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OCEAN AND SOCIETY

Ocean Climate Governance: Eclectic Viewpoints of a Multi-dimensional Nexus

Edited by George Dikaios

Volume 3

2026

Open Access Journal

ISSN: 2976-0925

Ocean and Society, 2026, Volume 3
Ocean Climate Governance: Eclectic Viewpoints of a Multi-dimensional Nexus

Published by Cogitatio Press
Rua Fialho de Almeida 14, 2º Esq.,
1070–129 Lisbon
Portugal

Design by Typografia®
http://www.typografia.pt/en/

Cover image: © Karwin Luo

Academic Editor
George Dikaios (Leiden University)

Available online at: www.cogitatiopress.com/oceanandsociety

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Ocean and Society
2026 • Volume 3 • Article 12949
https://doi.org/10.17645/oas.12949

EDITORIAL

Open Access Journal

An Inter- and Multi-disciplinary Approach to Ocean Climate Governance: An Introduction

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Submitted: 15 June 2026 **Published:** 14 July 2026

Issue: This editorial is part of the issue "Ocean Climate Governance: Eclectic Viewpoints of a Multi-dimensional Nexus" edited by George Dikaios (Leiden University), fully open access at https://doi.org/10.17645/oas.i488

Abstract

This editorial introduces the thematic issue Ocean Climate Governance: Eclectic Viewpoints of a Multi-dimensional Nexus. Ocean governance is gradually being connected to climate governance, as there is an understanding that climate change leads to oceanic change. This connection needs to be evolved in an inter- and multi-disciplinary approach, as ocean governance entails all human activities that occur in the seas and, as such, diverse disciplines ought to be in conversation with each other for comprehensive solutions to be developed. The six articles of this thematic issue approach the ocean climate governance nexus from their own viewpoints, while collectively they aspire to begin an open dialogue that will lead the way to an all-encompassing ocean governance.

Keywords

climate governance; interdisciplinarity; multi-disciplinarity; ocean-climate nexus; ocean governance

1. Introduction

The interrelation between ocean and climate (governance) has been gaining significant attention and systematic interest in the last few years. Indeed, during the 25th Conference of the Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC) in 2019, the first (informal) discussions on a diplomatic level regarding the nexus between climate and oceans took place. This marked the first official attempt to bring two subjects that are intrinsically linked under the same institutional–climate umbrella (Chan, 2021) and to overcome the reality that "climate and ocean policies have been historically siloed" (Dobush et al., 2022, p. 254) and largely disconnected (Barros-Platiau et al., 2023; Borg, 2023; Morgera et al., 2023). Nevertheless, although several pledges for blue action have taken place since then, during COP30 in 2025, it was emphatically apparent that the silos still remained in place, as no mention of oceans—which play a crucial role in tackling climate change—was made in the final output (Garcia-Soto, 2026).

The reason for this, according to Garcia-Soto (2026, p. 1), is that “the UNFCCC system lacks the mechanisms needed to integrate ocean science into core decision-making.” This fact highlights the common criticism against the fragmentation of the international governance system regarding climate change (Zelli, 2011), a criticism that has been made with more intensity about the oceans (Barros-Platiau et al., 2023; Chan, 2021). This thematic issue explores a series of very different cases in order to highlight and showcase the extensive influence that the efforts to combat the effects of climate change have immediate effects on ocean governance.

According to the literature, ocean governance covers the totality of the institutional arrangements that govern human activity regarding the seas and the oceans. For example, Mondré and Kuhn (2022, p. 6) define ocean governance “as all rules, policies, laws, and institutions designed by governmental and/or non-governmental actors on all levels of decision-making, which regulate any human activities concerning the sea.” They also make an interesting claim/observation on the form of ocean governance, which is simultaneously twofold: spatial and sectoral (Mondré & Kuhn, 2022). For Haas et al. (2022, p. 254), “oceans are governed by numerous actors, formal and informal institutions, and nation-states, for a variety of often conflicting services and uses.”

The above is apparent in the literature that vastly claims that the current—significantly complex and fragmented—governance structure and institutional arrangements regarding the oceans have led to the failure of protecting the marine environment and, at the same time, put obstacles to the evolution of a substantive transition to a sustainable ocean governance (Brodie Rudolph et al., 2020; Craig, 2012; Mondré & Kuhn, 2022; Stephens, 2022). This is even more true for efforts to combine climate action with ocean governance. The six articles of the thematic issue shed light on different angles through diverse perspectives in this relation, with the aim of further understanding the Byzantine nature of ocean climate governance.

2. Presentation of the Contributions in this Thematic Issue

This thematic issue followed a novel, for a scholarly journal, process of putting together articles that do not come from a single discipline. The contributions, therefore, cover a broad array of disciplines; in particular, they emanate from political science and international relations, economics, maritime economics and maritime studies, geography, and sociology. The term *governance*, which in the case of the oceans encompasses every action that takes place in the seas, acts as the connecting link among the different approaches. The lineup of the articles follows a geographical order: it begins at the local level, then goes to the national, the transnational, the regional, and, lastly, the international.

Avrami et al. (2026), in their article, unpack the stance of the local population of three small islands at the western end of Greece (the Diapontian islands) regarding the installation of offshore wind farms. Offshore wind farms are considered to be a significant tool in the efforts to decarbonize and are being promoted by the EU to achieve climate neutrality. The article highlights the importance of the interrelation between social, economic, and environmental aspects of such efforts in order, first, to convince local communities of the benefits of such a change and, second, to ensure its effectiveness.

Gavalas et al. (2026) focus on the green transition of the Greek coastal shipping services, with an emphasis on electrification and hybridization. The article discusses the lessons that Greece can take from Norway's example and employs two pilot case studies (Salamina–Perama and Chios-Oinousses) with the aim of presenting a scalable proposal for the introduction of electric and hybrid vessels to the Greek maritime connectivity grid, which will eventually lead to the decarbonization of the shipping sector.

Papadaki et al. (2026) emphasize the importance and the added value of projects (funded by the EU) in bringing together different stakeholders through participatory and system-based approaches to tackle shared challenges that have to do with the broad spectrum of the blue economy. The article utilizes the example of the Black Sea to unveil how different "blue" activities suffer from a series of barriers mostly attributed to governance issues, as well as to provide several solutions with the aim of developing a plan for sustainable blue action that could also be applied elsewhere.

Poersch (2026) performs an extended event ethnography to understand the influence of the UN Ocean Decade's vision on its realization in the North Sea. Through spheres of performance, the article examines different scenarios, projects, and impacts of developing blue policies, based on the experiences of key stakeholders in several events, such as the European Maritime Days, the Norwegian University of Science and Technology Ocean Weeks, and other regional and local meetings. The main argument of the article is that ocean governance events present similar characteristics in their spatial, temporal, and normative aspects.

Nantsou et al. (2026) delve into the issue of climate-induced migration from the Global South towards Europe through the Mediterranean Sea. The article presents data that challenges the dominant narrative that wants migrants fleeing their countries for other reasons (such as conflicts, human rights violations, poverty, etc.), by adding an important layer of climate and environmental factors, which are prevalent through extreme weather events. The article argues that climate-related mobility exists, is multifaceted, and calls for further action at all levels to ensure enhanced protection.

Dikaios et al. (2026) take as a starting point the growing use of the term "geopolitics," both in general and in the sphere of the shipping sector, and investigate the (potential) consequences of the decisions made by the International Maritime Organization and the EU regarding shipping decarbonization. The article focuses on maritime trade and on (alternative) fuel supply and explores the changes through the lens of geopolitics influenced by climate change, i.e., *climate geopolitics*, in an attempt to understand the analytical value of the term.

3. Conclusion

The thematic issue Ocean Climate Governance: Eclectic Viewpoints of a Multi-dimensional Nexus comes to add further research to the emerging literature on the attempts to understand, as well as to construct, a new notion of ocean governance impacted by climate change (e.g., Harris, 2019; Partelow et al., 2023). The thematic issue brings together scholars from across the social sciences in order to underscore the importance of inter- and multi-disciplinarity, which still lacks the necessary impetus to evolve. If the goal is to overcome the silos between climate and ocean governance, then the same applies to scientific knowledge and research. Bringing together work from diverse disciplines that undertake research on similar subjects from their own epistemological field might allow for further connections to be developed, potential collaborations, and, ultimately, possibly better solutions. Through unveiling this fragmented reality, the goal is to also open the discussion for the convergence of the scientific grid, if the desideratum is to advance an ocean governance that would serve the needs of coexistence of the (marine) environmental protection and human activities. The argument of this thematic issue is that this advancement can happen through the local, regional, national, and international efforts to combat climate change and to implement a substantial green transition and sustainable development.

Funding

This thematic issue has been supported by the Marie Sklodowska-Curie Action EU-CLIMT (GA no: 101150663). Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or European Research Executive Agency. Neither the European Union nor the granting authority can be held responsible for them.

Conflict of Interests

The author declares no conflict of interests.

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Ocean and Society
2026 • Volume 3 • Article 11539
https://doi.org/10.17645/oas.11539

ARTICLE

Open Access Journal

Local Communities' Perceptions of Offshore Wind Farms in Greece: Evidence From the Diapontian Islands

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Submitted: 15 October 2025 **Accepted:** 15 December 2025 **Published:** 29 January 2026

Issue: This article is part of the issue "Ocean Climate Governance: Eclectic Viewpoints of a Multi-dimensional Nexus" edited by George Dikaios (Leiden University), fully open access at https://doi.org/10.17645/oas.i488

Abstract

The development of offshore wind farms (OWFs) has become central to Europe's low-carbon transition, offering opportunities to decarbonize energy systems, reduce reliance on imported fossil fuels, and expand the blue economy. Greece, endowed with rich wind resources in its territorial waters, has recently adopted a comprehensive framework for offshore wind development, aiming to achieve 2 GW of installed capacity by 2030 and 12 GW by 2050. However, offshore wind deployment is not solely a technical or economic endeavor; it also depends on governance arrangements, social acceptance, and the ability to reconcile national ambitions with local realities. Drawing on 21 semi-structured interviews with local stakeholders conducted in September 2024, this article aims to map and analyze the attitudes and perceptions of local communities and stakeholders towards the potential environmental, social, and economic impacts of the planned OWF, focusing on the case of the Diapontian Islands. The sea area of the Diapontian Islands—a small island complex of the Ionian Sea, northwest of Corfu—has been designated as one of the potential areas for OWF installation. The findings demonstrate that perceived negative impacts on biodiversity and local economic activities, particularly tourism and fisheries, along with mistrust or distrust toward public authorities, fuel widespread opposition to the planned OWF in the area. Inclusive participation, transparent planning, and tangible reciprocal benefits emerge as key prerequisites for addressing public concerns and building trust around energy transition strategies.

Keywords

blue economy; Diapontian islands; energy justice; Greek islands; offshore wind farms; renewable energy governance; social acceptance

1. Introduction

The nexus between oceans and climate change represents one of the most pressing governance challenges of the 21st century. Oceans are vital carbon sinks and climate regulators; at the same time, they are increasingly threatened by climate change impacts such as sea-level rise, ocean acidification, and biodiversity loss, while also serving as indispensable sites of economic activity. Although the ocean economy is a significant driver of climate change—through sectors such as shipping, fishing, and tourism—ocean-based renewable energy technologies, including offshore wind farms (OWFs), offer substantial potential for emissions reduction and the achievement of climate neutrality, provided that their deployment minimizes adverse impacts on marine ecosystems (Cooley et al., 2022).

OWFs can be conceptualized as complex socioeconomic and environmental systems, involving synergies and trade-offs between human societies and natural environments. These interactions are dynamic and non-linear. Consequently, understanding the interplay among social, economic, and environmental priorities is crucial for minimizing the potential adverse effects of offshore wind energy strategies on both societies and ecosystems (Gill, 2005a; Katsanevakis et al., 2011).

Moreover, OWFs frequently encounter resistance from local communities, environmental organizations, and other stakeholders. Acceptance of such projects is strongly mediated by governance processes, distributional outcomes, and levels of trust in institutions (Firestone & Kempton, 2007; Wolsink, 2007, 2018; Wüstenhagen et al., 2007). In 2024, offshore wind accounted for only 7.3% of the total global wind capacity (83 GW), although the offshore market expanded at an average annual rate of approximately 10% throughout the 2010s (Global Wind Energy Council, 2025). Deployment has accelerated across Europe, positioning the sector as a cornerstone of the European Green Deal and the EU's strategy for climate neutrality by 2050. In 2020, the EU held 42% of the global offshore wind market and set binding targets of 60 GW by 2030 and 300 GW by 2050, signaling a rapid expansion of offshore renewables (European Commission, 2020).

With its extensive maritime zones and abundant wind resources, Greece has emerged as a potential leader in offshore wind energy production. In 2022, Greece adopted a dedicated legal framework for offshore wind development, and in 2024, it updated its National Energy and Climate Plan setting capacity targets of approximately 2 GW by 2030 and 12 GW by 2050. Furthermore, the 2023 National Development Program for Offshore Wind Farms (NDPOWF) designated relevant sites, underscoring the strategic importance of offshore renewable energy as a core component of Greece's decarbonization pathway and transition toward climate neutrality.

This article focuses on the case of the Diapontian Islands, a small island complex in the Ionian Sea, northwest of Corfu Island, which has been identified as one of the potential areas for OWFs installation. This case therefore offers a clear illustration of the interactions between national climate strategies and the lived realities of small, peripheral island communities. Drawing on 21 semi-structured interviews with local stakeholders conducted in September 2024, the study examines local perceptions and attitudes toward OWFs, as well as emerging sea-use conflicts that are exacerbated by the absence of comprehensive maritime spatial planning (MSP).

2. Contextualizing the Diapontian Islands as a Prospective Site for OWFs Development

2.1. The European Context

The EU, acting as a global leader in the pursuit of climate neutrality by 2050, has adopted a robust legislative and financial framework to promote renewable energy production, including OWFs. The Renewable Energy Directive (RED) 2009/28/EC (2009) first established binding targets of 20% renewable energy sources (RES) in total energy consumption and 10% in transport by 2020—targets that were ultimately achieved (European Environment Agency, 2021). Its revised version, RED II, Directive (EU) 2018/2001 (2018), adopted as part of the "Clean Energy for All Europeans" package, raised the 2030 target to 32%, while a separate Governance Regulation (EU) 2018/1999 (2018) required member-states to submit ten-year National Energy and Climate Plan for 2021–2030 and report progress biennially, which are considered essential strategic planning tools for delivering a fair, resilient, and climate-neutral Europe. The European Green Deal (European Commission, 2019) marked a decisive step in this direction. The European Climate Law, enacted through Regulation (EU) 2021/1119 (2021), made the EU's target of at least a 55% reduction in greenhouse gas emissions by 2030 legally binding, while the "Fit for 55" package (European Commission, 2021) was designed to align EU energy and climate legislation accordingly.

The Russia–Ukraine war revealed the energy vulnerability of the EU countries and the major energy security challenges, accelerating the transition toward green energy through the adoption of the REPowerEU plan (European Commission, 2022), which aims to reduce Europe's dependence on fossil fuels. In the same year, the EU introduced temporary measures to streamline permitting procedures for renewable energy projects. Subsequently, RED III (Directive (EU) 2023/2413, 2023) further increased the 2030 RES target to at least 42.5% (with an indicative 45% ambition), explicitly recognizing the strategic role of offshore renewable energy. Moreover, the directive mandates the integration of offshore RES generation into MSP, promotes cross-border cooperation, e.g., through joint projects, and introduces "renewables acceleration areas" with clearer and shortened time limits for environmental assessments and administrative procedures.

Moreover, the EU Offshore Renewable Energy Strategy (European Commission, 2020) established milestones to expand offshore capacity from 12 GW in 2020 to 60 GW by 2030 and 300 GW by 2050. In addition, the revised Trans-European Networks for Energy Regulation (Regulation (EU) 2022/869, 2022) strengthened cross-border planning and reaffirmed the importance of regional cooperation, explicitly enabling the development of joint projects. Political momentum was further reinforced by the European Commission (2023) communication, which set non-binding capacity objectives (111 GW by 2030, 317 GW by 2050) and outlined priority actions related to grids and regional cooperation, accelerated permitting, integrated MSP, infrastructure resilience, research and innovation, and supply chains and skills.

In parallel, multiple EU financial instruments support offshore renewable projects. The Recovery and Resilience Facility earmarked 37% of its resources for the green transition, while additional funding is available through the 2022 State Aid Guidelines for Climate, Environmental Protection and Energy, the InvestEU program, the European Regional Development Fund, and the Cohesion Fund, with a particular emphasis on less-developed regions. Since 2007, the EU budget has allocated €2.3 billion to offshore technologies, and the European Investment Bank has provided €14.4 billion in loans and equity financing for such projects (European Court of Auditors [ECA], 2023).

Moreover, the MSP Directive (Directive 2014/89/EU, 2014) emerges as an integral component of the offshore renewable energy development. It seeks to reduce conflicts among maritime activities, safeguard biodiversity, and the sustainable use of marine resources, as well as to create more stable and secure conditions for investments. To this end, the directive establishes a common EU framework for member-states to develop and implement maritime spatial plans that integrate economic, social, and environmental dimensions of sustainable blue economy, while promoting the coexistence of multiple sea uses.

2.2. The Greek Context

The development of OWFs remains central to Greece's energy transition strategy, as articulated in the NDPOWF and the relevant Strategic Environmental Impact Assessment (SEIA) drafted in late 2023 by the Hellenic Hydrocarbons and Energy Resources Management Company (HEREMA). HEREMA is the state-owned company responsible for managing Greece's exclusive rights to explore and identify suitable areas for OWFs (Hellenic Parliament, 2022). The NDPOWF aims to delineate specific zones for offshore wind development across Greek maritime space (HEREMA, 2023a). To this end, HEREMA applied a total of 20 exclusion criteria to safeguard environmentally sensitive areas and marine activities in the Greek territory, including, inter alia, national security and passenger navigation, airports, minimum distance from the coastline, areas of environmental and cultural importance, tourist activities, aquaculture areas, and other uses.

The NDPOWF further identifies 10 eligible areas for offshore wind energy projects by 2030, designated as Organized Development Areas for Offshore Wind Farms (ODAOWFs), with an estimated total capacity of approximately 4.9 GW, relying primarily on floating wind technology. More specifically, the ODAOWFs identified for the medium-term development phase are geographically distributed across Eastern Crete, Southern Rhodes, the Central Aegean, the Evia-Chios axis, and the Ionian Sea (see HEREMA, 2023b, p. 93). These areas do not include the marine area between Evros and Samothraki, which is defined by law as an area for the development of pilot OWF projects (Hellenic Parliament, 2022).

However, this legislative framework coexists with the Special Framework for Spatial Planning and Sustainable Development for RES, adopted in 2008 (Coordination Committee of Government Policy on Spatial Planning and Sustainable Development, 2008), which is widely regarded as outdated. Article 10 of this Joint Ministerial Decision sets out the criteria for wind installations in marine areas and on uninhabited islets, permitting them where wind conditions are favorable and no explicit prohibitions apply. It excludes marine protected areas (MPAs), underwater archaeological sites, and passenger-shipping routes, while establishing minimum distances from settlements (1,500 m from the coastline), heritage sites, and productive zones. It also requires compliance with landscape integration and electricity transmission constraints.

Furthermore, Law 4964/2022 forms part of a broader policy framework (Hellenic Parliament, 2022). As specified in Article 67, this framework encompasses the national energy planning and objectives as set out in the Greek National Energy and Climate Plan, the National Spatial Strategy, and the Special Spatial Framework for RES, alongside Article 13A of the spatial and urban planning legislation, the National Spatial Strategy for the Marine Space (Hellenic Parliament, 2014), and legislation on marine spatial plans (Hellenic Parliament, 2018). It also incorporates parameters such as national security, navigation safety, marine infrastructure, and biodiversity protection, as well as productive activities like fisheries and tourism.

To accelerate project deployment and align implementation with national energy objectives, permitting, and planning procedures were further streamlined, and HEREMA's NDPOWF was formally operationalized (Hellenic Parliament, 2024). In this context, a binding target of at least 2 GW of offshore wind capacity by 2030 was established, in line with Greece's commitments under the EU's 2030 climate and energy framework. Complementary provisions streamline environmental licensing for RES projects (Hellenic Parliament, 2020) and define the governance framework for spatial planning to ensure the compatibility of offshore projects with broader territorial strategies (Hellenic Parliament, 1999).

According to the NDPOWF (HEREMA, 2023a), one of the eligible areas for medium-term offshore wind energy projects to be developed by 2030 is the sea area of the Diapontian Islands, a small island complex located northwest of Corfu and marking Greece's westernmost point. This island complex consists of three larger islands and several smaller islets. Othoni, Erikoussa, and Mathraki are the three main islands, each hosting between approximately 330 and 500 permanent residents. The islands are characterized by rich fauna and flora, and a substantial part of their territory is included in the Natura 2000 network or has been recognized as an important area for birds (HEREMA, 2023b, p. 516). According to the NDPOWF, the planned OWF will be installed in the sea area between these islands, with the installation of dozens of wind turbines with a rotor diameter of 236 m and a height of up to 280 m. Accordingly, SEIA (HEREMA, 2023b, p. 436) indicates that the OWF would cover an area of 54 km^2 and comprise fixed-bottom wind turbines with a proposed total installed capacity of 270 MW, located at a minimum distance of 1,890.92 m from the coastline (for more, see Avrami et al., 2025).

The uniqueness of the area, combined with the scale and characteristics of the proposed project, poses significant challenges for local communities and the marine environment, leading to unanimous opposition among local stakeholders. Local and regional public authorities, representatives of the fisheries and tourism sectors, as well as civil society organizations, have publicly expressed concerns regarding the planned OWF in the area ("Baraz antidraseon gia," 2023; Syndesmos Epicheirimation Arilla Kerkyras, 2013).

Notably, the SEIA emphasizes the relatively low wind potential of the Diapontian Islands area compared to other designated sites. Low wind potential refers to conditions in which wind speeds are insufficient for conventional wind turbines to operate efficiently or even initiate operation, typically falling below the cut-in speed (approximately 10–15 km/h). In these cases, increasing both technical complexity and project costs (Nizamani et al., 2024). This issue was also emphasized by representatives of national agencies involved in the planning and implementation of offshore wind energy projects, who noted that wind speeds in the area are considered inadequate, rendering the investment economically non-viable. As a result, investment interest in the area remains extremely limited (Avrami et al., 2025).

In this context, the Diapontian Islands in the Ionian Sea appear likely to be excluded from HEREMA's medium- and long-term offshore wind energy planning following strong opposition from local communities and regional authorities. However, no formal decision to this effect has yet been adopted. In the meantime, the Greek Ministry of Culture approved the NDPOWF SEIA (HEREMA, 2023b) in August 2024, which continues to include the Diapontian Islands among the planned areas. Regardless of the final outcome, the Diapontian Islands constitute a highly relevant case study, as they illustrate how national offshore wind ambitions intersect with local perceptions and constraints in Greece's emerging offshore renewable energy landscape—particularly in a context where the social dimensions of offshore RES deployment remain largely understudied.

3. Potential Socioeconomic and Environmental Impacts of OWFs: Islandness and Social Acceptance in Greece and Abroad

The relevant literature highlights the potential negative environmental and social impacts associated with the development of OWFs. In particular, issues related to social (in)justice have been identified, including the displacement of populations and/or activities, the phenomenon of "ocean grabbing," the degradation of marine environments and ecosystem services, adverse impacts on fishers, and restricted access to marine resources for certain user groups. These challenges are frequently accompanied by social and cultural repercussions stemming from the disruption of traditional livelihoods, landscapes, and settlements, as well as from infringements of indigenous rights and the lack of inclusive and participatory governance processes in offshore renewable energy development (Bennett et al., 2019). Moreover, several studies emphasize the intensifying competition over marine space, particularly in the Mediterranean, where a wide range of activities—such as fisheries and aquaculture, maritime transport, and recreation—coexist with multiple, and often competing, uses of marine areas. These include MPAs, ports, military zones, sites of archaeological interest, tourism infrastructure, and submarine infrastructures (Soukissian et al., 2017).

3.1. Environmental Impacts

Offshore renewable energy farms play a decisive role in decarbonizing the energy sector and enhancing energy security (Gattuso et al., 2018; P. Liu & Barlow, 2021). However, a range of potential ecological impacts must be carefully addressed during the planning and implementation phases. In particular, the foundations of offshore wind turbines may function as artificial reefs, creating new habitats for fish and invertebrates and thereby enhancing local biodiversity (Kristensen et al., 2017; Lemasson et al., 2024). Empirical evidence from the North Sea, for example, has documented the colonization of turbine structures by diverse marine species (Wilhelmsson et al., 2006). OWFs may also contribute to conservation objectives by acting as de facto MPAs, where fishing activities are restricted and benthic habitats have the potential to recover (Gasparatos et al., 2017; Hammar et al., 2016). Additional evidence suggests possible increases in fish stocks and indirect protection of species due to the exclusion of bottom trawling (Ashley et al., 2014; Buck et al., 2017).

Nevertheless, the pressures exerted on marine ecosystems cannot be overlooked. The construction and operational phases involve seabed disturbance, sediment resuspension, and underwater noise, all of which may negatively affect sensitive species (Gill, 2005b). Marine mammals, such as whales and dolphins, are particularly vulnerable to acoustic disturbance, which can interfere with communication, navigation, and migration patterns (Brandt et al., 2012; Tougaard et al., 2009). Moreover, alterations in local hydrodynamics and sedimentation processes may affect the distribution of plankton, fish, and benthic organisms, with implications for ecological interactions and food-web stability (Chen et al., 2015; Möller et al., 2015). Physical modifications of seabed environments may also threaten endemic habitats, notably *Posidonia oceanica* meadows, potentially leading to biodiversity loss in affected areas (Langhamer et al., 2010).

Avian species may face comparable risks. Collision mortality associated with wind turbines has been linked to declines in local and migratory bird populations, particularly along major flyways where wind farms are densely developed (Arnett et al., 2010; Desholm, 2009; Krijgsveld et al., 2011). Recent studies further indicate that such impacts may remain significant even when mitigation measures are implemented (Ayadi & Forouheshfar, 2023), underscoring the importance of avoiding high-biodiversity areas and sites adjacent to existing MPAs (Lloret et al., 2022).

At the policy level, the European Court of Auditors (ECA) has emphasized the persistent challenges associated with assessing the cumulative impacts of offshore renewable energy developments in combination with other maritime activities, noting that impacts may vary across technologies and project life-cycle stages. In a recent report, the ECA highlights that environmental considerations are not yet sufficiently integrated into offshore energy planning processes. Potential consequences include species displacement, changes in population structures, and disruptions to marine and coastal biodiversity. Accordingly, the ECA warns that the large-scale expansion of offshore renewable projects in Europe could occur at the expense of the marine environment above and below the sea, if they are poorly sited and/or not adequately monitored (ECA, 2023).

3.2. Economic Impacts

Increasing renewable energy production is generally associated with a range of positive macroeconomic benefits, including job creation in the green technology sector, higher household disposable income resulting from reduced energy costs, and overall economic growth driven by investment and enhanced energy security. Nevertheless, OWFs frequently generate conflicts with other maritime and coastal sectors, such as fisheries, shipping, and tourism. The relevant literature indicates that OWF operation may reduce fishing activity and income, restrict navigation, and negatively affect tourism due to visual intrusion and landscape alteration (Hooper & Austen, 2014; Ladenburg & Lutzeyer, 2012; Veidemane & Ruskule, 2017; Westerberg et al., 2013).

At the same time, increasing attention has been paid to the potential synergies among activities sharing the same maritime space. The concept of multi-use offshore areas refers to zones in which diverse activities—such as aquaculture, tourism, and renewable energy production—are combined (Nassar et al., 2020). Empirical studies suggest that certain productive uses, including seaweed and mussel farming, can coexist with OWFs, generating both economic and environmental benefits through carbon sequestration, mitigation of ocean acidification, and the production of sustainable biofuels (Buck et al., 2017; Christensen et al., 2015; High-Level Panel for a Sustainable Ocean Economy, 2020; van den Burg et al., 2016). Evidence from the North Sea further indicates that such co-location arrangements can reduce operational costs and create mutual economic gains (Christensen et al., 2015; van den Burg et al., 2017). However, the success of multi-use models hinges on appropriate site selection, favorable biophysical conditions, and safe platform design (Demmer et al., 2022; Lacroix & Pioch, 2011).

Additional synergies may arise when multiple RES are integrated within the same offshore installation. Combining wind energy with wave or solar technologies can enhance efficiency and cost-effectiveness, thereby improving the overall economic viability of offshore renewable energy systems (Astariz et al., 2015; Demmer et al., 2022; Mikkola et al., 2018; Nogueira et al., 2023). Comparative studies across the Baltic, North Sea, Atlantic, and Mediterranean regions confirm the existence of such opportunities, while also emphasizing that local environmental conditions ultimately determine the feasibility of specific technology combinations (Christensen et al., 2015).

Although offshore wind farms have often been perceived as detrimental to tourism, recent evidence suggests that they may support complementary economic activities. Coastal OWFs may attract visitors for educational or recreational purposes, including diving tourism associated with artificial reef formation around turbine foundations (Beer et al., 2018; Carr-Harris & Lang, 2019; Fotiadou & Papagiannopoulos-Miaoulis, 2019; Frantál & Kunc, 2011; Klinger et al., 2018; D. Liu et al., 2016; Smythe et al., 2020). Fisheries may also experience indirect benefits, as restricted-access zones surrounding OWFs can facilitate stock recovery and higher yields over time (Hooper et al., 2017). Nevertheless, according to the ECA (2023), coexistence between offshore renewables and other maritime sectors—particularly fisheries—remains limited and requires more effective and integrated marine spatial planning. The ECA further highlights missed opportunities for cross-border offshore projects that could enable more efficient use of maritime space, as well as delays caused by fragmented licensing procedures across member-states. Moreover, while offshore renewables can enhance energy security and reduce dependence on energy imports (Krohn et al., 2009), increasing reliance on third countries—particularly China—for critical raw materials needed for clean energy technologies may create new strategic dependencies, potentially constraining deployment rates and undermining the EU's energy objectives (ECA, 2023).

3.3. Social Impacts

The social sustainability of offshore renewable energy installations is explicitly recognized in EU policy. Both the MSP Directive (Article 5) and the EU Strategy for Offshore Renewable Energy (European Commission, 2020) require member-states to consider social dimensions when designing maritime plans, emphasizing that offshore renewables can only be sustainable if they do not undermine social cohesion.

A key concern relates to the unequal distribution of costs and benefits associated with OWF development (Avila, 2018). The impacts of OWFs are socially and geographically uneven: while some communities bear visual disturbance and spatial restrictions (Kaldellis et al., 2016), others benefit from lower energy prices and environmental gains without experiencing comparable burdens. The literature warns that the expansion of OWFs may exacerbate existing inequalities through the uneven distribution of economic gains, as well as the displacement of local populations, restricted access to marine resources, and infringements of community rights (Bennett et al., 2019; Devine-Wright, 2005; Issifu et al., 2023; Zhang et al., 2017).

At the same time, research highlights notable social benefits, particularly job creation and improvements in infrastructure and services (Elisha, 2019; Esteban et al., 2011; Glasson et al., 2022; Hattam et al., 2015). Employment in the offshore wind sector increased from fewer than 400 workers in 2009 to approximately 77,000 in 2020, with Germany, Denmark, the Netherlands, and Belgium emerging as leading employers (ECA, 2023). However, a shortage of specialized labor may constrain further growth. According to ECA (2023), 30% of firms reported significant skills gaps in 2021. Consequently, reskilling workers from the oil and gas sector have been recommended as a strategy to meet the labor demands of the offshore renewable industry. Conversely, the expansion of offshore renewables may threaten employment in traditional sectors such as fisheries, where limited retraining opportunities and restricted access to fishing grounds raise concerns among local workers. Overall, empirical evidence on the broader social and economic impacts of offshore renewables remain limited. The ECA (2023) identifies the systematic assessment of these effects as a future EU priority, while several member-states, including France, Spain, and the Netherlands, have already initiated detailed studies on the socioeconomic consequences of offshore renewable energy deployment.

3.4. Islandness and Social Acceptance

A substantial body of literature demonstrates that islandness and insularity play a significant role in shaping social acceptance of large-scale infrastructure projects, such as OWFs. Islandness is a multidimensional concept that extends beyond the mere geographical boundedness of islands by the sea, encompassing distinct socio-cultural characteristics, economic dependencies, and political conditions shaped by small scale, limited resources, peripherality and/or isolation, as well as deeply rooted collective identities (Baldacchino, 2020; Mitropoulou & Spilanis, 2020). These studies show that island-specific conditions, such as strong attachment to place, heightened environmental vulnerability and awareness, dependence on a narrow set of economic activities, and distrust toward central government authorities, play a decisive role in shaping how island communities perceive large infrastructure projects, including OWFs. Consequently, such projects are often evaluated not solely on technical or economic grounds, but also through concerns related to territorial integrity, ecological risk, the preservation of local culture, and the reinforcement of centre-periphery power relations (Kaldellis et al., 2016).

Patterns of tension between local communities and central authorities have been widely documented across European islands, where tourism dependence, ecological sensitivity, and distrust toward national planning processes shape responses to offshore wind development. A study of the Greek island of Paros, for example, shows that stakeholders assess offshore wind projects by weighing environmental risks, economic trade-offs, and social justice considerations in ways that closely resemble findings from Northern European island contexts. This suggests that insularity amplifies both perceived risks and demands for participatory governance. Mediterranean islands, therefore, do not represent an exception but rather reflect broader European dynamics concerning the social acceptance of OWFs (Skiniti et al., 2026). These insights are consistent with earlier nationwide evidence from Greece, where survey data indicate that concerns about ecological impacts and distrust toward investors and public authorities are the strongest predictors of opposition to wind energy projects. Conversely, transparency, continuous information, and perceived fairness significantly enhance public acceptance. In this sense, opposition observed in island contexts should not be interpreted as an isolated phenomenon, but rather as an intensified manifestation of wider national patterns, in which social acceptance is closely linked to environmental considerations and the perceived legitimacy of decision-making processes (Skiniti et al., 2022).

4. Unpacking Local Communities' Attitudes and Perceptions Towards OWFs: Findings of the On-Site Qualitative Research in Corfu and the Diapontian Islands

4.1. Methodology

To identify the key factors shaping local resistance to or acceptance of OWFs, this study employed a qualitative research approach based on 25 semi-structured interviews conducted in Corfu and the Diapontian Islands in September 2024. The interviews were carried out by the research teams of the National Centre for Social Research (EKKE) and the Hellenic Centre for Marine Research (HCMR) within the framework of the JustReDI research project entitled Resilience, Inclusion and Development: Towards a Just Green and Digital Transition of Greek Regions and implemented within the framework of the National Recovery and Resilience Plan Greece 2.0 with funding from the EU NextGenerationEU.

All interviews were conducted face-to-face and had an average duration of approximately one hour. The interview guide covered the following thematic axes: local development challenges, knowledge, and perceptions of RES, perceived environmental, economic, and quality-of-life impacts of OWFs, trust in institutions, consultation processes, and governance transparency. All participants were informed about the objectives of the study and the intended use of the data, and anonymity was fully ensured. The research adhered to ethical standards, including informed consent, voluntary participation, and confidentiality.

A purposive sampling strategy was adopted to capture a wide range of perspectives from relevant stakeholders. This was subsequently complemented by snowball sampling in order to broaden participation through interviewee referrals. The final sample comprised 17 interviewees from Corfu, including representatives of local and regional authorities, professional associations, key economic sectors such as fisheries and tourism, and civil society organizations. In addition, two representatives of local authorities were interviewed on Othonoi Island, along with one representative of local authorities and one representative of local economic sectors on Erikoussa Island. Regarding the sample characteristics of interviewees in Corfu and the Diapontian Islands, more than half of the participants were over 60 years old (13 out of 21). Three participants were aged 50–59, one was in the 40–49 age group, and four were between 30 and 39 years old. In terms of educational attainment, the majority of respondents hold a university or technical university degree (13 interviewees), including two with postgraduate or doctoral qualifications. With respect to employment status, most participants reported permanent, non-seasonal employment, and the majority were employed outside the coastal zone of Corfu and the Diapontian Islands (17 interviewees).

The interviews were audio-recorded with the participants' consent and fully transcribed using a transcription tool developed by the ATHENA Research Center in Greece. For the data analysis, we applied open coding and subsequently axial coding, relying on a manual, non-software-assisted approach.

4.2. Findings

4.2.1. Level of Knowledge of RES and Attitudes Towards RES Projects

The research analysis revealed that all respondents had sufficient information of wind energy and other RES, as well as of good practices and the potential environmental, economic, and social impacts of RES development in Greece and other European countries. Most respondents recognized the need to increase green energy production and acknowledged the associated benefits; that is, they recognized the positive impacts of RES production in reducing energy costs and the environmental footprint of energy consumption, while enhancing energy security. However, almost all local stakeholders who participated in the research remained skeptical and expressed strong concerns regarding the potential impacts of OWFs in the sea area of the Diapontian Islands. Their concerns mainly revolved around issues of aesthetic and environmental degradation, negative impacts on local economic activities—especially tourism and fisheries—the absence of consultation with local communities in the designation of the specific ODAOWF, and the overall limited participation in decision-making processes.

Therefore, local stakeholders in Corfu and the Diapontian Islands underlined the need for all RES projects, and especially OWF planning, to be adapted to the specific characteristics of each region and to ensure the quality of life of local communities, along with the protection of cultural heritage and the natural environment. In this context, there was moderate acceptance of smaller-scale wind projects (e.g., stand-alone turbines) that would cover only local energy needs without supplying electricity to the national grid; in other words, respondents would accept wind turbines only if they were harmoniously integrated into the local setting. Moreover, there was also moderate acceptance of small-scale photovoltaic installations at the single or multi-residence level. Such installations were considered to have fewer negative social and environmental impacts and were therefore perceived as a more appropriate solution for the energy self-sufficiency of the Diapontian Islands, especially Erikoussa, where frequent power outages have been reported.

4.2.2. Perceived Impacts of the Planned OWFs in the Diapontian Islands

Our findings indicate that perceived negative impacts on biodiversity, local economic activities—especially tourism and fisheries—and marine transportation, along with mistrust or distrust towards public authorities, fuel widespread opposition to the planned OWF in the area. Almost all local stakeholders in Corfu and the Diapontian Islands who participated in the research assessed the potential effects of the operation of an OWF in the region as very negative for residents' quality of life.

As evidenced by the interviews conducted, as well as by protest resolutions issued by local bodies and authorities, it is widely considered that both the planned location of the OWF and the type of wind turbines proposed will maximize negative impacts on the local communities and the natural environment. According to the NDPOWF, the OWF is planned to be installed in the sea area among the three main islands (Othonoi, Erikoussa, and Mathraki) and at a distance of just 1.4 nautical miles from their coastlines (HEREMA, 2023a). The planned installation of offshore wind turbines with fixed foundations on the seabed (rather than floating ones), with a height of approximately 280 m—exceeding the highest natural peaks of Erikoussa and Mathraki—was described by local stakeholders as a "violent intervention" in a pristine natural landscape, with devastating consequences for the natural beauty and aesthetic value of the area.

