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Professional Maritime Sector Perceptions on Sustainability and Maritime Education in the Context of the Energy Transition

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ABSTRACT

The environmental transition of the international maritime industry is reshaping the technical and operational competencies required of maritime professionals. Decarbonization strategies, the adoption of alternative fuels, increasing environmental regulatory requirements, and the need to reduce the ecological impact of maritime operations are generating new challenges for maritime education and training. In this context, this study examines the perceptions of maritime professionals regarding the integration of sustainability and circular economy principles into current maritime education frameworks.

The research was conducted using a quantitative-descriptive approach based on surveys administered to active maritime professionals, including deck officers, engine officers, and shore-based technical personnel involved in maritime and logistics operations. The questionnaire addressed issues related to environmental training, regulatory awareness, preparedness of newly incorporated personnel, emerging competency requirements, and perceptions of the sector's adaptation to current environmental challenges.

The findings reveal a widespread perception that sustainability-related content has traditionally been incorporated into maritime education in a limited or superficial manner. Respondents also identify increasing regulatory and technological pressures associated with the maritime energy transition, highlighting the need to strengthen competencies in areas such as energy efficiency, alternative fuels, environmental management, and compliance with international environmental regulations. Furthermore, there is broad consensus regarding the importance of updating maritime curricula through applied methodologies, operational simulations, and specialized continuous professional development.

The study concludes that a significant gap exists between the environmental transformation currently underway in the maritime sector and the level of training perceived by industry professionals. Consequently, the paper highlights the need to advance toward more dynamic, interdisciplinary, and sustainability - oriented educational models aligned with international maritime environmental objectives.Keywords: maritime education and training, maritime sustainability, energy transition, environmental competencies, alternative fuels, maritime professionals.

1. Introduction.

The international shipping sector is currently undergoing one of the most significant transformations of recent decades. Growing regulatory pressure on environmental issues, the advancement of decarbonisation policies and the need to reduce the environmental impact of maritime transport are gradually changing both the sector's operations and the professional skills required on board and ashore.

The transition to cleaner maritime energy can no longer be seen solely as a long term strategy, but rather as an existing reality in which the way we operate our vessels is being driven by new technical, regulatory and environmental rules. As new

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fuel types and emissions control systems enter into operation, as vessel efficiency improves and as maritime operations continue to develop through greater use of technology and data; there exists a number of challenges to the industry as it relates to the training of future maritime staff.

As such, organizations like the International Maritime Organization (IMO), along with other entities such as the European Union have taken action to help expedite reductions in harmful emissions produced by vessels, while encouraging a more sustainable and environmentally responsible approach to shipping. The changes mentioned above do not only relate to the design and construction of new vessels, they also impact upon the professional backgrounds and technical skills required of future officer classes, technicians and specialist maritime personnel. However, the development of maritime education models have historically developed slower than the changes occurring in the shipping industry.

Traditionally, maritime education has focused primarily upon operational safety, navigation and compliance with key international conventions such as SOLAS, STCW and MARPOL. While educational programs relating to the protection of the marine environment have evolved over time and now feature in various forms across many curriculums and maritime vocational training programs; in most cases these have been incorporated into the curriculum as 'cross cutting' skills and often have been reactive, basic or limited to meeting regulatory minimums. This lack of focus creates uncertainty concerning how well prepared future maritime staff will be when facing operational conditions influenced by the ongoing energy transition, new environmental technologies and increased international regulatory obligations. It also provides a rationale for examining if the maritime training skills presently offered meet the developing needs of the maritime sector.

In terms of analyzing what maritime education must offer in order to prepare students for their role in an ever changing maritime sector; the views of working maritime professionals are especially important. Professionals who work aboard ships, ashore in ship management offices and who perform tasks that require them to interact with environmental regulations, new technologies and new approaches to maritime sustainability provide first-hand insight into where the gaps, needs and opportunities exist in current maritime training.

