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# A Roadmap towards the Decarbonization of Shipping: A Participatory Approach in Cyprus

**Olympia Nisiforou [1,*], Louisa Marie Shakou [2], Afroditi Magou [1] and Alexandros G. Charalambides [1]**

[1] Department of Chemical Engineering, Cyprus University of Technology, Corner of Athinon and Anexartisias 57, 3603 Lemesos, Cyprus; afroditi@energlab.ac.cy (A.M.); a.charalambides@cut.ac.cy (A.G.C.)
[2] Cyprus Energy Agency 2-12 Lefkonos Street, 1011 Nicosia, Cyprus; louisa.shakou@cea.org.cy
* Correspondence: olympia.nisiforou@cut.ac.cy

**Abstract:** Greenhouse gas (GHG) emissions from human activities are driving climate change and are currently at their highest levels in history. The international community, through the United Nations process, places great emphasis on the decarbonisation of our economies across all sectors. GHG emissions from maritime transport, even if considered the most carbon efficient method of transportation, are projected to increase if no action is taken to decarbonise, and thus pressure has extended to the maritime sector to contribute to the significant GHG emission cuts necessary. The paths by which the maritime sector can contribute to the achievement of the international target of GHG reduction by 2050 are still being determined, but numerous promising options exist. This paper aims to provide an overview of action towards decarbonisation by the international maritime sector, and to assess how Cyprus, an important flag state, can contribute to decarbonisation efforts. A participatory approach was used, through implementation of the EIT Climate-KIC's Deep Demonstrations methodology, as part of the ' Zero-Net Emissions, Resilient Maritime Hubs in Cyprus' project. The results were used to identify a portfolio of actions related to policy and regulatory development, education and re-skilling, technological development, and operation optimisation, which can support the decarbonisation of the maritime sector in Cyprus.

**Keywords:** maritime; sustainability; decarbonization; stakeholders; shipping



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## 1. Introduction

Shipping is a key factor of the global economy; in 2019 alone, eleven billion tons of seaborne trade were carried by ships weighing over 1000 gross tons (GT), which amounts to 80% and 70% of world trade by volume and value, respectively [1]. Even during the COVID-19 pandemic, ships continued to transport essential goods and medical supplies, and ports remained open to facilitate the distribution of goods [2].

Sea transport is considered the most carbon-efficient mode of transportation compared to other modes such as air, truck, or rail [3,4], since it emits less carbon dioxide per tonne-km compared to other forms of transport, accounting for 3% of global annual $CO_2$ emissions [5]. Yet, these emissions are expected to grow from 50 to 250% by 2050 across a range of plausible long-term economic and energy scenarios [5]. Thus, through the Unite Nations (UN) process, the international community has placed increasing emphasis on the decarbonisation of the maritime sector. The International Maritime Organization (IMO) has set a target for international shipping to decarbonise by at least 50% from 2008 levels by 2050 [6], while the Green Deal of the European Union (EU) has prioritised the transition to climate neutrality, and the need to cut GHG emissions across all sectors, including the maritime sector.

Many factors can catalyse action by the maritime sector towards more environmentally conscious and sustainable operations, including the enactment of major international protocols, the enforcement of governmental policies and regulations, research and innovation

into new technologies and fuels, among others. As with other sectors, there is no single optimum solution to decarbonisation. Decreasing carbon emissions will encompass a variety of options, including new fuel sources, increasing technical and/or operational efficiencies, drafting new policies and regulations, pivoting to new business models, and investing in education and re-skilling.

In moving away from heavy fuel oil (HFO), the maritime industry considers liquefied natural gas (LNG) as the currently most appealing alternate fuel to HFO, arguing that it can act as a bridging fuel until alternative renewable fuels become available, with reduced direct $CO_2$ emissions and air quality impacts [7]. However, increased LNG use has unintended negative consequences related to methane slip, with methane being a potent GHG with a greater warming potential than $CO_2$ [8], thus undermining decarbonisation efforts. In addition, the Global Methane Pledge announced at COP26 in Glasgow, UK, which commits signatories to reduce their overall methane emissions by 30 percent by 2030 compared to 2020 levels, further reduces the compatibility of LNG use with efforts to reduce GHG emissions [9]. This new initiative emphasises making cuts by tackling methane leakage from oil and gas wells, pipelines, other fossil fuel infrastructure, and other sources [9,10]. In view of this, other alternative fuels are being developed including biofuels, methanol, hydrogen, electric propulsion, and even nuclear fuels, but each offer differing levels of decarbonisation, with different economic costs and environmental profiles related to the release of both air and marine pollutants [11–15].

Various efficiency measures exist that can reduce fuel consumption, i.e., slow steaming, as well as emission reduction measures relating to energy efficiency or vessel design [16–19]. However, efficiency depends on various aspects, such as the class of vessel and their application.

Policy plays a significant role in decarbonisation, and various studies have assessed its importance [16,20,21]. A global review and taxonomy of policies, incentives, and measures [22] found that economic incentives that motivate the adoption of less environmentally damaging practices are the most commonly used measures, followed by infrastructure investments and policies. Several studies have also analysed market-based policy mechanisms (MBMs) to achieve shipping decarbonisation [22–26]. Market-based measures (MBMs) are more flexible measures that use price or other economic variables to provide monetary incentives for polluters to reduce emissions [23], and can be divided into three categories: environmental price control, environmental quantity control, and subsidies [27].

In line with the above, the literature suggests that technologies and policies should be used in combination, resulting in significant reductions [16,19]. Balcombe et al. [16] reviewed several combinations of fuels, technologies, and policies that may be used to reduce GHG emissions from international shipping and assessed combinations of possible reduction measures, while providing recommendations regarding effectiveness and economic–political feasibility. The impacts of other $CO_2$ equivalent gases (i.e., methane, $NO_x$, and $SO_x$) should also be considered [19].

While it is difficult to currently identify and implement 'best practices' for decarbonisation, the sector is taking its first steps, and it is important to understand the challenges that they face and opportunities that they see for the future. To that end, studies have been conducted focusing on different regions of the world, such as China [28], Italy [29], Denmark [30], and a study in Greece [31].

This paper presents the findings from the Deep Demonstrations project on 'Zero-Net Emissions, Resilient Maritime Hubs in Cyprus', funded by EIT Climate-KIC in 2019. The project was established to mobilise actors in the maritime sector to work together to achieve decarbonisation through systems innovation using a participatory approach. Through a series of interviews with thirty-eight stakeholders, across eight clusters of operations within the maritime industry in Cyprus, the needs of, and barriers to, decarbonisation faced by maritime stakeholders in Cyprus were identified. To date, there have been no relevant studies in the literature investigating the perspective of maritime stakeholders on decarbonisation in Cyprus, an important flag state. The findings from the interviews were

used to group and categorise the barriers, enablers, and potential challenges faced by the maritime sector in Cyprus and were applied in the development of a Vision and Roadmap for the decarbonisation of the sector.

The paper is organised in the following way: Section 2 provides a description of the Cyprus maritime sector; Section 3 presents an overview of the policies and regulatory framework governing the reduction of GHG emissions from shipping; Section 4 describes EIT CKIC's systems innovation and Deep Demonstrations methodology; and Section 5 presents the findings of the 'Zero-Net Emissions, Resilient Maritime Hubs in Cyprus' project.

## 2. Overview of Current State in Cyprus

Historically, shipping in Cyprus can be traced back thousands of years. The island developed its sailing and trading capabilities through interaction with the many civilisations that occupied Cyprus, each with its own maritime history, such as the Egyptians, Greeks, Romans, French, Venetians, and British [32]. Cyprus' drive for distinction in merchant shipping has been naturally facilitated by its ideal geographic location, at the crossroads of three continents: Europe, Asia, and Africa [32]. In recent decades, Cyprus recognised as early as 1963, the political, economic, and social importance of the maritime sector. It has built the country into a fully-fledged shipping centre, combining both a sovereign flag and a resident shipping industry, which successfully attracts entrepreneurs and international maritime organisations, drawn by the high-quality services and safety standards on offer [32].

Cyprus now constitutes a global maritime force; the Cypriot flag is ranked 11th globally with a merchant fleet of a gross tonnage exceeding 23 million [33]. The Cypriot merchant fleet ranks third in the EU, with about 11% of the EU Member States' total fleet. It represents 20% of the world third-party ship management market [33]. This is the result of various actions by the Cypriot government, including the development of advanced infrastructure and services that provide several advantages to maritime stakeholders and a competitive tax regime. In addition, Cyprus has introduced a Merchant Shipping Law, encompassing the Cyprus Tonnage Tax System, approved by the European Commission, which provides regulations for owners of Cypriot and foreign ships, charterers, and ship managers. Ships are subject to an annual tonnage tax, which is reduced if some environmental practices are used [34]. In addition to the above, maritime transport is the second biggest blue economic sector in Cyprus (after tourism), exhibiting a significant upward trend in employment, and accounts for 36% of the added value of the blue economy. A substantial number of new jobs are expected to be created in the maritime transport sector over 2016–2026, reaching 4.3% per year [35].

The high relevance of the sector for the country economy led to the establishment of the Cyprus Deputy Ministry of Shipping in March 2018. The deputy ministry is responsible for the coordination, development, and implementation of a complete national shipping strategy for the expansion of the Cyprus Register of Ships and the Cyprus shipping cluster; the continuous updating and implementation of shipping legislation; the registration of ships in the Cyprus Register of Ships and the issuing of relevant certificates and licenses; the promotion and support of investments in shipping; the promotion of maritime training and education; as well as the provision of support and information to shipping [36].