Although specific exclusion criteria were applied to safeguard "environmentally sensitive areas and marine activities in the Greek territory" (HEREMA, 2023a), as stated in the NDPOWF, survey participants believe that the selection of this specific area is based on "different" criteria and less transparent procedures, aimed at facilitating and attracting private investments. According to respondents, this is due to the relatively shallow waters in the area (approximately 70 m), which renders the installation of fixed-foundation OWFs less costly.

More specifically, the potential negative impacts of the planned OWF concern the destruction of coastal island landscapes, environmental degradation and biodiversity loss, the reduced attractiveness of coastal and marine tourism (both in northern Corfu and the Diapontian Islands), increased challenges for maritime transportation, and adverse effects on other maritime and coastal economic sectors, particularly tourism and fisheries. Several participants also expressed strong concerns regarding the environmental impacts associated with turbine installation activities, as well as the lifespan of the turbines and their end-of-life management. These concerns were intensified by the fact that the proposed wind farm would be located only 247.03 m from the two protected areas of the Natura 2000 network in the Diapontian Islands (HEREMA, 2023b, p. 516). Moreover, respondents highlighted potential impacts on local birdlife, given that the area constitutes a migratory bird corridor, increasing the risk of bird collisions with turbine blades.

Visual nuisance emerged as one of the main perceived impacts of the OWF operation, as reported by all survey participants. To clarify what constitutes visual nuisance for local stakeholders, participants were shown four archival images of proposed or existing OWFs in other countries (e.g., the UK and Spain), depicting wind turbines located at varying distances from the coastline, ranging from 13 km to 44 km. The images featured 20 MW wind turbines with a tower height of 190 m above sea level and a total height of approximately 300 m (including the blades). Given that both the turbine type and distances from the coastline were comparable to those proposed for the Diapontian Islands, these images functioned as "photo simulations," providing a visual representation of hypothetical scenarios and helping participants to better understand how the planned OWF might appear in the real landscape.

Participants were then asked to select the image that did not constitute a visual nuisance to them, without initially being informed of the exact distances from the coastline. Although perceptions of visual nuisance are inherently subjective and no universally accepted threshold exists for minimizing visual impacts, the vast majority of local stakeholders from both Corfu and the Diapontian Islands (19 out of 21 interviewees) considered all images—depicting OWFs at distances of 13 km, 24 km, and 35 km from the coastline—to constitute visual nuisance. Only two participants indicated that the fourth image, showing an OWF located 44 km from the coastline, did not represent a visual nuisance to them.

In addition, local stakeholders emphasized the negative impacts of the proposed project on maritime transportation, particularly concerning connections between Corfu and the Diapontian Islands, as well as among the islands themselves. According to their accounts, the existing ferry route intersects almost vertically with the delineated OWF area. As a result, daily island connections would need to be rerouted, leading to increased travel time and higher transportation costs.

These anticipated difficulties in maritime transportation, combined with the degradation of the natural landscape, visual disturbance, and noise generated by OWF operation, are perceived as having irreversible consequences for coastal and marine tourism and, consequently, for the well-being of local communities. Furthermore, most respondents highlighted the expected economic impacts on local fisheries, noting that the designated OWF area constitutes a traditional fishing ground. Restrictions and prohibitions on fishing activities were therefore perceived as posing severe challenges to the economic viability of the sector in Corfu and the Diapontian Islands. Strong concerns were expressed that fish stocks would decline due to disruptions of marine ecosystems and seabed conditions, alongside a prevailing belief that public authorities would fail to adequately support the approximately 150 professional fishers potentially facing economic hardship. While the NDPOWF states that fishing activities will be considered as an evaluation criterion in subsequent studies for the final siting of OWFs (HEREMA, 2023a), respondents emphasized that such considerations were entirely absent from the initial planning process.

Finally, most of the survey participants argued that the combined economic impacts of the planned project and the increasing difficulties in maintaining maritime connections with Corfu would ultimately force residents to abandon the islands. Given the Diapontian Islands' location at Greece's westernmost point, respondents stressed that ongoing population decline and demographic ageing raise issues of national importance, particularly concerning national sovereignty and jurisdiction over territorial waters and other designated maritime zones.

4.2.3. Trust, Consultation, and Information Deficit

The research analysis demonstrates an evident lack of trust in institutions, which, in turn, increases the skepticism of survey participants towards OWF planning and, in particular, regarding the selection criteria of the specific ODAOWF. It seems that local stakeholders' trust in public authorities is undermined by: (a) insufficient information provision and consultation with local stakeholders; (b) concerns regarding the transparency and reliability of the selection criteria and procedures used to delineate the ODAOWF; (c) uncertainty surrounding the potential reciprocal benefits of the OWF for local communities; (d) ambiguity regarding project management by the competent companies; and (e) the perception that there are no adequate safeguards or a strategic plan for the long-term future of the Diapontian Islands that would ensure the minimization of potential negative impacts on local society and the economy.

All informants, including representatives of public authorities, reported that they have never been invited to engage in discussions with the competent agencies regarding the planning and development of such a project in their area. In their view, the absence of official information and meaningful consultation has generated a sense of alienation, facilitated the spread of misinformation, and reinforced perceptions of limited transparency in governance. As a result, a prevailing view within the local community is that the companies involved operate solely on the basis of profitability and that broader RES planning serves external interests rather than addressing local needs and priorities (e.g., supplying the national grid). This finding resonates with insights from the literature, particularly those related to the procedural justice dimension of social acceptance: When citizens perceive decision-making processes as opaque or top–down, opposition tends to intensify regardless of a project's potential benefits.

Overall, local communities felt that they were being "sacrificed," bearing the negative consequences of RES projects without receiving any substantial benefits in return. Participants referred to experiences from other regions in Greece where RES projects had been developed, noting that although significant social and economic benefits were promised, these commitments were not fulfilled in practice. Consequently, respondents expressed strong skepticism that the reciprocal benefits promised for the planned project would materialize.

5. Conclusions

Our findings indicate that perceived negative impacts on biodiversity and local economic activities—especially tourism and fisheries—along with mistrust or distrust towards public authorities, fuel widespread opposition to the planned OWF in the area, even though local stakeholders acknowledge the need for and the national benefits of energy transition and RES development. These findings align with previous research on island communities' attitudes towards the energy transition, which shows that acceptance depends heavily on the perceived visual, social, economic, and environmental impacts of planned energy projects, as well as on the procedural justice dimensions of their development. At the same time, the specificities of islandness and place attachment significantly shape public acceptance (or lack thereof) at the local level.

Our analysis demonstrates that the concerns expressed by the local stakeholders in Corfu and the Diapontian Islands are primarily driven by perceived negative impacts on marine ecosystems and biodiversity, the fisheries and tourism sectors, landscape quality, and a deficit in participatory processes.

In other words, the analysis confirms that public opposition to RES projects is not rooted in a rejection of the energy transition itself, but rather in skepticism regarding how it is governed and regulated. Moreover, local communities' perceptions appear to be shaped less by technical considerations or projections of regional economic development than by issues of perceived fairness, transparency, and the distribution of costs and benefits. As such, local resistance tends to reflect a response to uncertainty and limited consultation with local stakeholders. Centralized decision-making traditions in Greece seem to amplify contestation and leave room for the spread of "fake news." In this sense, a more deliberative approach that combines early-stage consultation, transparent spatial criteria, and clear benefit-sharing mechanisms appears essential for building legitimacy for offshore renewable energy projects.

In this context, the non-delimitation of Greece's exclusive economic zone continues to pose significant constraints on the planning and development of offshore RES projects. Under current circumstances, OWFs must be located relatively close to the coastline, increasing visual nuisance and rendering the harmonious coexistence of different maritime economic activities more challenging. In parallel, the completion of MSP in Greece remains a crucial prerequisite for managing conflicts between human activities, fostering synergies, and enabling effective implementation of the national offshore renewable energy development plan.

Socioeconomic impact assessment during the planning phase, along with meaningful consultation with local stakeholders, is essential for minimizing the socioeconomic and environmental impacts on local communities and for building advocacy coalitions for the green transition at the local level. Although not all factors triggering local opposition—such as visual nuisance—can be fully addressed through these processes, trust, communication, and mutual understanding can be strengthened through co-decision and co-design procedures such as communities of practice. Planning processes should be transparent and open to all interested parties, and the reciprocal benefits of planned offshore RES projects should be clearly defined and measurable from the early stages of decision-making, in order to motivate local communities to engage (Demertzis et al., 2025). Moreover, systematically mapping potential socioeconomic impacts on local communities and adopting policy measures to offset potential adverse effects on both the environment and society appear essential for addressing public concerns and building trust around energy transition strategies.

Acknowledgments

The authors would like to thank the General Secretariat for Research and Innovation of the Greek Ministry of Development for funding this research, under the National Recovery and Resilience Plan Greece 2.0, with funding from the EU NextGenerationEU.

Funding

Funded by the research programme Resilience, Inclusion and Development: Towards a Just Green and Digital Transition of Greek Regions—JustReDI (TAEDR-0537352), an action implemented under the National Recovery and Resilience Plan Greece 2.0, with funding from the EU NextGenerationEU.

Conflict of Interests

The authors declare no conflict of interests.

Data Availability

The data are available at the JustReDI website (Section: Green Transition and Blue Economy): https://www.justredi.gr/galazia-oikonomia

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Ocean and Society
2026 • Volume 3 • Article 11441
https://doi.org/10.17645/oas.11441

ARTICLE

Open Access Journal

Bridging Seas Sustainably: Adopting Norway's Green Maritime Innovations in Greece

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Submitted: 29 September 2025 **Accepted:** 24 December 2025 **Published:** 21 January 2026

Issue: This article is part of the issue "Ocean Climate Governance: Eclectic Viewpoints of a Multi-dimensional Nexus" edited by George Dikaios (Leiden University), fully open access at https://doi.org/10.17645/oas.i488

Abstract

The transition to sustainable maritime transport is imperative for Greece's coastal ferry sector, which faces environmental, economic, and operational challenges. Drawing insights from Norway's pioneering experience in adopting electric and hybrid ferries, this study proposes a strategic roadmap for Greece to modernize its aging fleet. Norway's success stems from robust government policies, extensive infrastructure development, and public–private partnerships. Greece's fragmented ferry sector must address key issues such as seasonality, network complexity, and a lack of environmental incentives. The proposed roadmap emphasizes feasibility studies, pilot projects, and the establishment of charging infrastructure to facilitate the transition. Two pilot initiatives are highlighted: a hybrid vessel retrofit for the Perama–Salamina route and a fully electric vessel for the Chios-Oinousses route. These initiatives aim to demonstrate scalable solutions that reduce greenhouse gas emissions while ensuring economic viability. This research underscores the importance of strategic collaboration, regulatory frameworks, and targeted investments in achieving Greece's maritime decarbonization goals. By leveraging lessons from Norway's success, Greece can develop a sustainable, resilient, and efficient coastal shipping network that aligns with broader climate objectives and social cohesion goals.

Keywords

coastal ferry sector; decarbonization; electric ferries; environmental regulations; green shipping; hybrid vessels; sustainable maritime transport

1. Introduction

The Greek coastal shipping serves as the backbone of connectivity between mainland Greece and the islands, playing a crucial role in both passenger and freight transport (Lekakou et al., 2018). It consists of a complex network, providing services not only from mainland Greece to the islands but also between islands and between parts of the mainland. Greece's islands have a total coastline of 7,700 km. In total, the country's 9,837 islands, islets, rocky islets, and uninhabited islands cover 18.8% of the land area (24,739.4 square km). The remaining islands rely exclusively on coastal shipping for their needs. Therefore, coastal shipping is vital for the national and social cohesion of the country (Lekakou, 2007).

The network of companies operating in coastal shipping comprises 79 businesses, of which 49 serve short distances, while 30 focus on long-distance routes. Only three of these are classified as major companies. Most companies are small, adhering to a traditional management model where shipowners make decisions regarding investments and fleet management. Despite the market's potential, its fragmentation, aging fleet, high borrowing costs, and lack of transparency limit investment opportunities (Gavalas et al., 2024).

The coastal shipping system includes 153 passenger ships, with an average age of almost 30 years, most of which have a capacity of up to 1,000 Gross Tonnage. In the summer of 2024, 153 coastal shipping vessels belonging to long-distance companies served 115 islands daily, either connecting them to the mainland or linking islands with one another (XRTC Business Consultants, 2025). Out of 153 ships in the Greek coastal fleet, 45 vessels (29%) are 40 years old or older, highlighting the need for fleet renewal. Notably, over 40% of these 257 ships were built in Greece, supporting the Greek shipbuilding industry. However, these are primarily short-distance ferries serving inter-island routes. In the category of large ships, there is a gradual decline in the number of vessels operated by major, publicly listed companies (Gavalas et al., 2024).

The Greek coastal shipping system comprises 278 routes, divided into three main categories: 88 main routes covering distances between 50 and 257 nautical miles, 91 medium-distance routes ranging from 20 to 50 nautical miles, and 99 short-distance ferry routes of up to 20 nautical miles (XRTC Business Consultants, 2024). At the European level, there is a particularly large number of short-distance ferry routes. Half of these routes are located in Scandinavia, while the rest are found predominantly in countries with many islands, such as Greece, Denmark, and Croatia. In total, there are 222 ferry routes in Europe shorter than 16 km (8.6 nautical miles). Based on the share of these very short-distance ferry routes, Greece ranks second in Europe, after Norway, accounting for 9% of all such routes (Papaioannou, 2018). Of these 98 short-distance routes, for the purposes of this study, routes up to 10 nautical miles were selected, numbering 44 in total. Among them, two routes stand out as particularly suitable candidates for early electrification: the Chios–Oinousses route, which is 10 nautical miles long and currently served by a combination of low-frequency and dedicated daily services, and the Salamina–Perama shuttle. Both routes combine short distances with regular demand and manageable crossing times, making them promising options for pilot implementation. In this article, however, the Salamina–Perama route is selected as the main case study for detailed technical, regulatory, and stakeholder analysis, while the Chios–Oinousses connection is retained as an additional reference candidate for future pilot projects.

In 2024, short-distance routes transported approximately 19.5 million passengers and 4.0 million vehicles. In 2023, the corresponding figures for the entire year were almost 18.8 million passengers and 3.8 million vehicles (XRTC Business Consultants, 2025). Regarding ferry traffic (part of the short-distance routes), the most heavily used route remains Perama (Salamina)–Paloukia, with annual traffic exceeding 6.7 million passengers and 3.7 million vehicles in 2023, and having recorded over 7.6 million passengers and 4.0 million vehicles in 2024 (Hellenic Statistical Authority, 2024). Other important routes include Rio–Antirrio and Corfu–Igoumenitsa. On the Chios–Oinousses route, which is one of the two lines the authors have set as a case study, 17,252 passengers disembarked at the port of Oinousses in 2024, according to data from the Hellenic Statistical Authority (ELSTAT, 2024). Overall, ferry lines account for a significant volume of both passenger and vehicle traffic, as also illustrated in the Supplementary File under the category "Other," which refers to ferry lines beyond the 14 specifically listed in the Supplementary File. These traffic data reveal the geographical dispersion and extensive reach of the network (Papaioannou et al., 2022).

The coastal shipping market exhibits strong seasonality. During the summer, driven by increased tourist demand, routes to the Cyclades, Dodecanese, and Crete take center stage. In contrast, during the winter months, activity is limited, with emphasis on the transportation of essential goods. Excluding fuels and other commodities serving as production inputs (including liquid and dry bulk cargo), the share of goods delivered to the islands by truck (predominantly via ferry) reached 86% in 2022 (Foundation for Economic and Industrial Research [IOBE], 2025).

Greek coastal shipping significantly contributes to the Greek economy. According to data from IOBE, its total contribution to GDP in 2023 amounted to €11.8 billion, representing 5.4% of GDP. This contribution mainly stems from transport activities, the broader impacts of tourism, production on islands, and effects on foreign trade. Additionally, coastal shipping directly and indirectly employs 318,000 workers, accounting for 6.9% of total jobs in the country for 2023 (IOBE, 2025). These achievements highlight the vital role of coastal shipping in supporting island communities, tourism development, and overall economic activity in Greece.

Transitioning to a sustainable coastal shipping model is both a challenge and an opportunity. The adoption of electric and hybrid ships, combined with the upgrading of port infrastructure, is essential to reduce environmental impacts and achieve SDGs (Gavalas et al., 2024). Furthermore, initiatives such as those recently announced by the minister of maritime affairs for launching projects for the green transition of coastal shipping, fleet renewal for subsidized ferry routes with "green" ships through public–private partnerships, and the creation of a master plan for port infrastructure mark a new era of modernization and foster a positive climate for investments (Ministry of Maritime Affairs and Insular Policy, 2024a, 2024b).

The objective of this article is to develop a realistic roadmap for the electrification and hybridization of Greek coastal shipping, with emphasis on short-distance ferry routes and lessons from Norway's green maritime transport. The contribution of the study lies in integrating technical, industrial, regulatory, and stakeholder perspectives into a coherent framework for the transition to electric and hybrid vessels. The analysis is guided by three working hypotheses: first, that short-distance routes are suitable for early adoption of electric and hybrid vessels; second, that a coherent regulatory and financial framework is required for large-scale uptake; and third, that structured stakeholder consultation can enhance feasibility and social acceptance. The remainder of the article is structured as follows: Section 2 presents the methodology and case study design, Sections 3–6 provide the analysis and integrated roadmap, and Section 7 concludes.

2. Methodology and Case Study Design: Salamina–Perama Ferry Route

The Salamina–Perama ferry route is a vital maritime connection between the island of Salamina and the mainland port of Perama, near Piraeus. This short sea route is characterized by high-frequency operations, with departures every 15 to 30 minutes, 24 hours a day, facilitating both passenger and vehicle transport (ELSTAT, 2023). The fleet serving this route primarily consists of double-ended roll-on/roll-off passenger ferries. These vessels are designed for short-distance crossings, allowing for quick loading and unloading of vehicles and passengers. Quantitative traffic and fleet data for this short-sea route (e.g., frequency of sailings, passenger and vehicle volumes, and vessel characteristics) are combined with a review of technical literature, policy and legislative documents, international experience from Norway, and a structured stakeholder consultation. These sources are used jointly to assess the feasibility, challenges, and opportunities of introducing electric and hybrid vessels on the Perama–Paloukia line.

Analytically, the study combines descriptive statistics, qualitative content analysis of stakeholder consultation outputs, and comparative policy analysis between Greece and Norway, structured around a quadruple helix framework (academia–industry–government–civil society). The stakeholder consultation on 27 March 2025 at Salamis Town Hall is treated as a focused exploratory exercise; its findings are indicative rather than statistically representative, and the single-route case study limits the generalizability of results to similar short-distance ferry services.

The ferry services on the Salamina–Perama route are operated by multiple private companies, often family-owned, reflecting the decentralized nature of Greece's coastal shipping industry (Gavalas et al., 2024; Lekakou, 2007). One prominent operator is Tsokos Lines, a company based in Eretria. Founded in 2004, Tsokos Lines has developed a fleet of modern double-ended ferries, many of which have been constructed in Greek shipyards, including those in Perama and Amaliapolis (XRTC Business Consultants, 2024). Their vessels, such as the Protoporos X, Protoporos XI, and Protoporos XIII, have been deployed on various short sea routes, including the Salamina–Perama line. Another operator is Agios Fanourios Ferries, which owns and operates vessels like the M/F Elena A. The presence of multiple operators on this route indicates a competitive environment, with each company managing its own fleet and operations (Papaioannou et al., 2022).

The Salamina–Perama ferry route is characterized by its high-frequency service, with ferries departing every 15 minutes during peak hours. This frequent schedule necessitates a robust and reliable fleet to meet the transportation demands of both residents and visitors. The short crossing time of approximately 15 minutes allows for efficient turnaround and continuous service throughout the day. The Salamina–Perama ferry route is served by a fleet of double-ended roll-on/roll-off passenger ferries operated by various private companies, including Tsokos Lines and Agios Fanourios Ferries. The decentralized ownership structure and high-frequency operations underscore the route's importance in regional transportation and its role in facilitating the movement of people and vehicles between Salamina and the mainland (Gavalas et al., 2024; IOBE, 2021).

The Salamina–Perama ferry route serves as a critical maritime corridor, facilitating the movement of passengers and vehicles between the island of Salamina and the mainland port of Perama. This short sea route is characterized by high-frequency operations, accommodating both daily commuters and commercial transport needs (Gavalas et al., 2024; Papaioannou, 2018). Operational data indicates that ferry services commence at 05:30 and continue until 24:00, with departures occurring every 15 minutes between 05:30 and 22:00. From 22:00 to 00:00, services operate every 20 minutes, while from 00:00 to 05:30, ferries depart every 30 minutes, ensuring 24-hour connectivity between the two ports. This intensive schedule reflects the route's significance in regional transportation, catering to a substantial volume of daily traffic (ELSTAT, 2023).

The Perama–Paloukia ferry line has the highest traffic of any sea route in Greece. This line has the largest ferry traffic in Greece and ranks seventh among all the ports of the EU (based on the 2022 passenger traffic data). According to Eurostat, in 2022, about 7.1 million passengers and 3.7 million vehicles were transported on the Perama–Paloukia line (Hellenic Competition Commission, 2024).

The high-frequency service necessitates a robust and reliable fleet to meet the transportation demands of both residents and visitors. The short crossing time of approximately 15 minutes allows for efficient turnaround and continuous service throughout the day. This operational profile underscores the route's importance in regional transportation and its role in facilitating the movement of people and vehicles between Salamina and the mainland (IOBE, 2021; Papaioannou et al., 2022).

3. Background of the Shipbuilding Industry in Greece

Greece's rejuvenated shipbuilding sector is poised for a renaissance, bolstered by the consolidation of shipbuilding facilities in Syros and Elefsina, alongside the resumption of operations at the Skaramangas shipyard and heightened activity in Chalkida. Since ONEX Shipyards and Technologies, based in New York, took charge in 2019, Neorion Shipyard in Syros and Elefsis Shipyard have successfully repaired over 500 vessels for both Greek and international owners ("ONEX Elefsis Shipyard," 2023). With additional contributions from various ship repair and building operations, Greece is now recognized as a vital player in the annual output of European shipyards, which totals around €43 billion and exceeds that of competing Asian yards in terms of combined civil and naval orders (Hellenic Marine Equipment Manufacturers & Exporters, 2024).

Through a series of strategic alliances and significant investments, Greek shipyard operators, along with governmental support, aim to demonstrate their long-term commitment to an industry that currently represents about 1% of the national GDP (IOBE, 2021). The revival of this sector is set to bolster the economy and enhance national security. Collaborative projects are underway, including naval endeavors as the Greek government engages with the US on the joint design and co-production of the latest Constellation frigates (U.S. Embassy & Consulate in Greece, 2023). Increased shipyard operations will further empower Greek maritime equipment manufacturers, significantly contributing to Europe's commanding 50% market share in this sector (Hellenic Marine Equipment Manufacturers & Exporters, 2024).

Skaramangas Shipyards plans to maximize its substantial existing infrastructure, which includes the largest drydocks in the Mediterranean, capable of accommodating very large crude carriers, liquefied natural gas (LNG) carriers, and aircraft carriers. Skaramangas has been upgrading its facilities and enhancing fire safety systems while bringing back online a sizeable tank that has been dormant for roughly 20 years (Glass, 2024).

Across the board, Greek shipyards are investing to enhance their competitiveness and appeal, particularly to domestic shipowners who currently account for 80% of ship repair and new construction activities in Greece (XRTC Business Consultants, 2024). ONEX has outlined a business plan that allocates $550 million towards shipyard enhancements, targeting an increase in repair operations to reach 300 vessels annually (U.S. Embassy & Consulate in Greece, 2023). ONEX's vision includes transforming the shipyards into a comprehensive support hub for commercial shipping, energy transitions, defense initiatives, and industrial solutions, thus enhancing Greece's economic and geopolitical standing in the region.

Concurrently, Chalkis Shipyard is investing in photovoltaic systems for energy needs, both for the shipyard and vessels docked at its facilities, while also developing infrastructure for building specialized vessels up to 100 meters long. The goal is to expand capabilities to handle about 240 vessels per year, accommodate larger ships, and construct smaller vessels using innovative technology (Ministry of Environment and Energy, 2024).

Moreover, both private and institutional investors are recognizing the potential of Greece's geographic advantages, maritime legacy, and the commitment of the domestic shipping community, alongside governmental support, to invest in the industry. The recent acquisition of Skaramangas by shipowner George Prokopiou and the $125 million loan from the US International Development Finance Corporation for Elefsis Shipyards underscore the strong investor interest in the Greek shipbuilding landscape (U.S. Embassy & Consulate in Greece, 2023).

As maritime technologies continue to evolve, Greek shipyards have the chance to embrace and integrate innovations in AI, green energy, and automation, which promise operational efficiencies and enhanced productivity, thus strengthening their order books (Cadmatic, 2024; Gavalas et al., 2022). Chalkis Shipyards is already leveraging new technologies and implementing digitalization in programs related to repair design, new constructions, and customer relations management (CRM) systems. The yard is investing in 3D modeling and relevant equipment, while actively pursuing new AI integration to optimize operations and streamline tasks (Cadmatic, 2024). Skaramangas is focusing on emission-reduction technologies and scrubber installations, while also seeking collaborative opportunities for developing new ship designs utilizing the next generation of green fuels (Glass, 2024).

3.1. Importance of Electric and Hybrid Ships in Current Maritime Trends

In contrast to industries like road transport and aviation, the maritime sector utilizes fuels that are less refined or processed. The main fuel powering marine diesel engines in this sector is heavy fuel oil, which has a high viscosity and contains significant amounts of sulfur. This results in the production of harmful SOx emissions upon combustion. The shipping industry also utilizes other fuels with lower viscosity and reduced sulfur content, such as marine gas oil and marine diesel oil, with marine gas oil typically employed for smaller vessels (Hsieh & Felby, 2017).

There is potential for alternative fuels to achieve lower or even zero net emissions for vessel propulsion. Currently, the adoption of alternative fuels like LNG and hydrogen is on the rise. Additionally, alternative fuels can be used as "drop-in" options (like biodiesel), though their application in shipping is still largely experimental. Notably, Japan is undertaking four pilot projects, in line with its *Roadmap to Zero Emission from International Shipping* report. This report indicates that the pilot initiatives will follow two potential emission reduction pathways: the use of LNG, contingent upon its transition to carbon-recycled methane; and the implementation of hydrogen or ammonia as fuels (Jaques, 2020).

Clarksons research indicates that over 60% of the new ship orders made in 2022 were for vessels that utilize alternative fuels. The rise of green technologies and alternative fuel propulsion is significantly influencing ship design, particularly emphasizing the growing importance of electrical design. The increasing emphasis on alternative fuels has led to a substantial rise in the adoption of hybrid and electrified systems. This shift complicates ship designs, particularly when it comes to electrical systems, which play a crucial role in the overall design process. Consequently, electrical design must be approached in an integrated manner rather than as a separate component. To enhance project efficiency and ensure successful outcomes, it is essential that electrical design is incorporated into the wider ship design project from the outset, utilizing appropriately tailored tools (Cadmatic, 2024; Clarksons, 2024).

3.2. Overview of Electric/Hybrid Ship Technology

Energy storage options for providing power to zero-carbon electric propulsion include: batteries, flywheels, and supercapacitors. Electric motors, which are relatively economical, can drive propulsion systems. However, when considering the costs associated with batteries and their installation in ships, this option can become quite costly (International Transport Forum, 2018). A study by Lloyd's Register and UMAS (2018) evaluated electric vessels against alternative fuels like hydrogen, ammonia, and biofuels across various scenarios, concluding that electric vessels tend to be the least economically viable technology. Hybrid marine engines present an appealing solution as they can operate on diesel, LNG, or hydrogen, incorporating a fuel cell, batteries, or an electric motor (Newman, 2019). This hybrid approach can yield fuel savings of 10–40% and offer payback periods as short as one year. Furthermore, hybrid propulsion allows for design flexibility to meet both financial and environmental requirements of operators (Royal Academy of Engineering, 2013).

Electricity is generated by the movement of electrons through a conductive medium, commonly referred to as a circuit. A battery consists of three main components: the anode (–), the cathode (+), and an electrolyte. The cathode and anode represent the positive and negative terminals of a typical battery and are connected to an electrical circuit. Chemical reactions occurring within the battery lead to an accumulation of electrons at the anode, creating a voltage difference between the anode and cathode. The electrons, which are in a state of imbalance, seek to stabilize themselves. However, they do so in a specific manner, as electrons repel each other and tend to move towards areas with fewer electrons.

In the case of a battery, the only route available for the electrons is towards the cathode. The electrolyte acts as an insulator, preventing direct electron flow from the anode to the cathode within the battery. When the circuit is completed by connecting a wire between the cathode and anode, the electrons can travel through this wire, illuminating a light bulb in the process. This illustrates how electrical potential drives electron movement within the circuit. It is worth noting that the electrochemical reactions occurring in the battery alter the materials at the anode and cathode, ultimately limiting their ability to continue generating electrons. This leads to a finite power supply in the battery (Australian Academy of Science, n.d.).

When recharging a battery (a process applicable only to rechargeable batteries), an external power source, such as solar panels, is used to reverse the flow of electrons. This reversal allows the electrochemical processes to occur in the opposite direction, restoring the anode and cathode to their initial configurations, thus enabling them to generate power once more. Chemical reactions vary depending on the specific electrodes and electrolytes used. Nonetheless, the fundamental concept involves the movement of electrons through the circuit and the interaction of ions with the electrolyte. As a battery produces energy, the substances within it progressively transform into different compounds. This transformation leads to a diminished capacity for power generation, resulting in a decrease in voltage until the battery is depleted. In essence, when a battery can no longer generate positive ions due to the exhaustion of its chemicals, it cannot produce electrons for the external circuit either (Skundin & Kulova, 2024).

During the discharge process, the anode undergoes an oxidation reaction, releasing electrons to the negative terminal and ions into the electrolyte. Simultaneously, the cathode at the positive terminal receives these electrons, thereby completing the circuit necessary for electron flow. The role of the electrolyte is to allow the chemicals from both the anode and cathode to come into contact, enabling the equalization of chemical potential between the two terminals and transforming stored chemical energy into usable electrical energy.

There is a wide range of batteries available in various sizes, shapes, voltages, and capacities. While they can be constructed with different types of electrolytes and electrodes, batteries primarily fall into two categories: primary and secondary. Primary batteries are single-use disposables that cannot be recharged. Their electrochemical reactions are irreversible, meaning that once the reaction is depleted, the battery is no longer functional. Primary cells can be arranged in series to obtain the desired voltage; however, connecting them in parallel is not advisable, as one cell may attempt to charge another. On the other hand, secondary batteries, also known as storage batteries, can be recharged numerous times. Recharging reverses the internal chemical process, allowing the battery to restore its electrical supply simply by directing current in the opposite direction of its normal flow. This ability to recharge is not present in primary batteries (Skundin & Kulova, 2024).

In marine applications, batteries are utilized to power electrical systems, including wireless very high frequency devices, and they are charged via the engine, generator, or battery charger connected to the primary power source. All-electric vessels rely solely on batteries for power, eliminating the need for internal combustion engines. Secondary cells can be arranged in series, parallel, or a combination of both to achieve the required voltage and capacity. The main requirement is that each cell should have similar voltage, capacity, and chemical composition.

Lithium-ion batteries represent a transformative technology poised to significantly impact numerous industries, including consumer electronics, energy, oil and gas, and transportation, particularly in maritime contexts. The use of electric and hybrid ships equipped with substantial Lithium-ion battery storage and advanced power management systems can lead to reductions in fuel consumption and emissions. Additionally, these battery solutions may enhance maintenance efficiency and boost ship performance, reliability, adaptability, and safety during critical scenarios. Remarkably, a maritime battery can be several hundred times the size of a standard electric vehicle battery. However, the high energy density and demanding charging and operational conditions present new challenges for safety, integration, and longevity. To prevent accidents and other incidents that could pose serious safety risks and financial repercussions (and potentially impede technological advancement), it is crucial to ensure that battery-related systems are thoroughly verified and validated in accordance with established best practices (Det Norske Veritas–Germanischer Lloyd [DNV GL], 2016).

4. Legislative Review and Feasibility of Tech Adoption in Greek Shipping

The transition to electric vessels is a critical component of Greece's maritime decarbonization strategy. As global shipping regulations become increasingly stringent, the need for sustainable and low-emission maritime transport solutions has grown (DNV GL, n.d.). Electrification of vessels offers a viable alternative to traditional fossil fuel-powered ships, significantly reducing greenhouse gas (GHG) emissions and improving air quality in port areas (Buhaug et al., 2009). This report examines the existing legislative framework in Greece regarding the construction and operation of electric vessels, identifies regulatory gaps, and suggests improvements by drawing on best practices from Norway.

Internationally, the regulatory framework for electric vessels is influenced by policies such as the International Maritime Organization (IMO) updated GHG Emissions Strategy, which aims to achieve net-zero GHG emissions from international shipping by or around 2050, in line with global climate goals (IMO, 2023). To monitor progress, the IMO has set intermediate targets for reducing GHG emissions from shipping. By 2030, the goal is to reduce total annual GHG emissions by at least 20%, with a more ambitious target of 30%, compared to 2008 levels. By 2040, the IMO seeks to cut total annual emissions by at least 70%, striving for 80%, relative to 2008 levels (IMO, n.d.). These milestones are integral to the IMO's comprehensive strategy to decarbonize the shipping industry and align with global climate objectives.

In addition, the EU's push for greener maritime transport is complemented by investments in renewable energy production, particularly wind and solar power, which can further enhance the viability of electric vessels and contribute to the overall sustainability of the sector. Through these initiatives, the EU seeks to modernize the maritime industry, reduce its dependency on fossil fuels, and drive innovation in maritime electrification (European Climate, Infrastructure and Environment Executive Agency [CINEA], 2025).

Greece, as a leading maritime nation, has begun aligning its policies with these international directives. The country's National Energy and Climate Plan emphasizes the importance of reducing emissions from maritime transport and investing in alternative fuel infrastructure (Hellenic Ministry of Environment and Energy, 2019). However, despite these efforts, significant challenges remain in implementing a robust regulatory framework that facilitates the widespread adoption of electric vessels (Ministry of Maritime Affairs and Insular Policy, 2024b).

A review of previous studies on the adoption of electric vessels highlights both opportunities and barriers; challenges such as high initial investment costs and the lack of charging infrastructure hinder widespread adoption (Remoundos et al., 2025). Additionally, successful case studies from countries like Norway demonstrate that strong governmental incentives and well-developed shore-side electricity (SSE) infrastructure are key enablers for the transition to electric maritime transport (Lindstad et al., 2016).

This article aims to provide a comprehensive analysis of Greece's current legislative framework regarding electric vessels, identify gaps in existing policies, and propose potential regulatory measures. Furthermore, it will examine Norway's best practices to extract valuable lessons applicable to the Greek context. The development of electric vessels in Greece is governed by a combination of national laws, EU regulations, and international conventions. This section provides an overview of the key legislative instruments that define the regulatory landscape for building and operating electric vessels in Greece. It also highlights relevant funding mechanisms and policy initiatives that support the transition to maritime electrification (Ministry of Environment and Energy, 2024).

Greece has enacted a range of legislative measures to regulate shipbuilding and maritime operations. However, there is currently no specific reference to electric vessels within the existing legal framework (Ministry of Maritime Affairs and Insular Policy, 2024a). Despite the country's strong maritime industry, the regulations do not yet address the unique requirements of electric vessels, leaving them to comply with broader, traditional maritime laws and EU regulations related to alternative energy-powered vessels.

However, electric recreational vessels falling under the scope of Directive 2013/53/EU must comply with the relevant harmonized standards, such as (a) small craft–electric propulsion system, (b) electrical installations in ships–Part 507: pleasure craft, and (c) small craft–electrical systems—alternating and direct current installations (Cadmatic, 2024).

4.1. EU Legislative Framework and Funding Mechanisms

The EU has taken a leading role in steering the maritime sector toward greener horizons, much like a captain charting a course through turbulent waters toward a sustainable future. Through comprehensive legislative action, especially under the Fit for 55 initiative introduced in 2021, the EU aims to reduce net GHG by at least 55% by 2030 compared to 1990 levels (European Commission, 2021a). This initiative is a central part of the EU Green Deal and acts as the ship's rudder—guiding the maritime industry toward decarbonization. It includes key measures such as revising the Energy Taxation Directive to favor low-carbon fuels and incorporating maritime transport into the EU emissions trading system, effectively making carbon emissions a financial liability and incentivizing cleaner alternatives (European Commission, 2023).

In tandem with these policy shifts, the EU has also introduced financial mechanisms to support the electrification of maritime transport. Think of these as the wind in the sails—grants and financial tools are provided to help expand the use of electric and hybrid propulsion systems across the sector (CINEA, 2025). As a member of the EU, Greece is bound by these maritime decarbonization rules and plays a role in implementing them at the national level (Ministry of Maritime Affairs and Insular Policy, 2024a).

Several key legislative instruments underpin the EU's approach. These include the amended EU Emissions Trading System Directive, which now covers shipping emissions (European Commission, 2023); the Alternative Fuels Infrastructure Regulation, which supports the development of facilities like electric charging stations at ports (European Commission, 2023); and the revised Energy Taxation Directive, designed to promote the use of electricity and other low-carbon fuels (European Commission, 2021a). Additionally, the Renewable Energy Directive has been updated to encourage renewable energy use in maritime settings, while the Carbon Border Adjustment Mechanism ensures imported goods are taxed based on their carbon footprint, indirectly nudging the shipping industry toward cleaner technologies (European Environment Agency, 2025).

Taken together, these EU instruments define an increasingly stringent decarbonization pathway for maritime transport, but their effectiveness in Greece is constrained by several context-specific factors. Fragmented port governance and uneven grid capacity across the islands slow down the deployment of SSE and fast-charging infrastructure. Limited access to long-term, affordable finance for small ferry operators weakens the investment signal created by EU climate targets, while administrative complexity and legal uncertainty around state-aid rules may delay the absorption of available funds. As a result, the regulatory "push" from Brussels does not automatically translate into a credible, bankable framework for electrifying short-distance ferry services in Greece (European Commission, 2023; Ministry of Maritime Affairs and Insular Policy, 2024b).

To help navigate this transformative journey, Greece can draw from several funding reservoirs. The Recovery Fund, Greece 2.0—part of the EU's broader Recovery and Resilience Facility—acts like a lifeboat for economic and green recovery post-Covid-19 (Ministry of Maritime Affairs and Insular Policy, 2024b). The Greek Green Transition Fund provides domestic financial support for sustainable maritime technologies, including battery-powered vessels (Ministry of Environment and Energy, 2024). Meanwhile, the EU Innovation Fund offers additional support for the development of zero-emission maritime solutions, akin to providing blueprints and materials for building the next generation of eco-friendly ships (CINEA, 2025).

