A multiple-response frequency analysis was applied to identify the most commonly implemented decarbonization practices and the most frequently reported barriers. The verbal interpretations of weighted means followed a four-level scale where 3.25 to 4.00 corresponds to Highly Ready, 2.50 to 3.24 to Ready, 1.75 to 2.49 to Less Ready, and 1.00 to 1.74 to Not Ready. The discussion that follows is grounded in the data gathered from the survey instrument and interprets the results in direct relation to the objectives of the study.

Level of readiness in terms of policy awareness and compliance

The first dimension assessed the level of readiness of the Philippine domestic shipping sector for decarbonization in terms of policy awareness and compliance. This dimension examined the extent to which shipping companies understand, communicate, implement, and comply with environmental policies and maritime regulations, including organizational practices related to regulatory monitoring, environmental reporting, policy enforcement, and participation in certification programs. The results yielded an aggregate mean of 3.19 with an aggregate standard deviation of 0.49, interpreted as Ready. This finding indicates that shipping companies generally comply with maritime environmental regulations, communicate environmental policies within the organization, monitor compliance, and integrate compliance practices into operations.

Among the ten indicators, the highest weighted means were recorded by two items: environmental policies are clearly communicated within the organization, and management enforces strict environmental compliance policies, both of which obtained a weighted mean of 3.22 with standard deviations of 0.49 and 0.50, respectively. These results suggest that organizational communication structures and management-level enforcement mechanisms are among the most firmly established policy dimensions within the sector. Compliance with maritime environmental regulations and active monitoring of compliance with environmental standards each registered a weighted mean of 3.21 with a standard deviation of 0.51 and 0.49, respectively, further reflecting a generally consistent commitment to regulatory adherence at the operational level. Employee awareness of national and international maritime regulations

and participation in environmental certification programs both yielded a weighted mean of 3.18 with a standard deviation of 0.49, indicating moderate but positive readiness in these areas.

The comparatively lower-rated indicators in this dimension include the conduct of internal audits to ensure regulatory compliance, which registered the lowest weighted mean in the section at 3.14 with a standard deviation of 0.47. Regular updating of policies related to environmental standards, environmental compliance integration into company operations, and the presence of a clear system for reporting environmental issues each obtained a weighted mean of 3.17, with standard deviations of 0.47, 0.48, and 0.49, respectively. Although these values remain within the Ready range, they indicate that audit procedures, reporting mechanisms, and policy updating processes have not yet reached the same level of institutional entrenchment as communication and enforcement practices.

The aggregate mean of 3.19 positions the sector near the upper boundary of the Ready range, signaling that while a meaningful foundation for decarbonization through policy awareness and regulatory compliance exists, the sector has not yet attained a Highly Ready classification. This distinction is significant in the context of escalating international expectations for maritime sustainability. The International Maritime Organization's 2023 GHG Strategy calls for shipping to reduce carbon intensity by at least 40% by 2030 and to move toward net-zero GHG emissions by or around 2050, demanding not only awareness but active and advanced institutional integration of environmental compliance. The United Nations Conference on Trade and Development has similarly emphasized the need to accelerate maritime decarbonization while supporting vulnerable economies, a concern directly relevant to the Philippines as an archipelagic and developing country whose connectivity and trade depend heavily on domestic maritime transport. At the national level, the Maritime Industry Authority's 2025 decarbonization symposium underscored the urgency of equipping maritime stakeholders with the knowledge, skills, and collaborative strategies required for greener shipping operations, reinforcing the finding that while the policy awareness foundation is present, further strengthening in audits, certification program participation, and continuous policy updating is necessary to advance the sector's readiness to a higher level.

Level of readiness in terms of fleet readiness and vessel technological capability

The second dimension assessed the level of readiness of the Philippine domestic shipping sector in terms of fleet readiness and vessel technological capability. This dimension examined the preparedness of shipping companies to adopt and utilize modern vessel technologies, energy-efficient systems, and environmentally sustainable practices, including the condition of existing fleets, technological upgrades, fuel efficiency measures, and vessel capacity to meet emerging environmental standards. The results produced an aggregate mean of 2.93 with an aggregate standard deviation of 0.60, interpreted as Ready, indicating that respondents generally perceive their companies as prepared to support decarbonization through vessel modernization, technological improvements, and sustainable fleet management.