Cyprus is part of the Paris Agreement, which aims to reduce GHG emissions and the United Nations Convention on the Law of the Sea (UNCLOS), a highly ratified convention on protecting and preserving the marine environment [37]. Furthermore, as an EU country, Cyprus follows the directives and regulations imposed by the EU, including the regulations under the Green Deal and the IMO. It also follows the Sustainable Development Agenda of the UN, where one of the goals is to take urgent action to combat climate change and its impacts [38].

## 3. Regulations, Policies, and Frameworks Relevant to the Reduction of GHG Emissions in Shipping

### *3.1. International Maritime Organisation (IMO)*

The Fourth IMO GHG Study released in 2020 reports that GHG emissions from shipping increased by 9.6% from 2012 to 2018, with methane emissions increasing by 150%. With business as usual (BaU) scenarios, 2050 emissions are projected to increase to 90–130% more than 2008 levels and 0–50% more than 2018 levels. In the EU, domestic and international shipping accounted for 13.3% of the EU-28 transport-related emissions in 2019, with about 90% of all energy used in shipping activities attributable to international marine navigation [39]. Consequently, $CO_2$ emissions from maritime transport have increased by 48% between 1990 and 2008 at the EU level, making it responsible for the second-largest percentage increase in GHG emissions over 1990 levels in the EU-28 transport sector [40].

As a result of these increasing emissions, the International Maritime Organization (IMO) adopted the Initial Strategy on Reduction of GHG Emissions from Ships (Resolution MEPC.304(72)) [6], which sets out the targets found in Table 1. Strict targets have also been put in place to significantly reduce NOx and SOx air quality-related emissions [41,42].

**Table 1.** Targets of the IMO's Initial Strategy on the Reduction of GHG Emissions from Ships.

| Target | Explanation |
| --- | --- |
| Carbon intensity of the ship to decline | Via implementing further phases of the energy efficiency design index (EEDI) for new ships. The strategy calls for the review and strengthening of the EEDI requirements for ships (with the percentage improvement for each phase to be determined for each ship type) |
| Carbon intensity of international shipping to decline | To reduce $CO_2$ emissions per transport work, as an average across international shipping, by at least 40% by 2030, pursuing efforts towards 70% by 2050, compared to 2008. |
| GHG emissions from international shipping to peak and decline | To peak GHG emissions from international shipping as soon as possible and to reduce the total annual GHG emissions by at least 50% by 2050 compared to 2008 |

To achieve the abovementioned targets, the IMO Initial Strategy identifies the need for innovation and the development of a portfolio of design, technological, operational, and economical solutions for international shipping as essential. The IMO has created a list of short-, mid-, and long-term measures to achieve these targets, in the hope of providing regulatory certainty and signalling to the maritime industry the need for technology investments. The Strategy will be revised in 2023 to include more limitations and mechanisms for reducing GHG emissions [6].

Although many IMO and EU instruments are related to safety and security, environmental protection, health and safety and technical cooperation, and contribute to the Sustainable Development Goals (SDGs), there is no explicit link between them. The recent Initial IMO strategy on the reduction of GHG emissions from ships is an exception, as a commitment to the achievement of SDGs is directly addressed in this Strategy.

IMO's obligation to the implementation of the 2030 Agenda for Sustainable Development is definite in the vision statement of the Organization's Strategic Plan for the period 2018–2023, where it acknowledges its leading role for the promotion of the 2030 Agenda for Sustainable Development among its Member States while supporting its effective implementation. In this direction, IMO's Strategic Plan for the aforementioned strategic period includes seven SDGs to enable the achievement of its vision statement.

The International Convention for the Prevention of Pollution from Ships (MARPOL) is the main treaty of the IMO, first adopted in 1973, contributing to the reduction of

international marine pollution. It is divided into six Annexes, each dealing with different environmental challenges [40]. In 1997, the MARPOL Annex VI was adopted, which limits the main air pollutants contained in ships exhaust gas, including sulphur oxides ($SO_x$) and nitrous oxides (NOx), and prohibits the deliberate emissions of ozone depleting substances (ODS). It regulates shipboard incineration and the emissions of volatile organic compounds (VOCs) from tankers. Moreover, it sets mandatory energy efficiency standards for new ships and operational measures for energy efficiency, thus reducing carbon dioxide emissions from existing ships. The IMO's Marine Environment Protection Committee (MEPC) constantly revises Annex VI, with the intention of significantly strengthening the emission limits, based on technological improvements and implementation experience. For the short to medium term, mandatory energy efficiency standards for new ships and operational measures for promoting energy efficiency for existing ships entered into force in 2013, as amendments to MARPOL Annex VI [43].

In line with the above, the Energy Efficiency Design Index (EEDI) was made compulsory for new ships and the Ship Energy Efficiency Management Plan (SEEMP) for all ships at MEPC 62 (July 2011) with the adoption of amendments to MARPOL Annex VI (resolution MEPC.203(62)), by Parties to MARPOL Annex VI [44].

The (EEDI) measures the $CO_2$ emissions emitted by a ship per tonne of capacity and the mile of distance travelled (transport work). The EEDI is a measure of energy efficiency, as $CO_2$ emissions are directly proportional to the fuel and, therefore, a ship's energy consumption. The EEDI is related to the hardware used during the design phase of a ship, and aims to increase the efficiency of new ships over time by integrating innovative and technologically advanced (and thus energy-efficient) equipment onboard. The EEDI is a non-prescriptive mechanism that leaves the choice of technologies up to industry. Through successive energy efficiency requirements (there have been three phases of the EEDI until now), the EEDI stipulates that new ships constructed from 2022 are at least 30% more energy efficient than the baseline set by the IMO, which varies across different ship types. Although EEDI is directly related to the energy efficiency of the hardware used onboard new ships, it does not control how the equipment will be used over time, ensuring energy-efficient operation.

In addition to EEDI, the Energy Efficiency Operation Index (EEOI) is an IMO monitoring tool that aims to collect all relevant data for the ship's energy usage and, therefore, the consumption of fuel onboard. An overall mechanism for preserving operational energy efficiency is also provided by the Ship Energy Efficiency Management Plan (SEEMP), which encourages ship owners and management companies to monitor the energy efficiency of their ships. It includes clear schedules for the proper maintenance of the equipment on board. Technological innovations like autopilot upgrades, wind engines, etc., are adopted through effective EEDI and SEEMP implementation strategies, including speed reduction, weather routing, use of auxiliary power, and a focus on aerodynamics. The optimisation of operational and maintenance practices, such as regular propeller and hull cleaning, can considerably reduce power requirements as well. It also refers to a clear shift towards the use of alternative and renewable fuels.

IMO MEPC70 adopted, on 28 October 2016, a mandatory Fuel Oil Data Collection System (DCS) for international shipping. It requires ships of 5000 gross tonnage or above to collect and report data for the IMO database from 2019. It was adopted as an amendment to Chapter 4 of Annex VI of MARPOL, adding a new Regulation 22 A, requiring one to submit to the IMO Ship Fuel Oil Consumption, the collection and reporting data of ship fuel oil consumption and new appendices that cover the Information Database. The amendments came into force on 1 March 2018.

The IMO implemented amendments to Annex VI of the MARPOL convention in the 76th session of the Marine Environment Protection Committee (MEPC 76) conducted in June 2021. The amendments include the adoption of new energy efficiency requirements through the introduction of the Energy Efficiency Existing Ship Index (EEXI) and Carbon Intensity Indicator (CII). Whereas the EEXI is concerned with how ships are equipped or

designed, the CII indicates how the ships operate. These new adoptions are part of the global suite of measures to reduce greenhouse gas (GHG) emissions in shipping.

The Energy Efficiency Existing Ship Index (EEXI) is a component of IMO's technical approach to improving the efficiency of existing ships. Furthermore, IMO has established this new design index extension of EEDI, for existing ships constructed before 2013 that takes into account only the vessel's design parameters and not the operational factors.

Additionally, the Carbon Intensity Indicator (CII) is a new measure based on an operational approach that supports the IMO's objective "to reduce $CO_2$ emissions per transport work, as an average across international shipping, by at least 40% by 2030, pursuing efforts towards 70% by 2050, compared to 2008." In June 2021, IMO adopted a CII rating scheme for ships based on their operational efficiency, which will measure how efficient ships are when transporting cargo and passengers.

IMO's environmental regulations aim to facilitate the use of more environmentally friendly ships, and hasten the removal of inefficient/polluting existing ships from the global fleet. Both MARPOL legislation and the IMO's GHG ambitions are hoping to drive technology developments in ship propulsion and power generation, emission abatement technology, alternative fuels and renewable energy sources, and improvements in ship design and performance, stimulating an ever-reduced environmental footprint of the shipping industry. Even though an international approach to address GHG emissions from international shipping led by the IMO would be the most effective and thus desirable, IMO currently has no concrete measures to ensure the implementation of its targets, reducing the effectiveness of IMO's Initial Strategy [45]. The IMO's inability to enforce radical measures towards a carbon-free shipping industry has triggered the EU to take action to reduce shipping-related emissions [23].

