sustainability

MDPI

Article

Sustainable Maritime Governance of Digital Technologies for Marine Economic Development and for Managing Challenges in Shipping Risk: Legal Policy and Marine Environmental Management

Muhammad Bilawal Khaskheli [1], Yongchen Zhao [1] and Zhuiwen Lai [2,*]

[1] School of Law, Hainan University, No. 58 People's Avenue, Haikou 570228, China; 996679@hainanu.edu.cn (M.B.K.); yaashen@126.com (Y.Z.)
[2] Local Government Development Research Institute, Shantou University, No. 243 Daxue Road, Shantou 515063, China
* Correspondence: cwlai@stu.edu.cn

Abstract

This article addresses the pressing need for knowledge on how digital technologies, artificial intelligence, and blockchain can revolutionize opportunities in the marine economy and sustainably support business while balancing environmental protection and economic growth, and legal instruments and policy innovations for marine environmental protection. However, implementation, legal, and governance concerns still exist. This study discusses the development and challenges of these technologies according to their environmental, economic, business, and regulatory dimensions, following a literature review of more than 100 peer-reviewed articles, books, and a synthesis of global shipping policies, risk, policymakers, industry experts, and environmental scientists. The findings highlight the need for aligned international regulations to strike a balance between innovation and environmental goals, risks, and technology. This study introduces an innovative governance assessment framework, bridging the gap between technology scalability and equitable policy responses, as well as the environmental impact and ecosystem balance. We conclude with actionable recommendations for policymakers and companies to harness digital innovations while strategizing for long-term sustainability in the maritime sector and aligning UN Sustainable Development Goals with the principles of maritime law, the United Nations Convention on the Law of the Sea, and the United Nations Environment Programme Regional Seas Programme, offering ways to mitigate governance fragmentation. This study informs interdisciplinary discussion by bridging technical feasibility and legal feasibility, providing actionable suggestions to policymakers to reconcile digital innovation with the sustainability of the marine ecosystem.

Keywords: sustainable maritime governance; marine economy; shipping management; maritime environmental compliance; digital technologies; sustainable marine business; marine law and policy; marine protection

check for updates

Academic Editors: Hristos Karahalios, Emre Akyuz and Alexandros Dimitriadis

Received: 29 September 2025
Revised: 16 October 2025
Accepted: 24 October 2025
Published: 26 October 2025

Citation: Khaskheli, M.B.; Zhao, Y.; Lai, Z. Sustainable Maritime Governance of Digital Technologies for Marine Economic Development and for Managing Challenges in Shipping Risk: Legal Policy and Marine Environmental Management. *Sustainability* **2025**, *17*, 9526. https://doi.org/10.3390/su17219526

Copyright: © 2025 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

The marine economy, from fisheries and shipping to renewable energy and tourism around coasts, is a dominant support of global economic development with unparalleled challenges in sustainability [1]. The rise in sea temperatures, overexploitation of resources,

and contamination call for innovative solutions to offshore energy generation, which plays a significant role in global economic development and environmental sustainability [2]. Although its development is increasingly threatened by resource depletion, climatic effects, and regulatory fragmentation, digital technologies like artificial intelligence, blockchain, and the Internet of Things possess transformative potential for operational efficiency and ecological accountability. However, their integration into marine industries is situated within a complex array of global legal regimes that remain fragmented and often disregard technological developments [3]. While the international community faces the urgent mandate of decarbonization, the marine sector has become a key focus for mitigating emissions. Offshore operations and shipping are major contributors to world greenhouse gas emissions, and the establishment of sustainable routes in these sectors is critical to the realization of global climate targets. In this context, the use of nuclear power for offshore and marine activities is a new frontier in global efforts towards decarbonization [4]. Examining China's current progress in nuclear energy development for offshore and sea uses reveals remarkable advancements. China has also made concerted efforts in research and development, as well as technology innovations, to support the application of nuclear power in these activities. Non-military uses such as NPVs, FNPPs, nuclear-produced shore power, and sea radiation monitoring technologies demonstrate China's commitment to exploring all peaceful nuclear applications for the future [5].

International agreements provide the general framework for the regulation of sea activities. An example of a general framework is the United Nations Convention on the Law of the Sea (UNCLOS), which was enacted in 1982. It was authored, however, before the emergence of modern digital technology, and this has raised legal uncertainties regarding the deep-sea collection of data and the use of autonomous underwater vehicles [6]. Global initiatives to limit emissions, such as those under the Paris Agreement and the IMO 2020, indirectly influence the shipping sector. The regulations are accelerating the uptake of advanced technologies to optimize shipping routes and track fuel consumption and emissions digitally [7]. A higher importance is also placed on preserving marine life diversity, indicated by the Convention on Biological Diversity (CBD) and the 2023 UN High Seas Treaty (BBNJ). The technologies for enforcing compliance have remained ahead of sensor-based monitoring technology and defining models (as shown in Figure 1).

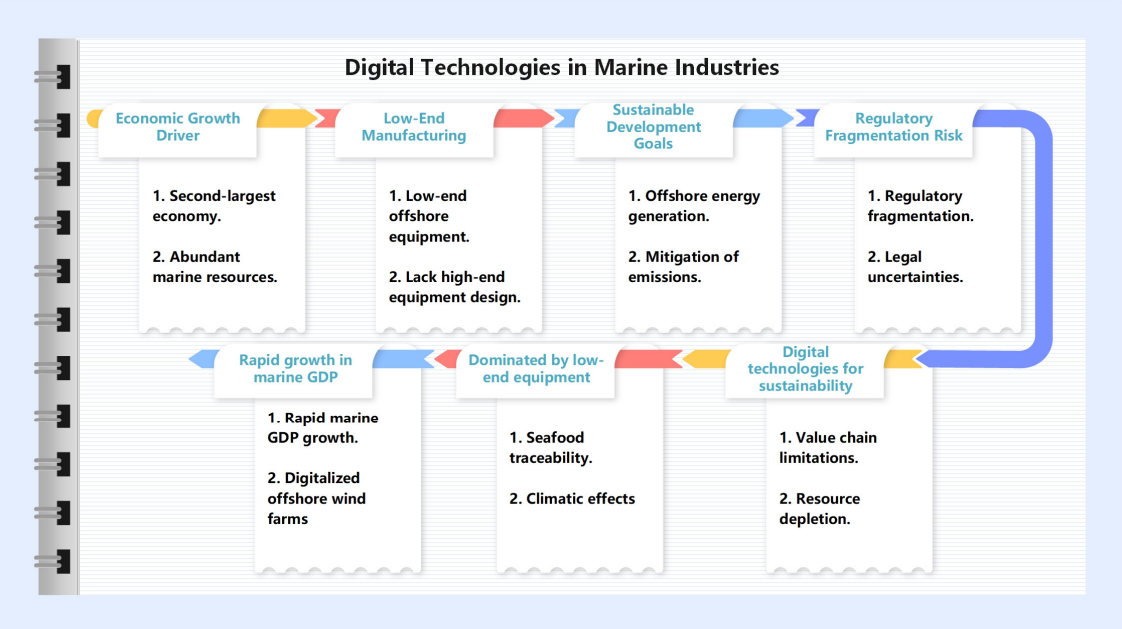


Figure 1. Flow diagram showing search and exclusion criteria.

Although autonomous navigation systems reduce shipping risks and improve efficiency, system failure within the Perception Planning Control (PPC) modules also raises complex legal issues. Fail-safe legality and responsibility distribution among stakeholders, such as remote operators, shipowners, algorithm developers, and data providers, are especially debated in this article, as it examines how well technology design matches current maritime law. Furthermore, regional laws such as the European Union's General Data Protection Regulation (GDPR) and Digital Services Act introduce an additional layer of complexity, as they cover international data transfers in the shipping industry [8]. This paper examines the connection between digital shipping sustainability and new legal frameworks. There are still huge gaps, including various interpretations among countries of the United Nations Convention on the Law of the Sea (UNCLOS) provision on setting out submarine cables and a lack of control by the International Seabed Authority (ISA) over artificial intelligence (AI)-enabled deep-sea mining [9]. To ensure digital technology contributes to economic resilience and ocean health in accordance with the UN Sustainable Development Goal, this paper discusses case studies on digitalized offshore wind farms through blockchain-enabling seafood traceability and proposes mechanisms for matching technological innovation with global law [10]. With the title of the world's second-largest economy, China is playing a leading role in the global economy and emerging as the world's most dynamic market. The marine economy, a tremendous human need for food, energy, transportation, recreational activities, and so on, has developed very quickly. China possesses more than three million square kilometers of oceanic land and is the fourth country in the world in terms of coastline length, with fertile oceanic resources [11]. China's marine GDP was 9.4628 trillion yuan in 2022, growing by 1.9% on an annual basis, and comprised 7.8% of the national GDP. As of mid-2023, the amount was 4.7 trillion yuan, representing a 6% increase. Marine economy exhibits robust expansion and resilience, particularly in major economic areas such as the Bohai Rim, Yangtze River Delta, and Pearl River Delta. The Chinese marine economy has made satisfactory progress in breaking away from a low-efficiency and pollution-based development condition [12]. Its offshore engineering equipment has been outsourced to the low end for many years, and it produces little high-end equipment. European or American companies lead the innovative design of marine products, but the downstream production is subcontracted to Asia, which poses extensive challenges [13].

The Chinese marine equipment producing industry is a global expert in the lower part of the value chain. To achieve sustainable development in MEMI, companies must leverage digital technology and expand their market access [14]. This paper follows this organization: Section 2 conducts a literature review of global marine economy models, the regulatory system, and technological innovation before progressing to the analysis of shipping vessel implementation principles for harmonized fairway fees. Section 3 describes the methodology framework, such as data selection criteria, harmonized research materials, and analytical methods employed herein. Section 4 explores and discusses research findings, taking into account practical limitations, potential optimizations, and real-world uses of the study's findings. Section 5 synthesizes conclusions that denote main points, recommendations, acknowledge research limitations, highlight novel contributions, and outline avenues for future research in this field.

2. Literature Review and Analytical Framework

The history, technological development, operational benefits, maritime economy, safety considerations, and environmental effects of nuclear ship propulsion have been discussed [15]. The literature has presented that the application of atomic energy in marine industries can become central to carbon neutrality aspirations. The need to reduce carbon

footprints has drawn nuclear energy into focus as a potential ocean power source, and its numerous contributions are being examined in ongoing research. After reviewing several definitions of digital trade, the United States International Trade Commission (USITC) determined that digital trade had three dimensions. Internet technology-based, transmitting and delivering digital data, and covering products and services [16]. Additionally, under data flow and utilization of the relevant platforms. As an increasing number of products depend on digital connectivity than ever, the Internet and global data flows are emerging as essential trade pipelines, and the digitalization of international commerce creates new trade opportunities for poor countries to participate in digital services [17]. Since electronic trade largely depends on its regulation, Meltzer suggests coordinating regulation globally to highlight the economic benefits of electronic trade. Most digital trade research focuses on describing digital enterprises and comparing sectional data. Gnangnon's exploration of electronic trade data for more than 110 nations discovers that digital technology has a more positive impact in developing nations [18]. As a result, with most of the industry's innovations coming under continuous legal and regulatory activities, there is increasing demand for experienced practitioners who are well-aware of the cutting-edge theories, policies, regulations, and legislation governing the energy transition. Generally speaking, these issues lie beyond the scope of classic maritime law subjects in China [19]. To keep up with the demands of an evolving maritime industry, prospective participants have to familiarize themselves with the evolving legal and regulatory environment of climate change, sustainable development, environmental social governance, and renewable energies. For example, there ought to be adequate knowledge of China's basic structure of its hydrogen economy, which is also transforming dramatically [20].

2.1. Digital Technology Adoption in Marine Sectors

The current situation of digital technology adoption in the maritime sector is a transformative process with plenty of opportunities and challenges. The shipping industry, tasked with keeping international commerce afloat, gradually embraces digitalization to increase business efficiency, safety, and environmental sustainability. Drawing from an integration of results from a range of different studies, this review highlights the most significant trends and technologies characterizing the industry [21]. The shipping industry faces unprecedented cultural barriers that inhibit the speedy adoption of digital technologies, necessitating a shift in attitudes to achieve effective change. While the prospects for digital technology adoption in the shipping industry are promising, the industry needs to overcome cultural and operational barriers to reap these gains in full. The ongoing evolution of digital practices heralds a rosy future, though the pace of change is uneven across shipping segments [22]. Recent literature unveils that digitalization is changing the maritime sector across operations, sustainability, and resilience. Evidence indicates that approximately 78% of maritime companies accelerated digital initiatives during the COVID-19 pandemic period by making serious investments in AI, cloud computing, digital twins, and blockchain, and achieving improved safety, efficiency, and predictive maintenance Autonomous ships, enabled by digital navigation and artificial intelligence, will be responsible for up to 40% of global shipping by 2030, offering massive fuel-saving and decarbonization opportunities. Smart ports, enabled by IoT, big data, and automation, are revolutionizing logistics by optimizing operations, enhancing security, and reducing environmental impact [23]. Despite such advancements, the literature also highlights challenges, including legacy systems integration, cybersecurity vulnerabilities, and industry-level standardization gaps, which hamper seamless digital uptake.