Given this context; the goal of this investigation is to analyze the perceptions of professionals operating within Spain's maritime sector regarding incorporating content regarding sustainability, energy transition and environmental competence into current maritime education. In order to obtain these perceptions, a quantitative descriptive methodology using surveys directed toward practicing professionals with varying levels of operational and technical expertise was used.

Additionally, the study examined issues including environmental education, regulatory knowledge, training for new entrants into the sector and perceived training needs stemming from current environmental concerns affecting the maritime sector. By conducting this analysis, the authors hope to add to the academic and professional discussion surrounding maritime education reform and contribute empirically derived evidence from the sector regarding its primary limitations and curricular adaptation needs in response to current developments in environmental transformations impacting maritime transportation.

2. Development.

2.1. Environmental transformation and the energy transition in the maritime sector.

International sea-faring transportation represents an essential component of contemporary global commerce; it carries approximately 80% of the total volume of global commerce [1]. Additionally, due to its importance for global commerce, it faces serious environmental issues resulting from fuel usage, air emissions, marine pollution, and the overall ecological implications of the maritime, port, and logistical activities associated with sea-faring transportation.

Recently, maritime sustainability has gained greater prominence in both national and international regulations dealing with transportation, energy, and the protection of the oceanic environment. The International Maritime Organisation (IMO) has been instrumental in driving regulatory changes toward a more sustainable model of protecting the marine environment through more effective environmental management models. Early regulatory models focused on accident prevention and operational discharges, whereas current regulatory models focus on more complex environmental management models to address air emissions, energy efficiency, and the de-carbonization of the maritime industry.

Annex VI to MARPOL, which addresses the prevention of air pollution from ships, has assumed additional importance since it includes several provisions intended to limit emissions of SOx, NOx and CO2 from ships [3], although some argue that those provisions do not go far enough. In addition, the introduction of mechanisms such as EEDI, SEEMP, EEXI and CII indicates a trend toward operational models based on energy efficiency and environmental performance standards [4]. Therefore, the international maritime regulatory community has evolved beyond simply focusing on preventing specific types of pollution incidents; today, it uses ongoing assessments of ships' energy and environmental performance across all phases of their operational lifecycles.

Moreover, IMO's Revised Strategy for Reducing Greenhouse Gas Emissions from Ships adopted in 2023 established a goal of reaching "net zero" emissions by or before 2050 and set intermediate reduction goals for 2030 and 2040 [5]. The adoption of this revised strategy has put considerable pressure on ship owners/operators, ports, and maritime education/training institutions to accelerate technological and operational innovation within the industry.

At the same time, the IMO has published numerous guidelines, codes, and technical circulars aimed at supporting the maritime energy transition and incorporating new and alternative fuels into the maritime industry safely. One example is the International Code of Safety for Ships using Gases or Other Low-Flashpoint Fuels (IGF Code), which provides specific requirements for ensuring the safe operation of alternative fuels

such as liquefied natural gas (LNG) [6]. In addition, the organization has issued a number of interim guidelines related to emerging fuels including those addressing methyl/ethanol alcohol as a fuel (MSC.1/Circ.1621) and those addressing ammonia as a fuel (MSC.1/Circ.1687). These latter two documents provide interim guidance regarding technical and operational criteria for the safe operation of new marine fuels [7][8]. The guidelines provided in Resolution MEPC.376(80), which outline the Life Cycle GHG Intensity of Marine Fuels (LCA Guidelines), further illustrate the increasing emphasis placed upon assessing all emissions associated with a marine fuel during its entire life cycle in the current efforts to decarbonize the maritime industry [9].

Therefore, the development and deployment of alternative fuels have emerged as one of the key pillars underpinning the maritime energy transition. Examples of such fuels include advanced biofuels, methanol, ammonia, LNG and hydrogen [10]. Nevertheless, there are still a range of barriers facing shipowners/operators who seek to implement these alternative fuels. Some examples of such barriers include concerns regarding operational safety, storage facilities at ports, port infrastructure to support new fuels, technological compatibility among different vessel types, and the level of technical knowledge possessed by seafarers involved in operating vessels utilizing new fuels.