### *3.2. Governmental and Intergovernmental Regulatory Frameworks*

#### 3.2.1. European Green Deal

Shipping carries 90% of European external trade, 40% of EU internal trade, and more than 400 million passengers aboard cruises and ferries, which embark and disembark at EU ports each year [46]. European companies and residents control about 40% of the world's shipping fleet, and 25% of the world fleet flies a European flag. Maritime transport is an important component of the European economy, and it includes sea and coastal passenger water transport, sea and coastal freight water transport, inland passenger water transport, inland freight water transport, and the renting and leasing of water transport equipment. At the EU level, the European Commission (EC) announced its Green Deal on 11 December 2019, which sets out how to make Europe the first climate-neutral continent by 2050 [47]. As part of the Green Deal, the Commission adopted the proposal for a European 'Climate Law', which enshrines the objective of achieving climate neutrality by 2050 in legislation, as it ensures that all EU policies and sectors contribute to the attainment of the climate neutrality objective. In its Communication on the Green Deal (COM (2019) 640), the Commission states that, to achieve climate neutrality, at least a 55% cut in carbon emissions is required by 2030, and a 90% reduction in transport emissions will be required in 2050. All transport sub-sectors, including road, rail, aviation, and waterborne transport, will have to contribute to this reduction. To ensure that these reductions will be met, the EC announced the amendment of the EU Emissions Trading System (ETS) Directive, by Directive (EU) 2018/410 of the European Parliament and the Council, which emphasises the need to act on shipping emissions [47]. The inclusion of the shipping industry within a dedicated and purposely developed ETS scheme may act as a radical market-based measure with a catalytic impact on the decarbonisation of the sector. The directive states the need for a regular review of the IMO actions by the EC, and states that the call for action to reduce emissions in the maritime sector will start from 2023, and will include preparatory work and stakeholder consultation [47].

In line with the IMO, and even a step forward [48], the EU expects a gradual approach to adding maritime GHG emissions in its emission reduction commitments. Motorways

of the Sea (MoS) [49] is an important EU initiative for shipping-related emissions. The concept was introduced along with the 2001 *'Transport White Paper—European Transport Policy for 2010: Time to Decide'* [50], and it constitutes the maritime pillar of the Trans-European Network (TEN-T) [51]. This initiative aims to promote green, viable, attractive, and efficient sea-based transport links integrated into the entire transport chain. The MoS concept builds on the EU's goal of achieving a clean, safe, and efficient transport system, by transforming shipping into a genuine alternative to overcrowded land transport. This can lower environmental costs by inducing a decrease in fuel consumption by road freight transport [52]. The EU has also implemented a system for monitoring, reporting, and verifying $CO_2$ emissions based on a ship's fuel consumption, which has been fully effective since 1 January 2018 [53]. The EU has also created a policy framework on the Integrated Maritime Policy (IMP), with a holistic approach to all sea-related EU policies, aiming to embrace all sea-based activities, and accordingly, strengthen the blue economy [54].

#### 3.2.2. EU MRV

In June 2013, the European Commission proposed a strategy for progressively integrating maritime emissions into the EU's policy for reducing its domestic GHG emissions. After a two-year legislative process involving all EU institutions, this strategy was adopted by the European Parliament in April 2015. The Regulation 2015/757 ('Shipping MRV Regulation') came into force on 1 July 2015.

The strategy consists of three consecutive steps:

- monitoring, reporting, and verification of carbon emissions from ships;
- GHG reduction targets for the maritime transport sector;
- further measures, including market-based measures (MBM).

The first step of the strategy is the design of a robust monitoring, reporting and verification (MRV) system of carbon emissions for ships exceeding 5000 gross tonnage (GT) on all voyages to, from, and between EU ports, applicable from 2018.

The list above is not exhaustive; thus, other regulations and frameworks may exist in support of the same goal.

## 4. Methodology

According to a report by the High-Level Panel of the European Decarbonisation Pathways Initiative, 'to let shipping reach its required contribution to achieving global climate change control, it will ultimately need to be decarbonised entirely' [55]. Papandreou et al. [27] have also found that virtually full decarbonisation would be needed in the longer term, meaning the fleet-wide deployment of near-zero carbon ships. The 'EIT CKIC Deep Demonstrations on Net-Zero Emissions, Maritime Hubs in Cyprus' was set up for precisely this objective: to accelerate the transformation of the maritime sector through working with a cohort of ambitious ports and other shipping industry actors to achieve net-zero carbon emissions. The project aims to work with stakeholders in the sector on the Deep Demonstrations process, which provides the objectives and tools to progress towards the different phases and roll out system innovation of the sector [56]. System innovation is the transition from one socio-technical system to another, like the industrial revolution. For this transition, the system requires continued evolution to transform economic, social, and financial systems that will trigger an exponential change in decarbonisation rates and strengthen climate resilience and achieve what the IPCC report calls "rapid, far-reaching and unprecedented changes in all aspects of society" [57]. Thus, the Deep Demonstrations process has four phases [58] which will assist in the systemic innovation approach: INTENT, FRAME, PORTFOLIO, and INTELLIGENCE.

### *4.1. INTENT*

The INTENT phase was the first phase of Cyprus' Deep Demonstrations maritime project, which started in 2019. It set up the Deep Demonstrations process, and was designed to establish directionality, assess the needs of the sector, and set the objectives needed for

systemic change within the maritime sector in Cyprus. It comprised system mapping and stakeholder interviews.

#### 4.1.1. System Mapping

This step aimed to understand and map the system, i.e., the Cyprus maritime sector [36]. As part of system mapping, an identification of existing innovation or transition activities in Cyprus, and internationally, in the maritime sector, as well as existing laws and treaties, were identified. In further support of this step, a comprehensive review of recent reports related to the decarbonisation of the maritime sector was undertaken to build an understanding of the features of the sector and the potential challenges, barriers, and opportunities in the area of decarbonisation. The System Mapping step resulted in a characterisation of the maritime sector in Cyprus, and an identification of the barriers that can become powerful enablers of transformation (levers), as well as the steps needed to instigate change. Within the system mapping process, critical stakeholders representing all significant operations across the maritime sector in Cyprus were identified [59].

#### 4.1.2. 1–1 Interviews

The review outlined in 4.1.1 led to a selection of the most relevant stakeholders for interview, which would be able to provide insight, know-how, and expert feedback [60,61] across the different sub-areas of the maritime industry, in relation to potential paths to decarbonisation. Emphasis was placed on ensuring the sufficient diversity of identified stakeholders in terms of activity area (ship owners, ship management companies, port authorities, etc.) and organisational affiliation (e.g., business, governmental and public authorities, non-governmental organisations). The identification of the relevant stakeholders to interview was also facilitated through the development of a list of selection criteria, as set out in Table 2, which acted as a simple rubric in the selection process (each stakeholder did not need to meet every selection criterion).

**Table 2.** Selection criteria which aided in the identification of the stakeholders.

| Number | Selection Criterion | Rationale |
|---|---|---|
| 1 | Sub-sector of the maritime industry | The maritime sector is diverse, with various actors across different areas of operations. It is important to capture actors from all aspects of the maritime sector in Cyprus. |
| 2 | Size of organisation | This is related to the number of resources available to the stakeholder and their ability to mobilise them, including human, financial, technological, etc. The level of resources can affect how a stakeholder will react to meeting the IMO targets and can determine the level of support or opposition to decarbonisation. |
| 3 | Level of influence | This is related to the ability to affect the achievement of the decarbonisation target and to garner support or even opposition. |
| 4 | Prior interest/involvement in innovation activities | Stakeholders who have shown an interest in or have participated in innovation activities in the past can give insight into how to engage the maritime sector in innovation interventions, including barriers and opportunities. It can also indicate their willingness to initiate, lead or partner on an innovation intervention. |

In addition, a general invitation to participate in the stakeholder engagement process was issued on social media platforms, and those who reached out and were identified as appropriate were included in the interviews. The purposive identification and selection of

stakeholders led to the mapping of 38 organisations that represented all major operations across the maritime sector in Cyprus.

The organisations were further analysed and grouped into eight clusters based on the area of their operations within the maritime sector in Cyprus, as shown in Table 3, using input from previous fieldwork and existing sectoral expertise within the project partners.

**Table 3.** Clusters of Stakeholders.

| Main Cluster | No. of Stakeholders Interviewed | Area of Operations | Description |
|---|---|---|---|
| 1 | Six | Shipmanagement companies | Companies which manage ships (crewing, technical, etc.) on behalf of the owners |
| 2 | Six | Ship owning companies | Companies that own or manage their fleet (small to large fleet) |
| 3 | Nine | Ship related companies | Companies providing services to the shipping industry in Cyprus and abroad |
| 4 | Three | Port operators | Private companies operating the most significant commercial port of Cyprus (Limassol) |
| 5 | Two | Public authorities | Government departments related to shipping and decarbonisation |
| 6 | Six | Industry associations | Professional associations related to the shipping industry |
| 7 | Three | Academia and Research | Organisations with degrees offered and/or research in the maritime field |
| 8 | Three | Energy companies | Public and Private companies within the offshore Oil and Gas industry |

Various topics were covered through the series of interviews, such as current activities related to decarbonisation, needs and challenges associated with achieving zero net emission maritime hubs, and market trends related to decarbonisation. A set of interview guidelines were prepared for use during the semi-structured interviews. These were enhanced and modified based on the baseline review during the System Mapping step, to better align them with the maritime sector in Cyprus and its stakeholders. The guidelines were structured to capture relevant information and feedback related to decarbonisation and included the following thematic areas:

- setting the scene;
- current activities related to decarbonisation;
- needs related to achieving zero net emission maritime hubs;
- market trends;
- challenges to achieving zero net emission maritime hubs.

Questions were developed to ensure that they were specific and open-ended wherever possible, to avoid simple "yes" or "no" answers. Extra prompts were prepared to be asked, if necessary, to obtain more information on one of the themes. Through the interviews, the complex nature of the challenges faced by the sector and the necessary scale for interventions were established.