2.2. Legal Implications of Autonomous Marine Systems

There are also complicated legal questions about whether autonomous marine gear is used for ocean surveillance, specifically concerning maritime jurisdiction, data ownership, and regulatory compliance. Such technologies are unclear under international law, such as UNCLOS, which also leaves some room for uncertainty about Exclusive Economic Zones (EEZs) and scientific research permission [24]. Data sovereignty issues and ethical considerations related to animal tagging necessitate streamlined regulations and the development of new global paradigms that encompass innovation, environmental protection, and legal frameworks. Unmanned marine systems (AMS) push the boundaries of conventional maritime law. Liability and fault in case of collisions are ambiguous because mainstream conventions like SOLAS and COLREGs were drafted with crewed ships in consideration [25]. Flag states are in command under UNCLOS, yet when they venture beyond their territorial waters, where cyberattacks or malfunctions are likely, their accountability is called into question [26]. Suggested regimes aim to modernize international maritime law, balancing innovation, legal certainty, and safety, as seen in the IMO's upcoming Maritime Autonomous Surface Ships (MASS) Code [27].

2.3. Governance Challenges in Transboundary Waters

Legal fragmentation and cross-cutting national interests are practical governance challenges in the effective management of transboundary water resources. Global compacts, such as the UNCLOS, necessarily lag developing challenges like groundwater management and autonomous monitoring technology [28]. Joint administration, the avoidance of being locked into fragmented controls, and the sustainability of counties' water use all depend on the coordination of river chief systems, institutional innovation, and overall water quality demands, as exemplified by good practices such as China's Sichuan-Chongqing cooperation. Multilateral agreements like the United Nations Convention on the Law of the Sea [29,30], which delineates rights of navigation and Exclusive Economic Zones (EEZs), regulates common waters. Electronic monitoring aids enforcement but is hindered by irregular administration and competing claims. Case studies of the South China Sea and the Arctic accentuate jurisdictional competition for legal commitments under the Regional Seas Conventions and the Convention on Biological Diversity. The authors argue that fair transboundary management necessitates greater international cooperation, web transparency, and binding arbitration [31].

2.4. Economic and Business Model Transformations

Today's businesses are embracing new, environmentally friendly practices that promote both environmental stewardship and economic growth. These developments include the transition from linear take-make-dispose business models to circular economies based on resource productivity and minimizing waste. Businesses like China's New Yus, for example, have made significant investments in green technology, such as acid regeneration plants and solar panels on rooftops, transforming high-consumption business models into models of eco-industrial innovation [32]. Such ventures are not only profitable but also promote market sustainability and long-term profitability, highlighting the interconnectedness of prosperity and sustainability. Blockchain, intelligent logistics, and digital twins are transforming maritime business models [33]. These technologies, according to the IMO Initial Greenhouse Gas Strategy (GHG) and the WTO Trade Facilitation Agreement [34], translate into substantial financial benefits and widen the divide between small-scale stakeholders and multinational corporate operators. Information services can reinforce lacunas as well as create new revenue streams for governments. In response, regulatory frameworks such

as the UNCTAD Maritime Transport Conventions and the OECD Blue Economy Principles invoke bilateral economic adjustment and inclusive finance [35].

2.5. Social Equity Dimensions

Put, social justice in environmental and economic development is a response to inclusivity and equitable accessibility of opportunities and resources. Empirical findings show that social inclusion is absent in China, as inequality is present on racial, economic, and geographic dimensions [36]. Perceived social justice hinges heavily on work status, income, and household registration. Therefore, in a bid to better promote social and environmental well-being, good policies should be designed to foster sustainable, equitable development, thereby ensuring vulnerable groups, such as rural communities, low-income families, and ethnic minorities, have equitable access to sustainability. Digitalization reveals access disparities between poor and rich countries [37]. Autonomous ships are programmed to go into fail-safe modes, such as bringing the ship to a halt or entering remote control, in cases of system failure. The fail-safe modes in ships are designed to meet navigational safety standards in compliance with COLREGs and maritime law as it stands. Depending on their participation in ship operation and command, several entities could be held accountable for failing to follow through on fail-safe procedures (as shown in Table 1). While developing nations experience exclusion from value chains due to inadequate infrastructure, major economies spend money on smart ports and self-navigating ships. The ILO Maritime Labour Convention, which only guarantees employment practices. Particularly in the Global South, where sailing as a profession is most common, automation goes against sailors' survival. For promoting equitable and participative engagement in the blue economy, scholars prefer technology transfer strategies cultivated by the UN Framework Convention on Climate Change [38].

Table 1. Stakeholders and responsibilities.

Stakeholder	Responsibility in Case of Failure	Legal Implications
Remote Operator	Monitoring and manual override	Liable for delayed or incorrect response
Shipowner	Maintenance and system oversight	Liable for negligence in vessel readiness
Algorithm Developer	Software design and decision-making logic	Liable if faulty algorithms caused the incident

Note: This table illustrates the allocation of responsibilities and potential legal risk. Having a clear vision of these roles is critical for effective maritime management and observance of global standards.

2.6. Environmental Sustainability in Treating Pollution

The environmental sustainability paradox explains the contradiction between ecological conservation and economic growth. Western modernization sought growth by causing damage to the environment, leading to vast ecological degradation. China's environmental policy is a combination of pragmatic management, economic priority, and a commitment to sustainability. Overall attitudes can be shaped by traditional values such as harmony between man and nature. Still, new policies are aimed at preventing and controlling pollution, ensuring compliance, and leveraging technology to monitor and manage the environment. Economic growth is balanced with environmental protection and sustainable maritime management in this policy [39]. This thinking demands a shift away from extractive resource utilization to a balance, peaceful coexistence with the natural world in a bid to avoid the End-of-pipe treatment pollute first, clean up later strategy and instead promote whole-systemic and anticipatory stewardship. Literature suggests a paradox where environmental and digital innovations reduce emissions but trigger disguised ecological expense [40]. Digital technologies such as IoT-based shipping routing reduce carbon emissions, favoring the MARPOL Convention 1973 of anti-pollution. Digital infrastructure relies on rare-earth mining and power-hungry data centers, indirectly

increasing emissions. Researchers argue that without policies securing renewable-powered digitalization, sustainability goals can be threatened. The 2015 Paris Agreement binds states to limits on greenhouse gas emissions, yet digital adoption in shipping may potentially shift rather than alter environmental pressures [41].

2.7. Circular Economy Integration

Being responsive to inclusiveness and equitable access to opportunities and resources is the essence of social justice in ecological and economic development. In China, there is inequity on ethnic, economic, and geographical lines, and social inclusion varies according to empirical findings [42]. Work status, income, and household registration status have a direct influence on perceived social justice. Therefore, good policies should prioritize balanced development to provide equal services to marginalized groups, including poor households, minorities, and rural dwellers, thereby promoting sustainability and social and environmental well-being [43]. Digitalization reveals access disparities between wealthy and developing nations. Prosperous economies are investing heavily in autonomous ships and smart ports, yet poor countries lack the infrastructure necessary to connect to global trading networks. The disparity violates the decent work conditions guaranteed by the International Labour Organization (ILO) Maritime Labour Convention [44]. Automation threatens the livelihood of seafarers, particularly in the Global South, where maritime labor is most valued. According to the UN Framework Convention on Climate Change, scientists develop technology transfer strategies for promoting inclusive and equitable participation in the blue economy [45].

2.8. Each Gap Findings from Literature Reviewed

The latest research agenda of sustainable maritime governance reflects growing interest in digital transformation, environmental sustainability, and legal development in the maritime sector [46]. However, our literature review's findings imply that these studies remain scattered and unevenly distributed across main thematic areas (as shown in Table 2. To structure these gaps, we systematically mapped the most critical research gaps into five broad categories: legal and regulatory, technological, environmental governance, socio-economic and equity, and interdisciplinary research.

Table 2. Systematic mapping of research gaps in sustainable maritime governance and digital technologies.

Gap Group	Explaining of Gap	Notes from Literature	Suggestions
1. Legal and Regulatory Gaps	Existing legal frameworks (UNCLOS, BBNJ, and national laws) are not fully adapted to digitalisation and AI in shipping.	Lack of clear legal standards for autonomous vessels, data governance, or real-time monitoring under international law.	Need for legal adaptation and harmonization across jurisdictions to support sustainable digital maritime operations.
2. Technological Gaps	Limited integration of advanced digital tools for risk management and environmental protection.	Few predictive AI tools are used for shipping risk analysis, and digital monitoring of marine ecosystems remains fragmented.	Research on scalable, interoperable digital solutions for sustainable maritime activities is required.
3. Environmental Governance Gaps	There is a lack of coordination between the use of digital technology and environmental protection frameworks.	Marine pollution monitoring and compliance tools are often sector-specific and lack integration with legal enforcement.	More interdisciplinary work linking environmental law, technology, and governance is needed.

Table 2. *Cont.*

Gap Group	Explaining of Gap	Notes from Literature	Suggestions
4. Socio-economic and Equity Gaps	Developing countries are underrepresented in digital maritime initiatives and governance debates.	Most case studies focus on developed economies with advanced infrastructure.	Further research is needed on inclusive governance and capacity building in developing nations.
5. Interdisciplinary Research Gaps	Few studies systematically link legal, technological, economic, and environmental perspectives.	Current research often isolates law, economics, or technology without cross-sector frameworks.	Stronger interdisciplinary frameworks are needed to address complex shipping and governance challenges.

Note: These gaps present such challenges for the evolution of a consistent and integrated maritime governance regime. Their resolution can underpin sustainable marine economic development, enhance environmental protection, and foster more inclusive domestic and international governance.

3. Research Methodology

This essay is based on data gathered from various collection procedures, including databases accessible through university libraries and the Internet, such as the Web of Science. The results are based on several credible sources, including the World Database, as well as on first-hand observations from personal experience working with the Global Environmental Protection Agency and other international organizations around the world, and including the main research question about how digital technologies can enhance sustainable maritime governance to promote marine economic development while effectively managing shipping risks and ensuring environmental compliance. They include the United Nations Convention on the Law of the Sea, UN Sustainable Development Goal 14 (SDG 14), the Paris Agreement, and the International Maritime Organization (IMO). The rest are the United Nations Environment Programme (UNEP), the European Commission (EC), and the Helsinki Commission, which are under international conventions. UNCLOS, in particular, is a global, all-encompassing legal document that serves as the master plan for a range of worldwide and regional study, observation, and management programs (as shown in Figure 2). The United Nations Conference on Environment and Development highlighted the importance of new approaches for managing and developing coastal and marine regions at the national, sub-regional, regional, and global levels [47]. We also sifted through official documents, economic and environmental reports, magazines, and articles written by scholars, professors, and legislators. We even read high-impact journals and high-authority publisher materials such as Springer Nature, MDPI, Elsevier, Frontiers, Wiley, Oxford University Press, and Cambridge University Press. We even downloaded secondary data, which was discussed and reviewed through the literature, showing all figures, tables, and analyses in the results section [48].

To comprehensively examine causality and assign responsibility, we present a Law technology observation, environmental conditions, and human conduct. The agenda identifies which stakeholder has primary or secondary responsibility. Such a basis unites technical design and legal responsibility, supporting risk management, maritime law enforcement, and sustainable governance. The alignment of a liability-focused law technology platform assists sustainable maritime regulation objectives. Legalizing the responsibility of autonomous systems enables shipping firms to manage risk better, conserve the marine environment, and promote responsible adoption of digital technology within the marine economy.