The maritime energy transition does not merely entail a change in propulsion systems or the fuels used on board, but rather a structural transformation of the maritime operating model itself [11]. The gradual introduction of digital tools designed for energy and environmental monitoring is progressively altering the technical skills required within the sector [12].

Consequently, international maritime transport is currently facing one of the most significant processes of technical, regulatory and environmental transformation in its recent history [13]. Adapting to this new landscape depends not only on technological innovation or regulatory updates, but also on the capacity of the maritime education system to prepare professionals capable of operating in an environment increasingly shaped by sustainability, the energy transition and advanced environmental management.

2.2. Maritime training and emerging skills in the face of new environmental challenges.

The evolving environmental and technological landscape of the global shipping industry is transforming the types of professional abilities being demanded within the maritime sector. The shift toward more sustainable operational modes—resulting from the adoption of decarbonization policies, the implementation of alternative fuels, and new international regulatory frameworks—will present significant challenges to existing maritime education and training structures.

Maritime training has historically focused primarily on providing seafarers with the operational competencies required by the 1978 International Convention on Standards of Training, Certification and Watchkeeping for Seafarers [14], and as such, maritime training programs have generally emphasized content related to navigation, maritime safety, bridge and engine room operations, stability, maritime regulations and the technical aspects of operating vessels.

For example, the Spanish government's current nautical science and maritime transport and marine technology curricula continue to have a strong link to the professional competences defined in the STCW Convention, as well as to the traditional technical competences of the maritime sector. Similarly, both the organization of higher education in accordance with the Royal Decree 822/2021, as well as the publication of the maritime curricula through the Official State Gazette (BOE) [15] reflect a predominance of content associated with navigation, maritime safety, bridge and engine room operations and technical aspects of operating ships.

However, it appears that the inclusion of content regarding marine pollution, energy efficiency and environmental protection at all levels is increasing; however, the competences directly linked to the maritime energy transition — including those relating to alternative fuels, decarbonization and applied sustainability — appear less frequently throughout university maritime curricula.

As such, this presents an increasingly relevant issue in today's maritime energy transition environment facilitated by the International Maritime Organization. As LNG, advanced biofuels, methanol, ammonia and hydrogen begin to enter the market as alternatives to petroleum-based fuels, they create new training demands relative to safe operation, fuel storage and management, emergency response procedures, as well as the technical management of onboard energy systems.

Therefore, maritime sustainability will become a key competency area in the continued development of international maritime transportation. With regards to maritime sustainability — energy efficiency, emission reductions, environmental management and adapting to new energy technologies — these issues can no longer be confined solely to regulatory frameworks. Rather, they must now be integrated into the technical and operational preparedness of future generations of maritime professionals.

However, integrating these competences into maritime training models represents a considerable challenge for numerous educational institutions. The rapidly evolving nature of the sector's technology, updating teaching methods, obtaining specialized simulators and modifying curricula that were developed based upon traditional concepts of maritime operations provide barriers for incorporating new content related to sustainability and the energy transition.

Under these conditions, there are a number of emerging training needs in terms of alternative fuels, applied simulation, ship energy management, emissions analysis and operational sustainability. In addition, as a result of the increasing technical complexity caused by the maritime energy transition — highlighting a need for a paradigmatic shift in training methodology and format — a number of training models will be required to be updated and modified to accommodate the new regulatory frameworks, technologies and environmental conditions which are currently shaping the operational futures of international maritime organizations.

2.3. The importance of professional perception in adapting maritime training.

The way environmental and technological development is taking place in the world's marine environment and the global maritime transportation system at present, is creating major change to how the maritime industry is regulated and how it operates. This means there will be significant change in what is required of all those working professionally in the industry. Thus, the views of professionals working in the maritime sector become particularly important tools to help identify any training deficits, and assess whether current education models have the necessary flexibility to accommodate the increased demands on both an operational and environmentally sustainable level.