4.2. Challenges and Legislative Gaps in Greece's Maritime Electrification Framework

Despite the existence of a relatively robust regulatory structure, several critical challenges persist in Greece's efforts to support maritime electrification. One major issue is the limited SSE infrastructure in Greek ports, which hampers the effective operation of electric vessels. Many ports still lack the necessary facilities, making it difficult to support electric ship operations (Maersk Mc-Kinney Møller Center for Zero Carbon Shipping, 2024; Remoundos et al., 2025). Compounding this is the complexity and fragmentation of the regulatory pathways for certifying electric vessels, leading to delays and uncertainty (DNV GL, 2025).

Furthermore, although funding mechanisms such as national and EU-level grants are available, smaller shipowners and operators often struggle to access this financial support (CINEA, 2025; Ministry of Environment and Energy, 2024). Technological barriers also pose a challenge, particularly due to the lack of standardized battery technologies and charging systems, which complicates large-scale adoption and interoperability (Bureau Veritas, 2025; DNV GL, n.d.).

In terms of legislative alignment, Greece has made strides to incorporate EU and international maritime regulations. However, significant gaps remain that hinder the broader adoption of electric vessels and the expansion of SSE infrastructure. These gaps include inconsistencies in regulation, inadequate infrastructure planning, limited certification clarity, insufficient financial incentives, and a lack of interoperability standards (European Commission, 2023; Ministry of Maritime Affairs and Insular Policy, 2024a).

One of the most pressing issues is the absence of a comprehensive national strategy dedicated to electric vessels. While Greece has integrated relevant EU directives into national law, it lacks a centralized framework—unlike frontrunners such as Norway—that outlines specific targets, incentives, and regulatory measures for maritime electrification (Norwegian Government, n.d.-a). This has resulted in fragmented policy implementation and poor coordination among government bodies, port authorities, and private stakeholders (Gavalas et al., 2024; Lekakou, 2007).

Another critical gap is the underdeveloped SSE infrastructure. Despite requirements outlined in Regulation (EU) 2023/1804, Greece has not yet devised a nationwide plan to fulfill its obligations (European Commission, 2023). The country faces several obstacles in this area, including a limited number of SSE-equipped ports, the high costs associated with installing the infrastructure, and a lack of standardized charging protocols, which leads to compatibility issues for electric vessels docking at various ports (Cadmatic, 2024; DNV GL, n.d.).

Certification and licensing processes also suffer from ambiguity. The current national framework does not clearly address the unique requirements of electric and hybrid propulsion systems. This leads to unclear compliance guidelines for shipowners, delays in vessel approvals, and inconsistencies between national and EU certification standards, all of which discourage innovation and investment (DNV GL, 2016).

Financial limitations represent another major barrier. Although programs like the Greek Green Transition Fund and the EU Innovation Fund provide some level of support, there is a lack of targeted financial instruments specifically for electric vessels (CINEA, 2025; Ministry of Environment and Energy, 2024). Missing elements include direct subsidies, tax incentives, and low-interest financing tailored to support the construction, retrofitting, and operation of battery-electric ships. Without these, electric shipping remains less competitive compared to conventional fuel-powered alternatives (Clarksons, 2024; DNV GL, n.d.).

Regulatory misalignment with European best practices further compounds these challenges. Greece has yet to adopt emissions-based port fee incentives, binding electrification requirements for new vessels, or strong enforcement mechanisms for existing EU directives—all of which are common in leading maritime nations like Norway (Tradewinds, n.d.; Norwegian Ministry of Climate and Environment, 2021).

Interoperability and technological standardization also pose a significant challenge. The lack of harmonized charging interfaces across ports, variations in battery technology, and limited integration of renewable energy into SSE grids all contribute to inefficiencies and limit the sustainability impact of electrification efforts (Bureau Veritas, 2025; European Commission, 2021b).

Addressing these legislative and infrastructural gaps is essential for Greece to accelerate its transition to maritime electrification. Developing a unified National Electric Vessel Strategy, expanding SSE infrastructure, and introducing well-targeted financial incentives will be vital steps. Moreover, aligning Greek regulations with European best practices and creating standardized certification and safety procedures will strengthen the country's position in the emerging low-emissions maritime sector (Gavalas et al., 2024; XRTC Business Consultants, 2024).

To address these issues, Greece is now moving toward a more structured regulatory approach. A key development is the upcoming Presidential Decree on Safe Electricity Supply, Safe Electric Charging, Testing, and Certification of Electric and Hybrid Ships. This decree, currently submitted to the European Commission's Technical Regulation Information System under Directive (EU) 2015/1535, is expected to provide a legal foundation for maritime electrification (Ministry of Maritime Affairs and Insular Policy, 2024a).

The draft decree covers multiple aspects essential to the regulation of electric and hybrid vessels. It introduces clear definitions for electric and hybrid ships, specifying that electric ships are entirely powered by zero-emission technologies, while hybrid ships use electric power in ports. It also broadens the scope of infrastructure by recognizing both onshore and offshore (floating) electricity supply installations. The decree mandates the inclusion of battery management systems for safety, defines specifications for electricity supply and charging infrastructure in line with EU Regulation 2023/1804, and outlines certification processes under the Hellenic Register of Shipping and other recognized bodies (ISO, 2018).

In addition to certification and infrastructure regulations, the decree sets out fire safety measures, requiring emergency power systems and specialized protocols for battery management. It also aligns national technical standards with those from international bodies such as IMO, the International Electrotechnical Commission, and ISO, ensuring consistency with global best practices (IMO, 2023; ISO, 2017).

5. Best Practices from Norway in Maritime Electrification

Norway is internationally acknowledged as a frontrunner in the adoption and regulation of electric and hybrid vessels. The country's progress in maritime electrification has been driven by a combination of proactive policies, strong financial incentives, and extensive infrastructure development. These efforts have enabled Norway to lead the global shift toward greener shipping practices (DNV GL, n.d.; Norwegian Government, n.d.-a). The following best practices from Norway can offer valuable guidance to Greece as it works to enhance its own regulatory framework for electric vessel adoption (Ministry of Maritime Affairs and Insular Policy, 2024b).

A cornerstone of Norway's success lies in its robust governmental support and strategic policy framework. The Norwegian National Transport Plan outlines ambitious targets for reducing maritime GHG emissions, including the requirement that all new fjord ferries be zero-emission by 2030 (Norwegian Government, n.d.-a). Complementing this is the Green Shipping Program, a collaborative initiative between public and private sectors designed to promote low and zero-emission shipping through regulatory and financial incentives (DNV GL, n.d.). Notably, Norway also enforces zero-emission requirements for publicly funded ferry services, mandating the use of electric or hydrogen-powered vessels—an approach that has significantly stimulated demand for green maritime technologies (Hessevik, 2022).

Norway's legislative framework provides further support through targeted laws and regulations. The Climate Action Plan 2021–2030 sets binding emission reduction targets for domestic shipping, ensuring compliance with international climate agreements (Norwegian Ministry of Climate and Environment, 2021). The Maritime Electric Infrastructure Act mandates the development of SSE infrastructure for high-traffic ports (Norwegian Government, n.d.-a), while the Alternative Fuel Act establishes safety and operational standards for vessels using alternative energy sources (Climate and Clean Air Coalition, n.d.). Additionally, Norway has implemented a progressive carbon taxation scheme for shipping, incentivizing cleaner operations (Norwegian Government, n.d.-b). Training and certification requirements for crews operating electric and hybrid vessels ensure that the workforce is prepared to manage these advanced technologies safely and efficiently (Norwegian Maritime Authority, 2022).

Financial support has played a pivotal role in accelerating Norway's green transition. Through the EVOVA Fund, the government covers up to 50% of the additional costs associated with adopting electric or hybrid propulsion (Tradewinds, n.d.). The NOx Fund (n.d.) offers further subsidies for emission-reducing maritime projects. Moreover, shipowners benefit from low-interest loans and tax exemptions when investing in clean technologies, making the financial case for electrification significantly stronger (Norwegian Government, n.d.-b).

Norway has also developed one of Europe's most advanced SSE networks. Major ports, including Oslo, Bergen, and Trondheim, are equipped with extensive cold ironing facilities, enabling ships to plug into the electric grid while docked and thereby reduce emissions (Port of Oslo, 2023). The country has standardized its charging systems to ensure interoperability between different ports and vessels (DNV GL, n.d.). Crucially, much of the SSE infrastructure is powered by renewable hydropower, making it a genuinely zero-emission solution.

In terms of fleet electrification, Norway has led the way with pioneering vessels that demonstrate the viability and benefits of electric shipping. The Ampere, launched in 2015, was the world's first all-electric ferry, setting a global precedent (Nordregio, 2016). This was followed by the Future of the Fjords, an all-electric passenger ship designed for eco-friendly tourism (Norwegian Ministry of Climate and Environment, 2018), and the Yara Birkeland, the first autonomous and fully electric container ship, showcasing the potential for zero-emission cargo transport (Skredderberget, n.d.).

The effectiveness of these Norwegian policies cannot be explained by their formal design alone, but also by the enabling conditions under which they were implemented. Abundant low-cost renewable electricity, a long-standing tradition of public procurement for ferry services, and a dense maritime cluster of shipyards, technology providers, and operators created a favorable environment for early adoption of electric and hybrid vessels, supported by systematic experimentation with battery-electric solutions (Bureau Veritas, 2025). Strong coordination between national authorities, regional counties, and state-owned financial institutions, combined with dedicated research and innovation funding, further reduced transaction costs and investment risks and nurtured a vibrant ecosystem of innovation (Research Council of Norway, n.d.). These structural features significantly amplified the impact of support schemes that, in isolation, might have been less transformative.

There are several clear lessons that Greece can draw from Norway's experience. These include implementing binding zero-emission requirements for public ferry operations to drive market demand (Ministry of Maritime Affairs and Insular Policy, 2024a), introducing comprehensive financial incentives such as grants, low-interest loans, and tax benefits to support green transitions (Ministry of Environment and Energy, 2024), and investing in standardized and renewable-powered SSE infrastructure.

From a transferability perspective, only selected elements of the Norwegian model can be directly transplanted to Greece. Norway's cold climate, fjord geography, and highly centralized transport governance differ markedly from Greece's milder climate, fragmented archipelagic network, and more decentralized institutional setting. Moreover, Norway's predominantly renewable energy mix and strong fiscal capacity allow for higher levels of public support than those currently feasible in Greece. This implies that Greek policy makers need to adapt, rather than copy, Norwegian solutions by prioritizing routes with favorable demand profiles, sequencing infrastructure investments, and designing support schemes that reflect domestic fiscal and administrative constraints, particularly where EU innovation and deployment programs are already present (Gavalas et al., 2024).

6. Stakeholder Consultation Report: Electric Vessels on the Salamina–Perama Line

6.1. Action and Implementation

The consultation brought together participants representing the four helices of the quadruple helix framework. Participants were selected through purposive sampling, based on their direct involvement in the Perama–Paloukia ferry line or in closely related domains (coastal shipping operations, port management, local and national administration, business associations, and environmental or community organizations). The aim was not statistical representativeness, but to capture a balanced set of informed perspectives from actors who are in a position to influence or be affected by the transition to electric vessels. The workshop combined a short plenary introduction with moderated group discussion and a working lunch to support relationship-building and further dialogue.

The primary goal of the consultation was to identify and analyse the key challenges, potential solutions, and stakeholder perspectives regarding the implementation of electric vessels on the Perama–Paloukia ferry line. The session included two structured rounds of discussion and voting. The authors adopted a quadruple helix approach to stakeholder engagement, integrating perspectives from academia, industry, government, and civil society. This inclusive framework ensured that diverse viewpoints were considered in the planning and decision-making processes related to the introduction of electric vessels on the Perama–Paloukia ferry line. The primary goal of the consultation was to identify and analyze the main challenges, enabling factors, and priority actions for the electrification of the Perama–Paloukia ferry line, using the quadruple helix framework as a structured lens. In this context, the framework was operationalized by explicitly distinguishing the roles of academia, industry, government, and civil society, and by inviting each helix to articulate both its own interests and its expectations from the others. The consultation design encouraged cross-helix interaction through open discussion, joint problem-framing, and co-creation of potential solutions, rather than separate siloed interventions, reflecting recent applications of quadruple helix approaches in sustainable transportation and regional innovation policy (Gavalas et al., 2024). During the consultation, stakeholders from each helix contributed the following insights:

- Academia: Provided research-based perspectives on the feasibility and implications of electrifying the ferry line.
- Industry: Shared practical considerations regarding the implementation of electric vessels, including technological and infrastructural requirements.
- Government: Discussed policy frameworks, regulatory considerations, and potential support mechanisms to facilitate the transition.
- Civil Society: Expressed concerns and expectations related to environmental impact, service reliability, and community benefits.

The integration of these diverse perspectives, combined with the two structured rounds of discussion and voting, helped to clarify the main trade-offs that need to be managed in the transition. As reflected in the identified challenges and proposed solutions, stakeholders recognize tensions between minimizing costs and travel times, ensuring system stability and reliability, and delivering broader environmental and community benefits. The ranked lists of challenges and solutions, together with the voting results, therefore capture both areas of broad convergence, such as the importance of incentives, a clear regulatory framework, targeted training, and issues that require further negotiation, including potential fare increases and uncertainties around business models and investment planning.

Although a full quantitative cost–benefit model is beyond the scope of this article, an indicative assessment suggests that the proposed electrification of the Perama–Paloukia ferry line can generate net socio-economic benefits under plausible assumptions. On the cost side, higher upfront capital expenditure for vessels and charging infrastructure is partially offset by lower operating costs, reduced exposure to volatile fuel prices, and the monetized value of emission reductions. The overall outcome is highly sensitive to the relative evolution of electricity and marine fuel prices, vessel utilization rates, battery lifetime, and the availability of investment subsidies or tax incentives. These parameters determine payback periods and can either accelerate or delay investment decisions by operators.

Stakeholders have the potential to either accelerate or delay the energy transition, depending on how effectively they are engaged. Poor management of stakeholder relationships can lead to project delays, increased costs, social tensions, and even implementation failures. On the other hand, including local communities in the planning and decision-making processes enhances the legitimacy and social acceptance of energy initiatives, fostering smoother execution and long-term success.

The application of the quadruple helix model in this consultation exemplifies a commitment to inclusive and collaborative decision-making. By actively involving stakeholders from academia, industry, government, and civil society, the authors have laid a robust foundation for the successful introduction of electric vessels on the Perama–Paloukia line.

6.2. Preliminary Phase: Stakeholder Perspectives

In the initial phase, participants shared a range of views regarding the transition to electric vessels on the route. The Norwegian representatives reaffirmed their commitment to supporting the study with technical expertise, recognizing the strategic potential of the Perama–Paloukia line. They emphasized that, with the existing technological capabilities, implementation is feasible, provided there is a well-structured framework in place. Reference was made to international examples where the emphasis was not only on shipbuilding, but also on system-wide planning.

Participants raised questions about how proposed measures would be implemented in practice and stressed the need for a clear strategic roadmap and institutional support. The importance of integrating sustainable energy solutions into the maritime ecosystem was highlighted. Infrastructure challenges, particularly concerning shipbuilding and port capacity, were seen as critical bottlenecks.

There was a strong sense of optimism about the future of electric shipping and technological advancements, but participants also stressed the importance of investment in charging infrastructure and adequate energy supply. Concerns were expressed about the cost of transition, with warnings that, without appropriate funding, the project could negatively impact island connectivity. Calls were made for local manufacturing of batteries to reduce reliance on external suppliers.

Additional views underscored the need for close integration between vessels and land-based infrastructure, the development of expertise and training, and the establishment of efficient systems for propulsion, loading, and vessel management. Participants also highlighted the symbolic and strategic importance of the study in positioning the region at the forefront of sustainable maritime innovation.

6.2.1. Round 1: Challenges in Introducing Electric Vessels

Eighteen key challenges to the implementation of electric vessels were identified during the first round of discussions:

1. Inadequate charging infrastructure;
2. Limited availability of suitable charging stations;
3. Absence of a clear regulatory framework;
4. High battery replacement and upgrade costs;
5. Lack of training and information for crew and operators;
6. Public hesitancy due to reliability concerns;
7. Potential fare increases linked to transition costs;
8. Spatial constraints for installing port-side infrastructure;
9. Absence of proven business models;
10. Insufficient policy support for sector development;
11. Lack of relevant data and monitoring systems;
12. Absence of a comprehensive subsidy scheme;
13. Uncertainty regarding the transition plan;
14. Lack of a pilot project;
15. Incomplete investment planning;
16. Legal and legislative ambiguities;
17. Market instability;
18. Lack of a systems-based approach.

Based on an individual voting exercise in which each of the 14 participants was invited to select up to three challenges they considered most critical, the percentages reported below represent the share of participants who voted for each challenge and therefore indicate relative salience rather than statistically representative frequencies. The resulting ranking, with financial and regulatory barriers appearing at the top, suggests that stakeholders view enabling government incentives and a clear legal framework as preconditions for investment, while the presence of training needs and potential fare increases among the leading concerns highlights worries about implementation capacity and the distributional effects of the transition:

1. Lack of government incentives and subsidies (78.6%);
2. Absence of a clear regulatory framework (28.6%);
3. Lack of information and training for staff (28.6%);
4. Potential fare increases due to transition costs (28.6%);
5. Unclear legislative framework (28.6%).

6.2.2. Round 2: Proposed Solutions to Key Challenges

In the second round, participants explored and prioritised 20 possible solutions in response to the top five challenges:

1. Introduction of tax incentives and subsidies for electric vessel adoption;
2. Development of financial instruments and funding programmes at national and EU levels;
3. Provision of subsidised financing for shipowners investing in electrification;
4. Establishment of cooperative funding mechanisms;
5. Creation of clear procedures for licensing and operational approval of electric ships;
6. Development of dedicated training and certification programmes;
7. Design of subsidised business models to offset initial costs;
8. Formulation of a cohesive national strategy;
9. Strategic infrastructure planning;
10. Expansion of cooperative financing schemes;
11. Creation of energy markets tailored to maritime transport;
12. Introduction of regulatory mandates;
13. Development of collaborative pilot projects;
14. Ship scrapping incentive schemes;
15. Public–private partnership initiatives;
16. Investor guarantees;
17. Feasibility permits with a specific duration;
18. Integration into national innovation funds;
19. Participation of national energy providers;
20. Adoption of a "green transport equivalent" mechanism.

Following the vote by 16 participants, the five most preferred solutions were:

1. Development of financial instruments and support programmes via national and EU funds (75%);
2. Formulation of a national strategy for electric maritime transport (56.3%);
3. Introduction of tax incentives and subsidies (37.5%);
4. Subsidised financing options for shipowners (37.5%);
5. Cooperative financing schemes (37.5%).

7. Conclusions

The transition to electric and hybrid vessels in Greek coastal shipping represents both a significant challenge and a transformative opportunity for the country's maritime sector. This study has systematically explored the technical, economic, regulatory, and infrastructural aspects of this transition, drawing valuable lessons from Norway's successful electrification model. The findings emphasize the urgent need for Greece to modernize its aging ferry fleet, expand shore-side charging infrastructure, and establish supportive policy frameworks to accelerate decarbonization efforts.

Key insights from the research highlight several critical areas. Regarding technical feasibility and fleet renewal, Greece's coastal shipping network, which is characterized by an aging fleet and high operational demands, necessitates targeted investments in electric and hybrid propulsion systems. Short-distance routes, such as Salamina–Perama and Chios–Oinousses, are particularly suitable for pilot electrification projects owing to their high frequency and manageable energy requirements. On the regulatory and policy front, while Greece has begun aligning with EU decarbonization directives, notable gaps remain in national legislation, certification standards, and financial incentives. The upcoming presidential decree on electric and hybrid ships is a positive development, however, further policy coherence (similar to Norway's binding zero-emission mandates and carbon taxation) is essential.

Infrastructural and investment considerations reveal that the absence of standardized charging infrastructure at Greek ports is a major barrier. Strategic investments, supported by EU funds such as the Recovery and Resilience Facility and the Green Transition Fund, alongside public-private partnerships, must prioritize port electrification and renewable energy integration. Stakeholder collaboration, as evidenced through the quadruple helix consultation, demonstrated a strong consensus on the necessity for financial incentives, training programs, and a comprehensive national strategy for maritime electrification. Stakeholders underscored the importance of subsidies, tax breaks, and cooperative financing mechanisms to enable shipowners to adopt cleaner technologies.

Lessons from Norway's experience highlight the effectiveness of a holistic approach that combines strict emissions regulations, state-backed funding (e.g., ENOVA, NOx Fund, etc.), and collaboration between industry and academia. Building on the preceding analysis and stakeholder consultation results, this article proposes a phased roadmap for maritime electrification in Greece. In the short term, priorities are pilot electric ferry projects on high-traffic routes such as Perama–Paloukia and Chios–Oinousses, deployment of standardized shore-side charging infrastructure at key ports, and targeted subsidies to support retrofits and newbuilds. The subsequent phase focuses on extending electrification to additional short-distance routes, increasing the share of renewable electricity in port operations, and progressively tightening national emissions and performance standards. Over the longer term, progress should be tracked through a limited set of indicators, including the share of short-distance traffic served by electric or hybrid vessels, installed shore power capacity, and reductions in well-to-wake GHG, in line with IMO and EU decarbonization targets.

This shift toward sustainable coastal shipping is not only an environmental necessity but also an economic opportunity, strengthening Greece's shipbuilding industry, enhancing energy security, and positioning the country as a Mediterranean leader in green maritime transport. By leveraging EU funding, fostering cross-sector collaboration, and adopting proven international best practices, Greece can transform its coastal shipping sector into a model of innovation and sustainability for the wider region. Future research should focus on advancements in battery technology, lifecycle cost analyses of electric ferries, and the socio-economic impacts of maritime decarbonization on island communities. Additionally, ongoing stakeholder engagement will be vital to refining policies and ensuring equitable implementation of these initiatives.

Acknowledgments

The authors would like to thank all participants of the consultation workshop.

Funding

The research was conducted and funded as part of the ELECTRA-GR project.

Conflict of Interests

The authors declare no conflict of interests.

Data Availability

Data is available upon request.

Supplementary Material

Supplementary material for this article is available online in the format provided by the author (unedited).

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Ocean and Society
2026 • Volume 3 • Article 11527
https://doi.org/10.17645/oas.11527

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ARTICLE

Open Access Journal

Navigating the Ocean-Climate Nexus Through Participatory Workshops for a Sustainable Blue Economy

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Submitted: 14 October 2025 **Accepted:** 16 December 2025 **Published:** 16 February 2026

Issue: This article is part of the issue "Ocean Climate Governance: Eclectic Viewpoints of a Multi-dimensional Nexus" edited by George Dikaios (Leiden University), fully open access at https://doi.org/10.17645/oas.i488

Abstract

The complex interrelations between ocean governance, climate change, and innovation create both challenges and opportunities for sustainable development in the Black Sea region. The blue economy—encompassing fisheries, tourism, ports, shipping, and marine transport—plays a crucial role in regional prosperity but faces mounting pressures from overfishing, pollution, geopolitical instability, and the low capacity for technological and institutional adaptation. The EU-funded projects DOORS and BRIDGE-BS address these challenges through participatory, system-based approaches that engage stakeholders from across the quadruple helix (academia, industry, government, and civil society). While DOORS sought to identify policy and innovation gaps at the regional level through multi-actor forums, BRIDGE-BS explored future pathways for a sustainable and resilient blue economy using living labs and participatory foresight. Together, they reveal a persistent disconnect between local implementation capacity and national policy ambition, as local actors often remain locked in existing practices and lack the skills and resources to embrace emerging sectors. The results indicate that the sectors have similar goals, such as capture fisheries, marine and coastal tourism, ports and shipping, and marine transport. They also face similar problems, such as weak law enforcement, fragmented governance, bureaucratic inefficiencies, and a lack of new technology. The study underscores the value of participatory multi-actor engagement in bridging the science–policy practice gap, supporting skills development, and co-designing actionable pathways toward climate-resilient ocean governance. Lessons from the Black Sea demonstrate that integrating systems innovation, participatory governance, and capacity building can inform broader regional and global initiatives under the

EU Mission: Restore our Ocean and Waters, the UN Ocean Decade, and the SDGs, providing a transferable model for advancing sustainable blue transitions in politically sensitive marine regions.

Keywords

Black Sea; blue economy; living labs; multi-actor forums; ocean governance; systems approaches; sustainability; systems innovation

1. Introduction

For many years, the role of the ocean was largely absent from the climate discourse. Its formal debut occurred in the preamble to the Paris Agreement in 2015, which acknowledges the significance of maintaining the integrity of ocean ecosystems. The ocean absorbs approximately 25% of human CO_2 emissions and 93% of the excess heat resulting from global warming, thereby mitigating the much higher warming that would have occurred on land (Oceans Aware, n.d.). However, these benefits are not without costs. The absorption of CO_2 results in acidification, while excessive heat causes the sea surface to warm, ice to dissolve, sea levels to rise, and oxygen to be depleted.

At the same time, oceans are central drivers of the prosperity of coastal regions and of the economy worldwide. Since 1995, the ocean economy has expanded by 2.5 times the average rate of global economic growth. In 2023, the global trade in ocean commodities and services reached record highs (approximately $899 billion for goods and $1.3 trillion for services; UN Trade and Development, 2025). It is estimated that fisheries and aquaculture generate approximately $100 billion annually and provide employment opportunities for approximately 260 million individuals worldwide (UN, n.d.). In numerous developing or low-income economies, small-scale fisheries, aquaculture, and coastal tourism are essential. Specifically, according to a recent report by the OECD, the livelihoods of over 3 billion individuals are contingent upon marine and coastal biodiversity, either directly or indirectly (OECD, 2025).

Ocean acidity (reduced pH), oxygen levels, ice cover, and ocean currents are all influenced by climate change (Pörtner, 2021). These alterations pose a threat to the structure and services of the ecosystem, including the preservation of coastlines, habitat, and fisheries. This risk is exacerbated by a variety of factors, including underinvestment, pollution, overfishing, habitat devastation, and weak governance. A sustainable blue economy strives to achieve a harmonious equilibrium between long-term ecosystem health and ocean-based economic development. This is achieved by enhancing human well-being and equity, mitigating environmental risks, and recognising the value of ecosystem services, including those that are not typically monetised, such as coastal protection and carbon sequestration (Copernicus Marine Service, n.d.). The World Bank (2025) defines the blue economy as "low-carbon, resource-efficient growth that reduces poverty and creates jobs," which integrates ocean sectors in a manner that restores ocean health.

The Black Sea (BS) is bordered by six nations, which collectively have around 17.5 million residents reliant on its resources (Salihoglu et al., 2024). The BS is a dynamic geopolitical area situated inside a complex socio-ecological system rich in resources. The BS presents both significant challenges and considerable opportunities within the blue economy sectors. It is a strategic bridge located on the perimeter of the EU that links the Mediterranean Sea, Asia, and the Middle East in southern Europe. However, the region's blue economy remains overlooked, despite its significant economic potential. The BS is among the most contaminated bodies of water globally and exemplifies the deteriorating environmental condition of European seas, despite its resource richness. Fish populations have been decimated, and species diversity has been undermined due to substandard water quality. A crucial shift towards a more sustainable blue economy development path is essential due to the socio-economic impacts of inadequate environmental conditions on employment, food security, tourism, and health.

The Burgas Vision and the Common Maritime Agenda (CMA) underlined the strategic importance of the blue economy for regional development (Common Maritime Agenda for the Black Sea, n.d.; European Commission, 2018), laying the groundwork for the BS Strategic Research and Innovation Agenda (SRIA; Connect Black Sea, 2019). Despite growing EU-funded efforts, such as ANEMONE (2018–2020) and BS CONNECT (2019–2023), stakeholder-focused analyses of the region remain limited (BS Connect, 2023; ANEMONE, n.d.). Early studies, such as Avoyan (2016), already highlighted fragmented governance, weak interinstitutional coordination, and poor implementation of strategic plans. Subsequent regional processes, including the 2019 BS Synergy: The Way Forward Stakeholder Conference, reaffirmed the need for coordinated, cross-sectoral governance (Afanasyev et al., 2020). Workshops and citizen-science activities under ANEMONE demonstrated that participatory engagement can build trust, strengthen data collection, and mobilise local communities around marine challenges (Gheorghe et al., 2021). Likewise, BS CONNECT's extensive national and regional consultations played a central role in co-developing and validating the SRIA, showing how structured stakeholder processes can support more inclusive and durable marine governance in the region.

Over the past decade, scholars have shown that participatory foresight tools—such as visioning, scenario co-development, and backcasting—play a critical role in empowering stakeholders to engage with long-term ocean–climate uncertainties (Ende et al., 2021; Matti et al., 2025). These methods help move governance beyond reactive policy cycles by fostering anticipatory capacity, collective sense-making, and experimentation. In parallel, marine governance research highlights co-creation as a pathway to more legitimate and adaptive decision-making, particularly in complex socio-ecological systems (Raha et al., 2024). A recent study by Bisinicu et al. (2025) shows that engagement is often consultative rather than co-creative, with stakeholders invited to events or surveys but rarely involved in decision-making or co-design of research and policy agendas. The impact and results of these mechanisms are further exacerbated by the limited representation of local communities, small-scale fishers, women, and youth in comparison to academia, NGOs, and government officials. The authors also observe that the institutional capacity to manage engagement processes is restricted due to the absence of trained facilitators, participatory methods, or evaluation frameworks.

Two EU-funded projects, DOORS and BRIDGE-BS, aim to address these gaps by investigating the potential of the blue economy in six BS countries: Bulgaria, Georgia, Moldova, Romania, Turkey, and Ukraine (BRIDGE-BS, 2021; DOORS-BS, n.d.). The DOORS project, supported by Horizon 2020, focuses on providing scientific assistance to address environmental challenges by creating a system-of-systems. This framework is designed to connect citizens, scientists, and industry, facilitating access to crucial datasets for addressing climate change and marine ecosystem impacts. Concurrently, the BRIDGE-BS project complements DOORS by enhancing the marine research and innovation ecosystem. It focuses on developing an ecosystem-based management framework, which promotes policy adoption and public engagement. Significant outputs of these projects are the identification of blue economy priorities and challenges and the co-designed transformative pathways for the blue economy, aiming for a sustainable use of ecosystem services impacted by various stressors, thereby guiding key sectors towards sustainability in the BS region.

Stakeholder engagement is achieved by employing two distinctive tools: national multi-actor forums (MAFs) in the DOORS project and local living labs (LLs) in the BRIDGE-BS project. Both approaches are based on systems innovation, specifically focusing on the co-creation of results rather than mere consultation, with stakeholders placed at the centre of discussions to collaboratively establish a path forward. These workshops are conducted with the assistance of experienced facilitators and common guidelines to ensure that all stakeholders participate equally and that the results are comparable. Stakeholder representativeness is guaranteed by a detailed stakeholder mapping conducted prior to the engagement of the stakeholders and founded on including stakeholders from the quadruple helix and diverse blue economy sectors.

MAFs bring together national stakeholders from Bulgaria, Georgia, Moldova, Romania, Turkey, and Ukraine of all different backgrounds to assist scientists in prioritising BS issues with a focus on blue economy sectors and policies and the use of innovations to fill identified gaps. The results of the MAFs were also validated by an online survey that was disseminated to stakeholders who did not participate in the MAFs (Akinsete et al., 2025a; Seyhan et al., 2025). Complementarily, LLs have been implemented in Ukraine (Odessa), Romania (Constanta), Bulgaria (Varna), Türkiye (Istanbul Bosphorus and Sinop), and Georgia (Batumi), focusing on ecosystem services and the blue economy. In the BRIDGE-BS context, LLs represent an instrument to empower local communities in the future sustainable management of the BS, breaking sectoral silos and ensuring a systemic approach for the sustainable development of the blue economy. Through a series of workshops, they create a new local participative dynamic to explore alternative forms of governance while acting as a focal point for greater interconnection between physical and socio-economic sciences (Guittard et al., 2023).

This study explores how participatory approaches in the form of LLs are used to support the transition towards a sustainable blue economy in the BS region through the coordinated implementation of LLs from two EU Horizon-funded projects working on sustainability issues in the BS. The article seeks to share insights on how participatory workshops at local and national levels have been used in the context of the ocean-climate nexus; how a system innovation approach (SIA) has been implemented to foster stakeholder engagement for a sustainable blue economy; and how collaboration across LLs can strengthen stakeholder engagement's process, foster trans-boundary networks of actors, and trigger bottom-up regional collaborations and policy recommendations.

2. Conceptual Framework

The SIA is a methodological framework that enables systemic change based on an interconnected set of innovations, where each influences the other, with innovation both in the parts of the system and in the ways in which they interconnect. SIA is rooted in system thinking (Meadows, 2008) and its implementation within the context of the transition management concept (Loorbach & Rotmans, 2006; Roorda et al., 2014). It aspires to address persistent problems and facilitate sustainability, while it is grounded on a highly participatory method in which stakeholders are actively engaged in workshops to co-identify an interconnected set of innovations that can drive sustainability. In this context, MAFs and LLs act as open innovation spaces that foster co-creation with users. The end result is expected to better solve stakeholder needs and engage actors from many different domains and scale levels in solving problem-oriented activities, co-producing knowledge, and co-designing solutions in an iterative process (Akinsete et al., 2023; Akinsete et al., 2025b; Geels & Schot, 2007; Roorda et al., 2014).

SIA can offer a more comprehensive perspective on marine governance, a complex socio-ecological system in which ecological, economic, technological, and social subsystems interact dynamically. Systems innovation encourages cross-sectoral, integrated change to target root causes and interdependencies, rather than addressing individual issues (e.g., pollution, fisheries, etc.) in isolation (Akinsete et al., 2025a). By prioritising stakeholders, governance can be transformed into a learning system in which policies are perpetually refined in response to stakeholder input and real-world experimentation. The concept of transition pathways is introduced by systems innovation, which involves the development of strategic, long-term trajectories to transition from unsustainable practices (e.g., overfishing, pollution, etc.) to sustainable alternatives. Ultimately, SIA ensures that decisions are socially legitimate and evidence-based by bridging gaps between research outputs (e.g., ecosystem models), policy instruments, and community requirements. These pathways combine institutional and behavioural change (e.g., new governance frameworks, incentives for collaboration, etc.) with technological innovation (e.g., clean transportation, digital monitoring, etc.; Akinsete et al., 2025c; Geels & Schot, 2007).

3. Methodology

3.1. Case Study Context: The DOORS and BRIDGE-BS Projects

DOORS BS created a series of MAFs to bring together citizens, scientists, and industry for the important restoration of the BS, creating new opportunities for the "blue economy," along with a system-of-systems to tackle the effects of humans and climate change on the marine ecosystem. To assist scientists in the prioritisation of BS issues, these forums are facilitating the collaboration of diverse national stakeholders in Georgia, Bulgaria, Turkey, and Romania. The primary emphasis is on the implementation of innovations to resolve identified deficiencies and blue economy policies. These forums are designed to assist scientists in the process of prioritising issues that are associated with the BS.

In the BRIDGE-BS context, LLs represent an instrument to empower local communities in the future sustainable management of the BS (Figure 1), breaking sectoral silos and ensuring a systemic approach. They create a new local participative dynamic to explore alternative forms of governance and simultaneously creating a nexus for greater interconnection between physical and socio-economic sciences. Various participative tools exploit and enhance the inter-actor exchanges to create a learning loop, raise awareness on ecosystem services and their multi-stressors, current and future, stimulate thinking out of the box, and develop trust and collaborations to foster the adoption and implementation of innovative eco-solutions. The primary outputs consist of transformative pathways for the blue economy that address key stressors on marine ecosystem services, including climate change, specific to each targeted country.

Figure 1. BS basin geographic coverage. Source: NASA Earth Observatory (2006).

Both the DOORS MAFs and BRIDGE-BS LLs are grounded in the SIA, which draws conceptually from the transition theory, particularly the multi-level perspective (Geels & Schot, 2007), and from the broader field of participatory and collaborative governance (Ansell & Gash, 2008; Bryson et al., 2013). Table 1 presents the step-by-step application of SIA in the two projects. Consistent with the multi-level perspective, the process begins by mapping key actors within the socio-technical system (step 1), identifying their positions within niches, regimes, and landscape pressures. This mapping, supported by the quadruple helix framework, recognises that transitions emerge from the interplay between established structures (regimes) and emerging innovations (niches), and therefore requires a systemic understanding of power, interests, and institutional dynamics. In step 2, the co-identification of challenges and needs across blue economy sectors surfaces the regime lock-ins, path dependencies, and cross-scale tensions that constrain sustainable transitions in the BS. This stage aligns with the participatory governance theory, which emphasises joint problem framing as a prerequisite for trust-building and collaborative action.

In step 3, participants co-develop desirable future visions, a central component of both systems innovation and transition management. Visioning provides a collectively negotiated direction for change and articulates long-term landscape-level aspirations that can guide regime destabilisation and niche development (Bennett et al., 2021; Milkoreit, 2017; Riedy & Waddock, 2022). Finally, step 4 employs a backcasting approach to translate visions into transformative pathways, consisting of innovations, management measures, governance reforms, and behavioural shifts sequenced across short, medium, and long-term time horizons. This reflects the transition management literature's emphasis on iterative experimentation, niche amplification, and the orchestration of systemic transformations through coordinated action by public, private, and civil actors. Across all steps, SIA operationalises participatory governance by positioning stakeholders as co-designers rather than consultees, enabling collective learning and enhancing the societal legitimacy of proposed pathways.

Table 1. Systems innovation methodology employed by the DOORS and BRIDGE-BS projects.

Step 1: Stakeholder analysis	Step 2: Problem scoping	Step 3: Envisioning a sustainable future	Step 4: Path towards sustainability
Step 1 aims at identifying the relevant stakeholders from the quadruple helix to be involved in the LL based on their level of power (decision-making) and influence, and on their interest in being actively engaged in activities aiming at solving the problem at stake. Stakeholder mapping tools are used (i.e., influence/interest matrix) to define the pool of stakeholders to engage in the LL activities	Step 2 focuses on unravelling key challenges, needs, risks, and opportunities around a sustainability problem, based on shared knowledge across key stakeholder groups. The result is a holistic and shared understanding of the key dynamics, driving a system (i.e., the blue economy system) around a sustainability change	Step 3 aims at co-developing a common vision describing a desirable, sustainable future ("what would the future look like in 2050?"). Visioning is not a predictive exercise but rather a means to provide a sense of direction, a goal to be achieved. It has to be credible, practical, and feasible enough in order to be useful	Step 4 consists of co-developing the path towards the future vision using a back-casting approach. A portfolio of social and technological innovations targeting different sectors is co-identified, along with the necessary policy instruments and governance arrangements, creating a trajectory for change with short, mid, and long-term solutions to be implemented

Table 2 offers a comparative analysis of the methodological approaches employed in the BRIDGE-BS and DOORS projects, both of which are dedicated to the development of the blue economy and sustainability transitions in the BS region. The table delineates the primary differences and shared components of the SIA frameworks. The DOORS project expands its scope to include Moldova, whereas BRIDGE-BS concentrates on two distinct Turkish sites (Istanbul-Bosphorus and Sinop) to capture local ecosystem variation, despite the fact that both projects span the primary BS countries—Bulgaria, Georgia, Romania, Turkey, and Ukraine. Each project implements a quadruple-helix strategy that encompasses academia, industry, government, and civil society. Nevertheless, DOORS primarily engages national-level stakeholders through the MAFs, whereas BRIDGE-BS emphasises community and site-specific innovation through LLs, which allows for local-level engagement. In regard to the general objective, DOORS is dedicated to identifying policy and innovation gaps across the blue economy sectors, while BRIDGE-BS is focused on understanding and

Table 2. A methodological comparison between the BRIDGE-BS and DOORS projects.