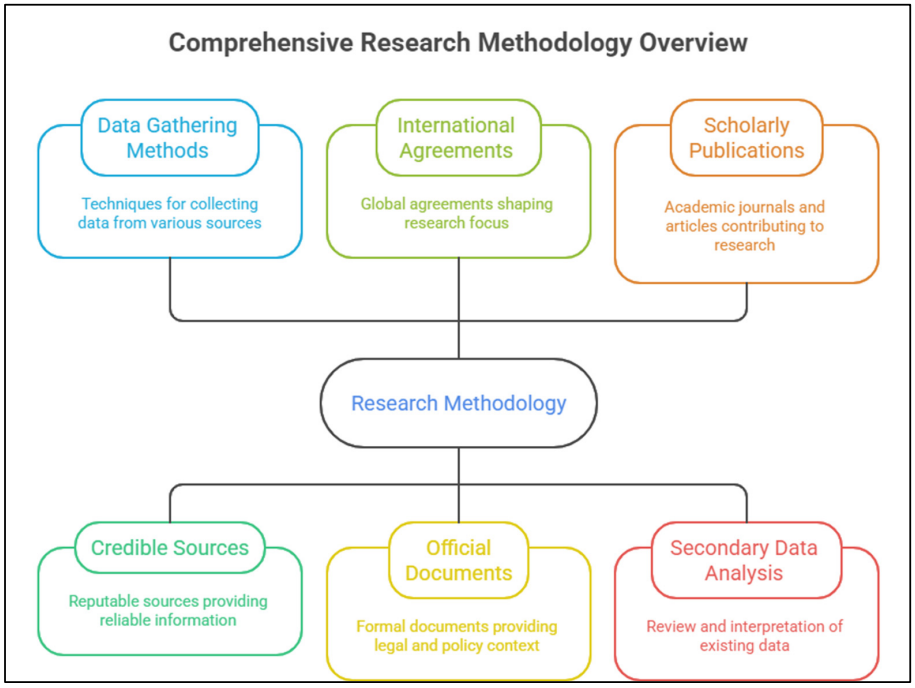


Figure 2. The influence of methodology on materials and comprehensive data.

3.1. Results and Analytical

The table identifies key trends in economic and business model changes toward sustainability, digital technology, and innovative business practices. It features case studies, including China's New Yus embracing green technology and blockchain for sustainability, as well as International Business Machines Corporation (IBM) Food Trust, demonstrating how technology supports environmental goals [49]. Similarly, the EU circular economy action plan and the AI act facilitate frameworks that encourage companies to make sustainability mainstream. Indicates how technology, regulatory frameworks, and green finance are shaping the industry's future, enabling one to make money while providing stewardship of the earth (as shown in Table 3).

Table 3. Recent data and ideas.

Year	Concept	Impact	Example	Technological	Laws	
2017	Circular Economy	Transition from traditional linear models to systems where resources are reused, repaired, and recycled to minimize waste.	China's New Yus with green tech and resource regeneration plants	Reduces raw material dependency and waste by utilizing technologies like 3D printing and AI for optimized resource usage.	The EU Circular Economy Action Plan encourages waste reduction, reuse, and recycling in member states.	[50]
2020	Eco-Industrial Innovation	Businesses adopt green technologies and practices that reduce environmental impact and promote long-term profitability.	New Yus's use of solar panels and acid regeneration plants	Clean tech like solar energy, bioengineering, and energy-efficient logistics.	The Paris Agreement is an International agreement to limit global warming to 1.5 °C, driving investments in green tech.	[51]

Table 3. *Cont.*

Year	Concept	Impact	Example	Technological	Laws	
2020	Blockchain in Sustainability	Blockchain technology enhances transparency, traceability, and accountability in sustainability efforts.	IBM's Food Trust Blockchain for supply chain transparency in food safety and sustainability	Verifies the sustainability claims of products, reduces fraud, and increases stakeholder trust.	EU Blockchain Regulation and Calls for Establishing a Common Regulatory Framework to Secure Blockchain Use in Sustainability.	[52]
2018	Smart Logistics and IoT	IoT-enabled logistics systems optimize resource use, improve efficiency, and reduce carbon footprints through intelligent routing and monitoring.	Maersk's intelligent container tracking system	Reduces fuel consumption and emissions; IoT sensors help manage temperature, time, and location data.	The EU Green Deal is a set of legislative measures aimed at making Europe climate-neutral by 2050, with an emphasis on green logistics.	[53]
2020	Digital Twins in Maritime	The use of virtual models of physical systems (digital twins) enables the monitoring and improvement of shipping operations' efficiency.	Rolls-Royce's digital twin for maritime engines to predict maintenance needs	Facilitates predictive maintenance, reduces downtime, and increases energy efficiency by simulating operations.	IMO's Initial GHG Strategy Framework aims to reduce emissions in the shipping industry by supporting the use of digital tools, such as digital twins.	[54]
2017	Blockchain for Maritime Trade	Blockchain technology enhances maritime trade by increasing the security, speed, and cost-efficiency of global trade networks.	Trade Lens platform by Maersk and IBM	Accelerates the transfer of documents, enhances security, and improves efficiency in the shipping process.	WTO Trade Facilitation Agreement Ensures smoother, quicker trade, potentially facilitated by blockchain in maritime logistics.	[55]
2019	Sustainable Finance and Inclusive Economics	Integrating sustainability into financial systems by incentivizing green projects and promoting access to finance for smaller players.	Green bonds finance large-scale renewable energy projects, such as wind and solar	Green finance mechanisms, including mobile money platforms, provide access to finance in emerging markets.	The EU Sustainable Finance Taxonomy Defines which economic activities can be considered sustainable for investment purposes.	[56]
2020	Regulatory and Policy Support	Regulatory frameworks and international conventions are being established to guide businesses toward more sustainable practices and inclusive finance.	OECD Blue Economy Principles; UNCTAD Maritime Transport Conventions	Legislation influences the adoption of green technologies and ensures compliance for global trade and industry players.	UNCTAD Maritime Transport Conventions set guidelines for environmentally sustainable practices in international maritime trade.	[57]

Table 3. *Cont.*

Year	Concept	Impact	Example	Technological	Laws	
2016	AI and Automation for Sustainable Business	Artificial intelligence and automation tools enable businesses to minimize waste, optimize processes, and improve production efficiency.	Google's AI tools for optimizing energy use in data centers	AI can predict demand, optimize supply chains, and automate processes to reduce waste and carbon footprints.	The AI Act of Legislation focuses on the responsible use of AI in European industries, including its role in green innovation.	[58]
2021	Impact of Sustainable Practices on Profitability	Implementing sustainable practices boosts profitability by appealing to conscious consumers and improving operational efficiency.	Patagonia's eco-friendly product lines and commitment to sustainability	Sustainable production reduces long-term costs and increases consumer loyalty through brand positioning.	The Corporate Sustainability Reporting Directive requires businesses to disclose how they address sustainability and climate impact.	[59]

Note: Regarding changes in economic and business models, mainly focusing on sustainability, circular economies, and emerging technologies. Based on the material covered, prepare a table of key data and ideas, including present related trends and innovations.

3.2. China's Legal Framework and Nuclear Marine Propulsion

China possesses an emerging legal and regulatory infrastructure targeted at nuclear marine propulsion development. It comprises nuclear safety, environmental protection, and energy policy legislation that serves as a foundation to incorporate nuclear propulsion technologies into its shipping sector. Underwrite statutes and rules, such as the Regulations on Nuclear Power Ships and the Nuclear Safety Standards for Ships, that address specific concerns for nuclear-powered vessels. Meanwhile, more generalized frameworks, like the National Energy Law and the 13th Five-Year Plan, enable broader advancement of nuclear technology across various industries, including marine propulsion [60]. There are no specific laws governing China's nuclear-powered vessels, platforms, and marine engineering equipment solely (as shown in Table 4). The integration between maritime and nuclear elements means the nuclear marine propulsion facilities are governed by a sequence of legislation and administration regulations scattered throughout marine environment protection, navigational safety administration, and nuclear security administration [61]. Flexibility provides broad latitude in developing technology for nuclear marine propulsion, allowing for minimal intervention from the legal framework. In terms of navigation safety management, legal regulation currently primarily targets either the control of foreign nuclear-powered vessels or handling nuclear fuel as cargo rather than as ship fuel, and acceptance of regulation by the relevant authorities on the part of NPVs and ships that transport radioactive materials upon arrival in the territorial waters of China; all these missions are limited to foreign nationality vessels [62].

Table 4. Impact on nuclear marine propulsion.

Year	Legal Framework	Description	Marine Propulsion	
2017	National Energy Law.	A key policy that outlines China's energy development strategy, including nuclear energy.	Supports the development and integration of nuclear power in various sectors, including the marine industry.	[63]
2003 And 2017	China Nuclear Safety Law.	Governs the safe use of nuclear technology in China, including nuclear propulsion for vessels.	Establishes safety protocols and regulatory processes for nuclear-powered vessels. Ensures compliance with safety standards in maritime nuclear technology.	[64]
	Regulations on Nuclear Power Ships (Draft).	China has developed draft regulations that specifically address the use of nuclear propulsion for marine vessels.	Provides the regulatory framework for the development and use of nuclear-powered ships, emphasizing safety, technological standards, and environmental considerations.	[65]
2016 and 2020	China's 13th Five-Year Plan for Maritime Development.	Outlines the strategic goals for China's maritime industry, including the development of advanced propulsion technologies like nuclear power.	Encourages the integration of cutting-edge technologies, such as nuclear propulsion, in China's maritime sector.	[66]
2022	Nuclear Safety Standards for Ships and Submarines (Draft).	A set of draft standards aimed at ensuring nuclear safety on vessels and submarines.	Focuses on specific safety protocols for nuclear propulsion, aiming to mitigate risks associated with nuclear-powered maritime vessels.	[67]
2014	Regulations on the Safe Transport of Radioactive Materials.	Governs the transport of radioactive materials within China, ensuring the safe and secure movement of nuclear material, which is critical for nuclear propulsion.	Ensures safe handling, transportation, and storage of nuclear fuel for marine applications, including on vessels utilizing nuclear propulsion.	[68]
2018	China's Marine Environmental Protection Law.	Focuses on preserving the marine environment through regulations that address pollution and resource use.	Ensures that nuclear propulsion technologies comply with environmental protection standards, minimizing marine pollution and radiological risks.	[69]
2014	Regulations on the Management of Nuclear Material.	Governs the handling and use of nuclear materials in all industries, including in maritime applications for nuclear-powered vessels.	Regulates the sourcing, usage, and disposal of nuclear materials, ensuring that nuclear marine propulsion adheres to strict safety protocols.	[70]
2020	China's State Council Opinions on Accelerating the Development of Nuclear Energy.	A policy document to accelerate the development of nuclear energy in various sectors, including marine transportation.	Supports research and development in nuclear propulsion for ships and submarines as part of broader nuclear energy ambitions.	[70]

Note: The information on China's legal framework and regulations regarding nuclear marine propulsion, including relevant policies and regulations, was provided by the authors.

3.3. Global Shipping Faces Fragile Growth

Since over 80% of global trade is transported by ocean, industry is facing overwhelming pressure from slow growth, rising costs, and mounting uncertainty brought on by political tensions, shifting trade patterns, and remapped routes. In accordance with the UN Trade and Development's (UNCTAD) review of maritime transport 2025, released on September 24, maritime trade is expected to grow at a modest rate of 0.5% in 2025, following a 2.2% expansion in 2024 [71,72]. The changing trade patterns and remapped trade routes are changing the geography of maritime commerce (as shown in Figure 3). While it was previously possible to cross the Red Sea in a few days, it now takes weeks for ships to reach their destination. Stratospheric and unpredictable prices, tenuous supply chains, and a virtual pandemic of port closures are all on display, diverting ships, causing ton-miles, which measure how far each ton of cargo is transported, to reach a record 6%, almost double the growth in volume of trade. Tonnage through the Suez Canal through May 2025 was down 70% from 2023 levels, and there were even threats of disruption along the Strait of Hormuz, which carries 11% of world trade and a third of seaborne petroleum [73].