The highest-rated indicator in this dimension was continuous improvement in vessel performance, which obtained a weighted mean of 2.98 with a standard deviation of 0.56. This finding suggests that shipping companies are actively pursuing measures to enhance operational performance and vessel efficiency as an ongoing strategic commitment. Two indicators, ships are monitored for fuel efficiency and emissions and equipment used onboard supports sustainability goals, shared the second-highest weighted mean of 2.96 with standard deviations of 0.59 and 0.58, respectively, reflecting the recognized importance of environmental performance monitoring and the utilization of sustainability-supporting onboard

technologies. Fleet modernization as part of company strategy registered a weighted mean of 2.95 with a standard deviation of 0.58, while ships comply with international energy efficiency standards obtained a mean of 2.94 with a standard deviation of 0.60, both affirming an orientation toward alignment with global sustainability benchmarks.

The lowest-rated indicator was the provision of energy-efficient technologies onboard vessels, which obtained a weighted mean of 2.84 with a standard deviation of 0.67. While this indicator remains within the Ready category, its position at the lower end of the range indicates that energy-efficient technologies have not yet been uniformly adopted across all vessels in the domestic fleet. The relatively higher standard deviation of 0.67 associated with this indicator further reflects greater variability in respondents' assessments of the extent of energy-efficient technology adoption, suggesting differences in fleet modernity and investment capacity among companies. The remaining indicators, including fleet capability to adapt to low-carbon technologies and adoption of advanced ship design technologies, both registered a weighted mean of 2.90 with standard deviations of 0.64 and 0.61, while regular upgrading of existing vessels for efficiency yielded a mean of 2.91 with a standard deviation of 0.60.

These findings collectively indicate that the Philippine domestic shipping sector has initiated meaningful steps toward fleet readiness, but that technological capability still requires stronger investment and more comprehensive modernization. Kondratenko et al. (2025) emphasized that ship decarbonization can be supported through retrofitting, improved ship design, fluid dynamics optimization, and artificial intelligence-based efficiency systems, reinforcing the finding that continuous vessel improvement is both necessary and strategically relevant for emission reduction. Sardar et al. (2025) similarly highlighted that ship energy efficiency depends on both technological advancement and operational practices, affirming that vessel monitoring, fuel-efficiency tracking, and equipment upgrades represent meaningful intermediate steps in the decarbonization pathway. Lloyd's Register (2024) noted that energy-saving technologies are increasingly being employed by fleets to manage emissions-related pressures, while the IMO CARES report on domestic shipping recognized that shipowners may select cost-effective onboard energy-efficiency options based on vessel size, age, type, and trading area. These considerations are particularly relevant for the Philippine domestic shipping context, where fleet diversity and varying company capacities necessitate differentiated and scalable approaches to technological upgrading and long-term fleet modernization.

Level of readiness in terms of availability and adoption of alternative fuels and energy-efficient technologies

The third dimension examined the level of readiness of the Philippine domestic shipping sector in terms of the availability and adoption of alternative fuels and energy-efficient technologies. This dimension assessed the extent to which shipping companies have access to and utilize cleaner fuel options and energy-efficient technologies that contribute to reducing greenhouse gas emissions. The results yielded an aggregate mean of 2.85 with an aggregate standard deviation of 0.64, interpreted as Ready, indicating that shipping companies are aware of and are taking initial steps toward adopting alternative fuels and energy-efficient technologies to support decarbonization.

The highest-rated indicator was awareness of future fuel transition strategies, which obtained a weighted mean of 2.92 with a standard deviation of 0.58, followed closely by collaboration with partners for green technology adoption at a weighted mean of 2.91 with a standard deviation of 0.59. These findings suggest that strategic awareness and inter-organizational partnerships represent the most developed aspects of this readiness dimension. Technological upgrades in support of emission reduction goals registered a weighted mean of 2.90 with a standard deviation of 0.61, while the company's support for innovation in green

shipping technologies and investment in clean energy technologies each recorded a weighted mean of 2.88 with a standard deviation of 0.62. Consideration or implementation of pilot projects for alternative fuels obtained a mean of 2.84 with a standard deviation of 0.65, regular evaluation of alternative fuel options registered a mean of 2.82 with a standard deviation of 0.65, and the installation of energy-saving systems in vessels yielded a mean of 2.81 with a standard deviation of 0.66.