The interviews were then analysed, and the results were used towards a working vision for the decarbonisation of the maritime sector in Cyprus.

### *4.2. FRAME*

Following the work undertaken in the INTENT phase, a preliminary set of needs and barriers were identified, which were then explored further in the FRAME phase, with

the aim of defining the areas in which innovation interventions will be deployed. This phase was made up of various steps, in which we defined where and why we want to deploy innovation, including determining what and who to leverage, and where to direct innovations and interventions in order to achieve decarbonisation.

The step for identifying the focus areas is called sensemaking. Accordingly, sensemaking played an integral part in the project, as the stakeholders and the project team jointly identified where transformation in the Cyprus maritime sector needs to take place and how.

#### 4.2.1. Workshop

The initial set of needs and barriers, as extracted from the interviews, were used as the basis of a dedicated Needs Mapping workshop, held on 24 July 2020, with organisations and broader stakeholders in the maritime sector in Cyprus. The stakeholders were split into different groups based on their background to achieve a combination of NGOs, research units, private companies, etc., in each team. Each team was provided with two different tools. The workshop utilised the EIT Climate-KIC Visual toolbox for system innovation [62], and specifically the canvases, 'Fishing for Barriers' (Figure 1) and 'Future Radars' (Figure 2). The 'Fishing for Barriers' tool helps the user to define a list of barriers (problems and their causes) for the deployment of innovations that would facilitate the decarbonisation of the maritime sector in Cyprus. To do this, the participants were given different coloured sticky notes with which to complete the canvas. Each colour represented a focus area in which barriers were identified, whereby orange represented the area of policy and regulation, pink represented operations, green represented education and skills, and yellow represented technical solutions.

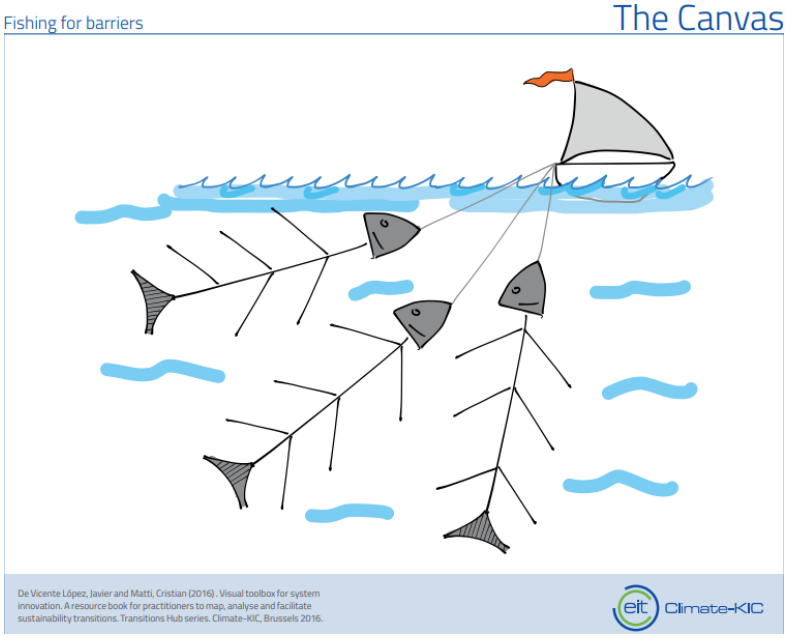


**Figure 1.** Fishing for barriers tool De Vicente López, Javier and Matti, Cristian (2016). Visual toolbox for system innovation. A resource book for practitioners to map, analyse and facilitate sustainability transitions. Transitions Hub series. Climate-KIC, Brussels 2016.

The 'Future Radars' canvas was then used to map out the actions that are needed to achieve a vision of net-zero emissions and tackle the barriers identified through the 'Fishing for Barriers' canvas. Workshop participants were divided into five teams; some teams used the 'Future Radars' tool to propose a possible path to decarbonisation by 2030, while the remaining teams proposed possible paths to decarbonisation by 2050. The Future Radars canvas is a type of backcasting tool, and it harnesses the user's imagination to first travel forward in time to an ideal future state of the Cyprus Maritime Sector (related to GHG

emissions) and then build the pathways towards this state. Workshop participants were thus asked to 'look back' on the path that led to a future decarbonised Maritime Sector and propose the steps that would allow them to achieve it.

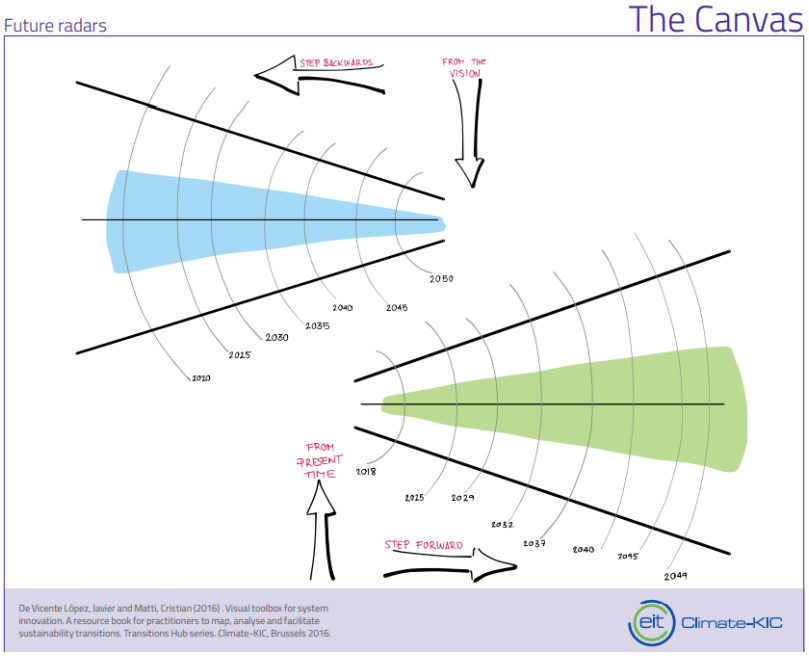


**Figure 2.** Future Radars tool De Vicente López, Javier and Matti, Cristian (2016). Visual toolbox for system innovation. A resource book for practitioners to map, analyse and facilitate sustainability transitions. Transitions Hub series. Climate-KIC, Brussels 2016.

#### 4.2.2. Reconnaissance

The results and outcomes from the previous steps led to the creation of eight problem spaces. A problem space is defined as an area within the system that the stakeholders are interested in intervening in, by testing innovation actions within it. After identifying the problem spaces, information on possible innovation interventions, available or emerging, which are appropriate for Cyprus, were collected, and the possible actors for implementing such interventions were identified. The final output of this step was the development of an Innovations Portfolio.

### *4.3. INNOVATION PORTFOLIO*

The INNOVATION PORTFOLIO is the third phase of the Deep Demonstrations process. It aims to help key stakeholders of the maritime sector, who participated in the project, to support rapid, sustainable and resilient decarbonisation in the Cyprus maritime sector. To do this, the portfolio of innovation actions was developed using a set of design principles which included to what extent an innovation action ensures future resilience, inclusivity, environmental protection, enhancement of social cohesion, solid financial returns and employs strategic risk management.

The results of the above stages were used to develop a vision and roadmap for the decarbonisation of the Cyprus maritime sector through system innovation processes.

## 5. Results and Discussion

### *5.1. Interviews*

Decarbonisation in the maritime sector is a complex problem; solutions require innovative approaches that benefit from different external actors' engagement, knowledge, and values, including governments and public authorities, researchers, and the private sector [63]. Through purposeful and strategic interaction between researchers/innovators, end-users and decision makers, the usability and legitimacy of the proposed innovation

interventions are increased [64]. Moreover, there is increasing recognition that actively involving stakeholders, including end-users, can ensure that the results and outcomes of research and innovation are legitimate and 'usable'. Furthermore, actively interacting with 'end-users' can result in accessing more data, information, and resources not readily available and obtaining actionable feedback in real time, resulting in improving the quality of the proposed innovations. The project's approach to stakeholder engagement, thus, had the central objective of being responsive and relevant to the needs of the stakeholders in the maritime sector to create benefits and value from the Deep Demonstrations process and achieve systemic transformation.

The responses of the stakeholder interviews and the results from previous fieldwork were transcribed, coded, and translated into a stakeholder analysis matrix (Table 4). The stakeholder analysis matrix arranges the information and data gathered into a more concise and systematised format, allowing for comparisons and clustering between and across the different stakeholders (38 stakeholders coding SH1-SH36).

**Table 4.** Stakeholder Analysis coding.

| | |
|---|---|
| Level of knowledge | Existing knowledge on decarbonisation in the maritime sector, including IMO, EU policies; existing technologies; potential future solutions. |
| Level of importance | How important decarbonisation is to the stakeholder's operations/strategy, now and in the near, mid- and long term. |
| Willingness to engage | Level of willingness to collaborate and join innovation interventions related to decarbonisation in the maritime sector in Cyprus. |
| Available Resources | The resources, including financial, technical, human and infrastructural, that the stakeholder can make available towards innovation interventions related to decarbonisation in the maritime sector in Cyprus. |

A stakeholder analysis matrix was then created, leading to the resources versus willingness to engage grid, which categorises the stakeholders in a three-by-three matrix, where the dimensions are a given stakeholder's willingness to engage in future innovation projects, in order to catalyse the transition towards decarbonisation, and the stakeholder's resources (including financial, human, and infrastructure resources) that they can make available towards future innovation projects in decarbonisation in the Cyprus maritime sector. The resources versus willingness to engage grid can help determine which stakeholders should be engaged and co-opted in the subsequent phases of the process. The grid results in nine categories of stakeholders, are illustrated in Figure 3.