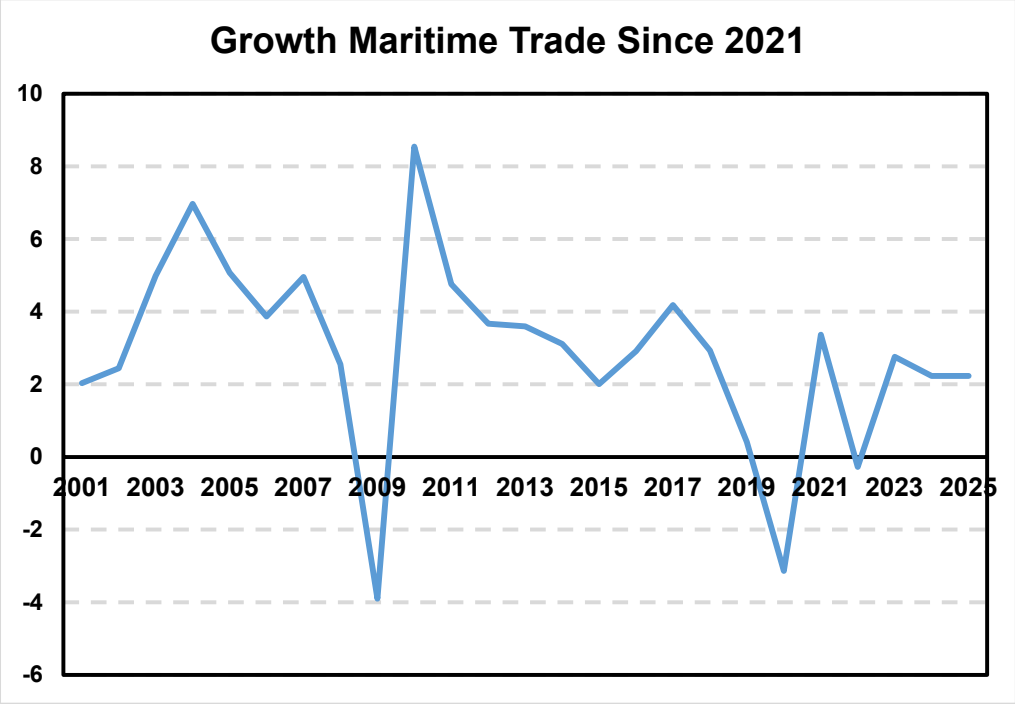


Figure 3. Trade, tons, annual percentage change. Noted according to data from Clarkson's research, as cited by UN Trade and Development (UNCTAD) and the Shipping Intelligence Network.

3.4. Maritime Cargo Rerouted

Several concurrent developments are shaping the marine trade environment. Policy measures, including recently implemented USA tariffs and port fees, are creating cost pressures and market uncertainty [74]. Concurrently, the energy shipping market is undergoing changes, marked by a short-term surge in coal despite a long-term decline, offset by level oil volumes due to longer hauls, and a growing liquefied natural gas trade (as shown in Figure 4). Moreover, the very critical minerals at the heart of the renewable energy and digital economies are increasingly a source of international contention, with respect to achieving supply and domestic value-added capability putting strains on existing transport and logistics networks [75].

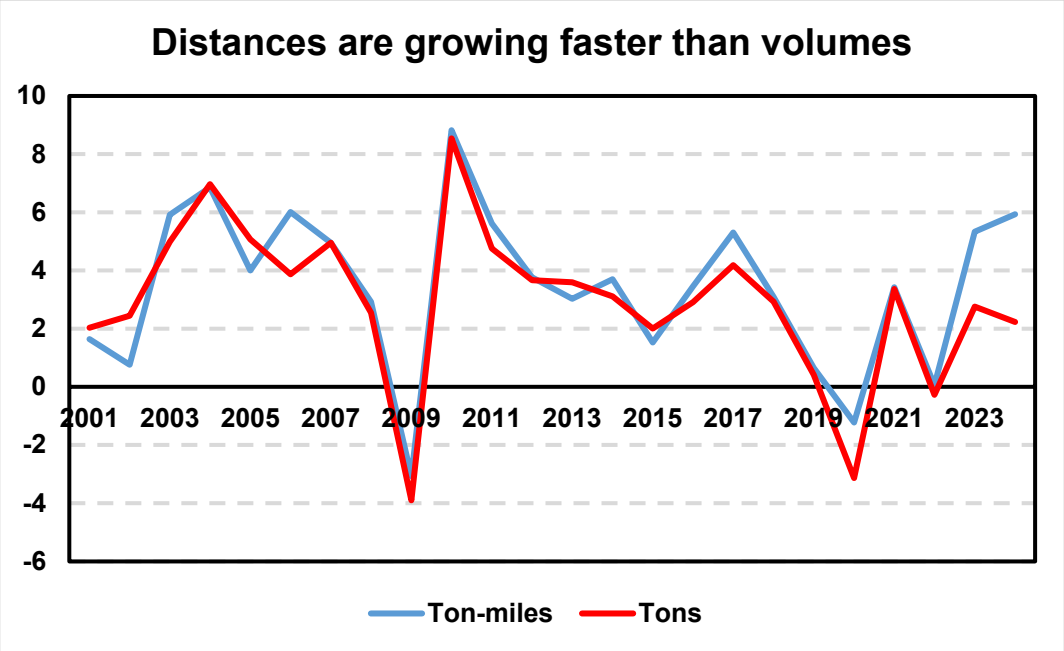


Figure 4. Maritime cargo rerouted. Note: UN Trade and Development (UNCTAD).

3.5. The Era of Persistent Freight Rate Volatility

The new freight norm is volatile, and Freight rates are the new norm for the shipping business, now considered in constant uncertainty. Record levels of container, bulk, and tanker rate volatility were the norm in 2024 and 2025 due to market disequilibria, changes in trade policy, and geopolitical tensions. Container shipping was not left behind. Spot and charter contract rates approached COVID-19 levels at the start of 2024. Prices were set at a vastly higher basis despite having fallen temporarily (as shown in Figure 5). The Shanghai Container Freight Index hit an average of 2496 points in 2024, up by 149% compared to the year prior, with July spot prices above RMB 3600 per box. This trend is readily apparent [76].

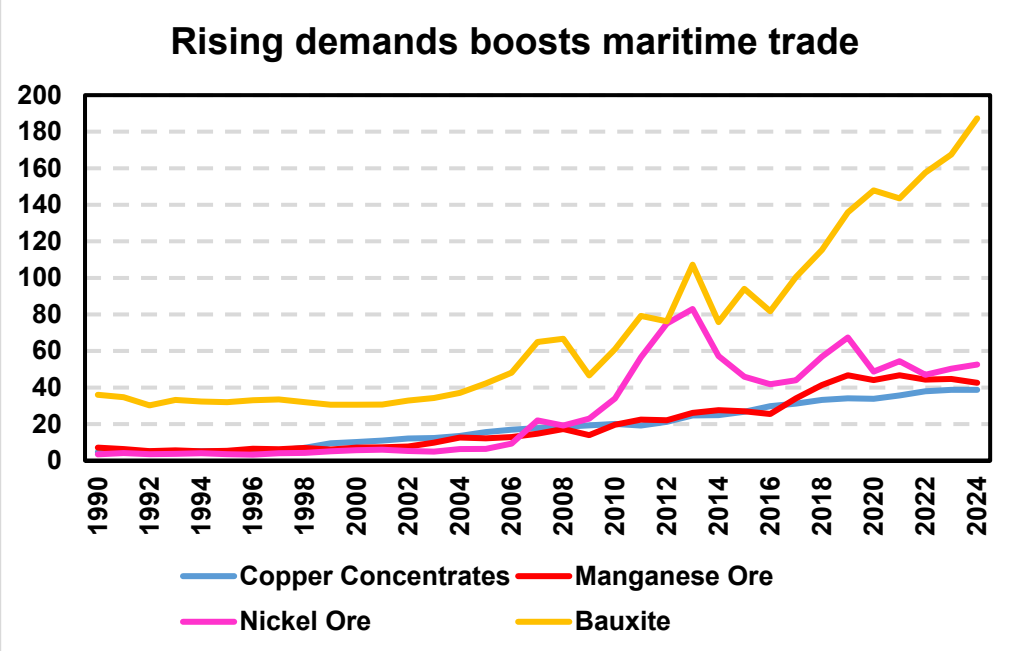


Figure 5. Critical minerals on the move. Note: All data were collected from the official UNCTAD.

3.6. Approach to Sectoral Transformation

The International Maritime Organization is discussing a historic net-zero framework. It would provide a clear road map to net-zero by 2050, based on a worldwide standard for fuels and a carbon price for shipping [77]. The revenues generated through this could finance a just transition, supporting vulnerable nations like small island developing states. But UNCTAD warns that shipping requires radical investment in new fleets, port infrastructure, and green fuel networks to become low carbon, which depends on clear regulations, massive investment, and international cooperation among governments, business, and financiers. Managing a multidimensional transition in addition to decarbonization, the industry is faced with concurrent changes precipitated by automation and digitalization (as shown in Figure 6). While making the industry more efficient, these do increase cyber risks. The shipping community is accustomed to challenges [78].

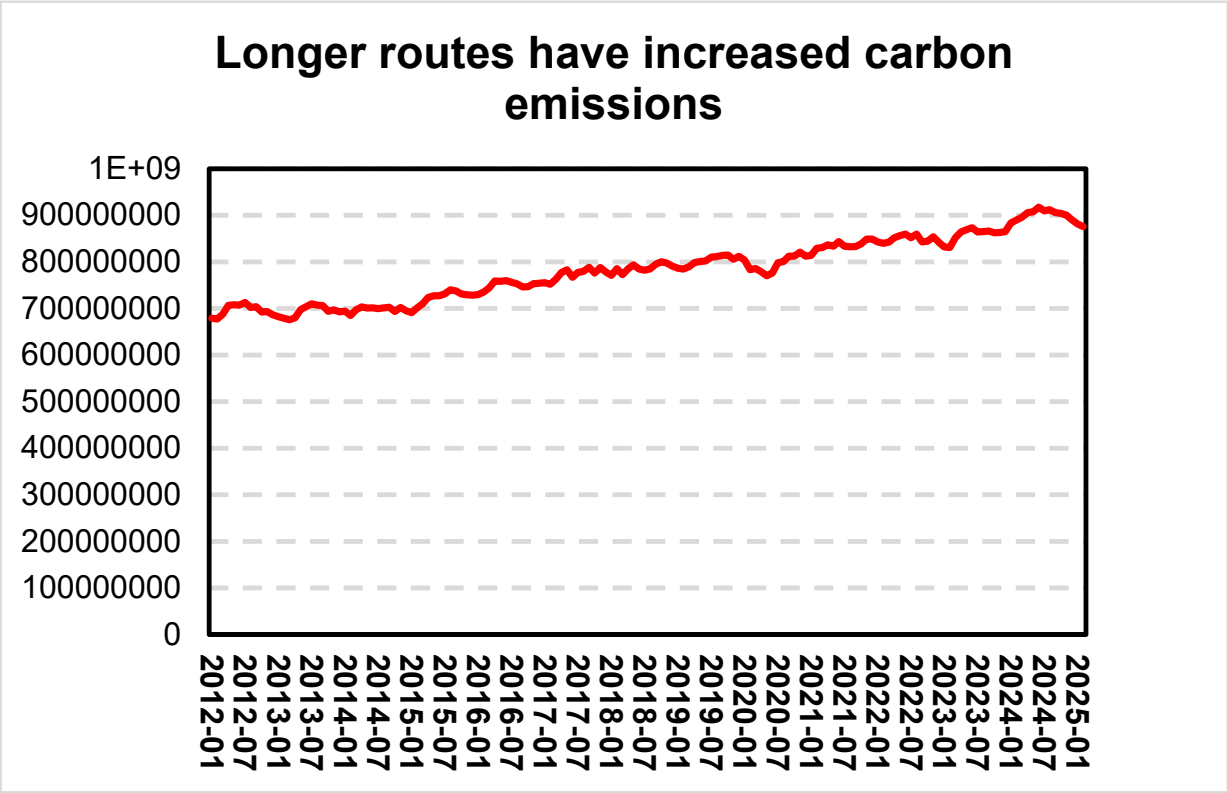


Figure 6. Rerouting climate costs. Note: Data are from the UNCTAD and ships, millions of tons.

3.7. The Evolving Landscape of Maritime Energy Trade

International maritime energy trade is undergoing a revolutionary shift in both volume and direction. While coal usage saw a temporary spike on the heels of decades-long decline, and oil volumes remained constant, both are being shipped across increasingly longer distances and billions of ton-miles, 1999–2025. Natural gas trade, on the other hand, experienced revolutionary growth (as shown in Figure 7). They are significantly shaped by shifting global demand, geopolitical realignments, and collaborative diversification policies, which collectively redefine energy flows, extend the distance of shipping routes, and refashion the geography of global energy trade [79].