The lowest-rated indicator in this dimension was the exploration of alternative fuels such as liquefied natural gas and hydrogen, which registered a weighted mean of 2.67 with a standard deviation of 0.77. This result, while still falling within the Ready category, signals that actual engagement with specific alternative fuel options remains comparatively limited relative to the higher levels of awareness and partnership orientation observed among the other indicators. The higher standard deviation of 0.77 also reflects greater divergence in respondents' perceptions regarding the extent to which alternative fuel exploration is being carried out, likely reflecting differences in company size, operational capacity, and technological exposure.

These findings suggest that the domestic shipping sector possesses a foundational level of readiness for fuel transition and technological innovation, but that significant investments and infrastructure development are still needed to accelerate adoption. The International Energy Agency (2023) has identified alternative fuels such as hydrogen, ammonia, and advanced biofuels as critical to reducing emissions from hard-to-abate sectors including maritime transport, while emphasizing that the transition requires substantial investments in fuel production, storage facilities, and supporting infrastructure. Deloitte (2024) reported that maritime decarbonization depends on the industry's ability to scale up the adoption of alternative fuels and energy-efficient technologies while overcoming the financial and operational challenges associated with fuel transition, a perspective that is directly consistent with the gap observed between strategic awareness and actual alternative fuel implementation in the present findings. Bureau Veritas (2024) further stressed that collaboration among shipping companies, technology providers, fuel suppliers, and regulatory agencies is essential for accelerating the adoption of low-carbon maritime technologies, lending contextual support to the high rating received by the partnership-related indicator. The Maersk Mc-Kinney Moller Center for Zero Carbon Shipping (2023) has also noted that while awareness of fuel transition strategies is a critical first step toward long-term decarbonization, it must ultimately be accompanied by concrete investments and pilot implementations, a principle that aligns with the present finding that awareness has preceded practical adoption in this dimension.

Level of readiness in terms of port and operational infrastructure readiness

The fourth dimension assessed the level of readiness of the Philippine domestic shipping sector in terms of port and operational infrastructure readiness. This dimension examined the adequacy of port facilities, operational systems, and supporting infrastructure needed to facilitate decarbonization initiatives, including access to cleaner energy infrastructure, operational efficiency measures, technological support systems, and the capacity to accommodate emerging low-carbon maritime practices. The aggregate mean for this dimension was 2.86 with an aggregate standard deviation of 0.64, interpreted as Ready, indicating that ports and related operational systems generally support sustainable maritime activities.

The highest-rated indicator was the extent to which ports used by the company support sustainable operations, which registered a weighted mean of 2.94 with a standard deviation of

0.59. Logistics systems that support efficient operations and infrastructure development that supports environmental goals both obtained weighted means of 2.90 with standard deviations of 0.61 and 0.60, respectively. Facilities equipped for modern maritime technologies received a weighted mean of 2.85 with a standard deviation of 0.66, while infrastructure available for alternative fuel usage registered 2.84 with a standard deviation of 0.66. One of the two recorded instances of the alignment of port operations with sustainability practices registered a weighted mean of 2.88 with a standard deviation of 0.61, while the other registered a mean of 2.78 with a standard deviation of 0.69. Access to energy-efficient port facilities and infrastructure that supports emission monitoring systems each obtained weighted means of 2.83 with standard deviations of 0.67, and ports providing adequate support for vessel maintenance registered the lowest weighted mean in this dimension at 2.82 with a standard deviation of 0.68.