The stakeholder analysis matrix of the 38 participant stakeholders showed that, at this early stage in the decarbonisation efforts, about 52% of the stakeholders engaged (20 out of 38 stakeholders) in the maritime sector in Cyprus currently have low levels of willingness to engage in decarbonisation innovation projects (12 out of 38 stakeholders are in the low–low category; 6 out of 38 stakeholders are in the medium–low category; and 2 out of 38 are the high–low category). This is further reinforced by the fact that 60% (23 out of 38) of the stakeholders engaged consider that decarbonisation is currently of low importance to their daily operations.

Ten out of 38 of the stakeholders (26%) have high levels of willingness to engage in innovation interventions, but different levels of available resources (6 out of 38 stakeholders are in the high–high category; 2 are in the medium–high category; and 2 are in the low–high category). The remaining stakeholders (9 out of 38 or 22%) have medium levels of willingness to engage in innovation interventions (4 out of 38 stakeholders are in the high–medium category; 3 are in the medium–medium category; and 1 is in the low–medium category).

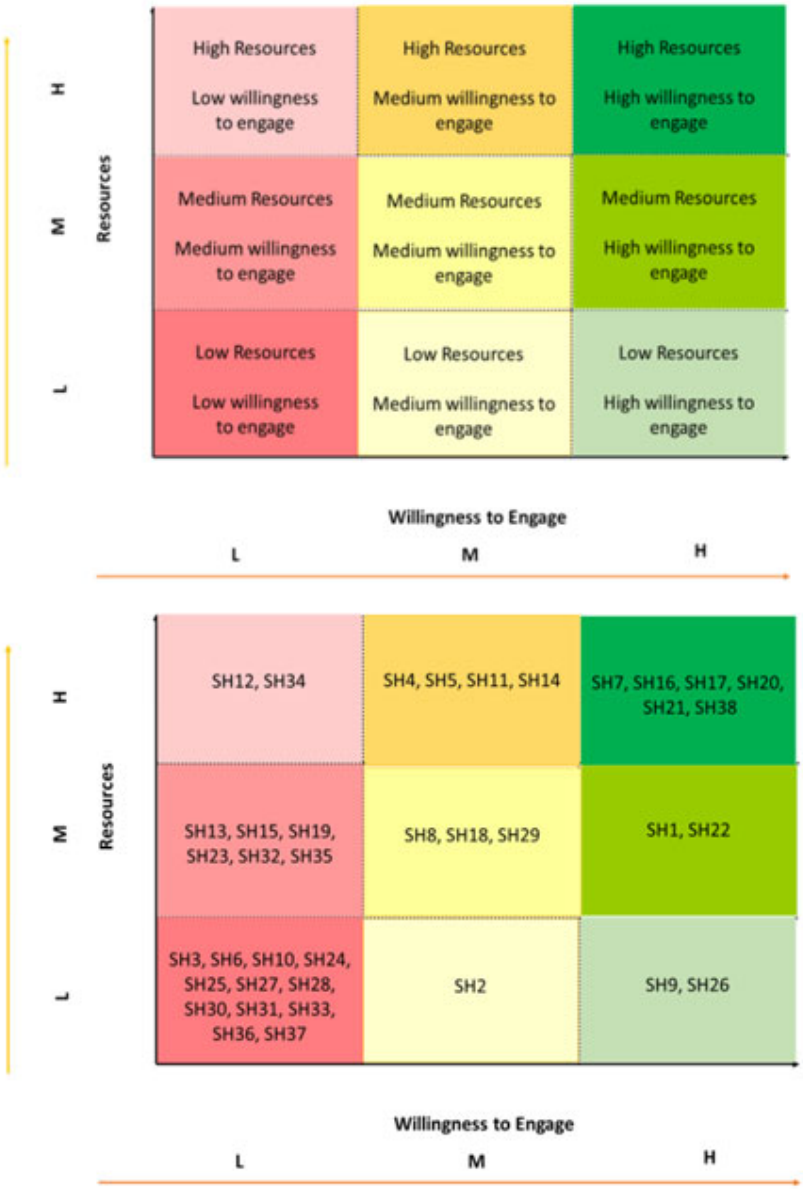


**Figure 3.** Stakeholder (SH1-SH38) analysis matrix based on a 'resources versus willingness to engage' grid.

Shipping companies are more likely to engage in sustainable activities when they are perceived to be aligned, rather than in conflict with their existing competitive strategies, capabilities, and resources [65]. The shipping company's stakeholder attitude, pressure, and behavioural control directly affect the adoption of sustainable shipping practices and indirectly influence business performance. Bulk shipping companies, particularly tanker shipping companies, are exposed to more significant safety risks or engaged in operations with a greater environmental impact; their stakeholders may exert significant pressure on them to implement sustainable shipping practices [66]. Thomas [67] showcased the willingness of the collaboration of a network of representatives for significant stakeholders in international trade, who evaluated positively, and are willing to invest, develop, and test the prototype of the Shipping Information Pipeline prototype. Yuen et al. [68] suggested that sustainable shipping practices create functional, social, and emotional values that could lead to shippers' satisfaction, and subsequently, loyalty, and willingness to pay more for a shipping service.

In addition, a further analysis of the stakeholder interviews indicates that stakeholders consider that to meet the targets in the IMO's Initial Strategy and achieve decarbonisation more widely; a mix of technological, operational and regulatory interventions will be required. The findings agree with the existing literature that suggests that a mix of technologies should be used, resulting in significant reductions [16,19]. This is illustrated by Figure 4, which provides an overview of the most common terms referred to by stakeholders related to decarbonisation. Under technological solutions, stakeholders pointed to the need for alternative fuels and the associated infrastructure, with batteries and renewable energy such as solar PV as potential options for further innovation interventions.


**Figure 4.** Most common terms mentioned by interviewees.

Ship design was another area identified by the stakeholders for further technological innovation, including hull design, propellers, flattener rotors, etc., which can be tied back to the IMO's EEDI. However, it is clear from stakeholders' responses (47% of interviewees) that an appropriate policy and regulatory regime, with a mix of taxes, levies, and incentives, will be essential to achieve decarbonisation. Policy initiatives are needed to promote the introduction of renewable marine fuels [69]. Lastly, it is important to note that one of the key solutions for decarbonisation that stakeholders pointed to, was the switch to LNG, with approximately 63% of stakeholders considering it the main solution (at least until 2030) towards meeting the IMO's targets. As conventional LNG is not a zero-carbon fuel, this reliance on LNG demonstrates the scale of the challenge in achieving 'Zero-Net Emissions, Resilient Maritime Hubs in Cyprus'. This result is supported by other studies where maritime stakeholders were interviewed, and an analysis of their interviews resulted in the stakeholder's identification of LNG as a short-term solution, and not long term [33]. Similarly, Swedish stakeholders' research states that groups rank LNG and HFO the highest from a list of alternative marine fuels followed by fossil methanol, and then various biofuels (LBG, renewable methanol, and HVO) [69]. Other studies have also ranked LNG highest amongst others [70].

They have also stated that policy initiatives are needed to promote the introduction of renewable marine fuels [67].

LNG has been proven to be a suitable fuel for the maritime sector [71], as it has been used as a main fuel on-board the LNG carriers for 58 years [72]. LNG-fuelled ships are shown to have a 20–25% reduction in $CO_2$ emissions [73]. The EU has promoted it through the European Commission's new infrastructure law, requiring ports to install gas refuelling infrastructure for ships, encouraging this action [74]. EU promotes the use of LNG for marine fuels, as the IMO has placed a 0.5% sulphur cap on ships, which contributes to

reducing air pollution and the protection of public health. Yet, even if it has reduced $CO_2$ emissions, LNG can be associated with methane gas emissions. This can result from methane slip from various actions, including the extraction of natural gas [75], cleaning and liquefaction processes, transport, and re-loading, etc [76]. Methane is a greenhouse gas, with a greater warming potential than $CO_2$; thus, methane slip can enhance the greenhouse effect.

Methane emissions have been in the priority initiatives of the European Green Deal. Thus, the European Commission has adopted the EU Methane Strategy [77]. The strategy sets out measures on how to cut methane emissions from methane leaks from the energy sector, including fossil fuel production sites, as well as the emissions from ships.

### *5.2. Vision*

A vision for a zero-net emissions, resilient maritime sector in Cyprus, was defined based on the outcomes of steps 4.1 and 4.2 of the methodology. The vision, as co-created with the local stakeholders, is: 'to establish Cyprus as an international and competitive testing and demonstration hub for innovative solutions that will support decarbonisation across the marine, maritime and shipping industry'. Figure 5 shows the categorisation of priorities and actions for achieving Cyprus' vision, as expressed by stakeholders.