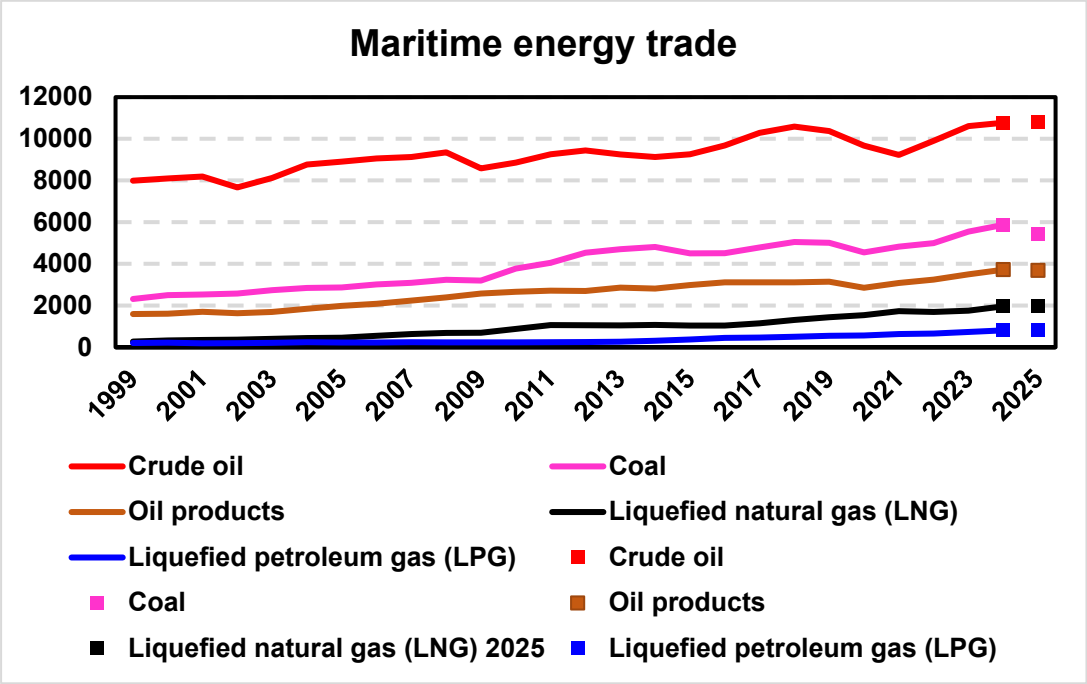


Figure 7. Reshaped by demand, geography, and geopolitics. Note: Data from the official UNCTAD.

3.8. Emissions Rise as Routes Lengthen

The lengthening of global trade routes is directly increasing greenhouse gas emissions from the maritime sector. This trend carries significant economic and environmental consequences. Persistently high transport costs disproportionately impact developing economies, particularly least developed countries and small island developing States, which are most vulnerable to price shocks (as shown in Figure 8). Furthermore, longer voyages contributed to a 5% rise in shipping's GHG emissions in 2024 [80]. The transition to cleaner operations is progressing slowly; only 8% of the global fleet by tonnage is currently equipped for alternative fuels, while low ship recycling rates further hinder the fleet's modernization.

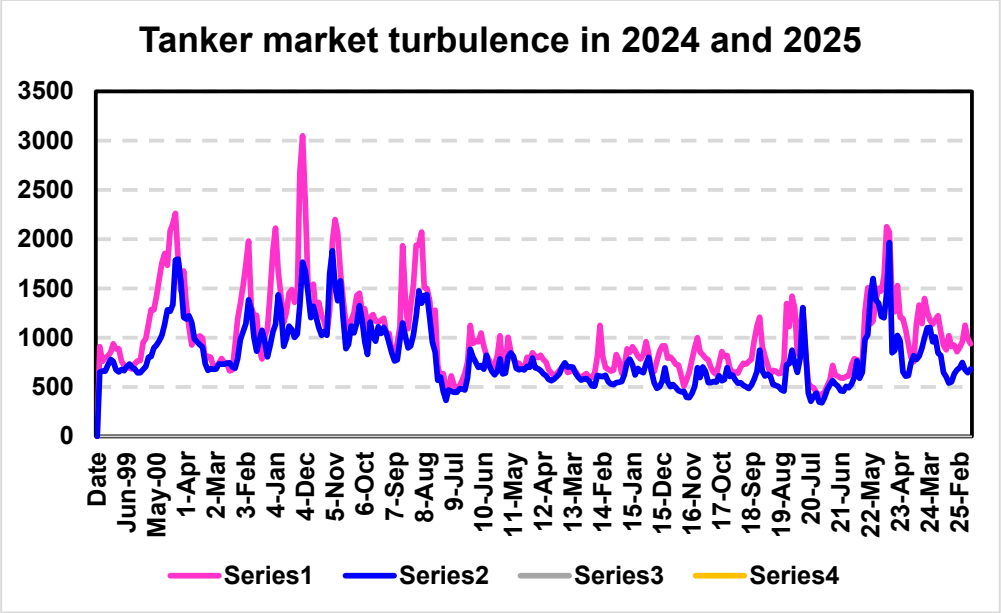


Figure 8. Data collected by the official UNCTAD.

4. Analysis and Discussion

Marine economy encompasses a broad spectrum of industries such as shipping, fisheries, aquaculture, tourism, offshore energy, and marine biotechnology [81,82]. As global demand for marine resources increases, so does the call for sustainable management. Digital technologies such as artificial intelligence, Internet of Things, big data analysis, remote sensing, and blockchain are increasingly being applied in marine industries to increase efficiency, reduce environmental footprint, and ensure regulatory compliance [83]. For instance, predictive analytics in shipping and fishing operations are driven by machine learning and AI, optimizing routes and minimizing fuel consumption. IoT sensors track water quality and sea biodiversity in real time to provide environmental compliance. Blockchain enhances traceability within seafood supply chains to combat IUU fishing operations. Such technologies assist in attaining sustainable marine resources management in accordance with the blue economy's framework [84].

Despite the optimistic prospects of digital technologies, several barriers hinder their widespread adoption in the maritime economy. One of the most significant barriers is the disparity in technological infrastructure across regions [85]. Developing nations lack the resources and expertise to implement sophisticated digital methods, resulting in unequal access to technology and information. Moreover, the rapid expansion of marine data raises issues regarding data security, confidentiality, and standardization. There is no standard data format or protocols to hinder information sharing and integration, thereby slowing cooperative initiatives in marine research and management. Furthermore, the green footprint of digital technologies, including energy consumption and e-waste, poses sustainability challenges. The adoption of digital solutions mustn't have the unforeseen effect of aggravating environmental deterioration [86].

The United Nations Convention for the Law of the Sea is the primary international law framework for the management and protection of marine resources. UNCLOS, which was signed in 1982, has guidelines for sustainable oceanic resource management and the protection of the marine environment [87]. UNCLOS explicitly allows the development and transfer of marine technology under Part XIV. Article 266 downplays the promotion of marine scientific research and the transfer of marine technology to developing countries as a method of enhancing their capacity to harness and conserve marine resources [88]. The article stresses equity [89]. Moreover, Article 145 of UNCLOS requires the protection of the marine environment against detrimental effects that might arise from such activity as marine scientific research. The article underscores the importance of precaution and environmental protection in the use of marine technology [90].

China has constructed a chain of marine eco-environmental protection systems, connecting land and sea through interconnection and coordination [91]. The country prioritizes science and technology in marine eco-environment protection and the high-quality development of the marine economy, and endeavors to eliminate the bottlenecks that are constraining further development. China employs land, sea, air, and space currently in its marine ecological environment monitoring, management, and administration, as well as in its emergency management capability and technology [92]. China revised its Marine Environmental Protection Law (MEPL), which is divided into nine chapters and 124 clauses, such as general supervision and administration of the marine environment, conservation of marine ecology, and prevention and control of pollution from all sources. The new MEPL adheres to several key principles, including priority to protection, priority to source prevention and control, land-sea integration, integrated management, public participation, and liability for harm. These regulatory structures provide a robust foundation to integrate digital technologies into the maritime economy and ensure technological advancements are in line with environmental conservation goals [93].

In addition to UNCLOS, various international agreements and initiatives aim to promote sustainable practices in the marine economy. The 2025 adopted High Seas Treaty is a significant step towards managing the seas internationally. The treaty establishes legally binding commitments on the conservation of high seas marine biodiversity, including the creation of marine protected areas and the management of activities that affect the marine environment [94]. The agreement also highlights the importance of scientific cooperation and capacity building, consistent with UNCLOS objectives of promoting fair access to marine technologies. However, the success of the High Seas Treaty is dependent upon universal acceptance and implementation of this agreement, and on the collaboration of all states to enforce its provisions [95]. Aside from UNCLOS, there exist some international treaties and agreements that aim at promoting sustainable marine economy practices [96]. The 2025 High Seas Treaty represents a new benchmark for the evolution of global marine governance. The treaty offers legally binding mechanisms for the protection of marine biodiversity in areas beyond national jurisdiction, including the creation of marine protected areas and the regulation of activities that can harm the marine environment. The treaty also invokes cooperation on science and capacity building, which is consistent with the objectives of UNCLOS to foster equitable access to marine technologies. The success of the High Seas Treaty, nevertheless, depends on its widespread adoption and implementation, for which all nations must adhere to its provisions [97].

The integration of digital technologies into the blue economy necessitates innovation in existing legal frameworks to address emerging challenges [98]. Issues of data ownership, cybersecurity, and the regulation of autonomous ships require a reformulation of marine legislation to maintain their applicability and effectiveness. For example, the use of AI in marine activities introduces liability and accountability problems in the event of accidents or environmental harm. Existing legal systems are perhaps not yet capable of addressing these problems effectively, and this highlights the need for the development of new legal instruments that incorporate the intricacies introduced by digital technologies [99]. Moreover, the interoperability of digital systems worldwide makes compliance and enforcement more challenging. Coordination among nations becomes imperative so that they can offer standardized protocols and regulations to facilitate the smooth passage of information and ensure uniform application of the law.

Despite the obstacles, numerous possibilities exist at the interface of digital technologies and maritime law for fostering sustainable development in the maritime economy. The development of digital platforms integrating environmental monitoring, regulatory compliance, and stakeholder engagement has the potential to foster transparency and accountability in maritime operations. In addition, the application of simulation models and digital twins can enable proactive management of marine ecosystems by predicting and preventing possible environmental impacts [100]. The models can be applied to guide decision-making, ensuring development activities align with sustainability objectives. Public–private partnerships are also necessary to facilitate innovation and the transfer of marine technologies. Collaborations between governments, international organizations, private sector organizations, and civil society can help ensure access to technology for everyone, the sharing of knowledge, and enable compliance with environmental and social standards [101].

The incorporation of digital technologies into the ocean economy has transformative potential for making operations more sustainable and efficient. Realizing this, however, will have to be supported by the coordination of technological innovation with rational legal frameworks and institutionalized governance arrangements. UNCLOS provides a general legal framework for managing marine resources sustainably, and its provisions regarding marine technology development and transfer are central to facilitating access on

an equitable basis and building capacity [102]. China's legislation and policy efforts further entrench the promise of marine conservation and sustainable use. The revised Marine Environmental Protection Law, along with the adoption of state-of-the-art monitoring technologies, reflects China's concerted efforts to integrate digital solutions into sea management. By fostering international collaboration, capacity development, and the equitable sharing of technological benefits, the blue economy can navigate digital transformation challenges while staying on track towards sustainability [103]. There must be alignment of digital innovation with ocean law and governance if the blue economy is to achieve its sustainable and resilient self.

5. Conclusions and Recommendation Letters

The application of digital technologies, AI-based monitoring systems, blockchain-based monitoring of emissions, and autonomous underwater drones has made significant progress in promoting the sustainability goals at a global scale. However, such progress is endangered by loopholes in international marine law, including jurisdictional uncertainties over activities such as deep-sea data collection and data transfers across boundaries, as well as traditional institutions like the United Nations Convention on the Law of the Sea [104]. The UN High Seas Treaty BBNJ Agreement of the present era is a landmark in addressing the gaps in marine biodiversity conservation and fair sharing of resources beyond national borders. Still, mechanisms of enforcement are underdeveloped compared to the capacities of technology [105].

China has emerged as the destination for plugging these gaps through legal innovation and global outreach. The world's second-largest economy, China, has revised national laws [106], including the 2025 Anti-Unfair Competition Law and the reporting of rare earths production, to align with digital market regulations and environmentally friendly dynamics, while also further amplifying extraterritorial application [107]. Regional-level Chinese initiatives, such as the Hainan Free Trade Port, focus on marine conservation innovation, coral reef preservation, and digital tracking technologies to strengthen the Association of Southeast Asian Nations cooperation through information sharing and collaborative research. Moreover, China's global leadership in the UN Decade of Ocean Science and digital twin oceans programs leads to global data sharing and capacity building, particularly in Global South countries [108]. Despite these efforts, challenges persist. Patchwork regional regulation, the EU General Data Protection Regulation, and the Digital Services Act are a drag on international trade and data governance in maritime logistics. Opportunities from now on include updating international marine law to be receptive to digital innovations, strengthening multilateral institutions like the BBNJ's Clearing-House Mechanism, and establishing public–private partnerships for equitable technology transfer. China's dual role as a regulator, innovator, and global partner showcases its ability to drive an internationally enabled, sustainable blue economy and find harmony between environmental sustainability and economic progress [109]. The governance gaps and disconnected policy suggestions emerging from these insights are to update international ocean law to accommodate digital innovation, increase multilateral enforcement practices, and facilitate equitable public–private partnerships. China's dual roles as a regulator and innovator underscore the potential for reconciling environmental sustainability and economic growth within a global blue economy.