SIA methodology	Common elements	Differences
Geographic coverage	BS countries (Bulgaria, Georgia, Romania, Turkey, and Ukraine)	DOORS reached an additional country, Moldova, while BRIDGE-BS looked at 2 different sites in Turkey, namely Istanbul-Bosphorus and Sinop
Stakeholders engagement	Blue economy representatives from the quadruple helix	DOORS engaged national-level stakeholders, while BRIDGE-BS targeted local-level stakeholders
General objectives	Support the development of a sustainable and resilient blue economy in the BS region	DOORS aimed at identifying policies and innovation gaps related to the BS, while BRIDGE-BS sought to tackle the marine ecosystem services multi-stressors

mitigating multiple stressors on marine ecosystem services. In general, Table 2 demonstrates how these complementary initiatives integrate systems innovation methodologies at varying scales (national vs. local) and foci (policy vs. ecosystem), thereby jointly contributing to a more comprehensive understanding of blue economy transitions in the BS.

3.2. Workshop Design and Implementation

As stated in Section 3.1, both projects together designed and implemented workshops in six BS countries: Bulgaria, Georgia, Moldova, Romania, Turkey, and Ukraine. The initial phase of implementing SIA entails a detailed stakeholder mapping and selection process. One key component of the SIA is the intentional mapping and selection of the stakeholders who are invited to the respective workshops. Stakeholders are listed and mapped using the quadruple helix model, namely, academia, industry, government, and civil society (Arnkil et al., 2010). The quadruple helix model assists in the identification of the interconnections between institutional actors and citizens within a socio-economic system. It is a diagnostic instrument that is used to identify individuals, the manner in which they interact, and the areas in which there are gaps or imbalances. Then, stakeholders are assessed using an "influence/interest" matrix (Figure 2), where "influence" denotes the stakeholder's power and capacity to effect change, and "interest" denotes the likelihood of the stakeholder participating in activities pertinent to the case study, whether due to potential benefits or negative consequences (Arnkil et al., 2010; Eden & Ackermann, 1998).

Figure 2. Influence-interest matrix. Note: Example from the DOORS MAF in Georgia.

In addition, stakeholders are mapped onto the EU blue economy sectors, which are relevant to the project objectives, including marine living and non-living resources, renewable energy, port activities, shipbuilding, transportation, and tourism (European Commission, 2021). The map is then evaluated by an external expert, such as members of the project advisory board or other local specialists, after the plotting process is complete. The analysis aims to identify the most suitable stakeholders to be involved in the corresponding workshops (MAFs and LLs). The primary participants are selected from the upper right quadrant of a stakeholder matrix, indicating individuals with substantial influence and interest. However, stakeholders from the lower right and upper left quadrants are also shortlisted; the former includes those who can implement recommendations, while the latter consists of individuals with local expertise who often lack decision-making power.

Importantly, both projects put emphasis on including groups that are traditionally under-represented in marine governance processes, such as women, small-scale fishers, coastal community groups, and NGOs working with marginalised populations. This was achieved by cross-checking invite lists with gender indicators and consulting local partners to identify informal or community-based actors who may not appear in formal institutional networks. This participant selection methodology helps highlight stakeholders who are most relevant to the workshop objectives and are more likely to engage in research efforts (Akinsete et al., 2025a, 2025d).

BRIDGE-BS LLs and DOORS MAFs were implemented through a series of three and two (respectively) participatory workshops (Table 3) following the SIA framework (Table 1). Both efforts engaged stakeholders

Table 3. DOORS and BRIDGE-BS implementation stages.

<table>
<tr><th>SIA steps</th><th>Project</th><th>Activities</th><th>Data collection</th><th>Tools used</th><th>Main outcomes</th></tr>
<tr><td rowspan="2">Step 1: Stakeholder analysis</td><td>BRIDGE-BS</td><td>Stakeholder mapping and selection of LL participants in six regions across the BS (see Figure 2)</td><td rowspan="2">Desk work in liaison with country leaders in each BS country</td><td rowspan="2">Influence/ interest matrix</td><td rowspan="2">20 to 30 representatives of the local blue economy community engaged in each workshop</td></tr>
<tr><td>DOORS</td><td>Stakeholder mapping and selection of MAFs participants in six countries across the BS (see Figure 2)</td></tr>
<tr><td rowspan="2">Step 2: Problem scoping</td><td>BRIDGE-BS</td><td>Workshop No. 1: Identification of the key ecosystem services and the related risks and pressures, blue economy needs, challenges, and opportunities</td><td rowspan="2">Online (due to the Covid-19 epidemic) or face-to-face participatory workshops</td><td rowspan="2">Individual and group mapping activities (e.g., PESTLE framework, etc.)</td><td>A system map providing a holistic and systemic view of challenges and opportunities, and a problem statement expressing the challenge focus of the LL</td></tr>
<tr><td>DOORS</td><td>Workshop No. 1: Prioritisation of the blue economy sectors per BS country and mapping of the challenges related to these sectors</td><td>A map of the most important blue economy sectors per country and of the common challenges</td></tr>
</table>

Table 3. (Cont.) DOORS and BRIDGE-BS implementation stages.

SIA steps	Project	Activities	Data collection	Tools used	Main outcomes
Step 3: Envisioning a sustainable future	BRIDGE-BS	Workshop No. 2: Validation of system map and co-development of a vision for a sustainable blue economy, integrating and representing all stakeholder perspectives	Participatory face-to-face workshops	Individual and group envisioning activities, as well as visuals to trigger imagination based on the concept of seeds for Anthropocene	A common understanding of the system and a future common vision at the pilot site level (BS coastal regions) was agreed upon across sector and stakeholder groups
	DOORS	Development of a shared vision that reflects the Burgas vision, the CMA for the BS, and the priorities identified in the first workshops	Desk work in liaison with country leaders in each BS country	—	—
Step 4: Path towards sustainability	BRIDGE-BS	Workshop No. 3: Validation of short, mid, and long-term milestones and identification of associated actions per key sectors to support the achievement of the vision	Online (due to the Covid-19 epidemic), face-to-face participatory workshop online (due to the Covid-19 epidemic, the ongoing conflict in Ukraine and limited resources), or face-to-face participatory workshops	Back-casting approach, the three Horizon framework, and the seed for the Anthropocene tool	Blue transformative pathways in each BS region
	DOORS	Workshop No. 2: Validation of the vision and of short, mid, and long-term milestones and identification of associated solutions from the Blue Growth Accelerator per key sector to support the achievement of the vision			

on a national (MAFs) and local (LLs) level from six BS countries, namely, Bulgaria, Georgia, Moldova, Romania, Turkey, and Ukraine. Stakeholders were involved in individual and group activities for scientists to harness valuable local knowledge to build upon and co-develop scenarios and pathways to guide policy-makers in designing strategy and investment plans for the sustainable development of the blue economy in the BS regions. In between workshops, further interactions with stakeholders occurred in response to project needs. It took the form of online meetings, questionnaires, and communications to keep stakeholders informed on the progress of the projects. These efforts aimed at reaching not only participants but also stakeholders identified as relevant during the stakeholder mapping phase. Additionally, effort was put into disseminating LLs and MAFs results at the regional and European level (i.e., participation in scientific conferences, blue economy community events, etc.) to further attract attention to the initiative and main outputs.

4. Findings

4.1. Blue Economy Priorities Across the BS: A Local and National Perspective

The prioritisation exercise, which is part of the "problem scoping" phase, aims to identify the most important blue economy sectors for the BS countries, as defined by the Caribbean Development Bank (2018). Two approaches were employed in both projects to identify those sectors. In DOORS, participants in each BS country were requested to rank the three most significant sectors in their country, whereas in BRIDGE-BS, the sectors were determined through an analysis of the vision in each local pilot site. In BRIDGE-BS, the participants were asked about the key sectors outlined in the vision, specifically those anticipated to continue propelling the blue economy sustainably over the next 25 years, and to identify the sectors that should be prioritised in the transformative pathways.

The sectors that have been identified as significant in the workshops (MAFs and LLs) conducted under the DOORS and BRIDGE-BS projects are detailed in Table 4. The sectors that are designated as significant in both projects are depicted in green. The sectors that are identified in the MAFs (DOORS project) are in blue, while the sectors in the LLs (BRIDGE-BS project) are in orange. It is straightforward that fisheries, tourism, ports and shipping, and marine transport sectors are prioritised as important in all BS countries in at least one of the workshops held in each country. Those sectors are traditional blue economy sectors and well-established in the region, currently driving the blue economy.

Table 4. BS blue economy sector prioritisation: results from the DOORS (MAFs, National level) and BRIDGE-BS (LLs—Local level).

Sector	Definition	Bulgaria	Georgia	Moldova	Romania	Turkey	Ukraine
Capture fisheries (established)	The practice of obtaining naturally occurring living resources in both freshwater and marine environments in a sustainable manner	National/ Local	National/ Local	National	National/ Local	National/ Local	National/ Local
Marine and coastal tourism (established)	The provision of tourism-related services in and around littoral or marine environments, which support the local community's sustainable development	National/ Local	National/ Local	National	National/ Local	Local	National/ Local
Ports and shipping (established)	It includes the management, operation, and coordination of port terminals, harbours, and maritime logistics services, ensuring the efficient, safe, and environmentally sustainable movement of goods and passengers through maritime gateways	National/ Local	National/ Local	National	Local	Local	National/ Local

Table 4. (Cont.) BS blue economy sector prioritisation: results from the DOORS (MAFs, National level) and BRIDGE-BS (LLs—Local level).

Sector	Definition	Bulgaria	Georgia	Moldova	Romania	Turkey	Ukraine
Marine transport (established)	The transportation of commodities, individuals, and valuable resources through waterways, encompassing lakes, rivers, oceans, and watercraft, in the company of vessels such as ferries, boats, and ships	Local	Local	National	Local	Local	National/Local
Marine aquaculture (emerging)	The practice of aquaculture and farming with the intention of minimising any adverse effects on the purity of air, water, and soil	Local	National	–	National/Local	National	Local
Marine research and development (established)	The activities are centred around the advancement of technology, knowledge, and capabilities pertaining to marine environments, encompassing oceans, seas, and other aqueous bodies	National	National	–	National	National	–
Offshore wind energy (emerging)	The design, deployment, and management of wind turbines situated in aquatic environments with the purpose of extracting sustainable energy reserves and generating electrical power	Local	–	National	Local	Local	–
Shipbuilding (established)	The goods and services necessary for the construction, upkeep, restoration, and repair of vessels used for ecologically conscious maritime transportation	–	–	–	–	National	National
Ocean renewable energy (emerging)	The production of pure and renewable energy from natural sources, such as wave, tidal, and solar, at sea, offshore, on land, and in close proximity	–	–	–	National	National	–
Marine business services (established)	The commercial activities that rely on water and are associated with marinas and other vessel service operations	National	–	–	–	–	–

Table 4. (Cont.) BS blue economy sector prioritisation: results from the DOORS (MAFs, National level) and BRIDGE-BS (LLs—Local level).

Sector	Definition	Bulgaria	Georgia	Moldova	Romania	Turkey	Ukraine
Safety and surveillance (established)	Transportation, public spaces, and critical infrastructure are among the domains in which the application of technologies and measures designed to ensure protection, monitoring, and security is underway	—	—	National	—	—	—
Offshore oil and gas (emerging)	The extraction of gas and hydrocarbons from submerged sources	—	—	—	—	National	—

Notes: The BRIDGE-BS project did not implement any LL in Moldova, while ports, shipping, and marine transport were considered as one sector only; green denotes national and local priorities; blue denotes national-level priorities; orange denotes local-level priorities.

The fishing sector is undoubtedly one of the main drivers of the blue economy in the BS, having generated $251 million of income in 2020 according to Food and Agriculture Organization (2020) estimates. However, the BS fleet heavily favours small vessels (Eca4Med, 2023). This activity, though, is also associated with negative externalities for the BS, which has experienced significant stock declines, particularly among predatory fish species, leading to an ecological shift favouring tiny pelagic species such as anchovy and sprat. Overexploitation is widely documented, with many commercial species in the BS being considered overexploited (e.g., turbot, anchovy, horse mackerel, whiting, etc.) or fished beyond sustainable levels (Altmayer, 2025).

Alongside fisheries, coastal tourism is a major economic sector in the BS region: many countries attract millions of tourists annually on a “sea, sand, and sun” basis. For instance, the Black Sea Economic Cooperation region as a whole received 143 million international arrivals in 2018, making it an important tourism region in Europe (UN World Tourims Organization, 2019). In coastal hubs such as Bulgaria’s BS coast, the sector has driven rapid infrastructure expansion and posted high foreign tourist flows (e.g., 1.2 million foreign visitors to the southern coast in one recent season; “The Southern Black,” 2024). However, the region faces pressing sustainability pressures, including excessive waste, coastline overdevelopment, pollution, eutrophication, and general environmental degradation in coastal zones (Varna University of Management, 2024).

Shipping in the BS has long been dominated by liquid bulk (hydrocarbons, chemicals, etc.) and dry bulk (raw materials) cargoes, which still constitute a large share of cargo volumes. The region’s ports have a combined nominal traffic capacity of nearly 700 million tons, though actual usage is significantly lower today (Chkhenkeli & Jikia, 2025). The BS hosts dozens of commercial ports across riparian states, many of them medium to large-scale hubs. Today, the sector faces serious headwinds: the ongoing war has severely disrupted maritime flows and infrastructure (e.g., port blockades, re-routing, sanctions, etc.). Moreover, reliance on fossil fuel traffic (liquid bulk, hydrocarbons, etc.) makes the future uncertain under global decarbonization trends, which could reduce demand for such cargoes and accelerate pressure for greener shipping technologies and more diversified trade flows.

Despite structural and contextual challenges, those three sectors remain a priority for stakeholders from local and national levels to support the development of the blue economy in the region. However, to ensure their long-term sustainability, they will have to transition to new business models and practices. When it comes to emerging blue economy sectors, priorities diverge between local and national levels. Besides marine aquaculture and marine renewable energies, which are perceived as future major economic sectors at the local and national levels, the other sectors have not been identified as a priority at the local level. When certain sectors such as "marine research and development" and "shipbuilding and repair" are considered strategic at the national level, they are not perceived as holding great economic potential at the local level.

4.2. National-Level Challenges and Needs

During the first MAF workshops, the challenges associated with each prioritised sector in each country were identified using the PESTLE framework. These challenges were further validated via an online survey that was completed by 136 stakeholders across the BS. Figure 3 illustrates the hierarchy of challenges that most significantly impact the sustainability of the blue economy for each BS country, both individually and collectively. On a national level, the majority of the participating countries in the BS are experiencing pollution and environmental degradation, which is followed by marine litter and waste management. The absence of a system for beach quality award, such as the Blue Flag, and poor salaries are relatively insignificant.

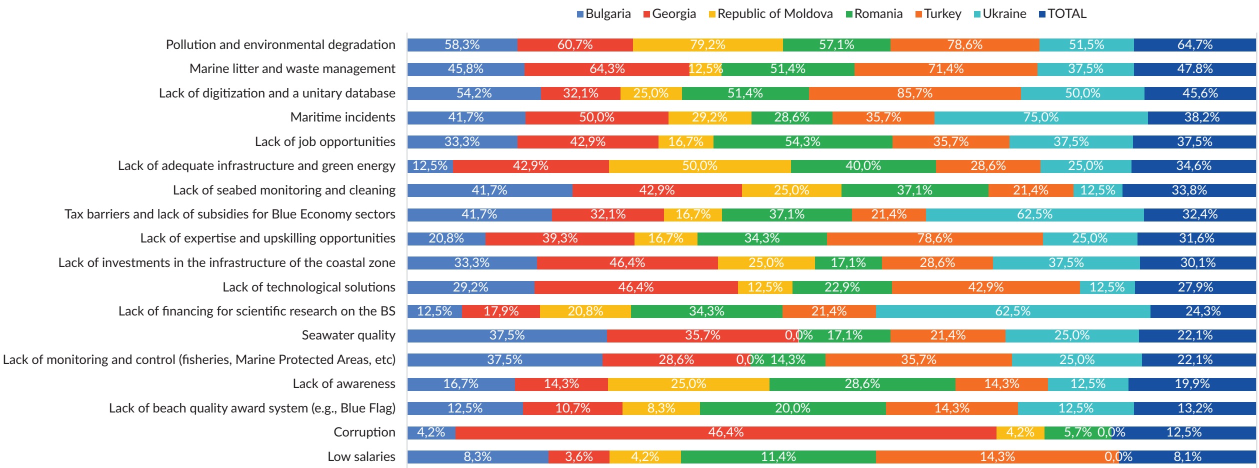

Figure 3. Challenges with the greatest impact on the blue economy development in each BS country. Note: Results from the online survey of the DOORS project.

A closer examination reveals that Bulgaria and Turkey confront their greatest challenge in the absence of digitization and a unified database. This suggests that the digital infrastructure of their governmental and organisational systems might be inadequate, thereby impeding the effectiveness of data management and communication. In the absence of digitization, operational procedures, including record-keeping, information sharing, and decision-making, might experience reduced efficiency and speed. Georgia, the Republic of Moldova, and Ukraine are significantly preoccupied with maritime-related incidents. This implies concerns such as maritime catastrophes, pollution in the seas, illicit fishing, or difficulties associated with port administration and security. It is imperative that these nations, which possess coastlines or substantial maritime investments, address these incidents in order to safeguard their economic and environmental interests.

Figure 4 shows the order of the challenges that exert the most significant influence on the work of individuals and groups in each BS country. For Turkey, Bulgaria, and Georgia, cooperation among national institutions emerged as a primary obstacle. This challenge signifies a formidable task in attaining efficient coordination and collaboration among diverse governmental entities within an individual nation. Insufficient collaboration may result in sluggish decision-making processes, policies that lack coherence, and suboptimal resource allocation. In order to surmount this obstacle, it is imperative to cultivate an environment that promotes collaboration, strengthen channels of communication between agencies, and potentially institute institutional changes that optimise workflows and increase productivity.

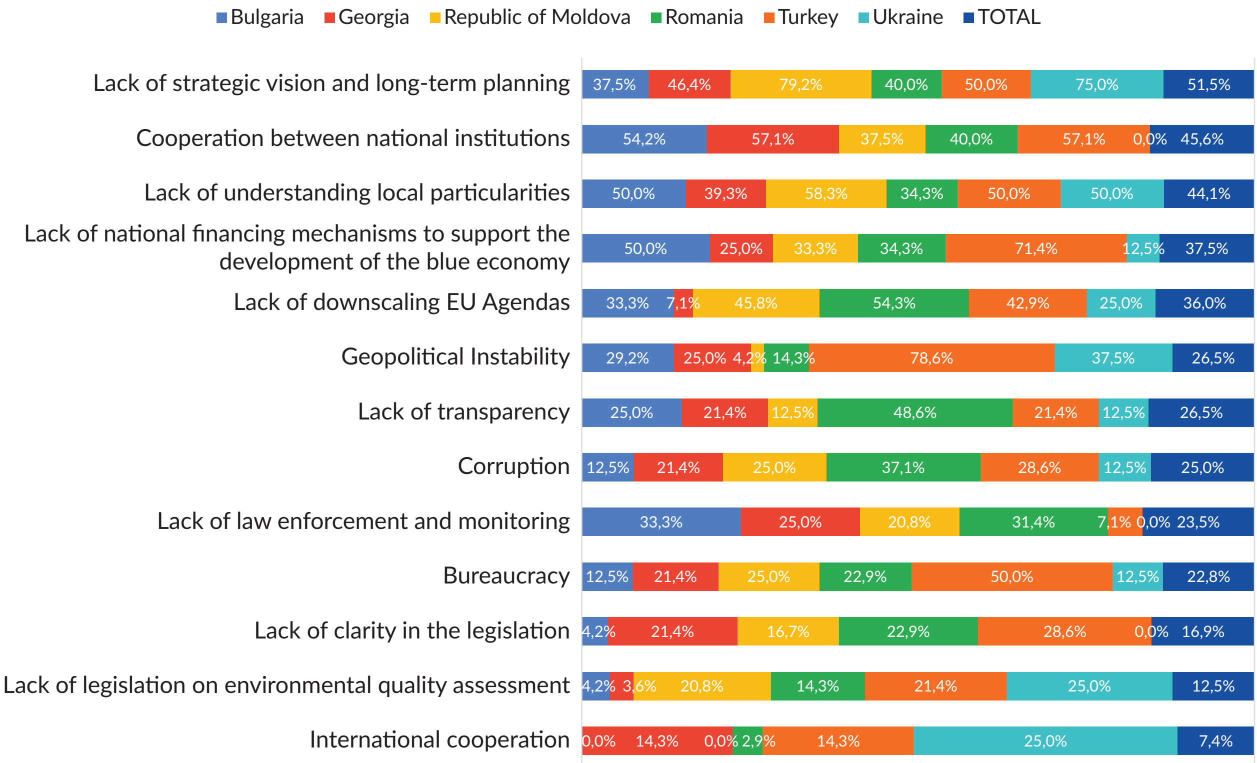

Figure 4. Challenges with the greatest impact on respondents' work in each BS country. Note: Results from the online survey of the DOORS project.

The necessity for interdisciplinary, international, and institutional collaboration to promote the adoption of the blue economy in the BS is readily apparent. Environmental degradation and pollution appear to be the most significant problems in each of the four BS states. At the national level, nevertheless, priorities vary. In Bulgaria, the lack of investments in infrastructure in coastal zones, inadequate infrastructure and renewable energy, and inadequate funding for scientific research on the BS appear to be the most significant obstacles. Georgia faces challenges pertaining to the administration of marine litter and waste, the absence of a beach quality award system, and inadequate funding for scientific research concerning the BS. In conclusion, both Turkey and Romania have prioritised the surveillance and control of marine litter and waste, with Romania emphasising the importance of digitalization.

4.3. Local-Level Challenges and Needs

Each country faces specific challenges and needs related to its historical, cultural, political, and economic environments. Nevertheless, common issues throughout the region can be noticed (Figure 5). The development of a sustainable blue economy in the BS faces numerous common social, economic, technological, and policy challenges, including low public engagement, lack of environmental awareness, weak law enforcement, and insufficient financial resources. Key priorities, across the sea basin, include raising public awareness of environmental and blue economy issues through education and citizen science programs, as the limited qualified workforce in maritime sectors (blue skills) is a challenge in all countries. Strengthening environmental protection by promoting marine protected areas is a common need from region to region. Common economic challenges in BS countries can be summarised in terms of general low financial incentives towards sustainable business models, practices, and sustainable infrastructure investment programs for effectively supporting a blue economy. Finally, BS countries are characterised by structural policy challenges, including a weak regulatory enforcement system, low horizontal and vertical institutional coordination, as well as corruption issues and regular political instability. Streamlining legislation for blue sectors, increasing research funding, and integrating environmental, economic, and social strategies will be critical to achieving a sustainable and thriving blue economy in the region.

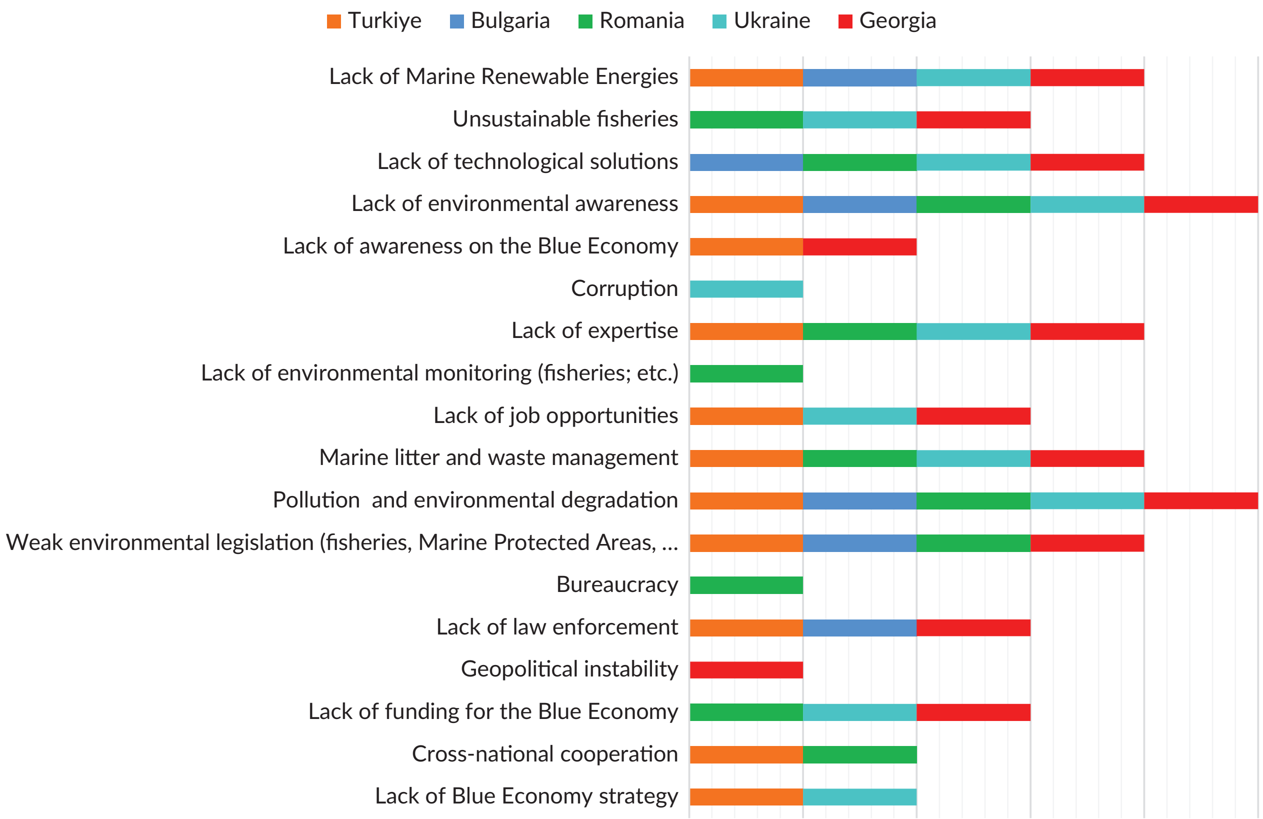

Figure 5. Challenges mentioned by local stakeholders in the BRIDGE-BS LL country workshop.

The challenge mapping shows that the region encounters challenges related to fragmented governance, insufficient institutional capacity, and inadequate policy coordination, which impede adherence to EU and regional frameworks. Environmental pollution, loss of biodiversity, unsustainable fishing practices, and inadequate local climate action continue to be critical challenges, underscoring the necessity for restoration efforts, ecological education, and nature-based solutions. There is a notable lack of awareness regarding the blue economy, accompanied by limited workforce skills and inadequate public engagement, highlighting the critical need for education and reskilling initiatives. Legally, outdated strategies, bureaucratic complexity, and ineffective law enforcement highlight the necessity for harmonised legislation and integrated marine spatial planning that aligns with EU directives. Technological gaps in innovation, research infrastructure, and digitalisation, such as the lack of marine observatories and smart port systems, hinder modernisation efforts. Limited access to finance, weak business engagement, and low investment in emerging blue sectors hinder sustainable growth. The analysis also illustrates a connected framework in which governance, innovation, and capacity deficits mutually reinforce each other. This interdependence underscores the necessity of cross-sectoral cooperation, stakeholder engagement, and ongoing funding to attain resilience in the blue economy of the BS.

4.4. Local vs. National Perspectives

Several challenges appear to have emerged at both local and national levels. The region encounters challenges related to fragmented governance, insufficient institutional capacity, and inadequate policy coordination, which impede adherence to EU and regional frameworks. Environmental pollution, loss of biodiversity, unsustainable fishing practices, and inadequate local climate action continue to be critical challenges, underscoring the necessity for restoration efforts, ecological education, and nature-based solutions. There is a notable lack of awareness regarding the blue economy, accompanied by limited workforce skills and inadequate public engagement, highlighting the critical need for education and reskilling initiatives. Legally, outdated strategies, bureaucratic complexity, and ineffective law enforcement highlight the necessity for harmonised legislation and integrated marine spatial planning that aligns with EU directives. Technological gaps in innovation, research infrastructure, and digitalisation, such as the lack of marine observatories and smart port systems, hinder modernisation efforts. Limited access to finance, weak business engagement, and low investment in emerging blue sectors hinder sustainable growth. The analysis shows a connected framework in which governance, innovation, and capacity deficits mutually reinforce each other. This interdependence underscores the necessity of cross-sectoral cooperation, stakeholder engagement, and ongoing funding to attain resilience in the blue economy of the Black Sea.

The sectors that should be prioritised include those within the economy that hold significant potential to bolster the blue economy in the BS, specifically fisheries, tourism, ports and shipping, and marine transportation (Table 4). It is clear that many of the local barriers (identified in the BRIDGE-BS Project) are not taken into account in the national challenges (identified in the DOORS Project). National challenges mention low economic resilience and financial crisis, but they do not capture the granular, project-level funding bottlenecks that local actors face—such as lack of investment capital, limited access to EU funds, or the high costs of technology deployment. On a national level, limited technological modernisation is raised, but it doesn't address digital readiness gaps, skills shortages, or standardisation issues that hinder innovation adoption locally. These represent critical enablers for modernisation that remain overlooked in policy discourse. "Fragmented governance" is a term that was frequently mentioned in the MAFs; however, it fails to account for the lack of incentives for local authorities to take action and the fragmentation that occurs at the port or municipal level. Bureaucratic silos, local institutional inertia, and inadequate prioritisation of tourism or fisheries policies are more operational than systemic.

Sociocultural resistance or low community ownership at the local level can affect the implementation of blue transition initiatives. Practical obstacles, such as community buy-in, change management, and stability, are not explicitly reflected in the "political interference" that is acknowledged in national challenges. In addition, tourism-related environmental pressures, waste infrastructure deficits, and regional inequalities in coastal economies are rarely recognised, despite the national discussion of "marine litter" and "environmental degradation." Finally, the skills and training dimensions that are essential for digitalisation, innovation, and sustainable management—particularly problematic in fisheries, tourism, and port operations—were also omitted by nationwide challenges, such as the "lack of education and awareness." The results show that local issues underscore finance deficiencies, digital readiness, and implementation capability, whereas national challenges focus on policy coherence and structural governance.

5. Discussion

5.1. The Added Value of MAFs and LLs

This research employs MAFs and LLs as a mechanism to integrate science with societal realities and acquire valuable insights into local practices. Understanding deeply the factors driving change, elucidating the relationships between coastal communities and the sea, and heightening awareness of human contributions to the ongoing degradation of the marine environment are some of the outcomes participatory approaches can bring. Furthermore, these tools enable participants to engage actively in discussions, consider diverse perspectives, and practice active listening rather than passively engaging in events or surveys. Before each workshop, train-the-trainer sessions were conducted in both projects to guarantee that the facilitators would be capable of handling discussions and facilitating the equal participation of all stakeholders.

MAFs and LLs influence governance learning through three mechanisms: (a) problem re-framing, where actors collectively redefine challenges through shared system maps and, in doing so, recognise interdependencies they previously overlooked; (b) social learning, generated through repeated interaction and reflection, which helps actors internalise alternative practices and understand others' constraints; and (c) experiential governance, where the co-design and testing of solutions (e.g., monitoring tools, new policy concepts, stakeholder networks, etc.) serve as "safe-to-fail" environments that allow institutions to experiment and adjust policies iteratively. Such mechanisms mirror the literature on experimentalist governance (Sabel & Zeitlin, 2012) and transition management.

Here, the stakeholder engagement efforts of both projects addressed the gaps highlighted by Bisinicu et al. (2025) by intentionally including vulnerable and often underrepresented groups—such as small-scale fishers and local community representatives—alongside institutional actors (see Figure 2). Stakeholder selection was guided through the quadruple helix model, which maps actors across academia, industry, government, and civil society (Arnkil et al., 2010). The quadruple helix framework helps identify interactions, gaps, and potential synergies within the socio-economic system, ensuring balanced representation and highlighting where influence, knowledge, and values intersect. As such, it provides a foundation for participatory governance by supporting "user-oriented innovation," where end-users participate as co-designers rather than passive consultees.

Across Romania, Bulgaria, Georgia, and Turkey, the first round of BRIDGE-BS LLs delivered a concrete set of shared key drivers, pressures, and opportunities, supporting the argument for a coordinated regional blue economy strategy. Similarly, the DOORS MAFs generated a stakeholder-owned national challenge map that is explicitly tied into existing regional governance frameworks, such as the CMA and the BS SRIA. In addition, the BRIDGE-BS and DOORS projects have demonstrated that the establishment of effective participatory governance in the ocean–climate nexus necessitates the reconciliation of a persistent disconnect between local and national levels of engagement. The LLs of the BRIDGE-BS project illustrated that local stakeholders frequently encounter difficulty in imagining new opportunities that extend beyond their current activities. Limited institutional capacity, low innovation preparedness, and a lack of skills to adapt to emerging sectors such as blue biotechnology, renewable energy, or digital maritime services have resulted in many communities remaining confined to existing practices. In contrast, policymakers at the national level tend to articulate forward-thinking visions; however, there are still voids in the provision of sufficient support mechanisms, training, and policy alignment to facilitate local transitions. This underscores the necessity of targeted upskilling and reskilling programs, such as those that assist fishers in acquiring competencies that are pertinent to sustainable aquaculture, coastal monitoring, or circular economy activities. In contrast, the MAFs of the DOORS project identified governance challenges predominantly at a higher policy level, frequently without concrete local illustrations, indicating a disconnect between abstract policy discourse and practical, place-based experience. Together, these teachings emphasise the necessity of participatory governance to progress beyond consultation and towards capacity-building, cross-scale alignment, and skill development. This will guarantee that ocean–climate strategies result in tangible, inclusive transformations throughout the blue economy.

5.2. Implications for BS Governance

Persistent disconnects between local and national perspectives reflect well-documented issues in multi-level governance systems, where mandates, resources, and responsibilities are unevenly distributed. In the BS, national ministries retain formal authority over fisheries, shipping, and environmental protection, while local authorities carry implementation burdens without corresponding capacity or financial autonomy. This structural asymmetry creates chronic misalignment between policy ambition and practical delivery. Using insights from the challenge mapping, the region exhibits several "lock-ins": Economic lock-ins, such as dependence on established sectors (fisheries, fossil-fuel shipping, etc.), which discourages risk-taking in emerging sectors; cognitive lock-ins, where actors reproduce familiar routines, hindering innovation uptake; and institutional lock-ins, including rigid hierarchies, bureaucratic procedures, and unclear mandates that impede cross-sector cooperation. These patterns are consistent with Geels (2005) multi-level perspective, where incumbent regimes resist change even in the face of environmental and market pressures.

An additional issue is that in several BS countries, the blue economy remains subordinated to short-term political objectives, patronage networks, and competing geopolitical interests. For instance, political constituencies often use small-scale fisheries, and local tourism sectors are often used as political constituencies, making enforcement politically sensitive. Similarly, fragmented port governance—split between national agencies, municipal authorities, and private operators—creates incentive misalignment that discourages coordinated planning or investment in environmental compliance. These dynamics explain why governance reforms remain slow despite international frameworks like the Marine Strategy Framework Directive, Water Framework Directive, and Common Maritime Agenda. While MAFs and LLs create spaces for co-learning, they cannot fully compensate for structural deficits such as underfunded local governments, weak regulatory enforcement systems, or politicised decision-making. Therefore, systemic disconnects persist not because participatory tools are ineffective, but because they operate within broader institutional environments shaped by conflicting interests, limited resources, and path-dependent governance traditions.

The MAFs and LLs have demonstrated the pressing necessity of enhancing regional cooperation and governance coherence in a basin that is both environmentally fragile and politically sensitive. Although the projects were conducted in different countries, they both designated the same priority sectors—capture fisheries, marine and coastal tourism, ports and shipping, and marine transport—which are the foundation of the regional blue economy. Nevertheless, these sectors are confronted with systemic governance challenges that impede their sustainable development. These challenges include a lack of interinstitutional cooperation across national borders, persistent political conflict, and limited conformance with EU political obligations. Technological and innovation gaps impede modernisation, particularly in fisheries management and monitoring systems, while environmental degradation, ineffective enforcement of laws, and bureaucratic inefficiencies continue to undermine effective policy implementation. Additionally, local actors are inadequately prepared to capitalise on emergent blue economy opportunities due to inadequate investment in capacity-building and skills. In order to resolve these concerns, it is necessary to establish coordinated regional mechanisms that convert research outputs into actionable governance measures, thereby bridging the science–policy practice divide. In order to establish a more collaborative, resilient, and adaptive governance model for the BS, it is necessary to invest in marine research, innovation, and workforce reskilling, support small-scale fisheries, and harmonise national and EU legislation.

5.3. Broader Lessons for the Ocean–Climate Nexus

Participatory approaches, such as MAFs and LLs, provide valuable, transferable models for governing the ocean–climate nexus in other regional seas. These tools can be customised to suit case studies beyond the BS, such as the Mediterranean, Baltic, or North Seas, where ecosystem-based management and multi-country cooperation are equally important, by integrating stakeholder dialogue, co-creation, and systems thinking. The implementation of global and European frameworks, such as the UN SDGs (SDG 13 on “climate action” and SDG 14 on “life below water”), the EU Mission: Restore our Ocean and Waters, and the UN Decade of Ocean Science for Sustainable Development (2021–2030), is directly influenced by their emphasis on inclusivity and science–policy–society integration. By establishing collaborative spaces for experimentation, innovation, and shared learning, MAFs and LLs assist in the operationalisation of these agendas. Within these spaces, stakeholders collaborate to co-design solutions for climate adaptation, sustainable resource use, and resilient coastal communities. Consequently, the BS experience offers a scalable governance model that demonstrates the effective use of participatory, science-informed processes to expedite the global transition to climate-resilient and sustainable ocean systems.

6. Conclusion

This study shows that despite structural differences across the BS region, the DOORS and BRIDGE-BS projects reveal a consistent pattern: The blue economy continues to rely on four mature sectors—capture fisheries, coastal tourism, ports and shipping, and marine transport—yet these sectors are constrained by governance fragmentation, weak enforcement, environmental degradation, and widening technological and skills gaps.

The findings highlight that sustainable transitions in the region hinge less on identifying new opportunities and more on addressing persistent institutional lock-ins that inhibit change. Limited local capacity, insufficient digitalisation, and the uneven integration of EU standards amplify vulnerabilities across the basin. The added value of participatory approaches lies in how LLs and MAFs surface implementation barriers that are often overlooked by national policies. These include funding bottlenecks, skills shortages, and bureaucratic obstacles that constrain effective action on the ground. By grounding governance dialogue in lived experience and co-creating actionable pathways, these platforms strengthen social legitimacy and accelerate the uptake of innovations essential to climate-resilient ocean management.