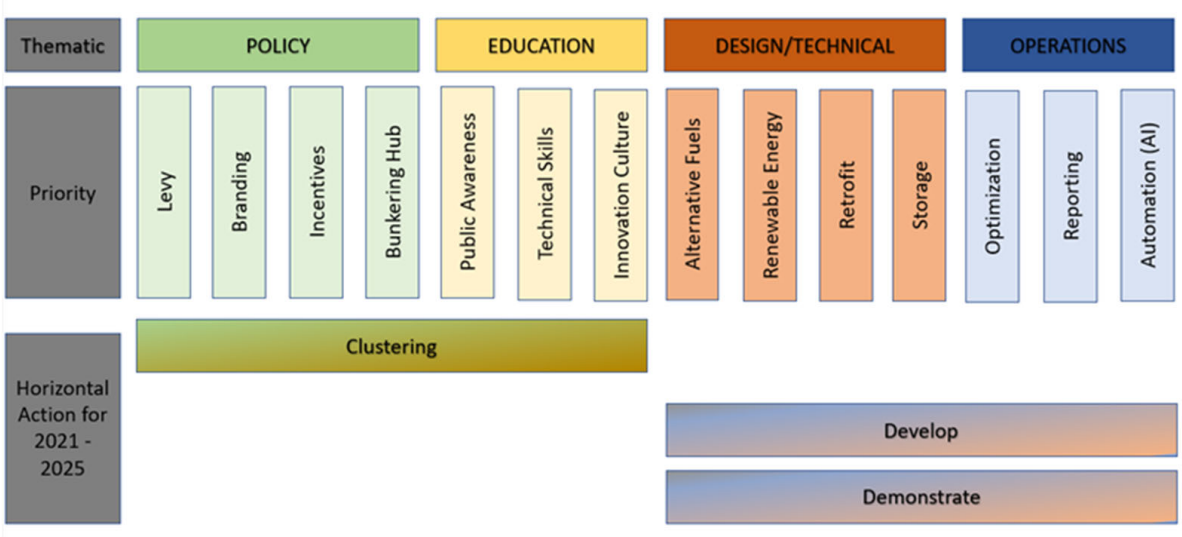


**Figure 5.** Categorisation of priorities and actions for achieving Cyprus' vision, as expressed by stakeholders.

Stakeholders expressed interest in various priorities under four thematics, namely policy, education, technical/design, and operational aspects. This is broadly in line with the literature, which points to a mix of technological, operational, policy and market measures for achieving decarbonisation [20]. Each priority had a different level of engagement or endorsement from the stakeholders. Furthermore, local stakeholders assigned a different weight to the difficulty and complexity of implementing such priorities in Cyprus.

From the categorisation of the various actions and the discussions with the stakeholders, it is apparent that as of today, and in the upcoming years (2022–2025), Cyprus should focus on designing actions around retrofit and efficiency measures and on how to improve the technical skills and the innovation culture of the human capital of Cyprus. A core priority area that emerges is thus the education, training and reskilling of the maritime labour force, as there is not enough know-how in the maritime sector in Cyprus for developing, but also implementing, technologies and solutions in support of decarbonisation. Over a longer horizon (2020–2030), Cyprus should focus on actions that promote alternative fuels, renewable energy sources, storage, and automation. This differentiation arises primarily because Cyprus does not currently possess the resources (i.e., lack of established maritime

research centres) to focus on such actions that will also have a larger impact, something that the government of Cyprus is working on.

Furthermore, through discussions with stakeholders, two types of horizontal actions are envisaged:

- **clustering**: Under this horizontal action, activities that enable the creation of a critical mass of researchers and innovators will be sought after, focused primarily on, but not limited to, the priorities set out in Figure 5 (i.e., summer schools, training visits, etc);
- **develop and demonstrate**: As Cyprus does not currently possess the critical mass needed to discover a plethora of solutions, or a large enough industrial base to develop and deploy new solutions, Cyprus should focus on becoming a testbed for the development and demonstration of solutions; primarily of solutions from abroad, and at a later stage of "in-house" developed solutions.

Cyprus should establish itself as a demonstration hub facilitating the testing and demonstration of new innovations, enabling their large-scale adoption, thus supporting the maritime industry reducing its carbon emissions.

### *5.3. Workshop*

The analysis of the results of the 'Fishing for Barriers' tool, Figure 6, identified the following current problems and barriers to the decarbonisation of the maritime sector in Cyprus, which centre around a lack of:

- appropriate policy and legislative framework;
- national targets for decarbonisation in the Cyprus shipping registry (the IMO targets have not been included in local legislation);
- infrastructure, industrial base, and innovation capital in Cyprus;
- incentives for innovative companies and start-ups to work in a lack of a skilled workforce;
- vision, the maritime is sector overly focused on barriers and does not see decarbonisation as a new business opportunity;
- willingness to engage and interest in decarbonisation by local stakeholders;
- appropriate culture and innovation mindset;
- suitable ship designs and energy/technological solutions that can be adopted immediately or in the short term to ensure that rapid decarbonisation is achieved;
- supporting infrastructure (e.g., fuel infrastructure), as current infrastructure is very costly to upgrade;
- connection between the maritime sector and the general public—as a result, there is no pressure from the public to move towards decarbonisation;
- funds—decarbonisation is considered costly and of limited added value.

Our findings are supported by [78–80], which in their evaluation of the barriers to low carbon shipping, have identified sunk costs and path dependence in the shipping sector, split incentives, and access to finance [20] as important barriers.

An analysis of the results of the 'Future Radar' exercise, Figure 7, indicated that stakeholders in Cyprus consider that the following must be put in place to support decarbonisation efforts:

- innovative business and finance models that ensure sustainability of decarbonisation actions;
- mandatory decarbonisation awareness training of crews and port staff;
- policies to encourage ships that use alternative fuels;
- regulations—minimum emission requirements—carbon tax, as a minimum for the IMO decarbonisation target to be enshrined in law;
- alternative fuels produced through renewable energy;
- finance and funds for research and development of greener technologies in ship engines;
- shipping workforce that fosters innovation and experimentation to capitalise on the good reputation Cyprus for being service-oriented;

- development of innovative service offerings, e.g., decarbonisation as vice techno-economical assessments to support the rapid adoption of zero emission vessels;
- demonstration of innovative fuels, technology, and other technical solutions;
- operations and logistics optimisation related to decarbonisation.

In addition to the stakeholder workshop and interview analysis, our desk research identified similar requirements across the international maritime sector, as reported by [20,23,79,81,82]. Stakeholders highlight the lack of policy and existing regulatory tools, financial incentives for shipping decarbonisation, and lack of enforcement framework [45,62] as barriers to decarbonisation. The lack of training and skilled workforce is another issue that concerns the stakeholders in Cyprus and the international community [64,83]. Training and re-skilling is considered essential for the systemic transformation of the maritime sector towards decarbonisation, as it targets the culture and the innovation mindset of the workforce [84].

### *5.4. Problem Spaces and Interventions*

The eight problem spaces where interventions would need to take place to address the decarbonisation of the maritime sector are set out in Table 5.