5.1. Recommendation Letters

- Enhance research and monitoring to understand the impact of digital technologies on marine sustainability and identify emerging opportunities and challenges. It should

include life-cycle assessments of the environmental impact of digital technology, socio-economic impact analyses, and ongoing evaluations of policy interventions [110].

- Invest in building capacity and digital infrastructure to bring the benefits of digitalization to everybody, and particularly to developing countries and small-scale operators. That is not merely physical infrastructure but also learning, technology transfer programs, and digital education. International cooperation mechanisms such as the United Nations Decade of Ocean Science for Sustainable Development should prioritize capacity building for sustainable digitalization above all else [111].
- Create uniform governance mechanisms that address the unique challenges posed by digital technologies in the sea setting and support sustainability goals. These mechanisms need to include clear guidelines on data management, such as those showcased by Zhoushan's intellectual property regulations for sea big data [112], and rules that promote sustainable activity through measures like the IMO's carbon intensity norms [113].
- Create innovation systems that bring together technology developers, marine industries, researchers, and policymakers to co-create solutions to technical and sustainability issues. Initiatives such as Wasseron's digital accelerator centers provide blueprints for how those environments can drive innovation while keeping technologies aligned with real needs and sustainability [114].
- Green digitalization of the marine economy is more than a technological issue but a socio-technical transformation that requires integrated action across sectors and scales. Through innovative and inclusive use of digital technology [115], we can create a blue economy that benefits human well-being while protecting the marine ecosystems on which we all depend. The path forward involves not only technology innovation but also innovation in governance, business model innovation, and most importantly, interdisciplinary, inter-sectoral, and inter-border cooperation [116].

5.2. Limitation

This study is constrained by the absence of information on the long-term ecological impact of marine digital technology, particularly in deep-sea habitats. Fragmented international norms and arbitrary application between jurisdictions constrain world governance systems. The tests of legal rules are only practicable through publicly available treaties and can even fail to capture new national policies [117]. Technological advancement can swamp the timeliness of recommendations for regulatory adjustments. Economic feasibility studies predominantly reflect the developed world's context with an underrepresentation of challenges in resource-poor regions. Interdisciplinary gaps between technological advancement, marine environmental science, and legal studies also constrain thorough sustainability analyses [118]. These deficiencies emphasize the need for large-scale data-sharing mechanisms and integrated transnational governance systems. One of the primary disadvantages of this research is that it does not fully capture the complex matching between legal, policy, and technical standards for digital and autonomous maritime systems. Specifically, the application of the MASS Code, interpretation of COLREGs in law, IACS Unified Requirements (UR E26/E27), and IEC 62443 cyber-physical security certification are not fully addressed.

5.3. Future Research Direction

Future research should explore the application of AI-based predictive analytics to optimize marine resources and leverage blockchain in supply chains to enhance transparency. The focus of research policy on sustainable maritime regulation led to an extensive technical analysis of digital composition, overcoming the limitations of this work. The

future will tackle this challenge head-on by integrating operational data streams and validation routines, thereby shaping a more solid relationship between marine environmental compliance and actual shipping management. Emerging research areas can be targeted towards cyber-physical security paradigms for underwater IoT networks and quantum computing applications, as well as climate modeling for coastal ecosystems [119]. Areas of research should include measuring the socio-economic impacts of autonomous fishing technology upon coastal communities and ethical uses of AI within maritime surveillance. Interdisciplinary research should cover biomimetic sensors from marine life-inspired designs and digital twin interoperability in multilateral marine contexts [120]. Emerging topics of study are digitalization challenges on Arctic shipping routes and marine spatial planning with mixed reality technologies. Cross-cultural examinations of indigenous environmental information, combined with the contemporary digital system, represent a largely unexplored field of scholarly study [121].

Author Contributions: Conceptualization, methodology, writing—original draft preparation, data curation, investigation, validation, formal analysis, and resources, M.B.K. and Y.Z.; Data curation, investigation, legal analysis, writing—original draft preparation, supervision, project administration, and funding acquisition, Z.L. All authors have read and agreed to the published version of the manuscript [122].

Funding: Research on the innovative mechanism of marine economy development in the waters under the jurisdiction of the South China Sea (20180408).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors on request.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript.

No.	Short Form	Full Form of Abbreviations
1	SDGs	UN Sustainable Development Goals
2	DSA	Digital Services Act
3	IMO	International Maritime Organization
4	UNCLOS	United Nations Convention on the Law of the Sea
5	UNEP	United Nations Environment Programme
6	RSP	Regional Seas Programme
7	CBD	Convention on Biological Diversity
8	AI	Artificial Intelligence
9	ISA	International Seabed Authority
10	USITC	United States International Trade Commission
11	NPVs	Non-Proliferation Verification Systems
12	FNPPs	Floating Nuclear Power Plants
13	GDP	Gross Domestic Product
14	BBNJ	Biodiversity Beyond National Jurisdiction
15	MEMI	Maritime Emissions Monitoring Initiative
16	USITC	United States International Trade Commission
17	GHG	Greenhouse Gas Strategy
18	EEZ	Exclusive Economic Zones
19	ILO	International Labour Organization
20	SOLAS	International Convention for the Safety of Life at Sea

21	MASS	Maritime Autonomous Surface Ships
22	EC	European Commission
23	IBM	International Business Machines Corporation
24	MEPL	Marine Environmental Protection Law
25	ASEAN	Association of Southeast Asian Nations
26	GDPR	EU General Data Protection Regulation
27	DSA	Digital Services Act

References

1. Rogosic, M.; Stanivuk, T.; Lucaci, D. A Study on the Application of Shore-Side Power as a Method to Reduce the Emissions of Greenhouse Gases by Cruise Ships. *J. Mar. Sci. Eng.* **2025**, *13*, 453. [CrossRef]
2. Yu, C.; Wang, J.; Mo, R.; Zheng, Z. Electromagnetic Performance Analysis of a Brushless Dual-Electrical-Port Dual-Mechanical-Port Machine Featured with Stat or-Excited Dual-Flux-Modulated for Offshore Energy Power Generation. *J. Electr. Eng. Technol.* **2025**, *20*, 2343–2356. [CrossRef]
3. Xiao, G.; Pan, L.; Lai, F. Application, Opportunities, and Challenges of Digital Technologies in the Decarbonizing Shipping Industry: A Bibliometric Analysis. *Front. Mar. Sci.* **2025**, *12*, 1523267. [CrossRef]
4. Liu, H.; Meng, Z.-H.; Lv, Z.-F.; Wang, X.-T.; Deng, F.-Y.; Liu, Y.; Zhang, Y.-N.; Shi, M.-S.; Zhang, Q.; He, K.-B. Emissions and Health Impacts from Global Shipping Embodied in US–China Bilateral Trade. *Nat. Sustain.* **2019**, *2*, 1027–1033. [CrossRef]
5. Wang, Q. China's Law and Policy Initiatives for Integrating Nuclear Energy in Maritime Applications: A Critical Review. *Prog. Nucl. Energy* **2025**, *179*, 105538. [CrossRef]
6. Kim, S.Y.; Kim, H.J. 'Common but Differentiated' Motivations? Requests for Advisory Opinions Concerning Climate Change and the Law of the Sea. *Int. Environ. Agreem. Polit. Law Econ.* **2025**, *25*, 61–77. [CrossRef]
7. Ji, J.S. The IMO 2020 Sulphur Cap: A Step Forward for Planetary Health? *Lancet Planet. Health* **2020**, *4*, e46–e47. [CrossRef]
8. Earsom, J. Making Waves or Ripples? The Influence of the European Green Deal on the Revised IMO GHG Strategy. *Int. Environ. Agreem. Polit. Law Econ.* **2025**, *25*, 231–246. [CrossRef]
9. Bauer, M.; Czech, H.; Anders, L.; Passig, J.; Etzien, U.; Bendl, J.; Streibel, T.; Adam, T.W.; Buchholz, B.; Zimmermann, R. Impact of Fuel Sulfur Regulations on Carbonaceous Particle Emission from a Marine Engine. *Npj Clim. Atmos. Sci.* **2024**, *7*, 288. [CrossRef]
10. Thompson, R. Implementing SDG 14: Opportunities and Challenges in a Caribbean Small Island Developing State. *Mar. Policy* **2025**, *178*, 106713. [CrossRef]
11. Li, Y.; Yu, D.; Yang, L.; Zhang, L.; Chen, P.; Tao, B.; Wang, W.; Kong, Q.; Dai, R.; Miao, B.; et al. A Review of the Applications of Digital Twin Technology in Marine Research. *China Ocean Eng.* **2025**, *39*, 383–394. [CrossRef]
12. Fang, X.; Zhang, Y.; Yang, J.; Zhan, G. An Evaluation of Marine Economy Sustainable Development and the Ramifications of Digital Technologies in China Coastal Regions. *Econ. Anal. Policy* **2024**, *82*, 554–570. [CrossRef]
13. Bilawal Khaskheli, M.; Wang, S.; Zhang, X.; Shamsi, I.H.; Shen, C.; Rasheed, S.; Ibrahim, Z.; Baloch, D.M. Technology Advancement and International Law in Marine Policy, Challenges, Solutions and Future Prospective. *Front. Mar. Sci.* **2023**, *10*, 1258924. [CrossRef]
14. He, X.; Ping, Q.; Hu, W. Does Digital Technology Promote the Sustainable Development of the Marine Equipment Manufacturing Industry in China? *Mar. Policy* **2022**, *136*, 104868. [CrossRef]
15. Van Kuik, G.A.M.; Peinke, J.; Nijssen, R.; Lekou, D.; Mann, J.; Sørensen, J.N.; Ferreira, C.; van Wingerden, J.W.; Schlipf, D.; Gebraad, P.; et al. Long-Term Research Challenges in Wind Energy—A Research Agenda by the European Academy of Wind Energy. *Wind Energy Sci.* **2016**, *1*, 1–39. [CrossRef]
16. Meltzer, J.P. Governing Digital Trade. *World Trade Rev.* **2019**, *18*, S23–S48. [CrossRef]
17. Obashi, A.; Kimura, F. New Developments in International Production Networks: Impact of Digital Technologies. *Asian Econ. J.* **2021**, *35*, 115–141. [CrossRef]
18. S, N.R. Trade Rules for the Digital Economy: Charting New Waters at the WTO. *World Trade Rev.* **2019**, *18*, S121–S141. [CrossRef]
19. Zhang, M.; Yu, S. A Review on the Preparedness of Chinese Maritime Law Education for Emerging Industry and Technology Trends: Sustainable Net-Zero Shipping, Maritime Digitalization, and Application of Artificial Intelligence Technologies. *Sustain. Futur.* **2025**, *9*, 100752. [CrossRef]
20. Zhang, M.; Yang, X. The Regulatory Perspectives to China's Emerging Hydrogen Economy: Characteristics, Challenges, and Solutions. *Sustainability* **2022**, *14*, 9700. [CrossRef]
21. Babica, V.; Sceulovs, D.; Rustenova, E. Digitalization in Maritime Industry: Prospects and Pitfalls. In *ICTE in Transportation and Logistics 2019*; Ginters, E., Ruiz Estrada, M.A., Piera Eroles, M.A., Eds.; Springer International Publishing: Cham, Switzerland, 2020; pp. 20–27, ISBN 978-3-030-39687-9.