Because they have regular day-to-day contact with the operational realities of the maritime industry, active maritime professionals provide a valuable resource for gaining insights into the practical implications of the maritime energy transition on contemporary professional practice. Engineers, bridge crew members, technical personnel and others working in various aspects of maritime and port operations work every day under the increasing influence of tighter environmental legislation; rapidly developing technical procedures and processes; and new systems designed to increase ship energy efficiency, reduce emissions and improve the operational environmental performance of vessels. These professionals provide first hand knowledge about how the maritime energy transition is affecting contemporary professional practice.

Moreover, the maritime professional community can provide a direct linkage between the regulatory body developments being implemented by organizations such as the IMO and the actual needs of professionals employed in the maritime sector. Even though most of the international strategies for achieving decarbonization in shipping have been based on a combination of regulatory and technical considerations; ultimately successful implementation will depend heavily upon the preparedness and ability of the professionals who operate ships and manage the new technology associated with the energy transition.

From this point of view, professional experience can be used to identify potential discrepancies between the formal education received by graduates and the skills needed today in the maritime industry. For example, although many years ago traditional maritime training programs did not include courses that taught students about alternative fuel types; or how to implement new energy technologies; etc., now these topics represent some of the key areas of knowledge that graduates need to acquire if they want to enter the modern workforce. Similarly, even though the degree of regulatory and technological complexity associated with international maritime transport continues to grow; it represents one reason why continuing education/training becomes more and more important. Because continuing education/training enables individuals to keep up-to-date with respect to advances in techniques, practices and standards; it becomes easier for them to adapt to a complex and ever-changing maritime environment characterized by regulatory changes, technological innovations, and new international sustainability requirements.

Thus, because today the maritime profession includes not only traditional skills related to navigating safely, maintaining safe conditions for passengers and crew aboard ships, etc.; but also skills related to improving energy efficiency; managing shipboard environmental issues; adapting to new technology; etc. it is critical that educators understand these changes so that they may create curricula that reflect contemporary maritime employment requirements. As such, analyzing opinions /ideas / views / experiences of those working in the maritime sector represents one way for educators to gain insight into future requirements for revising/adapting existing maritime education/training programs.

With this idea in mind, this study examines attitudes / needs / requirements among maritime professionals in Spain relative to integrating skills related to sustainability; the energy transition; and environmental management into current maritime education/training programs; with the goal of identifying needs / limitations / future directions for modifying / mutating / modernizing maritime education / training programs to address new environmental challenges faced internationally by those working in the maritime transportation system.

3. Methodology.

This study used an exploratory quantitative descriptive method to explore how professionals in the maritime industry view the inclusion of skill sets that relate to sustainability, energy transitions and environmental management within their current maritime education.

In order to collect this data, a structured questionnaire was developed to measure the views of active maritime personnel who are engaged in different operational and technical roles throughout the maritime sector.

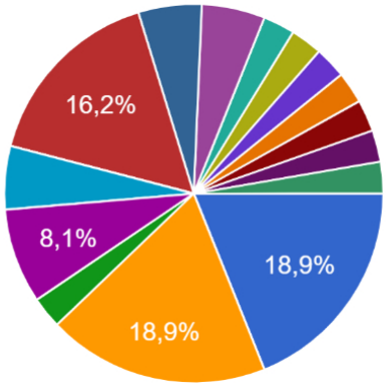
Active personnel were chosen because it is expected that they would provide responses that are relevant to today's operational environment of shipping, with regards to the energy transition, regulation changes and technology developments that have been mandated internationally through organizations like the IMO.

Of the 37 respondents selected from the Spanish maritime industry, there were bridge and engine officer's, managerial and technical employees working in a variety of shipping and logistics services.

Voluntary participation by all respondents ensured that responses remained confidential and were used solely for educational and research purposes.