For national policymakers, the key priority is institutional coherence: aligning fisheries, environment, tourism, and transport policies, while investing in enforcement capacity, digital monitoring, and targeted upskilling for vulnerable groups. Regional bodies such as CMA/SRIA and Black Sea Economic Cooperation can turn shared priorities into coordinated action on pollution, fisheries control, marine litter, and climate adaptation. For the EU and international organisations, supporting local implementation—skills, standards, data interoperability—remains critical to avoiding widening regional disparities. Future research should examine the durability of participatory outcomes over time, evaluate how LL and MAF processes reshape governance behaviours, and develop comparative evidence on their transferability to other regional waters. Strengthening cross-country longitudinal studies will be essential to understand how ocean–climate transitions can be scaled equitably and effectively across politically sensitive marine basins.

Acknowledgments

The authors gratefully acknowledge all stakeholders who participated in the multi-actor forums and living labs across the Black Sea countries, as well as the project partners and facilitators whose contributions made this research possible.

Funding

This article is a joint output of the science projects DOORS and BRIDGE-BS. DOORS and BRIDGE-BS have received funding from the EU's Horizon 2020 Framework Programme for Research and Innovation under grant agreement No. 101000518 and No. 101000240, respectively.

Conflict of Interests

The authors declare no conflict of interests.

Data Availability

The data supporting the findings of this study are not publicly available.

LLMs Disclosure

This work benefited from the use of AI tools, including ChatGPT and QuillBot, for editing text and data analysis. All analyses and interpretations are the sole responsibility of the authors.

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Ocean and Society
2026 • Volume 3 • Article 11355
https://doi.org/10.17645/oas.11355

ARTICLE

Open Access Journal

The UN Ocean Decade and Its Performative Impact on North Sea Governance: An Extended Event Ethnography

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Submitted: 29 September 2025 **Accepted:** 16 December 2025 **Published:** 25 February 2026

Issue: This article is part of the issue "Ocean Climate Governance: Eclectic Viewpoints of a Multi-dimensional Nexus" edited by George Dikaios (Leiden University), fully open access at https://doi.org/10.17645/oas.i488

Abstract

The UN Ocean Decade aimed to promote knowledge, understanding, and access to oceans that are variably envisioned and imagined by state and non-state actors. The UN Ocean Decade vision, "The science we need for the ocean we want," set the path for global oceanic water bodies from 2021 to 2030 and beyond. However, multiscalar ocean governance often presents as a confusing and unclear vortex. Fortunately, ocean governance events provide a spatial and temporal entry point for empirical analysis. This article draws on an extended event ethnography, designed at the intersection of geographies of knowledge and ethics of care, to argue that ocean governance events extend concentrically along spatial, temporal, and normative dimensions. The data was gathered from five extended field research stays as well as multiple ocean governance events. From a diachronic perspective, this contribution uses the European Maritime Day 2021 as a reference event and entry point. As such, it is possible to uncover how the UN's metaphorical vision is (a) *shifted* into scenarios, which are (b) *interlinked* to precise projects that (c) spatially and temporally *impact* governance itself, the physical materiality of the North Sea, and the senses of place of people living with the sea.

Keywords

climate imaginaries; ethics of care; extended event ethnography; geographies of knowledge; North Sea; ocean literacy; sense of place; UN Ocean Decade

1. Introduction

The UN Ocean Decade (OD) vision sets the path for the world's oceanic water bodies from 2021 through 2030 (Intergovernmental Oceanographic Commission, n.d.-a). Its mantra, "The science we need for the ocean we want" (Intergovernmental Oceanographic Commission, n.d.-a), has reached the world's oceans, delivering a profound impact on the world's blue 70%. Different scholars have pointed out that the oceans are often conceptualised as a type of the world's "last" (Constantinou & Hadjimichael, 2020, p. 2; Fawcett et al., 2023, p. 70), "new" (Constantinou & Hadjimichael, 2020, p. 16; Johnson & Braverman, 2020, p. 2), or "final" (Spalding & de Ycaza, 2020, p. 20) frontier. They are said to be: "riddled with 'knowledge gaps' and…under-researched relative to terrestrial space.…Only 0.04 to 4 per cent of total research dollars worldwide goes to ocean science, a pattern that has led humanity to know more about Mars than about Earth's oceans" (Fawcett et al., 2023, p. 70).

This contribution is interested in how global imaginaries, such as the UN OD vision travels, materialises, interacts with national, regional, and local governance spaces, and as such ultimately has an impact on a sea like the North Sea—one of the most used seas of the world (Couling & Hein, 2020; Jongman, 2022). The question arises as to how the UN OD vision would influence ocean governance. How do ocean governance events (OGEs) at different scales refer to this vision? Would this vision lead to an actual impact? Answering these questions necessitated doing event ethnography: "The sheer diversity of events is not a problem that researchers need to 'solve' with precise schemas and categories; rather it is a methodological opportunity for researchers who are open to thinking in and through events" (Koch, 2023, p. 5).

The following section outlines the research design, which is conceptualised at the intersection of geographies of knowledge and ethics of care. A threefold analytical lens is proposed, focusing on the temporal, spatial, and normative dimensions of performing OGEs. The methods used mark an extended event ethnography (EEE), which makes it possible to diachronically trace the concentric and ongoing spatial, temporal, and normative lives of OGEs.

Section 3 unpacks the extended normativities in three steps: (1) how the UN's metaphorical vision is *shifted* into scenarios; (2) how these are *interlinked* to precise projects; and (3) how these projects spatially and temporally *impact* governance itself, the physical materiality of the North Sea, and the senses of place of people who live with the sea.

Before concluding, the discussion part ties back to the conceptual framework and the approach of EEE to highlight (a) how multiple OGEs weave a polycentric web of North Sea governance and (b) how the way OGEs perform ocean knowledge-production might lead into a knowledge fix.

2. Research Design

The aim of this contribution is to understand how OGEs perform North Sea governance and how normativities—values, visions, scenarios, strategies, care-relations, etc.—are negotiated within an OGE and extend beyond spatial and temporal settings of an OGE itself.

2.1. Conceptual Framework

The notion of governance is "both a contested concept and an increasingly empirical concern" (Glückler et al., 2020, p. 1). The governing of oceans, seas, and waters (hereinafter referred to as "ocean governance" as this is the term normally used in this field) is a contextual (Partelow et al., 2023, p. 2), relational (Glückler et al., 2020, p. 5), and material-nonmaterial (Partelow et al., 2023, p. 2) phenomenon. It presents a "wicked problem…in the face of the growing ecological crises in the Anthropocene" (Johnson & Braverman, 2020,

p. 19). Therefore, governing the oceans is governing the climate (Partelow et al., 2023, p. 15). The "fluidity of land and sea requires a reconsideration of the existing institutions, temporal frameworks, and categories with which we engage the oceans, illuminating our responsibilities toward these spaces and to what lies and lives within them" (Johnson & Braverman, 2020, p. 19). Such responsibilities entail ethical qualities of caring, such as attentiveness, responsibility, competence, and responsiveness (Tronto, 2013, pp. 34–35).

Competence itself cannot be measured or experienced; it is merely the result of competent action, known as *performance* (North et al., 2013, p. 43). These actions can be experienced, described, and unpacked with an emphasis on the temporal, spatial, and normative dimensions, as shown by the following conceptual structure.

2.1.1. Temporal Dimension

The temporal dimension unfolds in two major strands: The chronological order of events indicates when events are taking place and allows a diachronic perspective on past, present, and future events. It is particularly interesting to analyse so-called "futuring practices" (Hulme, 2022, p. 229) in ocean governance, which influence both present and future events and politics. Hulme (2022, p. 195) argues that "climate governance has become much more than governing 'the climate', narrowly defined. Rather than denoting a specific new set of political institutions or processes, governing climate has become a synecdoche for governing the future." Hulme (2022, p. 229) goes on to identify "four *futuring practices* as applied to the climatic future, four creative ways in which groups of people apply their imaginative faculties and cultural resources to engage the future." Two are considered "realist techniques [which are] scenario planning and scientific modelling"; the other two techniques are "metaphors and creative fiction…speculative practices" (Hulme, 2022, p. 229). The present analysis takes up *metaphors* which are "powerful linguistic and visual devices for guiding human cognition, emotion, and behaviour [that] help us to grasp something new or unfamiliar by associating it with something more familiar and everyday" (Hulme, 2022, p. 235), and *scenario planning*, which "seeks to develop plausible and rational accounts of what the climatic future might look like" (Hulme, 2022, p. 229).

Furthermore, analysing the repetitive character of these OGEs allows to elucidate the relational character of these performances: Applying Tronto's (2013) four phases of care offers thoughtful tools to unravel complex care relations, their respective ethical qualities, and their expressions as practices of care. These four phases are attentiveness (i.e., caring about), responsibility (i.e., caring for), competence (i.e., care giving), and responsiveness (i.e., care receiving; Tronto, 2013, pp. 34–35). The first phase of care, attentiveness, forces us to dwell on the notion of caring about, a "suspension of one's self-interest, and a capacity genuinely to look from the perspective of the one in need" (Tronto, 2013, p. 34). As soon as these needs are "identified, someone or some group has to take the burden of meeting those needs. This is responsibility" (Tronto, 2013, p. 34). However, "the actual work of care…requires the moral quality of competence" (Tronto, 2013, p. 35). Caring requires an ability to listen to those being cared for: "Observing that response, and making judgements about it (for example, whether the care given was sufficient, successful, or complete?) requires the moral quality of responsiveness" (Tronto, 2013, p. 35).

2.1.2. Spatial Dimension

Governing the seas and oceans requires multi-sited and tremendously powerful practice across all political *scales*. At the global level, the UN OD acknowledges—cares about—that the world's seas and oceans are under threat (e.g., see SDG 14 "life below water"; The Global Goals, n.d.). The OD's vision, mission, seven goals, and 10 challenges (German Committee of the UN Ocean Decade, n.d.) aim to "take on the burden of meeting those needs" (Tronto, 2013, p. 34). In other words, the global directive calls for responsibly governing the oceans to enhance knowledge-production practices and achieve e.g., "healthy and resilient ocean" (German Committee of the UN Ocean Decade, n.d.). However, such knowledge is not produced at the global level or by the global institutions. Rather, responsibility is transferred to other institutional levels (especially political institutions and scientific communities) at different scales (i.e., supra, [inter-]national, [inter-]regional, and local). For a "geographer of knowledge…[it is therefore of interest to] explain the spatially differentiated ways in which knowledge claims emerge in places, how they become institutionalised, and how they travel through social and cultural worlds." (Hulme, 2022, p. XXIX)

Hulme (2022, p. 223) makes a valid point by suggesting that "a more plausible metaphor for climate governance is that of a clumsy multi-layered mashwork of overlapping and competing competences and interests." Therefore, it is of uttermost importance to scrutinise how these competences and interests perform responsiveness. In this light, OGEs are key to investigating as they are both organised *spaces* that shape polycentric governance (Hulme, 2022, p. 210) and *places* of (re)producing knowledge.

2.1.3. Normative Dimension

OGEs perform ocean governance and knowledge-building; they make it tangible and haptic in an "orchestrated" (Collaborative Event Ethnography, n.d.-a) way. Hulme's (2022) notion of climate imaginaries helps to unpack how the global UN OD imaginary influences OGEs and, in this case, how it interacts with national, regional, and local spaces of North Sea governance:

> *Climate imaginaries* can be understood as collectively shared sets of beliefs, narratives, technologies, discourses, and practices that condition what climate futures are thought of as possible, likely, or (un)desirable. Climate imaginaries envision not only possible climate futures, brought to life through different futuring practices. They are also suggestive of ways to deliver such futures. For this reason, all imaginaries are politically charged. (Hulme, 2022, p. 230)

Together with Tronto's approach to ethics of care, three normative modes of performance can be identified: At these events, the organisers performatively shifted the UN OD vision from "speculative" to "plausible" (Hulme, 2022, pp. 229–237). Concrete projects and practices were then performatively interlinked with a plausible scenario by other state and non-state actors. Finally, these specific projects led to concrete impacts on governance (e.g., policy strategies), polycentric knowledge production (Digital Twins, Ocean Literacy, etc.), the physical materiality of the North Sea (e.g., technological interventions), and the senses of place of people living with the sea:

> When considering *senses*, we mean the myriad ways in which people understand, interpret and interface with the world, which involve multiple sensibilities, physical senses and embodied identities. Changing *places* refers to the new patterns of socio-spatial relations and experiences of "placeness" that surface or are resignified, rescaled or revalued. (Raymond et al., 2021, p. 5)

Raymond et al. (2021, p. 9) argue that "innovations in technology and governance (law, policy, coalition-building) can also radically change the way in which we understand and negotiate senses of place." Knowledge as imagined and negotiated ultimately has a performative impact on senses of place. Indeed, "legal transformations, such as the proclamation of new nature protection directives across the European Union, challenge us to rethink the relationships between people and place" (Raymond et al., 2021, p. 9). Here, the idea of value must be viewed through the lens of geographies of knowledge and ethics of care. How is the North Sea valued by state and non-state actors? How do these perspectives shape the countless senses of place around and across the North Sea? Which perspectives are valued by OGEs? Answering these questions requires attending to how ocean governance is *performed* by different actors at OGEs.

2.2. Doing Research

Event ethnography is a well-established empirical method in human geography and has been widely used to experience, describe, and understand the complexity of environmental governance (Brosius & Campbell, 2010; Campbell et al., 2014; Corson et al., 2019; Gray et al., 2019; Koch, 2023). Gray et al. (2019) pioneered the method in their research on the 2008 World Conservation Congress in Barcelona. They "approached the large international event as a field site—a place where ideas about environmental conservation are circulated" (Gray et al., 2019, p. 1) and subsequently founded the collaborative event ethnography project (Collaborative Event Ethnography, n.d.-b), which calls on ethnographers to attend to:

> The meanings people attribute to their social and political realities....International meetings have mostly been studied by political scientists, often with a focus on outcomes. We are equally interested in the *processes* through which outcomes are achieved and the insights these provide into how global environmental governance is accomplished. (Collaborative Event Ethnography, n.d.-a, emphasis added)

2.2.1. Methods: Towards an EEE

Doing event ethnography over a four-year period (2021–2024) helped to understand how events do not necessarily stop at their supposed temporal and spatial end. The UN OD offers an illustrative example. It is a 10-year event whose influence will likely extend far into the future to shape the seas and oceans worldwide. Careful examination of the events' extended temporalities, spatialities, and normativities requires a unique methodical approach: In accordance with the threefold conceptual framework of the temporal, spatial, and normative dimensions of OGEs, this contribution presents the methodical approach of an EEE.

What makes this approach stand out is that, in addition to attending OGEs and doing classical event ethnography, gatekeepers and interviewees were also visited afterwards in their home region. This provided insights into how these state and non-state stakeholders are embedded in their national, regional, and local governance spaces, as well as how diverse knowledge about the North Sea is produced in different places:

> The essence of multi-sited research is to follow people, connections, associations, and relationships across space....Research design proceeds by a series of juxtapositions in which the global is collapsed into and made an integral part of parallel, related local situations, rather than something monolithic or external to them. In terms of method, multi-sited ethnography involves a spatially dispersed field

> through which the ethnographer moves—actually, via sojourns in two or more places, or conceptually, by means of techniques of juxtaposition of data. (Falzon, 2009, pp. 1–2)

In so doing, the aim was both to describe in an event ethnographic manner (Creswell, 2016, p. 6) how OGEs are being performed and how these perform ocean governance over time and space; and to explain the process (Creswell, 2016, p. 5) of how the global UN OD narratives materialise within OGEs, and interact with (supra-)national, (inter-)regional and local governance spaces within the North Sea region. Therefore, the data gathered from event ethnography and related field research have been coded in a grounded theory way (Section 2.2.2).

Below is an overview of how I implemented EEE and, consequently, how the approach applied leads to uncovering three spheres of how OGEs are performed towards their extended temporalities, spatialities, and normativities (Figure 1).

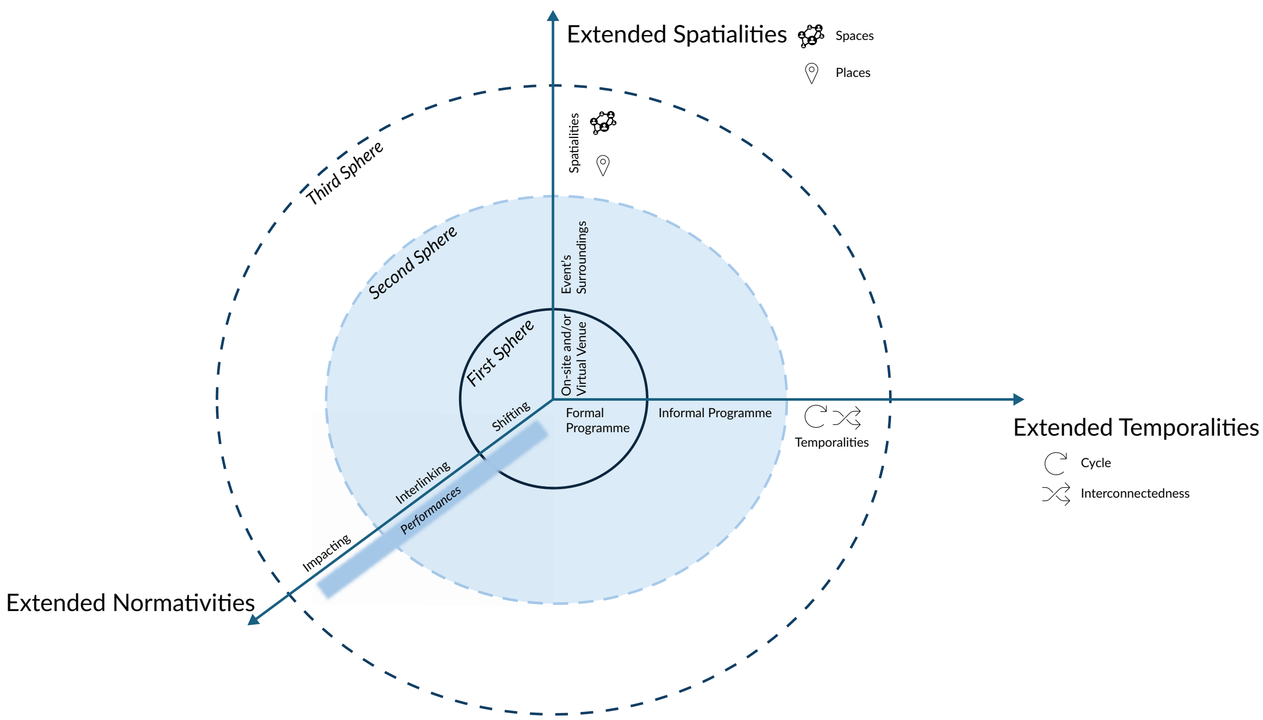

Figure 1. Towards an EEE.

In order to experience, describe, and understand how OGEs are performed and how global imaginaries materialise and ultimately impact governance spaces from different scales, I applied different sets of methods according to the different spheres of OGEs.

2.2.1.1. The Core of an OGE—The 1st Sphere

The first sphere allows an event ethnography which combines "participant observation…and many other forms of observation [such as photo documentation] to understand the world through social relations" (Koch, 2023, p. 2). As Koch (2023, p. 8) explains, "textual materials play an important role in linking events across time, and indeed, the repetitive approach…[is] useful for understanding how the field [is] changing."

All the attended conferences emphasised the UN OD vision, missions, and goals, as well as the myriad technological imaginaries of how the North Sea mattered to countless actors at all levels of politics, economics, science, and arts. Therefore, collecting and afterwards analysing all kinds of flyers, information brochures, stickers, or event merchandise was another pillar in the methodical spectrum.

OGEs occur at a specific time and are fixed by a formal programme. This schedule—shared with all participants, the media, and online—provides information about when and where discussions, keynotes, and workshops will take place and who will be involved. Specific topics are focused on in moderated discussions, workshops, and keynote speeches. Their results are of interest not only to the participants, but also to the organisers.

The spatial core of every OGE is its *venue*, whether on-site, virtual, or hybrid. On-site events are usually hosted in large event complexes, such as exhibition centres, universities, or cultural facilities (e.g., the concert hall in Bruges for the North Sea Conference 2022). Sessions may be more hybrid, and speakers and participants can often join via links. Apropos, the question of access is crucial. I attended OGEs free of charge; however, on the registration forms, I had to enter an organisational affiliation (in my case, the university). Most university attendees seemed to fall into two groups: project-based scientific partners (e.g., Horizon Europe projects) and scientific experts (e.g., as keynote speakers). All OGE participants fulfil a (state or non-state) function, indicating how access is planned.

On a normative level, I observed how the OD vision became a common mantra, recited by moderators at the beginning and end of each session or discussion (research notes, 2021, 2022, 2023). Experts in politics and science referred to the vision as a confirmation, while other participants (e.g., representatives from NGOs and artists) saw it more as a pledge. The organisers are the key actors guiding the programme, but not the only actors within this first sphere. Two other groups include the starring actors (mostly experts in politics, economy, science, and arts) who are invited to present their perspectives, and the listening actors. The starring actors play an important role in shifting "futuring practices" (Hulme, 2022, p. 229), and the quality of their performance is determined by using their expertise to confirm the shift (Section 3.1).

2.2.1.2. The Surroundings of OGEs—The 2nd Sphere

An event's second sphere includes everything that takes place beyond the official programme, where the variables of time and space soften. All people participating in an event—whether it be organisers, starring actors, or listening actors—fulfil the role of participants. And as such, all participants are key actors (research notes, 2021, 2022). Or in other words, this event's second sphere enables all different participants to speak, express their ideas and values, and to interlink their ideas and values in broader ways with plausible scenarios, here with the EU's "sustainable blue economy" scenario (European Commission, 2021a).

Regarding the temporal dimension, there are also informal parts of an event—spontaneous moments that are not listed on the official programme (e.g., when participants spontaneously have coffee, lunch, or dinner together). Post-events (see also European Commission, 2021b, p. 4) can be informal as well. Thematic sub-events organised by participating institutions and actors often occur around the formal event to enable networking and information exchange. This informal setting allows qualitative interviews to be conducted in addition to participant observations, photo documentations, and the collection of event materials.

The event's spatial surroundings include everything that can be accessed spontaneously. At the event, people take the same travel routes, creating opportunities to exchange and work on ideas. Participants will often walk together as they move between buildings or continue their discussions informally at a nearby restaurant or café. Driven by the phenomenological interest as a human geographer, I came across a sentence that other event participants (state and non-state actors) mentioned to me several times in different event settings: "You should go there" (research notes, 2021, 2022, 2023). The gist of what they were saying was that I should visit several places that they considered to be of high relevance to the topic at stake: the North Sea governance and respective local projects that are interlinked to OGEs' scenarios and strategies (Section 3.2).

2.2.1.3. Related Spaces and Places to OGEs—The 3rd Sphere

Taking the sentence "you should go there" to heart, I indeed travelled to certain cities, ports, beaches, and numerous locations and other events (e.g., World Port Days 2021, etc.) by train, by ship, by car, hiking, and cycling to meet other people. As such, it was possible to encounter different perspectives and practices of how the North Sea was governed in these places. Doing "go-alongs" (Sommer & Töppel, 2021, p. 206) and conducting additional follow-up interviews provided insights into how these state and non-state stakeholders are embedded in their national, regional, and local governance spaces as well as how diverse knowledge about the North Sea is produced in different places.

Furthermore, this methodical approach allows us to read temporalities beyond formal and informal settings. Events demonstrate a *cyclical* character and temporal *interconnectedness* to other events on different scales. Their nuances change as narratives, visions, and strategies intensify over the years, across events, and scales (Section 3.3).

2.2.2. Data and Mode of Analysis

The data were gathered from five extended field research stays (between 2021 and 2024) as well as multiple OGEs that I attended between 2021 and 2023 to meet participants, who were initially perceived as gatekeepers at these OGEs, and visit relevant places, people, projects, and other events (Table 1).

Due to the Covid-19 pandemic, I followed some OGEs virtually (i.e., European Maritime Day [EMD] 2021 in Den Helder, the Netherlands, and NTNU Ocean Week 2021 at the Norwegian University of Science and Technology in Trondheim) and The North Sea Conference 2022 in Bruges, Belgium, in person (Figure 2).

Doing field research was a logical consequence of the desire to learn more about how ocean governance is performed around the North Sea by the actors involved in these events, and how the global vision of the UN is likely to shape and interact with local governance spaces.

The data has been categorised into three sections as data from (1) the event's core, (2) the event's surroundings, and (3) its related fields. The event's core included the official information from organisers (e.g., the programme), the merchandise (the "classy" jute bags, pens, flyers, information brochures, stickers, notebooks, and name badges with logos and slogans), notes from the sessions, photos, and the event's website. Virtual events lacked material content but did produce a flood of emails to be analysed. The event's

Table 1. Overview of research.

Ocean governance event/field research	When	Where	Why
EMD 2021	2021	Online, Den Helder, the Netherlands	Annual, supranational EU level of OGE, focusing on the EU basins, located at the North Sea
NTNU Ocean Week	2021	Online, Trondheim, Norway	Annual, non-EU and national level of OGE, focusing on national waters, including the North Sea
Field research 2021a	2021 (7 weeks)	The Netherlands, Germany, Norway	Follow-up meetings after events, regional and local ocean governance
Field research 2021b	2021 (1 week)	The Netherlands	Follow-up meetings after events and field research 2021a, regional and local governance
The North Sea Conference 2022	2022	Bruges, Belgium	(Bi-)annual, interregional EU level of OGE, focusing on the North Sea
Field research 2022	2022 (3 weeks)	The Netherlands, Germany, Denmark	Follow-up meetings after events and field research 2021a, 2021b, regional and local ocean governance
EMD 2023	2023	Online, Brest, France	Comparing with EMD 2021 regarding intensifications and shifts of imaginaries
NTNU Ocean Week	2023	Online, Trondheim, Norway	Comparing with NTNU Ocean Week 2021 regarding intensifications and shifts of imaginaries
Field research 2023	2023 (2 weeks)	Norway	Regional and local ocean governance
Field research 2024	2024 (2 days)	Amsterdam	Regional and local ocean governance

Figure 2. The main stage at The North Sea Conference 2022 in Bruges, Belgium. Note: Own photo.

surroundings included research notes, memory minutes of informal conversations or notes taken during events, and photo-documentation. The event website was also checked for both on-site and virtual cases. Related fields contained data from follow-up meetings, interviews, and "go-alongs" (Sommer & Töppel, 2021, p. 206) with people I met at events. The fact that we stayed in contact over the years made it possible to text, chat, or meet whenever it was necessary (e.g., Fire of Freemantle Highway, 2023, the test drilling off Borkum, Germany, etc.).

The data was analysed based on the reflexive grounded theory (Breuer et al., 2019) according to the three-dimensional approach of the conceptual framework and the methodical approach of an EEE. This made it possible to show how OGEs unfold three concentric spheres of performing North Sea governance alongside extended temporalities, spatialities, and normativities. The following section elucidates how the UN OD vision normatively extends throughout these three OGE's spheres.

From a diachronic perspective, the very first OGE I attended—the EMD 2021—is used as the main case study and as a reference event for analysing the inherent normativity of the UN OD imaginary and how it resonates within the North Sea governance. For context: the EMD has taken place annually since 2008, six times in riparian states along the North Sea (European Commission, n.d.-c):

> The European Maritime Day (EMD) is the annual EU conference meeting point on maritime affairs and sustainable blue growth, and the place where "Ocean Leaders Meet" as the slogan goes. The European Commission, together with the EMD city and ministry/region, organise the conference. It is also a public event reaching out to young people and citizens across Europe through local events under the "EMD in my Country" label, organised by local stakeholders. (European Commission, n.d.-c)

The other events will be considered in chronological (e.g., EMD 2021, The North Sea Conference 2022, etc.), cyclical (EMD 2021 and EMD 2023), and interconnected (EMD 2021 and the Fifth One Ocean Summit 2022) terms.

3. Extended Normativities: Performances From Imaginaries to Impact

In the following, it will be shown how normativities extend through OGEs: Organisers performatively *shifted* the UN OD vision from "speculative" to "plausible" (Hulme, 2022, pp. 229–237). Concrete projects and practices were then performatively *interlinked with* the plausible scenario by other state and non-state actors. Finally, these concrete projects led to specific *impacts* on governance spaces across scale (e.g., policy strategies), polycentric knowledge production (digital twins, ocean literacy, etc.), the physical materiality of the North Sea (e.g., technological interventions), and the senses of place of people living with the sea (Figure 3).

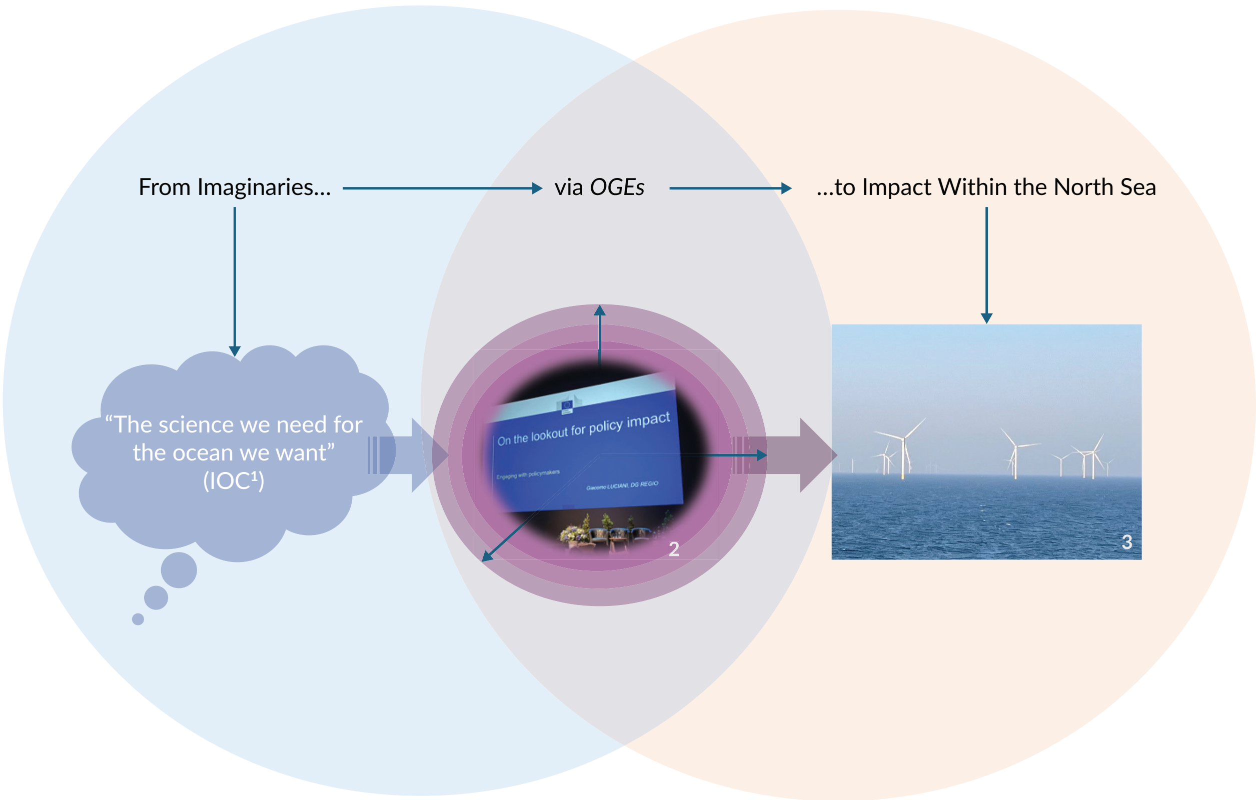

Figure 3. From imaginary to impact. Notes: (1) Intergovernmental Oceanographic Commission, n.d.-a; (2) own photo: The main stage at The North Sea Conference 2022 in Bruges, Belgium; and (3) own photo: The North Sea pictured from a ferry heading to Ijmuiden, the Netherlands, 2024.

3.1. Shifting

The UN OD vision “The science we need for the ocean we want” (Intergovernmental Oceanographic Commission, n.d.-a) entered the event’s first sphere through the formal programme and was often repeated by the formal moderators. Their work created a common narrative around the UN OD mission of “transformative ocean science solutions for sustainable development, connecting people and our ocean” (Intergovernmental Oceanographic Commission, n.d.-b). The UN formulated seven goals for the ocean “we” want. As this contribution focuses on investigating complex care relations in ocean governance, the following focuses on the second goal: how a “healthy and resilient ocean” (German Committee of the UN Ocean Decade, n.d.) is being performed at OGEs:

> Many of our activities on land and in the sea affect biodiversity and marine habitats. Added to this are the effects of climate change. We need to better understand what this means for the ecosystems as a whole through targeted research in order to use coastal and marine habitats sustainably and protect or restore them effectively. (German Committee of the UN Ocean Decade, n.d.).

At the EMD 2021, formal sessions aimed to connect to the UN’s vision-mission, as seen in the description of an EU policy session on “MARINE AND FRESHWATER RESEARCH & INNOVATION” (The EMD 2021 programme; European Commission, 2021b, p. 2):

> *This session will shed light on the expected marine and aquatic research and innovation in the Horizon Europe work programme. The discussion will explore what kind of research we need in the next years and how the proposed mission on healthy ocean, seas and waters will complement this research towards impactful policy-making. The session will also touch upon how EU research fits in the global spectrum through the UN Decade of ocean science.* (European Commission, 2021b, p.2)

This session blurb represents the performative, discursive work of connecting an EU policy session to the UN OD and its goal of "*healthy ocean, seas and waters*" (European Commission, 2021b, p. 2). This figurative expression can be read as a metaphor of "futuring practices" (Hulme, 2022, pp. 229–238). It "provoke[s] more imaginative ways of thinking about" (Hulme, 2022, p. 235) how a healthy North Sea can be achieved. For the UN OD, healthy oceans are "where marine ecosystems are understood, protected, restored and managed appropriately" (German Committee of the UN Ocean Decade, n.d.). Restoration is another metaphor in the context of climate imaginary: it "implies the possibility of reverting an ecosystem to some prior, 'natural' condition" (Hulme, 2022, p. 236) without specifying how the ecosystem would be restored and to which preexisting state. Would a restoration of the North Sea even be possible, whose knowledge would be considered, and what governance structures would be negotiated and performed? As such, this metaphor can be categorised as speculative:

> The desire to master and materially redesign the world according to human *need or want*—and the belief that it is possible to do so—is longstanding....This technoclimate imaginary can embrace a variety of geoengineering technologies that seek either to cool the planet or to protect human societies from extreme future climate scenarios. All of them, however, should be considered speculative. In this sense these imagined geo-technologies are another speculative futuring practice. (Hulme, 2022, p. 242, emphasis added)

The EMD 2021 was one of the first events to take place during the UN Ocean Decade. Its tagline was "towards a sustainable blue economy and ocean literacy for all" (European Commission, 2021c). And so, the discursive shift took place within the core sphere, as reflected in policy sessions and the keynote title of "*A NEW APPROACH FOR A SUSTAINABLE BLUE ECONOMY*" (European Commission, 2021b, p. 1) by Virginijus Sinkevičius, the EU Commissioner for Environment, Oceans and Fisheries. Every speech, discussion, or workshop was guided by this EMD's motto, which shifts speculative metaphors of healthy oceans into a plausible scenario—sustainable blue economy (research notes, 2021; Figure 4).

The scenario planning of a "*SUSTAINABLE BLUE ECONOMY*" (European Commission, 2021b, p. 1) was also part of the supranational EU's Green Deal (legislation period 2019–2024; European Commission, n.d.-d). This highlighted how "Europe's seas, oceans, and environment are a source of natural and economic wealth for Europe. We must preserve and protect them to ensure that they continue sustaining us in the future" (European Commission, n.d.-d). The EU's Green Deal was also a planned scenario, a "scenario resulted from concerted multi-lateral policy initiatives" (Hulme, 2022, p. 233; see also Bazilian et al., 2020).

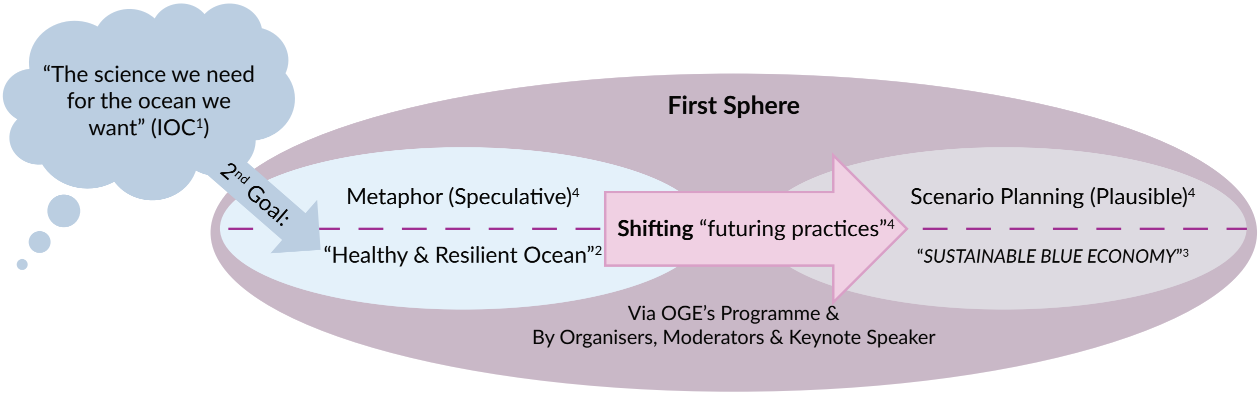

Figure 4. Performing the shift. Notes: (1) Intergovernmental Oceanographic Commission, n.d.-a; (2) Intergovernmental Oceanographic Commission, n.d.-b; (3) European Commission, 2021b; and (4) Hulme, 2022, pp. 229–238.

3.2. Interlinking

In 2021, a few days before the EMD 2021, the European Commission (2021a, p. 1) published "a new approach for a sustainable blue economy in the EU. Transforming the EU's Blue Economy for a Sustainable Future." This document addressed the "need to shift the focus from *'blue growth'* to a *sustainable* blue economy" (European Commission, 2021a, p. 2). This "*SUSTAINABLE BLUE ECONOMY*" (European Commission, 2021b) was imagined and discussed during interviews with different EMD 2021 participants, including as an "energy transition" (entrepreneur for tidal energy; research notes, 2021), a need to "mak[e] European food systems fair, healthy, and environmental friendly" (programme manager of animal welfare organisation; research notes, 2021), to create a "marine spatial plan to ensure the functioning of the many different activities in our borders" (representative of the Belgian Department of Marine Environment, research notes; 2021), and as "clean shipping" (project manager in a Dutch NGO, research notes; 2021). These statements were often followed by the admission that more information about ocean systems and social behaviour was needed to put these ideas into practice.