The pattern of results reveals that while basic infrastructure readiness is present, further improvements are needed in green port facilities, emission monitoring systems, and alternative fuel infrastructure. Sadiq et al. (2021) explained that greener seaports increasingly require electrified infrastructure, automation, and energy-efficiency measures to reduce energy consumption and emissions, an observation that directly supports the need for Philippine ports to enhance access to energy-efficient facilities and modernize their operational support systems. Elhussieny (2025) emphasized that smart green ports integrate advanced technologies and sustainable practices into port operations, demonstrating that digitalization and modern systems are necessary for achieving operational efficiency in a decarbonizing maritime environment. Minh et al. (2025) further noted that port decarbonization should integrate shore power, alternative fuels, and port-based infrastructure as interconnected rather than separate solutions, reinforcing the finding that the sector's moderate infrastructure ratings reflect a systemic gap rather than isolated deficiencies. The aggregate mean of 2.86 suggests that ports may already support some sustainable operational practices, but that full decarbonization readiness requires greater and more coordinated investment in alternative fuel infrastructure, emission monitoring technologies, energy-efficient facilities, and logistics system modernization.

Level of readiness in terms of financial capacity and investment readiness

The fifth dimension assessed the level of readiness of the Philippine domestic shipping sector in terms of financial capacity and investment readiness for decarbonization initiatives. This dimension examined the extent to which shipping companies possess the financial resources, investment strategies, funding opportunities, and organizational commitment necessary to support decarbonization efforts, including the capacity to mobilize financial capital for green technologies, energy-efficient vessels, alternative fuels, digital monitoring systems, and supporting infrastructure. The results yielded an aggregate mean of 2.83 with an aggregate standard deviation of 0.63, interpreted as Ready, indicating that respondents generally perceive their organizations as having adequate financial preparedness and investment commitment to support decarbonization efforts.

Among the indicators, the company prioritizes sustainability in financial planning obtained the highest weighted mean of 2.86 with a standard deviation of 0.61, suggesting that sustainability considerations are increasingly integrated into organizational financial decision-making and that domestic shipping companies recognize the strategic importance of aligning financial plans with environmental sustainability objectives. Four indicators, the company allocates budget for sustainability initiatives, investment planning includes decarbonization strategies, long-term budgeting considers sustainability goals, and the company evaluates cost-benefit of green investments, each registered a weighted mean of 2.85, with standard deviations of 0.64, 0.64, 0.61, and 0.62, respectively. The company invests in green technologies obtained

a weighted mean of 2.84 with a standard deviation of 0.62, while external funding opportunities are explored registered a mean of 2.83 with a standard deviation of 0.63. Funding available for research and development yielded a mean of 2.81 with a standard deviation of 0.65, and financial support available for fleet upgrades registered a mean of 2.80 with a standard deviation of 0.64.

The lowest-rated indicator in this dimension was the sufficiency of financial resources for modernization, which registered a weighted mean of 2.79 with a standard deviation of 0.65. This finding, while still within the Ready range, signals that concerns regarding the adequacy of financial resources required for large-scale modernization projects, vessel retrofitting, alternative fuel adoption, and acquisition of low-carbon technologies remain present within the sector. The relatively consistent standard deviation values across indicators reflect moderate agreement among respondents regarding their financial readiness, suggesting a broadly shared but not uniform perception of financial preparedness.

These findings are supported by Bastug et al. (2024), who emphasized that successful maritime decarbonization depends heavily on the availability of financing mechanisms and investment frameworks capable of supporting costly technological transitions, identifying access to capital and investment decision-making as among the most critical determinants of decarbonization implementation within the shipping industry. The International Maritime Organization's Innovation Forum (2024) similarly highlighted that achieving the targets established under the 2023 IMO Greenhouse Gas Strategy requires substantial investments in zero- and near-zero-emission technologies, fuels, and supporting infrastructure, affirming that financial commitment and innovation funding are fundamental prerequisites for maritime decarbonization. The findings also point to the need for stronger collaboration among government agencies, financial institutions, and shipping companies to expand access to green financing programs, sustainability-linked loans, grants, and investment incentives, as supportive financing policies have been identified as essential in reducing cost barriers and encouraging industry-wide adoption of sustainable maritime practices. While the sector demonstrates a positive level of financial preparedness, achieving full-scale decarbonization will require enhanced investment capacity, broader access to financing opportunities, and sustained financial support from both public and private stakeholders.