This sample was made up of a variety of job types (bridge, engine room etc.) and technical/logistic/training jobs ashore that are involved in the operation of vessels in Spain. These various job titles and descriptions allowed us to obtain viewpoints from many different functional areas of the Spanish maritime industry. The inclusion of these different viewpoints will allow an enrichment of our understanding of how the Spanish maritime industry is transitioning to sustainable practices and how we can be adapting today's education and training systems to meet those changes.

Figure 1: Professional background of the study participants.



Source: Author.

Table 1: Professional background of the study participants.

PROFESSIONAL PROFILE	NUMBER
Captain	7
Chief Engineer	1
Chief Officer (Deck)	7
First Engineer Officer	1
Second Officer (Deck)	3
Second Engineer Officer	1
Shore-based technical staff (Inspection, etc.)	8
Retired	2
Pilot Boat Skipper	1
Lecturer	1
Harbor Pilot	1
Port Captain / Loading Master	1
Academy Instructor	1
Head of Personnel in Ship Repair Workshop	1
President of CSIAD, Group Energy & Transport LNG (Hong Kong)	1

Source: Author.

Our data collection tool had two components: closed-ended multiple choice type items, Likert scale rated items and open-ended items that would allow us to get both quantitative data (descriptive) and qualitative perceptions about maritime sustainability and vocational training. The structure of the questionnaire was set-up so that we could assess the respondents' knowledge of environmental principles and training in addition to their views of what changing educational curricula should include in order to prepare students for the evolving demands of the modern maritime sector.

The questionnaire was organized into 5 major sections. Section one collected basic demographic data about the respondent's age, work experience and employment title. Section two dealt with specific items dealing with maritime training and sustainability, including the respondents' opinions on the amount of environmental training they received during their initial training program, knowledge of applicable international conventions / regulations, awareness of maritime sustainability concepts and the circular economy. In section three we examined emerging skill needs / requirements in the maritime sector including the training of youth staff, marine environmental regulation compliance, updating existing training programs, preparing ships technologically to deal with future environmental challenges. Section four contained proposed improvements to the way training is provided, and included topics concerning pedagogical methods, continuing professional development opportunities and prioritized required skills for future generations of maritime trainees. In section five there were open-ended questions which gave us an opportunity to collect reflective comments / professional experiences/personal contributions to maritime sustainability and how contemporary maritime training might evolve.

There were several key subject matter areas queried in each question including; previous environmental training, knowledge of international environmental regulations like MARPOL (Marine Pollution), or the Hong Kong Convention (International Convention for the Safe and Environmentally Sound Recycling of Ships); perceptions on whether youth employees entering the workforce have been adequately trained / prepared; perceived need for specialized education / training in maritime sustainability; perception on competence levels pertaining to energy conservation, use of alternative fuels and operational environmental management. Also included were open-ended questions to allow for collection of individual reflections and/or professional experiences associated with environmental challenges affecting global marine transportation.

All questionnaires were sent electronically through digital distribution during the time frame in which this research was conducted. Following electronic submission of all completed questionnaires the data collected was compiled and analyzed utilizing a descriptive methodology focusing upon frequency distributions, generalized trends and comparative interpretations of perceptions expressed by respondents.

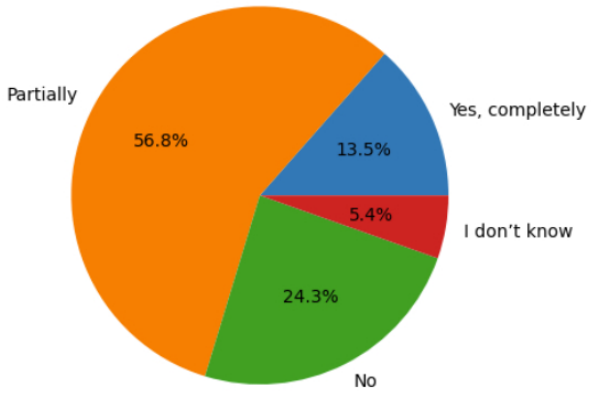
Due to the exploratory nature of this research project and due to its relatively small sample size, no attempts were made to derive generalizable findings across the entire maritime industry. Rather, it was our intention to generate a descriptive snapshot of Spanish maritime practitioners' perceptions on how maritime education/training may need to adapt to present day environmental/energy challenges facing the industry.