In view of the twofold motto of the EMD 2021, the first part emphasised the shift towards a concrete scenario planning, and the second part introduced the strategy "ocean literacy" to fulfil this shift. The term ocean literacy has washed up globally as part of the UN OD. Literacy denotes the "ability to 'read' a specified subject or medium; competence or knowledge in a particular area" (Literacy, n.d.). The term was introduced "in 2004 by a group of ocean scientists and education professionals in the USA, who recognised a lack of ocean-related subjects in formal education" (McKinley et al., 2023, p. 1). Approximately 100 participants at an online conference in October 2004 explicitly drew attention to "the need for ocean literacy, the definition of ocean literacy, identification of key ocean concepts…and alignment of these concepts to the National Science Education Standards" (Cava et al., 2005, p. 4). These scholars formulated the following definition in their workshop summaries (Cava et al., 2005):

> Ocean literacy is an understanding of the ocean's influence on you and your influence on the ocean. An ocean-literate person:
>
> - understands the fundamental concepts about the functioning of the ocean;

- can communicate about the ocean in a meaningful way; and
- is able to make informed and responsible decisions regarding the ocean and its resources. (Cava et al., 2005, p. 5)

Subsequently, the concept transcended both national and institutional boundaries. Ocean literacy is now understood as a global concept that can be "a mechanism for change" (McKinley et al., 2023, p. 1). The EMD 2021 went one step further and put this into practice in an event announced as a post-event to the official programme:

> OCEAN LITERACY FESTIVAL–CELEBRATING THE ATLANTIC OCEAN AND THE NORTH SEA
>
> A *post EMD* special event, organised by the EU4Ocean coalition (EU4Ocean Platform, Youth4Ocean Forum and EU Network of Blue Schools) addressed to families, young people, pupils, teachers, marine science educators, researchers, policy makers, entrepreneurs and other professionals.
>
> The festival will showcase diverse virtual events, activities and digital educational content from the European countries bordering the Atlantic Ocean and the North Sea.
>
> Main themes:
>
> - Food from the Ocean
> - Ocean and Climate
> - Healthy Oceans" (European Commission, 2021b, p. 4, emphasis added)

Therefore, the scenario planning for a "*SUSTAINABLE BLUE ECONOMY*" (European Commission, 2021b, p. 1) was interlinked with ocean literacy as the main strategy and its various projects, so that meaning and values were eventually ascribed (Figure 5).

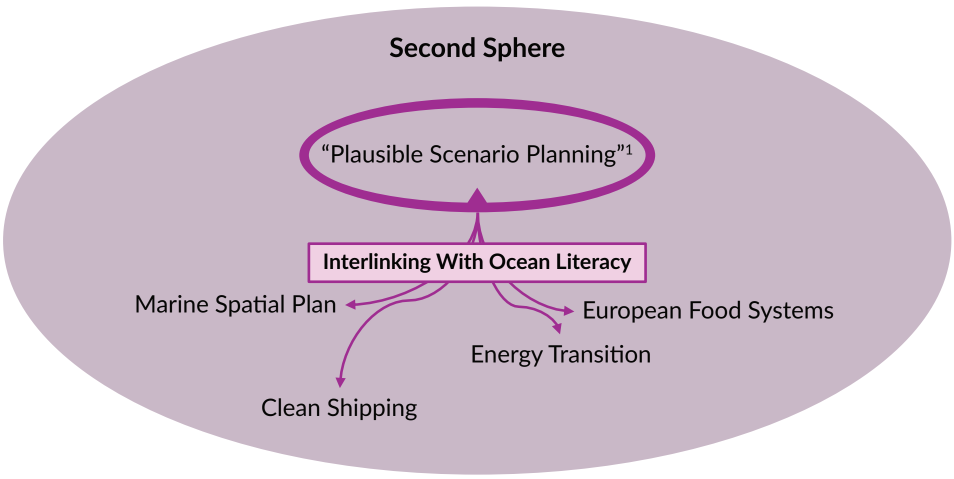

Figure 5. Interlinking scenarios and strategies. Note: (1) Hulme, 2022, p.229.

Ocean literacy is no longer a "knowledge-centric model [but] one which draws on and fosters active participation, connection, and engagement" (McKinley et al., 2023, p. 2). The EMD 2021 Ocean Literacy Festival emphasised that participation was encouraged:

> The aim of the Festival is to raise awareness of the importance of the ocean, marine resources and ocean science for the blue economy in the region. The festival activities are aimed at families, young people, pupils, teachers, marine science educators, researchers, entrepreneurs, policy makers, and other professionals. (European Commission, 2021d)

However, interviews conducted at the EMD 2021 revealed that some participants understood participation to mean *taking part in* decision-making processes to protect marine ecosystems, rather than simply *being aware* that oceans harbour resources on which economies are based. This raises a broader ethical question about who is permitted to participate in decision-making processes and at what age. Whose competence counts? A representative of Youth Environment Europe, section Arctic and Ocean, recalled during an interview that young people are often excluded from political decision-making processes with long-reaching consequences, in temporal, spatial, and normative terms (research notes, 2021).

3.3. Impacting

The new normativity in ocean governance involves fostering ocean knowledge, and OGEs serve as places to (re)produce such knowledge. Their normative impact extends outward to change other senses of place and (re)produce organised spaces, thereby shaping polycentric governance (Figure 6).

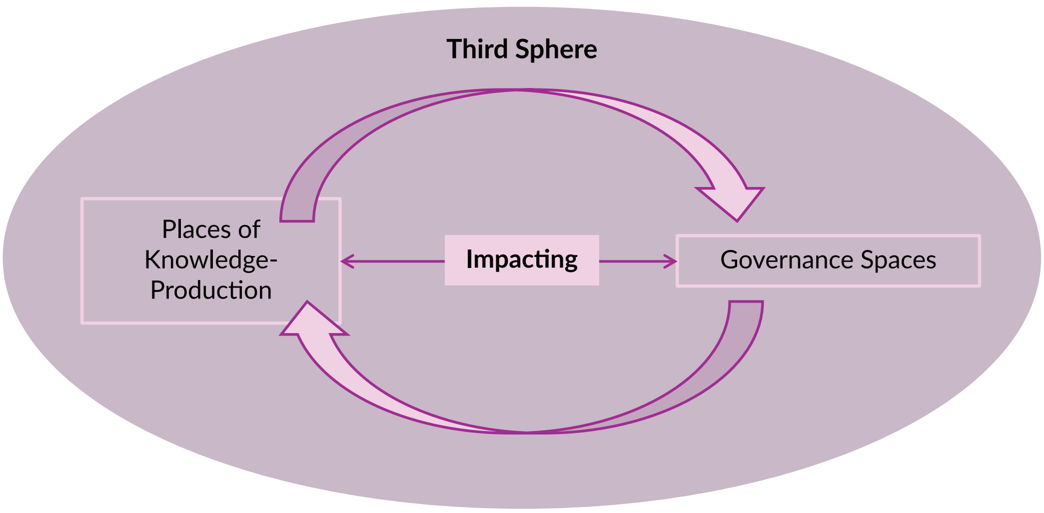

Figure 6. Impacting governance spaces and places of knowledge-production (vice versa).

3.3.1. Places

The host cities of the EMD, "the place where 'Ocean Leaders Meet'" (European Commission, n.d.-c), in 2021 and 2023 were Den Helder, the Netherlands and Brest, France. The EMD takes place every year at or near a European coast, drawing attention to the host city, its region, and the adjacent sea. However, it is not just about governing the North Sea or the English Channel, but also about ocean-related technology and innovation.

The water bodies are a projection surface for the UN OD imaginary, which merges with other imaginaries, principally with the national imaginary of the event's host. A global imaginary, such as the UN OD, aims to make the EMDs (even more) specific and grounded:

> Climate imaginaries are created through social processes that *meld* together stories, ideologies, values, institutions, and technologies. They shape the practices, lived experiences, and identities of different social groups and provide a collective orientation towards the climatic future. Some imaginaries instinctively default to the global; others may be grounded in specific places. Geography matters. (Hulme, 2022, p. 244, emphasis added)

A cyclical perspective allows us to compare the EMD 2021 with the EMD 2023 to understand how and which imaginaries have merged and which nuances have changed or intensified. The organisers of the EMD 2021 in Den Helder came from the supranational level (European Commission), the national level (Ministry of Infrastructure and Water Management of the Netherlands), the regional level (Provincie Noord-Holland), and the local level (Gemeente Den Helder). Many participants registered for the event also came from the Netherlands. Numerous port companies were represented, as were shipping agencies, energy companies, fishing companies, algae producers, stakeholders of the offshore wind farm sector, companies that extract and use sand, various universities, shipbuilders, software engineers, biologists, and artists (research notes, 2021).

The EMD 2021 focused on Dutch technological know-how and how Dutch actors imagine ocean knowledge. Multiple references were made to Dutch strategy and policy papers as well as legal frameworks throughout the EMD's programme. One pitch session was even titled "*Ocean Literacy and Soft Power: Stories from the Netherlands*" (European Commission, 2021b, p. 3). This focus on the Netherlands was also confirmed by the interviews (with representatives of shipping agencies, NGOs, energy companies, etc.) and field research (especially in Germany, 2021 and 2022, and the Netherlands, 2021 and 2022). The EMD 2023 was located in Brest, France, and "organised by the European Commission, the City of Brest, the Secretariat General for the Sea and the Region of Bretagne" (Mercator Ocean International, n.d.). Again, most registered participants were French, and many scientific institutions from Brittany (e.g., European Institute for Marine Studies, UBO Brest, Ifremer, Campus mondial de la mer, etc.) presented innovations from their region (research notes, 2023).

The temporal lens of the interconnectedness of the events reveals an intensification of "The science we need" (Intergovernmental Oceanographic Commission, n.d.-a) that can be traced back to the Fifth One Ocean Summit 2022—which took place between EMD 2021 and EMD 2023—and was also held in Brest. The organisation of the Fifth One Ocean Summit 2022 was "in the context of the French Presidency of the Council of the European Union and with the support of the United Nations" (One Planet Summit, 2022a). The announcement of the European Digital Twin of the Ocean (DTO; von der Leyen, 2022) by the president of the European Commission, Ursula von der Leyen, marked a turning point in the management of European waters. The event concluded with the "Brest Commitments for the Oceans" (One Planet Summit, 2022a):

> Place the ocean at the top of the global political agenda....To decide, one must first understand. The digital revolution is an opportunity to build an integrated model of the oceans, covering physics, chemistry, marine life and human activities. This "Digital Twin" initiative will inform political decisions

> and track their effects, enable the marine economy to develop with respect for ecosystems and fuel dialogue with stakeholders and the public. The European Union has pledged to produce a "Digital Twin of the Ocean" to gather knowledge and test scenarios for action, supporting European blue growth and global governance. UNESCO has pledged to ensure at least 80% of the sea bed is mapped by 2030. (One Planet Summit, 2022b, p. 3)

The intensification of the "science we need" (Intergovernmental Oceanographic Commission, n.d.-a) came with the announcement of the European DTO. During the EMD 2023, certain event strands continued to focus on modelling and predicting the climate, ocean systems, and all aspects related to marine resources (research notes, 2023). Pledges made by different institutions set the tone for the future of European waters through the EU's calls for "making ocean sustainability a reality by 2030" (European Commission, n.d.-a) and a "European Ocean Pact at the third UN Ocean Conference" (European Commission, 2025), which will have an impact on how people coexist with the seas.

3.3.2. Spaces

The attendees of the EMDs and other OGEs (e.g., at the EU's interregional level: Interreg's North Sea Conference, 2022; and at the national, non-EU level: NTNU Ocean Weeks 2021 and 2023) were polycentrically interconnected. Often, the participants from previous events were met, including national EU advisors at supranational and interregional OGEs, and NGO representatives and scientists at supra and national OGEs (research notes, 2022, 2023). Polycentric thinking "recognises that multiple semi-autonomous authorities are active at many different scales. These nonstate authorities operate above, below, and beyond the state" (Hulme, 2022, pp. 210–211).

The different OGEs produce "organized spaces and knowledge [which] are both conditions as well as consequences of th[is] governance process" (Glückler et al., 2020, p. 1). The very first EMD "included a stakeholder conference in Brussels 19–20 May [2008], which focused on the regional approach to the implementation of Maritime Policy, and dialogue with stakeholders" (European Commission, n.d.-c). This set the conditions and, over the years, the EMDs "pay[ed] tribute to 'maritime Europe' and put all maritime sectors and activities in the spotlight" (European Commission, n.d.-b). The EMD's polycentristic character around the EU's sustainable blue economy will change the physicality of the North Sea and how people live with the sea. This resonates with Hulme's (2022) notion that:

> The idea of climate is performative, it has effects in the real world. How one comes to know climate—and the account one gives of its changes—is *never politically neutral nor without effect* on the social ordering of today's and tomorrow's worlds. One cannot separate the merely descriptive from the intentionally normative. Any description of what climate change is carries with it latent but preferential modes of acting *in* the world in ways that substantively *change* the world. (Hulme 2022, p. XXXI)

The North Sea OGEs were *cyclical* and *interconnected*, negotiating and restructuring their respective organised spaces to align them with the UN OD vision, EU goals, nation-building strategies, interregional and regional projects, and local needs. This created new governance structures that, for example, supported new technologies (such as the EU's DTO) and promoted citizen science (see also EMD in MyCountry, beach clean-ups; research notes, 2021, 2022, 2023). The iterative character also reflected Tronto's fourth ethical quality of care, responsiveness:

> Once care work is done, there will be a response from the person, group…environment, or thing that has been cared for. Observing that response, and making judgments about it (for example, whether the care given was sufficient, successful, or complete?) requires…*responsiveness*….And the response will often involve noting that new needs emerge as the past ones are met, thus the process continues. (Tronto, 2013, p. 35)

The normative impact manifests itself iteratively through legal frameworks, documents, and agreements (e.g., European Ocean Pact, 2025, The North Sea Programme 2022–2027, the Netherlands, etc.).

4. Discussion

Climate policy in general suffers from a vague definition of responsibility, where a multitude of different actors operate at various levels to form a complex system of action (Tosun & Rosello, 2020, p. 18). Therefore, doing EEE helps to investigate and, thus, address care relations in the large-scale institutions governing the oceans and seas.

4.1. OGEs and North Sea Governance

This EEE has shown how ocean knowledge is imagined, negotiated, (re)produced, and finally diffused through OGEs. In this regard, "we must take knowledge to be performative" (Turnhout, 2018, p. 364). In any case, "ethics precedes [sic] knowledge-making" (Fawcett et al., 2023, p. 77), and, so too, "scientific knowledge is typically considered as preceding the law and as providing the foundation for legal inscription. But, of course, scientific and legal practices are deeply entangled" (Johnson & Braverman, 2020, pp. 5–6).

Tying the given analysis and findings back to the UN OD vision of "The science we need for the ocean we want" (Intergovernmental Oceanographic Commission, n.d.-a), this vision can be understood as the most powerful "technoclimate" (Hulme, 2022, pp. 242–244) imaginary that the world's oceans and seas have ever faced. It expresses an undisputable belief that everything is possible. And yet, the UN OD's key strategy of ocean literacy is negotiated at OGEs to comprehensively connect all people, especially young people, with the oceans so that they become "ocean literate person[s]" (Cava et al., 2005, p. 5). However, profound technological and ensuing (upcoming) legal transformations are taking place within the North Sea region. Against this backdrop, EEE not only reveals how a single OGE performs North Sea governance but also how multiple events from different scales are interconnected along temporal, spatial, and normative dimensions and how these OGEs together weave a polycentric web of North Sea governance. Doing EEE, then, allows to address precise responsibilities, agencies, actors, time frames, and the level or scale at which care practices are performed, but also to identify where care must be provided in order to be effective.

4.2. OGEs and North Sea Knowledge-Production

With regard to knowledge-production in the North Sea region, DTOs and the process of becoming an ocean literate person are subject to lively discussions at these North Sea OGEs. Currently, there are only a few scientific publications on the topic of DTOs. A side glance at the DTO's twin—the Digital Twin of the Earth—is worth mentioning. For instance, one major criticism is that it "lacks a clear and shared definition and may be misleading. It conceals that all digital representations are models and, as such, will always be detached from reality" (Reinecke et al., 2024, p. 1). Our lives, in contrast, are attached *to* the seas and oceans: "the sea *touches* our everyday lives [and] alerts us to the material and tangible reality of water worlds" (Anderson & Peters, 2016, p. 16). And this also includes thinking about meaningful relationships between humans and non-humans. As Sammler (2020) vividly puts it:

> The geophysical, hydrological, and biological materiality and mobility of oceans partially influence the logic of UNCLOS [UN Convention on the Law of the Sea] and national enactments of the international treaty, even as attempts are made to legislate around these intrinsic ocean features. Regulators must contend with the agency of the living and nonliving natures as they enact static borders among mobile bodies. (Sammler, 2020, p.64)

Consequently, we must address "the changing relationships between knowledge-making, institutional practice and human culture in evolving places. We need kinds of knowledge which are 'liquid'—i.e., mobile and responsive" (Hulme, 2010, p. 563). Moreover, different imagined and negotiated time frames have to be considered and connected to questions such as "*whose* future is being envisioned and by whom" (Hulme, 2022, p. 141). If not, ocean governance might be heading towards a certain *knowledge fix*. Political, economic, scientific, and social stakeholders often and repeatedly point to knowledge gaps, which they ultimately translate into enormous investment opportunities by closing these gaps through ocean technology innovations (e.g., DTO's), and to the fact that "sustainable blue economy will create tangible opportunities for new jobs and businesses" (European Commission, 2021a, p. 2).

Ocean literacy, in turn, encompasses the ongoing pursuit of scientific and technical research and innovation. Due to "technological and legal transformations" (Manzo et al., 2021, p. 332), the aimed closure of these knowledge gaps will shape the North Sea's governance and its physical materiality, leading to profound "changing senses of places" (Raymond et al., 2021). This would lead us to the continuation of a *dilemmatic ocean* rather than to a "healthy and resilient ocean" (German Committee of the UN Ocean Decade, n.d.), as the economic use and the environmental protection of the oceans, seas, and other water bodies are too difficult to reconcile technologically without "ethical-based approaches" (Fawcett et al., 2023). Hulme's reference to Collingridge (1980) shows that the impact of a certain technology on the economy, environment, and society can only really be foreseen once that technology has been fully developed and implemented. At this point, it is complicated to make changes or to supervise this technology because of its complexity:

> At the heart of responsible innovation lies the question of which people and whose interests are to shape the processes and scrutiny of technology development and deployment. Collingridge's "technology control dilemma" applies equally, among many other technologies, to solar geoengineering...and carbon capture and storage. (Hulme, 2022, p. 205)

In order to not heading towards *dilemmatic oceans*, political, economic, scientific, and social actors need to "take the burden" (Tronto, 2013, p. 34) of discussing and informing in transparent and comprehensible ways (responsibility) how evaluations, measurements, and judgements are made and "whether the care given was sufficient, successful, or complete" or not (Tronto, 2013, p. 35). This follows Sevenhuijsen's (1998, as cited in Tronto, 2013, p. 35) call for "tak[ing] collective responsibility."

5. Conclusion

This article demonstrated a multi-perspective approach to North Sea governance from the intersection of geographies of knowledge and ethics of care through extended normativities alongside temporalities (e.g., competences a priori and a posteriori, circular learning experience, and interconnected events) and spatialities (e.g., places of (re)producing knowledge and organised spaces shaping polycentric governance). An EEE approach was presented, a deeply relational, situational, contextual method that questions how normativity enters the worlds and changes, in this case, oceans, seas, and senses of place by combining classic event ethnography with field research. These methods were enhanced by important works on imaginaries (Hulme, 2022), ethics of care (Tronto, 2013), and senses of places (Raymond et al., 2021).

The EEE revealed the relational architecture of OGEs through three emerging spheres of performance. First, the UN OD metaphorical vision was performatively shifted into scenarios. Secondly, concrete projects and practices were then performatively interlinked with those scenarios. Thirdly, these concrete projects led to concrete impacts in governance (e.g., policy strategies), polycentric knowledge production (digital twins, ocean literacy, etc.), the physical materiality of the North Sea (e.g., technological interventions), and the senses of place of those who live with the sea.

However, EEE is a new approach and, of course, has to be proven in many more cases. The UN OD is still in full swing; the first half of the decade has passed. As such, it would be of interest for further studies to investigate both how the UN's global imaginaries are being negotiated and how these resonate in different ocean governance spaces and basins over the upcoming years.

Acknowledgments
I would like to thank the anonymous reviewers sincerely for their insightful comments and constructive feedback, which improved this manuscript. Furthermore, I would like to express my gratitude to everyone who shared their insights on how they value, care for, and manage the North Sea together.

Funding
Publication funded by Johannes Gutenberg-University, Mainz, Germany.

Conflict of Interests
The author declares no conflict of interests.

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Ocean and Society
2026 • Volume 3 • Article 11445
https://doi.org/10.17645/oas.11445

ARTICLE

Open Access Journal

From Ravaged Livelihoods in the Global South to Mediterranean Crossings: The Reality of Climate Migration

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Submitted: 29 September 2025 **Accepted:** 16 December 2025 **Published:** 28 January 2026

Issue: This article is part of the issue "Ocean Climate Governance: Eclectic Viewpoints of a Multi-dimensional Nexus" edited by George Dikaios (Leiden University), fully open access at https://doi.org/10.17645/oas.i488

Abstract

The Mediterranean Sea is the focus of our research, as it is a major migration corridor from Africa and Asia, with Greece serving as a key entry point to Europe. Based on 70 semi-structured interviews with migrants, refugees, and asylum seekers currently residing in Greece and Belgium, this article examines how individuals from climate-vulnerable regions in South Asia, sub-Saharan Africa, and the Middle East shaped their decision to migrate away from their home countries. Employing the testimonies and data collected through the interviews, we investigated how disasters due to extreme weather, such as floods, droughts, and heatwaves, which have been inarguably linked to climate change, intersect with traditional migration drivers such as poverty, conflict, and human rights violations. While perceptions of the role of climate change as a factor in the movement of people who have already come to Europe as refugees or asylum seekers may vary, our findings based on their own statements reveal that climate-related disasters triggered their displacement. Our research reveals that climate migrants are not a future reality; rather, many have already reached Europe seeking safer livelihoods. By anchoring personal narratives in verifiable climate events, this article underscores the need to acknowledge climate-related mobility as a fact and a multifaceted issue—one that calls for revisiting conventional categories of forced migration and protection and prioritising climate action in the Global South.

Keywords

climate migration; cross-border migration; Global South; Mediterranean Sea

1. Introduction

Climate-induced migration is often framed as a future challenge on a rapidly warming planet. Despite the Intergovernmental Panel on Climate Change's (IPCC) "low confidence" in climate-induced cross-border migration to Europe as a current reality (Pörtner et al., 2022, p. 1867), our evidence suggests that the impacts of climate change are already interwoven into desperate and life-threatening migration pathways from vulnerable countries in the Global South towards safer destinations in Europe.

According to the UN Refugee Agency, the Mediterranean Sea is a major migration crossing, with a total of 139,550 arrivals in 2025 (UN High Commissioner for Refugees, 2025), of which 131,856 (94.5%) by sea. Greece, a migration hotspot in the Eastern Mediterranean route, recorded 41,271 in the same period.

Climate-induced migration is the subject of increasing scholarly attention. Nonetheless, the majority of existing research predominantly addresses internal displacement, with comparatively limited focus on cross-border migration (Burzyński et al., 2022; Mastrorillo et al., 2016). Although concerns have been raised about the quantitative studies carried out mainly by international organizations regarding the reliability of calculations and/or models for estimating the number of climate-displaced persons in the future (International Organization for Migration, 2023), there is a common view that cross-border climate displacement exists as a phenomenon and as a trend and that climate change is directly or indirectly linked with the movement of people (Czaika & Münz, 2022; Perch-Nielsen et al., 2008).

In this article, we use the term climate-induced migration to refer to human mobility in which climatic and environmental factors act more as contributory or interactional drivers of movement, rather than sole or deterministic causes. Drawing on Black et al. (2011), climate-induced migration exists as a result of climate change interacting with political, economic, and social factors. Through this definition, it becomes clear that climatic stressors such as droughts, floods, extreme heat, sea-level rise, or ecosystem degradation rarely exist in isolation. Instead, they affect mobility through various routes, including livelihood disruption, declining habitability, and reduced adaptive capacity (McLeman, 2014; UK Government Office for Science, 2011).

The majority of existing qualitative studies focus on the causes of migration or on conceptual approaches (Doussis & Psatha, 2024; Gemenne et al., 2018). While Powell (2022) argues that empirical research studying how migrants residing in Europe understand climate change remains comparatively limited, subsequent scholarship has begun to investigate these interconnections more systematically. For instance, Van Praag et al. (2021) contribute with an empirical study on how migrants interpret environmental change within the broader context of factors shaping their migration aspirations. Their findings suggest that perceptions of environmental degradation do not operate in isolation but intersect with economic, social, and political considerations in ways that complicate linear understandings of climate-related mobility. Taken together, this emerging body of work within migration studies and environmental sociology demonstrates that migrant perceptions of climate and environment-related risks are more heterogeneous.

In the context of a joint initiative, the Greek Council for Refugees (GCR) and WWF Greece investigated the underexplored role of climate-related factors in the displacement of migrants now residing in Greece and Belgium, focusing on individuals from climate-vulnerable countries in South Asia and sub-Saharan/Central Africa.

In this article, we do not seek to quantify the role of climate-related disasters in migration decisions. Instead, we seek a qualitative investigation into how climate change interacts with other structural drivers of displacement (i.e., economic hardship, human rights violations, war, conflicts, etc.), thus amplifying, reinforcing, or co-evolving with them. In addition, drawing on original empirical data, we sought to understand how displaced individuals themselves interpret and articulate the significance of climate-related events, within their broader migration narratives. Furthermore, drawing on data from the narratives and responses of the survey participants, this article examines specific climate events affecting the regions they come from and which played or may have played a role in their decisions to leave their countries.

2. Research Design

In our research, we developed a qualitative framework in order to examine the perceptions and lived experiences of migrants originating from 18 countries across South and Southeast Asia (8), the Middle East (3), and sub-Saharan Africa (7). The migrants invited to participate in the survey originated from countries that represent some of the most significant sources of refugee and asylum-seeker arrivals to Europe in recent years. Their countries of origin were identified through existing climate vulnerability research as highly sensitive to the impacts of climate change, experiencing recurrent environmental stressors such as droughts, floods, extreme heat, and land degradation. By engaging individuals from these contexts, the study aims to capture both the human dimension of climate vulnerability and the broader migration dynamics shaping contemporary displacement toward Europe.

During the research, we conducted in-person interviews with a total of 70 individuals who migrated from their countries of origin towards Europe and during the research period resided in Greece and Belgium. The 18 countries of origin (Figure 1) were Afghanistan (9), Angola (1), Bangladesh (5), Cameroon (2), Democratic Republic of the Congo (DR Congo; 2), Egypt (7), Eritrea (1), Gabon (1), Iraq (1), Iran (2), Morocco (3), Pakistan (9), Philippines (1), Republic of the Congo (1), Sierra Leone (2), Somalia (4), Sudan (7), Syria (11), and one (1) stateless person.

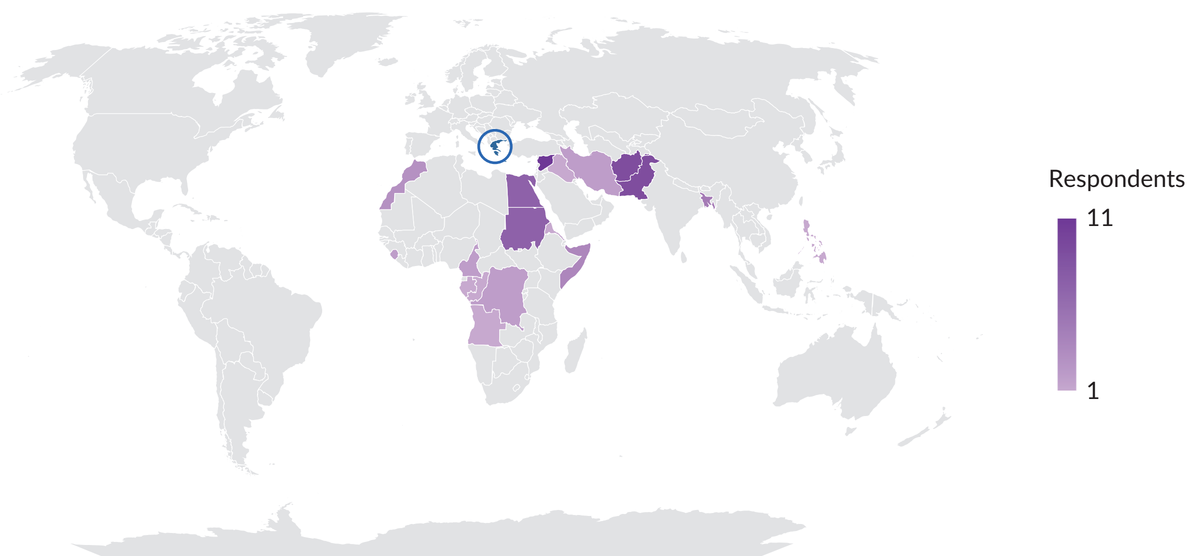

Figure 1. The 18 countries of origin of the 70 respondents to the GCR and WWF survey on climate migration. Note: Greece in a circle.

Of the 18 countries of origin of the participants in our survey, eight are included in the UN's list of Least Developed Countries, which are the characterised by the lowest income indicators and are particularly vulnerable to environmental and economic crises.

Participants were engaged through semi-structured interviews. With the help of an interpreter present in all interviews, the survey was structured using a standardized questionnaire organized into six thematic sections:

1. **Demographics:** Questions recording basic data (age range, gender, and country of origin).
2. **Displacement background:** Questions exploring the broader context of migration, including primary drivers (climate disasters, environmental degradation, or other), the abruptness or gradual nature of displacement, and any internal migration prior to crossing international borders.
3. **Climate dimensions of migration:** In eight structured questions, participants were invited to identify climate-related hazards and their impacts as direct or indirect factors influencing their decision to migrate. The participants were presented with a list of climate-related acute or chronic events (e.g., prolonged droughts, floods or storms, rising temperatures, desertification or land degradation, sea-level rise, coastal erosion, etc.) and associated impacts (e.g., loss of livelihoods in agriculture or fisheries, destruction of housing, food and water insecurity, health impacts such as malnutrition or heat stress, etc.). Participants were also asked about adaptation strategies at the individual, community, and governmental levels. Based on answers to the prompt "did climate-related factors (e.g., floods, drought, sea level rise, etc.) influence your decision to leave in any way?" each participant's climate profile was categorized as *Yes* (primary), *Yes* (secondary), or *No*. This helped in developing an initial "climate profile" of the migrants participating in the survey.
4. **Multi-causality of displacement and the role of climate change:** This section probed participants' awareness on the perceived interactions with other structural stressors, such as conflict, human rights violations, and socio-economic pressures (e.g., unemployment, resource competition, etc.).
5. **Current challenges:** This section included two questions on the support participants need in order to rebuild their lives in their host country, providing insights into post-migration vulnerabilities.
6. **Personal narratives:** An open-ended section encouraged participants to share their stories in their own words, offering space for reflection beyond the structured interview format.

The last part, which allowed the participants to freely express their personal narratives on the impact of extreme disasters or slow-onset impacts on their livelihoods, focused on explicit references that the migrants made to specific disasters. These were then fact-checked through attribution studies and were found to have been linked to climate change.

Based on their replies to the question whether climate-related hazards influenced their decision to migrate, respondents were categorised as: "No climate profile"; "yes, primary climate profile" (i.e., climate hazards were their primary driver in their migration decision); and "yes, secondary climate profile" (i.e., climate hazards did indeed influence their migration decision, but were not the sole reason). On certain occasions, participants in the survey requested more explanation about the term "climate hazard," in which case the interviewer replied, "extreme weather events, such as destructive floods and storms, or heatwaves."

This methodological framework enabled a multidimensional understanding of how climate-related and structural drivers intersect in shaping migration decisions, while foregrounding the voices and agency of affected individuals. All interviews were anonymous in order to create a safe space for the participants.

The interviews took place in the following locations: 14 at the closed controlled access centre of Lesvos; 5 at the Amygdaleza pre-departure detention centre; 11 migrants residing in and employed in farms in Achaia (Peloponnese region); 16 migrants currently residing in Belgium, through interviews conducted by the law firm DLA Piper; 8 interviews at polyclinics operated by the Global Brigades in Athens, where migrants and asylum applicants seek medical care and support; 12 migrants currently residing in Athens, hosted by the Melissa Network for Migrant and Refugee Women in Greece and Mazi Housing Project; and 4 migrants currently residing in Athens, interviewed at the office of GCR.

Collecting data through interviews was not without difficulties and obstacles. Obtaining official permits to access migrant detention centres and closed controlled access centres (CCAC) proved more challenging than initially anticipated, ultimately resulting in fewer days available for interviews.

3. Ethical Considerations

Conducting surveys based on personal interviews with migrants, especially persons held in detention centres and CCAC entails heightened ethical obligations. The vulnerable position of the interviewed migrants and the power imbalance between the researchers and the participants, language barriers, and cultural sensitivities are key challenges that require pre-emptive attention at the survey planning stage. The need to communicate the framework and scope of the survey with clarity and to create a safe space within which participation is explicitly voluntary, while avoiding triggering distress and indirectly influencing their responses, as their disadvantaged position undermines their autonomy, is among the priorities (Davidson et al., 2024).

The structure of our survey and the interviews was developed in line with the European Commission's guidance on research with migrants (European Commission, 2020). The Commission's note outlines ethical, methodological, and data protection considerations that need to be taken into account during interviews with vulnerable migrants and refugees. It highlights the principles of treating participants with care and sensitivity, being objective and transparent, neutral with regard to ethnicity, language, religion, and gender/sexual orientation, and respecting their values and beliefs.

Personal data protection is a principle of paramount importance, especially acknowledging the vulnerability of migrants and refugees. Prioritising the need to protect the participants' personal data, we conducted only anonymous interviews. The requested demographic data were basic (country of origin, gender, and age range) and made it impossible to establish any links between the responses and the responders, especially in the context of the migrant detention centres in Lesvos and Amygdaleza.

At the planning and design phase, our team prioritized structuring the entire survey in a way that would ensure that participants were neither coerced nor encouraged to respond to questions they did not fully understand. Accordingly, the key question determining a respondent's climate profile was framed objectively, and subsequent sections of the interview were contingent on their binary ("yes" or "no") response to whether climate change had, in any way, influenced their decision to migrate. In the case of "no" replies, when the participants mentioned conflicts and wars, persecution, or family reunification reasons for their migration, the survey was concluded. In the cases where a participant replied that their reason for migration was economic, then the next questions in the same section sought a deeper understanding of the perceived causes of economic hardship that led them to migrate and whether they thought that weather extremes had any impact on their economic situation.

During the survey, the research team was also mindful to establish communication in the native language of the participants, through interpreters employed by the GCR, whom the participants knew and trusted. Building trust in the objectivity of the survey was crucial throughout the research; the structure was clear and communicated to each participant in simple language from the beginning.

4. Background

4.1. Greece, a Migrant Gateway to Europe

This research focuses predominantly on migrants currently living in Greece. Given the country's geographical position at Europe's southeastern front door, Greece is a major hotspot for migration flows from the continents of Asia and Africa. Hence, research on the role of climate-related displacement in migrant communities in Greece is important in better understanding broader migration dynamics.

Drawing from the EU data on asylum applications, which are indicative of the total migration flows to Greece from various countries, we observe that a total of 376,045 individuals from the countries of origin represented in our research have arrived in Greece and sought asylum during the decade spanning 2015 to 2024. Nationals of Syria constitute the predominant group of first-time asylum seekers, with a total of 120,535 applicants, followed by Afghanistan (91,110), Iraq (41,245), Pakistan (40,400), Egypt (15,975), and Bangladesh (13,150). The significance of Greece as a pivotal gateway for migrants to Europe is underscored by the fact that in 2024, Greece accounted for 5% of the total first-time asylum applications in the EU from nationals of Pakistan (5%), from Afghanistan (20.98%), from Bangladesh (2%, drop from 13% in 2021), from Sierra Leone (27%, down from 32% in 2023), from Sudan (16%), from Somalia (8%), and from Syria (15%; Table 1).

Table 1. Asylum applications (first-time applicants) in Greece, by country of citizenship, over the period 2015–2024.

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	Country total
Syria	3,325	26,630	16,305	13,145	10,750	7,415	2,945	4,280	13,865	21,875	120,535
Afghanistan*	1,545	4,295	7,480	11,820	23,665	11,100	3,195	4,085	8,770	15,155	91,110
Iraq	575	4,770	7,870	9,640	5,590	1,465	990	2,030	6,080	2,235	41,245
Pakistan	1,505	4,420	8,345	7,185	6,420	3,515	3,415	2,555	1,965	1,075	40,400
Egypt	230	260	810	915	1,695	710	775	1,335	2,160	7,085	15,975
Bangladesh*	535	1,055	1,255	1,435	2,375	1,625	2,480	1,280	340	770	13,150
Somalia*	95	125	230	715	2,270	1,530	1,485	1,985	2,840	1,390	12,665
DR Congo*	110	225	1,085	1,450	3,570	1,850	565	465	1,255	185	10,760
Iran	190	1,085	1,295	1,730	2,325	835	575	415	620	755	9,825
Eritrea*	135	415	320	330	305	200	140	630	1,810	2,255	6,540
Cameroon	165	210	455	1,035	855	395	190	250	615	250	4,420
Sudan*	115	45	85	80	90	50	55	455	970	1,490	3,435
Sierra Leone*	25	40	45	85	120	75	90	880	1,190	675	3,225
Morocco	65	460	425	355	260	175	115	200	195	150	2,400
Angola*	–	–	10	10	50	40	15	20	25	5	175
Philippines	5	5	5	5	10	5	10	5	15	60	125
Gabon	5	5	10	10	5	5	0	5	10	5	60
Year total	53,8145	122,8230	121,6690	677,205	629,655	703,840	453,095	558,645	902,805	110,7405	376,045

Note: Marked with an asterisk are those classified as least developed countries. Source: Eurostat (n.d.).

4.2. Climate Change as a Migration Driver

Social research exploring the impact of the climate crisis on vulnerable communities in the Global South projects that the increasing frequency and severity of climate-induced "natural" disasters will result in "a mass exodus of entire populations on a biblical scale" (Guterres, 2023). Social research examining the differentiated impacts of the climate crisis on vulnerable communities in the Global South consistently shows that climate-related hazards—such as prolonged droughts, intensified cyclones, sea-level rise, and extreme heat—disproportionately undermine livelihoods, food security, and habitation conditions (Almulhim et al., 2024; Ngcamu, 2023). Studies of agrarian, coastal, and informal-settlement populations document that these recurrent shocks erode adaptive capacity and can precipitate both temporary and permanent displacement (Mamba et al., 2025; Tavares et al., 2024). A growing body of work, therefore, anticipates that, as these pressures accumulate, large-scale population movements—both internal and cross-border—may become increasingly common in the absence of viable adaptation pathways (Almulhim et al., 2024). At the same time, it is widely believed that:

> Ascertaining the role of climate change in migration is difficult and contested…with observation-based studies either linking extreme event incidence, weather anomalies and environmental change with migration numbers or drivers, and projection studies looking at particular risks such as SLR or drought by linking increasing warming (often through representative concentration pathways, RCPs) and population growth. (Pörtner et al., 2022, p. 1469)

Fieldwork by the GCR, in years prior to this research, has revealed strong evidence that individuals living in migrant camps in Greece cite environmental degradation and climate disasters as key factors that compelled them to flee their home countries. One specific example is the case of a survivor of the devastating Pylos migrant boat disaster, one of the deadliest in the Mediterranean Sea, which claimed the lives of more than 650 people. The Pylos survivor, a national of Pakistan, stated that the primary reason he fled his country was due to repeated and intensifying climate disasters in his region (Survivor of the Pylos Shipwreck, 2023). He recounted that his home and fields were located near a river that was repeatedly flooded with increasing frequency, leading to the complete loss of his property and crops. This left him with no choice but to risk his life, ultimately surviving one of the deadliest shipwrecks in the Mediterranean in recent years.