22. Mazzuto, G.; Pietrangeli, I.; Ciarapica, F.E.; Bevilacqua, M.; Antomarioni, S. Navigating Future Horizons: The Emergence and Evolution of Vessel Digital Twins. In Proceedings of the 2024 IEEE International Conference on Engineering, Technology, and Innovation (ICE/ITMC), Funchal, Portugal, 24–28 June 2024; pp. 1–8.
23. Intellect, M.R. Marine Big Data And Digitalization Market Size and Projections. Available online: https://www.marketresearchintellect.com/product/global-marine-big-data-and-digitalization-market-size-forecast/ (accessed on 27 August 2025).
24. Yüksel, S.; Eti, S.; Dinçer, H.; Gökalp, Y.; Olaru, G.O.; Oflaz, N.K. Innovative Financial Solutions for Sustainable Investments Using Artificial Intelligence-Based Hybrid Fuzzy Decision-Making Approach in Carbon Capture Technologies. *Financ. Innov.* **2025**, *11*, 1–30. [CrossRef]
25. Sajwan, R.S.; Solanki, C.; Jindal, M.K.; David, A.; Ullah, M.H.; Khandaker, M.U. Detection Approach and Monitoring Technologies of Marine Radioactivity. In *Radiation Status in the Marine World*; Jindal, M.K., David, A., Khandaker, M.U., Eds.; Springer Nature Switzerland: Cham, Switzerland, 2025; pp. 133–163, ISBN 978-3-031-82403-6.
26. Custers, B.; Lahmann, H.; Scott, B.I. From Liability Gaps to Liability Overlaps: Shared Responsibilities and Fiduciary Duties in AI and Other Complex Technologies. *AI Soc.* **2025**, *40*, 4035–4050. [CrossRef] [PubMed]
27. Chae, C.-J. The Evolution of Maritime Technology Development: A Dynamic Positioning System Perspective of Maritime Autonomous Surface Ship. *WMU J. Marit. Aff.* **2025**, *24*, 99–127. [CrossRef]
28. Shih, Y.-C. Ocean Governance in Practice: A Study of the Application of Marine Science and Technology Research Techniques to Maritime Law Enforcement in Taiwan. *Mar. Policy* **2024**, *163*, 106081. [CrossRef]
29. Zhou, Z.; Wang, L. An Empirical Study on the Impact of Language Service Industry Development on High-Quality Economic Growth in the Sichuan-Chongqing Region. *J. Lang. Serv. Stud.* **2025**, *1*, 4–20. [CrossRef]
30. Wam, R. Climate Change Loss and Damage: A Case for Mandatory Cooperation and Contribution under the United Nations Convention of the Law of the Sea (UNCLOS). *UCLA J. Environ. Law Policy* **2024**, *42*, 47. [CrossRef]
31. Lachenmeier, D.W.; Montagnon, C. Convention on Biological Diversity (CBD) and the Nagoya Protocol: Implications and Compliance Strategies for the Global Coffee Community. *Foods* **2024**, *13*, 254. [CrossRef]
32. Peng, J.; Qiao, R.; Wang, Q.; Yu, S.; Dong, J.; Yang, Z. Diversified Evolutionary Patterns of Surface Urban Heat Island in New Expansion Areas of 31 Chinese Cities. *Npj Urban Sustain.* **2024**, *4*, 14. [CrossRef]
33. Nguyen, S.; Chen, P.S.L.; Du, Y. Blockchain Adoption in Container Shipping: An Empirical Study on Barriers, Approaches, and Recommendations. *Mar. Policy* **2023**, *155*, 105724. [CrossRef]
34. Bertram, C.; Van Coppenolle, H. Strengthening the Paris Agreement through Trade? The Potential and Limitations of EU Preferential Trade Agreements for Climate Governance. *Int. Environ. Agreem. Polit. Law Econ.* **2024**, *24*, 589–610. [CrossRef]
35. Zhao, X.; Chen, Q.; Yuan, X.; Yu, Y.; Zhang, H. Study on the Impact of Digital Transformation on the Innovation Potential Based on Evidence from Chinese Listed Companies. *Sci. Rep.* **2024**, *14*, 6183. [CrossRef] [PubMed]
36. Deng, X.; Huang, N.; Yu, M. Cultural Inclusion and Social Trust: Evidence from China. *Asian J. Soc. Sci.* **2022**, *50*, 16–26. [CrossRef]
37. Wang, X.; Liu, Z. Neighborhood Environments and Inclusive Cities: An Empirical Study of Local Residents' Attitudes toward Migrant Social Integration in Beijing, China. *Landsc. Urban Plan.* **2022**, *226*, 104495. [CrossRef]
38. Exarchopoulos, G.; Zhang, P.; Pryce-Roberts, N.; Zhao, M. Seafarers' Welfare: A Critical Review of the Related Legal Issues under the Maritime Labour Convention 2006. *Mar. Policy* **2018**, *93*, 62–70. [CrossRef]
39. Lai, M.; Jung, J. Internationalisation with Chinese Characteristics: Exploring the Paradox in Students' Experiences at Sino-Foreign Cooperative Universities. *Stud. High. Educ.* **2025**, *50*, 1514–1527. [CrossRef]
40. Ni, Q.; Dong, H.; Kaniadakis, A. Low-Carbon Practices and Cultural Adaptation Among Older Chinese Migrants: Insights from Walking Interviews on Environmental Policy and Social Integration. *Int. J. Environ. Res. Public. Health* **2025**, *22*, 832. [CrossRef]
41. Rajamani, L. Interpreting the Paris Agreement in Its Normative Environment. *Curr. Leg. Probl.* **2024**, *77*, 167–200. [CrossRef]
42. Xia, Y.; Wang, G.; Yang, F. A Nationwide Study of the Impact of Social Quality Factors on Life Satisfaction among Older Adults in Rural China. *Sci. Rep.* **2024**, *14*, 11614. [CrossRef] [PubMed]
43. Zhang, P.; Wei, X.; Mao, G. Cultural Diversity, Social Integration, and Migrant Entrepreneurship—Evidence from the China Migrants Dynamic Survey. *Small Bus. Econ.* **2024**, *62*, 1135–1155. [CrossRef]
44. Bilawal Khaskheli, M.; Li, Y.; Zhao, Y.; Shumin, W. The Legal and Socioeconomic Challenges for Environmental Protection in Marine Policy and the Silk Route Maritime. *Front. Mar. Sci.* **2025**, *12*, 1597932. [CrossRef]
45. Qi, J.; Mazumdar, S.; Vasconcelos, A.C. Understanding the Relationship between Urban Public Space and Social Cohesion: A Systematic Review. *Int. J. Community Well-Being* **2024**, *7*, 155–212. [CrossRef]
46. Tijan, E.; Jović, M.; Aksentijević, S.; Pucihar, A. Digital Transformation in the Maritime Transport Sector. *Technol. Forecast. Soc. Change* **2021**, *170*, 120879. [CrossRef]
47. Weiss, E.B. United Nations Conference on Environment and Development. *Int. Leg. Mater.* **1992**, *31*, 814–817. [CrossRef]

48. Nielson, D.L.; Tierney, M.J. Delegation to International Organizations: Agency Theory and World Bank Environmental Reform. *Int. Organ.* **2003**, *57*, 241–276. [CrossRef]
49. Xia, L.; Lai, Z.; Khaskheli, M.B. The Business Innovation of Consumer Choices and Challenges for Economic Sustainability Practices and Law. *Sustainability* **2025**, *17*, 5968. [CrossRef]
50. Geissdoerfer, M.; Savaget, P.; Bocken, N.M.P.; Hultink, E.J. The Circular Economy—A New Sustainability Paradigm? *J. Clean. Prod.* **2017**, *143*, 757–768. [CrossRef]
51. UNIDO. United Nations Industrial Development Organization. Available online: https://www.unido.org/ (accessed on 25 September 2025).
52. The World Economic Forum. Available online: https://www.weforum.org/ (accessed on 25 September 2025).
53. IMO. Coming Soon. Available online: https://www.imo.org/en/ourwork/environment/pages/climate-change.aspx (accessed on 25 September 2025).
54. Wang, Z.; Liao, P.; Long, F.; Wang, Z.; Ji, Y.; Han, F. Maritime Electrification Pathways for Sustainable Shipping: Technological Advances, Environmental Drivers, Challenges, and Prospects. *eTransportation* **2025**, *26*, 100462. [CrossRef]
55. *Policy-Making After the WTO Trade Facilitation Agreement: Towards a Broader Trade Logistics Approach?* UN Trade and Development (UNCTAD): Geneva, Switzerland, 2018. Available online: https://unctad.org/news/policy-making-after-wto-trade-facilitation-agreement-towards-broader-trade-logistics-approach (accessed on 25 September 2025).
56. Liu, J.; Li, J. Educational Equity, Inclusive Finance, and Sustainable Economic Growth. *Financ. Res. Lett.* **2025**, *77*, 106966. [CrossRef]
57. Rodrigues, J.N.; Bhattacharya, S.; Sachdev, B.K.; Cabete, D.C.R. Policy Frameworks for Green Innovation in Maritime Trade and Sustainable Development. *Marit. Policy Manag.* **2025**, *52*, 1–27. [CrossRef]
58. Cancela-Outeda, C. The EU's AI Act: A Framework for Collaborative Governance. *Internet Things* **2024**, *27*, 101291. [CrossRef]
59. HBS. The Importance of Sustainability in Business. Available online: https://online.hbs.edu/blog/post/business-sustainability-strategies (accessed on 25 September 2025).
60. Wang, Y.; Chen, X.; Lin, Y.; Zhang, S.; Chang, L.; Tang, X.; Xiang, P.; Lin, H. Potential Risk from and Prevention of Phytoplankton Outbreaks in Blocking the Cooling Water System in a Nuclear Power Plant on the Southeast China Coast. *Front. Mar. Sci.* **2022**, *9*. [CrossRef]
61. Maritime Code of the People's Republic of China. Available online: https://english.dbw.cn/system/2009/09/18/000162337.shtml (accessed on 27 September 2025).
62. Wu, X.; Khaskheli, M.B. Systems Thinking of Marine Policies in Promoting Environmental Law, Sustainability, and Digital Technologies: Social Challenges in Belt and Road Initiative Countries. *Systems* **2024**, *12*, 400. [CrossRef]
63. Liu, J. China's Renewable Energy Law and Policy: A Critical Review. *Renew. Sustain. Energy Rev.* **2019**, *99*, 212–219. [CrossRef]
64. Du, W.; You, W.; Xu, Z. Review and Prospect of Legal Development in Commercial Nuclear Energy. *Energies* **2022**, *15*, 4310. [CrossRef]
65. Liu, X.; Cao, S.; Liu, Y. Legal Challenges of Regulating Cross-Border Nuclear Pollution from Ship Ballast Water under the Background of Fukushima Wastewater Release and China's Response. *Mar. Policy* **2024**, *167*, 106288. [CrossRef]
66. Hu, Z.; Wu, G.; Wang, T.; Yuan, H. Convergence of Sustainable Development Goals Evolution and Five-Year Plans Reform: Lessons from China. *Socioecon. Plann. Sci.* **2025**, *98*, 102156. [CrossRef]
67. Si, J.; Li, Y.; Zhao, C.; Zhan, H.; Zhang, S.; Zhang, L. Carbon Emissions and Drivers across Five Urban Agglomerations of China: Comparison between the 12th and 13th Five-Year Plan Periods. *Stoch. Environ. Res. Risk Assess.* **2024**, *38*, 4577–4593. [CrossRef]
68. Ju, W.; Liang, C.; Zhichao, Z.; Xingguang, Z.; Xiao, T.; Ruili, J.I.; Hongsu, M.A.; Shengfei, C.A.O.; Hui, L.; Mingliang, K. Geological Disposal of High Level Radioactive Waste in China: Progress and Breakthrough during 2019–2024. *At. Energy Sci. Technol.* **2024**, *58*, 217–230. [CrossRef]
69. Du, Z.; Cheng, Y. A Systematic Review and Codification of China's Ecological Restoration Policies and Laws. *Restor. Ecol.* **2025**, *volume 33*, e70169. [CrossRef]
70. Zhao, Q. The DOC and China? ASEAN Maritime Cooperation. In *Sustainable Peace of the South China Sea*; Series on Asian Regional Cooperation Studies; World Scientific: London, UK, 2024; Volume 11, pp. 29–48, ISBN 978-981-12-9602-4.
71. Hellenic Shipping News Worldwide. Maritime Trade under Pressure—Growth Set to Stall in 2025. Available online: https://www.hellenicshippingnews.com/maritime-trade-under-pressure-growth-set-to-stall-in-2025/ (accessed on 26 September 2025).
72. Zis, T.P.V.; Psaraftis, H.N.; Tillig, F.; Ringsberg, J.W. Decarbonizing Maritime Transport: A Ro-Pax Case Study. *Res. Transp. Bus. Manag.* **2020**, *37*, 100565. [CrossRef]
73. Xu, L.; Chen, Y. Overview of Sustainable Maritime Transport Optimization and Operations. *Sustainability* **2025**, *17*, 6460. [CrossRef]