4. Results.

International shipping has been through an environmental and technological revolution over recent years which will slowly start to impact on what professional skills are required for careers within the maritime industry. As the International Maritime Organisation (IMO) pushes forward with the energy transition, as do governments through increasing levels of environmental regulations and the introduction of new technologies, alternative fuels etc., we see the old maritime business models being fundamentally changed.

The majority of professional respondents feel that technology in the maritime industry is currently at a very early stage of implementation to meet today's changing environmental and energy needs. The data also shows that there are many complex issues involved with implementing marine sustainable practices and transitioning to alternative forms of fuel for ships. In addition to perceiving the need for greater technological and operational advancements in the industry, there is a strong per-

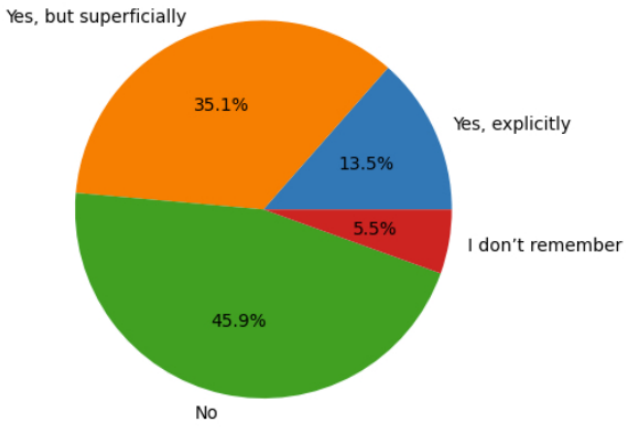
Figure 2: Perceptions of ships' technological readiness to meet the challenges of maritime sustainability.



Source: Author.

ception of dissatisfaction among maritime professionals concerning how much (if any) emphasis is being placed on integrating sustainability education into existing maritime education/training programs. A high percentage of survey respondents reported receiving no formal education or training in sustainability during their educational experiences. Another large segment of respondents felt that while some environmental education was included, it was provided only superficially. Overall, the data collected indicate that while increasing amounts of environmental education / awareness have become part of the culture in the maritime industry; however, there remains a widespread belief among the industry stakeholders surveyed that environmental education and awareness in the maritime education system is presently inadequate.

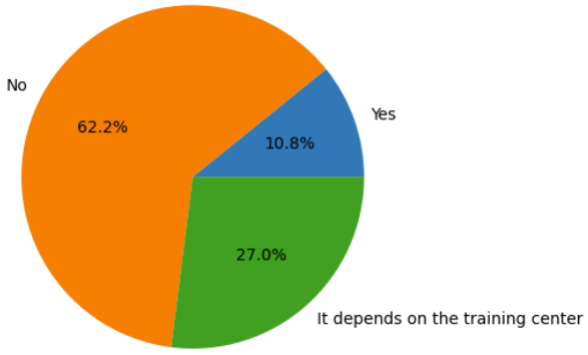
Figure 3: Perceptions regarding the inclusion of sustainability-related content in initial maritime training.



Source: Author.

Furthermore, the research highlights a widespread perception that there is a gap between technical and regulatory developments in maritime transport and the training of staff currently entering the sector. Most of the professionals involved believe that young staff are not sufficiently prepared in terms of maritime sustainability, which reinforces the need to progressively review certain traditional curricular approaches that are still primarily focused on conventional operational skills derived from the STCW framework..