Cross-border climate displacement cannot be reduced to a linear chain of cause and effect. As a growing body of research acknowledges, displacement is driven by a web of interlocking forces: economic marginalization, social exclusion, conflict and war, and demographic pressure and political instability, interacting across time and space (Black et al., 2011; Czaika & Münz, 2022) and further aggravated by the low adaptation capacity and climate resilience of the countries of origin.

In this study, we build a conceptual framework that focuses on the role of climate change as an amplifier/multiplier of the pressures that lead to displacement, mainly structural vulnerabilities and conflicts. This approach aligns with scholarship describing climate as a "threat multiplier" (Abel et al., 2019; Nett & Rüttinger, 2016), especially in fragile contexts where environmental shocks intensify food insecurity, disrupt livelihoods, and accelerate economic precarity. For example, in rural agricultural areas, erratic rainfall or salinization may diminish crop yields and livestock health (Afifi, 2011; Di Falco & Veronesi, 2014), compounding already unstable income streams. In such cases, climate change heightens existing social and economic fragility, serving as a magnifier of displacement risk rather than a primary driver.

5. Empirical Evidence

5.1. Climate Profile of Respondents

According to Pörtner et al. (2022, pp. 929–930):

> The complexity of migration drivers (as push or pull factors) explains why there is little agreement around quantitative estimates on migration (especially international) triggered by climate change (I. M. Otto et al., 2017; Silja, 2017), and why estimates of future displacement attributed to climate change and other environmental causes vary between 25 million and 1 billion in 2050 (Heslin et al., 2019).

During our research, we confirmed the indications stemming from everyday interaction with migrants (either asylum applicants or persons sweepingly classified under the broad category of "economic migrants") that persons displaced by climate change are not a future prediction. Involuntary displacement caused by the climate crisis is already happening.

As shown in Figure 2, 50% of the respondents (i.e., 35 individuals) replied that their migration decision was influenced by climate factors. Eighteen individuals (26% of the total people interviewed) stated that climate was the sole or primary reason for cross-border migration, while 17 (24%) mentioned climate events as their secondary reason for migration.

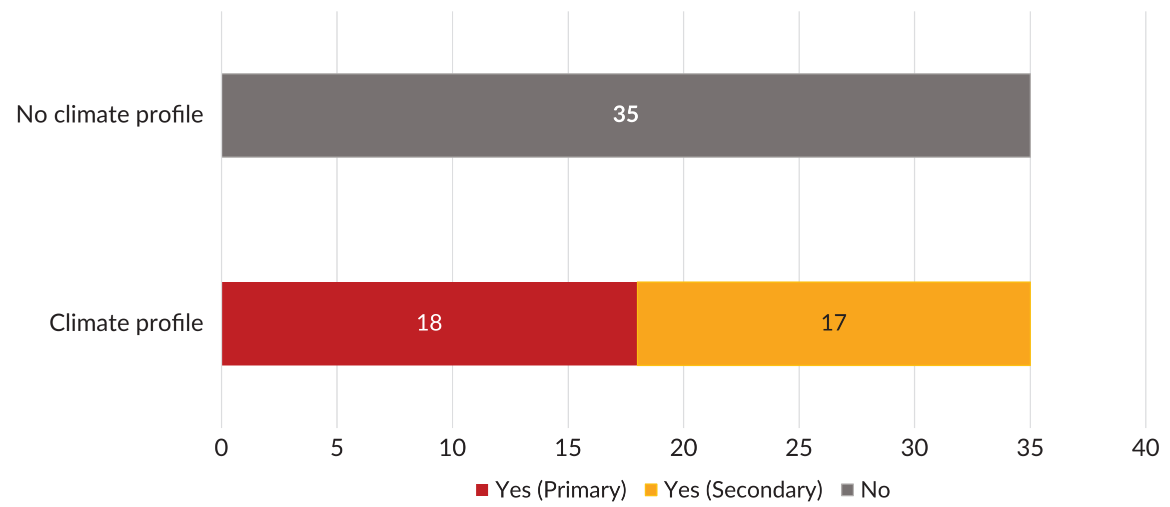

Figure 2. Profile of respondents with relation to the role of climate change in their decision to migrate.

By country of origin of the respondents who declared a climate profile, we see that eight out of the ten are included in the UN's list of Least Developed Countries. The severe economic hardship facing these states, which are at the same time particularly vulnerable to disastrous weather extremes, renders their communities least resilient to the impacts of climate change.

Although the number of participants in the survey (Figure 2) is not statistically representative of the total migrant population per country of origin, the results are nonetheless indicative of the fact that climate change is already decisively influencing people's decision to migrate cross-border away from their native lands. The main research question of our survey is whether people displaced by climate change have already arrived in Europe. The results are compelling, since half of the respondents identified a distinct climate-related profile, either as a primary or secondary factor.

As shown in Figure 3, 100% of the respondents from three countries, included in the UN Least Developed Countries list, declared a climate profile, either as the primary or secondary cause of displacement: Somalia, DR Congo, and Sierra Leone.

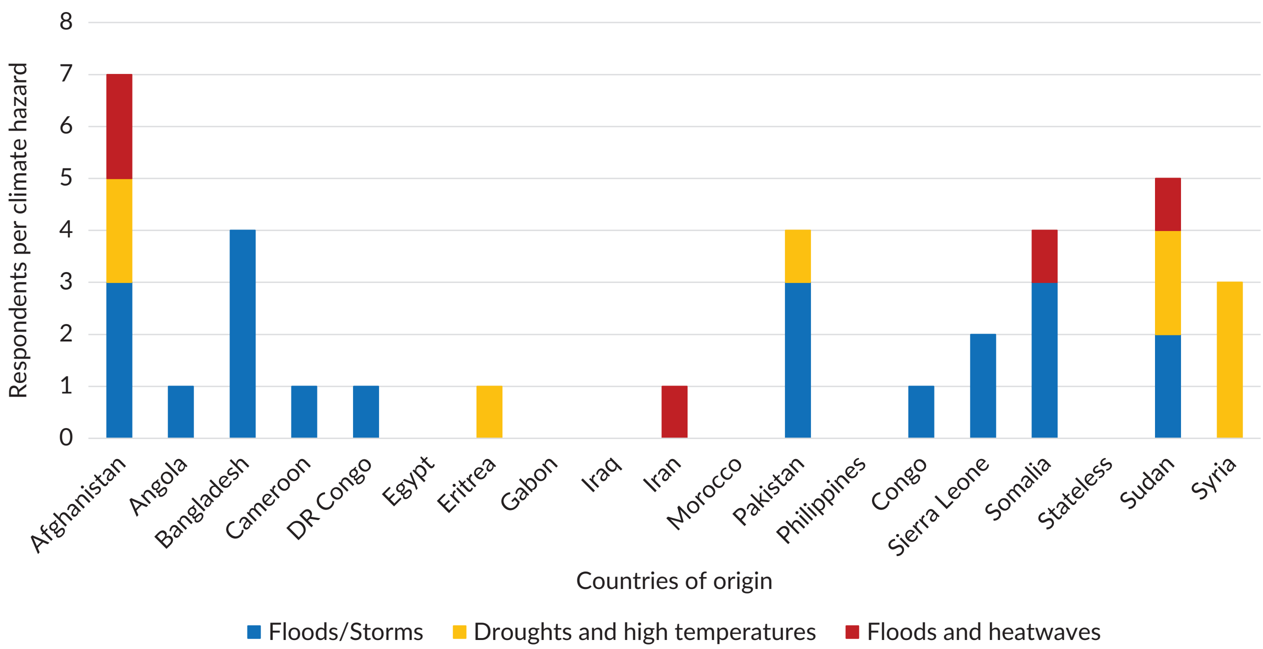

Figure 3. Number of respondents with a climate-related migration profile who identified specific climate hazards as the primary or secondary driver of their displacement.

In more detail, all four migrants from Somalia stated climate extremes as the primary reason for their decision to migrate: three mentioned floods and storm and one person mentioned floods and high temperatures, while all four stated that their homes were repeatedly destroyed and their means of subsistence, i.e., productive lands and cattle, were lost in the waters. Health problems caused in the flooded areas and lack of food and potable water made these dire conditions even worse.

The two migrants from Sierra Leone, the first interviewed at the Lesvos CCAC and the second in Athens, mentioned massive floods as their primary cause for migration. One of the two left the country after the deadly floods and mudslides that ravaged Freetown in 2019, which have been attributed to climate change. The second migrant, a woman in the age range of 18–24, stated specifically that:

> We experience flooding, we lose our properties, clothes, [and] house items. All infrastructure is destroyed. Most people lose their homes and the government provides accommodation in the national stadium. The poor, those who are living in the slum areas, are those affected the most. It also takes weeks to go again to schools. Some lose their jobs. Some families lose their children, especially

> babies. They are trying to build the houses again in the drain period. There was a time when I was in school and the water was up to the first floor, in the next-door class. The teacher urged us to go out, otherwise we will sink and drown. We didn't sleep in the house; we slept at the national stadium. My skin was full of rash.

One of the migrants from the DR Congo mentioned disastrous floods, coupled with persecution and conflicts, as his primary cause for migration in 2017, also stating that he did not even try to move within the country. The second migrant from DR Congo mentioned prolonged droughts, caused by increasing temperatures, as his primary cause for migration, which was further aggravated by conflict and the lack of support from the state.

In Table 2, we present the categorisation of the respondents per country (a total of 70), sub-categorized according to their stated climate profile and climate displacement cause (this category includes only the 35 migrants who declared climate change as their primary or secondary cause for cross-border migration).

Table 2. Respondents (n = 70) per country, categorised (a) according to their stated climate profile (primary, secondary, and none) and (b) according to their stated climate displacement cause (n = 35).

Country of origin	Total participants	Climate as primary cause of migration	Climate as secondary cause of migration	No climate profile	Climate displacement causes		
					Floods/ Storms	Droughts and high temperatures	Floods and heatwaves
Afghanistan	9	3	4	2	3	2	2
Angola	1	0	1	0	1	0	0
Bangladesh	5	3	1	1	4	0	0
Cameroon	2	1	0	1	1	0	0
DR Congo	2	0	2	0	1	0	0
Egypt	7	0	0	7	0	0	0
Eritrea	1	0	1	0	0	1	0
Gabon	1	0	0	1	0	0	0
Iraq	1	0	0	1	0	0	0
Iran	2	0	1	1	0	0	1
Morocco	3	0	0	3	0	0	0
Pakistan	9	2	1	6	3	1	0
Philippines	1	0	0	1	0	0	0
Congo	1	0	1	0	1	0	0
Sierra Leone	2	2	0	0	2	0	0
Somalia	4	4	0	0	3	0	1
Stateless	1	0	0	1	0	0	0
Sudan	7	3	2	2	2	2	1
Syria	11	0	3	8	0	3	0

Our findings reveal that while many self-identify as "economic migrants," the majority of respondents described disastrous events (particularly massive floods, prolonged droughts, and heatwaves) as major contributors to local economic and social breakdowns. In some cases, one particular event is described as the immediate cause of displacement. For example, South Asian workers in the Peloponnese identified the

2022 floods in northeastern Bangladesh as the decisive factor, although their personal understanding of the origin of this calamity was different from the scientific attribution: they stated their belief that the floods were acts of God and were unaware of the reality of climate change. Respondents from sub-Saharan Africa described how environmental degradation, erratic weather patterns, and disappearing livelihoods shaped their need to relocate.

As shown in Figure 4, developed on the mapping background of the climate-conflict-vulnerability index, all 35 participants with a climate profile migrated to Greece from countries that are already exposed to climate hazards or are subject to the compound risk of climate, conflict, and socio-economic vulnerabilities. Sixteen migrants described the deteriorating climate conditions as the culmination of multiple stressors, which devastate local economies in countries with weak institutional capacity to protect their citizens and adapt to climate change. Two migrants, one from Afghanistan and one from Somalia, stated the unbearable climate conditions and floods as the single cause for their migration. Health problems and social disruption followed environmental shocks, as participants reported outbreaks of diarrhoeal diseases, skin infections, and respiratory illnesses after floods, while one migrant from Sierra Leone stressed long interruptions to schooling as the norm for families affected by the increasing flood events.

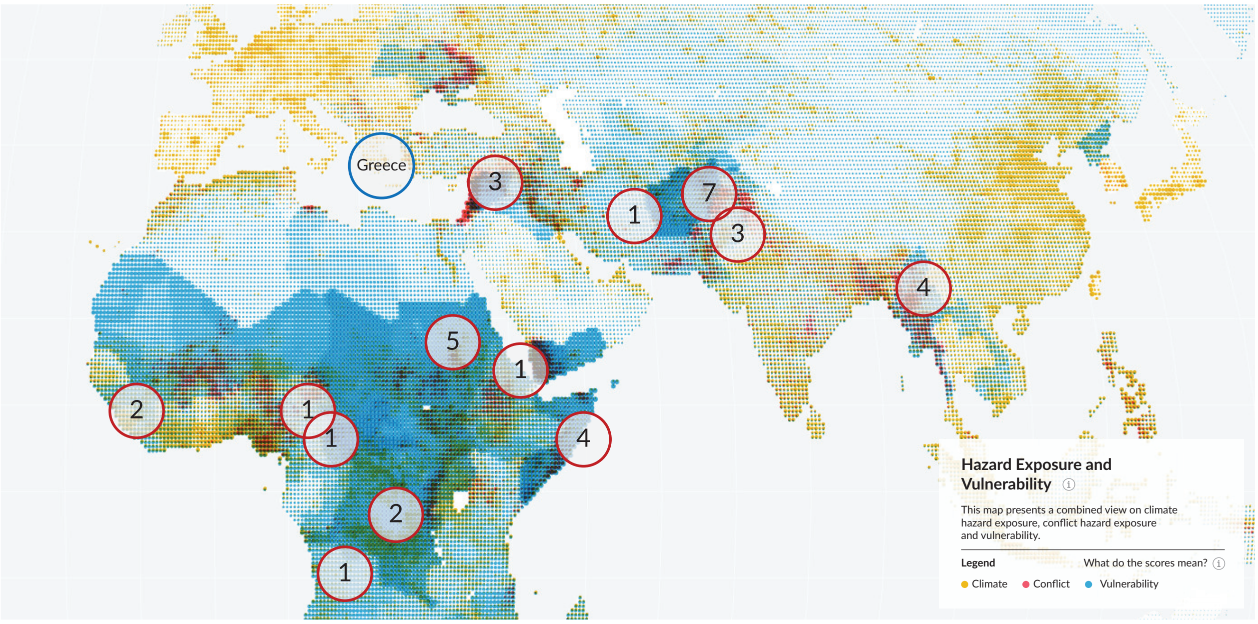

Figure 4. Countries of origin of the migrants with a climate profile, projected on the climate-conflict-vulnerability map. Note: All participants originated from countries experiencing high vulnerability to climate change, on most occasions combined with conflict hazard exposure and socio-economic and/or political vulnerability. Source: Climate–Conflict–Vulnerability Index (n.d.).

Another interesting finding relates to the efforts of the migrants who declared a climate profile to adapt to climate stress. Specifically, 18 (five from Afghanistan, four from Bangladesh, three from Sudan, one from Sierra Leone, one from Cameroon, one from Pakistan, one from Syria, and two from Somalia) out of the 35 migrants (51.5%) with a climate profile stated that they did not wish to leave their home countries, so initially they moved within their country, while six mentioned that during their movement within their country they also changed profession after having lost their source of income locally.

An unexpected finding was the difference in climate-related narratives between migrants from sub-Saharan Africa and those from North Africa. Notably, all 10 North African migrants interviewed—seven from Egypt and three from Morocco—indicated that climate change did not influence their decision to migrate to Europe. Further research is necessary in order to better understand the social and religious perspectives on climate change within North African communities. Additionally, region-specific factors, including traditional migration routes linking the African and European parts of the Mediterranean, might provide context for this stark differentiation between the respondents from Egypt and Morocco compared to those from other countries. Important insight into better understanding the Moroccan context on climate issues is provided by Van Praag et al. (2021). Their analysis is based on 48 interviews with migrants from Tangier and Tinghir, Morocco, to Belgium, and concludes that while deteriorating environmental conditions and economic opportunities exist, the Moroccan migrant communities in Belgium perceive family-related reasons as the main factors shaping their migration aspirations. As evidenced in Van Praag et al. (2021), geographical proximity and cultural exchanges facilitating migration in recent Mediterranean history may be the reason for the absence of climate-related narratives from respondents in our research originating from Egypt and Morocco.

The majority of the interviewed migrant workers from South Asia in the Peloponnese initially reported that they consider themselves "economic migrants," while they did not know anything about climate change. They denied any causality between their economic situation and the effects of climate-related events and expressed their belief that other forces brought these disasters upon them. As the interview and the discussion progressed, they repeatedly mentioned extreme climate conditions, primarily more frequent massive flooding events, while some eventually realised and concluded that the definitive cause of their decision to leave their home country was a particular climate disaster (like the 2022 floods in northeastern Bangladesh).

Individual perceptions of environmental change are shaped by a range of factors, including how each person acquires and processes information about these changes (Weber, 2010), the nature of their livelihoods (Bollig & Schulte, 1999; Mbow et al., 2008; Mertz et al., 2010), and the influence of traditional knowledge systems and local narratives (Berkes & Berkes, 2009; Bollig & Schulte, 1999). Demographic characteristics—such as household composition or patterns of labor migration—also play a role (Mertz et al., 2010), as do representations in the media (Marin & Berkes, 2013). Furthermore, cultural and religious frameworks shape how environmental risks are perceived, interpreted, and managed, grounded in shared understandings of vulnerability and threat (Leclerc et al., 2013; Mertz et al., 2010; Vedwan, 2006).

Our interviews with the migrants declaring a climate profile revealed that the impact of climate change on their livelihoods and economic activities was immense and led to their eventual cross-border displacement and migration, either as a primary or secondary driver (Figure 5).

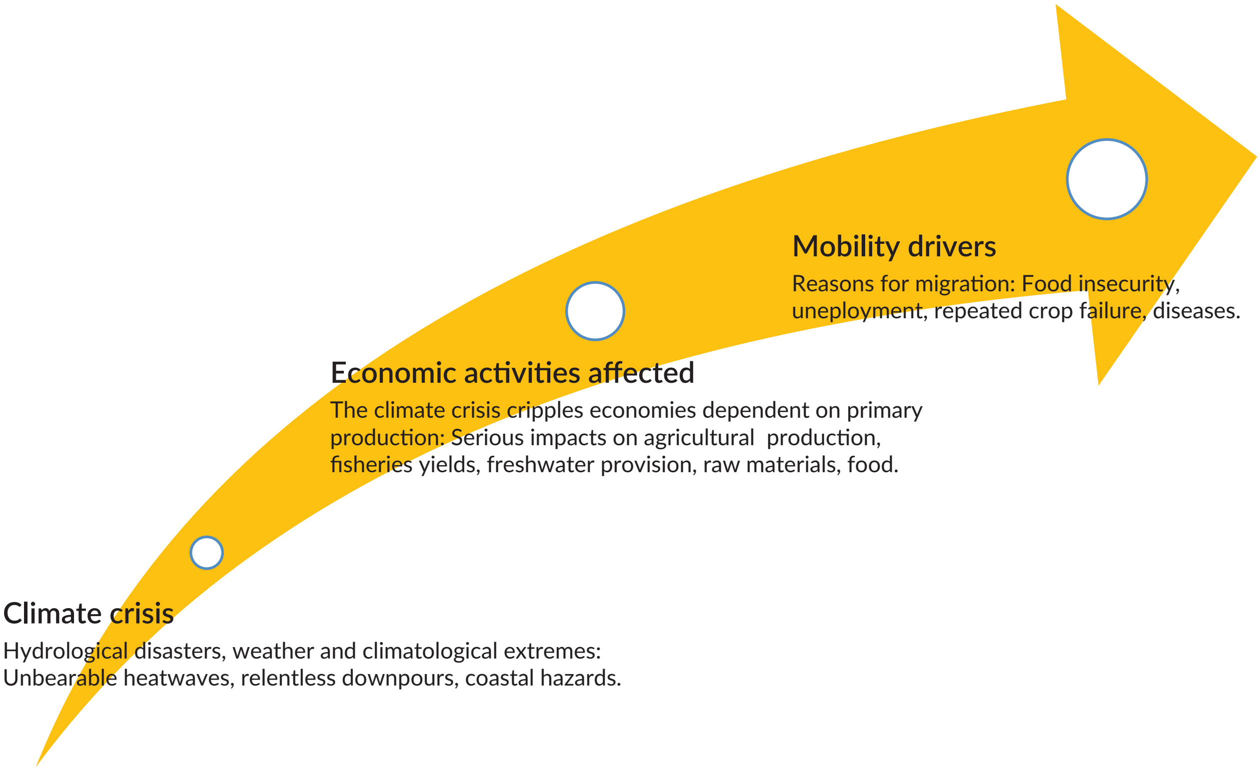

Figure 5. Links between climate change, the state of economies heavily dependent on primary production, and no resilience to the impacts of climate change and human mobility.

5.2. Testimonies of Climate-Induced Migration

The stories of many migrants who participated in the research focused on the plight caused by repeated and relentless storms and floods, unbearable heatwaves, lost crops, dry wells, barren soils, fewer fish, harder to secure food of the day, vanishing communities, and homes. The diminishing adaptation capacity of the already weak economies in their home countries, combined with their high dependence on healthy natural ecosystems, made their families and communities particularly vulnerable to climate change and extreme weather events. Selected testimonies are listed below.

Testimony of a 19-year-old migrant from Baghlan, Afghanistan. He burst into tears while narrating his traumatic personal story during the interview, at the camp of CCAC of Mavrovouni, on Lesvos Island:

> There have been many floods causing destruction to homes. Over the past five months, things have worsened. We have no access to clean water and must fetch it from the city using donkeys. Everything is destroyed. I lost my farming job and was mostly unemployed due to floods. Many people leave at night to escape, as during the day, people drown or die. I lost my mother and brother in a flood last year that struck early in the morning and swept through the village.

Testimony of a migrant from Sylhet, Bangladesh, now working as a strawberry farmer in the Peloponnese, Greece. Interviewed on 27 March 2025, in the village of Lappas, Achaia:

> Since the very first day we begin to understand life in Bangladesh, we think of leaving. Because of poverty and repeated disasters.

Testimony of a migrant from El Geneina, Sudan, interviewed at the Lesvos CCAC:

> We cannot cultivate anything. People are dying from drought due to [a] lack of drinking water. No help comes from the government or organizations. In 2022, sudden floods broke the dams due to [a] lack of maintenance, forcing people into the streets. The poor are suffering and remain unaided.

Migrant from Sialcot, Pakistan, interviewed in Athens:

> Every year, our village is flooded. And the water reaches the middle of the house. But we consider it normal. Most people leave. Some go to relatives in town. Others go and stay in schools that don't flood. I was in Pakistan about 10 years ago, in 2014. Then it was a big disaster. Many people from my village were killed, like my neighbour. All the houses were destroyed.

Migrant from Takhar, Afghanistan, interviewed at the Lesvos CCAC:

> Every time it rains, villages flood and suffer extensive damage. Floods affect everyone, especially those with farmland. No help is available. We must pay for road repairs ourselves. Under the previous government, there was some support. Under the Taliban, there is none. People are in shock, with no access to food, water, or healthcare. A few days ago, my brother told me there was another major flood.

5.3. Attribution of Extreme Events to Climate Change

Respondents reported having suffered the catastrophic impacts of weather events, which have been scientifically attributed to climate change. In one of the interviews, a responding 19-year-old migrant from Afghanistan broke into tears as he recounted losing his mother and brother in the catastrophic floods of 2023 in Baghlan, after having already suffered repeated flood disasters in previous years (see full testimony in the previous section). The events mentioned by interviewed migrants as contributing or decisive factors for their displacement were checked in relation to the influence of climate change on their intensity and frequency.

Specific disasters mentioned as life-changing events that shaped their decision to migrate are the following:

- **2017 mudslides in Freetown, Sierra Leone:** The mudslides that ravaged Freetown, capital city of Sierra Leone, in August 2017, killed almost 1,000 people and caused over 3,000 to be involuntarily displaced (Kpaka, 2020). The deadly mudslides were caused by the unusually heavy rainfall, which scientifically has been attributed to climate change. This beautiful and biodiversity-rich country of Western Africa, whose economy relies heavily on agriculture and ecosystem services (Convention on Biological Diversity, n.d.), is a climate change hotspot. Mentioned as a defining event that shaped their decision to leave, two Sierra Leoneans stated that the mudslides and floods made living conditions in their homeland unbearable for them.

- **2019 floods in Darfur, Sudan:** The 2019 massive floods in Sudan were the worst in 25 years (Pörtner et al., 2022, p. 1332). The compound of armed conflict, poverty, and inadequate water management heightens the vulnerability of communities to extreme flood events, which have become increasingly frequent and severe under the influence of climate change (Pinto et al., 2024).
- **2022 massive flood in Bangladesh:** Bangladesh, being one of the world's most vulnerable countries to climate change, is seeing more frequent and intense flash floods—especially in the Sylhet region. The floods of June 2022 have been linked to climate change (Raulerson, 2022). A few years earlier, in 2017, "flash flood affected ~850,000 households, ~220,000 ha of nearly harvestable Boro rice damaged. Crop failure contributed to a record 30% rice price hike compared to the previous year" (Pörtner et al., 2022, p. 575).
- **2022 massive floods in Cameroon:** Throughout 2022, a large region in West Africa, including Cameroon, Mali, Nigeria, and Niger, was hit with massive floods resulting from rainfall above average, resulting in the displacement of 1.5 million people. "Climate change made the event about 80 times more likely and approximately 20% more intense," according to a specific attribution study by Zachariah et al. (2022, p. 2).
- **2022 extreme floods in Pakistan:** The extreme rainfall of 2022 and the resulting flooding affected over 33 million people, destroyed 1.7 million homes, and nearly 1,500 people lost their lives. The 2022 extreme monsoon season has been attributed to climate change, according to a specific attribution study (F. E. L. Otto et al., 2025).
- **2024 floods in Afghanistan:** In April and May 2024, large regions of South Asia were hit by a series of storms resulting in heavy downpours and flash flooding, which have been attributed to climate change. The worst-affected country was Afghanistan, where 540 fatalities have been reported. In Pakistan, at least 124 people died in severe flooding in Pakistan in April, while 18 people died in Iran in May. In addition, the heavy rainfall damaged thousands of homes and submerged agricultural lands (Zachariah et al., 2024).
- **2024 Extreme heatwave in the Sahel region:** The extreme Sahel heatwave that hit highly vulnerable populations at the end of Ramadan would not have occurred without climate change (Barnes et al., 2025).

6. Conclusions and Recommendations

As shown in this study, climate-induced displacement and cross-border migration are already happening and are expected to intensify.

During the research conducted by GCR and WWF Greece, all interviewed migrants with a climate profile confirmed that the increasing frequency and severity of disasters induced by climate change devastate local economies in the Global South, amplify inequalities, and overwhelm the limited response and adaptation capacity of their countries of origin. Although more research and a deeper understanding of the need for stronger climate adaptation and governance mechanisms are needed, this reality bears serious policy implications and raises the bar even higher for international climate action and humanitarian support.

6.1. Policy Implications

Recognising cross-border climate migration from the Global South as an established reality carries significant policy implications on both ends: the countries of origin, where displacement occurs, and the host countries, where climate migrants seek safety and protection.

In the legal context opened by the groundbreaking advisory opinion issued by the International Court of Justice on 23 July 2025, states clearly have a legal duty to protect climate migrants and not return them (principle of non-refoulement under the 1951 Geneva Convention) to their country of origin. "Conditions resulting from climate change which are likely to endanger the lives of individuals may lead them to seek safety in another country or prevent them from returning to their own" (International Court of Justice, 2025, para. 378). As highlighted by many commentators (e.g., Riemer, 2025), the International Court of Justice opens the way for the strengthening of the legal protection framework for persons forced by climate change to cross-border displacement, despite refraining from articulating an obligation for a comprehensive protection system for climate migrants.

It is now the time for states to bring the issue of climate displacement and cross-border migration to all relevant international fora on climate and migration, and recognise cross-border displacement caused by climate change as a fact, and develop frameworks that include climate in the national and international protection policy frameworks.

Given the high rate of responses to our survey by migrants stating that they first tried to migrate within their country, as they did not wish to leave, international support towards the Global South for the enhancement of the adaptation and disaster response mechanisms and improved governance systems in climate-vulnerable states gains particular significance. Supporting vulnerable communities whose economies and livelihoods are dependent on natural ecosystems (through agriculture or fisheries) is essential in allowing people to feel safe in the face of climate extremes and disasters.

It is important that climate-induced migration be addressed at all levels as early as possible, in order to avoid humanitarian disasters and unexpected massive flows of displaced people towards safer locations. In the words of the IPCC (2023, p. 104), "migration, when voluntary, safe and orderly, allows reduction of risks to climate and non-climatic stressors."

6.2. Recommendations for Further Research

Our research offers qualitative and narrative-based insights from 70 migrants, refugees, and asylum seekers residing in Europe. Further research is needed in order to better understand the extent of climate as a cause of displacement within current migrant communities and to capture its interaction with other factors in various contexts. With Greece being one of the main countries of entry to Europe for migrants originating from regions of the Global South, and already suffering the severe impacts of climate change, further research should be encouraged, also aiming at reaching statistically significant conclusions about climate change as a displacement driver among migrant and refugee communities. A deeper understanding is also needed with regard to the social aspects of climate migration and particularly its impact on different groups, primarily women and children. It is also necessary to create the conditions for further research that includes how migrants perceive climate change and how social, religious, political, and other factors shape their perceptions of the role of climate in human mobility.

It is therefore recommended that: (a) migrant reception countries include climate change in the official forms of incoming migrant interviews; (b) NGOs offering support to migrants include in their surveys questions about climate change and the impact on local societies and livelihoods caused by rapid events (disasters) or slow onset changes (e.g., prolonged droughts or repeated floods); (c) state and international migration agencies link data on migration with environmental parameters (such as climate attribution studies and disaster reports) remote sensing data and economic reports on loss of livelihoods in the primary sector (fisheries and agriculture from the countries of origin); and (d) recognizing cross-border migration due to climate change as a current reality is essential for shaping legal protections, climate-resilient development policies in the Global South, and international cooperation in support of communities vulnerable to extreme events and slow-onset impacts of the climate crisis.

Acknowledgments

The authors would express gratitude to the Melissa Network for Migrant Women and DLA Piper for assisting with surveys. Special thanks are also due to the two anonymous reviewers for their valuable comments, Demetres Karavellas of WWF Greece, for proofreading the final manuscript, and Leon Kapetas, Resilient Cities Network, for comments on the first draft of the article.

Funding

Part of this work was supported by a grant from the European Climate Foundation awarded to the Greek Council for Refugees.

Conflict of Interests

The authors declare no conflict of interests.

Data Availability

Data is available from the authors upon request.

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Ocean and Society
2026 • Volume 3 • Article 11894
https://doi.org/10.17645/oas.11894

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Geopolitical Upheaval Through Climate Measures: IMO and EU Decisions for International Shipping

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Submitted: 29 December 2025 **Accepted:** 14 May 2026 **Published:** 14 July 2026

Issue: This article is part of the issue "Ocean Climate Governance: Eclectic Viewpoints of a Multi-dimensional Nexus" edited by George Dikaios (Leiden University), fully open access at https://doi.org/10.17645/oas.i488

Abstract

The contribution of the shipping sector to the fight against climate change and, particularly, to the mitigation of greenhouse gas emissions has been high on the maritime agenda for the last decade. In this context, the International Maritime Organization and the European Union, two international organizations that strive to regulate shipping emissions, adopt several policies, measures, or tools to that end. This article explores whether and to what extent the decisions of the two respective organizations will have geopolitical repercussions that might affect shipping and trade operations. The findings, at least for the time being, suggest that existing climate policies are diverging, thereby increasing the complexity and uncertainty of the geopolitical landscape. This results in multiple potential scenarios concerning which countries will assume leadership in maritime fuel trading.

Keywords

climate geopolitics; climate policy; European Union; geopolitics; greenhouse gas emissions; International Maritime Organization; shipping

1. Introduction

For the past decade or so, the debate over reducing greenhouse gas (GHG) emissions from shipping has been prominent in climate change discussions. Although the sector contributes roughly 3% of global GHG emissions, its emissions have increased by 20% over the past decade (UN Trade and Development, 2023). This fact has led international actors, such as the International Maritime Organization (IMO) and the European Union (EU), to engage systematically with efforts that would lead to the decarbonization of the shipping industry.

The decisions of these two international organizations are expected to have a series of ramifications, including geopolitical repercussions.

The examination of this case offers an opportunity to explore whether the renewed attention to geopolitics—intrinsically connected to shipping and maritime affairs recently (Doppen et al., 2025; Polemis & Bentsos, 2025)—offers a convincing narrative to understand how climate decisions from influential international actors will affect aspects of international shipping and maritime trade. The article explores an under-researched topic in the literature, namely the connection between current climate developments, geopolitics, and shipping. The focus on geopolitics is rather topical, as the term regains significant attention in international affairs; the article takes a different path to understand how climate action interferes with geopolitics, and thus it emphasizes *climate geopolitics*, and what are the results of this entanglement in a field that more and more gets affected by politics.

To that end, the article cumulatively examines the IMO's and the EU's climate decisions for the following reasons: While the IMO is the responsible international organization to regulate all the aspects related to international shipping, it is the EU which endeavors to be a normative power in that field and export its shipping climate policy globally, in an attempt to make shipping greener (Dikaios, 2024). The EU has repeatedly pledged that it will follow the international system should it believe that it will substantially contribute to the fight against climate change. Else, it will be implementing its own, trying to lead the way for the rest of the world, especially the part of the world that has trade relations with the EU. It is worth noting that the global maritime industry accounts for over 80% of the world's trade, whereas 77% of European external trade and 35% of intra-EU trade by value are facilitated via sea routes (European Environment Agency & European Maritime Safety Agency, 2021). Thus, the EU has (or aspires to have) a say on how this trade will be made; currently, the EU's goal is to lead international shipping towards a green/climate transition.

In a recent article on the geopoliticization of energy policy, Herranz-Surralles (2024) argues that "the energy transition brought to the fore intense rivalries and geostrategic concerns about foreign energy investment and the dependencies created by global value chains of green technologies" (p. 2). Based on this, as well as on the aforementioned starting points, this article will attempt to analyze whether and to what extent the IMO's and the EU's climate decisions concerning shipping will have broader geopolitical repercussions. We investigate whether these initiatives influence the reconfiguration of global maritime power dynamics through the realignment of fuel supply and trade routes. After this introductory part, the article will take form as follows: First, a contextual part is presented justifying the reasoning behind the article; second, the discussion on green/climate/environmental geopolitics will be unfolded in an attempt to draw a conceptual framework; third, the current climate decisions of the IMO and the EU will be presented and the analysis of broader geopolitical repercussions will follow; finally, the concluding section will discuss the findings.

2. Context and Justification

In 1997, a "suggestion" made towards the IMO within the framework of the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC) set the agenda for the mitigation of GHG emissions from shipping. It was this semi-formal action that led to the first concrete attempt at GHG emissions reductions from shipping. However, it took the IMO over 20 years to create a more consistent policy proposal. More specifically, in 2018, the IMO adopted the Initial Strategy on Reduction of

Greenhouse Gas Emissions from Ships. At this point, it is interesting to mention that GHG emissions from ships are not taken into account when the percentage of each country's emissions is calculated. Further, shipping is exempted from the UNFCCC and its complements (Kyoto Protocol and Paris Agreement), which is the main framework of combating climate change. Lastly, it is also worth noting that, since 1992, the IMO is recognized as the responsible international organization to work on this matter.

The adoption of the Initial Strategy was considered a success for the IMO member states, as they managed to officially put the mitigation of GHGs from international shipping on the agenda. Nonetheless, the Initial Strategy did not gain a significant percentage of support within the Organization (Doelle & Chircop, 2019), leading to a weakened commitment. Additionally, the Initial Strategy is only an—initial, as its name suggests—roadmap for the examination of the possibility to reduce GHG emissions from ships by 50% by 2050 (based on the emissions of 2008). Nevertheless, and after a halt to the negotiations due to the Covid-19 pandemic (Dikaios, 2024), which created delays to the development of more specific measures on how the *initial* goal would be achieved, in July 2023, the 2023 IMO Strategy on Reduction of GHG Emissions from Ships was adopted. The ultimate goal of this Strategy is to achieve the target of net-zero for shipping emissions, by 2050.

Going back in time, one of the most significant international actors that put heavy pressure on the international community to adopt climate measures for international shipping was the EU. The reasons for this can be summed up in the latter's ambitious climate policy, which has been shaped within the EU's framework, one of the most comprehensive ones globally. In conjunction with its climate policy, the EU performs an active climate diplomacy in a series of international fora to promote climate-friendly policies for all and from all (Earsom & Delreux, 2021a). Within this framework, and with GHG emissions from shipping constantly growing, the EU has initiated internal measures since 2015, with an aim to convince the IMO to take action as well (Dikaios & Blavoukos, 2023; Earsom & Delreux, 2021b). After the adoption of the Initial Strategy in 2018, the new president of the European Commission was elected on the promise of the European Green Deal, which was presented in late 2019; the Deal's main goal was—and still is—to achieve climate neutrality in the European continent. Moreover, it encompasses specific measures directed to shipping, both internally and externally, targeting to decarbonize shipping and all related industries as much as possible.

The climate decisions both in the IMO and the EU, which have yet to be put into full operation, will probably lead to geopolitical changes. Mitigation of ships' GHG emissions will probably create new "green" corridors, or shorten the existing corridors allowing for new trade relations that are more climate- and environmental-friendly; they will also likely require a change in fueling, and thus, alter the global importance of some countries; they will, also, demand the development of new green(er) infrastructure to host this new green(er) trading activity and, as such, countries which are more prepared than others to build said infrastructure will potentially benefit. It is apparent, therefore, that the above decisions might have geopolitical repercussions, and alter the power or significance of some countries compared to others that today are important for international trade. This possible change of geopolitical status quo will coincide with the renewed attention given to geopolitics, which is yet again becoming a buzzword and an analytical tool (e.g., Bremberg & Michalski, 2024; Eichengreen, 2024; Herranz-Surralles, 2024). This was also highlighted by the recent reaction of the president of the United States, who demanded that the IMO not vote in favour of green rules in shipping (Lin & Brennan, 2025).