74. Shen, M.; Zhao, Z.; Wang, H.; Wan, Z.; Liu, W.; Wang, X.; Yang, K.; Gao, Y. Identifying Recovery Coupling in Port-Maritime-Trade Networks: Empirical Analysis from the Global Container Shipping Market. *Int. J. Shipp. Transp. Logist.* **2025**, *20*, 61–95. [CrossRef]
75. Tsao, Y.-C.; Banyupramesta, I.G.A.; Lu, J.-C. Optimal Resilient Fleet Route Policy in Shipping Industry: Two-Stage Model for Minimizing Disruption-Related Effect. *Proc. Inst. Mech. Eng. Part M J. Eng. Marit. Environ.* **2025**, *239*, 284–300. [CrossRef]
76. UN Trade and Development (UNCTAD). High Freight Rates Strain Global Supply Chains, Threaten Vulnerable Economies. Available online: https://unctad.org/news/high-freight-rates-strain-global-supply-chains-threaten-vulnerable-economies (accessed on 27 September 2025).
77. IMO Approves Net-Zero Regulations for Global Shipping. Available online: https://www.imo.org/en/mediacentre/pressbriefings/pages/imo-approves-netzero-regulations.aspx (accessed on 27 September 2025).
78. A Guide to the IMO's Net-Zero Framework. Available online: https://globalmaritimeforum.org/news/a-guide-to-the-imos-net-zero-framework/ (accessed on 27 September 2025).
79. Li, D.; Jiao, J.; Wang, S.; Zhou, G. Energy Import Resilience Evaluation Considering Maritime Transport Disruptions: A Case of China. *Transp. Res. Part Transp. Environ.* **2024**, *133*, 104242. [CrossRef]
80. Mycoo, M.A.; Roopnarine, R.R. Water Resource Sustainability: Challenges, Opportunities and Research Gaps in the English-Speaking Caribbean Small Island Developing States. *PLOS Water* **2024**, *3*, e0000222. [CrossRef]
81. Wang, L.; Yin, K.; Xuemei, L.; Zhou, S.; Liang, Y. Analysis of Research Fronts in Marine Economy and Management. *Mar. Econ. Manag.* **2025**, *8*, 43–72. [CrossRef]
82. Baghizadeh, K.; Pahl, J.; Lützen, M.; Rytter, N.G.M. Using AIS Data to Analyze and Optimize Vessel Operations for Offshore Wind Farm Maintenance. In Proceedings of the Innovations in Sustainable Maritime Technology—IMAM 2025; Spyrou, K.J., Themelis, N., Eds.; Springer Nature Switzerland: Cham, Switzerland, 2025; pp. 405–422.
83. Sahu, S.; Mallick, N.; Hossain, I. Regulating the Future: Policy Frameworks for AI in Environmental Monitoring and Governance. In *Addressing Environmental Challenges With AI, Robotics, and Augmented Reality*; IGI Global Scientific Publishing: Hershey, PA, USA, 2025; pp. 83–112, ISBN 979-8-3373-1892-9.
84. Miller, T.; Durlik, I.; Kostecka, E.; Kozlovska, P.; Łobodzińska, A.; Sokołowska, S.; Nowy, A. Integrating Artificial Intelligence Agents with the Internet of Things for Enhanced Environmental Monitoring: Applications in Water Quality and Climate Data. *Electronics* **2025**, *14*, 696. [CrossRef]
85. Janmethakulwat, A.; Thanasopon, B. Institutionalization and Adoption of Digital Technology in Thai Maritime Industry. *Marit. Bus. Rev.* **2025**, 1–24. [CrossRef]
86. Gavalas, D.; Syriopoulos, T.; Roumpis, E. Digital Adoption and Efficiency in the Maritime Industry. *J. Shipp. Trade* **2022**, *7*, 11. [CrossRef]
87. Dong, B.; Bautista, L.; Zhu, L. Navigating Uncharted Waters: Challenges and Regulatory Solutions for Flag State Jurisdiction of Maritime Autonomous Surface Ships under UNCLOS. *Mar. Policy* **2024**, *161*, 106039. [CrossRef]
88. Rometius, S.; Wei, X. Blue Horizons for Resilient Islands: Legal–Technological Synergies Advancing SDG 7 and 13 Through the UNCLOS–Paris Agreement Integration in SIDS' Energy Transitions. *Sustainability* **2025**, *17*, 6011. [CrossRef]
89. International Tribunal for the Law of the Sea. *The M/T "San Padre Pio" Case; (Switzerland v. Nigeria)*; Cambridge University Press: Cambridge, UK, 2023; Volume 204, pp. 413–527. [CrossRef]
90. McDonough, L. UNCLOS and the Law of Occupation: On the Rights and Duties of Occupying States in Maritime Areas. *Int. Law Stud.* **2024**, *103*, 8.
91. Li, Z.; Zhang, C. Spatial Evolution and Resilience Analysis of Marine Eco-Environmental Protection Enterprises. *Mar. Pollut. Bull.* **2025**, *216*, 117953. [CrossRef]
92. Liu, X.; Liu, S.; Wang, Y. The Improvement of Judicial Protection of Marine Environment in China: Based on the Analysis of 2,443 Judicial Cases. *Front. Mar. Sci.* **2024**, *11*, 1486230. [CrossRef]
93. Chen, X.; Guo, F. Semiotic Construction of Strong Maritime Country in Marine Eco-Environmental Protection in China: Systemic Functional Lingustics Perspective. *Int. J. Linguist. Lit. Transl.* **2025**, *8*, 109–128. [CrossRef]
94. Duan, X.; Zhao, X.; Zou, M.; Chang, Y.-C. Maritime Laws and Sustainable Development of Blue Economy: Conference Report. *Mar. Policy* **2024**, *169*, 106339. [CrossRef]
95. Batool, M.; Chang, Y.-C. Marine Scientific Research in the Protection of the Marine Environment Under the International Legal Framework: A Sustainable Development Goals Perspective. In *Viability of UNCLOS amid Emerging Global Maritime Challenges*; Nguyen, L.A.T., Vu, H.D., Eds.; Springer Nature: Singapore, 2025; pp. 99–120, ISBN 978-981-97-5838-8.
96. Chang, Y.-C.; Saqib, M. International Legal Systems in Tackling the Marine Plastic Pollution: A Critical Analysis of UNCLOS and MARPOL. *Water* **2025**, *17*, 1547. [CrossRef]

97. Broman, G.I.; Robèrt, K.-H. Operative System for Strategic Sustainable Development—Coordinating Analysis, Planning, Action, and Use of Supports Such as the Sustainable Development Goals, Planetary Boundaries, Circular Economy, and Science-Based Targets. Available online: https://onlinelibrary.wiley.com/doi/full/10.1002/sd.3357 (accessed on 25 September 2025).
98. Arfanuzzaman, M. Navigating the Blue Economy: Unlocking Ocean-Based Solutions for Sustainable Growth and Global Stewardship. In *The Palgrave Encyclopedia of Sustainable Resources and Ecosystem Resilience*; Palgrave Macmillan: Cham, Switzerland, 2025; pp. 1–16. ISBN 978-3-030-67776-3.
99. Tariq, M.U. Leveraging Open Innovation for Sustainable Growth in the Digital Era. In *Mastering Innovation in Business*; IGI Global Scientific Publishing: Hershey, PA, USA, 2025; pp. 157–192, ISBN 979-8-3693-3759-2.
100. Chen, J.; Xu, Y.; Li, H.; Zhao, X.; Su, Y.; Qi, C.; Qu, K.; Cui, Z. The Application of Digital Twin Technology in the Development of Intelligent Aquaculture: Status and Opportunities. *Fishes* **2025**, *10*, 363. [CrossRef]
101. Ye, Y.; González-Vidal, A.; Cisterna-García, A.; Pérez-Ruzafa, A.; Izquierdo, M.A.Z.; Skarmeta, A.F. Advancing Towards a Marine Digital Twin Platform: Modeling the Mar Menor Coastal Lagoon Ecosystem in the South Western Mediterranean. *arXiv* **2024**, *2409*, 10134.
102. Wickberg, A.; Lidström, S. Digital Twins of the Ocean: Wet Environing Media and Marine Futures. *New Media Soc.* **2025**. [CrossRef]
103. Pan, Y. China's Participation in Arctic Governance from the Perspective of International Law. *Law Econ.* **2025**, *4*, 38–45. [CrossRef]
104. Lewis, R. The 'Constitution for the Oceans'? The Law of the Sea Convention as a Living Treaty. *Int. Comp. Law Q.* **2025**, *74*, 1–31. [CrossRef]
105. Li, J. Urgent Need to Establish a Specialized Committee for Marine Science, Innovate Marine Science-Policy Financing Models, and Build Data-Sharing and Capacity-Building Platforms!_Global_Cooperation. Available online: https://www.sohu.com/a/www.sohu.com/a/926934742_726570 (accessed on 24 August 2025).
106. Zhang, M.; Xia, L.; Wang, Y. The Anti-Unfair Competition Law and Total Factor Productivity of Enterprises. *Financ. Res. Lett.* **2025**, *86*, 108252. [CrossRef]
107. Reporters from ASEAN Visit Hainan Free Trade Port to See How It Develops. Available online: https://tass.com/economy/2006061 (accessed on 24 August 2025).
108. Wei, Z.; Chen, X.; Tang, G.; Xie, Y. South China Sea Issue and Southeast Asian Countries' Perception of China's Image: An Empirical Study Based on GDELT Big Data. *PLoS ONE* **2025**, *20*, e0323218. [CrossRef]
109. The Copenhagen Post. China to Build Maritime Community with Shared Future in South China Sea with Regional Countries: Report. Available online: https://cphpost.dk/2025-08-22/life-in-denmark/opinion/china-to-build-maritime-community-with-shared-future-in-south-china-sea-with-regional-countries-report/ (accessed on 24 August 2025).
110. Berkhout, F.; Hertin, J. De-Materialising and Re-Materialising: Digital Technologies and the Environment. *Futures* **2004**, *36*, 903–920. [CrossRef]
111. Christodoulou, A.; Echebarria Fernández, J. Maritime Governance and International Maritime Organization Instruments Focused on Sustainability in the Light of United Nations' Sustainable Development Goals. In *Sustainability in the Maritime Domain: Towards Ocean Governance and Beyond*; Carpenter, A., Johansson, T.M., Skinner, J.A., Eds.; Springer International Publishing: Cham, Switzerland, 2021; pp. 415–461. ISBN 978-3-030-69325-1.
112. Guo, X.; Jaepil, P. Exploration and Innovation of Zhoushan Marine Tourism Industry in the Context of Free Trade Zone. In *Tourism, Aviation and Hospitality Development During the COVID-19 Pandemic*; Springer: Singapore, 2022; pp. 101–118, ISBN 978-981-19-1661-8.
113. Polejack, A. The Importance of Ocean Science Diplomacy for Ocean Affairs, Global Sustainability, and the UN Decade of Ocean Science. *Front. Mar. Sci.* **2021**, *8*, 664066. [CrossRef]
114. Qin, Y.; Zhao, X. A Study on the Development Status and Countermeasures of "Specialized, Refined, Distinctive, and Innovative" SMEs in Zhoushan under the Vision of Common Prosperity. *Open Access Libr. J.* **2024**, *11*, 1–13. [CrossRef]
115. Jin, X.; Li, M.; Lei, X. The Impact of Digitalization on the Green Development of the Marine Economy: Evidence from China's Coastal Regions. *Front. Mar. Sci.* **2024**, *11*, 1457678. [CrossRef]
116. Wu, X.; Zhao, Z.; Zhou, B. Legitimacy in Adaptive Business Model Innovation: An Investigation of Academic Ebook Platforms in China. *Emerg. Mark. Financ. Trade* **2019**, *55*, 719–742. [CrossRef]
117. Zhang, Y.; Bilawal Khaskheli, M. The Role of Digital Technologies in Advancing Sustainable Economic Development into Intersections of Policy, Law, Environmental Economics, and a Comparative Study of China, the EU, and the USA. *Sustainability* **2025**, *17*, 8666. [CrossRef]
118. *Law, Science & Ocean Management*; Nordquist, M., Long, R., Heidar, T., Moore, J.N., Eds.; Martinus Nijhoff Publishers: Leiden, The Netherlands, 2007; ISBN 978-90-474-3149-7.

119. Lloret, J.; Cowx, I.G.; Cabral, H.; Castro, M.; Font, T.; Gonçalves, J.M.S.; Gordoa, A.; Hoefnagel, E.; Matić-Skoko, S.; Mikkelsen, E.; et al. Small-Scale Coastal Fisheries in European Seas Are Not What They Were: Ecological, Social and Economic Changes. *Mar. Policy* **2018**, *98*, 176–186. [CrossRef]
120. Kronen, M.; Vunisea, A.; Magron, F.; McArdle, B. Socio-Economic Drivers and Indicators for Artisanal Coastal Fisheries in Pacific Island Countries and Territories and Their Use for Fisheries Management Strategies. *Mar. Policy* **2010**, *34*, 1135–1143. [CrossRef]
121. Han, X.; Liu, J.; Tan, B.; Duan, L. Design and Implementation of Smart Ocean Visualization System Based on Extended Reality Technology. *J. Web Eng.* **2021**, *20*, 557–574. [CrossRef]
122. van Boven, F.; van Vliet, B.; Bush, S.; Stremke, S. Inclusive Intent, Instrumental Outcomes: How Developer Rationales Shape Participation in Solar Energy Projects. *Energy Res. Soc. Sci.* **2025**, *125*, 104110. [CrossRef]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.