Level of readiness in terms of workforce knowledge and technical competence

The sixth dimension assessed the level of readiness of the Philippine domestic shipping sector in terms of workforce knowledge and technical competence in implementing sustainable maritime practices. This dimension examined the extent to which personnel within the sector possess the expertise, training, and competencies required to operate emerging technologies, implement energy-efficiency measures, monitor environmental performance, and comply with evolving sustainability regulations. The results yielded an aggregate mean of 2.97 with an aggregate standard deviation of 0.53, interpreted as Ready, indicating that respondents generally perceive their workforce as adequately prepared to support the transition toward environmentally sustainable and low-carbon maritime operations.

The highest-rated indicator was the extent to which employees are trained in sustainable maritime practices, which registered a weighted mean of 3.03 with a standard deviation of 0.52, indicating that training programs have been established to enhance employees' understanding of sustainability principles and environmentally responsible operations. The company supports continuous learning on sustainability obtained a weighted mean of 3.02 with a standard deviation of 0.50, while there is strong awareness of environmental responsibility among staff

registered a mean of 3.01 with a standard deviation of 0.52. These high-rating items collectively reflect a positive organizational culture that promotes environmental awareness and professional development. Training programs on environmental practices are conducted regularly and workforce readiness supports environmental compliance each obtained a weighted mean of 2.99 with a standard deviation of 0.51. Technical skills support new maritime technologies and the company provides seminars on sustainability both registered a mean of 2.96 with standard deviations of 0.55 and 0.54, respectively. Employees adapt to new technologies effectively obtained a mean of 2.95 with a standard deviation of 0.52.

The lowest-rated indicators in this dimension, the workforce has technical knowledge on green technologies and employees are aware of decarbonization strategies, each registered a weighted mean of 2.91 with standard deviations of 0.58 and 0.57, respectively. Although both values remain within the Ready category, they indicate that while employees possess a general understanding of sustainability concepts, specialized knowledge related to alternative fuels, green shipping technologies, emission-reduction systems, and advanced decarbonization strategies may still require further development. The relatively low standard deviations across all indicators in this dimension reflect a high degree of consistency in respondents' assessments of workforce readiness and technical competence.

These findings are consistent with Caesar et al. (2023), who emphasized that the maritime industry's transition toward sustainability requires a highly skilled and adaptable workforce capable of responding to technological and environmental changes, identifying skill development, continuous learning, and workforce resilience as critical factors for sustainable maritime transportation. Dewan et al. (2024) found that effective implementation of decarbonization measures in shipping is strongly influenced by seafarers' knowledge, awareness, education, and training, highlighting the need for comprehensive programs that address knowledge gaps and prepare maritime personnel to utilize new technologies and environmental management systems. The Maritime Just Transition Task Force (2023) stressed that the transition to low- and zero-carbon fuels will create new competency requirements for maritime professionals, requiring specialized training and upskilling to manage emerging technologies and alternative fuel systems safely. Sijabat (2025) further emphasized that preparing seafarers for green shipping transitions requires industry-academia collaboration, curriculum enhancement, and practical training opportunities that build competencies in sustainable maritime operations. These perspectives collectively affirm that while the sector demonstrates meaningful workforce readiness, sustained investment in specialized training, technical certifications, and maritime sustainability education will be essential to ensure that personnel remain capable of supporting the industry's long-term decarbonization transition.

Summary of the overall level of readiness for decarbonization

The summary assessment of the Philippine domestic shipping sector's overall level of readiness for decarbonization consolidates the weighted means and standard deviations across all six dimensions examined in the study. The results produced a grand mean of 2.94 with a grand standard deviation of 0.59, interpreted as Ready. This finding indicates that the sector generally demonstrates preparedness to support decarbonization efforts across the dimensions of policy awareness and compliance, fleet readiness and vessel technological capability, availability and adoption of alternative fuels and energy-efficient technologies, port and operational infrastructure readiness, financial capacity and investment readiness, and workforce knowledge and technical competence.

Among the six components, policy awareness and compliance obtained the highest weighted mean of 3.19 with a standard deviation of 0.49, indicating that regulatory awareness and compliance practices constitute the strongest pillar of the sector's decarbonization

readiness. This is followed by workforce knowledge and technical competence, with a weighted mean of 2.97 and a standard deviation of 0.53, and fleet readiness and vessel technological capability at a weighted mean of 2.93 and a standard deviation of 0.60. Port and operational infrastructure readiness registered a weighted mean of 2.86 with a standard deviation of 0.64, while availability and adoption of alternative fuels and energy-efficient technologies obtained a weighted mean of 2.85 with a standard deviation of 0.64. Financial capacity and investment readiness for decarbonization initiatives received the lowest weighted mean of 2.83 with a standard deviation of 0.63, though this value remains within the Ready range.