Nevertheless, as the IMO and EU work towards specifying or implementing their climate decisions, it is crucial to consider the potential impact on global trade patterns and the various actors involved. For instance, countries with extensive coastlines or significant maritime trade routes may be disproportionately affected by changes in shipping regulations. Similarly, countries that rely heavily on international trade may face challenges in adapting to new fueling requirements and infrastructure demands. By examining the interconnectedness of these factors, we can better understand the far-reaching implications of climate decisions on the global stage and identify opportunities for cooperation and adaptation (Wilmsmeier & Monios, 2020).

3. Towards Climate Geopolitics

According to Flint (2006), "geopolitics is the practice of states controlling and competing for territory" (p. 13). The writer also connects geopolitics to the "ideas of war, empire, and diplomacy" (Flint, 2006, p. 13). This, unsurprisingly, is a common understanding of the term geopolitics, which in the majority of—if not all—literature, is inextricably related with security issues and securitization (Mamadouh & Dijkink, 2006; Murphy et al., 2004; Ó Tuathail & Dalby, 1998). Coming back to Flint's perspective, geopolitics also has to do with the resources within a territory and, taking a step forward, "geopolitics is a way of 'seeing' the world" (Flint, 2006, p. 13).

Since the late 1990s, when the notion of "critical geopolitics" appeared (Dittmer & Gray, 2010), a part of the literature has also attempted to take a view on green geopolitics or climate change geopolitics. The growing challenges arising due to climate change and the (ab)use of resources, made some scholars—mostly coming from a political geography perspective—delve into it. Still, the literature is relatively limited and mostly coined by the political geographer Dalby (2003, 2013, 2014).

Dalby, in 2003, intertwined green/climate geopolitics with security. It was a period in time when almost the totality of the discussions around geopolitics focused on wars and great powers or on how the term is utilized publicly to create specific images of the world (Dittmer & Gray, 2010). Dalby considers environmental, climate, or green challenges as "postmodern" issues that transcend borders—a reality that goes beyond the traditional perceptions of demarcated spaces in a geopolitical worldview. He also allows the reader to assume that any "new" issue that will be added in any geopolitical discussion will not alter the way geopolitics influences strategies and power, but rather will append to the prevailing discourses. For Dalby, it seems that green geopolitics will be an area of contestation between which power will manage to develop the better suiting technologies and their control over resource possession, management, and processing. Therefore, our first expectation is that, under current climate policies, power contestation will focus on states with the most advanced technologies for producing and exporting alternative low- or zero-emission fuels, rather than on countries that produce traditional fuels, such as the OPEC countries.

Ten years later, Dalby (2013) repeated his argumentation, taking it a step further by adding that climate change as a geopolitical challenge falls into "the spaces of the global neo-liberal economy" (Dalby, 2013, p. 38). Accordingly, he writes about the reduction of geopolitical distances, applying an example of the past, i.e., nuclear power, to explain how climate change, as an anthropogenic activity, influences geopolitics. While shipping is indeed a crucial part of the global economy, is it a straightforward "pillar" of the neoliberal economy? Neoliberalism is an economic philosophy that emphasizes free market principles, privatization, and deregulation, and while shipping is certainly a key component of global trade, it's not necessarily a direct reflection of neoliberal ideology.

The interpretation of climate change as a geopolitical issue within the spheres of the global neoliberal economy introduces the concept of geoeconomics, which is central to linking shipping and geopolitical significance. Luttwak (1990) initially defined geoeconomics in 1990, following the Cold War, prompting extensive scholarly debate that currently predominantly centers on whether it can substitute geopolitics (Shahzad, 2022), function as a tool for geostrategy (Lipkan et al., 2023), or be comprehended across various domains such as policy, military economics, and technology (Mohr & Trebesch, 2024). For the purposes of this article, the term will be used only to emphasize the geopolitical importance of shipping, without engaging in the debate surrounding the conceptualization of the term. Returning to the initial exploration of the concept of geoeconomics, within the neoliberal framework, geoeconomics emphasises the utilisation of economic strength, trade flows, and market instruments as means to exert geopolitical influence, i.e., market-based measures (MbMs). As economic globalization has progressed, economic interests have become integral components of the strategic priorities of states. In this context, economic and market instruments—including trade agreements, supply chain management, investment in critical infrastructure, and regulatory standards—have gradually supplemented or replaced traditional political and military tools, which were historically central to geopolitics (Topalidis et al., 2024).

Shipping does play a significant role in facilitating globalization and the movement of goods across borders, which is often associated with neoliberal economic policies, and therefore constitutes a key area in which geopolitical dynamics materialize. The globalization of trade and commerce has led to the growth of container shipping and the expansion of international trade networks, which have contributed to increased economic interdependence and connectivity across the world. Furthermore, shipping has indeed reduced distances between countries and regions by facilitating the rapid movement of goods over long distances. This has enabled global trade to grow and has had a significant impact on global commerce, culture, and communication. However, it's worth noting that while shipping has reduced distances in some respects, it has also created new forms of spatial inequality and connectivity. For example, some regions may be more connected to global markets than others, while certain communities may be more vulnerable to the impacts of globalization due to their geographical location or lack of infrastructure. In this sense, shipping both reflects and reshapes the geoeconomic landscape, redistributing power and dependence, thereby acquiring geopolitical significance.

Revisiting Dalby's arguments concerning climate geopolitics in 2014, he further substantiated his claims by asserting that, in addition to the tangible factors influencing geopolitics, there also exist intangible elements that are not directly linked to the conventional state-centric framework and its associated mechanisms (Dalby, 2014). The focus is turning towards "what is ruled over" (Dalby, 2014, p. 14) and by whom. The latter is closer to classic geopolitics and leads to the question of which powers are going to be prevailing in the new geopolitical landscape that the IMO's and EU's climate decisions on shipping construct. This also comes to add to a recent observation by some scholars that the green transition will lead to the rise of new leaders and the fall of new laggards, with transportation routes having to play a role in these developments (Vakulchuk et al., 2020).

The division between leaders and laggards has been a classical explanatory tool of countries' climate change performance, usually not being conceptualized but rather used as a categorization (Borzel, 2000; Liefferink et al., 2009; Tobin, 2017). The most prominent attempts to conceptualize leaders and laggards have been made by Knill et al. (2012) and Melidis and Russel (2020). Both pieces agreed on the definition of what one expects—leaders are the ones who either propose or are the first to implement an ambitious climate/environmental policy, while laggards are the ones who are either reluctant and indifferent to adopt such a policy or they purposefully sabotage it. In this article, a similar rationale will be followed so as to examine which countries will be the leaders and which will be the laggards in the new geopolitical context that climate change imposes on shipping. Accordingly, since nearly 50% of fuel trade is conducted via shipping (J.P. Morgan, 2025), our second expectation is that countries which implement climate decisions first—particularly those linked with changes in fuels—will be leaders in this trading reality; conversely, countries that are hesitant will be laggards.

The discussion on leaders and laggards is also enriched by the contribution of Barnett, who, in 2007, argued that climate change is a complicated geopolitical challenge, as those who emit anthropogenic GHG emissions and those who suffer the most from the impacts of climate change might differ (Barnett, 2007). In this article, one of the goals is to examine whether climate decisions can possibly change the strategic significance of countries or regions. Thus, this article distances itself from the deterministic point of view that geopolitics shared largely in the past (the geographic fate of each country) and moves towards strategic geopolitical thinking, where strategic decisions of some actors can affect the geopolitical weight of others.

4. Conceptual Framework for Climate Geopolitics

Before engaging in the broader analysis, we elucidate how we conceptualize geopolitical repercussions, effects, and change within the specific context of climate change and international shipping.

Drawing on critical geopolitics (Dittmer & Gray, 2010), and more specifically on Dalby's work on green/climate geopolitics (2003, 2013, 2014), climate geopolitics is understood here as a field of contestation over which actors can develop the most suitable technologies and secure control over possession, management, and processing of resources (Dalby, 2003). Crucially, climate geopolitics also brings into focus intangible, non-state-centric factors that can shape geopolitical dynamics beyond state borders. This opens space for a variety of actors, entities, and organizations to exert influence—for our purposes, most notably the EU's and IMO's climate regulatory frameworks on shipping. This emphasis not only intensifies competition over resources but also prompts further questions about what is ruled over and by whom (Dalby, 2014). In this article, *geopolitics* is therefore understood, through the lens of climate geopolitics, as the manner in which the arrangements of resources, technologies, and infrastructures among various powers can be influenced by both tangible and intangible factors, including regulatory measures enacted by the IMO and the EU.

Within this framework, we distinguish between *geopolitical repercussions*, *effects*, and *change*. Although there is no single, widely accepted definition of these terms, the academic literature that employs them allows us to identify some key distinctions. Namely, *geopolitical effects* refer to observable shifts in incentives, behavior, or positions that do not necessarily modify the overall structure of the international system. *Geopolitical repercussions* also pertain to observable shifts but describe indirect and unintended consequences (Burrows & Harris, 2009; Gupta et al., 2018; Mampuys et al., 2025). In the context of this article, this signifies that efforts to mitigate ships' GHG emissions driven by the IMO's and the EU's climate policies, as well as the promotion of alternative fuels, will likely necessitate changes in fuel utilization and the development of new, environmentally friendly infrastructure and technologies to support this emerging trade pattern. Furthermore, climate policies may establish new "green" corridors or shorten existing ones, thereby enabling trade relations that are more aligned with climate and environmental objectives. In contrast, *geopolitical change* refers to structural transformations within the international system (Cohen, 1991; Forbes, 2003). It concerns the ways in which these effects and repercussions can reshape the relative global importance of specific powers. In our context, such changes may be recognized as advantageous to states that are more effectively equipped to develop the requisite infrastructure and adopt essential technologies, thereby facilitating the identification of potential leaders and laggards in the green transition within the maritime sector.

It is notable that the term *geopolitical change* appears more frequently in earlier literature, whereas more recent analyses tend to refer to *geopolitical effects*, *geopolitical repercussions*, or *risks*. This change may reflect the emerging international order, which exists between a highly fluid power landscape—where alliances are temporary—and a structure based on multiple blocs (Mampuys et al., 2025).

Given the complexity of analyzing geopolitical change, our article examines whether the IMO's and EU's climate decisions for shipping generate such change by focusing on two core dimensions. The first is regulatory power, which captures how these decisions use rule-making, standard-setting, and MbMs to influence the choices of other actors. Geopolitical effects at this level include the ability to extend regulatory preferences beyond one's own jurisdiction. The second is economic-strategic positioning, which concerns the distributional implications of climate decisions for fuel producers and trade. Geopolitical repercussions here include the emergence of new fuel hubs, green shipping corridors, and port alliances, as well as risks of carbon leakage and the relocation of transhipment hubs. These two dimensions provide the analytical framework for examining the geopolitical effects and consequences of the IMO's and EU's climate decisions and support our discussion of leaders and laggards, enabling us to identify which countries are likely to assume leadership and which are likely to lag behind within the new geopolitical landscape imposed by climate change on shipping, and thus to trace potential geopolitical shifts.

5. Research Design

This article adopts a qualitative policy content analysis, combined with doctrinal policy analysis, to examine how climate regulations in international shipping may generate geopolitical repercussions. The analysis focuses on policy and regulatory content, specifically the EU's Fit for 55 package and the 2023 IMO Strategy on Reduction of GHG Emissions from Ships, encompassing short-term measures implemented by the IMO to reduce GHG emissions. Additionally, potential repercussions on key variables—such as fuel markets and trade patterns—are mapped. The selection of these policies is based on the fact that the EU and the IMO are the only two international organizations that have adopted climate measures to decarbonize the shipping sector and are expected to shape part of the future shipping activity, influencing how the rest of the world will develop respective policies. Nonetheless, the article does not seek to provide a definitive causal explanation of fully realized geopolitical changes; rather, it advances theoretically informed expectations and scenarios concerning how IMO and EU climate policies for shipping may influence the incremental reorganization of maritime relations along regulatory and economic-strategic dimensions.

The analysis is supplemented by scholarly literature and empirical observations, including fuel uptake and alliance positions from 2019 to 2025. The selection of particular policy content related to the IMO was intended to focus on climate-related decisions adopted and employed within international shipping. It is noteworthy that the IMO has adopted other climate measures that are more indicative than prescriptive, such as the resolution Marine Environment Protection Committee (MEPC) 376(80) regarding Guidelines on the Life Cycle GHG Intensity of Marine Fuels (Life Cycle Assessment (LCA) guidelines), which clarifies that these guidelines are not intended to serve as a comprehensive IMO GHG inventory for international shipping. Concerning the EU, measures related to climate decisions in the maritime sector with territorial extension were analyzed, specifically the EU Emissions Trading System (ETS) Maritime and FuelEU Maritime. Both extend their regulatory reach to intercontinental voyages, thereby their impacts are felt beyond EU borders and influence international shipping activities (Dobson & Ryngaert, 2017; Scott, 2014). As the topic at hand is under-researched, the analysis begins from the official documents of the international organizations and, through a process that resembles the snowball effect, which is used for under-explored studies (Ting et al., 2025), it follows the lead that is given through the reports and literature on the future scenarios in the fuels markets and the maritime trade.

6. Climate Decisions on Shipping

This section analyzes the climate decisions of the IMO and the EU on maritime transport through two core analytical dimensions. The first dimension concerns regulatory power. It explores how the IMO's and EU's climate decisions on shipping use rule-making, standards-setting, and MbMs to steer the behavior of other actors. The geopolitical implications at this level include the capacity to project regulatory preferences beyond their own jurisdictions. The second dimension concerns economic-strategic positioning. It analyses the distributional effects of climate decisions on fuel-producing countries and trade. Geopolitical repercussions here include the emergence of new fuel hubs, green shipping corridors, and port alliances, as well as the risks of carbon leakage and relocation of transhipment hubs. In conjunction, these two aspects provide the analytical framework for assessing the geopolitical effects and repercussions of IMO and EU climate policies on shipping.

6.1. Regulatory Power

6.1.1. IMO

In July 2023, the MEPC of IMO adopted the 2023 IMO Strategy on Reduction of GHG Emissions from Ships (hereafter referred to as the Revised Strategy). The goal was to complement and put into force what had been agreed at the Initial Strategy in 2018, which was deemed insufficient. The Revised Strategy marks a significant advancement in setting more robust objectives as it "strengthened the ambitions for international shipping compared with the Initial Strategy's ambition for a 50% GHG reduction by 2050" (DNV, 2023, p. 12). In more concrete terms, it represents the Organization's initial commitment to achieve near-zero GHG emissions. Specifically, the Revised Strategy delineates two indicative checkpoints: (a) a 20% reduction in emissions by 2030, accompanied by an additional non-legally binding effort of 30%, and (b) a 70% reduction by 2040, with a further targeted reduction of 80% (IMO, 2023, p. 6).

Simultaneously, for reaching the targets mentioned above, the potential coupling with other short-term measures, such as the Carbon Intensity Indicator (CII) aiming at enhancing the energy efficiency of ships, were emphasized in the text (IMO, 2023, p. 8). Among the existing technical and operational measures, it is worth mentioning, in addition to CII, the Energy Efficiency Existing Ship Index (EEXI). These are both mandatory measures adopted within the framework of the Initial Strategy, with implementation having started in 2022 for EEXI and in 2023 for CII, for all ships, i.e., existing and new (IMO, 2021). EEXI concentrates on design parameters, whereas CII evaluates operational efficiency for existing vessels. Both measures greatly impact vessel speed and the supply–demand dynamic, targeting carbon fuel-based ships with a goal to cut GHG emissions by 30% by 2030, as outlined in the Revised Strategy. Their effectiveness is scheduled for review in January 2026 (IMO, 2021).

Although it is apparent that the IMO has made some efforts to acknowledge and address the issue of emissions in international shipping, the text of the Revised Strategy does not explicitly reference complete decarbonization within its vision. Instead, it states that the IMO remains committed to reducing GHG emissions, with an aim to phase out emissions as expeditiously as possible (IMO, 2023, p. 5). This hesitance from the part of the Organization to commit to the decarbonization of international shipping can be attributed to the fact that, prior to the adoption of the Revised Strategy, at MEPC 78 no consensus could be reached regarding whether the 2050 target date would imply a phase-out or a state of net-zero emissions, or whether the Revised Strategy should encompass only CO_2 or additional GHG emissions as well. These differences in opinions have prevented the MEPC from adopting a document that sets forth an ambitious target of net-zero GHG emissions by 2050 (Handl, 2023). Although there is significant room for increased ambition in the Revised Strategy, it is scheduled for revision in 2028 concerning the established level of ambition for reducing emissions in international shipping (IMO, 2023).

6.1.2. EU

On the contrary, as articulated in Section 2, the EU has developed one of the most comprehensive frameworks for climate policy, culminating in the presentation of the European Green Deal in 2019, which establishes an ambitious objective of achieving climate neutrality by 2050, by prioritizing the transformation of the economy and the reduction of carbon footprints across all sectors. In this context, with regard to the shipping industry, the European Commission (2025) seeks to advance its objectives through two primary strategies: firstly, by improving energy efficiency to minimize fuel consumption, and secondly, by advocating for the adoption of renewable and low-carbon fuels to facilitate a shift towards cleaner energy sources.

The Fit for 55 package, which is the interim implementation package of the European Green Deal with the goal of reducing emissions by 55% by 2030, was published in 2021. Moreover, regarding the decarbonization of shipping, one of the most significant legislation initiatives of the package is the extension of the EU ETS to the maritime sector (EU ETS Maritime; European Commission, 2025). ETSs, in general, are categorized within the so-called market-based measures (MbMs). In the context of decarbonizing the maritime sector, these measures employ economic incentives and disincentives to encourage shipping companies to reduce their emissions and to invest in innovative, regulation-compliant technologies and fuels. This can be achieved either by imposing a tax (levy) on maritime bunker fuel or by establishing a specific annual emissions cap that requires companies to buy or sell emissions allowances to meet their respective emission reduction targets, as in the case of an ETS (Christodoulou et al., 2021; Harahap et al., 2023; Lagouvardou et al., 2020). The EU extended its ETS to the maritime sector, covering CO_2 emissions from all large ships entering EU ports from January 2024, regardless of their flag. The latter ensures that emissions from maritime transport are included in the overall ETS cap, which sets the maximum amount of GHGs that can be emitted within the system. Overall, the cap decreases over time to ensure that all ETS sectors contribute to the EU's climate objectives; this ultimately promotes energy efficiency and low-carbon solutions and reduces the price gap between alternative fuels and traditional maritime fuels (European Commission, 2025).

Furthermore, central to the decarbonization of the maritime sector, aside from the EU ETS, is the introduction of Regulation 2023/1805 on the use of renewable and low-carbon fuels in maritime transport (FuelEU Maritime). This regulation aims to promote the consistent use of renewable and low-carbon fuels in maritime transport across the EU (Regulation of 13 September 2023, 2023). It sets a maximum limit on the GHG content of energy used by ships that arrive at, stay in, or depart from ports under the jurisdiction of a member state, while promoting the use of on-shore power supply or zero-emission technologies in ports under the jurisdiction of a member state. The regulation also applies to large ships exceeding 5,000 gross tons, regardless of their flag (Regulation of 13 September 2023, 2023, Article 1). The FuelEU Maritime Regulation complements the extension of the EU ETS Maritime, aiming to progressively decrease the GHG intensity of fuels utilized in voyages to and from European ports. The geographical scope of both regulations extends beyond European voyages—defined as voyages between member states—to include intercontinental voyages, which involve voyages from a member state to a third country and vice versa (Kotzampasakis, 2023). Thus, ships that do not meet the acceptable technological and fuel standards established by EU ETS Maritime and FuelEU Maritime can be barred from entering the EU's internal market (Regulation of 13 September 2023, 2023). Historically, the EU market has served as a conduit for the "Brussels effect," where the requirement to access the EU encourages third countries to align with EU standards, prompting them to amend their laws to remain competitive (Blazo, 2025), extending the EU's regulatory influence beyond its borders. It is worth noting that previous research on EU–IMO relations in climate change (Dikaios, 2024) found that the EU was unable to exert significant influence at the international institutional level. Nonetheless, the analysis in this article indicates that specific EU maritime climate policies with extraterritorial effects possess the potential to influence other actors within the international system (Blazo, 2025; Otto, 2025).

Ultimately, both the IMO and the EU have enacted climate measures targeting GHG emissions from shipping (see Supplementary File), but they differ significantly in scope, legal nature, enforcement mechanisms, and geopolitical implications. In particular, the IMO, as the "competent international organisation," is responsible for establishing global rules and standards on shipping safety, security, and environmental protection (Li & Fu, 2025). Its Revised Strategy aims to cut emissions by 70–80% by 2040 through an overall framework supported by mandatory operational and technical measures, i.e., EEXI and CII, that apply to all international shipping activities, regardless of flag. Compliance varies between these binding measures—enforced mainly via mandatory reporting and port inspections—and the non-binding Revised Strategy, which sets sector-wide goals and checkpoints (IMO, 2021, 2023). Notably, the lack of a clear phase-out date and legally binding regulations on technological and fuel advancements raises concerns about the IMO's consistency with the Paris Agreement's long-term temperature targets, as well as future technological and fuel investments by countries. Conversely, the EU has established a broader and more stringent regional framework, including measures such as the EU ETS Maritime and FuelEU Maritime, which apply to both intra-EU and international voyages. These measures impose binding obligations on shipping companies and port authorities and are supported by detailed monitoring, reporting, verification rules, financial penalties for violations, and access restrictions to EU ports for ships entering or leaving European ports (European Commission, 2025; Regulation of 13 September 2023, 2023), expanding the EU's regulatory influence beyond its borders. Collectively, the EU's maritime climate policies encourage the adoption of alternative fuels and the improvement of energy efficiency in shipping. Nevertheless, their extraterritorial influence could induce geopolitical tensions, as certain third countries interpret the EU's measures as unilateral, potentially constituting trade discrimination, and as encroaching upon the IMO's role as the principal global regulator of international shipping. This aspect will be examined in the subsequent section, which will focus on economic-strategic positioning, prompted by the climate policies of both the IMO and the EU.

6.2. Economic-Strategic Positioning

6.2.1. Fuel Geopolitics

To analyze the potential impact of these climate initiatives, it is essential first to comprehend the alternatives to traditional fossil-based bunker fuels and to understand the role that they may play in driving a shift in fuel demand and benefiting specific countries. More specifically, the research conducted by Mahia Prados et al. (2024), which identified maritime fuels, indicates that six types of fuels are currently utilized or possess the potential for utilization by the maritime sector, namely fossil fuels, electrofuels (e-fuels), blue fuels, hydrogen, and nuclear energy. Within the category of fossil fuels, liquefied natural gas (LNG) and liquefied petroleum gas (LPG) are also included, along with a sub-category known as biofuels, which are derived from a combination of fossil fuels and environmentally friendly organic mixtures (Mahia Prados et al., 2024). Based on the relevant literature (Christodoulou & Cullinane, 2022; Handl, 2023; Harahap et al., 2023; J.P.Morgan, 2025), which discusses the most promising low- and zero-carbon maritime fuels in the context of decarbonizing the maritime sector with regard to efficiency, and in alignment with recent climate policy decisions, the fuels identified include LNG, hydrogen, ammonia, and bio-methanol.

To begin with, LNG, a gas derived from fossil fuels, is regarded as one of the most promising low-carbon fuels due to its compatibility with existing ship engines. In addition, LNG is distinguished from alternative options by its significantly higher technical and operational maturity (Christodoulou & Cullinane, 2022; Handl, 2023). Since 2019, the United States has been the leading contributor to LNG export capacity, accounting for more than half of the total (International Energy Agency, 2025). While LNG produces lower emissions compared to other fossil fuels, it still falls into the fossil fuel category, and a methane slip occurs during combustion that limits its classification as a short-term drop-in or intermediate fuel. Since methane is a potent GHG, LNG alone cannot fully decarbonize the maritime sector (Christodoulou & Cullinane, 2022). Despite aligning with present IMO decisions, more specifically, LNG is expected to achieve a higher energy efficiency rating under the CII assessment (Mahia Prados et al., 2024). The EU's stricter climate policies will begin to favor cleaner fuels, especially from 2026 onwards, as the EU ETS Maritime cap decreases and expands to cover more GHGs, including oxides and methane. This shift may impact LNG's use, as indicated by the significant drop in scheduled LNG carrier deliveries after 2028 (Lloyd's List, 2025).

Continuing with methanol, especially bio-methanol—which is produced from carbon-neutral sources—is seen as one of the emerging leading alternatives for decarbonizing the maritime sector. Its primary advantages include its significant flexibility, as it can be used in fuel cells or internal combustion engines, prompting many companies to order methanol-fueled ships (Handl, 2023; Harahap et al., 2023).

Furthermore, its importance has increased again amid geopolitical tensions from the war in Ukraine and rising LNG prices, leading shipping companies to invest more in methanol-fueled vessels. For example, Alphaliner reported a 28% increase in dual methanol–gas oil engine vessels from 2021 (Mahia Prados et al., 2024). A notable drawback is that methanol production depends on biomass availability, and large-scale manufacturing could threaten food security, as biofuels are often made from crops (Handl, 2023). Although bio-methanol aligns with IMO regulations, its deployment faces specific limitations that prevent full compliance with the EU framework. Importantly, biofuels from food or feed crops are not consistent with FuelEU Maritime (Regulation of 13 September 2023, 2023). Because of limited availability and these restrictions on ships arriving, staying, or departing from European ports, investing in bio-methanol might be a short-term, less costly option.

Among the leading zero-carbon fuel options are hydrogen and ammonia. There are various methods of producing them both; if sourced from carbon-free elements, they can be considered acceptable long-term marine fuels. Moreover, green hydrogen and ammonia offer development opportunities for numerous countries (Handl, 2023). Nevertheless, their development is associated with various safety concerns, such as explosiveness and environmental damage in the event of leaks, as well as substantial capital investments required for new engine technologies (Harahap et al., 2023; Institute for Energy Economics and Financial Analysis, 2025). Currently, IMO safety regulations prohibit the use of hydrogen and ammonia due to hydrogen's high explosiveness and ammonia's toxicity (Christodoulou & Cullinane, 2022). Simultaneously, in the EU's climate framework, there is an understanding of these restrictions alongside recognition of hydrogen's vital role in achieving climate neutrality. Hence, to ensure its production from renewable sources and support its development, the European Commission published a hydrogen strategy in 2020 for a climate-neutral Europe. This strategy is further complemented by a document outlining EU regulations for renewable hydrogen (European Commission, 2020; European Parliament, 2023).

Unlike traditional fuels such as oil and gas, which are produced only in certain geographic regions, low- and zero-carbon fuels depend mainly on technology and infrastructure for their production (Altiparmak, 2023; Morgan, 2025). As mentioned above, zero-carbon options such as green hydrogen and ammonia offer opportunities for countries that have not been major fuel producers to gain a competitive edge in the alternative fuel shift and reduce their dependence on fossil fuels. Japan has reduced its energy consumption of short-term fuels such as LNG and has implemented various energy and climate strategies, including the Sixth Strategic Energy Plan, to decrease LNG exports and promote renewable energy sources (Institute for Energy Economics and Financial Analysis, 2025). Japan's and South Korea's National Action Plans submitted to the IMO emphasize hydrogen- and ammonia-powered ships as high-potential vessels, with plans to implement these engines by 2030 (Ministry of Land, Infrastructure, Transport and Tourism, 2020; Ministry of Oceans and Fisheries, 2023). Additionally, South Korea intends to establish 14 hydrogen ports by 2040 and create legal frameworks to facilitate the transition to a hydrogen economy (Ministry of Oceans and Fisheries, 2023). Singapore is advancing a multi-fuel bunkering approach, employing interim solutions such as biofuels and electrification, alongside long-term options like ammonia and hydrogen, and has signed a Memorandum of Understanding with Rotterdam and a Memorandum of Cooperation with Japan, to harmonize standards for future marine fuels (Maritime and Port Authority of Singapore, 2022). Meanwhile, Norway has established an ambitious goal to make its ports emission-free by 2030 through the provision of on-shore power supply and comprehensive bunkering services for hydrogen and biogas (Norwegian Government, 2019). Currently, the supply infrastructure needed for low- and zero-carbon shipping fuels, i.e., green hydrogen and green ammonia, is located all in Europe and the Baltic. Importantly, for some of these fuels, i.e., bio-methanol and green ammonia, there is little to no supply infrastructure available outside European waters (Mahia Prados et al., 2024).

Although projects for alternative fuels are not currently the main trend in international shipping, there is an indication that they are beginning to gain momentum and will play a significant role in long-term maritime decarbonization. In this transition, leadership is likely to be assumed by countries with advanced infrastructure, such as electrified ports and fuel bunkering facilities, as well as cutting-edge technology, particularly in electrolysis, which is essential for hydrogen production. This supports our initial expectation that, under existing climate policies, the competition for power is likely to revolve around countries capable of producing and exporting low- or zero-emission fuels, rather than those focused on traditional fuels. However, IMO's more modest and less binding targets, which favor short-term fuels like LNG, could put forward-looking countries at a disadvantage and enable traditional fuel producers to retain their influence.

6.2.2. Trade Realignment

The divergence between the IMO's global approach and the EU's regional measures is likely to result in varying rates of transformation across international shipping. This may lead to the emergence of two distinct dynamics within established maritime routes, as the regulatory scope of FuelEU Maritime and EU ETS Maritime extends to international maritime activities, encompassing all large ships arriving, staying, or departing from European ports.

In particular, considering that we are approaching the mid-century and the targets for decarbonization are also increasing—for instance EU ETS Maritime will reduce the set limit (cap) for emitted emissions, and FuelEU Maritime will reduce the energy intensity allowed to 80%—the cost for emitting carbon and using traditional fuels in European ports will be much higher in contrast to alternative fuels (Regulation of 13 September 2023, 2023). Nonetheless, due to the fact that these initiatives are regional and not global, the cost of entering European ports might prompt ships to reroute to avoid regulatory costs. Generally, the implementation of MbMs such as the EU ETS at the regional level within the shipping sector presents the risk of carbon leakage. This implies that shipping companies may register their vessels in other jurisdictions or engage in maritime trade in different geographical regions to circumvent the additional costs imposed by regional ETSs (Christodoulou & Cullinane, 2024). Furthermore, there is a potential risk that specific carbon pricing schemes might induce the relocation of European transshipment hubs to competitors in near non-European regions, thereby altering maritime routes to circumvent additional costs (Lagouvardou & Psaraftis, 2022). Such shifts are possible to occur only if carbon prices and compliance costs related to EU climate policies become significantly higher than the costs of non-compliance, which is not the case at present (Christodoulou & Cullinane, 2024).

Simultaneously, a second trend has emerged, recognizing that the costs associated with compliance in a more regulated market—stemming from international and regional climate initiatives—will enable smaller participants to surpass larger, slower-moving competitors. As the delay in compliance with new regional and international climate regulations lengthens, the financial impact will increase, thereby widening the gap between those who act proactively and those who do not (Lloyd's List, 2025). Thus, numerous countries have undertaken significant initiatives in recent years to facilitate this transition.

More specifically, while reducing speed is a measure employed by ships to comply with climate regulations—particularly for CII and EEXI, established by IMO—without necessarily utilizing low- or zero-carbon fuels, it may result in delays in the estimated time of arrival; potentially impact the total volume of transshipment goods adversely; and fail to keep pace with increasingly stringent regional climate regulations. In alignment with the climate commitments adopted by the IMO, in November 2021, during COP26, 22 countries signed the Clydebank Declaration. The signatory nations acknowledge the imperative transition to environmentally sustainable maritime fuels and the worldwide accessibility of land-based infrastructure to facilitate such fuels. They endorse the creation of green corridors, which are zero-emission maritime routes connecting two or more ports, and by 2025, they aim to establish at least six green corridors (Department for Transport, 2021). To that end, the United Kingdom has initiated funded studies for green corridor routes between the United Kingdom and Ireland, the Netherlands, Norway, and Denmark, in order to reduce the risk of future investments in these corridors (Department for Transport, 2025). It is noted that, aside from the Clydebank Declaration and MEPC's overall endorsement of the green corridor concept, it has not yet obtained formal international legal recognition (Handl, 2023).

Nevertheless, numerous corridors are actively enhancing their preparedness for zero-emission voyages. For instance, Singapore, Rotterdam, and Gothenburg have each successfully conducted ship-to-ship methanol bunkering trials. Additionally, Singapore and several other ports are currently engaged in safety and feasibility assessments for ammonia bunkering (Boyland et al., 2023). At the same time, the Australia–Japan Iron Ore route for zero-emission ammonia, the Portugal–Brazil route for green hydrogen, and the Shanghai–Long Beach route were also introduced (Pole Star Global, 2025). Thus, green corridors are linked to strategic investments and alliances in eco-friendly ports and fuels, drawing attention from the EU, especially the European Commission and the Directorate-General for International Partnerships. Moreover, the European Commission launched an ambitious initiative, the Global Gateway Green Shipping Corridor (GGGSC), to facilitate the transition to sustainable, renewable, and low-carbon fuels for international shipping while also contributing to sustainable development at the global level (Christidis et al., 2024). The identified potential partner countries for this project include Morocco, other African nations, Chile, Colombia, and Panama; all of which have existing trade agreements with the EU. Furthermore, based on Christidis et al. (2024) research, which identifies suitable ports for this corridor, any investments in GGGSC ports could alter shipping costs, making them more cost-effective for participating countries, and could also influence the port's standing within the global logistics chain. Finally, the research also emphasizes that the alternative networks developed through the establishment of GGGSCs can circumvent chokepoints and the subsequent geopolitical risks associated with those points (Christidis et al., 2024).

Hence, our analysis of economic-strategic positioning indicates that countries such as Norway, Singapore, Japan, and several EU member states, including Ireland, the Netherlands, and Denmark, have already initiated projects for alternative fuels and advanced infrastructure. Their proactive approach to implementing climate policies affords them a competitive advantage and establishes them as leaders amid this transition. This leadership could be further reinforced through the creation of "green corridors." Consequently, this supports our second expectation that countries that implement climate policies early will become leaders in this evolving trading landscape. Conversely, hesitant countries risk falling behind. Nevertheless, owing to disparities between global regulations, such as those established by the IMO, and regional regulations, exemplified by the EU, transshipment hubs may relocate to competitors, potentially leading to alterations in maritime routes as shipping companies seek to avoid increased costs associated with stricter climate policies.

7. Concluding Remarks

Both IMO and EU have implemented climate measures aimed at reducing GHG emissions from shipping. These initiatives are driving shifts in energy and fuel geopolitics, increasingly focusing on low- and zero-carbon fuels such as LNG, bio-methanol, green hydrogen, and ammonia. The choice of the most favorable option varies depending on the climate framework employed. Moreover, currently LNG is one of the most popular fuels, largely supported by the IMO's climate framework. However, it is not favored by the EU's long-term climate policies due to concerns over methane slip. Similarly, biofuels, i.e., bio-methanol, are supported by IMO but face scrutiny under the EU's stricter rules, as large-scale bio-methanol production may threaten food security. In contrast, hydrogen and ammonia are seen as promising alternative shipping fuels because they can achieve zero carbon emissions. Nonetheless, the IMO's current safety framework restricts their use and discourages capital investment, whereas the EU has created a safety framework to facilitate the safe adoption and stimulate investment in hydrogen technologies.

Our first expectation was that, under current climate policies, power contestation would focus on states with the technology to produce and export low- or zero-emission fuels, rather than on traditional fuel-producing countries. Our analysis initially confirms this, as the competition mainly lies between technologically advanced countries and regions making long-term commitments: Singapore is developing multi-fuel bunkering for biofuels, electrification, ammonia, and hydrogen, Japan and South Korea aim to introduce hydrogen- and ammonia-powered ships by 2030, and Europe possesses the necessary supply infrastructure for low- and zero-carbon shipping fuels. While our hypothesis appears to be initially supported, the IMO's more modest and less binding targets, which favor short-term fuels such as LNG, can disadvantage forward-looking countries and allow traditional fuel producers to remain influential. For instance, while the United States has led LNG exports since 2019, in 2024 over 70% of LNG exports came from the Middle East, including the United Arab Emirates, and in 2022 significant amounts originated from the Republic of Congo, ensuring that OPEC countries remain key players (U.S. Energy Information Administration, 2024). At the same time, this introduces complexity in investing in specific long-term alternative fuels for shipping.

Our second expectation was that countries that implement climate decisions early—particularly those related to fuel changes—will be leaders in this new trading reality, while countries that hesitate will fall behind. In particular, our analysis highlighted examples like Norway, Singapore, Japan, and several EU countries such as Ireland, the Netherlands, and Denmark, which have already established advanced infrastructure and projects for alternative fuels. These efforts, aligning with stricter climate policies, should theoretically give them a competitive advantage and position those countries as leaders in this transition, supporting our second expectation. Nonetheless, our findings also show this is not always the case. Due to differences between global and regional measures, there are also situations where these leaders' competitive advantages are not fully realized. For instance, transshipment hubs may relocate to competitors, and maritime routes could shift as shipping companies seek to avoid additional costs from stricter climate regulations.

To sum up, our main objective was to investigate whether international climate policies, especially those established by the IMO and the EU concerning the maritime sector, could alter the strategic standing of different countries or regions. Considering that geopolitics is the process of observing and creating scenarios regarding the influence of geographical necessities on political events and on changes in political situations in states (Hagan, 1942), our analysis revealed that current climate decisions are diverging in two different directions, making the geopolitical landscape more complex and uncertain. This creates several possible scenarios regarding which states will lead in maritime fuel trading. The competition for influence may not be limited to a simply rivalry between traditional fuel exporters, such as OPEC countries, and producers of alternative fuels. Instead, both groups could play important roles depending on how the climate framework evolves. Thus, there are numerous potential outcomes for how global power and trade relations around fuels might shift in response to these policy changes. Furthermore, the differences between the IMO and EU climate frameworks highlight that approaches of green geopolitics often focus on questions about governance, technological advancement, and resource control. However, these approaches typically assume the adoption of a single, comprehensive climate policy. In practice, since climate decisions can diverge, we cannot predict a single set of geopolitical changes; instead, it is important to consider a range of scenarios based on which policies are adopted. To that end, the initiatives of the IMO and the EU could foster innovation; however, they also pose risks of creating inconsistencies, compliance challenges, and imbalances in competitiveness. Finally, they open new *corridors* for future research, especially when the implementation of these measures is in full operation and changes to the system(s) are visible.

Acknowledgments

The authors would like to thank the three anonymous reviewers and Billy Tsagkroni for their constructive feedback. GD would like to thank the participants of the ECR workshop “The Return of Geopolitics or a New Age of Multiplexity? EU and Global Governance in the 21st Century” at the 12th SGEU Conference 2024 for their comments on an earlier draft. GD would also like to warmly thank Mina Akhavan for her contribution to the editorial work of this issue.

Funding

Publication of this article in open access was made possible through the institutional membership agreement between Leiden University and Cogitatio Press.

Conflict of Interests

In this article, editorial decisions were undertaken by Mina Akhavan (University of Amsterdam).

LLMs Disclosure

Grammarly has been used to a limited extent for proofreading and improving language clarity. No AI tools were used for content generation or writing.

Supplementary Material

Supplementary material for this article is available online in the format provided by the author (unedited).

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OCEAN AND SOCIETY
ISSN: 2976-0925

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