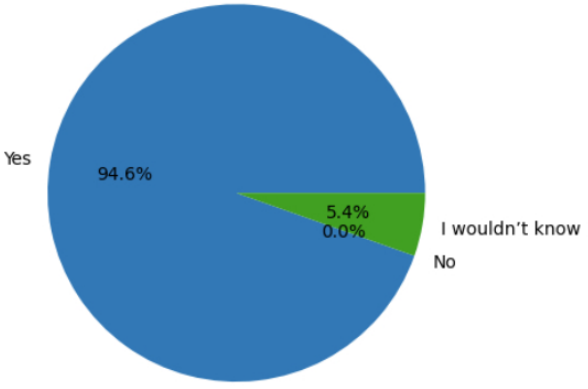
Figure 4: Perceptions regarding the training of young staff in maritime sustainability.



Source: Author.

Likewise, the data clearly shows there is a general agreement on increased environmental regulatory pressures for the global maritime industry. All of the respondents agree that there has been an increase in environmental regulations over the last few years, and this increase can be attributed to the effects of the first steps taken internationally to reduce emissions from ships (decabonization) through regulations set by the International Maritime Organization (IMO) as well as other world-wide bodies.

Figure 5: Perceptions regarding the increase in environmental regulatory requirements in the maritime sector.



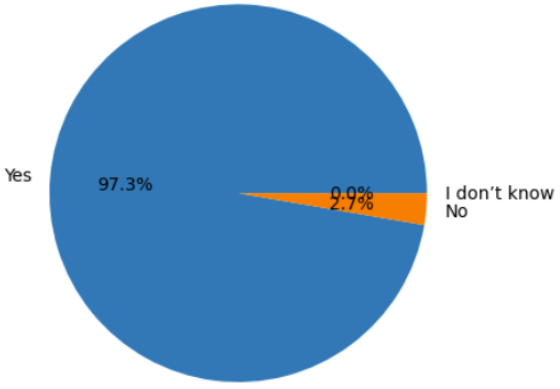
Source: Author.

The regulatory changes now underway are already impacting the working lives of maritime professionals in terms of how they operate, the technology they use, and their technical skill requirements onboard and in maritime and port operations.

Amongst the most important outcomes of this study was an overwhelming consensus from those participating that there exists a pressing need to modernize maritime education using

methods that mirror real-world operational practices as much as possible. All but one participant felt that simulations or case studies related to sustainability aboard could be incorporated into existing academic curricula. This indicates a growing demand for practical, multi-disciplinary training approaches to address the environmental concerns affecting maritime transportation today.

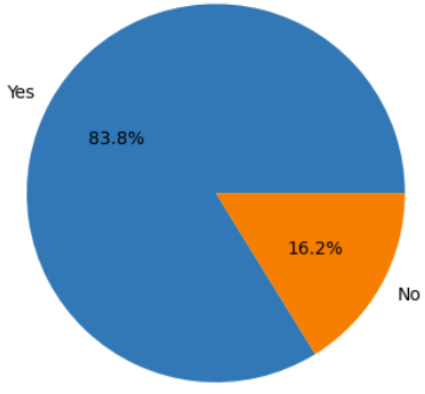
Figure 6: An assessment of the incorporation of simulations and case studies in maritime sustainability.



Source: Author.

In like manner, a very large percentage of the professionals who were questioned believed that certain topics specifically pertaining to sustainability would need to be included as mandatory parts of the curriculum for those pursuing degrees in nautical science, marine transport and marine technology. The significance of this viewpoint cannot be overstated since a high number of the respondents indicated that they have never received education regarding the marine circular economy or at least have been exposed to the idea only casually.

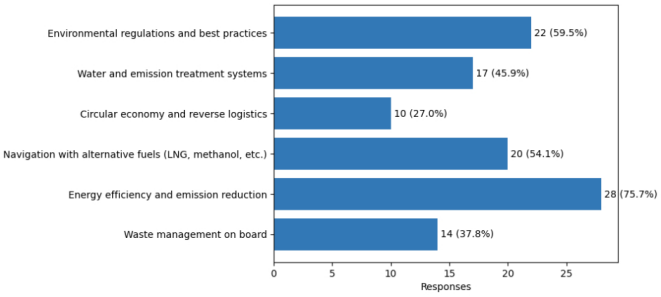
Figure 7: Perceptions regarding the need to introduce a specific course on maritime sustainability.