The overall pattern reveals that the sector's readiness is strongest in policy awareness and workforce competence and comparatively weaker in financial capacity, alternative fuel adoption, and infrastructure readiness. The grand mean of 2.94 situates the sector clearly within the Ready range but at a considerable distance from the Highly Ready threshold of 3.25, underscoring that readiness is present but uneven across dimensions. The IMO CARES report on decarbonizing domestic shipping emphasized that domestic shipping decarbonization requires coordinated action involving policy, technology, financing, capacity-building, and port infrastructure, and recognized that domestic shipping systems often require country-specific pathways because vessel types, routes, funding access, and infrastructure conditions vary widely, a framing that is directly applicable to the Philippine context. The OECD report on shipbuilding and maritime decarbonization further noted that alternative-fuel-capable ships can only contribute effectively to decarbonization if reliable fuel supply chains, storage systems, and bunkering infrastructure are available, reinforcing the implication that the lower ratings in alternative fuel adoption and port infrastructure reflect a structural interdependency that cannot be resolved through vessel-level upgrades alone. Clean Air Asia's 2025 report on shipping decarbonization in Asia highlighted that ports play a central role in enabling alternative fuel adoption by providing the required fuel availability and supporting systems, while Khabir et al. (2025) demonstrated that maritime decarbonization is increasingly connected with digitalization and human capital development, supporting the finding that workforce knowledge and technical competence constitute important existing strengths in the sector's readiness profile. Halpe (2025) further emphasized that achieving net-zero emissions in ports involves challenges related to economics, technology, and policy implementation, reinforcing the need for the sector to move from a state of general readiness toward full implementation through greater investment, stronger infrastructure support, wider access to clean technologies, and sustained workforce development.

Current decarbonization practices implemented by domestic shipping companies

Recognizing that readiness assessments benefit from being examined alongside actual implemented practices, this section presents the current decarbonization practices being carried out by domestic shipping companies in the Philippines. Since multiple responses were permitted, the frequencies reported reflect the number of respondents who identified each practice as being implemented within their respective organizations. The results indicate that energy-efficient operations ranked first with a frequency of 476, making it the most commonly implemented decarbonization practice in the sector. This finding suggests that companies prioritize operational measures such as fuel optimization, voyage planning, speed management, equipment efficiency improvements, and energy conservation as practical and cost-effective approaches to emission reduction, consistent with the observation that such measures can be adopted without major vessel modifications or substantial infrastructure investments.

Environmental compliance programs ranked second with a frequency of 452, followed by waste management practices at a frequency of 430. These results indicate that shipping companies place considerable emphasis on regulatory adherence and environmentally responsible operational practices, demonstrating the sector's commitment to meeting national and international environmental standards. The use of cleaner fuels ranked fourth with a frequency of 417, while sustainable logistics operations ranked fifth at 410, suggesting that some companies have already begun transitioning toward lower-emission fuel options and improving supply chain efficiency. Participation in green initiatives registered a frequency of 400 and ranked sixth, while energy monitoring systems ranked seventh with a frequency of 384.

In contrast, fleet modernization ranked eighth with a frequency of 372, adoption of alternative fuel technologies ranked ninth at 350, and emission reduction programs registered the lowest frequency of 313, ranking tenth. These comparatively lower figures indicate that while shipping companies recognize the importance of technological transformation, large-scale investments in vessel upgrades, alternative fuel systems, and comprehensive emission reduction programs remain less prevalent, likely attributable to high capital requirements, technological uncertainties, infrastructure limitations, and financial constraints. The dominance of operational and compliance-based practices over capital-intensive and technology-driven initiatives reveals that Philippine shipping companies are currently implementing decarbonization at an accessible and incremental level rather than through transformative structural change.