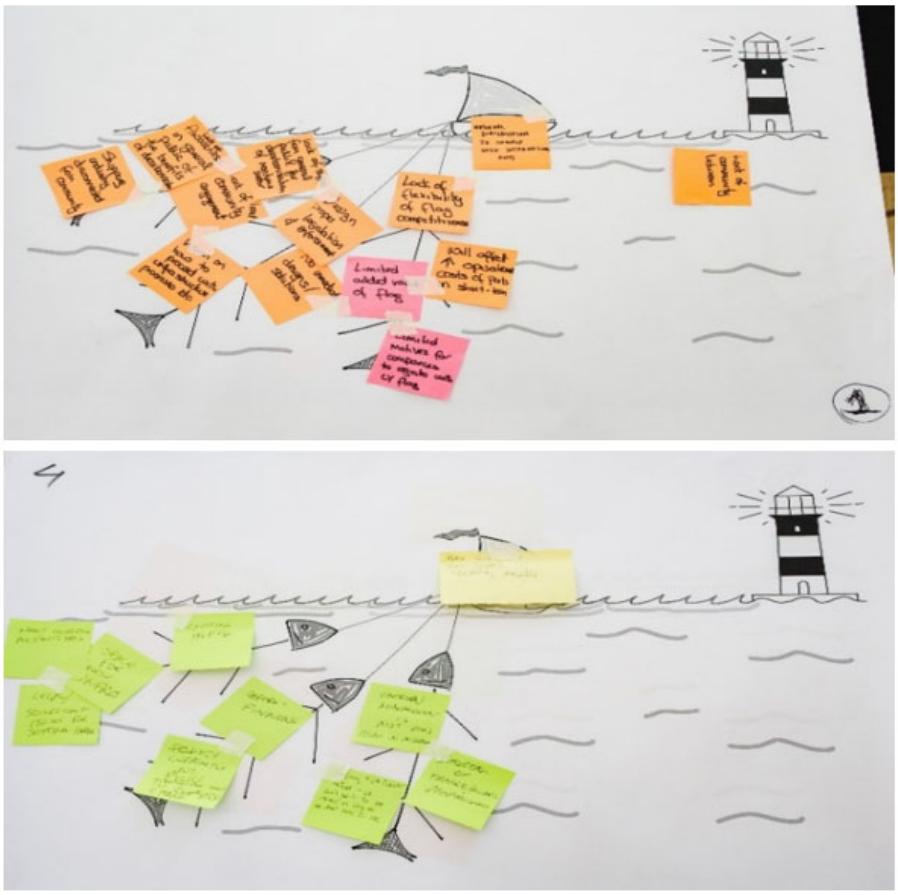


**Figure 6.** Tool, fishing for barriers used by teams 1 and 4.

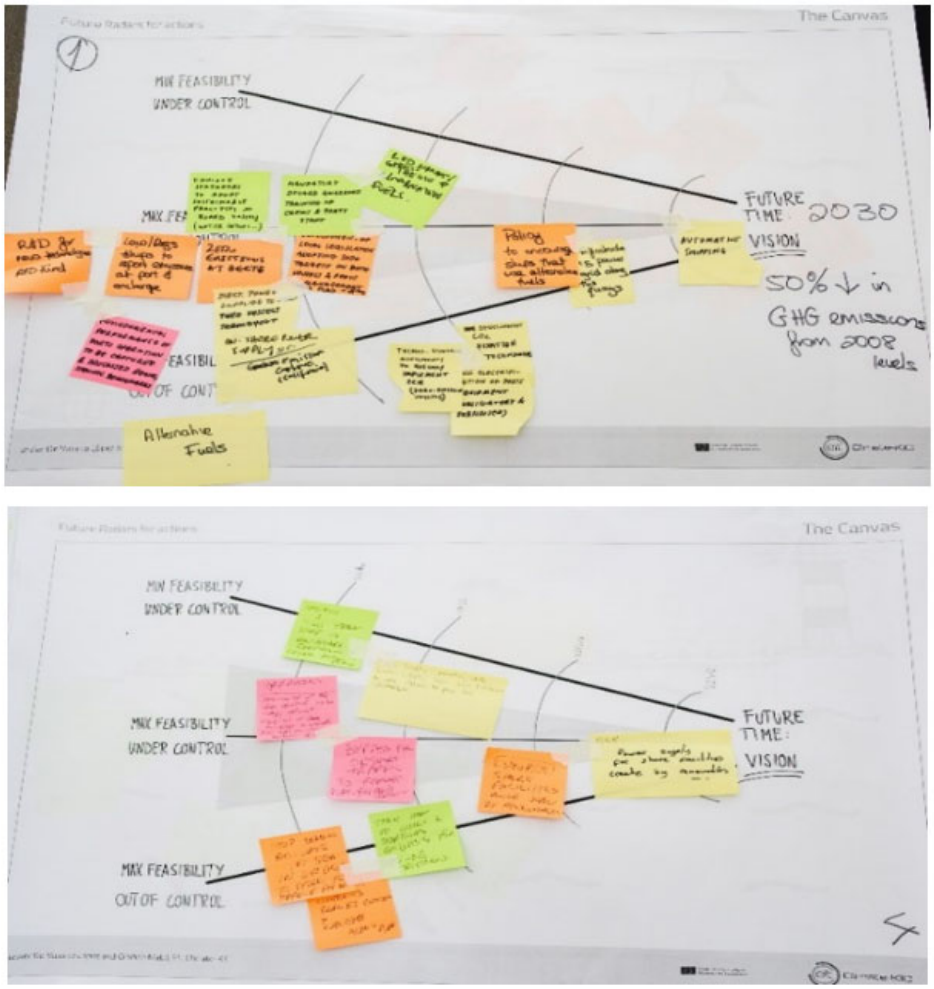


**Figure 7.** Future for radars tool used by teams 1 and 4.

### *5.5. Barriers to Transformation*

Our analysis of the data and information collected through our research indicates certain barriers that hinder the transition of the shipping sector in Cyprus to net zero emissions.

#### 5.5.1. Policy Barriers

Policy development in Cyprus is slow and cautious, yet it can influence the shipping sector and lead to a sustainable transition. Laws, regulations, programmes, incentives, etc., are all considered to be under the umbrella of public policy. Still, public policies in Cyprus create a great barrier for the zero-net emissions' transitions for the following reasons:

- *Sustainability is not considered a priority by policymakers*, as the regulatory framework in Cyprus fails to link the maritime sector to sustainability.
- *Legislative processes* in Cyprus related to sustainability are "re-active", thus they are responding to market needs rather than leading it.
- *Policymaker risk aversion*, as they fear losing customers if any sustainability requirements are imposed.
- *There are no incentives for innovative technology adoption*, as those who want to innovate will be burdened by the cost of innovation without any appropriate reward for their actions.

**Table 5.** Problem Spaces and Innovation Positions.

| Problem Space | Positions (Where Shall We Intervene?) |
| --- | --- |
| **Clustering (coalitions/lobbying)** | • Discussions are taking place by national government to design new incentive/funding schemes up to 2030 |
| **Education/talent attraction** | • The Ministry of Education, universities and other relevant bodies design new syllabi<br>• The Human Resource Development Agency and Deputy Ministry of Shipping develop new lifelong learning programmes and Continuing Professional Development (CPD) requirements for seafarers<br>• Schemes and policy design for attracting talent including students, industry experts, start-ups and established companies |
| **Innovative finance schemes** | • Discussions are taking place by national government to design new incentive/funding schemes up to 2030<br>• Banks design new bonds/loans, including ECB and CY central bank and ministry of finance |
| **Effective policy and regulation** | • Where the National Energy and Climate Plan is being designed so as to include decarbonisation of shipping<br>• Where tenders for expertise or studies are required/being commissioned and/or smart specialisation strategy being developed |
| **Technology demonstration development** | • Schemes and policy design for attracting talent including students, industry experts, start-ups and established companies |
| **Business models (expand our competitive advantage)** | • Discussions are taking place by national government to design new incentive/funding schemes up to 2030<br>• Where tenders for expertise or studies are required/being commissioned and/or smart specialisation strategy being developed |
| **Application for feasible decarbonised energy solutions** | • Schemes and policy design for attracting talent including students, industry experts, start-ups and established companies<br>• Discussions are taking place by national government to design new incentive/funding schemes up to 2030 |

Similarly, the literature states that it is crucial to adopt fiscal instruments and incentives. For example, the government should offer financial incentives for green shipping, e.g., via public procurement and temporary exemptions of electricity taxes for electric ships or reduce trade tariffs for energy-efficient technologies [57,85]. Such national or regional incentive schemes could lead to carbon pricing at a global level. The impact of states and regions that act as first-movers and apply firmer targets at a national or regional level has been debated, however [21] demonstrated that it can play a vital part in achieving progress at a global level. Without applicable national and supra-national policies that can deliver strong incentives and mechanisms that favour the adoption of low-carbon technologies, ambitious targets and strict regulations can be challenged by relevant industry stakeholders. Consequently, any targets and mitigation measures imposed on the industry must be accompanied by incentives and supporting policies, if they are to be effective and widely accepted by stakeholders [20].

#### 5.5.2. Technology Barriers

Technology is derived from the application of scientific knowledge for practical purposes, like developing tools, equipment, machinery, and products that meet human needs.

Consequently, technology is also needed for the decarbonisation of the maritime sector, and it creates barriers in the shipping sector in Cyprus:

- *Technology adoption and innovation actions* are delayed due to the slow legislative processes related to sustainability.
- *Low maturity level of new technologies* as the decarbonisation of the maritime sector is a new topic compared to other sustainability initiatives such as pollution control and uncertainty on which technologies will be dominant in the future.
- *Companies are reluctant to invest* in technology adoption and innovation actions, as the costs are very high and can reduce companies' profit.
- *Lack of incentives* for the adoption of innovative technology.
- *Limited alignment between key stakeholders:* for example, the shipping sector is not aligned with ports on the quality and quantity of alternative fuels to be required in the future, creating a barrier for investments on new innovative technologies on both ships and ports.

In agreement with the above statements, technologies face several challenges, including space requirements, cost, and infrastructure [86].

A better understanding of the potential for different fuel options is needed, and the low maturity of technologies deserves further attention [87,88].

Additionally, the literature showcases that a closer collaboration of the maritime sector with land-based activities will lead to synergies and new solutions. For instance, ballast water solutions were firstly used in wastewater and water treatments [89].

#### 5.5.3. Skills Barriers

According to the European Commission's Cedefop glossary [90], skills refer to the "ability to perform tasks and solve problems", while competencies extend cognitive elements to encompass functional aspects, interpersonal attributes, and ethical values. OECD produced an education working paper on "21st Century Skills and Competences for New Millennium Learners in OECD Countries", referring to the 21st century skills including a wide range of skills, knowledge, work habits, and character traits that are critically important for someone's success in today's world [91]. Consequently, those skills are needed to face the challenges of the 21st century arising from the digital transformation, creative progress, and fast-paced changes.

Nonetheless, Cyprus is facing a brain drain, and at the same time, there is a lack of local resources to support the envisaged development of the maritime sector in the country. Shifting to new innovative technologies and actions for the decarbonisation of the maritime sector in Cyprus will require new skillsets and capabilities that the local force and the decision makers, directly involved in the transition, will need to be equipped with. Accordingly, the above add up to the following barriers:

- *Lack of workforce with required skills to support the sustainability transition of the Cyprus shipping sector*. Due to the slow legislative processes related to sustainability, low sustainability requirements are supported by a culture of low innovation in the shipping sector in Cyprus, leading to an under-skilled workforce unable to support the innovative sustainability transition of the sector.
- *Key stakeholders (policymakers, shipping companies, etc) lack skills for the 'Cypriot economy of the future'*. The EU already imposed sustainability requirements upon all the sectors within its member states. Yet, Cyprus' educational institutions and structures are not currently prepared for the sustainability requirements needed in the maritime sector.
- *Limited opportunities for attracting/retaining a talented workforce* due to a lack of diversity of jobs in the maritime sector in Cyprus.