Source: Author.

These results reflect the emergence of new training needs in the areas of energy efficiency, environmental management, alternative fuels and the decarbonisation of the maritime sector.

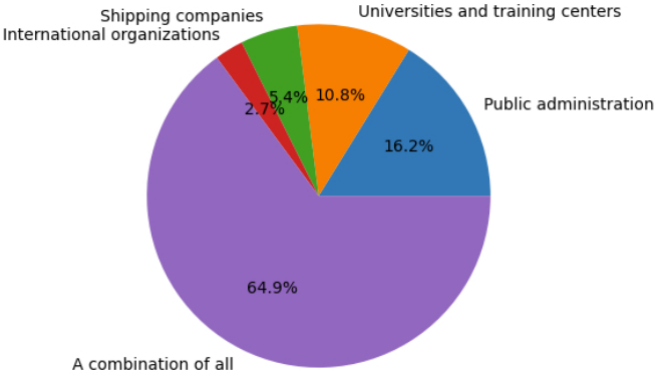
Figure 8: Key content identified by professionals for future maritime training.



Source: Author.

The study underlines the rising role of continuing professional development as well as other forms of development for professionals working in today's increasingly globalized maritime environment. A number of those with whom we spoke have taken part in refresher training or seminars about issues relating to sustainability in the last few years; however, a large proportion of them said that they did not currently have access to such training although many expressed an interest in having the opportunity to do so. These are two reasons why there is a greater need for developing programs of continuing professional development which can be responsive to the rapidly changing nature of technology, energy policy and regulation facing the modern-day maritime industry.

Figure 9: Perceptions regarding the stakeholders responsible for leading the transition towards more sustainable maritime training.



Source: Author.

Conclusions.

The findings of the study also reflect what has been a commonly - held belief about the need to adapt maritime education and training through collaboration among the many different organizations and professionals involved in the maritime industry. Most respondents agreed that while there were clearly important roles for universities and other training centers to play in developing the more sustainable training models needed

for the maritime industry, they would need to work collaboratively with governments (at all levels), international organizations, shipping companies and other academic institutions to achieve those models. The respondent's beliefs demonstrate that the maritime energy transition will not be simply a matter of educating people to understand how to meet their responsibilities under increasingly stringent environmental regulations, but rather it will involve changes at both the regulatory and organizational level which require coordinated efforts to ensure that there is a workforce trained to support these transitions.

Academically, this study provides input into the ongoing discussion about adapting Maritime Education and Training in response to the challenges posed by the maritime energy transition. By collecting data from respondents, we have identified trends concerning the major barriers to changing existing maritime training models as well as growing areas of emphasis among the skills required of Spain's maritime workforce. These observations suggest that adapting the content of maritime curricula is now less about being an educational concern than it is about being a strategic imperative for ensuring the long-term viability of international maritime transportation in terms of its operational capacity and environmental responsibility.

However, one of the major limitations of our research was that it was conducted using a qualitative methodology; therefore, our sample size was very small and our ability to generalize our results beyond our sample was severely constrained. Future studies may want to consider expanding the scope of their analyses by increasing their sample sizes; conducting comparative analyses across countries or regions; and/or conducting detailed analyses related to specific aspects of maritime skills such as those related to environmental issues like emissions reduction; the development of alternative fuels; or the application of digital technologies to energy use in marine transportation.

Overall, the study's results provide evidence that the maritime energy transition is having significant impacts not just on the technology used in and regulations governing the operation of vessels operating in the global marketplace, but also on the knowledge, skills and attitudes required of seafarers who are expected to operate efficiently and safely in this environment. As such, maritime sustainability can no longer be viewed as an add-on component in the context of preparing seafarers to function in today's and tomorrow's complex, technologically-advanced and environmentally-sensitive maritime world – but rather as an essential part of a broader set of competencies necessary for successful participation in that world.

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