The 2023 UNCTAD Review of Maritime Transport identified operational efficiency measures, digitalization, hydrodynamic improvements, and machinery optimization as among the most practical approaches for reducing shipping emissions, noting that such measures can significantly contribute to emission reductions even before large-scale alternative fuel adoption becomes widespread, a finding that contextualizes the primacy of energy-efficient operations among respondents. The Maritime Industry Authority continues to strengthen regulatory frameworks and compliance mechanisms that support sustainable maritime operations in the Philippines, reinforcing the institutional significance of the high ranking accorded to environmental compliance programs. Loizidou et al. (2024) affirmed that effective waste management is a critical component of sustainable maritime operations because proper handling and disposal of ship-generated waste contribute directly to environmental protection and port sustainability, supporting the strong placement of waste management practices in the sector's current decarbonization profile. The comparatively lower adoption of alternative fuel technologies and fleet modernization is consistent with global patterns documented in recent maritime decarbonization literature, wherein alternative fuels remain constrained by technological maturity, infrastructure availability, investment requirements, and fuel supply uncertainties. These findings collectively suggest that as global pressure to reduce maritime emissions intensifies, shipping companies will need to transition from compliance-driven approaches toward more transformative and technology-based decarbonization solutions supported by integrated policy, investment, and infrastructure frameworks.

Challenges and barriers in adopting decarbonization strategies

The final section of this chapter identifies the challenges and barriers encountered by shipping companies in adopting decarbonization strategies. Since multiple responses were permitted, the frequencies reflect how often each barrier was identified by respondents across the sample. The leading barrier was the high cost of technology, which ranked first with a frequency of 492, indicating that the adoption of low-carbon vessels, energy-efficient equipment, emission monitoring systems, and alternative fuel technologies is financially

demanding for a large proportion of domestic shipping companies. Financial constraints ranked second with a frequency of 436, confirming that funding limitations represent a serious and pervasive concern in implementing decarbonization programs.

Limited access to alternative fuels ranked third with a frequency of 370, followed by limited government support at 366, and lack of infrastructure at 360. These findings suggest that even when companies are motivated to adopt greener technologies, implementation may be delayed by the limited availability of clean fuels, insufficient port facilities, inadequate policy incentives, and weak systemic support. Lack of technical knowledge ranked sixth with a frequency of 293, while limited industry collaboration registered a frequency of 289. Lack of skilled workforce ranked eighth at 261, regulatory challenges ranked ninth at 254, and resistance to change registered the lowest frequency of 194, ranking tenth. The comparatively lower frequencies for attitudinal barriers such as resistance to change and regulatory challenges relative to structural barriers such as costs, financing, fuel access, and infrastructure suggest that the sector's transition challenges are primarily resource-based and systemic rather than motivational.

Zhang et al. (2025) explained that alternative marine fuels continue to face significant barriers including inadequate port infrastructure, safety concerns, and challenges in practical adoption, directly supporting the finding that limited fuel access and infrastructure gaps remain major obstacles. The OECD (2025) emphasized that alternative fuel adoption requires not only low- or zero-emission vessels but also investment in fuel supply chains, bunkering systems, and supporting infrastructure, reinforcing the significance of the third- and fifth-ranked barriers identified in the present data. The DNV and Maritime Just Transition Task Force report (2022) found that decarbonized shipping will require immediate training and upskilling of seafarers because new fuels and technologies will generate new safety and competency requirements, lending support to the finding that lack of technical knowledge and skilled workforce remain important barriers in the sector. Laskar et al. (2025), drawing on expert assessments of maritime shipping decarbonization, highlighted that the transition involves uncertainty across technology, policy, fuel availability, and investment decisions, a characterization that is directly aligned with the multi-dimensional barrier profile emerging from the present findings. Nisiforou et al. (2022) further emphasized that shipping decarbonization requires coordinated action among government, industry, ports, and other stakeholders, underscoring the significance of limited government support and weak industry collaboration as barriers that collectively slow the adoption of decarbonization strategies.