A skilled workforce is required for substantial technology transitions to be successful [92]. Current reports on skill trends in marine and maritime industries stress that these industries are experiencing technological and environmental transitions with far-reaching repercussions. They emphasise three key drivers of change: digitisation and automation,

the drive for greater environmental sustainability, and global competition and upgrading into more knowledge-intensive activities. They also emphasise the problems of attracting young people into the sector. They resulted in the adoption of education and training systems to respond to the growth of new technologically related skills. Opportunities for clusters might limit such challenges. The provision of a multi-user boatyard that SMEs could rent and share, linked to innovation centres, would be incredibly beneficial, by allowing knowledge sharing and skilled labour pooling [93].

#### 5.5.4. Barriers of Organisational Structure

In the digital transformation and information age, information is easily flowing among people of different groups, setting the pace of transformation. However, the flow of information must be moving linearly with decision making within public and private organisations. This is not the case in Cyprus, creating various barriers:

- *Lack of cross-departmental* collaboration, as future visions might be conflicting and lack a common understanding aligned across governmental departments on sustainability issues and their integration within legislation.
- *Long-term future outlook for shipping companies does not prioritise environmental topics*, as they have the tendency to focus on topics directly related to economic competitiveness in the market, and compliance with legislation. As there is a limited amount of binding legislation related to environmental and social topics, and the existing legislation may be vague, most companies might be compliant with the legislation, yet these do not go far enough.

#### 5.5.5. Barriers of Citizen and Stakeholder Engagement

The EU is now raising the issue of public engagement in decision making, especially when it is related to environmental decisions, as seen also in the 2003/35/EC directive of the European Parliament and Council [94]. Thus, for the transition of the maritime sector in Cyprus towards a zero-carbon paradigm by 2050, public engagement and collaboration among various stakeholders (businesses, policymakers, citizens, etc.) are essential. As a small country, Cyprus has strong linkages between various stakeholders, yet:

- *There is no shared vision for the country's maritime sector*, between various stakeholder groups, leading to each stakeholder working in isolation and being out of sync with the vision of the rest of the stakeholders. This is also a result of the lack of a regular space for stakeholder discussion, leading to the needs of each stakeholder being ignored by the rest of the stakeholders.
- *Currently, decision making in business/shipping companies does not necessarily include multi-stakeholders/citizens*.
- *Low citizen engagement by policymakers*; even if it is mentioned within the EU legislation, public consultation comes at a late stage in the policy-making process.

The literature identifies the importance of stakeholder engagement in the decision making processes [28,31,59,66,69]. Alexandropoulou et al. [31] mention that stakeholders have drastically different views and different frames for understanding the problem; incorporating their perspectives is crucial. Because of the different stakeholders' perspectives, they all have their agendas and priorities. In complex situations and problems, as sustainability is, the problem definition might focus after adopting a future vision. In such a case, the vision is the seed for the challenge, and not its result. Visioning should be a participatory tool where stakeholders from broad backgrounds ensure a richer and broader vision.

#### 5.5.6. Behavioural Change—Mindset Shift Barriers

Behaviour is the way in which one acts or conducts oneself, especially towards others. Our current behaviours are often dictated by our perceptions, wishes, and future outlooks. A mindset shift consists of a change to general attitudes, and how one typically thinks and behaves in relation to events occurring in their environment or events that come to their

attention. In Cyprus, the mindset shift is a crucial barrier for moving the maritime sector towards a net-zero carbon transition because:

- *Cyprus has a primarily centralised governance system*, with decisions taken centrally by the government and the higher management in the country.
- *Cyprus can be defined as being mostly a follower and not a first mover*, as it mostly follows either the EU existing guidelines or following the best practice examples on an international level.
- *Economic actors' behaviour is driven by the values of the current financial and decision making system* which is often in contradiction to what is needed for a better future in general.
- *The maritime sector is not considered an integral part of Cypriot citizens' identity*, even if it is an island with a strong maritime sector.
- *Sustainability is not a priority* for Cypriot citizens during decision making.

Knowledge is one important mechanism that motivates mindset, attitude, and awareness, and all these factors are mechanisms driving behavioural change [95], which can lead to sustainability [96].

#### 5.5.7. Business Model Barriers

A business model is the core strategy for the profitable operation of a business. The model identifies revenue sources, target markets, services/products offered, and a financing plan, aiming to have a social and environmental impact. Nonetheless, Cyprus lacks new business models that can support the cost-effective adoption of new innovative technologies and actions for the following reasons:

- There is a need for innovative businesses to focus on *"Shipping Decarbonisation as-a-service"* rather than "shipping services provision".
- *The current generation of entrepreneurs in Cyprus does not engage adequately with the maritime sector in Cyprus.*
- *There is a need for new sustainable business models in Cyprus to deliver profit and new innovative technologies and actions in the maritime sector.*

#### 5.5.8. Finance Barriers

Finance encompasses different ways of managing money, including the provision of funding or the flow of capital between entities for investment, borrowing, lending, etc. The current financial landscape in Cyprus is placing some barriers relating to the transition of its maritime sector to zero-carbon emissions:

- The maritime sector is economically thriving, showing its strength, yet that money is not reinvested in sustainability innovation.
- The current financial system is mainly focused on generating economic value and returns.

Financial institutions could build green finance programmes to encourage sustainable shipping. Papandreou et al. [27] consider that several initiatives are needed to create the appropriate financial framework to raise the necessary funds to bridge the finance gap needed for sustainable investments.

If carefully designed, additional policies can help address market barriers and the burden of a potential carbon price. To boost access to finance for companies willing to adopt low-carbon technology, governments can also create favourable conditions for financial instruments such as "Blue Bonds" that aim to channel private finance towards "green" shipping. Shipping stakeholders could be further encouraged to assess the carbon footprint of their supply chain and target zero-carbon shipping options [27].

Scaling up financial resources and investments will also be an essential enabler. This is a role that regional and national development banks can undertake, e.g., the European Investment Bank (EIB), and ING signed an agreement to support the European shipping market with USD 370 million worth of green investment [97]. Green bonds are another potential instrument for significant infrastructural investments [20].

Subsequently, if acted upon, these current barriers can become very powerful enablers of transformation, as they will influence various systems and have exponential impact. Therefore, we consider them as 'levers' for transformation.

### *5.6. INNOVATION PORTFOLIO*

An initial innovation portfolio was designed based on the results of the research, with the following priority of interventions:

1. Run regulatory sandboxes to test the implementation of technologies/other innovation that the current legislator framework does not allow.
2. Implementation of demonstration projects: any projects that are mature enough to "leave the lab", but not mature enough to secure funding on commercial terms, will be able to "test" their solution in Cyprus.
3. Inclusion of the decarbonisation of shipping in the National Energy and Climate Plan.
4. The enactment of regulations for minimum emission requirements or carbon tax, and as a minimum for the IMO decarbonisation target to be enshrined in law in Cyprus.
5. Creation of multi-stakeholder groups, bringing together technology innovators and scientists/professionals/citizen groups, to ensure cross-fertilisation around various areas (e.g., circularity, biodiversity, etc).
6. Bunkering Hub: Cyprus to become a regional bunkering hub for any fuel, and, in particular, alternative renewable fuels.
7. Finance and funds should be directed towards the research and development of greener technologies in ship engines.
8. Decarbonisation awareness training of crews and port.
9. Capitalisation of the good reputation that Cyprus has for being service-oriented, and developing new innovative service offerings, e.g., decarbonisation as a service.

## 6. Conclusions and Further Agenda

Achieving decarbonisation in the maritime sector is a multifaceted challenge, requiring a portfolio of innovative solutions across the entire industry. The current work was undertaken through the Deep Demonstrations project on 'Zero-Net Emissions, Resilient Maritime Hubs in Cyprus' funded by EIT Climate-KIC. It was established to mobilise actors in the maritime sector in Cyprus to work together to achieve decarbonisation within the sector through systems innovation and a participatory approach. This paper presented research undertaken to identify the possible ways in which Cyprus can support the decarbonisation of its maritime sector, through the use of participatory approaches and systems innovation.

Our findings and analysis show that stakeholders within the maritime sector in Cyprus identify that a lack of: (1) an appropriate policy and legal framework that will support rapid decarbonisation; (2) appetite and innovation capital in the maritime sector; (3) the appropriate skillset and talent in the local workforce; (4) ship designs and energy/technological solutions that can be adopted immediately or in the short term; and (5) the necessary bunkering infrastructure; are the main barriers to achieving decarbonisation.

We suggest the following levers of change, where actions can be taken to catalyse the decarbonisation of the maritime sector in Cyprus:

1. Policy.
2. Technology.
3. Skills.
4. Organisational Structures.
5. Business Models.
6. Finance.
7. Information Flows.

Thus, the maritime sector in Cyprus requires the following if it is to achieve rapid decarbonisation: innovative business and finance models that ensure the sustainability of decarbonisation actions; a modern shipping workforce that fosters innovation and experimentation; the demonstration of innovative fuels, technology and other technical

solutions (e.g., operations and logistics optimisation) related to decarbonisation; finance and funds for research and development of greener technologies in ship engines; an appropriate policy and legal framework; and to capitalise on the good reputation that Cyprus has for being service-oriented, and develop new innovative service offerings, e.g., decarbonisation as a service.

A closer collaboration of the maritime sector with land-based activities will lead to synergies and new solutions, building on previous successful collaborations, such as the development of scrubbers and other land wastewater techniques used for ballast water treatment.

Cyprus' maritime sector can be decarbonised, but it needs time, finance, and cooperation between key stakeholders. Consequently, the sector is in a unique position to contribute to climate change mitigation by leveraging its important role as a flag state and directly reducing emissions, becoming leaders in climate innovation, and enacting a policy and regulatory framework that supports the decarbonisation action of the ships that are part of the Cyprus Ship Registry.

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