The findings presented across this chapter collectively establish that the Philippine domestic shipping sector occupies a state of general readiness for decarbonization, with a grand mean of 2.94 confirming moderate preparedness across all six dimensions assessed. Policy awareness and compliance represent the strongest component of this readiness at a weighted mean of 3.19, while financial capacity and investment readiness constitutes the most critical area requiring strengthening at a weighted mean of 2.83. The current decarbonization practices being implemented by shipping companies are predominantly operational and compliance-based, with energy-efficient operations, environmental compliance programs, and waste management practices leading in adoption frequency, while fleet modernization, alternative fuel technology adoption, and formal emission reduction programs remain comparatively underdeveloped. The barriers impeding further progress are primarily structural and resource-based, with high technology costs, financial constraints, limited alternative fuel access, insufficient government support, and inadequate infrastructure identified as the most prevalent challenges. Taken together, these findings demonstrate that the sector possesses an existing foundation for decarbonization that is meaningful but incomplete, and that translating current

readiness into full implementation will require stronger investment mechanisms, expanded infrastructure, accelerated technological adoption, and enhanced cross-sector collaboration. These conclusions, along with the policy and operational recommendations that follow from them, are elaborated in the subsequent chapter.

CONCLUSION

The findings of this study collectively indicate that the Philippine domestic shipping sector has attained a generally adequate level of readiness for decarbonization. Across the six dimensions examined, namely policy awareness and compliance, workforce competence, fleet readiness and technological capability, infrastructure support, technology adoption, and financial planning, shipping companies have demonstrated sufficient preparedness to serve as a foundation for a broader transition toward low-carbon maritime operations. The sector has already undertaken various sustainability initiatives, including energy-efficient operations, environmental compliance programs, and waste management practices, all of which reflect a meaningful commitment to reducing environmental impacts and aligning with the demands of sustainable maritime development. These efforts signal that the industry is not approaching decarbonization from a position of inaction, but rather from one of emerging readiness that requires focused and sustained support to advance further.

Nevertheless, the findings also reveal that the pathway toward full decarbonization remains constrained by a set of persistent and interrelated challenges. High technology costs, financial limitations, limited access to alternative fuels, insufficient infrastructure, and inadequate government support continue to impede the more comprehensive adoption of decarbonization strategies across the sector. While the existing foundation is promising, these barriers underscore the reality that readiness in principle does not yet translate into full operational and structural capacity for the deep transitions that decarbonization ultimately demands. Addressing these gaps will require deliberate, coordinated, and well-resourced action from multiple stakeholders, including shipping companies themselves, government agencies, port authorities, and supporting institutions.

In light of these findings, this study advances several interconnected recommendations aimed at accelerating the sector's decarbonization trajectory. Shipping companies are encouraged to strengthen their decarbonization efforts by increasing investments in fleet modernization, energy-efficient technologies, alternative fuels, and emission reduction programs as direct means of advancing toward low-carbon maritime operations. Complementing these technological investments, management and industry leaders should enhance workforce knowledge and technical competence through regular training, seminars, certifications, and capacity-building programs that are specifically oriented toward sustainability and green technologies, ensuring that human capital development keeps pace with operational and regulatory demands.

At the policy and governance level, government agencies, particularly maritime and environmental regulators, are urged to provide stronger and more consistent policy support through financial incentives, tax benefits, grants, and green financing mechanisms that lower the barriers to decarbonization technology adoption. Port authorities and infrastructure developers similarly bear a critical responsibility, and the study recommends prioritizing the development of sustainable port facilities, alternative fuel infrastructure, energy-efficient systems, and environmental monitoring mechanisms as essential enablers of sector-wide decarbonization. Beyond infrastructure, multi-stakeholder collaboration among shipping companies, government agencies, academic institutions, and industry organizations should be actively cultivated to facilitate research, innovation, technology development, and knowledge sharing in support of sustainable maritime solutions.

The study further recommends the adoption and implementation of a Strategic Action Plan for Maritime Decarbonization Readiness, specifically designed to address the identified gaps in technology adoption, infrastructure readiness, financial capacity, and workforce development within the Philippine domestic shipping sector. This proposed output represents a practical and evidence-grounded mechanism through which the sector can translate the study's findings into concrete institutional and operational improvements. Finally, future researchers are encouraged to conduct similar studies involving a larger number of shipping companies, a wider range of maritime stakeholders, or comparative assessments across different regions, in order to further examine decarbonization readiness, validate the findings reported here, and contribute to the growing body of knowledge on sustainable maritime transport in the Philippine and broader regional contexts.

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